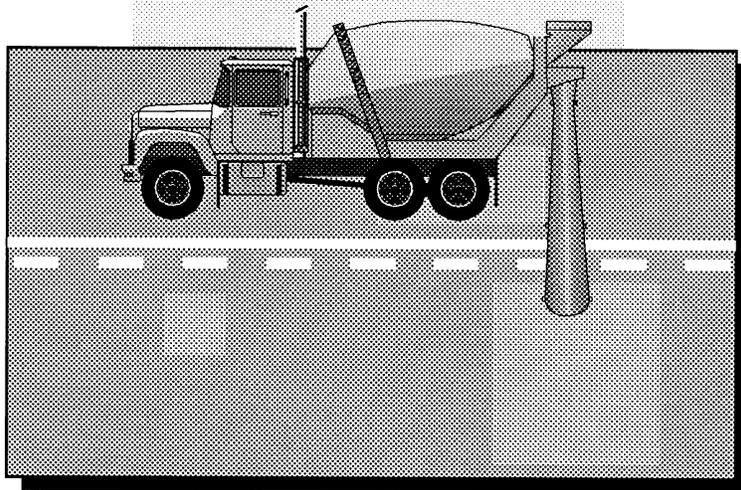


FINAL REPORT

# A FIELD INVESTIGATION OF CONCRETE PATCHES CONTAINING PYRAMENT BLENDED CEMENT



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1. Report No. FHWA/VA-94-R26	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle A Field Investigation of Concrete Patches Containing Pyramment Blended Cement		5. Report Date June 1994	
		6. Performing Organization Code 2963-010-940	
7. Author(s) Celik Ozyildirim		8. Performing Organization Report No. VTRC 94-R26	
9. Performing Organization Name and Address Virginia Transportation Research Council 530 Edgemont Rd. Charlottesville, Virginia 22903		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Virginia Department of Transportation 1401 E. Broad Street Richmond, Virginia 23219		13. Type of Report and Period Covered Final Report May 1990 to May 1994	
		14. Sponsoring Agency Code	
15. Supplementary Notes In Cooperation with the U.S. Department of Transportation, Federal Highway Administration.			
16. Abstract <p>During roadway repairs, state highway officials try to minimize lane closure times. This reduces inconvenience to travelers, reduces traffic control needs, and helps minimize work zone accidents. For rapid repairs, materials that provide high early strength are needed.</p> <p>Pyramment blended cement (PBC) is marketed to produce concretes having a high early strength and long-term durability in varying climatic conditions. Concretes containing PBC were placed in full-depth patches in August 1989 and March 1990 under different temperature conditions. Type III cement concretes were used as controls in patches placed during August only, since specifications did not permit their use when the ambient temperature was below 13°C (55°F).</p> <p>Tests of the concretes and the field performance of the patches indicated that PBC concrete has high early and 28-day strengths, even in cold weather, and that the temperature and strength development is faster than in the control concretes. PBC concretes have the low permeability needed for durability and provide satisfactory resistance to freezing and thawing without the addition of an admixture during mixing.</p>			
17. Key Words Pyramment blended cement, strength, durability, cold-weather concreting, temperature		18. Distribution Statement No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 11 pages	22. Price

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(The opinions, findings, and conclusions expressed in this  
report are those of the author and not necessarily  
those of the sponsoring agencies.)

Virginia Transportation Research Council  
(A Cooperative Organization Sponsored Jointly by the  
Virginia Department of Transportation and  
the University of Virginia)

In Cooperation with the U.S. Department of Transportation  
Federal Highway Administration

Charlottesville, Virginia

June 1994  
VTRC 94-R26

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## ABSTRACT

During roadway repairs, state highway officials try to minimize lane closure times. This reduces inconvenience to travelers, reduces traffic control needs, and helps minimize work zone accidents. For rapid repairs, materials that provide high early strength are needed.

Pyrament blended cement (PBC) is marketed to produce concretes having a high early strength and long-term durability in varying climatic conditions. Concretes containing PBC were placed in full-depth patches in August 1989 and March 1990 under different temperature conditions. Type III cement concretes were used as controls in patches placed during August only, since specifications did not permit their use when the ambient temperature was below 13°C (55°F).

