LABORATORY COMPARISON OF
VARIOUS PROTECTIVE SYSTEM CONCRETES

REPORT 80 - 1

Reporting On Work Plan Nos. 77-R-15, 78-C&R-13
78-C&R-14, 78-C&R-15 & 78-C&R-16

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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Tests Conducted By
Structural Concrete and Research and Development Subdivision Personnel

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Materials & Research Engineer
Date: Jan. 20/81
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LABORATORY COMPARISON OF
VARIOUS PROTECTIVE SYSTEM CONCRETES

Introduction

Premature failure of concrete bridge decks is a serious problem in the State of Vermont. There have been many approaches to solving the problem. In the "protective system" approach, the Federal Highway Administration (1) classifies acceptable alternatives as:

(a) Epoxy-coated rebars - top layer.
(b) Low water - cement ratio, Dense concrete LSDC (Iowa System)
(c) Polymer modified concrete overlays - PMC
(d) Membrane system with bituminous concrete overlays.
(e) Cathodic protection.

Alternatives (a) and (d) are the subjects of recent Materials & Research Division reports. The purpose of this investigation was to compare in the laboratory alternatives (b) and (c) using two Styrene butadiene latex modified concretes, one concrete mix containing silicone admixture, one low water - cement ratio dense concrete mixture, and two typical State of Vermont conventional Class AA mixtures.
Materials

(a) Styrene - butadiene latices;
   Thermoflex 8002
   Reichhold Chemicals, Inc.
   Dover, Delaware

   Arco Dylex 1186
   Arco Polymers, Inc.
   Philadelphia, PA

(b) Silicone Admixture;
   Silane Z 6020
   Dow Chemical Company
   Midland, Michigan

(c) Aggregate;
   (i) Stone;
      3/8" Dolomite
      F.W. Whitcomb Construction Co.
      Winooski, Vermont

      3/8" Granite
      Cooley Asphalt Paving Corp.
      Websterville, Vermont

   (ii) Sand;
      Lawrence Sangravco
      Guildhall, Vermont

   (iii) Cement;
      Flintkote Cement Company
      Glens Falls Division Type II
      Glens Falls, New York
Concrete Mixes

Fresh Concrete Tests

Three batches were prepared and mixed in the laboratory for each type of concrete tested. Admixture and latices were dispensed and mixed according to the manufacturer's recommendations. Slump, Air Content, and Unit Weight tests were performed in accordance with AASHTO T119, T152, and T121 respectively. Table 1 presents the results of these tests.

TABLE 1

SLUMP, AIR CONTENT AND UNIT WEIGHT OF VARIOUS CONCRETES

<table>
<thead>
<tr>
<th>CONCRETE</th>
<th>SLUMP, INCHES</th>
<th>AIR CONTENT, PERCENT</th>
<th>UNIT WEIGHT, LB/FT³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class AA/Dolomite (Reference)</td>
<td>1.8</td>
<td>7.4</td>
<td>142.2</td>
</tr>
<tr>
<td>Class AA/Granite</td>
<td>1.8</td>
<td>6.8</td>
<td>140.1</td>
</tr>
<tr>
<td>Silane Z6020</td>
<td>1.8</td>
<td>6.2</td>
<td>143.9</td>
</tr>
<tr>
<td>LSDC</td>
<td>0.8</td>
<td>5.8</td>
<td>146.1</td>
</tr>
<tr>
<td>Arco Dylex 1186</td>
<td>4.8</td>
<td>5.7</td>
<td>142.6</td>
</tr>
<tr>
<td>Thermoflex 8002</td>
<td>6.6</td>
<td>5.1</td>
<td>142.6</td>
</tr>
</tbody>
</table>

Compressive Strength:

The compressive strengths of the various concretes were determined using 4 - by 8 - inch cylinders in accordance with AASHTO- T22. All specimens were cured in the moist room until a few hours before testing. The Arco Dylex 1186 and the Thermoflex 8002 concretes yielded the lowest strengths, however, all concretes had average 28 - day compressive strengths over 4000 psi. Table 2 presents the results of the compressive strength tests.
TABLE 2
COMPRESSIVE STRENGTH

<table>
<thead>
<tr>
<th>CONCRETE</th>
<th>14 DAYS</th>
<th>28 DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class AA/Dolomite (Reference)</td>
<td>4702</td>
<td>5405</td>
</tr>
<tr>
<td>Class AA/Granite</td>
<td>4655</td>
<td>5038</td>
</tr>
<tr>
<td>Silane Z6020</td>
<td>5604</td>
<td>6337</td>
</tr>
<tr>
<td>LSDC</td>
<td>5499</td>
<td>5890</td>
</tr>
<tr>
<td>Arco Dylex 1186</td>
<td>4102</td>
<td>4748</td>
</tr>
<tr>
<td>Thermoflex 8002</td>
<td>3407</td>
<td>4087</td>
</tr>
</tbody>
</table>

1. Average compressive strength of nine 4 - by 8 - inch cylindrical specimens at each age. (Three specimens from each of three separate batches).

Bond Strength

The bond strength of all concretes, except the Silane Z6020 and the Arco Dylex 1186 concretes were tested at 10 days, in accordance with Vt AOT-MD3. Bond strengths higher than 548 psi (obtained with the reference concrete) were produced by all other concretes. Table 3 presents the Bond Strength test results.

TABLE 3
BOND STRENGTHS

<table>
<thead>
<tr>
<th>CONCRETE</th>
<th>BOND STRENGTH(^1),PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class AA/Dolomite (Reference)</td>
<td>548</td>
</tr>
<tr>
<td>Class AA/Granite</td>
<td>1035</td>
</tr>
<tr>
<td>LSDC</td>
<td>699</td>
</tr>
<tr>
<td>Thermoflex</td>
<td>838</td>
</tr>
</tbody>
</table>
1. Average bond strength of four 2.75 - by 3 - by 12 - inch specimens (two specimens from each of two separate batches.)

Freeze - thaw Durability

The resistance of the concretes to freeze-thaw damage was studied using the procedures described in Vt AOT-MD4. The Class AA concrete with granite aggregate performed poorly compared to the reference mix. Testing of the Class AA/Granite concrete was discontinued at the completion of 25 freeze-thaw cycles. The specimens had deteriorated to a point where continued testing was no longer practical.

All other concretes yielded better results than the reference mix. The concrete containing Dylex Latex 1186 showed no weight loss at 100 cycles for all curing age groups. Table 4 presents the results of the Freeze-Thaw Durability test.

<table>
<thead>
<tr>
<th>CURE TIME PRIOR TO TESTING AND CONCRETE TYPE</th>
<th>25Cycles</th>
<th>50Cycles</th>
<th>75Cycles</th>
<th>100Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cured 28 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class AA/Dolomite (Reference)</td>
<td>7</td>
<td>9</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Class AA/Granite</td>
<td>17</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silane Z6020</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>LSDC</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Arco Dylex 1186</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thermoflex 8002</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

| 2. Cured 60 days                            |          |          |          |          |
| Class AA/Dolomite (Reference)               | 8        | 8        | 8        | 8        |
| Class AA/Granite                            | 33       | -        | -        | -        |
| Silane Z6020                                 | 1        | 2        | 2        | 3        |
| LSDC                                        | 4        | 4        | 5        | 5        |
| Arco Dylex 1186                              | 0        | 0        | 0        | 0        |
| Thermoflex 8002                              | 0        | 0        | 0        | 2        |
3. Cured 90 days
   Class AA/Dolomite (Reference) 9 10 10 10
   Silane Z6020 1 2 2 2
   LSDC 2 3 3 3
   Arco Dylex 1186 0 0 0 0
   Thermoflex 8002 0 0 1 1

