

## CHAPTER 5

# THE USE OF PAPER FOR CURING CONCRETE PAVEMENTS

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In the 1932 report<sup>1</sup> on this subject, reference was made to the fact that the practical use of paper for curing concrete pavements was too recent to permit the evaluation of its effects upon hair cracking, transverse cracking, surface hardness, scaling, permeability and durability. Since it is but three years since observations were begun on full scale field projects, insufficient time has elapsed for the full development of some of these characteristics. A report at this time must, therefore, be a progress report for the presentation of new data, and for the interpretation of both old and new data through the aid of an increased knowledge of the subject.

During the two years just passed, paper as a curing agent has had a very limited use on account of the restrictions incidental to the emergency highway program, also the general reduction of investigational activities by the several state highway departments has been an additional hindrance to the collection of authoritative data for the study of the general use of paper for curing concrete pavements. It now appears, therefore, that the only data available at this time are those obtained from the same projects which supplied the major portion of the information used last year.

Some of the data reported and summarized here merely support similar data of the previous report, particularly those referring to the effect of the use of paper curing on strength of concrete. Other data offer for the first time some indication of what may be expected for other characteristics of the concrete in the circumstances attending the use of paper on the several projects studied. It must be borne in mind, however, that such information, from a single source and for a limited range of climatic and construction conditions, can only be offered for its factual value.

### STRENGTH OF CONCRETE

Additional data relative to the strength of concrete cured under suitably prepared paper coverings has become available from tests upon cores taken from an 18 mile paving project built during the

<sup>1</sup> "The Use of Paper for Curing Concrete Pavements," by Mark Morris, Proceedings, Highway Research Board, Volume 12, page 339

season of 1932 under the supervision of the Minnesota State Highway Department. This project was started on June 6 and completed on August 10 of that year. The short construction period in mid-summer provides a more constant climatic condition than is usually available for projects of this length, and offers opportunity for a more direct comparison of methods of curing than can ordinarily be expected upon field projects.

Paper was used as a curing agent on this project in several different ways. Field specimens were prepared for the determination of moisture losses, and beam specimens were molded for the determination by field tests of the effects of the several methods upon the

TABLE XXI  
STRENGTH TESTS ON CORES FROM PAVEMENT  
Paper Cured Project S P 20-37-1, Fillmore County, Minnesota

Number and Description of Curing Methods	No of Specimens	Crushing Strength Lb per Sq In			Mean Variation Per Cent	Relation to Strength of Method No 1 Per Cent
		Max	Min	Ave		
1 Wet Burlap 24 hours, Moist Earth, 72 hours	4	5926	4759	5473	6 88	100 0
2 Paper applied directly and left on 72 hours	7	6633	5126	5944	6 77	109
3 Wet Burlap 24 hours, Paper 72 hours	5	6448	5457	5817	5 64	106
4 Wet Burlap for water film, Paper 72 hours	9	6661	5227	5943	6 77	109
5 Spray of Water, Paper 72 hours	7	6490	5294	5739	4 73	105
6 Wet Burlap covered with Paper, 72 hours	3	6595	6468	6526	0 70	119

Notes 1 Age of all specimens approximately 6 months  
2 Proportions, 1—2 3/4—3 0/3, by weight

strength of the concrete. The results of these preliminary tests indicated a favorable comparison between the paper curing methods used and standard wet-burlap-moist-earth control. During the following winter, cores were drilled from each of the several sections of the pavement and tested in compression. A summary of the results of these crushing tests appears in Table XXI.

These data check those of the field tests at the earlier ages, when it was found that the paper cured specimens gave average moduli of rupture varying from 97 to 102 per cent of those obtained for the

standard earth cured specimens. It will be recalled that the cores drilled from the paper cured pavements of the Missouri and Iowa investigations gave strength values of from 92 to 105 per cent of those of the wet methods used as standards in each case. The close agreement of these three independent sources of strength data indicates that suitably prepared paper, properly handled, may be expected to provide for the attainment of satisfactory strength under climatic conditions similar to those surrounding these projects. For additional data see Table XII, Chapter 3.

