Research Report
KTC 93-17

CONSTRUCTION AND INTERIM PERFORMANCE OF A PYRAMENT CEMENT CONCRETE BRIDGE DECK

by

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in cooperation with
Kentucky Transportation Cabinet

and

Federal Highway Administration
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16. Abstract

Pyrament Blended Cement (PBC) is a high performance cement developed by Lone Star Industries and is a blend of 65% portland cement, 30% fly ash, and 5% trademark additive. Concrete made with PBC has been characterized by its rapid set, high early strength, and low permeability. This report summarizes the construction and interim performance of a full-depth concrete bridge deck slab constructed using Pyrament Cement concrete.

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METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO METRIC UNITS					APPROXIMATE CONVERSIONS FROM METRIC UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in.	inches	25.40000	millimetres	mm	mm	millimetres	0.03937	inches	in.
ft	feet	0.30480	metres	m	m	metres	3.28084	feet	ft
yd	yards	0.91440	metres	m	m	metres	1.09361	yards	yd
mi	miles	1.60934	kilometres	km	km	kilometres	0.62137	miles	mi
		AREA					**AREA**		
in.^{2}	square inches	645.16000	millimetres squared	mm^2	mm^2	millimetres squared	0.00155	square inches	in.^{2}
ft^2	square feet	0.09290	metres squared	m^2	m^2	metres squared	10.76392	square feet	ft^3
yd^2	square yards	0.83613	metres squared	m^2	m^2	metres squared	1.19599	square yards	yd^2
ac	acres	0.40469	hectares	ha	ha	hectares	2.47103	acres	ac
mi^3	square miles	2.58999	kilometres squared	km^2	km^2	kilometres squared	0.38610	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57353	millilitres	ml	ml	millilitres	0.03381	fluid ounces	fl oz
gal.	gallons	3.78541	litres	l	l	litres	0.26417	gallons	gal.
ft^3	cubic feet	0.02832	metres cubed	m^3	m^3	metres cubed	35.31448	cubic feet	ft^3
yd^3	cubic yards	0.76455	metres cubed	m^3	m^3	metres cubed	1.30795	cubic yards	yd^3
		MASS					**MASS**		
oz	ounces	28.34952	grams	g	g	grams	0.03527	ounces	oz
lb	pounds	0.45359	kilograms	kg	kg	kilograms	2.20462	pounds	lb
T	short tons (2000 lb)	0.90718	megagrams	Mg	Mg	megagrams	1.10231	short tons (2000 lb)	T
		FORCE AND PRESSURE					**FORCE**		
lbf	pound-force	4.44822	newtons	N	N	newtons	0.22481	pound-force	lbf
psi	pound-force per square inch	6.89476	kilopascal	kPa	kPa	kilopascal	0.14504	pound-force per square inch	psi
		ILLUMINATION					**ILLUMINATION**		
fc	foot-candles	10.76426	lux	lx	lx	lux	0.09290	foot-candles	fc
fl	foot-Lamberts	3.42583	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.29190	foot-Lamberts	fl
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation and gratitude to Mr. Ed Kirk, Kentucky Department of Highways' Resident Engineer for Bullitt County, and his staff for their invaluable assistance during construction and monitoring activities associated with the Pyrament Cement Concrete Bridge Deck project. The authors also wish to acknowledge the support of Mr. Bernie Roach, Kentucky Department of Highways District 5 materials engineer; Mr. Jim Nelson, foreman with the Matsuda Bridge Company; and Mr. Bob Meade and Mr. Edgar Courtney of the Kentucky Transportation Center's Materials and Testing Section.

EXECUTIVE SUMMARY

Pyrament Blended Cement (PBC) is a high performance cement developed by Lone Star Industries. Concrete made with PBC is rapid setting, has high strength and low permeability. The Kentucky Transportation Cabinet chose to use PBC concrete in a full-depth bridge deck and requested the Kentucky Transportation Center (KTC) to monitor placement activities and the subsequent performance of the experimental bridge deck. The long-term objectives of this study are to evaluate the construction and performance of a full-depth bridge deck constructed of PBC concrete and to compare the construction and performance data obtained from the experimental deck concrete to historical knowledge of the construction and performance characteristics of conventional, Class AA bridge deck concrete. The work plan for the research task required documentation of placement activities, determining characteristics of the experimental PBC deck concrete, and monitoring the bridge deck for the occurrence of shrinkage cracks. This report provides information relative to the construction activities and the short-term performance of the experimental bridge deck.

Construction activities, materials characteristics and short-term performance of an experimental Pyrament Blended Cement (PBC) concrete bridge have been described herein. Some difficulties were encountered during the placement operations but these problems appeared to be easily remedied by making slight adjustments to the mixture. During placement operations, the primary obstacle encountered was the lack of necessary time to properly finish the surface of the concrete deck. This resulted in distinct differences in the surface texture of the experimental deck. Some areas of the deck are quite smooth while other areas are markedly rough. Slump, air content, and temperature of the concrete were monitored at various times during the deck placement. All measurements of the properties of the fresh concrete were within allowable tolerances. In addition to measurements performed on the fresh concrete, measurements of the air temperature and relative humidity also were obtained to document environmental conditions at the time of the placement operations.

The PBC concrete was characterized relative to its durability, compressive strength, modulus of elasticity, relative permeability to chloride ions, and air content. Concrete prisms made during placement operations did not fair well when evaluated for their resistance to rapid freezing and thawing. The average expansion of the prisms exceeded the permissible expansion allowed for aggregates used in concrete pavements. The freeze/thaw test is a very severe test and the poor performance of the prisms during the test is indicative of the resistance of the coarse aggregate to freezing and thawing.

The PBC concrete easily achieved the required 7,500 psi compressive strength at 28 days. The average 28-day compressive strength of specimens cast by KTC personnel was 9,680 psi. Tests indicated a static chord modulus of elasticity of about 5.5 million psi at 28 days. The chloride ion permeability of the PBC concrete was rated as very low. The air contents of core specimens obtained from the experimental PBC concrete bridge deck averaged 8.0 percent. The air content of the hardened concrete exceeded the maximum air content specified in the Special Note for construction for the experimental PBC concrete bridge deck.

INTRODUCTION AND BACKGROUND

Pyrament Blended Cement (PBC) is a high performance cement developed by Lone Star Industries. Concrete made with PBC is rapid setting, has high strength and low permeability. The manufacturer of PBC reports that PBC concrete can obtain compressive strengths of 2,500 psi in four hours and achieve ultimate compressive strengths of over 12,000 psi. It is also reported that PBC concrete can be placed at temperatures as low as 0°F to 10°F. Pyrament cement is a blend of 65 percent portland cement, 30 percent fly ash, and five percent trademark additive. Pyrament blended cement concrete requires no special admixtures or air entrainment be added.

The Kentucky Transportation Cabinet chose to use PBC concrete in a full-depth bridge deck and requested the Kentucky Transportation Center (KTC) to monitor placement activities and performance of the experimental bridge deck. The long-term objectives of this study are to evaluate the construction and performance of a full-depth bridge deck constructed of PBC concrete and to compare the construction and performance data obtained from the experimental deck concrete to historical knowledge of the construction and performance characteristics of conventional, Class AA bridge deck concrete. The work plan for the research task required documentation of placement activities, determining characteristics of the experimental PBC deck concrete, and monitoring the bridge deck for the occurrence of shrinkage cracks. This report provides information relative to the construction activities and the short-term performance of the experimental bridge deck.

