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# Alkali Aggregate Reactions in Concrete: An Annotated Bibliography 1939-1991

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This paper represents the views of the author only, and is not necessarily reflective of the views of the National Research Council, the views of SHRP, or SHRP's sponsor. The results reported here are not necessarily in agreement with the results of other SHRP research activities. They are reported to stimulate review and discussion within the research community.

# Foreword

Alkali-silica reactivity continues to be a serious cause of deterioration of concrete in pavements, bridges and other highway structures in the United States. This phenomenon was identified over 50 years ago, and, since then, has remained a subject of much research and discussion. Although there are still noticeable gaps in our knowledge on alkali-silica reactivity, significant advances have been made in our understanding of the phenomenon, and in developing means to control it.

The Strategic Highway Research Program (SHRP) is addressing the problem through its Project C-202, Eliminating or Minimizing Alkali-Silica Reactivity. This is a five-year study being carried out at the Construction Technology Laboratories, Skokie, Illinois; Purdue University, West Lafeyette, Indiana; and Ecole Normale Supériore de Cachan, Paris, France. The first task of this project dealt with background studies which included a compilation and critical assessment of our knowledge on alkali-silica reactivity. This bibliography is a product of this effort.

The bibliography contains over 1300 references pertinent to the phenomenon of alkali-silica reactivity, and is the most comprehensive and updated publication of its kind currently available on the subject. It covers a period of over 50 years since the phenomenon was first reported in literature, and was compiled by Professor Sidney Diamond and his associates at Purdue University. Professor Diamond has been involved in research on alkali-silica reactivity for over 30 years with a number of pioneering studies to his credit on the subject.

SHRP research on alkali-silica reactivity has contributed to an increased awareness of the problem among highway engineers. They want to learn more about what underlies the problem. This publication should satisfy this need by providing an easy access to a wealth of knowledge and experience, both past and present, on the problem of alkali-silica reactivity.

Inam Jawed
Project Manager

# Acknowledgments

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Project C-202, under which this bibliography was compiled, is conducted by Construction Technology Laboratories, Skokie, Illinois, as the prime contractor, and Purdue University, West Lafayette, Indiana as the U.S. subcontractor. The advice and assistance of Mr. David Stark, principal investigator for CTL, is gratefully acknowledged.

Most of the original citations were prepared and entered by Mr. Shaode Ong, a graduate student at Purdue University. Mr. Ong also translated many of the Chinese language citations included in this bibliography. This compilation would not have been possible without Mr. Ong's diligence and dedication. Contributions were also made by Dr. Qizhong Sheng, formerly a graduate student at Purdue University.

We are especially indebted to several overseas colleagues for compilations of papers in languages other than English. Professor Micheline Moranville-Regourd of the Ecole Normale Supériore de Cachan, Paris, provided citations in English for a considerable number of papers in several European languages. Professor Mitsunori Kawamura, of Kanazawa University, Japan, contributed citations for almost two hundred papers from the Japanese literature, many in Japanese. We are indebted to Dr. Keisuke Matsukawa, then a graduate student at Purdue University, for preparation of the English language citations from the Japanese language originals contributed by Professor Kawamura. Professor Tang Ming-Shu of the Nanjing Institute of Chemical Technology also contributed a number of Chinese citations.

Finally, it is a pleasure to record my gratitude to Mr. Tommy Nantung, a graduate student at Purdue University, for his assistance in all matters relating to the setting up of the computer aspects of this effort, and for the final printout. Mr. Nantung's expertise in both the IBM and Macintosh system were essential in making the effective processing of this compilation possible.

Great efforts have been made to include citations to nearly all relevant papers, but in the nature of things, important papers may have been missed. The writer apologizes to the authors involved, and would appreciate having his attention called to specific instances of such omissions. Also, inevitably some distortions in the meaning or

emphasis of aspects of the original papers will have occurred in some of the annotations, and the writer apologizes for these as well. Nevertheless, it is hoped that the considerable effort that has gone into the preparation of this bibliography will have been justified in terms of its utility to civil engineers and researchers actively involved in finding and applying answers to the many problems caused by alkali aggregate reactions.

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# Abstract

This annotated bibliography contains nearly 1300 citations, from before 1940 to 1991. It includes numerous contributions from international literature in languages other than English, especially Japanese, French, Chinese, and German.

# Executive Summary

While no research literature bibliography can ever be complete, the present work represents an attempt to be as comprehensive as reasonably possible. The almost 1400 citations included contain numerous contributions from the international literature in languages other than English, especially Japanese, French, Chinese, and German.

The alkali aggregate reaction problem is generally considered to have been recognized first by T.E. Stanton in 1940, although the bibliography includes citations to a few older papers containing information foreshadowing explicit recognition of the problem. Citations for the years prior to 1975 mostly include only the literature reference and key words; for 1975 onwards, nearly all entries contain an abstract, a set of conclusions, or a discussion compiled from the original paper whenever possible. The original coverage was to be complete through the year 1989, but citations for 1990 and some citations for 1991 were added during the extensive revision.

The literature covered includes the proceedings of all of the seven published international conferences on alkali aggregate reactions, and incorporates an earlier non-annotated bibliography published by Cembureau in 1977.

Alkali aggregate reactions in concrete constitute a family of potentially damaging reactions rather than a single reaction. Most alkali aggregate reaction problems arise from reactions with siliceous aggregates, and such reactions are usually referred to as alkali silica or alkali silicate reactions. Alkali carbonate reactions constitute a separate class of alkali aggregate reactions, which because of their relative rarity, were not included in the SHRP. Accordingly, papers concerning alkali carbonate reactions are generally not included in this bibliography.

The compilation of an annotated bibliography as extensive as this one is made practical only by the availability of modern computer technology. The present document is a "hard copy" output of a computer data base on which all of the entries are stored. The original version of the data base was compiled on another literature data base program and then converted to Pro-Cite™, a commercial literature data base program marketed by Personal Bibliographic Software, Inc. Pro-Cite™ has been selected as the standard data base program for the entire SHRP.

Use of the bibliography in the computer data base form offers many advantages over use in the present hard-copy form. The Pro-Cite™ program permits full document

searching for any character string and permits search strategies based on Boolean combinations of search elements; thus searches can be made with a high degree of specificity. Pro-Cite™ is available in both IBM-compatible and Macintosh versions. The present data base is available on floppy disks in both formats, and it is hoped that the disks can be distributed to interested parties by the Transportation Research Board on behalf of the SHRP.

Before 1940

1000. Pearson, J. C. and Loughlin, G. F., "AN INVESTIGATION CASE OF DANGEROUS AGGREGATE," Proceedings of the American Concrete Institute, 1923, Vol. 19, pp. 142-154.

KEY WORDS: aggregates

1001. Platzmann, C. R., "THE INFLUENCE OF THE ALKALIES IN PORTLAND CEMENT BUILDING TROUBLES (in German)," Bauterschutz, 1937, Vol. 8, p. 21. Chemische Zentralblatt, 1937, Vol. 1, p. 3042. Chemical Abstracts, Vol. 32, 8100.5.

KEY WORDS: alkali effects; alkali aggregate reactions

1002. Blanks, R. F., Meissner, H. E. and Rawhauser, C., "CRACKING OF MASS CONCRETE," Proceedings of the American Concrete Institute, 1938, Vol. 34, p. 477.

KEY WORDS: mass concrete; cracking

1003. Gibson, W. E., "A STUDY OF MAP-CRACKING OF SAND-GRAVEL CONCRETE PAVEMENTS," Proceedings of the Highway Research Board, 1938, Vol. 18, Part 1.

KEY WORDS: map-cracking; "sand-gravel" aggregates; reactive aggregates; pavement structures; cracking

1004. Campbell, L. and Cantrill, C., "SELECTION OF AGGREGATES FOR CONCRETE PAVEMENT BASED ON SERVICE RECORDS," Proceedings of the American Society for Testing and Materials, 1939, Vol. 39, pp. 937-949.

KEY WORDS: pavement structures; aggregates

1005. Mattimore, H. S., "RESEARCH ON CONCRETE DISINTEGRATION," 20th Annual Meeting of Highway Research Board, December 1940, Journal of the American Concrete Institute, February 1941, p. 524.

KEY WORDS: deterioration

1006. Schonberg, W., "EXPERIMENTS ON THE REDUCTION OF CRACK FORMATION IN ROAD CONCRETE (in German)," Betonstrasse, 1940, Vol. 15, No. 11, pp. 135-137.

KEY WORDS: pavement structures; cracking; preventive measures

1007. Stanton, T. E., "INFLUENCE OF CEMENT AND AGGREGATE ON CONCRETE EXPANSION," Engineering News-Record, 1940, Vol. 123, No. 5, pp. 59-61; Vol. 124, pp. 171-173. Building Science Abstracts, 1940, 509.

KEY WORDS: expansion; cement; aggregates; expansion

1008. Stanton, T. E., "EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE," Proceedings of the American Society of Civil Engineers, 1940, Vol. 66, pp. 1781-1811. Discussion, Proceedings of the American Society of Civil Engineers, 1941, Vol. 67, pp. 265, 509, 671, 899, 1104, 1402. Transactions of the American Society of Civil Engineers, 1942, Vol. 107, pp. 54-126 (with discussion). Building Science Abstracts, 1941, 605; 1942, 168.

KEY WORDS: alkali aggregate reactions; expansion

Generally considered to be the paper first explicitly recognizing the nature of alkali aggregate reactions in concrete.

1009. Sweet, H. S., "CHERT AS A DELETERIOUS CONSTITUENT IN INDIANA AGGREGATES," Highway Research Board Proceedings, 1940, Vol. 20, p. 599.

KEY WORDS: aggregates; chert; reactive aggregates

1940

1010. Wuerpel, C. E., "DETECTING UNSOUND CHERT IN AGGREGATES," Engineering News-Record, 1940, Vol. 124, pp. 652-654.

KEY WORDS: aggregates; chert; test methods

1011. Wuerpel, C. E. and Rexford, E. P., "THE SOUNDNESS OF CHERT AS MEASURED BY BULK SPECIFIC GRAVITY AND ADSORPTION," Proceedings of the American Society for Testing and Materials 1940, Vol. 40, pp. 1021-1054.

KEY WORDS: chert; adsorption; reactive aggregates; aggregates

1012. Ash, G., "THE EFFECT OF ALKALIES ON CONCRETE," Pit and Quarry, October 1941, Vol. 34, No. 4, p. 40.

KEY WORDS: alkali effects

1013. Berkey, C. P., "THE NATURE OF PROCESSES LEADING TO THE DISINTEGRATION OF CONCRETE WITH SPECIAL REFERENCE TO EXCESS ALKALI," Conference Proceedings, U.S. Bureau of Reclamation and Cement Industry Representatives, Denver, Colorado, February 14-15 1941, pp. 16-19. Journal of the American Concrete Institute, June 1941, Vol. 21, No. 6 pp. 689-92; Proceedings Vol. 37. Discussion, Journal of the American Concrete Institute, November 1941, Supplement, pp. 692-1 to 692-3.

KEY WORDS: alkali effects; cracking; deterioration

1014. Blank, A. J., "MUCH ADO OVER ALKALIES AND SULFATES IN PORTLAND CEMENTS," Concrete, Cement Mill Section, 1941, Vol. 49, No. 6, p. 182.

KEY WORDS: cement; alkali effects; sulfates; deterioration

1015. Blanks, R. F., "DISCUSSION OF EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE, BY THOMAS E. STANTON," Proceedings of the American Society of Civil Engineers, 1941, Vol. 67, pp. 904-911. Transaction of the American Society of Civil Engineers, 1942, Vol. 107, pp. 98-105.

KEY WORDS: alkali aggregate reactions; expansion; field experiences

1016. Blanks, R. F., "CONCRETE DETERIORATION AT PARKER DAM," Engineering News-Record, 27 March 1941, p. 16. Chemical Abstracts, Vol. 35, 37899.

KEY WORDS: dam structures; deterioration

1941

1017. Blank, A. J., "ALKALIES IN PORTLAND CEMENTS," Rock Products, June 1941, Vol. 44, No. 6, p. 46.
KEY WORDS: alkali effects; cements

1018. Bureau of Reclamation, "ALKALIES IN CEMENT AND THEIR EFFECT ON AGGREGATE AND CONCRETE," Proceedings of Conference, Denver, Colorado. 14-15 February 1941.

KEY WORDS: alkali effects; cement; aggregates; reactive aggregates

1019. Delano, P. H. and Weber, P. J., "ALKALI RESISTANCE OF PORTLAND CEMENT - EFFECT OF SODIUM SULFATE," Industrial and Engineering Chemistry, May 1941, p. 692.

KEY WORDS: alkali effects; sodium sulfate; cement

1020. Hinds, J. and Tuthill, L.H., "DISCUSSION OF CRACKING IN CONCRETE DUE TO THE EXPANSIVE REACTION BETWEEN AGGREGATE AND HIGH ALKALI-CEMENT AS EVIDENCED IN PARKER DAM BY H.S. MEISSNER, Journal of the American Concrete Institute, 1941, Vol. 12, No. 5, pp. 549-568.," Proceedings of the American Concrete Institute, 1941, Vol. 37, p. 508.

KEY WORDS: cracking; alkali aggregate reactions; expansion; dam structures; field experiences

1021. Kammer, H. A. and Carlson, R. W., "INVESTIGATION OF CAUSES OF DELAYED EXPANSION OF CONCRETE IN BUCK HYDRO-ELECTRIC PLANT," Journal of the American Concrete Institute, June 1941, Vol. 12, No. 6, pp. 665; Proceedings, No. 37.

KEY WORDS: alkali aggregate reactions; expansion; deterioration; field experiences

1022. Meissner, H. S., "CRACKING IN CONCRETE DUE TO EXPANSIVE REACTION BETWEEN AGGREGATE AND HIGH-ALKALI CEMENT AS EVIDENCED IN PARKER DAM," Journal of the American Concrete Institute, April 1941, Vol. 12, No. 5, pp. 549-568; Proceedings, Vol. 37. Discussion, Journal of the American

1941

Concrete Institute, November 1941, pp. 568-1 to 568-4.

KEY WORDS: alkali aggregate reactions; cracking; cement; dam structures; field experiences

1023. Stadfelt, N. T., "DISCUSSION OF PAPER, EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE, BY T.E. STANTON, Proceedings of the American Society of Civil Engineers, 1940, VOL. 66, PP. 1787-1871.," Proceedings of the American Society of Civil Engineers, 1941, Vol. 67, p. 672.

KEY WORDS: alkali aggregate reactions; expansion

1024. Tremper, B., "EVIDENCE IN WASHINGTON OF DETERIORATION OF CONCRETE THROUGH REACTIONS BETWEEN AGGREGATE AND HIGH-ALKALI CEMENTS," Journal of the American Concrete Institute, June 1941, Vol. 12, No. 6, pp. 673-686; Proceedings, Vol. 37.

KEY WORDS: alkali aggregate reactions; deterioration; field experiences

1025. Barona de la O, F., "SAN GABRIEL DAM NO. 1.," Transactions of the American Society of Civil Engineers, 1942, Vol. 107, p. 1642.

KEY WORDS: dam structures

1026. Blanks, R. F., "EXPANSION OF CONCRETE," American Society of Civil Engineers, Transactions 1942, Vol. 107, p. 98.

KEY WORDS: expansion

1027. Bureau of Reclamation, "PROGRESS REPORTS. ALKALIES IN CEMENTS AND THEIR EFFECTS ON AGGREGATES AND CONCRETE," U.S. Department of Interior, Bureau of Reclamation, Denver, Colorado, Laboratory Report CE-40, July 1942.

KEY WORDS: alkali effects; cements; alkali aggregate reactions

1028. Carlson, R. W., "EXPANSION OF CONCRETE," Transactions of the American Society of Civil Engineers, 1942, Vol. 107, p. 85.

KEY WORDS: expansion

1029. Carlson, R. W., "DISCUSSION OF EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE BY THOMAS E. STANTON," Proceedings of the American Society of Civil Engineers, 1942, Vol. 47, pp. 265-266. Transactions of the American Society of Civil Engineers 1942, Vol. 107, p. 85.

KEY WORDS: alkali aggregate reaction; expansion

1030. Coombs, H. A., "EXPANSION OF CONCRETE DUE TO REACTION BETWEEN ANDESITIC AGGREGATE AND CEMENT," American Journal of Science, 1942, Vol. 240, pp. 288-297.

KEY WORDS: alkali aggregate reactions; andesite; reactive aggregates

1942

1031. Hanna, W. C., "EXPANSION OF CONCRETE," American Society of Civil Engineers, Transactions, 1942, Vol. 107, p. 93.

KEY WORDS: expansion

1032. Hansen, W. C., "STATUS OF LABORATORY TESTS ON ALKALI-AGGREGATE REACTION," Portland Cement Association Research Laboratory Report, February 1942.

KEY WORDS: alkali aggregate reactions; test methods

1033. Jackson, F. H. and Kellerman, W.F., "VOLUME CHANGES IN SAND-GRAVEL CONCRETE," Proceedings of the Highway Research Board, 1942, No. 22, pp. 252-284; Discussion, pp. 284-286.

KEY WORDS: expansion; "sand-gravel" aggregates; reactive aggregates

1034. Meissner, H. S., "CALIFORNIA EXPERIENCE WITH THE EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE," Proceedings of the American Concrete Institute, November 1942, Vol. 38, Supplement 236-1 to 236-39.

KEY WORDS: expansion; alkali aggregate reactions

1035. Mielenz, R. C., "STUDIES OF DETERIORATION OF PAVEMENT CONCRETE AT KIMBALL, NEBRASKA," Petrographic Laboratory Report No. Pet-36, Bureau of Reclamation, Denver, Colorado, October 1942, 28 pages. Building Science Abstracts, 1948, Vol. 21, 299.

KEY WORDS: pavement structures; deterioration

1036. Stanton, T. E., Porter, O.J., Meder, L.C. and Nicol, A., "CALIFORNIA EXPERIENCE WITH THE EXPANSION OF CONCRETE THROUGH REACTION BETWEEN CEMENT AND AGGREGATE," Journal of the American Concrete Institute, January 1942, Vol. 13, No. 3, pp. 209-236; Proceedings, Vol. 38, Discussion, Supplement pp. 236-1 to 236-39.

1942

KEY WORDS: alkali aggregate reactions; expansion; field experiences

1037. Sweet, H. S. and Woods, K.B., "A STUDY OF CHERT AS A DELETERIOUS CONSTITUENT IN AGGREGATES," Purdue University, Engineering Bulletin No. 5, 26 September 1942.

KEY WORDS: reactive aggregates; chert

1038. Tremper, B., "EXPANSION OF CONCRETE," Transactions of the American Society of Civil Engineers, 1942, Vol. 107, p. 85.

KEY WORDS: expansion

1039. Woods, H., "REMOVING ALKALIES BY HEATING WITH ADMIXTURES," Rock Products, 1942, 45, No. 2, pp. 66-68.

KEY WORDS: alkali effects; admixtures

1040. Woods, H., "EXPANSION OF CONCRETE," Transactions of the American Society of Civil Engineers, 1942, Vol. 107, p.88.

KEY WORDS: expansion

1041. Alderman, A. R., "A REVIEW OF THE EVIDENCE CONCERNING EXPANSIVE REACTION BETWEEN AGGREGATE AND CEMENT IN CONCRETE," Australia, Council for Scientific and Industrial Research, Melbourne, Bulletin No. 161, 1943, 15 pages.

KEY WORDS: alkali aggregate reactions; expansion

1042. Anon., "VOLUME CHANGE IN CONCRETE," Engineering News-Record, 28 January 1943, Vol. 130, No. 4, p. 147.

KEY WORDS: expansion

1043. ASTM, "REPORT OF COMMITTEE C-1 ON CEMENT," Proceedings of the ASTM, 1943, Vol. 43, pp. 195-220.

KEY WORDS: cements; test methods

1044. Blanks, R. F., "EFFECT OF ALKALIES IN PORTLAND CEMENT ON THE DURABILITY OF CONCRETE," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43, pp. 199-207; Discussions, pp. 208-218.

KEY WORDS: alkali effects; cements

1045. Hanna, W. C., "EFFECT OF ALKALIS IN PORTLAND CEMENT ON CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43. pp. 208-211.

KEY WORDS: alkali effects; cement

1046. Hornibrook, G. B., Insley, H. and Schuman, L., "EFFECT OF ALKALIES IN PORTLAND CEMENT ON CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43, p. 218.

KEY WORDS: alkali effects; cements

1943

1047. Jackson, F. H., "EFFECT OF ALKALIS IN PORTLAND CEMENT ON CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1943, No. 43, pp. 215-218.

KEY WORDS: alkali effects; cements

1048. Kennedy, H. L., "ALKALI-AGGREGATE REACTIONS IN CONCRETE AS MEASURED BY DYNAMIC MODULUS," Pit and Quarry, July 1943, Vol. 36, No. 1, pp. 64-69.

KEY WORDS: alkali aggregate reactions; test methods

1049. Mclarmour, M. et al., "PORTLAND CEMENT WITH LOW ALKALI CONTENT," Cement and Lime Manufacture, 1943, Vol. 16, No. 9, pp. 127-130.

KEY WORDS: cements; alkali effects

1050. Stanton, T. E., "STUDIES TO DEVELOP AN ACCELERATED TEST PROCEDURE FOR THE DETECTION OF ADVERSELY REACTIVE CEMENT-AGGREGATE COMBINATIONS," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43, pp. 875-894; Discussion, pp. 894-902. Chemical Abstracts, Vol. 38, 3792.

KEY WORDS: alkali aggregate reactions; test methods

1051. Tremper, B., "EFFECT OF ALKALIES IN PORTLAND CEMENT ON CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43, pp. 211-212.

KEY WORDS: alkali effects; cements

1052. Wuerpel, C. E., "EFFECT OF ALKALIES IN PORTLAND CEMENT ON CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1943, Vol. 43, pp. 212-215.

KEY WORDS: alkali effects; cements

1053. Bates, P. H. and Blanks, R.F., " TILE FLOORS EXUDE SODIUM SILICATE," Journal of the American Concrete Institute, April 1944, Vol. 15, No. 5, p. 469.

KEY WORDS: sodium silicate; silica; alkali silica gel

1054. Bean, L. and Tregoning, J.J., "REACTIVITY OF AGGREGATE CONSTITUENTS IN ALKALINE SOLUTIONS," Journal of the American Concrete Institute, September 1944, Vol. 16, No. 1, pp. 37-52, Proceedings, Vol. 41 Technical News Bulletin, National Bureau of Standards, July 1944, Discussion, Journal of The American Concrete Institute, November 1945, Vol. 16, Supplement, p. 52-1.

KEY WORDS: reactive aggregates; alkali effects

1055. Brown, L. S., "SOME OBSERVATIONS ON THE MECHANICS OF ALKALI-AGGREGATE REACTION," Research and Development Laboratory, Portland Cement Association, Research Department Bulletin No. 54, April 1944, pp. 1-17.

KEY WORDS: alkali aggregate reactions; mechanisms; test methods; petrography

1056. Bureau of Reclamation, "SUPPLEMENTARY PETROGRAPHIC EXAMINATION OF CONCRETE SAMPLES FROM STEWART MOUNTAIN DAM, SALT RIVER PROJECT, ARIZONA," U. S. Dept. of the Interior, Bureau of Reclamation, Petrographic Laboratory Report No. Pet-64, 22 July, 1944, 7 pp.

KEY WORDS: dam structures; petrography

1057. Carlson, R. W., "ACCELERATED TESTS OF CONCRETE EXPANSION DUE TO ALKALI-AGGREGATE REACTION," Proceedings of the American Concrete Institute, January 1944, Vol. 40, No. 3, pp. 205-212. Discussion by T.E. Stanton, Proceedings of the American Concrete Institute, June 1944, Vol. 40, No. 3, p. 212-1.

KEY WORDS: alkali aggregate reactions; expansion; test methods

1944

1058. Hansen, W. C., "STUDIES RELATING TO THE MECHANISM BY WHICH THE ALKALI- AGGREGATE REACTION PRODUCES EXPANSION IN CONCRETE," Journal of the American Concrete Institute, January 1944, Vol. 15, No. 3, pp. 213-27; Proceedings, Vol. 40. Tremper, B., Stanton, T.E., Kalousek, G.L., Discussion, Journal of the American Concrete Institute, June, 1944, Vol. 1, pp. 228-1 to 228-12.

KEY WORDS: alkali aggregate reactions; expansion; mechanisms

1059. McConnell, D. and Irwin, W. H., "NOTES ON THE BEHAVIOR OF ZEOLITES IN MORTAR BARS (WITH APPENDIX ON THE IDENTIFICATION OF A ZEOLITE IN SIERRA GRANITE AGGREGATE)," U.S. Bureau of Reclamation, Petrographic Laboratory Report No. Pet-62. Bureau of Reclamation, Denver, Colorado, April, 1944. Building Science Abstracts, 1948, Vol. 21, 296.

KEY WORDS: mortar bars; zeolites; aggregates

1060. Parsons, W. H. and Insley, H., "ALKALI ETCHING TESTS ON CONCRETE AGGREGATES," Journal of the American Concrete Institute, 1944, Vol. 15, No. 3, pp. 299-243; Proceedings, Vol. 40. Technical News Bulletin, January 1944, No. 321, p. 4. Discussion of above Paper, Supplement p. 244-1.

KEY WORDS: aggregates; test methods

1061. Runner, D. G., "A STUDY OF THE PAT TEST FOR DETERMINING ALKALI REACTIVE AGGREGATES," Public Roads, 1944, Vol. 24, No. 2, pp. 47-54.

KEY WORDS: reactive aggregates; test methods

1062. Runner, D. G., "TESTS TO DETERMINE ALKALI-REACTIVE AGGREGATES," Concrete, 1944, Vol. 52, pp. 154-156.

KEY WORDS: reactive aggregates; test methods

1944

1063. Sporn, P. and Kammer, H.A., "REPAIRS TO BUCK POWERHOUSE AND DAM," Civil Engineering, July 1944, p. 285.

KEY WORDS: dam structures; field experiences; repairs

1064. Tremper, B. Stanton, T.E., Kalousek, G.L. and Hansen, W.C., "STUDIES RELATING TO THE MECHANISM BY WHICH THE ALKALI-AGGREGATE REACTION PRODUCES EXPANSION IN CONCRETE," Proceedings of the American Concrete Institute, 1944, Vol. 40, No. 6, p. 228.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion

1065. Tremper, B., "THE EFFECT OF ALKALIES IN PORTLAND CEMENT ON THE DURABILITY OF CONCRETE," Journal of the American Concrete Institute, November 1944, Vol. 16, pp. 89-104; Proceedings, Vol. 41. Chemical Abstracts, Vol. 39, 1523.3.

KEY WORDS: alkali aggregate reactions; alkali effects

1066. Alderman, A. R., Gaskin, A.J. and Vivian, H.E., "A QUALITATIVE TEST FOR CEMENT-AGGREGATE REACTION," Journal of the Council for Scientific and Industrial Research, November 1945, Vol. 18, No. 4, pp. 433-440. Chemical Abstracts 1946, Vol. 40, 3581.

KEY WORDS: alkali aggregate reactions; test methods

1067. Blanks, R. F. and Meissner, H.S., "DETERIORATION OF CONCRETE DAMS DUE TO ALKALI-AGGREGATE REACTION," Proceedings of the American Society of Civil Engineers, 1945, Vol. 41, January, No. 1, pp. 3-18; June, No.6, p. 722; Transactions 1946, Vol. 111, pp. 793-804. Discussions, Proceedings of The American Society of Civil Engineers, 1945, Vol. 71, p. 1089. Author's Closure, Proceedings of American Society of Civil Engineers, 1946, Vol. 72, p. 655; Transactions, 1946, Vol. 141, pp. 793. Chemical Abstracts, 1946, Vol. 40, 3582.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences

1068. Jackson, F. H., "DISINTEGRATION OF BRIDGE CONCRETE IN THE WEST," Public Roads, 1945, No. 24, May-June, p. 98.

KEY WORDS: bridge structures; deterioration; field experiences; U.S.A.

1069. Mather, B., "DISCUSSION OF PAPER BY BEAN, L. AND TREGONING, J.J., Journal of the American Concrete Institute, 1944. Vol. 16, No. 1, pp. 37-52," Journal of the American Concrete Institute, November 1945, Vol. 16, Supplement 52-1 to 52-4; Proceedings, Vol. 41.

KEY WORDS: reactive aggregates; alkali effects

1070. McConnell, D. and Irwin, W.H., "NOTES ON CEMENT-AGGREGATE REACTION IN CONCRETE," American Mineralogist, 1945, Vol. 30, pp. 78-80.

KEY WORDS: alkali aggregate reactions

1945

1071. McConnell, D., "PETROGRAPHIC EXAMINATION OF CONCRETE SAMPLES FROM COOLIDGE DAM," U.S. Bureau of Reclamation, Petrographic Laboratory Report No. Pet-70, May 1945, 28 pages. Building Science Abstracts, 1948, Vol. 21, 298.

KEY WORDS: dam structures; petrography; field experiences; U.S.A.

1072. McConnell, D. and Mielenz, R.C., "PETROGRAPHIC EXAMINATIONS OF CONCRETE FROM PAVEMENTS NEAR PHOENIX, ARIZONA, OF CONCRETE FROM MORMON FLATS DAM, AND OF CONCRETE AGGREGATE FROM PHOENIX, ARIZONA," U.S. Bureau of Reclamation, Petrographic Laboratory Report No. Pet-74, Bureau of Reclamation, Denver, Colorado, September 1945. Building Science Abstracts, 1948, Vol. 21, 297.

KEY WORDS: petrography; field experiences; U.S.A.; reactive aggregates

1073. Blanks, R. F. and Meissner, H. S., "THE EXPANSION TEST AS A MEASURE OF ALKALI-AGGREGATE REACTION," Journal of the American Concrete Institute, April 1946, Vol. 17, No. 5, pp. 517-540; Proceedings, Vol. 42.

KEY WORDS: alkali aggregate reactions; expansion; test methods

1074. Blanks, R. F., "EFFECT OF ALKALIES IN PORTLAND CEMENT ON DURABILITY OF CONCRETE," American Society for Testing and Materials, Bulletin No. 142, October 1946, pp. 28-34. Ceramic Abstracts, 1948, Vol. 31, 170f.

KEY WORDS: alkali effects; cements

1075. Gibson, W. E., "USE OF SAND-GRAVEL AGGREGATE IN CONCRETE," Proceedings of the Kansas Highway Engineering Conference, Kansas State College Bulletin, 1946, Vol. 30, p. 83.

KEY WORDS: "sand-gravel" aggregates; reactive aggregates

1076. Jackson, F. H., "THE DURABILITY OF CONCRETE IN SERVICE," Proceedings of the American Concrete Institute, October 1946, Vol.43, No.2, pp. 165-180.

KEY WORDS: durability; field experiences

1077. Kammer, H. A., "ALKALI-AGGREGATE REACTION," Transactions of the American Society of Civil Engineers, 1946, Vol. 111, pp. 766.

KEY WORDS: alkali aggregate reactions

1078. Lerch, W., "STUDIES OF THE ALKALI-AGGREGATE REACTION PART I - TESTS FOR SANDS AND COARSE AGGREGATE FROM DIFFERENT SOURCES FOR ALKALI AGGREGATE REACTION; PART II - THE EFFECT OF THE GYPSUM CONTENT OF THE CEMENT, AND POWDERED ADMIXTURES ON THE ALKALI-AGGREGATE REACTION," Portland Cement Association, Research Laboratory Report, November 1946.

1946

KEY WORDS: alkali aggregate reactions; reactive aggregates; cements

1079. Meissner, H. S., "DETERIORATION OF CONCRETE DAMS DUE TO ALKALI-AGGREGATE REACTION," Transaction of the American Society of Civil Engineers, 1946, Vol. 111, p. 743.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences

1080. Mielenz, R. C., "PETROGRAPHIC EXAMINATION OF CONCRETE AGGREGATES," Bulletin of Geological Society of America, April 1946, Vol. 57, p. 309.

KEY WORDS: petrography; aggregates

1081. Oakley, K. P., "THE NATURE AND ORIGIN OF FLINT," Science Progress, London, 1946, Vol. 34, pp. 277-286.

KEY WORDS: flint; reactive aggregates

1082. Spencer, R. W., "ALKALI-AGGREGATE REACTION," Transactions of the American Society of Civil Engineers, 1946, Vol. 111, p. 776.

KEY WORDS: alkali aggregate reactions

1083. Stanton, T. E., "ALKALI-AGGREGATE REACTION," Transactions of the American Society of Civil engineers, 1946, Vol. 111, p. 768.

KEY WORDS: alkali aggregate reactions

1084. Alderman, A. R., Gaskin, A. J., Jones, R. H. and Vivian, H. E., "AUSTRALIAN AGGREGATES AND CEMENT," Studies in Cement-Aggregate Reaction I, Australia, CSIRO Bulletin No. 229, 1947, pp. 1-46.

KEY WORDS: alkali aggregate reactions; reactive aggregates; cements

1085. Bureau of Reclamation, "CALCINED REACTIVE SILICIOUS MATERIAL FOR USE IN CONCRETE," U.S. Department of Interior, Bureau of Reclamation, Denver, Colorado, Specification No. 1904, 21 August 1947.

KEY WORDS: pozzolans; mineral admixtures; silica; preventive measures

1086. Bureau of Reclamation, "DURABILITY OF CONCRETE CONTAINING REACTIVE AGGREGATE FROM A PIT NEAR KIMBALL, NEBRASKA," U.S. Dept. of the Interior, Bureau of Reclamation, Materials Laboratory Report No. C-361, 1 November 1947, 8 pages.

KEY WORDS: alkali aggregate reactions; durability

1087. Gaskin, A. J., "THE EFFECT OF CARBON DIOXIDE," Studies in Cement-Aggregate Reaction VI, Australia, CSIRO Bulletin No. 229, 1947, pp. 78-84.

KEY WORDS: alkali aggregate reactions; carbon dioxide effects; mechanisms

1088. Hanna, W. C., "UNFAVORABLE CHEMICAL REACTIONS OF AGGREGATES IN CONCRETE AND A SUGGESTED CORRECTIVE," Proceedings of the American Society for Testing and Materials, 1947, Vol. 47, pp. 986-999. Discussion, pp. 1000-1009.

KEY WORDS: alkali aggregate reactions; preventive measures

1947

1089. McConnell, D. Mielenz, R.C., Holland, W.Y., and Green, K.T., "CEMENT-AGGREGATE REACTION IN CONCRETE," Journal of American Concrete Institute, 1947, Vol. 19, No. 2, pp. 93-128; Proceedings, Vol. 44. Applied Mechanics Review, August 1949, Vol. 2, No. 8, p. 180. Beton-Teknik, 1948, Vol. 14, No. 1, p. 35.

KEY WORDS: alkali aggregate reactions

1090. Mielenz, R. C. and McConell, D., "TESTING CHEMICAL REACTIVITY OF CONCRETE AGGREGATE," Rock Products, October 1947, Vol. 50, No. 10, pp. 112- 113.

KEY WORDS: reactive aggregates; test methods; chemical tests

1091. Runner, D. G., "ROCK WEATHERING AS A POSSIBLE FACTOR IN THE ALKALI AGGREGATE REACTION," Pit and Quarry, July 1947, Vol. 40, No. 1, pp. 102-103.

KEY WORDS: alkali aggregate reactions; rock weathering; reactive aggregates

1092. Stanton, T. E., "DURABILITY OF CONCRETE AS AFFECTED BY AGGREGATE," Paper Presented at Joint Session of National Sand and Gravel Association and National Ready-mixed Concrete Association, Los Angeles, 6 March 1947.

KEY WORDS: durability; aggregates

1093. Steele, B. W., "CRACKS IN CONCRETE," Proceedings of the American Concrete Institute, February 1947, Vol. 43, No. 6, pp. 629-636.

KEY WORDS: cracking; field experiences

1094. Vivian, H. R., "THE EFFECT OF ALKALI MOVEMENT IN HARDENED MORTAR," Studies in Cement-Aggregate Reaction II, Australia, CSIRO Bulletin No. 229, 1947, pp. 47-54.

1947

KEY WORDS: alkali aggregate reactions; pore solutions; mortar bars

1095. Vivian, H. E., "THE EFFECT OF STORAGE CONDITIONS ON EXPANSION AND TENSILE STRENGTH CHANGES OF MORTAR," Journal of Council for Scientific and Industrial Research (Australia), 1947, Vol. 20, No. 4, pp. 585- 594. Chemical Abstracts, 1948, Vol. 42, 5641a.

KEY WORDS: alkali aggregate reactions; expansion; tensile strength; test methods

1096. Vivian, H. E., "THE EFFECT OF VOID SPACE ON TENSILE STRENGTH CHANGES OF MORTAR," Studies in Cement-Aggregate Reaction IV, Australia, CSIRO Bulletin No. 229, 1947, pp. 74-77.

KEY WORDS: alkali aggregate reactions; mortar bars; tensile strength

1097. Vivian, H. E., "THE EFFECT OF EXPANSION ON THE TENSILE STRENGTH OF MORTAR," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 229, 1947, pp. 67-73.

KEY WORDS: alkali aggregate reaction; mortar bars ; expansion; tensile strength

1098. Vivian, H. E., "THE EFFECT OF VOID SPACE ON MORTAR EXPANSION," Studies in Cement-Aggregate Reaction III, Australia, CSIRO Bulletin No. 229, 1947, pp. 55-56.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars

1099. Allen, C. W., "INFLUENCE OF MINERAL AGGREGATES ON THE STRENGTH AND DURABILITY OF CONCRETE," American Society for Testing and Materials, Special Technical Publication No. 83, 1948, pp. 152-159.

KEY WORDS: strength; aggregates

1100. Anon., "CONCRETE DETERIORATION," Engineering News-Record, 1948, Vol. 140, No. 1, p. 11.

KEY WORDS: deterioration

1101. ASTM, "SYMPOSIUM ON METHODS AND PROCEDURES USED IN IDENTIFYING REACTIVE MATERIALS IN CONCRETE," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1055-1125.

KEY WORDS: test methods; reactive aggregates; conferences

1102. Blanks, R. F. and Price, W. H., "NEW DEVELOPMENTS IN CONCRETE AND APPLICATIONS IN THE DESIGN AND CONSTRUCTION OF CONCRETE DAMS," Proceedings of the 3rd International Congress on Large Dams, Stockholm 1948, Vol. III, Q.11, R.62.

KEY WORDS: dam structures

1103. Burwell, E. B., Jr., "ANDESITE AGGREGATE - BACK IN 1928," Journal of American Concrete Institute, September 1948, Vol. 45, No. 1, p. 84.

KEY WORDS: andesite; reactive aggregates

1104. Hutton, C. O., "PROBLEM OF REACTION BETWEEN AGGREGATE MATERIALS AND HIGH ALKALI-CEMENTS," New Zealand Journal of Science and Technology, 1945, Vol. 26B, No. 4, pp. 191-200. Ceramic Abstracts, 1948, No. 27, 171e.

KEY WORDS: alkali aggregate reactions; alkali effects

1948

1105. Lerch, W. and Ford, C. L., "LONG-TIME STUDY OF CEMENT PERFORMANCE IN CONCRETE, CHAPTER 3 - CHEMICAL AND PHYSICAL TESTS OF THE CEMENTS," Journal of the American Concrete Institute, April 1948, Vol. 44, No. 10, pp. 745-796.

KEY WORDS: cements; test methods

1106. Mather, B., "DISCUSSIONS OF AGGREGATE REACTIVITY AND ITS EFFECT ON THE DURABILITY OF CONCRETE," U.S. Army Corps of Engineers, Office of the Chief of Engineers. Concrete Durability Conference, 1948, pp. 63-67.

KEY WORDS: alkali aggregate reactions; durability

1107. Mather, B., "PETROGRAPHIC IDENTIFICATION OF REACTIVE CONSTITUENTS IN CONCRETE AGGREGATE," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1120-1125. Chemical Abstracts, 1950, Vol. 44, 3693h.

KEY WORDS: petrography; reactive aggregates

1108. Mather, B., "CHEMICAL REACTIVITY OF DOLERITE (DIABASE)," Journal of the American Concrete Institute, June 1948, Vol. 44, No. 10, pp. 1058-1060.

KEY WORDS: dolerite; reactive aggregates

1109. McConnell, D., Mielenz, R. C. and Holland, W. Y., "CEMENT-AGGREGATE REACTION IN CONCRETE," Proceedings of the American Concrete Institute, 1948, Vol. 44, pp. 93-128.

KEY WORDS: alkali aggregate reactions

1110. Meissner, H. S., "EXPANSION CRACKS CAUSED IN CONCRETE DAMS, BY ACID AGGREGATES AND CEMENT WITH HIGH-ALKALI CONCRETE," 3rd International Congress on Large Dams, Stockholm, June 1948. Revue des Materiaux et Constructions, February 1949, No. 401, p. 54.

KEY WORDS: dam structures; alkali aggregate reactions;

field experiences

1111. Mielenz, R. C. and Witte, L. P., "TESTS USED BY THE BUREAU OF RECLAMATION FOR IDENTIFYING REACTIVE CONCRETE AGGREGATES," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1071-1107. Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, Materials Laboratory Report No. C-400, 3 September 1948.

KEY WORDS: reactive aggregates; test methods

1112. Mielenz, R. C., Green, K. T. and Benton, E. J., "CHEMICAL TEST FOR THE REACTIVITY OF AGGREGATES WITH CEMENT ALKALIES: CHEMICAL PROCESSES IN CEMENT-AGGREGATE REACTION," Proceedings of the American Concrete Institute, 1948, Vol. 44, pp. 193-221; Discussion, pp. 224-1 to 224-4.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; chemical tests

1113. Parsons, W. H. and Insley, H., "AGGREGATE REACTION WITH CEMENT ALKALIES," Journal of the American Concrete Institute, April 1948, Vol. 19. No. 4, pp. 625-632; Proceedings, Vol. 44. Chemical Abstracts, 1948, Vol. 42, 6075g. Discussion of above Paper, Journal of the American Concrete Institute, December 1948, Vol. 19, No. 12, Supplement 632-1 to 632-6.

KEY WORDS: alkali aggregate reactions; mechanisms

1114. Rexford, E. P., "DISCUSSION OF AGGREGATE REACTIVITY AND ITS EFFECT ON THE DURABILITY OF CONCRETE," Proceedings of Concrete Durability Conference, U.S. Department of the Army, Office of the Chief of Engineers, 1948, pp. 40-56.

KEY WORDS: reactive aggregates; durability

1115. Rhoades, R. and Mielenz, R.C., "PETROGRAPHIC AND MINERALOGICAL CHARACTERISTICS OF AGGREGATES," American

1948

Society for Testing and Materials, Symposium on Mineral Aggregates. ASTM Special Technical Publication No. 83, 1948, pp. 20-48.

KEY WORDS: reactive aggregates; petrography

1116. Scholer, C. H. and Gibson, W. E., "THE EFFECT OF VARIOUS COARSE AGGREGATES UPON THE CEMENT-AGGREGATE REACTION," Journal of the American Concrete Institute, June 1848, Vol. 19, pp. 1009-1032. Kansas State College, Bulletin No. 58, 15 July 1948.

KEY WORDS: alkali aggregate reactions; reactive aggregates

1117. Sprague, J. C. and Mather, B., "DISCUSSION OF AGGREGATE REACTIVITY AND ITS EFFECT ON THE DURABILITY OF CONCRETE," U.S. Department of the Army, Corps of Engineers, Concrete Durability Conference, 1948, pp. 55-56.

KEY WORDS: reactive aggregates; durability

1118. Sprague, J. C., "DISCUSSION OF AGGREGATE REACTIVITY AND ITS EFFECT ON THE DURABILITY OF CONCRETE," U.S. Department of the Army, Corps of Engineers, Concrete Durability Conference, 1948, pp. 56-60.

KEY WORDS: reactive aggregates; durability

1119. Stanton, T. E., "CORRELATION OF LABORATORY TESTS WITH FIELD EXPERIENCE OF EXCESSIVE CONCRETE EXPANSION INDUCED BY A REACTION BETWEEN THE CEMENT AND AGGREGATE," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1057-1062; Discussion pp. 1063-1064. Chemical Abstracts., 1950, Vol. 44, 3693f.

KEY WORDS: alkali aggregate reactions; expansion; test methods; field experiences

1120. Stanton, T. E., "DURABILITY OF CONCRETE EXPOSED TO SEA WATER AND ALKALI SOILS - CALIFORNIA EXPERIENCE," Journal of

the American Concrete Institute, May 1948, Vol. 19, No. 9, pp. 821-847; Proceedings,Vol. 44. Discussion, Journal of the American Concrete Institute, December 1948, Supplement pp. 848-1 to 848-18. Beton-Teknik 1948, Vol. 14, No. 3, pp. 96-97.

KEY WORDS: durability; sea water; alkali soils; field experiences; U.S.A.

1121. Steele, B. W., "CONCRETE IN LARGE DAMS: PAST, PRESENT AND FUTURE," Proceedings of 3rd International Congress on Large Dams, Stockholm, 1948, Vol. III, Q11, R44.

KEY WORDS: dam structures

1122. Sweet, H. S., "RESEARCH ON CONCRETE DURABILITY AS AFFECTED BY COARSE AGGREGATE," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, p. 988.

KEY WORDS: durability; aggregates

1123. Sweet, H. S., "PHYSICAL AND CHEMICAL TESTS OF MINERAL AGGREGATES AND THEIR SIGNIFICANCE," American Society for Testing and Materials, Symposium on Mineral Aggregates, Special Technical Publication No. 83, 1948, pp. 49-73. Chemical Abstracts, Vol. 43, 5167h.

KEY WORDS: aggregates; test methods

1124. Terzaghi, R. D., "CONCRETE DETERIORATION IN A SHIPWAY," Proceedings of the American Concrete Institute, 1948, Vol. 44, pp. 977-1005.

KEY WORDS: deterioration; field experiences

1125. Tremper, B., "CORRELATION OF LABORATORY TESTS WITH FIELD EXPERIENCE IN ALKALI-AGGREGATE REACTION," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1057-1070. Chemical Abstracts, Vol. 42, 6078f.

1948

KEY WORDS: alkali aggregate reactions; field experiences; test methods

1126. U.S. Army Corps of Engineers, "AGGREGATE REACTIVITY AND ITS EFFECT ON THE DURABILITY OF CONCRETE," Proceedings of Concrete Durability Conference, U.S. Army Corps of Engineers, Office of the Chief of Engineers, 1948.

KEY WORDS: durability; reactive aggregates

1127. Vivian, H. E., "THE EXPANSION OF COMPOSITE MORTAR BARS," Journal of the Council for Scientific and Industrial Research, Australia, 1948, Vol. 21, No. 2, pp. 148-159.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars

1128. Woolf, D. O. and Smith, T.R., "A RAPID METHOD OF TESTING MATERIALS FOR THE ALKALI-AGGREGATE REACTION," Proceedings of the American Society for Testing and Materials, 1948, Vol. 48, pp. 1108-1114. Discussion, p. 1115.

KEY WORDS: alkali aggregate reactions; test methods

1129. Anon., "ADMIXTURE COMBATS ALKALI REACTION IN DAVIS DAM CONCRETE," Engineering News-Record, 20 January 1949, Vol. 142, No. 3, pp. 83-85.

KEY WORDS: dam structures; alkali aggregate reactions; mineral admixtures; silica

1130. Blanks, R. F., "MODERN CONCEPTS APPLIED TO CONCRETE AGGREGATE," Proceedings of the American Society of Civil Engineers, April 1949, Vol. 75, pp. 441-468; Transaction, 1950, Vol. 115, p. 403.

KEY WORDS: aggregates

1131. Blanks, R. F., "THE USE OF PORTLAND-POZZOLAN CEMENT BY THE BUREAU OF RECLAMATION," Proceedings of the American Concrete Institute, October 1949, Vol. 46, No. 4, pp. 89-108.

KEY WORDS: cements; pozzolans; mineral admixtures; preventive measures

1132. Gilbert, J. R., "THE U.S. CORPS OF ENGINEERS' APPROACH TO MORE DURABLE CONCRETE," The Crushed Stone Journal, June 1949, Vol. 24, No. 2, pp. 3-30.

KEY WORDS: durability; aggregates

1133. Gilliland, J. L. and Moran, W. T., "SILICEOUS ADMIXTURE SPECIFIED FOR DAVIS DAM CONCRETE," Engineering News-Record, 3 February 1949, Vol. 142, No. 5, pp. 62-64. Engineering Index No. 49-6106.

KEY WORDS: silica; mineral admixtures; pozzolans; dam structures; preventive measures

1134. Jackson, F. H. and Timms, A. G., "VOLUME CHANGES IN SAND-GRAVEL CONCRETE," Presented at 29th Annual Meeting, Highway Research Board, December 1949. Highway Research Abstracts,

December 1949, Vol. 19, No. 11, p. 26.

KEY WORDS: expansion; "sand-gravel" aggregates; reactive aggregates

1135. Kelly, T. M., Schuman, L. and Hornibrook, G. B., "A STUDY OF ALKALI-AGGREGATE REACTIVITY BY MEANS OF MORTAR BAR EXPANSIONS," Journal of the American Concrete Institute, September 1948, Vol. 20, No. 1, pp. 57-80; Proceedings, Vol. 45. Discussion of above Paper, Journal of the American Concrete Institute, June 1949, Supplement, pp. 80-1 to 80-8.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; test methods

1136. Lea, F. M. and Davey, N., "THE DETERIORATION OF CONCRETE IN STRUCTURES," Journal of the Institution of Civil Engineers, 1949, Vol. 32, p. 248.

KEY WORDS: deterioration; field experiences

1137. Lenhard, W. B., "AGGREGATES FOR DAVIS DAM," Rock Products, June 1949, Vol. 52, No. 6, pp. 101-103.

KEY WORDS: aggregates; dam structures

1138. Scholer, C. H., "A WETTING AND DRYING TEST FOR PREDICTING CEMENT-AGGREGATE REACTION," Proceedings of the American Society for Testing and Materials, 1949, Vol. 49, pp. 942-953.

KEY WORDS: alkali aggregate reactions; test methods

1139. Slate, F. O., "CHEMICAL REACTION OF INDIANA AGGREGATE IN DISINTEGRATION OF CONCRETE," Proceedings of the American Society for Testing and Materials, 1949, Vol. 49, pp. 954-963.

KEY WORDS: deterioration; aggregates

1949

1140. Stanton, T. E., "STUDIES OF USE OF POZZOLANS FOR COUNTERACTING EXCESSIVE CONCRETE EXPANSION RESULTING FROM REACTION BETWEEN AGGREGATE AND THE ALKALIES IN CEMENT," American Society for Testing and Materials, Special Technical Publication No. 99, 1949, pp. 178-301.

KEY WORDS: alkali aggregate reactions; expansion; pozzolans; preventive measures

1141. Woods, K. B., "RESEARCH AS A FACTOR IN DEVELOPMENT OF AGGREGATE SPECIFICATIONS," Paper Presented at the Mississippi Valley Conference of State Highway Department, Chicago, Illinois, 11 March 1949.

KEY WORDS: aggregates

1142. Woolf, D. O. and Smith, T.R., "RAPID TEST FOR ALKALI-AGGREGATE REACTION," Concrete, 1949, Vol. 57, No. 2, pp. 18-20, 22. Chemical Abstracts, Vol. 43, 35891.

KEY WORDS: alkali aggregate reactions; test methods

1143. Alderman, A. R., Gaskin, A. J., Jones, R. J. and Vivian, H. E., "AUSTRALIAN AGGREGATES AND CEMENTS IN RELATION TO CEMENT-AGGREGATE REACTION," Proceedings of the American Concrete Institute, April 1950, Vol, 46, pp. 613-616.

KEY WORDS: alkali aggregate reactions; reactive aggregates; cements; Australia

1144. Anon., "SOME STUDIES TO MINIMIZE ALKALI-AGGREGATE REACTION TROUBLES," Concrete, 9 January 1950.

KEY WORDS: alkali aggregate reactions; preventive measures

1145. ASTM, "SYMPOSIUM ON USE OF POZZOLANIC MATERIALS IN MORTARS AND CONCRETE," American Society for Testing and Materials, Special Technical Publication, No. 99, 1950, 203 pages.

KEY WORDS: pozzolans; mineral admixtures; preventive measures; conferences

1146. Backstrom, J. E., "INVESTIGATION OF ASPHALTIC COATINGS OF AGGREGATE FOR CONTROLLING EXPANSION DUE TO ALKALI-AGGREGATE REACTION AND OTHER CAUSES," U.S. Bureau of Reclamation, Materials Laboratory Report No. C-507, Denver, Colorado, 1950, 7 pages.

KEY WORDS: alkali aggregate reactions; aggregates; asphaltic coating; expansion; preventive measures

1147. Blanks, R. F., "SOME STUDIES TO MINIMIZE ALKALI-AGGREGATE REACTION TROUBLES," Concrete, January 1950, p. 9.

KEY WORDS: alkali aggregate reaction; preventive measures

1148. Blanks, R. F., "FLY ASH AS A POZZOLAN," Proceedings of the American Concrete Institute, May 1950, Vol. 46, p. 601.

KEY WORDS: fly ash; pozzolans; mineral admixtures; preventive measures

1950

1149. Cox, H. P., Coleman, R.B. and White, L., "EFFECT OF BLASTFURNACE-SLAG CEMENT ON ALKALI-AGGREGATE REACTION IN CONCRETE," Pit and Quarry, November 1950, Vol. 45, No. 5, pp. 95- 96.

KEY WORDS: alkali aggregate reactions; slag; mineral admixtures; preventive measures

1150. Davis, R. E., "POZZOLANIC MATERIALS AND THEIR USE IN CONCRETE," American Society for Testing and Materials, Special Technical Publication No. 99, 1950, pp. 3-15.

KEY WORDS: pozzolans; mineral admixtures; preventive measures

1151. Davis, R. E., Hanna, W. D. and Brown, E. H., "STRENGTH, VOLUME CHANGES, AND SULFATE RESISTANCE OF MORTARS CONTAINING PORTLAND-POZZOLAN CEMENT," American Society for Testing and Materials, Special Technical Publication No. 99, 150, pp. 131-152.

KEY WORDS: cements; pozzolans; strength; expansion; sulfate resistance

1152. Gaskin, A. J., "CARBON DIOXIDE AND THE CEMENT-AGGREGATE REACTION," Journal of the American Concrete Institute, 1950, Vol. 21, No. 8, pp. 625-627; Proceedings Vol. 46.

KEY WORDS: alkali aggregate reactions; carbon dioxide; carbonation; preventive measures

1153. Gilliland, J. L. and Bartley, T. R., "WATER SOLUBILITY OF ALKALIES IN PORTLAND CEMENT," Journal of the American Concrete Institute, 1950, Vol. 22, pp. 153-60; Proceedings Vol. 47.

KEY WORDS: alkali effects; cements

1950

1154. Jones, H. R. and Vivian, H.E., "STUDIES IN CEMENT-AGGREGATE REACTION. PART IX, SOME OBSERVATIONS ON MORTAR CONTAINING REACTIVE AGGREGATE," Australia, Commonwealth Scientific and Industrial Research Organization, Bulletin No. 256, 1950, pp. 7-12.

KEY WORDS: alkali aggregate reactions; mortar bars; reactive aggregates

1155. Kennedy, T. B., "CONCRETE AGGREGATE," Transactions of the American Society of Civil Engineers. 1950, Vol. 115, p. 432.

KEY WORDS: aggregates

1156. Lerch, W., "STUDIES OF SOME METHODS OF AVOIDING EXPANSION AND PATTERN CRACKING ASSOCIATED WITH ALKALI-AGGREGATE REACTION," Portland Cement Association, Research and Development Laboratories Bulletin No. 31, 1950, 26 pages. American Society for Testing and Materials, Special Technical Publication No. 99, Philadelphia, PA, February 1950, pp. 153-177.

KEY WORDS: alkali aggregate reactions; expansion; cracking; preventive measurements

1157. Mather, B., "CONCRETE AGGREGATES," Proceedings of the American Society for Testing and Materials, 1950, Vol. 115, pp. 1288-1313.

KEY WORDS: aggregates

1158. Mather, K. and Mather, B., "METHODS OF PETROGRAPHIC EXAMINATION OF AGGREGATES FOR CONCRETE," Bulletin of the American Society for Testing and Materials, 1950, Vol. 50, pp. 1288-1313.

KEY WORDS: aggregates; petrography

1950

1159. McConnell, D., Mielenz, R. C., Holland, W. Y. and Green, K. T., "PETROGRAPHY OF CONCRETE AFFECTED BY CEMENT-AGGREGATE REACTION," Engineering Geology, Geological Society of America, 1950, pp. 255-50. Chemical Abstracts, February 1951, Vol. 45, No. 4, 1747c.

KEY WORDS: alkali aggregate reactions; petrography

1160. Meissner, H. S., "POZZOLANS USED IN MASS CONCRETE," American Society for Testing and Materials, Special Technical Publication, No. 99, 1950, pp. 16-30.

KEY WORDS: pozzolans; mineral admixtures; mass concrete

1161. Mielenz, R. C., Witte, L. P. and Glanz, O. J., "EFFECT OF CALCINATION ON NATURAL POZZOLANS," American Society for Testing and Materials, Special Technical Publication No. 99, 1950, pp. 43-92.

KEY WORDS: pozzolans; mineral admixtures; preventive measures

1162. Moran, W. T., "USE OF ADMIXTURES TO COUNTERACT ALKALI-AGGREGATE REACTION," Proceedings of the American Concrete Institute, 1950, Vol. 47, p. 43.

KEY WORDS: alkali aggregate reaction; mineral admixtures; preventive measures

1163. Moran, W. T. and Gilliland, J. L., "SUMMARY OF METHODS FOR DETERMINING POZZOLANIC ACTIVITY," American Society for Testing and Materials, Special Technical Publication No. 99, 1950, pp. 109-125.

KEY WORDS: pozzolans; test methods; preventive measures

1164. Moran, W. T., Jackson, F. H., Foster, B. E. and Powers, T. C., "ADMIXTURES IN CONCRETE," Proceedings of the American Concrete Institute, September 1950, Vol. 47, No. 3, pp. 25-52.

1950

KEY WORDS: admixtures

1165. Scholer, C. H. and Peyton, R. L., "EXPERIENCE WITH POZZOLANIC MATERIALS IN KANSAS," American Society for Testing and Materials, Special Technical Publication No. 99, 1950, pp. 31-42.

KEY WORDS: pozzolans; mineral admixtures; preventive measures; field experiences; U.S.A.

1166. Vivian, H. E., "THE EFFECT ON MORTAR EXPANSION OF AMOUNT OF REACTIVE COMPONENT IN AGGREGATE," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 13-20.

KEY WORDS: alkali aggregate reactions; expansion; reactive aggregates; mortar bars

1167. Vivian, H. E., "THE EFFECT OF MORTAR EXPANSION OF AMOUNT OF AVAILABLE WATER IN MORTAR," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 21-30.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars

1168. Vivian, H. E., "THE EFFECT OF ADDED SODIUM HYDROXIDE ON THE TENSILE STRENGTH OF MORTAR," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 48-52.

KEY WORDS: alkali aggregate reactions; tensile strength; mortar bars; alkali effects

1169. Vivian, H. E., "THE EFFECT OF AMOUNT OF ADDED ALKALIES ON MORTAR EXPANSION," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 31-47.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; alkali effects

1950

1170. Vivian, H. E., "THE REACTION PRODUCT OF ALKALIES AND OPAL," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 60-81.

KEY WORDS: alkali aggregate reactions; opal; reactive aggregates; alkali-silica gel

1171. Vivian, H. E., "THE EFFECT OF SMALL AMOUNTS OF REACTIVE COMPONENT IN THE AGGREGATE ON THE TENSILE STRENGTH OF MORTAR," Studies in Cement-Aggregate Reaction, Australia, CSIRO Bulletin No. 256, 1950, pp. 53-59.

KEY WORDS: alkali aggregate reactions; tensile strength; mortar bars; reactive aggregates

1172. Vivian, H. E., "SOME AUSTRALIAN STUDIES ON CEMENT-AGGREGATE REACTION IN MORTAR," Proceedings of the American Concrete Institute, April 1950, Vol. 46, p. 617.

KEY WORDS: alkali aggregate reactions; mortar bars; test methods; mechanisms; Australia

1173. Walker, S. and Bloem, D.L., "THE PROBLEM OF DELETERIOUS PARTICLES IN AGGREGATES," National Sand and Gravel Association, Circular No. 35, 1950.

KEY WORDS: aggregates; deleterious particles

1174. Wheeler, W. E., "CONCRETING METHODS AT HUNGRY HORSE," Western Construction News, 15 April 1950; 15 May 1950.

KEY WORDS: dam structures

1175. Woods, K. B., "AGGREGATES AND THEIR INFLUENCE ON DURABILITY OF CONCRETE," Crushed Stone Journal, March 1950, Vol. 25, No. 1, p. 21. Engineering Index, 1950 - 12136.

KEY WORDS: aggregates; durability

1176. Anon., "THE PROBLEM OF ALKALI-SENSITIVE AGGREGATES AND THEIR INVESTIGATION," Zement-Kalk-Gips, 1951, Vol. 4, No. 8, pp. 216-221.

KEY WORDS: alkali aggregate reaction; aggregates

1177. Anon., "SELECTED BIBLIOGRAPHY ON EFFECT OF ALKALIES IN CEMENT ON DURABILITY OF CONCRETE," Bureau of Reclamation (U.S. Department of Interior), Technical Bibliography No. 216, 1951, 40 pages.

KEY WORDS: alkali effects; durability; bibliography

1178. Barona de la O, F., "ALKALI-AGGREGATE EXPANSION CORRECTED WITH PORTLAND-SLAG CEMENT," Journal of the American Concrete Institute, 1951, Vol. 22, No. 7, pp. 545-552.

KEY WORDS: alkali aggregate reactions; expansion; slag; mineral admixtures; preventive measures

1179. Blanks, R. F., Meissner, H.S., and Cordon, W.A., "THE PROPERTIES OF MASS CONCRETE MADE WITH COMBINATION OF PORTLAND POZZOLAN CEMENT AS USED BY BUREAU OF RECLAMATION," Proceedings of the 4th International Congress on Large Dams, New Delhi, 1951, Vol III, Q.15, R.37.

KEY WORDS: dam structures; pozzolans; mineral admixtures; preventive measures

1180. Davis, C. E. S., "THE EFFECT OF SODA CONTENT AND COOLING RATE OF PORTLAND CEMENT CLINKER ON ITS REACTION WITH OPAL IN MORTAR," Australian Journal of Applied Science, 1951, Vol. 2, pp. 123-131.

KEY WORDS: alkali aggregate reactions; opal; alkali effects; cements

1181. Gonnerman, H. F., "DURABILITY OF CONCRETE IN ENGINEERING STRUCTURES," Building Research Congress, 1951, Collected

1951

Papers (Division 2), pp. 92-104.

KEY WORDS: durability; field experiences

1182. Haskell, W. E., "AN EXAMPLE OF THE DEVELOPMENT OF A TEST METHOD AND ITS PRACTICAL CONSEQUENCES," California Highways and Public Works, 1951, Vol. 30, No. 9/10, pp. 39-41.

KEY WORDS: test methods

1183. Kitagawa, K. I., "A STUDY ON ALKALI-AGGREGATE REACTION, PART 2 (in Japanese)," Cement & Concrete (Japan), No. 5, 1951.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; pozzolans; mineral admixtures; Japan

The discussion was carried out on the results of geological survey, chemical test, and mortar bar test on various aggregates in Japan, and also on the effect of pozzolan on controlling the reaction.

1184. Kondo, Y., "A STUDY ON ALKALI-AGGREGATE REACTION, PART 1 (in Japanese)," Cement & Concrete (Japan), No. 5, 1951.

KEY WORDS: alkali aggregate reactions; field experiences; Japan

A discussion of two bridges damaged by alkali aggregate reaction, and especially on the most damaged part, where volcanic ash was used as an aggregate.

1185. McCoy, W. J. and Caldwell, A.G., "NEW APPROACH TO INHIBITING ALKALI-AGGREGATE EXPANSION," Journal of the American Concrete Institute, May 1951, Vol. 22, No. 9, pp. 693-706; Proceedings, Vol. 47. Beton-Teknik, 1952, Vol. 18, No. 1, pp. 38-39.

KEY WORDS: alkali aggregate reactions; expansion; preventive measures

1951

1186. Midgley, H. G., "CHALCEDONY AND FLINT," Geological Magazine, 1951, Vol. 88, pp. 179-184.

KEY WORDS: reactive aggregates; chalcedony; flint

1187. Palmer, W. H., "NEBRASKA SEEKS MORE DURABLE CONCRETE," Engineering News-Record, 24, May 1951, Vol. 146, No. 21, pp. 28-29.

KEY WORDS: durability

1188. Price, W. H., "FACTORS INFLUENCING CONCRETE STRENGTH," Journal of the American Concrete Institute, 1951, Vol. 22, No. 6, pp. 417-432; Proceedings Vol. 47.

KEY WORDS: strength

1189. Raphael, J. M. and Rawhauser, C., "CRACKING CAUSED BY INTERNAL STRESSES IN LARGE DAMS," Proceedings of 4th International Congress on Large Dams, New Delhi, 1951, Vol. IV, Q15, R13.

KEY WORDS: dam structures; internal stresses; cracking; field experiences

1190. Stanton, T. E., "REPORT ON FURTHER STUDIES TO DEVELOP AN ACCELERATED TEST PROCEDURE FOR THE DETECTION OF ADVERSELY REACTIVE CEMENT AGGREGATE COMBINATIONS," Proceedings of the American Society for Testing and Materials, 1951, Vol. 51, pp. 1087-1096.

KEY WORDS: alkali aggregate reactions; test methods

1191. Steele, B. W., "CONCRETE FOR LARGE DAMS," Proceedings of 4th International Congress on Large Dams, New Delhi, 1951, Vol. III, Q15, R25.

KEY WORDS: dam structures

1951

1192. Vivian, H. E., "SOME EFFECTS OF TEMPERATURE ON MORTAR EXPANSION," Australian Journal of Applied Science, 1951, Vol. 2, pp. 114-122.

KEY WORDS: alkali aggregate reactions; expansion; temperature effects; mechanisms; mortar bars; test methods

1193. Vivian, H. E., "THE EFFECT OF HYDROXYL IONS ON THE REACTION OF OPAL," Australian Journal of Applied Science, 1951, Vol. 2, pp. 108-113.

KEY WORDS: alkali aggregate reactions; opal; hydroxyl ions; alkali effects

1194. Vivian, H. E., "THE EFFECT ON MORTAR EXPANSION OF THE PARTICLE SIZE OF THE REACTIVE COMPONENT IN AGGREGATE," Australian Journal of Applied Science, 1951, Vol. 2, pp. 488-494.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; particle size effects; reactive aggregates

1195. Blanks, R. F., "GOOD CONCRETE DEPENDS ON GOOD AGGREGATE," Civil Engineering, American Society of Civil Engineers, September 1952, p. 651.

KEY WORDS: aggregates

1196. Conrow, A. D., "STUDIES OF ABNORMAL EXPANSION OF PORTLAND CEMENT CONCRETE," Proceedings of the American Society for Testing and Materials, 1952, Vol. 52, pp. 1205-1227.

KEY WORDS: expansion; deterioration

1197. Cook, H. K., "THE REACTION OF ALKALIES IN CEMENT WITH CERTAIN CONSTITUENTS OF MINERAL AGGREGATES," Proceedings of International Symposium on the Reactivity of Solids, Gothenburg, 1952, Part 2, Royal Swedish Academy of Engineering Sciences and Chalmers University of Technology, Gothenburg, 1954, pp. 653-663.

KEY WORDS: alkali aggregate reactions; reactive aggregates

1198. Folk, R. L. and Weaver, C.E., "A STUDY OF THE TEXTURE AND COMPOSITION OF CHERT," American Journal of Science, 1952, Vol. 250, No. 7, pp. 498-510.

KEY WORDS: chert; reactive aggregates

1199. Jones, F. E., et al., "REACTION BETWEEN AGGREGATE AND CEMENT. PART II. ALKALI-AGGREGATE INTERACTION: BRITISH PORTLAND CEMENT AND BRITISH AGGREGATES," Research Paper No. 15, HMSO, London, 1952.

KEY WORDS: alkali aggregate reactions; cements; reactive aggregates; U.K.

1200. Jones, F. E., et al, "REACTION BETWEEN AGGREGATE AND CEMENT. PART I. ALKALI-AGGREGATE INTERACTION: GENERAL.," Research Paper No. 14, HMSO, London, 1952.

1952

KEY WORDS: alkali aggregate reactions

1201. Jones, F. E., et al., "REACTION BETWEEN AGGREGATE AND CEMENT. PART III. ALKALI-AGGREGATE INTERACTION: THE EXPANSION BAR TEST: CEMENTS OF MEDIUM ALKALI CONTENT," Research Paper No. 17, HMSO, London, 1952.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; alkali effects; test methods

1202. Landgren, R. and Sweet, H. S., "INVESTIGATION OF THE DURABILITY OF WYOMING AGGREGATES," Proceedings of the Highway Research Board, 1952, Vol. 31, pp. 202-217.

KEY WORDS: aggregates; durability

1203. Mather, B., "CRACKING OF CONCRETE IN THE TUSCALOOSA LOCK," Proceedings of the Highway Research Board, 1952, Vol. 31, pp. 218-233.

KEY WORDS:
dam structures; cracking; alkali aggregate reactions; field experiences; U.S.A.

1204. Mather, B., "DISCUSSION OF PAPER BY A.D. CONROW, STUDIES OF ABNORMAL EXPANSION OF PORTLAND CEMENT CONCRETE, Proceedings of the American Society for Testing and Materials, 1952, Vol. 52, pp. 1205-1227.," Proceedings of the American Society for Testing and Materials, 1952, Vol. 52, pp. 1226-1227.

KEY WORDS: expansion; alkali aggregate reactions

1205. McGowan, J. K. and Vivian, H. E., "STUDIES IN CEMENT-AGGREGATE REACTION. XX. THE CORRELATION BETWEEN CRACK DEVELOPMENT AND EXPANSION OF MORTAR," Australian Journal of Applied Science, 1952, Vol. 3, pp. 228-232. Chemical Abstracts, January 1953, Vol. 47, No. 1, 287e. Reprint, Australia, Council for Scientific and Industrial Research.

1952

KEY WORDS: alkali aggregate reactions; cracking; expansion; mortar bars

1206. Mielenz, R. C., Green, K. T., Benton, E. J. and Geier, F. H., "CHEMICAL TEST FOR ALKALI REACTIVITY OF POZZOLANS," Proceedings of the American Society for Testing and Materials, 1952, Vol. 52, pp. 1128-1144. Journal of the American Concrete Institute, 1953, Vol. 25, No. 3, p. 268. Beton-Teknik, 1954, Vol. 20, No. 2, p. 53.

KEY WORDS: pozzolans; test methods; chemical tests; preventive measures

1207. Moridaira, S. I., "ON ALKALI-AGGREGATE REACTION IN TSUBURO DAM (in Japanese)," Cement & Concrete (Japan), No. 62, 1952.

KEY WORDS: alkali aggregate reactions; reactive aggregates; phyllite; test methods; Japan

A discussion of a phyllite rock suspicious for alkali aggregate reaction, on which alkali reactivity was examined.

1208. Nerenst, P., "INFLUENCE OF AGGREGATES ON THE DURABILITY OF CONCRETE," Beton-Teknik, 1952, Vol. 18, No. 1, pp. 21-35.

KEY WORDS: aggregates; durability

1209. Porter, C. B., Gilmore, R. W., Jackson, F. H., Tuthill, L. H. and Steele, B. W., "DURABILITY," Proceedings of the American Concrete Institute, May 1952, Vol. 48, No. 11, pp. 725-752.

KEY WORDS: durability

1210. Scholer, C. H. and Smith, G. M., "USE OF CHICAGO FLY-ASH IN REDUCING CEMENT-AGGREGATE REACTIONS," Journal of the American Concrete Institute, 1952, Vol. 23, No. 6, pp. 457-464.

1952

KEY WORDS: alkali aggregate reactions; fly ash; mineral admixtures; preventive measures

1211. Scholer, C. H., "SIGNIFICANT FACTORS AFFECTING CONCRETE DURABILITY," Proceedings of the American Society for Testing and Materials, 1952, Vol. 52, pp. 1145-1156.

KEY WORDS: durability

1212. Steele, B. W., "DURABILITY OF HYDRAULIC STRUCTURES," Proceedings of the American Concrete Institute, 1952, Vol. 48, p. 748.

KEY WORDS: hydraulic structures; durability

1213. Tuthill, L. H., "DURABLE CONCRETE IN HYDRAULIC STRUCTURES," Proceedings of the American Concrete Institute, 1952, Vol. 48, p. 740.

KEY WORDS: hydraulic structures; durability

1214. Woolf, D. O., "REACTION OF AGGREGATE WITH LOW ALKALI CEMENT," Journal of the American Concrete Institute, 1952, Vol. 24, No. 3, p. 255. Beton-Teknik, 1953, Vol. 19, No. 3, pp. 165-166. Chemical Abstracts, September 1952, Vol. 46, No. 17, 83436.

KEY WORDS: alkali aggregate reactions; cements; alkali effects

1215. Buck, A. D., Houston, B. J. and Pepper, L., "EFFECTIVENESS OF MINERAL ADMIXTURES IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION," U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report No. 6-481, July 1953, 53 pages. Journal of the American Concrete Institute, 1959, Vol. 30, No. 10, p. 1160.

KEY WORDS: alkali aggregate reactions; expansion; mineral admixtures

1216. Bureau of Reclamation, "LABORATORY AND FIELD INVESTIGATIONS OF CONCRETE, HUNGRY HORSE DAM," U.S. Dept. of the Interior, Bureau of Reclamation Denver, Colorado, Concrete Laboratory Report C-699, December 1953.

KEY WORDS: dam structures; field experiences

1217. Hester, J. A. and Smith, O. F., "ALKALI-AGGREGATE PHASE OF CHEMICAL REACTIVITY IN CONCRETE," Highway Research Board, 1953, Vol. 32, pp. 306-16; Vol. 33, pp. 74-90. Beton-Teknik, 1955, Vol. 21, No. 2, P.68. Journal of the American Concrete Institute, 1954, Vol. 26, No. 3, p. 312.

KEY WORDS: alkali aggregate reactions

1218. Hester, J. A., Smith, O. F. and Chase, A. S., "THE ALKALI-AGGREGATE PHASE OF CHEMICAL REACTIVITY IN CONCRETE," Alabama Polytechnic Institute of Engineering Bulletin, No. 20, 1953, p. 15.

KEY WORDS: alkali aggregate reactions

1219. Holland, W. Y. and Cook, R. G., "ALKALI REACTIVITY OF NATURAL AGGREGATES IN WESTERN UNITED STATES," Mining Engineering, 1953, Vol. 5, No. 10. pp. 991-997. Beton-Teknik, 1954, Vol. 20, No. 1, pp. 26-27. Engineering Index No. 54-3244.

KEY WORDS: reactive aggregates; U.S.A.

1953

1220. Jones, F. E., "ALKALI-AGGREGATE INTERACTION IN CONCRETE," Chemistry and Industry, 1953, Vol. 52, pp. 375-382. Chemical Abstracts, Vol. 47, 2952e, 4576e, 5088g. Chemical Abstracts, 10 July, 1954, Vol. 48, No. 13, 7871i. Cement and Lime Manufacture, July 1954, Vol. 27, No. 4, pp. 61-64.

KEY WORDS: alkali aggregate reactions

1221. Kammer, H. A., "MOVEMENTS IN THE STRUCTURAL CONCRETE AT THE CONOWINGS HYDRO-PLANT," American Society of Civil Engineers, Power Division, Separate No. 378, 1953, pp. 13-20.

KEY WORDS: dam structures; field experiences

1222. Lerch, W., "SIGNIFICANCE OF TESTS FOR CHEMICAL REACTIONS OF AGGREGATES IN CONCRETE," Proceedings of the American Society for Testing and Materials, 1953, Vol. 53, pp. 972-990.

KEY WORDS: reactive aggregates; test methods

1223. Merriam, R., "ALKALI-AGGREGATE REACTION IN CALIFORNIA CONCRETE AGGREGATES," California Department of Natural Resources, Special Report, No. 27, 1953, pp. 1-10. Chemical Abstracts, 25 June 1953, Vol. 47, No. 12, 6111h.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; U.S.A.

1224. Mielenz, R. C., "POTENTIAL REACTIVITY OF AGGREGATE IN CONCRETE AND MORTAR," Bulletin of the American Society for Testing and Materials, 1953, No. 193, pp. 41-45. Beton-Teknik, 1954, Vol. 20, No. 1, p. 26.

KEY WORDS: reactive aggregates; petrography; test methods

1225. Moyer, S. and Hansen, V., "MOVEMENTS IN THE STRUCTURAL CONCRETE AT CONOWINGS HYDRO-PLANT," Proceedings of the American Society of Civil Engineers, 1953, Vol. 79,

1953

Separate No. 308.

KEY WORDS: dam structures; field experiences

1226. Raphael, J. M., "DEVELOPMENT OF STRESSES IN SHASTA DAM," Transactions of the American Society of Civil Engineers, 1953, Vol. 118, p. 289.

KEY WORDS: dam structures; internal stresses; field experiences

1227. U.S. Army Corps of Engineers, Waterways Experiment Station, "TESTS FOR CHEMICAL REACTIVITY BETWEEN ALKALIES AND AGGREGATES, QUICK CHEMICAL TEST AND MORTAR BAR TEST," Technical Memorandum No. 6-368, Reports 1 and 2, August 1953 and September 1956 Respectively, Vicksburg, Mississippi.

KEY WORDS: alkali aggregate reactions; test methods; chemical tests; mortar bars

1228. Curry, R. L. and Woosley, J.C., "CHEMICAL ACTION BETWEEN AGGREGATES AND CEMENT IN CONCRETE AGGREGATE FOR MASS CONCRETE," U.S. Waterways Experiment Station, Corps of Engineers, U.S. Army Bulletin No. 39, Vicksburg, Mississippi, August 1954, pp. 33-41.

KEY WORDS: reactive aggregates; alkali aggregate reactions; mechanisms; mass concrete

1229. Mielenz, R. C., "PETROGRAPHIC EXAMINATION OF CONCRETE AGGREGATES," Proceedings of the American Society for Testing and Materials, 1954, Vol. 54, pp. 1188-1218.

KEY WORDS: aggregates; petrography

1230. Thorvaldson, T., "CHEMICAL ASPECTS OF THE DURABILITY OF CEMENT PRODUCTS," Proceedings of the 3rd International Symposium on the Chemistry of Cement, London, 1952, Cement and Concrete Association, 1954.

KEY WORDS: durability

1231. Anon., "ASTM CONVENTION CONTRIBUTES NEW KNOWLEDGE ON CEMENT AND CONCRETE," Rock Products, 1955, Vol. 58, No. 9, pp. 100, 102, 105, 106.

KEY WORDS: alkali aggregate reactions

1232. Bennett, I. C. and Vivian, H. E., "STUDIES IN CEMENT-AGGREGATE REACTION XXII. THE EFFECT OF FINE-GROUND OPALINE MATERIAL ON MORTAR EXPANSION," Australian Journal of Applied Science, 1955, Vol. 6, pp. 88-93.

KEY WORDS: alkali aggregate reactions; expansion; opal; mortar bars

1233. Brown, L. S., "SOME OBSERVATIONS ON MECHANICS OF ALKALI-AGGREGATE REACTION," The American Society for Testing and Materials, Bulletin No. 205, April 1955, pp. 40-56; Discussion pp. 44-6. Portland Cement Association, Research Bulletin No. 54, April 1955, 1-17. Beton-Teknik, 1955, Vol. 21, No. 3, p. 111. Portland Cement Association, Research and Development Laboratory Bulletin No. 228, July 1969.

KEY WORDS: alkali aggregate reactions; mechanisms

1234. Gaskin, A. J., Jones, R. H. and Vivian, H. E., "THE REACTIVITY OF VARIOUS FORMS OF SILICA IN RELATION TO THE EXPANSION OF MORTAR BARS," Australian Journal of Applied Science, 1955, Vol. 6, pp. 78-87.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; reactive aggregates; silica

1235. Kammer, H. A., "CONCRETE MOVEMENT," Transactions of the American Society of Civil Engineers, 1955, Vol. 120, p. 1196.

KEY WORDS: displacements; expansion

1955

1236. McGowan, J. K. and Vivian, H. E., "THE EFFECT OF SUPERINCUMBENT LOAD ON MORTAR BAR EXPANSION," Australian Journal of Applied Science, 1955, Vol. 6, pp. 94-99.

KEY WORDS: alkali aggregate reactions; expansion; restraint; mortar bars

1237. Moyer, S., "MOVEMENTS IN STRUCTURAL CONCRETE IN A POWER HOUSE," Transactions of the American Society of Civil Engineers, 1955, No. 120, p. 1183.

KEY WORDS: dam structures; displacements; field experiences

1238. Pike, R. G., Hubbard, D. and Insley, H., "MECHANISMS OF ALKALI-AGGREGATE REACTION," Journal of the American Concrete Institute, 1955, Vol. 27, No. 1, pp. 13-34. Beton-Teknik, 1956, Vol. 22, No. 2, p. 77.

KEY WORDS: alkali aggregate reactions; mechanisms

1239. Poulsen, E., "DISCUSSION OF: AN INVESTIGATION OF SOME PUBLISHED RESEARCHES ON THE ALKALI-AGGREGATE REACTION, BY T.C. POWERS AND H.H. STEINOUR," Journal of the American Concrete Institute, December 1955, Vol. 27, No. 4, pp. 812-6 to 812-17; Proceedings, Vol. 51.

KEY WORDS: alkali aggregate reactions; mechanisms

1240. Powers, T. C. and Steinour, H. H., "AN INTERPRETATION OF SOME PUBLISHED RESEARCHES ON ALKALI-AGGREGATE REACTION. I. THE CHEMICAL REACTIONS AND MECHANISM OF EXPANSION," Journal of the American Concrete Institute, 1955, Vol. 26, No. 6, pp. 497-516.

KEY WORDS: alkali aggregate reactions; mechanisms; osmotic effects

1241. Powers, T. C. and Steinour, H. H., "AN INTERPRETATION OF SOME PUBLISHED RESEARCHES ON ALKALI-AGGREGATE REACTION. II. A HYPOTHESIS CONCERNING SAFE AND UNSAFE REACTIONS WITH

1955

REACTIVE SILICA IN CONCRETE," Journal of the American Concrete Institute, 1955, Vol. 26, No. 8, pp. 785-811. Discussion Supplement, pp. 812-1 to 812-20.

KEY WORDS: alkali aggregate reactions; mechanisms; silica

1242. Roberts, J. A. and Vivian, H. E., "THE RESTORATION OF CRACKED MORTAR WHICH HAS DETERIORATED THROUGH ALKALI-AGGREGATE REACTION," Australian Journal of Applied Science, 1955, Vol. 6, pp. 101-104.

KEY WORDS: alkali aggregate reactions; repairs

1243. Verbeck, G. and Gramlich, C., "OSMOTIC STUDIES AND HYPOTHESIS CONCERNING ALKALI- AGGREGATE REACTION," Proceedings of the American Society for Testing and Materials, 1955, Vol. 55, pp. 1110-1131. Portland Cement Association, Research and Development Laboratories, Bulletin No. 57, 1956. Journal of the American Concrete Institute, 1956, Vol. 28, No. 4, pp. 428-429. Building Science Abstracts, November 1955, Vol. 28, No. 11, 1746. Beton-Teknik, 1957, Vol. 23, NO. 2, p. 86.

KEY WORDS: alkali aggregate reactions; osmotic effects; mechanisms

1244. Idorn, G. M., "DISINTEGRATION OF FIELD CONCRETE," Denmark. Danish National Institute of Building Research Committee on Alkali Reactions in Concrete, Progress Report No. 1, 1956, 39 pages.

KEY WORDS: concrete; field experiences; deterioration; alkali aggregate reactions; Denmark

1245. Lerch, W., "CHEMICAL REACTIONS," American Society for Testing and Materials, Special Technical Publication No. 169, 1956, pp. 334-345.

KEY WORDS: alkali aggregate reactions; test methods

1246. McCoy, W. J. (assignor to Lehigh Portland Cement Company, Allentown, Pa.), "INHIBITING ALKALI-REACTIVITY OF PORTLAND CEMENT," U.S. Patent, 2,374,831, Patented May 1956.

KEY WORDS: alkali aggregate reactions; preventive measures; patents

1247. Meissner, H. S., "MINERAL ADMIXTURES," American Society for Testing and Materials, Special Technical Publication No. 169, 1956, pp. 375-387.

KEY WORDS: mineral admixtures; test methods

1248. Mielenz, R. C., "CONCRETE AGGREGATES, PETROGRAPHIC EXAMINATION," American Society for Testing and Materials, Special Technical Publication No. 169, 1956, pp. 253-273.

KEY WORDS: petrography; aggregates

1249. Pike, R. G. and Hubbard, D., "ALKALI-AGGREGATE REACTION AND IONIC CHARGE ON HYDRATED CEMENT," Highway Research Board, Bulletin No. 171, 1956, pp. 16-38. Highway Research Abstracts, 1956, Vol. 26, No. 11, pp. 58.

KEY WORDS: alkali aggregate reactions; cement paste;

mechanisms

1250. Swenson, E. G. and Chaly, V., "BASIS FOR CLASSIFYING DELETERIOUS CHARACTERISTICS OF CONCRETE AGGREGATE MATERIALS," Journal of the American Concrete Institute, May 1956, Vol. 27, No. 9, pp. 987-1002; Proceedings, Vol. 52.

KEY WORDS: reactive aggregates; test methods; petrography

1251. Tye, R. V. and Mather, B., "TESTS FOR CHEMICAL REACTIVITY BETWEEN ALKALIES AND AGGREGATE REPORT 2: MORTAR-BAR TEST," U.S. Army Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Technical Memorandum 6-368, 1956, 20 pages.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars

1252. Walker, S. and Gayon, R. D., "DISCUSSION OF: BASIS FOR CLASSIFYING DELETERIOUS CHARACTERISTICS OF CONCRETE AGGREGATE MATERIALS, BY E.G. SWENSON AND V. CHALY, Journal of the American Concrete Institute, May 1956, Vol. 27 No. 9, pp. 987-1002.," Journal of the American Concrete Institute, December 1956, Vol. 28, No. 6, pp. 1449-1450; Proceedings, Vol. 52.

KEY WORDS: reactive aggregates; petrography; test methods

1253. Aalborg Portland-Cement-Fabrik, "METHOD FOR THE PROTECTION OF CONCRETE FROM ATTACK BY ALKALIES AND CEMENT FOR USE IN SAME," Danish Patent 81959, 28 January 1957.

KEY WORDS: alkali aggregate reactions; preventive measures; patents

1254. Andreasen, A. H. M. and Hauland Christensen, K. E., "INVESTIGATION OF THE EFFECT OF SOME POZZOLANS ON ALKALI REACTIONS IN CONCRETE," Danish National Institute of Building Research and Academy of Technical Sciences, Committee on Alkali Reactions in Concrete, Progress Report L1, Copenhagen, 1957, 50 pages.

KEY WORDS: alkali aggregate reactions; pozzolans; mineral admixtures

1255. Bosschaert, R. A. J., "ALKALI REACTIONS IN CONCRETE AGGREGATES," Cement, 1957, Vol. 9, No. 11/12. pp. 494-500. Zement-Kalk-Gips, 1958, Vol. 11, No. 3, pp. 100-108. Beton-Teknik, 1958, Vol. 24, No. 2, pp. 122-123, No. 3, p. 182.

KEY WORDS: alkali aggregate reactions; reactive aggregates

1256. Davis, C. E. S., "STUDIES IN THE CEMENT-AGGREGATE REACTION. XXV. COMPARISON OF THE EXPANSIONS OF MORTAR AND CONCRETE," Australian Journal of Applied Science, 1957, No. 3, pp. 422-434. Chemical Abstracts, 1957, Vol. 51, No. 21, 171331. Reprint, Australia, CSIRO, Division of Building Research.

KEY WORDS: alkali aggregate reactions; expansion; test methods

1257. Nerenst, P., "ALKALI REACTIONS IN CONCRETE - GENERAL," Danish National Institute of Building Research and the Academy of Technical Sciences, Committee on Alkali Reactions in Concrete, Progress Report A1, Copenhagen, The Institute, 1957.

KEY WORDS: alkali aggregate reactions

1957

1258. Pike, R. G. and Hubbard, D., "DESTRUCTIVE ALKALI-AGGREGATE REACTION IN CONCRETE," U.S. Bureau of Standards, Technical News Bulletin, 1957, Vol. 47, No. 12, pp. 199-200.

KEY WORDS: alkali aggregate reactions; mechanisms

1259. Pike, R. G. and Hubbard, D., "PHYSICOCHEMICAL STUDIES OF THE DESTRUCTIVE ALKALI-AGGREGATE REACTION IN CONCRETE," Journal of Research, National Bureau of Standards, 1957, Vol. 59, No. 2, pp. 127-132. Journal of the American Concrete Institute, 1958, Vol. 29, No. 8, p. 713. Beton-Teknik, 1958, Vol. 24, No. 3, p. 183.

KEY WORDS: alkali aggregate reactions; mechanisms

1260. Swenson, E. G., "CEMENT AGGREGATE REACTION IN THE CONCRETE OF A CANADIAN BRIDGE," Proceedings of the American Society for Testing and Materials, 1957, Vol. 57, pp. 1043-1056.

KEY WORDS: alkali aggregate reactions; bridge structures; field experiences; Canada

1261. Torborg-Jensen, A. et al., "A CLASSIFICATION OF DANISH FLINTS ETC. BASED ON X-RAY DIFFRACTION," Danish National Institute of Building Research and Academy of Technical Science, Committee on Alkali Reactions in Concrete, Progress Report, D1, 1957, 37 pages.

KEY WORDS: flint; silica; reactive aggregates

1262. Anderson, J. and Ditlevsen, L., "METHODS FOR THE DETERMINATION OF ALKALIES IN AGGREGATE AND CONCRETE," Copenhagen, Danish National Institute of Building Research and the Academy of Technical Sciences. Progress Report F3, 1958, pp. 16-21.

KEY WORDS: test methods; alkali effects; aggregates

1263. Anon., "DESTRUCTIVE ALKALI-AGGREGATE REACTION IN CONCRETE," Concrete, March 1958, Vol. 66, No. 3, p. 31.

KEY WORDS: alkali aggregate reactions

1264. Chauret, E., "CEMENT-AGGREGATE REACTIONS IN CONCRETE," L'Ingenieur (Montreal), 1958, Vol. 44, No. 174, pp. 12-19. Journal of the American Concrete Institute, 1959, Vol. 30, No. 12, p. 1322.

KEY WORDS: alkali aggregate reactions

1265. Christensen, K. E. H., "EVALUATION OF ALKALI REACTIONS IN CONCRETE BY THE CHEMICAL TEST," Denmark, Danish National Institute of Building Research, Committee on Alkali Reactions in Concrete. Progress Report H1, 1958, 58 pages.

KEY WORDS: alkali aggregate reactions; chemical tests; test methods

1266. Davis, C. E. S., "STUDIES IN CEMENT-AGGREGATE REACTION. XXVI. COMPARISON OF THE EFFECT OF SODA AND POTASH ON EXPANSION," Australian Journal of Applied Science, 1958, Vol. 9, pp. 52-62. Reprint, Australia, CSIRO, Division of Building Research.

KEY WORDS: alkali aggregate reactions; expansion; alkali effects; mortar bars

1267. Gibson, W. E., "FIELD EXPERIENCE WITH ALKALI-AGGREGATE REACTION IN CONCRETE: CENTRAL UNITED STATES," Highway

Research Board, Research Report No. 18C, 1958, pp. 6-7.

KEY WORDS: alkali aggregate reactions; field experiences; U.S.A.

1268. Halstead, W. J., "CHEMICAL REACTIONS OF AGGREGATES IN CONCRETE," Highway Research Board Special Report No. 31, 1958, pp. 1-12.

KEY WORDS: alkali aggregate reactions

1269. Halstead, W. J. and Chaiken, B., "A REVIEW OF FUNDAMENTAL RESEARCH ON ALKALI-AGGREGATE REACTION," Highway Research Board Research Report No. 18C, 1958, pp. 47-51.

KEY WORDS: alkali aggregate reactions; mechanisms; reviews

1270. Hauland, C. K. E., "EVALUATION OF ALKALI REACTIONS IN CONCRETE BY THE CHEMICAL TEST," Danish National Institute of Building Research and the Academy of Technical Sciences, Copenhagen, Progress Report H1, 1958, 58 pages.

KEY WORDS: chemical tests; alkali aggregate reactions; test methods

1271. Highway Research Board, "CHEMICAL REACTIONS OF AGGREGATES IN CONCRETE. IDENTIFICATION OF DELETERIOUSLY REACTIVE AGGREGATES AND RECOMMENDED PRACTICES FOR THEIR USE IN CONCRETE," Special Report 31, Washington, 1958. Journal of the American Concrete Institute, 1958, Vol. 30, No. 5, p. 661.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods

1272. Highway Research Board, "ALKALI-AGGREGATE REACTION," Highway Research Board, Bulletin No. 171, Washington D.C., 1958, 36 pages.

KEY WORDS: alkali aggregate reactions

1958

1273. Highway Research Board, "THE ALKALI-AGGREGATE REACTION IN CONCRETE," Highway Research Report 18C, 1958, 51 pages.

KEY WORDS: alkali aggregate reactions

1274. Highway Research Board, "RAPID TESTS FOR AGGREGATES AND CONCRETE," Highway Research Board, Bulletin, No. 201, 1958.

KEY WORDS: test methods; aggregates

1275. Jones, F. E. and Tarleton, R. D., "REACTION BETWEEN AGGREGATE AND CEMENT. PART IV. ALKALI-AGGREGATE INTERACTION: THE EXPANSION BAR TEST: CEMENTS OF HIGH ALKALI CONTENT," Research Paper No. 20, HMSO, London, 1958.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; alkali effects

1276. Jones, F. E. and Tarleton, R. D., "REACTION BETWEEN AGGREGATE AND CEMENT. PART IV. ALKALI- AGGREGATE INTERACTION: OTHER TEST CRITERIA PART V. ALKALI-AGGREGATE INTERACTION: TEST PROCEDURES," Research Paper No. 25, HMSO, London, 1958.

