STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

Addendum To Report 86-6

Preliminary Report On Emsac F-100 Microsilica Additive For Concrete (Work Plan No. 85-C-24)

Background

Stimulated by claims of the enhanced performance of Portland Cement Concrete when Silica Fume is used as an additive, testing was initiated in November of 1985 to determine if conventional Vermont Agency of Transportation concrete mixtures used in bridge deck construction could be improved with the introduction of Emsac F-100 Microsilca additive from Elkem Chemicals, Inc..

Preliminary Report No. 86-6 recommended that prolonged testing for resistance to freezing and thawing and Chloride Ion penetration be conducted based on the favorable initial performance of Emsac F-100. This Update presents the results of continued testing and recommends a dosage for experimental use in the field.

It should be noted that Preliminary Report 86-6 indicated laboratory mixed concrete containing 10 to 30 percent condensed Silica Fume (Microsilica) by weight of cement was evaluated. This should be revised to read 4.5 to 13.5 percent condensed Silica Fume by weight of cement as Emsac F-100 is only 45 percent condensed Silica Fume by weight. 55 percent of Emsac F-100 is water and chemical admixtures.

Test Results

Given in Tables 1 and 2 are results of testing for compressive strength, resistance to Chloride Ion penetration and freeze-thaw durability.

Two 4" x 8" cylinders from each batch were tested for compressive strength (AASHTO T22-82) at 1, 3, 7, 14, and 28 days following standard moist curing. After 14 days of moist curing and 28 days of air drying, specimens to be used for determining resistance to Chloride Ion penetration were tested for base level Chloride Ion content. Upon completion of 100 and 200 days of continuous ponding with a 3% NaCl solution, the specimens were resampled for total Chloride Ion content at depths of 0.25" to 1" and 1" to 2" in accordance with AASHTO T260-84I. Specimens used to determine freeze-thaw durability were cycled from 40°F to 0°F and back to 40°F in a 3% NaCl solution 500 times following an initial 14 day moist curing period. The specimens were tested for weight loss and fundamental transverse frequency at 50 cycle intervals.

A complete summary of testing procedures and materials used in this evaluation along with fresh concrete test results can be found in Preliminary Report 86-6.

Summary

Laboratory testing conducted on Emsac F-100 Microsilica based concrete additive has demonstrated that conventional Portland Cement concrete can be enhanced significantly with its use.

Results indicate that Microsilica may be a more effective pozzolan than fly ash or blast furnace slag which demonstrate less rapid strength gain at early ages of test. Compressive strength of concrete produced with Silica Fume was substantially higher than the control concrete at all ages of test. As the per cent of Microsilica in the mix increased, the cylinder strengths increased markedly. Class AA concrete with 30% Emsac F-100 (13.5% Microsilica) by weight of cement exhibited the most dramatic increase in strength, an average of 91% higher than the control.

After subtracting baseline Chloride Ion levels, Emsac F-100 test batch specimens were found to be 5 to 80 times more resistant to Chloride Ion penetration in the top one inch of sample than the Class AA control mixture after 200 days of ponding.

Relative to the control, Class A concrete mixed with Emsac F-100 allowed approximately four times less Chloride Ion penetration in the top one inch of sample after 200 days of ponding.

None of the samples permitted Chloride ingress below the one inch depth greater than the threshold level of 1.3 lbs/cy, the level generally reported necessary to initiate corrosion.

Durability, as indicated by fundamental transverse frequency testing, was approximately equal for all samples. Weight loss after 500 cycles of freezing and thawing in a 3% NaCl solution decreased as the percent of Microsilica in the concrete mix increased. The high durability factors indicate a sound internal structure but the greater weight loss for the control mixtures and test batches with 10% Emsac F-100 are indicative of moderate to severe surface sealing.

Recommendations

Based on the favorable results given in this Update and Preliminary Report 86-6, it is recommended that condensed Silica Fume concrete be used in the field on a trial basis. Due to the extreme difficulty in finishing specimens fabricated with 30% Emsac F-100 and the less than spectacular permeability and freeze-thaw test values for the 10% addition rate, it is suggested that 15 to 20% Emsac F-100 by weight of cement be used.

Microsilica concrete should be considered as an alternative on bare deck or overlay construction not protected by a membrane and bituminous

concrete overlay system. Class AA mix should be used when the depth of concrete is 2½" or less and Class A when the depth exceeds 2½".

