REPORT OF COMMITTEE ON CHARACTER AND USE OF ROAD MATERIALS

Chairman, H S MATTIMORE

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The Committee has aimed to investigate and encourage research on character and use of road materials, and has selected problems for investigation which are deemed to be of major importance at the present time in the highway field

Separate reports are being submitted on different assigned subjects. These have been prepared, with one exception, by individual members of the Committee The report contributed on Alkali Action on Portland Cement Concrete is by Dalton G Miller, of the U S Bureau of Public Roads, who is not a member of the Committee, but it is felt that we are fortunate in securing the co-operation of Mr Miller, who, as an expert, was in charge of this line of investigation for the Bureau of Public Roads at their St Paul, Minnesota, station

The reports represent individual work in compiling the data, but each has been concurred in by the entire Committee

Brief Review of Alkali Action on Portland Cement Concrete, reported by Dalton G Miller

Concrete and Concrete Aggregates, reported by M O Withey

Field Control of Concrete Making, reported by R W Crum

Investigations of Asphaltic Paving Mixtures Relative to Deformation of Surfaces Under Traffic, and Bituminous Materials for Surface Treatment, reported by B A Anderton

Subgrade Materials and Tests, reported by H S Mattimore

BRIEF REVIEW OF ALKALI[1] ACTION ON PORTLAND CEMENT CONCRETE

DALTON G MILLER

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Alkali may consist of any one or more of the sulfates, chlorides and carbonates of sodium, magnesium and calcium Sea water in this sense is an alkali water The sulfates of sodium and magnesium, usually in combination, are the two salts of most common

[1] The word "alkali," meaning water soluble salts, is used here in the same sense as it is in the arid and semi-arid regions

occurrence deleterious to concrete In general it may be assumed that it is the physical result of the chemical action of one or both of these sulfates, and possibly to some slight extent calcium sulfate and some of the chlorides, that is meant when reference is made to alkali action on concrete

Portland cement was invented in 1824 and since then many studies have been made, and a large amount of research is still under way, looking towards complete or partial solution of the problem of deterioration when in contact with alkali waters Published papers along this line have been very numerous, and in 1925 the U S Department of Agriculture, to facilitate in the library studies, issued in bulletin form[1] quite a complete compilation of references to articles published prior to 1924 by the many authorities on this subject Anyone interested in reviewing the work of any authority, whether or not mentioned in this brief paper, should consult the bulletin for information as to publications

Among the earlier workers in Europe we find such men as Le Chatelier in 1887 signing his name to a paper, "Search for Materials Capable of Resisting Sea Water", Michaelis in 1891 writing on, "Behavior of Portland Cement in Sea Water", Feret in 1890 contributing to the literature along this line with, "Experiments on Decomposition of Mortars by Sulfate Waters", Poulsen in 1923 issuing the report "Concrete and Reinforced Concrete," in which he describes a series of field experiments started in 1896 on a comprehensive scale by the Scandinavian Association of Manufacturers of Portland Cement to determine the influence of various factors on the resistance of concrete exposed to sea water, while in the Engineering Record[2] of November 27, 1897, we find the translation by Capt O M Carter and Mr E A Giesler of an article, "The Influence of Sea Water on Mortars," by E Candlot, in which is reviewed results and conclusions by Viennot and various other French engineers, based largely on 40 years of investigations of experimental cubes, 60 centimeters on an edge, exposed between the years of 1856 and 1875 to the open sea in the harbor of La Rochelle, showing that the French engineers and chemists acknowledged the existence of the problem three quarters of a century ago in the early history of cement making As a matter of fact studies along this line by the French are in reality older than Portland cement, for Vicat recog-

[1]A Bibliography Relating to Soil Alkalies Compiled with Special Reference to the Deleterious Action of Soil Alkalies and Various Other Chemical Agents on Cement and Concrete Department Bulletin No 1314 U S D A

[2]Volume XXXVI, No 26

nized the problems as far back as 1818 in connection with his work on limes and natural cements

In America, where so much is new, it is sometimes difficult to realize that many problems new to us are in reality of long standing tively recent years that American engineers, in general, have recog- So it is with the concrete-alkali work, for it is only within comparanized its actuality As a consequence it is only within the past two decades that we find much along this line written by American engineers appearing in American engineering literature However, as the use of concrete has become more and more general, with the consequent result of a greater number of structures being subjected to intimate contact with sulfate waters of one kind and another, a great many published papers have appeared

Among some of the earlier and outstanding works by American engineers will be mentioned that of the Aberthaw Construction Company, consisting largely of observations of variously made specimen piers approximately 16 inches square and 16 feet long installed in sea water at the Navy Yard at Charlestown, Massachusetts, field and laboratory work started by the U S Geological Survey and transferred in 1910 to the U S Bureau of Standards and there continued on different phases of the problems up to the present time, the work of this Bureau comprising observations and chemical examination of hollow test cylinders 3½ inches outside diameter and 10 inches long, through which were passed solutions of various kinds, compression tests of 8 x 16-inch cylinders installed in sea water, observation and tests of experimental 8-inch drain tile exposed in seven Western States to eight different alkali soil conditions and physical and chemical work on cement, field and laboratory physical and chemical investigations by the Montana and Wyoming Agricultural Experiment Stations between the years 1907-1917.

