Laboratory Test Results on Concrete Mixtures Containing Water-Reducing, Set-Retarding Admixtures

James H. Havens
Kentucky Highway Materials Research Laboratory
April 21, 1965

MEMORANDUM

TO: Harold Mays
   Director of Materials

FROM: Jas. H. Havens
   Director of Research

SUBJECT: Laboratory Test Results on Concrete Mixtures Containing Water-Reducing, Set-Retarding Admixtures

In response to your request of March 4, 1965, the Concrete Section of this Division has initiated tests on nine (9) water-reducing, set-retarding admixtures delivered to this laboratory for tests in accordance with the Department's Special Provision for Set-Retarding Admixtures for Concrete, dated April 14, 1964. The properties of all concrete mixtures containing the individual admixtures were compared with those of one reference mixture containing the same cement and aggregates but without any water-reducing, set-retarding admixture. All mixtures were proportioned to be within the limits of values designated under Section II C-2 of the Special Provision. To date, tests for properties as outlined under Section II C-3 have been completed except the freeze-thaw tests. Freeze-thaw testing will be completed by mid-June, 1965. Flexural-strength tests were not required.

All mixtures contained Type I cement produced by the Louisville Cement Company, No. 6 crushed limestone produced by Central Rock Company of Lexington, and Ohio River Sand. The S.S.D. specific gravity of the limestone was 2.72 and the S.S.D. specific gravity of the river sand was 2.64. All mixtures were proportioned to contain 37 percent fine aggregate by solid volume of the total aggregate. Mixtures were adjusted in order to maintain a constant cement factor of 6.0 bags per cubic yard. Neutralized vinsol resin was used as the air-entraining agent for each mixture. The A.E.A. was added to each mixture after approximately 20 percent of the total mix water had been added and the water-reducing, set-retarding admixture was added to each test mixture after 80 to 90 percent of the total mix water had been added. Mixture designs, mixture properties, and laboratory test results are contained in Tables I and II included herein. The admixtures tested are as follows:
1. Daratard - Dewey and Almy Chemical Division
2. Plastiment Liquid - Sika Chemical Corporation
3. Plastiment Powder - Sika Chemical Corporation
4. HPS-R - Hunt Process Corporation Southern
5. Eucon - The Euclid Chemical Corporation
6. Pozzolith HP-18 - The Master Builders Company
7. Pozzolith Low Heat - The Master Builders Company
8. Sonotard-CH 92 - Sonneborn Building Products, Inc.
9. Sonotard - 6050 - Sonneborn Building Products, Inc.

Sonotard-CH92 and Sonotard-6050 detrained air to some extent in that a greater quantity of air-entraining agent was required to produce approximately the same air content in mixtures containing these admixtures than was required for the control mixture. The HPS-R admixture had little or no effect upon the air-entraining characteristics of the mixture in which it was employed. The remaining water-reducing, set-retarding admixtures entrained air to various degrees. All powdered admixtures were pre-mixed with water to form a liquid solution. The Plastiment powder would not stay in solution, thus it was necessary to stir vigorously before its addition to the mixture. Both Pozzolith Low Heat and Pozzolith HP-18 had a tendency to cake when mixed with water and considerable agitation was required in order to obtain desirable solutions. The initial setting time as determined by procedures outlined under A.S.T.M. C 403 for the control mixture was 4-1/2 hours. A sufficient quantity of each water-reducing, set-retarding admixture was added to test mixtures to cause an increase in the initial setting time over that of the control mixture of 50 to 60 percent. Several trial mixtures were required for some of the test mixtures in order to determine the quantity of admixture necessary for the required retardation.

Four of the admixtures tested failed to meet that section of the Special Provision requiring the compressive strength of the admixed concrete to be at least 10 percent greater than that of the control concrete at 3, 7, and 28 days. Admixtures failing to meet this requirement were: 1) Daratard, 2) HPS-R, 3) Eucon, and 4) Sonotard CH92. The remaining admixtures have met all requirements specified except for the durability factor. Freeze-thaw tests will be completed by mid-June, 1965; and results of these tests will be reported at a later date. Flexural-strength tests were not required for this series of admixtures. We will continue freeze-thaw tests on specimens cast from those admixtures having failed the compressive-strength tests until further notification from your office.

I am inclined to believe that the mandatory use of a water-reducing set-retarding admixture for the conditions as set forth under our present Special Provision for such admixtures may not be in the best interest of the Department. The required
use of such admixtures may constitute an indulgence of undesirable concreting practices such as delayed finishing, re-vibration, re-finishing, postponement of curing, etc. Provision for the use of such admixtures should be made subject to request for use by the Contractor and approved by the Engineer. Permission for use of water-reducing, set-retarding admixtures should not be granted in lieu of requirements that the Contractor provide sufficient personnel and/or equipment for satisfactory performance of work under normal conditions.