The experimental bridge deck under study is located on County Route 8586 (Cooper Chapel Road) over McNeely Lake in Jefferson County (see Figure 1). The bridge is a single span structure having a total length of 88 feet and width of 43.5 feet. Pyrament blended cement concrete was used to construct the full-depth deck slab. The contractor for the project was Matsuda Bridge Company. The experimental concrete was batched at American Builders and Supply Company.

MATERIALS

The PBC concrete mixture design was for a seven bag mix, having a target compressive strength of 7,500 psi at 28 days. The mix design submitted for the one cubic yard trial batch is contained in Table 1.

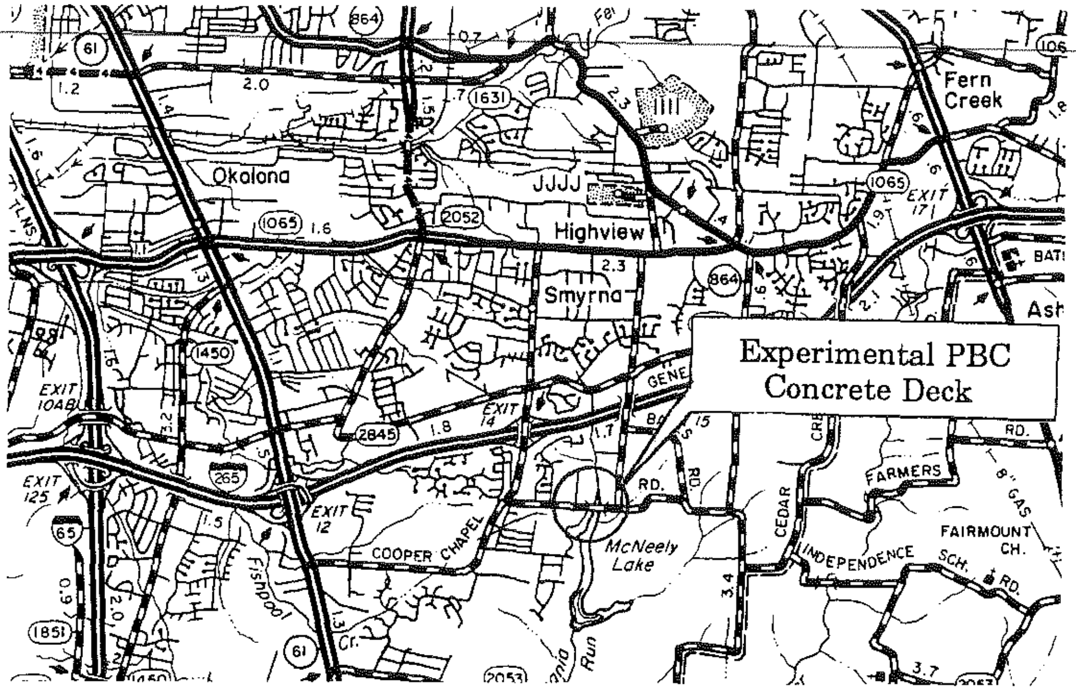


Figure 1. *Location of experimental PBC concrete bridge deck project.*

TABLE 1. SUBMITTED MIXTURE DESIGN FOR THE ONE CUBIC YARD TRIAL BATCH

	Solid Weights	Solid Volumes (ft^3)
Pyrament Blended Cement	658 lbs	3.64
No. 57 Limestone Aggregate	1,788 lbs (SSD)	10.46
Natural Concrete Sand	1,408 lbs (SSD)	8.56
Air Content	5.5 percent	1.49
Water	178 lbs	2.85

MIXTURE REQUIREMENTS	
Slump	4 in. to 8 in.
Coarse Aggregate Percentage	55
Fine Aggregate Percentage	45
Water/(Cement + Pozzolan) Ratio	0.27

The fine aggregate source was Nugent Sand Company. The coarse aggregate supplier was Bullitt County Stone. Compensation for free and negative moisture was made at the time of batching. The Special Note for construction for the project altered some of the normal specifications used for bridge deck concrete. The changes to the normal specifications included a higher slump tolerance of eight inches, a higher compressive strength requirement of 7,500 psi, and a lower water/(cement + pozzolan) ratio of 0.29 (3.27 gal/bag). The Special Note for Construction for the PBC concrete bridge deck has been reproduced in Appendix I of this report.

CONSTRUCTION

Placement of the experimental concrete bridge deck began on the east end of the bridge deck at 2:00 am., July 30, 1991. The PBC concrete was placed using a Schwing 32 meter pump. A Bidwell rolling drum finisher was used to finish the deck. The first truckload of concrete was extremely stiff and there was difficulty removing the concrete mixture from the chute. This problem was corrected and placement of the experimental concrete mixture began. Slump, air content, and temperature of the experimental PBC concrete mixture were determined periodically during placement of the bridge deck. Air temperature and relative humidity also were checked at different times during placement of the deck. Results of these measurements are contained in Table 2.

Overall, the placement of approximately 154 cubic yards of the experimental PBC concrete mixture went smoothly. However, the PBC concrete stiffened very quickly. This

TABLE 2. FRESH CONCRETE TESTS AND WEATHER CONDITIONS

Load/Truck Number	Slump (in.)	Air Content (%)	Concrete Temperature (°F)	Ambient Temperature (°F)	Relative Humidity (%)
1	8.00	6.8	86	77	72
6	7.50	6.5	86	75	74
13	4.50	4.8	85	73	71
18	6.75	5.0	84	71	71

characteristic of the experimental PBC concrete effected a noticeable decrease in the amount of time available to properly finish the concrete. The concrete finishers working the PBC concrete complained that there was not adequate time to give the proper finish to the deck. Water had to be sprayed on the deck surface to aid in the finishing work. The experimental PBC concrete was observed to be very sticky during the finishing operation. The contractor's foreman confirmed the concrete finishers' complaint of inadequate finish time. He stated that although the higher slump tolerance made placement somewhat easier, the early stiffening of the PBC concrete made finishing the deck extremely difficult and required much more finish work than a conventional Class AA concrete bridge deck.

The barrier walls for the bridge were poured seven days after the experimental deck. The barrier walls also were constructed of PBC concrete. One air content and one slump measurement was made by KTC personnel. The measured air content of the fresh concrete was 6.5 percent and the slump was seven inches. Three test cylinders were made from the PBC concrete used in the barrier walls.

