In making accelerated tests to determine the durability of concrete to ordinary weathering conditions, it is desirable to avoid the inclusion of injurious treatments which differ materially in their effects from those produced by natural agencies Consequently, it is doubtful if the sodium sulphate test,[1] as outlined in the previous problem, can be considered a satisfactory criterion for measuring the resistance of concrete to freezing and thawing It would seem highly desirable, however, to carry on freezing and thawing tests of concrete, modeling the tests after the specification of the A S T M Ser Des C4–24, Sec C, but running the tests for one hundred or more cycles Also it would seem desirable to run sodium chloride accelerative tests like the one described under Problem 1, in parallel with the freezing and thawing tests In these tests, it would be desirable to include as variables, different brands of cement, variation in richness of proportions, aggregates of different degrees of durability, and differences in grading of aggregates which would produce marked differences in the density of the concretes made from these aggregates The accelerated test should be made on concretes at least one month old It would also be well to have auxiliary tests made to determine the cross-bending and the compressive strengths of the concrete before and after the soundness test To ascertain the influence of the soundness test on the dimensions of the specimens, measurements of the linear expansion and contraction of the specimens should also be included

The durability of concrete to alkali waters has been studied quite extensively Information concerning the resistance of drain tile, and a bibliography of the more important literature on the subject may be found in Technologic Papers, Nos 44, 95, and 214 of the U S Bureau of Standards An interesting paper on "Laboratory Investigations of the Influence of Curing Conditions and Various Admixtures on the Life of Concrete Stored in Sulphate Solutions as Indicated by Physical Changes," by D. G. Miller, is reported in the Proceedings of the A. S T. M Vol 24, 1924. A report on the durability of concrete drain tile when embedded in peat soils, and bibliography on the literature bearing upon this subject will be found in a paper entitled, "Effect of Organic Decomposition Products from High Vegetable Content Soils upon Concrete Drain Tile," by G R B Elliott, Journal of Agricultural Research, Vol XXIV No 6, 1923

GRADING OF AGGREGATES

R W Crum

Iowa State Highway Commission, Ames, Iowa

The present status of our knowledge on this subject is as follows A large amount of research work has been done in the endeavor to ascertain the laws governing the relationships of the raw materials in Portland cement concrete with the result that several methods have been proposed and more or less extensively used, for evaluating the

[1] This test appears to produce chemical as well as mechanical disintegration when applied to concrete

sieve analysis of concrete aggregates Through this work, several important principles such as the function of the water in the concrete have been established Other points raised by different investigators have not yet been fully reconciled It can be said at this time that the science of combining materials is far ahead of the art of fabrication Although mixtures can be designed with some degree of scientific exactness, the actual mixtures, especially in large volumes, as, for instance, in pavements, depart very widely from the characteristics assumed in the design. Research work and improvement in preparation and manipulation of materials looking toward a high degree of uniformity in the finished product is the most important objective at the present time.

RESEARCHES

Many experimenters are working on the problems of proportioning mixtures and grading of aggregates. The greater part of these researches are with reference to the use of local materials, but the work of a few men has been of great value with respect to fundamental principles, notably, the work of Feret, Fuller, Abrams, Edwards, and Talbot

M. Feret, Chief of the Laboratory of the French Department of Bridges and Roads, experimented with the composition of mortars and derived a fundamental formula for strength, 1897. His extensive work on concrete mixtures has not yet appeared in this country

W. B Fuller, experimented with sieve analyses of aggregates and proposed the mixing of various sizes of materials to conform to a curve of supposed maximum density By screening aggregates into a number of sizes, or by combining various materials to approximate the so-called ideal curve, economy in cement could be effected

D. A Abrams, Chief of the Structural Materials Research Laboratory of Lewis Institute, has evolved a numerical function of the grading called the fineness modulus Abrams called attention to the specific effect of the amount of mixing water upon the strength of concrete

L. N. Edwards, now Bridge Engineer, State Highway Department of Maine, developed a useful relation between the actual surface area of the aggregate and the strength of concrete.