KEY WORDS: alkali aggregate reactions; test methods

1277. Jones, F. E., "INVESTIGATIONS OF DANISH AGGREGATES AT THE BUILDING RESEARCH STATION, ENGLAND.," Danish National Institute of Building Research, Committee on Alkali Reactions in Concrete, Progress Report II, 1958, 62 pages. Journal of the American Concrete Institute, November 1958, Vol. 30, No. 5, p. 663c; Proceedings, Vol. 55.

KEY WORDS: reactive aggregates; Denmark

1278. Mather, K., "CEMENT-AGGREGATE REACTION: WHAT IS THE PROBLEM?," Geological Society of America, Engineering Geology Case Histories, No. 2, March 1958, pp. 17-19. Engineering Index, 1960. U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi, Miscellaneous

1958

Paper, 6-169, 1956, 7 pages.

KEY WORDS: alkali aggregate reactions; field experiences

1279. McCoy, W. J. and Eshenour, O.L., "SIGNIFICANCE OF TOTAL AND WATER-SOLUBLE ALKALI CONTENTS OF PORTLAND CEMENT," Journal of Materials, American Society for Testing and Materials, 1958, Vol. 3, No. 3, pp. 684-694.

KEY WORDS: cements; alkali effects

1280. Meyer, E. V., editor., "ALKALI REACTIONS IN CONCRETE," Danish National Institute of Building Research and the Academy of Technical Sciences, Progress Reports A1-D1- D2-L1. Beton-Teknik, 1958, Vol. 24, No. 2, pp. 113-117.

KEY WORDS: alkali aggregate reactions

1281. Meyer, E. V., "A NEW DANISH ALKALI-RESISTANT CEMENT," Copenhagen, Danish National Institute of Building Research and the Academy of Technical Sciences, Progress Report F2, 1958, pp. 12-15. Beton-Teknik, 1955, Vol. 21, No. 1, pp. 21-24.

KEY WORDS: cements; preventive measures

1282. Meyer, E. V., "THE ALKALI CONTENT OF DANISH CEMENTS," Danish National Institute of Building Research and the Academy of Technical Sciences, Progress Report F-1, The Institute, 1958, 11 pages.

KEY WORDS: cements; alkali effects

1283. Midgley, H. G., "THE NOMENCLATURE OF FLINT AND CHERT," Building Research Station, England, Note No. A66, 1958.

KEY WORDS: reactive aggregates; chert; flint; silica

1958

1284. Mielenz, R. C. and Benton, E. J., "EVALUATION OF THE QUICK CHEMICAL TEST FOR ALKALI REACTIVITY OF CONCRETE AGGREGATE," Highway Research Board, Bulletin No. 171, 1958, pp. 1- 15. Journal of the American Concrete Institute, 1958, Vol. 30, No. 4, p. 521.

KEY WORDS: reactive aggregates; chemical tests; test methods

1285. Pike, R. G., "PRESSURES DEVELOPED IN CEMENT PASTE AND MORTAR BY ALKALI-AGGREGATE REACTION," Highway Research Board Bulletin No. 171, 1958, pp. 34- 36. Journal of the American Concrete Institute, 1958, Vol. 30, No. 4, p. 520.

KEY WORDS: alkali aggregate reactions; mechanisms; internal stresses

1286. Plum, N. M., Poulsen, E. and Idorn, G. M., "PRELIMINARY SURVEY OF ALKALI REACTIONS IN CONCRETE," Ingenioren, January 1958, Vol. 2, No. 1, pp. 26-40. Danish National Institute of Building Research, Reprint No. 94, 1958, 15 pages.

KEY WORDS: alkali aggregate reactions; field experiences; Denmark

1287. Swenson, E. G., "A REACTIVE AGGREGATE UNDETECTED BY ASTM TESTS," Proceedings of the American Society for Testing and Materials, 1957, Vol. 57, No. 226, pp. 48-51. Beton-Teknik, 1958, Vol. 24, No. 2, p. 126.

KEY WORDS: reactive aggregates; test methods

1288. U.S. Waterways Experiment Station, "EFFECTIVENESS OF MINERAL ADMIXTURES IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION," Vicksburg, Mississippi, Technical Report 6-481, July 1958.

KEY WORDS: alkali aggregate reactions; expansion; preventive measures; mineral admixtures; pozzolans

1958

1289. Wakeman, C. M., Dockweiler, E. V., Stover, H. E. and Whiteneck, L. L., "USE OF CONCRETE IN MARINE ENVIRONMENTS," Proceedings of the American Concrete Institute, April 1958, Vol. 54, No. 10, pp. 841-856.

KEY WORDS: field experiences

1290. Woolf, D. O., "FIELD EXPERIENCE WITH ALKALI-AGGREGATE REACTION IN CONCRETE: EASTERN UNITED STATES," Highway Research Board Research Reports, 1958, No. 18-c, pp. 8-11.

KEY WORDS: reactive aggregates; alkali aggregate reactions; pavement structures; bridge structures; field experiences; U.S.A.

Failure of concrete pavements and bridges in the eastern United States due to chemical reaction between alkali in the cement and silica bearing aggregate is covered. Severe pavement distress in Georgia, South Carolina, and Alabama was associated with cement of over 0.6 percent alkali content. Quartz gravels were more definitely associated with cracking than others. Factors such as high magnesium content, blast furnace slag aggregate, and the use of wet concrete were seen as contributory. It is suggested that the ability to carry the imposed load without excessive repairs is far more important than the maintenance of an uncracked surface.

1291. Anon., "DAMAGING REACTIONS IN CONCRETE," Engineering, 23 January 1959, Vol. 187, No. 4846, p. 128. Highway Research Abstracts, May 1959, Vol. 29, No. 5, 15.

KEY WORDS: alkali aggregate reactions

1292. Brown, L. S., "PETROGRAPHY OF CEMENT AND CONCRETE," Journal of the Portland Cement Association, Research and Development Laboratory, 1959, Vol. 1, No. 3, pp. 23-25.

KEY WORDS: petrography

1293. Chaiken, B. and Halstead, W. J., "CORRELATION BETWEEN CHEMICAL AND MORTAR BAR TESTS FOR POTENTIAL ALKALI REACTIVITY OF CONCRETE AGGREGATES," Highway Research Board Bulletin No. 239, 1960, pp. 24- 40. Public Roads, June 1959, Vol. 30, No. 8, pp. 177-184.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; chemical tests

1294. Hansen, W. C., "RELEASE OF ALKALIES BY SANDS AND ADMIXTURES IN PORTLAND CEMENT MORTARS," American Society for Testing and Materials Bulletin, No. 236, 1959, pp. 35-38.

KEY WORDS: alkali effects; reactive aggregates; mineral admixtures

1295. Hansen, W. C., "EXPANSION AND CRACKING STUDIED IN RELATING TO AGGREGATE AND MAGNESIA AND ALKALI CONTENT OF CEMENT," Journal of the American Concrete Institute, February 1959, Vol. 30, No. 8, pp. 867-892; Proceedings, Vol. 55.

KEY WORDS: expansion; cracking; reactive aggregates; alkali effects; MgO

1296. Idorn, G. M., "CONCRETE ON THE WEST COAST OF JUTLAND," Danish National Institute of Building Research and Academy of Technical Sciences, Committee on Alkali Reactions in

1959

Concrete, Progress Report B1, Copenhagen, 1959.

KEY WORDS: field experiences; Denmark

1297. Kennerley, R. A. and Clelland, J., "AN INVESTIGATION OF NEW ZEALAND POZZOLANS," New Zealand, Department of Scientific and Industrial Research, Bulletin, No. 133, 1959.

KEY WORDS: pozzolans; mineral admixtures; New Zealand

1298. Lang, E. H., "DAMAGING REACTIONS IN CONCRETE," Engineering, 17 April 1959, Vol. 187, No. 4858, p. 483.

KEY WORDS: alkali aggregate reactions

1299. Larsen, G., "PETROGRAPHIC INVESTIGATION OF CONCRETE AGGREGATES - HOW AND WHY," Beton-Teknik, 1959, Vol. 25, No. 3, pp. 73-104.

KEY WORDS: petrography; aggregates

1300. Lerch, W., "A CEMENT-AGGREGATE REACTION THAT OCCURS WITH CERTAIN SAND-GRAVEL AGGREGATES," Journal of the Portland Cement Association, Research and Development Laboratories, Vol. 1, No. 3, pp. 42-50.

KEY WORDS: alkali aggregate reactions; "sand-gravel" aggregates; reactive aggregates

1301. Mather, B. and Verbeck, G., "REACTION BETWEEN AGGREGATES AND CEMENT CONCRETE," Proceedings of the 12th Regional Meeting, American Concrete Institute, Mexico, November 1959, pp. 9-21.

KEY WORDS: alkali aggregate reactions

1302. Meyer, E. V., editor, "ALKALI REACTIONS IN CONCRETE," Danish National Institute of Building Research and the

1959

Academy of Technical Sciences, Progress Reports E1 and K2. Beton-Teknik, 1959, Vol. 25, No. 4, pp. 160-161.

KEY WORDS: alkali aggregate reactions; Denmark

1303. Narayanswami, B. S. S., "ALKALI-AGGREGATE REACTION IN CONCRETE," Indian Concrete Journal, 1959, Vol. 33, No. 6, pp. 203- 206; No. 8, pp. 282-285.

KEY WORDS: alkali aggregate reactions; India

1304. Pepper, L. and Mather, B., "EFFECTIVENESS OF MINERAL ADMIXTURES IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION," Proceedings of the American Society for Testing and Materials, 1959, Vol. 59, pp. 1178-1203.

KEY WORDS: mineral admixtures; pozzolans; alkali aggregate reactions; expansion

1305. Powers, T. C., "CAUSES AND CONTROL OF VOLUME CHANGE," Journal of the Portland Cement Association, Research and Development Laboratories, January 1959, Vol. 1, No. 1, pp. 29-39.

KEY WORDS: expansion

1306. Sturrup, V. R., "EVALUATION OF TESTS MADE BY ONTARIO HYDRO, " Highway Research Board, Bulletin No. 206, 1959, pp. 1-13.

KEY WORDS: test methods

1307. Anon., "CONCRETE QUALITY CONTROL, AGGREGATE CHARACTERISTICS AND THE CEMENT-AGGREGATE REACTION," Highway Research Board Bulletin No. 275, 1960, 44 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; preventive measures

1308. Bredsdorff, P., Idorn, G. M., Kjaer, A., Plum, N. M. and Poulsen, E., "CHEMICAL REACTIONS INVOLVING AGGREGATE," Fourth International symposium on Chemistry of Cement. Washington D.C., 2-7 October 1960, Session 6, Paper 1, National Bureau of Standard, Monograph No. 43, 1960, pp. 749-783. Danish National Institute of Building Research, Report No. 128, Copenhagen, 1963. Magazine of Concrete Research, 1961, Vol. 13, No. 38, p. 104.

KEY WORDS: alkali aggregate reactions

1309. Efsen, A. and Glarbo, O., "EXPERIMENTS ON CONCRETE BARS - EXPANSIONS DURING STORAGE IN CLIMATE ROOM," Danish National Institute of Building Research and Academy of Technical Sciences, Committee on Alkali Reactions in Concrete, Progress Report K1, 1960, 38 pages.

KEY WORDS: expansion; test methods

1310. Emmons, W. F., "CONTROL OF CRACKING IN TVA CONCRETE GRAVITY DAMS," American Society of Civil Engineers, Journal of the Power Division, February 1960, p. 11.

KEY WORDS: dam structures; cracking; field experiences; U.S.A.

1311. Hagerman, T. H. and Roosaar, H., "INVESTIGATION OF AGGREGATES FOR CONCRETE WITH REFERENCE TO RISK OF REACTIONS BETWEEN ALKALIS AND SILICA," Nordisk Beton, 1960, Vol. 4, No.2, pp. 110-141.

KEY WORDS: alkali aggregate reactions; reactive aggregates; preventive measures

1960

1312. Hansen, W. C., "INHIBITING ALKALI-AGGREGATE REACTION WITH BARIUM SALTS," Journal of the American Concrete Institute, 1960, Vol. 31, No. 9, pp. 881-883.

KEY WORDS: alkali aggregate reactions; preventive measures; barium effects

1313. Highway Research Board, "PHYSICAL AND CHEMICAL PROPERTIES OF CEMENT AND AGGREGATE IN CONCRETE," Highway Research Board, Bulletin No. 239, 1960, 65 pages.

KEY WORDS: cement; aggregates; test methods

1314. Mather, B., "PETROLOGY OF CONCRETE AGGREGATE," Florida Geological Survey - 11th Symposium of Highway Engineers, Proceedings, 1960, pp. 9-21. Engineering Index, 1964.

KEY WORDS: aggregates; petrography

1315. Mather, K. and Mielenz, R. C., "COOPERATIVE EXAMINATION OF CORES FROM THE MCPHERSON TEST ROAD," Proceedings of the Highway Research Board, 1960, Vol. 39, pp. 205-216.

KEY WORDS: pavement structures; field experiences; U.S.A.; petrography

1316. Pike, R. G., Hubbard, D. and Newman, E. S., "BINARY SILICATE GLASSES IN THE STUDY OF ALKALI SILICATE REACTION," Highway Research Board Bulletin No. 275, 1960, pp. 39- 44.

KEY WORDS: alkali aggregate reactions; mechanisms; glass; silica

1317. Roper, H., "VOLUME CHANGES OF CONCRETE AFFECTED BY AGGREGATE TYPE," Journal of the Portland Cement Association, Research and Development Laboratories, September 1960, Vol. 2, No. 3, pp. 13-19.

KEY WORDS: expansion; aggregates

1960

1318. Sargent, C., Swenson, E. G., et al., "CONCRETE QUALITY CONTROL, AGGREGATE CHARACTERISTICS AND THE CEMENT-AGGREGATE REACTION," Highway Research Board, Bulletin No. 275, 1960, 44 pages. Journal of the American Concrete Institute, 1962, Vol. 59, No. 1, pp. 123-124.

KEY WORDS: alkali aggregate reactions; aggregates

1319. Weigel, J. F., "INVESTIGATION OF THE FINE AND COARSE AGGREGATES OF NORTHERN ILLINOIS FOR ALKALI REACTIVITY," Proceedings of the American Society for Testing and Materials, 1960, Vol. 60, pp. 1036-1046.

KEY WORDS: reactive aggregates; U.S A.

1320. Anon., "CONCRETE CONSTRUCTION AND DELETERIOUS ALKALI REACTIONS," Ingeniorens Ugeblad, 1961, Vol. 5, No. 44, pp. 12-15.

KEY WORDS: alkali aggregate reactions

1321. Babatschev, G. N. and Radeva, K. K., "THE ALKALIES IN PORTLAND CEMENT CLINKER," Silikattechnik, 1961, Vol. 12, No. 1, pp. 33-35.

KEY WORDS: alkali effects; cements

1322. Grieb, W. E. and Werner, G., "FINAL REPORT OF TESTS OF CONCRETE CONTAINING PORTLAND BLAST-FURNACE SLAG CEMENT," Public Roads, August 1961, Vol. 31, No. 9, pp. 183-193.

KEY WORDS: slag; mineral admixtures

1323. Highway Research Board, "TESTS FOR CONCRETE DURABILITY AND DURABILITY OF CONCRETE AGGREGATES," Highway Research Board, Bulletin No. 305, 1961.

KEY WORDS: aggregates; durability; test methods

1324. Idorn, G. M., "DETERIORATION OF CONCRETE STRUCTURES," RILEM International Symposium on Durability of Concrete, Prague, 1961, Proceedings, pp. 589-593.

KEY WORDS: field experiences; deterioration

1325. Idorn, G. M., "STUDIES OF DISINTEGRATED CONCRETE. - PART I.," Denmark, Danish National Institute of Building Research, Committee on Alkali Reactions in Concrete, Progress Report N2, 1961, 77 pages.

KEY WORDS: alkali aggregate reactions; deterioration; field experiences; Denmark

1961

1326. Idorn, G. M., "STUDIES OF DISINTEGRATED CONCRETE. - PART II.," Danish National Institute Building Research, Committee on Alkali Reactions in Concrete, Progress Report N3, Copenhagen, The Institute, 1961.

KEY WORDS: alkali aggregate reactions; deterioration; field experiences; Denmark

1327. Jeppesen, A., "MAINTENANCE AND REPAIR OF CONCRETE AND REINFORCED CONCRETE STRUCTURES," Alkali Committee Recommendations 2, Danish National Institute of Building Research, Copenhagen, 1961.

KEY WORDS: alkali aggregate reactions; repairs; field experiences; Denmark

1328. Jessen, J. J., "ON THE PREVENTION OF ALKALI DAMAGE AND REPAIR OF DETERIORATED CONCRETE BUILDING WORKS," Beton-Teknik, 1961, Vol. 27, No. 2, pp. 79-84.

KEY WORDS: alkali aggregate reactions; preventive measures; repairs; field experiences

1329. Jessing, J., Kjaer, A., Larsen, G. and Trudso, B., "ALKALI-SILICA REACTIONS IN CONCRETE," RILEM International Symposium on the Durability of Concrete, Prague, Preliminary Report, Vol. II, 1961, pp. 103-133.

KEY WORDS: alkali aggregate reactions

1330. Lawrence, M. and Vivian, H. E., "THE REACTIONS OF VARIOUS ALKALIES WITH SILICA," Australian Journal of Applied Science, 1961, Vol. 12, No. 1, pp. 96-103.

KEY WORDS: alkali aggregate reactions; alkali effects; silica; mechanisms

1331. Plum, N. M., "PROVISIONAL RECOMMENDATIONS FOR THE PREVENTION OF DELETERIOUS ALKALI REACTIONS IN CONCRETE, ALKALI COMMITTEE RECOMMENDATION, 1," Danish National

1961

Institute of Building Research, Copenhagen, 1961, 60 pages.

KEY WORDS: alkali aggregate reactions; preventive measures

1332. Ponomarev, I. F. and Azelitskaya, R.D., "INVESTIGATION OF CONCRETES MADE WITH ALKALI-CONTAINING CEMENT AND ACTIVE SILICA AGGREGATES," Beton & Jernbeton, 1961, No. 8, pp. 370-374.

KEY WORDS: alkali aggregate reactions

1333. Price, G. C., "INVESTIGATION OF CONCRETE MATERIALS FOR SOUTH SASKATCHEWAN RIVER DAM," Proceedings of the American Society for Testing and Materials, 1961, Vol. 61, pp. 1155-1179.

KEY WORDS: dam structures

1334. Brown, L. S., "DISCUSSION OF CHEMICAL REACTIONS INVOLVING AGGREGATE BY BREDSDORFF, P., IDORN, G.M., KJAER, A., PLUM, N.M. AND POULSEN, E.," 4th International Symposium on the Chemistry of Cement, Proceedings, Washington, 1960, Vol. 2, pp. 801-802. U.S. Department of Commerce, NBS Monograph No. 43, 1962.

KEY WORDS: alkali aggregate reactions

1335. Coutinho, A. de Sousa, "DISCUSSION OF CHEMICAL REACTIONS INVOLVING AGGREGATE BY BREDSDORFF. P., IDORN, G.M., KJAER, A., PLUM, N.M. AND POULSEN, E., 4TH INTERNATIONAL SYMPOSIUM ON THE CHEMISTRY OF CEMENT, WASHINGTON, 1960.," Proceedings, U.S. Department of Commerce, N.B.S. Monograph No. 43, 1962, Vol. 2, pp. 800-801.

KEY WORDS: alkali aggregate reactions

1336. Fliert, C. van de, Hove, J. F. and Schrap, L. W., "ALKALI-AGGREGATE REACTION IN CONCRETE," Cement (Holland), 1962, Vol. 14, No. 1, pp. 20-28.

KEY WORDS: alkali aggregate reactions

1337. Lerch, W., "CHEMICAL REACTIONS OF AGGREGATES IN CONCRETE," Modern Concrete, March 1962, Vol. 25, No. 11, pp. 41-44.

KEY WORDS: alkali aggregate reactions

1338. Mielenz, R. C., "PETROGRAPHY APPLIED TO PORTLAND CEMENT CONCRETE," Reviews in Engineering Geology, Fluhr, T. and Leggett, R.F., Editors, Geological Society of America, New York, Vol. 1, 1962, pp. 1-38.

KEY WORDS: petrography

1339. Tang, M. S. and Xue, W. R., "EXPANSIVE REACTION OF CEMENT AND REACTIVE SILICA IN AGGREGATE (in Chinese)," Journal of the Chinese Silicate Society, Vol. 1, No. 1, 1962, pp. 20-29.

1962

KEY WORDS: alkali aggregate reactions; expansion; opal; silica; mechanisms

1340. Anon., "EFFECT OF DIFFERENT CEMENTS ON THE EXPANSION OF 1 BY 1 BY 10 INCH MORTAR BARS CURED IN SEALED CONTAINERS AT 100F," Nebraska Department of Roads, Materials and Tests Division, Report HPP-1/3, 63-8, A-3, 1963.

KEY WORDS: expansion; mortar bars; cements; test methods

1341. Hansen, W. C., "ANHYDROUS MINERAL AND ORGANIC MATERIALS AS SOURCES OF DISTRESS IN CONCRETE," Highway Research Record No. 43, 1963, pp. 1-7.

KEY WORDS: deterioration

1342. Larsen, G., "INVESTIGATION OF LOW GRADE FLINT AGGREGATE FOR CONCRETE," Ingenioren, 15 June 1963, Vol. 72, No. 12, pp. 415-426.

KEY WORDS: flint; reactive aggregates

1343. Liu, C. H., "ON THE EXPANSION MECHANISM OF ALKALI-AGGREGATE REACTION IN CONCRETE (in Chinese)," Silicate Journal (China), 1963, Vol. 2. No. 2, pp. 84- 95. Cement Lime Gravel, 1965, Vol. 40, No. 2, p. 78.

KEY WORDS: alkali aggregate reactions; expansion; mechanisms

1344. Mielenz, R. C., "REACTION OF AGGREGATES INVOLVING SOLUBILITY, OXIDATION, SULPHATES OR SULPHIDES," Highway Research Board, 1963, No. 43, pp. 8-18.

KEY WORDS: reactive aggregates; mechanisms

1345. Oleson, C. C., "ABNORMAL CRACKING IN HIGHWAY STRUCTURES IN GEORGIA AND ALABAMA," Journal of the American Concrete Institute, 1963, Vol. 60, No. 3, pp. 329-353.

KEY WORDS: pavement structures; cracking; alkali aggregate reactions; field experiences; U.S.A.

1963

1346. Tang, M. S. and Xue, W.R., "SEVERAL QUESTIONS ON THE ALKALI SILICA REACTION (in Chinese)," Journal of the Chinese Silicate Society, Vol. 2, No. 2, 1963, pp. 110-116.

KEY WORDS: alkali aggregate reactions; expansion; calcium hydroxide; calcium chloride; mechanisms

1347. Tang, M. S., Xue, W. R., Chen, Z. W., Wang, W. D. and Jia, H. M., "EFFECTS OF GYPSUM SLAG CEMENT ON ALKALI SILICA REACTION (In Chinese)," Building Material Industry, No. 11, 1963, pp. 16-23.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; mechanisms; slag; mineral admixtures; preventive measures

There is no ASR expansion in mortar bars made with gypsum slag blended cements containing 0.61% and 0.51% alkali content respectively. There is no ASR expansion in mortar bars containing $Na_2SO_4$, $Na_2CO_3$, and NaCl. NaOH accelerates the ASR.

1348. Tang, M. S., Dong, D. K. and Cheng, Z. C., "EFFECTS OF NON-REACTIVE BLENDED MATERIALS ON ALKALI SILICA REACTION (In Chinese)," Building Material Industry, No. 9, 1963, pp. 18-22.

KEY WORDS: alkali aggregate reactions; expansion; carbonates; preventive measures

1349. Trojer, F., "CEMENT AND CONCRETE FROM MINERALOGICAL VIEW (in German)," Zement und Beton, 1963, No. 25, pp. 5-11.

KEY WORDS: mineralogy; petrography

1350. Anon., "POP-OUTS ON CONCRETE SURFACES," Nature (London), 1964, Vol. 204, p. 929.

KEY WORDS: deterioration

1351. De Puy, G. W., "PETROGRAPHIC AND MORTAR BAR EXPANSION TESTS OF ALKALI-REACTIVE CONSTITUENTS IN SAND-GRAVEL AGGREGATE," Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, Report No. CLE-36, 4 September 1964, 30 pages.

KEY WORDS: alkali aggregate reactions; petrography; expansion; mortar bars; "sand-gravel" aggregates; reactive aggregates

1352. Feld, J., "FAILURE LESSONS IN CONCRETE CONSTRUCTION. PART 5 - CONCRETE DISINTEGRATION CAUSED BY INTERNALLY EMBEDDED REACTIVE MATERIALS OR INGREDIENTS," Concrete Construction, May 1964, Vol. 9, No. 5, pp. 127-128.

KEY WORDS: deterioration; alkali aggregate reactions; field experiences; U.S.A.

1353. Idorn, G. M., "STUDIES OF DISINTEGRATED CONCRETE. - PART III.," Danish National Institute of Building Research, Committee on Alkali Reactions in Concrete, Progress Report N4, Copenhagen, The Institute, 1964.

KEY WORDS: alkali aggregate reactions; deterioration; field experiences; Denmark

1354. Idorn, G. M., "STUDIES OF DISINTEGRATED CONCRETE. - PART IV.," Danish National Institute of Building Research, Committee on Alkali Reactions in Concrete, Progress Report N5, Copenhagen, 1964.

KEY WORDS: alkali aggregate reactions; deterioration; field experiences; Denmark

1964

1355. Mather, K., Buck, A. D. and Luke, W. I., "ALKALI-SILICA AND ALKALI-CARBONATE REACTIVITY OF SOME AGGREGATES FROM SOUTH DAKOTA, KANSAS AND MISSOURI," Highway Research Record No. 45, Publication 1167, National Academy of Science - National Research Council, 1964, pp. 72-109.

KEY WORDS: alkali aggregate reactions; reactive aggregates

1356. Mielenz, R. C., "DIAGNOSING CONCRETE FAILURES," Stanton Walker Lecture Series on the Materials Sciences, No. 2, University of Maryland, 1964, pp. 5-47.

KEY WORDS: field experiences; test methods

1357. Pepper, L., "INFLUENCE OF ALKALI CONTENT OF FLY ASH ON EFFECTIVENESS IN PREVENTING EXPANSION OF CONCRETE," U.S. Army Engineers, Waterways Experiment Station, Technical Report No. 6-627, 17 pages. Journal of the American Concrete Institute, 1964, Vol. 61, No. 3, p. 366.

KEY WORDS: alkali effects; preventive measures; fly ash; mineral admixtures

1358. Steopo, A., "REINFORCED CONCRETE IN AGGRESSIVE ENVIRONMENTS," Revue des Materiaux, 1964, No. 591, pp. 359-362.

KEY WORDS: field experiences; reinforced concrete

1359. Anon., "BIBLIOGRAPHY - ALKALI REACTION IN CEMENT AND CONCRETE (1941-1964)," Bibliography N 979, 1965, 7 pages. CEMBUREAU Bibliographical News, BN 5, No. 105, 1965.

KEY WORDS: alkali aggregate reactions; bibliography

1360. Balasz and Kunszt, "CAUSES FOR DETERIORATION OF STEAM-CURED CONCRETE STRUCTURES," Magyer Epitorpari, 1965, No. 9, pp. 98-99.

KEY WORDS: steam-cured concrete; deterioration

1361. Chang, X. S., Tang, M. S., Chui, X. W., Zhou, G. and Wang, Q. W., "THE INFLUENCE OF ALKALI ON THE PRODUCTION AND PROPERTIES OF CEMENT (in Chinese)," Journal of the Chinese Silicate Society, Vol. 4, No. 3, 1965, pp. 175-183.

KEY WORDS: alkali effects; cements; clinkers

A small content of alkali does not influence the formation of cement clinker. However, a high alkali content of the clinker increases the free CaO content. In hydration, alkali increases the demand of water, accelerates the hydration rate, decreases strength, especially compressive strength, and decreases the bleeding. Gypsum and slag can compensate the deteriorating effects of alkali.

1362. Forum, C. S., "ALKALI REACTION OF AGGREGATES IN CONCRETE," Beton und Stahlbetonbau, 1965, Vol. 60, No. 7, pp. 163-168.

KEY WORDS: alkali aggregate reactions; reactive aggregates

1363. Michaels, E. L., Volin, M. E. and Ruotsala, A. P., "THE PROPERTIES OF CHERT AGGREGATES IN RELATION TO THEIR DELETERIOUS EFFECT IN CONCRETE," Michigan Technological University, Institute of Mineral Resources, Final Report, Project R-121, July 1965, 122 pages. Highway Research Abstracts, 1966, Vol. 36, No. 7, p. 8.

1965

KEY WORDS: chert; reactive aggregates

1364. Murata, S., Seki, S. and Fujiki, Y., "A CASE STUDY OF A CONCRETE DAMAGED BY ALKALI-AGGREGATE REACTION (In Japanese)," Cement & Concrete (Japan), No. 220, 1965.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences,Japan

In this report a case in which reaction-rims were observed around the aggregate was discussed.

1365. Swedish Committee on Aggregates, "ALKALI-SILICA REACTIONS WITH SWEDISH AGGREGATES," Stockholm, 1965, 23 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; Sweden

1366. Tang, M. S. and Huang, J. J., "INFLUENCE OF ALKALI ON THE SULPHATE RESISTANCE AND THE FORMATION OF CALCIUM-ALUMNA-SULPHATE (In Chinese)," Building Material Industrial Technique, No. 1, 1965, pp. 20-23.

KEY WORDS: alkali effects; sulfate attack

1367. Bredsdorff, P., Poulsen, E. and Spohr, H., "EXPERIMENTS ON MORTAR BARS PREPARED WITH SELECTED DANISH AGGREGATES," Danish National Institute of Building Research and Academy of Technical Sciences, Committee on Alkali Reactions in Concrete, Progress Report I 2, Copenhagen, 1966, 82 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mortar bars; expansion; Denmark

1368. Bredsdorff, P., Poulsen, E. and Spohr, H., "EXPERIMENTS ON MORTAR BARS PREPARED WITH A REPRESENTATIVE SAMPLE OF DANISH AGGREGATE," Danish National Institute of Building Research and Academy of Technical Sciences, Committee on Alkali Reactions in Concrete, Progress Report I 3, Copenhagen, 1966.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mortar bars; expansion; Denmark

1369. Brown, H. E., "AN INVESTIGATION OF DURABILITY OF STEAM-CURED CONCRETE," Virginia Council of Highway Investigation and Research, Charlottesville, Interim Report, 1966, 23 pages.

KEY WORDS: steam-cured concrete; deterioration

1370. Bureau of Reclamation, "CONCRETE MANUAL," U.S. Department of Interior, Bureau of Reclamation, Denver, Colorado, 7th Edition, Revised Reprint 1966.

KEY WORDS: alkali aggregate reactions; test methods; preventive measures

1371. De Puy, G. W., "EXPERIMENTS WITH ALKALI-SILICA REACTIVE CONSTITUENTS OF SAND-GRAVEL AGGREGATE," Highway Research Record, 1966, No. 124, pp. 41-49.

KEY WORDS: alkali aggregate reactions; "sand-gravel" aggregates; reactive aggregates

1966

1372. Hansen, W. C., "CONCRETE AGGREGATES - CHEMICAL REACTIONS," American Society for Testing and Materials Special Technical Publication No. 169-A, 1966, pp. 487-496.

KEY WORDS: alkali aggregate reactions; test methods

1373. Highway Research Board, "AGGREGATE CHARACTERISTICS AND EXAMINATION," Highway Research Record, 1966, No. 120, 40 pages.

KEY WORDS: aggregates; test methods; petrography

1374. Highway Research Board, "AGGREGATE FOR CONCRETE," Highway Research Record, 1966, No. 124, 84 pages.

KEY WORDS: aggregates

1375. Idorn, G. M. and Nepper-Christensen, P., "CASE HISTORIES," For Presentation at the Highway Research Board Annual Meeting, January 1967. Concrete Research Laboratory, Report No. 133, 1966.

KEY WORDS: alkali aggregate reactions; field experiences

1376. Kneller, W. A., "A STUDY OF CHERT AGGREGATE REACTIVITY BASED ON OBSERVATIONS OF CHERT MORPHOLOGIES USING ELECTRON OPTICAL TECHNIQUES," Proceedings of 17th Annual Symposium on Highway Geology. Iowa State University, April 1966, Department of Earth Sciences, Publication No. 1, July 1968.

KEY WORDS: chert; reactive aggregates; silica; test methods

1377. Ponomarev, I. F., Azelitskaya, R.D. and Chernikh, V.F., "REACTION OF ALKALI-CONTAINING CEMENTS WITH AGGREGATES IN FINE CONCRETE," Beton i Zhelezobeton, 1966, No. 6, pp. 20-23.

KEY WORDS: alkali aggregate reactions

1966

1378. Portland Cement Association, "AGGREGATES FOR CONCRETE," Skokie, Portland Cement Association, Publication ST91-2, 1966, 8 pages.

KEY WORDS: aggregates

1379. Anon., "EFFECT OF SIX AGGREGATE GRADINGS ON CEMENT AGGREGATE REACTION," Nebraska Department of Roads, Materials and Tests Division, 1967.

KEY WORDS: reactive aggregates; alkali aggregate reactions; particle size effects

1380. Hansen, W. C., "BASIC CHEMISTRY OF REACTIONS OF AGGREGATES IN PORTLAND CEMENT CONCRETE," Journal of Materials, 1967, Vol. 2, No. 2, pp. 408-431.

KEY WORDS: alkali aggregate reactions; mechanisms

1381. Highway Research Board, "AGGREGATE AND CONCRETE - DURABILITY," Highway Research Record, 1967, No. 196, 74 pages.

KEY WORDS: aggregates; reactive aggregates

1382. Houston, B. J., "TESTS FOR CHEMICAL REACTIVITY BETWEEN ALKALIES AND AGGREGATE. REPORT 3, FURTHER INVESTIGATION OF THE MORTAR BAR TEST," U.S. Army Engineers, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Technical Memorandum No. 6-368, October 1967.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars

1383. Idorn, G. M., "DURABILITY OF CONCRETE STRUCTURES IN DENMARK," Dansk Kemi, 1967, Vol. 48, No. 8, pp. 113-117.

KEY WORDS: alkali aggregate reactions; field experiences; petrography; mechanisms; Denmark

1384. Idorn, G. M., "DURABILITY OF CONCRETE STRUCTURES IN DENMARK: A STUDY OF FIELD BEHAVIOR AND MICROSCOPIC FEATURES," D.Sc. Thesis, Technical University of Denmark, Copenhagen, January 1967, 208 pages.

1967

KEY WORDS: alkali aggregate reactions; field experiences; Denmark; petrography; mechanisms; alkali silica gel

1385. Jansen, R. B., "BEHAVIOR AND DETERIORATION OF DAMS IN CALIFORNIA," Proceedings of the 9th International Congress on Large Dams, Istanbul, 1967, pp. 435-454.

KEY WORDS: dam structures; deterioration; field experiences; U.S.A.

1386. Jansen, R. B., "EVALUATION OF DAM SAFETY IN CALIFORNIA," Journal of the American Society of Civil Engineers, S.M. & F. Division, 1967, Vol. 93, pp. 23-36.

KEY WORDS: dam structures; field experiences; U.S.A.

1387. Kandantseva, K. L., Malyshev, N. I. and Tokarev, P. Y., "REACTIVITY OF ROCKS (in Russian)," Sbornik Trudov - Vsesoyuznyi Nauchno, Issledovatelskii Institute Nerudnykh Stroitelnykh Materialev i Gidromekhanizatsii 1967, No. 22, pp. 78-88. Chemical Abstracts, 1968, Vol. 69, 45807.

KEY WORDS: alkali aggregate reactions; reactive aggregates; USSR

1388. Klieger, P. and Isberner, A. W., "LABORATORY STUDIES OF BLENDED CEMENTS - PORTLAND BLAST- FURNACE SLAG CEMENTS," Journal of the Portland Cement Association, Research and Development laboratories, 1967, Vol. 9, No. 3, pp. 2-22.

KEY WORDS: slag; cements; preventive measures

1389. Mather, B., "FACTORS WHICH INFLUENCE THE DETERIORATION OF CONCRETE IN DAMS AND MEASURES FOR PREVENTION OF DETERIORATION," 9th International Congress on Large Dams, Istanbul, 1967, Proceedings, pp. 419-433.

KEY WORDS: dam structures; deterioration; preventive measures

1967

1390. Noli, A., "INVESTIGATION OF THE PERFORMANCE OF CONCRETE UNDER VARIOUS CONDITIONS OF EXPOSURE," L'Acqua, 1967, Vol. 45, No. 4, pp. 119-121.

KEY WORDS: field experiences; deterioration

1391. Hadley, D. W., "FIELD AND LABORATORY STUDIES ON THE REACTIVITY OF SAND-GRAVEL AGGREGATES," Journal of the Portland Cement Association, Research and Development Laboratories, 1968, Vol. 10, No. 1, pp. 17- 33. Portland Cement Association, Bulletin No. 221, 1968.

KEY WORDS: reactive aggregates; "sand-gravel" aggregates; field experiences; test methods; U.S.A.

1392. Highway Research Board, "CONCRETE ADMIXTURES, AGGREGATES AND DURABILITY," Highway Research Record, 1968, No. 226, 68 pages.

KEY WORDS: reactive aggregates; durability

1393. Kneller, W. A., Kriege, H. F., Saxer, E. L., Wilband, J. T. and Rohrbacher, T. J., "THE PROPERTIES AND RECOGNITION OF DELETERIOUS CHERTS WHICH OCCUR IN AGGREGATE USED BY OHIO CONCRETE PRODUCERS, - FINAL REPORT 1014," Research Foundation, The University of Toledo, Ohio, U.S.A., 1968, 201 pages.

KEY WORDS: reactive aggregates; chert; silica; test methods; petrography

1394. Lambert, R. H. and Pfister, I., "CONSTRUCTION OF HYDROELECTRIC POWER STATION AT HONGRIN - LEMAN. SILICEOUS AGGREGATES AND ALKALIS FROM PORTLAND CEMENTS (In French)," Travaux, Science et Industrie, Suisse, 401, pp. 830-831.

KEY WORDS: dam structures; alkali aggregate reactions; preventive measures; pozzolans; mineral admixtures

In order to prevent ASR in a concrete used in a dam to be constructed in Switzerland a petrographic analysis of the sand has been done. As this sand contained a reactive silica, a pozzolanic cement has been produced especially from pozzolans imported from Italy.

1395. Malyshev, N. I. and Novozhilova, N. P., "DISINTEGRATION OF CONCRETES MADE WITH REACTIVE AGGREGATES (in Russian),"

1968

Beton Zhelezobeton, 1968, Vol. 14, No. 4, pp. 21-23.
Chemical Abstracts, Vol. 69, 29906.
KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; USSR

1396. Mather, B., "CRACKING INDUCED BY ENVIRONMENTAL EFFECTS," Symposium on the Causes, Mechanism and Control of Cracking of Concrete, American Concrete Institute, Special Publication No. 20, 1968, pp. 67-72.

KEY WORDS: cracking; field experiences

1397. Mielenz, R. C., "CRACKING OF CONCRETE RELATED TO THE ALKALI-SILICA REACTION," U.S.-Japan Joint Seminar on Research on Basic Properties of Various Concrete, Session A. Paper 2, Tokyo, 1968.

KEY WORDS: cracking; alkali aggregate reactions

1398. Waugh, W. R., "DETERIORATION OF CONCRETE IN EISENHOWER LOCK," Civil Engineering, May 1968, P. 62.

KEY WORDS: alkali aggregate reactions; field experiences; hydraulic structures; U.S.A.

1399. Woods, H., "DURABILITY OF CONCRETE CONSTRUCTION," American Concrete Institute, ACI Monograph No. 4. Detroit, Michigan, A.C.I., The Iowa State University Press, Ames, Iowa, 1968.

KEY WORDS: deterioration

1400. Buck, A. D. and Mather, K., "CONCRETE CORES FROM DRY DOCK NO. 2. CHARLESTON NAVAL SHIPYARD," U.S. Waterways Experiment Station, Miscellaneous Paper C-69-6, Vicksburg, the Station, June 1969.

KEY WORDS: hydraulic structures; alkali aggregate reactions; field experiences; U.S.A.; petrography

1401. Buzhevich, G. A., Kurbatova, I. I., Kac, K. M. and Figarov, R. G., "EVALUATION OF THE REACTION OF SILICA IN EXPANDED CLAY AGGREGATE (KERAMSITE) (in Russian)," Stroitel'nye Materialy, Moscow, USSR, 1969, No. 10, pp. 35-36.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; U.S.S.R.

1402. Crumpton, C. F., Pattengill, M. G. and Badgley, W. A., "BRIDGE DECK DETERIORATION STUDY, PART VIII," State Highway Commission of Kansas, Planning and Development Department, Research Division, 1969, 8 pages.

KEY WORDS: bridge structures: deterioration; field experiences; U.S.A.

1403. Dolar-Mantuani, L., "ALKALI-SILICA-REACTIVE ROCKS IN THE CANADIAN SHIELD," Highway Research Record, No. 268, 1969, pp. 99-117.

KEY WORDS: reactive aggregates; petrography; Canada

1404. Highway Research Board, "PORTLAND CEMENT CONCRETE: SEALERS, DURABILITY, CREEP, REACTIVITY AND CEMENT DETERMINATION," Highway Research Record. 1969, No. 268, 130 pages.

KEY WORDS: alkali aggregate reactions; preventive measures; sealants

1405. Idorn, G. M., "THE DURABILITY OF CONCRETE," Concrete Society Publication No. 51-046, 1969, 16 pages.

1969

KEY WORDS: alkali aggregate reactions

1406. Kennerley, R. A. and St. John, D. A., "REACTIVITY OF AGGREGATES WITH CEMENT ALKALIES," National Conference on Concrete Aggregates, Hamilton, New Zealand, 4-6 June 1969, Proceedings pp. 35-47; Discussion, pp. 200-204.

KEY WORDS: alkali aggregate reactions; reactive aggregates; New Zealand

1407. Pickering, R. E., "PREVENTION OF ALKALI-AGGREGATE REACTIONS IN CONCRETE," U.S. Patent No. 3,433,657. Patented 18 March 1969.

KEY WORDS: alkali aggregate reactions; preventive measures; patents

1408. Watters, W. A., "PETROLOGICAL EXAMINATION OF CONCRETE AGGREGATES," Proceedings of the National Conference on Concrete Aggregates, Hamilton, New Zealand, 1969, pp. 48-54, 204.

KEY WORDS: aggregates; petrography

1409. Bukovatz, J. E., Wendling, W. H. and Wallace, H. E., "EXPANDED SHALE USED AS AN ADMIXTURE FOR SAND-GRAVEL AGGREGATE CONCRETE," State Highway Commission of Kansas, Planning and Development Department, Research Division, Kansas, U.S.A., 1970, 25 pages.

KEY WORDS: reactive aggregates; "sand gravel" aggregates; preventive measures

1410. Gillott, J. E., "EXAMINATION OF ROCK SURFACES WITH THE SCANNING ELECTRON MICROSCOPE," Journal of Microscopy, 1970, Vol. 19, No. 3, pp. 203- 205.

KEY WORDS: petrography; scanning electron microscopy

1411. Idorn, G. M. and Nepper-Christensen, P., "DISINTEGRATION OF CONCRETE IN FOUNDATION AND ANCHORAGE BLOCKS FOR AN AERIAL MAST," Highway Research Board, Special Report No. 106, 1970, pp. 67-69.

KEY WORDS: field experiences; deterioration; Denmark

1412. Idorn, G. M. and Thomsen, A. G., "DETERIORATION OF CONCRETE CHIMNEYS," Highway Research Board, Special Report No. 106, 1970, pp. 62-64.

KEY WORDS: field experiences; deterioration

1413. Kallauner, O., "THE ALKALIES IN PORTLAND CEMENT AND THEIR EFFECT ON THE PROPERTIES OF CONCRETE AND MORTAR (in German)," Baustoffindustrie, 1970, Vol. 13, No. 11, pp. 381-382.

KEY WORDS: alkali effects; cements; alkali aggregate reactions

1414. Pirtz, D., Strassburger, A.G. and Mielenz, R.C., "INVESTIGATION OF DETERIORATED CONCRETE ARCH DAM," Proceedings of the American Society of Civil Engineers,

1970

Journal of the Power Division, 1970, Vol. 96, No. 1, pp. 23-38.

KEY WORDS: dam structures; field experiences; U.S.A.

1415. Swenson, E. G., "ALKALI-EXPANSIVITY OF SOME CONCRETE AGGREGATES IN NOVA SCOTIA," Halifax, Nova Scotia Technical College, 1970, 50 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; Canada

1416. Copen, M. D. and Wallace, G. B., "DETERMINATION OF IN SITU STRESSES IN CONCRETE DAMS," American Society of Civil Engineers, Journal of the Power Division, March 1971, Vol. 97, pp. 455-473.

KEY WORDS: dam structures; internal stresses

1417. Dolar-Mantuani, L., "PRECAMBRIAN ALKALI-REACTIVE SEDIMENTARY ROCKS IN ONTARIO," Paper Presented at the Annual Meeting of Geological and Mineralogical Associations of Canada, Sudbury, 13 May 1971, 9 pages.

KEY WORDS: reactive aggregates; Canada; petrography

1418. Gudmundsson, G., "ALKALI AGGREGATE REACTION IN CONCRETE," Building Research Institute, Reykjavik, Iceland, Report No. 12, 1971, 93 pages.

KEY WORDS: alkali aggregate reactions

1419. Highway Research Board, "MINERAL AGGREGATES," Highway Research Record, 1971, No. 353, 46 pages.

KEY WORDS: aggregates

1420. Porter, L. C., "DETERIORATED CONCRETE IN NORTH PLATTE RIVER PROJECT SUBSTATIONS," Bureau of Reclamation, Denver, Colorado, Report No. RED- ERC-71-7, January 1971, 7 pages.

KEY WORDS: deterioration; field experiences; U.S.A.; electric power structures

1421. Anon., "ALKALI REACTIONS IN CONCRETE (in German)," Report on Activities 1972-74. Verein Deutscher Zementwerk e.V., Forschungsinstitut der Zementindustrie, Dusseldorf, April 1975, pp. 105-111.

KEY WORDS: alkali aggregate reactions

1422. Anon., "TESTS TO SHOW JERSEY DAM STILL SOUND," New Civil Engineer, 19 October 1972, No. 12, pp. 12-13.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences; U.K.

1423. Astakhova, M. A., Shtejert, N. P., Podobrjanskaja, B. I. and Tureckij, A. M., "REACTION OF CEMENT CONTAINING ALKALIS WITH DIFFERENT AGGREGATES (In Russian)," C.R. 9, pp. 14-1a.

KEY WORDS: alkali aggregate reactions; alkali effects; expansion; mortar bars

Expansions of mortars containing cements with 0.40 to 2.34% $Na_2O$ eq. and different aggregates with reactive minerals (chalcedony, andesite, Pyrex glass) are higher than 0.05% at 6 months and 0.10% at one year for cements with 2.00 to 2.34% $Na_2O$ eq. Cements with 0.91 to 1.34% $Na_2O$ lead to expansion in the presence of Pyrex glass.

1424. Ciach, T. D., "STUDY OF REACTIONS BETWEEN CEMENT PASTE AND ACTIVE SILICA IN AGGREGATES (In Polish)," Cement Wapno Gips, 7-8, pp. 237-240.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive measures

ASRs form complexes. If the reaction product is an alkali silicate concrete expands. If the alkali silicate contains calcium the risk of expansion is lower. If the amount of alkalis in cement is high the reaction product is expansive. The addition of silica dust or pozzolan is a protection against ASR.

1972

1425. Dokumentationsstelle fur Bauteknik in der Franuhofer-Gesellschaft, "ALKALI REACTION IN CEMENT AND CONCRETE, BIBLIOGRAPHY 1965-1971 (in German)," Bibliography N1777. Stuttgart,1972, 5 pages.

KEY WORDS: alkali aggregate reactions; bibliography

1426. Fairbarin, P. E. and Robertson, R. H. S., "THE DECOMPOSITION OF FLINT," Scottish Journal of Science, 1972, Vol. 1, No. 3, pp. 165-174.

KEY WORDS: flint; silica; reactive aggregates

1427. Grzelak, E., "INFLUENCE OF THE AGGREGATE REACTIVITY ON THE QUALITY OF CONCRETE (In Polish)," Cement Wapno Gips, 7-8, pp. 240-244.

KEY WORDS: alkali aggregate reactions

Concrete deterioration can be due to the reactivity of the siliceous part of aggregates. In order to avoid expansion low alkali cements have to be used and coarse aggregates are better than fine grains because the silica inclusions are not liberated and do not react with alkalis from the cement paste. Reactive aggregates contain all kinds of silica.

1428. Hirche, D., "THE ALKALI SILICA REACTION (in German)," Dissertation; Rheinische-Westfalischen Technischen Hochschule, Aachen1972, 355 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; silica; infrared spectroscopy

1429. Kennerley, R. A., "CONCRETE AGGREGATES OF NEW ZEALAND," Chemistry Division, Department of Scientific and Industrial Research, Lower Hutt, New Zealand, Report CD 2039, March 1972.

KEY WORDS: aggregates; New Zealand

1972

1430. Moskvin, V. M., "ON A METHOD FOR ASSESSING THE ALKALI-DETERIORATION OF CONCRETE (in Russian)," Beton i Zhelezobeton, 1972, No. 7, pp. 20-21.

KEY WORDS: alkali aggregate reactions; test methods

1431. Salnikov, N. S. and Ivanov, F. M., "CORROSION OF CONCRETE CONTAINING AGGREGATE WITH AMORPHOUS SILICA UNDER INFLUENCE OF VARIOUS ANIONS (in Russian)," Colloid Journal(USSR) 1972, Vol. 33, p. 735.

KEY WORDS: alkali aggregate reactions; mechanisms

1432. Shepherd, W., "FLINT, ITS ORIGIN, PROPERTIES AND USES," Faber & Faber, London 1972.

KEY WORDS: flint; silica; reactive aggregates

1433. Swenson, E. G., "INTERACTION OF CONCRETE AGGREGATE AND PORTLAND CEMENT - SITUATION IN CANADA," Engineering Journal (Montreal), May 1972, Vol. 55, No. 5, pp. 34-39. Division of Building Research, National Research Council, Ottawa, Technical Paper No. 375, June 1972, 6 pages.

KEY WORDS: alkali aggregate reactions; field experiences; Canada

1434. Viktorov, A. M., "PREDICTION OF ALKALI-DETERIORATION OF CONCRETE (in Russian)," Beton i Zhelezobeton, 1972, No. 7, pp. 18-19.

KEY WORDS: alkali aggregate reactions

1435. Anon., "CRUMBLING DAM ON SNAKE RIVER TO BE REPLACED," Engineering News Record, 12 February 1973, Vol. 190, No. 7, p. 15.

KEY WORDS: dam structures; field experiences; U.S.A.

1436. Anon., "A CONCRETE AGGREGATE PROBLEM IN NOVA SCOTIA," Division of Building Research, National Research Council of Canadian, Ottawa, Building Research News, No. 47, July 1973, pp. 2-3.

KEY WORDS: reactive aggregates; field experiences; Canada

1437. Betterman, P., "RESEARCH ON THE ALKALI-SENSITIVITY OF GLACIAL FLINT FROM SCHLESWING-HOLSTEIN (in German)," Zement-Kalk-Gips, November 1973, No. 11, pp. 523-528.

KEY WORDS: reactive aggregates; flint; silica; Germany

1438. Bonzel, J., "ALKALI REACTION UNDER CONDITIONS ENCOUNTERED IN CONSTRUCTION PRACTICE (in German)," Vorbeugende Massnahmen Gegen Alaklireaktion im Beton, Dusseldorf, Verein Deutsch Zementwerke, e.V., Schriftenreihe der Zementindustrie, Heft 40, 1973, pp. 23-35.

KEY WORDS: alkali aggregate reactions; field experiences; Germany

1439. Bonzel, J. and Dahms, J., "ALKALI-AGGREGATE REACTION IN CONCRETE (In German)," B.H.V., Vol. 23, 11, pp. 495-500, 12, pp. 547-554.

KEY WORDS: alkali aggregate reactions; reactive aggregates; opal; silica; field experiences; Germany

Degradation of massive concrete due to alkali-aggregate reaction has appeared in humid environments and in the presence of opaline sandstone. The most deleterious composition of concrete with respect to aggregates is an amount of 15-25% by weight of reactive minerals in the size range of 3-7 mm. High damages correspond to concretes

containing at least 400 kg of high alkali cement, which are exposed to humid environments or submitted to cycles of humidification-desiccation. Attention has to be paid to the possible increasing in alkalis coming from aggregates or admixtures.

1440. Canadian Standards Association, "METHOD OF TEST FOR CONCRETE: TEST FOR ALKALI AGGREGATE REACTION," CSA Standard A23.2.24., 1973, pp. 190-191.

KEY WORDS: test methods; alkali aggregate reactions

1441. Dahms, J., "TESTS ON CONCRETE RELATED TO THE ALKALI-AGGREGATE REACTION (In German)," Schriftenreihe der Zementindustrie, Vol. 40, pp. 79-90.

KEY WORDS: alkali silica reactions; test methods; field experiences; Germany

Pop-outs, spalling and cracking have been observed in concretes containing at least 400 kg/m$^3$ of high alkali cement and aggregates with opaline sandstone from Schleswig-Holstein, when stored in a high humidity.

1442. Duncan, M. A. G., Swenson, E. G., Gillott, J. E. and Foran, M. R., "ALKALI-AGGREGATE REACTION IN NOVA SCOTIA I. SUMMARY OF A FIVE-YEAR STUDY," Cement and Concrete Research, Vol. 3, pp. 55-69, 1973.

KEY WORDS: alkali aggregate reactions; reactive aggregates; greywackes; argillites; phyllites; expansion; preventive measures; mineral admixtures; fly ash; Canada; field experiences

Certain rock types in Nova Scotia, otherwise acceptable for concrete aggregate, were shown to be alkali-expansive to an excessive degree when used in conjunction with high alkali cement. The length-change expansion tests confirmed field observations and results of examination of field concrete. Culprit rocks were greywackes, argillites, phyllites, and some of the quartzites, schists and rhyolites. A highly moist environment was shown to be necessary for this reaction to develop to any serious extent. Accelerated methods of evaluation were developed because of the very slow reaction.

Preventive measures, demonstrated in the laboratory, are the use of low alkali cement or a pozzolan of fly ash.

1443. Duncan, M. A. G., Gillott, J. E. and Swenson, E. G., "ALKALI-AGGREGATE REACTION IN NOVA SCOTIA II. FIELD AND PETROGRAPHIC STUDIES," Cement and Concrete Research, Vol. 3, pp. 119-128, 1973.

KEY WORDS: alkali aggregate reactions; field experiences; Canada; petrography; greywackes; argillites; phyllites; quartzites

Rock used as concrete aggregate are of the type to be expected from the geology of Nova Scotia - a glaciated portion of the Appalachian province. Microscopic examinations of concrete cores from many structures, and rock and sand sampling from widely separated parts of Nova Scotia show that gravel and beach deposits have frequently been used as aggregate sources; hence many of the concretes contain a heterogeneous mixture of Appalachian rock types. The field surveys along with petrographic examinations indicate concrete distress caused by an alkali aggregate reaction in widely separated parts of the Province. The most common rocks in affected cases are greywackes, argillites, phyllites, and some quartzites and schists. These findings were confirmed by length change experiments on mortar bars, concrete prisms and rock cylinders.

1444. Duncan, M. A. G., Swenson, E. G. and Gillott, J. E., "ALKALI-AGGREGATE REACTION IN NOVA SCOTIA III. LABORATORY STUDIES OF VOLUME CHANGE," Cement and Concrete Research, Vol. 3, pp. 233-245, 1973.

KEY WORDS: alkali aggregate reactions; expansion; test methods; mortar bars; argillites; phyllites; greywackes; concrete prisms; rock cylinders

Good agreement was obtained between the various tests with mortar bars, concrete prisms, and rock cylinders in distinguishing potentially alkali-expansive rocks from non-expansive rocks. To some degree this was remarkable considering the heterogeneity of rock types and minerals in any given sample. Some correlation data and the recommended test conditions are outlined in the first paper. Further detailed test data are to be found in the doctoral thesis of the first author. As in other types of alkali aggregate

reactions which have been studied and reported, the mortar bar and concrete prism tests continue to be good direct methods for evaluation. The rock cylinder test, heretofore limited to the alkali carbonate rock reaction, has been shown to be applicable to evaluation of the rocks in Nova Scotia.

1445. Gillott, J. E. and Swenson, E. G., "AN INVESTIGATION OF ROCKS FROM ALERT, NORTH WEST TERRITORY, FOR CONCRETE AGGREGATES," Department of Civil Engineering, University of Calgary, Calgary, Alberta, Canada, Research Report No. CE 73-8, May 1973.

KEY WORDS: reactive aggregates; Canada

1446. Gillott, J. E., Duncan, M.A.G. and Swenson, E. G., "ALKALI-AGGREGATE REACTION IN NOVA SCOTIA IV. CHARACTER OF THE REACTION," Cement and Concrete Research, Vol. 3, pp. 521-535, 1973.

KEY WORDS: alkali aggregate reactions; mechanisms

It is concluded that there are extractable interlayer precipitates between the basal planes of the vermiculite-like mineral in alkali-expansive Nova Scotia rocks and that once this precipitate is removed by NaOH the mineral expands and causes an increase in the volume of the rock. There are small amounts of smectites present which also may contribute to expansion.

1447. Gillott, J. E. and Swenson, E. G., "SOME UNUSUAL ALKALI-EXPANSIVE AGGREGATE," Engineering Geology, December 1973, Vol. 7, No. 3, pp. 181-195.

KEY WORDS: alkali aggregate reactions; reactive aggregates; Canada

1448. Gogte, B. S., "AN EVALUATION OF SOME COMMON INDIAN ROCKS WITH SPECIAL REFERENCE TO ALKALI-AGGREGATE REACTIONS," Engineering Geology, 1973, Vol. 7, pp. 125-153.

KEY WORDS: alkali aggregate reactions; reactive

aggregates; India

1449. Idorn, G. M., "ALKALI-SILICA REACTIONS 1973 AND ONWARDS," Concrete Research Laboratory Internal Report No. 306, Karlstrup, April 1973, 3 pages.

KEY WORDS: alkali aggregate reactions

1450. Kjaer, U. and Nepper-Christensen, P., "ALKALI REACTIONS IN CONCRETE," Beton-Teknik, (3/02), Cement Technical Information Service (Cto) Copenhagen, 1973, p. 6.

KEY WORDS: alkali aggregate reactions

1451. Kordina K., et al, "INVESTIGATION INTO THE EFFECTIVENESS OF IMPREGNATION MATERIALS FOR THE CONSERVATION OF BRIDGEWORKS AFFECTED BY DELETERIOUS ALKALI-AGGREGATE REACTIONS (in German)," Report for the Schleswig-Holstein Motorway Authority by the Institute for Building Materials and Reinforced Concrete, Technical University of Brunswick, 30 April 1973.

KEY WORDS: alkali aggregate reactions; bridge structures; repairs; field experiences; Germany

1452. Locher, F. W., "CAUSES AND MECHANISM OF ALKALI REACTION (in German)," Vorbeugende Massnahmen gegen Alkalireaktion im Beton, Dusseldorf, Verein Deutscher Zementwerke e.V., Schriftenreihe der Zementindustrie, Heft 50, 1973, pp. 11-22.

KEY WORDS: alkali aggregate reactions; mechanisms

1453. Locher, F. W. and Sprung, S., "CAUSES AND MECHANISM OF ALKALI-AGGREGATE REACTION (in German)," Beton, 1973, Vol. 23, No. 7, pp. 303-306. English Translation, Association Portland Cement Manufacturers, p. 355, 1973.

KEY WORDS: alkali aggregate reactions; mechanisms

1973

1454. Locher, F. W. et al., "ALKALI REACTIONS IN CONCRETE (in German)," Betonwerke und Fertigteil-Teknik, 1973, Vol. 39, No. 3, pp. 225-227.

KEY WORDS: alkali aggregate reactions

1455. Locher, F. W. and Sprung, S., "CAUSES AND ACTION OF ALKALI-AGGREGATE REACTION (In German)," B.H.V., Vol. 23, 7, pp. 303-306, 8, pp. 349-353.

KEY WORDS: alkali aggregate reactions; opal; alkali effects; expansion; field experiences; Germany

Siliceous aggregates react in concrete when the amount of alkalis is at least 3 $kg/m^3$ of $Na_2O$ eq. Alkalis are provided by cements but also by admixtures, sea water, and deicing salts. There is no concrete expansion when the cement is low in alkalis and its amount less than 500 $kg/m^3$. The reactivity of aggregates from Schleswig-Holstein is due mainly to the amount of opaline sandstone. Flint with a specific mass higher than 2.50 $g/cm^3$ gives a low expansion of concrete.

1456. Mather, B., "A DISCUSSION OF THE PAPER "ALKALI-AGGREGATE REACTION IN NOVA SCOTIA. I. SUMMARY OF A FIVE-YEAR STUDY," BY M.A.G. DUNCAN, ET. AL.," Cement and Concrete Research, Vol. 3, pp. 333-334, 1973.

KEY WORDS: alkali aggregate reactions

1457. Mather, K., "EXAMINATION OF CORES FROM FOUR HIGHWAY BRIDGES IN GEORGIA," U.S. Army Corps Engineers, Miscellaneous Paper, C-73-11, Vicksburg, Mississippi, November 1973.

KEY WORDS: bridge structures; alkali aggregate reactions; field experiences; U.S.A.

1458. Mindess, S. and Gilley, J.C., "THE STAINING OF CONCRETE BY AN ALKALI-AGGREGATE REACTION," Cement and Concrete Research, Vol. 3, pp. 821-828, 1973.

KEY WORDS: alkali aggregate reactions; field experiences;

1973

Canada

Certain concrete aggregates in British Columbia were found to react with water-soluble alkalis in cement to produce brown stains and popouts on concrete surfaces. The particles responsible for the reaction have not yet been positively identified, but are known to contain iron compounds. The only solution to the problem appears to be the use of cement with a water soluble alkali content less than 0.18% (as $Na_2O$).

1459. Niemeyer, E. A., "CONCRETE AGGREGATES IN SCHEWIG-HOLSTEIN (in German)," Vorbeugende Massnahmen gegen Alkalireaktion im Beton, Dusseldorf, Verein Deutscher Zemetwerke e.V. Schriftenreihe der Zementindustrie, Heft 40, 1973, pp. 37-55.

KEY WORDS: reactive aggregates; Germany

1460. Smolczyk, H. G., "TESTING AND ASSESSMENT OF AGGREGATE FOR CONCRETE (in German)," Vorbeugende Massnahmem gegen Alkalireaktion im Beton, Dusseldorf, Verein Deutscher Zementwerke e.V., Schriftenreihe der Zementindustrie, Heft 40, 1973, pp. 57-67.

KEY WORDS: aggregates; test methods

1461. Sprung, S., "INFLUENCE OF CEMENT AND ADDITIVES ON THE ALKALI-REACTION (in German)," Vorbeugende Massnahmen gegen Alkalireaktion im Beton. Dusseldorf, Verein Deutscher Zementwerke e.V., Schriftenreihe der Zementindustrie, Heft 40, 1973, pp. 69-78.

KEY WORDS: alkali aggregate reactions; cements; alkali effects

1462. Wischers, G. et al., "PREVENTIVE MEASURES AGAINST ALKALI-AGGREGATE REACTION IN CONCRETE," Schriftenreihe der Zementindustrie, Heft 40, 1973. English Translation by C.V. Amerongen, London, Cement and Concrete Association, T. 27, 1973, 72 pages.

1973

KEY WORDS: alkali aggregate reactions; preventive measures

1463. Anon., "PRECAUTIONARY MEASURES AGAINST DELETERIOUS ALKALI-AGGREGATE REACTION IN CONCRETE (in German)," Tentative Code of Practice, February 1974 Edition. Beton: Herstellung Verwendung, May 1974, Vol. 24, No. 5, pp. 179-185, English translation by C.V. Amerngen, London, Cement and Concrete Association, T55, 1974, 21 pages.

KEY WORDS: alkali aggregate reactions; preventive measures

1464. Coffin, H., "RECOMMENDED PRECAUTIONS AGAINST DELETERIOUS ALKALI REACTIONS IN CONCRETE," Beton, 1974, Vol. 24, No. 5, pp. 179-186.

KEY WORDS: alkali aggregate reactions; preventive measures

1465. Diamond, S., "MECHANISMS OF ALKALI-SILICA REACTION AND EXPANSION - A REVIEW AND REASSESSMENT," Purdue University, Indiana, U.S.A., 1974, 71 pages.

KEY WORDS: alkali aggregate reactions; mechanisms

1466. Diamond, S. and Thaulow, N., "A STUDY OF EXPANSION DUE TO ALKALI-SILICA REACTION AS CONDITIONED BY THE GRAIN SIZE OF THE REACTIVE AGGREGATE," Cement and Concrete Research, Vol. 4, pp. 591-607, 1974.

KEY WORDS: alkali aggregate reactions; particle size effects; opal; cristobalite; mortar bars; expansion; cracking

Mortars made from high alkali cement and reactive aggregate in the usual proportions and in size ranges down to 30 microns to 20 microns show excessive expansion due to ASR, the order of magnitude of expansion being as much as 2.5 percent. For size ranges of reactive aggregate of this order, the onset of expansion is sudden, and expansion terminate after a few months. For comparable specimens with somewhat coarser reactive aggregate, up to 125 microns and beyond, expansion is slower and the period of active expansion is much more prolonged. ASR and expansion can occur without necessarily causing the extensive cracking observed by other workers; in consequence the identification of expansion with the sum of crack widths in the direction of

expansion is not universally valid.

1467. Epstein, G. and Stevens, E. R., "ALKALI AGGREGATE REACTION IN MAINE," U.S. National Technical Information Service, P.B. Report, 1974, No. 238887/4GA, 22 pages.

KEY WORDS: alkali aggregate reactions; field experiences; U.S.A.

1468. Gillott, J. E., Ward, M. A. and Langan, B. W., "ROLE OF AGGREGATES IN STRENGTH AND DURABILITY OF CONCRETE IN THE VICINITY OF CALGARY, ALBERTA," University of Calgary, Research Report, CE 74-6, April 1974.

KEY WORDS: aggregates; field experiences; Canada

1469. Idorn, G. M., "AALBORG PORTLAND R & D SEMINAR ON ALKALI-SILICA REACTIONS - HOTEL HVIDE HUS, KOGE, DENMARK, 20-21 MAY 1974.," Concrete Research Laboratory Internal Report No. 342, Karlstrup, 1974, 25 pages.

KEY WORDS: alkali aggregate reactions; conferences

Report of what proved to be first in a numbered series of international conferences on alkali aggregate reactions.

1470. Johnston, C. D., "WASTE GLASS AS A COARSE AGGREGATE FOR CONCRETE," Journal of Testing and Evaluation, 1974, Vol. 2, No. 5, pp. 344-350.

KEY WORDS: glass; reactive aggregates

1471. Narnberg, H. W., Wolff, G., Hirche, D. and Ludwig, U., "PHYSICO-CHEMICAL ASPECTS OF ALKALI-AGGREGATE REACTION AND THEIR SIGNIFICANCE IN CONCRETE EXPANSIONS (In German)," Sprechs Keram Glas Baust, Vol. 106, 24, pp. 982-992, 3, pp. 83-93, 5, pp. 187-204.

KEY WORDS: alkali aggregate reactions; mechanisms; reactive aggregates; infrared spectroscopy

In siliceous minerals the intensity of the alkali aggregate reaction is a function of crystal disorders related to the amount of silanol groups characterized by IR spectroscopy. On external surfaces of silica there is at first an exchange between $H^+$ ions of silanol groups and cations which then diffuse towards silica grains. Alkalis $K^+$ and $Na^+$ differ from $Ca^{2+}$ ions from the point of view of diffusion kinetics and reaction products. The swelling of siliceous grains is due to a water absorption. An important role is played by $Ca^{2+}$ ions as calcium silicates attract water molecules from alkaline silicates. Moreover $Ca(OH)_2$ provides OH necessary to the further reaction.

1472. Oberholster, R. E. and Brandt, M. P., "AN EXAMPLE OF CEMENT-AGGREGATE REACTION IN SOUTH AFRICA," Proceedings of South African Electron Microscopy Society, 1974, Vol. 4, pp. 59-60.

KEY WORDS: alkali aggregate reactions; field experiences; South Africa

1473. Pedersen, E. J., "ALKALI-SILICA REACTIONS IN CONCRETE," Nordisk Betong, 1974, No. 5, pp. 11-13.

KEY WORDS: alkali aggregate reactions

1474. Penkala, B., "REDUCTION OF CONCRETE EXPANSION DUE TO REACTIVE LIMESTONE AGGREGATES (In Polish)," Cement Wapno Gips 10, pp. 308-312.

KEY WORDS: alkali aggregate reactions; preventive measures

In order to decrease concrete expansions due to the reaction between alkalis and limestone aggregates, the amount of cement has been diminished, a low alkali cement (< 0.6% $Na_2O$ eq.) has been used and granite aggregates of good quality have partly replaced the reactive aggregates. Also a surface tension active admixture called Kutanit and oleic acid have improved the behavior of concrete. However oleic acid must not be used in highly humid environments.

1974

1475. Smolczyk, H. G., "SLAG CEMENTS AND ALKALI-REACTIVE AGGREGATES," 6th International Symposium on the Chemistry of Cement. Moscow, 1974, Supplementary Paper to Main Session on Slag Cement.

KEY WORDS: slag; reactive aggregates; alkali aggregate reactions; preventive measures

1476. Anon., "PREVENTIVE MEASURES AGAINST DELETERIOUS ALKALI REACTION IN CONCRETE (in German)," Gazette of the Free Hansa City of Bremen, 20 February 1975, No. 16, pp. 157-165.

KEY WORDS: alkali aggregate reactions; preventive measures

1477. Anon., "ALKALI-AGGREGATE REACTION CONFIRMED IN JERSEY DAM," New Civil Engineer, 20 November 1975, pp. 24-25.

KEY WORDS: alkali aggregate reactions; dam structures; field experience; U.K.

1478. Building Research Institute, Iceland, "SYMPOSIUM ON ALKALI AGGREGATE REACTION - PREVENTATIVE MEASURES," Reykjavik, 1975, 170 pages.

KEY WORDS: alkali aggregate reactions; conferences

Proceedings of the Symposium that became the second of the series of international conferences on alkali aggregate reactions, indexed as the 2nd Intl. Alkali Conf.

1479. Coombes, L. H., Cole, R. G. and Clark, R. M., "REMEDIAL MEASURES TO VAL DE LA MARE DAM, JERSEY, CHANNEL ISLANDS, FOLLOWING ALKALI-AGGREGATE REACTIVITY," BNCOLD/University Symposium, Newcastle upon Tyne, England, September 1975, Paper 3.3, 9 pp.

KEY WORDS: alkali aggregate reactions; dam structures; repairs; field experiences; U.K.

1480. Diamond, S., "PORE SOLUTIONS AND ALKALI-AGGREGATE ATTACK," Proc. 2nd Intl. Alkali Conf. 1975, pp. 165-181.

KEY WORDS: alkali aggregate reactions; pore solutions; alkali effects; mechanisms

(1) Pore solutions in concrete made from reasonably high alkali cement rapidly become concentrated alkali hydroxide solutions of the order of 0.7 M or more. (2) Calcium

concentrations are reduced after few days to the order of only 0.002 M, and maintained at this level for several months; the level represents saturation with respect to calcium hydroxide in the high ionic strength and high hydroxyl concentration solutions. (3) There is evidence to suggest that even this low level of calcium is reduced to essentially zero after a few months. If so, the explanation likely involves isolation of the calcium hydroxide crystals from the pore solution, presumably by development of a later of low-lime calcium silicate around the crystals. (4) Analyses recently reported indicate that as reaction product "gel" moves outward from the reacting grain it increases in calcium content and decreases in alkali content. The calcium probably comes from calcium hydroxide crystals enveloped by the liquified reaction product which is really a sol at this stage. Alkalies are lost to the surrounding cement paste by diffusion. (5) The relative absence of calcium in the original aggressive solution in the pores of the concrete mitigates strongly against the likelihood that calcium plays s significant role in the formation of the original reaction product, which is viewed as the local product of attack of strong alkali hydroxide solution on the siliceous aggregate grains.

1481. Diamond, S., "Conference Summary for Symposium on Alkali Aggregate Reactions- Preventative Measures," Proc. 2nd Intl. Alkali Conf. , Reykjavik, 1975 pp 263-268.

KEY WORDS: alkali aggregate reactions; conferences

Technical summary of conference proceedings.

1482. Diamond, S., "THE Ph FACTOR IN ALKALI-SILICA REACTION," Conference on Alkali-Silica Reactions in Concrete. 54th Annual Meeting of the Transportation Research Board, Sheraton-Park Hotel, Washington D.C., 16 January 1975.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects

1483. Diamond, S., "A REVIEW OF ALKALI-SILICA REACTION AND EXPANSION MECHANISMS 1. ALKALIES IN CEMENTS AND IN CONCRETE PORE SOLUTIONS," Cement and Concrete Research, Vol. 5, pp. 329-346, 1975.

KEY WORDS: alkali aggregate reactions; alkali effects; cements; pore solutions; mechanisms

The revival of interest and concern with respect to the classical ASR is due to field reports of damage, increases in alkali contents of available cements, use of lower water contents and higher cement contents in some applications, and the necessity of employing marginal aggregates with unknown service behavior in many places. The mechanism involves hydroxide ion attack on the susceptible aggregates, resulting in alkali silicate reaction products that develop pressure, expand, and crack in cement. The reaction is primarily an attack of hydroxide ions on the affected siliceous aggregate, and not a direct consequence of the presence of alkali cations in the concrete pore solutions. However, the content of hydroxide ions is strongly conditioned by the content of alkali ions. The conventional expression of alkali content of the cement (as equivalent percent $Na_2O$) is less closely related to the problem than expression on the bulk basis, or better, expression in terms of concentration actually in the pore solutions. Alkalies in cement are partly soluble (occurring as alkali sulfates of various kinds) and partly insoluble (occurring in solid solution form primarily within tricalcium aluminate and belite). Rates of transfer to solution should depend on the form involved, but may not in fact do so. Alkali cations persist in solution, and build up to concentrations as high as 0.7M in the pore solution of pastes made from high alkali cements. Hydroxide ion concentrations tend to equal the combined concentration of alkali cations after a few days, but are lower for the first day or so. Generation of hydroxide ions from neutral alkali sulfates appears to be delayed until the precipitation of ettringite is essentially completed. This is probably not true of alkali cations derived from solid solution, which should hydrolyze directly to yield hydroxide ions. The pH values of pore solution within pastes made from high alkali cements reach values of 13.7 and higher; the concentrations of the hydroxide ions are of the order of 15 times greater than that of pure saturated calcium hydroxide solutions.

1484. Dolar-Mantuani, L. M., "PETROGRAPHIC ASPECTS OF SILICEOUS ALKALI REACTIVE AGGREGATES," Proc. 2nd Intl. Alkali Conf., Reykjavik 1975, pp. 87-100.

KEY WORDS: reactive aggregates; quartz; silica; undulatory extinction angle; test methods; petrography

The results obtained using both the general method for determination of quartz instability and that of the Undulatory Extinction Angle are only preliminary, and far more data must be obtained before any evaluation of precision and exactness of the methods can be attempted. There is no doubt that the method of the UE angle which offers numerical results is more promising. Some agreement has been indicated between the average values of these angles in the quartz grains and the expansion of the rocks exposed to high alkali cement and to 1N sodium hydroxide solution, respectively.

1485. Figg, J. W., "PRELIMINARY APPRAISAL OF PROBLEM AREAS AND REACTIVE AGGREGATES WITH APPROPRIATE PREVENTIVE MEASURES," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 245-255.

KEY WORDS: alkali aggregate reactions; bibliography

A bibliography on alkali aggregate reactions up to 1974 has been compiled by C and CA, London, on behalf of Cembureau, and will be published shortly.

1486. Gillott, J. E., "PRACTICAL IMPLICATIONS OF THE MECHANISMS OF ALKALI-AGGREGATE REACTIONS," Proc. 2nd Intl. Alkali Conf. 1975, pp. 215-230.

KEY WORDS: alkali aggregate reactions; mechanisms; petrography; field experiences;

Emphasis is placed on differentiation between "alkali silica" and "alkali silicate" reactions. The petrography of reactive aggregates is reviewed, especially for alkali silicate reactive rocks. Limitations of mortar bar and concrete prism expansion tests are indicated. Field indications of alkali aggregate reactions are described. Mechanisms of alkali silicate reactions, especially those involving little gel formation, are reviewed.

1487. Gillott, J. E., "THE ALKALI-AGGREGATE REACTION," Conference on Alkali-Silica Reactions in Concrete, 54th Annual Meeting of the Transportation Research Board, Sheraton Park Hotel, Washington D.C., 16 January 1975.

KEY WORDS: alkali aggregate reactions; mechanisms

1975

1488. Gudmundsson, G., "INVESTIGATION ON ICELANDIC POZZOLANS," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 65-75.

KEY WORDS: pozzolans; mineral admixtures; alkali aggregate reactions; Iceland

Many of the pozzolans included in this investigation have sufficient pozzolanic activity to be used in pozzolan cement. The different fineness of the pozzolans make an exact evaluation of the pozzolanic properties very difficult, since the relation between fineness and strength development and reduction in expansion is not known for these materials.The next step in this investigation will be to investigate these properties and how they will affect strength and expansion.

1489. Gudmundsson, G. and Asgeirsson, H., "SOME INVESTIGATIONS ON ALKALI AGGREGATE REACTION," Cement and Concrete Research, Vol. 5, pp. 211-220, 1975.

KEY WORDS: alkali aggregate reactions; field experiences; Iceland

Nearly all Icelandic concreting aggregates are volcanic basalt. Many of these basalt have not crystallized extensively and include glass, which through metamorphic surface changes have weathered into alkali reactive aggregates. Icelandic aggregates however, have relatively low reactivity compared with concreting aggregates in places where alkali expansion has been a problem. In connection with methods to prevent the risk of damage due to alkali aggregate reactivity, Iceland pozzolans were investigated. The results showed that many pozzolanic materials can prevent damaging expansion in concrete with reactive Icelandic materials, if sufficient quantity of the pozzolan is used. In large constructions under wet conditions such as in some harbors and hydraulic dams, careful tests must be performed and preventive measures taken. The use of low alkali cements may be a practical solution in some cases, but as a general amendment for Icelandic conditions pozzolanic cement should be used.

1490. Hirche, D., "IR-SPECTROSCOPY, A MODERN METHOD TO TEST THE ALKALI REACTIVITY OF SILICA AGGREGATES," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 205-211.

1975

KEY WORDS: alkali aggregate reactions, reactive aggregates; silica; infrared spectroscopy

1491. Idorn, G. M., "ALKALI-SILICA REACTION," Proc. 2nd Intl. Alkali Conf. Reykjavik, 1975, pp. 13-16.

KEY WORDS: alkali aggregate reactions

A general review and discussion of the field.

1492. Idorn, G. M., "A DISCUSSION OF THE PAPER "SOME INVESTIGATIONS ON ALKALI AGGREGATE REACTION" BY G. GUDMUNDSSON AND H. ASGEIRSSON," Cement and Concrete Research, Vol. 5, pp. 261-262, 1975.

KEY WORDS: alkali silica reactions

1493. Johansson, L., "TESTS AND QUALITY CONTROL OF AGGREGATES FOR CONCRETE (in Swedish)," Cement Betong Inst (CBI) Report No. 4, 7 pages.

KEY WORDS: aggregates; Sweden

Siliceous Swedish aggregates do not react with alkalis and are usually resistant to freezing and thawing. Tests carried on aggregates determine (i) the granularity (the optimum of which depends on water to cement ratio, amount of cement, concrete production and construction process), (ii) the presence of organic materials, and (iii) the mineralogical composition.

1494. Kennerley, R. A., St John, D. A. and Smith, L. M., "ALKALI-AGGREGATE REACTIVITY IN NEW ZEALAND," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 35-53.

KEY WORDS: alkali aggregate reactions; greywacke; glass; rhyolite;andesite; dacite; field experience; New Zealand

(1) Certain New Zealand aggregates, particularly glassy andesite, rhyolite and dacite, react expansively with cement alkalis. (2) The good performance of concrete containing potentially reactive aggregates in service is

due mainly to the use of low-alkali cement. (3) At one time there were doubts regarding the occurrence of expansion of concrete containing reactive aggregate and low-alkali cement, and additional protection was provided by the use of a pozzolan. (4) The only known instances of cracking due to ASR in New Zealand have occurred where, contrary to a specification, a high alkali cement was inadvertently used with a glassy andesite. (5) The period required for significant expansion to occur depends on the storage or exposure conditions. (6) The contribution of alkali ions from seawater during marine exposure for 7 years has not caused a significant increase in the expansion of concrete of moderate cement and alkali contents and containing Egmont andesite aggregate.

1495. Knudsen, T., "pH-IMPRESSIONS OF CONCRETE SURFACES," Cement and Concrete Research, Vol. 5, pp. 395-396, 1975.

KEY WORDS: alkali silica reactions; test methods

1496. Knudsen, T. and Thaulow, N., "QUANTITATIVE MICROANALYSES OF ALKALI-SILICA GEL IN CONCRETE," Cement and Concrete Research, Vol. 5, pp. 443-454, 1975.

KEY WORDS: alkali silica gel; EDX analysis; scanning electron microscopy

Quantitative microanalyses by means of scanning electron microscope and energy dispersive spectrometer have been performed on alkali-silica gels situated inside a concrete specimen. As an important point in the experimental procedure the analyses are corrected for the effect of electron beam being diffuse. Fifteen percent of the electrons do not hit the microvolume of interest but cover an area of at least 3 mm in diameter. By placing the analyzing spot in the epoxy impregnating the crack, the result of diffuse electrons hitting the adjacent area of concrete matter could be quite well established and corrections in the analyses of gel microvolumes could be performed. Two main conclusions of the results of these microanalyses stand out in this investigation. A high content up to 20 percent of CaO in the gels analyzed was found. This makes likely the correctness of some of the earlier analyses of the elemental composition of alkali-silica gels in concrete that showed high contents of CaO. The elemental compositions of the gels analyzed in this

investigation follow the same linear relationship between CaO and $SiO_2$ (when plotted in a four-component diagram) as the gels earlier synthesized by Kalousek. The agreement of the results of the two investigations when represented in a weight percent diagram is contradictory to the supposition that $Na_2O$ and $K_2O$ in alkali-silica gels should behave in these according to simple stoichiometric rules. An increasing calcium content in the gels analyzed with increasing distance along the crack from a single reacted particle is found in this investigation. This observation is tentatively explained as being due to additional exposure of such gels to the calcium rich cement paste matrix.

1497. Kocacitak, S., "A NOTE OF INFORMATION REGARDING TO ALKALI-AGGREGATE REACTIONS IN TURKEY," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 259-262.

KEY WORDS: alkali aggregate reactions; cements; mineral admixtures; pozzolans; dam structures; field experiences; Turkey

Reactive aggregates have been used in dam structures in Turkey with low alkali cements and in some cases with pozzolans. These preventive measures have so far been effective.

1498. Krogh, H., "EXAMINATION OF SYNTHETIC ALKALI-SILICA GELS," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 131-163.

KEY WORDS: alkali silica gels; mortar bars; expansion; alkali effects

From the experiments it can be concluded that the gels of $Na_2O$-$SiO_2$, of $K_2O$-$SiO_2$, and of $Na_2O$-(low CaO)-$SiO_2$ are swelling; gels of $Na_2O$-high CaO-$SiO_2$ and of $K_2O$-high CaO-$SiO_2$ are not swelling. Further these high-calcium gels stayed rigid even at 0.97 RH. It appears that the deformation properties of gels of $K_2O$-$SiO_2$ and of $Na_2O$-$SiO_2$ compositions are different. Measurements of these properties have not yet been carried out. Perhaps this phenomenon can explain the smaller expansion of mortar when $K_2O$ is the dominating alkali oxide than when $Na_2O$ is. From the knowledge of the water adsorption and the viscosity of gels of known composition one might determine which reaction products will give an expansion and roughly how

much expansion to expect.

1499. Locher, F. W. and Sprung, S., "INFLUENCES ON ALKALI-SILICA REACTION IN CONCRETE (in German)," Zement Kalk Gips, Vol. 28, 4, pp. 162-169.

KEY WORDS: alkali aggregate reactions; cement; alkali effects; expansion; pore solutions, test methods

The expansion of concrete containing siliceous aggregates reacting with alkalis proceeds by water imbibition pressure. For a given amount of alkalis in concrete the expansion increases with the amount of reactive aggregates and then decreases. The alkali concentration of the pore solution is related to the amount of alkali in the cement and the cement dosage in concrete. For Portland cements the amount of reactive alkali is that of the cement. For slag cements the available alkalis are only partly from the cement. Concretes with 300 kg/m3 cement are not deteriorated by AAR. In laboratory tests the dimensions of samples related to the size of aggregates can play an important role and result in different behavior than concrete on the site.

1500. Ludwig, U. and Sideris, K., "MECHANISM AND ACTION OF THE ALKALI-AGGREGATE REACTION (in German)," Sprechsaal Keram. Glas. Baustoffe, Vol. 108, 5-6, pp. 128-147.

KEY WORDS: alkali aggregate reactions; osmotic effects; mechanisms

Expansion and stresses due to the alkali aggregate reaction are related to an osmotic dynamical equilibrium where the hardened cement plays the role of a semipermeable membrane between the gel formed in the reactive aggregate and the pore solution containing alkali and calcium ions.

1501. Mather, B., "NEW CONCERN OVER ALKALI-AGGREGATE REACTION," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 17-19.

KEY WORDS: alkali aggregate reactions

It is concluded that new research, or a reinterpretation of the results of previous research, is needed to better

characterize the relevant parameters: degree and rate of aggregate reactivity; influence of concrete mixture proportions, especially unit cement content; influence of environment of service of the concrete; and influence of dimensions of structures.

1502. Mather, K., "PETROGRAPHIC EXAMINATION OF CORES FROM FONTANA DAM," Conference on Alkali-Silica Reactions in Concrete, 54 Annual Meeting of the Transportation Research Board, Sheraton-Park Hotel, Washington D.C., 16 January 1975.

KEY WORDS: dam structures; alkali aggregate reactions; field experiences. U.S.A.

1503. Mather, B., "NEW CONCERN OVER ALKALI-AGGREGATE REACTION," National Sand and Gravel Association, Circular No. 122. National Ready Mixed Concrete Association, Publication No. 149, March, 1975.

KEY WORDS: alkali aggregate reactions; field experiences; U.S.A.

1504. Nielsen, H. C. A., "ALKALI REDUCTION IN CEMENT KILNS," Proc. 2nd Intl. Alkali Conf., Reykjavik,1975, pp. 55-63.

KEY WORDS: alkali effects; cements; clinkers

It has been shown how the alkali contents may be brought down at various types of cement plants; the extra fuel costs are estimated on a relative scale, taking a 4-stage preheater kiln as 100%.

1505. Ozol, M. A., "THE PESSIMUM PROPORTION AS A REFERENCE POINT IN MODULATING ALKALI-SILICA REACTION," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 113-130.

KEY WORDS: alkali aggregate reactions; mechanisms; chert; silica; reactive aggregates

Mortar bar expansions for a chert aggregate used in varying proportions were studied. The existence and importance of the pessimum proportion of reactive to total

aggregates in mortars was confirmed, and mechanisms discussed.

1506. Poole, A. B., "ALKALI-SILICA REACTIVITY IN CONCRETE FROM DHEKELIA, CYPRUS," Proc. 2nd Intl. Alkali Conf. 1975, pp. 101-111.

KEY WORDS: alkali aggregate reactions; petrography; reactive aggregates; mechanisms; field experiences; marine structures; Cyprus

A case study description of alkali aggregate reaction leading to structural deterioration of a concrete jetty in Cyprus. The reactive aggregate is described in detail, mechanisms are discussed, and detailed analyses are presented of the cement, the aggregates, and the reaction products.

1507. Radenkova-Janeva, M. and Simeonov, J. T., "INTERACTION BETWEEN AGGREGATES AND CEMENT DURING HYDRATION (in Russian)," Dokl. Bulgar. Akad. Nauk, Vol. 28, 6, pp. 779-782.

KEY WORDS: alkali aggregate reactions; alkali effects; expansion; mechanisms

Concretes containing reactive aggregates show a decrease in mechanical strength and a slight contraction, then an expansion and a secondary shrinkage. The expansion depends on the amount of alkalis and their appearance in cement. If alkalis occur as sulfates 50% of $K_2O$ and 25% of $Na_2O$ are soluble in the first minutes. This high dissolution allows an interior reaction with $SiO_2$ and an expansion. However the high pressure created in the hardened cement leads to the appearance of Van der Waals forces which contribute to the secondary shrinkage.

1508. Saemundsson, K., "GEOLOGICAL PROSPECTING FOR POZZOLANIC MATERIALS IN ICELAND," Proc. 2nd Intl. Alkali Conf. 1975, Reykjavik, pp. 77-86.

KEY WORDS: reactive aggregates; pozzolans; mineral admixtures; rhyolites; dacites; andesites; glass

The results obtained on the pozzolanic properties of the rhyolite rocks are generally poorer than those obtained for the andesite and dacites. This is possibly due to higher crystallinity of the rhyolites of which the glass appears to be liable to devitrification.

1509. Smolczyk, H. G., "INVESTIGATION ON THE DIFFUSION OF Na-ION IN CONCRETE," Proc. 2nd Intl. Alkali Conf. 1975,, Reykjavik, pp. 183-188.

KEY WORDS: alkali aggregate reactions; alkali effects; slag; mineral admixtures; pore solutions

The results indicate that vitreous blastfurnace slag has a strong bonding effect on Na ions. That means that in a given concrete with a given amount of alkali the slag not only limits the movability of the Na but also reduces the Na concentration of the pore solution. These two phenomenons are probably the main reasons for the protective influence of the slag and also of certain pozzolanic materials against ASR.

1510. Sprung, S., "INFLUENCES ON THE ALKALI-AGGREGATE REACTION IN CONCRETE," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 231-244.

KEY WORDS: alkali aggregate reactions; test methods; alkali effects; glass

The AAR, which only in special case leads to damaging expansion, will be influenced by several factors. Investigations carried out with sensitive concrete prisms, 2.5 x 2.5 x 28.5 cm, have shown that the reactivity of opal, Pyrex glass (Duran glass) and flint can obviously be classified according to the pessimum content that leads to the maximum expansion. Opal has maximum, Duran glass a somewhat lower and flint (with a bulk density of > 2.53 g/cm3) the lowest reactivity. Reactive aggregates with small porosity may cause a higher expansion than more porous aggregates of the same kind. Portland cement with less than 0.6 and portland blast furnace cement (with a minimum content of 50 wt.% slag) of about 0.8 to 1.0 wt.% total alkali content produced equivalent results. In full accordance with practical experience, the utilization of such cements is one of the important precautions to avoid damaging in concrete structures. It was possible to

estimate that quantity of alkalis responsible for the extent of AAR. The investigation have shown that for cement contents of 350 kg/m$^3$ and effective alkali contents of up to 1.3 wt.% the results of the glass test agree with the practical behavior of concrete.

1511. St John, D. A., "CONFIRMATION OF ALKALI-AGGREGATE REACTIVITY IN THE TE MENUI BRIDGE," New Zealand Journal of Science, 1975, Vol. 18, No. 3.

KEY WORDS: alkali aggregate reactions; field experiences; bridge structures; New Zealand

1512. Svendsen, J., "THE PRESENT AND FUTURE SITUATION WITH REGARD TO ALKALIES IN CEMENT," Conference on Alkali-Silica Reactions in Concrete. 54th Annual Meeting of the Transportation Research Board, Sheraton-Park Hotel, Washington D.C., 16 January 1975.

KEY WORDS: alkali aggregate reactions

1513. Thaulow, N. and Kundsen, T., "QUANTITATIVE MICROANALYSES OF THE REACTION ZONE BETWEEN CEMENT PASTE AND OPAL," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 189-203.

KEY WORDS: alkali silica gel; alkali effects; calcium effects; scanning electron microscopy; EDX analyses

The observation of the present investigation of a broad reaction zone of calcium silica hydrate on opal in cement paste, combined with our recent findings of up to 20 percent calcium oxide in gel deposited in cracks in concrete, call for a reexamination of the role of the calcium ion in the ASR.

1514. Transportation Research Board, "CEMENT-AGGREGATE REACTIONS, " Transportation Research Record 525, Transportation Research Board, Washington, 1975, 63 pp.

KEY WORDS: alkali aggregate reactions; Conferences

1975

1515. Veronelli, J. E., and Dante, J., "DURABILITY OF CONCRETE - ALKALI-AGGREGATE REACTION (in Spanish)," Inst. Cemento Portland Argentino ICPA - Series R, 64, 51 pages. - Cemento Hormigon, Vol. 47, 508, pp. 620-637, 509, pp. 731-756.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive measures

In concrete soluble alkalis react with silica from aggregates and form a semi-permeable membrane creating an osmotic pressure able to reach 13 MPa. The reaction proceeds in two stages (1) formation of a soluble Na, K silicate (2) reaction with $Ca(OH)_2$ and formation of a complex silicate, insoluble in water. The alkali aggregate reaction can be avoided by partial or total replacement of reactive aggregates or by using additions of calcined clays, fly ashes, or slags, all with high specific surfaces.

1516. Vivian, H. E., "ALKALI-AGGREGATE REACTION," Proc. 2nd Intl. Alkali Conf., Reykjavik, 1975, pp. 21-34.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects; water effects

AAR and expansion in concrete depend on a series of interdependent factors such as: (1) The aggregate must contain sufficient but not too much reactive material. Although maximum expansion is usually caused by 3-5% of reactive material in the aggregate, the presence of greater or less amounts can cause significant mortar and concrete expansions. (2) The cement must contain sufficient but not too much alkali. Portland cements contain up to approximately 1% total alkali expressed as $Na_2O$ with the majority within the range 0.4 - 0.8%. A total alkali content < 0.6% has been widely adopted as the permissible maximum in cement which are to be used in concrete containing potentially reactive aggregate. (3) The concrete must contain sufficient free water but not an excessive amount. Most concretes of relatively large dimensions contain adequate amounts of uncombined mix water to permit aggregate reaction and expansion to proceed. (4) Cement paste in concrete is sufficiently permeable to allow water or water vapor to move to the reacting aggregate but is sufficiently impermeable to envelop the reacting particle and prevent its rapid dispersal into unoccupied void spaces. Removal of any one of the above factors will either inhibit reaction or prevent expansion.