Tests of the concretes and the field performance of the patches indicated that PBC concrete has high early and 28-day strengths, even in cold weather, and that the temperature and strength development is faster than in the control concretes. PBC concretes have the low permeability needed for durability and provide satisfactory resistance to freezing and thawing without the addition of an admixture during mixing.

## **FINAL REPORT**

### **A FIELD INVESTIGATION OF CONCRETE PATCHES CONTAINING PYRAMENT BLENDED CEMENT**

**Celik Ozyildirim  
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#### **INTRODUCTION**

Fast repair of deteriorating hydraulic cement concrete pavements is an important goal for state highway agencies. Lane closure times of the shortest duration reduce inconvenience to the traveling public, minimize work zone accidents, and result in significant cost savings in terms of reduced traffic control. On heavily traveled roads, time constraints usually limit repairs to the night hours or between the daytime rush hours. During these limited times, removal of deteriorated concrete, preparation of the patch area, and placement of the new concrete are performed. Thus, there is a need for materials that set and harden in a relatively quick time but that are also durable.

The Virginia Department of Transportation (VDOT) has widely used concretes containing Type III cements and an accelerating admixture (calcium chloride) to attain a 14 MPa (2,000 psi) compressive strength in 6 hr when the concrete and air temperatures are above 13°C (55°F). There are also many pre-packaged, proprietary concrete materials available that are usually more expensive but that may set and harden in a short period of time. These proprietary materials usually require mixing in small quantities in mobile mixers, may not attain a high early strength at cold temperatures (below 13°C [55°F]), and may not be durable, thus requiring frequent repairs.

A proprietary material by the name of Pyrament blended cement (PBC) produced by Lone Star Industries is marketed to provide workable concretes that have a high early strength (17 MPa [2,500 psi] in 4 hr), even in cold weather, and that are durable.<sup>1-3</sup> PBC concrete (PBCC) has been shown to provide remarkable corrosion protection to the embedded steel.<sup>3</sup> Concretes made with this cement have a very low water-cement ratio (w/c), less than 0.29. Acceptable freeze-thaw resistance is claimed without the addition of an air-entraining admixture during mixing. However, in one SHRP project, PBCC did not perform satisfactorily when tested in accordance with the modified AASHTO T 161 (or ASTM C 666) Procedure B. The modification was that the specimens were wrapped with a towel during the test.<sup>4</sup> In another SHRP study, it was concluded that an adequate amount of air entrainment (at least 5%) was needed for

satisfactory resistance to freezing and thawing.<sup>5</sup> The SHRP reports indicated that PBCC exhibits a rapid gain in strength and reaches a high strength (70 MPa [10,000 psi]) at 28 days.

PBC contains portland cement blended with pozzolanic materials and special functional additives. A study by Husbands et al. cautioned that PBCC had an alkali content of 2.73 and thus may be capable of producing alkali-silica reactivity.<sup>6</sup> That study indicated that PBCC has better resistance to damage during cycles of freezing and thawing, sulfate expansion, damage from underwater abrasion, penetration of dissolved chlorides, and scaling from deicing chemicals than is generally expected of high-quality conventional concretes. The alkali-aggregate reactivity should be considered and tested when reactive aggregates are used and long-term performance is expected.

PBC costs more than ordinary cements. However, it is a desirable product for the construction industry because PBCC can be truck mixed, develop a high early strength and durability in varying temperature conditions, and enable the extension of the maintenance and construction season.

## **PURPOSE AND SCOPE**

The objective of this study was to evaluate under field conditions the properties and performance of concretes containing PBC for the repair of hydraulic cement concrete pavements.

## **METHODS**

### **Overview**

Full-depth concrete patches were placed in a repair project on Rte. 44. This route carries heavy traffic to a resort area in eastern Virginia (Virginia Beach). The patches, spanning a lane width, were prepared following VDOT specifications. The deteriorated concrete in the repair area was removed by full-depth sawcutting of the perimeter and lifting of the slab vertically from its location. Dowel bars were used for load transfer across patch joints. The joint was fixed on one end of the patch, and on the other end, it was a working construction joint. PBCC was placed in six full-depth patches at ambient temperatures exceeding 13°C (55°F). No admixture was added. During similar ambient conditions, concretes containing Type III cement and water-reducing and accelerating and air-entraining admixtures were placed as controls in nine patches.