A. N Talbot, University of Illinois, has demonstrated certain fundamental principles in the properties of concrete

ESTABLISHED FACTS AND PRINCIPLES

As a result of the work of the various authorities, the following fundamental fact has been practically established. The strength of Portland cement concrete varies with the amount of actual solid material present in a given volume, and with the relative parts of this volume that are cement and aggregate Different experimenters have expressed this relation in different ways, but appear to be in substantial agreement as to the underlying principle

Figures 1, 2, 3, and 4, show the typical relationship between strength of concrete and the various expressions proposed, for a given series of tests In these expressions

c = absolute volume of cement
s = absolute volume of fine aggregate.
g = absolute volume of coarse aggregate.
d = coefficient of density = c+s+g.

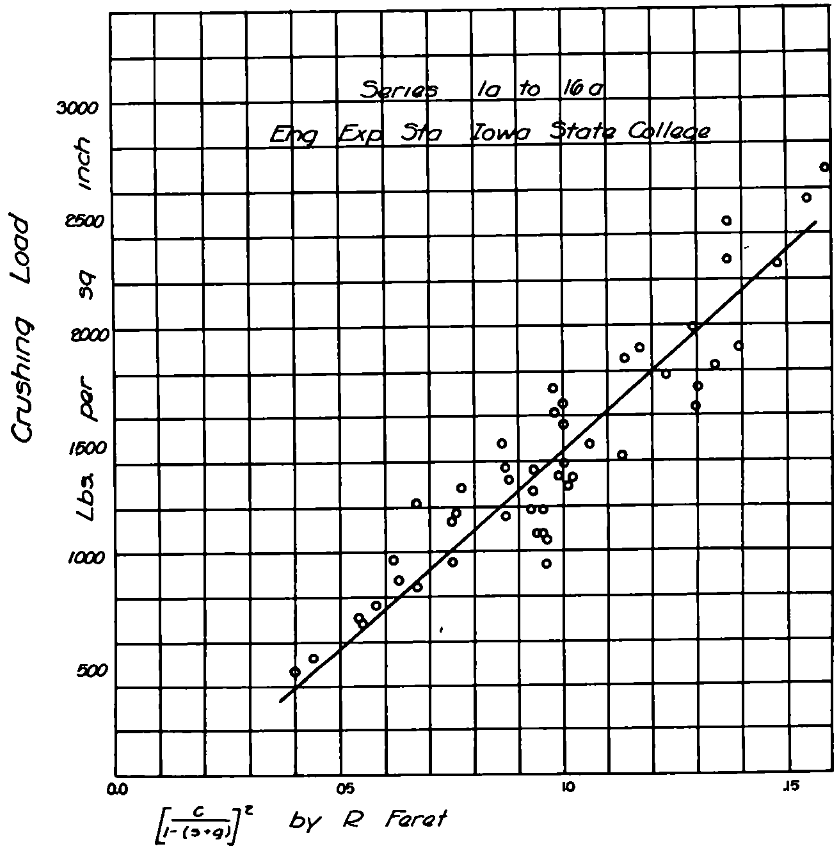

FIGURE 1

These various formulæ are of value in making studies into the constitution of various concretes, but Abrams has proposed a function called the water-cement ratio which can be actually used in designing the mixtures beforehand. For instance, the function $\frac{c}{1-d}$ cannot be computed until the concrete is made and the yield measured, but if all of the cement used and all of the mixing water stays with the concrete when molded and if the mixing water practically fills all of the void space in the concrete, the ratio between the absolute volume of the cement used and the volume of mixing water should also be a function varying with the strength of the concrete. This has been well substantiated and is illustrated by Figure 5 taken from the same data as Figures 1 to 4, and by Figure 6 from Bulletin No. 1, Structural Materials Research Laboratory, Lewis Institute