EVALUATIONS

The PBC concrete was characterized relative to the freeze/thaw durability of the mixture, compressive strength development, static chord modulus of elasticity, air content of hardened concrete, and chloride permeability. Twelve length change prisms were cast during the placement operation to perform rapid freeze and thaw testing of the PBC concrete. The concrete length change prisms were made in accordance with ASTM C 31, [1]. Results of this testing activity are presented in Appendix II. Unfortunately, the slump and air content of the concrete was not determined at the time the freeze/thaw beams were made. Although slump and air content data were obtained, it was not from the specific truckloads of concrete from which the beams were cast. The rapid freeze/thaw tests were performed in accordance with ASTM C 666, Method B, Freezing in Air and Thawing in Water [2]. The average durability factor, based on 350 cycles of rapid freezing and thawing, for the 12 prisms was 71 percent. The average expansion of the 12 prisms was 0.115 percent. Kentucky Standard Specifications for Road and Bridge Construction 805.04.01(B)[3] for coarse aggregates used in portland cement concrete pavements require that concrete prisms have expansions no greater than 0.06 percent when tested in accordance with ASTM C 666, Method B. Therefore, the average percent expansion of the PBC concrete prisms failed to meet the specifications for coarse aggregates for portland cement concrete pavement. It should be noted that the rapid freeze/thaw test is indicative of the resistance of the coarse aggregate to freezing and thawing.

Six-inch by 12-inch concrete cylinders were cast in accordance with ASTM C 31 during placement operations. Compression tests were performed on the cylinders at various ages in accordance with ASTM C 39, [4]. The test specimens were capped prior to testing activities in accordance with ASTM C 617, [5]. Compression tests were performed at 1 (27 hours), 3, 7, 14, and 28 days. Compression tests of the specimens cast from the PBC concrete used in the barrier walls were performed at 56 days. The average compressive strengths are reported in Table 3. Static chord modulus of elasticity tests were performed in accordance with ASTM C 469 at 7, 14, and 28 days [6]. Results of this testing activity are also presented in Table 3. Average compressive strength and modulus of elasticity results are shown graphically in Figure 2 as a function of time. All test cylinders cast at the site, including those cast by Kentucky Department of Highways' (KDOH) inspectors, exceeded the 28-day requirement of 7,500 psi for compressive strength.

Seven core specimens were obtained from the experimental PBC concrete deck approximately 28 days after placement of the deck concrete in accordance with ASTM C 42, [7]. Six of the cores were forwarded to Construction Technology Laboratories, Inc., (CTL), for independent determination of the air content of the hardened concrete and evaluation of the relative permeability of the concrete to chloride ions. The remaining specimen was damaged upon extraction and was not evaluated. Three of the core specimens were tested for air content in accordance with ASTM C 457, [8]. The air contents of the cores were reported as 8.3 percent, 8.2 percent, and 7.6 percent. The

TABLE 3. RESULTS OF KTC CYLINDER TESTS

Age	Average Unit Weight (PCF)	Average Compressive Strength (psi)	Average Modulus of Elasticity (psi x 10^6)
27 hours	146.6	5,210	- -
3 days	148.3	7,100	- -
7 days	147.5	7,880	4.91
14 days	145.8	8,560	5.43
28 days	148.4	9,680	5.45
56 days	153.3	10,700	- -

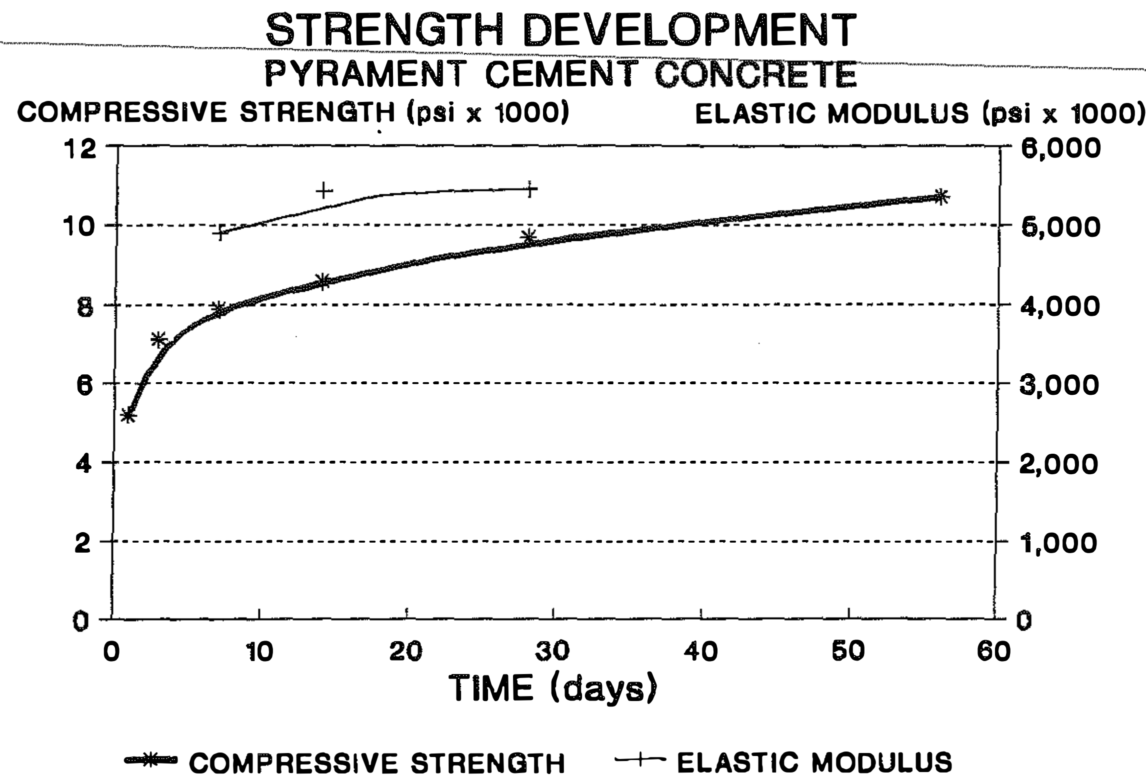


Figure 2. *Strength development properties of the PBC concrete mixture.*

measured air contents of the hardened concrete exceeded the maximum allowable air content of 7.0 percent specified in the Special Note for construction. The remaining three core specimens were evaluated for rapid chloride permeability in accordance with AASHTO T 277, [9]. This specification appraises the relative permeability of the concrete to chloride ions by the amount of charge, in coulombs, that is capable of passing through the sample. The categories of rating are high, moderate, low, very low, and negligible. The relative chloride permeability of all three concrete core specimens was rated "very low".

PERFORMANCE MONITORING

Visual inspections of the deck were made to determine the quality of finish, shrinkage cracking patterns, and to document any other problems that might occur. An initial visual inspection was performed approximately seven days after placement of the deck.

Little was gained during the inspection due to the amount of equipment and supplies the contractor had placed on the deck. The first detailed visual inspection to document the occurrence of shrinkage cracking in the experimental deck was performed on August 30, 1991, approximately 28 days after placement. The lack of adequate time to provide a proper finish to the deck was readily apparent when observing the deck. As shown in Figures 3 and 4, the tyning depths are very inconsistent. Some areas of the experimental deck are smooth, almost slick, and other areas of the bridge deck exhibit deep tyning. Aggregates near the surface were displaced in the deeply tyned areas causing these areas of the bridge deck to be extremely rough. A shrinkage crack in the deck is shown in Figure 3. The surface of the deck was observed to be generally uneven. As seen in Figure 5, the surface of the deck has dips or rolls. Six shrinkage cracks were observed during the 28 day inspection. A grid was created during the 28 day inspection in order to diagram the locations of shrinkage cracks. In addition to shrinkage cracks, there were numerous microcracks observed throughout the deck as illustrated in Figure 6. These microcracks do not extend through the full depth of the slab as do the shrinkage cracks.