PBCC was also placed in six full-depth patches when the ambient temperature was below 13°C (55°F). All patches except for two of the nine control patches were 1.8 m (6 ft) long, 3.7 m (12 ft) wide, and 230 mm (9 in) deep. The two control patches were 2.1 m (7 ft) long.

The temperature profiles of the concretes at early ages were determined. Specimens were prepared to determine the strength, permeability, freeze-thaw resistance, absorption, and drying shrinkage of the hardened concretes. Visual observations of the patches were made until April 1994.

### Higher Temperature PBCC Patches

On August 22, 1989, three loads of PBCC were prepared in truck mixers and delivered to the job site, which was about 20 min away from the plant. The six patches were placed on the outside east bound lane (EBL) of Rte. 44 between stations 438 + 35 and 447 + 55 at ambient temperatures exceeding 13°C (55°F). The PBC-XT was delivered to the plant in super sacks weighing 1,706 kg (3,760 lb), enough to make 3.8 m<sup>3</sup> (5 yd<sup>3</sup>) of concrete. The XT designation indicates that the time of setting is at least 90 min, providing sufficient work time. The mixture proportions are given in Table 1. The first and second truckloads were tested for air content (ASTM C 231) and slump (ASTM C 143). From the second load, specimens were prepared for tests at the hardened stage as shown in Table 2. Temperature profiles of the concrete in a patch and in a specimen were recorded using thermocouples. One set of three cylinders was subjected to temperature-matched curing (TMC) whereby their temperature rise followed that of the slab. The molds used in TMC have a heating element, and a controlling unit senses the temperature of the slab through a thermocouple and tries to match it with the molds that contain the heating elements. The specimens were cured by covering them with plastic sheeting except for the TMC molds, which were sprayed with white pigmented curing compound. Specimens were kept at the job site 4 to 6 hr, and then transported to the plant for testing. After the initial curing period of 4 to 6 hr, specimens were air cured.

Table 1  
MIXTURE PROPORTIONS (kg/m<sup>3</sup>)

Ingredient	PBCC	Control
Cement	446	446
W/C	0.26	0.35
Coarse Aggregate	943	1,127
Fine Aggregate	876	543

Table 2  
SIZE OF SPECIMENS AND TESTS

Tests	Method	Size (mm)
Comp. Strength <sup>a</sup>	AASHTO T 22	100 x 200
Flex. Strength	ASTM C 78	75 x 75 x 285
Bond Strength	<sup>b</sup>	100 x 100
Permeability	AASHTO T 277	100 x 50 <sup>c</sup>
Freeze-Thaw <sup>d</sup>	ASTM C 666	75 x 100 x 405
Absorption	ASTM C 642	<sup>e</sup>
Shrinkage	ASTM C 157 <sup>f</sup>	75 x 75 x 285

<sup>a</sup>Neoprene pads in steel end caps were used for capping.

<sup>b</sup>50-mm-thick overlays were sheared at the interface.

<sup>c</sup>50-mm-thick slabs cut from the top of 100 x 200 mm cylinders.

<sup>d</sup>PBCC covered for 4 hr and then air dried until tested 6 months later. Controls cured 2 weeks moist, 5.5 months dry. All tested in 2% NaCl.

<sup>e</sup>Concrete pieces at 1 month were tested to determine absorption after immersion.

<sup>f</sup>Initial measurements made at 25 hr. Length change determined at weekly increments without the standard 28-day moist curing.

The concrete was deposited from the trucks into the patch hole, vibrated using internal vibrators, and screeded with a metal board. Then, the surface was smoothed by a float, textured with a broom, and sprayed with white pigmented curing compound. Manufacturers of PBCC highly recommend the curing compounds and caution against the use of extra water on the surface of the freshly mixed PBCC, which may result in an increased w/c.

### Control Patches

The next day, August 23, 1989, four loads of concrete containing Type III cement and water-reducing and accelerating and air-entraining admixtures were delivered to the job site to prepare nine patches on the outside EBL between stations 430 + 40 and 438 + 45 on Rte. 44. Two of the loads were tested. Air content and slump were determined in the freshly mixed state. Specimens were prepared from Load 1 for tests at the hardened state as described in Table 2. One set of three cylinders was also subjected to TMC. Specimens from Load 2 were tested for compressive strength only. The samples were covered with wet burlap and plastic sheeting. One of the slabs was monitored for a temperature profile. After demolding, the specimens were moist cured as required in the standard test procedures.