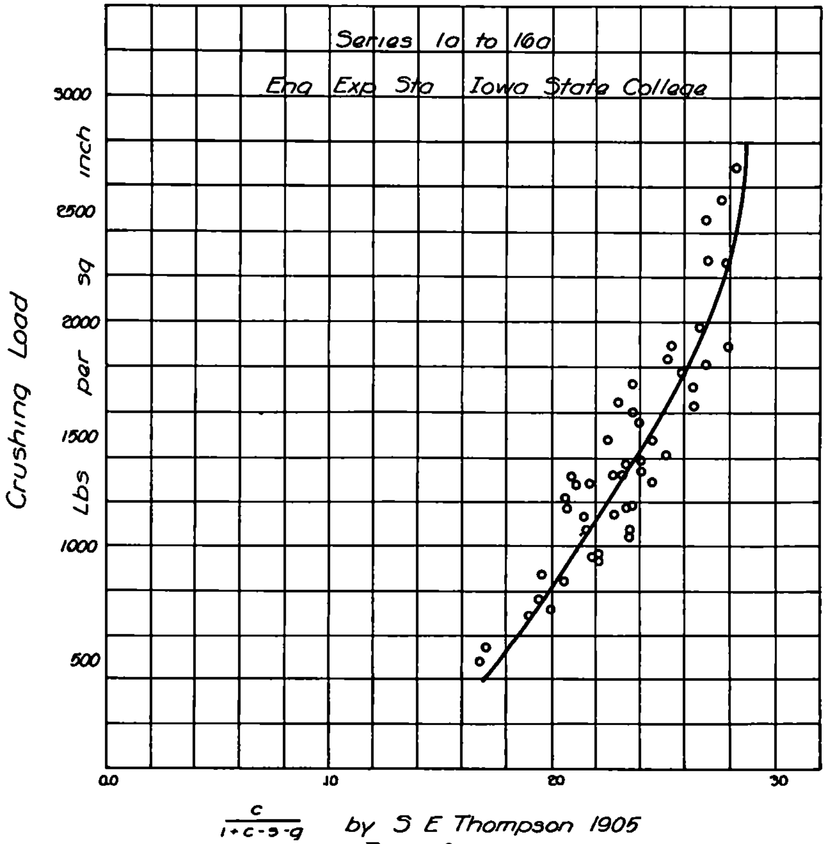

FIGURE 2

The fact having been established, that, for the same amounts of cement and aggregate, other conditions remaining the same, the strength of concrete varies with the amount of mixing water, it readily follows that concrete should be mixed with as little water as will yield a workable mixture for the use at hand. It has also been reasonably well established, other conditions being the same, that the grading of the aggregate has a decided effect upon the amount of water that may be used to yield a workable mixture We have here, therefore, an explanation of the benefit of using well-graded aggregates.

CONTROVERSIAL FACTORS

The various suggested methods of evaluating the sieve analyses of aggregates have not yet been reconciled or the fundamental laws fully established Concretes have been designed and made both experimentally and in actual construction, with success, by each of the various methods. The "Fineness Modulus,"[1] and the "Surface Area"[2] methods depend upon a complete sieve analysis

