STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

INVESTIGATION OF CONCRETE CURING MATERIALS, TESTING EQUIPMENT AND PROCEDURES

REPORT 79-4
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REPORTING ON WORK PLAN NO. 78-C-42

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Abstract

Tests were performed on polyethylene film, waterproof paper and curing compound to examine their performance when tested in accordance with AASHTO T 155 "Water Retention Efficiency of Liquid Membrane-Forming Compounds and Impermeable Sheet Materials for Curing Concrete", and to determine if the equipment capability existed in the Materials and Research Division to perform the desired tests as specified.

Results indicate the materials examined comply with applicable specifications and the Materials and Research Division has the equipment capability to perform the required tests, as specified. Further testing of curing compounds is warranted. The results may suggest a re-evaluation of the Agency's position on their use for curing concrete.

Introduction

Curing is defined as the process adopted to ensure the hardening of concrete by preventing excessive evaporation of moisture or extremes of temperature. Early and effective curing of concrete is an essential operation if desired properties such as high compressive strength, durability, impermeability and abrasion resistance are to be realized.

Some of the more common methods of curing include:

a. Covering surfaces with a layer of moisture-retaining material such as burlap, straw or sand, which must be kept continuously wet.

b. Applying water to concrete surfaces by continuous spraying or ponding.

c. Applying impermeable paper or plastic sheets to the surfaces of concrete to prevent evaporation of water.

d. Applying curing compounds which, after the evaporation of solvent carriers, leave a membrane that reduces the evaporation of water from the concrete surface.

Monitoring the curing process is an important part of an inspector's duties. Water pumping and spraying equipment must be checked to see that it is operating properly and concrete surfaces are maintained in a moist condition. Joints and edges of impermeable sheets must be sealed to insure moisture is not allowed to evaporate from the concrete. Curing compounds must be tested for compliance with applicable specifications and their application carefully monitored if they are to be an effective curing method.

The purpose of this report is twofold; (1) to examine the performance of curing materials when tested in accordance with AASHTO T-155 "Water Retention Efficiency of Liquid Membrane-Forming compounds and Impermeable Sheet Materials for Curing Concrete", (2) to determine if the equipment capability existed in the Materials and Research Laboratory to perform the desired tests as specified. One sample each of polyethylene film, waterproof paper and curing compound was obtained and subjected to the water retention test.

Since earlier tests involving curing compounds yielded a variability of results, the curing compound examined in this report was subjected to repetitive tests for water retention. The effects of Type I and Type II cement were studied as well as different compounds and methods used to seal the edges of the mortar test specimens. Testing equipment and procedures were carefully monitored and any deviations or problems documented. The results of tests using the curing compound were compared with results obtained using polyethylene film, waterproof paper and with specimens stored under the same climatic conditions but without any curing materials applied.

Materials and Equipment

Following are listed the materials and various pieces of equipment used in this investigation, and their sources:

Materials

Curing Compound:

AR-30-D- W.R. Meadows, Inc. Elgin, Illinois.
Description: AR-30-D is a 100% resin-base product containing a red fugitive dye.

Cement:
Type I- Glens Falls Portland Cement Co. Glens Falls, N.Y.
Type II- Glens Falls Portland Cement Co. Glens Falls, N.Y.

Fine Aggregate:

Graded Standard Sand- Ottawa Silica Co. Ottawa, Illinois.

Sealing Compounds:

Paraffin-Fisher Scientific Co. Fair Lawn, N.J.
Description: Melting point about 63° C.

Sikaflex 1a- Sika Chemical Corp. Lyndhurst, N.J.

Sonolastic- Building Products Division of Contech Inc. Minneapolis, Minn.

Tape- Shurtape- Shuford's Hickory, N.C.
(Used for sealing Polyethylene Film and Waterproof Paper)

Polyethylene Film:

4 mil.- Natural (Clear)- Monsanto Co. Kenilworth, N.J.