1517. A. B. Poole, ed, "THE EFFECTS OF ALKALIS ON THE PROPERTIES OF CONCRETE," Cement and Concrete Assn., Wexham Springs 1976.

KEY WORDS: alkali aggregate reactions; conferences

Cited as Proc. 3rd Intl. Alkali Conf., 1976. Contains 28 papers on alkali effects and alkali aggregate reactions in concrete.

1518. Baker, A. F., "THE INFLUENCE OF ALKALI-SILICA REACTIVITY ON THE DEVELOPMENT OF TENSILE BOND STRENGTH," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 99-108.

KEY WORDS: alkali silica gel; opal; tensile strength; mechanisms; alkali silica reaction

The tensile bond strengths for both opal and quartz are similar in the early stages of the curing of a concrete, after which the strength of the reactive aggregate bond falls off, while that for quartz only levels off. The photomicrographs taken at an early stage in the curing of the experimental specimens show an increase in alkalies near the interface. The anomaly of an increase in strength at the interface, combined with a reported decrease in micro-hardness in the adjacent paste is a difficult one to resolve.

1519. Coombes, L. H., "VALE DE LA MARE DAM, JERSEY, CHANNEL ISLANDS," Proc. 3rd Intl. Alkali Conf., London,1976, pp. 357-370.

KEY WORDS: dam structures; alkali aggregate reactions; repairs; field experiences; U.K.

Vale de la Mare Dam is the principal storage reservoir for the Island of Jersey. The dam has been regularly inspected since its completion in 1962. In Jan. 1971 small upstream relative movements of the handrail of the crest walkway bridge were noted. Darkening and damp patches were observed on the downstream face of the dam, and parts of the concrete surface showed random cracking. Alkali aggregate reactivity was diagnosed. Remedial works implemented included provision for drainage into the gallery, installation of anchors along with instrumentation

to monitor loads developed on the anchors, future movements, and uplift pressures.

1520. Dahms, J., "INFLUENCES ON THE ALKALI-AGGREGATE REACTION UNDER FIELD CONDITIONS," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 277-290.

KEY WORDS: alkali aggregate reactions; field experiences; water content; alkali effects; opal; flint; relative humidity effects

A deleterious AAR could only be found on concrete of unfavorable composition when the specimens had been subjected to wet storage, or on concrete construction in wet environment. However, tests on concrete samples whose drying process had been inhibited also showed that in massive constructions the moisture inherent in the concrete is sufficient to cause deleterious AAR. The degree of damage was mainly dependent on the composition of the total aggregate. Especially unfavorable were those which contained very alkali reactive aggregate in amounts of approximately 15 to 25% by weight of the total aggregate in the size range 2 to 8 mm. Marked deterioration occurred on wet stored concrete specimens with very alkali reactive aggregate when the cement content was 500 kg/m$^3$ (for 0.9% $Na_2O$ equiv. cement) and in the case of a cement with an effective alkali content of 1% with a cement content of 400 kg/m$^3$. In general, the damage increased with higher w/c ratio. When the deterioration as a result of AAR was assessed, it became clear that this damage on concrete constructions can easily be confused with damage due to other causes. For the study of unknown aspects of the AAR it is not enough to measure the expansions of the specimens when their behavior is to be investigated; it is also necessary to consider deterioration of other kinds of specimens, for instance 30 cm sized cubes.

1521. Diamond, S. and Barneyback, R. S., Jr., "A PROSPECTIVE MEASURE FOR THE EXTENT OF ALKALI-SILICA REACTION," Proc. 3rd Intl. Alkali Conf., London,1976, pp. 149-162.

KEY WORDS: alkali aggregate reaction; pore solutions; alkali effects; alkali effects; mechanisms

A method of measuring the alkali silica reaction itself, as distinguished from measurement of expansion accompanying

the reaction, has been developed. Expansion may or may not accompany reaction, depending on various factors. The method involves determination of the alkali ion contents of pore solutions expressed from mortars in a special 75,000 psi pressuring device. After appropriate corrections, the reduction in alkali ion concentration experienced by reacting mortars as compared to companion mortars without reactive aggregate is used to calculate the degree of reaction and estimate the amount of gel formed. Illustrative data are provided for mortar with ground Beltane opal hydrated for periods up to 70 days

1522. Diamond, S., "A REPLY TO W.C. HANSEN'S DISCUSSION OF THE PAPER "A REVIEW OF THE ALKALI-SILICA REACTION AND EXPANSION MECHANISMS, I. ALKALI IN CEMENT AND IN CONCRETE PORE SOLUTIONS," Cement and Concrete Research, Vol. 6, pp. 327-328, 1976.

KEY WORDS: osmotic effects; mechanisms; alkali silica gel; alkali aggregate reactions; expansion; reviews

1523. Diamond, S., "A REVIEW OF ALKALI-SILICA REACTION AND EXPANSION MECHANISMS," Cement and Concrete Research, Vol. 6, pp. 549-560, 1976.

KEY WORDS: alkali aggregate reactions; reactive aggregates; quartz; tridymite; silica; flint; cristobalite; chert; chalcedony; opal; glass; reviews

(1) Relatively unstrained quartz may eventually become reactive and expansive. (2) The degree of susceptibility of megascopic quartz is a function of strain, which can be determined quantitatively by special petrographic measurements. (3) Chert and flint vary in reactivity probably in conjunction with variations in microstructure and perhaps in crystallite size. Microstructural features promoting reactivity include the presence of interconnected pores, and possibly the presence of a partial deposit of amorphous silica in these pores. Chalcedonic types are particularly characterized by such microstructures. A genetic sequence among cherts has been proposed which correlates with microstructure as observed by electron microscopy, and with reactivity. (4) Opals are highly reactive in consequence of their amorphous or quasi-amorphous crystal character and their unusual organizational structure which provides an extremely

interconnected pore system. (5) Glasses vary in reactivity, with acidic volcanic glasses and hydrated glasses more reactive among natural volcanic types, and glasses bearing alkali but not lithium cations among synthetic types. (6) Expansion and distress in concrete made with certain silicate rock aggregates apparently involve components other than the usual ASR mechanism, possibly including limited lattice expansion and exfoliation of certain layer lattice silicates.

1524. Diamond, S., "A REPLY TO BRYANT MATHER'S DISCUSSION OF THE PAPER "A REVIEW OF ALKALI-SILICA REACTION AND EXPANSION MECHANISMS, 2. REACTIVE AGGREGATES," Cement and Concrete Research, Vol. 6, pp. 815-816, 1976.

KEY WORDS: reactive aggregates; reviews

1525. Dolar-Mantuani, L., "PETROGRAPHIC INVESTIGATION OF ALKALI-REACTIVE SILICATE ROCKS IN SEVERAL STRUCTURES," Proc. 3rd Intl. Alkali Conf., London,1976, pp. 203-216.

KEY WORDS: alkali aggregate reactions; reactive aggregates; petrography

The petrographer examining concrete aggregates for alkali reactivity deals with two different problems: (1) to determine whether a concrete is prematurely deteriorated because it contains alkali reactive aggregates and (2) to determine whether an aggregate source is potentially alkali reactive. Detailed examination of deteriorated concrete containing alkali reactive aggregates helps to become better acquainted with some varieties of the numerous silicate rocks which are alkali reactive.

1526. Figg, J. Moore, A. E. and Gutteridge, W. A., "ON THE OCCURRENCE OF THE MINERAL TRONA ($NA_2CO_3.NAHCO_3.2H_2O$) IN CONCRETE DETERIORATION PRODUCTS," Cement and Concrete Research, Vol. 6, pp. 691-696, 1976.

KEY WORDS: deterioration; alkali effects; carbonation; $CO_2$ effects

Tron is formed by reaction of atmospheric $CO_2$ with Na ions in concrete; resulting damage to concrete

superficially resembles sulfate attack and includes severe surface spalling.

1527. French, W. J., "THE ROLE OF SOLVENT MIGRATION IN ALKALI-SILICATE REACTIVITY," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 177-190.

KEY WORDS: alkali aggregate reactions; alkali effects; mechanisms; water content; pore solutions

Cement paste is conceived as being composed of solid inert phases and a mobile solution phase consisting of water and dissolved species. The dissolved ions may vary in concentration from place to place. Migration of the mobile phase may occur after the early stages of ASR, the flow effecting a chromatographic transfer of ions in the flow direction, and giving rise to high local ion concentrations. Alkalis in the mobile phase are transmitted with the solvent front. The higher the mass ratio of mobile to inert phases the closer is the peak concentration of the alkalis to the aqueous front. Formulae are given to describe the possible form of the concentration distribution along the length of flow in simple circumstances. Tests may be developed to detect the propensity of a given aggregate to create solvent flow.

1528. French, W. J. and Poole, A. B., "ALKALI-AGGREGATE REACTIONS AND THE MIDDLE EAST," Concrete (London), Vol. 10, No. 1, Jan. 1976, pp. 18-20.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; field experiences; Middle East

Examples of the effects of ASR and alkali carbonate reaction are presented. Examples are drawn of various reactions from the Middle East. Tests for potentially reactive aggregates are described.

1529. Grattan-Bellew, P. E. and Litvan, G. G., "TESTING CANADIAN AGGREGATES FOR ALKALI EXPANSIVITY," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 227-242.

KEY WORDS: alkali aggregate reactions, reactive aggregates; test methods; field experiences; Canada

Applications of the ASTM quick chemical, mortar bar, and rock cylinder tests and of concrete prism tests to Canadian aggregates are discussed. The quick chemical test is unsatisfactory. The concrete prism test is slow, but satisfactory in other respects, and an accelerated rock prism test is proposed.

1530. Gudmundsson, G. and Asgeirsson, H., "ADDENDUM - THE EFFECT OF CEMENT MIXTURES ON ALKALI EXPANSION," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 247-253.

KEY WORDS: alkali aggregate reactions; expansion; pozzolans; mineral admixtures; test methods; field experiences; Iceland

1531. Hansen, W. C., "DISCUSSION OF THE PAPER "QUANTITATIVE MICROANALYSIS OF ALKALI-SILICA GELS IN CONCRETE" BY T. KNUDSEN AND N. THAULOW," Cement and Concrete Research, Vol. 6, pp. 159-160, 1976.

KEY WORDS: alkali silica gel; opal; alkali effects; EDX analysis; mechanisms

This discussion suggests why the authors found, in general, that the calcium content of the alkali-silica gel increased as the distance from the site of formation increased. It also supports their conclusion that the variation of calcium content is not accidental.

1532. Hansen, W. C., "A DISCUSSION OF THE PAPER "A REVIEW OF THE ALKALI-SILICA REACTION AND EXPANSION MECHANISMS, I. ALKALIS IN CEMENT AND IN CONCRETE PORE SOLUTIONS," BY SIDNEY DIAMOND," Cement and Concrete Research, Vol. 6, pp. 323-326, 1976.

KEY WORDS: expansion; alkali effects; osmotic effects; mechanisms; reviews

1533. Hirche, D., "WATER ABSORPTION AND VOLUME CHANGES OF ALKALI SILICATES IN FLINT MEASURED BY THERMOGRAVIMETRY," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 139-147.

KEY WORDS: alkali aggregate reaction; mechanisms; test methods; thermogravimetry; alkali effects

(1) In presence of alkali and $OH^-$ ions in solution the water sorption of flint grains increases. On heating in a vacuum the flint loses bound water between 500°C and 600°C (2) In presence of calcium and $OH^-$ ions the water sorption of flint increases, too. The binding energy of water in calcium silicates is higher and bound water will be released between 650°C and 700°C. (3) On storing the flint grains in an alkali solution without $OH^-$ ions (NaCl/KCl solution), one could not find any increasing water sorption. (4) The binding energy of water bound at alkali silicate interfaces in fine flint grains is very low. The fine flint grains lose bound water between 200°C and 400°C. The formation of the alkali hydrosilicates occurs near the grain surfaces. A single flushing of the grains washed out all hydrosilicates.

1534. Hirche, D., " INFRA RED SPECTROSCOPY: A MODERN METHOD FOR THE ANALYSIS OF SILICEOUS AGGREGATES IN REGARDS OF THEIR REACTIVITY WITH ALKALIS (in German)," Zement Kalk Gips, Vol. 29, pp. 412-415.

KEY WORDS: IR spectroscopy; silica; reactive aggregates; test methods

The amount of silanol groups in siliceous minerals can be directly evaluated by IR spectroscopy in the range 3800-2800 $cm^{-1}$ (the OH vibrations). IR used for opal, flint, sandstone and glass has shown that total absorption higher than 106 cm/mole corresponded to reactive silicas able to swell in concrete. Well crystalline quartz gave a low IR signal. IR spectroscopy is considered an appropriate technique for evaluating the reactivity of amorphous or cryptocrystalline silicas.

1535. Johansen, V., "INFLUENCE OF ALKALIES ON THE STRENGTH DEVELOPMENT OF CEMENTS," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 81-96.

KEY WORDS: cements; alkali effects; clinkers; strength; alkali sulfates

(1) It has been shown that the 28 day strength of cements may adequately be predicted from the $K_2SO4$ and $C_3S$

contents in the clinker. This relationship holds good when the clinker is ground to 3000 Blaine and with addition of 4% gypsum. (2) Experiments with two different cements show that the effect of adding $K_2SO4$ to these systems gives 28-day strengths which may be described by the same relationship as mentioned above. (3) The amount of combined water after 3 minutes of hydration of the cements mentioned correlates negatively to the 28-day strength.

1536. Knudsen, T. and Thaulow, N., "A REPLY TO W.C. HANSEN'S DISCUSSION OF "QUANTITATIVE MICROANALYSES OF ALKALI-SILICA GEL IN CONCRETE," Cement and Concrete Research, Vol. 6, p. 161, 1976.

KEY WORDS: alkali silica gel; scanning electron microscopy; EDX analysis

1537. Ludwig, U. and Bauer, W., "STUDIES ON THE ALKALI-AGGREGATE REACTION (in German)," Zement Kalk Gips, Vol. 29, 9, pp. 401-411.

KEY WORDS: alkali aggregate reactions; mortars bars; expansion; opal; reactive aggregates

Expansion tests carried out on mortar prisms prepared with a Portland cement containing 0.9% $Na_2O$ eq. and 4% of opaline sandstone from Schleswig-Holstein resulted in (1) a reduction of 50% of expansion with a white-grey opaline sandstone high in calcite compared to a green opaline sandstone low in calcite and (2) no expansion with sandstones of 40% porosity by volume.

1538. Mander, J., "ALKALI COMPOUND FORMATION OF COMMERCIAL PORTLAND CEMENT CLINKERS," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 27-34.

KEY WORDS: alkali effects; clinkers; cements

The effect of kiln atmosphere in the burning zone on the formation of alkali compounds was studied. It was concluded that the double salt $K_3Na(SO_4)_4$ was produced under reducing kiln conditions, while $Ca_2K(SO_4)_3$ tended to be formed under oxidizing conditions.

1976

1539. Mather, B., "A DISCUSSION OF THE PAPER "A REVIEW OF ALKALI-SILICA REACTION AND EXPANSION MECHANISMS. 2. REACTIVE AGGREGATES" BY SIDNEY DIAMOND," Cement and Concrete Research, Vol. 6, pp. 813-814, 1976.

KEY WORDS: alkali aggregate reactions; alkali silicate reactions; reactive aggregates; reviews

It was recommend that there be only one category of ASR, i.e., the reaction of alkalies with thermodynamically metastable silica. The alkali carbonate rock reaction is second category with a variety of subgenera as has been discussed in detail elsewhere. Swelling clay is not regarded as needing recognition as a category of alkali silica or alkali carbonate rock or alkali aggregate reaction. The harm done by swelling clays in aggregates has been recognized at least since 1928.

1540. Midgley, H. G., "THE IDENTIFICATION OF OPAL AND CHALCEDONY IN ROCKS AND METHODS OF ESTIMATING THE QUANTITIES PRESENT," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 193-201.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; opal; chalcedony; silica; petrography

Opal and chalcedony have been identified as secondary minerals in igneous rocks. The quantities of these minerals may be estimated by area measurement of thin sections of either concrete or aggregate particles. If the rocks have similar porosities, then the expansion of mortar made with similar cement of high alkali contents will be related to the quantities of reactive silica present.

1541. Oberholster, R. E. and Brandt, M. P., "REPORT ON REACTIVE CONCRETE AGGREGATE FROM THE CAPE PENINSULA, SOUTH AFRICA," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 291-304.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; shale; South Africa; alkali silica gel

The cracking observed in the Cape Peninsula for structures built with concrete containing Malmesbury shales as coarse aggregate has not so far been simulated in the laboratory. No expansion of mortar bars made with Malmesbury shale and either low alkali or high alkali cements and tested in accordance with ASTM C 227 was

observed. The ASTM C 289 yielded anomalous results in the case of Malmesbury shale. A reaction product was observed in all the affected structures. In all instances X-ray diffraction data give high d-values for the product. It could not be proven that the reaction product is the cause of the deterioration of the concrete. A gelatinous reaction product is produced when saturated lime water is added to Malmesbury shale. X-ray diffraction data for the crystalline component agree closely with the values reported by Carlson and Berman for calcium silico-aluminate.

1542. Pandurovic, N. and Ducic, V., "REVIEW OF UP TO DATE INVESTIGATIONS OF ALKALI REACTION IN CONCRETE WITH AGGREGATES FROM BASIC SOURCES IN SOME REGIONS OF YUGOSLAVIA," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 311-318.

KEY WORDS: alkali aggregate reactions; chert; field experiences; Yugoslavia

No alkali aggregate damage has been observed to date in Yugoslavia, but aggregates from the Velika Morava basin are thought to be potentially alkali reactive. Gravel containing chert has been extensively tested and found to be innocuous by standard tests.

1543. Poole, A. B., "ELECTRON PROBE MICROANALYSES OF REACTION ZONES AT CEMENT/OPAL INTERFACES," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 163-175.

KEY WORDS: alkali aggregate reactions; mechanisms; scanning electron microscopy; EDX analyses; Beltane opal

The results show that maximum local concentrations of sodium ions occur close to the reaction site within the opal reaction zones, and as a result of these local high concentrations some calcium ions must be removed from solution. Some analyses show very high concentrations of calcium at the edge of the reaction zone and this insoluble calcium phase may form a physical barrier to the further movement of alkalies towards the reaction site. This provides an explanation for the reduced reactivity of specimens containing high alkali concentrations of this type.

1976

1544. Sar, D. L., "TENTATIVE PROGRAMME OF INVESTIGATION TO PREVENT CEMENT- AGGREGATE REACTION OCCURRING IN HARDENED CONCRETE," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 305-309.

KEY WORDS: alkali aggregate reactions: cracking; shale; pozzolans; mineral admixtures; field experiences; South Africa

Map cracking followed by disruptive expansion is occurring in a few concrete structures in the Cape area of South Africa. It is associated with abnormally wet conditions when Malmesbury shale is used as the coarse aggregate. The shale appears to react with calcium hydroxide liberated from the hardened cement. Use of a pozzolan as a preventive measure is being examined.

1545. Smolczyk, H.-G., "ALKALI REACTION TESTS WITH SOUND AGGREGATE," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 219-224.

KEY WORDS: test methods; reactive aggregates; silica; Germany; Denmark

If the experimental conditions of accelerated laboratory tests are powerful and sophisticated enough, it is likely that almost all $SiO_2$ containing aggregates can be forced to a reaction with concentrated alkali solutions even those which would never be harmful to a concrete. When such laboratory tests are applied, it is therefore necessary to compare the results of an unknown material with the results of a familiar reference material that was tested exactly the same way. As far as the northern part of Europe is concerned comprehensive research work on natural aggregates has been done in Denmark and in Germany and the difference between harmful and innocuous material of this area is well known.

1546. Spierings, G. A. C. M. and Stein, H. N., "THE INFLUENCE OF $Na_2O$ ON THE HYDRATION OF $C_3A$. I. PASTE HYDRATION," Cement and Concrete Research, Vol. 6, pp. 265-272, 1976.

KEY WORDS: alkali effects

Low NaOH concentrations prevent a very early appearance of the second heat evolution peak, indicating a

more controlled formation of $C_3AH_6$ nuclei. Higher NaOH concentrations advance the second peak; this is ascribed to a decreased stability of the hexagonal hydrates with increasing NaOH concentrations.

1547. Spierings, G. A. C. M. and Stein, H. N., "THE INFLUENCE OF $NA_2O$ ON THE HYDRATION OF $C_3A$. II. SUSPENSION HYDRATION," Cement and Concrete Research, Vol. 6, pp. 487-496, 1976.

KEY WORDS: alkali effects

The influence of $Na_2O$ on the hydration of $C_3A$ was studied in suspensions. The heat evolution increased in the very early stages of hydration for higher $Na_2O$ concentrations; for concentrations larger than 0.1M, the reaction mechanism changes, and is thought to be initially controlled by an amorphous layer of calcium hydroxide.

1548. Sprung, S. and Rechenberg, W., "INFLUENCE OF ALKALIES ON THE HYDRATION OF CEMENT," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 109-123.

KEY WORDS: alkali effects

The setting of cement is closely related to the composition of the mixing water solution. Rapidly dissolved alkalis, especially the alkali sulfates of the clinker, increase the Ph and lower the calcium hydroxide concentration of the solution. This seems to increase the hydration rate of $C_3A$, particularly during the first few minutes, before the dormant period stops further reaction. $C_3A$ rich cements with a lack of gypsum show rapid setting caused by formation of aluminate hydrates. With excess gypsum rapid setting by formation of large amounts of ettringite may occur. Increasing temperature of fresh concrete mixes has a similar effect on setting as increasing OH ion concentrations caused by alkalis dissolved from the cement.

1549. Sprung, S. and Adabian, M., "THE EFFECT OF ADMIXTURES ON ALKALI-AGGREGATE REACTION IN CONCRETE," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 125-137.

KEY WORDS: alkali aggregate reaction; mineral admixtures;

fly ash; trass; cristobalite; preventive measures

The expansion of opal-containing aggregates in the concrete can be avoided by the use of suitable mineral admixtures. Their efficiency is mainly due to the chemical reactivity, but possibly also to an increase in the total volume of the concrete. The reactivity of glasses with $SiO_2$-contents of approximately 50% by weight is apparently greater than that of the tested crystalline substances with similarly high SiO2 content or that of the glasses and crystalline substances with more than 95% of $SiO_2$, if the real quantity of active surface area is taken into consideration.s

1550. St John, D. A. and Smith, L. M., "EXPANSION OF CONCRETE CONTAINING NEW ZEALAND ARGILLITE AGGREGATE," Proc. 3rd Intl. Alkali Conf. 1976, London, pp. 319-352.

KEY WORDS: alkali aggregate reactions; reactive aggregates; expansion; greywackes; argillites; field experiences; New Zealand

In the case of Matahina greywacke-argillite, expansive AAR should not have been possible, as both low alkali cement and pozzolan were used and there should be insufficient alkali available to initiate the reaction. Yet expansion has occurred in a manner similar to that reported for the Nova Scotia greywackes and argillites. While the underlying mechanism of the expansion in the Matahina greywacke-argillite is still unknown, the physical expansion of concrete containing this aggregate is an indisputable fact. In the case of the fired Oxford argillite, the cause of concrete expansion, at first suspected as an expansive clay reaction, is probably due to rehydration of lime mediated by alkali attack on sintered or glassy coatings.

1551. Svendsen, J., "ALKALI REDUCTION IN CEMENT KILNS," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 51-78.

KEY WORDS: cements; clinkers; alkali effects

Comparison is made between the wet and dry processing plants for cement manufacture. Typical alkali reduction capabilities for various kiln systems are given and dry process kilns with energy efficient preheater systems are

seen to produce clinkers with higher alkali contents than normal for older systems, wet or dry. Modern calcining technology has made construction of efficient bypass systems possible which allow alkali reduction.

1552. Vivian, H. E., "ALKALIES IN CEMENT & CONCRETE," Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 9-25.

KEY WORDS: alkali effects

The presence of small amounts of alkalis may modify the compound composition of clinkers, and affect its behavior. Alkali compounds; which are highly soluble, may affect the physical properties and hydration characteristics of cement pastes. Alkali may contribute to surface staining, efflorescence, scaling, and alkali aggregate reactions in concrete.

1553. White, C., "ION-EXCHANGEABLE SODIUM IN CONCRETE AGGREGATES, " Proc. 3rd Intl. Alkali Conf., London, 1976, pp. 353-355.

KEY WORDS: ion exchange effects; alkali effects; mechanisms

An experience is related in which field difficulty was caused by the occurrence of a zeolite in an altered basalt aggregate in Australia. Alkali ions were liberated by ion-exchange reaction with calcium from the cement produced a white deposit on the surface of fresh concrete.

1554. Berard, J. and Lapierre, N., "ALKALI REACTIVITY OF POTSDAM SANDSTONE IN CONCRETES (in French)," Canadian Journal of Civil Engineering, Vol 4, pp. 332-344.

KEY WORDS: alkali aggregate reactions; reactive aggregates; sandstone; field experiences; Canada; EDX analysis; petrography; alkali silica gel

Concrete structures in the Beauharnois-Valleyfield southwest of Montreal show signs of disintegration like expansion, cracking, spalling and gel exudation. Silica gel is found in cracks and air bubbles in site concrete. The composition of gels measured by EPMA reveals that Na and K concentrations are similar to that of cements. Superposed layers of silica gel of various composition and texture have been analyzed, i.e., clear gel and opaque gel. The first one is richer in CaO, $SiO_2$, and $K_2O$ but poorer in $H_2O$ and $Na_2O$ than the second. The Na/K ratio is found to increase in the more recent layers of silica gel suggesting that sodium could have been added within the concrete structures as winter de-icing salts. Secondary minerals like calcite and hydrocalcite and chalcedony crystals or amorphous opal in silica gels are identified by microscopy and X-ray diffraction. Even if a low alkali cement is used with the Potsdam sandstone, alkali silica reactivity could still occur in the presence of alkalis from external sources.

1555. Deloye, F. X., "USE OF AUTOMATIC CALCULATION IN QUALITATIVE MINERALOGICAL ANALYSIS (in French)," Bulletin de Liaison des Laboratoires des Ponts & Chaussées 90, pp. 103-105.

KEY WORDS: alkali effects; cements

Mineralogical analysis involves a series of investigatory techniques: chemical analysis X-ray diffraction, optical and electron microscopy. Subsequently mineralogical calculation makes it possible to proceed from the chemical composition of the material to the quantitative mineralogical composition. To facilitate this calculation a special programme called "Minerals" has been written in Fortran IV. It processes the results of chemical analyses and other methods directly on a computer and gives the quantitative composition of the sample in terms of mineral species.

1977

1556. Hasaba, S., Kawamura, M. and Okada, M., "FUNDAMENTAL STUDY OF ALKALI-AGGREGATE REACTION (in Japanese)," Zairyo/Journal of the Society of Materials Science, Japan, Vol. 26, No. 290, Nov. 1977, pp. 1078-1084.

KEY WORDS: alkali aggregate reactions; reactive aggregates; particle size effects; test methods; expansion; mortar bars

The paper reports on a study aimed at revealing the effects of the particle size and content of reactive aggregates on the expansion of mortar bars. The reactive aggregates used were opaline amorphous silica from Kagoshima in Japan and powder of pyrex glass (borosilicate glass). They were mixed with the nonreactive aggregate of Yoyoura standard sand and a normal portland cement. The amount of the reactive aggregate was varied from 5, 10, 20, 50, 60, to 100 percent. The effect of the reactive aggregate content on the expansion was studied.

1557. Jawed, I. and Skalny, J., "ALKALIES IN CEMENT: A REVIEW I. FORMS OF ALKALIES AND THEIR EFFECT ON CLINKER FORMATION," Cement and Concrete Research, Vol. 7, pp. 719-730, 1977.

KEY WORDS: alkali effects; cements; clinkers

1558. Lesage, R. and Sierra, R., "NOTE ON ALKALI-AGGREGATE REACTIONS IN CONCRETE (in French)," Bulletin de Liaison des Laboratoires des Ponts & Chaussées 90, pp. 103-105.

KEY WORDS: alkali aggregate reactions

This first paper published in French gives a review on the different alkali aggregate reactions and accelerated tests.

1559. Majumdar, A. J. and Larner, L. J., "THE MEASUREMENT OF POZZOLANIC ACTIVITY," Cement and Concrete Research, Vol. 7, pp. 209-210, 1977.

KEY WORDS: pozzolans; mineral admixtures

1977

1560. Nelson, J. A. and Young, J. F., "ADDITIONS OF COLLOIDAL SILICAS AND SILICATES TO PORTLAND CEMENT PASTES," Cement and Concrete Research, Vol. 7, pp. 277-282, 1977.

KEY WORDS: pozzolans; silica

Additions of colloidal silicas and silicates act as very reactive pozzolans, and the pozzolanic reaction is evident as early as the first day of moist curing. Amorphous silicas are more effective pozzolans than quaternary ammonium silicates and approach complete pozzolanic reactivity within 60 days. All material, with the exception of one quaternary ammonium silicate, increased the rate of early strength development in agreement with earlier reports. Conflicting data was obtained on their influence on later strengths. Amorphous silicas have high water requirement and must be used with moderately large additions of an efficient water-reducing admixture.

1561. Thaulow, N. and Knudsen, T., "QUANTITATIVE MICROANALYSIS OF THE REACTION ZONE BETWEEN CEMENT PASTE AND OPAL," Cement Wapno Gips, 1, pp. 1-6.

KEY WORDS: alkali aggregate reactions; opal; reactive aggregates; scanning electron microscopy; EDX analysis

The reaction zone between cement paste and opal has been examined by combined techniques such as scanning electron microscopy with EDAX. Opal is transformed into a hydrated calcium silicate with a molar $CaO/SiO_2$ ratio between 0.8 and 1 which appears as a zone of 50 to 150 microns in width. Mortar prisms prepared with this cement and opal expanded greatly and ruptured at one month.

1562. Van Aardt, J. H. P. and Visser, S., "FORMATION OF HYDROGARNETS: CALCIUM HYDROXIDE ATTACK ON CLAYS AND FELDSPARS," Cement and Concrete Research, Vol. 7, pp. 39-44, 1977.

KEY WORDS: alkali effects; reactive aggregates; sericites; shales; alkali release

The reaction of calcium hydroxide with sericite, with shales, and with some igneous rocks gives rise to hydrogarnets, hydrated calcium silicates, and free alkalis. In the experiments described, slurries of the ground rock

and calcium hydroxide were heated to 95°C; hydrothermal treatments were also carried out at 1 MPa and at 2 MPa. It was considered that the free alkalis released by such reactions may subsequently promote alkali aggregate attack.

1563. Van Aardt, J. H. P. and Visser, S., "CALCIUM HYDROXIDE ATTACK ON FELDSPARS AND CLAYS: POSSIBLE RELEVANCE TO CEMENT-AGGREGATE REACTIONS," Cement and Concrete Research, Vol. 7, pp. 643-648, 1977.

KEY WORDS: calcium hydroxide; feldspars; alkali effects; alkali release

The marked reactivity of feldspars towards $Ca(OH)_2$ in the presence of water at 39°C and the release of alkalies as well as the formation of the less stable C4A hydrates (in contrast with the silica-bearing type hydrogarnet obtained at higher temperatures) underlines the statement made previously that the use of feldspathic rocks that can liberate alkalies should be regarded as suspect in concrete. Rocks containing calcium rich feldspars such as dolerites and norites are perhaps less deleterious than rocks that contain alkali feldspars such as granites. Rocks like feldspathic sandstones and shales, as well as greywackes and others that contain alkali feldspar, could be regarded as suspect with respect to cement aggregate reaction unless otherwise shown to be nonreactive. The particle size of the feldspars in the greywackes and other similar rocks is small and they are likely to be particularly reactive. A "solution theory" for the reaction is advanced.

1564. Bhatty, M. S. Y. and Greening, N. R., "INTERACTION OF ALKALIES WITH HYDRATING AND HYDRATED CALCIUM SILICATES," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 87-111.

KEY WORDS: alkali effects

In cement systems, the average lime to silica ratio of the hydrates of the major calcium silicates is about 1.5. The present results show that such high lime to silica ratio hydrates do not have as high a capacity for alkali retention as hydrates of lower lime to silica ratio. It is also seen that when high lime to silica ratio hydrates react with alkali, some lime is released by the alkali from the hydrate and more alkali is retained. However, some alkali may then be released, resulting in the recycling of alkali which may then be available for deleterious reactions. The results also show that $Li_2O$ is retained more than $Na_2O$ and $K_2O$ in the hydrating $C_3S$ and $C_2S$.

1565. Brotschi, J. and Mehta, P. K., "TEST METHODS FOR DETERMINING POTENTIAL ALKALI-SILICA REACTIVITY IN CEMENTS," Cement and Concrete Research, Vol. 8, pp. 191-200, 1978.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; expansions; cements

The ASTM C 227 test can be modified to develop performance tests for predicting potential alkali silica reactivity of both portland and blended cements. Two test methods are suggested, one using pyrex glass and the other Beltane opal as the standard reactive aggregate. Low water:cement and aggregate:cement ratios are helpful in accelerating expansion of test mortar bars, which are maintained at 43°C. A 14 day test period was found adequate to assess the relative alkali silica reactivity of a cement. Test data on 17 portland cements and 10 blended portland cements are reported.

1566. Buck, A. D. and Mather, K., "ALKALI-SILICA REACTION PRODUCTS FROM SEVERAL CONCRETES: OPTICAL, CHEMICAL, AND X-RAY DIFFRACTION DATA," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 73-85.

KEY WORDS: alkali aggregate reactions; alkali silica gel;

X-ray diffraction; field experiences; U.S.A.

It appears that ASR product in its early stages contains very little calcium, a high concentration of silica, and more total alkali than calcium. Calcium moves into the product from the large supply available in the cement paste and calcium hydroxide, but moves at varying rates over unknown distances. The crystalline $Ca(OH)_2$ is depleted in parts of the mortar where reaction has proceeded. Ultimately, at late ages in field structures, complex products develop. They include products giving X-ray diffraction spacings that suggest that part at least of the products are related to CSH(I) and possibly to CSH(II). The CSH(I) and CSH(II) both have variable long spacings.

1567. Buck, A. D. and Burker, J. P., "ALKALI-SILICA REACTION IN CONCRETE FROM HIWASSEE DAM, NORTH CAROLINA," National Technical Information Service, Report No. WES-MP-C-78-10; CTIAC-32.

KEY WORDS: alkali aggregate reactions; dam structures; petrography; field experiences; U.S.A.

The TVA requested a petrographic examination of concrete cores from Hiwassee Dam to determine whether an ASR had occurred. There is substantial cracking of the concrete in the dam and such a reaction could be responsible for the cracking. Construction of Hiwassee Dam was completed in 1940, so the concrete is over 38 years old. Signs of ASR were found in the top and bottom portions of two 6-in.-diam. cores taken from the dam. The main signs of the reaction were white alkali silica gel in some voids, on old broken surfaces or at aggregate-paste contacts, and the presence of reaction rims on many particles of the brown quartzite. Some cracking of aggregate and paste was also detected. The presence of this reaction does not automatically prove it was the cause of the cracking in the concrete, but it would seem to be a reasonable assumption that it was one cause of the cracking since no other evidence of potentially deleterious chemical or physical damage was found. This conclusion is based on laboratory observation only.

1568. Buck, A. D. and Mather, K., "ALKALI-SILICA REACTION PRODUCTS FROM SEVERAL CONCRETES: OPTICAL, CHEMICAL, AND X-RAY DIFFRACTION DATA," National Technical Information

Service, Report No. WES-MP-C-78-7.

KEY WORDS: alkali aggregate reactions; alkali silica gel; field experiences, U.S.A.

ASR products from six different concretes were examined by X-ray diffraction and light microscope, and four of the gels were chemically analyzed. Most of the reaction products were crystalline in considerable part and were composed of one or more of four phases. Two of the phases were tentatively identified as variants on CSH(I) and CSH(II).

1569. Chatterji, S., "AN ACCELERATED METHOD FOR DETECTION OF ALKALI-AGGREGATE REACTIVITIES OF AGGREGATES," Cement and Concrete Research, Vol. 8, pp. 647-650, 1978.

KEY WORDS: alkali aggregate reactions; test methods, mortar bars, expansion, NaCl effects

The proposed method consists of making 1:3 sand/cement mortar prisms and exposing them to saturated NaCl solutions at 50°C. Length change measurements are made as functions of time.

1570. Deloye, F. X., "MINERALOGICAL ANALYSIS - APPLICATION TO HARDENED CONCRETES RELATED TO THEIR SERVICE LIFE (in French)," Research Report of the Central Laboratory of Bridges and Roads No. 83, 56 pages.

KEY WORDS: alkali aggregate reactions; mechanisms

Thanks to the computer program called "Minerals" it is possible to know the composition of concrete in terms of mineral species. Carbonation, sulfate attack, alkali aggregate reactions are examined from the mineralogical aspect. This approach allows to elucidate the mechanisms of concrete deteriorations.

1571. Diamond, S., "BELTANE OPAL, ITS ALKALI REACTION PRODUCT, AND SOME SYNTHETIC ALKALI-SILICA GELS - A BRIEF LOOK AT MICROMORPHOLOGY," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 181-197.

1978

KEY WORDS: reactive aggregates; Beltane opal; opal; silica; scanning electron microscopy; alkali silica gel

(1) Beltane opal has a characteristic opal micromorphology, being composed of spherical grains of the order of 150 nm in diameter. (2) When ground to the fineness characteristic of pozzolans, the product consists of relatively unaltered coarse grains of the order of 50 microns or so, and of much finer clusters of a few spheres each. (3) The reaction product of beltane opal in mortar is a material displaying a homogeneous porous structure (on a fine scale) with characteristic fuzzy outlines that prevent high resolution scanning microscopy. (4) Synthetic sodium-silica gels do not possess this microstructure but appear to be non-porous.

1572. Diamond, S. ed, "PROC. 4TH INTL. CONF. ON THE EFFECTS OF ALKALIS IN CEMENT AND CONCRETE," Purdue University, West Lafayette, IN, 1978, 376 pp.

KEY WORDS: alkali aggregate reactions; conferences

Listed as Proc. 4th Intl. Alkali Conf. Proceedings contains 26 papers, mostly on alkali aggregate reactions in concrete.

1573. Dolar-Mantuani, L., "PRACTICAL ASPECTS OF IDENTIFYING ALKALI-REACTIVE AGGREGATES BY PETROGRAPHIC METHODS," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 267-280.

KEY WORDS: reactive aggregates; petrography

Brief descriptions of the petrographic features used to identify reactive and other minerals and rocks are provided.

1574. Figg, J. W., Lambert, M. P. and Pillay, N., "INVESTIGATION OF THE ALKALI REACTIVITY OF SOME MIDDLE EAST AGGREGATES," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 309-319.

KEY WORDS: reactive aggregates; petrography; chemical test; Middle East

Results of investigations of aggregates from a number of Middle East countries are reported. Methods used include petrographic examination and the ASTM quick chemical test.

1575. French, W. J., "THE MIGRATION AND PRECIPITATION OF WATER-SOLUBLE IONS IN CONCRETE," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 47-67.

KEY WORDS: alkali effects; deterioration; salt effects; pore solutions; field experiences; Middle East

From the field evidence in Middle East concretes it is apparent that the precipitation of salts within concrete paste and aggregate can induce the spalling and disintegration of both the paste and aggregate. In general the smaller the cross-section of the concrete, the greater the damage that may result. The experimental work shows that even good quality concrete may have sufficient porosity to transmit water and build up saturated solutions within them. Rocks and concrete transmitting these solutions are effectively chromatographic materials and the transmission of the salts can be effected by evaporative transference of the solvent into and through the porous medium. Taken together with previous work on the lines of the soundness test, the present work suggests that thermal effects are a prime factor in causing destructive crystallization of salts and this is especially true where acicular crystal forms result. The prevention of such mechanical damage may therefore be accomplished by (1) the prevention of chromatographic transfer by the impregnation of concrete or rocks with a decapillary medium; (2) the creation of peripheral surface concrete around pillars and piles or other structures of small cross-sectional area so that the effective cross-sectional area is increased.

1576. Gillott, J. E., "INTRODUCTION TO PETROGRAPHIC TECHNIQUES IN CONCRETE TECHNOLOGY," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 263-266.

KEY WORDS: petrography; reactive aggregates

Microscopic examination should be performed by a petrographer familiar with concrete. Such examination is of considerable help in assessing the causes of distress in concrete displaying poor durability and in assessing the suitability of rocks and gravels prior to their use as

concrete aggregates.

1577. Grattan-Bellew, P. E., "STUDY OF EXPANSIVITY OF A SUITE OF QUARTZWACKES, ARGILLITES AND QUARTZ ARENITES," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 113-140.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; quartzwackes; arenites; argillites

(1) It has been demonstrated that the slope of the regression line drawn through the expansion curve for concrete prisms is, for the first 200 to 300 days, directly related to the expansivity of the samples. Samples with slopes greater than 20 x 10E-5 are considered deleteriously expansive. (2) The expansion of these concrete prisms is largely controlled by expansion of the aggregate when it reacts with alkalies in the cement paste. (3) The amount of expansion of mortar bars was proportional to the grain size of the aggregate; the larger the grain size, the greater the expansion. The reason is not clear.

1578. Idorn, G. M., "FEAR OF FLYING?," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 1-10.

KEY WORDS: alkali aggregate reactions

An introductory review and interpretation of the significance of alkali aggregate reactions.

1579. Idorn, G. M., "ALKALI-SILICA REACTIONS - SIMPLICITY AND COMPLICITY," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 199-214.

KEY WORDS: alkali aggregate reactions; field experiences

The range of variations of the decisive conditions for alkali aggregate reactions was originally limited during the early 1940's when the original investigations took place. The paper describes important changes of conditions which make the classic prescriptions insufficient. Modern concrete technology, structural design changes, and global range of variation of exposure conditions are important technical factors. Energy and materials resource problems, economy of maintenance, and structural safety

considerations for concrete are also factors.

1580. Idorn, G. M., "A DISCUSSION OF THE PAPER "CALCIUM HYDROXIDE ATTACK ON FELDSPARS AND CLAYS: POSSIBLE RELEVANCE TO CEMENT- AGGREGATE REACTIONS" BY J. H. P. VAN AARDT AND S. VISSER," Cement and Concrete Research, Vol. 8, pp. 391-392, 1978.

KEY WORDS: reactive aggregates; calcium hydroxide effects; mechanisms; alkali effects; feldspars; clays; alkali release

1581. Jawed, I. and Skalny, J., "ALKALIES IN CEMENT: A REVIEW II. EFFECTS OF ALKALIES ON HYDRATION AND PERFORMANCE OF PORTLAND CEMENT," Cement and Concrete Research, Vol. 8, pp. 37-52, 1978.

KEY WORDS: alkali effects; pore solutions; cements; clinkers

1582. Knudsen, T., "BETTER MICROANALYSIS RESOLUTION BY DATA UNFOLDING," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 245-262.

KEY WORDS: EDX analysis

The numerical data correction known as deconvolution has inherent possibilities in the improvement of resolution in microprobe work within cement and concrete research.

1583. Lenzner, D. and Ludwig, U., "THE ALKALI AGGREGATE REACTION WITH OPALINE SANDSTONE FROM SCHLESWIG-HOLSTEIN," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 11-3.

KEY WORDS: alkali aggregate reactions; opal; mechanisms; swelling pressure

Immediately after the addition of the dry aggregate to the mortar mixture, porous opaline sandstone imbibes the solution which is already enriched with lime and alkalis. The ASR already begins during the preparation of the mortar. With progressing ASR, the alkali ions dissolved in

the pore solution of the mortar diffuse to the reactive grains until the reactive silicate is consumed completely. Simultaneously, the lime which is also present within the solution reacts with the alkali silicates to form stable lime alkali silicates. However, this stabilizing reaction progresses more slowly than the formation of the swelling alkali silicate. The already formed layer of lime alkali silicate strongly hinder the diffusion of lime to the core of the reactive grains. Therefore, the remaining amount of alkali silicate in the interior of not too small grains is sufficient to produce osmotic pressures by continuous imbibition of water. The hardened cement structure does not permit large elastic deformations. The swelling pressure due to the ASR produces small plastic deformations but mostly cracks. Pozzolanic or latent hydraulic additions reduce the damage due to the ASR. With non-restrained lateral expansion, the maximum swelling pressure transmitted through the mortar structure is at least 2 MPa.

1584. Locher, F. W., "THE GERMAN REGULATIONS OF LOW ALKALI CEMENT," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 215-228.

KEY WORDS: alkali aggregate reactions; alkali effects; slag; cements;

In the Federal Republic of Germany the following are considered to be cements with a low effective alkali content: Portland cement with a total alkali content of not more than 0.60% $Na_2O$ equivalent; blast furnace slag cement with a slag content of at least 50% and a total alkali content of not more than 1.10% $Na_2O$ equivalent; blast furnace slag cement with a slag content of at least 65% and a total alkali content of not more 2.00% $Na_2O$ equivalent.

1585. Majid, A. H. and Grattan-Bellew, P. E., "POTENTIAL REACTIVITY OF CONCRETE AGGREGATES FROM IRAQ," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 321-334.

KEY WORDS: alkali silica reactions; reactive aggregates; chert; Iraq

This paper evaluates the major aggregate sources in Iraq in terms of susceptibility to the alkali silica reaction. There is a general relation between the chert content of an aggregate and expansivity of mortar bars made with that

aggregate and high alkali cement.

1586. Mather, K., "THE ADVANTAGES OF FREE-ABRASIVE MACHINED SURFACES IN THE STUDY OF POSSIBLE ALKALI-SILICA REACTION IN CONCRETE," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 281-284.

KEY WORDS: petrography; test methods

Lapping concrete core samples with a free abrasive lapping machine produces excellent plane surfaces suitable for detained microscopic investigations.

1587. McCoy, W. J., "EFFECT OF HYDRATION ON WATER SOLUBILITY OF ALKALIES IN PORTLAND CEMENT," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 35-45.

KEY WORDS: cements; alkali effects; hydrated cement pastes

Comparisons between total and water-soluble alkalis of a number of cements are provided. The portion of the alkalis that are water soluble can vary from 10% to over 60% of the total. After the cements have hydrated for a year, the pastes were ground and tested. A significant portion of the alkalis in the hydrated pastes were found to be insoluble as well.

1588. Mehta, P. K., "EFFECT OF CHEMICAL ADDITIONS ON THE ALKALI-SILICA EXPANSION," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 229-234.

KEY WORDS: alkali silica reactions; alkali effects; expansions; mortar bars; NaCl effects; pore solutions; mechanisms

Added alkali sulfates, chlorides, and carbonates used to augment the alkali content of a cement produced different effects on mortar bar expansions. The nitrates did not cause additional expansion. Alkali sulfates, chlorides, and to a lesser extent carbonates increased expansions. Expansions with potassium salts were lower than with corresponding sodium salts.

1978

1589. Moore, A. E., "EFFECT OF ELECTRIC CURRENT ON ALKALI-SILICA REACTION," Proc. 4th Intl. Alkali Conf., West Lafayette, 1978, pp. 69-72.

KEY WORDS: alkali aggregate reactions; mechanisms; electrical effects

Passage of direct electric current through a mortar specimen containing reactive aggregate appeared to accelerate the destruction due to reaction with alkali.

1590. Moore, A., "AN ATTEMPT TO PREDICT THE MAXIMUM FORCE THAT COULD BE GENERATED BY ALKALI-SILICA REACTION," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 363-368.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion; osmotic effects; thermodynamic effects

A thermodynamic equation is provided from which maximum expansive stress generated by alkali silica gel can be calculated, assuming the gel acts as an osmotic pressure generating system.

1591. Oberholster, R. E., Brandt, M. P. and Weston, A. C., "THE EVALUATION OF GREYWACKE, HORNFELS AND GRANITE AGGREGATES FOR POTENTIAL ALKALI REACTIVITY," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 141-161.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; expansion; mortar bars; concrete prisms; field experiences; South Africa

Widespread deterioration of concrete structures in the Cape Peninsula area of South Africa is attributed to an expansive cement-aggregate reaction similar to that reported to occur in Nova Scotia, Canada. Difficulties are encountered in evaluating the available local aggregates (greywackes, hornfels, and granites) using ASTM and other common test methods. Tests with concrete prisms stored at 38°C at 100% RH showed that the Malmesbury aggregate, consisting mainly of greywacke and hornfels, is potentially alkali reactive. Mortar prisms give values close to those of the concrete prisms, although expansions are less than the minimum limits set in the ASTM C 227 test method specification.

1978

1592. Palmer, D., "ALKALI-AGGREGATE REACTION: RECENT OCCURRENCES IN THE BRITISH ISLES," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 285-298.

KEY WORDS: alkali aggregate reactions; field experiences; electrical structures; U.K.

In late 1976 and early 1977 AAR was found to be the cause of deterioration in concrete foundations at some electrical substations in South West England and South Wales. This was the first time that AAR had been confirmed on mainland of the United Kingdom. Since then further cases have been found, and research has been initiated.

1593. Penkala, B., "SOME PROBLEMS RELATED TO THE ADMITTED AMOUNTS OF ALKALIS IN CEMENT (in Polish)," Cement Wapno Gips, Vol. 31, 6, 1978, pp. 165-167.

KEY WORDS: alkali aggregate reactions; alkali effects; slag; mineral admixtures; cements

The addition of fly ashes or natural pozzolans can reduce the deterioration of concretes by alkali aggregate reaction. Blended cements containing 50% blast furnace slag can accept 0.9% $Na_2O$ eq., alkalis and be considered as low alkali cement. As an example, such cement can contain 55% slag, 42% clinker and 3% gypsum with $Na_2O$ eq. < 0.9%.

1594. Penkala, B., "THE INFLUENCE OF THE AMOUNT OF ALKALIS IN CEMENT ON THE BEHAVIOR OF GRAVEL CONCRETES (in Polish)," Cement Wapno Gips, Vol. 31, 6, pp. 167-171.

KEY WORDS: alkali aggregate reactions; alkali effects; reactive aggregates; gravels

Alkalis from cement are more or less soluble. The alkali aggregate reaction has been delayed in the case of a cement containing 90% insoluble alkalis compared to another cement containing 82-86% soluble alkalis with 66% as potassium ions. Microscopic observation revealed the formation of a colloidal silica and Na, K silicates. The rate of alkali aggregate reactions is not proportional to the total amount of alkalis in cement.

1978

1595. Sims, I. and Poole, A. B., "POTENTIAL ALKALI-REACTIVE AGGREGATES FROM THE MIDDLE EAST," Proc. 4th Intl. Alkali Conf., West Lafayette, 1978, pp. 359-361.

KEY WORDS: reactive aggregates; Middle East

Extensive studies of aggregates in Middle East countries have been carried out. Certain rocks are shown to be potentially, or in a few cases, actually alkali reactive, including both silica/silicate and carbonate types. The carbonate types include rocks that display complex reaction mechanisms in concrete.

1596. St John, D. A. and Smith, M. L., "ALKALI-AGGREGATE STUDIES IN NEW ZEALAND - PROGRESS REPORT," Proc. 4th Intl. Alkali Conf. , W. Lafayette, 1978, pp. 299-307.

KEY WORDS: alkali aggregate reactions; reactive aggregates; greywackes; andesites; expansion; field experiences; New Zealand

Aggregates from poorly indurated or marginal facie greywacke may be expansive in concrete. Slow expansion occurs even when the alkali content is as low as 0.32% $Na_2O$ equiv. and pozzolan is present. Thus alkalies do not seem necessary for expansion to occur and a clay rehydration may be occurring.

1597. Stark, D., "ALKALI SILICA REACTIVITY IN THE ROCKY MOUNTAIN REGION," Proc. 4th Intl. Alkali Conf., W. Lafayette, 1978, pp. 235-243.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesites; rhyolites; field experiences; U.S.A.; mineral admixtures; pozzolans

Serious alkali silica reactivity has developed in pavements and bridge structures in the Rocky Mountain Region, where low alkali cements have been used. The reactive components are andesites and rhyolites. ASTM C 227, as it exists, does not appear to be suitable as a basis for recommended remedial measures. Thus far, a minimum 20% replacement of cement by fly ash appears to be the most feasible method of avoiding harmful reactivity.

1978

1598. Van Aadt, J. H. P. and Visser, S., "REACTION OF CA(OH)2 + CASO4.2H2O AT VARIOUS TEMPERATURE WITH FELDSPARS IN AGGREGATES USED FOR CONCRETE MAKING," Cement and Concrete Research, Vol. 8, pp. 677-682, 1978.

KEY WORDS: alkali effects; feldspars; reactive aggregates; alkali release

It has been shown that if calcium hydroxide and feldspars and some other minerals containing alumina are stored together in water, $C_4A$-hydrates and hydrogarnet are formed; the former at room to medium temperatures (22°C to 40°C) and the latter at higher temperatures (40°C to 95°C). The $C_4A$-hydrates react with calcium sulfate to form ettringite. The alkalies released from minerals containing them are then available for alkali aggregate reactions.

1599. Veronelli, D. J. E., "DURABILITY OF CONCRETE; ALKALI AGGREGATE REACTION (in Spanish)," Monografias 352, Madrid, Instituto Eduardo Torroja, 1978, 36 pp. (with (English Summary).

KEY WORDS: alkali aggregate reactions

1600. Veronelli, D. J. E., "DURABILITY OF CONCRETE : ALKALI-AGGREGATE REACTION (in Spanish)," M.C.E. Vol. 171, pp. 5-33.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive measures

Alkalis coming from raw materials (feldspars, schists, clays) are present in the clinker (between 0.2 to 1.8%) usually as sulfates highly soluble in the mixing water. Highly potential reactive rocks are vitreous volcanic silicas (opal, rhyolites, chalcedony). In complex silicates; only the amorphous silica is reactive with alkalis. The ASR proceeds in two stages (1) formation of an alkaline metasilicate (2) formation of a gel; the composition of which depends on the ionic concentration (Na, K, Ca, Fe, Mn), temperature, and time. All these factors contribute to form a semi-permeable membrane giving rise to an osmotic pressure. High pressures correspond to a pessimum content of alkalis and silica. For minimizing the AAR, high alkali cements have to be used in low dosage in concrete and siliceous additions like pozzolans rich in

1978

fine and active silica or fly ash are recommended in the range 15 - 20%.

1601. Asgeirsson, H. and Gudmundsson, G., "POZZOLANIC ACTIVITY OF SILICA DUST," Cement and Concrete Research, Vol. 9, pp. 249-252, 1979.

KEY WORDS: alkali aggregate reactions; silica fume; preventive measures;expansion; alkali silica gel; field experiences; Iceland

(1) Silica fume added to our alkali rich cement will not only counteract the expansion in our concretes but greatly increase their strength. Much research, however, is still needed to follow up the preliminary investigations. (2) The addition of reactive silica fume to alkali rich mortars does not reduce the formation of silica gel. On the contrary one should expect an increase in that substance.

1602. Bager, D. H. and Sellevold,E. J., "HOW TO PREPARE POLISHED CEMENT PRODUCT SURFACES FOR OPTICAL MICROSCOPY WITHOUT INTRODUCING VISIBLE CRACKS," Cement and Concrete Research, Vol. 9, pp. 653-654, 1979.

KEY WORDS: test methods; petrography

1603. Chatterji, S., "THE ROLE OF Ca(OH)2 IN THE BREAKDOWN OF PORTLAND CEMENT CONCRETE DUE TO ALKALI-SILICA REACTION," Cement and Concrete Research, Vol. 9, pp. 185-188, 1979.

KEY WORDS: alkali aggregate reactions; mechanisms; Ca(OH)2 effects

The presence of free $Ca(OH)_2$ is a necessary condition for destructive alkali silica reactions. Complete removal of free $Ca(OH)_2$ by leaching with conc. $CaCl_2$ or by reacting with a pozzolan suppresses ASR, even when alkali hydroxides are present. Practical implications are discussed.

1604. Dent Glasser, L. S., "OSMOTIC PRESSURE AND THE SWELLING OF GELS," Cement and Concrete Research, Vol. 9, pp. 515-517, 1979.

KEY WORDS: alkali aggregate reactions; alkali silica gels; osmotic effects; mechanisms; expansion

1979

A note discussing osmotic effects in expansion associated with alkali silica reactions.

1605. Diamond, S., "CHAPTER 40 - CHEMICAL REACTIONS OTHER THAN CARBONATE REACTIONS," American Society for Testing and Materials, Special Technical Publication 169B, pp. 708-721, 1979.

KEY WORDS: alkali aggregate reactions; test methods; chemical tests; mortar bars; reviews

A review and guide to interpretation of results of standard ASTM test methods having to do with chemical reactions (other than carbonate reactions) involved in the durability of concrete. ASTM tests for alkali aggregate reactions in particular are discussed in detail.

1606. Furlan, V. and Houst, Y., "REACTION OF CEMENT ALKALIS WITH AGGREGATE AND GLASS (in French)," Chantiers (Suisse) No.11, pp. 45-48.

KEY WORDS: alkali aggregate reactions; pozzolans; preventive measures

Aggregates for concrete can be tested by different ways: petrographic examination, expansion of mortar prisms, pat-test. If from an economical point of view reactive aggregates have to be used, a low alkali Portland cement or a pozzolanic cement with trass is a preventive measure.

1607. Gutt, W. and Nixon, P., "ALKALI AGGREGATE REACTIONS IN CONCRETE," Construction, No. 31, Oct. 1979, pp. 30-31.

KEY WORDS: alkali aggregate reactions; reactive aggregates; alkali effects; preventive measures

Alkali aggregate reaction (AAR) may cause deterioration in concrete when alkaline solutions attack certain siliceous aggregates. This article describes signs of the trouble, including cracking in concrete and weeping of gel from cracks. Alkali aggregate reaction depends upon sufficient alkali, a reactive aggregate and adequate moisture. Low alkali cements and rock types found to be reactive are discussed. Reference is made to tests for

aggregates, and the vulnerability to attack of certain structures due to the presence of water. The article concludes with possible precautions against this type of failure.

1608. Kawamura, M., Hasaba, S. and Takemoto, K., "A FUNDAMENTAL STUDY ON ALKALI-AGGREGATE REACTION (in Japanese)," Transactions of the Japan Concrete Institute, Vol, 1, pp. 191-198, 1979.

KEY WORDS: alkali aggregate reactions; expansion; pore solutions; scanning electron microscopy

1609. Lenzner, D. and Ludwig, V., "THE DETECTION OF ALKALI-SILICA REACTIONS IN CONCRETE STRUCTURES (in German)," Zement Kalk Gips, Vol. 32, 8, pp. 401-410.

KEY WORDS: alkali aggregate reactions; expansion; field experiences; Germany; repairs

The concrete expansion of samples from deteriorated structures is a possible measure of the degradation. Reactive aggregates can be observed and counted for the evaluation of the deterioration. Due do the distribution and irregular size of reactive aggregates, deterioration can be different from one point to another. The chemical reaction can be slow, as observed in concretes over more than seven years. During repairs alkali chlorides and silicates have increased the expansion. Treatment with Ba solutions seemed beneficial in all cases.

1610. Nixon, P. J., Collins, R. J. and Rayment, P .L., "THE CONCENTRATION OF ALKALIES BY MOISTURE MIGRATION IN CONCRETE - A FACTOR INFLUENCE ALKALI AGGREGATE REACTION," Cement and Concrete Research, Vol. 9, pp. 417-423, 1979.

KEY WORDS: alkali aggregate reactions; alkali effects; pore solutions; water effects

The concentration of alkali metal ions caused by the movement of moisture in concrete has been examined by chemical analysis and X-ray microprobe analysis. It has been found that there is a significant increase in the concentration of these ions close to the surface from which

moisture is evaporating . Local very high concentrations have been shown to be due to crystallizing alkali sulfates. The significance of this effect in promoting alkali aggregate reaction is discussed.

1611. Popa, R., Popa, E., Pau, F. and Crisan, D., "RESEARCH ON THE HYDRAULICITY OF SILICEOUS BY PRODUCTS FROM SERPENTINE (FROM ROMANIA)," M.D.C. Vol. 9, 1, pp. 19-22.

KEY WORDS: alkali aggregate reactions; pozzolans

By products of the serpentine industry can be used as hydraulic materials after having been tested by DTA and XRD. The amount of amorphous silica has to be determined when considering the alkali aggregate reaction.

1612. Regourd, M., "MICROSTRUCTURE OF CONCRETES DETERIORATED BY THE ALKALI- AGGREGATE REACTION (in French)," Annales de Chimie - Science des Materiaux, 4, pp. 179-185.

KEY WORDS: alkali aggregate reactions; field experience; France; EDX analysis; scanning electron microscopy; alkali silica gel; feldspar; alkali release

Damaged concrete by alkali aggregate reactions have been observed by SEM and analyzed by Electron Probe Microanalysis. Two cases have been studied. They concerned concretes with expanded glass aggregates and with schistous aggregates. Amorphous gels and crystals appeared as alkali silicate gels. As cement was low in potassium the $K^+$ ions came from the altered feldspars.

1613. Sideris, K., "THE TEMPERATURE EXPANSION MAXIMUM IN THE ALKALI-AGGREGATE REACTION (in German)," Zement Kalk Gips, Vol. 32, 10, pp. 508-509.

KEY WORDS: osmotic effects; alkali aggregate reaction; expansion; temperature effects

Studies carried on alkali-silicate colloidal solutions with osmotic cells at 18°C, 40°C, and 60°C have clearly shown a parallelism between the concentration of colloidal silicate and expansion of concretes with temperature increases.

1979

1614. Stein, V., "PREVENTIVE MEASURES AGAINST THE ALKALI-AGGREGATE REACTION IN CONCRETE (in German)," B.H.V., Vol. 28, 9, pp. 329-330.

KEY WORDS: alkali aggregate reactions; petrography; test methods

Only the petrographic examination of aggregates can estimate their potential reactivity with alkalis. Finest fractions of crushed rocks can react in 10% NaOH solutions although they do not in concrete as massive aggregates.

1615. Woermann, E., Hahn, Th. and Eysel, W., "THE SUBSTITUTION OF ALKALIES IN TRICALCIUM SILICATE," Cement and Concrete Research, Vol. 9, pp. 701-711, 1979.

KEY WORDS: alkali effects; cements; clinkers

Up to 1.4% of $K_2O$ or $Na_2O$, and 1.2% of $Li_2O$ can be incorporated in $C_3S$ at 1500°C. Various substitution types were found. The effects of such substitutions were to increase the decomposition temperature of $C_3S$. The alite phase in clinkers should show similar effects.

1616. Anon., "THEME VII: INTERFACE REACTIONS BETWEEN CEMENT AND AGGREGATE IN CONCRETE AND MORTAR," Proceedings of 7th International Congress on the Chemistry of Cement, Paris, 1980. Paris, Editions Septima, 1980, Vol. 3, pp. VII/1-138.

KEY WORDS: alkali aggregate reactions; mechanisms; conferences

1617. Baker, A. F. and Poole, A. B., "CEMENT HYDRATE DEVELOPMENT AT OPAL-CEMENT INTERFACES AND ALKALI-SILICA REACTIVITY," Quarterly Journal of Engineering Geology, Vol. 13, No. 4, 1980, pp. 249-254.

KEY WORDS: alkali aggregate reactions; mechanisms; opal

Electron probe microanalysis data indicates that sodium, potassium, and calcium ions migrate into opal aggregate from the cement paste in experimental alkali silica reactive concretes. The reaction also modified the development of cement phases at the interface with the opal and these modifications are reflected in modifications of the tensile strength of the opal/cement bond. It is suggested the calcium silicate hydrates which develop in the cement at the interface with opal may control the migration of alkali ion into the opal. With high alkali concentration in the cement pore solution this hydrate layer at the interface may not develop completely allowing high concentrations of alkali ions to reach the reacting opal causing a change in the composition and properties of the alkali silica gel reaction product.

1618. Baller, R., "CAUSES OF THE INCREASED RESISTANCE OF SLAG CEMENT CONCRETE AGAINST ALKALI SILICA REACTION AND SULPHATE ATTACK (in German)," Aachen, Technischen Hochschule, 1980, 145 pages.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive measures; slag; mineral admixtures

1619. Calleja, J., "DURABILITY," Proceedings of 7th International Congress on the Chemistry of Cement, Paris, 1980, Paris, Edition Septima, 1980, Vol. 1. pp. VII-2/1-48.

1980

KEY WORDS: alkali aggregate reactions; deterioration

1620. Dent Glasser, L. S., "A REPLY TO P.K. MEHTA'S DISCUSSION OF "OSMOTIC PRESSURE AND THE SWELLING OF GELS"," Cement and Concrete Research, Vol. 10, pp. 125-126, 1980.

KEY WORDS: expansion; osmotic effects; mechanisms

1621. Durniak, G., "COMPATIBILITY EXPANDED GLASS AGGREGATES-CEMENT. CONTRIBUTION TO THE ALKALI-AGGREGATE REACTION STUDY (in French)," Thesis CNAM Engineer Diploma Paris, 214 pages.

KEY WORDS: alkali aggregate reactions; glass; pore solutions; reactive aggregates; field experiences; France

Expanded glass aggregates can be used in light-weight concretes if they are in a dry atmosphere. In humid environments the ASR forms gels which occupy the available space in the porous glass aggregates. Alkalis are provided by the glass itself. The nature of cement is not an important factor as silicate gels are formed with low alkali cements.

1622. French, W. J., "REACTIONS BETWEEN AGGREGATES AND CEMENT PASTE - AN INTERPRETATION OF THE PESSIMUM," Quarterly Journal of Engineering Geology, Vol. 13, No. 4, pp. 231-247.

KEY WORDS: reactive aggregates; pessimum effects

This paper is about the reaction between the alkalis present in the pore solution of cementitious phases of concrete and siliceous aggregates. The reaction may be expansive and consequently deleterious. Maximum expansion occurs at some definite or "pessimum" concentration of reactive aggregate for any given mortar. The nature of the reaction is discussed and formulae are given which describe the curve of expansion against proportion of reactive aggregate. The magnitude and significance of the coefficients of these expressions are discussed and suggestions are made for the limits to be set on the allowable expansion and other design parameters if the effects of the reaction are to be minimized.

1980

1623. Grattan-Bellew, P. E. and Beaudoin, J. J., "EFFECT OF PHLOGOPITE MICA ON ALKALI-AGGREGATE EXPANSION IN CONCRETE," Cement and Concrete Research, Vol. 10, pp. 789-797, 1980.

KEY WORDS: alkali aggregate reactions; mica; alkali effects; expansion; alkali release

A small amount of $K^+$ in phlogopite is soluble in $Ca(OH)_2$ and NaOH solutions and in the pore solution of hydrated portland cement paste. Addition of small amounts of phlogopite to concrete made with potentially alkali-expansive aggregate results in a small increase in the rate of expansion of the concrete stored under humid conditions. The increase in the rate of expansion, however, is not sufficient to cause concern about the use of phlogopite mica as a reinforcement, even in concrete made with deleteriously alkali-expansive aggregate and low alkali cement.

1624. Gutteridge, W. A. and Hobbs, D. W., "SOME CHEMICAL AND PHYSICAL PROPERTIES OF BELTANE OPAL AND ITS GELATINOUS ALKALI SILICA REACTION PRODUCT," Cement and Concrete Research, Vol. 10, pp. 183-193, 1980.

KEY WORDS: alkali aggregate reactions; reactive aggregates; Beltane opal; mechanisms; alkali silica gels; alkali effects

Beltane opal rock, which has been described as an hydrothermally altered rhyolite, contains approximately 15 weight percent quartz, small quantities of kaolinite and alunite and approximately 82 weight percent of potentially alkali reactive siliceous material. The latter comprises opal-A, opal-C material and tridymite, which dissolve at different rates in 3M NaOH solution. Between 20°C and 80°C opal-A dissolves faster than opal-C which dissolves faster than tridymite. Results suggest that the distress observed in mortar bars containing Beltane opal as an aggregate will be due principally to the dissolution of opal-A when bars are stored at 20°C and due to the dissolution of opal-A and opal-C when stored at 35°C and above. X-ray diffraction and X-ray photoelectron scattering data were obtained for reaction product gels.

1625. Hasaba, S., Kawamura, M. and Takemoto, K., "THE EXPANSION CHARACTERISTICS OF MORTAR CAUSED BY ALKALI AGGREGATE

REACTION," Cement Association of Japan - Review of the 34th General Meeting/Technical Session, pp. 71-73, 1980.

KEY WORDS: alkali aggregate reactions; expansion; pore solutions; opal

1626. Idorn, G. M., "A DISCUSSION OF THE PAPER "SOME CHEMICAL AND PHYSICAL PROPERTIES OF BELTANE OPAL ROCK AND ITS GELATINOUS ALKALI SILICA REACTION PRODUCT" BY W.A. GUTTERDGE AND D.W. HOBBS," Cement and Concrete Research, Vol. 10, pp. 581-582, 1980.

KEY WORDS: alkali aggregate reactions; Beltane opal; temperature effects

1627. Johansen, C. et al., "PROPERTIES OF INTERNALLY SEALED CONCRETE MADE WITH REACTIVE AGGREGATES," Nordisk Betong, Vol. 24, No. 5-6, 1980, pp. 29-32.

KEY WORDS: reactive aggregate; preventive measures

1628. Mather, B., "A DISCUSSION OF THE PAPER: THE CONCENTRATION OF ALKALIES BY MOISTURE MIGRATION IN CONCRETE - A FACTOR INFLUENCING ALKALI AGGREGATE REACTION" by P. J. Nixon, R. J. Collins, and P. L. Rayment," Cement and Concrete Research, Vol. 10, pp. 111-112, 1980.

KEY WORDS: alkali aggregate reactions; alkali effects; pore solutions; field experiences; U.S.A.

1629. Mehta, P. K., "A DISCUSSION OF THE PAPER ON "OSMOTIC AND SWELLING OF GELS" BY L..S. DENT GLASSER," Cement and Concrete Research, Vol. 10, p. 123, 1980.

KEY WORDS: alkali aggregate reactions; mechanisms; osmotic effects; expansion

1630. Nixon, P. J., Collins, R. J. and Rayment, P. L., "REPLY TO DISCUSSION BY B. MATHER OF THE PAPER "THE CONCENTRATION OF ALKALIES BY MOISTURE MIGRATION IN CONCRETE - A FACTOR

INFLUENCING ALKALI AGGREGATE REACTION," Cement and Concrete Research, Vol. 10, p. 113, 1980.

KEY WORDS: alkali aggregate reaction; alkali effects; pore solution

1631. Pettifer, K. and Nixon, P. J., "ALKALI METAL SULFATE - A FACTOR COMMON TO BOTH ALKALI AGGREGATE REACTION AND SULFATE ATTACK ON CONCRETE," Cement and Concrete Research, Vol. 10, pp. 173-181, 1980.

KEY WORDS: alkali aggregate reactions; sulfate attack; petrography; mechanisms; field experiences; U.K.

Cases of deterioration of concrete in which evidence of both sulfate attack and alkali aggregate reactions has been detected are described, and a possible connection between these two mechanisms of attack is discussed. Sulfate attack on concrete by alkali sulfates may promote alkali aggregate reaction.

1632. Stark, D., "ALKALI SILICA REACTIVITY: SOME RECONSIDERATIONS," Cement, Concrete, and Aggregates, Vol. 2, No. 2, 1980, pp. 92-94.

KEY WORDS: alkali aggregate reactions; reactive aggregates; volcanic aggregates; glass; alkali effects; test methods; field experiences, U.S.A.; alkali release

Field and laboratory observations indicate that alkali silica reactions may occur with certain glassy volcanic aggregates even with low alkali cements. The presently specified ASTM C 227 test method may not identify such aggregates as reactive, and the 0.6% $Na_2O$ equivalent alkali content for cements may not be low enough to prevent distress with such aggregates.

1633. Tang, M. S. and Han, S. F., "EFFECT OF Ca(OH)2 ON ALKALI-SILICA REACTION," Proc. 7th Intl. Conf. on the Chemistry of Cement, Vol. II, p. 94, 1980.

KEY WORDS: alkali aggregate reactions; mechanisms; pore solutions; preventive measures; pozzolans

ASR is actually a base-acid neutralization reaction. Hence, when the concentration of $R^+$ ions is fixed, the more concentrated the $OH^-$ ions solution is, the more vigorous is the reaction. The differences of expansion caused by ASR in different types of cements are mainly due to the difference of $OH^-$ ion concentrations in the pore solutions of cement paste. The ASR may be effectively inhibited, if a sufficient amount of pozzolanic materials is added to the cement. A large part of $Ca(OH)_2$ would be vanished in reaction and the last remained $Ca(OH)_2$ could be embedded by the hydrated products. The ASR caused by alkali from sources other than cement can be prevent by the use of supersulphated cement or cement with additive such as pozzolan or blastfurnace slag.

1634. Veronelli, J. E. and Calleja, J., "NEW POINT OF VIEW ABOUT ATTACK OF CONCRETE BY SULFATES AND ALKALINE CHLORIDES (in Spanish)," M.C., 180, pp. 5-13, - Cemento Hormingon, Vol. 52, 568, pp. 271-281.

KEY WORDS: alkali aggregate reactions; alkali effects; mechanisms; preventive measures

Alkaline sulfates and chlorides which react with $Ca(OH)_2$ form alkaline hydroxides. The high resulting alkalinity can favor the alkali aggregate reaction with siliceous aggregates, if concrete is permeable so low alkali cements are not enough in avoiding AAR when sulfates and chlorides are in contact with concrete. Pozzolanic cements are recommended as they are able to take up alkalis.

1635. Allen, R. T. L., "ALKALI SILICA REACTION IN GREAT BRITAIN - A REVIEW," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, SE 252/18.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.; reviews

The history of some of the cases of AAR discovered in Great Britain since 1971 is examined, and proposed future work is outlined.

1636. Bakker, R. F. M., "ABOUT THE CAUSE OF THE RESISTANCE OF BLASTFURNACE CEMENT CONCRETE TO THE ALKALI-SILICA REACTION, " Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/29.

KEY WORDS: ASR; slag; sulphate attack

Th behavior of blast furnace cement with high slag content, in regard to both the ASR and sulphate attack, can be explained as being due to the same cause, namely the low permeability of blastfurnace cement stone to ions and water. It is therefore not by pure accident that blastfurnace cement with about 65-70 percent slag will withstand two totally different detrimental reactions.

1637. Barneyback, R. S. Jr., and Diamond, S., "EXPRESSION AND ANALYSIS OF PORE FLUIDS FROM HARDENED CEMENT PASTE AND MORTARS," Cement and Concrete Research, Vol. 11, pp. 279-285, 1981.

KEY WORDS: alkali aggregate reactions; alkali effects; pore solutions; mechanisms

A pore solution expression device suitable for hardened cement pastes and mortars is described, with particulars provided on design, fabrication, and operation. Methods of analysis of the resulting small volumes of recovered pore solution are described.

1638. Bensted, J., "A DISCUSSION OF THE PAPER "THE CHEMISTRY OF ALKALI- AGGREGATE REACTION" BY L.S.D. GLASSER," Cement and Concrete Research, Vol. 11, pp. 807-808, 1981.

KEY WORDS: alkali aggregate reactions; alkali silica gels; IR spectroscopy; mechanisms

1639. Blight, G. E., McIver, J. R., Schutte, W. K. and Rimmer, R., "THE EFFECTS OF ALKALI-AGGREGATE REACTION ON REINFORCED CONCRETE STRUCTURES MADE WITH WITWATERSRAND QUARTZITE AGGREGATE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/15.

KEY WORDS: alkali aggregate reactions; reactive aggregates; quartzite; moisture effects; field experiences; South Africa

Testing in according with ASTM C 289 indicates that Witwatersrand quartzite is susceptible to reaction with alkali. Deterioration only appears to occur under conditions of cyclic wetting and drying. In the worst cases investigated to date, the compressive strength has been approximately halved, but the tensile strength has probably been reduced to zero. The instantaneous Young's modulus of a deteriorated concrete may be only about third of that of a sound concrete, while the creep strain may be two and half to four times as large.

1640. Brandt, M. P., Oberholster, R. E. and Westra, W. B., "THE ALKALI-AGGREGATE REACTION: A CONTRIBUTION CONCERNING THE DETERMINATION OF THE REACTIVITY OF PORTLAND CEMENTS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/10.

KEY WORDS: alkali aggregate reactions; reactive aggregates; glass; Beltane opal; test methods

(1) The expansion of pyrex glass mortar prisms does not appear to be related to either total alkali or water soluble alkali content. (2) Beltane opal is unsuitable for determining the reactivity of cements since the expansion of prisms is strongly influenced by the pessimum effect. (3) The determination of the available alkali content of cement in order to establish its reactivity is promising because of the good relationship found between the available alkali and the expansion of mortar prisms containing Malmesbury hornfels aggregates.

1981

1641. Buttler, F. G., Morgan, S. R. and Walker, E. J., "STUDIES ON THE RATE AND EXTENT OF REACTION BETWEEN CALCIUM HYDROXIDE AND PULVERIZED FUEL ASH AT 38C," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/38.

KEY WORDS: alkali effects; mechanisms; fly ash; pozzolans

(1) The rate and amount of extraction of sodium and potassium ions increases as the pfa:$Ca(OH)_2$ mass ratio decreases. (2) Provided the mass ratio pfa:$Ca(OH)_2$ is low, all of the sodium and potassium ions in the pfa samples would ultimately be extracted. (3) For the ASTM C 311 ratio of 5 g pfa:2 g $Ca(OH)_2$ there is little change in the amount of sodium and potassium ions extracted if the paste are stored at 38°C for periods longer than 28 days.

1642. Christensen, P. et al., "MICROSCOPIC STUDIES OF AGGREGATES IN DANISH CONCRETE," Proceedings of the Third International Conference on Cement Microscopy, March 16-19 1981, Houston, Texas, pp. 374-385.

KEY WORDS: reactive aggregates; petrography; field experiences; Denmark

1643. Cole, W. F., Lancucki, C. J. and Sandy, M. J., "PRODUCTS FORMED IN AN AGED CONCRETE," Cement and Concrete Research, Vol. 11, pp. 443-454, 1981.

KEY WORDS: dam structures; field experiences; Australia; cracking; alkali aggregate reactions; alkali effects; petrography; alkali silica gel; alkali release

At a dam in Australia concrete shows a widespread reaction that has caused surface cracking and some functional damage to the structure. The reactive aggregate component appears to be siltstone and sandstone. The reaction has produced reaction rims and crystallization of a zeolite A - like product within the aggregate and in pores in the concrete; hardened amorphous alkali silica gel is present in other pores, sometimes associated with trona. The gel is metastable and appears to transform to the zeolite-like material or to analcite. The reaction products tend to be low in alumina and high in silica. The reaction is unusual in that the aggregate has supplied some of the alkali through leaching of the aggregate by $Ca(OH)_2$ solution.

1981

1644. Coull, W. A., "CHARACTERISTICS AND SERVICE RECORD OF COMMONLY USED AFRICAN AGGREGATES," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/37.

KEY WORDS: reactive aggregates; petrography; field experiences; South Africa

1645. Damp, D. E., "THE IMPLICATIONS OF PRODUCING A LOW ALKALI ORDINARY PORTLAND CEMENT IN THE SOUTH WESTERN CAPE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/3.

KEY WORDS: cements; alkali effects

1646. Dent Glasser, L. S. and Kataoka, N., "THE CHEMISTRY OF ALKALI-AGGREGATE REACTIONS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/23.

KEY WORDS: alkali aggregate reactions; mechanisms; osmotic effects; expansion

Model systems using silica gel and sodium hydroxide solutions suggest that the mechanism of alkali aggregate reaction can be described as follows: Ill-crystallized and absorbent silicas absorb alkali and hydroxyl ions from the pore fluid, and after any silanol groups locally present have been neutralized, the hydroxyl ions attack siloxane bridges, with consequent loosening of the structure. More sodium ions diffuse in, and the resulting polyelectrolyte exerts considerable imbibition pressure. Water is thus absorbed, and the loosened framework of the aggregate particle swells, pushing aside adjacent material in the process. Totally disintegrated material may ooze into any cracks formed, and may further contribute to the disintegration of the concrete; for example if cycles of drying and wetting of the concrete occur such that the dried gel picks up water during the wet cycle more rapid than it can ooze away.

1647. Dent Glasser, L. S. and Kataoka, N., "THE CHEMISTRY OF "ALKALI-AGGREGATE" REACTION," Cement and Concrete Research, Vol. 11, pp. 1-9, 1981.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects

To clarify ideas about ASR reaction mechanisms, the reaction between sodium hydroxide and silica gel has been studied. When silica gel is stirred with sodium hydroxide solution, there is an immediate drop in both [Na+] and [OH-], due to adsorption on and reaction with solid silica gel. Subsequently, as the alkali gel dissolves, [$OH^-$] decreases continuously but [$Na^+$] rises again. When other silicas whose surface area is less than silica gel are stirred with sodium hydroxide solution, the dissolution is much slower and the initial drop in [$Na^+$] is not observed. Under the conditions without stirring, perhaps nearer to those in concrete, the reaction is controlled by diffusion of solution. There is solubility curve limiting the dissolution of silica. When silica gel is mixed with sodium hydroxide solution, silica gel dissolves and the pH of solution simultaneously decreases. When the dissolution path reaches the solubility curve, dissolution of silica gel ceases. If a large quantity of silica gel is used, the excess silica gel removes $OH^-$ from solution and the dissolution path reaches the solubility curve at lower pH, and the final concentration of dissolved silica is also lower. Thus, the maximum final concentration of dissolved silica is obtained at intermediate total $SiO_2/Na_2O$ mole ratio. This ratio is near to that of maximum final concentration of dissolved silica. This phenomenon suggests an explanation for observation about "pessimum" proportions of reactive aggregate in mortar and concrete.

1648. Dent Glasser, L. S. and Kataoka, N., "A REPLY TO J. BENSTED'S DISCUSSION OF "THE CHEMISTRY OF ALKALI-AGGREGATE REACTION," Cement and Concrete Research, Vol. 11, pp. 809-810, 1981.

KEY WORDS: alkali aggregate reactions; mechanisms

1649. Diamond, S., Barneyback, R. S. and Struble, L. J., "ON THE PHYSICS AND CHEMISTRY OF ALKALI-SILICA REACTIONS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/22.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects; temperature effects; expansion; osmotic effects; Beltane opal.

(1) It is possible to follow the kinetics of the chemical reaction between dissolved alkali and reactive aggregates in mortar by monitoring the rate at which

alkalis are withdrawn from the pore solutions. (2) The chemical reaction is much more rapid at 40°C than at 20°C and in one series of mortars tested it was found to reach equilibrium by the third day. (3) Mortar specimens sealed in butyl rubber jackets to prevent either entry or evaporation of water were found to expand in the normal manner. Thus expansion is not necessarily dependent on external water being supplied, but may occur in consequence of the absorption of pore solution into reaction product gels without the external entry of additional fluid (4) Expansion (in the absence of external water) significantly lags behind the chemical reaction, both at ordinary (20°C) and at elevated temperature (40°C), confirming the separability of the two processes. (5) Expansion at elevated temperature (40°C) is initially accelerated as compared to expansion at ordinary temperature (20°C), but it may subsequently slow down and falls below the ordinary temperature response, leading to a net negative temperature effect on long-term expansions. (6)Expansions of synthetic soda:silica gels on exposure to water under free swelling conditions were either very high (of the order of 60 to 80 percent) or quite low (less than 4 percent), with no clear correlation to soda:silica ratio. Calcium-containing gels expanded modestly. (7) Measured swelling pressure responses of the synthetic soda:silica gels also fell into two classes: a few gels capable of exerting high swelling pressure (4 to about 11 MPa), and the remainder exerting swelling pressures of less than 0.5 Mpa. Again there was no clear correlation with chemical composition, although there was some indication that gels of soda:silica just over 0.3 tend to develop high swelling pressure. (8) Gels showing large free swelling expansions did not necessarily develop high swelling pressures. The gel exhibiting the highest expansion developed only negligible pressure, and the gel exhibiting by far the highest swelling pressure exhibited only modest expansion on free swelling exposure. 9) Spot analyses of reacted opal grain by energy dispersive X-ray analysis indicate the rapid penetration of potassium completely through sand size aggregate grains within a few weeks. Such analyses also indicate the penetration of calcium, although it is concentrated primarily around the perimeter of the grains.

1650. Diamond, S., "EFFECTS OF TWO DANISH FLY ASHES ON ALKALI CONTENTS OF PORE SOLUTIONS OF CEMENT-FLY ASH PASTES," Cement and Concrete Research, Vol. 11, pp. 383-394, 1981.

KEY WORDS: alkali effects; pore solutions; fly ash;

pozzolans; alkali release

The specific Danish cement used in these experiments produces pore solution alkali concentrations approaching 0.4M in potassium ions and exceeding 0.2M in sodium ions in w:c 0.4 pastes. About 80 percent of the total potassium and about 60 percent of total sodium of the cement remains in solution indefinitely. One of the fly ashes, with an alkali content of 2.4 percent $Na_2O$ equivalent, behaves in an entirely inert manner with respect to alkalies: that is, it neither contributes to nor removes alkali from the pore solutions, when the dilution effect is taken into account. The second fly ash with an even higher alkali content (Na2O equivalent 3.3 percent) again shows no augmentation of the alkali content of the pore solution, event though it is ground to high fineness. It does show some small activity in terms of removal of a limited portion of the sodium and potassium contributed by the cement between 10 and 30 days, dropping the concentration-based pH slightly. Incorporation of either of these fly ashes in concrete is not likely to increase the risk of alkali aggregate attack by increasing the alkali in pore solution, nor is the limited absorption of alkalies observed for the ground fly ash likely to materially affect the maintenance of the passivation of embedded steel.

1651. Dolar-Mantuani, L. M., "UNDULATORY EXTINCTION IN QUARTZ USED FOR IDENTIFYING POTENTIALLY ALKALI-REACTIVE ROCKS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/36.

KEY WORDS: reactive aggregates; quartz; test methods; petrography

When using the UE-angle method for identifying potentially alkali reactive rocks, the following parameters should be determined: (1) The amount of quartz in the rock. (2) The number of quartz grains with undulatory extinction (by estimation or point count). (3) The intensity of undulatory extinction as demonstrated by the size of the undulatory angle.

1652. Dunstan, E. R. Jr., "THE EFFECT OF FLY ASH ON CONCRETE ALKALI-AGGREGATE REACTION," Cement, Concrete and Aggregates, Vol. 3, No. 2, 1981, pp. 101-104.

KEY WORDS: alkali aggregate reactions; fly ash; pozzolans;

preventive measures

The effectiveness of fly ash to reduce alkali aggregate reaction distress appears to depend, in part, on the chemical composition of the fly ash and also on the percent weight replacement of cement by fly ash.

1653. Figg, J. W., "REACTION BETWEEN CEMENT AND ARTIFICIAL GLASS IN CONCRETE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/7.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mechanisms; glass; Beltane opal

(1) Glasses of a wide range of compositions are capable of reacting expansively with cements. (2) The most reactive glasses have a high boron content and/or metal content or have relatively porous or phase-separated structure. (3) The reaction between glass and alkali in concrete is qualitatively different from that of other reactive more porous aggregates and has a pessimum relationship for particle size, unlike more porous aggregates. (4) Glasses ( and possibly also other aggregates) which contain both alkali metal oxides and silica in appropriate proportions can give rise to damaging expansions even with low alkali portland cement. (5) Neither pyrex glass nor Beltane opal rock completely model the behavior of real alkali-susceptible aggregates in concrete. A possible standard expansive aggregate would be fused silica which is a consistent, readily available material.

1654. Flanagan, J. C., "ALKALI-AGGREGATE REACTION: PRACTICAL PREVENTIVE AND REMEDIAL MEASURES," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/17.

KEY WORDS: alkali aggregate reactions; preventive measures; repairs

Deleterious AAR can occur only when three conditions are satisfied. They are: 1) that the aggregate is reactive, 2) that sufficient alkalis are present, and 3) that the environment is suitable. Preventive measures include use of non-reactive aggregate; use of low alkali cement; and incorporating a suitable admixture such as slag or a proven pozzolan. Remedial measures should include removal of moisture, prevention of steel corrosion, and where

necessary the restoring of structural stability.

1655. Freeme, C. R. and Shackel, B., "EVALUATION OF A CONCRETE PAVEMENT AFFECTED BY THE ALKALI-AGGREGATE REACTION USING A HEAVY VEHICLE SIMULATOR," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/20.

KEY WORDS: pavement structures; field experiences; South Africa

1656. Gebauer, J., "ALKALIS IN CLINKER: INFLUENCE ON CEMENT AND CONCRETE PROPERTIES," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/4.

KEY WORDS: alkali effects; cements; pore solutions

The influence of alkali on the properties of cement, cement paste, mortar and concrete, which is quite apparent under standardized conditions but is less pronounced in industrially produced cement, may have completely disappeared in concrete produced under practical conditions. The influence of alkalis on the properties of hardened concrete may still recognized with regard to the early strength and the rate of strength development. Especially at early ages, the alkali concentration in the pore solution may play an important role in the hydration and hardening process. The influence of alkalis on the properties of fresh concrete is marginal and it is probable that other influencing factors are predominant thus concealing the influence of the alkalis. As isolated assessment of the alkalis with regard to cement or concrete properties may be misleading if other influencing parameters, their interrelations and their interactions are neglected. Our study has demonstrated how complex the relationships are between clinker composition and cement properties. Frequently, published data generated by a single laboratory experiment which is performed on a small number particular test conditions may lead to false or exaggerated statements.

1657. Gillott, J. E. and Beddoes, R. J, "CONTINUING STUDIES OF ALKALI-AGGREGATE REACTIONS IN CONCRETE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/25.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mechanisms; osmotic effects; test methods;

(1) External morphology does not provide an accurate guide to aggregate reactivity in alkali. Despite the mathematical precision possible with the Fourier method of shape analysis, changes in the shape of materials on reaction are too slow to be useful as a method for the recognition of expansive aggregates. (2) It was shown by X-ray diffraction that the crystallinity of opal was reduced by reaction with sodium hydroxide, but the original cristobalite did not alter to another crystal form. (3) Studies with an "osmotic cell" show that flow becomes negligible once solution ion concentration reaches a certain level although the solution is still strongly basic at this concentration. Continued increase in volume was noted for alkali solution/silica system after flow had ceased. (4) Attention is drawn to the fibrous structures described in the literature in "silica gardens" and the possibility of related growth mechanisms is discussed in the light of the fibrous, and possibly tubular, structures observed in alkali-reacted opal.

1658. Grattan-Bellew, P. E., "CANADIAN EXPERIENCE OF ALKALI-EXPANSIVITY IN CONCRETE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/6.

KEY WORDS: alkali aggregate reactions; expansion; test methods; mortar bars; concrete prisms

The limit of expansion of concrete test prisms in CAN3-A23.2-14A is 0.02 percent at three months in a moist environment. It may not, however, be a reliable guide to the expansivity of concrete. A number of slowly expanding aggregates have been found that expanded less than 0.02 percent at three months, but showed excessive expansion and cracking after two years of storage at 100 percent RH. The ASTM C 227 (mortar bar test) limit of expansion of 0.10 percent at six months, is unsatisfactory for the same reason. Apart from the difficulty of setting limits for the expansion of test prisms, the main disadvantage of the concrete prism test is that it may take two years or more to obtain conclusive results. Petrographic examination of aggregates prior to testing is very desirable in order that the type of alkali reactivity to be expected may be identified and an appropriate test method selected.

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1659. Grattan-Bellew, P. E., "A REVIEW OF TEST METHODS FOR ALKALI-EXPANSIVITY OF CONCRETE AGGREGATES," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/9.

KEY WORDS: alkali aggregate reactions; test methods; expansion; mortar bars; concrete prisms; reviews

The expansion of mortar bars and concrete prisms was found to be diffusion controlled. The rate of expansion, expressed as the square root of time, during the main expansive phase of the reaction was shown to be linearly related to the ultimate expansion of the sample. Approximate minimum rates of expansion, above which samples would be considered deleteriously expansive, were determined for mortar bars made with alkali silica reactive aggregates and for concrete prisms made with slowly expanding siliceous aggregates and alkali expansive carbonate aggregates.

1660. Grattan-Bellew, P. E., "EVALUATION OF MINIATURE ROCK PRISM TEST FOR DETERMINING THE POTENTIAL ALKALI-EXPANSIVITY OF AGGREGATES," Cement and Concrete Research, Vol. 11, pp. 699-711, 1981.

KEY WORDS: rock prisms; test methods; expansion; reactive aggregates; alkali aggregate reactions

The expansion in 2N NaOH of miniature rock prisms of carbonate aggregate corresponds well with the expansion of concrete prisms made with the same aggregate and high alkali cement stored at 38°C and 100% RH. Better results were obtained with the LVDT cell than with the Huggenberger gauge. This is thought to be due to erratically high values obtained with the Huggenberger gauge owing to weakening of the prisms as the reaction proceeds. One of the major advantage of the miniature rock prisms test is its rapidity. The small size of the samples, 3 x 6 x 30 mm, is also an advantage for storage during the test. It would be particularly useful in evaluating the potential expansivity of the horizons in a quarry containing thinly bedded carbonate rocks. The small size of the samples, down to 15 mm if an LVDT is used, permits evaluation of the potential expansivity even of pebbles from a gravel deposit. For slowly expanding siliceous aggregates (quartzite, argillites, quartz biotite gneiss, and greywackes) the miniature rock prism test results are not as promising. This may be due, in part, to the testing of non-representative samples. To overcome the problem it is

recommended that four of five rock prisms tested from each sample be cut from different blocks of the rock. Agreement of rates of expansion for miniature rock prisms and concrete prisms would probably be improved by use an LVDT system of measurement in place of the Huggenberger gauge. Miniature rock prisms made from classical alkali silica reactive aggregates first expanded, then contracted and disintegrated. Although the rates of expansion or contraction do not give a measure of the potential expansivity of concrete prisms made with these aggregates, they do indicate that the rock is potentially deleteriously expansive in concrete.

1661. Hasaba, S., Kawamura, M. and Takemoto, K., "EXPANSIVE CHARACTERISTICS OF CONCRETE DUE TO ALKALI- SILICA REACTION AND ITS MECHANISM (in Japanese)," Cement & Concrete (Japan), No. 408, 1981.

