Part IV. ANNOTATED BIBLIOGRAPHY

Alkali Reactivity of Carbonate Rocks

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1945

WOODS, K. B., SWEET, H. S. and SHELBURNE, T. E. "Pavement Blowups Correlated with Source of Coarse Aggregate." Proc. HRB, 25: 147-168 (1945).

Conclusions: (1) an outstanding correlation existed between certain coarse aggregates used in the concrete mix and the blowup performance of the pavements; (2) no correlation existed between the cement, fine aggregate, traffic or subgrade soils used and blowup performance; (3) extensive laboratory research is necessary to determine the basic reason for variation in performance between aggregate sources and to develop new and better test methods by which those aggregates which produce concrete of an unsatisfactory quality can be identified before they are incorporated in the concrete pavement.

1948

SWEET, H. S. "Research on Concrete Durability as Affected by Coarse Aggregate." Proc. ASTM, 48: 988-1016 (1948).

Extensive field surveys in Indiana showed a correspondence between certain types of pavement disintegration and the source of coarse aggregate. The physical properties of 16 representative aggregates were determined and the performance of these aggregates in laboratory freeze-thaw tests studied. Those aggregates with poor field service records also performed poorly in freeze-thaw tests.

1949

SLATE, F. O. "Chemical Reactions of Indiana Aggregates in Disintegration of Concrete." Proc. ASTM, 49: 954-961 (1949).

Previous field work had shown a correspondence between certain types of disintegration and the source of the coarse aggregate. For the aggregates studied, no appreciable chemical reaction was found that would cause disintegration of concrete.

Sponsored by Committee on Performance of Concrete—Chemical Aspects.

1954

PATTON, J. B. "Petrology of Laminated Limestones in Indiana." Roads and Streets, 97: 8, 85, (Aug. 1954).

Petrographic studies showed many poorly performing carbonate aggregates to have similar lithologies. The poor service record of these aggregates was attributed to their susceptibility to freezing and thawing.

1955

LEWIS, D. W. "Deterioration of Structural Concrete in Indiana." Proc. 41st Ann. Purdue Road School, Ext. Series 88, 39: 5, 97-114 (1955).

Deterioration of a bridge was attributed to chemical reactivity of carbonate coarse aggregate.

ROY, C. J., THOMAS, L. A., WEISSMAN, R., and SCHNEIDER, R. "Geologic Factors Related to Quality of Limestone Aggregates." Proc. HRB, 34:400-411 (1955).

Correlation of petrographic characteristics with service records gave no explanation for the poor service record of carbonate rocks at LeGrand, Iowa. The study of concrete cores indicated that fresh stone gave satisfactory service, whereas weathered stone produced distress. Increased absorption and other effects of weathering produced distress by permitting reactions between cement and aggregates.

1957

BISQUE, R. E. "Limestone Aggregate as a Possible Source of Chemically Reactive Substances in Concrete." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1957).

Limestone from five Iowa quarries was studied by chemical methods as part of a project to determine criteria to differentiate between potentially good and poor concrete aggregates.

RUSH, F. E. "Petrography and Physical Properties of Some Devonian Limestone of Iowa." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1957).

Limestone from two quarries in eastern Iowa, one with a proven undesirable service record as aggregate for concrete highway construction and the other with an apparent acceptable service record, were compared on the basis of porosity, bulk and powder specific gravity, calcite-dolomite ratios, insoluble residue, clay mineralogy and detailed megascopic and microscopic descriptions.

SWENSON, E. G. "A Reactive Aggregate Undetected by ASTM Tests." ASTM Bull. 226, pp. 48-51 (with dis.) (TP236-TP239) (Dec. 1957); HRB Abs., 28: 4, 29 (Apr. 1958).

A Canadian dolomitic limestone coarse aggregate has been found that produces excessive expansion and cracking in concrete. The rate and degree of expansion increased with increasing alkali content of the cement. Pozzolans and chemical admixtures, usually effective in controlling alkali-aggregate reaction, showed somewhat limited beneficial influence. The results of ASTM Test Method C 289 on the limestone were negative. The results of the ASTM mortar bar test were also negative but indicated some alkali-reactivity in the limestone.