Waterproof Paper:

Orange Label SisalKraft- St. Regis Laminated & Coated Products Division Attleboro, Mass.- Tracy, Ca.

Equipment

Curing Cabinet:

Constant temperature Cabinet- Blue M Electric Co. Blue Island, Illinois.

Mortar Mixer:

Reco, two speed, twelve quart paddle mixer-Reynolds Electric Co. River Grove, Illinois.

Scales:

0.1- 800g Model K-7- Mettler Instrument Corp. Princeton, N.J.
1.0- 3000g Model P-3- Mettler Instrument Corp. Princeton, N.J.
1.0- 10000g Model P-10- Mettler Instrument Corp. Princeton, N.J.

Model K-7 was used to monitor the application of the curing compound.
Model P-3 was used to weigh the materials for the batches.
Model P10 was used to weigh the completed specimens during testing.

Molds:

a. Specimen molds
   7"W x 11½L x 2"D Stainless Steel Pans-
   Fisher Scientific Co. Fair Lawn, N.J.

b. Volatile pan
   7"W x 11½"L x 3/16"D Aluminum pan- Fabricated at the Vermont Materials and Research Laboratory

This pan was used to determine the loss in weight of volatile matter from liquid curing materials during test.

Tamper:

A rubber mallet with a 2" diameter head was determined to provide the best consolidation.

Paint Brushes:

a. 2" Medium bristle- Linzer
   This brush was used to remove the laitance and glaze from the specimens.

b. 1" Softbristle - Hi-Value
   These brushes were used to apply curing compound to the specimens.

Wood float:

3"W x 11"L x 3/4"T Wood float
When necessary the float was lightly sanded with fine sandpaper to remove any roughness caused by the screeding.

Miscellaneous equipment:

a. Hot plate- used to melt paraffin.

b. Crucible- container in which paraffin was melted.

c. Large dropping pipette- used to apply paraffin.

d. Freezer- used for demolding specimens.

Procedures

A. General

The various methods and procedures used in this testing program generally followed those outlined in AASHTO Standards. When specific details were not shown, acceptable procedures were determined through experimentation.

Tests were conducted on one brand of curing compound to determine if consistant results could be obtained . Different sealants were used on the edges of the mortar specimens to determine their acceptability. One specimen was deliberately damaged by placing pinholes in the curing compound, 4 hours after it had been applied. The pinholes were spaced, 3 per square inch, over the entire surface of the specimen.

Specimens were tested using Polyethylene Film and Waterproof Paper as curing materials and several specimens were tested with no form of curing material applied.

Both Type I and Type II cements were used to study their effect on the test results.

B. Mix design

The mix design was established using procedures outlined in AASHTO T155. The weights per batch necessary to provide a flow of 35 are as follows:

Ottawa Sand	3979g
Cement	1580g
Water	632g

C. Mixing

Each specimen prepared for testing required the mixing of one batch of mortar. The following mixing sequence was established and used throughout the testing program:

Time (seconds)	Mixing Sequence
0-60	Add water and cement and hand mix with a rubber spatula.
60-75	Using speed #1, start mixer and add Ottawa sand.
75-120	Continue mixing at speed #1.
120-135	Stop mixer and scrape down the bowl with a rubber spatula.
135-195	Mix at speed #1.

D. Molding Specimens

Mortar was placed in the molds to a depth of approximately one inch and tamped 50 times with the rubber mallet. The second layer of mortar, sufficient in amount to slightly overfill the mold, was placed in the mold and tamped in a similar manner. The surface of the specimens was approximately leveled by compacting and smoothing the mortar by hand. Rubber gloves were worn during the compacting and smoothing operation.

E. Finishing Specimens

Specimens were finished with a 3"x 11" x 3/4" wood float with the 3" face kept firmly in contact with the mortar and edges of the pan, as specified.