KEY WORDS: alkali aggregate reactions; mechanisms; opal; reactive aggregates; expansion

(1) For an opal aggregate used in the experiments, the amount of mortar expansion caused by ASR is proportional to the surface area of the aggregate up to 1.6 $m^2/g$. Above this limit, OH ion concentration becomes low so that the reaction becomes inactive. (2) The fact that the amount of expansion is not proportional to the pore volume but to the surface area of the aggregate indicates that speed of OH ion intrusion into the pores of the opal does not govern the speed of ASR.

1662. Hobbs, D. W., "EXPANSION DUE TO ALKALI-SILICA REACTION AND THE INFLUENCE OF PULVERIZED FUEL ASH," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/30.

KEY WORDS: alkali aggregate reactions; Beltane opal; expansion; mechanisms; alkali effects

(1) Cracking due to ASR is only observed in specimens with Beltane opal that have water soluble alkali contents, expressed as equivalent $Na^2O$, greater than 2.5 $kg/m^3$. This figure includes the contribution from both the pulverized fuel ash and the cement. (2) The relationships between the expansion at 200 days and the water soluble alkali content for specimens tested at their most critical alkali:Beltane opal ratio is approximately independent of the content of

pulverized fuel ash. (3) Replacement of part of a cement by pfa can sometimes increase the expansion due to the ASR. This situation arises when the resultant water soluble alkali content is in excess of 2.5kg/$m^3$.

1663. Idorn, G. M., "THE RELEVANCE OF RESEARCH ON ALKALI-AGGREGATE REACTIONS TO PRECAUTIONS IN CONTEMPORARY ENGINEERING PRACTICE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/16.

KEY WORDS: alkali aggregate reaction; concrete structures; engineering practice

Alkali silica hydration in concrete is only one cause of growing world-wide concern over the unsatisfactory performance reliability of structures and buildings. Therefore it might be thought that a reorientation in research thinking is not justified in relation to the importance of the issue. However, the adjustment needed in relation to alkali silica hydration will lead to the acceptance of concept which will be relevant to the whole field of concrete technology development, including such problems as sulphate attack and corrosion of reinforcement. This perspective is not massive expenditure on new research, but rather to economies by channeling some of the ongoing work into more rewarding goal-setting. It is only necessary to use that knowledge adequately to design effective concrete technology for each specific structure along with the structural design and the specifications for the job-operation.

1664. Idorn, G. M., "ALKALI-SILICA REACTION - 1981 STATE OF AFFAIRS," Naerum, Denmark 1981, G.M. Idorn Consult Aps. 38 pages.

KEY WORDS: alkali aggregate reactions; reviews

A summary report based upon the 5th International Conference on Alkali Aggregate Reactions in Cape Town, South Africa, 30th March - 4th April 1981, and preceding international meetings.

1665. Johnson, B. D. G., "THE USE OF FLY ASH IN CAPE TOWN RMC OPERATIONS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981,

S252/33.

KEY WORDS: alkali aggregate reactions; fly ash; pozzolans; preventive measures

The use of fly ash in concrete is well established in other countries. In South Africa however it has been available for use in concrete for only two years although its use is now gaining support from consulting engineers and contractors because of the advantages offered to concrete in terms of durability and other properties. Fly ash is currently being specified for use in 10 percent of all ready mixed concrete produced in Cape Town. This will obviously increase if fly ash is accepted as a means of eliminating or reducing AAR.

1666. Kennerley, R. A., St John, D. A. and Smith, L. M., "A REVIEW OF THIRTY YEARS OF INVESTIGATION OF THE ALKALI-AGGREGATE REACTION IN NEW ZEALAND," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/12.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; field experiences; New Zealand; chemical tests; rock prism tests; expansion; cracking; pozzolans; preventive measures

(1) Petrographic examination of aggregates is only useful for initially grouping rocks into potentially reactive or non-reactive types. (2) Petrographic examination of large area thin sections of concrete is a valuable method for investigating the alkali aggregate reaction. The smaller thin sections normally used by geologists are not as suitable for this purpose. (3) The quick chemical test (ASTM C 289) has proved to be a reliable method of indicating potential reactivity of New Zealand aggregates. (4) The modified rock prism test ASTM C-586 is not applicable to the New Zealand greywacke sequence of rocks since it is indicating high potential reactivity which is not occurring in either laboratory testing or service concretes. (5) Where rock prisms of New Zealand greywacke are attacked in alkaline solution the whole fabric of the rock appears to be attacked. The mechanism of expansion has not been determined. Rock prisms of New Zealand greywacke do not expand in either saturated calcium hydroxide solution or distilled water. (6) There is good correlation between cracking and expansion of mortar bars with the cracking usually preceding expansion. (7) Laboratory testing of pozzolans

indicates that the ASTM C 441 requirement of an Rc value of 75 percent may be conservative. (8) Modulus and strength testing of expanded concretes do not correlate with either expansion or cracking. Measurement of expansion appears the only method of directly determining AAR in concrete.

1667. Kordina, K. and Schwick, W., "INVESTIGATIONS ON CONCRETE ADDITIONS TO PREVENT ALKALI- AGGREGATE REACTION (in German)," Betonwerke & Fertigteile-Technik, Vol. 47, No. 6, pp. 328-331.

KEY WORDS: alkali aggregate reactions; fly ash; fly ash; pozzolans; preventive measures; alkali effects; admixture effects

It is possible to reduce the expansion due to the alkali aggregate reaction by using siliceous products like fly ashes. It is not yet possible to precise the appropriate dosage of fly ash as preliminary tests are necessary for determining their pozzolanic reactivity as functions of the available alkalis and amount of cement in concrete. Admixtures have also to be taken into consideration as they can provide alkalis.

1668. Lenzner, D., "INFLUENCE OF THE AMOUNT OF MIXING WATER ON THE ALKALI- SILICA REACTION," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/26.

KEY WORDS: alkali aggregate reactions; admixture effects; alkali effects

The tests reveal that ionic plasticizers which release alkalis to the solution significantly accelerated ASR. After rapid expansion accompanied by a steep decrease in the natural resonance frequency, an early rehealing is indicated by an increase in frequency.

1669. Ludwig, U., "THEORETICAL AND PRACTICAL RESEARCH ON THE ALKALI-SILICA REACTION," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/24.

KEY WORDS: alkali aggregate reactions; mechanisms; field experiences; Germany; opal

The results of theoretical and practical investigations on the alkali silica reaction performed by the group at the RHTH Aachen are summarized. The influences of the different properties of the aggregate, the cement, and other parameters such as temperature and relative humidity on ASR with opaline sandstone were investigated. A concept has been worked out to evaluate the residual hazard in concrete construction damaged by ASR.

1670. Meinert, H., "CONTROL AND UTILIZATION OF AGGREGATES IN RELATION TO THE ALKALI-REACTION IN CONCRETE (in German)," B.S.I. Vol. 24, 6, pp. 178-179.

KEY WORDS: alkali aggregate reactions; reactive aggregates

It is not possible to control aggregates at the quarry. So the concrete producer has to chose the other materials carefully in order to avoid alkali aggregate reaction.

1671. Mills, R. H., "PREFERENTIAL PRECIPITATION OF CALCIUM HYDROXIDE ON ALKALI-RESISTANT GLASS FIBERS," Cement and Concrete Research, Vol. 11, pp. 689-697, 1981.

KEY WORDS: alkali effects; glass; calcium hydroxide

Carbon disks were coated with equal areas of portland cement and alkali resistant glass; with cement and slag; with cement and fly ash; and with various other combinations. The dry materials were separated by strips of carbon. The reaction was started by wetting the dry components, and the disks stored at 100% RH until being dried and coated for SEM examination. In all cases it was found that calcium hydroxide released into solution by the hydration of the portland cement displayed a remarkable affinity for precipitating on alkali resistant glass rather than on slag or fly ash. The morphology of the deposits on glass were such as to suggest that in glass fiber reinforced cements any tendency of the fiber to move relative to the matrix would result in principal compressive stresses normal to the fiber axis, which would serve to reduce the longitudinal strength of the fibers.

1672. Nilsson, L.-O., "POP-OUTS DUE TO ALKALI-SILICA REACTIONS - A MOISTURE PROBLEM?," Proc. 5th Intl. Alkali Conf., Cape

Town, 1981, S252/27.

KEY WORDS: alkali aggregate reactions; field experiences; Sweden; popouts; moisture effects

Problems attributable to the alkali silica reaction in Sweden are new. They occur principally as popouts on certain structures, mainly concrete floors on ground. These appear to be linked to moisture conditions.

1673. Nixon, P. J. and Gaze, M. E., "THE USE OF FLY ASH AND GRANULATED BLASTFURNACE SLAG TO REDUCE EXPANSION DUE TO ALKALI-AGGREGATE REACTION," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/32.

KEY WORDS: alkali aggregate reactions; fly ash; pozzolans; slag; expansion; preventive measures; alkali effects

(1) All the fly ashes and the one ground granulated blastfurnace slag tested have been found to produce significant reductions in the expansion of mortar bars when these materials replace a proportion of a high alkali portland cement. Such reductions have been found both when pyrex glass and chert have been used as the reactive aggregate. (2) 30 percent fly ash or 50 percent slag is judged to be sufficient to reduce the expansion to a level equivalent to that produced by a low alkali portland cement. (3) There were only small differences between the effectiveness of the fly ashes. These differences correlated best with a measure of pozzolanic activity. The alkali content of the ashes may have secondary effect but the results do not support the ASTM limit on available alkalis of 1.5 percent equivalent $Na_2O$. (4) These results are consistent with the DIN limits on the alkali content of slags for use in low alkali slag cements, i.e.: 1.1 per cent equivalent $Na_2O$ when the cement contains at least 50 per cent slag or 2.0 per cent equivalent Na2O when the cement contains at least 65 per cent slag.

1674. Oberholster, R. E., "ALKALI-AGGREGATE REACTION IN SOUTH AFRICA - A REVIEW," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/8.

KEY WORDS: alkali aggregate reactions; field experiences; South Africa; reviews

The events leading to the diagnosis of alkali aggregate reaction in South Africa are reviewed. Alkali aggregate reaction in concrete was first tentatively diagnosed in South Africa in 1974 and confirmed in 1976. Initial research was aimed at established the extent of the problem, evaluating aggregates and cement with existing methods and against different criteria for assessing aggregates and cements in respect of alkali reactivity, evaluating mineral admixtures for use in prevention of AAR and systematically collecting laboratory and field data to assist in advising the construction industry on practical preventive and remedial measures.

1675. Oberholster, R. E. (ed.), "PROC. 5TH INTERNATIONAL CONF. ON ALKALI AGGREGATE REACTION IN CONCRETE," Cape Town, South Africa, 1981.

KEY WORDS: alkali aggregate reactions; conferences

Indexed as Proc. 5th Intl. Alkali Conf., Cape Town, 1981. Contains 38 papers on alkali effects and alkali aggregate reactions in concrete.

1676. Oberholster, R. E. and Westra, W. B., "THE EFFECTIVENESS OF MINERAL ADMIXTURES IN REDUCING EXPANSION DUE TO ALKALI-AGGREGATE REACTION WITH MALMESBURY GROUP AGGREGATES," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/31.

KEY WORDS: alkali aggregate reactions;reactive aggregates; expansion; preventive measures; alkali effects; slag; fly ash; pozzolans

(1) Several admixtures effectively reduced expansion due to AAR with Malmesbury aggregate when they replaced a certain amount of high alkali cement. (2) With the Malmesbury aggregate a reduction in expansion to less than 0.1 percent after 555 days for mortar prisms was taken as indicating an adequate reduction in expansion. This is less than the expansion obtained by extrapolation, for mortar prisms made with Malmesbury aggregate and a cement with an $Na_2O$ equivalent of less 0.6 percent. (3) The reduction in expansion obtained by blending admixtures with a high alkali cement is greater than can be ascribed to a mere dilution effect. (4) Although the available alkali content of an admixture may be an important factor to take into account when considering it for the amelioration of alkali

aggregate expansion, other factors such as surface area and pozzolanic reactivity may be more relevant. (5) Blends of the high alkali cement and slag effectively reduced expansion although the total alkali content of the blends used was more than the 1.1 percent Na2O equivalent given by the West German guidelines for 50 percent portland cement and 50 percent granulated blast furnace slag. (6) When evaluating admixtures for their effectiveness in suppressing expansion in combination with a natural aggregate one must ensure that the aggregate dose not show a pessimum effect. The Malmesbury aggregate showed no pessimum effect. (7) Slag added to a high alkali cement in sufficient quantities to reduce expansion effectively did not reduce the compressive strength of concrete cubes; pfa and calcined shale, however, reduced the compressive strength. (8) Up to an age of 1 year, cubes made with a combination of reactive Malmesbury aggregate and high alkali cement showed no decrease in compressive strength when compared with the combination containing low alkali cement, even though distinct cracks were present.

1677. Petttifer, K. and Nixon, P., "A REPLY TO A DISCUSSION BY D.A. ST JOHN OF "ALKALI METAL SULFATE - A FACTOR COMMON TO BOTH ALKALI AGGREGATE REACTION AND SULFATE ATTACK ON CONCRETE"," Cement and Concrete Research, Vol. 11, pp. 801-802, 1981.

KEY WORDS: alkali aggregate reactions; field experiences; ettringite

The majority of situations where ettringite occurs is simply due to leaching, but the situation can become confused when the original cause of distress in a concrete (such as sulfate attack or AAR) causes cracking that then gives rise to leaching so that, perhaps, it is possible to find primary ettringite due to hydration, a secondary form due to the reaction causing the distress, and a tertiary form due to re-crystallization from solution percolating through these cracks.

1678. Poole, A. B., "ALKALI-CARBONATE REACTIONS IN CONCRETE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/34.

KEY WORDS: alkali aggregate reactions

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1679. Regourd, M. Hornain, H. and Poitevin, P., "THE ALKALI-AGGREGATE REACTION - CONCRETE MICROSTRUCTURAL EVOLUTION," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/35.

KEY WORDS: alkali aggregate reactions; mechanisms; microstructure; scanning electron microscopy; alkali silica gel; recrystallized alkali silica gel

The AAR is indicated by the formation of gels and Ca, Na and K silicate crystals: gel of high $SiO_2$ content (molar ratio $CaO/SiO_2$ of 0.2 to 0.4) around the aggregates, and richer calcium gels ($CaO/SiO_2$ of 1.3 to 1.4) in the cement paste. The crystals in contact with the aggregates have a higher concentration of sodium in the case of glass aggregates, and of potassium in the case of natural aggregates, than the gel, but their composition is close to that of the gel surrounding the aggregates ($CaO/SiO_2$ of near 0.23). It appears likely that the formation of crystalline silicates follows that of the gel, of which the progressive structural formation has been observed in the case of glass aggregates. The alteration of the gel structure is promoted by a rise in temperature. The texture and the morphology of the crystals formed appear close to well crystallized tobermorites. Ettringite crystallization in abundance may also reinforce the AAR in two ways. First, the creation of stress states which lead to the cracking of the concretes, and secondly a change in the composition of the paste interstitial solution. The formation of ettringite absorbs calcium and allows a larger dissolution of $Ca(OH)_2$ which in turn liberates hydroxyl ions which attack the aggregate.

1680. Regourd, N., "CHEMICAL DURABILITY OF CONCRETE," Proceedings of Conference, Contemporary European Concrete Research Stockholm, June 9-10, 1981. Stockholm, Swedish C&CRT, pp. 121-142.

KEY WORDS: alkali aggregate reactions; mechanisms; field experiences

1681. Semmelink, C. J., "FIELD SURVEY OF THE EXTENT OF CRACKING AND OTHER DETAILS OF CONCRETE STRUCTURES SHOWING DETERIORATION DUE TO ALKALI-AGGREGATE REACTION IN THE SOUTH WESTERN CAPE PROVINCE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/19.

KEY WORDS: alkali aggregate reactions; field experiences; South Africa

The AAR seems to depend on a critical balance between free moisture, temperature, wet/dry cycles and the composition of the mix. It was found to be totally impossible to assess the cost of the damage in term of replacement cost of the damaged elements. The only value that could be approximately determined was the present worth of the structures.

1682. Sims, I., "THE APPLICATION AND RELIABILITY OF STANDARD TESTING PROCEDURES FOR POTENTIAL ALKALI-REACTIVITY," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/13.

KEY WORDS: alkali aggregate reactions; test methods; chemical tests; mortar bars; rock cylinders

Some form of petrographic examination should never be omitted, as it will identify the most pertinent sequence of tests required and help in the correct interpretation of the results. The ASTM C 289 chemical test is attractive but rigorous, and can give misleadingly pessimistic results even when applied to seemingly appropriate materials. The significance of a mortar bar test result depends upon the combinations tested, and it seems more relevant to employ the cement type and aggregate blend actually proposed for use. The ASTM C 586 rock cylinder test works well for North American dolomites, but the results for Middle Eastern reactive carbonates are more difficult to interpret.

1683. Skalny, J. P. and Klemm, W. A., "ALKALIS IN CLINKER: ORIGIN, CHEMISTRY, EFFECTS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/1.

KEY WORDS: alkali effects; clinkers; cements

Changes in pyro-processing technology and the use of coal as the primary fuel in clinker burning have resulted in renewed interest in the content and form of alkalis in cement, and in possible effects which alkalis may have on concrete. Alkalis, mostly present in the form of sulphates, do have a pronounced effect on the rate and sequence of certain reactions during clinker production by influencing the temperature of melt formation as well as its viscosity and surface tension. Because of their

relatively low melting point, alkali sulfates remain fluid below the solidification points of other clinker phases and then crystallize in the form of highly soluble deposits on the surfaces of the major clinker minerals formed. Upon contact with water, the alkali sulphates rapidly dissolve and influence the reaction processes by changing the solution pH and the solubilities of other clinker minerals. Solid products of hydration incorporate alkali in their structures. This may result in compositional and morphological changes which, in turn, influence the physical properties of the fresh and hardened concrete. In particular, the presence of alkalis in the cement paste pore solution may lead to abnormal setting phenomena, decrease strength, and reactions with siliceous aggregate.

1684. St John, D. A., "A DISCUSSION ON THE PAPER OF "ALKALI METAL SULFATE - A FACTOR COMMON TO BOTH ALKALI AGGREGATE REACTION AND SULFATE ATTACK ON CONCRETE" BY K. PETTIFER AND P.J. NIXON," Cement and Concrete Research, Vol. 11, p. 799, 1981.

KEY WORDS: alkali aggregate reaction; ettringite

Ettringite found in concrete cracks associated with ASR may only represent the results of movements of fluids through the concrete, rather than any association with ASR.

1685. Struble, L. and Diamond, S., "UNSTABLE SWELLING BEHAVIOR OF ALKALI SILICA GELS," Cement and Concrete Research, Vol. 11, pp. 611-617, 1981.

KEY WORDS: alkali silica gels; expansion

A suite of synthetic alkali silica gels tested for swelling behavior produced unexpected results. Gels were provided with access to liquid water and separately tested for behavior in the free-swelling mode (with no applied pressure), and for maximum swelling pressure (by continuing to apply loading just sufficient to counteract the swelling tendency). In some cases the swelling while gels were loaded was greater than in the free swelling condition; in some cases this swelling behavior under load was suddenly terminated by liquification of the gel. These effects are attributed to structural rearrangements within the gels during the testing. In one case a gel stored in a sealed container for several months lost the ability to swell

almost completely.

1686. Svendsen, J., "ALKALI REDUCTION IN CEMENT KILNS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/2.

KEY WORDS: alkali effects; cements; clinkers

The manufacture of low alkali cement was previously confined to wet or semi-wet process systems and raw materials possessing good nodule strengths. Today, however, low alkali cement can be economically produced in dry process systems using a kiln with separate precalciner and full or variable by-pass of kiln gases. The specific fuel consumption of this system does not exceed about 900 to 950 kcal/kg clinker. The system provides a theoretical minimum content of alkali in clinker determined by the volatility of the alkalis at sintering temperature. The by-pass does not reduce the specific kiln production.

1687. Tang, M. S., "SOME REMARKS ABOUT ALKALI-SILICA REACTIONS," Cement and Concrete Research, Vol. 11, pp. 477-478, 1981.

KEY WORDS: alkali aggregate reactions; mechanisms

Remarks on several aspects of the mechanisms of ASR are presented.

1688. Van der Walt, N. Strauss, P. J. and Schnitter, O., "REHABILITATION ANALYSIS OF A ROAD PAVEMENT CRACKED BY ALKALI-AGGREGATE REACTION," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/21.

KEY WORDS: alkali aggregate reactions; pavement structures; structural effects; repairs; field experiences; South Africa

(1) AAR apparently reduces both slab and subbase stiffness, leading to higher stresses under traffic loading. (2) Cracks initiated by AAR and resulting increases in stress under load increase the extent of structural cracking of the slab which generally manifests itself as secondary cracking close to the transverse joints. The resulting cracked pavement can have its service life prolonged by maintenance and light rehabilitation

procedures, or it may be overlayed after consideration of its residual structural capacity.

1689. Vivian, H. E., "ALKALIS IN CEMENT," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/5.

KEY WORDS: alkali effects

Alkalis have different and sometimes undesirable effects on freshly mixed and on hardened cements pastes. These effects are discussed, with particular attention paid to the role of cyclic wetting and drying and to the effects of uncombined lime.

1690. Vivian, H. E., "A WORKING APPRAISAL OF ALKALI-AGGREGATE REACTION IN CONCRETE," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/14.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences

This paper sets out to define a set of criteria for the recognition of potentially reactive materials and for the assessment of their soundness, volume stability, and durability in new structures. Some guidelines are given for the evaluation of distress in existing buildings which are showing signs of the alkali aggregate reaction.

1691. Vivian, H. E., "THE EFFECT OF DRYING ON REACTIVE AGGREGATE AND MORTAR EXPANSIONS," Proc. 5th Intl. Alkali Conf., Cape Town, 1981, S252/28.

KEY WORDS: alkali aggregate reactions; drying effects

(1) The magnitude of the drying shrinkage movement of hydrated cement paste in mortar or concrete is very small compared with the expansion movement produced by reacting aggregate particles. (2) Although drying induces a limited shrinkage in hydrated cement paste and inhibits the expansion of reacted aggregate particles, moisture re-absorption reverses both processes. On resorbing moisture, hydrated cement generally expands by amounts slightly less than or equivalent to the magnitude of the initial shrinkage, while reacted aggregate particles resume their

excessive swelling tendencies and, provided their non-deforming properties are maintained, will further increase the overall mortar or concrete expansion. (3) In the presence of large amounts of alkali and free water, aggregate particles not only react rapidly but the reaction product also transforms very rapidly from a rigid gel which expands and disintegrates mortar and concrete, to a deformable gel or to a sol which cannot cause expansion.

1692. Bakker, R. F. M., "DURABILITY OF SLAG CEMENT CONCRETES (in French)," Silicates Industriels - Belgique Vol. 47, 3, pp. 91-95.

KEY WORDS: alkali aggregate reactions; slag; preventive measures

A concrete prepared with a slag cement containing at least 65% blast furnace slag is resistant to the sea water, sulfate, and alkali aggregate reactions. This is due to a very low permeability to aggressive ions and related to the development of less porous hydrates than in Portland cements.

1693. Chatterji, S., Thaulow, N. and Christensen, P., "POZZOLANIC ACTIVITY OF BYPRODUCT SILICA FUME FROM FERROSILICON PRODUCTION," Cement and Concrete Research, Vol. 12, pp. 781-784, 1982.

KEY WORDS: silica fume; pozzolans; preventive measures

1694. Comite Euro-International du Beton, "DURABILITY OF CONCRETE STRUCTURES: STATE-OF-THE-ART REPORT," CEB Bulletin information No. 148, Paris, CEB, 1982, 329 pages.

KEY WORDS: alkali aggregate reactions; durability; reviews

1695. Deloyer, F. X., Leroux, A. and Lesage, R., "PATHOLOGICAL ASPECTS AT THE CEMENT PASTE - AGGREGATE INTERFACE (in French)," Proc. RILEM Intl. Colloq. on Bonding Between Cement Paste and Associated Materials, Toulouse, pp. B-1 to B-10, 1982.

KEY WORDS: alkali aggregate reactions; field experiences; France; scanning electron microscopy; mechanisms

Five field occurrences of alkali aggregate reactions are described. In some of the cases, the alkalinity of the cement paste merely acted as the trigger of the process, which subsequently became self-sustaining because of the basicity of the medium.

1982

1696. Dent Glasser, L. S. and Kataoka, N., "ON THE ROLE OF CALCIUM IN THE ALKALI-AGGREGATE REACTION," Cement and Concrete Research, Vol. 12, pp. 321-331, 1982.

KEY WORDS: alkali aggregate reactions; alkali effects; mechanisms; silica; calcium hydroxide effects

When silica gel is placed in alkali/calcium hydroxide solution there is an immediate drop in the concentrations of both alkali and OH ions due to adsorption and reaction with the solid silica. If a limited supply of calcium ions is also present, its concentration also drops immediately due to adsorption on the solid silica and precipitation of C-S-H. Once the Ca ion concentration becomes sufficiently low, the dissolved silica concentration increases, some of the adsorbed alkali ions being released at the same time. If the silica gel is highly reactive and the system is not stirred, outgrowths may form on the silica gel and subsequently grow. Although the skin appears at first sight to behave as a semipermeable membrane, it seems more likely that its apparent selectivity toward ions is a result of continuing chemical reaction.

1697. Gramain, P., "A NEW TYPE OF CHELATING AGENTS: THE POLYMACRO-CYCLES. APPLICATION TO CATALYSIS AND CATION SEPARATION (in French)," Informations Chimie, Special No. 226, pp. 231-236.

KEY WORDS: crown ethers; alkali complexing agents; alkali effects; preventive measures

Crown ethers like dicyclohexyl-18-Crown 6 are able to form stable complexes with alkalis. The stability of the crown ether complexes depends on several factors, i.e., cavity size of the ligand, cation diameter, spatial distribution of ring binding sites, and type of solvent. In polar solvents such as water (dielectric constant=80) the only important constant is the association constant. Tight complexation of cations by these chelating agents occurs and has various chemical effects.

1698. Grattan-Bellew, P. E., "A DISCUSSION OF "A CHEMICAL APPROACH TO THE PROBLEM OF ALKALI-REACTIVE CARBONATE AGGREGATES" BY M.A. PAGANO AND P.D. CADY," Cement and Concrete Research, Vol. 12, pp. 541-542, 1982.

KEY WORDS: alkali aggregate reactions; admixture effects; expansion; osmotic effects

1699. Jensen, A. D., Chatterji, S., Christensen, P., Thaulow, N. and Gudmundsson, H., "STUDIES OF ALKALI-SILICA REACTION - PART I. A COMPARISON OF TWO ACCELERATED TESTS METHODS," Cement and Concrete Research, Vol. 12, pp. 641-647, 1982.

KEY WORDS: alkali aggregate reactions; test methods; alkali effects; chloride effects

The alkali silica reactivity of a number of sands were evaluated by both the "German" and the NaCl bath methods. The salt bath method gave preferable results. From the results obtained the following inferences were drawn: (1) NaCl solution accelerates ASR in structures containing portland cement and reactive silica. (2) Intrusion of alkali salt into a portland cement concrete structure from outside sources accelerates its breakdown if it contains reactive silica. This may happen even if a low alkali cement has been used. (3) An internal migration of sodium salts due to differential drying etc. may also accelerate ASR at the regions of high salt concentration. (4) Two concrete samples made with identical portland cement and reactive aggregates may develop different extent of ASR depending on, among other things, the extent of salt migration from outside sources. Thus field experience with an aggregate source may not be completely reliable.

1700. Kawamura, M., Takemoto, K. and Hasaba, S., "ELUCIDATION OF ALKALI-SILICA REACTION MECHANISMS BY THE COMBINATION OF EDXA AND MICROHARDNESS MEASUREMENTS (in Japanese)," Transaction of Japan Concrete Institute, Vol. 4, pp. 1- 8, 1982.

KEY WORDS: alkali aggregate reactions; test methods; microhardness; expansion; mechanisms; scanning electron microscopy

The softened region in the vicinity of periphery of homogeneous opal particles embedded in hardened cement paste gradually progressed inward with time as the alkalis intruded into the reacting opal particles. Enlargement of the softened region corresponds to the increase in the expansion of mortar bars. Softening in the peripheral region of a reacting particle at early ages appears to

mainly result from a chemical reaction between silica and the alkali supplied from the hardened cement paste matrix. A relatively great amount of calcium also moved into the reacting particles. The movement of calcium into the opal particles were always behind the intrusion of alkalis. These results obtained in this study are not inconsistent with the hypothesis of Powers and Steinouer except that the concentrations of calcium in the gels formed are far less than those postulated by them.

1701. Ludwig, U., "ALKALI-AGGREGATE REACTION IN CONCRETE (in German)," TIZ Vol. 106, 1 pp. 2-5.

KEY WORDS: alkali aggregate reactions

Papers presented at the 5th International Conference on Alkali Aggregate Reactions in Cape Town, South Africa in April, 1981 have concentrated on the influence of alkalis in concrete. Particular attention has been paid to reactive aggregates containing finely crystallized quartz and crystal defects, and to accelerated tests at high temperatures. A mineralogical and petrographic analysis of aggregates and concretes can offer a good evaluation of the alkali aggregate reaction.

1702. Metso, J., "THE ALKALI REACTION OF ALKALI-ACTIVATED FINNISH BLAST FURNACE SLAG," Silicates Industriels, Vol. 47, Nos. 4-4, 1982, pp. 123- 127.

KEY WORDS: alkali aggregate reactions; slag; preventive measures

1703. Pagano, M. A. and Cady, P. D., "A CHEMICAL APPROACH TO THE PROBLEM OF ALKALI-REACTIVE CARBONATE AGGREGATES," Cement and Concrete Research, Vol. 12, pp. 1-12, 1982.

KEY WORDS: alkali carbonate reactions; mechanisms; osmotic effects

This paper presents the results of a laboratory investigation of postulated mechanisms and potential remedial measures involving alkali carbonate reactions in concrete. A significant decrease in expansion was found with the additions of either lithium carbonate or ferric

chloride,suggesting that an osmotic swell mechanism is probably the cause for the alkali carbonate reaction and expansion. DMSO additions performed poorly.

1704. Pagano, M. A. and Cady, P. D., "A REPLY TO A DISCUSSION BY P.E. GRATTAN-BELLEW OF "A CHEMICAL APPROACH TO THE PROBLEM OF ALKALI-REACTIVE CARBONATE AGGREGATES," Cement and Concrete Research, Vol. 12, pp. 543-545, 1982.

KEY WORDS: osmotic effects; admixture effects

1705. Regourd, M., Hornain, H., Mortureux, B., Poitevin, P. and Peuportier, H., "ALTERATION OF THE CEMENT PASTE-AGGREGATE BOND IN CONCRETE BY THE ALKALI AGGREGATE REACTION (in French)," Proc. RILEM Colloq. Intern. on Bonding Between Cement Paste and Associated Materials, Toulouse, 1982, pp. B17-B2.

KEY WORDS: alkali aggregate reactions; petrography; scanning electron microscopy; alkali silica gel; field experiences; France

Reactions between alkalis dissolved in the concrete pore solutions and some aggregates can lead to a destruction of the paste-aggregate bond and cracking of the concrete. The complexity of concrete deteriorations by AAR is revealed in the microstructure of samples from two different structures containing aggregates from various origins.

1706. Tang, M. S., Zhen, S. H. and Han, S. F.., "EFFECT OF ALKALI ON THE INTERFACE REACTION BETWEEN CEMENT AND AGGREGATE," Proc. Intl. Colloq. on Bonding between Cement Paste and Associated Materials, Toulouse, pp. A10-A12, 1982.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive effects

Attempts are described to study the details of the processes of AAR in order to attempt to turn the destructive action into favorable factors. Mechanical properties may be improved by use of very fine powdered reactive aggregate. Glassy reactive material which contains high contents of $Al_2O_3$, $Fe_2O_3$ and CaO may combine

with alkali of the cement to form a transitional zone which provides a certain bond strength instead of causing expansive stress. The removal of alkali from the pore solution and its concentration by absorption at the interface is beneficial for preventing ASR.

1707. Van Aardt, J. H. P. and Visser, S., "REACTIONS BETWEEN ROCKS AND THE HYDROXIDES OF CALCIUM, SODIUM AND POTASSIUM," CSIR Research Report BRR 577, 1982, 34 pages.

KEY WORDS: reactive aggregates; calcium hydroxide effects; alkali effects; alkali aggregate reactions; alkali release

Identification of reaction products and a study of the dimensional changes of cement-bonded mortar specimens immersed in alkali solution at 40°C and 80°C.

1708. Way, S. J. and Cole, W. F., "CALCIUM HYDROXIDE ATTACK ON ROCKS," Cement and Concrete Research, Vol. 12, pp. 611-617, 1982.

KEY WORDS: reactive aggregates;siltstone; sandstone; hornfels; granites; basalt; feldspars; calcium hydroxide effects; alkali release

Nineteen samples of Australian rocks, all containing feldspars, were examined for their reactivities in calcium hydroxide solution at 50°C. The results confirm that powdered basalts and granites release large quantities of alkalis as a result of breakdown of feldspars in the powdered rock. However, the known field performance of such rocks in Australia is good. On the other hand, known deleteriously reactive sedimentary rocks tested did not show an unusual release of alkalis under the test conditions.

1709. Ye, Y. F., Yuan, M. Q. and Tang, M. S., "THE PREVENTIVE EFFECT OF ZEOLITE ON ALKALI SILICA REACTION (in Chinese)," Jiangsu Building Materials, No. 2, 1982, pp. 28-35.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; zeolites; fly ash; slag

Zeolite blended material can effectively inhibit the

ASR. The effectiveness in inhibiting ASR is in the following the order: zeolite > fly ash > slag.

1710. Zhen, S. H. and Tang, M. S., "THE ALKALI REACTIVITY OF IGNEOUS ROCK AND THE INTERFACE REACTION BETWEEN CEMENT AND IGNEOUS ROCK (in Chinese)," Research Report of Nanjing Institute of Chemical Technology, China, No. 2, 1982, pp. 44-59.

KEY WORDS: reactive aggregates; igneous rock

1711. Andersen, S. Lyngvig, J., Andersen, J. and Sommer, O., "THE RAW MATERIALS ACT AND CONCRETE AGGREGATES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 111-117.

KEY WORDS: aggregates

This paper contains a brief description of the Danish Raw Materials Act, and the required activities it imposes with respect to mapping of concrete materials and planning aspects with respect to the concrete industry.

1712. Bakker, R. F. M., "THE INFLUENCE OF TEST SPECIMEN DIMENSIONS ON THE EXPANSION OF ALKALI REACTIVE AGGREGATE IN CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 369-375.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars

The cross-section of the test specimen when testing the alkali reactivity of aggregates can have a great influence on the amount of expansion. To decrease the risk of "missing" reactive aggregates the cross-section employed should be larger than used in ASTM C 227.

1713. Baronio, G., "EXAMPLES OF DETERIORATION BY ALKALI IN ITALIAN CONCRETE STRUCTURES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 503-510.

KEY WORDS: alkali aggregate reactions; field experiences; Italy

An 8-year old concrete building in the Lower Molise region of Italy was found to show severe map cracking and other symptoms of alkali aggregate reaction.

1714. Berra, M., "PERFORMANCE OF SOME ITALIAN CEMENTS TESTED FOR ALKALI-SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 377-382.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; pozzolans; cements

The reactive pessimum percentage of pyrex glass, considered as a standard aggregate with regard to alkali silica reactivity is found to be 100%. The effectiveness of some Italian portland-pozzolan, portland-blast furnace slag, and sulphate resisting cements in reducing the expansions induced in mortar bars by the ASR has been verified. Therefore they can successfully replace the portland cement when the aggregate is suspected to be reactive to alkali in concrete.

1715. Blight, G. E., Alexander, M. G., Schutte, W. K. and Ralph, T. K., "THE EFFECT OF ALKALI-AGGREGATE REACTION ON THE STRENGTH AND DEFORMATION OF A REINFORCED CONCRETE STRUCTURE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 401-410.

KEY WORDS: alkali aggregate reactions; bridge structures; field experiences; South Africa; structural effects

A portion of a major double-deck highway structure in Johannesburg has deteriorated to a visually alarming extent as a result of alkali aggregate reaction. Load tests on the structure support the view that deterioration of concrete as a result of alkali aggregate reaction is alarming in appearance but not necessarily structurally dangerous.

1716. Cement and Concrete Association, "ALKALI-AGGREGATE REACTION-MINIMIZING THE RISK OF ALKALI-SILICA REACTION (GUIDANCE NOTES)," Monograph, Cand CA, Wexham Springs,1983, 8 pages.

KEY WORDS: alkali aggregate reactions; preventive measure; field experiences; U.K.

These notes give the basic essential information on the circumstances under which damage due to ASR could occur and on ways to avoid or minimize and practice in new concrete construction. The notes apply to materials, conditions and practice in the UK. Structural elements which have been known to suffer from ASR include foundations, columns, bridge beams, parapets, retaining wall and structures subject to high humidity such as multi-story car parks. Notes are included on: limiting the amount of reactive alkali available, assessment of aggregates, alkali migration, effect of precautions on concrete properties.

The chemistry of ASR is described and a worked example to illustrate the recommendations is included. The location of reported cases of ASR in the UK is shown.

1717. Chatterji, S., Thaulow, N., Christensen, P. and Jensen, A. D., "STUDIES OF ALKALI-SILICA REACTION WITH SPECIAL REFERENCE TO PREVENTION OF DAMAGE TO CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 253-260.

KEY WORDS: alkali aggregate reactions; mechanisms; calcium hydroxide effects

The presence of free $Ca(OH)_2$ appears to be a prerequisite for the development of destructive ASR. Experimental work is described in which mortar bars made with sufficient diatamaceous earth pozzolan to prevent the accumulation of free $Ca(OH)_2$ have shown no expansion when subjected to exposure to a hot saturated NaCl bath.

1718. Christensen, P., Chatterji, S., Jensen, A.D. and Thaulow, N., "PRELIMINARY INVESTIGATION OF ALKALI-SILICA REACTIVITY OF DENSITY SEPARATED COARSE AGGREGATE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 105-109.

KEY WORDS: alkali aggregate reactions; reactive aggregates; flint; opal; chalcedony

Danish flint is a mixture of chalcedony-bearing and opal bearing components, both of which can be calcareous. The opaline type is lighter, and the two types can be separated by heavy media separation. Samples were fractionated into several density fractions, and also hand separated. The alkali reactivity of each fraction was tested by incorporation into mortar bars exposed to saturated NaCl solution at 50°C. It was found that the lighter fractions, containing mostly opaline flint, produced pop outs and large amounts of gel but little cracking; the heavier fractions, containing mostly chalcedonic flint with opaline crusts, produced some gel, and extensive cracking. A sample of pure chalcedonic flint produced no sign of attack.

1719. Christensen, P., Chatterji, S., Thaulow, N. and Jensen, A. D., "ALKALI-SILICA REACTIVITY OF VARIOUS DANISH FLINT

TYPES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 315-319.

KEY WORDS: alkali aggregate reactions; reactive aggregates; flint; chalcedony; opal

Measurement of the reactivity of Danish sands by the saturated NaCl bath method show various responses over time, which can be correlated to the rock type present in the sand. Opaline flint reacts very quickly; chalcedonic flint slowly if it is porous, otherwise so slowly that its reactivity may be ignored.

1720. Christensen, P., Brandt, I. and Henriksen, K.R., "QUALITY CONTROL OF SAND BY MEANS OF POINT-COUNTING IN LIGHT-OPTICAL MICROSCOPE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 449-454.

KEY WORDS: reactive aggregates; petrography

Among the methods available to measure the content of alkali silica reactive particles in concrete aggregates, the optical methods seem most promising. The present experience shows that the measurements can be carried out within four days which is reasonably quick in a quality control situation. Provided the reactive particles can be identified in petrographic microscope, the content is easily measurable with standard techniques like point-counting.

1721. Cole, W. F. and Lancucki, C. J., "PRODUCTS FORMED IN AN AGED CONCRETE: THE OCCURRENCE OF OKENITE," Cement and Concrete Research, Vol. 13, pp. 611-618, 1983.

KEY WORDS: alkali aggregate reactions; alkali silica gel; recrystallization; okenite

In a dam constructed 30 years ago in Australia, the reaction product that forms inside the reaction rim of the siltstone and sandstone aggregate is found to be okenite ($CaO.2SiO_2.2H_2O$) or an associated similar compound of higher hydrate state ($4H_2O$). Some of the Ca is replaced by K and Na. When the sample is wet the precursor with a characteristic X-ray spacing at 12 Å predominates, but as the sample dries out the 12 Å spacing disappears and new diffraction lines appear characterized by spacing at 10.6

and 8.85 Å for okenite. The transformation cannot be reversed by rewetting.

1722. Comberbach, C. D., Fookes, P. G. and Cann, J., "DETERIORATION OF CONCRETE STRUCTURES IN SOUTH WEST ENGLAND: THE USE OF CRACK MAPPING AS AN INVESTIGATORY TOOL, " Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 455-469.

KEY WORDS: alkali aggregate reactions; field experience; building structures; U. K.

Detailed field investigation of a multi-story car park affected by alkali aggregate reaction is reported. Detailed mapping and testing of selected locations provided evidence to help identify the cause or causes of cracking. Crack maps were prepared. Leaching of calcium hydroxide, sometimes locally in large quantities, and the precipitation of calcium carbonate on surfaces were phenomena frequently recorded. This was considered to be a secondary effect and together with other signs and varying amounts of drying shrinkage cracking, together with the effects of reinforcement corrosion, frost attack, structural distress and plastic cracking were regarded as additional factors which had contributed in varying extents to a total picture of deterioration which was largely due to alkali silica reactivity.

1723. Dahl, G., Poulsen, E. and Timm, A., "DAMAGE OF CONCRETE CYLINDERS WITH REACTIVE SAND AND NON-REACTIVE, COARSE AGGREGATES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 249-252.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; expansion

A model for estimation of the expansion to be expected in concrete based on known expansion of the mortar and the proportion of non-reactive coarse aggregate used, when the reactive aggregate is in the sand. Details of the several sands used and of their reactive components were provided, along with observations relating to the necessity for the presence of $Ca(OH)_2$ for deleterious reaction to take place.

1983

1724. Datta, R. K. and Raj, T., "ESTIMATION OF POZZOLANA CONTENT IN PORTLAND POZZOLANA CEMENT," Cement and Concrete Research, Vol. 13, pp. 861-868, 1983.

KEY WORDS: test methods; pozzolans; cements

The pozzolan content in portland pozzolan cements can be determined fairly accurately (within 7.5% error) by the cold and dilute Hcl method described here even in the absence of original samples of ingredients used in the manufacture of the cement. The results obtained by this method are better than using picric acid. The method is simple and rapid and is applicable for various pozzolans. including fly ash, calcined clay, rice husk ash, calcined clay, etc.

1725. Daugherty, K. E., Faust, R. J., Zgambo, T. P. and Griffin, J. G., "POTASSIUM SULFATE IN KILN DUST," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 85-91.

KEY WORDS: alkali effects; test methods; chemical methods; X-ray diffraction

An X-ray diffraction technique using the method of standard additions has been developed for the quantitative measurement of the potassium sulfate content of cement plant kiln dust. Numerous kiln dust amples have been analyzed with satisfactory results.

1726. Deloye, F. X., Le Roux, A. and Lesage, R., "PATHOLOGICAL ASPECTS OF PASTE - AGGREGATE INTERFACE (in French)," Bulletin de Liaison des Laboratoires des Ponts et Chausses, 126, pp. 37-44.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mechanisms; alkali release

Among five cases of reaction between aggregates and cement paste in old concretes, three of them were related to the alkali aggregate reaction. Two were with siliceous aggregates (gneiss, granite, serpentinite) and one was with a dolomitic aggregate. In ASR, gneiss and granite provided alkalis and serpentinite liberated silica and magnesium.

1983

1727. Diamond, S., "ALKALI REACTIONS IN CONCRETE-PORE SOLUTION EFFECTS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 155-166.

KEY WORDS: alkali aggregate reactions; pore solutions; alkali silica gel; silica fume; preventive measures; calcium hydroxide effects

Progress in understanding the behavior of alkalis in concrete is reviewed. The mechanism of the conversion of dissolved alkali sulfate from cement to the corresponding alkali hydroxide in concrete pore solutions is illustrated, and the long term status of concrete pore solutions is reviewed and related to alkali aggregate reactions. Reactions of dissolved alkali hydroxide with aggregates and with mineral admixtures are considered, as is the effect of calcium on the reaction product gel formed. The demonstrated great ability of silica fume and of some slags to remove alkali hydroxide from concrete pore solutions may point the way to reliable prevention of alkali aggregate problems in the future.

1728. Figg, J., "AN ATTEMPT TO PROVIDE AN EXPLANATION FOR ENGINEERS OF THE EXPANSIVE REACTION BETWEEN ALKALI AND SILICEOUS AGGREGATES IN CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 137-144.

KEY WORDS: alkali aggregate reactions; cracking

ASR is a complicated process involving a number of different factors, some of which may be conveniently described via triangular diagrams. It is important to distinguish between alkali ions and alkalinity ( i.e.hydroxyl ion concentration) to avoid ambiguity when considering ASR. Three-branched (Manx) cracking is common in ASR, and may be associated with various ternary relationships among parameters of the reaction.

1729. Forss, B., "EXPERIENCES FROM THE USE OF F-CEMENT, A BINDER BASED ON ALKALI-ACTIVATED BLASTFURNACE SLAG," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 101-104.

KEY WORDS: slag; cements

"F-cement", developed in Finland, is a finely ground blast furnace slag cement activated with alkaline

admixtures and incorporating a superplasticizer. Technical properties are considered good, and results of early uses are described.

1730. Gudmundsson, G. and Asgeirsson, H., "PARAMETERS AFFECTING ALKALI EXPANSION IN ICELANDIC CONCRETES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 217-221.

KEY WORDS: alkali aggregate reaction; reactive aggregates; alkali effects; silica fume; preventive measures; field experiences; Iceland

Icelandic cement, produced from sea shells and perlitic rock, is necessarily high in alkali content, the glassy aggregates available are reactive, and salt spray provides additional difficulties. Severe problems with ASR have been apparently relieved in future construction by incorporation of silica fume in all cement. Various technical details are provided.

1731. Idorn, G. M., "30 YEARS WITH ALKALIS IN CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 19-38.

KEY WORDS: alkali effects; temperature effects; alkali aggregate reactions; reviews

Alkali effects in concrete technology are reviewed on a historical basis, and several new interpretations provided. The influence of temperature actually experienced by the concrete is emphasized. It is a reasonable assumption that about 20% of the concrete production in the world is made with alkali-susceptible aggregates (more types of aggregates are susceptible than 40 years ago due to the development of concrete), and that there are enough slag and fly ash available to ensure their utilization without deleterious effects. By using slag and fly ash properly, improved general resistance of concrete can be attained, and energy saved. Moreover, the development with the most refined substitution materials is on the threshold of sophisticated innovations.

1732. Idorn, G. M. and Rostam, S. (eds.), "ALKALIS IN CONCRETE - RESEARCH AND PRACTICE," Proc., 6th Intl. Conf., Copenhagen, June 1983, Technical University of Denmark, 532 pp.

1983

KEY WORDS: alkali aggregate reactions; conferences

Indexed as Proc. 6th Intl. Alkali Conf., Copenhagen, 1983. Contains 56 papers, mostly on alkali aggregate reactions.

1733. Idorn, G. M., "EDUCATION FOR EFFECTIVE UTILIZATION OF ALKALIS IN CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 145-149.

KEY WORDS: alkali effects; alkali aggregate reactions

Contemporary concrete deserves to be considered as a continuously reacting system which must be monitored all the way through its processing from the mixer to load application. Alkalis have noticeable influence throughout the chemical processes involved. It is proposed to recognize this situation by appropriate changes in engineering education and in research.

1734. Jawed, I., Struble, L. and Epp, J., "DISSOLUTION AND HYDRATION OF C3A-Na2O SOLID SOLUTIONS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 209-215.

KEY WORDS: alkali effects; pore solutions

Studies are reported on the dissolution and hydration of several $C_3A$ preparations containing $Na_2O$ in solid solution to different extents. (1). $Na_2O$ from $C_3A$-$Na_2O$ solid solutions appears to enter the liquid phase at the same rate as the solid solution dissolves and nearly all $Na_2O$ is in the liquid phase within a few hours. (2) Little difference is apparent in the rate of hydration at different levels of $Na_2O$ in the solid solution. (3) With increasing $Na_2O$ content in the solid solutions, there is a decrease in CaO concentration and increase in the $Al_2O_3$ concentration of the liquid phase. This trend was found to be independent of the source of sodium in the liquid phase. (4) In the presence of $C_3S$, the concentration of $Na_2O$ in the liquid phase does not seem to be affected, but the concentration of $Al_2O_3$ is drastically decreased.

1983

1735. Kawamura, M., Takemoto, K. and Hasaba, S., "APPLICATION OF QUANTITATIVE EDXA ANALYSIS AND MICROHARDNESS MEASUREMENTS TO THE STUDY OF ALKALI- SILICA REACTION MECHANISMS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 167-174.

KEY WORDS: EDX analysis; microhardness; scanning electron microscopy; opal; alkali silica gel; mechanisms; expansion

(1) The intrusion of water into the affected portion inside reacting opal particles after 7 days is evidenced by a great reduction in microhardness. (2) Subsequent solidification of the softened region within about 50 microns from the interface after 14 days in a coarse opal grain embedded in cement paste appears to relate to the intrusion of a relatively large amount of calcium. (3) The early expansion of the mortars depends upon the amount of gels formed rather than upon their chemical compositions. (4) The fly ash used in this study did not inhibit ASR at all, but facilitated the mobilization of calcium into reactive aggregate particles.

1736. Kawamura, M., Takemoto, K. and Hasaba, S., "CASE STUDIED OF CONCRETE STRUCTURES DAMAGED BY ALKALI- AGGREGATE REACTION IN JAPAN," CAJ Review of the 37th General Meeting; Technical Session, pp. 86-87, 1983.

KEY WORDS: alkali aggregate reactions; alkali silica gel; cracking; field experience; Japan

1737. Kawamura, M., Takemoto, K. and Hasaba, S., "THE MECHANISMS OF PREVENTION OF EXPANSION DUE TO ALKALI- SILICA REACTION BY POZZOLANIC ADDITIVES (in Japanese)," Transactions of the Japan Concrete Institute, Vol. 5, pp. 91-96, 1983.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; fly ash; mechanisms

The fly ash used in this study did not inhibit ASR at all, but facilitated the mobilization of calcium into reactive aggregate particles. This result can not necessarily be predicted from the theory concerning the mechanisms responsible for the reduction or prevention of alkali silica expansion by pozzolanic additives.

1983

1738. Lenzner, D., "COMPARATIVE LABORATORY TESTS ON THE ALKALI-SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 321-327.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; mortar bars

Three different reactive aggregates from several countries were investigated; marked differences in reactivity were found by mineralogical and chemical analyses. Accelerated progress of ASR brought about by using high alkali content cement or by elevated curing temperatures may actually cause a reduction in the subsequent damage done by ASR, perhaps due to rehealing of early microcracking.

1739. Malek, R. I. A. and Roy, D. M., "EFFECT OF SLAG CEMENTS AND AGGREGATE TYPE ON ALKALI- AGGREGATE REACTION AND ITS MECHANISMS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 223-238.

KEY WORDS: alkali silica reactions; mechanisms; reactive aggregates; slag; alumina effects

The effects of various cement and aggregate types on ASR have been investigated. Ordinary portland cements of normal alkali content was used with a partly glassy basalt aggregate and with Beltane opal. Some dissolution of silica but little expansion was found with the basalt. Slag incorporation diminished ASR significantly. $Al_2O_3$ appeared to also play a role in diminishing ASR effects.

1740. Marr, J. and Glasser, F .P., "EFFECT OF SILICA, PFA AND SLAG ADDITIVES ON THE COMPOSITION OF CEMENT PORE FLUIDS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 239-242.

KEY WORDS: pore solutions; alkali effects; slag; silica; fly ash

The pore fluid of a moderately low alkali cement with and without several mineral admixtures were analyzed after 30 and 90 days at room temperature (18°C). During this time typical pfa's are not sufficiently reactive to significantly affect the aqueous phase composition and pH, but slag and a very high surface area synthetic silica do

exhibit significant effects.

1741. Morup, H., "A SWIMMING POOL DETERIORATED BY ALKALI-AGGREGATE REACTIONS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 435-440.

KEY WORDS: alkali aggregate reactions; hydraulic structures; field experience; Denmark; repairs

The investigation of a concrete swimming pool deteriorated by ASR is described, and repairs needed are indicated.

1742. Nielsen, A., "SORPTION PROPERTIES OF CONCRETE WITH ALKALI-SILICA REACTIVE AGGREGATE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 195-200.

KEY WORDS: alkali silica gel; moisture effects; alkali aggregate reactions

Measurements of connected values of relative humidity and water content by weight make it reasonable to assume that alkali-silica gel contributes essentially to the selfdesiccation of sealed concrete in which ASR is taking place. Further research is needed to clear out the rules of calculation for the desorption curve of the alkali silica gel.

1743. Nielsen, A., "SERVICE LIFE PREDICTION AND ALKALI-SILICA REACTIONS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 411-418.

KEY WORDS: alkali aggregate reaction, field experiences; Denmark; cracking; moisture effects

Based on Danish field experience, the hypothesis is set forward that damage due to ASR only occurs in structural members in which cracks previously were created during the production of the concrete. Structures without initial cracks from vibration, bleeding, thermal stresses etc., will not show cracking due to ASR. For structures with initial cracks there will be an initiation period, in which the water penetrates the concrete. After this period the cracks propagate to a certain degree, then come to rest and

nothing more happens unless the structure is exposed to one-sided water pressure, to de-icing salts or to freezing in saturated condition. In these cases the deterioration may continue. These ideas explain the frequent observation that only one part of a structure is cracked, while the remainder is seemingly unaffected by ASR.

1744. Nilsson, L. O., "MOISTURE EFFECTS ON THE ALKALI-SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 201-208.

KEY WORDS: alkali aggregate reactions, popouts; moisture effects; field experiences; Sweden; test methods; preventive measures; fly ash; silica fume

Problems in Sweden due to ASR appear to be manifested only as popouts where the aggregates contain opaline flint and sandstone components. Moisture effects are critical, with RH greater than 90% being associated with the distress. Laboratory experiments are described, and a test method for popouts has been developed, in which "moisture history" is used to reproduce damage in the laboratory. The effects of some preventive measures, especially incorporation of some fly ashes and silica fume, seem promising.

1745. Nilsson, L. O. and Peterson, O., "ALKALI SILICA REACTION IN SCANIA, SWEDEN: A MOISTURE PROBLEM CAUSING POP-OUTS IN CONCRETE FLOORS," Lund Institute of Technology, TVBM - 3014, Lund, Lund Institute of Technology, 1983, 106 pages.

KEY WORDS: floors on ground structures; alkali aggregate reactions; moisture effects; popouts; field experiences; Sweden

1746. Nishi, H., Minakami, K., Imai, T. and Etoh, K., "ALKALI REACTIVITY OF ANDESITIC ROCKS (in Japanese," Cement & Concrete (Japan), No. 435, 1983.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite;test methods; test; alkali content

(1) Two kinds of andesite rocks containing tridymite and glass were judged harmful by the potential reactivity test.

(2) In the mortar bar test, all aggregates tested caused expansion at 0.75% $Na_2O$ equivalent alkali content of cement, and some aggregates did it at 1.13% $Na_2O$ equivalent alkali content. (3) Expansion in the mortar bar test was at maximum when reactive and non-reactive aggregates were mixed at a proportion of 6:4. (4) In concrete tests, one aggregate caused a large amount of expansion at 1.5% Na2O equivalent alkali. (5) Concrete specimens did not always undergo expansion even when mixed with reactive aggregate judged harmful by potential reactivity test or by mortar bar test.

1747. Nixon, P. J. and Gaze, M. E., "THE EFFECTIVENESS OF FLY ASHES AND GRANULATED BLASTFURNACE SLAGS IN PREVENTING AAR," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 61-68.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; fly ash; slag

The effectiveness of slags and fly ashes in preventing AAR damage has been assessed in a number of ways. Mortar bar expansion tests with pyrex glass, Beltane opal, or crushed chert as the expansive component and tests with concrete prisms containing flint sand have been carried out. In all test methods expansions caused by alkali aggregate reaction were reduced very significantly if sufficient fly ash (about 30%) was used to replace the portland cement. When beltane opal is used as the reactive aggregate in mortars there are some mixes where 10 or 20% replacement by a high alkali fly ash produces greater expansion than the control. Low alkali ashes were much more effective in preventing expansion and 20% of low alkali ash suppressed expansion to negligible levels. The expansion of concrete containing chert aggregate is effectively suppressed by 20% of a high alkali fly ash. It may not therefore be necessary to consider the alkali level of the fly ash for its use in suppressing AAR in concrete in the UK, but this is being investigated further. The limited amount of information on the effect of granulated blast furnace slags on AAR suggests that with British portland cement and slags a 50% replacement level is sufficient.

1748. Nixon, P. J. and Bollinghaus, R., "TESTING FOR ALKALI REACTIVE AGGREGATES IN THE UK," Proc. 6th Intl. Alkali

Conf., Copenhagen, 1983, pp. 329-336.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; concrete prisms; expansion; U.K.

The results so far of the assessment of possible test methods indicate that ASTM test methods, especially the C 227 mortar bar test, can give misleading answers for UK materials but that test using concrete specimens are more helpful. Tests using such concrete specimens have shown definite pessimum effects of some aggregates. The lack of expansion in mortar bars when concrete prisms containing the same amount of alkali and made with the same water/cement ratio and aggregate/cement ratio crack and expand markedly is puzzling.

1749. Oberholster, R. E., "ALKALI REACTIVITY OF SILICEOUS ROCK AGGREGATES: DIAGNOSIS OF THE REACTION, TESTING OF CEMENT AND AGGREGATE AND PRESCRIPTION OF PREVENTIVE MEASURES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 419-433.

KEY WORDS: alkali aggregate reactions; test methods

(1) Cement can be standardized in respect of their active alkali content by employing the method for available alkalis (ASTM C 331) or by selective dissolution methods. (2) Methods such as the determination of the undulatory extinction angle of quartz grains, the amount of silica dissolved in 1N NaOH at 80°C after 3 or 7 days; and the XRDA of the gel formed when aggregate is reacted with CH and 1N NaOH at 80°C for 7 days are suitable for the provisional identification of alkali-reactive aggregates. (3) The concrete and mortar prism tests performed under ASTM C 227 conditions are suitable for the determination of the potential alkali reactivity of cement-aggregate combinations, provided that the active alkali content of the cement used is specified. These two tests are also suitable for the determination and comparison of the alkali reactivity of aggregates. (4) The accelerated test proposed by Van Aardt and Visser is also suitable for the determination of the alkali reactivity of aggregates.

1750. Odler, I. and Wonnemann, R., "EFFECT OF ALKALIES ON PORTLAND CEMENT HYDRATION I. ALKALI OXIDES INCORPORATED INTO THE CRYSTALLINE LATTICE OF CLINKER MINERALS," Cement

and Concrete Research, Vol. 13, pp. 477-482, 1983.

KEY WORDS: alkali effects; clinkers; cements

(1) Both $Na_2O$ and $K_2O$ added to the raw meal in the absence of $SO_3$ are incorporated preferentially into the $C_3A$-phase of clinker, altering the crystalline form of this phase from cubic to orthorhombic. (2) The progress of $C_3A$ hydration is slowed down in cements made out of $Na_2O$-doped clinkers and accelerated in those made out of $K_2O$ doped clinker. The progress of $C_3S$ hydration is not altered significantly by alkali oxide doping. (3). The setting time is moderately extended by $Na_2O$ doping and shortened by $K_2O$ doping. The development of strength is not altered significantly.

1751. Odler, I. and Wonnemann, R., "EFFECT OF ALKALIES ON PORTLAND CEMENT HYDRATION II. ALKALIES PRESENT IN FORM OF SULFATES," Cement and Concrete Research, Vol. 13, pp. 771-777, 1983.

KEY WORDS: alkali effects; cements; clinkers

Alkalies present in cement in the form of $Na_2SO_4$ or $K_2SO_4$ do not alter the progress of $C_3S$ and $C_3A$ phase hydration. The setting of cement is accelerated especially with $K_2SO_4$, due to the formation of acicular crystals of syngenite $CaSO_4.K_2SO_4.H_2O$. The compressive strength is decreased significantly.

1752. Olafsson, H., "REPAIR OF VULNERABLE CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 479-485.

KEY WORDS: alkali aggregate reactions; field experiences; Iceland; repairs; moisture effects

For permanent repair of cracks in concrete caused by alkali aggregate reaction the chemical process has to be stopped. The most obvious way of stopping the deleterious process is to reduce moisture content of concrete below a critical point. This paper shows the effect of various repair and renovation methods used on houses in the period 1979 to 1982 on the moisture content of exterior walls. The results already obtained show ventilated panels or claddings to be most effective. Impregnation with silanes/ silicones have also shown most promising results.

1983

1753. Osbaeck, B., "ALKALIS AND CEMENT STRENGTHS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 93-100.

KEY WORDS: alkali effects

The potential of soluble alkali to enhance early strength and diminish late strength of Portland cement has been demonstrated in ISO-mortars as well as in two concrete compositions. The strength changes expressed on a relative basis were of the same order of magnitude in these systems. The tendency of extra negative effect to the strengths at all ages exists if the effect of alkali is evaluated on a constant slump basis. Preliminary tests with blends of Portland cement with a slag, a fly ash and a microsilica have indicated that the influence on strength from such mineral admixtures is only modestly - if at all - dependent on the content of soluble alkalis on the cement.

1754. Peterson, O., "POP-OUT FORMATION: A LABORATORY STUDY WITH SWEDISH OPALINE GRAVEL," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 291-298.

KEY WORDS: alkali aggregate reactions; popouts;

Cement mortar specimens with and without reactive fine aggregate components were prepared, each with a single 5 mm stone suspected of reactivity. In only one case was a popout produced; in this case the sand was non-reactive. However, in slices through mortars with reactive sand wet spots small local pop outs had developed, even in the presence of silica fume.

1755. Petersen, S. E., "DAMAGES TO SWIMMING POOLS DUE TO ALKALI SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 441-447.

KEY WORDS: alkali aggregate reactions; hydraulic structures; field experiences; Denmark; repairs

Damage to a number of Danish swimming pools due in part to AAR have been reported. Design practices, and recommended remedial measures are discussed.

1983

1756. Poitevin, P., "EFFECTS IN PRACTICE OF ALKALIS IN CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 391-399.

KEY WORDS: alkali aggregate reactions; field experiences; structural effects

Concrete structures suffering from AAR can develop severe cracking, even when prestressed. In practice such structures can continue to be used as is, if a sufficient structural safety factor remains. It is usually impractical to dry out the entire structure. Strengthening by post-tensioning is a possible alternative to replacement. Specifiers and designers of structures may overestimate the danger of ASR when assessing new aggregate sources.

1757. Poitevin, P. and Regourd, M., "DURABILITY OF CONCRETES. CASES OF REACTIVE AGGREGATES (in French).," Annales ITBTP 413 Serie Materiaux 59, pp. 110-143.

KEY WORDS: alkali aggregate reactions; alkali silica gel; recrystallized gel; scanning electron microscopy; alkali release; mechanisms

The reactivity of aggregates can be due to the presence of clay, organic material, sulfur or sulfate, or reactive silica. ASR has been observed in dams, bridges, roads, breakwaters, etc. Petrographic examinations have shown gels around aggregates and in the pores of cement paste. Crystals of potassium calcium silicate have been observed in cleavage planes of feldspars and micas. The reactivity of siliceous aggregates can seen on polished sections observed on SEM before and after treatment in soda or potash solutions at 80°C for 3 to 5 days. Well crystallized quartz grains do not react. Amorphous silica, altered feldspars, chlorite and vermiculite transform into foliated crystals.

1758. Poitevin, P. and Regourd, M., "THE DURABILITY OF CONCRETE: THE CASE OF REACTIVE AGGREGATES," Annales de I'Institut Technique du Batiment et des Travaux Publics, No. 413, March-April 1983, pp. 109-143 (in French with English summary).

KEY WORDS: alkali aggregate reactions; reactive aggregates

1983

1759. Poole, A. B., "ALKALIS IN CONCRETE: A MATTER OF EDUCATION FOR ENGINEER AND RESEARCH SCIENTIST," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 125-131.

KEY WORDS: alkali aggregate reactions

Alkali aggregate reaction studies are reviewed. Practical information should be communicated to practicing engineers regarding their occurrence and consequences.

1760. Poole, A. B. and Al-Dabbagh, I., "REACTIVE AGGREGATES AND THE PRODUCTS OF ALKALI-SILICA REACTION IN CONCRETES," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 175-185.

KEY WORDS: reactive aggregates; flint; scanning electron microscopy; EDX analysis

Potentially alkali reactive flint particles from U. K. aggregates have been examined and compared to similar non-reactive particles using electron probe analysis and scanning electron microscopy. It is found that reactivity correlates with impurity contents and with color. There is an indication that microtextures in flint also relate to reactivity.

1761. Regourd, M., "METHODS OF EXAMINATION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 275-289.

KEY WORDS: scanning electron microscopy; alkali aggregate reactions; mechanisms; alkali effects; calcium hydroxide effects; recrystallized gels; alkali release; zeolites; carbonation effects

The microstructure study of core samples extracted from damaged constructions has shown that the source of alkali can be both cement and aggregates. The reactive parts of polyphased aggregates are not only dolomite and amorphous or cryptocrystalline silica, but also strained quartz, altered feldspars and micas,and clay-like materials. Beside the well known alkali silica gel found around or within aggregates, crystalline alkaline zeolite-like silicates and carbonated hydrates such as trona, carboaluminates and thaumasite can be found. Ettringite very often found in large amount and may be nearly amorphous. These coexisting compounds result from the diffusion of various types of ions ($Ca^{2+}$, $SO_4^{2-}$,and $CO_3^{2-}$ions as well as the $Na^+$, $K^+$ and

OH ions always considered in the alkali aggregate reaction.

1762. Regourd, M., "INTERNAL ALTERATION OF CONCRETES: THE ALKALI-AGGREGATE REACTION (in French)," Travaux No. 577, pp. 62-67, 1983.

KEY WORDS: alkali aggregate reactions

1763. Regourd, M. and Poitevin, P., "DURABILITY OF CONCRETES - CASES OF REACTIVE AGGREGATES (in French)," Annales I.T.B.T.P., 413, Series Materiaux 59, pp. 110- 143, 1983.

KEY WORDS: reactive aggregates; field experiences; France

1764. Regourd, M., "INTERNAL ALTERATION OF CONCRETES. THE ALKALI-AGGREGATE REACTION (in French)," Travaux No. 577, pp. 62-67.

KEY WORDS: alkali aggregate reactions; field experiences; preventive measures

This overview on alkali aggregate reaction gives examples of deteriorated structures as visited during the 5th International Symposium held in Cape Town. Mechanisms of ASR and dedolomitisation, reactive aggregates and preventive measures and more particularly the choice of cement are presented.

1765. Sarkar, S. L., "ALKALI COMPOUNDS IN NIGERIAN PORTLAND CEMENT CLINKERS," Cement and Concrete Research, Vol. 13, pp. 431-434, 1983.

KEY WORDS: alkali effects; clinkers; scanning electron microscopy; EDX analysis

Four out of the six Nigerian portland cement clinkers examined contain alkali bearing compounds in the form of single or double sulfates. An attempt has been made to identify them and derive their compositions from SEM-EDXA study.

1983

1766. Sever, A., "CAUSES OF CONCRETE PAVEMENT DAMAGES," Fakuletet Gradjevinskih Znanosti kacieva 26 Zagreb,Croatia, Yugoslavia 1983, Monograph 83 pages.

KEY WORDS: alkali aggregate reactions; pavement structures; field experiences; Yugoslavia

The paper deals with concrete pavements which are divided (1)according to their causes into technological, mechanical and temperature damages, (2)according to time dependence into primary and secondary damages, and (3)according to external and internal factors, the main internal causes being aggregate reaction to alkali, aggregate change and hardened cement paste. The external causes are high and low temperature, abrasion, high axial pressure and salt action. Hygrometric and temperature concrete shrinkage and damages due to frost are discussed. The behavior of the hardened cement paste, ice, diffusion process, expansion due to freezing and the action of deicing salts are the object of a special study. The author is of the opinion that the only kind of protection against damages caused by freeze-thaw and the action of salts is in the use of microaerated cement paste. Based on the literature and Yugoslav standards, a suggestion is presented for qualitative criteria for concrete pavement construction, governing basic materials and additives, fresh concrete, hardened concrete and its manufacture.

1767. Shin, G. Y. and Glasser, E. P., "INTERDEPENDENCE OF SODIUM AND POTASSIUM SUBSTITUTION IN TRICALCIUM ALUMINATE," Cement and Concrete Research, Vol. 13, pp. 135-140, 1983.

KEY WORDS: alkali effects; clinkers

The maximum extent of $K_2O$ substitution in cubic $C_3A$ is 1.0 wt.% at 1000-1200°C. Na is required to form orthorhombic solid solutions. These when formed, exhibit appreciably higher solubilities for $K_2O$, ranging up to 2.5 wt.%.

1768. Sims, I., "THE INFLUENCE OF GROUND GRANULATED BLASTFURNACE SLAG ON THE ALKALI-REACTIVITY OF FLINT AGGREGATE CONCRETE IN THE UNITED KINGDOM," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 69-84.

KEY WORDS: alkali aggregate reactions; reactive aggregate;

flint; preventive measures; slag

A program of mortar bar testing has been carried out to evaluate the beneficial effect of ground granulated blast furnace slag on AAR. All the mortar bar tests carried out have suggested that the flint aggregates have a relatively low alkali reactivity potential, even when blended with limestone aggregate and/or high alkali cement. The high alkali cement used typically produced greater mortar bar expansion than the lower alkali cement, even with supposedly inert limestone aggregate. Dilution of flint aggregate by addition of a limestone aggregate only had a worsening effect at the higher alkali content level. At total acid soluble alkali content (of the binder) of 0.80% or less, reduction of the flint aggregate content seem to have a beneficial effect. The addition of slag reduced expansion when the total alkali content was high, and particularly when the flint aggregate content was diluted by the addition of limestone aggregate.

1769. Sims, I. and Sotiropoulos, P., "STANDARD ALKALI-REACTIVITY TESTING OF CARBONATE ROCKS FROM THE MIDDLE EAST AND NORTH AFRICA," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 337-350.

KEY WORDS: reactive aggregates; test methods; rock cylinder tests

Rock cylinders from Middle Eastern and North African carbonate rocks frequently show initial contraction when immersed in alkaline solution. No guidance regarding such behavior is given in ASTM C 586. This contraction should be monitored until a stable length change has been achieved, thus ensuring that delayed expansion is unlikely to take place. Should delayed expansion take place, it should be similarly monitored until either a stable length change has been achieved or the +0.1% level has been exceeded, whichever is the sooner. These tentative recommendations inevitably will tend to increase the length of time required for the satisfactory completion of a test program.

1770. Spellman, L. U., "USE OF GROUND GRANULATED SLAG TO OVERCOME THE EFFECTS OF ALKALIS IN CONCRETE AND MORTAR," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 55-60.

KEY WORDS: alkali aggregate reactions; preventive measures;

slag

Substituting finely granulated slag at substantial percentages of the total cementitious component markedly reduces the potential for alkali aggregate reaction distress.

1771. Stark, D., "OSMOTIC CELL TEST TO IDENTIFY POTENTIAL FOR ALKALI- AGGREGATE REACTIVITY," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 351-357.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; osmotic cell tests; osmotic effects

An osmotic cell procedure for evaluating the potential for deleterious aggregate reactivity is described and a test criterion in terms of limiting flow rate is developed. Slowly reactive aggregates which pass existing ASTM tests but fail in field structures have been identified as potentially reactive in the osmotic cell test.

1772. Tang, M. S. and Han, S. F., "KINETICS OF ALKALI-SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 261-267.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mechanisms

Rates of reaction between various aggregates and high alkali cement have been measured at different temperatures, assuming that the expansions of mortar bars are proportional to the accumulation of reaction products. The Arrhenius equation is shown to describe the temperature dependence of these reaction rates. The activation energies and frequency factors are different for different aggregates, suggesting that they can be used to compare alkali reactivities of different aggregates.

1773. Tang, M. S. and Han, S. F., "RAPID METHOD FOR DETERMINING THE PREVENTIVE EFFECT OF MINERAL ADMIXTURES ON ALKALI-SILICA REACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 383-386.

KEY WORDS: alkali aggregate reactions; preventive

measurements; test methods

A rapid method suggested by us for determining the preventive effect of mineral admixtures on ASR in two days, can be used for the primary selection and comparison of the effectiveness of admixtures. The method involves steam curing mortar bars at 100°C for 4 hours, then immersing them in 10% KOH solution and autoclaving at 150°C for 6 hours, and measuring the resulting expansions.

1774. Tang, M. S., Ye, Y. F., Yuan, M. Q. and Zheng, S. H., "THE PREVENTIVE EFFECT OF MINERAL ADMIXTURES ON ALKALI-SILICA REACTION AND ITS MECHANISM," Cement and Concrete Research, Vol. 13, pp. 171-176, 1983.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; fly ash; tuff; slag; mechanisms

The preventive effects of tuff, fly ash, and blast furnace slag on ASR has been investigated. For the same amount of addition the order of effectiveness is tuff > fly ash > slag. The preventive effects may be related to contents of acid oxides in the admixture. Adding 10% CaO increases the expansion and the "basicity" of the cement. The authors consider that the concentration of alkali ions on the surfaces of admixture particles may contribute to the preventive effect.

1775. Tang, M. S., Hang, S. F. and Zheng, S. H., "A RAPID METHOD FOR IDENTIFICATION OF ALKALI REACTIVITY OF AGGREGATE," Cement and Concrete Research, Vol. 13, pp. 417-422, 1983.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; expansion; mortar bars; autoclave treatment; alkali effects

The rapid method developed involves steam curing mortar bars, immersing them in 10% KOH, and then autoclaving at 150°C for 6 hours; expansions indicate reactive aggregates. Measurements of expansion are reported as a function of content of reactive components for various known reactive aggregates. The rapidity of the test is helpful in practice; furthermore, laboratory study of the reactions taking place at the several stages of testing are helpful in elucidating the mechanisms of ASR.

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1776. Thaulow, N. and Olafsson, H., "ALKALI-SILICA REACTIVITY OF SANDS, COMPARISON OF VARIOUS TEST METHODS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 359-364.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; alkali effects; mortar bars; expansion; chemical tests

Comparison of 5 different test methods for evaluation of the alkali silica reactivity of sands was performed on 14 Icelandic, 15 Danish, and 1 Swedish sand. Generally a good agreement was found between the different methods. After modification of the exposure time for the T.I.-mortar bar expansion method to 20 weeks and modification of the borderline between reactive and non-reactive aggregates in the Quick Chemical Test, excellent agreement was found. The other chemical method ("Vorbeugende Massnahmen") was not suitable to test Icelandic sands and failed on some of the Danish sands, too.

1777. Thaulow, N., "ALKALI-SILICA REACTION IN THE ITEZHITEZHI DAM PROJECT, ZAMBIA," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 471-477.

KEY WORDS: alkali aggregate reactions; field experiences; Zambia; petrography; reactive aggregates; opal

The granitic coarse aggregate, used to make concrete for the intake towers of the Itezhitezhi Dam, was found to be alkali-reactive. The reactive material seemed to be a secondary opaline filling in the cracks of weathered rocks. Expansion of the 30 m. high towers was of the order of 40 mm. The expansion of the towers seems to have ceased by 1982. Repair is deemed unnecessary at this stage.

1778. Vivian, H. E., "THE PROCESS OF ALKALI-AGGREGATE REACTION, WATER ABSORPTION; REACTED AGGREGATE SWELLING, EXPANSION OF MORTAR AND CONCRETE AND POZZOLAN BEHAVIOR," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 187-194.

KEY WORDS: alkali aggregate reactions; mechanisms; moisture effects; expansion

The reaction of alkalis and reactive aggregate components produces a reaction product which may absorb water and swell. Penetration of water or water vapor into

concrete can occur but will tend to transform reaction product on the surfaces of reactive particles into deformable gel or sol which can dissipate, without causing undue concrete distress, into spaces in the surrounding cement paste. While large amount of absorbed water increase the swelling, excess water promotes reaction product dispersion and sol formation. Dissipation of sol into space in the cement paste bring the alkali-silica complex into contact with calcium hydroxide and may promote the formation of calcium hydroxide-alkali hydroxide-silica reaction products which do not absorb water and cause concrete expansion but may improve strength and reduce cement paste permeability.

1779. Vivian, H. E., "THE POZZOLANIC BEHAVIOR OF FLY ASH IN BLENDED PORTLAND- FLY ASH CEMENTS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 243-248.

KEY WORDS: fly ash; pozzolans; preventive measures

Variations in the physical and chemical compositions of fly ashes derived from different coals in different combustion processes are discussed. Although fly ashes are useful in improving some properties of concrete, they are not universal cure-alls for all of the defects of portland cement concrete.

1780. Vivian, H. E., "ASSESSMENT OF AGGREGATE REACTIVITY TESTS AND SIGNIFICANCE OF TEST RESULTS," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 365-368.

KEY WORDS: alkali aggregate reactions; test methods

Difficulties with existing test methods are reviewed. (1) The chemical test is said to give a rapid and reliable assessment of the potential reactivity of an aggregate. (2) The potential reactivity of aggregate can be confirmed by petrographic examinations, various qualitative tests, and by quantitative expansion measurements of mortar or concrete specimens. (3) All the essential symptoms must be clearly present at significant levels in mortar or concrete specimens to confirm aggregate reactivity as the specific cause of expansion and disruption. (4) Correct assessment of test results is essential and should be made only by an experienced assessor.

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1781. Wood, J. G. M. and Wickens, P. J., "STRUCTURAL EFFECTS OF AAR ON REINFORCED CONCRETE AND CONSIDERATION OF REMEDIAL ACTION," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 487-494.

KEY WORDS: alkali aggregate reactions; structural effects; field experiences; repairs

The actual behavior of reinforced concrete structures with AAR is contrasted with laboratory mortar bar tests. Expansion, microcracking, and tensile strength loss form AAR in concrete will reduce structural strength most rapidly in elements subject to shear stress, and those with high bond stresses. Methods of strengthening and rendering structures less sensitive to deterioration are discussed.

1782. Worning, I. and Johansen, V., "ALKALIS IN CEMENT AND CEMENT MANUFACTURE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 41-53.

KEY WORDS: alkali; clinker production

The current technology of alkali reduction in cement plants under modern economic conditions is reviewed. The reduction of alkali in clinker produced from large kilns with large bypasses has not been as pronounced as expected. This is because such kiln systems were based on experience gained from preheater kiln system without bypass. Analyses of statistical data from great numbers of kilns have shown that the high evaporation coefficients are due partly to a large amount of circulating alkali chlorides. In kiln system with bypass which exceed a certain size the internal circulation is stopped and only the proportion of the alkali which evaporates "first time" can contribute to the alkali reduction. Investigations have shown that, contrary to previous assumptions, the evaporation coefficient is not constant and independent of the size of the bypass. The results attained in practical operation show that $Na_2O$ can be reduced by up to 20% of the $Na_2O$ admitted and that up to some 30% of the $K_2O$ admitted can be removed. Practical experience also seems to show that alkali bypasses become far less efficient once their size exceeds 60%. Various other aspects of plant operation are considered.

1783. Xu, H. and Chen, M., "INVESTIGATION FOR NATURAL REACTIVE AGGREGATES IN GRAVEL ALLUVIUM OF YANGTZE RIVER BASIN,"

Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 511-516.

KEY WORDS: alkali aggregate reactions; reactive aggregates; rhyolite; trass; flint; field experiences; China; hydraulic structures; dam structures; mechanisms; lithium effects; preventive measures; slag; fly ash; clays

Investigations of reactive aggregates in gravels of the Yangtze River have been carried out for many years; many problems relating to alkali aggregate reactions in dams and hydraulic structures along this river have been studied. Results of extensive research are summarized. (1) The reactive aggregates involved are rhyolite, trass, and flint. (2) In the investigation of reactive aggregates, it is important to relate the classification with the safe alkali content of cement. Based on test results, it only needs a short time to determine the type of reactive aggregates by means of optical identification etc. without performing lengthy tests. (3) In the study of classification of reactive aggregates, mathematical expressions are derived. It is believed that these expressions are new and practicable. (4) Reaction products of alkali-silica close to the interfaces of unreacted aggregates produce swelling pressure due to water absorption, which prevails at early age, while those close to the interface of semi-membrane of hardened cement paste produce osmotic pressure, which prevails at later age, causing concrete to expand. (5) Water-quenched slag, fly ash, kaolinite and montmorillonite are effective in inhibiting expansion due to ASR, but kaolinite and montmorillonite should be calcined at 600°C before they are used. (5). LiF is effective in inhibiting expansion due to ASR, but LiCl promotes the expansion due to ASR. The mechanism of lithium salt together with the effect of lithium salt should be studied further.

1784. Zatler, B. and Mali, E., "ALKALI-AGGREGATE REACTION IN LIGHTWEIGHT CONCRETE," Proc. 6th Intl. Alkali Conf., Copenhagen, 1983, pp. 495-502.

KEY WORDS: alkali aggregate reactions; lightweight concrete; test methods

Lightweight concretes were studied with respect to potential alkali aggregate reactivity. On the basis of experimental work it can be concluded that in lightweight concretes made of expanded clay and expanded perlite alkali

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silica reactivity is small and does not cause deterioration.

1785. Abet Yao, M., "ON THE CAUSES OF BEAUHARNOIS DAM DEFORMATIONS (in French)," Memoire de Maitre des Sciences Appliques (MSc thesis), Universite de Montreal, 246 pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; orthoquartzite; test methods; dam structures; field experiences; Canada

Alkali aggregate reaction has been identified as the main cause of the abnormal structural behavior of the Beauharnois hydroelectric power station. Petrographic examination of concrete cores revealed that the reaction part of orthoquartzite aggregates is the siliceous cement and that there is a possibility of a deleterious migration of the alkalies from the concrete into the subjacent bedrock. Accelerated tests were ASTM C 289, C 227 and C 586, several CSA tests, a new technique of sample preparation for microscopic examination that was an acetate replica, and uniaxial compression tests on rock specimens previously immersed in alkaline solutions. Tentative suggestions for repairing the concrete structure included decreasing of bulk permeability of the concrete by chemical treatment, filling in the cracks with a thin grout, locally replacing the altered concrete, and making stress release cuts at strategic places.

1786. Blight, G. E., Alexander, M. G., Schutte, W. K. and Ralph, T. K, "REPAIR OF REINFORCED STRUCTURES AFFECTED BY ALKALI-AGGREGATE REACTION," Civil Engineer in South Africa, Vol. 26, No. 11, Nov. 1984, pp. 525-538.

KEY WORDS: alkali aggregate reactions; repairs; field experiences; South Africa

The occurrence of damage as a result of alkali aggregate reaction has been identified in the Western and Eastern Cape and also in the Witwatersrand area. Very little is known of how to repair structures that have deteriorated as a result of alkali aggregate reaction. The paper describes the effects of alkali aggregate reaction on exposed reinforced concrete structures and some of the techniques that have been developed to effect repairs to structures in the Witwatersrand area of South Africa. Subjects covered include restoring moment continuity in a portal restoring a cracked cantilever, resin injection applications, and others.

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1787. Buck, A. D. and Mather, K., "REACTIVITY OF QUARTZ AT NORMAL TEMPERATURES," Tech. Rept., US Army Eng., Waterw. Exp. Stn., SL-84-12, July 1984, 28 pages.

KEY WORDS: reactive aggregates; strained quartz; test methods; petrography

This project involved a study of eight natural gravels composed largely of quartz and quartzite. It was shown that strained quartz can be a potentially deleteriously reactive constituent of concrete aggregate, and criteria were developed to recognized such material before its use as concrete aggregate. An aggregate should be regarded as potentially deleteriously reactive if it contains more than 20 percent strained quartz having an average undulatory extinction angle larger than 15 deg.

1788. Chatterji, S. and Clausson-Kass, N.F., "PREVENTION OF ALKALI-SILICA EXPANSION BY USING SLAG- PORTLAND CEMENT," Cement and Concrete Research, Vol. 14, 1984, pp. 816-818.

KEY WORDS: alkali aggregate reactions; mechanisms; calcium hydroxide effects

A previously postulated hypothesis that concrete or mortar prisms devoid of free $Ca(OH)_2$ will not suffer from alkali-silica expansion has been tested. In this investigation. High slag-Portland cements were used to make mortar prisms with a reactive sand. Storage of these prisms in a saturated NaCl bath at 50°C caused no expansion. At the end of the storage period in NaCl bath, the prisms were found to be free of $Ca(OH)_2$. The results are consistent with the proposed hypothesis.

1789. Eberendu, A. R. N. and Daugherty, K. E., "THE QUANTITATIVE DETERMINATION OF GLASS IN SLAG BY INFRARED SPECTROSCOPY," Cement and Concrete Research, Vol. 14, pp. 873-883, 1984.

KEY WORDS: slag; glass content; IR spectroscopy

The glass content of slags can be determined inexpensively with this method. It is simple and can be performed in any laboratory equipped with an infrared spectrometer capable of scanning down to 400 wavenumbers. It minimizes time consuming sample preparations, such as sample particle sizings and washings, common in optical

microscopy methods. Impurities effects which affect the glass content determinations in luminescence and ultraviolet methods are absent. The correlation between microscope determination of glass and infrared absorption R-values is good.

1790. Fookes, P. G., Gann, J. and Comberbach, C. D., "FIELD INVESTIGATION OF CONCRETE STRUCTURES IN SOUTH-WEST ENGLAND, " Concrete (London), Vol. 18, No. 11, Nov. 1984, pp. 12-16.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.; petrography; diagnosis

A diagnosis of the alkali aggregate reaction in concrete made solely from an examination of surface effects is not always accurate, since similar effects may sometimes be produced by, for example, sulfate attack, shrinkage, freezing and thawing, or structural cracking. For confirmation, it is necessary to make a laboratory examination of concrete samples taken from the affected structures. As discussed in Part 1 and part 2, deterioration due to alkali aggregate reactivity is often combined with other phenomena, which complicates field recognition. The following laboratory work was normally carried out: field inspection (megascopic); laboratory examination of cores and concrete samples (macroscopic); and petrographic examination. Additional supplementary laboratory tests if required include: chemical analyses, X-ray diffraction, electron probe analysis, and infrared spectrophotometry.

1791. Futamura, S. and Fukushima, M., "EXPANSION DUE TO ALKALI-SILICA REACTION OF CRUSHED STONE FOR CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1984.

KEY WORDS: reactive aggregates; test methods

(1) Potential for expansion by ASR of aggregates should be checked by chemical test and by powder X-ray diffraction analysis. (2) Mortar bar test should be performed in high alkali condition considering other possible sources of alkali in practical situations.

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1792. Han, S. F. and Tang, M. S., "ALKALI SILICA REACTION UNDER THE AUTOCLAVE CONDITION (in Chinese)," Research Report of Nanjing Institute of Chemical Technology, China, No. 2, 1984, pp. 1-10.

KEY WORDS: alkali silica reactions; autoclaved concrete

1793. Hobbs, D. W., "EXPANSION OF CONCRETE DUE TO ALKALI-SILICA REACTION," Structural Engineer, Part A, Vol. 62A, No. 1, Jan. 1984, pp. 26-33.

KEY WORDS: alkali aggregate reactions; expansion; field experience; U.K.

An illustrated article reviews literature dealing with the expansion of concrete due to ASR and describes some current experimental work. It is shown that concrete containing a reactive aggregate and a UK cement is unlikely to exhibit deleterious expansion due to ASR if the alkali content of the concrete, expressed as equivalent $Na_2O$, is less than 4 $kg/m^3$.

1794. Jensen, A. D., Chatterji, S., Christensen, P. and Thaulow, N., "STUDIES OF ALKALI-SILICA REACTION - PART II EFFECT OF AIR-ENTRAINMENT ON EXPANSION," Cement and Concrete Research, Vol. 14, 1984, pp. 311-314.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion; air void effects

From an extensive petrographic investigation of concrete samples suffering from alkali-silica reaction, it has been hypothesized that a deliberately introduced air-bubble system will reduce expansion due to alkali-silica reaction. The above hypothesis has been tested using mortar bars made from 35 sand types of differing degrees of alkali-silica reactivity. The results show that on the average the introduction of 4% air decreased the expansion by about 40%. A petrographic examination of mortar bars has shown that in the case of reactive sand the air-bubbles tend to get filled up by gel, but the air-bubbles remain empty in the case of unreactive sand. It has also been noted that this filling up of the air-bubbles will decrease their effectiveness in a freeze-thaw environment.

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1795. Kawamura, M., Takemoto, K. and Hasaba, S., "EFFECT OF VARIOUS POZZOLANIC ADDITIVES ON ALKALI-SILICA EXPANSION IN MORTARS MADE WITH TWO TYPES OF OPALINE REACTIVE AGGREGATES, " CAJ Review of the 38th General Meeting-Technical Session, 1984, pp. 88-91.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans

(1) The effect of pozzolanic additives on alkali silica expansion considerably varied with the types of reactive aggregates used and with pozzolanic additives. (2) A pozzolanic material judged as an effective pozzolan in preventing alkali silica expansion by ASTM C 441 test even increased the expansion in mortars containing opal II.

1796. Kawamura, M. and Hasaba, S., "MECHANISMS OF ALKALI-SILICA REACTION - A REVIEW (in Japanese)," Concrete Journal (Japan), Vol. 22, No. 2, 1984, pp. 7-14.

KEY WORDS: alkali aggregate reactions; mechanisms

1797. Kawamura, M. and Hasaba, S., "ALKALI-SILICA REACTION AND ITS PREVENTIVE MEASURES (in Japanese)," Proc. of JSCE, No. 348, V-1, 1984.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive measures

The discussion is carried out on some problems in ASR, such as mineralogical investigation of reactive aggregates, forms of alkali in clinker and its mechanism of the reaction, and preventive methods and repairing methods of concrete affected by ASR.

1798. Kishitani, K. and Yun, Z., "INFLUENCES OF Ca(OH)2 ON ALKALI-SILICA REACTION (in Japanese)," Semento Gijutsu Nenpo (Annual Bulletin of Japan Cement Assoc.), No. 38, 1984.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; mechanisms; calcium hydroxide effects

Experiments consisting of mortar bar tests,

quantitative analysis of $Ca(OH)_2$, XRD, SEM, pH, and mercury intrusion porosimetry of hydration products were reported. (1) $Ca(OH)_2$ produced by hydration must exist for ASR, and it increases OH ion concentration and activates ASR. (2) The amount of pozzolans required to control expansion by ASR depends on the reactivity of the aggregates and on the capacity of the pozzolan to consume $Ca(OH)_2$.

1799. Koh, E., Kamata, H., Tabata, M. and Murakami, M., "POSSIBILITY OF ALKALI-SILICA REACTION IN CASE OF CRUSHED STONE OF ANDESITE AROUND SAPPORO AREA (in Japanese)," Proc. of Annual Meeting, JCI, 1984.

KEY WORDS: reactive aggregates; andesites; field experiences; Japan

There were found many aggregates which contained cristobalite or tridymite, and might cause expansion by AAR in high alkali content.

1800. Minakami, K., "HOW CAN WE PREVENT ALKALI-AGGREGATE REACTION? (in Japanese)," Kensetsu Gijutsu (Construction Technology), No. 10, 1984.

KEY WORDS: alkali aggregate reactions

A lecture on alkali aggregate reaction based on researches performed in foreign countries.

1801. Morino, K., "MICROSCOPIC OBSERVATION OF ALKALI-REACTIVE AGGREGATE AND REACTION PRODUCTS," CAJ Review of the 38th General Meeting-Technical Session, pp. 104-107, 198.

KEY WORDS: alkali aggregate reactions; alkali silica gel; crystallized gel; expansion

(1) Secondary reaction products with various types of crystal forms were observed within cracks in aggregates and in mortar. These crystalline minerals had a larger volume than primary alkali silica gel. (2) In addition to the swelling of alkali silica gel, the expansion and the cracking of the damaged alkali aggregate reacted concrete was thought to be caused by the porous secondary minerals of acicular and platy crystal forms.

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1802. Morino, K., "THE PETROGRAPHICAL STUDY OF ALKALI-REACTIVE AGGREGATE," Transactions of the Japan Concrete Institute, Vol. 6, pp. 207-214, 1984.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; glass; crystallized gel; expansion; petrography

(1) The distributions of the reactive rocks in the andesite quarries were observed in two cases. In one case, reactive rocks were distributed in narrow belts of distinctive strata, and in the other case, in an irregular complex state. The former may be controlled, but the latter cannot. (2) The reacted andesite aggregate caused cracking, and formed reaction-rim and reaction products in the aggregate and mortar matrix. These reactions were mostly due to volcanic glass contained in andesite. (3) The reaction products showed various types of crystal forms. They greatly varied from gel like material to crystalline material. The typical crystal forms were rosette-like and globular aggregate states. Since the crystals were observed as cracks were developed, it was considered that the crystallization might be cause of expansion of concrete.

1803. Nakano, K., Kobayashi, S. and Arimoto, Y., "INFLUENCE OF REACTIVE AGGREGATE AND ALKALI COMPOUNDS ON EXPANSION OF ALKALI-SILICA REACTION," CAJ Review of the 38th General Meeting-Technical Session,1984, pp. 96-99.

KEY WORDS: alkali aggregate reactions; expansion; alkali effects; admixture effects; chloride effects

(1) When the alkali content was 0.95%, mortar bars showed a little expansion,considerably smaller than the limit of ASTM C 227 criteria. (2) But when alkali content was increased up to 1.95% by addition of alkali compounds, large expansions were observed, and the expansion proceeded rapidly in early stages. The amount of expansion at the age of 28 days reached almost 80% of maximum expansion. (3) Addition of various alkali compounds exerted large influences on expansion of mortar bars. Especially, the influence of NaCl was the most, and secondly $NaNO_2$. Even though equivalent $Na_2O$ contents were the same, extent of expansion varied widely dependent on the specific ion. Generally sodium compounds produced greater expansion than potassium compounds. (4) The expansion caused by ASR varied fairly widely with different types of aggregates. (5) Addition of chemical admixtures showed a unique phenomenon, in that high-range water-reducing agents produced

especially larger expansions. Expansions by the addition of other admixtures were considered to influenced by entrained air, performance of dispersant, content of alkali ions and chloride ions in admixtures, but to clarify these phenomena, further investigation is necessary.