Ponding of specimens with 3% NaCl should be continued for the 300 day period outlined in Preliminary Report 86-6 and a Final Report should be written documenting the results upon completion.

"The information contained in this report was compiled for the use of the Vermont Agency of Transportation. Conclusions and recommendations contained herein are based upon the research data obtained and the expertise of the researchers, and are not necessarily to be construed as Agency policy. This report does not constitute a standard, specification or regulation. The Vermont Agency of Transportation assumes no liability for its contents or the use thereof."

Reviewed By:

R. F. Nicholson

R. F. Nicholson, P.E.
Materials & Research Engineer

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TABLE 1

COMPRESSIVE STRENGTH, FREEZE-THAW, AND CHLORIDE ION CONCENTRATION TEST RESULTS CONCRETE CLASS A

	Control Batches		EMSAC F-100 Test Batches				
Laboratory Batch #	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7
Cement Content, lbs/cy	660	660	660	660	660	660	660
Percent EMSAC F-100 (Percent Silica Fume) by wgt. of cement	N.A.	N.A.	10(4.5)	10(4.5)	30(13.5)	30(13.5)	30(13.5)
Compressive Strength, PSI: 1 day	2834	2944	3401	3282	4525	4823	4416
3 days	4038	4495	5231	5131	7319	7628	7290
7 days	4644	4963	5808	5997	8145	8592	8304
14 days	5441	5500	6813	6962	9767	10,264	10,085
28 days	5887	6136	7399	7409	10,084	11,028	10,998
Resistance To Freezing & Thawing: Weight Loss, percent 500 cycles	5.0	6.4	3.3	2.3	1.2	0.7	0.6
Durability Factor 500 cycles	103.7	100.7	103.7	104.5	101.5	102.9	102.2
Chloride Ion Penetration, PPM (lbs/cy) of concrete							
Base Level Cl^-		53(0.2)		53(0.2)			83(0.3)
100 Day Ponding							
¼" to 1" depth		160(0.6)		86(0.3)			110(0.4)
1" to 2" depth		62(0.2)		53(0.2)			89(0.4)
200 Day Ponding							
¼" to 1" depth		466(1.9)		153(0.6)			198(0.8)
1" to 2" depth		62(0.2)		53(0.2)			92(0.4)

TABLE 2

COMPRESSIVE STRENGTH, FREEZE-THAW, AND CHLORIDE ION CONCENTRATION TEST RESULTS CONCRETE CLASS AA

	Control Batches		EMSAC F-100 Test Batches					
Laboratory Batch #	Batch 8	Batch 9	Batch 10	Batch 11	Batch 12	Batch 13	Batch 14	Batch #15
Cement Content, lbs/cy	705	705	705	705	705	705	705	705
Percent EMSAC F-100 (Percent Silica Fume) by wgt. of cement	N.A.	N.A.	10(4.5)	10(4.5)	20(9)	20(9)	30(13.5)	30(13.5)
Compressive Strength, PSI: 1 day	2854	2596	3411	3530	4087	4256	5042	5141
3 days	3938	3709	5390	5002	5748	6513	7260	7578
7 days	4624	3998	6514	6017	7409	7687	8851	9397
14 days	5300	5002	7518	7180	8234	8980	10,054	10,223
28 days	6126	5798	8373	7707	9736	10,293	11,088	11,715
Resistance To Freezing & Thawing: Weight Loss, percent 500 cycles	6.7	5.7	7.5	6.7	3.0	1.9	1.5	1.4
Durability Factor 500 cycles	103.7	105.2	105.2	103.7	107.5	104.4	103.7	103.7
Chloride Ion Penetration, PPM (lbs/cy) of concrete								
Base Level Cl^-		47(0.2)		65(0.3)		65(0.3)		100(0.4)
100 Day Ponding								
¼" to 1" depth		918(3.7)		317(1.3)		98(0.4)		154(0.6)
1" to 2" depth		110(0.4)		83(0.3)		80(0.3)		95(0.4)
200 Day Ponding								
¼" to 1" depth		2907(11.6)		634(2.5)		142(0.6)		136(0.5)
1" to 2" depth		121 (0.5)		74(0.3)		80(0.3)		98(0.4)