1958

BISQUE, R. E., and LEMISH, J. "Chemical Characteristics of Some Carbonate Aggregates as Related to the Durability of Concrete." HRB Bull. 196, pp. 29-45 (1958).

In a study of rocks from several quarries in north-eastern Iowa, certain carbonate rocks developed marked reaction rims in concrete. These rims were not merely a staining phenomenon but represented an increase in silica in the rim zone. The rocks developing rims contained clay, a high percentage of acid insoluble residue, and a high magnesium content.

HILTROP, C. L. "Relation of Pore Size Distribution to the Petrography of Some Carbonate Rocks." Unpubl. M.S. Thesis, Iowa State College (1958).

The pore size distribution curves for the carbonate rocks from five quarries in eastern Iowa were obtained by application of Ruska's mercury injection capillary pressure apparatus. Those rocks were then classified on the basis of their pore size distributions. The relationships between pore size distribution and textural properties, some chemical and physical properties, freeze-thaw results and service record as aggregate for concrete highway were investigated statistically. As is apparent from the scope of this study, the conclusions cannot be extrapolated to encompass all carbonate rocks. Knowledge of pore size distribution might be helpful in predicting service record as concrete aggregate. Further sampling and investigations are necessary to test that possibility.

LEMISH, J., RUSH, F. E., and HILTROP, C. L. "Relationship of Physical Properties of Some Iowa Aggregates to Durability of Concrete." HRB Bull. 196, pp. 1-16 (1958).

A petrographic study was made of carbonate rocks having a poor service record as concrete aggregate and developing reaction rims in concrete. The insoluble residue, clay mineralogy, porosity and pore size distribution were determined. The reaction rims indicated a chemical reaction with the cement that was believed to weaken the concrete and condition it to later failure by freezing or external stresses.

1959

BISQUE, R. E. "Silicification of Argillaceous Carbonate Rocks." Doctoral dissertation, Iowa State College (1959).

A study was undertaken to determine and define the nature of the chemical activity which results in the growth of "reaction shells" in certain carbonate rocks used as coarse aggregate in concrete. The formation of these shells is shown to be due to stabilization of silica from some outside source, in this case the cement paste. Similar reaction shells were grown in aqueous solution under controlled conditions. Only argillaceous carbonate rocks are host to this type of silicification, because the clay material functions as a site of stabilization for silica. The type of chemical activity involved in the growth of these shells is deleterious to the stability of cement paste and distinct from the alkali-aggregate reaction.

BISQUE, R. E., and LEMISH, J. "Insoluble Residue-Magnesium Content Relationship of Carbonate Rocks from the Devonian Cedar Valley Formation." Jour. Sed. Petrol. 29: 1, 73-76 (1959).

The insoluble residue content of carbonate rocks from several quarries in the Devonian Cedar Valley Formation of Eastern Iowa is related to the magnesium content. The relationship of "soluble iron" content to magnesium content is

plotted to demonstrate that a high soluble iron content is found only in rocks with a high magnesium content.

HILTROP, C. L., and LEMISH, J. "Treatment of Carbonate Rocks with a Vaporous Mixture of $(CH_3)_2SiCl_2$ and CH_3SiCl_3." Proc. Iowa Acad. of Sci., 66: 214-221 (1959).

Preliminary investigations of the treatment of dry carbonate rocks with some derivatives of silane in the vapor state are described. The treated rocks appear similar to affected aggregates observed in some inferior concretes.

HILTROP, CARL L. and LEMISH, J. "Relationship of Pore-Size Distribution and Other Rock Properties to Serviceability of Some Carbonate Aggregates." HRB Bull. 239, pp. 1-23 (1959).

Rock properties which might affect concrete durability were investigated. Properties studied were effective porosity, total porosity, calcium-to-magnesium ratio, insoluble residue, amount of clay present, freeze-thaw loss, and texture.