1804. Nakano, K., Kobayashi, S., Nagaoka, S. and Arimoto, Y., "EFFECTS OF ALKALI COMPOUNDS ON THE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION (in Japanese)," Cement & Concrete (Japan), No. 446, 1984.

KEY WORDS: alkali aggregate reactions; alkali effects; expansion; chloride effects; mechanisms; dissolved silica

(1) NaCl and $Na_2SO_4$ of 2.0% $Na_2O$ equiv. accelerated AAR expansion. (2) The acceleration effect with Na was more significant than that with K. The greatest accelerating effect was shown when NaCl was used. (3) When pyrex glass was used, only 0.6% $Na_2O$ equiv. amount caused significant expansion. (4) Dissolved Si amount and 28 days mortar bar expansion accelerated by NaCl were correlated linearly.

1805. Nielsen, A., "ALKALI SILICA REACTION AND CRACK DEVELOPMENT, " Nordisk Beton, No. 3-4, 1984, pp. 87-90.

KEY WORDS: alkali aggregate reactions; cracking; field experiences; Denmark

1806. Pomeroy, C. D., "DURABILITY OF CONCRETE STRUCTURES: PHYSICAL PROCESSES RELATED TO CONCRETE," Proceedings of International Workshop, Durability of Concrete Structures, Copenhagen, Technical University of Denmark, 1984, pp. 35-47.

KEY WORDS: alkali aggregate reactions; deterioration

Concrete durability problems, including AAR, are assessed from a mechanistic point of view.

1807. Reffell, D. E., Parolis, H. C. and Labrum, P. R., "THE GROOT RIVER BRIDGE," Civil Engineer in South Africa, Vol. 26, No. 4, Apr. 1984, p. 175.

KEY WORDS: alkali aggregate reactions; preventive measures; bridge structures

Mention is made of precautions taken against alkali aggregate reaction and a break-down of cost is shown.

1808. Regourd, M., "DURABILITY PHYSICO-CHEMICAL AND BIOLOGICAL PROCESSES RELATED TO CONCRETE," Proceedings of International Workshop, Durability of Concrete Structures, 18th-20th May 1983, Copenhagen, Lyngby, Technical University of Denmark, pp. 48-71.

KEY WORDS: alkali aggregate reactions; deterioration

An overview of deterioration processes in concrete, including AAR.

1809. Regourd, M., "CHEMICAL CORROSION OF MINERAL BUILDING MATERIALS (in French)," Chantiers/ Suisse, Vol 15, 1984, pp. 115-120.

KEY WORDS: building materials; corrosion; chloride diffusion; sulfate expansion; alkali aggregate reaction

The diffusion of chloride ions, the formation of expansive ettringite and ASR are examples of chemical corrosion of building materials. Processes of deterioration include the transport of aggressive ions like $Cl^-$, $SO_4^{2-}$, $OH^-$, the reactions at the fluid-solid interfaces and the resulting erosion or cracking of materials. Driving forces are related to potential gradients like capillary pressure in the water imbibition of silicate gels or crystal growth of ettringite, chemical composition of the pore solution (sursaturation in $Ca^{2+}$, $Na^+$, $K^+$, $OH^-$, $Al^{3+}$ ions). Fluid transport is also directly related to the porosity of materials. The resistance of porous systems to the fluid transport depends on the pore size distribution of the cement paste and cement-paste aggregate interfaces.

1810. Le Roux, A. and Cador, C., "IMPORTANCE OF THE PETROGRAPHIC ANALYSIS FOR APPROACHING THE MECHANISM OF ALKALI-AGGREGATE REACTION (in French)," Bulletin of the International Association of Engineering Geology No. 30, 1984 , pp. 255-

258.

KEY WORDS: alkali aggregate reactions; reactive aggregates; alkali release; scanning electron microscopy

Aggregates used in concrete are submitted to an aggression by the hyperbasic medium. This chemical reaction is known as the alkali aggregate reaction and can be either limited or sometimes so well developed that it lead to the ruin the whole structure. The evolution of the reaction depends on several factors: the petrographic characteristics, the penetration of aggressive solution into the aggregates and above all the state of alteration of specific area measurements and visualized by petrographic analysis in optical and electronic microscopy. The examples presented in the paper point out the development of reaction and the evolution of the phenomenon on function of the petrographic properties and of the state of alteration of aggregates used. Reactive gneiss, granites, mica schists, rhyolites, diorites and quartzites are depicted microscopically. The reactions result in: (1) formation of phyllitic materials from altered feldspars (2) opening of cleavage planes in micas, and (3) formation of etch pits at the surface of quartz grains. In a deteriorated concrete different zones of reaction products surround aggregates. They are massive and cracked gel, structured gel, and cement paste partly gelified. Deteriorated minerals provide alkalies. Calcium ions also favor the reaction.

1811. Samuel, G., Mullick, A. K., Ghosh, S. P. and Wason, R. C., "ALKALI SILICA REACTION IN CONCRETE - SEM AND EDAX ANALYSES," Proceedings of the 6th International Conference on Cement Microscopy, 1984, pp. 276-291.

KEY WORDS: alkali aggregate reactions; scanning electron microscopy; EDX analysis; IR spectroscopy; field experiences; India

In an exhaustive investigation of the cause of cracking in a concrete dam, a number of techniques like physical and non-destructive testing, chemical analysis, XRD, DTA and IR-spectroscopy, optical and electron microscopy were employed, which led to the diagnosis of ASR as the cause, the first of its kind in the country. This paper presents the results of microstructural investigation along with energy dispersive X-ray analysis of ASR on SEM.

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1812. Tamura, H., Hoshino, Y. and Saito, H., "AN EXPERIMENT ON RAPID IDENTIFICATION OF ALKALI REACTIVITY OF AGGREGATE," CAJ Review of the 38th General Meeting-Technical Session, 1984, pp. 100-103.

KEY WORDS: alkali silica reaction; cracking; Young's modulus; pulse velocity

(1) By the accelerated methods, cracking of mortar due to alkali aggregate reaction will occur rapidly. (2) As far as these experiments are concerned, mortar made with innocuous sample does not crack. However, mortar made with deleterious or potentially deleterious sample cracks. As for the reductions in dynamic Young's modulus and ultrasonic pulse velocity, there are significant differences between mortar made with innocuous aggregate and with deleterious or potentially deleterious aggregate. (3) The reduction ratios of dynamic Young's modulus and ultrasonic pulse velocity of mortar made with aggregate inclusive of 50% innocuous sample by weight are greater than mortar with aggregate inclusively of innocuous sample.

1813. Yuan, M. Q., Ye, Y. F., Lu, Y. N. and Tang, M.-S., "THE ALKALI REACTIVITY OF ELECTRICAL CERAMIC SAND (in Chinese)," Silicate Circular, Vol. 3, No. 6, 1984, pp. 22-27.

KEY WORDS: reactive aggregates; ceramic sands; field experiences; China

1814. Aitcin, P. C. and Regourd, M., "THE USE OF CONDENSED SILICA FUME TO CONTROL ALKALI-SILICA REACTION - A FIELD CASE STUDY," Cement and Concrete Research, Vol. 15, pp. 711-719, 1985.

KEY WORDS: alkali aggregate reactions; preventive measures; field experiences; Canada; silica fume

In 1980 a sidewalk was built at Becancour, Quebec, with condensed silica fume. The addition of condensed silica fume in a series of concretes made with the reactive aggregates and cement rich in alkalies controlled the alkali aggregate reaction. Despite the calcareous nature of the coarse aggregate, it is actually an ASR that is involved due to the presence of very reactive fine vitreous silica particles more or less uniformly distributed in the mass of the limestone. The alkali aggregate reaction is still under control in most of the concrete. These field results are in good agreement with published conclusions of previous laboratory research. The two leaner mixes, where the total amount of alkalies was 1.6 and 2.2 $kg/m^3$ and the condensed silica fume dosages quite high at 40 percent and 20 percent, did not show any trace of silicate gel formation. In the two richer mixes, where the total amount of alkalies was 3.6 and 4.7 $kg/m^3$ and the condensed silica fume dosage only 15 percent, it has been possible to find, in a few places, some traces of potassium silicate gel. The severe scaling observed just after one winter of exposure in the leanest concrete (G-2) and the start of scaling in other lean concrete (E-4) has been clearly identified as the result of severe exposure conditions: freeze-thaw cycles and frequent applications of deicing salts.

1815. Akashi, T. and Takagi, N., "STUDY ON NON-DESTRUCTIVE TESTS OF ALKALI-SILICA REACTION," CAJ, Review of the 39th General Meeting-Technical Session, 1985, pp. 250-253.

KEY WORDS: alkali aggregate reactions; pulse velocity; modulus of elasticity; mortar bars

1816. Benshtejn, I. I., Ershova, L.A. and Pamina, N.S., "THE EFFECT OF SILICA-BASED ADDITION IN THE INTERNAL CONCRETE CORROSION PROTECTION (in Russian)," Z.P.K. Vol. 58, pp. 1308-1312.

KEY WORDS: alkali aggregate reactions; preventive measures; silica; pozzolans; opal

The addition of 5 to 20% of finely ground opal increases the silica concentration in the pore solution and reduces the osmotic pressure due to the reactivity of aggregates with alkalis.

1817. Berard, J., "PETROGRAPHIC STUDY OF REACTIVE AGGREGATES IN QUEBEC (in French)," Atelier International sur les Reactions Alcalis-Granulats Dans le Beton et sur la Construction et Rehabilitation de Parcs de Stationnement Etages en Beton - Montreal, 25 Pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; limestone; granite; quartzite; field experiences; Canada

After having studied a large number of concrete structures in Quebec it can be concluded that the majority of rocks containing silica are reactive. The ASR is either slow as with granites or rapid with limestone containing amorphous silica. Three classes of ASR have been found: (1) Peripheral attack of non porous aggregates (granite). (2) Attack and bulk swelling of porous rocks (quartzite). (3) Swelling by formation of silica gel veins through rocks (limestone)

1818. Berube M. A., Fournier B. and Vezina, D., "EVALUATION OF THE POTENTIAL ALKALI REACTIVITY OF LIMESTONE AGGREGATES IN QUEBEC PROVINCE (in French)," ACI Section - Ottawa GGL - 85-31 Report, 55 pages.

KEY WORDS: reactive aggregates; limestone; field experiences; Canada; petrography

Four limestone quarries have been explored and rock samples analyzed for their potential reactivity with alkalis. Concrete structures built with these aggregates have been inspected. The reactivity of limestones has been related to a very fine network composed of reactive silica and clays. Deterioration of concretes has been increased when deicing salts were used. The petrographic examination of rocks before their use in concretes is a reliable preventive test.

1985

1819. Bhatty, M. S. Y., "MECHANISM OF POZZOLANIC REACTIONS AND CONTROL OF ALKALI- AGGREGATE EXPANSION," Cem. Concr. Aggregates, Vol. 7, No. 2, Winter 1985, pp. 69-77.

KEY WORDS: alkali aggregate reactions; expansion; mechanism; alkali effects; pozzolans

The mechanism of pozzolanic reactions and their control of expansion caused by alkali aggregate reaction was investigated. Mixtures of tricalcium silicate, opal, sodium hydroxide, and water having calcium oxide to silica mole ratios from 1.07 to 3.0 were prepared and reacted from seven days to four years before filtering. Results suggest that pozzolans reduce or eliminate alkali aggregate expansion by producing additional calcium silicate hydrate and low lime calcium silicate hydrate.

1820. Blanchard, J., Figg, J., Pettifer, K. and Rayment, P., "OBSERVATION ON THE MECHANISM OF ALKALI-SILICA REACTIONS IN CONCRETE: RHYTHMIC REACTIONS (LIESEGANG RING FORMATION)," Cement and Concrete Research, Vol. 15, pp. 21-26, 1985.

KEY WORDS: alkali aggregate reactions; reactive aggregates; glass; mechanisms

Studies of reacted glass particles in concretes affected by deleterious alkali-silica reaction appear to show that the relatively slow diffusion of hydroxyl ions followed by comparatively fast reaction induces rhythmic reaction and periodic cracking analogous to Liesegang Ring formation. No evidence for sodium ion diffusion into the cement paste could be obtained by EPMA. At least for glassy silicate materials the reaction mechanism for ASR may be envisaged as steady penetration of hydroxyl ions from the cement paste into the siliceous aggregate until some constant value of concentration is attained at a distance x from the outside where a significant number of siloxy bonds are ruptured to create negatively-charged silicate fragments. Near electrical neutrality will be restored by diffusion of alkali metal ions ($Na^+$ or $K^+$) either within the aggregate (if an alkali containing glass) or from the cement pore fluid. Water molecule diffusion into the gel reaction product may then in turn create sufficient stress to exceed the strain capacity of the silicate particle to induce cracking and expansion of the cement matrix. Further diffusion of hydroxyl ions into the reactive silicate aggregate would then repeat the process. In practice both diffusion-reaction and swelling phases would progress

contemporaneously.

1821. Chatterji, S. and Fordos, Z., "EFFECT OF FLYASH ADDITION ON ALKALI-SILICA EXPANSION," Nordic Concrete Research, No. 4, Dec. 1985, pp. 36-44.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; preventive measures; pozzolans; fly ash

The influence of fly ash on the ASR was investigated by preparing cement paste, mortar and concrete specimens with 25-30 weight percent replacement of cement with fly ash. Standardized (ASTM C 411) and modified accelerated test methods have been used. Results obtained so far indicate that the presence of fly ash reduces the expansion in cement paste, mortar and concrete.

1822. Comite Euro International du Beton, "DRAFT CEB GUIDE TO DURABLE CONCRETE STRUCTURES," CEB Bulletin information No. 166, Lausanne, CEB, 1985, 306 pages.

KEY WORDS: durability; alkali aggregate reactions

1823. Costa, U. and Massazza, F., "INFLUENCE OF SUPERPLASTICIZERS ON THE PORE SOLUTION COMPOSITION OF PORTLAND CEMENT MORTARS," Proceedings of the AITEC Symposium "Cement and Concrete in Eighties", Parma, October 17-18, 1985; II Cemento, Vol. 83, No. 4, October/December 1986, pp. 415-426 (In English and Italian).

KEY WORDS: pore solutions; admixture effects; alkali effects; chemical admixtures; superplasticizers

1824. Dobie, T. R., "CORRELATING WATER-SOLUBLE ALKALIES TO TOTAL ALKALIES IN CEMENT - CONSIDERATIONS FOR PREVENTING ALKALI-SILICA POPOUTS ON SLABS," Alkalies in Concrete, ASTM STP 930, 1985, pp. 46-57.

KEY WORDS: alkali aggregate reactions; popouts; alkali effects; pore solutions

Increased alkali concentration at the slab surface due

to mixing water migration and evaporation increases the likelihood of popouts. Increases in alkali concentration of over 600% are possible. Those alkalies in the concrete making materials which are ready soluble in the fresh concrete mix are implicated in the formation of alkali-silica shale popouts. All the materials in the concrete should be considered, particularly the cement and fly ash. In the field, precautions should be taken to minimize the rate of evaporation of water from the slab surface prior to final finishing. Moist curing methods are preferable to membrane methods.

1825. Federation Nationale de Travaux Publics, "PREVENTION OF AGGRESSIVE ATTACKS ON CONCRETE: ALKALI AGGREGATE REACTION (in French)," Paris, France, FNTP, 1985. pp. 1-22.

KEY WORDS: alkali aggregate reactions; preventive measures

1826. Fujiwara, Y. Matsuoka, Y., Kaneko, S. and Naito, T., "CHEMICAL MINERALOGICAL STUDY OF CONCRETE WITH NON-STRUCTURAL CRACKS (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; cracking;

Causes of deterioration in 4 concrete structures and other examples on which similar deterioration was observed were investigated by chemical and mineralogical approaches.

1827. Futamura, S. and Fukushima, M., "MECHANISM OF ALKALI-SILICA REACTION OF CRUSHED STONE FOR CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: reactive aggregates; field experiences; Japan

Some crushed stones used as aggregates around the Osaka area were investigated and their chemical reactivity were reported.

1828. Idorn, G. M. and Roy, D. M., "OPPORTUNITIES WITH ALKALIES IN CONCRETE TESTING, RESEARCH, AND ENGINEERING PRACTICE,"

Alkalies in Concrete, ASTM STP 930, 1985, pp. 5-15.

KEY WORDS: alkali effects; preventive measures; mechanisms

(1) The deleterious effects of the hydration of silica in the presence of alkalies, known as ASR when occurring with siliceous aggregates, can be mitigated or prevented when adequate silica is available in finely ground slag, fly ash, natural pozzolana, or silica fume. (2) The alkalies may have a beneficial effect on the rheology of fresh concrete with mineral admixtures. (3) Alkalies may have a corresponding densifying effect on the microstructure of the hardened cement paste, important for the durability of concrete towards aggressive exposure conditions. (4) Updating of the applications of silica chemistry can be helpful for development of testing to represent adequate laboratory modeling of the characteristics of contemporary concrete with advantageous uses of the alkalies present in the system and mineral admixtures.

1829. Kasami, H., Yoshioka, Y., Shinozaki, M., Ohno, S., Takahata, A. and Morikawa, T., "STUDY ON THE ALKALI REACTIVE AGGREGATE IN JAPAN AND AN ACCELERATED METHOD TO EVALUATE THE REACTIVITY OF AGGREGATES (in Japanese)," Takenaka Technical Research Report, No. 34, Nov. 1985, pp. 49-65.

KEY WORDS: reactive aggregates; andesites; field experiences; Japan; test methods; mortar bars

Deterioration due to alkali aggregate reaction has been reported in Japan. The aggregate causing the deterioration was an andesite which contained cristobalite or volcanic glass. This paper discusses tests to evaluate reactivity and to confirm the preventive effect of pozzolans against the expansion. The andesite aggregate were evaluated as potentially deleterious by the chemical method (ASTM C 289). High alkali content in the materials increased the expansion of concrete and mortar specimens due to alkali aggregate reaction. Using a blend of ordinary cement with pozzolan avoids the expansion due to alkali aggregate reaction. An accelerated method is proposed to evaluate the reactivity of aggregates. Various aggregates in Japan were investigated by the accelerated method gave good agreement with the results of the mortar bar test.

1985

1830. Katawaki, K. and Moriya, S., "EXPERIMENTAL STUDY FOR CONTROL OF ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; preventive measures; moisture effects; coatings

This paper is interim report of research on coating materials for controlling AAR.

1831. Kawamura, M. Takemoto, K. and Hasaba, S., "AN INVESTIGATION ON CONCRETE PIERS DAMAGED BY ALKALI SILICA REACTION," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 262-265.

KEY WORDS: alkali aggregate reactions; pier structures; field experiences; Japan

1832. Kawamura, M. and Takemoto, K., "EFFECT OF SILICA FUME ON ALKALI-SILICA EXPANSION AND ITS MECHANISM," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 258-261.

KEY WORDS: alkali aggregate reactions; expansion; Beltane opal; mortar bars; EDX analysis; microhardness; silica fume

1833. Kawamura, M. and Hasaba, S., "MECHANISM OF ALKALI-SILICA REACTION AND ITS PREVENTION METHODS (in Japanese)," Gypsum & Lime (Japan), Vol. 194, 1985.

KEY WORDS: alkali aggregate reactions; pore solutions; alkali effects; pozzolans; preventive measures

Thanks to researches on mechanism of ASR, it has been found that some alkali aggregate reactions do not occur in pore solutions of which OH concentration is below certain limit. One way to achieve low OH concentration of pore solution is to apply pozzolans and other mineral admixtures.

1985

1834. Kishitani, K. and Yoon, J. H., "ALKALI-SILICA REACTIVITY OF GLASSY ORTHOPYROXENE ANDESITE (in Japanese)," Trans. Japan. Concr. Inst., Vol. 7, 1985, pp. 105-112.

KEY WORDS: alkali aggregate reactions; alkali effects; field experiences; Japan; preventive measures

This paper is about the reaction between the alkalis present in the pore fluids of the cementitious phases of concrete and glassy orthopyroxene andesite occurring in the Setouchi volcanic rocks in Japan. Geological and petrological characteristics of the reactive aggregate are investigated. Cement alkali content necessary to show deleterious expansion by ASTM C227 mortar bar method is given. A formula which can predict the pessimum content for any given mortar is presented as the function of critical alkali silica ratio. An estimate of the maximum alkali content which does not show deleterious expansion in mortar and concrete is obtained.

1835. Kishitani, K. and Hwan, Y.J., "SAFE LIMIT OF ALKALI CONTENT IN ALKALI-SILICA REACTION," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 240-243.

KEY WORDS: alkali aggregate reactions; mortar bars; alkali effects; preventive measures

(1) When alkali reactivity aggregate is evaluated by ASTM C-227 method, it is necessary to increase the alkali level of cement to about 1.0% $Na_2O$ eq. or if possible 1.2-1.4% $Na_2O$ eq. (2) Within the range of test results, it is concluded that safe limit of alkali content is 3-5 kg/$m^3$ $Na_2O$ eq. in mortar and 5 kg/$m^3$ $Na_2O$ eq. in concrete. (3) Great care must be taken to use reactive aggregate limiting alkali content of concrete because alkali content in concrete can be enhanced from other than cementitious materials.

1836. Kishitani, K. and Hwan, Y. J., "ALKALI-SILICA REACTIVITY OF GLASSY ORTHOPYROXENE ANDESITE (in Japanese)," Transaction of the Japan Concrete Institute, Vol. 7, pp. 105-112, 1985.

KEY WORDS: alkali aggregate reactions; field experience; Japan; reactive aggregates; andesites; alkali effects; preventive measures

(1) The occurrence of volcanic glass and cristobalite in the glassy orthopyroxene andesite (Sanukitoid) was confirmed by petrographical investigation. (2) Sanukitoid was estimated to be potentially deleterious by ASTM C-289 and showed deleterious expansion by ASTM C-227 when the alkali content of cement was enhanced over a certain level. (3) The pessimum content of reactive aggregate varied according to the mix proportions of mortar and cement alkali content, but the critical alkali:silica ratio which shows maximum expansion is constant. (4) If the critical alkali:silica ratio of a reactive aggregate is known, the pessimum content of a certain mix proportion of mortar with a certain content of alkali can be calculated by the presented method. (5) Safe limits of alkali content that did not show deleterious expansion was 3 $kg/m^3$ $Na_2O$ eq. in mortar and 5 $kg/m^3$ $Na_2O$ eq. in concrete when Sanukitoid was used as the reactive aggregate.

1837. Knudsen, T., "ON THE POSSIBILITY OF FOLLOWING THE HYDRATION OF FLYASH MICROSILICA AND FINE AGGREGATE BY MEANS OF CHEMICAL SHRINKAGE," Cement and Concrete Research, Vol. 15, pp. 720-722, 1985.

KEY WORDS: alkali aggregate reactions; test methods; chemical shrinkage

Reaction between the cementitious materials and an aqueous solution containing alkali hydroxides, calcium hydroxide, calcium sulfate, etc. can be followed by measuring chemical shrinkage. A project has been started at our institute with the aim of studying the hydration reactions of other materials than Portland cements and in particular the alkali-silica reactions taking place in concrete. The experiments have used 10 molar sodium hydroxide as the reactive solution and we have obtained "well-behaved hydration curves" with total chemical shrinkage ranging from 0.2 ml/100g for some Danish sands to 5 ml/100g for opal and pyrex glass. The possibility of studying the alkali-silica reaction per se, and not by means of following its resulting expansion in mortar or concrete, seems to offer a remarkable opportunity of separating reaction from the expansion.

1838. Kobayashi, S., Ono, K., Kohno, H. and Sasaki, I., "INFLUENCE OF VARIOUS ALKALI IONS ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; alkali effects

The following conclusions were obtained from the results of mortar bar tests,: (1) Alkali from outside affected the reaction as well as alkali in the mortar bars. (2) Chloride ions did not affect alkali aggregate reaction. (3) Amount of expansion was determined by alkali content per unit volume of mortar when alkali content was comparatively low. (4) K and Na ions influenced reaction to the same degree when the alkali content was low. When the alkali content was high, the Na ion influenced reaction more than the K ion.

1839. Koh, E., Kamata, H., Suzuki, H. and Ichinohe, Y., "EVALUATION OF ALKALI REACTIVE AGGREGATES BY SEVERAL TESTING METHODS (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: reactive aggregates; andesites; Japan; test methods; quartz; tridymite; cristobalite

Experiments on commercial 9 reactive aggregates, 4 non-reactive aggregates, and 2 reactive sands were performed. (1) Andesite aggregates showing significant expansion and being judged as harmful by chemical test, contained cristobalite or tridymite. (2) If the silica in andesite aggregates turned out to be quartz by XRD, the aggregate did not expand and was classified as harmless by chemical test. But this rule did not hold for sands made of sedimentary rock. (3) Concrete specimens expanded more slowly and continuously than mortar bars. (4) The reactive aggregates used did not show harmful expansion by mortar bar test as long as commercial cements were used. Other factors which supposed to increase alkali, should be checked.

1840. Koyanagi, W., Rokugo, K. and Ishida, H., "EFFECT OF REINFORCEMENTS ON CONCRETE DETERIORATED BY ALKALI-SILICA REACTION," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 266-269.

KEY WORDS: alkali aggregate reactions; cracking; reinforced concrete

1985

1841. Kusano, M., Kobori, M., Yamada, M. and Tazawa, E., "POSSIBILITY OF ALKALI-AGGREGATE REACTION IN CASE OF CHERT AND SLATE PRODUCED IN HIROSHIMA DISTRICT (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; reactive aggregates; chert; slag; preventive measures

A chert and a slate produced in the same quarry were investigated and the chert turned out to be harmful. Class B blast furnace slag and sulfate resistant cement were effective in controlling expansion due to AAR. NaOH caused more expansion by AAR compared to NaCl.

1842. Li, S. Q., Roy, D.M. and Kumar, A., "QUANTITATIVE DETERMINATION OF POZZOLANAS IN HYDRATED SYSTEMS OF CEMENT OR Ca(OH)2 WITH FLY ASH OR SILICA FUME," Cement and Concrete Research, Vol. 15, pp. 1079-1086, 1985.

KEY WORDS: pozzolans; fly ash; silica fume; preventive measures; test methods

The experimental results reported here have shown that a selective dissolution method using a picric acid-methanol-water solution is suitable to remove reacted cementitious products, and leave a residue of unhydrated pozzolanas, such as fly ash and silica fume that was mixed with the cement. This enables their quantitative determination at various ages of hydration. Silica fume was found to have a much higher early stage reactivity than low-calcium fly ash, although only 78% of the silica fume in a 10% silica fume:90% cement mixture reacted in 90 days at 38°C.

1843. Makita, M., Katawaki, K. and Moriya, S., "EXPERIMENTAL STUDY FOR ALKALI-REACTIVITY OF AGGREGATES (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; test methods; chemical test

Experimental conditions of the chemical test method were investigated. (1) Alkali reactivity of aggregates varied significantly so the specified period of reaction, 24 hours, was not always appropriate. (2) High temperature promoted reaction and 80°C was found to be feasible in the experiment. (3) Shaking action of the container accelerated

the reaction. (4) Reactivity to NaOH and KOH were so different that the standard formula to convert alkali content of cement into $Na_2O$ equivalent should be reconsidered.

1844. Makita, M., Kobayashi, S., Kohno, H. and Ishii, Y., "SOME PROBLEMS ON MORTAR BAR TEST (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: test methods; mortar bars

The following problems on ASTM C 227 were stated. (1)The flow value in ASTM was different from that of Japanese standard, which caused some confusion. (2) The expansion value might differ by setting the specimen or the calibration scale upside down. (3) The amount of expansion varied with environments of humidity in which the specimens were stored. (4). The alkali content of the standard test for judging the reactivity of aggregates should be adjusted to 1.1% to 1.2%.

1845. McIver, J. R. and Davis, D. E., "A RAPID METHOD FOR THE DETECTION AND SEMI-QUANTITATIVE ASSESSMENT OF MILLED GRANULATED BLASTFURNACE SLAG IN HARDENED CONCRETE," Cement and Concrete Research, Vol. 15, pp. 545-548, 1985.

KEY WORDS: slag; petrography; test methods; preventive measures

Conventional petrographic study provides a rapid method of establishing the presence of MGBS in the cement fraction of hardened concretes; the method requires no knowledge of the chemistry of the constituents of the concrete. Although only semi-quantitative results can be reported these are likely to be adequate for the purpose required and at least comparable to results based on chemical analysis.

1846. Millet, J. C., "ALTERATION OF CONCRETE IN THE CHAMBON DAM (in French)," Seminar CEIFICI (Centre d'Etudes, d'Information et de Formation pour les Ingenieurs de la Construction et de l'Industrie).

KEY WORDS: alkali aggregate reactions; field experiences; France; mechanisms; reactive aggregates; dam structures;

repairs

The Chambon Dam built in 1935 started to deform in 1950 and to crack in 1981. Laboratory studies on concrete cores have shown that: (1) the amount of alkalis in cement was between 0.6% and 0.8% $Na_2O$ eq. (2)the reactive part of siliceous aggregates was composed of schists, feldspars, and micas. (3) Altered feldspars and micas liberated alkali (4) the ASR was a slow reaction. In order to repair the dam several possibilities have been looked at. They are (i) a mask in reinforced concrete able to slide on the actual dam (ii) stress release cuts at strategic places.

1847. Nakano, K., Kobayashi, S., Nagaoka, S. and Araigawa, H., "A STUDY OF TESTING METHOD FOR ALKALI REACTIVE AGGREGATE BY X-RAY DIFFRACTION ANALYSIS," CAJ Review of the 39th General Meeting-Technical Session,1985, pp. 234-237.

KEY WORDS: reactive aggregates; test methods; X-ray diffraction

(1) It was confirmed that the amount of alkali reactive minerals included in the aggregates can be detected by treating with NaOH solution and using X-ray diffraction method. (2) To treat aggregates with 20% NaOH solution at 80°C for 6 hours was the optimum condition. (3) This method is suitably applied to aggregates which Sc is more than 100 Mm/l.

1848. Ohno, S., Kasami, H., Yoshioka, Y. and Morikawa, T., "ACCELERATED TEST METHOD FOR EVALUATING ALKALI-REACTIVITY OF AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; autoclaving; alkali effects

(1) A pyroxene andesite used in this experiment judged harmful by chemical test method, did not always show harmful expansion by mortar bar test in such case that alkali content was below 1.1 %. (2)When the mortar bars were immersed in 1 N NaOH solution for 24 hours and autoclaved at temperature of 80°C, significant expansion was observed in 7 days with reactive aggregates. (3) The results of the mortar bar test and this accelerated test were well correlated when different factors of reactive

aggregate contents or alkali contents were explored.

1849. Ohoshima, H. and Ikenaga, H., "A STUDY ON PROMOTION FOR ALKALI-AGGREGATE REACTION OF CONCRETE DUE TO SEA SAND," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 248-249.

KEY WORDS: alkali aggregate reactions; sand; field experiences; Japan

1850. Okada, K., Imai, H., Ono, K. and Minamigawa, Y., "EXPANSION CHARACTERISTICS OF CONCRETE SPECIMENS AND MORTAR BARS WITH REACTIVE AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; test methods; concrete prisms; mortar bars; expansion

Expansion of a 10 cm x 10 cm x 40 cm concrete specimen with a reactive aggregate was measured. Though expansion was less than that of the mortar bars tested, it became significant at a certain alkali content. Concrete made of non-reactive coarse aggregate but of reactive sand seemed to expand.

1851. Okada, K., Mizumoto, Y. and Ono, K., "EXPERIMENTAL STUDY ON CORRELATION BETWEEN CHEMICAL METHOD AND MORTAR BAR METHOD (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; test methods; chemical methods; mortar bars; cracking

Results of the chemical method and the mortar bar method were compared for a reactive aggregate. Also crack conditions of concrete structures made of the same aggregate were investigated.

1852. Perry, C. and Gillott, J. E., "FEASIBILITY OF USING SILICA FUME TO CONTROL CONCRETE EXPANSION DUE TO ALKALI-AGGREGATE REACTIONS," Durability of Building Materials, Vol. 3, No. 2, Nov. 1985, pp. 133-146.

1985

KEY WORDS: alkali aggregate reactions; expansion; silica fume; chemical admixtures; preventive measures; superplasticizers

The influence of silica fume on expansion due to ASR and alkali carbonate reaction was studied at cement replacement levels of 0-40%. Specimens were stored at temperatures of 23°C, 38°C and 50°C, and length-change data were obtained for up to 2 years. The expansion of mortar bars containing reactive silica (opal) was increased when 5% cement was replaced by silica fume, but was eliminated at replacement levels of 20% or more. Superplasticizers of the sulphonated naphthalene formaldehyde type increased expansion of mortar bars containing opal and 0-10% silica fume, whereas lignosulphonate-based admixtures decreased expansion. The reduction in the latter case was probably due to air entrainment by the admixtures. Silica fume was ineffective in suppressing expansion due to alkali carbonate reactions, although some reduction was observed.

1853. Saji, Y., Matsufuji, Y. and Tateno, K., "STUDY ON THE RAPID ESTIMATION METHOD OF ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; mortar bars; test methods; moisture effects

Several aggregates were investigated for their reactivity by mortar bar tests, and a test on water absorption of aggregates was suggested for a rapid estimation method for AAR.

1854. Smith, R. L. and Raba, C. F., Jr., "RECENT DEVELOPMENTS IN THE USE OF FLY ASH TO REDUCE ALKALI-AGGREGATE REACTION," Alkalies in Concrete, ASTM STP 930, 1985, pp. 58-68.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; fly ash

The use of pozzolans such as fly ash to mitigate alkali aggregate reactions may not always be effective and in fact such use may increase expansion if the fly ash is characterized by a high sodium content, particularly in combination with low amorphous silica content.

1985

1855. Stark, D. and Bhatty, M. S. Y., "ALKALI-SILICA REACTIVITY: EFFECT OF ALKALI IN AGGREGATE ON EXPANSION," Alkalies in Concrete, STP 930, pp. 16-30.

KEY WORDS: aggregates; alkali effects; alkali release; reactive aggregates; feldspars

Significant amounts of alkali can be released from certain alkali-bearing aggregates, especially feldspar-bearing aggregates, when these materials are powdered and immersed in saturated $Ca(OH)_2$ solution. Greater amounts of alkali were leached at 80°C than at 38°C. Removal of alkali from aggregates by such leaching in $Ca(OH)_2$ prior to their incorporation in mortar bars was shown to reduce expansions.

1856. Stievenard-Gireaud, D., "CONTRIBUTION TO THE ALKALI-SILICA REACTION IN CONCRETES (in French)," (1) Thesis 3rd cycle - Mineralogy - University Paris XI; (2) Rapport de Recherche, Laboratoire Central des Ponts et Chaussees No. 144, 104 Pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; mechanisms

This thesis deals with the setting up of a classification test of aggregates based on linear thermodynamics of irreversible processes. This theory makes it possible to attribute to each mineral a specific kinetic dissolution constant and thus to compare the specific constant with the dissolution of aggregate components in various environments.

1857. Struble, L. and Diamond, S., "INFLUENCE OF CEMENT ALKALI DISTRIBUTION ON EXPANSION DUE TO ALKALI-SILICA REACTION," Alkalies in Concrete, STP 930, pp. 31-45.

KEY WORDS: alkali aggregate reactions; expansions; alkali effects; cements; pore solutions

A study was carried out to show whether the distribution of alkalis among different cement minerals influences the expansion of mortar containing reactive aggregates. The distribution of alkalies was determined in four high alkali portland cements. Some differences in expansions resulted, especially with opal as the reactive aggregate. Cements

rich in soluble alkali sulfates showed greater rates and ultimate levels of expansion.

1858. Suzuki, K., Nishikawa, T. and Ohkubo, S., "INVESTIGATION OF CONCRETE DETERIORATION BY ALKALI- AGGREGATE REACTION AND TRIAL TO IMPROVE AGGREGATE," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 266-269.

KEY WORDS: alkali aggregate reactions; alkali silica gel; preventive measures

(1) The solidification of exuded silica gel caused by alkali aggregate reaction by carbonation corresponds to the theoretical precipitation process of solid phases from liquid with $Ca^{2+}$ and $HSiO_3^-$ ions. Thus the investigation of the reaction processes is possible by the analysis of exuded matter. (2) Coating of reactive aggregates with $MnO_2$ by burning is effective to prevent alkali aggregate reaction. This method is easier than manufacturing lightweight foamed aggregate.

1859. Suzuki, K., Nishikawa, T. and Ikenaga, H., "KINETIC INVESTIGATION OF ALKALI-SILICA REACTION BY USING QUARTZ POWDER," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 254-257. 1985.

KEY WORDS: alkali aggregate reactions; reactive aggregates; quartz; silica

1860. Suzuki, K. Nishikawa, N. and Ohkubo, S., "STUDIES ON DETERIORATION OF CONCRETE STRUCTURES DUE TO ALKALI-AGGREGATE REACTION (in Japanese)," Semento Gijutsu Nenpo (Annual Bulletin of Japan Cement Assoc.), No. 39.

KEY WORDS: alkali aggregate reactions; alkali silica gels; carbonation; preventive measures

Structures in service in which alkali aggregate reaction occurred were investigated. (1) Reaction products inside of concrete were mostly silica gel and that exuded outside of the structures was mostly $CaCO_3$. (2) Dissolved Ca ion was diffused out through the cracks propagated in the microstructure due to AAR and was carbonated and solidified. (3) The process of the reaction can be

postulated by analyzing the reaction product. (4) $MnO_2$ coated aggregates were resistant to AAR at early hydration stage.

1861. Swamy, R. N. and Al-Asali, M. M., "INFLUENCE OF ALKALI-SILICA REACTION ON THE ENGINEERING PROPERTIES OF CONCRETE," Alkalies in Concrete, STP 930, pp. 69-86.

KEY WORDS: alkali aggregate reactions; structural effects; field experiences, U. K.; compressive strength effects; tensile strength effects; elastic modulus effects; cracking; silica

(1) Alkali aggregate reactions may cause substantial reductions in the engineering properties of concrete. At 0.1% expansion, the loss of compressive strength is only about 12%, but the loss in tensile and flexural strengths is substantial, amounting to about 50%. Elastic modulus loss at this stage is about 20%. (2) The compression test is not a good indicator of the beginning and progress of ASR, particularly in the early stages. Modulus of rupture or tensile strength measurements are more sensitive and reliable methods of measuring the deterioration of concrete affected by ASR. (3) The ASTM limit of 0.1% expansion over six months may need modification if it is to be applied to field structures. (4) Both dynamic modulus and pulse velocity give good indications of the deterioration of concrete affected by ASR. However, the dynamic modulus appears to be more sensitive. (5) The pulse velocity tests show that the core of the concrete is as much affected by ASR as the outer surfaces, despite lack of visible cracking. (6) Fused silica appears to be an ideal artificial reactive aggregate to simulate expansion due to ASR in the laboratory.

1862. Tamura, H., Hoshino, Y., Takahashi, T. and Saito, H., "A PROPOSAL OF THE RAPID TEST ON ALKALI REACTIVITY OF AGGREGATES (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: reactive aggregates; test methods

There were some problems in using conventional tests for checking alkali reactivity of aggregates. A rapid test method of judging alkali reactivity of aggregates (GBRC method) was proposed, and test results on 61 kinds of

reactive aggregates were reported.

1863. Tzawa, E., Nakamoto, M. and Ito, Y., "ALKALI-AGGREGATE REACTIVITY OF MATERIAL ROCK FOR CONCRETE AGGREGATE IN HIROSHIMA DISTRICT," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 244-247.

KEY WORDS: reactive aggregates; test methods; field experiences; Japan

(1) When the rock materials in the Hiroshima district were tested by random sampling, 30% were found to have the possibility of deleterious alkali aggregate reactivity by the ASTM C-227 method, and 20% by the ASTM C-289 method. Consequently, the aggregates in the Hiroshima district need to be investigated for alkali aggregate reaction. (2) As regards the accelerated curing method, it is considered that H.T.P. curing is more effective than autoclave curing. (3) When chemical reaction of the specimen containing adequate NaCl is accelerated by H.T.P. curing, a judgment with respect to alkali aggregate reactivity can be rapidly passed.

1864. Uchikawa, H., Uchida, S. and Ogawa, K., "DIFFUSION OF ALKALI ION IN HARDENED CEMENT PASTE CONTAINING SLAG OR FLY ASH (in Japanese)," Journal Research, Onoda Cement Company, Vol. 37, 113, pp. 1-9.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; fly ash; pozzolans; mechanisms

Slags and fly ashes have a beneficial effect in the resistance of concrete to alkali aggregate reaction. The pozzolanic reaction consumes $Ca(OH)_2$. Sodium ions do not penetrate and practically do not diffuse through these blended cements.

1865. Watari, Y., Kusano, M., Katayama, H. and Tokunaga, Y., "A STUDY ON THE RAPID TEST METHOD FOR ALKALI-AGGREGATE REACTIVITY (in Japanese)," Proc. of Annual Meeting, JCI, 1985.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars

Two rapid tests using mortar bars, high temperature curing (80°C, 100% R.H.) and cyclic wetting and drying curing (80°C, 30-100% R.H.), were investigated for their effectiveness. (1) Expansions in 13 days by high temperature curing were close to normal mortar bar expansions. (2) Ratios of expansion by high temperature curing and expansion by cyclic wetting and drying curing to normal mortar bar expansion approached consistent values with age. (3) Under these test conditions, NaOH accelerated expansion more than NaCl. (4) Alkali aggregate reaction products were observed in the specimens cured by both rapid methods and by normal mortar bar tests.

1866. Yasu, S. and Maushima, N., "CASE STUDY OF ALKALI-AGGREGATE REACTION BY APPLYING PHOSPHORIC ACID METHOD," CAJ Review of the 39th General Meeting-Technical Session, 1985, pp. 238-239.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods

Quantitative analysis of free silica which is dissolved in minerals (except $SiO_2$ and $SiO_2$-$nH_2O$) by phosphoric acid is adopted as a standard testing method for working environment in Japan. This is called the phosphoric acid method. The results of case studies of the alkali aggregate reaction by applying the phosphoric acid method are reported.

1867. Akashi, T., Amasaki, S., Takagi, N. and Tomita, M., "THE ESTIMATE FOR DETERIORATION DUE TO ALKALI-AGGREGATE REACTION BY ULTRASONIC METHODS," Proc. 7th Intl. Alkali Conf. 1986, pp. 183-187.

KEY WORDS: alkali aggregate reactions; test methods; mechanical properties; field experience; pulse velocity measurement; ultrasonic methods

In this study, the deterioration of a reinforced concrete structure due to alkali-aggregate reaction was estimated by using ultrasonic methods.Tests were carried out for concrete with reactive bronzite andesite, crushed stone and total equivalent $Na_2O$ of 6 $kg/m^3$. The specimens were cured in the chamber at 40°C and 100% RH for two months after the age of 14 days. The pulse velocity was measured during the accelerating curing period, and after the age of 10 months, the spectral analysis of ultrasonic pulse waves transmitted through concrete was applied to estimate the deterioration. The pulse velocity of test specimens decreased abruptly along with compressive strength and modulus of elasticity because of deterioration due to the reaction. On the other hand, the pulse velocity of the concrete cores slightly decreased due to the residual expansion after sampling the core, and then it increased to more than the velocity of the test specimen because the silicate gel formed by the reaction may have filled in the cracks. It is easy to estimate the deterioration due to the reaction by the ultrasonic pulse velocity method and the spectral analysis of ultrasonic pulse waves transmitted through concrete.

1868. Al-Dabbagh, I., "FLINT CHARACTERISTICS AND ALKALI-SILICA REACTIVITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 413-417.

KEY WORDS: alkali aggregate reactions; mechanisms; flint; silica; reactive aggregates

As would be expected, shape, sizes, distribution, continuity, and percentage of micropores in flint particles will affect the rates of internal reaction between the particles and alkaline solutions. Three varieties of flint particles chosen on the basis of color were utilized to determine pore entry radii, pore size, and interior surface area distributions using mercury intrusion porosimetry. A careful visual examination was carried out of the reaction

products formed on these natural aggregates after being immersed in alkaline solutions. Photographic records of the different silica gels were also obtained and compared. The results suggest that the grey/black flint has two distinct sizes of individual pore spaces which allow the ready movement of both air and solution. The pure white and cream/brown flints showed that the smaller micropores are predominant. There is also an indication that cream-brown flint is more reactive in alkaline solutions than the other two varieties, and apparently produces four distinct types of gel morphology at different temperatures under these conditions.

1869. Albert, P. and Raphael, S., "ALKALI-SILICA REACTIVITY IN THE BEAUHARNOIS POWERHOUSES, BEAUHARNOIS," Proc. 7th Intl. Alkali Conf. 1986, pp. 10-16.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences; Canada

Concrete expansion due to ASR is the main cause of the abnormal behavior of the structures investigated. The life span of the reaction exceeds 50 years. The deformations at the junction of the wingwalls and water intakes may be detrimental. The overall stability of the structures is consistent with USBR standards. The complexity of the problem due to the alkali silica reactivity denotes the importance of making a global analysis at first to identify the cause and effects, and then to formulate corresponding corrective measures.

1870. Andriolo, F. R. and Sgaraboza, B.C., "THE USE OF POZZOLAN FROM CALCINED CLAYS IN PREVENTING EXCESSIVE EXPANSION DUE TO THE ALKALI-AGGREGATE REACTION IN SOME BRAZILIAN DAMS," Proc. 7th Intl. Alkali Conf. 1986, pp. 66-70.

KEY WORDS: alkali aggregate reactions; field experiences; Brazil; preventive measures; pozzolans; calcined clay

Alkali silica reaction was observed during studies for the construction of the Jupia hydroelectric power plant in Brazil. The methods of evaluation used are described. It was found that the utilization of pozzolan obtained from calcination of kaolinitic clay was an appropriate preventive measure, since besides reducing the expansion stemming from ASR of the aggregate, it presented various

other benefits.

1871. Asakura, E., Murata, Y. and Tateyashiki, H., "THE EFFECT OF SODA AND POTASH ON EXPANSION DUE TO ALKALI-AGGREGATE REACTION," CAJ Review of the 40th General Meeting/Technical Session, pp. 250-253, 1986.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; cement effects

In the present study, mortar-bar test were carried out in order to clarify the effect of both Na and K alkalis on the expansion of the mortar bars, using cements of different alkali sources and reactive aggregates, and varying their proportions.

1872. Baronio, G., Berra, M., Bachiorrini, A., Delmastro, A., Montanaro, L. and Negro, A., "INFRARED SPECTROSCOPY IN THE EVALUATION OF AGGREGATES IN ASR DETERIORATED CONCRETES FROM MANY PARTS OF THE WORLD: COMPARISON WITH OTHER METHODS," Proc. 7th Intl. Alkali Conf. 1986, pp. 309-313.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; petrography; IR spectroscopy

To verify the suitability of infrared spectroscopy for the evaluation of microstructural disorder in concrete aggregates, and to determine their potential alkali reactivity, fifteen concrete samples drawn in several countries from ASR deteriorated structures were examined. Optical microscopy has confirmed the close relationship between disordered aggregates and their alkali reactivity. The sensitivity of infrared spectroscopy to microstructural disorder variations of the samples was exploited and a disorder coefficient (Cd) obtained from a simple graphic elaboration of the IR spectrum was defined. Based on the collected data, a mutual relation between the Cd values and the alkali reactivity of aggregates was determined. Aggregates that have a disorder coefficient (Cd) <120 are not reactive; those with a Cd between 120 and 200 are reactive over a long time; those with Cd between 200 and 300 are reactive over a medium time; and those aggregates with Cd > 300 are reactive in a short time.

1986

1873. Batic, O. R., Cortelezzi, C.R., Sota, J.D., Maiza, P.J., Pavlicevic, R. and Iasi, R., "BEHAVIOR OF VOLCANIC GLASSES REACTING WITH PORTLAND CEMENT ALKALI," Proc. 7th Intl. Alkali Conf. 1986, pp. 484-488.

KEY WORDS: alkali aggregate reactions; mortar bars; reactive aggregates; glasses; Argentina

Experimental work focused on samples of volcanic glass from different zones of the Argentine Republic. It included petrography, X-ray, and chemical analysis. In order to determine the degree of reactivity, mortar bars with crushed aggregates and high and low alkali cement were prepared according to ASTM C 227. Mortar bars made with some of the glassy aggregates with high alkali cement showed evidence of reactivity at early stages. Bleeding, gel, small cracks, and increases in length characterize the deterioration process. Some of the aggregates showed evidences of reaction even with low alkali cement, especially glasses with a perlitic structure.

1874. Berard, J. and Roux, R., "THE SERVICE LIFE OF CONCRETES IN QUEBEC: THE ROLE OF AGGREGATES (in French)," Canadian Journal of Civil Engineering, Vol. 13, N1, pp. 12-24, 1986.

KEY WORDS: alkali aggregate reactions; mechanisms; test methods; concrete prisms; field experiences; Canada

Coarse aggregates can react in three different ways: (1) by peripheral reaction: massive granitic rocks, (2) by bulk swelling: Potsdam orthoquartzite (3) by existence of silica gel veinules within the aggregate: Trenton limestone. Considering these three mechanisms it is easy to understand why certain aggregates react rapidly (Trenton limestone) whereas others show signs of distress only after scores of years (granites). The petrographic examination of concrete cores is a good method of diagnosis. The ACNOR A23.2.14 A test on concrete during one year gives linear expansion and detects easily the reactivity of limestone aggregates, but not easily in the case of peripheral reaction of granites.

1875. Berra, M. and Baronio, G., "THE POTENTIAL ALKALI-AGGREGATE REACTIVITY IN ITALY: COMPARISON OF SOME METHODS TO TEST AGGREGATES AND DIFFERENT CEMENT -AGGREGATE COMBINATIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 231-236.

1986

KEY WORDS: alkali aggregate reactions; petrography; test methods; mortar bars; IR spectroscopy; chemical tests

Laboratory tests on a reactive aggregate of Italian origin in combination with different types of portland cement having progressively higher alkali contents, show that the reaction does not only depend on the alkali from cement clinker but also on alkali originating from possible raw mineral addition, which cannot be detected by conventional cement test methods. Among the tests used to characterize the aggregate, the quick chemical method, ASTM C 289, was found to be unreliable, while infrared spectroscopy seems more promising. With regard to evaluating the reactivity of cement aggregate combinations, the mortar bar method suggested by RILEM appears to be the most exhaustive; this method also allowed us to ascertain the tolerable amount of reactive aggregate in combination with the cements tested.

1876. Bérubé, M. A., and Fournier, B., "THE ALKALI-SILICA REACTION PRODUCTS IN CONCRETE: STUDY OF CASES IN QUEBEC (in French)," Canadian Mineralogist Vol. 24, pp. 271-288.

KEY WORDS: concrete; aggregates; alkali aggregate reaction; reaction products; SEM; Quebec

Concrete samples from about 20 deteriorated structures have been examined by SEM: (1). Reaction products are silicate gels and crystals. Gels of the oldest structures are greatly recrystallized. (2). There is a zonation in the reaction products. On reactive aggregates and from the cement paste interface massive and isotropic gels become botryoidal then rosette-like crystals. (3). Gels contain more calcium on the cement paste side; on aggregates, gels are richer in Si and K. The composition of crystals appears stable whatever the type of aggregate. (4). In aggregate cracks or cement paste pores occur crystalline phases characterized by XRD reflections at 11, 12, 10, 6 and 8.5, 8.8 Å. This could be okenite. (5). Reactive aggregates either calcareous are mudstones with a microscopic and reticulated network of silica and clay or quartzites with chlorites in Quebec. In the Beauce, rhyolitic tuffs with a devitrified matrix containing microcrystalline quartz are also chemically instable in concrete.

1986

1877. Berube, M.-A. and Fournier, B., "PRODUCTS OF ALKALI-SILICEOUS AGGREGATE REACTION IN CONCRETE: STUDY OF A CASE OF THE QUEBEC REGION," Canadian Mineralogist, Vol. 24, Part 2, Jun. 1986, pp. 271-288.

KEY WORDS: alkali aggregate reactions; petrography; field experiences; Canada

The reactions between alkaline solutions and siliceous aggregates in concrete are usually revealed by a typical polygonal cracking and by exudations of silica alkaline gels on the concrete surface. The gels and other reaction products are also present in pores and cracks of the damaged concrete. The characteristics of the reaction products observed in samples taken from a certain number of damaged concrete structures in Quebec City area are discussed and compared with case studies found in the literature. Aggregates considered as alkali reactive in these structures have been identified in thin sections with an optical microscope.

1878. Bhatty, M. S. Y. and Greening, N.R., "SOME LONG TIME STUDIES OF BLENDED CEMENTS WITH EMPHASIS ON ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 85-92.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects; pozzolans; fly ash; calcined shale

Portland cement pastes and blended cement pastes containing opal, calcined shale, and Class F fly ash at various addition levels were hydrated for up to 14 years. Long term exposure has shown that as much as 95% of the total alkali can be retained in the blended cement pastes compared to only 15% of total alkali in portland cement paste. The amount of alkali retained in the paste depends on the nature and amount of pozzolan used in the blended pastes. It can be concluded that the lower the amount of leachable alkali from the paste, the less likely the deleterious expansion of concrete or longer the delay in deleterious expansion if insufficient pozzolan is present. In other words, more alkali tied up in the calcium silicate hydrate produces a more stable system with respect to deleterious alkali aggregate reaction. The amount of alkali retained in blended cement pastes increased as the amount of calcium hydroxide deceased. The decrease in the amount of calcium hydroxide resulted from the reaction with pozzolan and subsequent formation of calcium silicate

hydrate. It was also possible to determine the amount of pozzolan required to completely react with the calcium hydroxide produced by the hydration of cement.

1879. Blight, G. E. and Alexander, M.G., "ASSESSMENT OF AAR DAMAGE TO CONCRETE STRUCTURES," Proc. 7th Intl. Alkali Conf. 1986, pp. 121-125.

KEY WORDS: alkali aggregate reactions; structural effects; test methods; field experiences

(1) Ultrasonic pulse transmission is a useful method of assessing the condition of concrete affected by AAR. However, the results of such measurements should be calibrated with reference to a direct physical method such as the examination of cores. (2) The visual condition of cores, quantified by the petrographic examination score, provides a useful means of comparing the state of damage of one structure with another. However, the correlation between the examination score and the strength of the concrete is poor. (3) Mechanical strength and stress-strain testing of carefully site cores provide a good means of assessing the degree of damage to concrete caused by AAR. (4) The best means of assessing the extent of AAR damage to a concrete structure is to test-load the instrumented structure, or to measure the strains and deformations suffered by the structure under working load conditions.

1880. Bonzel, J., Krell, J. and Siebel, E., "ALKALI REACTION IN CONCRETE (in German)," Beton, Herstellung, Verwendung, Vol. 36, No. 9, Sep. 1986, pp. 345-348.

KEY WORDS: alkali aggregate reactions; preventive measures; field experiences; Germany

Alkali damage, arising from the use of alkali reactive North German concrete aggregate, can be avoided by strictly following the guideline "Preventive measures against damaging alkali reaction in concrete". The guide sets a limits for all types of concrete on the $Na_2O$ equivalent in cement and also limits the cement content to 500 kg/m$^3$, when aggregate containing a high level of alkali is used. The report examines to what extent the alkali reactive process can be altered and damage avoided, as a result of controlling the composition of concrete, particularly the w/c ratio, the strength of the cement and insertion of air

voids. Tests were carried out over long periods of humid storage, and the results corroborate the stipulations laid down in the guideline mentioned above.

1881. Buck, A. D., "PETROGRAPHIC CRITERIA FOR RECOGNITION OF ALKALI-REACTIVE STRAINED QUARTZ," Proc. 7th Intl. Alkali Conf. 1986, pp. 419-423.

KEY WORDS: reactive aggregates; strained quartz; petrography;test methods; undulatory extinction angles

The use of criteria based on measurement of undulatory extinction angles has been shown to be effective in predicting potential reactivity of concrete aggregates containing strained quartz. Since the procedure for measurement of the UEA by microscope is subject to several interpretations, agreement on a single universal method is urgently needed.

1882. Buck, A. D., "A DISCUSSION OF THE PAPER "INTERACTION BETWEEN CARBONATE ROCK AND CEMENT PASTE" BY P.J.M. MONTIERO AND P.K. MEHTA," Cement and Concrete Research, Vol. 16, p. 973, 1986.

KEY WORDS: reactive aggregates; interface reactions

1883. Cal, Z. Y. and Qin, W., "CHINESE EXPERIENCE IN THE USE OF ASTM METHOD," Proc. 7th Intl. Alkali Conf. 1986, pp. 76-78.

KEY WORDS: alkali aggregate reactions; preventive measures; test methods; mortar bars; blended cements; slag

This article briefly describes the experiences gained with selected cements in preventing excessive expansion of concrete due to the alkali aggregate reaction in a large hydraulic construction in China. The accelerated test method, ASTM C 441, used to evaluate the ability of individual cements to control the alkali-aggregate reaction plays an important role in insuring that satisfactory concrete is used in construction. The main conclusions drawn from the experiments are the following: (1) A maximum expansion of 0.020 percent as specified for the average of mortar bars at the age of 14 days in ASTM is quite strict.

(2) The method of evaluating the relative effectiveness of a number of different blended cements is more effective for controlling expansion than controlling the alkali content in cement. (3) Portland blast-furnace slag cements, or other blended cements are readily available in China, and also are safer than using low alkali cements.

1884. Chatterji, S., Thaulow, N., Jensen, A. D. and Christensen, P., "MECHANISMS OF ACCELERATING EFFECTS OF NaCl AND Ca(OH)2 ON ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 115-119.

KEY WORDS: alkali aggregate reactions; mechanisms; calcium hydroxide effects,; NaCl effects; preventive measures; silica fume

Mechanisms have been proposed to explain the accelerating action of NaCl and the roles of $Ca(OH)_2$ on the alkali silica reaction. Practical implications are discussed. The proposed mechanisms suggest that the expansion due to ASR may be reduced either by reducing the rates of movement of ions and water molecules and/or by a substantial removal of the free $Ca(OH)_2$ from the structure. The addition of microsilica reduces the rates of movement of ions and water molecules. However, this effect may disappear when microsilica particles are consumed by free $Ca(OH)_2$. A small addition of microsilica will delay the onset of ASR, but may not eliminate the expansion; especially if alkali salts migrate into the sample from an outside source.

1885. Chatterji, S., Jensen, A. D., Thaulow, N. and Christensen, P., "STUDIES OF ALKALI-SILICA REACTION. PART 3. MECHANISMS BY WHICH NACl AND Ca(OH)2 AFFECT THE REACTION," Cement and Concrete Research, Vol. 16, pp. 246-254, 1986.

KEY WORDS: alkali aggregate reactions; mechanisms; calcium hydroxide effects; NaCl effects;

Recently it has been observed that a concentrated solution of NaCl accelerates alkali-silica reaction and that the presence of free $Ca(OH)_2$ is a prerequisite for expansion to occur. This paper reports work done to understand the chemical processes involved. From the results of this investigation the following mechanism has been proposed to explain the above observations. In the presence of free $Ca(OH)_2$, $Na^+$ ions from alkali salts and

$OH^-$ ions from $Ca(OH)_2$, together with water molecules, penetrate the reactive grains. Si-O-Si bonds in reactive grains are broken by penetrating $Na^+$ and OH ions, thereby opening the grains for further penetration of materials. At the same time silica ions tend to diffuse out of the reactive grains. Expansion occurs when more materials enter the reactive grains than diffuse out.

1886. Chino, H., Yoshida, D., Moriya, S. and Katawaki, K., "EXPERIMENTAL STUDIES OF ALKALI REDUCTION DUE TO AGGREGATES IN ALKALI SOLUTION (in Japanese," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; mechanisms; chemical tests; alkali reduction;

For alkali reduction due to aggregate, its analysis method, cause, and influence on silica dissolution were studied. (1) Alkali reduction was related to carbonate and silica ions dissolved, for which the end points of the titration were Ph 8.0 and Ph 4.0. (2) One of the causes of the alkali reduction was adsorption of Na on the surfaces of aggregates. However, Na or K dissolved from the aggregate might compensate in part for some aggregates. (3) For aggregates for which alkali reduction was large, when the amount of aggregate per unit alkali content increased, the amount of silica dissolved from the aggregate was suppressed. This might have something to do with the pessimum proportion effect.

1887. Cmiljanic, S. and Rsumovic, M., "STUDY OF POTENTIAL ALKALI-SILICATE REACTIVITY OF AGGREGATE FROM FLUVIAL DEPOSITS IN SERBIA (YUGOSLAVIA)," Proc. 7th Intl. Alkali Conf. 1986, pp. 242-246.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; Yugoslavia; chert; silica

Fluvial deposits in rivers which drain terrains in Serbia contain sandy gravel with grains of amorphous silica. Several variants of chert are separated with different contents of amorphous silica. Amorphous grains of minerals and rock are in most cases recrystallized and appear in more stabilized forms. Petrographic investigations and chemical tests according to ASTM C 289

show that harmful alkali-silicate reaction may occur with some of river aggregates. The results of investigation according to ASTM C 227 have shown that linear expansion in mortar prisms is proportional to the content of alkalies only. Traces of the products of alkali silicate reaction were observed

1888. Denmark Ministry of Transport, "LOAD CARRYING CAPACITY OF BRIDGES SUBJECTED TO ALKALI-SILICA REACTIONS. INTERIM REPORT NO.1: THE SHEAR STRENGTH OF CONCRETE BEAM SUBJECTED TO ALKALI SILICA REACTIONS," Copenhagen, Ministry of Transport, 1986, 37 pages.

KEY WORDS: alkali aggregate reactions; field experiences; Denmark; structural effects; bridge structures

1889. Durand, B., Berard, J. and Soles, J. A., "COMPARISON OF THE EFFECTIVENESS OF FOUR MINERAL ADMIXTURES TO COUNTERACT ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 30-35.

KEY WORDS: alkali aggregate reactions; preventive measures; reactive aggregates; scanning electron microscopy; calcium hydroxide effects

Two fly ashes, one silica fume and one granulated slag were used as admixtures to test the effectiveness of these pozzolans in reducing expansion of concrete due to alkali-aggregate reaction. Standard mortar bar (ASTM C-227) and concrete prism (CSA.A23.2-14A) expansion tests were used to show the effects. Three type of aggregate were used, to represent the best known alkali-aggregate reactions: 1) Trois Riveres siliceous limestone--alkali-silica reactive; 2) Kingston dolomitic limestone--alkali-carbonate reactive; 3) Lady Evelyn Lake argillite--alkali-silica/silicate reactive. Other experimental work included the measurement of $Ca(OH)_2$ content in the cement pastes, and microstructural examination of the pastes by scanning electron microscopy. The effectiveness of the mineral admixtures in reducing expansion was different for each of the three aggregates. $Ca(OH)_2$ measurements and scanning electron microscopy revealed important differences related to the role and the efficiency of mineral admixtures according to the type of alkali aggregate reaction involved. A mineral admixture that efficiently counteracts one type of alkali aggregate reaction could be quite

inefficient for reducing another type.

1890. Factor, D. F., "INHIBITION OF ALKALI-SILICA REACTION BY NON-POZZOLANIC MECHANISMS," Proc. 7th Intl. Alkali Conf. 1986, pp. 105-109.

KEY WORDS: alkali silica reactions; mechanisms; preventive measures; complexing agents

Results to date of non-pozzolanic alkali-silica reaction inhibition mechanism studies are reported. ASTM C441 mortar bars made with a high alkali cement were used to test the abilities of a variety of admixtures to reduce expansion caused by the alkali-silica reaction. Some of the materials tested are new to concrete technology. Others are currently used in concrete but were applied in novel ways. A number of possible inhibition mechanisms were tested for effectiveness against expansion caused by reaction of alkalis with pyrex-glass aggregates. Among the alkali sequestrents examined were three crown ethers, B-cyclodextrin, and two proprietary complexing agents capable of removing alkalis from high Ph solutions. It was found that the proprietary agents effectively removed K from solution, but not Na; nevertheless, mortar bar expansions were effectively eliminated.

1891. Farbiarz, J., Carrasquillo, R. L, and Snow, P. G., "ALKALI-AGGREGATE REACTION IN CONCRETE CONTAINING FLY ASH," Proc. 7th Intl. Alkali Conf. 1986, pp. 55-59.

KEY WORDS: alkali aggregate reactions; mechanisms; preventive methods; pozzolans; fly ash; silica fume; mortar bars; expansions

Fly ash alkalis may in part be released into the pore solution, contributing to the alkali aggregate reaction. However, in general, the more cement replaced with ash, the more effective the fly ash in reducing the alkali aggregate expansions. For fly ashes with more than 1.5 percent alkali content there is a "pessimum limit" below which no beneficial effect is achieved. This limit is inherent to each particular fly ash. Test results suggest that the replacement of a portion of the cement with silica fume is more effective in reducing the alkali aggregate expansions. However, more research is needed since it seems that the silica fume can eventually become the source of silica to

react with the alkali in the mixture.

1892. Figg, J., "ASR -- INSIDE PHENOMENA AND OUTSIDE EFFECTS (CRACK ORIGIN AND PATTERN)," Proc. 7th Intl. Alkali Conf. 1986, pp. 152-156.

KEY WORDS: alkali aggregate reactions; field experiences; cracking; temperature effects

It is important that engineers should realize that deleterious ASR is a time-dependent volume-change phenomenon, with maximum expansion occurring at lower temperatures than maximum rate of reaction. Authenticated cases of ASR (except for autoclave cured concrete) all involve considerable elapsed time after casting before damage ensued (measured in years rather weeks). For an internally expanding concrete the actual direction of movement depends on the restraint imposed on the concrete member. Random cracking can only be expected in unreinforced unconstrained concretes. Whilst ASR may result in Manx or map-cracking, the opposite, that random cracking is always due to ASR, is certainly untrue. Only where cracks have been shown to originate from reacted aggregate can ASR be definitely diagnosed.

1893. Fournier, B., "THE ALKALI-SILICA REACTION PRODUCTS IN CONCRETE: STUDY OF CASES IN QUEBEC (in French)," MSc Thesis, Laval University, 61 pages.

KEY WORDS: alkali aggregate reactions; mechanisms; petrography; field experiences; Canada; alkali silica gels; reactive aggregates

SEM examination and XRD analysis of concrete extracted from ten structures deteriorated by alkali aggregate reaction in the Quebec area have shown that (1) Reaction products exhibit different micro-textures (mostly siliceous gels and rosette crystals). (2) There is a zonation between the cement paste and aggregates. Gels are more homogeneous at the cement paste border than at the aggregate surface where crystalline deposits appear. (3) The chemical composition of gels is variable inside a sample and more from one sample to another. Gels are higher in calcium near the cement paste. Reaction products are richer in Si and K near the aggregates. (4) The reactive aggregates in the concretes examined are calcareous mudstones with a

siliceous cement, quartzite sandstones; and rhyolitic tuffs.

1894. Fournier B., Berube M. A. and Vezina, D., "INVESTIGATION OF THE ALKALI-REACTIVITY POTENTIAL OF LIMESTONE AGGREGATES FROM THE QUEBEC CITY AREA (CANADA)," Proc. 7th Intl. Alkali Conf. 1986, pp. 23-29.

KEY WORDS: alkali aggregate reactions; field experiences; Canada; reactive aggregates; limestones; petrography

Laboratory tests on quarry samples and petrographic examination of concrete cores revealed a marginal potential of alkali silica reactivity for the limestone aggregates produced in the Quebec City area. The early occurrence of superficial map-cracking and the internal particle microcracking which affect the exposed concrete components seem to involve deterioration mechanisms which imply the presence of limestone aggregates in combination with wetting and drying cycles, freezing and thawing cycles, and deicing salts. More research is needed to explain this behavior.

1895. French, W. J., "A REVIEW OF SOME REACTIVE AGGREGATES FROM THE UNITED KINGDOM WITH REFERENCE TO THE MECHANISM OF REACTION AND DETERIORATION," Proc. 7th Intl. Alkali Conf. 1986, pp. 226-230.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experience; U.K.; expansion; cracking; mechanisms; ettringite

Some 40% of over 300 structures show evidence of alkali aggregate reactivity. The reactions range from just detectable to serious destructive processes. The reactive aggregates are mostly highly polymictic sands and gravels but include crushed rocks. Reactive lithologies include chert, flint, siliceous ironstone, meta-argillite, greywacke to argillite, metaquartzite, siliceous volcanics, and calcitic dolomites. The expansive reactions mostly appear to take place within the aggregate and serious expansion and cracking is often related to the juxtaposition of two or more reactive particles. Cracks developed within the aggregate are thick in the central parts of the rock fragment and become thinner towards the aggregate surface. Gel occurs within the pores of the

aggregate and issues from the rock fragments into cracks in the paste. These cracks are most damaging where a few reactive particles are close together and here the cracks tend to link the adjacent rock particles. In samples where aggregate particles have produced alkali-silicate gel it is sometimes found that very high levels of alkalies have been developed within other aggregate fragments without the particles themselves reacting. The reactions encountered do not appear to conform with the normal pessimum levels for particular lithologies and the uneven distribution of aggregate is thought to be of particular significance in producing damage. At a late stage in some reactions ettringite has been found to form in the gel and this appears to lead to further potential for deleterious expansion.

1896. Fujii, M., Kobayashi, K., Kojima, T. and Maehara, H., "THE STATIC AND DYNAMIC BEHAVIOR OF REINFORCED CONCRETE BEAMS WITH CRACKING DUE TO ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 126-130.

KEY WORDS: alkali aggregate reactions; structural effects; mechanical properties

A total of 26 model reinforced concrete beams were fabricated using the same aggregate as that involved in ASR on piers of the Hanshin Expressway in Osaka. The effects of steel ratio and arrangement of steel bars on expansion and on deterioration due to ASR were examined, and the static and dynamic behavior of the deteriorated beams was investigated. No decrease of the static load bearing capacity due to ASR was observed. Compressive stresses of 20-40 $kgf/cm^2$ were introduced to the concrete of the ASR specimen by constraint of expansion due to reinforcement. The diagonal cracks observed in the normal concrete specimens could not be clearly observed in ASR specimens. Deformational behavior of the ASR specimens was almost the same as that of the normal concrete specimens, although marked potential surface cracks due to the ASR reaction were observed. Fatigue failure was eventually induced in all specimens breaking the main reinforcing bars; the fatigue life was not affected by ASR. Slight increases of bending compressive strength in some of ASR specimens were observed with increase of load repetitions.

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1897. Fukuda, R., Kasai, Y., and Hisaka, M., "AN EXPERIMENTAL STUDY ON ALKALI-AGGREGATE REACTION BY STREAMING POTENTIAL (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; streaming potential

An electro-chemical approach to checking the reactivity of aggregate by measuring the streaming potential was examined.

1898. Futamura, S. and Fukushima, M., "INFLUENCE OF ADMIXTURES ON MORTAR EXPANSION DUE TO ALKALI-SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; mortar bars; admixture effects; alkali effects

The influence of alkali supplied by admixtures on mortar bar expansions was studied experimentally.

1899. Gavalcanti, A. J. C.T., "ALKALI-AGGREGATE REACTION AT MOXOTO DAM, BRAZIL," Proc. 7th Intl. Alkali Conf. 1986, pp. 168-172.

KEY WORDS: alkali aggregate reactions; field experiences; Brazil; dam structures; petrography

A severe cracking in the concrete structures was observed at Moxoto Dam and it was also noticed that the turbines had moved as much as 2 mm. The drilled cores showed that alkali-silica reaction was present throughout, although the extent of the reaction and the deleterious effects produced are widely variable. The paper deals on the extent of distress and describes the present condition of the dam's concrete structures and the investigation works being conducted.

1900. Giovambattista, A., Batic, O. R. and Traversa, L. P., "REACTIVITY OF ALKALIS AND SANDSTONES CEMENTED WITH OPAL AND CHALCEDONY," Proc. 7th Intl. Alkali Conf. 1986, pp. 408-412.

KEY WORDS: alkali aggregate reactions: reactive aggregates;

field experiences; Argentina; opal

An appointed Commission studied more than 400 sources of aggregate in Argentina. Three areas of the country were defined as having potentially reactive aggregates, but only 5% of the potentially reactive aggregates actually were shown to give rise to deleterious expansion in concrete. Most of these contained opal in chalcedony or in sandstone. Case studies are described.

1901. Grattan-Bellew, P. E., "IS HIGH UNDULATORY EXTINCTION IN QUARTZ INDICATIVE OF ALKALI-EXPANSIVITY OF GRANITIC AGGREGATES?," Proc. 7th Intl. Alkali Conf. 1986, pp. 434-439.

KEY WORDS: reactive aggregates; test methods; petrography; undulatory extinction angle

No definite evidence of a correlation between high UEA in quartz in granitic rocks and the expansion of concrete containing them was found. The observed expansion of the concrete probably correlates, rather, with the microcrystalline quartz content of the rocks.

1902. Grattan-Bellew, P. E. and Lefebvre, P. J., "EFFECT OF CONFINEMENT ON DETERIORATION OF CONCRETE MADE WITH ALKALI-CARBONATE REACTIVE AGGREGATE," Proc. 7th Intl. Alkali Conf. 1986, pp. 280-285.

KEY WORDS: alkali aggregate reactions; mechanical properties; carbonates

The effect of confinement on expansion and deterioration of concrete made with alkali-carbonate reactive aggregate was studied using post-tensioned concrete prisms and concrete disks confined in ring moulds. Flexure strength of confined three-year old concrete containing reactive aggregate was 80% of that of unconfined concrete made with reference limestone, while the flexure strength of unconfined concrete was only 50% of that of the reference limestone. No evidence of dedolomitization was found in either concrete made with reactive aggregate. This suggests that the expansion of concrete containing reactive alkali-carbonate aggregate cannot be initiated by dedolomitization, as postulated for the mechanism of reaction.

1986

1903. Grattan-Bellew, P. E. (ed)., "Concrete Alkali Aggregate Reactions," Noyes Publications, Park Ridge, NJ, 1986, 509 pp.

KEY WORDS: alkali aggregate reactions; conferences

Indexed as Proc.7th Intl. Alkali Conf. 1986. Contains 89 papers, mostly on alkali silica reactions.

1904. Greeman, A., "FRENCH TO ABANDON CRUMBLING CHAMBON," New Civil Engineer, 14 August 1986, pp. 18-21.

KEY WORDS: alkali aggregate reactions; field experiences; France; dam structures

1905. Han, S. F. and Tang, M. S., "THE RAPID TEST METHOD FOR ALKALI REACTIVITY OF CONCRETE AGGREGATE AND ITS APPLICATION IN FIELD (in Chinese)," Concrete and Cement Products, No. 3, 1986, pp. 1-5.

KEY WORDS: alkali aggregate reactions; test methods; autoclave method

1906. Hobbs, D. W., "SOME TESTS ON FOURTEEN YEAR OLD CONCRETE AFFECTED BY THE ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 342-346.

KEY WORDS: alkali silica reactions; field experiences; U.K.; mechanical properties

Laboratory measurements are reported of compressive strength, tensile strength, elastic modulus and ultrasonic pulse velocity tests on a range of 14 year old concretes affected by the alkali-silica reaction. The concretes were made using a number of UK cements and a UK aggregate. It is shown that cracking and expansion due to the alkali-silica reaction had the most marked effect upon elastic modulus, reducing the modulus by up to 40%.

1907. Hobbs, D. W., "ALKALI-SILICA REACTION IN CONCRETE," Structural Engineer, Part A: Monthly Vol. 64A, No. 12, Dec. 1986, pp. 381-383.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.; preventive measures; structural effects

A cause of concrete deterioration which has received considerable publicity and debate in recent years is ASR. There are three main issues associated with ASR: diagnosis of it as the cause of cracking; assessment of its implications in existing structures; and derivation of specifications to minimize the risk of damage due to the reaction in new structures. Specifications are currently being developed for use by engineers at a time when scientific data are incomplete and when available data have been fully supported by the published literature and recent observations. Some suggestions on dealing with the ASR problem are made.

1908. Honda, H., Shiraishi, F., Ueda, K. and Hayashi, Y., "INFLUENCE OF RESTRAINT OF RE-BAR ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; structural effects; restraint effects; field experiences; Japan

There are many examples of damage due to alkali aggregate reaction seen in non-reinforced concrete or mass concrete. It is said that crack patterns in reinforced concrete were related to the rebar arrangement. An experiment of expansion under rebar restraint and a strength test of concrete in which alkali aggregate reaction occurred were reported.

1909. Hooton, R. D., "EFFECT OF CONTAINERS ON ASTM C 441 - PYREX MORTAR BAR EXPANSIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 351-357.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; wick effects; ASTM tests

From preliminary tests and participation in a recent ASTM interlaboratory program, it was found that the container type, and especially the distance of the mortar bars from the wicking, had a large effect on resultant expansions of ASTM C 441 Pyrex mortar bars. Recently, a larger evaluation program of ten different containers and wicking arrangements was initiated. After 84 days at 38°C

and 100% RH, mortar bar expansions had levelled off and were found to vary from 0.179% to 0.471%, with the proposed new ASTM standard container giving 0.446%.

1910. Hoppe, G. E., "REHABILITATION OF AN ARCH BRIDGE," Proc. 7th Intl. Alkali Conf. 1986, pp. 199-203.

KEY WORDS: alkali aggregate reactions; bridge structures; field experiences; South Africa; repairs

The rehabilitation of a 100m span concrete arch bridge involving the widening and strengthening of the structure as well as the treatment of existing concrete affected by alkali aggregate reaction (A.A.R.). The widening of the superstructure involved the replacement of the existing cantilevers with larger ones of lightweight construction. To enable the bridge as a whole to carry the increased loads, it was necessary to strengthen the superstructure as well as the arch rib by the addition of externally bonded steel reinforcement. In view of the age of the bridge and because it had been subjected to many cycles of wetting and drying, it was concluded that the concrete had established an equilibrium system. Ideally, the concrete should have been dried out, the cracks epoxy injected and the surfaces sealed, but since it is impractical to dry out the concrete structure, the moisture inside the concrete would cause the injected cracks to open up again, and then further cracking usually occurs rapidly. It was therefore decided that in this case the appropriate solution was the impregnation of the concrete with a hydrophobic substance which prevents external water penetrating the concrete while keeping the surface open enough for moisture to escape.

1911. Houde, J., Lacroix, P. and Morneau, M., "REHABILITATION OF RAILWAY BRIDGE PIERS HEAVILY DAMAGED BY ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 163-167.

KEY WORDS: alkali aggregate reactions; field experiences; Canada; repair methods

The evaluation of damage caused by an alkali aggregate reaction on railway bridge piers in a Quebec structure was carried out, and the repair methods described.

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1912. Iiyama, J. T., Kusano, M. and Tokunaga, Y., "EVOLUTION OF THE PETROGRAPHIC TEXTURES OF CONCRETES SUFFERING ALKALI-AGGREGATE REACTIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 386-391.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; reactive aggregates; bronzite; andesite; mechanisms; petrography

Petrographic examination of concrete specimens suffering damages caused by the alkali-aggregate reaction revealed the "histological" evolution of this disease as follows: 1) The deterioration of concrete begins with the formation of fine reaction veins along the aggregate-cement matrix boundaries and in the matrix itself. 2) The width of the veins increases with time. 3) Carbon dioxide in the air diffuses deep in the structure and carbonates are formed in the matrix. 4) Finally, the whole part of the matrix is carbonated and the concrete itself tends to disintegrate. The use of crushed andesite, chert, and granite cause most frequently this type of reaction. However. a possible reaction, caused by other kinds of rocks is also indicated in this study. The physical differences between crushed rocks and natural gravels are pointed out in this report together with the discussion about the causes of this disease of concrete occurring recently in Japan.

1913. Imai, H., Yamasaki, T., Miyagawa, T. and Maehara, H., "THE DETERIORATION BY ALKALI-SILICA REACTION OF HANSHIN EXPRESSWAY CONCRETE STRUCTURES - INVESTIGATION AND REPAIR," Proc. 7th Intl. Alkali Conf. 1986, pp. 131-135.

KEY WORDS: alkali aggregate reactions; bridge pier structures; structural effects; repair methods; field experiences; Japan

This paper deals with the structural behavior of the reinforced concrete structures deteriorated by alkali silica reaction on the Hanshu Expressway in Osaka, Japan, and with repair methods developed using synthetic resins. It was found that the stiffness and load carrying capacity of the deteriorated T-shaped cantilever reinforced concrete piers were almost the same as those of sound piers. Filling cracks with an epoxy injected under pressure, and epoxy coating or silane impregnation were found to be very effective for controlling the reinforcement corrosion and the expansion of the piers.

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1914. Inderwick, A. F., "SHOULD ACID SOLUBLE SODIUM EQUIVALENT ALKALI BE THE MEASURE OF POTENTIAL PORTLAND CEMENT REACTIVITY?," Proc. 7th Intl. Alkali Conf. 1986, pp. 456-460.

KEY WORDS: alkali aggregate reactions; alkali effects; cements

This paper examines some of the variables in the composition of cement that can affect the reactivity of the metal alkali components. The author suggests that recent changes in the design and operation of cement plants have exacerbated the problem of alkali-aggregate reactivity, for when kilns that incorporate preheaters or precalciners are operating efficiently, most of the sodium and potassium will be in the form of sulphates, and so are readily available for conversion to hydroxides as a part of the hydration process. The author suggests that the chemical analyses of cements should have a percentage availability factor applied to the total equivalent alkali figure in order that the user shall be able to compare the reactivity potential of the various products available. The percentage availability factor recommended is the percentage of "active" alkali determined by the South Africa Method.

1915. Ishii, Y., Makita, M., Kobayashi, S. and Ono, K., "EXPERIMENTAL STUDY FOR CONTROL OF ASR EXPANSION BY FLY ASH AND BLAST FURNACE SLAG POWDER (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; fly ash; slag; alkali effects

(1) For mortar specimens, some fly ashes or slags had a controlling effect on ASR. The degree of the effect varied with the material, but was related to the ratio of alkali content to fly ashes or slags. (2) For concrete specimens, the dynamic modulus of elasticity was related to the degree of reaction, and was proportional to the amount of expansion. (3) For concrete specimens, an ASR-controlling effect of fly ashes and slags was observed. Significant expansion occurred for the usual aggregates only at alkali content as high as 6.4 kg/cu. m.

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1916. Johnston, C. D., "ALKALI-SILICA REACTIVITY IN CONCRETE - IMPORTANCE OF CEMENT CONTENT AND ALKALI EQUIVALENT," Proc. 7th Intl. Alkali Conf. 1986, pp. 477-482.

KEY WORDS: alkali aggregate reactions; reactive aggregates; glass; cements; mortar bars; expansion

Crushed glass, a high reactive siliceous aggregate, can produce widely varying degrees of reactivity in concrete. What happens with each cement-aggregate combination depends strongly on cement content, which is not a variable in the standard mortar bar test, and on the cement alkali equivalent, both of which determine the amount of alkali in the concrete available to fuel the reaction. The 0.05 - 0.10% range includes a potential problem category of slowly expansive combinations where the reaction cannot be proven deleterious in tests lasting 6 months or 1 year.

1917. Jones, T. N. and Poole, A. B., "ALKALI-SILICA REACTION IN SEVERAL U.K. CONCRETES: THE EFFECT OF TEMPERATURE AND HUMIDITY ON EXPANSION, AND THE SIGNIFICANCE OF ETTRINGITE DEVELOPMENT," Proc. 7th Intl. Alkali Conf. 1986, pp. 446-450.

KEY WORDS: alkali aggregate reactions; petrography; field experiences; U.K.; temperature effects; relative humidity effects; moisture effects; expansion; ettringite; mechanisms; structural effects; repairs

The effects of temperature and relative humidity on alkali-silica reactive concretes from three UK structures are being investigated in a series of long-term experiments, and interim findings are presented here. Preliminary indications are that temperature has both the opposite and a far more significant effect on expansion behavior than previously recognized. Expansion rate is initially proportional to temperature, but falls off more rapidly at higher temperatures than at lower temperatures. Maximum expansion is inversely proportional to temperature, and final expansion at lower temperatures may be more than twice that at 38°C. The cutoff humidity (defined as that below which expansion due to ASR does not occur) is higher at elevated temperatures, and expansion variability between concretes is most visible at lower temperatures and higher humidities. Petrological examination of test samples reveals moderate alkali contents but only small quantities of gel, and concretes from one structure contain an abundance of ettringite. In the absence of external sulphate it is

concluded that the ettringite formed by recrystallization of primary sulphate minerals, and was stabilized by reaction of the limestone aggregate. This was probably facilitated by ASR, and it is proposed that the resulting pressures contributed to concrete distress. The accepted model of alkali-silica reaction is reviewed in the light of these findings. It is proposed that temperature has a direct effect on both reactant transport and aggregate attack processes. Moisture availability is considered fundamental to expansion of the reaction product, but its effect is thought to be modified by temperature which alters the gel structure, and hence its swelling properties. It is observed that other factors may interact with ASR to cause deterioration, and that secondary processes may continue after ASR is exhausted. The implications of these findings to the management of affected structures are discussed.

1918. Katayama, T. and Kaneshige, Y., "DIAGENETIC CHANGES IN POTENTIAL ALKALI-AGGREGATE REACTIVITY OF VOLCANIC ROCKS IN JAPAN - A GEOLOGICAL INTERPRETATION," Proc. 7th Intl. Alkali Conf. 1986, pp. 489-495.

KEY WORDS: reactive aggregates; Japan; glasses; tridymite; cristobalite

Japanese volcanic rocks have undergone extensive burial diagenesis. They can be classified into the following alteration zones based on the mineral assemblages of altered rocks: the unaltered zone, the slightly altered zone, the smectite zone, and the chlorite zone. Reactive minerals. such as volcanic glasses, cristobalite, and tridymite are mostly confined to fresh and less altered volcanic rocks ranging in age from middle Miocene to Quaternary. These minerals are substantially stabilized due to recrystallization through burial diagenesis in more altered rocks before middle Miocene. Results of the quick chemical test (ASTM C 289 ) indicate that the potential alkali reactivity of volcanic rocks gradually decreases from the unaltered zone toward the chlorite zone, which is consistent with the mineralogical changes in rocks during diagenesis.

1919. Katayama, H., Kusano, M., Yamada, M. and Sasabe, M., "EXPERIMENTAL STUDY ON CONTROLLING EFFECT OF ALKALI-AGGREGATE REACTION BY THE ELASTIC COATING MATERIALS (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

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KEY WORDS: alkali silica reactions; preventive measures; coatings

An elastic coating material was tested for its controlling effect on ASR. Expansion due to ASR was controlled after the coating was applied. The controlling effect varied with the kind of primers or coatings used. Controlling the effect of ASR depended not only on the impermeability of the coating, but also on the ability to pass through the humidity inside of the coating.

1920. Kawamura, M. and Takemoto, K., "EFFECTS OF POZZOLANS AND A BLAST FURNACE SLAG ON ALKALI HYDROXIDES CONCENTRATIONS IN PORE SOLUTIONS AND ALKALI-SILICA EXPANSION," CAJ Review of the 40th General Meeting/Technical Session, pp. 262-265, 1986.

KEY WORDS: alkali silica reactions; preventive measures; pozzolans; slag; pore solutions; alkali effects

It was found that various pozzolans and blast furnace slag were different in their effect on alkali ion concentration in the pore solutions extracted from mortars. All of the additives selected in this study reduced alkali ion concentrations in the pore solution to varying degrees, except that the addition of between 5% and 30% of the blast furnace slag increased the amount of alkalies a little in the pore solution. Some factors other than reduced alkalinity in pore solutions also appear to be related to prevention or reduction of ASR induced expansion by incorporation of pozzolans and slag. However, it should be noted that there was an excellent correlation between $OH^-$ ion concentration of pore solutions and the ASR expansion of mortars containing various blast furnace slags or fly ashes produced in Japan.

1921. Kawamura, M., Takemoto, K. and Hasaba, S., "EFFECTIVENESS OF VARIOUS FLY ASHES AND BLAST FURNACE SLAGS IN PREVENTING ALKALI-SILICA EXPANSION (in Japanese)," CAJ, 40, 1986, pp. 276-279.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; slag; pore solutions; alkali effects; opals

Preventive ability of fly ash or blast furnace slag against the ASR expansion correlates with the reduced

alkalinity in pore solution due to their addition, the pozzolanic activity of fly ashes, and the alkali reactivity of blast furnace slags. Different fly ashes vary widely in their effect on the alkali silica expansion of mortars containing Beltane opal.

1922. Kawamura, M., Takemoto, K., and Hasaba, S., "EFFECT OF SILICA FUME ON ALKALI-SILICA EXPANSION IN MORTARS," ACI SP-91, Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, Vol. 2, pp. 999-1012, 1986.

KEY WORDS: alkali aggregate reactions; preventive measures; silica fume; mortar bars; EDX analysis; microhardness; alkali silica gel

The expansion of mortars containing up to at least 10% silica fume by weight of cement were about three times as great as that of the additive-free mortar. Concentrations of calcium and of alkalies within opal grains in the silica fume mortars were determined by energy dispersive X-ray analysis (EDXA). The intrusion of smaller amounts of calcium into opal grains in the mortars at early ages seems to show that the conversion of alkali-silica gels into sols was delayed by the presence of silica fume. The delay of this conversion was also confirmed by microhardness measurements.

1923. Kishitani, K., Nishibayashi, S. and Morinaga, S., "RESPONSE OF JCI TO ALKALI-AGGREGATE REACTION PROBLEM - GUIDELINE FOR DETERMINING POTENTIAL ALKALI REACTIVITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 264-268.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; test methods

JCI established an AAR Committee in 1983 and started to carry out investigations and studies with three subcommittees. It is the aim of the AAR Committee to establish a test method and to develop deterioration diagnosis and repair methods for structures based on the results of the investigations and studies of these subcommittees.

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1924. Knudsen, T., "A CONTINUOUS, QUICK CHEMICAL METHOD FOR THE CHARACTERIZATION OF THE ALKALI-SILICA REACTIVITY OF AGGREGATES," Proc. 7th Intl. Alkali Conf. 1986, pp. 289-293.

KEY WORDS: reactive aggregates; test methods; chemical shrinkage

Measurements of the chemical shrinkage accompanying ASRs have been used in testing of the reactivity of sand. The major experimental difficulty in applying the method lies in the preparation of completely water saturated samples of sands prior to testing.

1925. Kobayashi, S., Kawano, H., Numata, S. and Chikada, T., "SOME CONSIDERATION ON THE MECHANISM OF EFFECTIVENESS OF GROUND GRANULATED BLAST FURNACE SLAG," CAJ, 40, 1986, pp. 266-267.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; fly ash; mechanisms

It is known that ground granulated blast furnace slag possesses a preventive effect on expansion caused by the ASR in concrete. However, the preventive mechanism of blast furnace slag for ASR is not sufficiently understood yet. It this study, the expansion of mortar made by reactive aggregate, cement and admixtures such as ground granulated blast furnace slag and fly ash was measured, and the reactions of ground granulated blast furnace slag and fly ash in alkali solution were investigated. Also the preventive mechanism of blast furnace slag for ASR was discussed.

1926. Kobayashi, S., Ono, K., Kohno, H. and Hinuma, T., "STUDIES ON SOME FACTORS INFLUENCING ASR MORTAR BAR EXPANSION (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; alkali effects; air content effects

Addition of NaOH caused more expansion than addition of KOH for any aggregate. Even for low alkali cement, expansion due to ASR increased when a large amount of the cement was used. Thus the total alkali content in concrete has to be limited. The effect of the air content varied with different aggregates and with the conditions of air.

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1927. Kodama, K. and Nishino, T., "OBSERVATION AROUND THE CRACKED REGION DUE TO ALKALI-AGGREGATE REACTION BY ANALYTICAL ELECTRON MICROSCOPE," Proc. 7th Intl. Alkali Conf. 1986, pp. 398-402.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; scanning electron microscopy

Mortar bars were prepared from Japanese andesites, mud stone, and a quartz sand, with portland cement or slag cement, and in some cases added NaOH. Expansion measurements indicated a dependence on proportions of reactive cristobalite and albite in each aggregate. Modulus of elasticity was substantially reduced with the expansion. The expansion was much reduced if the reactive component was present only in finely-divided form (under 0.15 mm). Backscatter electron microscopy of polished specimens of highly expansive mortars was reported, and some implications drawn.

1928. Koh, E., Kamata, H. and Suzuki, H., "AN EXPERIMENT ON THE PESSIMUM CONTENT OF AN ALKALI-REACTIVE ANDESITIC AGGREGATE (in Japanese)," Semento Gijutsu Nenpo (Annual Bulletin of Japan Cement Assoc.), No. 40.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; mortar bars; expansion; pessimum effect

(1) Expansion was maximum when the proportion of the reactive aggregates was less than 100%. (2) In highly alkaline conditions, maximum expansion was achieved at proportions of reactive aggregate of 40 to 60%.

1929. Koyanagi, W., Rokugo, K. and Ishida, H., "FAILURE BEHAVIOR OF REINFORCED CONCRETE BEAMS DETERIORATED BY ALKALI-SILICA REACTIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 141-145.

KEY WORDS: alkali aggregate reactions; structural effects; mechanical properties; restraint effects; steel fibers

Laboratory tests were carried out o assess the effects of deterioration due to ASR on the failure behavior of reinforced concrete beams, with and without added steel fibers. For short term static loading the effects of the cracking caused by ASR were not significant. The modulus of elasticity decreased with the increasing age but

compressive toughness and compressive strength remained unaltered. The expansion of concrete caused by ASR was restrained by reinforcement. Because of this restraint, compressive stress was induced in the concrete. Cracks decreased in number with increase of the reinforcement ratio. The direction of cracks coincided with the direction of reinforcement. The presence of steel fibers improved all the mechanical properties of concrete, even reinforced concrete beams deteriorated by the effects of ASR.

1930. Krell, J., "INFLUENCE OF MIX DESIGN ON ALKALI-SILICA REACTION IN CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 441-445.

KEY WORDS: alkali aggregate reactions; cement effects; water:cement ratio effects

The speed of deterioration induced by ASR in concrete made with German opaline sandstone is a function of the type of reactive aggregate, and the alkali content of the cement. In these tests the influence of concrete mix proportions on the extent of deterioration was explored. The tolerable alkali content of concrete is increased at lower water:cement ratios, but is decreased for concretes having higher early (2-day) strength because of finer grinding of the cement.