The concrete was consolidated using internal vibrators, screeded with the metal board, smoothed with the float, and moist-cured with wet burlap covered with white plastic sheeting.

## Lower-Temperature PBCC Patches

On March 28, 1990, three loads of concrete containing PBC-XT were placed in six patches on the outside EBL between stations 479 + 25 and 483 + 50 on Rte. 44 when the ambient temperature was below 13°C (55°F). The night before placement, the temperature was slightly above the freezing point. In cold weather above freezing, the manufacturer recommends that the temperature of PBCC exceed 18°C (65°F), so the drums of the trucks were warmed with hot water. Mix water was added at 63°C (145°F) to increase the concrete temperature. Load 1 was tested for air content and slump, and specimens were made to test for compressive, flexural, and bond strengths; permeability; and drying shrinkage. TMC was used in one set, and TMC specimens were sprayed with a curing compound. The remaining specimens were covered with plastic for 5 to 6 hr. Afterward, the specimens were air cured. The drying shrinkage of PBCC was determined in accordance with ASTM C 157 except that the specimens were exposed to air after the first 6 hr. During the initial 6 hr, specimens were covered with plastic sheeting. The length change was determined at weekly increments without the 28-day moist-curing period required in ASTM C 157. Initial measurements were made at 25 hr. The temperature profile of one of the slabs was determined. The patches were placed in the same manner as those placed in August except that a vibratory screed was used.

## RESULTS AND DISCUSSION

### Freshly Mixed Concretes

The air content and slump of concretes are given in Table 3. The air contents of PBCC and controls were similar even though an air-entraining admixture was not added to the PBCC. In August, the PBCC was difficult to consolidate at slump values of 75 mm (3 in) or less. The internal vibrators left holes upon withdrawal from the concrete, and the metal screed board tore the concrete surface. Much monomolecular film was brushed onto the surface from

Table 3  
AIR CONTENT AND SLUMP DATA

Month	Cement	Load	Air (%)	Slump (mm)
August	PBC-XT	1	5.0	75
		2	4.1	70
August	Type III	1	4.5	50
		2	4.6	75
March	PBC-XT	1	5.5	180

a bucket to enable closing of the surface irregularities. The control concrete was easier to finish, even at a lower slump. In the March placement, the PBCC had a high slump, and a vibratory screed was used to make finishing easy. The slump of PBCC could be increased by using aggregates with better particle shape, reducing the concrete temperature, or increasing the amount of PBC. All of these measures would increase cost, and the third option would increase the volumetric change of the concrete.

### Temperature Profile

The temperature profile of the concretes is given in Figures 1 through 3. The thermocouples were placed at 13 mm (0.5 in), 115 mm (4.5 in), mid-depth, and 200 mm (8 in) from the top. The ambient temperature and the temperature of a TMC specimen matched to the mid-depth of the patch were also monitored. In August, the temperature rise of the PBCC occurred in 90 min. The increase was sudden, and the maximum temperature was 51°C (124°F) when the ambient temperature was 32°C (90°F) to 38°C (100°F). In the control patches in August, the rise in temperature occurred in a little over 2 hr. The increase was gradual, and the peak temperature was about 60°C (140°F) when the ambient temperature was close to 38°C (100°F). In cold weather, the rise in temperature in PBCC occurred at 2.5 hr. The increase was rapid, and the peak temperature was about 32°C (90°F) when the ambient temperature was in the low 10s (50s in

