REPORT OF COMMITTEE ON MATERIALS AND CONSTRUCTION

H S MATTIMORE, *Chairman,*
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THE EFFECT OF HOT CEMENT ON TIME OF SET AND WORKABILITY OF CONCRETE

PROGRESS REPORT

H S MATTIMORE, *Project Chairman*

SYNOPSIS

Under certain conditions cement received on the work retains considerable of the heat generated during manufacture Occasional temperatures as high as 150° to 200° F have been noted The purpose of this investigation is to ascertain what effect this heat has upon the setting time of the cement and the workability of the concrete in highway work The report includes the comparative setting time of at least four different cements at temperatures of 70°, 100°, 150°, and 200° F, mixed with water at 70°, 100°, and 150° F The set is recorded at twenty-five minutes, forty-five minutes, and at ten minute intervals thereafter until initial set is attained In order to simulate severe field conditions the specimens were stored in air at 100° F, with controlled humidity of from forty-five to fifty per cent Tests of the workability of concrete made with cement and water at the same temperatures as in the setting tests are also reported

It has been reported that cement ranging in temperature from 150°F to 200°F has been received on certain construction projects Naturally the engineers are interested in knowing how the quality of the work will be affected if cement is used at these high temperatures The condition may be aggravated by the temperature of the water, the temperature and humidity of the air and the character of the subgrade

Some tests by individual laboratories have indicated that hot cement affects the setting time, and workability of concrete and some engineers specify as a safety measure that cement having a temperature in excess of 125° F shall not be used

The purpose of the committee in making this investigation was to ascertain the effect upon the setting time of cement of mixing cement and water at several different temperatures higher than the normal laboratory temperature of 70° Tests were also made to show the effects of high temperatures upon the workability of mixed concrete as measured by the flow table and slump

TIME OF SET

Five laboratories cooperated in the work and tests were made upon the product of twenty cement mills The results indicate that the use of hot cement has the effect of shortening the setting time In order to determine the effect under a severe atmospheric condition, the test specimens for time of set were stored in air at a temperature of 100°F , and with the humidity between 45 and 50 per cent Such conditions are encountered during highway construction This investigation definitely shows that both hot cement and hot water result in shortening the setting time of the cement, as compared with the standard normal temperature of 70°F Figures 1 and 2 illustrate the magnitude of these effects

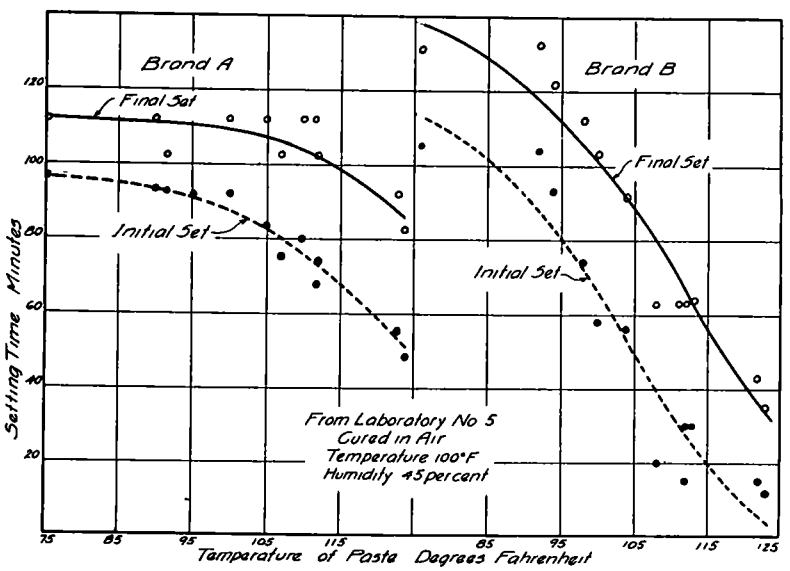

Figure 1. Effect of Temperature of Cement Paste upon Time of Set

NORMAL CONSISTENCY

The percentages of water needed for normal consistency of the cements of the standard 70° temperature were used in most of the time of setting specimens regardless of any possible effect of higher cement and water temperatures A few tests were made in which the amount of water necessary to produce paste of normal consistency with the materials at the higher temperatures was used In these cases also a shortening of the setting period was noticed

Figure 3 shows the effects upon the amounts of water needed for normal consistency of cement paste, of varying the temperatures of the cement and water Four different cements, one of which was a high early strength brand, were used