In further consideration of some of the problems experienced during testing of the aforementioned admixtures and upon review of literature regarding such admixtures, I am of the opinion the special provision covering set-retarding admixtures needs some modification. The requirement for an increase in the initial setting time of 50 to 60 percent relative to that of the control concrete is somewhat restrictive in that a quantity of admixture must be added to the test mixture(s) so as to provide an initial setting time of approximately 6-3/4 to 7-1/4 hours. ASTM C494 for Chemical Admixtures for Concrete provides for a delay in setting time of 1 to 3 hours over that of the control mixture. I feel the 1- to 3-hour period would be more desirable than our present 50 to 60 percent. Moreover, it would be desirable to include a clause requiring the manufacturer(s) of the admixture(s) to supply reliable recommendations regarding the dosage of their admixture to use for the conditions as set forth in the Special Provision.

It should also be required that any admixtures which are to be supplied in powder form be completely and permanently soluble in water and that the powdered admixtures be thoroughly mixed with water prior to their placement in an automatic dispenser. Provision should also be made for the addition of the retarder at a specified time during the mixing operation. Reports indicate that the time of addition of such admixtures may appreciably affect their set-retarding and (or) air-entraining characteristics of the air-entraining agent. The general consensus of opinion presented in reports devoted to such admixtures is that desirable results are generally obtained through addition of the water-reducing, set-retarding admixture at that time when approximately 80 percent of the total water has been added to the mixture—but definitely after the air-entraining agent has been added. The Special Provision should specify the order and the time of addition of the admixtures but should include a statement providing for another time of addition in cases where manufacturers recommend otherwise.

A.S.T.M. C 494 lists a minimum durability factor of the test mixture(s) of 80 percent relative to that of the control mixture; whereas, the Department's current special provision
requires the durability factor of the test mixture(s) be 90 percent (or greater) than that of the control mixture. I believe that we should reasonably expect no less than 100 percent relative durability. Past experience with certain set-retarding admixtures indicate that some may produce extensive bleeding; therefore, I feel the inclusion of the bleeding test is essential for this special provision. For this purpose, the increase in bleeding of the admixed mixture(s) over that of the control mixture as outlined in A.S.T.M. C 494 should be applicable. I am attaching a proposed Special Provision for Water-Reducing, Set-Retarding Admixture for Concrete for your review and comments.

RDH: skb

Attachments

cc: W. B. Drake
    S. T. Collier
<table>
<thead>
<tr>
<th>Retarder</th>
<th>Control</th>
<th>Daretard</th>
<th>Plastiment Liquid</th>
<th>Plastiment Powder</th>
<th>HPS-R</th>
<th>Eucon</th>
<th>Pozzolith HP-18</th>
<th>Pozzolith Low Heat</th>
<th>Sonotard CH 92</th>
<th>Sonotard 6050</th>
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</thead>
<tbody>
<tr>
<td>Water, gal./yd.</td>
<td>29.70</td>
<td>25.71</td>
<td>27.20</td>
<td>27.25</td>
<td>27.37</td>
<td>25.00</td>
<td>26.60</td>
<td>26.20</td>
<td>27.50</td>
<td>26.85</td>
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<tr>
<td>Water, % of Control</td>
<td>100</td>
<td>86.5</td>
<td>91.6</td>
<td>91.7</td>
<td>92.1</td>
<td>84.1</td>
<td>89.6</td>
<td>88.2</td>
<td>92.6</td>
<td>90.4</td>
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<tr>
<td>NVX-Fl.Ounces</td>
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<td>2.54</td>
<td>3.75</td>
<td>3.75</td>
<td>4.36</td>
<td>3.50</td>
<td>2.54</td>
<td>2.54</td>
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<td>Retarder, per Sack</td>
<td>0</td>
<td>7.50</td>
<td>2.50</td>
<td>0.625</td>
<td>3.00</td>
<td>5.00</td>
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<td>0.15</td>
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<td>Retardation, %</td>
<td>0</td>
<td>57.4</td>
<td>59.2</td>
<td>51.3</td>
<td>58.3</td>
<td>59.2</td>
<td>51.8</td>
<td>56.1</td>
<td>55.6</td>
<td>50.6</td>
</tr>
<tr>
<td>Slump, In.</td>
<td>2</td>
<td>2 1/2</td>
<td>2 1/2</td>
<td>2 1/2</td>
<td>3</td>
<td>2 5/8</td>
<td>2</td>
<td>2 7/8</td>
<td>2 1/2</td>
<td>2 3/4</td>
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<tr>
<td>Air Content, %</td>
<td>6.2</td>
<td>6.9</td>
<td>6.1</td>
<td>5.1</td>
<td>6.1</td>
<td>7.0</td>
<td>5.8</td>
<td>6.5</td>
<td>6.3</td>
<td>5.8</td>
</tr>
<tr>
<td>Unit Wt., pcf.</td>
<td>146.4</td>
<td>145.9</td>
<td>146.6</td>
<td>148.0</td>
<td>146.0</td>
<td>145.8</td>
<td>147.5</td>
<td>146.8</td>
<td>146.6</td>
<td>147.0</td>
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</table>
TABLE II - COMPRESSIVE STRENGTH TEST DATA (Avg. of 3 each)

