HIGHWAY RESEARCH REPORT

POLYMER IMPREGNATION OF PORTLAND CEMENT CONCRETE

INTERIM REPORT

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

TRANSPORTATION LABORATORY

RESEARCH REPORT

CA-DOT-TL-5150-1-73-29

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16. ABSTRACT

Oven-dried concrete specimens were impregnated with methacrylate monomers and the monomers polymerized by thermal-chemical means. Subsequent tests for compressive strength, abrasion resistance, and moisture absorption showed the impregnated concrete to be superior to untreated concrete.

Measured penetration of the polymer was approximately 19 mm after 18 hours soaking in the catalyzed monomer solutions.

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DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY
5900 FOLSOM BLVD., SACRAMENTO 95819

September, 1973

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Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is an interim research report titled:

POLYMER IMPREGNATION OF PORTLAND CEMENT CONCRETE

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Very truly yours,

JOHN L. BEATON, P. E.
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Attachment

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The Cement and Concrete Sections prepared the concrete specimens and performed the strength and abrasion tests under the direction of Mr. James H. Woodstrom.

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The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

This project was performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Agreement No. D-5-15.

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POLYMER IMPREGNATION OF PORTLAND CEMENT CONCRETE

INTRODUCTION

Since 1965, many agencies, principally the U. S. Bureau of Reclamation, the U. S. Atomic Energy Commission, and the Office of Saline Water, have been investigating the improvement of concrete by impregnation with monomer systems followed by polymerization by irradiation or thermal-catalytic methods[1-4]. These agencies have found the impregnated concrete to be significantly superior to normal concrete.

As a result of these and other reports[5], a preliminary investigation into this procedure was undertaken by the Transportation Laboratory (Materials and Research Department) in 1972 to determine possible applications in areas of interest. We were specifically interested in depth of penetration and improvements in physical properties of partially impregnated concrete obtained by soaking the specimen rather than improvements by fully impregnated concrete, which requires the use of vacuum or pressurization techniques.

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CONCLUSIONS

Specimens soaked in the catalyzed monomer for 18 hours and cured, showed that polymer impregnated concrete is superior to untreated concrete in terms of compressive strength (250% increase), moisture absorption (essentially zero), and durability as measured by abrasion loss (75-80% decrease in loss). Depth of penetration was about 19 mm.

The monomer system penetrates or is absorbed by the dry concrete quite readily indicating that a ponding or multiple application method would be satisfactory.

One hundred percent (100%) impregnation of all voids and cracks is not possible without the application of vacuum to remove entrapped air. However, the significant improvement in the treated concrete even without complete impregnation would seem to justify a more thorough examination of this process for use by the California Department of Transportation.

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IMPLEMENTATION

The findings in this investigation indicate that concrete can be significantly improved by polymer impregnation. Based on these findings, we believe that further investigations on larger specimens in the laboratory as well as field applications on a trial basis, would contribute much to the further development of this technique and yield valuable information as to other possible uses of the process.

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IMPREGNATION, TESTING, AND TEST RESULTS

Due to the limited scope of this investigation, all testing was performed using either 50.8 x 50.8 mm sand mortar cubes, or 50.8 mm high x 101.6 mm diameter cylinders prepared from 6.3 mm maximum aggregate and portland cement. The water-cement ratio was 0.6 (Table 5). All specimens were cured a minimum of 28 days in 100% humidity. Additionally, each cylinder, when fabricated, was finished cement-lean on one diameter surface and cement-rich on the reverse. After curing, all specimens were dried to constant weight at 105°C, then cooled and stored in moisture-tight containers until use.

The polymerization of monomers has been accomplished by radiation and by the use of chemical and thermal-chemical methods(1). Since irradiation would not be feasible from a highways viewpoint (except in certain instances, such as precast structures), polymerization in the study was achieved using thermal-chemical methods.

Perhaps the most common catalyst for polymerization is benzoyl peroxide, although there are several other free radical forming materials that can be used. In this investigation, the catalyst was azodiisobutyronitrile (AIBN), selected because it has a shorter half-life or faster rate of decomposition and free radical formation than benzoyl peroxide(6).

Polymerization of monomers can be accomplished at room temperatures through the use of accelerators or promoters(7). However, our experience using these promoters showed that the rate of polymerization was increased such that very little penetration into the concrete was obtained. It should be possible to vary the proportions of catalyst and promoter to achieve some control of the rate of polymerization. However, this was felt to be beyond the scope of this investigation and no further work was done along this line.