1931. Lane, D. S., "LONG-TERM MORTAR-BAR EXPANSION TESTS FOR POTENTIAL ALKALI-AGGREGATE REACTIVITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 336-341.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; expansion; long-term effects

ASTM C 227 mortar-bar tests have been extended for up to 5 years with several aggregates and low to high alkali cements. These tests illustrate several areas of concern in the use of such tests to identify potentially reactive aggregates. In several instances cements with alkali contents just below the traditional 0.6% limit developed high levels of expansion. Often the cement-aggregate combinations developed expansion slowly so that they met the ASTM C 33 limits at 3 and 6 months, but developed very significant expansions between 6 months and 4 or 5 years. In at least two instances, the aggregates with later-age expansion produced deleterious expansion in service. With one

aggregate, the replacement of 7.5% cement with Class F fly ash reduced expansion at 6 months sufficient to meet current ASTM C 33 limits but large expansions developed at later ages. In this instance 15% fly ash prevented the development of significant expansion through 4 years.

1932. Liu, C., "CONTRIBUTION TO THE STUDY OF ALKALI-AGGREGATE REACTION. APPLICATION TO THE SANDOUPING DAM IN CHINA (in French)," PhD Thesis, Paris University, Paris VI, 170 pages.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion; modeling

(1) Different types of expansion have been measured in ASR, including "explosive" expansion, progressive expansion, and step-by-step expansion. (2) Different morphologies of the alkali silica gel have been observed, including isotropic gel, microcrystalline gel, reticulated structure, needles, gelified cement paste. (3) The expansion process can be modeled by the catastrophe theory established by Zeeman. There are three periods (i) preliminary, (ii) catastrophic, and (iii) dormant. (4) Osmotic pressure seems to be the main process in the expansion.

1933. Magni, E. R., Rogers, C. A. and Grattan-Bellew, P. E., "THE INFLUENCE OF THE ALKALI-SILICATE REACTION ON STRUCTURES IN THE VICINITY OF SUDBURY, ONTARIO," Proc. 7th Intl. Alkali Conf. 1986, pp. 17-22.

KEY WORDS: alkali aggregate reactions; field experiences; Canada; argillites; graywackes; reactive aggregates; cracking; concrete prisms; test methods

A large number of concrete structures in Sudbury and vicinity were studied in the field. Most show signs of an alkali aggregate reaction including pattern cracking and expansion. At least five structures have been replaced and many required extensive maintenance. Petrographic examination of concrete from many of these structures showed evidence of reaction rims, alkali-silica gel and cracking on a microscopic scale. It is concluded that gravels of the Sudbury area that contain rocks of the Huronian Supergroup are potentially alkali reactive and can cause deterioration of concrete. Argillites give rise to

greater expansion than greywackes in the concrete prism expansion test. These in turn cause more expansion than quartz-arenites. There is no evidence that concrete fine aggregates produced from the Sudbury gravels are reactive. Many of the structures affected by the alkali silicate reaction have also experienced freeze-thaw damage and corrosion of reinforcing steel. It is concluded that initial cracking resulting from the alkali aggregate reaction accelerated these other destructive mechanisms. Acknowledging the fact that the structures examined vary significantly in construction method and material content, a definite relationship between age of concrete and extent deterioration was recognized. Pattern cracking can generally be observed between 5 and 10 years after construction, significant maintenance is usually necessary after 25 years, and a number of structures have been replaced at 40 years. Selection of concrete aggregates in the region is currently based on petrographic examination. A maximum of 15 percent argillites, greywackes, quartz arenites and arkoses of the Huronian Supergroup is allowed in concrete coarse aggregate. The most promising test is the concrete prism expansion test at 38°C and 100 percent humidity. However, a reliable maximum expansion value to separate deleterious from satisfactory aggregates has not yet been determined. Preliminary work suggests an expansion of 0.04 percent or greater at 1 year would rate aggregate as deleterious.

1934. Makita, M., Kobayashi, S., Kawano, H. and Ishii, Y., "TENTATIVE GUIDELINE OF MINISTRY OF CONSTRUCTION FOR ASR MORTAR BAR METHOD," Proc. 7th Intl. Alkali Conf. 1986, pp. 472-476.

KEY WORDS: test methods; mortar bars; Japan

There are some factors which vary the results of the ASR mortar bar test. Experiments were carried out with Japanese domestic aggregates to clarify the influence of the mixing proportion, the difference of alkali metal ion, the alkali content of the cement, the kind of curing condition etc. From the results of the experiments, the Ministry of Construction, Japan published "Tentative Guidelines for an ASR Mortar Bar Method", which was advanced in precision from the ASTM C 227 mortar bar test method.

1986

1935. Makita, M., Kobayashi S., Moriyama, and Hoshi, H., "EFFECT OF JAPANESE PULVERIZED GRANULATED BLAST FURNACE SLAG FOR PREVENTION OF ALKALI-SILICA REACTION (in Japanese)," CAJ, 40, 1986, pp. 268-271.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; Japan

A number of studies have been reported on the effectiveness of blast furnace slag against ASR. In Japan, however, there have been only a few reports on the influence of slag properties. In this study, blast furnace slags were evaluated based on ASTM C 441 and ASTM C 227 for their effect in prevention of ASR. The slags obtained were milled at different plants.

1936. Matsuda, T., Ishii, K. and Morino, K., "EFFECT OF VOLCANIC GLASS ON ALKALI-AGGREGATE REACTION," CAJ Review of the 40th General Meeting-Technical Session, pp. 242-243, 1986.

KEY WORDS: reactive aggregates; andesites; glass; tridymite; cristobalite

It has been observed under a microscope that one of the andesites which caused ASR was dominant in volcanic glass. Volcanic glass has higher free energy than tridymite and cristobalite under room temperature conditions. It is therefore predicted that volcanic glass will have a higher tendency to react with alkali in cement than tridymite and cristobalite.

1937. Meland, I., "USE OF FLY ASH IN CEMENT TO REDUCE ALKALI SILICA REACTIONS," ACI SP-91, Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, Vol. 1, pp. 591-597, 1986.

KEY WORDS: alkali aggregate reactions; swimming pool structures; tiles; expansion; preventive measures; fly ash

This report presents results from an investigation where fly ash has been used in cement to try to reduce an observed alkali-silica reactivity in tile covered mortar and concrete constructions such as swimming pools and larger shower cabinets. Examinations of ceramic tiles showed that soluble silica formed when the material was exposed to sodium hydroxide solution. For testing according

to ASTM C227-81 "Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)" concrete prisms were moulded using ordinary Portland cement or fly ash bearing cement with crushed ceramic tiles as aggregate. All the prisms showed changes in length; however, the changes are less in prisms made with the fly ash in the cement. From these observations it seems that it is possible to reduce the damage caused by alkali-silica reactions in such structures by use of fly ash in cement. Long term tests are being done on tile covered concrete slabs.

1938. Mizumoto, Y., Kosa, K., Ono, K. and Nakano, K., "STUDY ON CRACKING DAMAGE OF A CONCRETE STRUCTURE DUE TO ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 204-209.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; mechanisms

Investigations have been carried out on the ASR problems undergone by concrete piers in the Hanshin Expressway in Osaka, Japan. The main cause of cracking was inferred to be alkali aggregate reactivity. A significant amount of alkali was provided to the concrete by the cristobalite and volcanic glass in the aggregate.

1939. Morino K. and Shibata, K., "ALKALI REACTIVITY OF ANDESITE AND CHERT AGGREGATES (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; chert; Japan; expansion

Several kinds of andesite and chert aggregates were investigated. One andesite aggregate did not cause expansion in mortar bar at 0.8% $Na_2O$ equivalent alkali, but it caused large expansions when it was batched together with 80% of a non-reactive aggregate. At the pessimum composition of andesite aggregate, expansion characteristics were different so that the speed of expansion varied depending on the amount and on the kinds of reactive minerals in the aggregate. The chert aggregate used in the experiment was classified as harmful by the quick chemical test, but it did not cause expansion in mortar bar test at 0.8% $Na_2O$ equivalent alkali. It caused large expansion at 1.2% alkali with 30% to 50% non-reactive

aggregates.

1940. Mukherjee, P. K. and Bickley, J.A., "PERFORMANCE OF GLASS AS CONCRETE AGGREGATES," Proc. 7th Intl. Alkali Conf. 1986, pp. 36-42.

KEY WORDS: alkali aggregate reactions; glass; field experiences; cladding panels

A condition survey was carried out on three buildings where glass had been used as concrete aggregate in pre-cast cladding panels. At the time of the survey the buildings had been in service for over ten years. Degradation had occurred and was in the form of cracking, spalling and bowing of panels and is believed to be due to alkali-aggregate reaction. Deleterious expansion due to the reactivity was demonstrated by conducting tests on specimens obtained from selected panels. The type, grading and amount of glass along with the exposure conditions appeared to be the main factors controlling the expansion of the concrete.

1941. Mullick, A. K., Wason, R. C., Sinha, S. K. and Rao, L. H., "EVALUATION OF QUARTZITE AND GRANITE AGGREGATES CONTAINING STRAINED QUARTZ," Proc. 7th Intl. Alkali Conf. 1986, pp. 428-433.

KEY WORDS: alkali aggregate reactions; reactive aggregates; strained quartz; petrography; undulatory extinction angle

Results of optical microscopy, mortar bar expansion tests at 38°C and 60°C, and rapid chemical tests on quartzitic and granitic aggregates containing strained quartz are summarized. Limits are suggested for acceptable expansion in mortar bar tests at 60°C regime, and for the percentage of quartz showing strain effects and angle of undulatory extinction.

1942. Mullick, A. K. and Samuel, G., "REACTION PRODUCTS OF ALKALI-SILICA REACTION - A MICROSTRUCTURAL STUDY," Proc. 7th Intl. Alkali Conf. 1986, pp. 381-385.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences; India; scanning electron microscopy;

alkali silica gel; cracking

Microstructural studies of the products of prolonged ASR in concrete dams are reported. The microstructure of ASR products are predominantly the amorphous gel type, with occasional crystalline habit. In the case of metastable silica minerals, the products seem to be of separate formation, whereas in the case of strained quartz, it is more nearly a direct alteration of the aggregates.

1943. Nagashima, M., Komastsu, R. and Asakura, E., "ALKALI-SILICA REACTIVITY OF VOLCANIC ROCKS IN JAPAN," CAJ Review of the 40th General Meeting-Technical Session, pp. 245-249, 1986.

KEY WORDS: reactive aggregates; field experiences; Japan; andesites; test methods

The alkali reactive rocks known in Japan are andesite, chert and slate. Andesite with 52-65 wt% silica is one of the chief sources of crushed stone for concrete aggregate and may be classified as being "potentially deleterious" or occasional "deleterious" by ASTM C 289. When an aggregate is classified as being potentially deleterious by ASTM C 289, it must be examined by ASTM C 227, but the latter is too time consuming. Volcanic rocks in Japan were investigated by a petrographic method, and were classified.

1944. Nagahashi, H., Uchida, H., Tamura, H. and Nakamoto, T., "A STUDY ON THE PREVENTIVE EFFECT OF COATING MATERIAL OF CONCRETE SURFACE ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings;

Several coating materials were applied to the mortar specimens and these specimens were stored in such conditions as cyclic wetting and exposing to high temperature and high humidity, cyclic wetting and drying, and exposing to natural environment. Also other specimens without coatings were stored in various humidity conditions. Then changes in weight and in ultrasonic velocity of the specimens were measured over time.

1986

1945. Nakano, K., Kobayashi, S., Nakaue A. and Ishibashi, H., "INFLUENCE OF ALKALI CONTENTS AND CURING CONDITIONS ON EXPANSION OF MORTAR BARS DUE TO ALKALI-SILICA REACTION (in Japanese)," CAJ, 40, 1986, pp. 254-257.

KEY WORDS: alkali aggregate reactions; expansion; cement effects; alkali effects; curing conditions

As factors which may influence the expansion of mortar bars by ASR, alkali contents in portland cement, additional alkali, and curing conditions were examined.

1946. Nakano, K., Nagaoka, S. and Nikawa, T., "CHANGING OF ALKALI CONTENTS WITH TIME IN MORTAR USING ALKALI REACTIVE AGGREGATES," CAJ Review of the 40th General Meeting/ Technical Session, pp. 258-261, 1986.

KEY WORDS: alkali aggregate reactions; pore solutions; preventive measures; pozzolans; slag; alkali effects

It was found that various pozzolanic materials and blast furnace slags were different in their effect on alkali ion concentrations in pore solutions extracted from mortars. All of the additives selected in this study reduced alkali ion concentrations in the pore solution to varying degrees except that the addition of 5% and 30% of the blast furnace slag increased a little the amounts of the alkalies in the pore solution. Some factors other than reduced alkalinity in pore solutions also appear to be related to the prevention or reduction of expansion due to the ASR by incorporation of pozzolans and slag. However, it should be noted that there was an excellent correlation between $OH^-$ ion concentrations of pore solution and the alkali silica expansions of mortars containing various blast furnace slags or fly ashes produced in Japan.

1947. Natesaiyer, K. and Hover, K. C., "INVESTIGATION OF ELECTRICAL EFFECTS ON ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 466-471.

KEY WORDS: alkali aggregate reactions; electrical effects; field experiences; electrical power structures

The incidence of ASR in structures such as precast electrical transmission poles and the bases and foundations of electrical equipment has raised the question of a

possible effect of electrical fields on ASR. This question has been raised again as it pertains to the application of cathodic protection systems to reinforcing steel in bridge decks and substructures. If ASR can be influenced by electric current or potential difference, then the application of cathodic protection to control corrosion of the reinforcing steel could initiate or accelerate ASR. Research is currently in progress to investigate this question.The experimental program includes mortar-bar expansion tests with and without applied current, measurements of the rate of diffusion of sodium and potassium ions through concrete as influenced by a potential difference, and a small scale cathodic protection installation.

1948. Nimura, S. and Fukushima, M., "INVESTIGATION ON DETERIORATION OF CONCRETE BUILDING CAUSED BY ALKALI-SILICA REACTION," CAJ Review of the 40th General Meeting/Technical Session, pp. 236-239, 1986.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; bronzite; expansion; alkali silica gel

The X-ray powder diffraction pattern of bronzite-andesite crushed stones indicate that they contain cristobalite. Such aggregates fall into the "potentially deleterious" group (Sc = 392-565 Mm/l, Rc = 115-160 Mm/l) in the ASTM quick chemical test. Some test concrete cores have expanded about 0.04%, but other cores have not expanded at all. The X-ray diffraction patterns of white deposits indicate that these are composed of pure $CaCO_3$. The chemical composition of the alkali silica gels, as determined by EDXA contain more than 65% $Na_2O$.

1949. Nishibayashi, S., Yamura, K. and Matsushita, H., "A RAPID METHOD OF DETERMINING THE ALKALI-AGGREGATE REACTION IN CONCRETE BY AUTOCLAVE," Proc. 7th Intl. Alkali Conf. 1986, pp. 299-303.

KEY WORDS: alkali aggregate reactions; test methods; autoclave tests; Japan

This study was planned to clarify the behavior of mortar with reactive aggregate cured in an autoclave, as part of the development of a rapid method for determining alkali aggregate reaction potential. The following conditions for

the autoclave rapid method are suggested from this study: (1) Total alkali content as $Na_2O$ equivalent should be about 1.5%. (2) NaOH is the most suitable alkali to be added. (3) The specimen should be pre-cured for 24 hours after casting. (4) The autoclave treatment should be maintained for four to five hours. (5) The pressure in the kiln during autoclave treatment should be about 0.15 Mpa.

1950. Nishibayashi, S., Hayashi, A. and Ohnishi, T., "DAMAGE DUE TO ALKALI SILICA REACTION IN CONCRETE STRUCTURE AND REACTIVITY OF AGGREGATES USED," CAJ Review of the 40th General Meeting/Technical Session, pp. 240-241, 1986.

KEY WORDS: alkali aggregate reactions; field experiences; Japan

1951. Nishimura, A., Fujii, M., Miyamoto, F. and Tomita, T., "HIERARCHY MODELING OF DAMAGE FACTORS IN RC BRIDGES AND ITS APPLICATION TO DAMAGE ASSESSMENT (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: bridge structures; deterioration; models; Japan

A hierarchical model was constructed to describe correlations between factors of damages in RC bridges, using a fuzzy function. A checking system for bridges was constructed to predict and evaluate damages.

1952. Nishizaki, I. and Moriya, S., "SOME EXPERIMENTAL STUDIES FOR ANALYSIS OF ALKALIES IN CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali effects

Most of Na and K found in cement paste was water soluble. The ratio of the two alkalies extracted from cement paste depended on temperature, solid to liquid ratio, and time period.Extraction of alkalies from mortar was similar to that from cement paste.

1953. Nixon, P. J., Canham, I., Page, C. L. and Bollinghaus, B., "SODIUM CHLORIDE AND ALKALI-AGGREGATE REACTION," Proc. 7th

Intl. Alkali Conf. 1986, pp. 110-114.

KEY WORDS: alkali aggregate reactions; alkali effects; NaCl effects; pore solutions; OH ion concentration

Introduction of sodium chloride or synthetic sea water to a cement paste, mortar or concrete at the mixing stage results in an elevation of the hydroxyl ion concentration of the pore solution to a level similar to that produced by a portland cement with an equivalent alkali level. This in turn can increase the likelihood and severity of damage from alkali aggregate reaction, if the mortar or concrete contains a reactive aggregate, to an extent in line with the effect produced by an equivalent amount of alkali in the cement. If the alkali content of the concrete is being controlled in order to avoid damage from alkali aggregate reaction, the alkali contributed by salt contamination of the aggregate or other source of sodium chloride should be taken into account.

1954. Nixon, P. J. and Gillson, I. P., "AN INVESTIGATION INTO ALKALI-SILICA REACTION IN CONCRETE BASES AT AN ELECTRICITY SUBSTATION AT DRAKELOW POWER STATION, ENGLAND," Proc. 7th Intl. Alkali Conf. 1986, pp. 173-177.

KEY WORDS: alkali aggregate reactions; electrical power structures; electrical effects; field experiences; U.K.

Cracks in the concrete bases to substation installations at Drakelow Power Station near the town of Burton-on-Trent in the Midlands area of England were identified in 1982. The bases had been constructed in three phases: 1953/4, 1962/3 and 1969/70. It was suspected that the cause of cracking might be alkali silica reaction (ASR). The aggregates were of a type which had been identified as suffering alkali attack in other cases of ASR. It was thought that the cement content of these mass concrete bases was relatively low. Consequently the alkali concentration was also expected to be low and less than that generally believed to be necessary for damaging ASR to occur. Because of the important implications of this for the specification of concrete materials to avoid damage caused by ASR, a detailed investigation of the concrete at Drakelow substation has been carried out. The objectives were to establish the cause of the cracking, the extent of the deterioration, the nature of the component materials and, most specifically, the cement contents and alkali contents of the concrete. The possibility of loss or

migration of the alkalies since construction has been studied by taking cores for analysis and other studies from sheltered and weathered concrete and from different levels. The investigation revealed some general problems in analyzing set concrete and in particular the precise assessment of the alkali content. The paper discusses the overall results and implications of the investigation.

1955. Nixon, P. J., "TESTING THE ALKALI SILICA REACTIVITY OF UK AGGREGATES," Chemistry and Industry (London), No. 14, pp. 488-489, 1986.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; U.K.

ASR is a mechanism of deterioration in concrete in which the alkaline pore solution in the concrete reacts with a siliceous aggregate. This reaction produces an alkali silicate gel which has the property of absorbing water and expanding, so disrupting the concrete. One way of avoiding ASR is to identify and use aggregates which do not contain such critical amounts of reactive silica. The aim of developing test methods to assess alkali reactivity of aggregates is to enable specifiers to do this.

1956. Oberholster, R. E. and Davies, G., "THE EFFECT OF MINERAL ADMIXTURES ON THE ALKALI-SILICA EXPANSION OF CONCRETE UNDER OUTDOOR EXPOSURE CONDITIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 60-65.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; slag; silica fume

Replacement of cement by 50% (on a volume/volume or mass/mass basis) of slag appears to be effective in preventing the deleterious expansion due to ASR found using graywacke-hornfels aggregate, even when the active alkali content is as high as 4.95 kg/m$^3$ $Na_2O$ equivalent. Replacement by 15% of an approved fly ash appears to be effective in concrete with an active alkali content of up to 4.07 kg/m$^3$ $Na_2O$ equivalent. Replacement of cement by 10% of silica fume appears effective even when the active alkali content of the concrete is as high as 5 kg/m$^3$ $Na_2O$ equivalent. Replacement of cement by 15% of calcined shale or 5% of silica fume is not effective in preventing deleterious expansion caused by ASR in concrete with active

alkali content of up to 4.07 and 3.87 kg/m$^3$ $Na_2O$ equivalent, respectively.

1957. Oberholster, R. E., "RESULTS OF AN INTERNATIONAL INTER-LABORATORY TEST PROGRAM TO DETERMINE THE POTENTIAL ALKALI REACTIVITY OF AGGREGATES BY THE ASTM C-227 MORTAR PRISMS METHOD," Proc. 7th Intl. Alkali Conf. 1986, pp. 368-373.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; expansion; ASTM C227

Laboratories in Canada, New Zealand, Germany, the Netherlands and South Africa have cooperated in a programme to determine the alkali reactivity of the same aggregate-cement combinations by the ASTM C 227 mortar prism method. Four of the laboratories recorded similar, low expansions after one year, while significantly greater expansions were recorded in South Africa. An important observation is that gel exudations and other clear signs of ASR were present in the South Africa mortar prisms that expanded. It is clear that the reason for the difference in expansion can only be determined by conducting a new series of experiments in which the relative humidity is carefully monitored. It appears, however, that the ASTM C 227 criteria for distinguishing deleterious from innocuous aggregates do not apply to reactive quartz-bearing aggregates.

1958. Oberholster, R. E. and Davies, G., "AN ACCELERATED METHOD FOR TESTING THE POTENTIAL ALKALI REACTIVITY OF SILICEOUS AGGREGATES," Cement and Concrete Research, Vol. 16, pp. 181-189, 1986.

KEY WORDS: alkali aggregate reactions; test methods; NBRI method; South African method; mortar bars; expansion

Experience at the NBRI over a period of three years has shown the accelerated test proposed by Van Aardt and Visser to be a quick reliable test for the determination of potential alkali reactivity of aggregates, as long as reasonable care is taken in the execution of the test. The method involves storage of ASTM C 227 - type mortar prisms in 1N. NaOH at 80°C for 12 days and recording expansions.

1986

1959. Okada, K., Agawa, T., Adachi, M. and Takahashi, K., "ALKALI-AGGREGATE REACTION: A STUDY ON CAUSATIVE FACTORS," Proc. 7th Intl. Alkali Conf. 1986, pp. 347-350.

KEY WORDS: alkali aggregate reactions; NaCl effects; admixture effects; mechanisms

Recently the alkali-aggregate reaction has received a great deal of public attention in Japan. While a lot of studies are under way on this problem, details of the reaction system and the expansion mechanism still remain unclarified. In this study, tests were carried out to examine the effects of salt content of aggregate and proportion of reactive material in the aggregate on the alkali-silica reaction by using the expansion of mortar as a parameter. The effects of chemical admixtures for concrete on the reactions were also investigated. ASR is affected by the salt content of aggregate. Expansions of mortars made with non-reactive aggregate may sometimes be increased by the presence of salt. Vinsol resin is expected to have a constraining effect on the ASR.

1960. Okada, K., "PRESENT SITUATION OF ALKALI-AGGREGATE REACTION IN JAPAN," Proc. 7th Intl. Alkali Conf. 1986, pp. 216-220.

KEY WORDS: alkali aggregate reaction; field experiences; Japan; test methods

Practical aspects on the ASR problems in Japan were briefly described in this paper. Prompt and practical testing methods for identifying reactivity of aggregates in actual concrete, evaluating methods for structural soundness and successful repair methods for concrete structures damaged by ASR attack can be expected to be established in the near future through systematic laboratory investigations and field tests.

1961. Okada, K., Adachi, C., and Nagao, Y., "EFFECT OF THE PROPERTIES OF BLAST FURNACE SLAG ON EXPANSION CAUSED BY ALKALI-SILICA REACTION (in Japanese)," CAJ, 40, 1986, pp. 262-265.

KEY WORDS: alkali aggregate reactions; preventive measures; slag

Recently, deterioration of concrete structures

considered to be caused by ASR has been found in Japan. It has been known that blast-furnace slag prevented expansion due to ASR, and there has been considerable interest in preventive measures by using blast furnace slag. In this paper experimental results are presented on the effect of the properties of blast furnace slag, including fineness, glass content, rate of addition, and gypsum content on ASR-induced expansion.

1962. Okada, K., "DETERIORATION OF CONCRETE STRUCTURES AFFECTED BY ALKALI-SILICA REACTION (in Japanese)," Journal of the Society of Material Science, Japan, Vol. 35, No. 397, 1986.

KEY WORDS: alkali aggregate reactions; deterioration

ASR and the characteristics of damaged concrete structures were described in general.

1963. Olafsson, H., "THE EFFECT OF RELATIVE HUMIDITY AND TEMPERATURE ON ALKALI EXPANSION OF MORTAR BARS," Proc. 7th Intl. Alkali Conf. 1986, pp. 461-465.

KEY WORDS: alkali aggregate reactions; preventive measures; moisture effects; relative humidity effects; expansion; coatings; temperature effects

In recent years considerable research and full scale experiments have been carried out in order to diminish deleterious expansion in exterior walls of concrete houses in Iceland. All attempts have primarily been aimed at reducing the moisture content of concrete. Too little is hitherto known of the effect of different moisture contents on the expansions. This paper shows expansion of mortar bars stored at different RH levels, ranging from 73% to 100% at two different temperatures for up to two years. The bars were cast with high alkali cement (1.5% $Na_2O$ equiv.) and contained natural aggregates known to have caused deleterious expansion in concrete. The results are presented and discussed with special regard to both rate of expansion and total expansion. By reducing the relative humidity from 100% to below 90% the total expansion caused by alkali aggregate expansion can be reduced. The lower the RH the greater is the reduction in expansion. Decreased rates of expansion delay deterioration. Expansion is also a function of temperature. By preventing high temperatures in concrete, e.g. by using light colors on exterior walls

instead of dark ones, or by shielding them from the sunshine, expansion and rate of expansion are both diminished.

1964. Ono, K., Kaneyoshi, A., Minamigawa, Y. and Kanemitsu, S., "EFFECT OF WATERPROOF COATING ON THE CONTROL OF ALKALI-SILICA REACTION OF CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; coatings

In this laboratory experiment, a polymer cement type coating through which water inside can pass through and a silane coating both turned out to be effective for controlling ASR.

1965. Penkala, B., "ALKALI-AGGREGATE REACTIVITY INVESTIGATIONS IN POLAND - A REVIEW," Proc. 7th Intl. Alkali Conf. 1986, pp. 221-225.

KEY WORDS: alkali aggregate reactions; petrography; reactive aggregates; Poland

The paper presents the results of investigations covering twenty six deposits of limestones varying in age and twelve deposits of dolostones and dolomitic limestones, as well as twenty deposits of sandstones and chalcedonite. The research included also ten deposits of gravel aggregates from postglacial formations. Few of them have proven to be alkali reactive.

1966. Perry, C., Day, R. L., Joshi, R. C., Langan, B. W. and Gillott, J. E., "THE EFFECTIVENESS OF TWELVE CANADIAN FLY ASHES IN SUPPRESSING EXPANSION DUE TO ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 93-97.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; pozzolans; mortar bars; expansion

Fly ashes with wide ranges of physical and chemical properties were obtained from twelve sources across Canada. They were used to replace 20%-40% by weight of cement in mortar bars containing reactive opal, and expansions were monitored for a period of 12 months. The quantity of fly

ash required to reduce expansion to below a limit of 0.1% at 6 months varied from less than 20% to more than 40%. The reduction in expansion at 12 months ranged from 5% to 81% at 20% replacement, 34% to 89% at 30% replacement, and 47% to 92% at 40% replacement. Regression analyses were carried out to relate performance to a number of physical and chemical properties of the fly ashes. Some reasonable correlations were found; however, more fundamental work is required to identify the principal characteristics responsible for the range in performance of the fly ashes.

1967. Poole, A. B., Rigden, S. and Wood, L., "THE STRENGTH OF MODEL COLUMNS MADE WITH ALKALI-SILICA REACTIVE CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 136-140.

KEY WORDS: alkali aggregate reactions; structural effects; columns

Longitudinal cracks due to ASR in prestressed concrete support columns for the roof of a covered reservoir gave concern because tests indicated that, if the columns behaved as four independent sub-columns, the factor of safety under axial load was only 1.4 and would be lower if there was eccentricity of loading. Quarter scale model concrete columns were constructed to study this problem. Four of these columns were constructed using reactive aggregate from Cyprus (5%) and a KOH-enhanced high alkali content (10 kg/m$^3$). Slices of this concrete were also stored in 100% RH at 15°C and monitored for dimensional change, as were the model columns themselves. Expansions were monitored over a period of 78 days. The columns exhibited considerable and random variations in expansion at different points along their length and did not produce macroscopic cracks within this period. A series of concrete mix design experiments are now in progress with the objective of establishing a model mix that will reliably develop ASR cracking within a short time scale using readily obtainable reactive components. Testing of model columns cracked longitudinally by other methods is currently in progress. Results so far indicate that, if the column is appropriately strapped, it will remain effective up to the design load.

1968. Regourd, M. and Hornain, H., "MICROSTRUCTURE OF REACTION PRODUCTS," Proc. 7th Intl. Alkali Conf. 1986, pp. 375-380.

KEY WORDS: alkali aggregate reactions; scanning electron microscopy; alkali silica gel; crystalline reaction products; ettringite; thaumasite; hydrocalcite

The major alkali aggregate reaction products include siliceous gels (either massive or textured) and crystals in lamellae or fibers. The microstructures of cracked concretes, as observed by light and electron microscopy, show a weak cement paste - aggregate bond. Elemental analysis by EPMA or EDAX of the interface reveals ionic diffusion of alkalies but also of calcium carbonate and sulfate, which gives rise to secondary minerals as hydrocalcite, ettringite and thaumasite.

1969. Robert, E. C., "THE INFLUENCE OF PULVERIZED FUEL ASH ON A.S.R., BEHAVIORAL DIFFERENCES BETWEEN MORTARS CONTAINING PYREX GLASS AND BELTANE OPAL," Proc. 7th Intl. Alkali Conf. 1986, pp. 98-103.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; Beltane opal; Pyrex glass; mechanisms; time effects

The influence of pulverized fuel ash (pfa) on the expansion of mortar bars containing either Pyrex glass or Beltane opal has been studied. The experiments were conducted using a storage temperature of 38°C and generally followed the procedures described in ASTM C 227 and C 441. In addition to the expansion tests, the mortar bars and the liquid from the bottom of the storage containers were analyzed to determine the level of alkalis present. The results show significant behavioral differences between Pyrex glass and Beltane opal, both with respect to pfa and also independent of this material. When used with Pyrex glass, the pfa was found to reduce the expansions of the mortar bars for all mixes found to be expansive in the absence of pfa. For mortar bars containing Beltane opal, however, the pfa increased the expansion observed in all cases except at the pessimum. Certain time dependent features of the ability, or otherwise, of pfa to reduce expansions were also noted. Again the effects produced with Pyrex glass and Beltane opal were found to differ. The experimental evidence that expansion may continue longer in mixes containing pfa is indicative that pfa should be regarded as a "delayer" rather than a permanent inhibitor. There was no indication, however, that the expansion at later ages would cancel out the large expansion reductions achieved by using pfa in most of the highly reactive mixes.

Under normal circumstances, therefore, the use of pfa in concrete represent an extra safeguard which can be provided against the often disastrous effects of ASR, provided that care is taken to examine aggregates for Beltane opal type behavior. In practice the pfa would be used with aggregates which are only mildly reactive in comparison to Pyrex glass or Beltane opal, but which could cause serious problems if used with a high alkali cement. The inference is, therefore, that when the stage is reached where the pozzolanic reaction begins to diminish then the secondary factors which act will be capable of restricting ASR to acceptably low levels. Finally, it should be emphasized that for pfa to delay the onset of ASR successfully a sufficiently high cement replacement level should be used. On the basis of this experimental work 30-45% pfa is recommended.

1970. Rogers, C. A., "TESTING CANADIAN AGGREGATES FOR ALKALI REACTIVITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 259-263.

KEY WORDS: alkali aggregate reactions; cement effects; Canada; reactive aggregates; field experiences

Geographic variation in cement alkalies determines the incidence of alkali aggregate reactivity in Canada. The West, with low alkali cements, has few cases compared to the East, where high alkali cements are used. Three different categories of AAR have been recognized. Each category applies to specific rock types with a need for different test methods. Flow charts have been developed to show the testing and decisions necessary to properly evaluate the potential AAR of an aggregate source.

1971. Rogers, C. A., "ALKALI-AGGREGATE REACTIONS IN ONTARIO," Proc. 7th Intl. Alkali Conf. 1986, pp. 5-9.

KEY WORDS: alkali aggregate reactions; field experiences; Canada

Over 130 concrete structures in Ontario are affected by alkali-aggregate reactions. Three different types of reaction are found: alkali-silica, alkali-carbonate, and the so-called alkali-silicate reaction.

1972. Royak, G. S., Granovskaya, I. V. and Traktirnikova, T. L., "PREVENTING OF CONCRETE ALKALI CORROSION BY ACTIVE MINERAL ADMIXTURES," Beton i Zhelezobeton, No. 7, July 1986, pp. 16-17 (in Russian).

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans

1973. Rsumovic, M. and Cmiljanic, S., "INVESTIGATIONS OF DEVELOPMENT AND PRODUCTS OF ALKALI-SILICA REACTION ON CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 403-407.

KEY WORDS: alkali aggregate reactions; mechanisms; opal, alkali silica gel; carbonation effects

Development of alkali-silicate reaction was observed on test concrete samples made of mixtures of highly reactive silicate (chert) grains described as opal, and of inert reactive aggregate. First signs of alkali-silicate reaction on opal were observed with an alkali concentration in cement of 2.1% $Na_2O$ equivalent. Expansive destructive effects are shown under ideal conditions for reaction at an alkali concentration of 3.42% $Na_2O$ equivalent in cement. With higher alkali concentrations alkali-silicate reaction develops more rapidly. Reaction products are produced in different phases. Infrared absorption spectra of these products show some of the intermediate reactions which preceded the formation of alkali silicate gel. Infrared adsorption spectra of the products of the alkali silicate reaction can be used to provide an explanation of the processes and mechanisms of some of the reactions with $Ca^{2+}$ ions in gel. Carbonate forming in gel is an intermediate reaction. With the formation of calcium silicate and calcium carbonate, partial or total destruction of the gel occurs; this will limit further expansion.

1974. Rugen, M. A., "DURABILITY OF FLY ASH CONCRETE," Texas Civil Engineer, Vol. 56, No. 6, July 1986, pp. 15- 21.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; pozzolans

Alkali aggregate attack is a difficulty that affects concrete when certain susceptible aggregate components are combined in concrete with cements of relatively high alkali contents. A reaction takes place leading to the production

of potentially expansive gel, which in a wet environment may swell and cause cracking and subsequent deterioration of the affected concrete. The use of pozzolans, especially fly ash, to mitigate the effects of alkali aggregate reaction in receiving renewed attention.

1975. Scott, J. F. and Duggan, C. R., "POTENTIAL NEW TEST FOR ALKALI-AGGREGATE REACTIVITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 319-323.

KEY WORDS: test methods; Duggan expansion test; temperature effects

This paper describes a simple and rapid concrete core test method which distinguishes between deleterious and non-deleterious expansions in concrete. By testing the concrete, all effects from sand, aggregate, cement, water-cement ratio, additives and concrete curing are included in the results. The test may be used to classify laboratory trial mixes, and to evaluate existing concrete structures ranging in age from one month to one hundred years old. It is believed, but not confirmed, that the heating cycles prior to immersion activate chemicals and microcrack the cores, allowing water to penetrate rapidly and greatly accelerate the reactions. Concretes that may take years to expand in the field can be shocked into very rapid expansions.

1976. Shayan, A. and Lancuki, C. J., "ALKALI-AGGREGATE REACTION IN THE CAUSEWAY BRIDGE, PERTH, WESTERN AUSTRALIA," Proc. 7th Intl. Alkali Conf. 1986, pp. 392-397.

KEY WORDS: alkali aggregate reactions; bridge structures; alkali silica gel; crystalline reaction products; field experience; Australia

Alkali aggregate reaction has taken place in the Causeway Bridge in Perth, Western Australia, and, in view of the dimensional stability of the aggregates used, is the likely cause of the observed pattern cracking. All aggregate types in the bridge had reacted in the cracked portions where the cement alkali was presumably high, but none had reacted in the uncracked portions where the alkali level was presumably low. The reaction product is broadly similar to those of some other reported cases of AAR and include partially crystalline hydrated Na-K-Ca silicates

with a 12.2 Å X-ray basal spacing. The product is unlike any documented mineral or compound and requires further work for its precise identification.

1977. Shayan, A., Diggins, R., Ritchie, D. F. and Westgate, P., "EVALUATION OF WESTERN AUSTRALIAN AGGREGATES FOR ALKALI-REACTIVITY IN CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 247-252.

KEY WORDS: reactive aggregates; Australia; test methods

Nine aggregate sources from Western Australia have been assessed for use in concrete with particular reference to dimensional stability and alkali-reactivity. The aggregates include siliceous river gravel, metamorphosed basalts and dolerite, sandstone, granite, limestone, and amphibolite schist. Petrological examinations, X-ray powder diffraction, quick chemical tests, mortar bar tests, concrete prism tests, and dimensional stability measurement of aggregate and concrete have been used in the evaluation of these sources. Two levels of cement alkali. 0.84% and 1.38% equivalent $Na_2O$ were used in the mortar bar and concrete prism tests. The applicability of each test method is discussed. Two river gravels and a metadolerite were judged as potentially reactive when used with high alkali cement and other aggregates as innocuous even at the high alkali content employed. The quick chemical test is unreliable, whereas petrographic examination for identifying alkali-reactive aggregate was helpful but not always conclusive. The results of this work show that the standard mortar bar test does not always predict reactivity. A separate interpretation of longer term results and visual inspection of the specimens was needed for deciding on the potential reactivity of the aggregates.

1978. Shibuya, T., Fujisaki, K., Yamamoto, H., Imadate, F. and Horiuchi, S., "PETROGRAPHICAL INVESTIGATION ON ALKALI-REACTIVE AGGREGATES IN JAPAN (in Japanese)," Journal of the Society of Materials Science, Japan, Vol. 35, No. 392, pp. 496-502, 1986.

KEY WORDS: reactive aggregates; Japan; petrography

1986

1979. Sims, I., "THE IMPORTANCE OF PETROGRAPHY IN THE ASR ASSESSMENT OF AGGREGATES AND EXISTING CONCRETES," Proc. 7th Intl. Alkali Conf. 1986, pp. 358-367.

KEY WORDS: reactive aggregates; petrography; U.K.

A range of procedures currently available for the assessment of aggregates in the U.K. is reviewed. The importance of petrographical examination is emphasized, either as the main approach or as an essential preliminary approach. A new procedure for petrographical examination of U.K. aggregates is described and some interpretative commentary is provided. Investigation of structures for any evidence of ASR involves both site inspection and laboratory analysis, but petrographical examination of concrete is considered to be the only unequivocal means of identifying or discounting the occurrence of ASR. However, it is difficult to demonstrate definite causal links between microscopic evidence of ASR and damage observed on the structure. Suggestions are made to assist in the evaluation of laboratory findings to achieve more definite diagnoses. Core expansion tests to indicate continued expansion of the concrete are briefly considered.

1980. Soeda, M., Yamato, T. and Emoto, Y., "EXPANSION AND PORE SIZE DISTRIBUTIONS OF CONCRETES CONTAINING REACTIVE AGGREGATES (in Japanese)," Semento Gijutsu Nenpo (Annual Bulletin of Japan Cement Assoc.), No. 40, 1986.

KEY WORDS: alkali aggregate reactions; test methods; mercury intrusion porosimetry; aggregates

Aggregate which was judged as harmful by the chemical method, showed increase in pore volume of 40%. Expansion in concrete depended on the amount of alkali, and on the amount of the reactive aggregate. The effect of silica fume on suppressing reaction can be estimated by the pore size distribution of the aggregate reacted with silica fume. Expansion of concrete or mortar by AAR was detected by the pore size distribution measurement.

1981. Soles, J. A., Malhotra, V. M. and Suderman, R. W., "THE ROLE OF SUPPLEMENTARY CEMENTING MATERIALS IN REDUCING THE EFFECTS OF ALKALI-AGGREGATE REACTIVITY: CANMET INVESTIGATIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 79-84.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; slag; silica fume; expansion

The effect of mineral admixtures in reducing expansion of concrete from alkali aggregate reaction is being investigated. A total of 15 fly ashes, slags, silica fumes and several natural pozzolans were chosen, to have a wide range in physical-chemical features of additives commercially available in Canada. One reactive carbonatic and two reactive siliceous aggregates were used. This paper reports test data on the materials used, the performance of concretes containing each admixture in different proportions, and 12 month expansion measurements of mortar bars and concrete prisms made with them. The data are used to provide indications of optimum replacement levels and determine the effectiveness of the different admixtures in reducing deleterious reactions.

1982. St. John, D. A., "NEW ZEALAND'S APPROACH TO EVALUATING THE ALKALI-AGGREGATE PROBLEM," Proc. 7th Intl. Alkali Conf. 1986, pp. 237-241.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; pozzolans; alkali effects; cements; field experiences; New Zealand

The true extent of the alkali-aggregate problem in New Zealand is being evaluated in a five part program. 4500 sources of aggregates have been located and identified from existing geological maps to define potential problem areas more closely. All alkali aggregate test data for the last forty years has been collated and is being reviewed. The application and economic appraisal of the use of pozzolans is being reviewed. An economic appraisal of the manufacture of low-alkali cement has been completed. Surveillance programs of structures are in progress, and damaged structures located are being investigated.

1983. Strauss, P. J. and Schnitter, O., "REHABILITATION OF A PORTLAND CEMENT CONCRETE PAVEMENT CRACKED BY ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 210-214.

KEY WORDS: alkali aggregate reactions; pavement structures; overlays; repairs; field experiences; U.S.A.

Alkali aggregate reaction resulted in a decrease in slab stiffness which caused, together with the entrance of surface water, an increase in deflection and relative vertical movements at the joints. This increase in slab movement induced higher stresses on the sublayers which destroyed slab integrity and caused structural failures. Two goals in rehabilitation are the reduction of relative movements at joints, and the successful sealing of the pavement. The aim of rehabilitation therefore was to avoid cracking in the overlay which was intended as a seal.

1984. Swamy, R. N. and Al-Asali, M. M., "NEW TEST METHODS FOR ALKALI-SILICA REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 324-329.

KEY WORDS: alkali aggregate reactions; test methods

Test methods are suggested to determine alkali reactivity; the effects of ASR on concrete properties; and the effectiveness of mineral admixtures in controlling ASR expansion. Evidence is presented to support the validity of the proposed test methods.

1985. Swamy, R. N. and Al-Asali, M. M., "ENGINEERING IMPLICATION OF ASR EXPANSION IN CONCRETE AND THE EFFECTIVENESS OF MINERAL ADMIXTURES," Durability of Concrete. Aspects of Admixtures and Industrial By-Products, International Seminar, April 1986, Swedish Council for Building Research 1986, Stockholm, pp. 133-153.

KEY WORDS: alkali aggregate reactions; preventive measures; expansion; structural effects

1986. Takeyoshi, T., Noda, K., Taki, T. and Katawaki, K., "CONTROL OF ALKALI-AGGREGATE REACTION WITH CONCRETE SURFACE COATING (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings

Several commercially available coating materials were investigated for controlling AAR. The impermeability to water and to salt were checked for each kind of coating material.

1987. Tamura, H., "A TEST METHOD ON RAPID IDENTIFICATION OF ALKALI REACTIVITY AGGREGATE (GBRC RAPID METHOD)," Proc. 7th Intl. Alkali Conf. 1986, pp. 304-308.

KEY WORDS: test methods; autoclave methods; GBRC rapid method; alkali aggregate reactions; reactive aggregates

Since 1984, the GBRC Rapid Method has been developed by a group belonging to the General Building Research Corporation of Japan in order to rapidly identify the alkali reactivity of aggregates. It is also available for the determination of future susceptibility to alkali aggregate reaction of fresh concrete. We have published the results of studies on the GBRC Rapid Method several times in Japan . In this report, we present an outline of the test method and a description of the investigation to develop the test. We also present test results on 152 aggregate samples using this method, a correlation of the results of the GBRC Rapid Method with the ASTM Chemical and Mortar Bar Methods, and applications for the identification of future susceptibility to alkali aggregate reaction of fresh concrete.

1988. Tamura, H., Takahashi, T. and Igarashi, C., "A STUDY ON RAPID TEST METHOD OF SUSCEPTIBILITY OF ALKALI-AGGREGATE REACTION IN CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; test methods; GBRC rapid test; autoclave tests

Research in progress towards developing a rapid test method of alkali aggregate reaction for concrete was reported. The GBRC accelerated test, which has been used for rapid testing of alkali reactivity of aggregates, was applied for concrete and the results implied that the test method would be effective.

1989. Tang, M. S., Han, S., Zhen, S., Yuan, M., Ye, Y. and Lu, Y., "APPLICATION OF AUTOCLAVE RAPID TEST METHOD IN PRACTICAL ENGINEERING PROJECTS IN CHINA," Proc. 7th Intl. Alkali Conf. 1986, pp. 294-298.

KEY WORDS: alkali aggregate reactions; test methods; autoclave tests; reactive aggregates

The results obtained by the autoclave rapid test method are consistent with these of ASTM C 227 and C 289 and of petrographic analysis. It is concluded that this method can be used to identify the alkali reactivities of aggregates. It is particularly suitable for a primary test when there are a large number of aggregates to be identified.

1990. Tatematsu, H., Takata, J. and Takinaga, S., "CHARACTERIZATION OF ALKALI AGGREGATE REACTION PRODUCTS (in Japanese)," Journal of the Clay Science Society of Japan, Vol. 26, No. 3, pp. 143-150, 1986.

KEY WORDS: alkali aggregate reactions; alkali silica gels; crystalline reaction products; reactive aggregates; mica; clay mineral effects; alkali removal

In this work, in order to elucidate the reaction mechanism, scanning electron microscopic observation and electron probe microanalysis were carried out on reaction products on the fracture surfaces of aggregate in concrete. The results clarified that these reaction products are classified into the following three types, i.e., (1) $Na_2O$-$K_2O$-$SiO_2$ system, (2) $Na_2O$-$K_2O$-CaO-$SiO_2$ system, and (3) ($Na_2O$)-$K_2O$-CaO-$SiO_2$ system, based on the chemical compositions. Products of the (1) and (2) types are jelly-like materials probably caused by the ASR, but those of (3) type are rosette-like and probably caused by removal of K from layer silicates. From these facts, it is indicated that the latter material is one of the ASR products, and that this material is developed in the presence of mica clay minerals in the aggregate. Furthermore, the mineralogical compositions of the above aggregates were investigated by means of X-ray diffraction technique, giving the results that they had still a little amount of reactive minerals.

1991. Tenoutasse, N. and Marion, A. M., "THE INFLUENCE OF SILICA FUME IN ALKALI-AGGREGATE REACTIONS," Proc. 7th Intl. Alkali Conf. 1986, pp. 71-75.

KEY WORDS: alkali aggregate reactions; silica fume; preventive measures; alkali silica gels; crystalline reaction products

A systematic study of pozzolanic activity of silica fume at different temperatures has permitted us to draw some

conclusions concerning the beneficial influence of silica fume in alkali aggregate reaction. The microscopical examination of hydrated silica fume blended cement reveals the presence, not only of expansive gel, but also well crystallized plates such as have already observed in alkali-aggregate damaged concretes. The morphological characteristics of this gel seem to be influenced by its potassium content.

1992. Tenoutasse, N. and Marion, A. M., "INFLUENCE OF FLY ASH IN ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 44-48.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; crystalline reaction products

A systematic study of the long term hydration of PFA + cements and PFA + $Ca(OH)_2$ systems has permitted us to draw some conclusions concerning the behavior of alkalis. Alkalis are not released from Belgian fly ash particles. Some well crystallized hydrates in the hexagonal system are observed in the investigated hydrated mixtures. The potassium content of this crystalline compound is significant. The authors suggest that the beneficial role of PFA particles in the reduction or the inhibition of the expansion due to alkali-aggregate reaction could be attributed to the formation of the stable compound.

1993. Thorsen, T. S., "ALKALI-SILICA REACTIONS IN REINFORCED CONCRETE BEAMS WITH PARTICULAR REFERENCE TO BEARING CAPACITY," Proc. 7th Intl. Alkali Conf. 1986, pp. 146-151.

KEY WORDS: alkali aggregate reactions; structural effects; field experiences; Denmark

This paper contains a brief description of a laboratory research program on alkali-silica reactions in reinforced concrete beams, concrete prisms, and concrete test cylinders. The purpose of the investigation was to clarify a connection between a visual evaluation of damage of a beam and the shear and anchorage strength. In the laboratory thin sections and polished concrete slabs from the test beams have been investigated. Three weeks after casting and subsequent wet curing some of the beams were stored in a saturated NaCl solution at 50°C. During the storage period longitudinal and transverse expansions were

measured. After different storage periods, the extent of damage in the beams was evaluated, and the load carrying capacity of the beam in shear was tested in a test set-up.

1994. Vanderstraeten, A. T., "REPAIR OF ALKALI-AGGREGATE REACTION DAMAGE TO THE MOTORWAY STRUCTURES OF THE PELL STREET INTERCHANGE, PORT ELIZABETH, REPUBLIC OF SOUTH AFRICA," Proc. 7th Intl. Alkali Conf. 1986, pp. 194-198.

KEY WORDS: alkali aggregate reactions; column pile caps; structural effects; repairs; field experiences; South Africa

The paper outlines investigations undertaken to determine the presence and effects of AAR in the concrete structures, in particular the pile caps, of the Pell Street Interchange in Port Elizabeth, South Africa. Findings, conclusions and the adopted repair method of encapsulating affected pile caps with reinforced and prestressed concrete are described, as are the remedial measures adopted for other affected elements.

1995. Visvesvaraya, H. C., Rajkumar, C. and Mullick, A. K., "ANALYSIS OF DISTRESS DUE TO ALKALI-AGGREGATE REACTION IN GALLERY STRUCTURES OF CONCRETE DAM," Proc. 7th Intl. Alkali Conf. 1986, pp. 188-193.

KEY WORDS: alkali aggregate reactions; field experiences; India; dam structures; expansion; displacements; structural effects

A case study on the behavior of penstock gallery structure of a concrete dam due to expansion caused by alkali aggregate reaction is presented. After nearly 25 years it was found that the reinforced concrete columns of the penstock gallery showed wide flexural cracks associated with snapping of mild steel reinforcement. A multi-disciplinary investigation on material,geological and structural aspects identified alkali aggregate reaction in the concrete mass as the most probable cause related to the distress noticed. By imposing various ranges of horizontal and vertical displacements at different elevations and studying the combined effect of these displacements on the columns, the distresses noticed were correlated to the possible combination of vertical and horizontal displacements. Thus, a most probable combination was arrived

at for further verification. In order to ensure that this order and combination of movement had indeed occurred, recourse was taken to physical observations such as closing of expansion joints, etc. The potential of residual expansion was assessed by carrying out long-term expansion tests on concrete core samples taken from the dam. As the potential for expansion was still existing, remedial actions were suggested taking into consideration the possible future expansion.

1996. Vivian, H. E., "THE REACTIVITIES OF FINE-GRAINED QUARTZ IN RAPID TESTS AND IN CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 424-427.

KEY WORDS: reactive aggregates; quartz; field experiences

The histories of concrete structures made with fine-grained quartz do not invariably confirm the deteriorating effects pretended by the test data. It is emphasized that the determination of the crypto-crystalline quartz content of aggregate is essential to indicate potential deleterious reactivity in concrete and to permit fair assessment of all the test data.

1997. Wakizaka, Y., Hirano, I, Kuwahara, K., and Makita, M., "CHARACTERISTICS OF AGGREGATES IN CONCRETE AND ALKALI-SILICA REACTIONS IN JAPAN," Proc. 7th Intl. Alkali Conf. 1986, pp. 331-335.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; reactive aggregates; andesites; cherts

Visual examination and sampling of test pieces were carried out on 21 concrete structures in Japan in which map-like cracks had occurred. Measurements of length changes were performed on these test pieces. In addition, measurements of the alkali reactivities of the coarse aggregates separated from the test pieces and analysis of their mineral assemblages by means of X-ray diffraction were undertaken. The results showed that in 20 structures the cracks were due or possibly due to alkali silica reactions. The rocks which were the cause of these reactions were aphyric bronzite andesite (so-called sanukitoids) and other andesites and cherts.

1998. Wood, J. G. M., Young, J. S. and Ward, D. E., "THE STRUCTURAL EFFECTS OF ALKALI-AGGREGATE REACTION ON REINFORCED CONCRETE," Proc. 7th Intl. Alkali Conf. 1986, pp. 157-161.

KEY WORDS: alkali aggregate reactions; mechanical properties; expansion; restraint effects; relative humidity effects; particle size effects

The structural assessment of the effects of alkali aggregate reaction requires the reaction to be quantified in terms of expansive strain, stiffness and the forces generated when restrained. The control of AAR requires the measurement of RH in structures and the determination of the effects of RH on expansion. This paper sets out the results of tests to quantify these effects. It has become clear that the physical effects of AAR are highly sensitive to the type and size range of the reactive aggregate particles and that the characteristics of AAR cannot be generalized.

1999. Wood, J. G. M., Johnson, A., and Norris, P., "MANAGEMENT STRATEGIES FOR BUILDINGS AND BRIDGES SUBJECT TO DEGRADATION FROM ALKALI-AGGREGATE REACTION," Proc. 7th Intl. Alkali Conf. 1986, pp. 178-182.

KEY WORDS: alkali aggregate reactions; structural effects; building structures; bridge structures; field experiences; U.K.

Once a serious problem (Overall Structure Rating A or B) is encountered in affected structures, the management strategy adopted needs to be tailored to ensure the continuity of function of the structure for the owner. This sometimes necessitates early decisive action. In other cases (Overall Structure Rating C or D), a low key, long term monitoring and maintenance programme is sufficient to enable them to serve their function for many years to come despite the presence of the reaction in their structure.

2000. Xu, H., "ON THE ALKALI CONTENT OF CEMENT IN AAR," Proc. 7th Intl. Alkali Conf. 1986, pp. 451-455.

KEY WORDS: alkali aggregate reactions; models; reactive aggregate; particle size effects

This paper discusses methods for the control of the alkali content of cement in AAR based upon the reaction product, the type, grain size, and content of reactive aggregate, and the cement content of the concrete. The problems have been theoretically analyzed and several important deductions have been made.

2001. Xu, H. Y. and Chen, M., "AAR IN CHINESE ENGINEERING PRACTICES," Proc. 7th Intl. Alkali Conf. 1986, pp. 253-257.

KEY WORDS: alkali aggregate reactions; field experiences; China; reactive aggregates; preventive measures

This paper summarizes studies on AAR in Chinese engineering practices during the last thirty years including reactive aggregates, inhibiting measures, case histories, and a discussion on specifications for construction with reactive aggregate.

2002. Yamamoto, C. and Makita, M., "EFFECT OF GROUND GRANULATED BLAST FURNACE SLAG ADMIXTURE, AND GRANULATED OR AIR-COOLED BLAST FURNACE SLAG AGGREGATE ON ALKALI-AGGREGATE REACTION AND THEIR MECHANISMS," Proc. 7th Intl. Alkali Conf. 1986, pp. 49-54.

KEY WORDS: alkali aggregate reactions; preventive measures; slag

Reactions of alkalis and several types of blast furnace slags are studied using the chemical method and the mortar bar method. The beneficial effect of reducing expansion caused by alkali-reactivity is shown by the use of granulated slag either as an aggregate or as a cementitious admixture in concrete. The paper also describes the results of an experiment conducted to study the mechanism of interaction of slag in suppressing AAR.

2003. Yamamoto, Y. and Akiyama, A., "ALKALI REACTIVITY OF FERRO-NICKEL SLAGS FOR CONCRETE AGGREGATE," Proc. 7th Intl. Alkali Conf. 1986, pp. 496-501.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; Japan

Experiments were conducted to generally clarify the alkali reactivity of ferro-nickel slags. The slag samples tested include all the seven slags available in Japan, three samples prepared by reheating the most reactive slag up to 700, 1000 or 1100°C, and one glassy slag. It was found that slags which were composed of only forsterite and glassy phase and contained little CaO possessed alkali-silica reactivity. The existence of the glassy phase was responsible for their reactivity. When about 15% CaO existed in slag, the dissolution of silica into the alkali solution was greatly suppressed, thereby making this kind of slag innocuous.

2004. Yamamoto, C., Chiga, H., Moriyama, Y. and Numata, S, "THE STABILITY OF BLAST FURNACE SLAG AGGREGATE ON ALKALI- SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1986.

KEY WORDS: alkali aggregate reactions; preventive measures; slag

Blast furnace slags seemed stable for alkali from the following reasons: (1) By the chemical test, values of Sc and Rc for slags were small so that they were classified as harmless. (2) There was no harmful expansion shown in mortar bar tests (3) Powdered slags were effective for controlling AAR; 40% to 50% of slag replacement was required for the 0.02% limit of expansion at 14 days of ASTM C 595.

2005. Yoshioka, Y., Kasami, H., Ohno, S. and Shinozaki, Y., "STUDY ON A RAPID TEST METHOD FOR EVALUATING THE REACTIVITY OF AGGREGATES," Proc. 7th Intl. Alkali Conf. 1986, pp. 314-318.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; mortar bars; accelerated test method

In this paper, a rapid test method is proposed based on experiments on acceleratory conditions of the mortar bar test. Specimens were immersed in NaOH solution under elevated temperature at early age, and then cured under high humidity and elevated temperature. The method was found to be effective to accelerate the reaction from the

analysis of dissolved silica and of the pore solution. In order to confirm the relationship between the rapid test and the mortar bar method, some andesite aggregates which authors obtained in Japan were tested by both the rapid test and the ASTM mortar bar test. The rapid test showed a good correlation with the ASTM mortar bar test.

2006. Abe, M., Tanaka, S., Azumagasaki, K. and Tomozawa, F., "EXPERIMENT ON A RAPID TEST METHOD OF ALKALI REACTIVITY OF AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; accelerated test methods

The proposed test method is an accelerated method such that mortar bars are cured at high temperature and relative humidity. Test results by this method agreed with those of the conventional mortar bar test.

2007. Akiyama, A. and Yamamoto Y., "ALKALI-SILICA REACTIVITY OF FERRO-NICKEL SLAGS (in Japanese)," Proceedings of JSCE, No. 378/V.6, pp. 157-163, 1987.

KEY WORDS: slag; reactive aggregates; Japan; ferro-nickel slag

Experiments were carried out to generally clarify alkali silica reactivity of ferro-nickel slags. The slag samples tested include one slag that was found to be most reactive in the previous study, three samples prepared by reheating the most reactive slag up to 700. 1000 or 1100°C, and one glassy slag. The slags which were composed of only forsterite and glassy phase and contained little CaO in their compositions were found to be reactive. In the case of these slags, amorphous silica in them was considered to be responsible for their reactivity. When about 15% CaO existed in slag, the dissolution of silica in alkali solution was greatly suppressed, thereby making the slag innocuous. The reactive slag could be converted to an innocuous one by reheating it to 1100°C. Replacing a part of cement with such mineral fines as fly ash and blast furnace slag was quite effective in reducing the expansion of concrete due to ASR.

2008. Akiyama, A. and Yamamoto, Y., "THE EFFECTIVENESS OF FERRO-NICKEL SLAG FINES IN SUPPRESSING ALKALI-SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; fly ash; expansion; ferro-nickel slag

(1) When replacing cement with finely powdered reactive ferro-nickel slag, the slag consumed alkali and functioned as an inhibitor for the reaction with some kinds of aggregates. But it may cause strength loss. (2) When replacing aggregate with the slag fines, no strength loss occurred but prevention of the reaction was not sufficient. (3) The mechanisms of preventing alkali aggregate reaction by blast furnace slag and by fly ash were different. Small amounts of the slag addition may promote expansion sometimes. (4) The necessary amounts of admixture for controlling AAR determined by ASTM C 441 are too severe in the practical sense.

2009. Baronio, G., Berra, M., Montanaro, L., Delmastro, A. and Bacchiorini, A., "INTERACTION OF SOME PHYSICAL PARAMETERS ON THE DEVELOPMENT OF THE ALKALI AGGREGATE REACTION (in French)," Proc. 1st Intl. Rilem Congress: From Materials Science to Construction Materials Engineering, Vol. 3, Durability of Construction Materials, pp 919-926, 1987.

KEY WORDS: alkali aggregate reactions; expansion; mechanisms; opal; RH effects; water content effects; particle size effects

Mortar prisms with a sand containing 4% opal, a Portland cement at 1.23% $Na_2O$ eq. and with three different water to cement ratios (W/C = 0.4, 0.5, 0.6) have been stored at two relative humidities (50 and 95%) and two temperatures (20°C and 38°C). Moreover the added opal was ground at three different sizes: 0-0.1, 0.1-1, and 1-3 mm. Conclusions are the following: (1) Expansions occurred at 95% RH only. There was no expansion at 50% RH. (2) Early expansions were highest with the finest opal (0-0.1 mm) at 95% RH and 38°C. (3) At 95% RH and 38°C more longitudinal cracks were observed for W/C = 0.6 than for W/C = 0.4. (4) At 95% RH and 20°C more transverse cracks and map cracking were visible for W/C = 0.4 than for W/C = 0.6. (5) Gel exuded more from samples containing coarse opal grains but the corresponding expansion was low. (6) Pores higher than 500 A increased with the amount of gel.

2010. Buck, A. D. and Mather, K., "METHODS FOR CONTROLLING EFFECTS OF ALKALI-SILICA REACTION IN CONCRETE," Technical Report SL-87-6, U.S. Army Corps of Engineers, Washington, 1987.

1987

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; strained quartz

(1) The portion of this project dealing with the ability of different pozzolans, when used at their most effective level with high-alkali cement, to control ASR when the reactive aggregate is at its pessimum (worst) amount was generally successful. Expansions of over 0.1 percent were reduced safely below those levels by this procedure. This is verification of the ability of different pozzolans to control ASR reaction without the necessity of using low-alkali cement. However, as found by Pepper and Mather, it may and probably will be necessary to use large amounts of a given pozzolan (up to 60 percent by solid volume replacement of cement). (2) The work with reactive granite gneiss did not specifically identify either mica or feldspar as being the reactive material in these rocks. It is believed that strained quartz was the reactive constituent since it was all that was left. Expansion data were generally similar to those obtained in the project devoted to reactivity of quartz. These data formed part of the basis for revision of Appendix B of EM 1110-2-2000, Standard Practice for Concrete (US Army of Engineers 1983) to include strained quartz as reactive material. (4) The final portion of this work dealt with the reaction of silica fume and calcium hydroxide with water; it showed the high reactivity of silica fume and provided data on the well crystallized calcium silicate hydrate Type I that developed by this reaction.

2011. Canham, I., Page, C. L. and Nixon, P. J., "ASPECTS OF THE PORE SOLUTION CHEMISTRY OF BLENDED CEMENTS RELATED TO THE CONTROL OF ALKALI SILICA REACTION," Cement and Concrete Research, Vol. 17, pp. 839-844, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; slag; pore solutions; alkali effects

(1) PFAs, when blended with portland cement of moderate alkali content, are generally capable of reducing the concentrations of hydroxyl ions in the pore solution phase to a greater extent than would be expected if they were assumed to behave as cement of zero alkalinity. (2).The reduction of alkalinity of the pore solution caused by PFA proceeds over a relatively long time, which suggests that it is probably associated with the incorporation of alkalis into CSH gel formed by the slow pozzolanic reaction. (3) The alkali content of PFA is an important factor governing

its ability to remove hydroxyl ions from the pore solution phase of blended cement pastes but the fineness or pozzolanicity of the ash may also have a limited effect. (4) Slags (GGBFS), when blended with portland cement of moderate alkali content, tend to reduce the hydroxyl ion concentration of the pore solution phase but generally to a less extent than would be expected if they were assumed to behave as cement of zero alkalinity. (5) The effectiveness of slags in lowering the hydroxyl ion concentrations of cement pore liquid is not primarily controlled by the alkali content of the slag and it appears that other factors influencing the nature and composition of the CSH gel formed may be important. (6) Whilst the work described in this paper has been concerned exclusively with the role of cement replacement materials in modifying the alkalinity of the pore solution phase, it is recognized that other characteristics of the materials, such as their influences on matrix permeability, may also contribute to their effects in controlling expansion associated with ASR.

2012. Carrasquillo, R. L. and Snow, P. G., "EFFECT OF FLY ASH ON ALKALI-AGGREGATE REACTION IN CONCRETE," ACI Mater. J., Vol. 84, No. 4, Aug. 1987, pp. 299-305.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; alkali effects

The main objective of work described herein was to identify the most relevant components of fly ash, cement, and concrete aggregate affecting the alkali aggregate reaction in concrete. Test results are based on the average of at least eight specimens exposure tested for at least six months. The main variable affecting alkali aggregate reaction in concrete is the amount of alkalis in the cement. Clearly, the replacement of a portion of cement with fly ash is an effective measure to control the expansion in concrete due to alkali aggregate reaction for any aggregate or cement.

2013. Chatterji, S., Thaulow, N. and Jensen, A. D., "STUDIES OF ALKALI-SILICA REACTION. PART 4. EFFECT OF DIFFERENT ALKALI SALT SOLUTIONS ON EXPANSION," Cement and Concrete Research, Vol. 17, pp. 777-783, 1987.

KEY WORDS: alkali aggregate reactions; mechanisms; alkali effects

It has been shown that the extent of expansion due to alkali-silica reaction depends on the type of alkali compound and its concentration in the surrounding liquid phase. It is of particular interest to note that a 3N alkali hydroxide solution causes less expansion than a 3N alkali salt solution. The results also showed that the expansion due to alkali-silica reaction is not directly proportional to the degree of chemical reaction. These results, though at variance to a generally held belief, are consistent with a recently proposed mechanism of alkali-silica reaction. The results indicate that in an accelerated alkali-silica test the use of an alkali salt is preferable to an alkali hydroxide.

2014. Collins, R. J. and Bareham, P. D., "ALKALI-SILICA REACTION: SUPPRESSION OF EXPANSION USING POROUS AGGREGATE," Cement and Concrete Research, Vol. 17, pp. 89-96, 1987.

KEY WORDS: alkali aggregate reactions; reactive aggregates; porous aggregates

Porous aggregates can significantly reduce disruptive expansion due to ASR in concrete. It is possible that some gel due to ASR can be accommodated in porous aggregate but more importantly the amount of gel produced in concrete containing porous aggregates appears to be reduced through the dilution of alkali metal concentrations by water absorbed in the aggregates, and/or (in some cases) by the porous aggregates themselves being susceptible to alkali attack. Further investigation are being carried out to determine the reactive importance of these mechanisms and their possible use in specifications to minimize the risk of damage due to ASR.

2015. Davies, G. and Oberholster, R. E., "USE OF THE NBRI ACCELERATED TEST TO EVALUATE THE EFFECTIVENESS OF MINERAL ADMIXTURES IN PREVENTING THE ALKALI-SILICA REACTION," Cement and Concrete Research, Vol. 17, pp. 97-107, 1987.

KEY WORDS: alkali aggregate reactions; test methods; preventive measures; reactive aggregates; strained quartz

The NBRI accelerated test for determining the potential alkali reactivity of aggregates can also be used to assess the ability of mineral admixtures to prevent deleterious expansion in concrete, which is caused by the alkali-silica

reaction of quartz-bearing aggregates. Results from the accelerated test, the ASTM C227 mortar prism test, and tests undertaken on concrete beams and cubes exposed outdoors, are compared and discussed.

2016. Fujisaki, K., Furusawa, Y. and Maruyama, T., "EFFECTIVENESS OF FINELY GRADED SILICEOUS MATERIALS IN PREVENTING EXPANSION DUE TO ALKALI-SILICA REACTION," CAJ Review of the 41st General Meeting/Technical Session, pp. 308-311, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; silica; glass; mineral admixtures

Effectiveness in preventing expansion due to ASR by using finely graded highly reactive siliceous materials has been confirmed. Especially, glassy materials with low alkali contents were recognized as good reducers. Other conventional mineral admixtures, for example, fly ash and silica fume are known to have preventive effect in concrete expansion. The present tests were performed only for the case of glass materials. However, it might be considered that a similar mechanism as recognized in the present study would occur in the usual mineral admixture.

2017. Gin-Yama, I., Kawamura, M., Tashiro, Y. and Yamamoto, C., "THE EFFECTS OF ALKALI, GROUND GRANULATED SLAG AND AIR IN CONCRETE ON ALKALI AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; slag; pessimum effects; alkali effects; entrained air

(1)The pessimum proportions of a reactive aggregate in mortar and in concrete were not identical. (2) Replacement with slag and use of low alkali cement were effective in preventing expansion by AAR. (3) Entrained air in concrete relieves expansion by AAR.

2018. Hidejima, S., Nohmachi, H., Takada, M. and Nishibayashi, S., "EFFECTS OF ADMIXTURE ON THE EXPANSION OF CONCRETE USING POTENTIALLY REACTIVE AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: reactive aggregates; admixtures; expansion

Concrete specimens were made such that controlling factors were kinds of reactive aggregate, mix proportion, and kinds of admixtures. Then expansion characteristics were related to these factors.

2019. Kawamura, M. and Takemoto, K., "CORRELATION BETWEEN PORE SOLUTION COMPOSITION AND ALKALI-SILICA EXPANSION IN MORTARS CONTAINING JAPANESE FLY ASHES AND BLAST FURNACE SLAGS," CAJ Review of the 41st General Meeting/Technical Session, pp. 320-323, 1987.

KEY WORDS: alkali aggregate reactions; pore solution; expansion; mechanisms; preventive measures; slag

The effectiveness of fly ash in inhibiting the expansion of mortar containing siliceous aggregate which reacts very quickly varies widely depending upon their alkali content, pozzolanic activity and specific surface area. The fact that there exists a blast furnace slag being able to inhibit the ASR expansion without a great reduction in the alkalinity of the pore solution shows that such factors as the reduction in ionic diffusivity and permeability strongly function in reduction in expansion due to ASR in slag-Portland cement system.

2020. Kawai, K. and Kobayashi, K., "A STUDY ON ESTIMATION OF ALKALI CONTENT IN HARDENED CEMENT (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali effects; chemical analysis; petrography

(1) A method in which the hardened concrete sample was completely dissolved by HF and total Ca was analyzed, was effective even for the concrete containing limestone aggregates. (2) Estimated values of cement content were highly affected by the sample pre-treatment such as crushing. (3) Estimated values of alkali content in cement were smaller and more scattered than that in concrete. (4) A mineralogical approach by using a polarizing microscope was effective in estimation of CaO, $Na_2O$ and $K_2O$ in fine aggregates.

2021. Kirimura, K. and Endo, S., "CONSIDERATION FOR ACCELERATED TEST METHODS OF ALKALI AGGREGATE REACTION (in Japanese),"

1987

Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; accelerated tests; coatings; repairs

Effects of repairing materials on preventing AAR were measured by accelerated tests. (1) AAR was affected by OH and Cl ions as well as water. (2) For evaluating the effect of suppressing AAR, drying and wetting cycles should be applied for air permeable materials such as polymer cements. Deterioration of the repairing material coated on the surface might occur due to the test condition.

2022. Kobayashi, K., Inoue, S., Yamazaki, T. and Nakano, "STRUCTURAL BEHAVIORS OF PRESTRESSED CONCRETE BEAMS AFFECTED BY ALKALI-AGGREGATE REACTION," Transaction of the Japan Concrete Institute, Vol. 9, pp. 211-218, 1987.

KEY WORDS: alkali aggregate reactions; structural effects; restraint; prestressed beams;

Expansive, and static and fatigue loading characteristics of prestressed concrete beams affected by ASR were examined. (1) Compressive strength, tensile strength and elastic modulus of ASR concrete cylinder specimens decreased to 60%, 50% and 45% of those of normal concrete. (2) Effective restraint of ASR expansion can be obtained even by introducing small amounts of prestress of about 10kgf/cm$^2$, although longitudinal expansive strain was fairly dependent upon the amount of introduced prestress. (3) All tested beams failed finally in flexure under static loading irrespective of concrete mixes. Reduction in the maximum ultimate load of ASR concrete beams was at most 10% compared to normal concrete. (4) Mid-span deflection at design load of ASR concrete beams was much smaller than predicted from the elastic modulus of cylinder specimens. Overall deformation characteristics of the PC beams, including the falling branch region, were similar to those of normal concrete beams. (6) The structural behavior of PC beams, even if seriously affected by ASR, were scarcely deteriorated under static loading. However, further investigations may be required as to the behavior under dynamic loading, for instance, reversed cyclic loading as experienced in seismic action.

1987

2023. Kobayashi, S., Kawano, H. and Tsujiko, M., "A STUDY ON TESTING METHOD TO DETERMINE EXPANSION DUE TO AAR FROM CRACKS," CAJ Review of the 41st General Meeting/Technical Session, pp. 304-307, 1987.

KEY WORDS: alkali aggregate reactions; test methods; cracking; expansion

In Japan, it is believed that the mortar bar method adopted in JIS is the most reliable method to determine alkali silica reactivity of aggregates. But this method has several problems, such as the necessity of particular apparatus, technique and long period to get the result. To solve those problems, we tried to investigate a new method to determine the reactivity more simply and promptly from the measurement of cracks. Two practical testing methods are introduced in this report.

2024. Kurihara, T. and Katawaki, K., "EFFECT OF MOISTURE CONTROL ON THE PREVENTIVE CONTROL OF ALKALI-SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; water content effects; coatings

Effects on preventing ASR of coating materials were examined by measuring the water content and the expansion of the specimen cured in a cyclic drying and wetting environment. It was possible to prevent ASR expansion by controlling the water content of the specimen. The limiting water content to stop expansion was 7 wt.% for sand:coarse aggregate ratio 2.25, alkali content 1.2% concrete. With waterproof coatings, water content could be controlled within the limit and moisture did not hinder its preventive effect.

2025. Kuwahara, K., Kobayashi, S., Hirano, I. and Kawano, H., "EXPANSION OF CORE SPECIMENS FROM ASR DAMAGED STRUCTURE," CAJ Review of the 41st General Meeting/Technical Session, pp. 318-319, 1987.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; test methods; non-destructive tests; expansion

The Ministry of Construction, Japan, has carried out investigations on ASR since 1983. After the first

investigation, which was the nationwide questionnaire with photos aiming to grasp the state of ASR in Japan, 90 structures with the pattern cracks were selected and tested using a non-destructive in-situ testing method. That was followed by an investigation in which 21 structures with high probability of ASR were chosen to be cored to get concrete specimens. These specimen were tested in detail in laboratory. The result of the core specimen expansion tests are reported, along with results of some additional tests.

2026. Miyagawa, T., Sugashima, A., Kobayashi, K. and Okada, K., "REPAIR OF CONCRETE STRUCTURES DAMAGED BY ALKALI- AGGREGATE EXPANSION (in Japanese)," Transactions of the Japan Concrete Institute, Vol. 9, pp. 227-232, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings

It was possible to control alkali aggregate expansion by controlling water content in the concrete, that is, to prevent water penetration from outside or to diffuse water out of inside of the concrete. Water-proof coatings on the surface were effective to prevent AAR when concrete was relatively dry or was in condition such that whole surface of the concrete was wetted. Surface treatments which promoting evaporation of water from inside were effective when concrete was in a condition such that water inside was expected to evaporate from the surface.

2027. Morino, K., Shibata, K. and Iwatsuki, E., "ALKALI-AGGREGATE REACTIVITY OF ANDESITE CONTAINING SMECTITE (in Japanese)," Journal of Clay Science Society of Japan, Vol. 27, NO. 3, pp. 170-179, 1987.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; clay

The measured value of Rc (alkalinity reduction) increased with the content of smectite (montmorillonite) in the andesite samples. It was shown by X-ray diffraction that the (001) spacing of smectite contained in andesite shifted from 1.5 nm to 1.26 nm, and the diffraction intensity became lower after ASTM C-289 chemical test. This effect is evidence that smectite takes part in the reduction in alkalinity. The pessimum phenomenon was observed in expansion tests of mortar bars made of andesite

aggregates. The magnitude of expansion of mortar made at the pessimum ratio was inversely correlated to amount of smectite in the andesite used.

2028. Morino, K., Shibata, K. and Iwatsuki, E., "ALKALI-AGGREGATE REACTIVITY OF CHERTY ROCK (in Japanese)," Journal of the Clay Science Society of Japan, Vol. 27, No. 4, pp. 199-210, 1987.

KEY WORDS: alkali aggregate reactions; reactive aggregates; chert; chalcedony; opal

The chert particles used were composed largely of cryptocrystalline to microcrystalline quartz, with some chalcedony. The amount of chalcedony showed a considered variation with the types of chert particles. Quartzite particles containing stained quartz with structural defects were also found in small quantities. The texture of the chalcedony under the polarizing microscope was radiating fibers. They were embedded in a matrix of apparently non-fibrous silica (opal). Under the scanning electron microscope, chalcedony showed still a fibrous texture at low magnification, but appeared at high magnification as an assemblage of rod-like particles with uneven surfaces and of different sizes. The rod-like particles were seen clearly after etching with hydrofluoric acid, which partly dissolved the filling of opal. The X-ray diffraction patterns of chalcedony were different in features from those of quartz: the 2.46 Å (301) peak of chalcedony was less intense and the 1.382 Å (212), 1.375 Å (203) and 1.372 Å (301) peaks were much less resolved than in quartz. Such features of X-ray diffraction patterns could be utilized to establish the presence of chalcedony in some cherts. Expansion of mortar was negligible when the alkali content was kept at 0.8%. On increasing the alkali content to 1.5%, however, expansion occurred and its magnitude was in the order of white-> green-> dark gray-> reddish brown - colored cherts. ASTM C-289 chemical test revealed that chert were deleterious or potentially deleterious aggregates, though mortar bars did not expand when normal Portland cement of about 0.8% $Na_2O$ equivalent was used. The expansion of mortar bar made with cherts from pit gravels changed remarkably upon the change of alkali content and curing temperature. Crystals showing the appearance of staurolite twins were observed around the reaction products in chert aggregate in a damaged concrete bridge.

1987

2029. Nakano, K., Kobayashi, S. and Suzuki, H., "INFLUENCE OF CURING CONDITIONS AND DIMENSION OF SPECIMENS ON EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION," CAJ Review of the 41st General Meeting/Technical Session, pp. 300-303, 1987.

KEY WORDS: alkali aggregate reactions; test methods; Japan

ASTM C-227 is one of the effective test method for estimating the potential alkali aggregate reactivity. As this method is easy and reliable compare with other methods, it has been used frequently. But some aggregates show little expansion in mortars, but show deleterious expansions in concrete. Needs for improved concrete prism methods and standards for the evaluation of potential alkali aggregate reactivity still exist in Japan.

2030. Nakano, K., Kobayashi, S. and Nakaue, A., "RELATION BETWEEN DEGREE OF DAMAGE CAUSED BY ALKALI-SILICA REACTION AND PHYSICAL PROPERTIES OF CONCRETE," CAJ Review of the 41st General Meeting/Technical Session, pp. 314-317, 1987.

KEY WORDS: test methods; drying effects; ultrasonic measurements

To examine the optimum drying period for ultrasonic pulse velocity testing to evaluate the various degrees of damage due to ASR, the relation between pulse velocity of dried core specimens and other physical properties were measured.

2031. Nishibayashi, S., Yamura, K. and Torigai, K., "STUDY ON THE EFFECTS OF TESTING CONDITIONS ON ALKALI-AGGREGATE REACTION, " Transaction of the Japan Concrete Institute, Vol. 9, pp. 227-232, 1987.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; pessimum effects; alkali effects; mechanical properties

The pessimum content for reactive aggregate tends to shift to smaller values with increase of total alkali content, and with increasing time. The expansion of mortars containing NaOH as the additional alkali is larger than those containing NaCl. There is almost no difference between the expansions of ASTM specimen and those of JIS

specimens. In the range of low total alkali content, expansion becomes smaller with increasing water:cement ratio. On the other hand, when the total alkali content is large, the contrary tendency is seen. The expansion of mortar is reduced with the increasing ratio of sand to cement. The expansion of mortar is scarcely affected by the differences in crushing methods of aggregate used in mortar. Long time vibrating compaction increases the expansion of mortar. Both strength and dynamic modulus of elasticity are closely correlated with expansion.

2032. Nishibayashi, S., Yamura, K., Hayashi, A. and Izutsu, K., "EVALUATIONS OF ALKALI-AGGREGATE REACTION BY CONCRETE SPECIMENS (in Japanese)," Transaction of the Japan Concrete Institute, Vol. 9, pp. 233-240, 1987.

KEY WORDS: alkali aggregate reactions; expansion; mortar bars; concrete prisms; alkali effects; pessimum effects; RH effects; temperature effects; sea water effects

(1) When the alkali content per cement weight ($R_2O$) is equal, in concrete specimens the rate of expansion is slower and the maximum value of expansion is smaller than in mortar bar specimens. (2) The expansion of concrete is affected by the reactivity of each aggregate, the alkali content, the mixture ratio of reactive and non-reactive aggregate, and the storage condition. For some aggregates, the expansion at the pessimum content is about 1.5 times as large as that of reactive aggregate alone. (3) In concretes stored at 20°C, and 100% RH, or immersed in water or sea water, the expansions start at about 6 months. Expansion in sea water at 12 months becomes approximately same as that at 40°C and 100% RH. (4) The crack patterns occurring in concrete specimens are characterized by fine width and many cracks at high temperature (40°C, 100% RH), and by large widths and few cracks at low temperature (20°C, 100% RH) and also in water and sea water. (5) For concretes stored in the same condition, it can be recognized that the expansion is closely related to reduction in the dynamic modulus of elasticity. The decrease in dynamic modulus of elasticity that indicates the extent of deterioration in concrete is more severe when rapid reaction occurs, such as at high temperatures and with highly reactive aggregate, than in mild condition of test and with slowly reactive aggregate.

1987

2033. Nishibayashi, S., Yamura, K. and Torikai, K., "STUDY ON THE EFFECTS OF TESTING CONDITIONS ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; mortar bars; test methods

Various factors affecting the amount of expansion in mortar bar test were examined and basic data for establishing better conditions of mortar bar test were obtained.

2034. Noda, K., Takeyoshi, S., Taki, T. and Katawaki, K., "POTENTIAL EFFECT OF COATING FROM ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings; cracking

Initial coatings on the concrete surface were effective in preventing cracking by alkali aggregate reaction. Coatings applied after cracks occurred were effective in preventing further propagation of the cracks. No correlation between impermeability of the coating and the amount of cracking that occurred was observed.

2035. Okada, K., Nakano, K., Ono, K. and Matsumura, M., "REPRODUCTION OF ASR CRACKING IN A LARGE SCALE CONCRETE MODEL (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; test methods; model structures; ultrasonic testing; preventive measures; slag; fly ash

A large scale concrete model was made with a reactive aggregate, cured at 40°C, 100% RH for 1 year, and exposed to natural environment for 2 years. A crack pattern similar to that experienced on real structures was reproduced. This report investigated (1) cracks and velocity of supersonic transmission, (2) expansion of the model and of its core, (3) effect of accelerated curing, and (4) suppression of ASR by fly ash and slags.

1987

2036. Ono, K., Imae, M., Kaneyoshi, A. and Shinohara, N., "EFFECT OF A WATER-PROOF ON RESTRICTION OF ASR (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; coatings;

Using large specimens of concrete, effects of air-permeable coatings such as polymer cements or silane monomers on controlling alkali aggregate reaction were investigated.

2037. Prince, A. W., "STUDY OF THE REACTIVITY OF NATURAL MATERIALS ACTIVATED THERMALLY OR MECHANICALLY IN THEIR USE AS BINDER," These de Doctorate d'Etat Specialite Mineralogic 226 Pages, June 1987.

KEY WORDS: reactive aggregates; pore solutions; alkali release; ettringite

In the hardening of hydraulic binders or the alteration of concrete aggregates the composition of the pore solution plays an important role. The $Ca^{2+}$ and $OH^-$ ions are provided by $Ca(OH)_2$ which increases the Ph of the solution and favors the dissolution of silica. A granite containing 33% quartz, 21% feldspars, 35% plagioclases and 11% micas has reacted in the same way as activated clays. In presence of $Ca(OH)_2$ and $CaSO_4$ the altered feldspars have given ettringite which formed through a dissolution process.

2038. Rajaokarivony-Andriambololona, Z., "STUDY OF THE REACTIVITY OF TWO SYNTHETIC SILICEOUS GLASSES IN WATER AND ALKALINE SOLUTION (in French)," Thesis 3rd cycle - Mention Geochimie - Université d'Orléans, 285 Pages.

KEY WORDS: alkali aggregate reactions; reactive aggregates; glass; mechanisms

The hydration of two synthetic glasses close to slag has been studied in water at pH = 6.5 and in NaOH and KOH solutions at Ph = 12.9, at 20°C and at 40°C. The glass-solution interaction was studied by chemical analysis of solution, XRD, ESCA, SEM, TEM. The formation of three different zones in the hydrated glass particle was observed as follows: (i) an internal zone with residual glass and hydrated products, (ii) an intermediate lamellar zone of hydrotalcite type which corresponds to the initial glass-

solution interface and (iii) an external zone with hydrates. The existence of two competing processes for the formation of hydrated products, dissolution-precipitation for the external hydrates and diffusion for the internal hydrates, was observed.

2039. Sersale, R., "PORTLAND-ZEOLITE-CEMENT FOR MINIMIZING ALKALI-AGGREGATE EXPANSION," Cement and Concrete Research, Vol. 17, pp. 404-410, 1987.

KEY WORDS: alkali aggregate reactions; preventive measures; blended cements; zeolite; volcanic tuff

The authors give an account of the performance modifications induced in blended cements by replacing the typical pozzolanas with a zeolitic material, i.e. a ground volcanic tuff. The advantages of such a replacement in terms of minimization of alkali aggregate expansion and of strength increase at long ages are discussed, emphasizing also the favorable influence on expansion abatement provided by previous thermal treatment of the zeolitic addition. The improved strength gain is interpretated in terms of higher reactivity of the zeolite minerals in comparison to pozzolanic glass. The improved ASR expansion abatement is attributed to the ability of the large amount of amorphous hydrated silicates produced by the tuff to incorporate large amounts of alkali.

2040. Soriano, J., "INTERACTION REACTIONS BETWEEN SOME AGGREGATES AND INTERSTITIAL PHASES IN CONCRETE," Proceedings of the First International Congress Held by RILEM and AFREM, Versaillles, France, 7-11 September 1987, J. C. Maso, ed., Vol. 1. Pore Structure and Construction Materials Properties. London, Chapman and Hall, 1987, pp. 25-32.

KEY WORDS: alkali aggregate reactions; clay; alkali silica gel; reactive aggregates

2041. Stievenard-Gireaud, D., "CONTRIBUTION TO THE ALKALI-SILICA REACTION IN CONCRETE (In French with English Summary)," Rapport des Recherche LPC No. 144, Paris, Laboratorie Central des Ponts et Chaussees, 1987, 104 pages.

KEY WORDS: alkali aggregate reactions; preventive measures;

test methods; fly ash; pozzolans

2042. Sugiura, K. and Aimoto, Y., "ALKALI-SILICA REACTION IN MORTAR SAMPLES STORED IN SEA WATER (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; sea water effects; NaCl effects; pessimum effects

Mortar bars containing reactive sands of different ratios were immersed in water and in sea water, and their expansions were measured at different immersion periods. There was a significant increase in expansion ratio of mortar bars immersed in the sea water with age due to ASR. A correlation between amount of reactive sand and the expansion ratio was observed, and a pessimum composition was also observed.

2043. Takemoto, K. and Hasaba, S., "EFFECTIVENESS OF POLYMER ADMIXTURE IN PREVENTING ALKALI-SILICA REACTION," CAJ Review of the 41st General Meeting/Technical Session, pp. 324-327, 1987.

KEY WORDS:

It was found that alkali silica expansion could be prevented by coating the reactive aggregate with polymer materials. The effect of coated aggregate in preventing alkali silica expansion depends strongly upon the content of coating polymer material. As the polymer material used in this study was a water soluble polymer emulsion, the effect also varied with time after coating the aggregates.

2044. Takeyoshi, S. and Katawaki, K., "A STUDY ON THE EFFECT OF CONCRETE SURFACE COATING PREVENTING THE ALKALI-SILICA REACTION BY A NEW ACCELERATED TEST METHOD (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; coatings; accelerated test methods; cracking

A new accelerated test method developed turned out to be effective to accelerate cracking in concrete by alkali aggregate reaction. The experiments on various coating

materials on concrete showed that some impermeable coatings prevented or delayed cracking by alkali aggregate reaction. A silane coating, which was air permeable, was simple but its effect did not last long.

2045. Tang, M. S., Xu, Z. Z. and Han, S. F., "ALKALI REACTIVITY OF GLASS AGGREGATE," Durability of Building Materials, Vol. 4, No. 4, 1987, pp. 377-385.

KEY WORDS: reactive aggregates; glass

The alkali reactivities of glass aggregates depend on their chemical compositions. The reactivities increase with increasing silica + alkali (S+N) contents, and correspondingly decrease with the increase of calcium + aluminum (C+A) contents. So far, the alkali reactivities of glass aggregates can be predicted by a reactivity index K=(C+A)/(S+N) (in mol%). The reactivity sharply increases when K is less than 0.1-0.2, and the aggregates are not reactive when K is more than 0.3.

2046. Tang, M. S., "RESEARCH ON ALKALI AGGREGATE REACTION - INTRODUCTION OF 7TH INTERNATIONAL ALKALI CONGRESS (in Chinese)," Concrete and Cement Products, No. 4, 1987, pp. 20-22.

KEY WORDS: alkali aggregate reactions; reviews

2047. Tang, M. S., "INSPECTION ON HIGHWAYS, BRIDGES AND DAMS IN CANADA (in Chinese)," Research Report of Nanjing Institute of Chemical Technology, China, No. 2, 1987, pp. 124-128.

KEY WORDS: alkali aggregate reactions; field experiences

2048. Tang, M. S., "STUDIES OF THE EFFECT OF ALKALI IN CEMENT AND CONCRETE IN CHINA - A REVIEW," Durability of Building Materials, Vol. 4, No. 4, Apr. 1987, pp. 371-376.

KEY WORDS: alkali aggregate reactions; cement effects; reviews

This paper is a brief review of the studies of alkali in

cement and concrete since 1958 in China. It includes: (1) the effect of alkali on the process of cement making; (2) the effect of alkali on the properties of cement (strength, setting time, sulfate resistance and hydration rate); and (3) some significant results about alkali aggregate reaction obtained by Chinese scientists.

2049. Tatematsu, H. and Takada, J., "CHARACTERISTICS OF ALKALI AGGREGATE REACTION PRODUCTS AND DETERIORATION OF CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1987.

KEY WORDS: alkali aggregate reactions; reactive aggregates; alkali effects; expansion; alkali silica gel

A correlation between chemical characteristics of the AAR reaction product and the deterioration of the concrete was investigated. For volcanic rock aggregates, the chemical composition of the reaction product changed when expansion characteristic changed. For sedimentary rocks, this correlation was not observed. Effects of kind of alkali on expansion depended on the kind of aggregate. In highly alkaline conditions, the effect of alkali type on expansion was in the order NaCl > NaOH > $Na_2SO_4$ irrespective of the kind of aggregate.The $Ca(OH)_2$ amount in mortar correlated with the amount of expansion, but the amount of ettringite did not.

2050. Tuel, A., "STRUCTURE CHARACTERIZATION OF PRECIPITATED SILICA BY NUCLEAR - MAGNETIC RESONANCE - MORPHOLOGY OF AGGREGATES (in French)," These de Doctorat - Specialise Chimie Physique - Universite Paris 6, 219 Pages, June 1987.

KEY WORDS: silica; NMR

Precipitated silica appears as colloidal particles which coagulate in aggregates of 500-6,000 Å in size. Three species are present at the silica surface: geminal silanols:Si = $(OH)_2$, free silanols Si - OH, and siloxane bridges Si - O - Si . Magic Angle Spinning and Cross-Polarization 29 Si Nuclear Magnetic Resonance can distinguish between geminal and free silanols that Infra Red spectroscopy cannot do. Silanol groups adsorb water molecules. As silica surface is covered by water molecules it is possible to use proton NMR. Precipitated silica is porous. Its surface present numerous irregularities. More protons are concentrated in micropores. So they are

clusters and present a disordered structure, although silanols are uniformly distributed. Polarizable siloxanes are located in a relatively homogeneous superficial layer.

2051. Uchikawa, H. and Hanehara, S., "THE EFFECT OF CHARACTER AND STRUCTURE OF HARDENED MORTAR PREPARED WITH ALKALI REACTIVE AGGREGATE AND BLENDED CEMENT ON ITS EXPANSION," CAJ Review of the 41st General Meeting/Technical Session, pp. 296-299, 1987.

KEY WORDS: alkali aggregate reactions; reactive aggregates; expansion; slag; fly ash; alkali effects; $CaF_2$ effects

Expansion of mortar due to alkali aggregate reaction was closely related to the degree of reaction experienced by the aggregate. In slag and fly ash mortar, a decreased degree of reaction produced less expansion of the mortar. The kind of alkali reactive aggregate had no influence on hydration of cement or of the blending component. Addition of alkali remarkably depressed cement hydration; in consequence, the hardened structure of the mortar remained porous and attack of alkali ion to aggregate was accelerated. The addition of $CaF_2$ had no effect on hardened structure of the mortar.

2052. Uomoto, T. and Nishimura, T., "EXPANSION AND CRACKING OF CONCRETE CAUSED BY ALKALI AGGREGATE REACTION," CAJ Review of the 41st General Meeting/Technical Session, pp. 312-313, 1987.

KEY WORDS: alkali aggregate reactions; expansion; cracking

It is the aim of this paper to study the behavior of concrete when alkali aggregate reaction takes place. The experiment was done mainly to clarify the expansion behavior and crack formation in concrete specimens.

2053. Urhan, S., "ALKALI SILICA AND POZZOLANIC REACTIONS IN CONCRETE. PART 1: INTERPRETATION OF PUBLISHED RESULTS AND AN HYPOTHESIS CONCERNING THE MECHANISM," Cement and Concrete Research, Vol. 17, pp. 141-152, 1987.

