REPORT OF PROJECT COMMITTEE ON CURING OF CONCRETE PAVEMENT SLABS

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INTERMITTENT CURING OF CONCRETE

BY F C LANG

SYNOPSIS

This is a progress report of experiments designed to show the effect upon concrete, from the standpoint of curing, of alternate wetting and drying The data appear to indicate that the amount of mixing water retained in the concrete during the curing period is an important factor in curing, and that satisfactory curing may be obtained in humid areas with a comparatively short initial wet curing period

Curing concrete pavements continuously for a number of days with water either by keeping a blanket of earth, straw or similar material saturated or by ponding has been considered the standard for comparing other curing methods The committee, however, has noticed that on most field curing experiments the 24 to 72 hours of wet burlap has given as good results as the longer periods of curing with water This indicates the possibility of a short water curing period being adequate, particularly in those areas having considerable rainfall If a short curing period is sufficient, then concrete must continue the curing action when it is wet by rain after a dry period A laboratory investigation was made by the Minnesota Highway Department in conformity with an outline approved by this committee to ascertain the effect of alternate wetting and drying on the strength of the concrete

The investigation included 240 compression tests on 6 by 12 inch concrete cylinders and periodic weights on 60 cylinders One-half the cylinders were made with a normal hardening portland cement, and one-half with a high early strength portland cement The same aggregates and the same consistency of concrete were used for all cylinders The mix, which was 1 2 79 4 95 by absolute volumes was somewhat harsh

The different initial curing periods and the subsequent treatments are shown in Figure 1 The initial curing periods of 1, 2, 3, 7, and 21 days under water, which included one day under wet burlap in the molds, were chosen because they correspond to the initial wet curing period which a concrete pavement might receive For each of these initial curing periods a concrete cylinder was made up on four different days for each of the six subsequent curing treatments This required 120 cylinders for each kind of cement

The subsequent curing treatments were.

No 1 Continuously under water For this series, and this series only, all the initial curing periods are the same

No 2 Repetitions of two days in laboratory air and one day under water

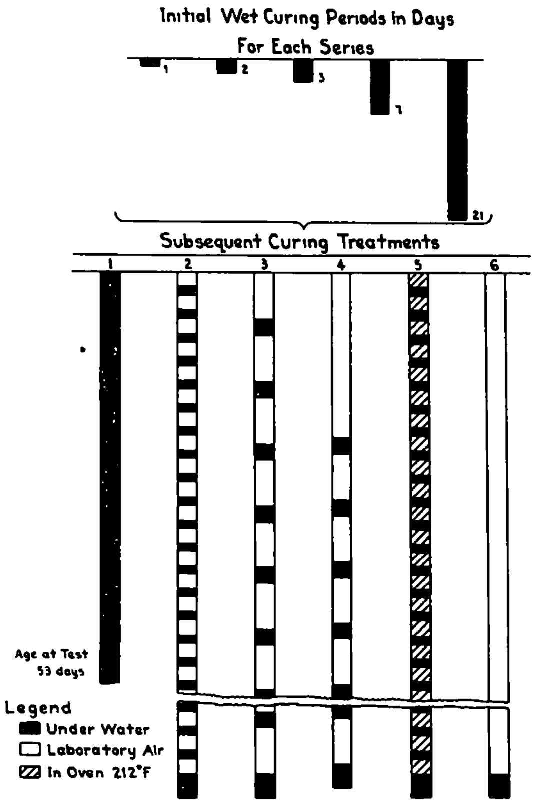

Figure 1. Initial Curing Periods and Subsequent Treatments Age at Test About 175 Days

No 3 Repetitions of six days in laboratory air and two days under water

No 4 Following the initial curing period the cylinders remained 21 days in the laboratory air after which there are repetitions of two days under water and six days in the laboratory air.

No 5 Repetitions of two days in the oven at approximately 212°F. and one day under water.