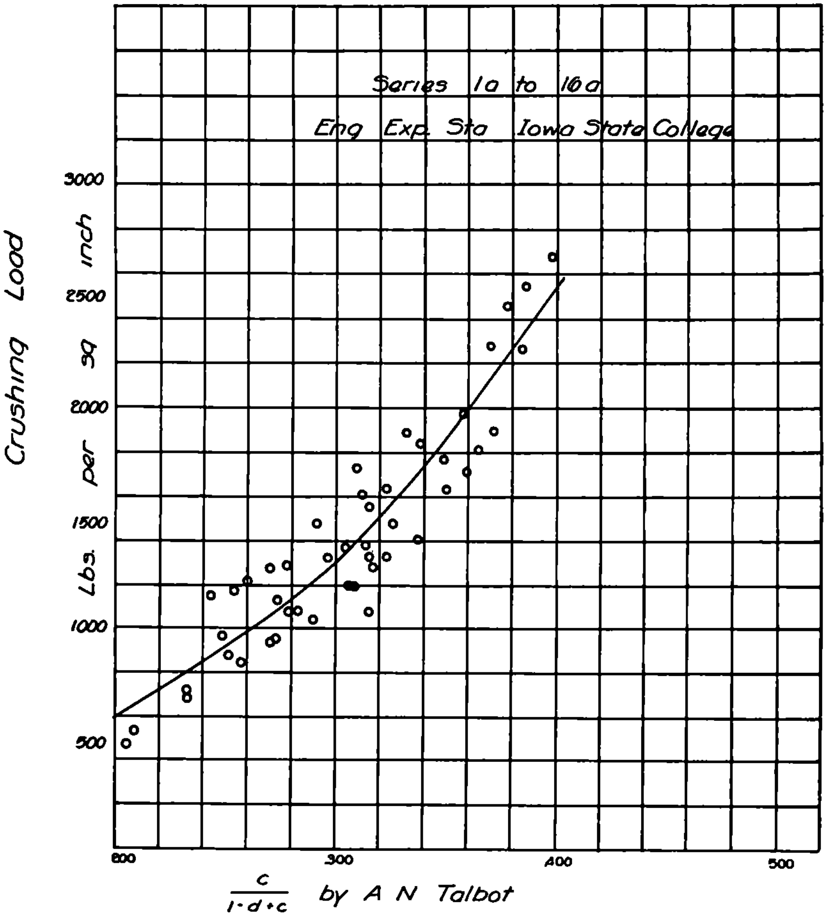

FIGURE 3

Professor Talbot's "Mortar Void Method"[3] depends upon the characteristics of the mortar portion of the concrete The Iowa Highway Commission[4] has used mixtures based upon the ratio of fine to coarse aggregate.

It can be shown that with materials from a given source, these various functions have definite relations with each other, but that with random materials from different sources, no such definite relations obtain. It is

[1] Bulletin No 1, Structural Materials Research Laboratory, Lewis Institute
[2] Proceedings A S T M, Vol 18, 1918, p 236
[3] Proceedings A S T M, Vol 21, 1921, p 940
[4] Bulletin No 60, Eng Exp Station, Iowa State College

probable that equivalent concrete mixtures can be designed by each method for aggregates generally similar, but varying in grading

Figures 6 and 7 show these relationships for two cases, (a) where the different aggregates were secured by mixing various amounts of the same fine and coarse aggregates, and (b) aggregates from different sources