#### TRANSVERSE CRACKING

The attainment of satisfactory strength constitutes but a part of the curing problem. Consideration must be given the effects of the curing upon other characteristics, such as appearance, permeability and durability. The color of the curing agent may permit absorption of an excess amount of solar heat which will produce abnormal volumetric changes particularly in the fresh concrete. Other curing agents, may through chemical action, introduce other objectionable features. The suitably prepared papers are inert with respect to fresh concrete. However, they are somewhat darker in color than the concrete.

In the previous report, a summary of the available temperature data from field projects was presented. The temperature of the concrete under the paper was shown to be higher than that under the water of the ponding method or under the earth of the earth curing method during the heat of the day. The daily temperature of the paper cured concrete was greater, therefore its volume change must be greater. Direct measurements in Missouri revealed this to be as expected. It was, however, but a slightly greater change than for the wet curing methods. The question is, "was it great enough to cause an appreciably greater amount of transverse cracking?" The early surveys in Missouri indicate that it was not, as the average slab length was 108 per cent of that of the ponded concrete. Recent surveys in Iowa on paper cured pavements slightly more than two years old check the Missouri data. The results of these recent Iowa surveys are given in Table XXII.

Similar data for short experimental sections upon other regular paving projects appear in Table XXIII. Apparently, the slightly greater early volume changes are insufficient to cause any more transverse cracking than will be obtained for the wet methods of curing.

In Table XI, Chapter 3 are given the Missouri data on the relation of waterproof paper covering to other curing methods as shown by the maximum top surface temperature compared with air temperature and maximum daily drop in top surface temperature compared with drop in air temperature.

TABLE XXII  
CRACK SURVEY  
Paper Cured Project F-324, Washington County, Iowa

Section Number	Method of Curing	Length of Sec Miles	No of Transverse Cracks	No of Construc-tion Joints	No of Expansion Joints	Average Slab Length Between	
						Expan Joints Feet	Cracks and Joints Feet
1	Wet Burlap 24 hours, Moist Earth 7 days	2 45	212 0	12	214	57 9	29 9
2	Wet Burlap 24 hours, Paper 7 days	4 07	366 5	19	352	57 9	29 1

Notes Proportion 1—1 946—2 919, by weight  
Coarse Aggregate River gravel  
One Brand of Cement  
Dates of Construction Sec 1—August 4 to 19, 1931  
Sec 2—August 21 to September 30, 1931  
Weather Conditions  
Sec 1—Hot and dry Precipitation 1 1 inch per week  
Sec 2—Hot and dry generally One wet week (3 5 in of rain)  
Precipitation (omitting wet week) 1 1 inch per week

The Missouri data relating to temperature, volume changes, and crack intervals are shown in Figures 9, 10 and 11, Chapter 3

TABLE XXIII  
CRACK SURVEY  
IOWA  
Paper Cured Experimental Sections, Construction Season of 1931

Location	Method of Curing	Length of Sec Feet	No of Transverse Cracks	No of Construc-tion Joints	No of Expansion Joints	Average Slab Length Between	
						Expan Joints Feet	Cracks and Joints Feet
<i>Gravel Coarse Aggregate</i>							
Dallas County	Earth	5017	30 0	5	83	57 1	42 5
Dallas County	Paper	1340	5 5	0	23	58 3	47 0
<i>Limestone Coarse Aggregate</i>							
Story County	Earth	4697	0 0	1	59	78 2	78 2
Story County	Paper	1009	0 0	0	12	83 5	83 5

## SCALING

None of the paper cured pavements in Iowa have as yet shown any signs of scaling. Since these projects are now a little more than two years old, it appears that sufficient time has elapsed for development of scaling were it to occur. The reports of the projects in Minnesota and Missouri omit any reference to scaling. Apparently it was a negligible item at the early ages of the concrete for which those reports were written.

The only possibility that paper could cause scaling or other surface defects of like nature, is that of a reaction between the cement of fresh concrete and the sizing of the paper in cases where paper is applied without any intermediate initial stage of curing. Several of the methods used on the Minnesota projects provided for the use of paper in this manner. In Iowa, the paper was applied only after an initial curing period of 20 to 24 hours of wet burlap. Samples of these papers applied directly to the surface of fresh concrete in the laboratory have failed to produce any noticeable effect on the nature of the concrete near to or in contact with the paper.