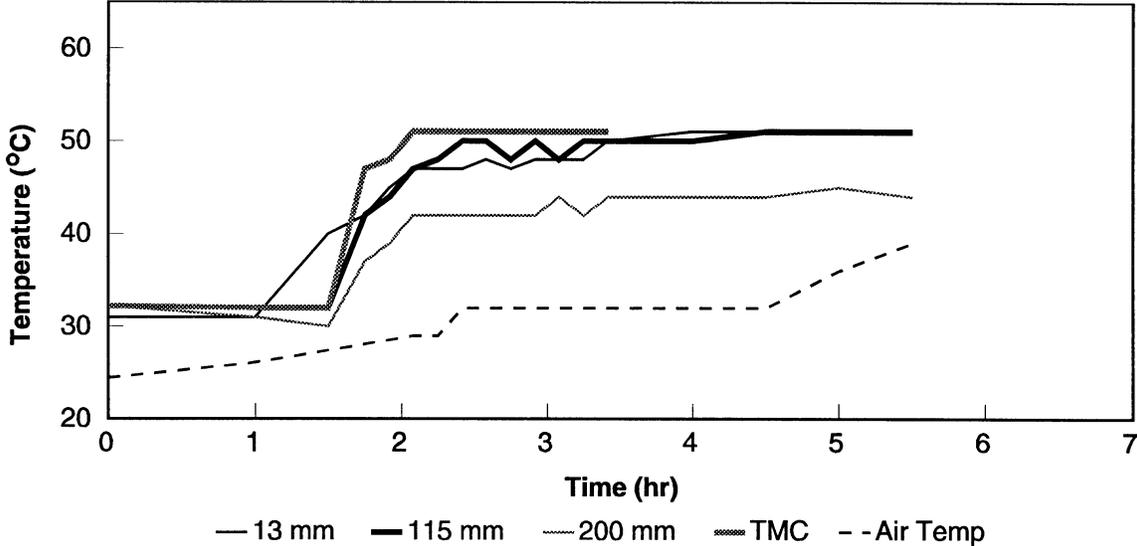


Figure 1. Temperature profile of PBCC placed in August.

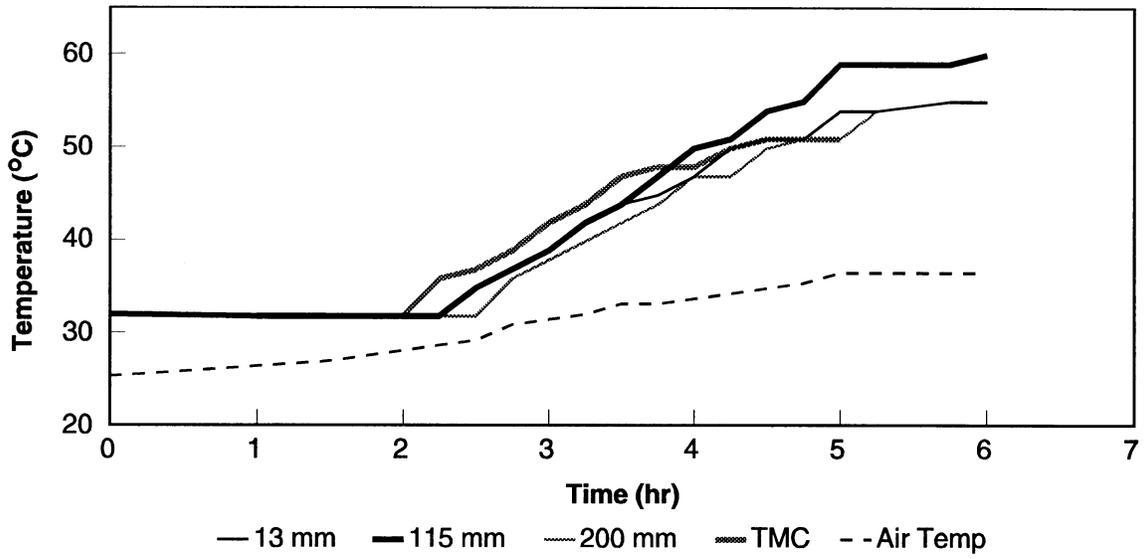


Figure 2. Temperature profile of control with Type III cement placed in August.