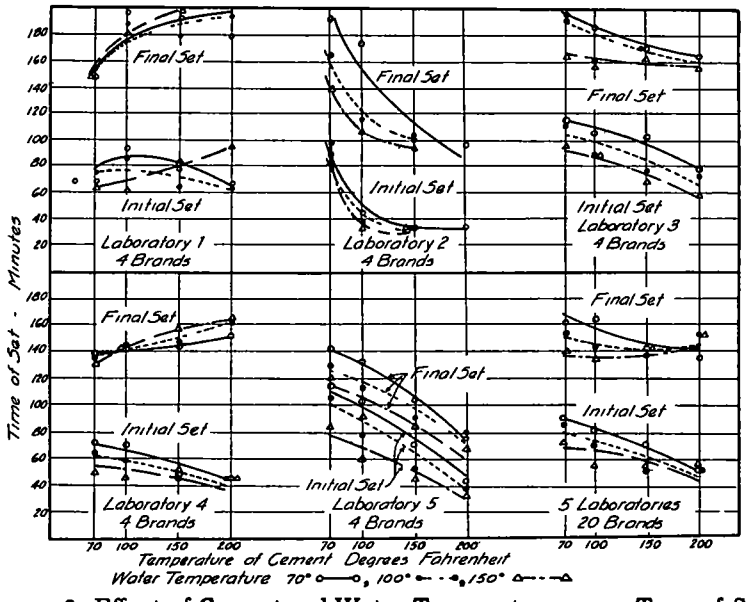

Figure 2 Effect of Cement and Water Temperatures upon Time of Set

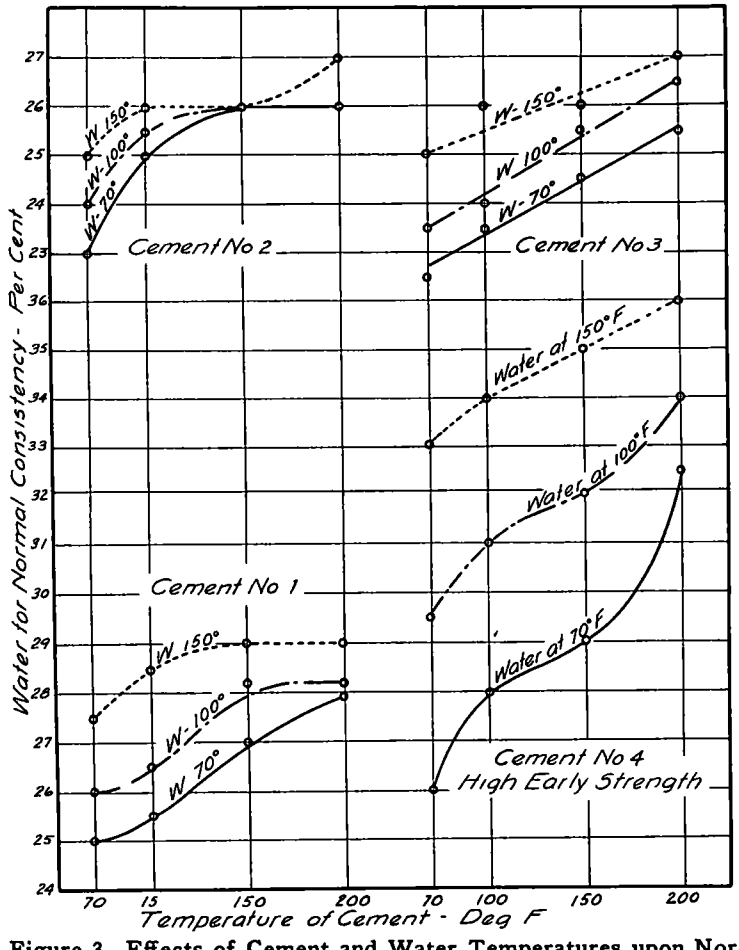

Figure 3 Effects of Cement and Water Temperatures upon Normal Consistency. Data from Laboratory Number 1

WORKABILITY OF CONCRETE

The investigations on workability of concrete were made with water and cement heated to the same temperatures as those used in the setting time experiments, but it was not practicable to expose the specimens to other than room temperatures and humidity Tests were made on the flow table immediately after the batch of concrete was