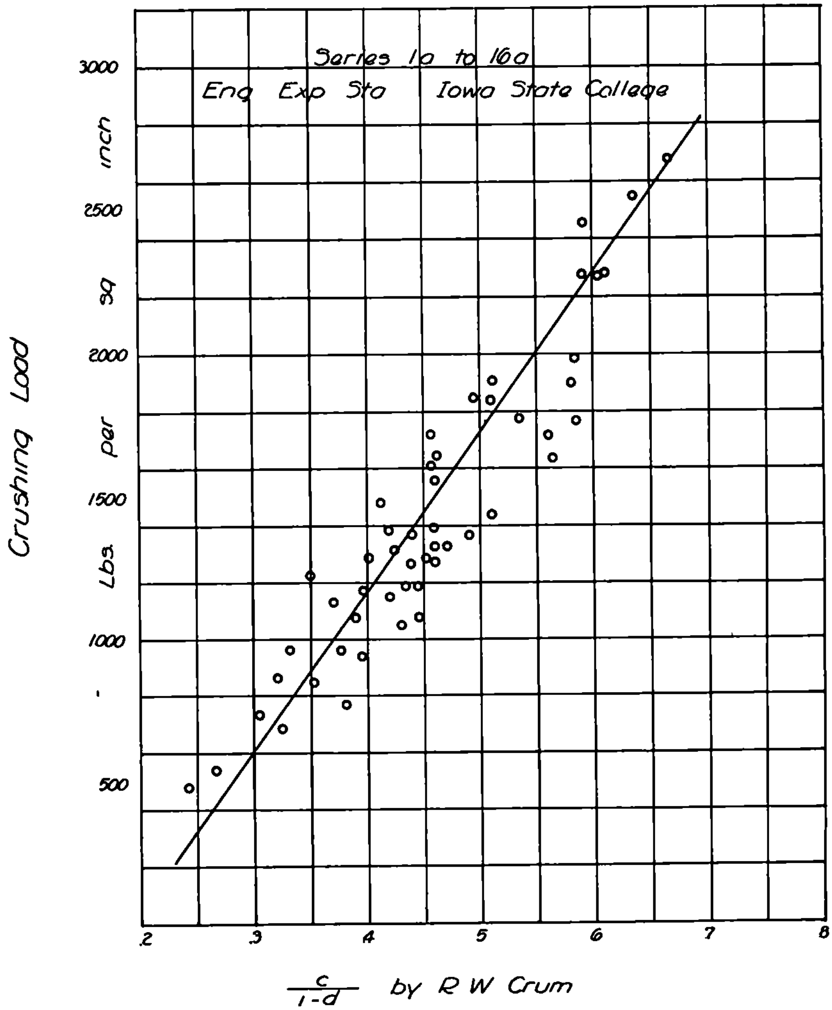

FIGURE 4

Figure 8 shows the proportions designed for the aggregates of case (a) for equivalent strength, by the three methods, Fineness Modulus, Surface Area, and the Sand Method of the Iowa Highway Commission, it being assumed that the right amount of water would be used in each case to maintain a uniform consistency.