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Impregnation of the specimens was accomplished by submersion in the catalyzed monomer solution for 18 hours. Specimens were then removed and wrapped in polyethylene sheet and aluminum foil to prevent evaporation losses and placed in an oven at 70°C for two hours to complete polymerization. After polymerization, the specimens were cooled and weighed to determine impregnation.

Using the above method, impregnation of all specimens averaged 6.3% by weight (Table 1). This appears to be the maximum for this type of mortar and treatment(8).

Table 1

Impregnation, Weight Percent

Methyl Methacrylate	Ethyl Methacrylate	Butyl Methacrylate
6.78	6.10	5.90
6.84	6.20	5.92
6.60	6.62	6.15

Depth of penetration, as measured from a halved cylinder, was approximately 19 mm (Figure 1).

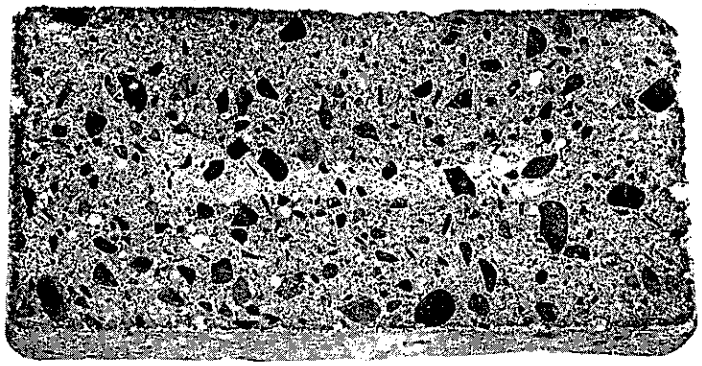

Figure 1. Interior of impregnated cylinder. Light area is center not impregnated.

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Two specimens each, impregnated with the three polymers listed in Table 1, and control specimens were subjected to an abrasion test based on Test Method No. Calif. 360, modified to use steel balls. Abrasion losses were measured on the cement-lean and cement-rich surfaces of each cylinder. For the cement-lean surface, abrasion loss of the impregnated specimens was about 75% less than the control. The cement-rich losses were 80% less than the control (Table 2).

Table 2

Abrasion Loss, Weight Percent

Methyl Methacrylate	Ethyl Methacrylate	Butyl Methacrylate	Control
	Cement-Lean Surface		
0.3	0.4	0.3	1.1
	Cement-Rich Surface		
0.3	0.4	0.6	2.2

The remaining polymer impregnated cylinders and a cylinder treated with a proprietary waterproofing material and a control were immersed in water treated with a wetting agent. All outside surfaces of each test specimen were thoroughly sandblasted to eliminate any possibility of the specimens being merely encapsulated with a thin layer of polymer or waterproofing material. Absorptions of the polymer impregnated specimens after 72 hours immersion were 99% less than the control. The absorption of the specimen treated with the proprietary waterproofing material was the same as the control. The polymer impregnated specimens were effectively sealed against any moisture penetration (Table 3).

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Table 3

Water Absorption, Weight Percent[a]

Methyl Methacrylate	Ethyl Methacrylate	Butyl Methacrylate	Water-Proofing Material	Control
0.13	0.12	0.16	9.4	9.2

[a] Specimens and control were weighed at 24-hour intervals. The values above are those obtained after approximately 24 hours immersion.

Compressive strengths were determined on two impregnated 50.8 mm square cubes and two controls. The impregnated specimens were approximately three times stronger in compression than the controls (Table 4).

Table 4

Compressive Strength, MPa

Control	Impregnated
36.2 (5250 psi)	91 (13,200 psi)
37.1 (5380 psi)	110 (16,000 psi)

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CLOSURE

The results of this investigation show that concrete strength and durability can be improved significantly by impregnation of the concrete with monomers and polymerizing these monomers within the concrete.

The study was made using three types of methacrylate monomers; methyl, ethyl, and butyl. There are other types that have been used, notably polyester-styrene[1-4], but it was felt that the methacrylates would be representative, as a class, of the possibilities of impregnation. Unfortunately, the technology necessary for impregnation of in-place decks and pavements has not been developed. However, as more agencies become aware of the advantages of this treatment, no doubt the technological capabilities will also appear.

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Table 5

Concrete Mix Design

Aggregate	Percent	Weight
4x8	26	18.4
8x16	15	10.6
16x30	16	11.3
30x50	26	18.4
50x100	17	12.1
Water Added		13.9
Moisture Correction		-1.4
Net Water		12.5
Cement, Permanente, II		20.8
Water-Cement		0.6

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