No 6 Continuously in the laboratory air after the initial curing period

The 20 specimens in treatment No 1 were tested at an average age of 53 days which corresponds approximately to the number of days that the cylinders in treatment No 3 were under water

All specimens were under water for at least 72 hours before testing

The laboratory air temperature during the test averaged about 80°F, the temperature of the water in which the specimens were submerged averaged about 74°F, the relative humidity of the laboratory air averaged about 51 per cent, and the temperature of the drying oven was set for 212°F

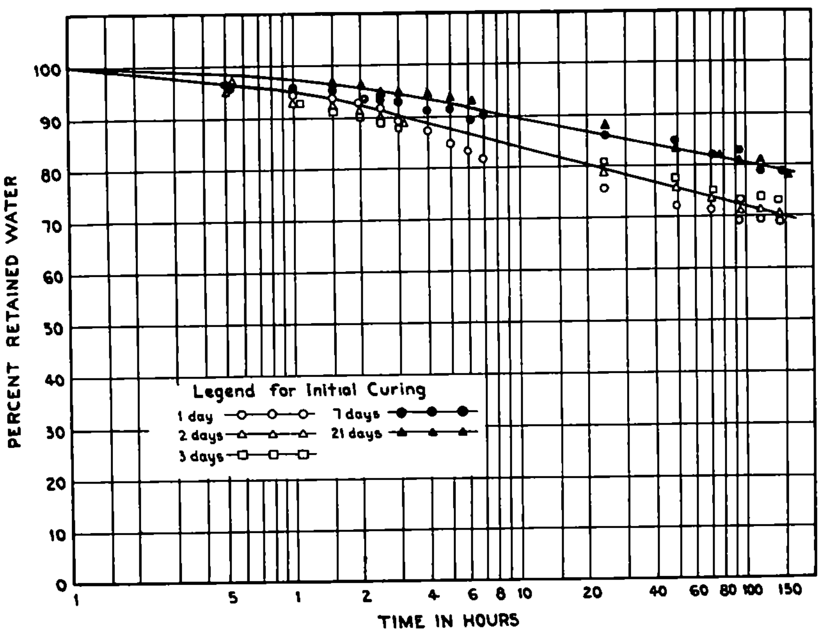

Figure 2. Relation Between Percentage of Retained Water and Drying Time

As shown in Figure 2 which was constructed from data obtained on cycle No 3 a straight line relationship is shown between the percentage of retained water and the logarithm of the time for the drying period This straight line relationship was found for all drying periods both in the laboratory and the oven There was also a straight line relationship between the percentage of retained water and the logarithm of the time when the cylinders were immersed in water The percentage of retained water is based on the ratio of the water in the specimen to the original mixing water

The increase in percentage of retained water with age or number of repetitions for treatment No 3 is shown in Figure 3. This is for repetitions of six days in laboratory air and two days under water. This shows that the percentages of retained water for each initial curing period fall on a straight line where the horizontal scale is the logarithm of the age The percentage of retained water increases with the length of the initial curing period but the lines are converging which indicates that with a sufficient number of repetitions the lower line, which represents an initial wet curing period of one day, may have the same percentage of retained water as the upper line, which represents an initial wet curing period of 21 days It will be shown later that the compressive strength increases as the percentage of retained water increases

This graph is typical of all the intermittent treatments except that on treatment No 5, which was the one where the specimens were dried