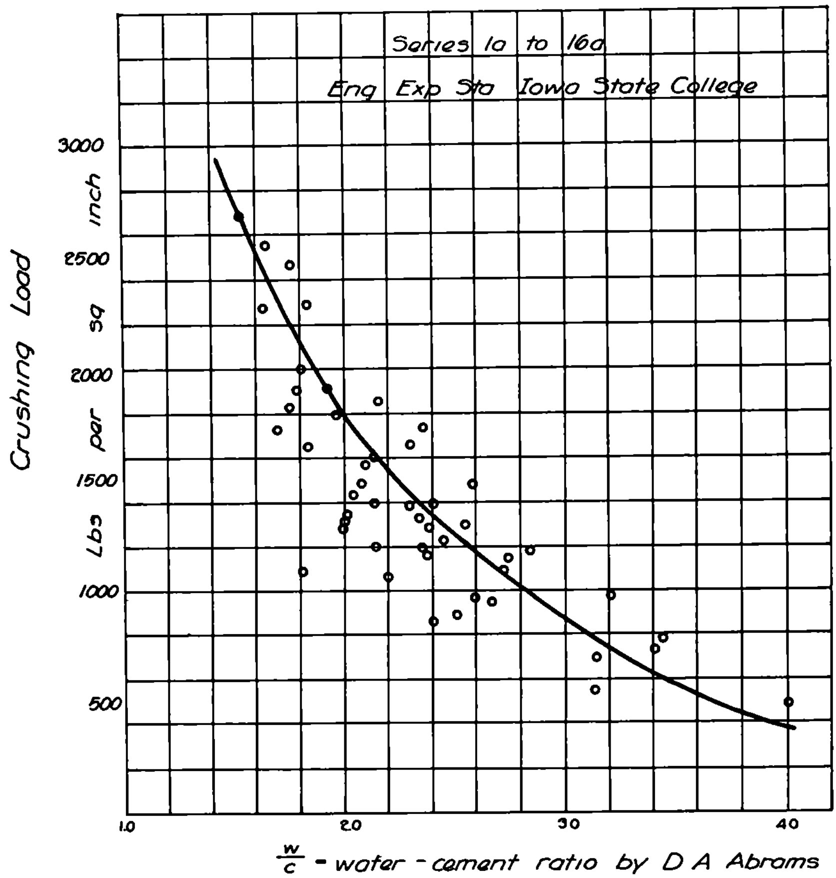

FIGURE 5

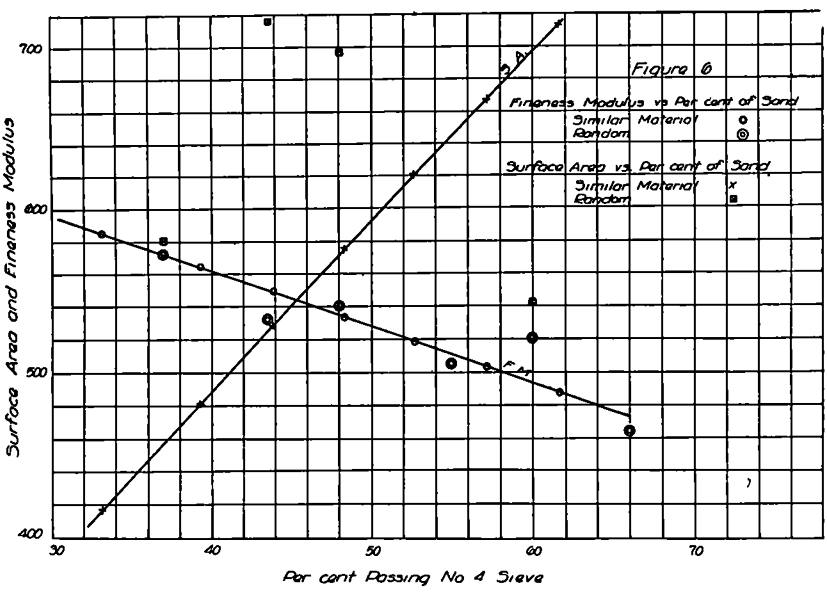

FIGURE 6

Further research is needed to harmonize the scientific data available and to finally evolve the best and most economical method for practical use, but it is doubtful if this end can be accomplished until better methods come into use for insuring uniformity in the concrete [1]

Figure 9, is typical of results noted upon a number of concrete paving jobs. The sieve analyses shown were obtained by taking samples of