1. Three 2 - inch cubes per batch per age.

Chloride Permeability

Chloride permeabilities of the various concretes were evaluated using the Vt. AOT-MD20 procedure. The Silane Z6020 concrete showed the lowest chloride permeability of all the concretes studied. The Class AA/Granite mix allowed slightly more chloride ingress at the 1 inch and deeper levels than the reference mix. All other mixes were approximately equal in performance to the reference mix. Following 200 days of continuous ponding with a 13 percent NaCl solution, none of the concretes contained an amount of chloride at the 1½ - 2 inch depth which would be considered harmful. Table 5 presents the results of the chloride permeability tests.

<table>
<thead>
<tr>
<th>CONCRETE</th>
<th>TOTAL CHLORIDE², PPM/LB. PER CY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEAN</td>
</tr>
<tr>
<td></td>
<td>SAMPLING DEPTH³, IN</td>
</tr>
<tr>
<td></td>
<td>100 DAYS</td>
</tr>
<tr>
<td></td>
<td>200 DAYS</td>
</tr>
<tr>
<td>Class AA/Dolomite (Reference)</td>
<td>0.75 965/3.8 987/4.0</td>
</tr>
<tr>
<td></td>
<td>1.25 136/0.5 138/0.3</td>
</tr>
<tr>
<td></td>
<td>1.75 100/0.4 108/0.4</td>
</tr>
<tr>
<td>Class AA/Granite</td>
<td>0.75 1000/4.0 944/3.8</td>
</tr>
<tr>
<td></td>
<td>1.25 153/0.6 221/0.9</td>
</tr>
<tr>
<td></td>
<td>1.75 90/0.4 177/0.7</td>
</tr>
<tr>
<td>Silane Z6020</td>
<td>0.75 89/0.4 119/0.5</td>
</tr>
<tr>
<td></td>
<td>1.25 59/0.2 73/0.3</td>
</tr>
<tr>
<td></td>
<td>1.75 51/0.2 60/0.2</td>
</tr>
<tr>
<td>LSDC</td>
<td>0.75 277/1.1 688/2.8</td>
</tr>
<tr>
<td></td>
<td>1.25 127/0.5 143/0.6</td>
</tr>
<tr>
<td></td>
<td>1.75 78/0.3 119/0.5</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>Arco Dylex 1186</td>
<td>0.75</td>
</tr>
<tr>
<td>Thermoflex 8002</td>
<td>0.75</td>
</tr>
</tbody>
</table>

1. Corrosion threshold range currently thought to be between 300 and 400 ppm at the rebar level.

2. Average of 2 samples from each 11 - by 11 - by 4 inch block. One block from each of two, three, or four batches.

3. Mean sampling depths are given. The actual depths were 1/16 to 1 inch, 1 to 1 1/2 inch and 1 1/2 to 2 inch.
Summary and Conclusions

I. The chloride permeability of concrete containing silicone admixture is slightly less than the conventional concretes.

2. The latex modified concretes are not significantly damaged by 100 freeze-thaw cycles.

3. All concretes exhibited average 28-day compressive strengths greater than 4000 psi.

4. Thermoflex 8002 concrete and the LSOC mixture had greater bond strengths than the reference concrete.

5. The laboratory evaluation indicates that all concretes except the class AA/Granite should perform equally well as low permeability bridge deck overlay concretes.

6. Should the need arise in the future for a concrete-related protective system, a field evaluation should first be conducted to determine the in-service performance of these concretes under Vermont conditions.
References

1. Federal-Aid Highway Program Manual, Transmittal 188, April 5, 1976. Vol. 6, Ch. 7; Sec. 2, Subsec. 7


4. Patterson, H. L. "Use of Silicone Admixture in Bridge Deck Concrete" Highway Research Record No. 370
Product Evaluation Work Plan

Product: Dow Corning Z-6020 Silane
Manufacturer: Dow Corning Corporation
Distributor or Representative: Midland, Mich. 48640

Evaluation Requested By: F. C. Scribner
Date: November 8, 1976
Date Information Required: N/A
Date Product Data & Application Instructions Received: N/A
Date Samples Received: February 10, 1977

Sample Quantity: 16 oz. liquid
Sufficient samples received: yes

Purpose of Evaluation:
To determine increase in freeze-thaw durability, compressive strength, bond strength,
resistance to chloride intrusion, base level chloride content.