AASHTO requires that " One pass only shall be made in the direction of the long axis of the specimen using a sawing motion of the float." In this investigation, several specimens required some additional floating to attain a surface which was free of cracks and voids.

F. Storage of Specimens

Immediately after molding, and for the duration of the test, the specimens were placed in the curing cabinet. The cabinet was maintained at a temperature of 100 ± 2°F and a relative humidity of 32 ± 2 percent. Intake and exhaust ports on the cabinet were adjusted to provide continuous fresh air. Specimens were stored on two wire rack shelves which permitted uniform circulation of conditioned air around all of the specimens. Humidity was controlled by placing several pans of water on the bottom shelf of the cabinet. Regular monitoring insured that temperature and humidity requirements were met.

G. Sealing Specimens

1. Curing Compound

Specimens were prepared for sealing by forming a V shaped grove approximately 1/8" deep by 1/16" wide between the edge of the mortar specimen and the mold.

Several methods were examined in an attempt to find a satisfactory sealant for the edges of the specimens. Two latex based caulking compounds were tried as well as paraffin wax heated at several different temperatures. The best results were obtained by heating paraffin to 105-115°C and applying the melted paraffin to the grove with a large dropping pipette.

2. Sheet Material

Specimens cured with sheet materials were not groved. These specimens were sealed with tape which was folded over the edges of the molds and lapped at the corners to prevent loss of moisture.

H. Application of Curing Materials

1. General

Probably the most critical point in the test and the one most difficult to determine is the time at which the specimens are considered ready to receive the application of curing materials. Specifications require the mortar surface shall have neither surface water on it nor be dry below the surface.

The proper surface condition is attained when brushing the surface with a medium-soft paint brush does not bring free water to the surface or produce smearing. This also can be determined by rubbing an area with the finger tip. The correct time or surface condition could be subject to considerable variation depending on the opinion of the operator conducting the test.

2. Curing Compound

The curing compound was applied to the surface of the specimens with a 1 inch wide soft-bristle brush. Every effort was made to apply the curing compound uniformly over the surface of the specimen. Proper coverage was determined by weighing the container and brush with the curing compound before and after application.

3. Sheet Material

Sheet materials were cut to the exact size of the mortar specimens and the sealing tape applied to the sheets on a flat bench. The sheet with the tape was then placed on the surface of the mortar and the tape sealed around the rim of the mold.

I. Demolding of Specimens

At the completion of testing, specimens were removed from the molds by first placing them in a freezer at 0°F for approximately ½ hour. The specimens were then taken from the freezer, inverted and immediately placed under a faucet of hot running water. Lightly shaking or tapping the mold easily removed the specimens. The ease with which specimens were removed from the molds, by use of this procedure, made it unnecessary to use mold release compounds.

Results

The results of all water retention tests are shown in Table I.

Table I

Test No.	Cement Type	Sealant Used	Moisture Loss = g/cm² of surface in 72 hours: Curing Compound Individual			Avg.	Pin-holes	Poly-ethylene Film	Water-proof Paper	No Curing
1	II	Paraffin	.023			.023				
2*[1]	II	Sikaflex 1A	.072			.072				
3A	II	Paraffin	.019	.029	.023	.024				
3B	II	Sonolastic	.024			.024				
4*[2]	II	Paraffin	.015	.012	.006	.011				
5	II	Paraffin	.022	.028	.031	.027				.121
6	II	Paraffin	.018	.018	.023	.020				.114
7	I	Paraffin	.014	.012	.014	.013				.106
8*[3]	I	Paraffin	.035	.039	.039	.038				.106
9	I	Paraffin	.012	.012	.023	.015				.111
10A	I	Paraffin	.011			.011	.021			
10B	I	Tape						.002	.021	

*1 The caulking compound exhibited some shrinkage, and although it adhered tightly to the mold it pulled away from the mortar, leaving the edge of the specimen unsealed.

*2 The paraffin was allowed to cool during the sealing operation and required re-heating. This resulted in a ½ hour delay in the application of the curing compound.