<table>
<thead>
<tr>
<th>Retarder</th>
<th>Compressive Str.-psi</th>
<th></th>
<th></th>
<th>Precent of Control</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>3-day</td>
<td>7-day</td>
<td>28-day</td>
<td>3-day</td>
<td>7-day</td>
<td>28-day</td>
</tr>
<tr>
<td>Control</td>
<td>3756</td>
<td>4301</td>
<td>5671</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Daratard</td>
<td>4345</td>
<td>4778</td>
<td>6082</td>
<td>124</td>
<td>129</td>
<td>120</td>
</tr>
<tr>
<td>Plastiment Liquid</td>
<td>4648</td>
<td>5556</td>
<td>6790</td>
<td>109</td>
<td>117</td>
<td>123</td>
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<tr>
<td>Plastiment Powder</td>
<td>4784</td>
<td>5630</td>
<td>6771</td>
<td>136</td>
<td>132</td>
<td>116</td>
</tr>
<tr>
<td>HPS-R</td>
<td>4110</td>
<td>5027</td>
<td>6984</td>
<td>116</td>
<td>118</td>
<td>107</td>
</tr>
<tr>
<td>Eucon</td>
<td>3824</td>
<td>4595</td>
<td>5808</td>
<td>148</td>
<td>134</td>
<td>114</td>
</tr>
<tr>
<td>Pozzlitb-HP-18</td>
<td>5122</td>
<td>5665</td>
<td>6606</td>
<td>136</td>
<td>132</td>
<td>116</td>
</tr>
<tr>
<td>Pozzlitb Low Heat</td>
<td>4730</td>
<td>5813</td>
<td>7025</td>
<td>116</td>
<td>118</td>
<td>107</td>
</tr>
<tr>
<td>Sonotard CH92</td>
<td>4354</td>
<td>5079</td>
<td>6073</td>
<td>148</td>
<td>134</td>
<td>114</td>
</tr>
<tr>
<td>Sonotard 6050</td>
<td>5570</td>
<td>5757</td>
<td>6473</td>
<td>148</td>
<td>134</td>
<td>114</td>
</tr>
</tbody>
</table>
This special Provision shall be applicable to individual projects only when indicated on the plans or in the proposal or when ordered in writing by the Engineer.

1. DESCRIPTION

This Special Provision covers the requirements for materials and construction procedures for water-reducing, set-retarding admixtures to be used in the construction of concrete bridge superstructures.

The Contractor shall add an approved water-reducing, set-retarding admixture to the concrete mixtures for use in spans of a continuous unit so as to permit placement and finishing of concrete in all spans in a single continuous operation, unless otherwise directed by the Engineer. Use of a water-reducing, set-retarding admixture for reasons other than the preceding stated condition shall be subject to the following conditions. When the prevailing air temperature is 75°F or higher at the time concrete is being placed, the Contractor may request permission to add an approved water-reducing, set-retarding admixture. The Engineer may grant permission to use such an admixture in the event con-
ditions are such to warrant their use. Water-reducing, set-
retarding admixtures shall not be used in lieu of sufficient
personnel and (or) equipment to perform the work satisfactorily.

All water-reducing, set-retarding admixtures shall be
approved by the Department prior to their use.

II. MATERIALS

A. General Requirements

The water-reducing, set-retarding admixture may or
may not exhibit air-entraining properties and may be furnished
in liquid or powder form. Admixtures which are furnished in
powder form shall be of such nature that they will be completely
soluble when mixed with water and thereby stay in solution and
not settle out.

The Admixture shall be one of the following types:

(1) A calcium, sodium potassium or ammonium
salt of lignosulfonic acid
(2) A hydroxylated, carboxylic acid or its salts

B. Approval

The admixture is subject to approval by the Department
on evidence of its compliance with the test requirements as
hereinafter specified under paragraph C-2.