LEMISH, J., and BISQUE, R. E. "Autoclave Method for Determining Susceptibility of Carbonate Aggregates to Silicification." Proc., Iowa Acad. of Sci., 66: 210-213 (1959).

Autoclave treatment of concrete bars made from argillaceous dolomitic carbonate aggregates at 420 ± 3 F and 295 ± 10 lb steam pressure for 3 to 9 hr caused the progressive development of silicified reaction shells on the coarse carbonate aggregate similar to those found in distressed concrete. Similar treatment of concrete bars made from pure limestone aggregates induced no reaction shell growth. The susceptibility of carbonate aggregates to silicification could be rapidly determined by the autoclave method.

1960

BISQUE, R. E., and LEMISH, J. "Silicification of Carbonate Aggregates in Concrete." HRB Bull. 239, pp. 41-55 (1960).

Reaction rims were experimentally "grown" by exposing aggregate particles to dilute solutions of sodium silicate or by placing them in mortar bars. The rim zones were more acid resistant than the surrounding rock and were believed due to the introduction of silica from the cement paste. The development of rims may represent a deleterious form of silica activity, distinct from the alkali aggregate reaction.

BISQUE, R. E., and LEMISH, J. "Effect of Illitic Clay on Chemical Stability of Carbonate Aggregates." HRB Bull. 275, pp. 32-38 (1960).

Reaction rims may be the result of polymerization of soluble silica on the surfaces of illitic clay particles within rock, causing formation of a three-dimensional network of clay particles "tied together" with stabilized silica. The development of compressive strength was diminished when rim development occurred in concrete subjected to a wetting and drying-heating and cooling cycle.

HARWOOD, R. J. "Compositional Variations Associated with Carbonate Aggregate-Cement Paste Reactions." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1960).

Cubes of various types of carbonate rocks were placed in bars of cement paste or alite. After 3 mo in hot distilled water, samples, taken at specified distances from the cement-aggregate interface, were analyzed chemically. Depending on the character of the aggregate, silica moved either in or out of the interface zone of the aggregate, calcium generally moved in, and magnesium could move in either direction.

HILTROP, C. L. "Silica Behavior in Aggregates and Concrete." Doctoral dissertation, Iowa State Univ., Ames, Iowa (1960).

To study the mobility and direction of movement of silicate ion in the development of reaction rims, samples of two carbonate rocks and three cements were refluxed in distilled water for 48 hr. Reaction rims were formed in a few days. Carbonate rocks were also treated with tetrachlorosilane vapor.

SWENSON, E. G. and GILLOTT, J. E. "Characteristics of Kingston Carbonate Rock Reaction." HRB Bull. 275, pp. 18-31 (1960).

The excessive expansion and cracking of concretes with argillaceous dolomitic limestones from Kingston, Ontario, used as aggregate may be due to a chemical reaction different from other previously described cement-aggregate reactions. Although standard ASTM methods of test for potential alkali-aggregate reactivity do not reveal the reactive tendencies of the aggregate, they may be detected by measuring the expansion of concrete prisms in a highly humid atmosphere. The variables influencing the expansion of affected concrete are discussed. A possible relationship between expansive reactivity and the reaction of dolomite with the cement alkalies is suggested. The use of cement with sufficiently low alkali content appears to have provided a satisfactory solution to the field problem in the Kingston area.

SWENSON, E. G. and LEGGET, R. F. "Kingston Study of Cement-Aggregate Reaction." Can. Cons. Eng., 2: 8 (Aug. 1960); Tech. Paper 103, Div. of Building Res., Nat. Research Council, Canada (NRC 5904).

The effect of alkali-carbonate reactivity on field concrete in the Kingston, Ontario, area is described. Laboratory studies are summarized and the construction practices believed best suited for concretes made with potentially reactive aggregates are listed.

1961

FELDMAN, R. F., and SEREDA, P. J. "Characteristics of Sorption and Expansion Isotherms of Reactive Limestone Aggregate." Jour. Amer. Conc. Inst., Proc., 58: 2, 203-214 (Aug. 1961).