*3 Problems were encountered finishing the surfaces of the specimens in this test. Several passes with the screed were required to obtain an acceptable finish.

The "Percent of Water Retained" in Figure I is shown in relation to the amount of water that would have been lost if there was no curing. This percent was obtained by comparing specimens stored under the same climatic conditions. The three tests exhibiting erratic results have been omitted from this comparison.

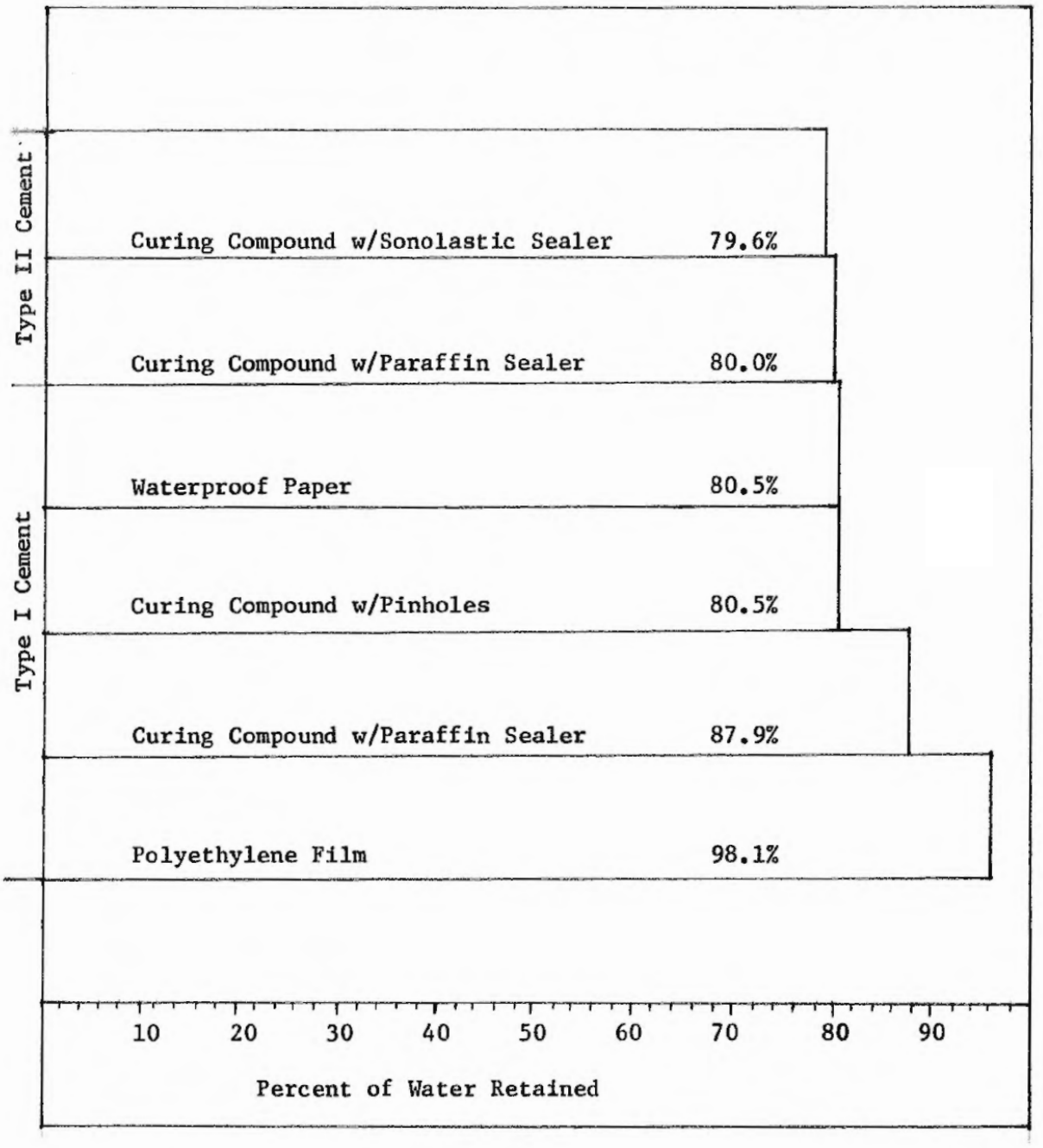

Figure I

Summary

1. The results of the water retention tests were consistant from one test to another and between individual specimens in a single test. The differences between individual specimens in each of the tests were within the .015 g/cm^2 permitted in AASHTO specifications. Unusual problems encountered during testing were documented and generally explain any erratic results.

2. Damaging the curing compound by placing three pinholes per square inch in the surface of the specimen did not significantly increase the moisture loss.

3. Tests using Type II cement exhibited higher moisture loss than did the tests using Type I cement. This was apparent in specimens treated with curing compound as well as in the specimens which received no curing.

4. Of the three sealants used with the curing compounds, the paraffin and sonolastic appeared to perform satisfactorily. The paraffin when heated to 105-115° C is the quickest and easiest to apply. The Sikaflex 1A exhibited shrinkage, after drying, and did not effectively seal the edge of the specimen. The tape used to seal the edges of the sheet materials worked well as is evidenced in the results of the test using polyethylene film.

5. Each of the curing materials tested; Polyethylene Film, Curing Compound, and Waterproof Paper, complied with the maximum .055 g/cm^2 moisture loss as required in AASHTO specifications.

Conclusions & Recommendations

1. The Materials and Research Laboratory has the equipment capability to perform water retention tests in accordance with AASHTO, T155 "Water Retention Efficiency of Liquid Membrane-Forming Compounds and Impermeable Sheet Materials for Curing Concrete."

2. Strict adherence to specifications is essential if meaningful test results are to be obtained. If problems are encountered and preparation of specimens or application of curing materials is delayed, the specimens should be discarded and new specimens prepared before testing is resumed.