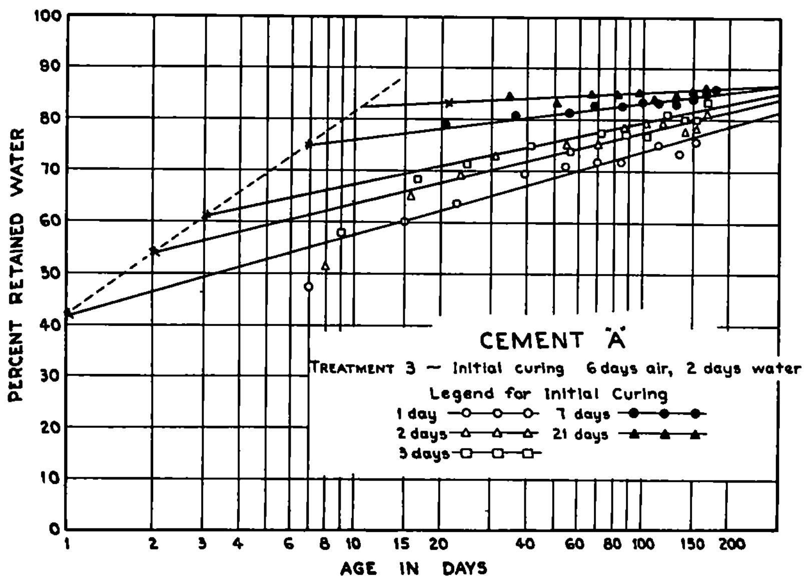

Figure 3 Relations Between Percentage of Retained Water and Age or Number of Repetitions of Treatment No 3

in the oven The data were not so regular on that treatment The retained water for the initial treatment of seven days which is typical of the others was about 65 per cent at 150 days whereas on treatment No 3 it was about 83 per cent Within the limits of this test it is not possible to determine the maximum percentages of retained water for any of the treatments At the final age all of the lines are pointing upward The percentages of retained water for the special portland cement were somewhat higher than for the normal portland but otherwise the graphs are very much the same

Figure 4 shows vertically the compressive strength and horizontally the days of initial curing plotted to a logarithm scale The compressive strength test was made on the cylinders for all treatments at 175 days of age except on those for No 1, which were about 53 days old This shows that for treatments No 2 to 6 inclusive the compressive strengths for each curing treatment fall on a straight line and that within the limits of this test the longer the initial curing period the stronger the concrete This appears to favor the long initial curing period and undoubtedly it does produce a stronger concrete at early ages and would be desirable for arid areas Treatment No 6 where the cylinders remained in the laboratory air has much lower strengths than the intermittent treatments No 2, 3, and 4 This shows that the intermittent curing has been decidedly beneficial