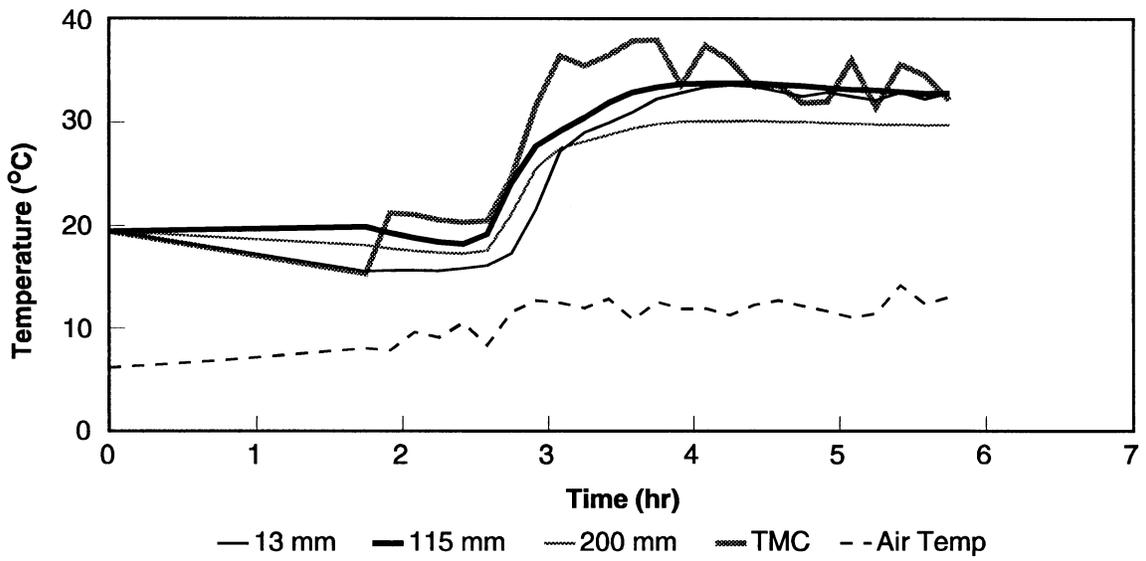


Figure 3. Temperature profile of PBCC placed in March.

°F). The results indicate that PBCC has a rapid gain in temperature that reaches a maximum value below that of the control mixtures. The temperature difference between the maximum and the ambient temperatures was lower in PBCC than in the control.

## Hardened Concrete Properties

### Strength

The compressive, flexural, and bond strengths of the concretes are given in Table 4. PBCC had a strength over 21 MPa (3,000 psi) in 4 hr in August and over 17 MPa (2,500 psi) in 5.5 hr in March. The delay in strength development in March is mainly attributed to cold weather even though this second batch of PBCC may also have had an inherently longer setting time and, inadvertently, a

Table 4  
STRENGTH DATA (MPa)

Strength	Age	PBCC (August)	Control (August)	Control (August)	PBCC (March)
Comp.	4 h	22.5			
	4 h	22.1*			
	5.5 h				17.9*
	5.8 h				19.2
	6 h	28.5		12.0	
	6.5 h			20.6	
	6.5 h			23.0*	
	8 h			25.0	
	24 h	43.6	34.3	30.1	37.7
	28 d	68.7	43.7	39.9	63.5
Flex.	4.5 h	3.70			
	6 h				4.15
	6.2 h	4.15			
	6.8		3.00		
	8.2		3.35		
	24 h	4.85	3.85		
Bond	4.5 h	1.75			
	6 h				1.40
	7 h		1.70		
	24 h	1.95	2.20		
	48 h	2.85			

Each test value is an average of two specimens except the TMC (temperature matched curing shown by asterisks) and the first compressive strength test result is the average of 3 specimens; the 24 and 48 hour bond test for PBCC is for 1 specimen.

higher w/c ratio than 0.26. In the March placement, the rapid increase in temperature at 2.5 hr after the addition of mixing water took 1 hr longer than in the August placement.

The first batch of the control concretes developed to 23.0 MPa (3,330 psi) in 6.5 hr using TMC. The same concrete had reached almost 21 MPa (3,000 psi) when it was covered with plastic for curing. The second control batch had reached 12.0 MPa (1,740 psi) in 6 hr when the samples were covered with plastic. Thus, there was a delay in strength development in the second batch. At 24 hr and 28 days, the difference in strength between controls was 4.2 MPa (610 psi) and 3.8 MPa (550 psi), respectively. This indicates that the second control batch was retarded and also had a lower strength. The lower strength was probably due to a higher w/c.

The compressive strength of all concretes at 28 days was high. Controls had around 41.4 MPa (6,000 psi). The PBCC had a strength of 63.5 MPa (9,210 psi) (placed in March) and 68.7 MPa (9,960 psi) (placed in August).