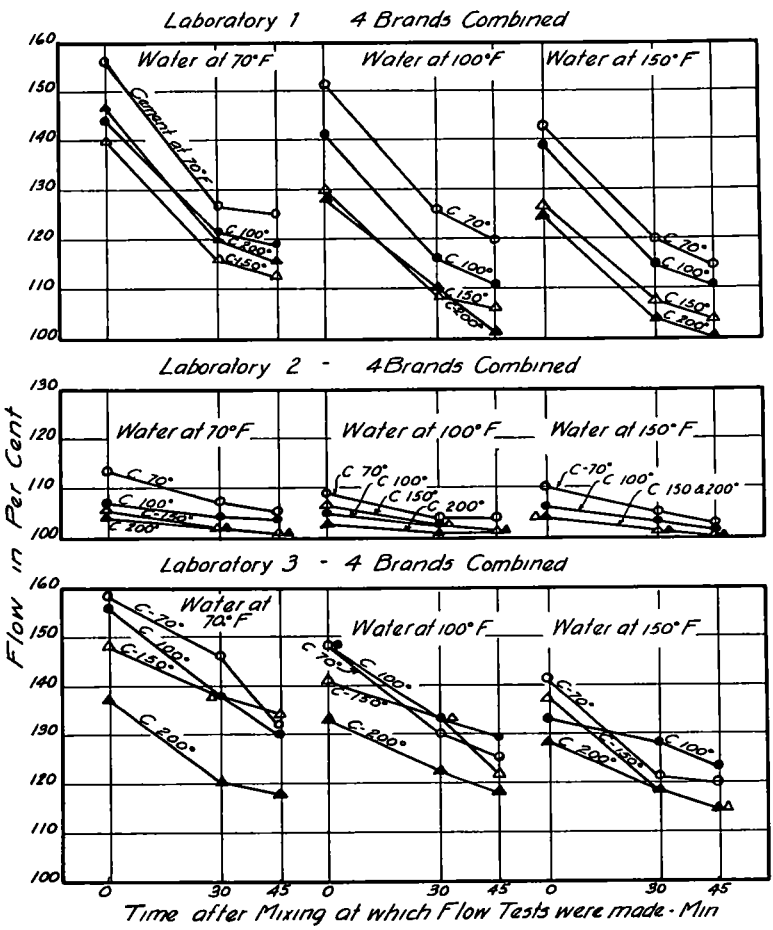

Figure 4A. Effect of Water and Cement Temperatures upon Consistency

mixed and at intervals of thirty and forty-five minutes thereafter These tests show that both the heated water and cement affect the flowability At the thirty and forty-five minute intervals some of the mixtures, especially those with cement and water heated to 150°, did not give any flow, but acted rather as crumbly masses The effects upon flow are shown in Figures 4a and 4b. The effects of higher temperatures upon slump as shown in Figures 5 and 6 are somewhat