Subsequent visual inspections of the experimental PBC concrete bridge deck have been performed periodically. The length of the shrinkage cracks had increased significantly

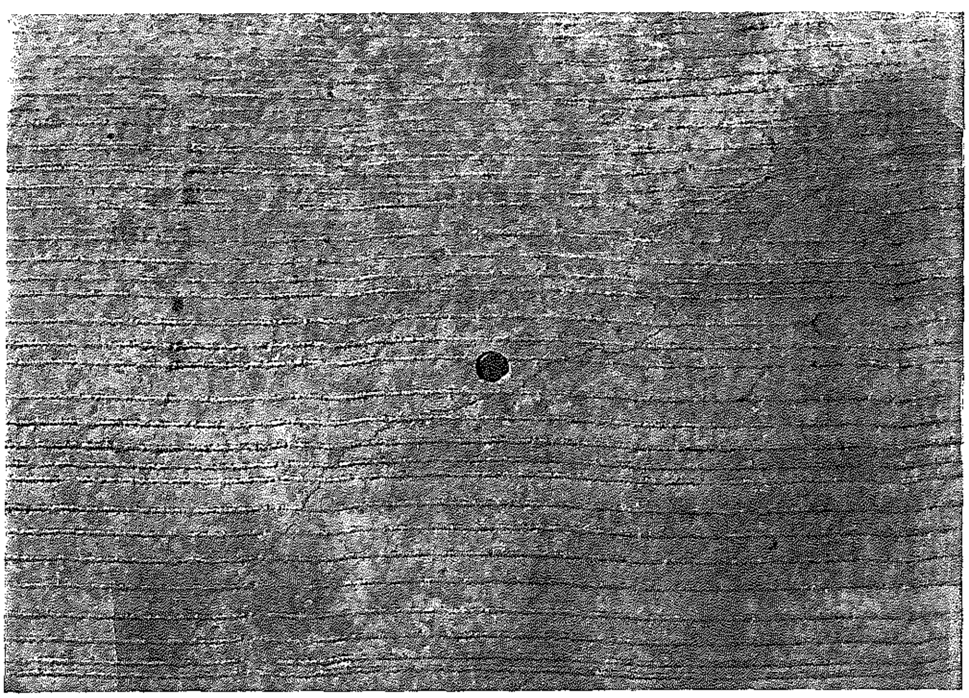


Figure 3. *Some areas of the experimental PBC concrete bridge deck were slick due to the lack of proper tyning.*

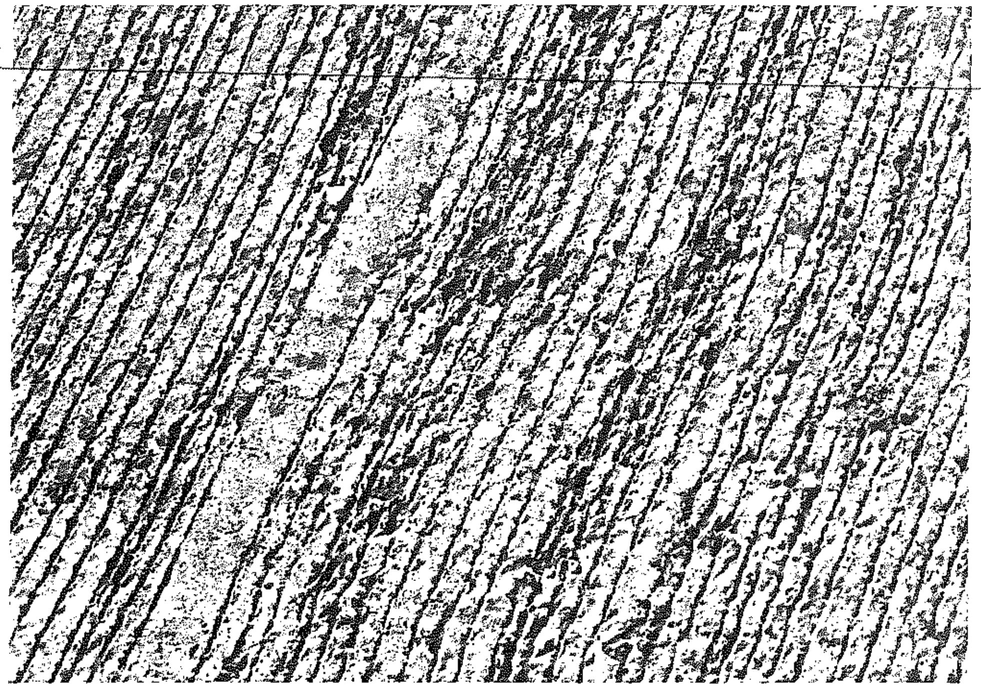


Figure 4. *Some areas of the experimental PBC concrete bridge deck were deeply tyned, dislodging aggregates near the surface.*

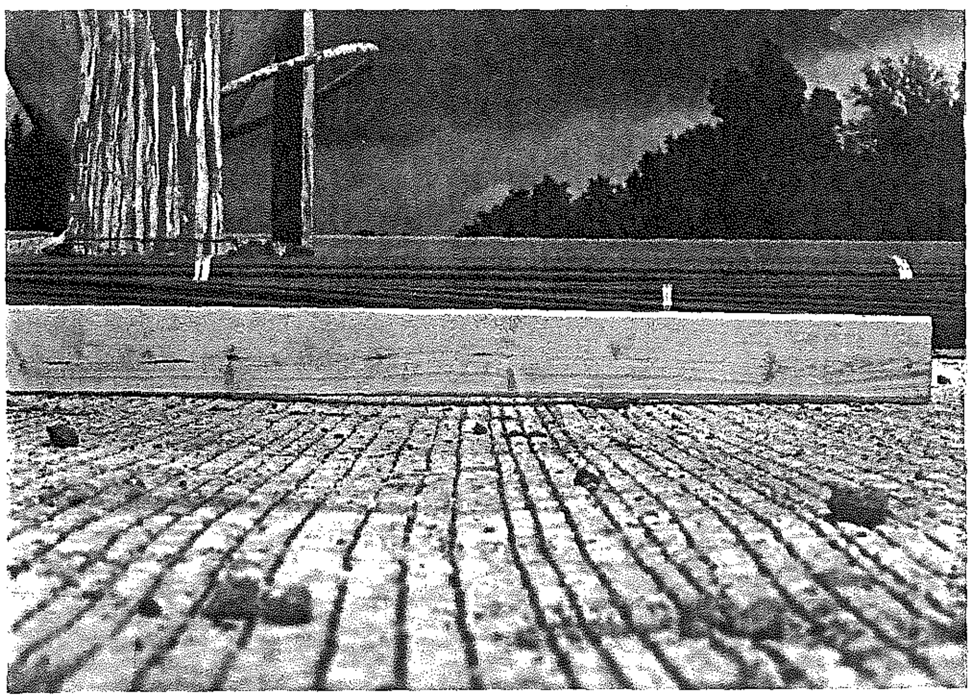


Figure 5. *The surface of the experimental PBC concrete bridge deck exhibited several dips or rolls.*

Figure 6. *Numerous microcracks were observed on the experimental PBC concrete bridge deck during the initial inspection.*

during the period from the initial inspection through the March 1992 inspection. The progression of the cracks were logged on the crack grid sheets during each inspection. The crack grid sheets will be reproduced in the final report. Inspections performed in September 1992 and March 1993 revealed no new cracks and no significant changes in those shrinkage cracks already documented. Presently, there are a total of eight shrinkage cracks located in the experimental bridge deck. The majority of the shrinkage cracking is located on the west end of the bridge deck and is random in nature. The cumulative total length of cracking is approximately 87 linear feet. During the latest inspection, performed in March 1993, the appearance of a whitish substance on the far east end of the bridge deck was observed. This area is shown in Figure 7. It is not presently known what produced the material.