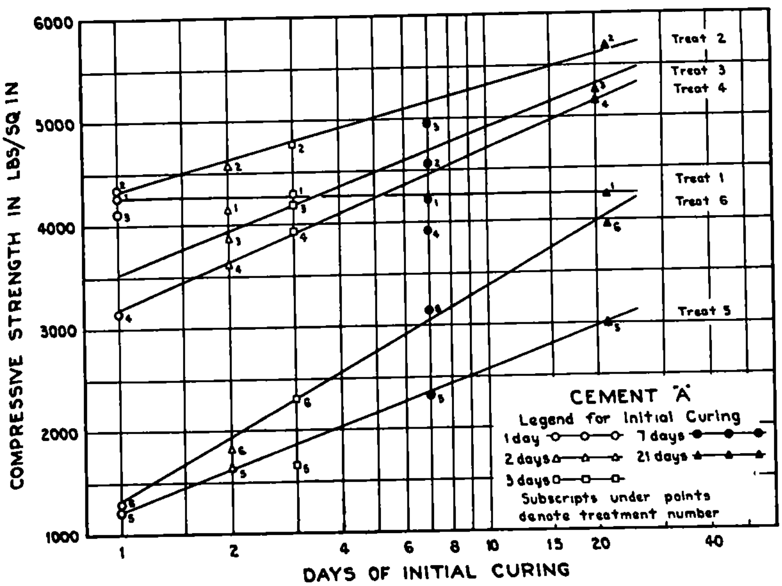

Figure 4. Relations Between Compressive Strength and Duration of Initial Curing

Treatment No 4 which remained in the laboratory air for 21 days after the initial curing period shows a big increase in strength over treatment No 6 which was stored continuously in air after the initial curing periods The one day initial curing with all the intermittent series is stronger than the seven day initial curing for treatment No 6 where the subsequent curing is in the laboratory air On treatment No 1 the test was intended to be made to correspond to the number of days that the cylinders in treatment No 3 were submerged This was not quite realized The specimens in series No 1 were under water all the time. In as much as there is no difference in initial curing periods the results plot on a horizontal line In treatment No 5 the specimens were placed two days in an oven at 212°F and then one day under water The cylinders were taken directly from the oven and submerged and also were placed in the oven immediately after being taken out of the water This sudden change resulted in considerable checking which probably lowered the strength This is, of course, much more violent treatment

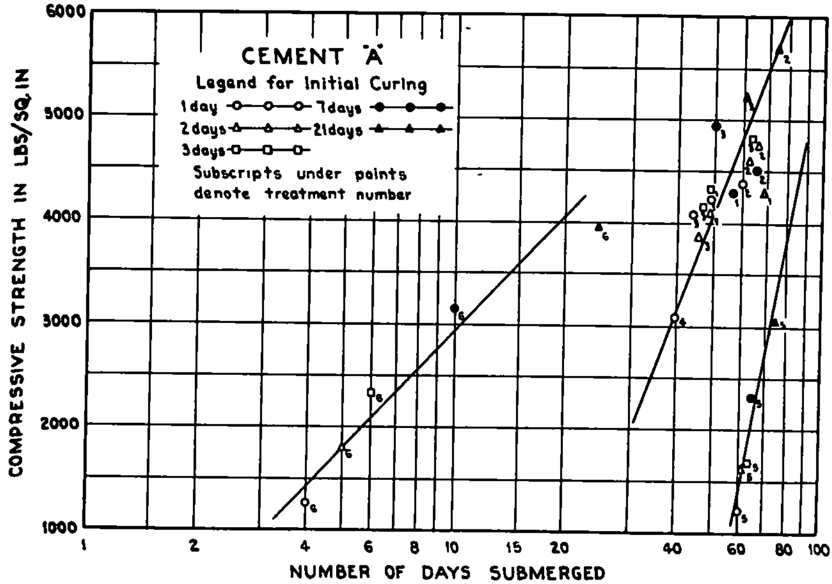

Figure 5. Relations Between Compressive Strength and Length of Time Specimens were Submerged

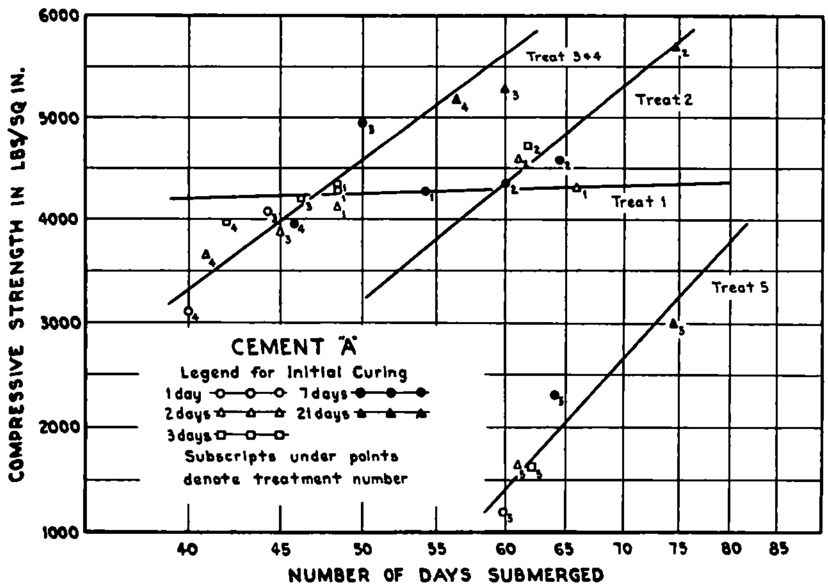

Figure 6. Relations Between Compressive Strength and Length of Time Specimens Were Submerged

than a concrete pavement would ever be subjected to and the results are of doubtful value, on the other hand outside exposure may be more severe than treatments No 2, 3 and 4