3. The paraffin wax (melting point about 63° C) should be used as a sealant in the future when curing compounds are subjected to water retention tests. The paraffin should be heated to 105-115° C immediately prior to application.

4. AASHTO, T155 states that the Portland Cement used shall conform to the requirements for Type I. Type I and Type II cements were used in this test. Tests using Type II cement exhibited higher moisture losses than Type I cement. Since the Agency of Transportation uses Type II cement exclusively, it is recommended that Type II cement be used in further testing of membrane curing products.

5. Membrane curing compounds compared favorably to other curing procedures tested. The results warrant further testing of membrane curing products. If these results are positive, it is recommended that the Agency re-evaluate its position on the use of membrane curing compounds for curing concrete.

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EFW Prepared By: E. Waibel
Date: 11/30/78

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

RESEARCH INVESTIGATION

Work Plan No. 78-C-42

Subject Liquid Membrane - Forming Compound

Investigation Requested By E. Waibel, Structural Concrete Engineer Date November 28, 1978

Date Information Required March, 1979

Purpose of Investigation The purpose of the investigation is to determine if existing lab equipment will yield consistent and accurate data for the computation of water loss. If positive results are obtained, specification compliance for future use on sidewalks and bridge decks will be checked. A sample of membrane forming compound will be obtained locally.

Proposed Tests or Evaluation Procedure

1. T-155-74 Water Retention Efficiency of Liquid Membrane - Forming Compounds and Impermeable Sheet Materials for Curing Concrete

Proposal Discussed With R. Frascoia, H. Haggerty

Projected Manpower Requirements Preparation & Testing - 20 man days, Report - 4 man days

Investigation To Be Conducted By Structural Concrete Subdivision

Proposed Starting Date December, 1978 Estimated Completion Date March, 1979

Approval/Disapproval by Materials Engineer R. F. Nicholson

Comments by Materials Engineer