Characteristic differences have been detected in the sorption and expansion isotherms of alkali-treated and untreated reactive limestone aggregate. These results are compared with those obtained from Vycor glass under similar conditions. The evidence establishes the presence, within the pores of the aggregate, of trace amounts of a material that causes expansion when water is made available to it. The mechanism of expansion is similar to the alkali-silica complex formed in the pores of Vycor glass although the composition of the materials in the two cases may be different.

HADLEY, D. W. "Alkali Reactivity of Carbonate Rocks – Expansion and Dedolomitization." Proc. HRB, 40: 462-474 (1961); PCA R&DL Bull. 139.

The reactive rocks expanded rapidly in concrete and in highly alkaline solutions. This expansion accompanied the chemical reaction $CaMg(CO_3)_2 + 2MOH \rightarrow M_2CO_3 + Mg(OH)_2 + CaCO_3$, in which M = K, Na, or Li. The reactive rocks were categorized by mineral composition and texture, and a simple and rapid laboratory test for the expansive reaction in alkali was described.

LEGGET, ROBERT F., and GIBBONS, E. V. "Concrete Durability Studies in Canada." RILEM Intern. Sym. on Durability of Concrete, Final Rep., Prague, 2: 303-310 (1961).

Studies are outlined which have contributed in making concrete durable to Canadian conditions of exposure. Reference is made to the work done in developing a sulfate-resisting type of cement, a basis for classifying deleterious characteristics of aggregates, and improved resistance to de-icing salts. Concrete failures due to alkali-aggregate reaction are briefly described with special mention of an unusual type involving a dolomitic limestone.

LEMISH, JOHN "Research on Carbonate Aggregate Reactions in Concrete." Trans. AIME, 220, pp. 195-198 (1961).

Distress in concrete related to carbonate aggregates is widely recognized. It generally occurs after 15 yr of service. The matrix is highly carbonated and dark borders or reaction shells outline the argillaceous carbonate aggregate fragments. Controlled laboratory experiments show that all components of the rock react to form a silicified dedolomitized shell. Na and K are not introduced into the shell which represents the presence of amorphous silica derived mostly from quartz in the rock. The silica is absorbed or fixed by the aggregate as a hydrated Ca silicate compound. Concrete in which the reaction has occurred does not gain in strength. Concrete bars unaffected by the reaction increased 50% in strength.

WERNER, M. A. "Equilibria in Cement Paste-Carbonate Aggregate Reactions." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1961).

Selected rocks and cements were placed in contact with solutions of various silicon concentrations and refluxed for 48 hr. The solutions were then analyzed for calcium, magnesium, and silicon. A definite silicon equilibrium existed between the rock and the aqueous solution.

1962

BISQUE, RAMON E. "Clay Polymerization in Carbonate Rocks: A Silicification Reaction Defined." Nat. Conf. on Clays and Clay Minerals, 9th Proc., 9: 365-373 (1962).

A carbonate rock silicification reaction was defined and shown to be dependent on the presence of clay in the host rock. Introduction of silica in soluble form(s) serves to polymerize the clay fraction, forming three-dimensional network which can be separated from the rock by leaching away the carbonate minerals. Laboratory silicification of argillaceous carbonate rocks under controlled conditions has served to define critical variables.

DE GAST, A. A. "The Study of the Physical Properties of Kingston Limestone Deleterious in Concrete." Unpubl. M.S. Thesis, Queen's Univ. (1962).

The role of the release of residual strain in the rock in observed expansion of concretes containing Kingston aggregate is studied and shown not to be significant factor.

LEMISH, J. Discussion of "Chemical Reactions Involving Aggregates," by Per Bredsdorff, G. M. Idorn, A. Kjaer, N. M. Plum and E. Poulsen. Intern. Sym. on Chemistry of Cement, 4th Proc., Washington, 2: 296-299 (1960); U. S. Dept. of Commerce NBS Mono. 43 (1962).