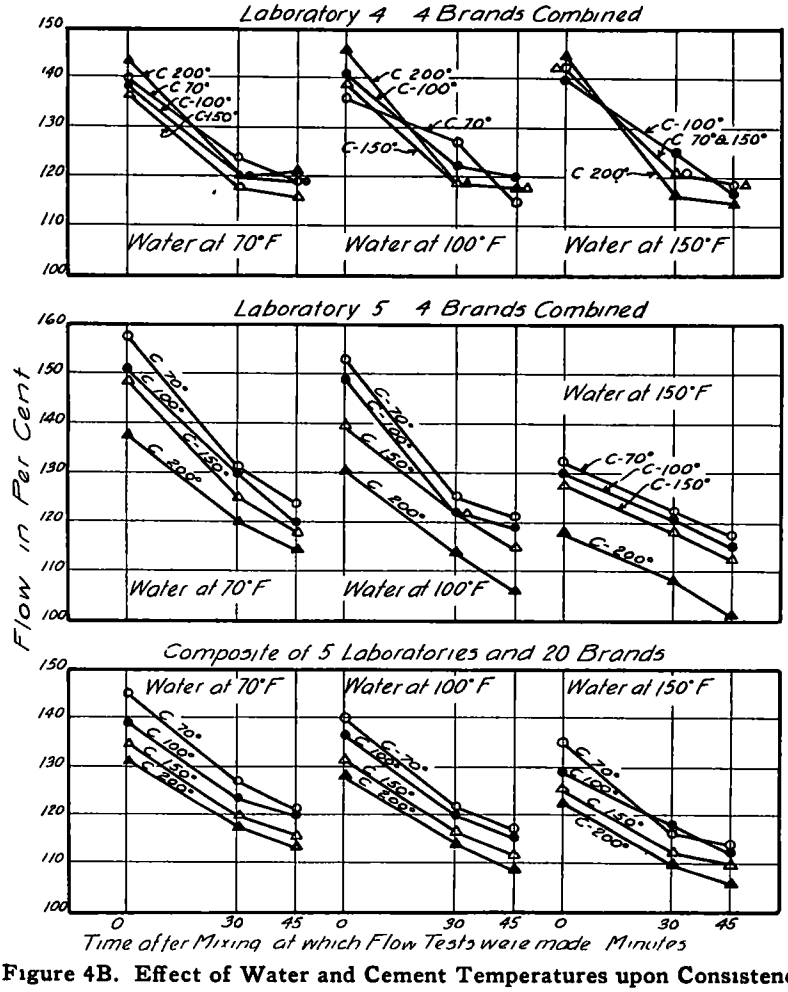

Figure 4B. Effect of Water and Cement Temperatures upon Consistency

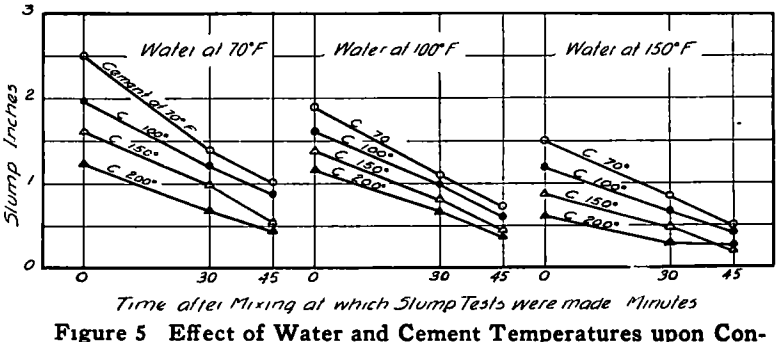

Figure 5 Effect of Water and Cement Temperatures upon Consistency. Slump Test. Composites of 8 Brands from Laboratories 2 and 3

more indicative of the actual conditions observed This condition would have been better illustrated if wetter concrete had been used

In this investigation when cement at 150° was used in concrete, it affected the flowability to such an extent that it might not be considered workable thirty and forty-five minutes after mixing This is an important point because in the construction of concrete highways it is not unusual for the manipulation to be carried on for forty-five minutes after the concrete has been discharged from the mixer This may result in effects similar to those caused by the so-called late working of concrete, and may cause scaling or other defects

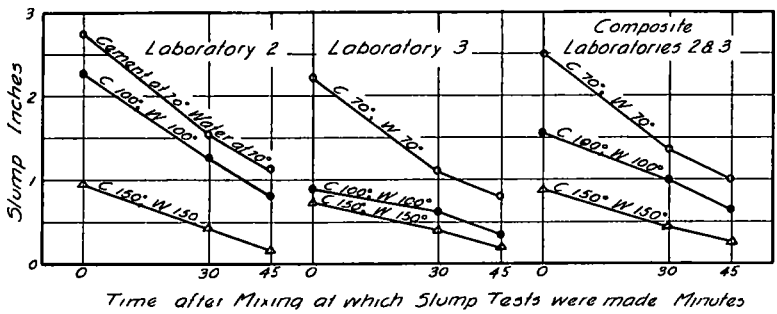

Figure 6 Effects of Various Combined Temperatures of Cement and Water upon Consistency Slump Tests Four Brands of Cement Combined at Each Laboratory

The committee considers that these data justify conclusions as follows

CONCLUSIONS

1 With a constant water cement ratio, increase of temperature of concrete, decreases workability

2 Increasing temperature of cement paste accelerates the initial and final set

RECOMMENDATION

In view of these conclusions, the committee recommends that a maximum allowable temperature be included in specifications for concrete

DISCUSSION ON HOT CEMENT

ABSTRACTED

Mr P D Miesenhelder, *Assistant Chief Engineer in Charge of Materials and Tests, Indiana State Highway Commission* The effect of hot cement was studied on a concrete pavement project in northern Indiana in the summer of 1931. Observations were made of the work-

ability, compressive strength, transverse strength, volume changes, checking, cracking, and temperature of the concrete Although the tests have not all been completed at this time, the data thus far secured do not indicate under the conditions existing on this job that the use of hot cement, at a maximum temperature of 167°F is of consequence on a road paving job with respect to workability, compressive strength, volume change, checking, and cracking The modulus of rupture was somewhat reduced, especially at early ages As this reduction becomes less with increasing age, the indication is that at later ages the moduli for concrete made with hot and cold cement may be the same.