Proposed Tests (Attach extra sheet if necessary)
1. Compressive strength 1 day, 7 days, 14 days, 28 days
2. Bond Test 10 days
3. Freeze-Thaw durability (wet loss @ 25 cycle intervals at ages 3 days, 14 days,
28 days, 50 days)
4. Chloride intrusion 50 day intervals after 28 day cure.
5. Chloride content analysis.

Proposal Discussed with Following Subdivisions: R. Frascoia, J. Talbot
Projected manpower requirements: 3 days preparation and daily handling
Evaluation to be Conducted by: Hodgdon
Proposed Starting Date: March 8, 1977
Estimated Completion Date: March, 1977
Approval by Materials Engineer: R. H. Snow 3/7/77

Contents by Materials Engineer
State of Vermont
Agency of Transportation
Materials Division - Research & Development Subdivision

PRODUCT EVALUATION

Work Plan No. 78-C&R-13

Product: "AA" Concrete Mix Utilizing 3/8" Granite Aggregate

Manufacturer: 3/8" aggregate source
Distributor or Representative
Cooley Asphalt
Websterville, Vermont

Evaluation Requested By: In House
Date: March 3, 1978

Date Evaluation Required: No Date Set
Date Product Information Received: N-A

Date and Quantity of Samples Received: N-A

Purpose of Evaluation: To determine if the mix is acceptable for use as a structural overlay in the construction of two course bridge decks.

Proposed Tests: Three (3) individual mixes each consisting of the following:

- Compressive Strength (6) 4"x8" cylinders 3 each at 14 & 28 days age
- Freeze-Thaw Durability (12) 2"x2"x2" cubes compressive strength at 28 days plus durability of 3 cubes aged 28, 60 and 90 days at 25 cycle intervals
- Flexural Strength (2) 3/4"x3"x12" beam sections using single point loading
- Resistance To Chloride Penetration (1) 11"x11"x4" slab

All test results to be compared against reference mix consisting of "AA" concrete mix utilizing 3/8" Dolomite aggregate

Proposal Discussed With: Talbot, Coti

Projected Manpower Requirements: Prep & testing - 6 man days report - 3 man days

Evaluation To Be Conducted By: Structural Concrete & R&D

Proposed Starting Date: March 20, 1978
Estimated Completion Date: June, 1979

Approval/Disapproval by Materials Engineer: [Signature]

Comments by Materials Engineer: 

[Signature]

Materials Division
Highway Department
Agency of Transportation
State of Vermont
Agency of Transportation
Materials Division - Research & Development Subdivision

PRODUCT EVALUATION
Work Plan No. 78-C&R-14

Product Iowa Concrete Mix Utilizing 3/8" Dolomite Aggregate

Manufacturer 3/8" aggregate source Distributor or N-A
Representative F.W. Whitcomb Construction Corp.
Winooski, Vermont

Evaluation Requested By In House Date March 6, 1978

Date Evaluation Required No date set Date Product Information Received N-A
Date and Quantity of Samples Received N-A

Purpose of Evaluation To determine if the mix is acceptable for use as a structural
overlay in the construction of two course bridge decks.