Research at Iowa State University has shown that cement-aggregate reaction is selective and that dolomitic argillaceous carbonate rocks characterized by relatively high residues react with cement. All components of the rock react to form a silicified "dedolomitized" shell. Silica can move either into or out of an aggregate.

MATHER, KATHARINE, and BUCK, ALAN D. "Alkali-Silica and Alkali-Carbonate Reactivity of a South Dakota Sand." U. S. Army Engineers Waterways Exp. Station, Misc. Paper 6-53 (Sept. 1962).

Studies of mortar bars and samples of two sands from Watertown, S. D., area at the Waterways Experiment Station revealed (a) alkali-aggregate reaction of the shale particles involving low cristobalite-tridymite, a form of silica present in the shale; (b) concurrent cation exchange involving the montmorillonite; (c) alkali-aggregate reaction involving carbonate rock particles, i.e., dedolomitization in which brucite is a reaction product. This represents the first evidence of alkali-carbonate rock reaction, dedolomitization, recorded by the Corps of Engineers.

NEWLON, H. H., Jr., and SHERWOOD, W. C. "Potentially Reactive Carbonate Rocks." Proc., 21st Meeting Southeastern Assoc. of State Highway Officials (1962).

This paper includes preliminary findings of a statewide survey of Virginia carbonate aggregate sources. Rock from seven quarries was found to expand more than 0.2% in the rock prism expansion test. This was the minimum rock expansion found to produce distress in laboratory concrete. Extensive laboratory studies are described.

NEWLON, H. H., Jr., and SHERWOOD, W. C. "An Occurrence of Alkali-Reactive Carbonate Rock in Virginia." HRB Bull. 355, pp. 27-44 (1962).

A highway bridge in Virginia, which had been instrumented to measure concrete shrinkage, was found instead to undergo a progressive expansion of considerable magnitude. The carbonate coarse aggregate was subsequently determined to be alkali-reactive. Extensive laboratory tests of the aggregate largely confirmed the published findings of earlier investigations.

WALLACE, C. M. "Relationship of Pore Size to Texture in Some Carbonate Rocks." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1962).

The effective porosity was determined for six different carbonate rocks from five Iowa quarries. A thorough knowledge of a rock's effective porosity, volume/surface ratio, and chemical composition may be helpful in predicting the suitability of the rock as a concrete aggregate.

1963

GILLOTT, J. E. "Petrology of Dolomitic Limestones, Kingston, Ontario, Canada." Geol. Soc. Amer. Bull., 74: 6, 759-778 (June 1963).

Dolomitic limestone from Kingston, Ontario, has importance as an example of rock which produces in concrete an alkali-aggregate reaction different from reported alkali-silica reaction. The expansive reaction causes deterioration and cracking of the concrete. A petrographic, mineralogical, and chemical comparison was made between rock showing high expansion in concrete and no reactivity. Although it is not possible on petrographic criteria alone to predict the degree of reactivity which a particular rock may show as aggregate, rocks of this petrographic type may be recognized.

LEMISH, J. "Carbonate Aggregate Research." Proc., 14th Ann. Highway Geology Sym., Texas A and M College, pp. 55-64 (1963).

Research concerning the reactivity of carbonate aggregates is reviewed. No one mechanism or variety of mechanisms for the contribution of carbonate rocks to distress in concrete can be postulated at this time.

LEMISH, J., HARWOOD, R. J., HILTROP, C. L., and WERNER, M. A. "Compositional Variations Associated with Carbonate Aggregate Reactions." Highway Res. Record 3, pp. 1-8 (1963).

Changes in the composition of aggregates and cement pastes were studied by placing cubes of various aggregates in cement paste bars and reacting them in a water bath at 130 F for 3 mo. The silica in the shell zone is locally derived from quartz present in the aggregate and migrates in the direction required to maintain equilibrium at the pH present. Dedolomitization and possibly an increase in new calcite occurs concurrently. Cement pastes are stable and are not considered the source of silica found in the shell zone.