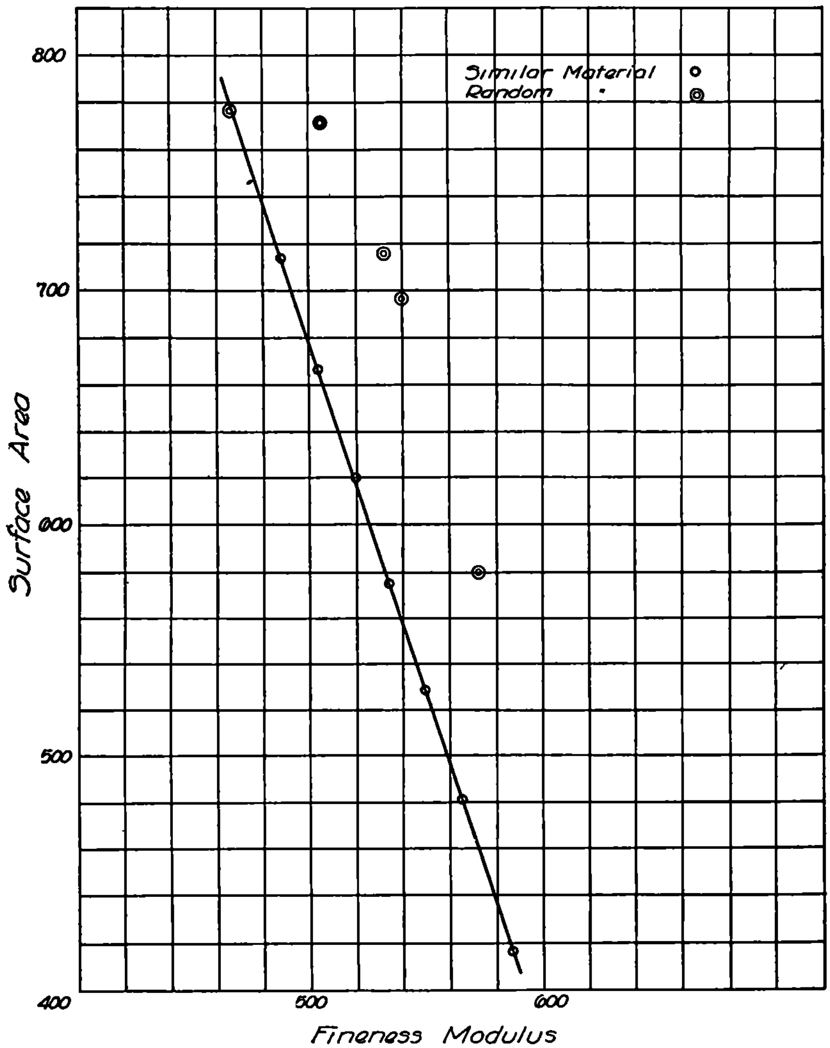

FIGURE 7

the green concrete, removing the cement by washing and running the analysis upon the remainder The wide variation from the intended analysis shown by the heavy line, must be overcome before exact

[1]For an interesting analysis of "Concrete Proportioning Theories" see paper by R B Young, Canadian Engineer, Nov 27, 1919

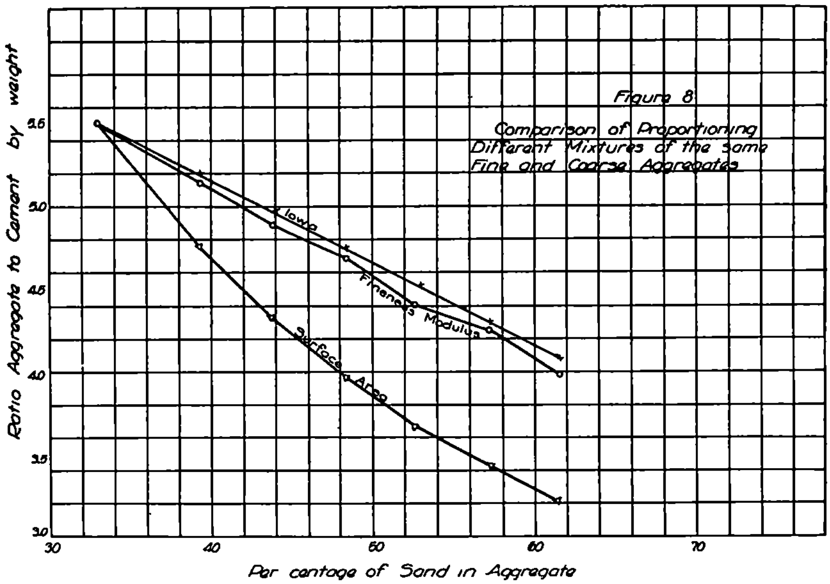

FIGURE 8

methods of design can be of full value In this case, the division between fine and coarse aggregate was intended to be on the No 4 sieve If the materials had been thoroughly screened and accurately measured in the required proportions, all of the curves must have passed very near the same point on the No 4 sieve ordinate, and the concrete would

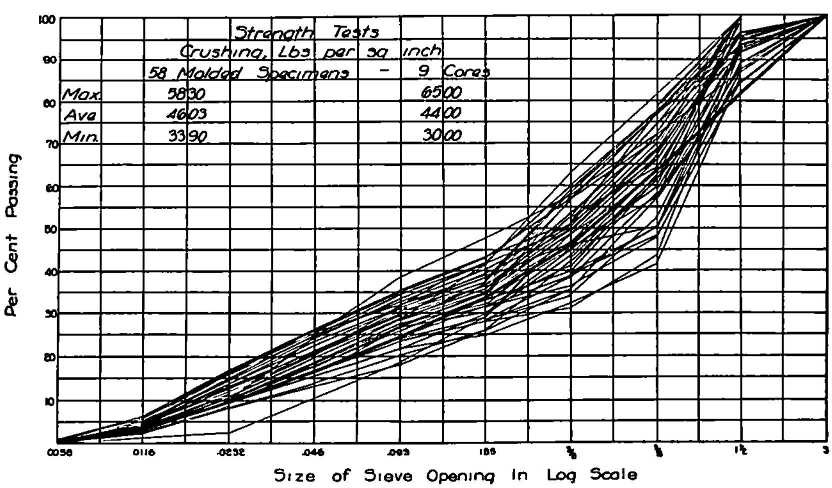

FIGURE 9

Material—Screened Sand and Gravel
Nominal Mix—1 2 3½ by Volume
Fineness Modulus—5 17 to 6 83