Proposed Tests Three (3) individual mixes each consisting of the following:
- Compressive Strength (6) 4"x8" cylinders 3 each at 14 & 28 days age
- Freeze-Thaw Durability (12) 2"x2"x2" cubes compressive strength at 28
days plus durability of 3 cubes aged 28, 60 & 90 days at 25 cycle intervals
- Flexural Strength (2) 2 3/4"x3"x12" beam sections using single point loading
- Resistance To Chloride Penetration (1) 11"x11"x4" slab
- All test results to be compared against a reference mix consisting of "AA"
  concrete mix utilizing 3/8" Dolomite aggregate

Proposal Discussed With Frascola and Corti

Projected Manpower Requirements Prep & testing - 6 man days Report - 3 man days

Evaluation To Be Conducted By Structural concrete & R&D

Proposed Starting Date March 9, 1978 Estimated Completion Date June 1979

Approval/Disapproval by Materials Engineer

Comments by Materials Engineer

Materials Division
Highway Department
Agency of Transportation
Product Latex Concrete Mix Utilizing Dylex Latex 1186 & 3/8" Dolomite Aggregate

Manufacturer ARCO Polymers Inc.  Distributor or Tex-Crete Inc. Representative Philadelphia  6305 Grand Ave. Pennsylvania 19101 Gurnee, Illinois 60031

Evaluation Requested By In House Date March 6, 1978

Date Evaluation Required No Date Set Date Product Information Received Jan. 10, 1978

Date and Quantity of Samples Received February 6, 1978

Purpose of Evaluation To determine if the mix is acceptable for use as a structural overlay in the construction of two course bridge decks.

Proposed Tests

Three (3) individual mixes each consisting of the following:

- Compressive Strength (6) 4"x8" cylinders 3 each at 14 & 28 days age
- Freeze-Throw Durability (12) 2"x2"x2" cubes compressive strength at 28 days plus durability of 3 cubes ages 28, 60 and 90 days at 25-cycle intervals
- Flexural Strength (2) 2 3/4"x3"x12" beam sections using single point loading
- Resistance To Chloride Penetration (1) 11"x11"x4" slab

All test results are to be compared against a reference mix consisting of AA concrete utilizing 3/8" Dolomite aggregate

Proposal Discussed With Fraconi and Corti

Projected Manpower Requirements Prep & testing - 6 man days report - 3 man days

Evaluation To Be Conducted By Structural concrete & R&D

Proposed Starting Date March 14, 1978 Estimated Completion Date June 1978

Approval/Disapproval by Materials Engineer

Comments by Materials Engineer

Materials Division Highway Department
Agency of Transportation
Product Latex Concrete utilizing Thermoflex 8002 & 3/8" Dolomite Aggregate

Manufacturer Reichhold Chemicals Inc. Distributor or Thermoflex Inc.
Emulsion Polymer Division Representative
P.O. Drawer K Box 21134
Dover, Delaware 19901 Louisville, Kentucky

Evaluation Requested By In House Date March 6, 1978
Date Evaluation Required No Date Set Date Product Information Received 6/21/77
Date and Quantity of Samples Received Feb. 14, 1978

Purpose of Evaluation To determine if the mix is acceptable for use as a structural overlay in the construction of two course bridge decks

Proposed Tests Three (3) individual mixes each consisting of the following:
- Compressive Strength (6) 4"x8" cylinders 3 each at 14 & 28 days age.
- Freeze-Thaw Durability (12) 2"x2"x2" cubes compressive strength at 28 days plus durability of 3 cubes aged 28, 60 and 90 days at 25 cycle intervals.
- Flexural Strength (2) 2 3/4"x3"x12" beam sections using single point loading.
- Resistance To Chloride Penetration (1) 11"x11"x4" slab.

All test results are to be compared against a reference mix consisting of AA concrete utilizing 3/8" Dolomite aggregate.

Proposal Discussed With Frascho and Corti

Projected Manpower Requirements Prep & testing - 6 man days report - 3 man days

Evaluation To Be Conducted By Structural concrete & R&D

Proposed Starting Date March 15, 1978 Estimated Completion Date June 1979

Approval/Disapproval by Materials Engineer

Comments by Materials Engineer