MATHER, K., LUKE, W. I., and MATHER, B. "Aggregate Investigations, Milford Dam, Kansas, Examination of Cores from Concrete Structures." U. S. Army Engineers Waterways Exp. Station, Tech. Rep. 6-629 (June 1963).

Cores from Kansas and Nebraska containing several sand-gravel and crushed limestone-sand gravel combinations were studied using petrographic and X-ray test methods. Both alkali-silica and alkali-carbonate reactions were found in most of the concretes examined. Reaction rims developed on some non-dolomitic aggregate particles.

MOORE, W. J. "Studies of Carbonate Aggregate Reactions: Expansion Behavior; Environmental Effects; Concrete Matrix Investigations." Unpubl. M.S. Thesis, Iowa State Univ., Ames, Iowa (1963).

Studies of the expansive behavior of reactive dolomitic limestones from Iowa largely confirmed the findings of earlier investigators. Appreciable expansion took place only in those rocks with an initial effective porosity of less than 8%. Results of research concerning the development of reaction rims in the laboratory are given, and preliminary studies of variations with depth in the chemical composition of cement paste separated from highway cores are described.

NEWLON, H. H., Jr., and SHERWOOD, W. C. Discussion of "Durability of Concrete in Service," Jour. ACI Proc., 60: 6, Pt. 2, 2071-2075 (June 1963).

Preliminary results are presented of a survey of carbonate rocks from all commercial sources in Virginia. A total of 284 samples were tested in the rock prism expansion test. Expansions of up to 2.85% were measured after 10-mo soaking in 1 M NaOH.

1964

AXON, E. O., and LIND, J. "Alkali Carbonate Reactivity — An Academic or a Practical Problem." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Although no serious reduction in the service life of the concretes on Missouri highways has been attributed to alkali reactive aggregates, results of the rock prism expansion test on more than 230 samples indicated that some rocks in Missouri were sufficiently reactive to cause concern.

DOLAR-MANTUANI, L. "Expansion of Gull River Carbonate Rocks in Sodium Hydroxide." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

The rocks of this formation were sampled over a broad area and tested in the rock prism expansion test. Certain of the reactive rocks were found to expand only after extended soaking in alkaline solution.

GILLOTT, J. E. "Study of Alkali Carbonate Rock Reactivity by a Cell Test Method." Paper submitted to ASTM.

GILLOTT, J. E. "Mechanism and Kinetics of Expansion in the Alkali-Carbonate Rock Reaction." Paper submitted to Geol. Soc. Amer.

HADLEY, D. W. "Alkali Reactivity of the Dolomitic Carbonate Rocks." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

The performance of the alkali-reactive carbonate rocks in field and laboratory concretes is described, and published and unpublished research concerning the causes and mechanisms of reactivity is reviewed and discussed. Known occurrences of potentially reactive rocks are noted, rapid laboratory tests for the recognition of the reactive rocks are summarized, and various remedial measures are discussed.

HADLEY, D. W. "Alkali Reactive Carbonate Rocks in Indiana – A Pilot Regional Investigation." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

A study of the carbonate rocks exposed in Indiana showed that by utilizing standard geologic field techniques coupled with specially developed but simple and rapid laboratory tests, the distribution of the reactive rocks within the vertical sequence of beds and the geographic areas in which these reactive rocks were exposed could be rapidly delineated. The reactive rocks were widely distributed in Indiana. Fortunately, however, the reactive beds are normally thin, the general level of reactivity is low and most of the highly reactive materials are of poor physical quality and consequently are not used as concrete aggregate. Studies on laboratory concretes indicate that many of the marginally reactive materials could be safely used as concrete aggregate if adequate precautions were taken.

LEGG, F. E., Jr., and VOGLER, R. H. "Alkali-Carbonate Rock Reactions in Michigan." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Laboratory studies have disclosed three quarried limestones having very mild expansions when incorporated in concrete made with high-alkali cement. The freeze-thaw durability of two of these limestones is dependent upon the alkali content of the cement when the aggregates are placed in the concrete in a vacuum saturated condition. Durability was improved with low alkali cement. The Michigan State Highway Department has not experienced distress of field concrete positively identified as being due to cement alkali-carbonate rock reaction.