In more recent years, American investigations along this line have become so numerous it is not possible here to do more than review the general plan of some of the unfinished work of more recent years by a few organizations that are known to have entered extensively on concrete-alkali programs of field and laboratory work.

(1) *Committee on Deterioration of Concrete in Alkali Soils, Engineering Institute of Canada*—G M Williams, Professor of Civil Engineering, University of Saskatchewan, is the Secretary of this Committee A large proportion of the funds for this work is devoted to chemical research under the direction of Dr Thorvaldson, head of the Chemistry Department at the University of Saskatchewan. The field studies consist of cylinders 7 inches in diameter and 21

inches long, installed at Cassels, Alberta, Grandora, Saskatchewan and Deacon, Manitoba.

(2) *Research Laboratory of the Portland Cement Association* — Work by this organization has been conducted under the direction of Professor Duff A Abrams In addition to work in the laboratory some 2,000 concrete cylinders, 10 inches in diameter and 24 inches long have been exposed to sulfate soils and water in Colorado, South Dakota and western Canada

(3) *U S Bureau of Public Roads Both as an Independent Organization and Cooperating with the Department of Agriculture of the University of Minnesota and the Minnesota State Department of Drainage and Waters* —For some years the Bureau of Public Roads has made concrete-alkali investigations and tests of various kinds. Since 1922 the Division of Tests has been experimenting with the use of water gas tar, coal tar and paraffin solutions applied by surface application or by immersion [1] The test specimens consist of 2 x 4 inch mortar cylinders and 4 x 6 inch concrete cylinders of different proportions coated with varying quantities of the protectives and stored in a 3 per cent solution of sodium and magnesium sulfate for periods of one, two and three years Dr E C E Lord, Petrographer of the Bureau, has had charge of this work. The chemical effects of alkali attack have been studied and the results of this investigation will shortly be published As a result of this investigation, a number of bridge structures, including concrete piles exposed to alkali action, in various sections of the country have received protective treatment and will be observed with much interest

Following field investigations in Minnesota in 1919 and 1920, the Bureau in cooperation with the Department of Agriculture of the University of Minnesota and the Minnesota Department of Drainage and Waters has conducted work through a laboratory established July 1, 1921, at University Farm, St Paul, Minnesota The work of this laboratory has been under the direction of Dalton G Miller, Drainage Engineer, Bureau of Public Roads Observations, studies and tests have been made of 2 by 4 inch Portland cement concrete and mortar cylinders of many types, most of which are suitable for drain tile, exposed in the laboratory to sulfate solutions while 2 x 4 inch experimental cylinders and 5 and 6 inch drain tile have been made and exposed to a wide range of field conditions in Minnesota, Wisconsin and the two Dakotas A total of 25,000 cylinders and

[1] Public Roads, Vol V, No 3, p 23, May 1924.
Public Roads, Vol VI, No 11, p 251, January 1926

several hundred drain tile have been made in connection with this work

(4) *U S. Bureau of Standards*—Investigations of the Bureau of Standards on the effect of alkali on concrete is of long standing and contributions on this subject by Bates, Wig, Williams and other workers have thrown much light on this perplexing problem At the present time, chemical studies of Portland cements and Portland cement clinkers are being carried on as well as some work on surface coatings The Portland Cement Association now has a Fellowship at the Bureau of Standards and fundamental studies on the constitution of Portland cement clinker, by Dr R H Bogue, may in the end have a direct bearing on the solution of this problem

(5) *Iowa Engineering Experiment Station*—Work at Ames has been conducted almost entirely in the laboratory along both physical and chemical lines by Professors W J Schlick, Drainage Engineer, and Geo W Burke, Chemical Engineer.

