CURING COMPOUND EVALUATION

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VERMONT DEPARTMENT OF HIGHWAYS

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ABSTRACT

The Materials Division of the Vermont Department of Highways in co-operation with W. W. Wyman, Inc. of Greenfield, Massachusetts has performed field tests to evaluate the relative effectiveness of two curing compounds as compared to moist curing methods normally practiced in Vermont bridge deck construction.

Three slabs were formed and cast exactly simulating the construction used in bridge decks. They were each six feet square, eight inches thick, and included reinforcement mats as per bridge standards. Surface hardness was monitored by Swiss Impact Hammer and cores were tested in compression at twenty-eight days.

The results of this investigation establish that the linseed oil emulsion curing compound may be acceptable for limited field applications.

INTRODUCTION

Throughout the past several years, pressure has been mounting to use commercial curing compounds for structural concrete - especially bridge decks. The use of these compounds has been discouraged for several reasons - none have been as effective as moist curing; rubber or wax based compounds leave a residue on the surfaces and inhibit bond; and equipment limitations prohibit laboratory testing as prescribed by AASHO procedures.

Recently developed products have received considerable attention and an opportunity to test two of them was afforded us by W. W. Wyman, Inc. This contractor offered to build simulated bridge decks for the purpose of evaluating the effects of two curing compounds compared to standard moist curing.

Comparisons were made using an Impact Hammer as well as cores and cylinders for compressive strength.

MATERIALS & DATA

CONCRETE: The concrete used in all slabs was placed from a single mixer batched by Calkins Redimix of Lyndon, Vermont. A standard mix proportioned to meet requirements of Class A (bridge deck concrete) was used having a 2 3/4" slump and 8% air. This entrained air content was slightly higher than normal but no attempt was made to reduce it.

CURING COMPOUNDS: Two curing compounds were evaluated as requested by the contractor.

SLAB A was cured with a linseed oil emulsion developed under the auspices of the U.S. Department of Agriculture. It is manufactured under patent by several companies. The product used in this evaluation was supplied by Darling & Co. of Chicago, Illinois and is called Tri-Dar 33. The sample was not white-pigmented as would be required in actual practice. The white-pigmented type would reflect the rays of the sun and help protect the concrete.

SLAB B was cured with a product manufactured by Dural Materials Corp. of Port Washington, New York under the trade name of Duralkote 605. This material is a clear, one-component polymeric sealer and curing compound.

PROCEDURE

Three test slabs were separately formed to simulate typical 8" poured in place highway bridge decks. The plywood forms were prepared several feet above ground and were completed with properly spaced and tied reinforcing bars. All slabs were cast, vibrated, screeded, bullfloated and burlap dragged.

SLAB A was sprayed with linseed oil emulsion curing compound immediately after the slab had been "dragged". The application was provided according to the manufacturer's recommendations of 1 gallon per 200 sq. ft. A second application was conducted at 14 days as suggested by the manufacturer.

SLAB B was sprayed with Duralkote 605 after the moisture sheen had disappeared, i.e. about 20 minutes after finishing. Only one application was deemed necessary by the manufacturer at the rate of 1 gallon per 200 sq. ft.

SLAB C was moist-cured using polyethylene sheeting. This slab was monitored several times daily to ensure that moisture remained constant throughout 14 days. The curing was initiated within an hour of the finishing operations.

All test slabs were monitored with a Swiss Impact Hammer at ages 4, 7, 14, 21, and 28 days. Slab A (linseed oil emulsion curing compound) was further monitored with this apparatus twice (5 hours and 24 hours) after the second application of curing compound (14 days) to determine if surface softening occurred.

Cylinders were cast for testing in compression at ages 7, 14, and 28 days. They were moist-cured until tested.

At 28 days, cores were obtained from all three slabs, then capped and broken in compression. They were sampled from both peripheral and interior locations to determine if there was variance in compressive strength at different locations within the test slabs.

RESULTS AND DISCUSSION

The two compounds differed markedly from each other in appearance.

Compound A (linseed oil emulsion) darkened the concrete throughout the full test period. It was easy to apply and did not tend to "gum up" or foul the spray apparatus. Coverage could easily be inspected due to the discoloration that it imparted to the concrete. This compound was applied immediately after the concrete was finished as recommended by the manufacturer while the water sheen remained on the surface. After two hours, it appeared to float on the bleed water. At five hours the chemical was sticky to the touch and at twenty-four hours, it had dried uniformly.

At fourteen days, a second application was sprayed on the slab and the compound remained "tacky" for several hours. The surface again softened somewhat as is indicated by the impact hammer results.

COMPOUND B (polymeric sealer) was applied after the bleed water had evaporated, i.e. twenty minutes after the concrete was finished. This chemical is very sticky and difficult to remove if in contact with the skin. In appearance, a glossy membrane resembling a thin plastic sheet or film developed upon drying. The chemical, not being white pigmented, was difficult to distinguish as to coverage. On further drying, bubbles developed over the entire surface and appeared to be full of water. At twenty-four hours, the bubbles had dried within but remained intact and became brittle. Following heavy rains on the fourth day after application, all bubbles in the film broke, exposing the concrete.