Acceptance shall be made on the basis of one of the
following procedures:

(1) Approval by the Testing Laboratory on the
basis of results of tests performed on samples
of material furnished by the Contractor;
(2) Approval by the Department upon evidence that
it has been tested by a recognized laboratory
and found to comply with all requirements - provided that two certified copies of the test report are furnished to the Department by the laboratory; or

(3) Approval by the Department upon certification by the manufacturer, furnished by the Contractor, stating that the admixture is identical in composition to a (named) admixture previously approved.

When the material is to be tested by the Testing Laboratory, the Contractor shall provide the Engineer with samples of the admixture and representative job aggregates for testing at least 70 days prior to the time of use. The Contractor shall supply the manufacturer's suggested quantity of admixture to use per sack of cement to provide the specified retardation for the mixture proportions as hereinafter designated in paragraph C-2.

If the admixture is to be approved on the basis of tests conducted by a recognized laboratory, the laboratory shall be one operated by a state highway department, the Bureau of Public Roads, or other cement or concrete laboratory regularly inspected by the Cement Reference Laboratory.

Either before or during construction, the Engineer may require the selected admixture to be retested.

C. Acceptance Tests

1. Test Data The test data shall be obtained by use of concreting materials and methods meeting the require-
ments of the current applicable standards of the Kentucky Department of Highways, the American Association of State Highway Officials or the American Society for Testing and Materials.

2. **Mixture Requirements** The properties of concrete containing the admixture under test shall be compared to those properties of a reference concrete containing the same cement and aggregate, but without the admixture. Both mixtures shall have the following composition:

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Content, bags per cubic yard</td>
<td>6.0 ± 0.1</td>
</tr>
<tr>
<td>Air Content, percent</td>
<td>5.0 to 7.0</td>
</tr>
<tr>
<td>Fine Aggregate, percent</td>
<td>35 to 40</td>
</tr>
<tr>
<td>Solid Volume of Aggregate</td>
<td>2 1/2 ± 1/2</td>
</tr>
<tr>
<td>Slump, inches</td>
<td></td>
</tr>
</tbody>
</table>

An approved, air-entraining admixture shall be used if the retarder does not entrain a sufficient quantity of air.

A sufficient quantity of the retarder shall be added to delay the initial setting time of the test mixture at least 1 hour but not more than 3 hours after the initial setting time of the reference mixture. The setting time for both mixtures shall be determined in accordance with A.S.T.M. C 403 (penetration pressure of 500 psi; temperature 73° ± 3°F).

3. **Properties** Concrete containing the admixture in the amount satisfying the requirements specified in paragraph C-2, when compared to the reference concrete, shall exhibit the following properties:
(a) The net mixing water shall be reduced at least 5 percent.

(b) The compressive strength at ages of 3, 7, and 28 days shall be increased at least 10 percent.

(c) The flexural strength at ages of 3, 7, and 28 days shall not be reduced.

(d) The relative durability factor for the freezing and thawing test shall not be less than 100.

(e) The increase in bleeding relative to the control mixture shall not exceed 5 percent of the net mixing water. For this purpose, bleeding is that which takes place during the period subsequent to the time the penetration resistance of the mortar screened from the reference mixture is equal to 100 psi and shall be expressed as a percent of the net mixing water.

Tests for flexural strengths and relative durability may be required only at the option of the Department.

III. CONSTRUCTION METHODS

Proportioning, mixing, and placing the concrete shall be done in accordance with the applicable requirements of the Department's current Standard Specifications for Road and Bridge Construction.
The admixture shall be delivered to the project in the manufacturer’s original container(s) labeled to designate the name of the manufacturer and the contents. Acceptance tests or certifications of approval shall be required for each shipment of material.

Admixtures which are supplied in powder form shall be prepared in a liquid form before addition to the concrete mixture. The admixture shall be metered accurately into the batch at the mixer by means of an automatic device and in quantities as recommended by the manufacturer or as directed by the Engineer. The admixture shall be metered into the batch after the addition of an air-entraining agent and at the time approximately 80 percent of the mix water has been metered into the batch - unless otherwise directed by the Engineer.

The quantity of the admixture per batch may be adjusted, as directed by the Engineer, for the purpose of decreasing the setting time of the concrete as work progresses toward completion of each placement.

The approved status of an admixture is dependent upon its satisfactory performance on the job, and tests to determine rate of hardening and strength of the concrete may be made at any time during work.

IV. METHOD OF MEASUREMENT AND BASIS OF PAYMENT

The water-reducing, set-retarding admixture shall not be measured for payment since the cost thereof shall be
included in the unit price bid per cubic yard of Class A Concrete.

No additional payment shall be allowed the Contractor for any testing services furnished by him toward certification and approval of an admixture nor for delays occurring as a result of tests or due to unsatisfactory performance of the admixtures.