MR W H KLEIN, *Penn-Dixie Cement Corporation* Attention was called to the possibility that it might prove to be more expensive in the end to control the temperature of the cement than to control some of the other factors Mr Klein also suggested that since evaporation of water from freshly mixed concrete affects the results at the higher temperatures, it might be permissible in extremely hot weather to increase the water to compensate for the evaporation

MR IRA PAUL, *New York State Department of Public Works* Tests in the New York State Laboratory on mortars in which the temperature of the cement used varied from 68 to 160°F. and that of the water from 60 to 100°F showed practically no effect of hot cement or warm water on the time of set and strength. It was found that in order to obtain the same consistency and workability of a concrete mixture with the cement and water at elevated temperatures, as that obtained with the same materials at lower temperatures, it was necessary to add more water

MR R B GAGE, *New Jersey State Highway Department* Whether or not high cement temperature is an adverse factor appears to be questionable Some cement was delivered to a pavement job in New Jersey located not far from the cement mill which was so hot that the workmen had to wear gloves in handling the bags, although on test it complied with the specification requirements Observations on pavements now three and four years old have not disclosed any adverse results attributable to the use of this hot cement Mr. Gage also called attention to the fact that differing characteristics of different cements appear to have much greater effects upon consistency or workability than do differences in temperature. Cements differ greatly in their characteristics For instance, in one case the addition of more water to overcome premature hardening and permit proper finishing of the concrete does not decrease the strength, while the use of such excess water with other cements would lower the strength materially.

MR. E W BAUMAN, *Engineer of Tests, Tennessee Department of Highways and Public Works* The source of the heat in cement, whether the kiln or the mechanical effect of grinding, appears to be of some importance Samples of cement made from (1) clinker direct from the kiln, (2) a mixture of 50 per cent clinker from the kiln and 50 per cent from the storage pile, and (3) clinker from the storage pile after aging, gave decidedly different results in soundness tests. The pats from the sample obtained from clinker direct from the kiln (1) were all unsound, whereas the others (2 and 3) were sound

MR W H MILLS, JR, *Testing Engineer, South Carolina State Highway Department* On account of trouble experienced in the summer of 1921 in finishing concrete pavements, due to the use of hot cement, a series of tests was conducted on two brands of cement in order to study the effects of the temperature of the cement on setting time, water ratio and strength From these tests, it was definitely established that the setting time and the normal consistency are directly affected by the temperature of the cement and the results check very closely with those reported by Mr Mattimore The results of tests on mortar briquettes and on concrete beams and cylinders in which hot cement was used were not definite and additional tests will have to be made before any conclusions can be drawn However, it was noted that the additional mixing water required for cement up to 150°F did not increase the water cement ratio enough to weaken the concrete materially, but the majority of the data showed a rather marked decrease in strength when the temperature of the cement used was more than 175°F Graphs of these data are shown in Figures 1, 2, and 3

From the tests made it was concluded that the principal objection to the use of hot cement was the difficulty experienced in finishing the concrete due to the acceleration in setting time

Mr Mills does not believe that the recommendations made by the committee, that a maximum temperature of concrete for use should be specified, is sufficient His experience leads to the belief that the temperature of the cement has much more effect upon the setting time of concrete than has the temperature of any other ingredient

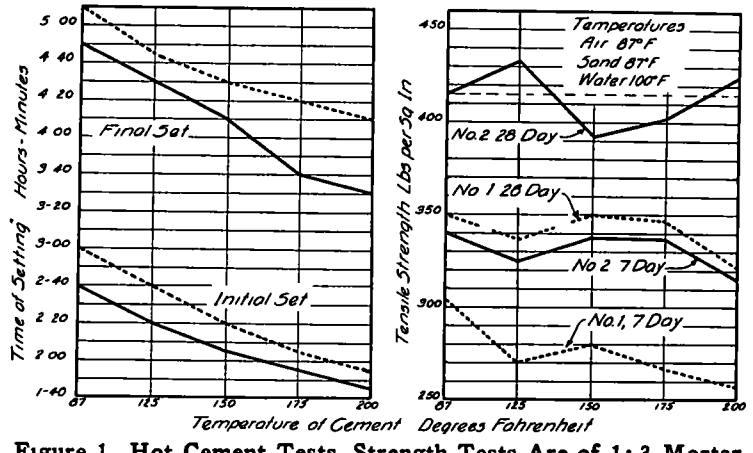

Figure 1 Hot Cement Tests, Strength Tests Are of 1: 3 Mortar. Each Value is the Average of Three Breaks

