# 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

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AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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## 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

| CONCRETE | SLUMP, INCHES | AIR CONTENT, PERCENT | UNIT WEIGHT, LB /FT$^3$ |
|---|---|---|---|
| Class AA/Dolomite (Reference) | 1.8 | 7.4 | 142.2 |
| Class AA/Granite | 1.8 | 6.8 | 140.1 |
| Silane Z6020 | 1.8 | 6.2 | 143.9 |
| LSDC | 0.8 | 5.8 | 146.1 |
| Arco Dylex 1186 | 4.8 | 5.7 | 142.6 |
| Thermoflex 8002 | 6.6 | 5.1 | 142.6 |

### 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

| CONCRETE | COMPRESSIVE STRENGTH[1], PSI AT 14 DAYS | 28 DAYS |
|---|---|---|
| Class AA/Dolomite (Reference) | 4702 | 5405 |
| Class AA/Granite | 4655 | 5038 |
| Silane Z6020 | 5604 | 6337 |
| LSDC | 5499 | 5890 |
| Arco Dylex 1186 | 4102 | 4748 |
| Thermoflex 8002 | 3407 | 4087 |

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

| CONCRETE | BOND STRENGTH[1], PSI |
|---|---|
| Class AA/Dolomite (Reference) | 548 |
| Class AA/Granite | 1035 |
| LSDC | 699 |
| Thermoflex | 838 |

1. Average bond strength of four 2.75 - by 3 - by 12 - inch specimens (two specimens from each of two seperate 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 4

FREEZE - THAW DURABILITY

| CURE TIME PRIOR TO TESTING AND CONCRETE TYPE | PERCENT WEIGHT LOSS[1] AFTER: 25CYCLES | 50CYCLES | 75CYCLES | 100CYCLES |
|---|---|---|---|---|
| 1. Cured 28 days | | | | |
| Class AA/Dolomite (Reference) | 7 | 9 | 13 | 14 |
| Class AA/Granite | 17 | - | - | - |
| Silane Z6020 | 4 | 4 | 4 | 4 |
| LSDC | 2 | 2 | 5 | 5 |
| Arco Dylex 1186 | 0 | 0 | 0 | 0 |
| Thermoflex 8002 | 0 | 0 | 1 | 1 |
| 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.[1] Table 5 presents the results of the chloride permeability tests.

TABLE 5

CHLORIDE PERMEABILITY RESULTS

| CONCRETE | MEAN SAMPLING DEPTH[3], IN | TOTAL CHLORIDE[2], PPM/LB. PER CY PONDING FOR, 100 DAYS | 200 DAYS |
|---|---|---|---|
| Class AA/Dolomite (Reference) | 0.75 | 965/3.8 | 987/4.0 |
| | 1.25 | 136/0.5 | 138/0.6 |
| | 1.75 | 100/0.4 | 108/0.4 |
| Class AA/Granite | 0.75 | 1000/4.0 | 944/3.8 |
| | 1.25 | 153/0.6 | 221/0.9 |
| | 1.75 | 90/0.4 | 177/0.7 |
| Silane Z6020 | 0.75 | 89/0.4 | 119/0.5 |
| | 1.25 | 59/0.2 | 73/0.3 |
| | 1.75 | 51/0.2 | 60/0.2 |
| LSDC | 0.75 | 277/1.1 | 688/2.8 |
| | 1.25 | 127/0.5 | 143/0.6 |
| | 1.75 | 78/0.3 | 119/0.5 |

| | | | |
|---|---|---|---|
| Arco Dylex 1186 | 0.75 | 232/0.9 | 219/0.9 |
| | 1.25 | 98/0.4 | 123/0.5 |
| | 1.75 | 72/0.3 | 95/0.4 |
| Thermoflex 8002 | 0.75 | 215/0.8 | 274/1.1 |
| | 1.25 | 84/0.3 | 113/0.5 |
| | 1.75 | 60/0.2 | 88/0.4 |

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

1. 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 LSDC 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

2. Clear, K. C. and Chollar, B. H. "Styrene - Butadiene Latex Modifiers for Bridge Deck Overlay Concrete", Federal Highway Administration Report No. FHWA-RD-78-35 April, 1978.

3. Peterson, P.C. "Concrete Bridge Deck Deterioration in Pennsylvania" Chloride Corrosion of Steel in Concrete ASTM STP 629.

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

Vermont Department of Highways

Materials Division

77-R-15

PRODUCT EVALUATION WORK PLAN

Product Dow Corning Z-6020 Silane

Manufacturer Dow Corning Corporation
Midland, Mich. 48640

Distributor or Representative

Evaluation Requested By F. C. Scribner Date November 8, 1976

Date Information Required N/A

Date Product Data & Application Instructions Received

Date Samples Received February 10, 1977

Sample Quantity 16 oz. liquid Were 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 (wgt. 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, 1978

Approval/~~Disapproval~~ by Materials Engineer R. H. Snow 3/7/77 RHS

Comments 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 N-A

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, 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 20, 1978 Estimated Completion Date June, 1979

Approval/Disapproval by Materials Engineer [signature] 3/13/78

Comments by Materials Engineer

Materials Division
Highway Department
Agency of Transportation

typed 3/13/78

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
F.W. Whitcomb Construction Corp.
Winooski, Vermont

Distributor or Representative N-A

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
Fexural 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 Frascoia 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 [illegible] 3/14/78

Comments by Materials Engineer

Materials Division
Highway Department
Agency of Transportation
Typed 3/14/78

Prepared By: J. Talbot
Date: 3/6/78
Sheet 1 of 1

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

PRODUCT EVALUATION

Work Plan No. 78-C&R-15

Product Latex Concrete Mix Utilizing Dylex Latex 1186 & 3/8" Dolomite Aggregate

Manufacturer ARCO Polymers Inc.
Philadelphia
Pennsylvania 19101

Distributor or Representative Tex-Crete Inc.
6305 Grand Ave.
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-Thaw 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 Frascoia 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 1979

Approval/Disapproval by Materials Engineer [signature] 3/14/78

Comments by Materials Engineer

Materials Division
Highway Department
Agency of Transportation
Typed 3/14/78

Prepared by: J. Talbot
Date: 3/6/78
Sheet 1 of 1

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

PRODUCT EVALUATION

Work Plan No. 78-C&R-16

Product Latex Concrete utilizing Thermoflex 8002 & 3/8" Dolomite Aggregate

Manufacturer Reichhold Chemicals Inc.
Emulsion Polymer Division
P.O. Drawer K
Dover, Delaware 19901

Distributor or Representative Thermoflex Inc.
Box 21134
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 Frascoia 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 E.J. Nicholson 3/14/78

Comments by Materials Engineer

Materials Division
Highway Department
Agency of Transportation



Transmitted 3/14/78