SUMMARY

Construction activities, materials characteristics and short-term performance of an experimental Pyrament Blended Cement (PBC) concrete bridge have been described

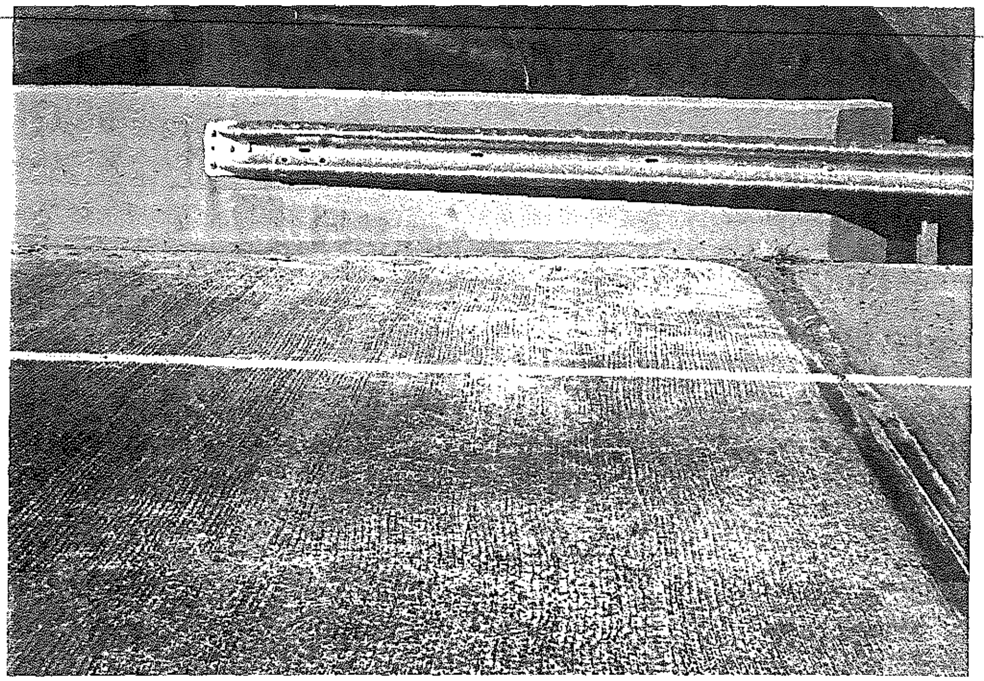


Figure 7. *A whitish substance was observed on the experimental PBC concrete bridge deck during the March 1993 inspection.*

herein. Some difficulties were encountered during the placement operations but these problems appeared to be easily remedied by making slight adjustments to the mixture. During placement operations, the primary obstacle encountered was the lack of necessary time to properly finish the surface of the concrete deck. This resulted in distinct differences in the surface texture of the experimental deck. Some areas of the deck are quite smooth while other areas are markedly rough. Also, the mix was observed to be very sticky during finishing operations. Slump, air content, and temperature of the concrete were monitored at various times during the deck placement. All measurements of the properties of the fresh concrete were within allowable tolerances. In addition to measurements performed on the fresh concrete, measurements of the air temperature and relative humidity also were obtained to document environmental conditions at the time of the placement operations.

The PBC concrete was characterized relative to durability, compressive strength, modulus of elasticity, relative permeability to chloride ions, and air content. Concrete prisms made during placement operations did not fair well when evaluated for their resistance to rapid freezing and thawing. The average expansion of the prisms exceeded the permissible expansion allowed for aggregates used in concrete pavements. The freeze/thaw test is a very severe test and the poor performance of the prisms during the test is indicative of the resistance of the coarse aggregate to freezing and thawing.

The PBC concrete easily achieved the required 7,500 psi compressive strength at 28 days. The average 28-day compressive strength of specimens cast by KTC personnel was 9,680 psi. Tests indicated a static chord modulus of elasticity of about 5.5 million psi at 28 days. The chloride ion permeability of the PBC concrete was rated as "very low". The air contents of core specimens obtained from the experimental PBC concrete bridge deck averaged 8.0 percent. The air content of the hardened concrete exceeds the maximum air content specified in the Special Note for Construction for the experimental PBC concrete bridge deck.

The forthcoming final report for this research task will contain all data collected throughout the study, including the documentation of deck cracking. The final report will present comparisons of the placement and performance histories of conventional Class AA concrete and the experimental PBC bridge deck concrete.

REFERENCES

1. ASTM C 31-91, Standard Practice for Making and Curing Concrete Test Specimens in the Field, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing Materials, Philadelphia, Pennsylvania.

2. ASTM C 666-90, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing Materials, Philadelphia, Pennsylvania.

3. 1991 Standard Specifications for Road and Bridge Construction, Kentucky Transportation Cabinet, Department of Highways, Frankfort, Kentucky.

4. ASTM C 39-86, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02. American Society of Testing and Materials, Philadelphia, Pennsylvania.

5. ASTM C 617-87, Standard Practice for Capping Cylindrical Concrete Specimens, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing and Materials, Philadelphia, Pennsylvania.

6. ASTM C 469-87a, Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing and Materials, Philadelphia, Pennsylvania.

7. ASTM C 42-90, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing and Materials, Philadelphia, Pennsylvania.

8. ASTM C 457-90, Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete, 1991 Annual Book of ASTM Standards, Concrete and Aggregates, Volume 04.02, American Society of Testing and Materials, Philadelphia, Pennsylvania.

9. AASHTO T 277-89, Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete, 1990 AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part II, Methods of Sampling and Testing, 15th Edition, American Association of State Highway and Transportation Officials, Washington, D.C.

APPENDIX I

SPECIAL NOTE FOR CONSTRUCTION PYRAMENT CEMENT CONCRETE

I. GENERAL

This work shall consist of furnishing, placing, finishing, and curing concrete containing Pyrament Blended Cement (PCB-XXT) in lieu of Type I cement. Pyrament Blended Cement Concrete shall be used in those locations as specified on the plans. Pyrament Blended Cement is a proprietary hydraulic cement; manufactured by Lone Star Industries, Incorporated; Houston, Texas; phone number 713-921-4861.