## HAIRCRACKING, SURFACE DEFECTS, PERMEABILITY

For other surface characteristics of concrete pavement slabs there are as yet few data available showing their reactions to paper curing. Numerous studies of the causes of haircracking indicate that it can be avoided if proper precautions are taken to prevent the rapid loss of moisture from the fresh concrete, either through evaporation from the surface, or by capillary action of the subgrade. Waterproof papers applied directly upon either the fresh or the hardened concrete have been found to prevent evaporation losses from the surface. Similar insulation of the subgrade had eliminated the effects of capillary action of the subgrade soil. Haircracks traceable to the method of curing are therefore unlikely to attend the use of paper. To date no haircracking has been observed in the several field projects reported upon. For surface defects such as holes, pits, discolorations, map crazing and blemishes, no information has become available to the Committee. The same statement applies to permeability.

## DURABILITY

The effect of a method of curing upon the durability of concrete cannot be determined in the three or four years that have elapsed since the use of paper was begun. As yet it can only be inferred that from the favorable effects of paper curing upon other major characteristics of concrete a similar effect may result upon its durability.

## INSULATION EFFECT

In the use of paper during the summer it has been noted, both on the Minnesota and Missouri projects that the paper had some apparent insulating effect against the loss of heat from the concrete during the portions of the day when the air temperatures were lower than those of the concrete. A brief study of the effectiveness of these papers for protection of concrete in cold weather has been made by Thompson & Lichtner. Concrete prepared at temperatures of 67° to 72° F, was exposed in molds to temperatures of 0° F in one series and of 25° F in another. As might be expected, the efficacy of the paper was found to be greatly increased when it was placed about one inch from the surface of the concrete, rather than in contact with it. In both cases the temperature of the concrete steadily decreased. After about five hours at 0° F air temperature, heat would be required to permit the continuation of the hydration processes past the setting stage. Reliance on the paper protection alone would be sufficient only in the milder cases of cold weather.

## LABORATORY TESTS

The laboratory work continued by the Iowa Highway Commission has been concerned principally with corroborative tests of moisture losses and the relationship between the strength of concrete or mortar and the total amount of mixing water retained. The tests with suitably prepared curing papers continue to indicate that they are effective in preventing the loss of moisture during the curing period under rather severe conditions of exposure at temperatures of 95° to 110° F, and a relative humidity of air of 30 to 40 per cent. This behavior is interpreted to mean that such papers properly applied in the field may be expected similarly to prevent moisture losses from the pavement slab.

## INFERENCES OF THE VALUE OF PAPER AS A CURING AGENT

At the present time, from the data presented in this and the previous report, there are several inferences with respect to the use of suitably prepared papers as curing agents, which seem fitting and proper. Evidence from the independent investigations of Lang, Gonnerman, Hansen, Reagel and Morris, indicates a close relationship between the attainment of strength in concrete and the amount of water either retained in the concrete or supplied to it during the curing period. Large water losses during the early curing or great deficiencies of water throughout the curing period are found to be accompanied by low strength. Small losses and small deficiencies are found to be associated with high strength. These higher strengths

may be assured, apparently, by either preventing moisture losses during the early curing period, or by replacing such deficiencies of water as may occur throughout the curing period. On the basis of this evidence it may be inferred that any curing agent that will prevent moisture losses from the concrete will provide for the attainment of a satisfactory strength. All of the field and most of the laboratory data support such an inference for the suitably prepared papers.

Further, in all respects for which data have become available regarding the effects of paper, it appears to produce similar results to those obtained from the use of standard wet methods. It then appears to be a reasonable inference that the proper use of suitably prepared papers will result in effects upon other characteristics similar to those of the standard methods. If this be accepted, the effects on permeability, durability and surface defects for which there are, as yet, practically no direct evidence, may be expected to be favorable.

#### CONCLUSION

In view of the facts revealed by the data in this and the previous report, there are strong indications that suitably prepared papers may be used satisfactorily as curing agents for concrete pavement slabs, under some restrictions as to manner of application and number of repetitions of use.