KEY WORDS: alkali aggregate reactions; mechanisms; pozzolans

Pozzolanic reactions and ASRs are briefly reviewed. The following mechanism is proposed for these reactions in concrete: $Ca^{2+}$, $Na^{+}$, $K^{+}$ and $OH^{-}$ are adsorbed on the silica surface in the first minutes of hydration. The adsorption of $OH^{-}$ increase the coordination number of silicon atoms on the silica surface and provokes the dissolution. As $Ca^{2+}$ is more strongly adsorbed than $K^{+}$ and $Na^{+}$ first it reacts with dissolving silica. If the rate of crystallization of CSH is higher than the rate of dissolution of silica CSH can be formed on the surface of silica and dissolution stops. Otherwise, dissolution goes on, and $K^{+}$, $Na^{+}$ can penetrates into the silica-lime complex to form silicate gel, and a subsequent volume increase can be expected. Influences of different parameters on alkali silica and pozzolanic reactions, according to the proposed mechanism, are discussed and the pessimum content is examined. With regard to reaction products of silica + lime + alkalis, it seems that there is progressive passage from low viscosity gel to CSH following the chemical composition, which is probably conditioned by the competition mechanism of the rates of dissolution of silica and crystallization of CSH. However it seems possible to find all types of reaction products, from low viscosity gel to CSH, in the same concrete made from reactive aggregate or from pozzolanic materials. The nature of the reaction products observed by different authors proposes that the expansion of concrete is primarily due to the swelling of solid alkali silicate gel rather than the osmotic pressure of low viscosity gel.

2054. Urhan, S., "ALKALI SILICA AND POZZOLANIC REACTIONS IN CONCRETE. PART 2: OBSERVATIONS ON EXPANSION PERLITE AGGREGATE CONCRETES," Cement and Concrete Research, Vol. 17, pp. 465-477, 1987.

KEY WORDS: alkali aggregate reactions; expansion; reactive aggregates; perlite; mechanisms; alkali silica gel; mechanical properties

Length change, mechanical strength, porosity measurements and SEM observations show that ASRs and pozzolanic reactions coexist in expanded perlite concretes. In humid conditions the strength gain after 28 days is better for low alkali cement expanded perlite aggregate concretes than those made from high alkali cement. However, for expanded perlite concretes exposed to 50% RH, 20°C the strength evolution is better for high alkali cement concretes. Discussion of perlite aggregate is generally observed on broken air bubble walls which can be considered as fine

particles. On the exterior part of aggregates the pozzolanic reaction develops and favors the bond strength between cement paste and aggregate. Alkali silicate gels formed have different morphologies and structures. The presence of lime stiffens the gel. Following the lime content of the reaction product, it seems that there is a progressive transition from low viscosity gel to CSH. Late expansion of expanded perlite concrete under very unfavorable conditions show that once a concrete is made from reactive aggregates or from pozzolanic materials there is always a small amount of alkali silicate gel produced. As the expansion is related to strength of the concrete, in normal weight concretes slight expansions can not be observed because of their high mechanical strengths. Very low free water in perlite concretes, which have shown late expansion, indicate that only the formation of alkali silicate gel which has a bigger volume than the original minerals may also cause expansion.

2055. Van Roode, M., Douglas, E. and Hemmings, R. T., "X-RAY DIFFRACTION MEASUREMENT OF GLASS CONTENT IN FLY ASHES AND SLAGS," Cement and Concrete Research, Vol. 17, pp. 183-197, 1987.

KEY WORDS: fly ashes; slags; glass ; X-ray diffraction

In this study, the Klug and Alexander quantitative X-ray diffraction (QXRD) method was used for determining the glass content of nine fly ashes and two slags. The mass percentages of $\alpha$-quartz, mullite, magnetite and hematite were computed and the glass content was obtained by difference. The technique was improved in the course of this study. The glass content of the materials studied ranged from 53.5 to 94.5 percent using the QXRD method.

2056. Wakizaka, Y., Moriya, S. and Kawano, H., "RELATIONSHIP BETWEEN MINERAL ASSEMBLAGES OF ROCKS AND THEIR ALKALI REACTIVITIES," CAJ Review of the 41st General Meeting/ Technical Session, pp. 292-295, 1987.

KEY WORDS: alkali aggregate reactions; test methods; mineral effects

Alkali reactivities of minerals are controlled by their chemical and physical properties such as silica contents and crystal structures. Felsic (high silica contents)

mineral have high Sc., whereas mafic (low silica contents) minerals have low Sc, and glasses have little bridging oxygen, so they show high Sc. Rc of expansible clay minerals is high, because they contain exchangeable alkali metal ions. Alkali reactivities of rock can be predicted semi-quantitatively when the mineral assemblage is known.

2057. Wood, J. G. M., "ALKALI SILICA REACTION DAMAGE TO CONCRETE STRUCTURES IN UNITED KINGDOM," Conf. Institute Technique du Batimnet et des Travaux Publics, 21 pages, March 1987.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.

2058. Abe, M., Tomozawa, F., Tamura, K. and Mano, K., "INFLUENCE OF THE KIND OF ADDED ALKALI ON TESTS OF ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; alkali effects; NaCl effects; NaOH effects; $NaNO_2$ effects; test methods

In tests for checking the effect of added alkali on the alkali aggregate reaction, it was found that addition of $Na_2CO_3$ lowered the flowability of the mortar significantly; addition of NaOH lowered it slightly. NaOH addition increased the air content of concrete slightly, and decreased compressive strength. Little change in compressive strength was observed when NaCl or $NaNO_2$ was added. NaOH addition decreased the drying shrinkage; NaCl or $NaNO_2$ did not affect it.

2059. Barlow, D. F. and Jackson, P. J., "THE RELEASE OF ALKALIS FROM PULVERIZED-FUEL ASHES AND GROUND GRANULATED BLASTFURNACE SLAGS IN THE PRESENCE OF PORTLAND CEMENTS," Cement and Concrete Research, Vol. 18, pp. 235-248, 1988.

KEY WORDS: cements; alkali effects; preventive measures; slag; fly ash

Various methods have been proposed and adopted to establish the quantity of alkali which becomes available for potential alkali silica reaction when pulverized-fuel ashes and ground granulated blastfurnace slags are incorporated in concrete and mortar. These methods are examined, compared and related to the results obtained from tests which involved direct reaction of the latent hydraulic binders with Portland cements. The evidence presented suggests that after 28 days at 38°C, 70% of the total alkalies in ground granulated slags can be released whilst at 20°C the corresponding figure is 45%. With pulverized-fuel ashes the amount of alkali released is dependent on the ratio of ash: opc and also upon the temperature, and can vary between 10 and 50% of the total alkali present. In the case of both latent hydraulic binders there is evidence that alkali continues to be released after 28 days.

1988

2060. Chandra, S. and Berntsson, L., "DETERIORATION OF CONCRETE IN SWIMMING POOLS IN THE SOUTH OF SWEDEN," ACI Materials Journal, Vol. 85, pp. 489-494, 1988.

KEY WORDS: alkali aggregate reactions; swimming pool structures; field experiences; Sweden; ettringite; sulfate attack; pyrites; feldspars; alkali release

Concrete placed at the back lining of the glazed tiles in swimming pools made 15 years ago in the south of Sweden has been damaged. The concrete looked porous, and tests showed that the strength of the concrete was not very high and its cement content was rather low.Systematic analysis of this concrete is reported here. Alkali-silica reaction is reported to be the major cause of swimming pool deterioration. Besides the alkali-silica reaction, tests showed the influence of sulfates forming ettringite and gypsum, leaching of pyrites, and disintegration of feldspar, as shown by petrographic analysis. Thus, deterioration has occurred as a combined effect.

2061. Chatterji, S., "ALKALI-SILICA REACTION AND MINERAL ADMIXTURES," Durability of Concrete. Aspects of Admixtures and Industrial By-Products. International Seminar, April 1986, Stockholm, Swedish Council for Building Research, 1988, pp. 125-131.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; slag; fly ashes

2062. Chatterji, S., Thaulow, N. and Jensen, A. D., "STUDIES OF ALKALI-SILICA REACTION, PART 6. PRACTICAL IMPLICATIONS OF A PROPOSED REACTION MECHANISM," Cement and Concrete Research, Vol. 18, pp. 363-366, 1988.

KEY WORDS: alkali aggregate reactions; mechanisms

In this paper various practical implications of a recently proposed alkali-silica reaction mechanism have been expressed in a coherent fashion. Aspects of alkali-silica reaction considered are: long latency, sources of alkalies, relative aggressivity of sodium and potassium ions, reduction of expansion, relationship between the degree of chemical reaction and the expansion, and accelerated testing of aggregates.

1988

2063. Chatteriji, S. and Jensen, A. D., "A SIMPLE CHEMICAL TEST METHOD FOR THE DETECTION OF ALKALI-SILICA REACTIVITY OF AGGREGATES," Cement and Concrete Research. Vol. 18, pp. 654-656. 1988.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; OH ion concentration; chemical tests

The method consists of suspending the aggregate in question with CaO in a saturated solution of KCl (or other alkali chloride) at 70°C for 24 hours, and measuring the OH ion concentration of the filtrate. This is compared to that of a control mix with non-reacting quartz aggregate. The degree of lowering of the OH ion concentration is taken as a measure of the potential alkali silica reactivity of the aggregate.

2064. Corneille, A., "ALKALI-AGGREGATE REACTION IN FRENCH DAMS (in French)," Ecole Nationale des Ponts et Chaussees - Session Durabilite des Structures en Beton, 14 pp., March 1988.

KEY WORDS: alkali aggregate reactions; field experiences; France; dam structures; petrography; ettringite; alkali silica gel

Among 472 dams built in France only four have been deteriorated by alkali aggregate reaction. Two examples are presented; (1) the Chambon dam built in 1930 with expansion occurring in 1950 and (2) Temple-sur-Lot dam built in 1947 with expansion in 1964. The concrete of the Chambon dam contains a Portland cement with 0.59% $Na_2O$ equivalent, and siliceous aggregates with gneiss, mica schist, altered feldspars (which were not potentially reactive after the ASTM C 289 test) and gels of alkali silicate around aggregates. The concrete of the Temple-sur-Lot dam contains a slag cement (CPJ), with less than 35% slag, calcareous and siliceous aggregates with quartz of high undulatory extinction, chalcedony, opal, and altered feldspars, and gels of alkali silicate and ettringite around aggregates.

2065. Davies, G. and Oberholster, R. E., "ALKALI-SILICA REACTION PRODUCTS AND THEIR DEVELOPMENT," Cement and Concrete Research. Vol. 18, pp. 621-635, 1988.

KEY WORDS: alkali aggregate reactions; test methods;

mechanisms; alkali silica gels

The work described was undertaken to investigate whether the NBRI accelerated test in fact mimics the natural alkali-silica reaction. The test specimens showed all the characteristics of the alkali-silica reaction and the reaction products proved very similar to those found in structures affected by the reaction in the field. These products can be grouped into (a) exuded and surface gels (amorphous material and a tobermorite gel) and (b) white reaction products generated within the concrete and mortar specimen. The NBRI test, therefore, appears to accelerate the reaction and not to modify the naturally occurring process. This in turn indicates that the test can be used to investigate the mechanism of the alkali-silica reaction. The alkalis Na and K in most of the reaction products that form during the test can be removed by soaking the concrete and mortar specimens in water. In some cases the Na and K are replaced by Ca. This suggests that when sufficient water is available, the reaction products are able to interact with a Ca-bearing phase in the cement matrix. If this phase is $Ca(OH)_2$, as expected, then it is very likely that alkali hydroxides are by-products of the interaction, and consequently that the alkali-silica reaction is self-perpetuating, since the alkali hydroxide would be continuously regenerated.

2066. Fukushima, M. and Futamura, S., "ALKALI REACTIVITY OF CRUSHED STONES FOR CONCRETE (in Japanese)," Cement & Concrete, No. 438, 1983.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; Japan

2067. Futamura, S. and Fukushima, M., "INFLUENCE OF ALKALI CONTENT OF PORE SOLUTION UPON MORTAR EXPANSION DUE TO ALKALI SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; mortar bars; pore solutions; expansion; mechanisms

This paper reported an analysis of pore solution expressed from the mortar bar samples made of a crushed pyroxene andesite, and changes in ion concentration and changes in expansion of the bar measured at different ages.

1988

2068. Glasser, E. P., Luke, K. and Angus, M. J., "MODIFICATION OF CEMENT PORE FLUID COMPOSITIONS BY POZZOLANIC ADDITIVES," Cement and Concrete Research, Vol. 18, pp. 165-178, 1988.

KEY WORDS: pore solutions; pozzolans; fly ashes; slag; silica fume; cement effects

The impact of blending agents (i.e. mineral admixtures) on the internal environment of cement systems is assessed by chemical analysis of the pore solutions. The short-term behavior of pfa-cement systems is complicated by soluble alkalis. Potassium levels are generally reduced by the presence of the pfa; sodium is not much altered. Silica fume has a more immediate effect; 10 to 20% additions can lead to order of magnitude concentration reductions, especially in cesium concentrations. The potential for chloride uptake is correlated with cement composition; the sum of C3A and ferrite contents are more significant in this regard than the C3A content alone. Slags markedly decrease the internal redox potential, from about +100 mV in plain cement pastes to -200 or -225 Mv in slag-rich blends.

2069. Grzeszczyk, S. and Kucharska, L., "THE INFLUENCE OF ALKALIS ON RHEOLOGICAL PROPERTIES OF FRESH CEMENT PASTES," Cement and Concrete Research, Vol. 18, pp. 1-8, 1988.

KEY WORDS: alkali effects; rheological properties

The measurement results indicate that it is possible to determine, using rheological methods, the differences in reactivity of clinkers and the impact of clinker reactivity on rheological behavior of corresponding cements. Built-in alkalis which gradually enter the solution during hydration, by bringing about changes in solution composition and solubility of cement pastes, decrease the efficiency of control over the hydration process by gypsum which is manifested in a rapid increase of stress in time. The more reactive the clinker is, the smaller is the influence of the alkalis introduced with the makeup water on the consistency of cement pastes and its changes in time.

2070. Herath, A. and Uomoto, T., "EFFECT OF STEEL REINFORCEMENT ON CONCRETE EXPANSION OF ALKALI SILICA REACTION (in Japanese)," Proceedings of the Japan Concrete Institute,

Vol. 10, No. 2, pp. 843-848, 1988.

KEY WORDS: alkali aggregate reactions; restraint; expansion

It was observed that the crack pattern in the reinforced concrete specimens was influenced by the rate of expansion, and by the detailing of the reinforcements etc. Steel strains and concrete expansions showed a similar trend.

2071. Iwase, H., Nakada, K., Rokugo, K. and Koyanagi, O., "QUANTITATIVE EVALUATION OF CONCRETE CRACKS DUE TO ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; cracking; restraint; prestress effects; structural effects

Crack patterns caused by alkali aggregate reaction were digitized and input into and analyzed by a personal computer. For reinforced concrete the crack length was decreased with increasing ratio of rebars in the compression side. Addition of steel fibers also decreased the crack length. For prestressed concrete, cracks parallel to the prestress direction became significant as the specimen was prestressed. The numbers of those cracks decreased for prestress up to 40 kgf/sq. cm, but increased beyond 80 kgf/sq. cm.

2072. Kanemitsu, S., Miura, S., Yamamoto, T. and Kawanishi, J., "INFLUENCE OF CURING CONDITION ON ASR DURING EARLY AGE (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; humidity effects

In this study, mortar bar tests were performed using a volcanic rock, at different humidities in early age, such that (1) ASR sufficiently occurred, (2) ASR did not occur sufficiently, and (3) cement hydration was hindered significantly. The results suggested that ASR occurred at high humidity and when cement hydration was proceeding significantly.

1988

2073. Kato, M., Yamamoto, C., Gin-Yama, I. and Tashiro, Y., "EXPOSURE TEST OF CONCRETE WITH DIFFERENT ALKALI AND BLAST-FURNACE SLAG CONTENT ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; alkali effects; slag

Results of 22-month exposure tests of concrete specimens made of high and low alkali cement and of blast-furnace slag are reported.

2074. Kawakami, H., "DEFORMATION OF A REINFORCED CONCRETE BUILDING DUE TO ALKALI AGGREGATE REACTION AND THERMAL EXPANSION," Transactions of the Japan Concrete Institute, Vol. 10, pp. 99-104, 1988 (in Japanese).

KEY WORDS: alkali aggregate reactions; expansion; thermal expansion; field experiences; building structures; Japan

With the investigation of potential expansion due to alkali aggregate reaction and thermal expansion of the cores, the deformation of a three story reinforced concrete building and its crack behavior were brought to a quantitative discussion. The effects on the structure were summarized as follows. Cracks at girder ends were slight three years after the construction. In five to ten years the expansion of the slabs by the alkali aggregate reaction extended to 0.006% (over 2 cm dislocation of roof ends were found in the longitudinal direction). With the remarkable progress of cracks at the girders and columns, the restraining effect of the structure against the expansion of the roof slab decreased and the thermal expansion behavior of the roof reached its full extent of 0.02% between summer and winter. The whole roof was covered with new sheet material ten years after the construction and no distinct progress of cracks was observed since. It is not clarified whether the whole potential expansion due to alkali aggregate reaction has appeared already, or whether part of it still remains, as a consequence of drying of the roof slab after the refinishing.

2075. Kawamura, M., Takemoto, K. and Terashima, N., "EFFECT OF SODIUM CHLORIDE SUPPLIED FROM THE SURROUNDING SOLUTION ON THE ALKALI-SILICA REACTION," CAJ Review of the 42nd General Meeting/Technical Session, pp. 254-257, 1988.

KEY WORDS: alkali aggregate reactions; test methods; pore solutions, chloride effects, alkali effects; NaCl effects

For mortars immersed in 1N NaCl solution, it was found that expansion occurred only when the pore solution $OH^-$ ion concentration exceeds about 0.3 mol/l. Above this, the expansion did not correlate with the $OH^-$ ion concentration, but correlated with the reduction of $Ca(OH)_2$ by the fly ash used, i.e.the pozzolanic activity of the fly ash. $OH^-$ ions in the pore solution causes ASR in mortars even when they are immersed in NaCl solution. Once ASR occurs under the above critical $OH^-$ ion concentration level, $Cl^-$ ions from the surrounding solution accelerate the reaction.

2076. Kobayashi, S., Morihama, K., Ishi, Y. and Hirama, A., "A STUDY ON NON-COMPLICATED ASR TESTING METHOD (DOUBLE CYLINDER) AND ITS PRACTICAL ASPECT," CAJ Review of the 42nd General Meeting/Technical Session, pp. 254-257, 1988.

KEY WORDS: alkali aggregate reactions; test methods; double cylinder test

In experiments with mortar, the double cylinder method seemed practical, since the correspondence with the mortar bar method is good. Continuous measurement of concrete is needed, since reaction is slower and evaluation consequently takes a long time. A simplified testing method is applicable, but it requires 13 weeks for mortar and about 26 weeks for concrete specimens to make an exact judgment. It is necessary to shorten the evaluation period, which may be possible by increasing the alkali quantity.

2077. Kobayashi, K., Seno, Y., Kawai, K. and Uno, Y., "PORE SOLUTION COMPOSITION OF MORTARS WITH REACTIVE AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; pore solutions

The results of pore solution composition analysis of mortars made of different aggregates, w/c ratios, alkali contents cured at 40°C and 100% RH were as follows: (1) Almost all pore solutions contained OH and alkali ions and little Ca ion. (2) Na, K, and OH ion concentrations of pore solution were decreasing with age, but the pH value was above 12 at age of 26 weeks. (3) Decreases in Na, K and OH

concentration depended on the aggregate; Greater decrease was observed when a reactive aggregate was used. (4) Decrease in (Na+K) concentration corresponded with the expansive pressure.

2078. Kobayashi, S., Nakano, T., Yanagida, R. and Hozumi, Y., "EFFECT OF DOMESTIC FLY ASHES ON CONTROLLING ALKALI-SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash

With a single reactive andesite aggregate used in this experiment, it was found that the chemical composition of the fly ashes used influenced the effect on ASR. Fly ashes with high $R_2O_3$ accelerated ASR. High $SiO_2$ in fly ashes suppressed ASR. The optimum content of fly ash to suppress ASR depended on the alkali content of the cement.

2079. Kuboyama, K., Tateyashiki, H. and Tatematsu, H., "EFFECT OF SLAG AND POZZOLAN IN PREVENTING ALKALI-AGGREGATE REACTION," CAJ Review of the 42nd General Meeting/Technical Session, pp. 262-265, 1988.

KEY WORDS: alkali aggregate reactions; preventive measures; slag; fly ash; pozzolans

2080. Miyagawa, T., Hisada, M., Sugashima, A. and Fujii, M., "CONTROL OF ALKALI AGGREGATE EXPANSION BY WATER REPELLENT (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; expansion; silane; preventive measures; coatings

Surface treatment by a silane which is supposed to permit the evaporation of water, was more effective in controlling alkali aggregate expansion than a water repelling surface treatment. As the ratio of surface area to volume of the structure increased, the surface treatment by silane was more effective in controlling expansion and in reducing water content inside. If the treated surface area was more than about 70% of the whole surface area, the effect was almost equivalent to that when the whole surface

was treated.

2081. Morino, K., Iwatsuki, E. and Gotoh, K., "MICROSTRUCTURE AND MORTAR BAR EXPANSION BEHAVIOR OF CHERTY AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; reactive aggregates; chert; pessimum effect

Three kind of cherty aggregates were investigated by polarizing microscope, chemical test and mortar bar test. All the cherts consisted primarily of quartz. Because of impurities, their reactivity varied significantly. There was a pessimum content of non-reactive aggregate which was added to the mortar made of chert. The comparative reactivity of cherts from the same quarry was indicated by their color.

2082. Natesaiyer, K. and Hover, K. C., "INSITU IDENTIFICATION OF ASH PRODUCTS IN CONCRETE," Cement and Concrete Research, Vol. 18, pp. 455-463, 1988.

KEY WORDS: alkali aggregate reactions; test methods; fluorescence test

A new technique to identify ASR products insitu is presented. It is proposed that the ASR products found in concrete be visualized as gelatinous silica, and its crystalline modifications, with adsorbed sodium, potassium and calcium ions. Based on this view a brief survey of the adsorption and cation exchange properties of silica gel is presented. It is shown that a wide variety of cations can replace previously adsorbed $Na^+$, $K^+$ or $Ca^{++}$ ions on silica gel. The uranyl ion ($UO_2^{++}$) is one such species, and is chosen for the proposed technique for gel identification. Under ultraviolet light, the uranyl ion fluoresces and identifies the areas where gel is present. The technique is applied to reactive aggregates, reactive aggregates treated with NaOH and mortar bars made with reactive aggregates. The limitations of the technique and its future refinements are discussed.

2083. Nishibayashi, S., Yamura, K. and Sadakiyo, T., "STUDY ON ALKALI AGGREGATE REACTION OF CONCRETE WITH REINFORCED STEEL

BARS (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; reinforced concrete; cracking; restraint; cover effects; expansion

Small specimens of reinforced concrete made with reactive aggregates were examined. Expansive strain due to AAR at the surface of the specimens was greater as the thickness of cover increased. In mild environments (such as exposure to natural weathering), expansive strain in the reinforced concrete specimen became relatively uniform. Expansion inside the specimen decreased as the amount of reinforcement increased. But the strain at the surface was not dependent to the amount of reinforcement. The largest number of cracks were observed on the placing face of the specimen, and the number of cracks increased as the thickness of cover increased.

2084. Nishibayashi, S., Yamura, K., Hayashi, A. and Imaoka, S., "EFFECTS OF CYCLIC WETTING AND DRYING ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; wetting effects; drying effects; test methods

More deterioration due to AAR was observed in a sample dried in the oven (60°C) than that at room temperature. More deterioration was observed in a sample immersed in plain water than that in sea water, under the condition that one cycle was one day drying and one day wetting, and the total exposure was for 50 cycles.

2085. Nishibayashi, S., Yamura, K. and Nakano, K., "RAPID TEST METHOD OF DETERMINING THE ALKALI-AGGREGATE REACTION BY AUTOCLAVING (in Japanese)," Concrete Journal, Vol. 26, No. 5, JCI, May 1988.

KEY WORDS: alkali aggregate reactions; test methods; autoclave methods; expansion

A proposed test method is such that mortar bars of cement/sand ratio = 1/2.25, W/C ratio = 0.45, and total alkali = 2.0% $Na_2O$ equivalent, are autoclaved for 4 hours at the age of 24 hours, and expansion is measured at 24 hours after autoclaving. The amount of expansion measured

in this method was about 30 % of the final expansion of mortar bar test at age of one year, and the limit of expansion for reactive aggregates was proposed to be 0.02%. The expansion in this method was due to the production of alkali silicate gel, according to the analysis of reaction product.

2086. Nishibayashi, S. and Yamura, K., "STUDY ON THE EVALUATION OF ALKALI REACTIVITY IN AGGREGATES; TESTING CONDITIONS IN MORTAR BAR METHOD (in Japanese)," Concrete Journal, Vol. 26, No. 6, JCI, June 1988.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; test methods; NaCl effects; NaOH effects

The effect of w/c ratio on expansion of mortar bars depended on total alkali content. The expansion increased with the period of compaction. When specimens were immersed in alkali solution, expansion in alkali solution containing OH ion was smaller than that in alkali solution containing Cl ion, but it continued longer. There were negative correlations between expansion and flexural strength, compressive strength, and dynamic modulus of elasticity.

2087. Nishiyama, T., Terao, S. and Nakano, K., "ALKALI-REACTIVE MINERALS AND REACTION PRODUCTS IN SOME ANDESITES (in Japanese)," Journal of the Society of Material Science Japan, Vol. 37, No. 418, July, 1988, pp. 825-831.

KEY WORDS: alkali aggregate reactions; alkali silica gel; reactive aggregates; cristobalite; tridymite; glass; andesites

ASR has a harmful effect on some andesites. In the present paper the ASR in andesitic rocks was examined by means of optical and X-ray diffraction analyses and the standard test ASTM C-227. Furthermore, by microscopic examination of dyed sections made from a mortar bar, various types of reaction products including cracks and spherules were identified and distinguished. The contents of alkali reactive minerals such as cristobalite, tridymite and glass which are present in andesites are irregular and change very much with the location. The results of the test on mortar bars had no direct correlation with any kind of alkali reactive minerals. It is difficult to determine the role of these alkali reactive minerals in the expansive ASR

because there are many factors in the reaction.

2088. Nishiyama, T., Terao, S. and Nakano, K., "COMPARISON OF LABORATORY TESTS RELATED TO ALKALI-SILICA REACTIONS IN SOME ANDESITES (in Japanese)," Journal of the Society of Materials Science, Japan, Vol. 37, No. 418, July, 1988, pp. 832-836.

KEY WORDS: alkali aggregate reactions; test methods; expansion; mortar bars; chemical tests; alkali effects; reactive aggregates; andesite; graywacke

ASTM C-227 and ASTM C-289 tests were performed on the aggregates of which the mineral characteristics were discussed in the previous report. The cement used for the mortar bar test was an ordinary portland cement with an alkali content of 1.6% equivalent $Na_2O$, adjusted by NaCl reagent. The results of the tests on 27 mortar bars showed that the rate of expansion was in the range of 0.02-0.65% in 6 months. Twenty-one aggregates were classified as being reactive according to ASTM criteria. In the chemical test, the determined concentration of silica in solution from 190 mmol/l to 670 mmol/l. The reduction in alkalinity of NaOH solution range from 65 mmol/l to 290 mmol/l. All of the 36 aggregates belonged to the reactive group. The specific gravity of the aggregates was in the range of 2.19 to 2.68. No relationship was observed between mortar bar expansion and aggregate specific gravity. To prevent excessive expansion, an isopleth map of the rate of expansion was based on the test results on a number of mortar bars to cover variables in alkali content of the cement and in mixing ratio of the reactive aggregate of andesite and the nonreactive aggregate of greywacke.

2089. Nomura, K. and Kobayashi, K., "FACTORS INFLUENCING EXPANSION BEHAVIOR OF CONCRETE AFFECTED BY ALKALI-SILICA REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; expansion; alkali effects; temperature effects; gradation effects

Expansion of concrete with reactive aggregates by AAR seemed to be governed by total alkali content. The limit of alkali, 3 kg/cu.m seemed to be appropriate. AAR expansion was significantly slower at 20°C than at 40°C, but the total

amount of expansion might be greater at 20°C. There was a pessimum composition of aggregates when andesite and chert were used. Aggregate gradation affected expansion.

2090. Okada, K., Kondo, S., Fujita, T. and Himeno, M., "EVALUATION OF THE STRENGTH OF REINFORCED CONCRETE BEAMS AFFECTED BY ALKALI AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; reinforced concrete; restraint; mechanical properties; cracking; ultimate strength

Flexural strength tests were performed on reinforced concrete specimens with reactive aggregate and on one with non-reactive aggregate. The observed decrease in ultimate strength of the sample with cracks due to AAR was less than 20% of the ultimate strength of the control sample.

2091. Okada, K., Kondo, S., Fujita, T. and Okamoto, J., "A STUDY ON THE PROGRESS OF ALKALI-AGGREGATE REACTION IN VARIOUS ENVIRONMENTS (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; cracking; expansion; concrete; environmental effects

Concrete specimens in six different environments (above ground, below ground, half under ground, half under sea water, under sea water, under water) have been examined for 39 months in order to check alkali aggregate reaction. The side walls of the specimens were much more deteriorated than the base, which seemed due to the reaction characteristics of the aggregates. Specimens exposed under sea water cracked most extensively. The more cracks due to AAR that appeared at the beginning, the less they tended to be propagating.

2092. Poole, A. B., McLachlan, A. and Ellis, D. J., "A SIMPLE STAINING TECHNIQUE FOR THE IDENTIFICATION OF ALKALI-SILICA GEL IN CONCRETE AND AGGREGATE," Cement and Concrete Research, Vol. 18, pp. 116-120, 1988.

KEY WORDS: alkali-silica gel; test methods; staining test

A simple technique is described for staining alkali-silica gel reaction product formed as a result of the interaction between alkali solution and siliceous concrete aggregate particles. The method involves allowing the developing gel to take up copper ions from a solution of cuprammonium sulphate. After appropriate washing the gel remains stained blue. Alternatively, the gel may be dissolved in hydrochloric acid and the copper content, which is proportional to the volume of gel, estimated calorimetrically by neutralizing the acid and reforming the blue cuprammonium complex under standard conditions.

2093. Saitoh, T., Ujiie, H. and Furuya, T., "STUDY ON THE ALKALI AGGREGATE REACTION TEST USING NATURAL SEA WATER FOR MIXING WATER (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; NaCl effects; sea water effects

When natural sea water is used as mixing water for mortar bar test specimens, significant test results were obtained more quickly.

2094. Shiraki, R., Maru, A. and Kobayashi, K., "A NEW METHOD FOR EVALUATION OF ALKALI-REACTIVITY OF SILICEOUS SEDIMENTARY ROCKS (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; test methods; chemical tests

There was a high correlation between amount of silica leached and the degree of crystallization of quartz for siliceous sedimentary rocks. The ratio of the change in amount of leached silica to the change in degree of quartz crystallization was greater in sandstones than in cherty rocks.

2095. Swamy, R. N. and Al-Asali, M. M., "EXPANSION OF CONCRETE DUE TO ALKALI-SILICA REACTION," ACI Materials Journal, Vol. 85, pp. 33-40, 1988.

KEY WORDS: alkali aggregate reactions; expansion; concrete; alkali effects; cements;

Although the phenomenon of ASR has been known for several decades, much of the available data is based on cement pastes and mortars. This paper presents comprehensive information on tests where synthetic fused silica was used as reactive aggregate, and the cement used was a portland cement with about 1 percent sodium oxide equivalent. The effects of temperature, cement content, and the presence of alkali from sources other than cement on expansion of concrete are reported. It is shown that when all alkali is cement bound, an alkali content of 3 to 4 $kg/m^3$ represents a critical band of alkalinity above and below which either a dramatic increase or decrease of expansion occurs.

2096. Swamy, R. N. and Al-Asali, M. M., "ENGINEERING PROPERTIES OF CONCRETE AFFECTED BY ALKALI-SILICA REACTION," ACI Materials Journal, Vol. 85, pp. 374, 1988.

KEY WORDS: alkali aggregate reactions; structural effects; mechanical properties; expansion

A detailed study of the effects of alkali-silica reaction (ASR) on the engineering properties of concrete such as compressive and tensile strength, elastic modulus, and pulse velocity is presented. Two types of reactive aggregates, a naturally occurring Beltane opal and a synthetic fused silica, were used. The tests were carried out at 20°C and 96% RH. The results showed that losses in engineering properties do not all occur at the same rate or in proportion to the expansion undergone by the ASR-affected concrete. The two major properties affected by ASR were flexural strength and dynamic modulus of elasticity. Compressive strength was not a good indicator of ASR, but the flexural strength proved to be a reliable and sensitive test for monitoring ASR. Nondestructive tests like dynamic modulus and pulse velocity were also able to identify deterioration of concrete by ASR. The data indicate that critical expansion limits due to ASR would vary depending on the type and use of a concrete structure.

2097. Takakura, M. Sakaguchi, Y., Tomozawa, F. and Abe, M., "AN EXPERIMENT ON INHIBITING EFFECTS OF LITHIUM COMPOUNDS ON ALKALI-AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; lithium effects; preventive measures

Lithium compound additions turned out to be effective in inhibiting expansion due to AAR of mortar samples with either pyrex glass or reactive aggregates. The effect was significant when the Li/Na mole ratio was greater than 0.9 for the mortars with both kinds of reactive aggregates. When specimens in which expansion due to AAR was occurring were immersed in $LiNO_2$ solution, the expansion was slowed or stopped.

2098. Tamura, H., Takahashi, T. and Ohashi, M., "A STUDY ON THE RAPID TEST METHOD FOR THE EVALUATION OF THE FUTURE EXPANSION OF CONCRETE DUE TO ALKALI- AGGREGATE REACTION (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; test methods; concrete; expansions; boiling methods; GBRC tests

This research was a preliminary experiment for a new rapid test method for AAR (the GBRC Method). Expansion of concrete specimens by boiling increased with their maximum previously experienced expansion, and it leveled off at 0.07% at the maximum experienced expansion of 0.1% or larger. This phenomenon was not affected by the shape of the time-expansion curve before boiling. Expansion of mortar specimens by boiling was too small to observe any significance.

2099. Tamura, H., Takahashi, T. and Ohashi, M., "A PROPOSAL ON THE RAPID TEST METHOD FOR THE EVALUATION OF THE FUTURE SUSCEPTIBILITY OF ALKALI-AGGREGATE REACTION IN FRESH CONCRETE (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; test methods

A "Rapid Test Method for the Evaluation of the Future Susceptibility of Alkali Aggregate Reaction in Fresh Concrete" was proposed, and the results were compared with mortar bar test results.

1988

2100. Tang, M. S., "DISCUSSION ON THE CHINESE STANDARD TEST METHODS FOR ALKALI CONTENT IN CEMENTS AND ALKALI REACTIVITY OF AGGREGATES (in Chinese)," Cement, No. 5, 1988, pp. 4-6.

KEY WORDS: alkali aggregate reactions; test methods

2101. Tatematsu, H., Takada, J. and Sasaki, T., "CHARACTERISTICS OF ALKALI-AGGREGATE REACTION DUE TO SEDIMENTARY ROCK AGGREGATE (in Japanese)," Proc. of Annual Meeting, JCI, 1988.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; chemical tests; expansion; concrete

Many results of the chemical method did not agree with the results of expansion tests when using sedimentary rock aggregate, as long as total alkali was 2.0% $R_2O$. Expansion of concrete containing sedimentary rock aggregates occurred more slowly and lasted longer.

2102. Tomita, Y., Kosa, K., Nakano, K. and Nakaue, "STUDIES ON ESTIMATION OF DAMAGE OF CONCRETE STRUCTURE BY ALKALI-SILICA REACTION USING DRILLED CONCRETE CORES," CAJ Review of the 42nd General Meeting/Technical, pp. 266-269, 1988.

KEY WORDS: alkali aggregate reactions; test methods; expansion; temperature effects

It is suggested that the expansion of cores under conditions of 20°C, 100% RH shows the degree of damage existing, and that at 40°C, 100% RH the expansion shows estimation of future degree of damage. In this study, the influence of reinforcement, diameter of cores and degree of expansion of concrete on the physical properties and the expansion of cores were examined.

2103. West, G. and Sibbick, R., "ALKALI SILICA REACTION IN ROADS," Highways, v. 56, No. 1936, 1988, pp. 19-24.

KEY WORDS: alkali silica reaction; field experiences, U.K.; pavement structures; petrography; alkali silica gel

Mechanisms of alkali silica reaction are reviewed, and criteria defined. A sampling survey for U.K. highways is

described. The alkali silica reaction was found in two of fourteen survey sites examined. Seventeen additional samples are being examined.

2104. Wood, J. G. M., "DISORDERS CAUSED BY THE ALKALI-AGGREGATE REACTION IN REINFORCED CONCRETE STRUCTURES (in French)," Annales de l'ITBTP No. 469 Series Beton 259, pp. 86-100.

KEY WORDS: alkali aggregate reactions; field effects; U.K.; repairs; preventive measures

The alkali aggregate reaction appeared in Great Britain in 1975. A few structures have already been reconstructed. Three questions have to be answered: (1) What went wrong? (2) When structures suffer from ASR, what can be done? (3) How can we prevent it in new structures? Petrographic studies have determined reactive aggregates. On structures crack growth is measured and the rate of deterioration can be predicted after 18 months. The monitoring of structures is accompanied by detailed testing of cores for stiffness and strength and restrained or free expansion in a range of environments. Actions on any structure diagnosed as having ASR are: (a) strengthen the weaknesses, i.e., duplication of main frame, (b) dry the concrete, i.e., waterproofing or crack sealing, or (c) replacement. Preventive measures include the use of low alkali OPC or blended cements.

2105. Abe, M., Tomosawa, F., Mano, T. and Togasaki, K., "A STUDY ON THE SIMPLE RAPID TEST METHOD USED TO JUDGE THE ALKALI REACTIVITY OF AGGREGATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 369-374.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; expansion; accelerated tests

The influence of various factors on expansion of mortar, and appropriate conditions for accelerated testing were investigated. Expansion is thought to be the best index of deterioration due to the fact that little influence on strength was observed. For accelerated testing, one should change three test conditions: alkali content, temperature and term of test.

2106. Abe, M., Kikuta, S., Masuda, Y. and Tomozawa, F., "EXPERIMENTAL STUDY ON MECHANICAL BEHAVIOR OF REINFORCED CONCRETE MEMBERS AFFECTED BY ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 691-696.

KEY WORDS: alkali aggregate reactions; reinforced concrete; restraint; structural effects; mechanical properties

The area investigated was the influence of alkali aggregate reaction on flexural yield strength and on ultimate shear strength of reinforced concrete members subjected to AAR, as functions of the reinforcement ratio and of the degree of deterioration produced by the reaction. The compressive strength of concrete cylinders affected by AAR was lower than that of unaffected cylinders. However, the compressive strength of core specimens drilled out from the concrete of the affected reinforced specimens was only slightly lower than that of unaffected specimens. In one of the series, the failure mode of unaffected specimens was in diagonal shear tension failure after flexural yield; however that for some of the affected specimens was horizontal slip failure along the horizontal cracks generated by AAR. As longitudinal expansion increased, the yield strength was slightly reduced and the deflection at yield drastically decreased. The ultimate shear strength of affected specimens was slightly higher than that of unaffected specimens in spite of lower compressive strength, because of increased ductility induced by the cracks generated by the reaction.

1989

2107. Alexander, M. G., McIver, J. R., and Glynn, S. M., "ASSESSMENT OF THE DETERIORATION OF AN AIRPORT CONCRETE APRON DUE TO AAR," Proc. 8th Intl. Alkali Conf. 1989, pp. 483-487.

KEY WORDS: alkali aggregate reactions; pavement structures; mechanical properties; pulse velocity measurements; field experiences; South Africa

The paper describes the deterioration due to AAR of an airport concrete apron. Techniques used to identify AAR included visual and petrographic examination and semi-quantitative analysis of reaction products by EDAX. The progress of deterioration was semi-quantitatively assessed by static stress-strain tests and ultrasonic pulse velocity (U.P.V.) tests on cores. Indexes comprising ratios of tangent to secant moduli, and percentage reductions in U.P.V. during testing, appeared to be sensitive to internal damage due to AAR. It was found that macroscopic and petrographic examination of AAR-affected concrete does not always provide conclusive answers as to the degree of deterioration; mechanical testing of cores provides a more accurate estimate. Further development of these techniques holds promise for assessment of damage due to AAR in concrete.

2108. Amasaki, S. and Takagi, N., "THE ESTIMATE FOR DETERIORATION DUE TO ALKALI-SILICA REACTION BY ULTRASONIC SPECTROSCOPY," Proc. 8th Intl. Alkali Conf. 1989, pp. 839-844.

KEY WORDS: alkali aggregate reactions; mechanical properties; test methods; ultrasonic spectroscopy

This paper deals with nondestructive testing of concrete by ultrasonic spectroscopy to assess the deterioration of concrete structures due to alkali silica reaction (ASR). The response function and its energy of specimens were calculated by applying a linear system theory, and the deterioration of specimens was assessed by the energy of the response function. Tests were carried out for mortar and concrete with reactive bronzite andesite crushed stone. Specimens were cured in a chamber at 40°C and 100% relative humidity for four months after curing in water. The deterioration of the specimens was assessed while the reaction was accelerated, and after the reaction was accelerated, cores were drilled from the reinforced concrete specimens and expansions of the cores were measured. The deterioration due to ASR, decreased the dynamic modulus of elasticity considerably, and the energy

of response function and pulse velocity of deteriorated concrete specimens were decreased to about 88% and 95% of the non-reactive specimens, respectively. The more the original concrete was reinforced, the larger the expansion of the core freed from restraint. It is easy to assess the deterioration of concrete structures due to ASR by ultrasonic spectroscopy method proposed in this study.

2109. Andersen, K. T. and Thaulow, N., "THE APPLICATION OF UNDULATORY EXTINCTION ANGLES (UEA) AS AN INDICATION OF ALKALI-SILICA REACTIVITY OF CONCRETE AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 489-494.

KEY WORDS: reactive aggregates; strained quartz; undulatory extinction angle; test methods

A round-robin test concerning the reproducibility of UEA measurements of quartz in various aggregates has shown significant variation between the 6 individual petrographers. This scattering of results suggests that the UEA measurement method in its present form may be too uncertain to produce reliable results.

2110. Andersson, K., Allard, B., Bengtsson, M. and Magnusson, B., "CHEMICAL COMPOSITION OF CEMENT PORE SOLUTIONS," Cement and Concrete Research, Vol. 19, pp. 327-332, 1989.

KEY WORDS: pore solutions; alkali effects

The cement pore solutions studied had fairly high ionic strengths (up to 0.3), Ph in the range 12.4-13.5, and positive redox potentials corresponding to oxidizing conditions (except for the slag containing slag cement and French portland cement). For standard portland, sulfate resistant, slag, silica and fly ash cements, the dominating cations in the pore solution were Na and K. Aluminate cement pore solution contained mainly Na and Al.

2111. Barisone, G., Bottino, G. and Pavia, R., "ALKALI-SILICA REACTION POTENTIALLY BEARING MINERALS IN ALLUVIAL DEPOSITS OF CALABRIA, UMBRIA, AND TOSCANA REGIONS (ITALY)," Proc. 8th Intl. Alkali Conf. 1989, pp. 507-512.

KEY WORDS: reactive aggregates; Italy

This paper reports the results of the second part of a large work the authors are carrying out over the Italian peninsular territory south of the Po. This work, which began in 1985 and is now near to its conclusion, attempts to individuate the presence and the distribution - in recent and actual deposits - of alkali-silica reaction potentially producing minerals. In particular, alluvial deposits of three Italian regions (Calabria, Umbria and Toscana) are here examined, and the results of the study are synthesized in three schematic maps at about 1:1,500, 000 scale.

2112. Baronio, G. and Berra, M., "THE OCCURRENCE OF AAR IN A CONCRETE STRUCTURE IN ITALY," Proc. 8th Intl. Alkali Conf. 1989, pp. 71-76.

KEY WORDS: alkali aggregate reaction; field experiences; Italy; chimney structures; salt spray; NaCl effects; ettringite

This paper describes a case of concrete structure deterioration due to AAR in a large concrete chimney built near the sea shore in the 1960's in Italy. The aggressive environmental condition (high temperature and humidity) and the vicinity of the sea certainly enhanced ASR. The presence of a sulphate attack also contributed to the concrete decay. The case in question and several other ascertained in Italy, particularly on concrete structures near the sea where concrete can absorb alkali from the sea water spray, confirm that alkali chlorides have a harmful influence on ASR.

2113. Blight, G. E., "EXPERIMENTS ON WATERPROOFING CONCRETE TO INHIBIT AAR," Proc. 8th Intl. Alkali Conf. 1989, pp. 733-739.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings

Laboratory experiments were undertaken to test the effectiveness of four surface treatments for waterproofing concrete. None of the surface treatments tested proved able to waterproof concrete. Once the concrete was wet, the treated surfaces were, however, sufficiently permeable to allow it to dry out again. When surface treated concrete that is wet internally is subjected to short period of

wetting followed by longer periods of drying, it is possible to progressively dry out concrete. This is directly applicable in climates where brief wet spells are followed by longer dry spells.

2114. Carles-Gibergues, A., Ollivier, J. P., Fournier, B. and Berube, M. A., "A NEW APPROACH TO THE STUDY OF ALKALI-AGGREGATE REACTION MECHANISMS," Proc. 8th Intl. Alkali Conf. 1989, pp. 161-166.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; mechanisms; pore solutions;

The reactions involved at the interfaces between three well-known reactive aggregates and high alkali cement pastes were studied using cement pastes in contact with polished surfaces of aggregate pieces. The various silica phases which can coexist in a given aggregate may be differentially attacked by the cement paste pore solution, according to their chemical, mineralogical and crystallographic characteristics, but also to their origin and geological history. For instance, the sedimentary quartz cement in the Potsdam sandstone is selectively attacked, even if it is recrystallized in optical continuity with the detrital quartz grains of igneous origin.

2115. Carse, A. and Dux, P., "ALKALI-SILICA REACTION IN AUSTRALIAN CONCRETE STRUCTURES," Proc. 8th Intl. Alkali Conf. 1989, pp. 25-30.

KEY WORDS: alkali aggregate reactions; field experiences; Australia; building structures; bridge structures; jetty structures; reactive aggregates; gravel; volcanic rocks

This research investigation has placed significant emphasis on collecting field information of alkali-silica distressed structures and using this data to calibrate laboratory tests for predicting safe cement/aggregate combinations. It was determined that alkali-silica reaction has occurred in concrete bridges, a wharf structure and an off shore bulk loading facility. The age of the structures investigated ranges from 8 to 29 years with a corresponding period of construction from 1959 to 1980. Documentation is provided showing that the occurrence of alkali-silica reaction may not always cause destructive expansion in the associated concrete matrix. Two structures

were analyzed and shown to exhibit alkali-silica reaction without any associated destructive cracking of the concrete structures. Four additional structures were shown to display similar alkali-silica reaction, however, in these cases associated destructive cracking of the concrete matrix had occurred. The reactive aggregates in the structures examined were identified as an extrusive volcanic source and a river gravel. It has been concluded from this project that the degree of alkali-silica reaction within a structure is dependant on environmental factors and can be magnified by an inadequate design concept. Details of an accelerated test for alkali-silica reaction on concrete samples are provided for use in determining safe cement/aggregate combinations.

2116. Cavalcanti, A. J. C. T. and Silveira, J. F. A., "INVESTIGATIONS ON THE MOXOTO POWERHOUSE CONCRETE AFFECTED BY ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 797-802.

KEY WORDS: alkali aggregate reactions; field experiences; Brazil; dam structures; repairs; reactive aggregates; strained quartz

The Moxoto powerhouse in Brazil consists of four 30.5 m wide concrete bays, each one housing a 110 MW turbine-generator group. It was constructed in the period from 1972 to 1977. Both the coarse and fine aggregates contain variable amounts of strained quartz, which caused the alkali-silica reaction development. A set of experiments was programmed to study the aggregates used in the construction as well as concrete cores taken from the structure, in order to assess the expansion potential of the reaction and the influence of moisture and temperature. The use of carbon dioxide injection was also tested to mitigate the concrete expansion. This procedure appeared at least partly successful in reducing expansion.

2117. Chatterji, S., "A CRITICAL REVIEW OF THE RECENT DANISH LITERATURE ON ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 37-42.

KEY WORDS: alkali aggregate reactions; mechanisms; field experiences; Denmark; reviews

Recent Danish research on alkali silica reactions is

reviewed.

2118. Chatterji, S., "MECHANISMS OF ALKALI-SILICA REACTION AND EXPANSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 101-105.

KEY WORDS: alkali aggregate reactions; mechanisms

From comparisons, it appears that many aspects of ASR are more easily explained on the basis of reaction mechanisms proposed by Chatterji et al. than on the classic mechanisms of Powers and Steinour.

2119. Chatterji, S., "A SIMPLE CHEMICAL TEST METHOD FOR THE DETECTION OF ALKALI-SILICA REACTIVITY OF AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 295-299.

KEY WORDS: alkali aggregate reactions; reactive aggregates; test methods; chemical tests

In this paper a simple and quick chemical test method is proposed for the detection of alkali-silica reactivity of aggregates. The proposed method consists of suspending a mixture of CaO and the aggregates to be tested in a saturated solution of Kcl maintained at an elevated temperature, eg 70°C. After 24 hours the suspension is cooled to 20°C, filtered, and the OH ion concentration of the filtrate determined. The measured OH ion concentration is then compared to that of a control suspension of a mixture of pure quartz sand and CaO treated in the same way. Any lowering of OH ion concentration in the test solution, compared to the control, indicates a potential alkali-silica reactivity of the test aggregate. The difference in the OH ion concentrations between the control and the test is a measure of the alkali-silica reactivity of the aggregate under test. Repeated measurements on a number of sand samples showed that the standard deviation of measured OH ion concentrations of the test solutions is about 2% of the mean. So far three different laboratories have tried this method and obtained similar standard deviations. This simple and quick method could be carried out in the field and the observed low standard deviation indicates that it could be used for the quality control of the aggregates.

1989

2120. Chen, H. and Grattan-Bellew, P. E., "EFFECT OF CEMENT COMPOSITION ON EXPANSION OF MORTAR BARS DUE TO ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 635-640.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; cement effects; alkali effects; ettringite

In the present study, a suite of cements were made under carefully controlled laboratory conditions so that the effects of changes in the $C_3A$, $C_3S$, and alkali content of the cements on expansion due to alkali-aggregate reaction, could be studied independently. This study confirmed that the total acid soluble alkali content is the only component which significantly affects the expansion of mortar bars made with reactive aggregate. Mortar bars made with high alkali cement (1.19% $Na_2O$ equiv.) containing high levels of $C_3A$ (12.8%), showed greater expansion than those with low level of $C_3A$ (3.7%) although no direct correlation was found between the $C_3A$ content of the cement and the expansion of the mortar bars. No correlation was found between the ettringite content of the mortar bars and their expansion.

2121. Clark, L. A. and Ng, K. E., "THE EFFECTS OF ALKALI SILICA REACTION ON THE PUNCHING SHEAR STRENGTH OF REINFORCED CONCRETE SLABS," Proc. 8th Intl. Alkali Conf. 1989, pp. 659-664.

KEY WORDS: alkali aggregate reactions; structural effects; slabs; reinforced concrete; restraint

This paper reports the results of punching shear tests on reinforced concrete slabs cracked due to alkali silica reaction (ASR). It has been found that for free expansions of up to about 6000 microstrain, alkali silica reaction did not have a significant effect on the punching shear strength of a slab although the tensile strength of the concrete was reduced by about 25%. In addition, the ductility of a slab with both top and bottom flexural reinforcement was found to increase as a result of alkali silica reaction expansion. This increase in ductility did not occur to such a large extent for slabs with only bottom flexural reinforcement. This difference in behavior is attributed to the different distributions of compressive stress in the concrete induced by the internal restraint to expansion.

1989

2122. Clayton, N., "STRUCTURAL PERFORMANCE OF ASR AFFECTED CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 671-676.

KEY WORDS: alkali aggregate reactions; structural effects; test methods; mechanical properties; expansion; prestressed beams; cracking

The tensile strength of the concrete specimens subjected to accelerated ASR is 60% below the 28 day value. The compressive strength loss, as determined from prisms, is 30%. The cylinder splitting (Brazilian) test cannot be used to assess tensile strength loss due to ASR. It is, however, a good indicator of compressive strength loss. There is no correlation between concrete strength and expansion. When expansion is about 0.5 mm/m and macrocracking has occurred, strength has already reached a minimum and there is no further significant strength change with continued expansion. In the prestressed beam testing programme currently being carried out, it is essential to test when macrocracking first occurs as well as at ultimate expansion in order to separate out the effect of concrete strength loss from the effect of concrete expansion.

2123. Clergue, C. and Corneille, A., "SEARCH TO NEW RAPID AND RELIABLE TEST METHOD, WITH A VIEW TO EVALUATE THE DAMAGE RISK IN CONCRETE, DUE TO ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 397-402.

KEY WORDS: alkali aggregate reactions; expansion; test methods; triaxial testing

A method of measuring the expansive stresses induced in a concrete specimen is illustrated.

2124. Davies, G. and Oberholster, R. E., "THE EFFECT OF DIFFERENT OUTDOOR EXPOSURE CONDITIONS ON THE EXPANSION DUE TO ALKALI SILICA-REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 623-628.

KEY WORDS: alkali aggregate reactions; wetting effects; NaCl effects; field experiences; South Africa

Three 300-mm concrete cubes made with highly reactive aggregate and a high alkali cement were exposed to several conditions of mist spray exposure. The action of NaCl solution spray increased expansion of concrete up to 70%

after about 7 years. This is probably because NaCl exacerbates the ASR by releasing additional Na+ and OH- ions, by reacting with $Ca(OH)_2$ and $C_3A$ in the cement matrix, but also possibly by the formation of an expansive monochloaluminate hydrate. Although the concrete was badly cracked, the penetration of both Cl and Na ions was limited to a depth of 90 mm. The Cl concentration in the outer 90 mm of the sample is more than twice the maximum which reportedly can be tolerated by reinforced steel. The expansion measured for the cube exposed to normal environmental conditions and that subjected to tap water spray, were very similar, which indicates that concrete exposed to normal atmospheric conditions (in Pretoria) does not dry out sufficiently to retard the reaction, even during the dry winter. This suggests there is apparently sufficient water in the concrete itself to sustain the reaction all year round.

2125. Diamond, S., "ASR - ANOTHER LOOK AT MECHANISMS," Proc. 8th Intl. Alkali Conf. 1989, pp. 83-94.

KEY WORDS: alkali aggregate reactions; mechanisms; pore solutions; osmotic effects; calcium hydroxide

It is now possible to estimate the alkali hydroxide concentration in the pore solution of a given concrete from the alkali content of the cement used and the water:cement ratio, at least for water:cement ratios near 0.5. Neither the specific alkali (K or Na) nor its form of occurrence in the cement appear to matter. The estimate necessarily assumes that no alkali is solubilized from the aggregate, or brought into the concrete from outside; that neither leaching nor local concentration effects have occurred; and that the concrete has not dried out appreciably. The concentration predicated provides a basis for estimating the relative potential for ASR among different concretes with the same aggregate. In systems similar to concretes undergoing ASR but lacking a source of calcium, the attacking solution simply dissolves the reacting aggregate, and the silica remains in solution. Gel formation occurs only in the presence of a source of readily mobilizable calcium. Thus ASR attack is conditional on having local available calcium hydroxide, and the calcium in reaction gels is functional rather than incidental. Despite the fact that ASR expansion is fundamentally osmotic in character, swelling pressures measured in synthetic gels and field observations of the effects of loading and of steel restraint both suggest that effective expansive stresses

are much lower than estimates derived from osmotic theory. The latter relate to local stresses only.

2126. Doran, D. K. and Moore, J. F. A., "APPRAISAL OF THE STRUCTURAL EFFECTS OF ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 677-682.

KEY WORDS: alkali aggregate reactions; structural effects; field experiences; U.K.

This paper outlines the approach used in compiling the recent U.K.Institute of Structural Engineers interim technical guidelines on the structural effects of ASR. Tables illustrating the compilation of structural severity ratings, and recommended management procedures are provided.

2127. Duggan, R. and Scott, F., "NEW TEST FOR DELETERIOUS EXPANSION IN CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 403-408.

KEY WORDS: alkali aggregate reactions; test methods; expansion

The Duggan expansion test for concrete cores taken from structures is described.

2128. Farbiarz, J., Schuman, D. C., Carrasquillo, R. L. and Snow, P. G., "ALKALI-AGGREGATE REACTION IN FLY ASH CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 241-246.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; expansion

A test program involving a range of fly ashes is described. Neither the 0.6% limit set up by ASTM C 150 for the alkali content of cement or the 1.5% maximum available content set up by ASTM C 618 for the fly ash can be used as the only measure to prevent damage to concrete due to alkali aggregate reaction. However, it is clear from the test results that the degree of alkali aggregate reactivity of concrete mixtures increases when the alkali content increases. The results also show that replacement of a portion of cement with fly ash is an effective measure to

reduce the expansion in concrete due to alkali aggregate reaction. Nevertheless, as the available alkali content of fly ash increases, there is a minimum percentage of cement replaced below which the fly ash cause expansion larger than those of a mixture without fly ash, and above which fly ash cause smaller expansion. This minimum is known as the "pessimum limit". The greater fineness of the fly ash in Type IP cement and not the additional blending of the cement and fly ash appears to be the factor enhancing its inhibiting effect on ASRs. However, there is not a consistent correlation between the variability of Class C fly ash fineness, within the ASTM limit, and mortar bar expansion.

2129. Figg, J., "AN HISTORICAL PERSPECTIVE ON ONE-AND-HALF DECADES OF AAR RESEARCH," Proc. 8th Intl. Alkali Conf. 1989, pp. 9-15.

KEY WORDS: alkali aggregate reaction; history; reviews

The history of alkali aggregate reaction research and the various international Conferences are described and a perspective developed.

2130. Fujii, M., Miyagawa, T., Tomita, M., Ono, K. and Imae, M., "EFFECT OF COATING TO INHIBIT ALKALI-AGGREGATE REACTION OF CONCRETE STRUCTURES," Proc. 8th Intl. Alkali Conf. 1989, pp. 869-874.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings; field experiences; Japan

From field tests of coating materials on bridge substructures, it was found that polyurethane, epoxy, and polybutadiene coatings were not effective in inhibiting ASR, but that coating by silane and polymer cement coatings were effective. However, additional observations and a wider range of testing are required to confirm their effectiveness.

2131. Fujii, M., Kobayashi, K., Miyagawa, T. and Hisada, M., "SURFACE TREATMENT FOR CONCRETE STRUCTURES DAMAGED BY ALKALI-AGGREGATE EXPANSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 875-880.

KEY WORDS: alkali aggregate reactions; preventive measures; repairs; coatings; field experiences; Japan

This paper deals with the repair of concrete structures damaged by ASR. From the expansions of the untreated reactive specimens, the drying and wetting conditions used in the tests accelerates ASR expansion. The rate of expansion is about twice as fast as the rate under normal outdoor conditions. When the repair for ASR is treated, silane monomer acts better than other surface treatment systems. The surface area/volume ratio of the particular concrete structure is one of the important factors affecting ASR expansion. A water repellent coating can control the ASR expansion when the water passing ability of the sheet is 3500 $ml/m^2/day$.

2132. Grattan-Bellew, P. E., "TEST METHODS AND CRITERIA FOR EVALUATING THE POTENTIAL REACTIVITY OF AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 279-294.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; concrete prisms; expansion

A large number of mortar bar and concrete prism test methods and chemical test methods are reviewed and critical factors assessed. Newer accelerated tests including the Danish test of mortar bars exposed to NaCl solution at 50°C; the NBRI test exposing mortar bars to 1N. NaOH solutions at 80°C, and autoclave test methods developed in China and in Japan are described. All the rapid test methods appear to give satisfactory results, at least with the limited range of aggregates which have been tested. All the methods are sensitive to minor changes in mix design, size of mortar bars and experimental procedure. The autoclave methods give expansions close to those obtained using ASTM C 227, but much greater expansion are obtained with the NBRI method. The larger expansions obtained with NBRI method creates a danger that aggregates with satisfactory field performance might be classified as deleteriously expansive.

2133. Hamada, H., Otsuki, N., and Fukute, T., "PROPERTIES OF CONCRETE SPECIMENS DAMAGED BY ALKALI-AGGREGATE REACTION, LAUMONTITE RELATED REACTION AND CHLORIDE ATTACK UNDER MARINE ENVIRONMENTS," Proc. 8th Intl. Alkali Conf. 1989, pp. 603-608.

1989

KEY WORDS: alkali aggregate reactions; field experiences; Japan; marine environments; NaCl effects; ettringite; mechanical properties

The durability of concretes exposed to marine environments for at least 10 years have been assessed. Specific damage mechanisms observed in different paces include chloride attack; combinations of chloride attack and AAR; and chloride attack coupled with the formation of laumontite. The residual compressive strengths and the modulus of elasticity are very low for cylinder specimens damaged by aggregate reactions, but the ultimate load carrying capacity of the damaged reinforced and prestressed concrete beam show little reduction. It was found that the chloride contents in the specimens damaged by the aggregate reaction are much higher than those in the specimens damaged only by salt attack, and the corrosion of the steel bars is heavier. Concrete damaged by the aggregate reaction is susceptible to subsequent sulphate attack in marine environments.

2134. Hobbs, D. W., "CRACKING AND EXPANSION DUE TO ALKALI-SILICA REACTION IN THE UNITED KINGDOM," Proc. 8th Intl. Alkali Conf. 1989, pp. 31-36.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; U.K.; preventive measures

A review of field occurrences of AAR in the U.K. is provided, and preventive measures are discussed.

2135. Hobbs, D. W., "EFFECT OF MINERAL AND CHEMICAL ADMIXTURES ON ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 173-186.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; slag; pozzolans; silica fume; chemical admixtures

This paper briefly reviews the literature dealing with the effectiveness of fly ash, slag, pozzolans, microsilica, and chemical admixtures in reducing the risk of abnormal expansion due to ASR.

1989

2136. Hooton, R. D. and Rogers, C. A., "EVALUATION OF RAPID TEST METHODS FOR DETECTING ALKALI-REACTIVE AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 439-444.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; accelerated tests; autoclave tests

Using 12 aggregates, mostly from Ontario, with known petrographic characteristics and field performances, a series of rapid test methods was evaluated along with standard ASTM C 227 mortar bar method. The rapid test methods involving mortar bars included those of Oberholster and Davies (14 days in NaOH at 80°C), Chatterji (8 to 20 weeks in NaCl at 50°C), Duncan (100% RH at 64°C), Nishibayashi (added NaOH in bars steamed at 125°C for 4 hours), and Tang (steam cured, then autoclaved in KOH). While some tests are still in progress, the NBRI 14-day test published by Oberholster and Davies appears to be the most promising in terms of distinguishing between non-reactive, marginal and reactive aggregates. However, the expansion limits proposed by Oberholster and Davies may only be suitable for distinguishing non-reactive and very reactive aggregates. Other testing may still be required to distinguish slowly expansive aggregates from petrographically marginal aggregates with good field performance. As well, it was found that washing of the aggregate normally done in ASTM C 227 to remove dust, may not be required with this test. While some of the other mortar bar methods may have been unfavorably influenced by the authors' decision to modify them by using ASTM standard mortar bars (25 mm by 25 mm cross-section) and C 227 aggregate gradations, many of these methods could not distinguish all of the reactive aggregates. Based on these findings, The CSA Standards Committee is presently investigating the possible adoption of the 14-day NBRI procedure.

2137. Hudec, P. P. and Larbi, A., "CHEMICAL TREATMENTS AND ADDITIVES TO MINIMIZE ALKALI REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 193-198.

KEY WORDS: alkali aggregate reactions; preventive measures; phosphate effects

Deterioration of alkali reactive concrete has been attributed to the expansion of the silica gel in the presence of water. Silica gel's affinity for water is due to its large, active surface which attracts ions and polar

water molecules. Chemical treatment to reduce the activity of the surface has proven successful in reducing the expansion due to alkali reaction. The phosphate ion was found to be one of the more effective agents in reducing expansivity in the lab tests. Hardened concrete specimens made with reactive aggregate were treated with phosphate solution prior to rapid AR testing, and expansion reduced to acceptable levels. Phosphate in various forms and concentrations was introduced into the mix containing reactive aggregate. Depending on the particular combination, AR was either reduced or unaffected.

2138. Hudec, P. P. and Larbi, J .A., "RAPID METHODS OF PREDICTING ALKALI REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 313-320.

KEY WORDS: alkali aggregate reactions; test methods; concrete prisms; accelerated tests

In an accelerated testing method, concrete blocks are exposed to 1N. NaOH solutions at 80°C or else hot saturated NaCl solutions. Length measurements are made with a specially designed double LVDT apparatus, over a three week period. Concrete shows significant AR expansions for samples that are relatively small compared to the size of the aggregate, but the expansion of concrete in the rapid test are smaller than the expansions of mortar containing the same aggregate. Rapid AR expansion is very dependent on the water to cement ratio of the mix. The pessimum effect is not found in the hot NaOH test, because the method provides an excess of alkalis. Good correlation is obtained between the ASTM C 227 mortar method expansion and the expansion of even the smallest size (19 mm) concrete cores in the rapid method. The regression equation can be used to predict the ASTM C 227 expansion from the rapid method results.

2139. Hudec, P. P. and Larbi, J. A., "A STUDY OF ALKALI-AGGREGATE REACTION IN CONCRETE: MEASUREMENT AND PREVENTION," Cement and Concrete Research, Vol. 19, pp. 905-912, 1989.

KEY WORDS: alkali aggregate reactions; test methods; accelerated tests; concrete prisms; expansion

Excellent correlation exists between the standard tests and a new accelerated test that measures the expansion of

concrete exposed to 80°C in 1 N. NaOH. The expansions produced are accurately measured using a computer-controlled double LVDT system. The method works equally well for ASR and alkali carbonate reactive aggregate types. The accelerated test could thus be used to screen all types of potentially reactive concrete aggregates.

2140. Ichihara, H., Shimamura, M. and Koshiishi, I., "ALKALI AGGREGATE REACTION IN RAILWAY PRESTRESSED CONCRETE BRIDGES," Proc. 8th Intl. Alkali Conf. 1989, pp. 753-758.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; elevated rail structures; reactive aggregates; andesite; alkali silica gel; repairs; epoxy injections; coatings

A ten-year-old viaduct on the Joetsu Shinkansen ("bullet train" route) in Nigata, Central Japan, has shown unusual cambering due to alkali-aggregate reaction. The aggregates found in the concrete are clay slate, chert, and andesite of local river gravel, and contain 36% of alkali-reactive minerals. The white deposit forming the rims within the aggregate periphery and mortar surface contains approximately 70% $SiO_2$. Map-cracking is not a uniform feature in the cambered prestressed concrete girders. Epoxy injection into the cracks, water repellent treatment with silane on the outside and waterproof cement coatings have been applied for the purpose of AAR suppression. Rail fastenings were replaced with special devices which can be adjusted up to 70mm to compensate for changes in alignment.

2141. Idorn, G. M., "ALKALI-SILICA REACTIONS IN RETROSPECT AND PROSPECT," Proc. 8th Intl. Alkali Conf. 1989, pp. 1-8.

KEY WORDS: alkali aggregate reactions

A personal review of alkali aggregate reactions and research and engineering practice with respect to their prevention and treatment.

2142. Inoue, S., Fujii, M., Kobayashi, K. and Nakano, K., "STRUCTURE BEHAVIORS OF REINFORCED CONCRETE BEAMS AFFECTED BY ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 727-732.

KEY WORDS: alkali aggregate reactions; reinforced concrete; mechanical properties; structural effects; beams

The behavior of reinforced concrete beams with and without ongoing alkali silica reaction have been compared. A large amount of tensile strain occurred in the longitudinal steel as a result of ASR expansion immediately after the accelerated curing for about 180 days. This induced chemical prestress of 42, 49 and 61 kgf/cm$^2$ for p=0.77, 1.20 and 1.74% respectively, in the bottom fiber of the beam section. At least 40% of this initial chemical prestress still remained even under drying condition for about two years. The flexural cracking strength of the ASR beam was larger than that of normal concrete beam because of the induced chemical prestress. The chemical prestress also acted effectively to improved the shear resistance of the concrete. The reduction in the yield strength and maximum ultimate strength of the ASR beam was almost 10%, although a considerable amount of tensile steel strain and expansive cracks existed potentially in the ASR beams. Deflection at the design load of the ASR beam was considerably smaller than predicted from the elastic modulus of cylinder specimens. The overall deformation behavior of ASR beam was similar to that of normal beam except for p=1.74% for which the ASR beam failed in flexure with high ductility exhibited, while the normal beam failed rather in shear.

2143. Ishikawa, K., Chino, H., and Katawaki, K., "STUDY ON NEW RAPID TEST METHOD FOR EVALUATING AGGREGATE REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 339-344.

KEY WORDS: reactive aggregates; test methods; chemical tests; dye absorption tests

Two simplified test methods on alkali silica reaction of aggregate are described, one by measurement of electrical conductivity of a hydrochloric acid solution in which the test aggregate is soaked, the other by color tone and methylene blue absorption. The accuracy of two summary test methods was investigated through experiments. Both methods have their advantages and disadvantages but it was found to be possible to make a speedy and rough appraisal of ASR in aggregates, allowing for some exceptions. These methods could be used as methods of carrying out summary tests on site. The electrical conductivity method has the advantage from the point of view of accuracy and procedure, and its future development can be expected.

1989

2144. Ishizuka, M., Utho, S., Kuzume, K., Sugimoto, M. and Nishiboshi, M., "CHARACTERISTICS OF ROAD STRUCTURES DAMAGED BY AAR ON THE HANSHIN EXPRESSWAY DUE TO CONTINUOUS OBSERVATION," Proc. 8th Intl. Alkali Conf. 1989, pp. 771-778.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; elevated highway structures

The results of continuous assessment of the ASR damage on the Hanshin Expressway near Osaka, Japan, are described in detail. The structural damages by ASR are still in progress. It will be extremely difficulty to prevent further effects by the treatment techniques which have been employed so far. Most of the observed structures are being utilized, so that attention is required with respect decreases of structural strength, falling of pop out concrete fragments and the growth of cracks.

2145. Jones, T. N., "MECHANISM OF REACTIONS INVOLVING BRITISH CHERT AND FLINT AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 135-140.

KEY WORDS: alkali aggregate reactions; reactive aggregates; opal; chert; flint; mechanisms; alkali effects; field experiences; U.K.

Research indicates a number of fundamental differences in ASR details between opal aggregate and cherts and flints, which account for most occurrences in the U.K. Styles of deterioration developed by different aggregates are considered so great that they should be regarded as different types of ASRs. At least three categories of reactive material are therefore recognized:(a)dense aggregates with disordered silica or polymorphs of silica other than quartz, e.g. opal and glass, (b)microporous aggregates consisting principally of microcrystalline quartz, e.g. chert and flint ,and (c)rocks with finely-divided siliceous and silicate matrimaterials, e.g. greywacke and argillite. Rocks containing strained and finely granulated quartz may form an additional category. The assumption that equal concentrations of Na and K are equal in effect is not valid. Alkali content expressed as $Na_2O$ equivalent is therefore unsuitable as measure of the potential for reaction. The 0.6% $Na_2O$ equiv. cement alkali and 3 kg/$m_3$ concrete alkali limits established using opal aggregates may be too high to prevent deleterious reaction in concretes containing reactive chert and flint, due to

the strong ability of these aggregates to concentrate reactants. Deicing salt contamination is unlikely to initiate or accelerate ASR in concrete containing chert and flint aggregates due to the inability of sodium to participate in the reaction at ambient temperature.

2146. Kanazu, T., Ohnuma, H., Nakano, T. and Ishida, H., "STUDY ON THE RAPID ESTIMATION METHOD OF ALKALI AGGREGATE REACTION USING CONCRETE SPECIMENS," Proc. 8th Intl. Alkali Conf. 1989, pp. 375-380.

KEY WORDS: reactive aggregates; test methods; steam curing; expansion

A study is reported on an accelerated test method using steam curing of concrete cores. A provisional criterion of the expansion strain to judge the alkali reactivity of aggregates was obtained for this method.

2147. Katawaki, K., Moriya, S., Wakisaka, Y. and Kato, O., "COMPARISON OF RESULTS OF THE CHEMICAL METHOD AND MORTAR BAR EXPANSION TEST FOR DETERMINING AGGREGATE REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 417-422.

KEY WORDS: reactive aggregates; test methods; chemical tests; Japan

Tests using the ASTM quick chemical method and mortar bar method were carried out for 300 aggregate samples collected all over Japan. A modification to the quick chemical method is proposed. A modified judgment chart is presented to replace the existing chart for separation of reactive, potentially reactive, and innocuous aggregates.

2148. Katayama, T. and Futagawa, T., "DIAGENETIC CHANGES IN POTENTIAL ALKALI-AGGREGATE REACTIVITY OF SILICEOUS SEDIMENTARY ROCKS IN JAPAN - A GEOLOGICAL INTERPRETATION," Proc. 8th Intl. Alkali Conf. 1989, pp. 525-530.

KEY WORDS: reactive aggregates; Japan; diagenesis; silica; opal; chert; quartz

Petrographic studies were made of siliceous sedimentary rocks in Japan including cherts, siliceous shales and their

derivative metamorphics, together with related hydrothermally silicified rocks. Microscopic observations, XRD analysis of silica minerals, and the ASTM C289 chemical test were carried out. It was revealed that the potential reactivity of siliceous sedimentary rocks decreases drastically from Neogene diatomaceous rocks through late Mesozoic to Paleozoic radiolarian cherts during diagenesis and further metamorphism. This tendency is also recognizable in petrographic examinations, i.e. siliceous materials constituting these rocks tend to recrystallize through these geologic processes from an amorphous opaline state through an intermediate fine-grained state. This is paralleled by an increase in the crystallinity index as determined by XRD.

2149. Katayama, T., St John, D. A. and Futagawa, T., "THE PETROGRAPHIC COMPARISON OF SOME VOLCANIC ROCKS FROM JAPAN AND NEW ZEALAND - POTENTIAL REACTIVITY RELATED TO INTERSTITIAL GLASS AND SILICA MINERALS," Proc. 8th Intl. Alkali Conf. 1989, pp. 537-542.

KEY WORDS: reactive aggregates; field experiences; Japan; New Zealand; cristobalite; tridymite; volcanic glass; chemical tests

The volcanic rocks in Japan and New Zealand contain similar amount of cristobalite and/or tridymite. The interstitial glass tends to be rhyolitic in composition and thus highly reactive. In contrast the glass in some basalts only contained 52% silica which explains their lack of reactivity. Testing of synthetic glass materials showed that where the glass contained less than 65% silica the glass was not reactive. Correlation of the presence of interstitial glass, cristobalite and tridymite with reactivity indicates that where glass dominates the matrix of the rock, will test as deleterious in ASTM C 289, and where silica minerals dominate the rock will test as potentially deleterious.

2150. Katayama, T. and Futagawa, T., "ALKALI-AGGREGATE REACTION IN NEW BRUNSWICK, EASTERN CANADA - PETROGRAPHIC DIAGNOSIS OF THE DETERIORATION," Proc. 8th Intl. Alkali Conf. 1989, pp. 531-536.

KEY WORDS: alkali aggregate reactions; petrography; scanning electron microscopy; EDXA; DTA; alkali silica gel

Petrographic examinations were made of deteriorated concretes, based on optical microscopy and SEM observations of internal textures, micro-XRD and EPM analyses of void-filling products, mercury intrusion porosimetry, DTA/TGA measurements, and chemical analyses of the mortar portions. It was found that reacted aggregates are predominantly pebbles of slate and siltstone which include cryptocrystalline to microcrystalline quartz in their matrix, and that similar slate contained in a local aggregate currently used in this region showed deleterious reactivity according to the ASTM C289 chemical test. Microscopic studies also revealed that alkalies are concentrated both in reaction rims within aggregates and in gel fillings in the concrete. It is believed that the major factor of the deterioration is alkali-aggregate reaction, though such processes as freezing and thawing and salt attack are strongly superimposed.

2151. Katawaki, K., "RECENT DIAGNOSIS AND REPAIR TECHNIQUES FOR DAMAGED CONCRETE STRUCTURE BY ASR - A GUIDELINE FOR PUBLIC WORKS STRUCTURE," Proc. 8th Intl. Alkali Conf. 1989, pp. 851-856.

KEY WORDS: alkali aggregate reactions; repairs; field experiences; Japan

A concrete structure damaged by the alkali silica reaction becomes less durable, because rain water and carbon dioxide in the air penetrate into the cracks which results in the neutralization of the surrounding concrete and erosion of reinforcing rods. For this reason, a study of development of repairing materials for concrete structures damaged by the alkali-silica reaction was conducted, and based on the results "Guideline for repairing concrete structure damaged by ASR (draft)" was prepared. The draft guideline includes diagnosis, repair design, repairing materials, and follow-up survey. The major contents of the repair guideline are described.

2152. Kato, O., Moriya, S., Chino, H., Ishikawa, K. and Katawaki, K., "STUDY ON ANALYTICAL TECHNIQUES FOR IMPROVING THE CHEMICAL METHOD," Proc. 8th Intl. Alkali Conf. 1989, pp. 469-473.

KEY WORDS: reactive aggregates; test methods; chemical tests

ASTM C289, the Standard Test Method for Potential Reactivity of Aggregates (Chemical Method) has been widely used as a method of evaluating alkali reactivity of aggregates for concrete since it was first approved as a Tentative Method in 1952. This method has the merits that test results can be obtained quickly and that testing can be done using a small sample of aggregates. However, a problem with this method is that there is scatter of test results. It has often been experienced that when the same aggregate samples were tested, the results obtained at different laboratories did not match each other. The authors have devised a method modifying a number of parts of ASTM C289 with the purpose of improving the testing precision. Tests were performed at pairs of laboratories using 371 varieties of aggregate samples, and as a result of investigating errors in testing,it was found that the accuracy had been improved. This study was made as a part of a comprehensive technology project of the Japan Ministry of Construction, and the revised method proposed herein is being used as a tentative method of the Ministry of Construction.

2153. Kawamura, M., Takemoto, K., and Ichise, M., "INFLUENCES OF THE ALKALI-SILICA REACTION ON THE CORROSION OF STEEL REINFORCEMENT IN CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 115-120.

KEY WORDS: alkali aggregate reactions; steel corrosion; NaCl effects; opal; pore solutions

The addition of the reactive aggregate increased the corrosion rate of steel bars embedded in concrete with a reactive aggregate. The occurrence of ASRs in mortars contaminated with NaCl raised the $Cl^-/OH^-$ ratio in pore solutions in the mortar. It was also confirmed that ASRs increased the corrosion rate of steel bars in the mortars even at a given $Cl^-/OH^-$ ratio in pore solution. Therefore, it is deduced from these results that the increase of the corrosion rate of steel bars embedded in mortars containing the reactive aggregate is attributable to the increase in the $Cl^-/OH^-$ ratio in pore solution as well as to some changes of the microstructure of mortar phase due to ASRs. It may be concluded that ASRs occurring in concretes contaminated with NaCl increase the risk of chloride induced corrosion of steel reinforcement.

1989

2154. Kawamura, M., Koike, M. and Nakano, K., "RELEASE OF ALKALI FROM REACTIVE ANDESITIC AGGREGATES AND FLY ASHES INTO PORE SOLUTION IN MORTARS," Proc. 8th Intl. Alkali Conf. 1989, pp. 271-278.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; pore solutions; alkali effects; alkali release

In saturated calcium hydroxide solution, relatively large amounts of alkali are leached from the alkali-bearing reactive aggregates (andesites) which have brought about deterioration in concrete due to ASR. In mortars containing the alkali-bearing reactive aggregate, the incorporation of a high alkali fly ash increases the alkalinity of the pore solution over that of the cement alone, even if the high alkali cement is used. Alkalis are found to be continuously released from the reacting aggregate into pore solution for at least 90 days. The failure of the addition of 5 and 10% fly ash in inhibiting expansion of mortars containing the alkali-bearing reactive aggregate can be explained by the fact that there is no reduction in $OH^-$ ion concentration of the pore solution in the corresponding mortars even at 30 days. No reduction in $OH^-$ ion concentration of the pore solution in mortars containing the fly ash at replacement levels up to 20% is found, due to the release of alkalis from both the high alkali fly ash and the alkali-bearing reactive aggregate.

2155. Kawakami, H., "A REINFORCED CONCRETE BUILDING DEFORMED BY ALKALI AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 597-602.

KEY WORDS: alkali aggregate reactions; reinforced concrete; field experiences; Japan; building structures

A three storied reinforced concrete school building showed excessive deformation and many cracks at the third story several years after the completion. The dislocation of longitudinal roof end of the 60 meter long building was over 2 cm and many cracks were found through the structural members such as girders, columns, floor slabs and walls. There was no leak in the roof. The maximum crack width was 8 mm in girders and 2 mm in columns. Window locking became impossible due to the deformation of the sash frame caused by column bending. The investigation of the detailed crack map and the deformation of the columns revealed that the damages were caused by the expansion of the roof slab. Observation of the behavior of the cracks and deformation

of the structure in summer and winter indicated that the temperature change contributed to the expansion of the roof slabs to some extent. Recently concrete cores were obtained from the roof slabs and walls. Observations and several tests on these cores revealed the deterioration of the concrete was caused by the alkali aggregate reaction. The report presents the description of the building deformation, the history and the state of the cracks and their behavior due to thermal response. Observation results of cores with X-ray analysis and pictures of scanning electron microscope of them are also presented. Contents of Na and K soluble in water were analyzed. The results of experiment on potential expansion of the cores and thermal expansion coefficient of the cores are reported.

2156. Kishitani, K. and Kobayashi, M., "DEVELOPMENT AND STANDARDIZATION OF A RAPID TEST METHOD FOR IDENTIFICATION OF THE ALKALI REACTIVITY OF AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 357-362.

KEY WORDS: reactive aggregates; test methods

This report describes in outline the research in which a new rapid test method for identification of the alkali reactivity of aggregates has been developed and standardized. This research has been carried out in the committee held by the Japan National Ready Mixed Concrete Industry Association, sponsored by Agency of Industrial Science and Technology in the Ministry of International Trade and Industry.

2157. Kobayashi, S., "A SIMPLE CONCRETE BAR TEST WITH DOUBLE LAYERED CYLINDRICAL SPECIMENS," Proc. 8th Intl. Alkali Conf. 1989, pp. 391-396.

KEY WORDS: reactive aggregates; test methods; accelerated tests; double cylinder test

The chemical method and the mortar bar method have been widely adopted to judge the alkali reactivity of aggregate. These methods have some shortcomings such as difficulties in testing, necessity of special equipment, and long testing periods. The authors have examined a simpler method in which expansion due to alkali aggregate reaction (ASR) is identified easily and visually. The specimens for this "double-cylinder" method are double layered cylindrical

specimens made of mortar or concrete using the aggregate to be tested and covered with mortar with inert fine aggregate. The determination of the reactivity is made by the occurrence of cracking on the outer mortar caused by expansion of the inner cylinder. Adaptability of the DC method as a simple testing method was examined for mortar and concrete samples and the results showed that there was a significant correlation between the DC method with mortar and the mortar bar method, and the DC method can yield results more quickly. It was found that cracking occurs on the outer mortar when the inner cylindrical specimen expands approximately 0.05 percent and expansion could be determined visually. The test speed is accelerated for temperatures of up to 60°C and increasing the amount of alkali also accelerates the test speed. However, if amount of alkali exceeds 10 kg/m$^3$, even inert aggregate expands in 4 weeks. Cracking for concrete specimens starts later than for mortar specimens at the same alkali level.

2158. Kobayashi, S., Kawano, H., Morihama, K. and Ishii, Y., "A STUDY ON ACCURACY OF 40MM MORTAR BAR TEST," Proc. 8th Intl. Alkali Conf. 1989, pp. 385-390.

KEY WORDS: reactive aggregates; test methods; mortar bars; chemical tests; Japan

This paper reports on the criteria and precision of the mortar bar method and the quick chemical method, based on the results of tests on more than 500 aggregates from all over Japan. The effects of specific rock types is considered. Approximately 30% of aggregates, including 38% of volcanic rocks and 31% of sedimentary rocks, were estimated harmful at 6 months test. Few aggregates were estimated as harmless at 6 months after being estimated as harmful at 3 months. Some aggregates had low expansion rates but expanded more than 0.1% after 12 months.

2159. Kobayashi, K., Shiraki, R. and Kawai, K., "INFLUENCE OF ALKALI CONCENTRATION DISTRIBUTION OCCURRING IN CONCRETE MEMBERS ON EXPANSION AND CRACKING DUE TO ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 641-646.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion; cracking; alkali effects

It has been demonstrated, based on alkali concentration

distributions occurring in cross sections of concrete structures, that macroscopic cracks formed at the surface layers of the structures due to ASR are caused by tensile stresses occurring as a result of expansion of central portions of the structure.

2160. Kobayashi, S., Kawano, H., Morihama, K. and Ishii, Y., "THE BACKGROUND OF AAR PREVENTIVE MEASURES ADOPTED BY THE JAPANESE MINISTRY OF CONSTRUCTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 803-808.

KEY WORDS: alkali aggregate reactions; preventive measures; Japan; slag; fly ash; alkali effects

This paper briefly describes the experimental background for recommendations for AAR prevention issued by the Japan Ministry of Construction regarding the use of cement blended with pozzolans, and regarding a limitation of the total amount of alkali in concrete to 3 $kg/m^3$.

2161. Kobayashi, S., Kirimura, K., Kuboyama, K. and Kojima, T., "EVALUATION OF SURFACE TREATMENT EFFECT FOR PREVENTING EXCESSIVE EXPANSION DUE TO ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 821-826.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings; silane; polymer-cement composite coatings; moisture effects

Concrete surface treatments with highly impermeable coating materials give a remarkable effect in reducing expansion due to ASR, provided that the moisture content of the concrete before being coated is approximately 4.5% or less. Modified silane and polymer-cement composite treatments are both effective.

2162. Kobayashi, K., Kojima, T., Utoh, S. and Ono, K., "REPAIR OF CONCRETE STRUCTURES DAMAGED BY ALKALI-SILICA REACTIONS AND ITS EFFECTS," Proc. 8th Intl. Alkali Conf. 1989, pp. 863-868.

KEY WORDS: alkali aggregate reactions; repairs; field experiences; Japan; structural effects

It was found that injection of the epoxy resin into ASR cracks did not slow down the expansion of reacting reinforced concrete beams and did not improve the rigidity and strength, but it protected against new cracking. The ultimate strength of the beam was not affected by ASR. A reacting concrete slab repaired by a steel plate did not show abnormal behavior such as bending or warping during the successive reaction, and the repair by steel plate improved the ultimate strength of the ASR damaged slab.

2163. Kohno, K., Sugimoto, A. and Kashiwai, T., "EFFECTS OF FINELY GROUND SILICA, SILICA FUME AND RED MUD ON ALKALI-SILICA REACTION AND CONCRETE STRENGTH," Proc. 8th Intl. Alkali Conf. 1989, pp. 247-252.

KEY WORDS: alkali aggregate reactions; preventive measures; ground silica; silica fume; red mud

The use of finely ground silica or silica fume and red mud decrease the expansion of mortar bars due to ASR, but the addition of red mud without siliceous materials increases the expansion. The compressive strength of concrete is improved by the use of finely ground silica or silica fume and red mud. The effect of finely ground silica having a high silica content is almost the same as that of silica fume.

2164. Koike, M., Katawaki, K. and Moriya, S., "DEVELOPMENT OF INJECTION MATERIALS AND THE STANDARD FOR REPAIRING DAMAGE TO STRUCTURES CAUSED BY AAR," Proc. 8th Intl. Alkali Conf. 1989, pp. 833-838.

KEY WORDS: alkali aggregate reactions; cracking; repairs

Six kinds of desirable injection materials to repair AAR cracks have been developed through experiments with 20 items. A practical standard and a specification for repair procedures have been established, including test methods for the repair materials. In this repair standard, the optimum repair (injection) material depends on the width of the crack and on its stability.

1989

2165. Kojima, T., Amasaki, S. and Takagi, N., "EFFECTIVENESS OF SILICA FUME IN REDUCING DAMAGE DUE TO ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 265-270.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; silica fume

Silica fume is found to be the most effective pozzolanic material in preventing damage due to ASR, even when the aggregate was in the pessimum condition, and the alkali content was high. There was no sign of deteriorating due to ASR in SF mortar and concrete specimens at the replacing ratio of 25%. In the deteriorated mortar and concrete specimens, pulse velocity, dynamic modulus of elasticity and energy of response function decreased with deterioration due to ASR, and then increased again. The secondary increase of the measured values may be attributed to the filling into cracks of the gel resulting from the ASR. The compressive strength and static modulus of elasticity of deteriorated concrete specimens decreased approximately 20 to 30% and 20 to 40% respectively, when compared with normal concrete. Large increases of Poisson's ratio were observed in the deteriorated concrete specimens.

2166. Kojima, T., Tomita, M., Nakano, K. and Nakaue, A., "EXPANSION BEHAVIOR OF REACTIVE AGGREGATE CONCRETE IN THIN SEALED METAL TUBE," Proc. 8th Intl. Alkali Conf. 1989, pp. 703-708.

KEY WORDS: alkali aggregate reactions; drying effects; mechanical properties; restraint; reinforced concrete

In a sealed specimen held at 20°C, alkali silica expansion developed linearly and the strain of expansion reached 60% of that of accelerated specimens, after a dormant period. Drying inhibited alkali silica expansion, but it was not effective for massive concrete structures. Modulus of elasticity, propagation velocity of ultrasonic waves, and compressive strength increased with restriction by reinforcement.

2167. Koyanagi, W., Rokugo, K., Morimoto, H. and Iwase, H., "CHARACTERISTICS AND SIMULATION OF CONCRETE CRACKS CAUSED BY AAR," Proc. 8th Intl. Alkali Conf. 1989, pp. 845-850.

KEY WORDS: alkali aggregate reactions; cracking; reinforced

concrete; steel fibers; prestressed concrete; finite element models

The present study had as its objectives a quantitative analysis of the effects of reinforcement and prestress on the cracking characteristics developed during AAR, and the development of a mathematical simulation of crack occurrence and propagation using a finite element approach. It was found that in the case of RC beam specimens, the total crack length and the crack component perpendicular to the beam axis decreased when compression reinforcement increased; cracks in the direction of the axis became dominant. Addition of steel fibers also made the total crack length shorter. In the case of PC specimens, cracks in the stressing direction became dominant gradually when the amount of prestress increased. Crack density decreased with the increase of prestress within 40 $kg/cm^2$. It increased, however, when the prestress became 80 $kg/cm^2$. It was found that the cracking processes could be modeled, although imperfectly, when tension softening was taken into consideration.

2168. Kurihara, T. and Katawaki, K., "EFFECTS OF MOISTURE CONTROL AND INHIBITION OF ALKALI SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 629-634.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings; moisture effects; drying effects

Expansion inhibiting effects can be gained by controlling the moisture content in mortar. Under the test conditions adopted in the present experiments, the effects were gained when the moisture content was inhibited to approximately 7-8 wt.%. Under the dry-wet repeating curing conditions of the present experiments, the moisture content in the mortar was successfully controlled by the moisture migration control functions of the coating materials employed. Expansion inhibiting effects corresponding to the degree to which the moisture content was inhibited were also gained.

2169. Lee, C., "ACTIVE ALKALIS IN CEMENT-FLY ASH PASTE," Proc. 8th Intl. Alkali Conf. 1989, pp. 223-228.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ashes; pore solutions; alkali effects

Active alkali content of cement-fly ash pastes was studied by using two types of cements, a type I high-alkali cement and a type II low-alkali cement, and three Class C fly ashes. The concentration of active alkalies was measured using the procedures modified from ASTM C 311 for the available alkali test. The purposes of this research were to study (1) the significance of standard available alkali test for analyzing active alkalis in actual cement-fly ash paste, and (2) the relationship between the active alkali concentration and the chemical compositions of the cement-fly ash paste. The results indicated that the available alkali test described in ASTM C 311 tends to underestimate the ultimately active alkali content in actual cement-fly ash pastes. An empirical equation was developed to estimate the ultimate concentration of active alkalies in cement-fly ash pastes from the known N/S mole ratio in the reacting system. It was also found that more than 85% of total equivalent alkalis contained in the paste tended to be mobilized into the pore solution when the C/S mole ratio in the paste was greater than 1.75

2170. Ludwig, U., "EFFECTS OF ENVIRONMENTAL CONDITIONS ON ALKALI-AGGREGATE REACTION AND PREVENTIVE MEASURES," Proc. 8th Intl. Alkali Conf. 1989, pp. 583-596.

KEY WORDS: alkali aggregate reactions; preventive measures; temperature effects; RH effects; alkali effects

The temperature necessary to cause damaging ASR in concrete structures does normally exist. Raised temperatures exceeding 20°C accelerate ASR and decrease the damaging effects. Temperatures > 55°C may be of lower interest. They can provoke decreased expansion with reactive aggregates or increased expansion with inert aggregates. At temperatures < 20°C, insufficient evidence exists, except in particular cases indicating poor reaction at lower temperatures. Temperature changes (including frost-thaw cycles) will increase the damage. The moisture content of concrete necessary to exhibit damaging ASR is present in concrete buildings, members and pavements exposed to open air weathering or being in contact with water. Decreased humidities will delay the beginning of expansion and damage but will induce more severe destruction, and will prevent the damaged structure from healing up. At about 20°C the minimum humidity causing ASR was determined to be 80 to 85%. This value might be lower at higher temperatures. Changes in humidity and migration of pore solution and alkalis will increase the damage and

its visible sign in structures. ASR can be prevented by reducing the total effective alkali content of a concrete mix to a value below 2 kg $Na_2O$ equiv./$m^3$ concrete. Water repellent impregnations of concrete surfaces can reduce the damaging influence of ASR.

2171. Lumley, J. S., "SYNTHETIC CRISTOBALITE AS A REFERENCE REACTIVE AGGREGATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 561-566.

KEY WORDS: reactive aggregates; cristobalite; calcined flint

Cristobalite as an artificial aggregate exhibiting ASR has been prepared from flint. At a reasonable particle size it reacts at a generally suitable rate for laboratory work at 20°C. Commercially produced batches have shown a high degree of reproducibility.