In Figure 5 is shown the relationship between the compressive strength of the concrete and the number of days that the specimens were submerged The points representing the intermittent treatments (2, 3 and 4) of submergence and drying in laboratory air and for the treatment (1) where the specimens remained under water lie approximately on a straight line

The points for the treatment (6) where the specimens remained in the laboratory air continuously after the initial curing periods are on the

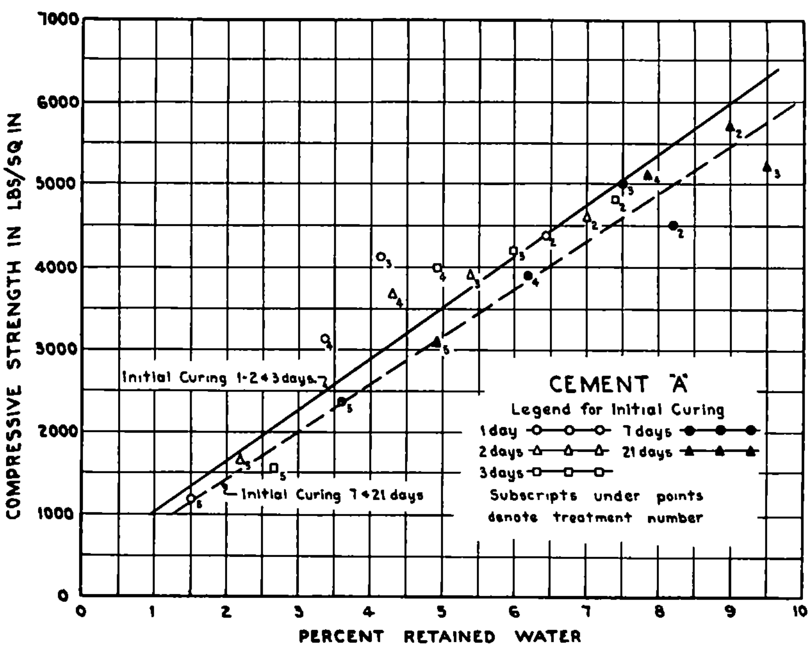

Figure 7. Relations Between Compressive Strength and Amount of Retained Water

line to the left and for the treatment (5) where the specimens were dried in the oven the strengths are shown on line to the right and are lower as might be expected

The data shown for the 40 to 85 day period in Figure 6 are the same as in Figure 5 only drawn to an expanded horizontal scale This shows that for any given number of days submerged the compressive strengths of the treatments which were alternately submerged and exposed to the laboratory air (2, 3 and 4) are higher than for the treatment where the specimens were continuously submerged (1) This is no doubt due to the curing action taking place after the wet specimens were placed in the laboratory air

As treatments 3 and 4 gave higher strengths than treatment 2 it appears that more cement is hydrated during a six day drying period than during a two day period The 21 day drying period which followed the initial curing period on treatment No 4 apparently did not in any way prevent the hydration of the cement when the specimens were again placed under water This is probably a longer and more severe drying period than concrete pavements would ever be subjected to in most sections of the United States Weather records will show that it rains at much more frequent intervals, also on most subgrades some water for curing purposes is probably obtained by capillarity from the subgrade