II. MATERIALS REQUIREMENTS

1. Pyrament Blended Cement shall conform to the requirements of ASTM C 595 for Type IP with the following test modification:

   a. Time of Setting, VICAT (ASTM C-191)

   Reference is made to ASTM C-305, Sections 6.1 - 6.1.5. Follow mixing procedure as listed in the method but increase the mixing time in Section 6.1.5 to 1-1/2 minutes.

   Determine the normal consistency according to ASTM C-187 and use the calculated water for both the time of setting specimens (ASTM C-191) and the autoclave expansion determination. (ASTM C-151)

   Normal consistency is generally achieved by use of 20.0 to 21.0 percent water by weight of cement. For the 650 gram specimen described in ASTM C-191 use 130 to 136.5 ml.

   b. Air Content of Mortar (Method ASTM C-185)

   Test the mortar made from Pyrament Blended Hydraulic cement exactly as outlined in ASTM C-185. When calculating the air content of the resulting mortar, Section 10.0, substitute the specific gravity of 2.90 for the value of 3.15 and substitute a flow of 40 ± 5 in place of the specified 87 1/2 ± 7 1/2; Section 9.4.

   c. Compressive Strength - ASTM C-109

   Batch, mix and mold specimens according to ASTM C-109 and C-109 and C-305 with one exception. When calculating mixing water needed (ASTM C-109, Sec. 9.1.1) use sufficient water to produce a flow of 70 ± 5. This mortar will be more workable than ordinary portland cement mortars at a flow of 110 ± 5. No modifications to mixing time are needed. Pyrament cement mortars do not require moist curing.

2. All other ingredient shall meet the requirements in Section 601 of the Department's Standard Specifications.

III. CONCRETE MIX REQUIREMENTS

1. Minimum compressive strengths shall be as follows:

   a. For removing falsework: 3,500 psi.
   b. For opening to traffic: 4,000 psi.
   c. 28 day strength: 7,500 psi.

2. The minimum cement factor shall be 7.0 bags (658 lbs.) per cubic yard.

3. Slump shall be within the range of 4 to 8 inches.

4. Air entraining admixture is not required but the air content shall not exceed 7.0 percent.

5. The water/cement ratio shall not exceed 0.29 (3.27 gal/bag).

6. A minimum of 5 sets (2 per set) of 6" x 12" cylinders per 50 cubic yards will be cast, cured, and tested by Kentucky Department of Highways' personnel.

7. The temperature of the mix immediately before placement shall not exceed 100°F.

8. The contractor shall make trial batches as necessary to demonstrate that the mix will meet the requirements for slump, air content, water/cement ratio, and compressive strength. The trial batches shall be made using the ingredients, proportions, and equipment (including batching, mixing, and delivery) to be used in the project. Department personnel shall observe all phases of the trial batching. At least two, three yard batches meeting all specifications shall be made. A report of test results and mix proportions for all trial batches shall be submitted to the Engineer for review and approval.

IV. COMPRESSIVE STRENGTH ACCEPTANCE REQUIREMENT

If the average strength of the 28 day cylinder test is less than 7,500 psi, two cores shall be taken from the concrete in question, and tested. If the cores average 7,500 psi, the concrete will be considered acceptable; but if the cores average less than 7,500 psi the concrete will be paid for in accordance with the following table.

Average Core Strength	% of Contract Unit Price
6,500 - 7,499	95%
5,500 - 6,499	90%
4,500 - 5,499	85%
4,000 - 4,499	75%
3,500 - 3,999	60%
Below 3,500	Remove and Replace at Contractor's Expense

V. OTHER REQUIREMENTS

1. Finishing should be completed as quickly as possible and then some type of curing should be applied immediately. If the curing cannot be applied immediately, the fresh concrete must be lightly fogged until the curing is commenced. The low water cement ratio of this concrete dictates that very good concreting practices be followed.

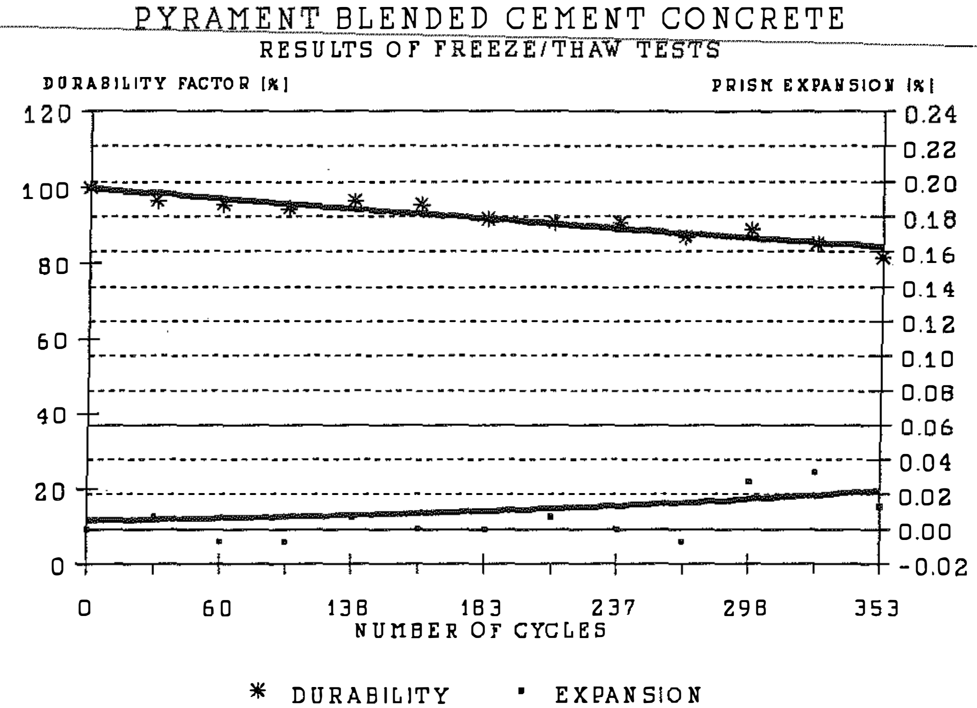
2. The batch size shall be no greater than 75% of the mixer capacity.

3. Batching, mixing, hauling, placing, finishing, curing of concrete method of measurement, and basis of payment shall conform to the requirements of Section 601, 608, and 609 of the Department's Standard Specifications.