PBCC also had high flexural and bond strengths at the early hours. At 4.5 hr, the flexural strength was 3.70 MPa (535 psi) and the bond strength was 1.75 MPa (255 psi). The control concrete had a flexural strength of 3.00 MPa (435 psi) in 6.8 hr and a bond strength of 1.70 MPa (250 psi) in 7 hr.

## Permeability and Absorption

The rapid permeability (AASHTO T 277) results shown in Table 5 indicate very low coulomb values except that in the PBCC (August), the 90-day value was in the low range. The 90-day value was unexpectedly higher than the 28-day value and could be a result of mishandling of specimens. The control concrete had a high coulomb value at 28 days and 90 days. Similarly, the absorption of PBCC was low compared to the control. The results indicate that PBCC would provide a high resistance to penetration by water or solutions.

Table 5  
PERMEABILITY AND ABSORPTION DATA<sup>a</sup>

Concrete	28-D	90-D	1-Y	Absorption (%)
PBCC (August)	785	1,414		3.9
Control	5,158	3,948		5.9 <sup>b</sup>
PBCC (March)	965	466 <sup>c</sup>	173	

<sup>a</sup>Permeability is in coulombs, and each coulomb value is an average of two specimens.

<sup>b</sup>The first batch is 6.0%, and the second batch is 5.8%.

<sup>c</sup>At 120 days.

## Resistance to Freezing and Thawing

The PBCC placed in August and the control concretes were tested for resistance to freezing and thawing, and the results given in Table 6 indicate that the resistance was satisfactory. All the concretes met the acceptance criteria even though the PBCC showed more scaling. The acceptance criteria used specify that the average of three specimens at 300 cycles must have a weight loss (WL) of 7 percent or less, a durability factor (DF) of 60 or more, and a surface rating (SR) of 3 or less. The surface rating was determined in accordance with ASTM C 672. The top and molded specimens were rated separately, and the values averaged.

Table 6  
FREEZE-THAW DATA AT 300 CYCLES

Concrete	WL (%)	DF	SR
Control	1.3	102	2.2
PBCC (August)	6.8	96	2.9

Each value is an average of three specimens.

## Drying Shrinkage

Two beams were prepared from the PBCC (March), and the length change was measured for a period of 2 years. Table 7 summarizes the data. The results indicate shrinkage values similar to those expected for ordinary concretes used in transportation facilities. Shrinkage is related to water and

Table 7  
DRYING SHRINKAGE (%)

Beam	8-W	16-W	1-Y	2-Y
1	0.032	0.044	0.063	0.068
2	0.031	0.046	0.070	0.079
Avg.	0.032	0.045	0.066	0.074

cement content, and length change data for concrete made with a variety of PBC contents can be found in SHRP Report S-344.<sup>7</sup>

## Field Evaluations

Periodic yearly evaluations, with the most recent one being in April 1994, indicated that all patches (control and PBCC) are in very good shape and show only very light scaling where some of the coarse aggregate is exposed. Thus, the field performance of the patches is satisfactory.

## CONCLUSIONS

1. PBCC can be prepared in truck mixers with sufficient time (90 min) for placing and finishing the concrete and cured by using a curing compound or by covering with plastic sheeting for a limited time (4 to 6 hr).
2. PBCC had a high early strength even in cold weather (< 13°C [55°F]). In hot weather, PBCC developed a high early strength sooner than did the control concretes with Type III cement.
3. The permeability of PBCC was low, whereas the permeability of the concretes with Type III cement was high.
4. The drying shrinkage of PBCC is comparable to that of ordinary concretes used in transportation facilities.
5. The freeze-thaw resistance of PBCC and the control concretes was satisfactory even though no additional admixtures were used with PBCC.
6. Low-slump PBCC was difficult to consolidate and screed in hot weather.
7. The field performance of all the patches was satisfactory after 4 to 4 1/2 years (as of April 1994).

## RECOMMENDATION

It is recommended that PBCC be used when a high early strength is needed, even in cold weather. PBCC should be consolidated and screeded using internal vibrators and vibratory screeds. Alkali-silica reactivity should be considered when aggregates are selected.

## ACKNOWLEDGMENTS

The report was reviewed by Claude Napier, Richard Steele, Stephen Lane, and Michael Sprinkel. The report was edited by Linda Evans and typed by Arlene Fewell.

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