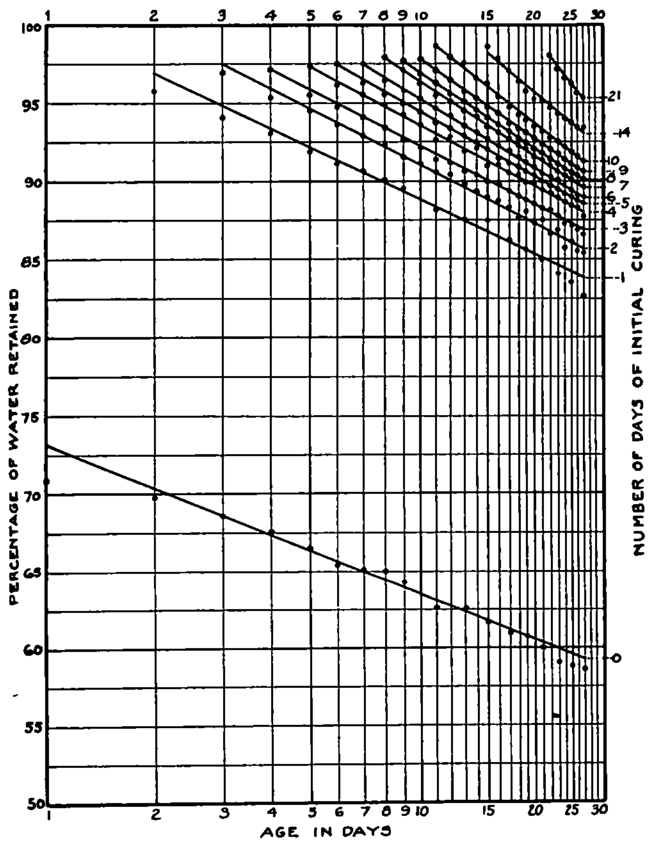

Figure 8. **Relations Between Amount of Mixing Water Retained, Duration of Initial Curing Period and Age of Concrete**

In Figure 7 is shown a very definite relation between the strength of the concrete and the percentage of retained water according to data obtained in this investigation for the intermittent treatments (2, 3, 4 and 5) It is interesting to note that the treatment with the oven drying (5) appears to check the other intermittent treatments.

The data used for constructing Figure 8 were obtained from an interesting investigation made at the laboratory of the Iowa Highway Commission Mortar slabs 13 by 14 by 2 inches were poured and left in pans. The slabs were cured under wet burlap in an incubator for the initial curing periods shown At the end of the initial wetting period the specimens were allowed to dry out in an incubator where the temperature was controlled between 92 and 100°F with an average of 95 8°F and the relative humidity varied from 30 to 40 per cent with an average of 38 5 per cent This diagram shows that the points representing the percentage of retained water for the different initial curing periods are on a straight line, and also the importance of the first day's curing The mortar slabs were sawed up and flexural tests made on 2 by 2 inch beams and compression tests on 2 inch cubes at 28 days age All specimens were immersed in water for 24 hours The strength corresponded to the percentage of retained water

This is submitted as a progress report In its 1929 report this committee stated, "There is evidence to indicate that the amount of mixing water retained in the concrete during the curing period is an important index to the effectiveness of the various curing methods " These data appear to corroborate this statement The committee is also of the opinion that these data indicate that satisfactory curing may be obtained in humid areas with a short initial wet curing period In some localities where climatic conditions are favorable this may be 24 hours The committee expects to continue the investigation

THE USE OF PAPER FOR CURING CONCRETE PAVEMENTS

By Mark Morris

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SYNOPSIS

A review of data relating to the use of specially prepared paper as a curing medium, obtained from pavement construction in Missouri, Minnesota and Iowa and from laboratory experiments The experience thus far indicates that within certain limits as to number of repetitions of use, the paper will serve to retain the moisture in the concrete and the concrete will attain strength that compares favorably with that from other curing methods in common use

THE PAPER

Papers prepared for use in curing concrete pavements are of two types, those consisting of a single sheet of paper, heavily impregnated and thoroughly coated with waterproof waxes particularly adapted to this purpose, and a compound type composed of two or more single sheets of paper cemented together with asphalt and reinforced with a network of string, twine, or a thin, open layer of vegetable fibers