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RESEARCH UPDATE

NUMBER U89-1

EMSAC F-100 MICROSILICA ADDITIVE FOR CONCRETE

Reference:

Report No. 86-6 Work Plan 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 Microsilica 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. An addendum written to report 86-6 documenting resistance to chloride ion penetration and freeze-thaw durability was published in December of 1986. Favorable test results at that time resulted in recommendations to continue ponding specimens with 3% NaCl for 300 days and that Silica Fume be used on an experimental basis in the field.

This RESEARCH UPDATE concludes the planned laboratory evaluation of Emsac F-100 Microsilica additive for concrete. During the summer of 1988, 7.5% Silica Fume by weight of cement was used in the concrete mix on a bridge deck overlay placed on the Winooski MEGC M5100(8) project. As the material used in that project was not manufactured by Elkem Chemicals, Inc., results will not be presented here but will appear in future updates.

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 T22-86) 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, 200 and 300 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 T260-84. 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 percent of Microsilica in the mix increased, the cylinder strengths increased markedly. Class AA concrete with 30% Emsac F-100 (13.5% Silica Fume) 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 3 to 95 times more resistant to chloride ion penetration in the top one inch of sample than the Class AA control mixture after 300 days of ponding.

Relative to the control, Class A concrete mixed with Emsac F-100 allowed approximately 2 to 5 times less chloride ion penetration in the top one inch of sample after 300 days of ponding.

After 300 days of ponding the chloride ion concentration below the one inch depth in the Class AA control specimen exceeded the threshold value of 1.3 lb/cy, the level generally reported necessary to initiate corrosion in reinforcing steel embedded in Portland cement concrete. Chloride ingress below the one inch depth was well under the threshold value in all the Emsac F-100 test batches.

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 indicated a sound internal structure but the greater weight loss for the control mixtures and test batches with only 10% Emsac F-100 are indicative of moderate to severe surface scaling.

Based on the favorable results given in the Preliminary Report 86-6 and its addendum, it was 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 was suggested that 15% to 20% Emsac F-100 by weight of cement be used.

Since those initial reports, use of Silica Fume has become more wide spread and its availability has grown. Handling of condensed Silica Fume has been overcome by combining the fine powder with liquid to form a slurry, as with Emsac F-100, or by shipping the Silica Fume blended with Portland Cement.

Recommendations:

Silica Fume 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 2-1/2" or less and Class A when the depth exceeds 2-1/2". The addition rate should be 7.5% Silica Fume by weight of cement and the use of high range water reducer required. (NOTE: 7.5% Silica Fume would be equivalent to approximately 16.7% Emsac F-100 by weight of cement. Emsac F-100 contains a high range water reducer in its formulation.)

In addition to overlays, it is recommended that Silica Fume concrete be used in structures where high compressive strengths and increased resistance to chloride induced corrosion of reinforcing steel are needed.

Applications in the field should include trial use in precast members and bridge curbing where abrasion and wear resistance can be monitored.

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 weight 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 and 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)
300 Day Ponding ¼" to 1" depth		824(3.3)		379(1.5)			243(1.0)
1" to 2" depth		83(0.3)		71(0.3)			83(0.3)

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 weight 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 and 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)
300 Day Ponding ¼" to 1" depth		4621(18.0)		1408(5.6)		218(0.9)		148(0.6)
1" to 2" depth		497(2.0)		77(0.3)		81(0.3)		109(0.4)