have been uniform as to aggregates and all of the concrete would have been in accordance with the design

At least two attempts are being made to overcome the variation in measuring The White Construction Company of New York uses a method devised by R L Bertin,[1] for measuring the aggregates and water simultaneously by measuring the aggregates in a vessel already containing a measured amount of water In this way, much more uniform volumetric measurements are made than would be possible with dry or damp granular materials The same method has also been used by the U S Navy Department, and checked by the U S Bureau of Standards

The Iowa Highway Commission is weighing the aggregates in pavement construction on a large scale, making correction for the moisture in the aggregates as often as necessary If, in this way, the grading of the aggregates as present in the finished concrete can be made to conform to a predetermined figure for any established point in the sieve analysis, the design of mixtures will be upon a much more reliable basis

RECOMMENDATIONS

The Committee recommends that research tending to coordinate the data now available be encouraged, and that research to develop methods of making more uniform concrete upon a large scale be strongly urged upon all interested agencies as a prerequisite to making effective use of the information already available on the design of concrete mixtures

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[1] A Method of Measuring Sands in an Inundated Condition, by R L Bertin, Proceedings, A S T M, 1922, p 404

Amer Conc Institute, Vol XVII, p 213, 1921 W K Hatt, R B Crepps Tolerance of Coarse Aggregate Passing ¼ inch Sieve as Affecting Specifications for Gravel Aggregates

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SIGNIFICANCE OF THE TALBOT-JONES RATTLER AS TEST FOR CONCRETE IN ROAD SLABS

H H SCOFIELD

Cornell University, Ithaca, New York

Tests of concrete that have been made to determine its resistance to wear have in the main been made with the Talbot-Jones rattler

The Structural Materials Research Laboratory, Lewis Institute, has published results of several investigations involving the use of this apparatus Their preliminary paper on this subject (See Proc A S T M, 1916, Part II) calls attention among other matters to the fact that (1) the concrete is subjected to a treatment which approximates that of service, (2) several tests may be made at the same time, and (3) test may be made on sections of concrete cut from roads which have been in service In the discussion of this paper, G P Hemstreet of the Hastings Pavement Company, stated that for ten years previously the Hastings Company had been using the Talbot-Jones apparatus for testing asphalt paving blocks Their results show that "material which shows up poorly in the rattler will invariably give poor results on the street"

In Bulletin No 2, Structural Materials Research Laboratory, it is shown that excess of mixing water produces concrete of greatest wear in this test There is, also, a relation between strength of concrete and its wear which may be expressed as follows $S = \frac{C}{W^n}$

where

S = compressive strength in lbs per sq inch,

W = wear in inches, C = a constant, and n = an exponent

In two investigations reported, $C = 2230$ and 1800, and $n = 1\ 07$ and $1\ 30$ respectively

In Bulletin No 8 of the Structural Materials Research Laboratory, the Talbot-Jones rattler was used in an investigation, the conclusion with respect to wear is as follows "The wear of concrete was not sensibly increased by hydrated lime or other admixtures up to 20 per cent of the volume of the cement"

In Bulletin No 10 of the Structural Materials Research Laboratory, entitled "Wear Tests of Concrete," the conclusions of significance among others are these (1) "The wear on separately moulded concrete blocks tested in the Talbot-Jones rattler was much more severe than any encountered in service, however, the test is believed to give trustworthy information on the wearing resistance of concrete of various proportions,