(6) *Washington State Highway Department*—Work for the Washington State Highway Department, Olympia, Washington, is under the immediate direction of Bailey Tremper, Engineer of Tests, and consists chiefly of studies of 2 x 4 inch cylinders exposed to artificial sulfate solutions in the laboratory

The agencies and individuals, both in America and Europe, constantly adding many valuable contributions to this very important subject are too numerous to mention in detail Recently, however, a paper along this line by Alfred H White,[1] Professor of Chemical Engineering, University of Michigan, and one by John R Baylis,[2] Principal Sanitary Chemist, Baltimore City Water Supply, has in each case been particularly interesting Regardless, however, of all that has been contributed on the concrete-alkali problem, due to its very complexity, the probabilities are that many years will yet elapse before the final word will have been said

GENERAL RESULTS OF INVESTIGATIONS

After all the years of research on the concrete-alkali problem it is still difficult to find much common ground of agreement among the conclusions variously arrived at by the many investigators There are, however, two exceptions to this statement in that nearly all workers advocate the use of very rich mortars, either 1 1 or 1 2, and also advocate that the concrete be "well made" of "carefully graded aggregate" and as "dense" or "impermeable" as it is pos-

[1] The Fundamental Cause of the Disintegration of Concrete Concrete, Vol 26, No 5, p 157-161, May 1925

[2] Corrosion of Concrete Proceedings of the A S C E, p 549-579, April, 1926

sible to make it, apparently being in agreement that it is desirable to prevent, so far as possible, penetration of alkali water into the mass of the finished concrete

Admixtures—While not entirely in agreement many European engineers incline to the belief that finely divided admixtures of silica in the form of volcanic ash, diatomaceous earths or blast furnace slag have some advantages American engineers, however, have not generally accepted as a fact the value of such admixtures indicating that at best their practical value is perhaps subject to question As to the value of admixtures other than silicas there is even less unanimity of opinion Michaelis[1] as long ago as 1891 recommended, among other things, the use of barium chloride dissolved in the mixing water in quantity equivalent to 2 to 3 per cent of the weight of the cement while in recent years calcium chloride has been similarly used with some evidence to indicate increased resistance Water gas tar, oils, asphalt, hydrated lime, soap solutions and many other preparations, patented and unpatented, have been used with reported results ranging all the way from highly beneficial to decidedly harmful.

Surface Treatments—Surface treatments group under the two very general classifications, (1) chemical and (2) physical. Under the chemical classification fall those treatments applied with the idea that through some chemical action between the coating and the cement of the concrete, or between the coating and the deteriorating agency certain new chemical combinations—more or less insoluble and consequently protective—will be formed, at or near, the surface of the concrete Under the physical classification fall treatments of the nature of tar, pitch, asphalt, paraffin, soap solutions, oils and paints of all kinds as well as many other preparations

In general it does not appear that surface treatments that afford protection only through chemical action have proven of much practical value On the other hand, one of the greatest difficulties with the treatments furnishing physical protection has been to find materials that meet the first essential requirements of properly adhering to the concrete and having sufficient weather resistance and general durability to make their use beneficial over long periods of years In the protective class fall coal and water gas tars, bituminous paints and certain oils More exact information than at present available, as to the actual value of these and various other materials

[1] The Behavior of Portland Cement in Sea-water. Eng. Rec, Vol. XXXV, No 12, Feb 10, 1897.

for surface treatments is to be hoped for when the results of some of the current American investigations are made available

Cements—Beginning almost with the first concrete-alkali studies, experiments have been carried out with cements differing from the average Portland cement in some one or more constituent As a consequence, scattered all through the literature on this subject we find reference to quick hardening cements, cements low or high in lime, iron, silica, alumina or magnesia, etc Here again, though individual conclusions when compared leave much to the imagination of the reader, in general there seems to be enough agreement to warrant the statement that there has been observed under some conditions a considerable difference in resistance among cements and that furthermore there is a difference, not entirely accounted for, even among modern standard Portland cements This is not surprising when the individuality of different Portland cements for many special purposes is becoming more and more to be generally recognized among the users of cements [1]

CONCLUSIONS

Investigations to date indicate that carefully made, long-time cured concrete, very rich in cement and of high compressive strength and low permeability best resists the action of alkali It is of particular importance that the cement mortar be as rich as 1 1 or1 2 if high resistance is to result

Admixtures, as a rule, have not proven greatly beneficial and at present not one is known to have given such outstanding results as seem to warrant an unqualified recommendation for use in concrete to be exposed to alkali Many admixtures, supposedly beneficial, when used have actually decreased the resistance of the concrete

Surface treatments apparently have some possibilities depending largely upon the physical protection afforded

There is sufficient evidence to indicate enough difference in resistance among cements to justify special preliminary tests of a cement for concrete to be exposed to the action of alkali

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[1]Why? (Editorial). Concrete, Vol 26, No 6, June, 1925

Some Requirements in the Study of Portland Cement Thaddeus Merriman. Engr News-Record, Vol 93, No 3, p 105, July 17, 1924