LEMISH, J., and MOORE, W. J. "Carbonate Aggregate Reactions: Recent Studies and an Approach to the Problem." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Expansion studies were made on a variety of carbonate rocks occurring in Iowa. Results reported favored a causative mechanism of expansion most closely related to rock texture and pore structure. The results of comparative studies on laboratory methods for inducing the development of reaction rims were given, and an approach to the problem of deleterious behavior of certain varieties of carbonate rocks in concrete through a systematic study of highway concrete was described.

MATHER, K., BUCK, A. D., and LUKE, W. I. "Alkali-Silica and Alkali-Carbonate Reactivity of Some Aggregates from Kansas, South Dakota, and Missouri." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Results of the detailed petrographic examination of concretes showing alkali-silica and/or alkali-carbonate reactions are presented.

NEWLON, H. H., Jr., and SHERWOOD, W. C. "A Study of Remedial Methods for Reducing Alkali-Carbonate Reaction." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Dilution with non-reactive aggregate and the use of low alkali cement were investigated as possible remedial measures for alkali-carbonate reactivity. The most important influence on the expansion of concrete affected by the alkali-carbonate rock reaction was the level of aggregate reactivity. Dilution with inert aggregate appeared to be a better procedure than limitation of cement alkalies.

SHERWOOD, W. C., and NEWLON, H. H., Jr. "Studies on the Mechanisms of Alkali-Carbonate Rock Reaction." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Results are reported of laboratory studies made to determine the chemical reactions that may contribute to the expansion of concrete made with the alkali-reactive carbonate rocks. The major mineral constituents of the reactive rocks were studied before and after treatment with alkaline solutions, and the evidences of reaction noted during this phase of the study were then looked for in thin sections, prisms, and in aggregate from laboratory and field concrete.

SHERWOOD, W. C., and NEWLON, H. H., Jr. "Statewide Survey for Reactive Carbonate Aggregates in Virginia." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Carbonate aggregate sources in Virginia were systematically sampled and the rock tested for expansion in alkali and for development of reaction rims in concrete.

SMITH, P. "Learning to Live with a Reactive Carbonate Rock." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

An investigation was made to determine the safest and most economical way of building a four-lane concrete highway for 30 mi west of Kingston, Ontario, where the local dolomitic limestone aggregates might show expansive reactivity in concrete. Aggregates were ultimately selected on the basis of the expansion of concretes made with cement high in alkalies and cured under standard conditions. The precautions taken to insure that only non-reactive aggregates were used and the other factors favoring minimized expansion are described.

SWENSON, E. G., and GILLOTT, J. E. "Alkali-Reactive Carbonate Rock — NRC Canada Studies." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

A review is made of 8 yr of published research on the alkali-carbonate rock reaction by the Division of Building Research, National Research Council, Ottawa, Canada. The Kingston case which first revealed excessive expansion in concrete by alkali-carbonate reactivity in a dolomitic limestone coarse aggregate is summarized. Further field studies are described as well as investigations into the nature of the reaction, methods of test and identification, and some hypotheses concerning the mechanism of reaction and expansion.

WELP, T. L., and DE YOUNG, C. "Variations in the Performance of Concrete with Carbonate Aggregates in Iowa." Paper presented at 43rd Ann. Meeting HRB (Jan. 1964).

Observation of concrete pavements for several years indicates that the majority of the carbonate aggregates used can be expected to perform satisfactorily for at least 20 to 25 yr. Several aggregates from various geologic sources were used in concrete pavement over 40 yr old. Of over 100 carbonate aggregate sources used, only a few have been associated with early deterioration of concrete. Three known geologic sources capable of meeting current test limits are associated with concrete that has shown extensive deterioration on pavements from 8 to 15 yr old. These three are in different stratigraphic horizons with different lithologies, but have no distinction properties that separate them from acceptable geologic sources. Carbonate content is 95% or more.