2172. Meland, I., "ALKALI-SILICA REACTION IN TILE-COVERED CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 107-113.

KEY WORDS: alkali aggregate reactions; ceramic tiles

Ceramic building materials may cause ASR when they are in contact with cement paste. ASTM C 227 and ASTM C 289 seem to be suitable methods for testing ceramic building materials with respect to alkaline reactivity. The use of fly ash cement and low alkali cement in mortars for fixing ceramic tiles will most likely reduce a possible ASR in ceramic building materials. Only a limited benefit of using silica fume blended cements to reduce alkali reactivity has been obtained.

2173. Miura, S., Kanamitsu, S., Yamamoto, T. and Kawanishi, J., "RELATION BETWEEN DISSOLUTION OF AGGREGATE IN ALKALI SOLUTION AND MORTAR-BAR EXPANSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 345-350.

KEY WORDS: alkali aggregate reactions; test methods; alkali effects; chemical methods; petrography

The relationship between the expansion due to alkali silica reaction of mixed aggregates in mortar-bars and the

solubility of those aggregates in alkali solution have been studied. The mixed aggregates used are produced from rocks which contain alkali reactive silica minerals, and non reactive rocks. A quick method for approximate evaluation of the deleterious extent of mixed aggregates in concrete according to their solubility in alkali solution is compared with the mortar-bar method which requires an examination period of at least 6 months. The results obtained show that the alkali silica reactivity of mixed aggregates containing chert can be evaluated by their solubility in alkali solution. However, no direct correlation is found between reactivity and solubility of andesite, which is recognized to have a pessimum proportion. The alkali reactivity of different aggregates used in mortar bars could be petrographically evaluated by means of polarizing microscope technique for the thin sections made from transparent alkali resistant epoxy resin matrix in which each aggregate was embedded, observing them appropriate intervals of immersion time in alkali solution.

2174. Moir, G. K. and Lumley, J. S., "INFLUENCE OF PARTIAL CEMENT REPLACEMENT BY GROUND GRANULATED SLAG ON THE EXPANSION OF CONCRETE PRISMS CONTAINING REACTIVE SILICA," Proc. 8th Intl. Alkali Conf. 1989, pp. 199-204.

KEY WORDS: alkali aggregate reactions; preventive measures; slag

The partial replacement of cement by slag significantly delayed the expansion of concrete containing cristobalite. Although expansion was delayed, the degree of expansion was little changed at slag levels of 30% and 40%. The prisms containing 50% slag have shown significant expansion and at the time of writing are still expanding slowly. Under the test conditions employed, the effective alkali contribution from the sources of slag was closer to 100% than 50%.

2175. Morino, K., "ALKALI AGGREGATE REACTIVITY OF CHERTY ROCK," Proc. 8th Intl. Alkali Conf. 1989, pp. 501-506.

KEY WORDS: reactive aggregates; chert; Japan

In this paper, alkali reactivity of cherty rocks was studied by method of mineralogy or petrography together with concrete technology. Chert samples were collected from Mesozoic sedimentary formation in Yoro mountain and pit

gravels in Aichi and Gifu prefectures, and chalcedony samples were selected from the laboratory collection. The properties of reactive minerals and rock-forming minerals in the samples were investigated with polarizing microscope, X-ray diffractometer and differential thermal analyzer. Chemical and expansion tests on the samples were carried out by chemical (ASTM C289 ) and mortar bar (ASTM C227) test methods. Special attention was paid to the test results with regard to amorphous silica and crystallinity of quartz (cryptocrystalline and chalcedonic quartz) ln chert. The relationship between the various results on microscopic properties of chert and the expansion behavior of mortar bar made with chert were presented. ASTM C 289 tests indicated that cherts were deleterious or potentially deleterious aggregates, although mortar bars did not expand when normal portland cement of about 0.8% Na2O eqv. was used. The expansion of mortar bars made with chert changed remarkably with the alkali content and mix proportion of non-reactive aggregate. There was a close connection between the crystallinity index and reactivity test results of cherts.

2176. Moriya, S., Obata, H. and Katawaki, K., "STUDY ON THE REDUCING REACTIVITY RATE OF CONCRETE USED WITH REPAIRING MATERIALS IN LABORATORY AND FIELD," Proc. 8th Intl. Alkali Conf. 1989, pp. 857-862.

KEY WORDS: alkali aggregate reactions; repairs; Japan

Repair materials for alkali aggregate reaction situations in concrete have been studied in detail. To cut the supply of water into the inner of concrete is a key for ASR repair works. For this purpose, appropriate materials are injected or filled depending on the width of existing cracks, and then the outside of the structure is coated with materials with excellent water insulation. However, when aggregate in the structure is in progress of the reaction, the effect of cutting water supply from the outside does not manifest itself so quickly. As a result, the water left in the inner concrete may slowly promote the reaction. Therefore, materials for repair require elongation for remaining expansive power, and strong adhesiveness of concrete. On the other hand, for a structure in which the reaction is almost over, it is important to prevent corrosion of reinforcing rods due to neutralization of concrete caused by water entering cracks and carbon dioxide in the air. For this reason, materials for repair do not necessarily require elongation, but strong adhesiveness to concrete is called for. Results of

the bearing test for reinforced concrete already cracked due to ASR show that cracking does not result in a decrease in durability and so reinforcement is practically unnecessary at this stage. When reinforcement is made, implementation is accordance with that for general reinforced concrete structures is good enough.

2177. Mullick, A. K., Wason, R. C. and Rajkumar, C., "PERFORMANCE OF COMMERCIAL BLENDED CEMENTS IN ALLEVIATING ASR," Proc. 8th Intl. Alkali Conf. 1989, pp. 217-222.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; pozzolans; field experiences; India

The commercially available portland pozzolan cements in India have superior performance both with natural reactive aggregates and pyrex glass when compared to OPC. Based on the data, a limit of 0.8 to 0.9% total alkalis can be considered as safe in case of PPC as against 0.6% in OPC. Although the performance of OPCs improve with the increase of pozzolan content, a dosage of around 15% as is common in India is adequate. Fly ash had the best and most consistent beneficial effects. Appreciable reductions in expansion were obtained with 25% dosage of pozzolans.

2178. Nakano, K., Ginyama, I., Yoneda, S., Shibazaki, F., Sone, T., Tomita, R., Watada, K., Murota, Y., Nagao, Y., Ushiyama, H., Tomita, Y. and Murata, Y., "STUDY ON EXPANSION PROPERTIES OF ALKALI REACTIVE AGGREGATE BY CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 409-415.

KEY WORDS: alkali aggregate reactions; reactive aggregates; andesite; chert; Japan

This paper reports results by a committee of the Concrete Cement Association of Japan on a major study involving 5 reactive andesite rocks and 1 reactive chert as considered typical of the reactive aggregates found in Japan. It was concluded that: (1) Alkali silica expansion is mostly determined total alkali content and mix proportion of reactive aggregate in concrete. (2) Andesite type aggregates all showed the existence of pessimum of mix proportion of aggregate and some showed the existence of pessimum of alkali content. (3) A threshold of alkali content was found to exist. (4) The minimum total alkali content which damages concrete is 3.0 kg/m$^3$ even for

aggregate with the highest alkali silica expansion.

2179. Natesaiyer, K. and Hover, K.C., "SOME FIELD STUDIES OF THE NEW INSITU METHOD FOR IDENTIFICATION OF ALKALI SILICA REACTION PRODUCTS," Proc. 8th Intl. Alkali Conf. 1989, pp. 555-560.

KEY WORDS: alkali aggregate reactions; alkali silica gel; test methods; uranyl acetate test

This paper presents the results of applications of the uranyl acetate gel fluorescence test to concrete specimens from field structures. The test was successfully applied to identify the products of the reaction between alkalis and quartzite aggregates. It appears that the gel fluorescence test can be used as a forensic tool to determine the progress of ASR in a concrete even when other symptoms of ASR are absent.

2180. Natesaiyer, K. C. and Hover, K. C., "FURTHER STUDY OF AN IN-SITU IDENTIFICATION METHOD FOR ALKALI-SILICA REACTION PRODUCTS IN CONCRETE," Cement and Concrete Research, Vol. 19, pp. 770-778, 1989.

KEY WORDS: alkali aggregate reactions; alkali silica gel; test methods; uranyl acetate test

The microscopic evidence presented confirms that the simple identification technique for ASR proposed earlier (based on uranyl acetate treatment and observation of the resulting fluorescence effect) identifies only the gel products of ASR; fluorescence on reaction rims is minor. Microprobe and petrographic analysis confirms that the fluorescence is associated with uranyl ions and occurs only where these ions have been adsorbed.

2181. Nishibayahi, S., "ALKALI-AGGREGATE REACTIVITY IN JAPAN - A REVIEW," Proc. 8th Intl. Alkali Conf. 1989, pp. 17-24.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; reactive aggregates; andesite; test methods; reviews

A review is presented of the occurrences of AAR in Japan and of research and test method development carried out in

various Japanese laboratories.

2182. Nishiyama, T., Kusuda, H., and Nakano, K., "A FEW REMARKS ON ALKALI-REACTIVE CHERT AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 543-548.

KEY WORDS: reactive aggregates; chert; X-ray diffraction; crystallinity index; test methods

Thirty chert aggregate pieces taken from 9 samples of deteriorated concrete were studied microscopically and by XRD and DTA. Three degrees (grades) of reactivity were noted. A crystallization index from the X-ray diffraction pattern is useful as a screening test for the potential reactivity of a given chert.

2183. Nishizaki, I. and Katawaki, K., "THE CHARACTERIZATION OF ASR PRODUCTS AND ALKALIS IN CEMENT PASTE," Proc. 8th Intl. Alkali Conf. 1989, pp. 549-554.

KEY WORDS: alkali aggregate reactions; alkali silica gel; alkali effects; lithium effects

Reactions between reactive aggregate and solutions of alkali salts and of NaOH were studied. The Na cation influences the promotion of the reaction, and the K cation also influences the promotion of the reaction a little. Lithium cations exert a restraining influence on the reaction. The reaction with sodium was said to produce mainly a mixture of sodium silicate and sodium hydroxide, and it was recognized that sodium cation adsorbed into the silicate.

2184. Nishibayashi, S., Yamura, K. and Sakata, K., "RESEARCH ON INFLUENCE OF CYCLIC WETTING AND DRYING ON ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 617-622.

KEY WORDS: alkali aggregate reactions; temperature effects; drying effects; wetting and drying effects

The behavior and degree of damage associated with reacting concrete in a wetting and drying environment was studied. It was found that: (1) The behavior of the various physical properties of concrete specimens in environments

of cyclic wetting and drying differ greatly depending on blending ratio of reactive aggregate and on alkali content. (2) Temperature has a considerable influence in the drying process, and deterioration due to alkali aggregate reaction is more prominent for a specimen dried in an oven (60°C) than one dried in air (20°C). (3) The degree of deterioration of concrete in an environment of cyclic wetting and drying can be evaluated to a certain degree by using a deterioration index (DW-DF).

2185. Nishibayashi, S., Yamura, K. and Sakata, K., "EVALUATION OF CRACKING OF CONCRETE DUE TO ALKALI- AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 759-764.

KEY WORDS: alkali aggregate reactions; expansion; cracking

This study was carried out to define the parameters governing cracking and the relationship between crack development and expansion in laboratory produced concrete. It was found that: (1) Expansion increases suddenly when alkali content exceeds a certain limit value, that is, the total alkali content of about 3 kg/m$^3$. (2) Expansion behavior differs according to the storage conditions, that is AAR is extremely dependent upon environmental conditions. (3) When the quantity of expansion increases, the total crack width becomes larger, and a fairly high correlation can be recognized between these two, but the total sum of crack width does not directly amount to the quantity of the expansion.

2186. Nixon, P. J., Page, C. L., Hardcastle, J., Canham, I., and Pettifer, K., "CHEMICAL STUDIES OF ALKALI SILICA REACTION IN CONCRETE WITH DIFFERENT FLINT CONTENTS," Proc. 8th Intl. Alkali Conf. 1989, pp. 129-134.

KEY WORDS: alkali aggregate reactions; reactive aggregates; flint; pessimum effect; pore solutions

Concretes have been made using different proportions of reactive flint in the aggregate and high alkali levels in the cement such that some show damaging expansion and others with greater proportions of flint do not expand. The concretes have been studied by optical microscopy, pore solution analysis and for increases in the amount of soluble silica. It has been found that in the concretes containing the higher, proportions of flint, which do not

expand, there is a greater reduction ln pore solution hydroxyl ion concentration, and more solubilization of silica. The pessimum effect appears to occur because at higher flint contents the gel produced seems able to dissipate itself into the cement paste without causing sufficient stress to damage the concrete.

2187. Nomachi, H., Takada, M., Harada, K. and Nishibayashi, S., "EFFECTS OF ADMIXTURES ON EXPANSION CHARACTERISTICS OF CONCRETE CONTAINING REACTIVE AGGREGATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 211-215.

KEY WORDS: alkali aggregate reactions; chemical admixture effects; expansion

The influence of chemical admixtures on alkali aggregate expansions in concrete was investigated. When an air entraining or an air entraining-water reducing admixture was used, concrete expansion due to ASR was lower than that of plain concrete. The relationship between the unit cement content and expansion in concrete shows the same tendency for AEWR admixture as for AE admixture. In actual use, however, the unit cement content was lower in AEWR containing concrete, and so the expansion was lower.

2188. Oberholster, R. E., "ALKALI-AGGREGATE REACTION IN SOUTH AFRICA: SOME RECENT DEVELOPMENTS IN RESEARCH," Proc. 8th Intl. Alkali Conf. 1989, pp. 77-82.

KEY WORDS: alkali aggregate reactions; field experiences; South Africa; preventive measures; pozzolans; fly ash; coatings; dam structures

This paper reviews current investigations on AAR in South Africa. The effects of mineral admixtures and of concrete surface treatments are being examined. A case study of AAR-caused expansion in a dam is described.

2189. Ohama, Y., Demura, K. and Kakegawa, M., "INHIBITING ALKALI-AGGREGATE REACTION WITH CHEMICAL ADMIXTURES," Proc. 8th Intl. Alkali Conf. 1989, pp. 253-258.

KEY WORDS: alkali aggregate reactions; preventive measure; chemical admixtures; sodium silicofluoride effects; lithium

effects; alkayl alkoxy silane effects; styrene-butadiene latex effects

This paper reports results of investigations of the effects of chemical admixtures designed to reduce or eliminate AAR expansion. The specimens were autoclaved mortars. It was found that the chemical admixtures which appear to be the most effective in reducing expansion resulting from the alkali aggregate reaction are $Na_2SiF_6$ and an alkyl allkoxy silane (AAS). In particular, the addition of $Na_2SiF_6$ causes a considerable increase in mortar strength. The recommendable $Na_2SiF_6$ and AAS contents are 0.7 to 1.0% and 0.5 to 1.0% respectively. It was found that the inhibiting effects of lithium compounds and polymer dispersions on the expansion due to alkali aggregate reaction are inferior to those of $Na_2SiF_6$ and AAS.

2190. Ohno, S., Yoshioka, Y., Shinozaki, Y. and Morikawa, T., "THE MECHANICAL BEHAVIOR OF BEAMS COATED AFTER ALKALI SILICA REACTION DAMAGE," Proc. 8th Intl. Alkali Conf. 1989, pp. 697-702.

KEY WORDS: alkali aggregate reactions; reinforced concrete; restraint; structural effects; mechanical properties

Reinforced concrete beams damaged by ASR were loaded in flexure after exposure to natural weather condition for 17 months and 45 months, respectively. The ultimate flexural strengths of the beams damaged by ASR were almost the same as that of the unaffected beams. Chemical prestress introduced by expansion due to ASR made the beam more elastic at the design load level.

2191. Ohtsu, M., "SHORT-TERM EVALUATION OF MORTAR BAR TEST BY ACOUSTIC EMISSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 301-306.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; expansion; acoustic emission

A short-term evaluation of the mortar bar test is proposed, based on two-week measurement. The ordinary curing conditions are retained, but the reactivity is evaluated by the rate process analysis of acoustic emission activity in the uniaxial compressive test at two weeks.

Final expansion (at six weeks) is successfully predicted from acoustic emission measurements, and all results are incorporated in an expert system to evaluate reactivity.

2192. Okada, K., Tezuka, M., Yoshikawa, T., Himeno, M., and Komada, M., "ALKALI AGGREGATE REACTION: AN INVESTIGATION ON ITS CAUSES AND STRENGTH EVALUATIONS OF MATERIAL SUBJECTED TO ITS EFFECTS," Proc. 8th Intl. Alkali Conf. 1989, pp. 609-615.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; slag; structural effects; reinforced concrete; mechanical properties

This report covers a portion of the research on AAR carried out by the authors over the period 1984-88, including work on effects of cement replacement by fly ash and slag, studies of environment condition effects, and studies of the effects on flexure and shear strengths of reinforced concrete members.

2193. Okada, K., Mizumoto, Y., Nakano, K. and Ono, K., "STUDY OF ALKALI-SILICA REACTION BY REINFORCED CONCRETE MODELS," Proc. 8th Intl. Alkali Conf. 1989, pp. 709-714.

KEY WORDS: alkali aggregate reactions; reinforced concrete; field experiences; preventive measures; fly ash; slag; cracking; expansion

This paper reports the results of experiments on large reinforced concrete blocks ("models" )undergoing ASR. The models reproduced the ASR phenomena of actual bridge piers.Cracking started at free end of each model, where restraint by reinforcement was relatively small. The ASR of a sheltered model was delayed. The usual cracking depth was down to the full level of cover over the steel, although expansion due to ASR was also occurring in the middle of the models. The released and residual expansions of cores drilled from ASR-damaged structures would represent the total expansion of the structure. ASR models made of fly ash cement or slag cement did not expand so much, and no cracking developed.

1989

2194. Okada, K., Utoh, S., Imai, H. and Ono, K., "CONCRETE STRUCTURES DAMAGED BY ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 791-796.

KEY WORDS: alkali aggregate reactions; field experiences; Japan; reactive aggregates; andesite; chert; slate; mechanical properties; Young's modulus

This paper reviews field experiences of affected concrete structures in Japan. Most of the alkali aggregate reaction occurring in Japan is alkali silica reaction. ASR in Japan is generally caused by coarse aggregate rather than sand. The main reactive aggregates found in the investigation are bronzite andesite, chert, and slate. The Young's modulus of affected concrete (measured on drilled cores) was typically very low.

2195. Okada, K., Nishibayashi, S., and Kawamura, M., eds., "Alkali Aggregate Reaction," 8th Intl. Conf. on Alkali Aggregate Reactions, Kyoto, Japan, 8th ICAAR Local Organizing Committee, The Society of Materials Science, Japan, 885 pp, 1989.

KEY WORDS: alkali aggregate reactions; conferences

Cited as Proc. 8th Intl. Alkali Conf. Contains 128 papers on alkali effects and alkali aggregate reactions in concrete.

2196. Olafsson, H., "AAR PROBLEMS IN ICELAND - PRESENT STATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 65-70.

KEY WORDS: alkali aggregate reactions; field experiences; Iceland; preventive measures; silica fume

Alkali content in Icelandic cement is high and some aggregates are reactive. Therefore precautions were taken concerning all constructions other than housing. In housing concrete cast in the period 1960-1979 serious AAR problems occur. From 1979 no serious AAR cases have been found, thanks to preventive measures taken, silica fume replacement in cement being the most important one. Research on remedial measures for AAR damaged concrete is of high priority.

1989

2197. Ono, K., "ASSESSMENT AND REPAIR OF DAMAGED CONCRETE STRUCTURE," Proc. 8th Intl. Alkali Conf. 1989, pp. 647-658.

KEY WORDS: alkali aggregate reactions; field experiences; Japan

A sudden increase of ASR in Japan started about 20 years ago and damaged structures occur in many places in Japan. Bronzite andesite, chert, slate, tuff, sandstone, and opal were identified as the reactive aggregates. The degree of damage by ASR depends mainly upon the characteristics and content of reactive aggregate used, the alkali content, the degree of restraint of the structure, the ambient temperature, and the moisture content. Cracks due to ASR have generally not reached great depths and reinforcing bars in damaged structures have not corroded severely yet, suggesting that damage has generally not reached a severe stage yet. However, progressive loss of concrete strength and rigidity of the damaged structures seem to be giving a warning for future deterioration of these structures. Therefore, constant inspection or investigation is essential, and effective methods to inhibit ASR of damaged structures are needed to prolong their life.

2198. Palmer, D., "ASPECTS OF THE DIAGNOSIS OF ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 741-746.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.

This paper deals with general aspects of the diagnosis of AAR in field structures in the U.K.

2199. Pleau, R., Berube, M. A., Pigeon, M., Fournier, B. and Raphael, S., "MECHANICAL BEHAVIOR OF CONCRETE AFFECTED BY ASR," Proc. 8th Intl. Alkali Conf. 1989, pp. 721-726.

KEY WORDS: alkali aggregate reactions; mechanical properties; temperature effects; NaCl effects

Concrete samples were prepared with two fine-grained limestone aggregates with similar physico-mechanical properties, but respectively reactive (0.26% expansion at one year in air at 100% RH and 38°C) and non-reactive (0.02% expansion at same conditions) The specimens were stored at 23°C and 38°C, in air at 100% RH. and in a 6% NaCl solution.

Measurements of the mass variations of the specimens and of ultrasonic pulse velocity could not clearly distinguish the ASR-affected concrete from the sound concrete. In air at 100% RH and 38°C, the non reactive concrete slowly improved its uniaxial compressive and Brazilian splitting tensile strengths, while the reactive samples presented strength increases up to 12 weeks, then strength loss between 12 weeks and 1 year (i.e. only after 0.12% of expansion). The ratio between the tensile and the compressive strengths was always normal (0.07 to 0.11). The elastic modulus is more rapidly affected by ASR than the strength. At 23°C, the same behaviors were observed, however at lower rates. Relatively to total alkalis, the 6% NaCl solution was assumed to be approximately in equilibrium with the concrete pore solution, explaining why the results were relatively similar in air and in NaCl solution.

2200. Qaqish, S. S. and Marar, N., "USE OF CHERT IN CONCRETE STRUCTURES IN JORDAN," ACI Materials Journal, Vol. 86, pp. 135-138, 1989.

KEY WORDS: reactive aggregates; chert; test methods; expansion; mortar bars; chemical tests

Short- and long-term tests from ASTM C 289-71 and ASTM C 227-81, respectively, were used to test wadi aggregate and wadi aggregate mixed with different percentages of limestone to determine if they produced any harmful effect on concrete. The long-term test results show that wadi aggregate containing chert from the Jafer, Jordan, area has no harmful effect on concrete, but that mixing this wadi aggregate with different percentages of limestone does produce harmful effects on concrete.

2201. Rao, L. H. and Sinha, S. K., "TEXTURAL AND MICROSTRUCTURAL FEATURES OF ALKALI REACTIVE GRANITIC ROCKS," Proc. 8th Intl. Alkali Conf. 1989, pp. 495-499.

KEY WORDS: reactive aggregates; granites; quartz; undulatory extinction angles; alkali feldspars; India

Textural and microstructural features are among the important parameters in evaluating a concrete aggregate for potential ASR studies, as these features are the indices of the geological processes which have been in operation. The experimental studies in NCB have revealed that the

parameters influencing ASR in granitic aggregates with strained quartz is combined effect of undulatory extinction angles and the textural and microstructural features. It is also established that the presence of alkali feldspar in granitic aggregate containing lower proportions of quartz than in quartzite also aggravates the ASR.

2202. Raphael, S., Sarkar, S. L. and Aitcin, P.-C., "ALKALI-AGGREGATE REACTIVITY - IS IT ALWAYS HARMFUL?," Proc. 8th Intl. Alkali Conf. 1989, pp. 809-814.

KEY WORDS: alkali aggregate reactions; dam structures; petrography; field experiences; Canada

In an extensive survey of the present state of aging of concrete in 8 dams built in Quebec between 1910 and 1960 with a wide range of aggregates, evidence of alkali-aggregate reactions were observed in almost all the core specimens tested. Alkali-aggregate reactions in these dams manifest themselves in a number of ways: reaction rims around aggregates, discoloration of aggregates in the peripheral region, polygonization of grains, loss of cohesion between paste and aggregate, inter- and intragranular fissures, and delamination of stratified rocks. Compressive and splitting strength, and permeability measurements show that in most cases these alkali-aggregate reactions did not cause any significant loss in the engineering properties of concrete. It may be stated that unless the aggregate deterioration is well advanced, mere evidence of alkali-aggregate reactivity itself need not cause alarm. It is possible that due to lack of favorable environment and limited amount of reactive materials available, the reactivity tends to stabilize at an innocuous level.

2203. Regourd-Moranville, M., "PRODUCTS OF REACTION AND PETROGRAPHIC EXAMINATION," Proc. 8th Intl. Alkali Conf. 1989, pp. 445-456.

KEY WORDS: alkali aggregate reactions; alkali silica gels; petrography; crystalline reaction products; reviews

Reaction products observed in concrete structures altered by alkali-aggregate reactions appear as gels and crystals. They have been characterized by various features including (1)their localization around aggregates in cracks

and pores of the cement paste, in veins or cleavage planes inside aggregates, and as concrete surface exudations; (2)their microstructures, as massive or textured gel and rose or lamella crystals; (3)their elemental compositions, containing alkalis, silicon, calcium, and minor elements such as aluminum and iron; and (4)their co-existence with secondary products like ettringite and carbonates. Many types of minerals have been found potentially reactive with alkalis. Petrographic examinations have identified aggregates which have reacted in concretes. They are mostly siliceous aggregates with microcrystalline silica and altered minerals or siliceous limestone aggregates with diffused silica. This paper presents a review of data published since the last international conference held in Ottawa in 1986.

2204. Rogers, C. A., "ALKALI-AGGREGATE REACTIVITY IN CANADA," Proc. 8th Intl. Alkali Conf. 1989, pp. 57-63.

KEY WORDS: alkali aggregate reactions; field experiences; Canada; preventive measures; test methods

In Canada, three types of alkali-aggregate reaction are recognized. Each type is evaluated using different tests. Corrective measures such as the use of low alkali cement, lower cement contents, or pozzolans are seldom used with reactive aggregates. Beneficiation or selective extraction is used with some reactive aggregates. Work is being conducted on multilaboratory study of existing tests and new, rapid tests.

2205. Rogers, C. A. and Hooton, R. D., "LEACHING OF ALKALIES IN ALKALI-AGGREGATE REACTION TESTING," Proc. 8th Intl. Alkali Conf. 1989, pp. 327-332.

KEY WORDS: alkali aggregate reactions; test methods; mortar bars; concrete prisms; alkali effects; alkali leaching

Mortar bars made with a known alkali silica reactive aggregate and stored in container with wicks as mandated in ASTM C 227, do not show significant expansion. If the mortar bars are stored in containers without wicks or are sealed in plastic bags, significant expansion takes place. Excessive leaching of alkalis out of mortar bars in the standard test reduces the expansion produced. The amount of expansion is significantly correlated with the amount of

alkalis remaining in the mortar bars after one year. Concrete prisms, made with a known alkali carbonate reactive aggregate, gives different expansions, depending on the condition of storage. The amount of expansion at 23°C is related to the amount of alkalis remaining in the prisms after 2.5 years.

2206. Sakaguchi, Y., Takakura, M., Kitagawa, A., Hori, T., Tomosawa, F. and Abe, M., "THE INHIBITING EFFECT OF LITHIUM COMPOUNDS ON ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 229-234.

KEY WORDS: alkali aggregate reactions; preventive measures; lithium effects; alkali silica gel

The addition of lithium compounds was effective for inhibiting the expansion of mortar due to ASR, whether pyrex glass or a reactive aggregate was used. When either mortar and concrete which had been expanded due to ASR was impregnated with $LiNO_2$ solution, any further expansion thereof could be retarded or inhibited. It was confirmed that lithium compound was concerned in the chemical reaction of ASR and inhibited the formation of alkali silica gel. The inhibiting effect of lithium is attributed to the production of a kind of lithium silicate which hardly swells and dissolves, at the surface of the aggregate.

2207. Schmitt, J. W. and Stark, D. C., "RECENT PROGRESS IN DEVELOPMENT OF THE OSMOTIC CELL TO DETERMINE POTENTIAL FOR ALKALI-SILICA REACTIVITY OF AGGREGATES," Proc. 8th Intl. Alkali Conf. 1989, pp. 423-431.

KEY WORDS: reactive aggregates; test methods; osmotic cell method

Preliminary research has shown the osmotic cell apparatus can identify potentially alkali-reactive siliceous aggregates intended for use in concrete. More recent efforts have focused on standardization of the apparatus, establishment of a data base, correlation with other test methods, applicability of the test in identifying slowly reactive rock types, and assessment of aggregate removed from structures exhibiting evidence of alkali-silica reaction. Results of these studies are presented.

1989

2208. Seno, Y. and Kobayashi, K., "EXPANSION PROPERTIES OF MORTARS AND VARIATION IN COMPONENTS OF PORE SOLUTIONS DUE TO ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 141-146.

KEY WORDS: alkali aggregate reactions; chert; andesite; pore solutions; alkali effects; expansion; mortar bars

This study contains the investigated result of expansion properties of mortar specimens and the investigated result of concentrations of alkali ions and hydroxide ions in pore solutions expressed from the specimens which were stored in the same environment as in the Mortar-Bar Method, and describes the relationship between the expansion and the concentration. The composition of pore solutions expressed from mortar specimens stored in a high humidity environment which is similar to the conditions of accelerated test such as the Mortar-Bar Method, is almost the same composition as for the specimen stored in a sealed condition. This composition consists of alkali ions and hydroxide ions, but these concentrations were different from the case of specimens stored in sealed conditions. And these concentrations rapidly decreased with the passage of time. However, the Ph of pore solutions did not decrease to less than 12 even at 6 months age. The concentrations of alkali ions and hydroxide ions in pore solutions showed good correlations with expansion, and the reduction in concentration of alkali ions would be useful as a measure for estimating the alkali reaction of aggregate and the degree of expansion.

2209. Shayan, A., "EXPERIMENTS WITH ACCELERATED TESTS FOR PREDICTING ALKALI-AGGREGATE REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 321-326.

KEY WORDS: reactive aggregates; test methods; mortar bars; accelerated test methods; expansion

The slow rate of reaction between alkali in the pore solution of cement mortar and some aggregates has necessitated the development of rapid accelerated methods for predicting reactivity of aggregate in concrete. In recent years attempts have been made worldwide to improve the methods for prediction of the potential reactivity of aggregates in concrete. In this study accelerated methods based on (I) storage of concrete prisms or mortar bars in 1M NaOH solution at 80°C, (II) storage of mortar bars made with IM NaOH solution above water at 80°C in sealed

conditions, (III) storage of mortar bars made with IM NaOH solution in water at 80°C, and (IV) storage of mortar bars and concrete prisms in saturated NaCl solution at 50°C have been applied to a number of aggregates with a wide range of rock types, including aggregates known to have reacted in existing concrete structures. Results obtained so far indicate that although very reactive aggregates may be identified by all these methods, method (I) was more suitable for the identification of slowly reactive aggregates. However, further testing is required to establish its general applicability to all rock types.

2210. Shayan, A. and Quick, G., "MICROSTRUCTURE AND COMPOSITION OF AAR PRODUCTS IN CONVENTIONAL STANDARD AND NEW ACCELERATED TESTING," Proc. 8th Intl. Alkali Conf. 1989, pp. 475-482.

KEY WORDS: alkali aggregate reactions; test methods; accelerated tests; alkali silica gel; temperature effects; reactive aggregates; crystalline reaction products; NaOH effects

Some Australian and overseas reactive and non-reactive aggregates were used in mortar bars and concrete prisms for expansion measurement under conventional standard and new accelerated testing, based on storage of specimens in Lm NaOH solution at 80°C, and storage at 38°C, 100% RH, respectively. Scanning electron microscopy (SEM) and energy-dispersive X-ray analysis (EDX) showed that specimens that did not expand in the tests contained no alkali-aggregate reaction product, whereas those that did expand in the new accelerated test contained large amounts of amorphous and crystalline reaction products. Specimens that expanded in the conventional standard mortar bar test also showed the same morphological and compositional types of reaction products but to a lesser degree. Although expansion of a given specimen occurred much more rapidly under the new accelerated than under conventional or field conditions, the reaction products appear to be the same, indicating that reaction mechanisms are the same but differ only in rates. Therefore, the use of the accelerated test to predict the alkali reactivity of aggregates in field concrete is justified.

1989

2211. Shayan, A. and Ivanusec, I., "INFLUENCE OF NAOH ON MECHANICAL PROPERTIES OF CEMENT PASTE AND MORTAR WITH AND WITHOUT REACTIVE AGGREGATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 715-720.

KEY WORDS: alkali aggregate reactions; alkali effects; NaOH effects; mechanical properties

The effects of added NaOH on the mechanical properties of cement pastes and mortars with and without reactive aggregate (5% opal in sand) were investigated by testing cubes (25 x 25 x 25 mm) and bars (13 x 13 x 100 mm), cured at 23°C in fog for 7, 28 and 90 days, for compressive strength and modulus of rupture respectively. Larger mortar bars (25 x 25 x 285 mm) were tested for expansion potential. Water/cement ratios of 0.4 and 0.6, a sand/cement ratio of 2.0, and a range of cement alkali from 0.8 to 10.5% $Na_2O$ equivalent were employed. Only the mixes containing opal and added alkali showed excessive expansion. In all mixes, increasing amounts of NaOH decreased the strengths. However, the sharpest decrease in strength occurred at alkali contents below about 3% $Na_2O$ content. The loss in strength of specimens containing the reactive aggregate was similar in trend to that for other specimens, indicating a significant interaction with cement of the added NaOH and the resulting effect on the strength loss. Alkali-aggregate reaction had little effect on compressive strength, whereas it significantly reduced the modulus of rupture in flexure. The loss in strength due to the addition of NaOH has been attributed to its influence on cement hydration and nature of the solid phases produced.

2212. Shayan, A., "RE-EXAMINATION OF AAR IN AN OLD CONCRETE," Cement and Concrete Research, Vol. 19, pp. 434-442, 1989.

KEY WORDS: alkali aggregate reactions; field experiences; dam structures; Australia; reactive aggregates; phyllites

Concrete from a dam which has been reported to have suffered AAR was re-examined to explore whether the damage was at least partly due to AAR. The re-examination of the concrete confirmed the previous identification of AAR. The phyllite aggregate that had been used in the concrete was also subjected to testing for alkali reactivity in comparison to known reactive and non-reactive aggregates, and provided further evidence that the damage was partially caused by the AAR. Although sensitivity of the aggregates to drying could have contributed to the cracking of the

thin exposed concrete members such as the retaining wall, cracking in the thicker, permanently moist, members such as the underground valve chamber must have occurred due to AAR.

2213. Shiraki, R. and Kobayashi, K., "QUALITY AND QUANTITY DETERMINATIONS OF REACTIVE SUBSTANCES IN VOLCANIC ROCKS," Proc. 8th Intl. Alkali Conf. 1989, pp. 567-572.

KEY WORDS: alkali aggregate reactions; mortar bars; reactive aggregates; andesites; image analysis

The present study shows the usefulness of image analysis and EPMA as methods to determine the contents of reactive substances in andesites. The authors also relate the physical properties of glassy andesites, such as porosity, thermal history, etc. to the expansion of mortar bars made with them.

2214. Sibbick, R. G. and West, G., "Examination of Concrete from the M-40 Motorway," Digest of Research Report 197, Transport and Road Research Laboratory, 1989.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; U.K.; pavement structures; NaCl effects; cracking

Results of a coring program on the Stokenchurch section of the M-40 motorway in England are reported. The alkali silica reaction found was associated with joints, and the onset of the reaction was attributed to the penetration of heavily salt-laden water to the interior of the concrete. The reactive aggregate was the porous white flint constituent of Thames river gravel.

2215. Silveira, J. F. A., Degaspare, J. C. and Cavalcanti, A. J. C. T., "THE OPENING OF EXPANSION JOINTS AT THE MOXOTO POWERHOUSE TO COUNTERACT THE ALKALI-SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 747-751.

KEY WORDS: alkali aggregate reactions; strained quartz; field experiences; Brazil; dam structures; repairs

Maxoto powerhouse in Brazil was constructed in the early

1970's with aggregate containing strained quartz. The resulting expansion due to AAR has caused serious difficulties with the power generating units. A 3-dimensional mathematical model of the structure was prepared, and was found to closely approximate the observed cracking pattern of the structure. Remedial measures consisting of joint cutting have been carried out with apparent success.

2216. Soers, E. and Meyskens, M., "PETROGRAPHICAL RESEARCH ON ALKALI-AGGREGATE REACTIONS IN CONCRETE STRUCTURES IN BELGIUM," Proc. 8th Intl. Alkali Conf. 1989, pp. 463-468.

KEY WORDS: alkali aggregate reactions; reactive aggregates; field experiences; Belgium; ettringite; porosity

Alkali aggregate reactions found in Belgium are of the alkali silica type, producing cracking damage in various types of concrete. Petrographic examination of damaged concrete indicates that the ASR is caused by rocks and minerals of varied nature, ranging from paleozoic formations to recent deposits, that are quarried all over the country. The presence of secondary ettringite associated with cracking due to ASR is frequent. In some cases, its abundance and crystal morphology suggests that the ettringite contribute to crack development. The deleterious effects of defective microstructure in concrete (high capillary porosity, microcracking) on the development of ASR is demonstrated by fluorescence microscopy.

2217. Sorrentino, D., Ranc, R. and Cariou, B., "METHODOLOGY OF AN INDUSTRIAL RESEARCH LABORATORY TO ASSESS THE REACTIVITY OF AGGREGATES. FOCUS ON REPRODUCTIBILITY PROBLEMS," Proc. 8th Intl. Alkali Conf. 1989, pp. 307-312.

KEY WORDS: alkali aggregate reactions; test methods; reactive aggregates; limestones

Lafarge Coppee has conducted investigations on ASR in Canada, and more recently in France. Tests on methods of identifying reactive aggregates are being carried out . Petrography is featured in the ongoing investigations. It has been found that for limestone aggregates with disseminated silica, the quick chemical test, ASTM C 289, is not satisfactory, even when conducted on the siliceous insoluble residue from acid dissolution. Mortar bar and

concrete prism tests may be satisfactory if used with cement of sufficiently high alkali content (1.25% $Na_2O$ equiv. Elevated temperature (38°C) and high cement content (410 kg/$m^3$) promote expansion, especially in the case of late-expanding silicate aggregates.

2218. St. John, D. A., "ALKALI-AGGREGATE REACTION IN NEW ZEALAND - A CONTINUING PROBLEM," Proc. 8th Intl. Alkali Conf. 1989, pp. 51-56.

KEY WORDS: alkali aggregate reactions; field experiences; New Zealand; bridge structures; alkali effects

Condition surveys of highway bridges in New Zealand are revealing that up to 20% of the bridges inspected may be suffering from AAR in those areas where reactive aggregates are present. This situation has largely occurred because, for the decade 1958-1968, a high-alkali cement available in the areas of concern was used with reactive aggregates. A review of the alkali-aggregate problem in New Zealand clearly shows that a serious problem will exist unless control is exercised. This paper describes the known extent of AAR in New Zealand, the recent and current investigations and discusses the actions considered necessary to bring the problem under control.

2219. Struble, L. and Diamond, S., "INFLUENCE OF CEMENT PORE SOLUTION ON EXPANSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 167-172.

KEY WORDS: alkali aggregate reactions; mechanisms; pore solutions; model solutions; silica dissolution

The influences of the aqueous solution on alkali-silica reaction have been studied from the reaction mechanism viewpoint. Mortar bar expansion studies were carried out using a variety of cements and aggregate materials. Pore solutions were expressed from companion non-reacting mortars prepared using the same cements, and their compositions determined. Model pore solutions of the same composition were prepared, and responses of the aggregates to these solutions were studied. It was found that expansion of mortar bars correlated directly with the amount of silica dissolved in the model pore solutions. The dissolution of silica from aggregates in solutions of identical composition to those produced by the specific cements

appears to provide a measure of the extent of alkali-silica reaction in mortars. The resulting expansion of the mortars (if water is freely available) appears to be a function of the extent of the reaction. This result suggests that ASR may involve dissolution of silica from the aggregate and subsequent precipitation of the gel.

2220. Struble, L. and Brockman, M., "STANDARD AGGREGATE MATERIALS FOR ALKALI-SILICA REACTION STUDIES," Proc. 8th Intl. Alkali Conf. 1989, pp. 433-437.

KEY WORDS: reactive aggregates; test methods; glass; Pyrex glass; Vycor glass; fused silica; fused quartz; cristobalite; calcined flint

Because of its reported poor reproducibility and expected influence of its alkali content, Pyrex glass is not satisfactory as a standard reactive aggregate in investigations of ASR. Expansion tests using possible alternatives showed the following: with high alkali cement, calcined flint (cristobalite) produced moderate expansion and a rapid early rate of expansion: with low alkali cement it produced very little expansion. With high alkali cement, Vycor glass, fused quartz, and fused silica produced high expansions and high early rates of expansion: with low alkali cement they produced moderate expansions. Based on these results, it is concluded that calcined flint, Vycor, fused quartz, and fused silica have good potential, and that calcined flint offers the best potential as a standard reactive material in ASR investigations. However, additional tests are required to determine reproducibility of the candidate materials before a final recommendation can be made.

2221. Swamy, R. N. and Al-Asali, M. M., "EFFECTIVENESS OF MINERAL ADMIXTURES IN CONTROLLING ASR EXPANSION," Proc. 8th Intl. Alkali Conf. 1989, pp. 205-210.

KEY WORDS: alkali aggregate reactions; preventive measures; mineral admixtures; slag; silica fume; fly ash

In this paper, some test data are presented to evaluate the effectiveness of fly ash, silica fume, and slag in controlling or reducing ASR expansion in concrete. In spite of difficulties in interpretation, these studies indicate that cement replacement materials can give useful

protection against ASR expansion, provided they are used in sufficiently large quantities. The reduction in expansion is generally not proportional to the percentage of cement replacement. At low replacement levels, the presence of additional free alkalis has a significant effect on expansion; at higher replacement levels their effect is only slight. The rate of reactivity, the type of mineral admixture, the replacement level, the method of replacement and the environment have all a profound influence on the protection against ASR afforded by mineral admixtures.

2222. Swamy, R. N., "STRUCTURAL IMPLICATIONS OF ALKALI SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 683-689.

KEY WORDS: alkali aggregate reactions; structural effects

This paper attempts to make a contribution to understanding of the effects of ASR on typical concrete structural elements. Few structures are likely to collapse because of ASR. The most significant ASR effect is on serviceability; even moderate expansions of 0.0% or 0.3% could create significant structural distress when the effects of ASR are superimposed on existing service loads.

2223. Takemura, K., Tazawa, E., Yonekura, A. and Abe, Y., "MECHANICAL CHARACTERISTICS OF REINFORCED CONCRETE COLUMN AFFECTED BY ALKALI AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 665-670.

KEY WORDS: alkali aggregate reactions; structural effects; columns; reinforced concrete; mechanical properties

This paper describes the test results on spirally reinforced concrete columns affected by alkali aggregate reaction which are subjected to axial loads. The variables examined are axial reinforcement, spiral reinforcement and water-cement ratio. The results are compared with corresponding result for expansive concrete and normal concrete. It was found that axial reinforcement is effective to restrain the axial expansion of concrete caused by ASR or expansive component but it is hardly effective to restrain the horizontal expansion. Spiral reinforcement is effective to restrain horizontal and axial expansion of the concrete. ASR concrete column have 15-30% higher ultimate load capacity than the other concrete columns when compared at the same compressive strength;

however, the ultimate load capacity of the ASR concrete column is decreased because of the reduction in compressive strength for the same water to cement ratio as normal concrete. The ductility of the ASR concrete column at the final stage is higher than that of normal concrete expansive concretes.

2224. Takeyoshi, M. and Katawaki, K., "STUDY ON THE EFFECT OF CONCRETE SURFACE COATING FOR PREVENTION OF ALKALI SILICA REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 815-820.

KEY WORDS: alkali aggregate reactions; test methods; coatings

The alkali silica reaction is now becoming a matter of social concern, with studies taking place on the reaction mechanism and on repair measures for deteriorated structures, as well as on prevention of such deterioration. This report describes testing equipment which can simulate actual ambient conditions and effectively accelerate the testing of candidate coatings designed to prevent concrete cracking by ASR, and the results of studies carried out with it at the Public Works Research Institute, Ministry of Construction.

2225. Taki, T., Takeyoshi, M., Noda, K. and Katawaki, K., "SUPPRESSION OF ALKALI-AGGREGATE REACTION BY CONCRETE SURFACE COATING," Proc. 8th Intl. Alkali Conf. 1989, pp. 827-832.

KEY WORDS: alkali aggregate reactions; preventive measures; coatings

Cracking due to ASR of concrete is expected to be suppressed by surface coatings of low water transmission rates. After cracking, further crack growth can be effectively suppressed by application of coatings.

2226. Tamura, H., Takahashi, T., and Ohashi, M., "A TEST METHOD ON RAPID IDENTIFICATION OF THE FUTURE SUSCEPTIBILITY OF ALKALI-AGGREGATE REACTION IN FRESH CONCRETE (FRESH-CON GBRC RAPID METHOD)," Proc. 8th Intl. Alkali Conf. 1989, pp. 351-356.

KEY WORDS: alkali aggregate reactions; test methods; GBRC

test; fresh concrete test

The Fresh-Con GBRC rapid test method for the identification of future susceptibility to ASR of fresh concrete containing reactive aggregates is described. This method is useful in order to not only prevent the deterioration of concrete structure due to ASR, but also reasonably utilize potentially deleterious aggregate.

2227. Tang, M. S., Wang, M. H. and Han, S. F., "MICROSTRUCTURE AND ALKALI REACTIVITY OF SILICEOUS AGGREGATE," Proc. 8th Intl. Alkali Conf. 1989, pp. 457-462.

KEY WORDS: reactive aggregates; strained quartz; chalcedony; opal; polarizing microscope methods; DSC; positron annihilation

By means of optical microscopy, DSC and positron annihilation, the microstructures of various kinds of sand grains containing cryptocrystallites and different forms of chalcedony were studied in detail. The results of observations under a polarizating microscope showed that from opal to quartz there are varieties of chalcedony. Their alkali reactivities are quite different according to their different microstructures. The classical examples of microstructures illustrated in this paper may help to distinguish the degree of reactivity of aggregate. At the same time, from the data obtained by DSC and positron annihilation could reflect the variety of cryptocrystalline quartz, which can be used to determine alkali reactivity of the quartz aggregate. These methods would be more meaningful than measurement of the undulatory extinction angle to investigate the disorder and alkali reactivity of strained or cryptocrystalline quartz.

2228. Tashiro, C. and Yamada, K., "STUDY OF RELATIONSHIP BETWEEN ALKALI-AGGREGATE REACTION AND ELECTRICAL RESISTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 381-384.

KEY WORDS: alkali aggregate reactions; test methods; expansion; electrical resistance; mortars; accelerated test methods

This paper deals with the detection of alkali silica reactivity at early hydration stages by measurement of electrical resistivity, which was found to be closely

related to the expansion of the mortar. The electrical resistivity of alkali containing cement mortar was about 60 ohm-cm, and that of the normal cement was 150 ohm-cm after molding. The resistivity of the expanded mortar which was made from pyrex glass sand and the alkali containing cement increased rapidly with curing time, from 60 to 5000 ohm-cm for 28 days. In contrast, that of the normal cement mortar increased only moderately. It was suggested that the electrical resistivity of the mortar can be utilized as a sensor for the early detection of alkali aggregate reaction.

2229. Tatematsu, H. and Sasaki, T., "PROPOSAL OF A NEW INDEX FOR A MODIFIED CHEMICAL METHOD," Proc. 8th Intl. Alkali Conf. 1989, pp. 333-338.

KEY WORDS: reactive aggregates; test methods; chemical tests

The ASTM Quick Chemical Method, known as a useful method because of its rapidity, is modified by incorporating a new index Rc-0, a value characteristic of each aggregate. The conventional Rc parameter changes linearly as a function of time. Rc-0 is determined by extrapolating measures of Rc vs. time to the zero time axis. The effects of temperature are also considered in a proposed "Modified Chemical Method" .

2230. Thaulow, N., Holm, J., and Andersen, K. T., "PETROGRAPHIC EXAMINATION AND CHEMICAL ANALYSIS OF THE LUCINDA JETTY PRESTRESSED CONCRETE ROADWAY," Proc. 8th Intl. Alkali Conf. 1989, pp. 573-581.

KEY WORDS: alkali aggregate reactions; field experiences; Australia; jetty structures; alkali silica gel; mechanisms

The 5.76 km long jetty at Lucinda Bulk Sugar Terminal, N. Queensland, Australia, was commissioned in 1979. The jetty serves as an outloading facility for bulk raw sugar which is transported off-shore on a conveyor belt housed in a gallery. Along the gallery is a roadway which provides access to the off-shore wharf structure. Each of the 288 twenty meter long roadway spans consists of six 0.60 m by 0.60 m hollow prestressed box girders which are joined by transverse post-tensioning bars. Within a few years after completion, longitudinal cracking became evident, and this

development has since continued, resulting in extensive cracking in the top and bottom surfaces of the roadway. The cause of the cracking is alkali-silica reaction. The reactive aggregate is a volcanic rhyolitic tuff coarse aggregate. The jetty roadway is the longest known prestressed concrete structure in the world suffering from alkali-silica reactions. It is characteristic of the reactions that their intensity is highly variable within elements and between elements and spans. Girders or parts of girders may exhibit little or no damage while in other places the reactions have caused the exudation of significant amounts of viscous gel which has been sampled for analysis. The present paper describes some of the observations which have resulted from petrographic examination and chemical analysis of samples extracted from the concrete roadway. These studies have revealed new aspects of gel chemistry and reactivity of aggregates. The field and laboratory studies have provided an excellent example of the complexity of ASR. The extreme variability in manifestations of cracking in the structure may partly be explained by variations in the inherent porosity of the aggregate particles which are otherwise similar. The gel produced during the ASR is shown to have varying composition and appearance depending on its location in the concrete. For instance, it appears that a low amount of calcium causes the gel to be very fluid which again causes it to be exuded onto the concrete surface. On the other hand, a high content of calcium gives the gel binding properties much similar to the hydrated cement paste. These observations suggest that it is only within a narrow range in calcium content that a gel possesses the right viscosity as to be expansive and deleterious to the concrete.

2231. Tomita, M., Miyagawa, T. and Nakano, K., "BASIC STUDY FOR DIAGNOSIS OF CONCRETE STRUCTURE AFFECTED BY ALKALI-SILICA REACTION USING DRILLED CONCRETE CORE," Proc. 8th Intl. Alkali Conf. 1989, pp. 779-784.

KEY WORDS: alkali aggregate reactions; reinforced concrete; restraint; mechanical properties; drilled cores

In this study the influence of reinforcement, diameter of drilled core, and degree of expansion of the concrete on the physical properties and expansion of cores was measured. It was found that alkali-silica expansion of restrained concrete with reinforcement was approximately half that of unrestrained concrete. The measured physical properties, i.e., compressive strength, static and dynamic modulus of elasticity, and ultrasonic pulse velocity, of

cores decreased with increase of expansion of the model specimens, Changes in the static modulus of elasticity were especially remarkable. It is suggested that the future damage of existing reinforced concrete structures affected by ASR could be estimated from measurements made on drilled cores.

2232. Tomosawa, F., Tamura, K. and Abe, M., "INFLUENCE OF WATER CONTENT OF CONCRETE ON ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 881-885.

KEY WORDS: alkali aggregate reactions; mechanisms; water content; expansion; drying effects; RH effects

The presence of vater is one of the three conditions necessary for alkali-aggregate reaction to occur. When we repair concrete construction that has been damaged by such a reaction a great deal of attention must be given to the water content of the concrete. This paper reports the relation between the water content of concrete and its expansion. An understanding of such a relation should certainly have great practical use as fundamental data for repair. In this experiment, five kinds of concrete mix were tested. These mixtures were varied in terms of kind of aggregate, alkali content and unit cement content. Concrete specimens were cured for 8 weeks at 40°C and above 95% RH. Following this, the specimens were divided based on five conditions, and stored for 1 year. During this storage period, the weight, length, dynamic elasticity, ultrasonic pulse velocity and water content of the various concrete specimens were measured at prescribed ages along the way. Length change vas thought to be the best index of deterioration due to the fact that the dynamic elasticity and ultrasonic pulse velocity had been influenced by the vater content of concrete. The expansion of concrete with the reactive aggregate increased in proportion to the vater content of concrete. Although the relation between the expansion and the vater content of concrete differed to some degree among the various concrete mixes, it vas possible to control the expansion below 0.1 % when the water content of concrete was kept below 4 %. The original water content of concrete is retained in the case of 100% RH exposure, but decreases with the reduction of humidity. For a concrete containing 8 kg/m$^3$ of unit alkali content, water contents of 4-5% are common at RH> 85%,and expansion occurs. When stored below 80% RH, the water content becomes about 3%, and the concrete almost stops expanding.

1989

2233. Uchikawa, H., Uchida, S. and Hanehara, S., "RELATIONSHIP BETWEEN STRUCTURE AND PENETRABILITY OF Na ION IN HARDENED BLENDED CEMENT PASTE, MORTAR AND CONCRETE," Proc. 8th Intl. Alkali Conf. 1989, pp. 121-128.

KEY WORDS: alkali effects; diffusion coefficient; cement paste; silica fume; slag

The diffusion coefficient of Na ion in hardened cement paste, measured by the diffusion cell method, varies from 0.2 to 20 $cm^2/s$, and reduces with age. The specific value depends upon the curing temperature and type of cements well as age. The values for mortar and concrete are in the same range as those for cement paste. The behavior in silica fume blended cement concrete is similar to that in slag cement concrete when curing at low temperature, and that in fly ash cement concrete when curing at high temperature. ASTM C 227 may underestimate the inhibitor effect of ASR by the addition of slag and overestimate the inhibitor effect by addition of fly ash at normal curing temperature.

2234. Ukita, K., Shigematsu, S., Ishii, M., Yamamoto, K., Azuma, K. and Moteki, M., "EFFECT OF CLASSIFIED FLY ASH ON ALKALI AGGREGATE REACTION (AAR)," Proc. 8th Intl. Alkali Conf. 1989, pp. 259-264.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; classified fly ash

Fine classified fly ash has an excellent expansion controlling effect on ASR even at small replacement percentages, as a result of its large specific surface area. The expansion controlling effect of classified fly ash was investigated in studies using several kinds of reactive aggregates from Western Japan. Incorporation of the fine classified fly ash increases the strength and reduces the permeability of concrete.

2235. Uno, T., "ALKALI-SILICA REACTIONS BY OPAL PARTICLES IN JAPAN," Proc. 8th Intl. Alkali Conf. 1989, pp. 513-518.

KEY WORDS: alkali aggregate reactions; petrography; reactive aggregates; opal; Japan

By petrographic observations, it is found that some ASR

resulted from opal particles included in river sand. Harmful expansion occurred for river sands with only 1% by weight of opal when used with cement of 1.2% Na2O equivalent alkali content.

2236. Van Gemert, D., "ALKALI-AGGREGATE REACTION IN BELGIUM: CONCRETE HIGHWAY AND OFFICE BUILDING," Proc. 8th Intl. Alkali Conf. 1989, pp. 43-49.

KEY WORDS: alkali aggregate reactions; field experiences; Belgium; highway structures; column structures; repairs

Two alkali-aggregate reaction damage cases in Belgium are presented, one in a concrete road and one in the columns of an office building. The general appearance of the damage is described, and the causes of the reactions in the concrete and aggregate composition are investigated . In the case of column damage a simple repair method is presented, which is based on the use of epoxy bonded steel reinforcements. The design philosophy of such an epoxy bonded reinforcing steel casing is explained.

2237. Wakizaka, Y., Moriya, S., Kawano, H., and Ichikawa, K, "MINERALOGICAL INTERPRETATIONS OF DISSOLVED SILICA AND REDUCTION IN ALKALINITY OF THE CHEMICAL METHOD," Proc. 8th Intl. Alkali Conf. 1989, pp. 519-524.

KEY WORDS: reactive aggregates; test methods; chemical tests; particle size effects; clays

The chemical method (JIS A 5308) and mineralogical experiments have been carried out on main rock forming minerals and rocks. The results indicate that dissolved silica (Sc) of the minerals are fixed by their silica content, thermodynamic instability, amount of non-bridging oxygen, crystallinity, and grain size. The reduction in alkalinity (Rc)is controlled by the presence of expanding clay minerals, and by the grain size. Thus, the measure of reactivity of rocks are roughly derived from the mineral assemblage present, and from the grain size of the rock.

2238. Wang, H. and Gillott, J. E., "THE EFFECT OF SUPERLASTICIZERS ON ALKALI-SILICA REACTIVITY," Proc. 8th Intl. Alkali Conf. 1989, pp. 187-192.

KEY WORDS: alkali aggregate reactions; preventive measures; silica fume; chemical admixtures; superplasticizers

Three types of superplasticizer were shown to increase the expansion of mortar bars caused by alkali silica reaction. When silica fume was incorporated into mortar bars as a partial replacement of cement the expansion decreased with increase in amount of silica fume up to 12%. Superplasticizers counteracted this effect and expansion could be doubled even when 12% silica fume was present in the mix. At the 24% fume replacement level, no expansion was registered either with or without superplasticizers. The increase in expansion due to the presence of superplasticizers is probably linked to changes in the opal itself and to changes in physical-chemical properties of the gel products such as viscosity and surface tension.

2239. West, G. and Sibbick, R. G., "A MECHANISM FOR ALKALI-SILICA REACTION IN CONCRETE ROADS," Proc. 8th Intl. Alkali Conf. 1989, pp. 95-100.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.; pavement structures; bridge structures; de-icing salts; NaCl effects;

A mechanism for alkali-silica reaction in concrete roads has been developed from observations made during a survey of concrete roads in Great Britain. The roles of cracks, reactive silica aggregate, water, and salt are each discussed and then brought together in a suggested four-stage process. It is suggested that two important conditions contribute to alkali-silica reaction: first water has to penetrate the concrete, and second, alkali solution has to be able to reach any reactive silica present in the aggregate. In British conditions, de-icing salt is seen as a likely additional contributor of alkali. Well constructed and sealed joints together with the minimum use of de-icing salt consistent with the safety of road users should reduce the likelihood of alkali-silica reaction in concrete roads.

2240. West., G. and Sibbick, R., "Alkali Silica Reaction in Roads, Part 2.," Highways, May 1989.

KEY WORDS: alkali silica reactions; field experiences; U.K.; pavement structures; reactive aggregates

Additional highway samples have been evaluated since the first report of this title. Five out of 33 samples show definite evidence of alkali silica reactions - four with silt gravels and one with a siltstone. Details of the observations are supplied, and recommendations as to highway practice are suggested for minimizing potential difficulties.

2241. Wood, J. G. M., Norris, P., and Leek, D., "PHYSICAL BEHAVIOR OF AAR DAMAGED CONCRETE IN STRUCTURES AND IN TEST CONDITIONS," Proc. 8th Intl. Alkali Conf. 1989, pp. 765-770.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.

For the structural appraisal and cost effective management of AAR damaged structures, Mott MacDonald have developed a range of insitu structural monitoring techniques and physical tests on concrete cores. Thjis paper reports some of the techniques currently being used in the management of over 100 structures with AAR in the UK.

2242. Wood, J. G. M. and Johnson, R. A., "AN ENGINEERS PERSPECTIVE ON U.K. EXPERIENCE WITH ALKALI-AGGREGATE REACTION," Proc. 8th Intl. Alkali Conf. 1989, pp. 785-790.

KEY WORDS: alkali aggregate reactions; field experiences; U.K.

This paper reviews the developments of studies on AAR in the UK where the reaction has been found since the 1970's to be developing in a substantial number of buildings, bridges and water retaining structures. UK developments in specification to minimize the risk of ASR are presented in the context of their impact on construction practice. The evolution of research on materials, for diagnosis for structural assessment and to quantify the physical severity of the reaction, is discussed. Gaps in our knowledge which necessitate research are identified. We now know how to minimize, but not eliminate, the risk of ASR in new structures on the basis set out by Hawkins Committee and the DTP. Techniques of diagnosis are available and can be used in a balanced and cost effective way to identify structures which may be at risk of damage from AAR.

1989

2243. Yonezawa, T., Ashworth, V. and Procter, R. P. M., "THE MECHANISM OF FIXING CL- BY CEMENT HYDRATES RESULTING IN THE TRANSFORMATION OF NaCl TO NaOH," Proc. 8th Intl. Alkali Conf. 1989, pp. 153-160.

KEY WORDS: NaCl effects; pore solutions; alkali effects

It is known that the alkali aggregate reaction is enhanced by introducing NaCl into mortar or concrete]. A possible reason for this enhancement is the transformation of NaCl to NaOH in the pore solution resulting from the fixing of Cl by cement hydrates. The mechanism by which NaCl is transformed to NaOH due to the fixing of Cl , however, has not been thoroughly investigated. Furthermore the mechanism leading to fixing of Cl is not yet completely understood, either. To understand the alkali aggregate reaction within concrete structures in an environment where NaCl is prevalent, such as in a marine environment, it is very important to determine the mechanism by which Cl is fixed leading to the transformation of NaCl to NaOH. In this paper, this mechanism is discussed based on the results of the pore solution analysis of mortar using a high pressure pore solution expression technique. It was found that when NaCl is added to mortar, $Cl^-$ ions are fixed but $Na^+$ ions are not. Fixed and free $Cl^-$ ions are equilibrium. When $Cl^-$ ions are fixed, the concentration of $OH^-$ ions increases, and the quantity of fixed $Cl^-$ ions is almost equal to the increase in the concentration of $OH^-$ ions.

2244. Andersen, K. T. and Thaulow, N., "THE STUDY OF ALKALI SILICA REACTIONS IN CONCRETE BY THE USE OF FLUORESCENT THIN SECTIONS," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp.71-93, 1990.

KEY WORDS: alkali aggregate reactions; field experiences; Australia; jetty structures; alkali silica gel; petrography; cracking; mechanisms

Detailed thin-section examination of the concrete in a jetty affected by alkali-silica reactions shows that the varying reactivity of the aggregates can be ascribed to variations in porosity of these aggregates. Examination of the alkali-silica gel found in association with the reacting particles shows that the gel occurs in three different morphologies depending on the location of the gel in the concrete. The examination also shows that cracks induced by alkali-silica reactions are for a large part devoid of gel indicating that deterioration of concrete due to swelling of gel in cracks is an unlikely mechanism.

2245. Batic, O. A., Sota, J. D., and Iasi, R., "CONTRIBUTION OF ALKALIS BY AGGREGATES TO ALKALI AGGREGATE REACTION IN CONCRETE," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp.159-170, 1990.

KEY WORDS: alkali aggregate reactions; alkali effects; alkali leaching; reactive aggregates; particle size effects

The cause of uncontrolled reactions can have different origins or explanations. This paper has the main objective of demonstrating that aggregates employed under certain circumstances also introduce alkalies in significant amounts. They can even exceed the amount of alkalies coming from other sources, mainly those brought by cement. Applying a technique as simple as ASTM C 311 to fine and coarse aggregates from different sources, treated in the presence of calcium hydroxide solution or deionized water, available alkalies were determined which can pass to the solution present in concrete pores. The influence of aggregate particle size was also studied. All determinations were realized at 28 days.

1990

2246. Carse, A. and Dux, P. F., "MEASUREMENT OF CONCRETE EXPANSIVE STRAINS DUE TO ALKALI SILICA REACTION IN AUSTRALIAN CONCRETE STRUCTURES," Cement and Concrete Research, Vol. 20, pp. 376-384, 1990.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences; Australia; expansion; strain

The results of measuring the concrete expansive strains due to Alkali-Silica Reaction (ASR) are presented for four high strength concrete bridge structures. It is concluded that some of the structures are expanding at significant rates at an age of 10 years even though they are already severely cracked due to ASR. Other structures have stabilized at an age of 10 years and subsequent expansion is expected to be minimal. The collection of this field data indicated that the concrete structures affected by ASR exhibited a maximum strain in the vicinity of 5000 microstrain after 12 years. This is important information to input into an accelerated testing programme for ASR and forms the basis of another paper in this series.

2247. Carse, A. and Dux, P. F., "DEVELOPMENT OF AN ACCELERATED TEST ON CONCRETE PRISMS TO DETERMINE THEIR POTENTIAL FOR ALKALI SILICA REACTION," Cement and Concrete Research, Vol. 20, pp. 869-874, 1990.

KEY WORDS: alkali aggregate reactions; test methods; concrete prisms; alkali effects; steam curing

An accelerated laboratory test on concrete prisms is being developed which shows good correlation with the observed field performance of concrete structures damaged due to Alkali-Silica Reaction (ASR). The procedure for the test was determined by collecting a substantial database on actual structures affected by ASR. The main factors common to the affected structures were the use of high cement contents in the range 450 to 500 kg/m$^3$ in association with the use of initial steam curing.

2248. Chatterji, S. and Christiansen, P., "STUDIES OF ALKALI SILICA REACTION. PART 7. MODELLING OF EXPANSION," Cement and Concrete Research, Vol. 20, pp. 285-290, 1990.

KEY WORDS: alkali aggregate reactions; temperature effects; pore solutions; expansions

It has been shown that expansion of mortar prisms due to alkali-silica reaction can be quantitatively related to their environment, i.e. alkali ion concentration and temperature, by an equation. The physical significance of negative signs of derivatives of length change with temperature and with concentration that appear in the equation have been discussed. The equation permits a rational choice of aggregates for a given environment.

2249. Cortelezzi, C. R., Maiza, P., and Pavlicevic, R. E., "STRAINED QUARTZ IN RELATION TO ALKALI SILICA REACTION," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp.145-158, 1990.

KEY WORDS: alkali aggregate reactions; field experiences; Argentina; strained quartz, X-ray diffraction; electron diffraction; mechanisms

Aggregates containing strained quartz crystals that have induced damage in concrete structures, are frequently mentioned in the literature. This kind of aggregate has generated economic as well as functional problems, with the consequent additional expenses for repair and maintenance. Samples of granitic, cataclastic migmatite aggregates from the Province of Buenos Aires were studied. Percentages of strained quartz, based on its undulatory extinction angle, are presented and the results are compared to those obtained by the mortar-bar test, the accelerated evaluation method, and the staining method. The reaction is ascribed to the polycrystallinity of the quartz grains, as shown by electron diffraction (TEM) and by X-ray diffractometry, both showing a disorder in the crystalline structure.

2250. DePuy, G. W., "PETROGRAPHIC INVESTIGATIONS OF CONCRETE AND CONCRETE AGGREGATES AT THE BUREAU OF RECLAMATION," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates, B. Erlin and D. Stark, eds., pp. 32-46, 1990.

KEY WORDS: reactive aggregates; petrography; field experiences; U.S.

The Bureau of Reclamation has had a strong interest in the development and application of concrete technology to the design, construction, and maintenance of water resources development projects. The application of petrographic methods to concrete technology has been a

natural outgrowth of Reclamation's involvement in the development of concrete technology. Reclamation's first petrographer was W. Y. Holland who, purely out of curiosity, employed petrographic techniques to see what types of rocks were failing in the sulfate soundness test for aggregates. As this provided useful information for the evaluation of the suitability of aggregates, Reclamation began to routinely perform petrographic examination of aggregate samples to provide information on the suitability of aggregates and to compare samples from different sources. The method was also used to examine concrete to identify rock types failing in the freeze-thaw test, and to determine the cause of distress in deteriorated concrete. The petrographic examination received its biggest impetus in the early 1940's in the investigations of alkali-aggregate reaction in concrete and the development of precautionary measures. Reclamation established its Petrographic Laboratory in 1941 to investigate deleterious chemical reactions in concrete. The petrographic method has become widely accepted and is now routinely applied in concrete technology investigations throughout the world. The main applications of petrographic methods are in the evaluation of concrete aggregates for use in concrete, the assessment of the quality of concrete and the diagnosis of the cause of distress in deteriorated concrete, and as a basic procedure in concrete research investigations.

2251. Durand, B., Berard, J., Roux, R., and Soles, J. A.,

KEY WORDS: alkali aggregate reactions; silica fume; preventive measures; pore solutions; mortar bars; expansion

The use of condensed silica fume (CSF) causes a reduction of $Na^+$, $K^+$ and $OH^-$ ion concentrations of the pore solution of cement paste and concrete samples. Expansion tests also showed that CSF reduces expansion caused by alkali-silica reactive rock in mortar bars and concrete prisms. The reduction of expansion seems to be proportional to the amount of CSF used. For a given amount of CSF, however, the reduction of expansion of the concrete prisms appears to be greater than the observed reduction of Na+, K+ and OH ions in pore solution would predict.

2252. Groves, G. W. and Zhang, X., "A DILATATION MODEL FOR THE EXPANSION OF SILICA GLASS-OPC MORTARS," Cement and Concrete Research, Vol. 20, pp. 453-460, 1990.

KEY WORDS: alkali aggregate reactions; mechanisms; expansion; mechanisms; models

A model for the expansion of a silica glass/alkaline OPC mortar has been developed which is based on the observation that the main reaction product of the glass is a layer of CSH gel formed at its surface. In the model, which takes into account the mechanical properties of the system, the increase in volume of the glass plus its reaction product layer above that of the original glass leads to a predicted mortar expansion which is slightly less than that observed, but of the correct order of magnitude.

2253. Hartwell, J. N., "ALKALI-AGGREGATE REACTION INVESTIGATIONS AT FRIANT DAM, CALIFORNIA," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp.93-105, 1990.

KEY WORDS: alkali aggregate reactions; dam structures; field experiences; U.S.; preventive measures; pozzolans; alkali effects; mechanical properties; expansion

Mass concrete at Friant Dam was produced with high- and low-alkali cements both with and without natural pozzolan (pumicite). Recent and previous investigations indicate (a) concrete deterioration due to alkali-aggregate reaction has taken place to varying extent and degree within the dam; (b) compressive strength and modulus of elasticity have decreased due to alkali-aggregate reaction; (c) preliminary tests suggest alkalies are not present in the concrete in sufficient quantity to contribute to expansive reactions; and (d) the potentially deleteriously alkali-reactive aggregate is of andesite affinity.

2254. Johansson, S. and Andersen, P. J., "POZZOLANIC ACTIVITY OF CALCINED MOLER CLAY," Cement and Concrete Research, Vol. 20, pp. 447-452, 1990.

KEY WORDS: preventive measures; pozzolans; Moler

In order to investigate the possibility of using an industrial by-product of calcined Moler from the production of Moler bricks as a pozzolan in cement and concrete, a number of tests were carried out to establish the pozzolanic properties. The experiments performed followed the tests of chemical and physical properties of a pozzolan

as prescribed by ASTM C 618, investigating the chemical composition, water soluble alkalies, particle size distribution, pozzolanic activity and potential prevention of alkali-silica expansions. The experiments have shown that the chemical and physical properties of finely granulated calcined Moler according to ASTM C 618 is an excellent pozzolan for the use in concrete.

2255. Kawamura, M. and Ichise, M, "CHARACTERISTICS OF ALKALI-SILICA REACTION IN THE PRESENCE OF SODIUM AND CALCIUM CHLORIDE," Cement and Concrete Research, Vol 20, pp. 757-766, 1990.

KEY WORDS: alkali aggregate reactions; NaCl effects; $CaCl_2$ effects; chloride effects

A role of $Cl^-$ ions in the alkali-silica reactions in mortars containing sodium and calcium chloride was discussed comparing the composition of pore solutions in mortars with and without Beltane opal with expansions of the corresponding mortars. It was found that the alkali-silica reaction can progress in the early stage of the process without consuming $OH^-$ ions in mortars containing NaCl and the reactive aggregate. A rapid expansion of NaCl-bearing mortars appears to be related to an acceleration of the alkali silica reaction in the presence of $Cl^-$ ions at the early stage (within 24 hours).

2256. Larbi, J. A., and Hudec, P. P., "A Study of Alkali Aggregate Reaction in Concrete: Measurement and Prevention Part II: Air Saturated Hot and Cold NaCl Solutions," Cement and Concrete Research Vol. 20, pp. 73-78, 1990.

KEY WORDS: alkali aggregate reactions; test methods; NaCl effects; temperature effects

The accelerating effects of hot and cold saturated sodium chloride solution on concrete containing alkali reactive aggregates have been studied. The results show that hot saturated NaCl solution accelerates AAR, and the results correlate well with the ASTM C 227-81 and CSA A23.2 14A test results. In cold saturated NaCl solution however, the AAR reaction is rock-specific, slow, and judged unsuitable for screening alkali-silica reactive rocks. Although alkali ions introduced from de-icing salts do initiate alkali-carbonate reaction, the rate of reaction is

slow under normal temperature conditions.

2257. Ozol, M. A., "ALKALI-SILICA REACTION OF CONCRETE IN ELECTRICAL SUBSTATION PIERS," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp.106-120, 1990.

KEY WORDS: alkali aggregate reactions; field experiences; electrical power structures; U.S.; reactive aggregates; quartz; chert; electrical effects

Concrete piers supporting towers at the corners of an electrical substation are expanded and severely cracked. Eight intermediate piers show no signs of expansion, cracking, or surface deterioration. All piers were constructed (1969) of the same concrete mixture. The corner piers are connected to both ground and the above steel structure. The intermediate piers are grounded only and not connected to the above steel structure. The coarse aggregate (CA) is a siliceous gravel composed essentially of quartz, quartzites, and cherts. The fine aggregate (FA) is a natural sand of essentially the same composition. Cores taken from the corner piers exhibit: a) internally cracked CA particles with cracks extending into the mortar and connecting with cracks from other particles; b) reaction rims around CA particles with adjacent pockets of dried ASR gel that has breached through the reaction rim; c) peripheral separations around CA particles, with peripheral cracks in the adjacent mortar, and CA particles loose in their sockets; and, d) dried ASR gel in voids, cracks, and CA sockets, commonly in association with ettringite crystals.

2258. Rogers, C. A., "PETROGRAPHIC EXAMINATION OF AGGREGATE AND CONCRETE IN ONTARIO," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Starks, eds., pp. 5-31, 1990.

KEY WORDS: reactive aggregates; petrography; field experiences; Canada

Petrographic examination of aggregate and hardened concrete has been conducted by the Ministry of Transportation since the late 1940's. There were problems in communicating results of petrographic examination of aggregates to engineers. This resulted in the development of the "Petrographic Number" (P.N.) as a way of expressing

the quality of coarse aggregate. Four quality categories are recognized: good aggregate (factor 1), fair (factor 3), poor (factor 6), and deleterious (factor 10). The Petrographic Number is calculated by multiplying the percentages of each rock type by the appropriate factor. The products are then added up to arrive at the P.N. The higher the P.N., the poorer the quality of the aggregate. A perfect aggregate would have a P.N. of 100. Petrographic examination is conducted on aggregates using automated equipment. The percent of deleterious (mica, shale) or alkali-reactive components (chert, glass) is reported. Petrographic examination of concrete is also conducted. Over the years, many problems have been investigated, such as: fire damaged concrete, frozen concrete, concrete damaged by alkali-aggregate reactions of various types, damage by freezing and thawing, causes of low strength and retarded concrete. In addition, petrographic examination has been used to detect additions of non-standard components to Portland cement.

2259. Rogers, C. A. and Tharmabala, T., "PRESTRESSED CONCRETE MEMBERS AFFECTED BY ALKALI SILICA REACTION," Concrete International, Vol. 12, pp. 35-39, 1990.

KEY WORDS: alkali aggregate reactions; prestressed concrete; field experiences; Canada; bridge structures; concrete railroad ties; visual rating schemes

Four 25-year old bridges owned by the Ontario Ministry of Transportation showed longitudinal cracks in the bottom flanges of exterior pre-stressed girders. The concrete used was the same as that used for concrete railroad ties that had shown similar signs of deterioration due to alkali silica reaction. Selected ties were tested to destruction, and a visual rating developed. The bridge girders were rated visually using the system developed. It was concluded that the bridge girders were not materially affected at the levels of deterioration present, but it was recommended that they be treated with silane to reduce the rate of further deterioration.

2260. St. John, D. A., "THE USE OF LARGE-AREA THIN SECTIONING IN THE PETROGRAPHIC EXAMINATION OF CONCRETE," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp. 55-70, 1990.

KEY WORDS: alkali aggregate reactions; petrography; large area thin sectioning

Large-area thin sectioning of a concrete core allows examination of micro-textural detail that is not observable by other petrographic techniques. Because the area of the section represents a large sampling of the core, this allows the relationship of faults and deterioration to both the outer surface and the internal texture to be determined and gives a good estimate of the degree of damage present in the concrete. The usefulness of the technique is illustrated by cases of alkali-aggregate reaction, soft water attack, high temperature corrosion and carbonation, and other textural faults in concrete. It is concluded that especially in the case of alkali-aggregate reaction the examination of large area thin sections should be the preferred technique for microscopy as it appears to provide the range of textural information necessary for unequivocal diagnosis.

2261. Stark, D., "DIAGNOSIS OF ALKALI-SILICA REACTIONS IN THE FIELD AND IN THE LAB, AND TEST METHODS," Proc. 12th Intl. Conf. on Cement Microscopy, Vancouver, pp. 431-4311, 1990.

KEY WORDS: alkali aggregate reactions; field experiences; test methods; petrography

Introduction and outline for an extensive workshop presentation on field diagnosis of ASR, together with a review of test methods.

2262. Swamy, R. N. and Al-Asali, M. M., "CONTROL OF ALKALI SILICA REACTION IN REINFORCED CONCRETE BEAMS," ACI Materials Journal, Vol. 87, pp. 38-46, 1990.

KEY WORDS: alkali aggregate reactions; structural effects; reinforced concrete; mechanical properties; restraint; expansion; cracking; preventive measures; fly ash

Test data on the use of a low-calcium Class F fly ash to control the structural deformations occurring in singly reinforced concrete beams undergoing alkali silica-reaction (ASR) are reported. A highly reactive aggregate producing concrete expansive strains of about 1.5% and a moderately reactive aggregate with a maximum concrete expansion of about 0.6% were used. The behavior of reinforced concrete beams containing 0, 30, and 50% cement replacement by

weight of fly ash was monitored over a period of 2 years to examine the controlling influence of the fly ash on strains, cracking, and deflection. The beams were then tested to failure to assess the effect of fly ash on the stiffness, strength, and failure modes of the ASR-affected beams. The results show that fly ash has a dual role; it controls deformations as well as preventing loss of strength due to alkali-silica reaction.

2263. Van Epps, R. J. and Erlin, B., "OPAL COATED AGGREGATES-INVESTIGATION AND PROCESSING FOR USE," ASTM STP 1061, Petrography Applied to Concrete and Concrete Aggregates; B. Erlin and D. Stark, eds., pp. 121-128, 1990.

KEY WORDS: reactive aggregates; opal; opal coatings; field experiences; dam structures; U.S.

Petrographic examinations of gravel aggregate for use in the reconstruction of a dam revealed the presence of opal in coatings on aggregate particles. It was considered likely that the aggregate crushing and classifying operations would reduce most of the coatings. However, the removed opal needed tracking to insure that it was not in the fine aggregate. Petrographic examinations were used to check the processed aggregate for opal. ASTM C227 tests, modified for use of the as-graded aggregate, was utilized to provide information on the potential for concrete expansion. The data indicated that concrete made with cements having alkali contents of 0.36, 0.55, and 0.92 percent did not have expansions considered deleterious. Because of the availability of low-alkali cement, the concrete was made using a cement having an alkali content of 0.4 percent. After over five years of service, the concrete does not contain outward evidence of alkali-silica aggregate reactions.

2264. Wang, H. and Gillott, J. E., "THE EFFECT OF A $CaCl_2$-BASED ACCELERATOR ON ALKALI SILICA REACTIONS," Cement and Concrete Research, Vol. 20, pp. 357-368, 1990.

KEY WORDS: alkali aggregate reactions; mortar bars; expansion; preventive measures; silica fume; chemical admixtures; chloride effects

Mortar bars containing a commercial accelerator and using opal as reactive component have been measured for

expansion due to alkali silica reaction up to a total age of 18 months. Ultimate expansion for bars containing 2% opal plus accelerator reached 2.18% - 61% greater than the control bars (without accelerator). When silica fume was incorporated in the bars, in amounts of up to 12%, it failed to effectively control the expansion. At the level of 24% replacement of cement with silica fume, no expansion was registered either with or without accelerator up to an age of 18 months. Results are discussed in terms of the microstructure and physicochemical properties of the mortar bars.

2265. Alasali, M. M. and Malhotra, V. M., "ROLE OF CONCRETE INCORPORATING HIGH VOLUMES OF FLY ASH IN CONTROLLING EXPANSION DUE TO ALKALI AGGREGATE REACTIONS," ACI Materials Journal, Vol. 88, pp. 159-163, 1991.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; concrete prisms; expansion; test methods; accelerated tests

This report presents the results of an investigation dealing with the role of concrete incorporating high volumes of fly ash in reducing the expansion of concrete due to alkali-aggregate reaction. The concretes investigated were made using portland cement and high volumes of a low-calcium flyash (ASTM Class F). The water: (cement + fly ash) ratio was 0.31 and the flyash: (cement + fly ash) ratio was 0.58. One of the high volume fly ash concretes incorporated additional alkalies at a dosage of 3.25 kg/m$^3$. Control concrete specimens containing ASTM Type I cement with and without additional alkalies were also investigated. The expansion of concretes was monitored under normal and various accelerated methods. The test results up to 275 days of storage indicate that, at high replacement levels, the fly ash was highly effective in inhibiting the alkali-silica reaction. The expansion of test specimens under both normal and accelerated tests were within acceptable limits.

2266. Clark, L. A., "MODELING THE STRUCTURAL EFFECTS OF ALKALI AGGREGATE REACTIONS ON REINFORCED CONCRETE," ACI Materials Journal, Vol. 88, pp. 271-277, 1991.

KEY WORDS: alkali aggregate reactions; cracking; expansion; modeling; reinforced concrete; restraint; field experiences; structural effects

The structural effects of alkali-aggregate reactions (AAR) are briefly described, and the implications of these effects on modeling of reinforced concrete structures with AAR are considered. The size and proportions of the reactive particles in the mix are shown to have significant effects on expansion due to AAR. Other important points which should be considered when simulating AAR are rate of expansion, the simulation of dead-load stresses, the size and shape of control specimens, and concrete compaction. The effects of absolute size on AAR expansion and cracking are not clear, and further research is

required to establish whether they are significant.

2267. Haavik, D. J. and Mielenz, R., "ALKALI-SILICA REACTION CAUSES CONCRETE PIPE TO COLLAPSE," Concrete International, Vol. 13, pp. 54-57, 1991.

KEY WORDS: alkali aggregate reactions; field experiences; U.S.; reinforced concrete; pipe structures; NaCl effects

A catastrophic failure to alkali-silica reaction is reported in a 36 in. reinforced concrete pipe installed in a drain line at a power generating plant in the southwestern U.S. The results of petrographic examination are reported. It was concluded that the failure occurred because the pipe was subjected to abnormal service conditions; it was used to convey brine at temperatures in excess of 40°C.

2268. Nagataki, S., Ohga, H., and Inoue, T, "EVALUATION OF FLY ASH FOR CONTROLLING ALKALI AGGREGATE REACTION," ACI SP-126, Durability of Concrete, V. M. Malhotra, ed., Vol. II, pp. 955-972, 1991.

KEY WORDS: alkali aggregate reaction; preventive measures; fly ash; mortar bars; expansion; alkali effects; glass

Mortar using Pyrex as an aggregate were made using water-binder ratio of 50%, replacement ratio of fly ash from 0 to 30% by weight and an alkali content of 1.2% per weight of cement. Eight fly ashes were used as supplementary cementing materials. These mortars were cured at a temperature of 40°C and a relative humidity more than 95%, and the expansion of these mortars was measured. The concentration of soluble alkali ion in fly ash immersed in the solution containing sodium hydroxide and calcium hydroxide was also determined.Expansion of mortar depended on the type and the replacement ratio of fly ash. The concentration of soluble alkali ion in fly ash depended on the type of fly ash. Although expansion of mortar was independent of equivalent sodium oxide content in fly ash, it correlated with the concentration of soluble alkali ion in fly ash. By studying effects of physical properties, chemical properties, and amorphous silicon dioxide in fly ash, a method to evaluate the expansion of mortar containing fly ash was proposed based on amorphous silicon dioxide, the replacement ratio and particle diameter of the fly ash.

1991

2269. Natesaiyer, K., Stark, D., and Hover, K. C., "GEL FLUORESCENCE REVEALS REACTION PRODUCT TRACES,"

KEY WORDS: alkali aggregate reactions; alkali silica gels; test methods; fluorescence test

The gel fluorescence test developed at Cornell University to reveal the presence of alkali silica reaction product gels in concrete is illustrated and the procedures described.

2270. Shrimer, F. H., "A CASE OF ALKALI AGGREGATE REACTIVITY IN SOUTHWESTERN BRITISH COLUMBIA," Proc. 2nd Canadian Symposium on Cement and Concrete, Vancouver, S. Mindess, ed., pp. 219-229, 1991.

KEY WORDS: alkali aggregate reactions, petrography, field experiences; Canada, reservoir structures; reactive aggregates

A case of deterioration of a concrete structure caused by alkali-aggregate reactivity has been confirmed in southwest British Columbia. The subject structure, a water reservoir located at Canadian Forces Base Chilliwack, was constructed in the 1940's. The condition of the structural components is described. The presence of certain diagnostic attributes associated with alkali-aggregate reactivity (AAR), such as silica gel, leachates, map and pattern cracking was noted in the field. Laboratory investigation revealed other AAR-related features, including silica gel in the mortar matrix, reaction haloes, and disruption. Potentially AAR reactive rock types were noted during the petrographic examination as well. The methodology of the study is outlined, and the results of the field and laboratory examinations are presented and discussed. Determination of the location of the aggregate source is also discussed. Implications of the study for the selection of concrete aggregates are given.

2271. Stark, D., "THE MOISTURE CONDITION OF FIELD CONCRETE EXHIBITING ALKALI-SILICA REACTIVITY," ACI SP-126, Durability of Concrete, V. M. Malhotra, ed., Vol. II, pp. 973-988, 1991.

KEY WORDS: alkali aggregate reactions; moisture effects; RH effects; field experiences; U.S.

The moisture condition of field concretes exhibiting evidence of alkali-silica reactivity was investigated utilizing relative humidity (RH) measurements. Prior determinations were made on laboratory mortar specimens to determine the threshold level required to sustain expansive reactivity. By comparing measurements on field concretes with the threshold level, environmental field conditions were identified under which expansive reactivity is liable to occur. Results indicated that RH values greater than 80% referenced to 21°C to 24°C are required to support expansive alkali-silica reactivity. Field measurements revealed that most of the concrete in highways and dams in desert areas are sufficiently damp to sustain expansive ASR. Bridge decks and columns in dry climates are sufficiently damp on a seasonal basis to sustain expansive reactions. Massive concrete members indoors in controlled environments may remain sufficiently damp for more than SO years to permit continued expansive reactivity. Both residual mixing water and external sources of moisture contribute to the moisture condition required for expansion to occur.

2272. Strunge, H., Chatterji, S, and Jensen, A. D., "STUDIES OF ALKALI:SILICA REACTION PART 8. CORRELATION BETWEEN MORTAR BAR EXPANSION AND DELTA VALUES," Cement and Concrete Research, Vol. 2, pp. 61-65, 1991.

KEY WORDS: reactive aggregates; test methods; chemical methods; Denmark

Recently a method for the detection of alkali-silica reactivity of sand has been proposed. In this method sand is digested in a mixture of $Ca(OH)_2$ and saturated Kcl for 24 hours. The OH ion concentration is determined by titration. The OH ion concentration for a control mixture without sand is determined and difference between control and sample OH ion concentration is termed "delta". This "delta" is a measure of alkali-silica reactivity. The method has been tested by six different laboratories. The reproducibility of the method is fairly high. To determine an acceptance criterion, 16 Danish sand types have been tested and value compared with flint content and expansion. A "delta" value of 110 separates expanding and non-expanding Danish sand types.

1991

2273. Thomas, M. D. A., Nixon, P. J., and Pettifer, K., "THE EFFECT OF PULVERIZED FUEL ASH WITH A HIGH TOTAL ALKALI CONTENT ON ALKALI SILICA REACTION IN CONCRETE CONTAINING NATURAL UK AGGREGATE," ACI SP-126, Durability of Concrete, V. M. Malhotra, ed., Vol. II, pp. 919-940, 1991.

KEY WORDS: alkali aggregate reactions; preventive measures; fly ash; chert; electron probe analysis; expansion; cracking; mechanical properties; carbonation; alkali silica gel; mechanisms

A number of seven-year-old, externally-stored 500 x 100 100 mm concrete beams, some of which had suffered severe cracking due to alkali silica reaction, have been examined. The concretes were produced using pfa at a range of addition levels and contained a fixed proportion of a known reactive sand. Following seven years exposure, severe cracking was observed in the specimens without pfa or with 5% pfa. Surface crack widths were often in excess of 1 mm and examination of sawn surfaces indicated that the depth of visible cracks was up to 20 mm. Specimens containing 20% or more pfa did not exhibit any visible cracking. Expansion measurements, USPV, dynamic modulus of elasticity and modulus of rupture tests were undertaken and the results broadly confirm the visual condition of the specimens, with cracked specimens displaying significantly reduced engineering performance. Average carbonation depths were less than 3 mm for all the concrete specimens. However, depths of up to 20 mm were observed at the location of some of the wider cracks. Petrographic examination of thin sections showed evidence that alkali silica reaction had occurred in all the concretes but had only led to cracking in the concretes with no pfa or 5% pfa. In the concretes containing higher levels of pfa the sites of gel were rare and there was no evidence of associated damage. Examination of polished sections by quantitative electron probe microanalysis showed differences between opc and pfa concrete in the composition of the alkali-silica gel and the cement hydrates. The gel in pores in the pfa concrete was lower in calcium than that in cracks in the opc concrete. In addition, hydrate rims around alite grains had lower Ca/Si ratios and higher K/Si ratios in pfa concrete. The lower quantity of available calcium in pfa concrete and the increased absorption of potassium by its hydrates are discussed with respect to their possible contributions to the suppression of damaging alkali silica reaction .

1991

2274. Walters, G. V. and Jones, T. R., "EFFECT OF METAKAOLIN ON ALKALI-SILICA REACTION (ASR) IN CONCRETE MANUFACTURED WITH REACTIVE AGGREGATE," ACI SP-126, "Durability of Concrete," V. M. Malhotra, ed., Vol. II, pp. 941-954, 1991.

KEY WORDS: alkali aggregate reactions; preventive measures; pozzolans; metakaolin; expansion

A recent report claimed that ASR expansion was suppressed when calcined clay was added to concrete used in hydro-electric dam construction containing reactive aggregates. We now report a laboratory study on the effectiveness of metakaolin in preventing ASR. Samples of metakaolin were prepared by calcining china clay (relatively pure kaolin) and several ball clays, all collected from South West England. Compression cube strength tests were carried out in which part of the cement content of a 1:6 mixture of aggregate and ordinary Portland cement (OPC) was replaced by calcined clay. Results showed that some of the mixtures containing calcined clay exhibited no reduction in the 28 day compressive strength even when 25% of the OPC was replaced. Tests for ASR were conducted using prisms produced in accordance with the Draft British Standard 812, Part 123, containing highly reactive natural aggregates which gave an expansion of 0.450% at twelve months. Prisms in which up to 25 wt % of the OPC was replaced by calcined clay have been monitored over a period of 18 months and have shown no expansion or deleterious surface appearance. As a result of these tests, it is concluded that expansion due to ASR is completely suppressed when sufficient metakaolin is added to the concrete formulation. Metakaolin does not reduce the ultimate compressive strength of the concrete, provided that the feed clay is relatively free of impurity minerals.

2275. Wang, H. and Gillott, J. E., "THE MECHANISM OF ALKALI SILICA REACTION AND THE SIGNIFICANCE OF CALCIUM HYDROXIDE, " Cement and Concrete Research, Vol. 21, pp. 647-656, 1991.

KEY WORDS: alkali aggregate reaction; mechanisms; $Ca(OH)_2$ effects; alkali silica gel; ion exchange; alkali effects

Experiments indicate that $Ca(OH)_2$ aggravates alkali-silica reaction causing increased expansion of mortar bars. $Ca(OH)_2$ has two major functions: firstly it acts a "buffer" to maintain a high pH, i.e. a high concentration of hydroxyl ions in pore solutions; secondly, $Ca^{++}$ ions may exchange for alkali ions on silica gel leading to further

production of swelling alkali-silica complex. A mechanism of alkali-silica reaction is proposed which emphasizes the effect of $Ca(OH)_2$ on reaction and expansion.

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Tokunaga, Y. 1912
Imai, H./Yamasaki, T./
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Kobayashi, S./Ono, K./Kohno, H./
Hinuma, T. 1926
Kobayashi, S./Ono, K./Kohno, H./
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Kodama, K./Nishino, T. 1927
Koh, E./Kamata, H./Suzuki, H. 1928
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Makita, M./Katawaki, K./Moriya, S. 1843
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Hoshi, H. 1935
Makita, M./Kobayashi, S./
Kawano, H./Ishii, Y. 1934
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Mizumoto, Y./Kosa, K./Ono, K./
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Mullick, A. K./Samuel, G. 1942
Mullick, A. K./Wason, R. C./
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Mullick, A. K./Wason, R. C./
Sinha, S. K./Rao, L. H. 1941
Murata, S./Seki, S./Fujiki, Y. 1364
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Tamura, H./Nakamoto, T. 1944
Nagashima, M./Komastsu, R./
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Nakano, K. Kobayashi, S./
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Nishibayashi, S./Hayashi, A./
Ohnishi, T. 1950
Nishibayashi, S./Yamura, K. 2086
Nishibayashi, S./Yamura, K./
Hayashi, A./Imaoka, S. 2084
Nishibayashi, S./Yamura, K./
Hayashi, A./Izutsu, K. 2032
Nishibayashi, S./Yamura, K./
Matsushita, H. 1949
Nishibayashi, S./Yamura, K./
Nakano, K. 2085
Nishibayashi, S./Yamura, K./
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Nixon, P. J. 1955
Nixon, P. J./Bollinghaus, R. 1748
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Nixon, P. J./Collins, R. J./
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Takahashi, K. 1959
Okada, K./Imai, H./Ono, K./
Minamigawa, Y. 1850
Okada, K./Kondo, S./Fujita, T./
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