The polymeric sealer type curing compound is unsuitable for highway structures regardless of its curing ability due to the following statement set forth in AASHO Specifications for Highway Materials - Designation M148-68 Liquid Membrane-Forming Compounds for Curing Concrete 6.1 Drying Time ------ "When dried, the compound shall not be tacky nor track off the concrete when walked upon, nor shall it impart a slippery surface to the concrete". The surface of Slab C was slippery even at twenty-eight days.

During the casting of the slabs, nine cylinders and one test beam were molded - the results of which are tabulated in Table A. They were moist-cured until tested. The test beam was broken in flexure at fourteen and twenty-eight days.

Table B shows the average of the impact hammer results for the various dates and ages of test during which each slab was monitored. Each figure represents the average of a minimum of ten readings per test. No attempt is made to correlate these readings with compressive strength. The averages are an indication of the surface hardness and are an excellent comparison between slabs as well as progression of strength with age.

Table C shows the location and results of cores (four inch diameter) tested at 28 days. An effort was made to establish differences between those drilled from the edges of the slabs as opposed to those from the interior but no constant variation appears to exist. In fact, at twenty-eight days, there is little difference in the compressive strength of any of the curing methods.

CONCLUSIONS

1. Core results show little difference due to curing methods at 28 days.
2. No difference in compressive strength could be determined due to location of core extraction.
3. The average compressive strength obtained from the cores after field curing was 99% of the compressive strength obtained from laboratory cured cylinders.
4. During the critical curing period (14 days), Swiss Impact Hammer results indicate that Slab "A" cured with linseed oil emulsion compared favorably with moist-curing.
5. A second application of linseed oil emulsion applied at 14 days temporarily softened the surface as anticipated. At 28 days however, the surface hardness was again comparable to that of the moist-cured slab.
6. Slab "B" cured with polymeric sealer was generally lower in all results and should not be further considered for use by the Department.
7. No tests for bond were conducted following the application of either curing compound.

RECOMMENDATIONS

Based on the foregoing investigation, it is recommended that "Tri-Dar 33" white pigmented linseed oil emulsion curing compound be further evaluated by limited field application. Due to lack of equipment and facilities, product certifications should be suitable in lieu of laboratory acceptance tests.

CONCRETE STRENGTHS OF
REFERENCE TEST SPECIMENS

MODULUS OF RUPTURE

		14 Day	28 Day
Test Beam		511 psi	541 psi

COMPRESSIVE STRENGTH

	7 Day	14 Day	28 Day
Cylinders	2573 psi	2785 psi	2997 psi
	2272	2812	3254
	2264	2741	3263
Average	2370 psi	2779 psi	3171 psi

TABLE A

CURING COMPOUND

TEST SLABS

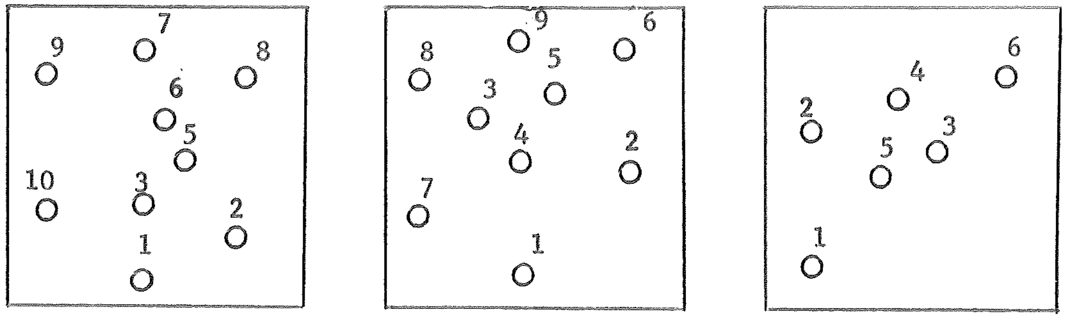
SWISS IMPACT HAMMER READINGS (AVG.)

Date	Age	Remarks	Slab A (Tri-Dar 33)	Slab B (Dural Kote 605)	Slab C (Moist Cured)
July 10th	4 days	Readings taken in rain	15.7	13.9	15.9
July 13th	7 days		20.4	19.2	19.6
July 20th 9:30 A.M.	14 days	Prior to re-coating Slab A	20.0	16.3	17.0
Jul7 20th 3:00 P.M.	14 days	Five hours after Slab A was re-coated	16.6		
July 21st	15 days	Twenty-four hours after Slab A was re-coated	15.4		
July 28th	22 days		17.3	19.0	24.5
August 3rd	28 days		20.4	18.0	21.8

TABLE B

CORE LOCATIONS

SLAB A (TRI-DAR 33) | SLAB B (DURAL KOTE 605) | SLAB C (MOIST CURE)



* Cores were taken a minimum one foot from edge of slab

COMPRESSIVE STRENGTH OF CORES (PSI)

	A	B	C
1	3392	2717	2876
2	3451	2731	3057
3	3542	3573	2854
4		3012	3184
5	3134	2880	2799
6	2862	2826	3419
7	3340	3116	
8	*4370	3274	
9	3143	3614	
10	3478		
Average Centrally Located	3179	3155	2946
Average Periferally Located	3367	3046	3117
Overall Average	3296	3082	3031
Average of All Cores			3144

* Extreme Result-Discard

TABLE C