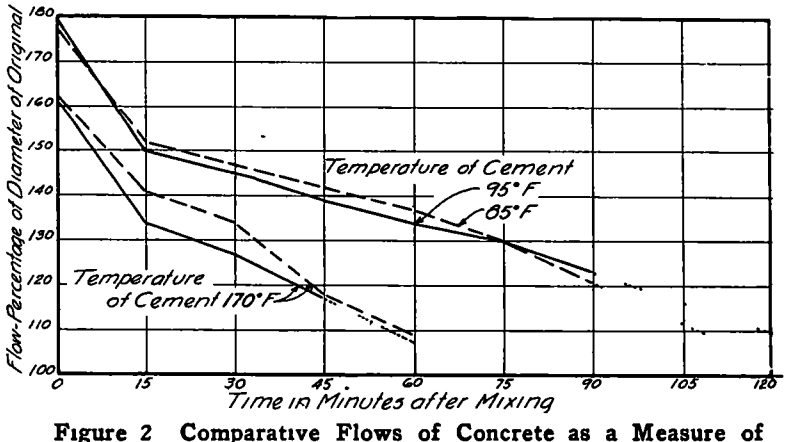

Figure 2 Comparative Flows of Concrete as a Measure of Consistency for Concretes Identical Except for Temperatures of Cement, Air at 85° F. Aggregates at 85° F. Water at 100° F. 1: 2: 4 Mixture. Any Horizontal Line Shows the Difference in Time for the Same Workability as Affected by the Temperature of the Cement

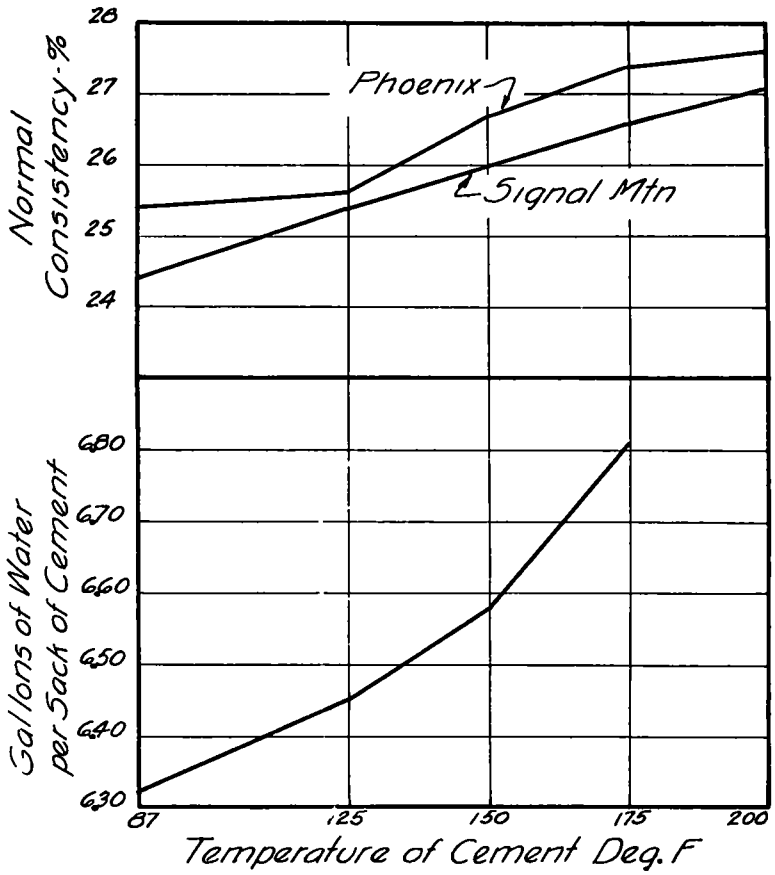

Figure 3. Effect of Cement Temperature upon Normal Consistency of Cement, and upon Amount of Water Required to Produce Equal Flows in 1: 2·4 Concrete

RESISTANCE OF CONCRETE TO FROST ACTION AS AFFECTED BY THE WATER-CEMENT RATIO

F H JACKSON, *Project Chairman,*
Engineer of Tests, U S Bureau of Public Roads

SYNOPSIS

On account of the growing tendency in some localities toward decreasing the amount of cement in concrete for highway use on the assumption that strength is the controlling factor, the committee has reviewed the evidence concerning, the relation between resistance to frost action and water-cement ratio, the maximum water-cement ratio allowable for concrete exposed to the weather, and the relation between strength and durability The available test data show a decided relation between water-cement ratio and durability