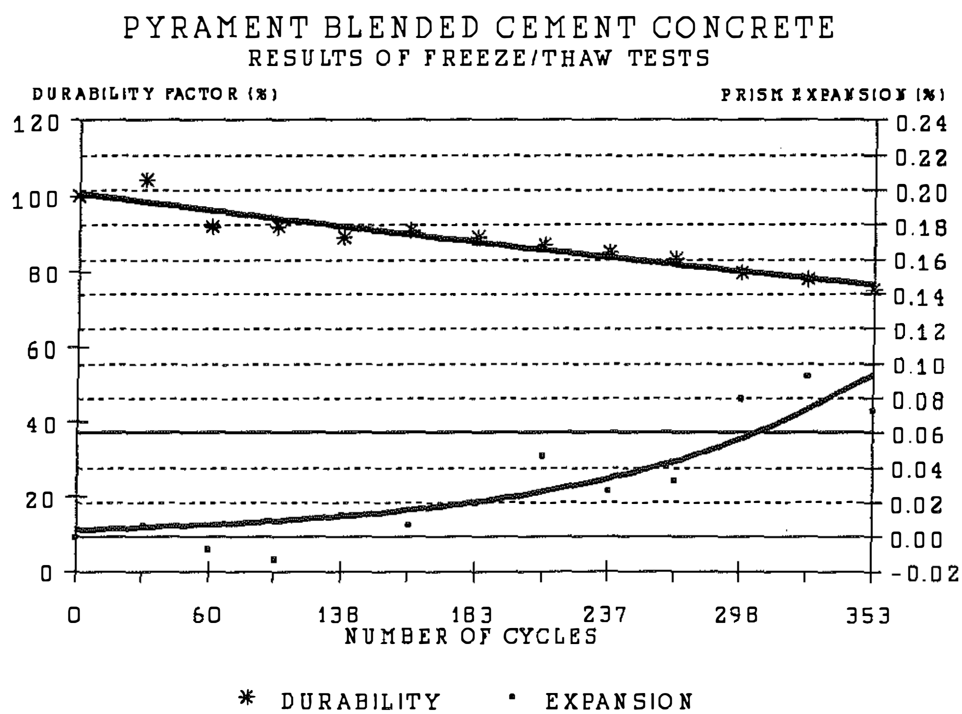
APPENDIX II

RESULTS OF FREEZE/THAW DURABILITY TESTS

PYRAMENT CEMENT CONCRETE

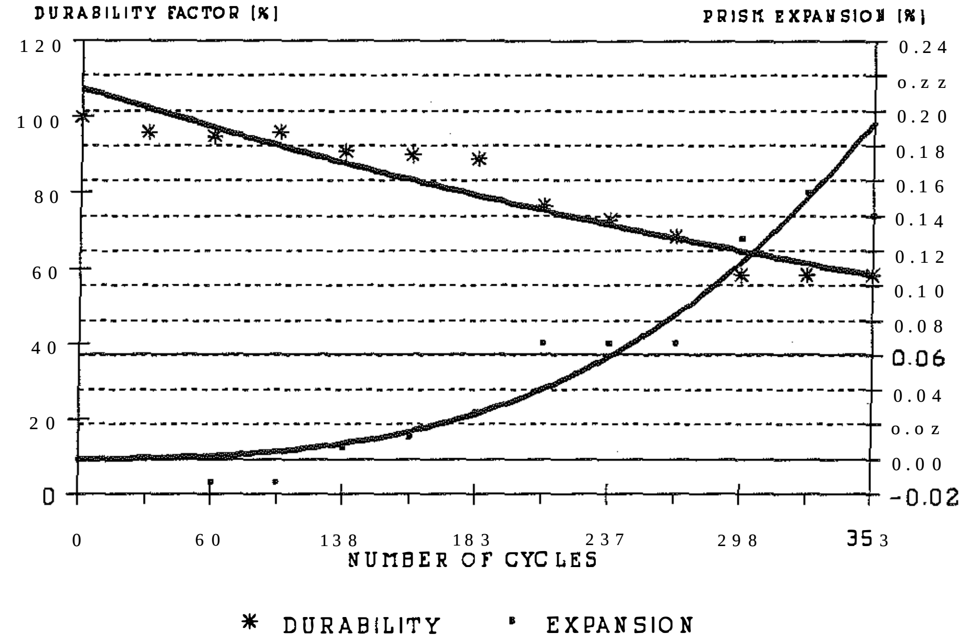


SPECIMEN NO. 2A



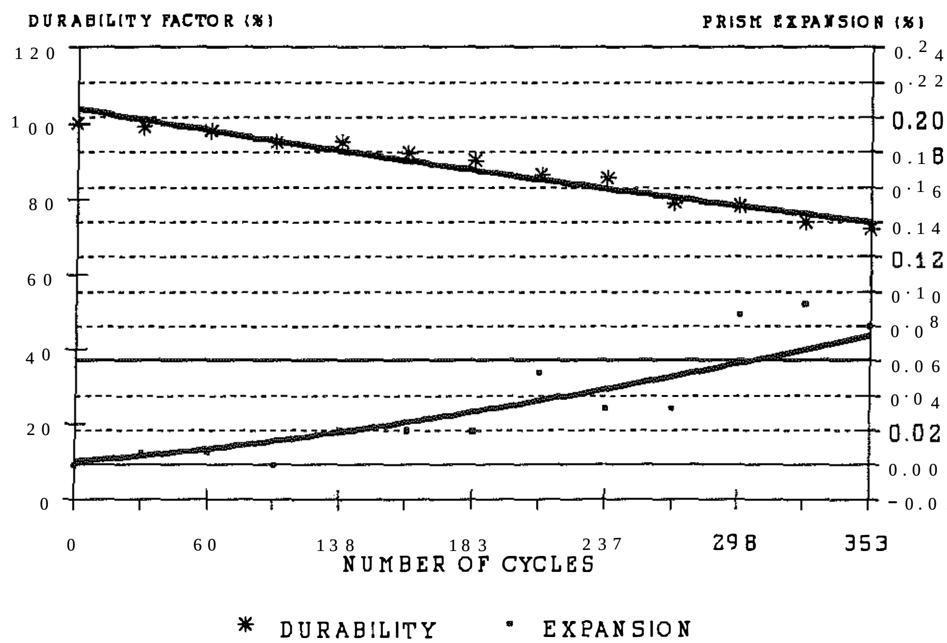
SPECIMEN NO 2B

PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS



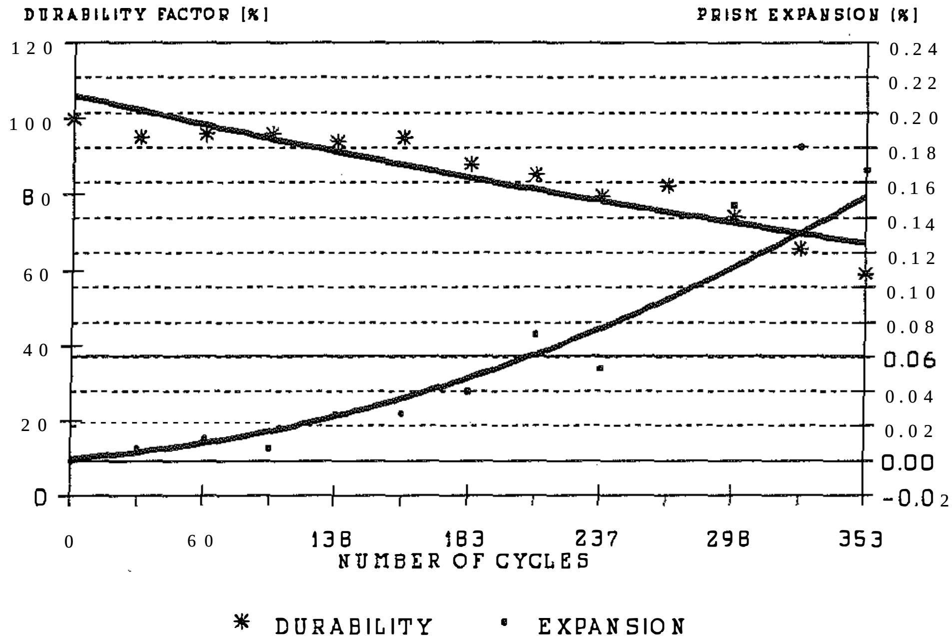
SPECIMEN NO. 2C

PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS



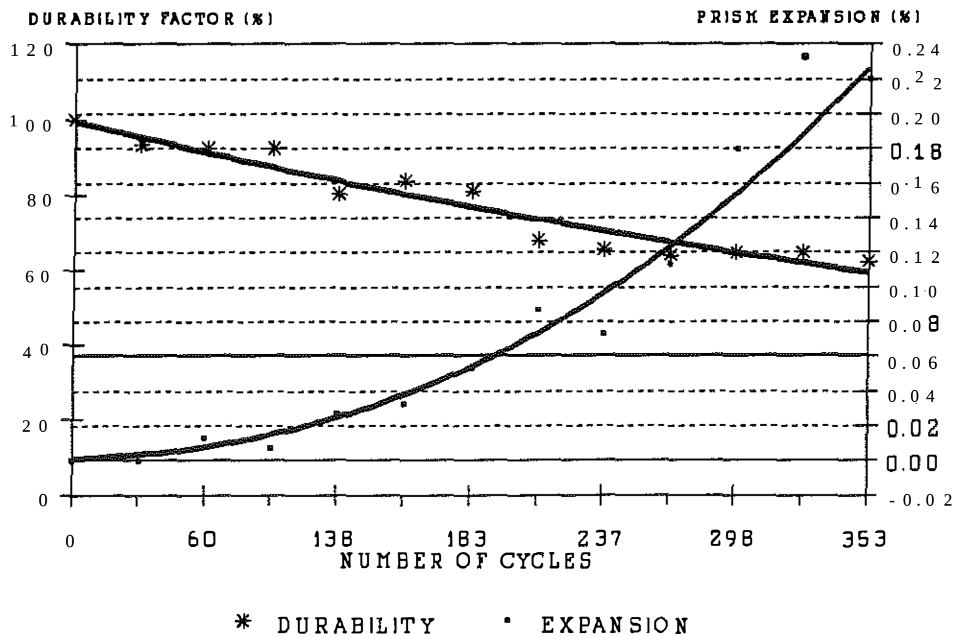
SPECIMEN NO 2D

PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS

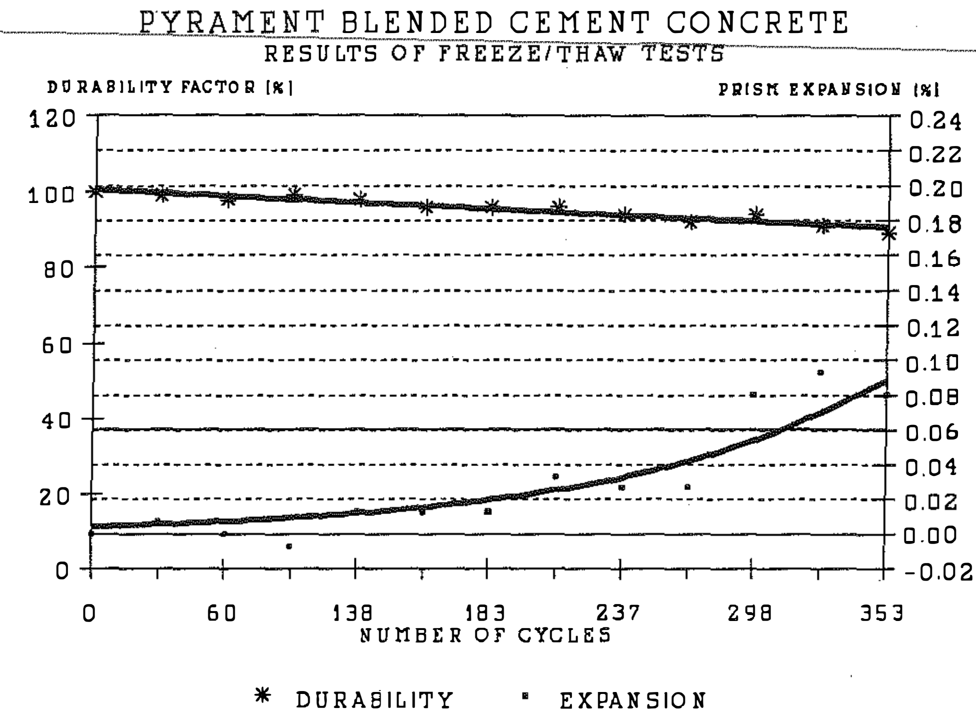


SPECIMEN NO. 2E

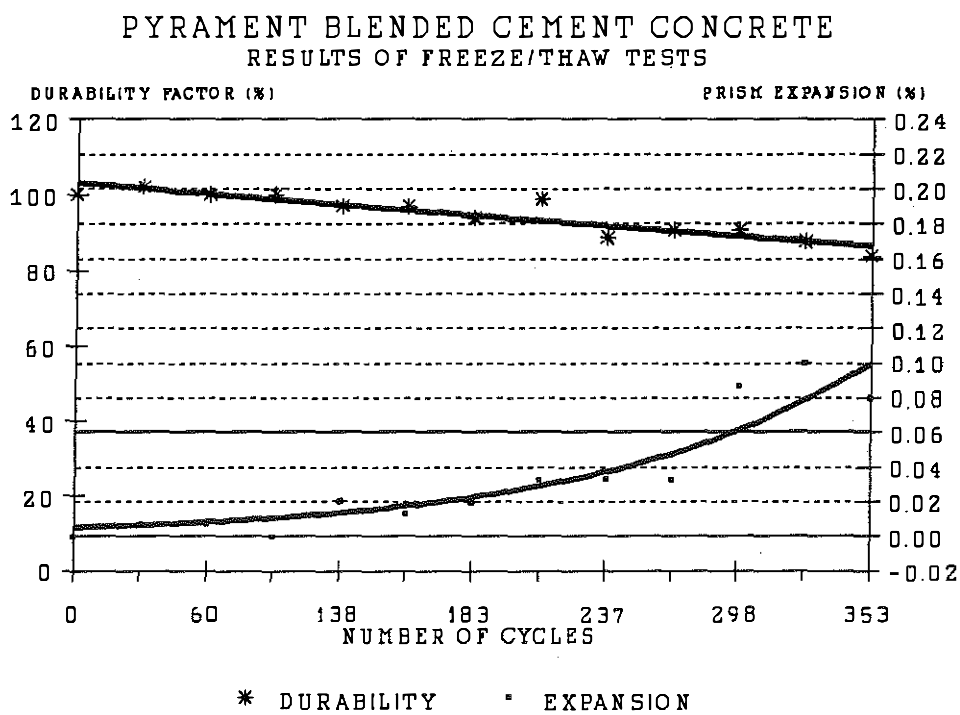
PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS



SPECIMEN NO 2F



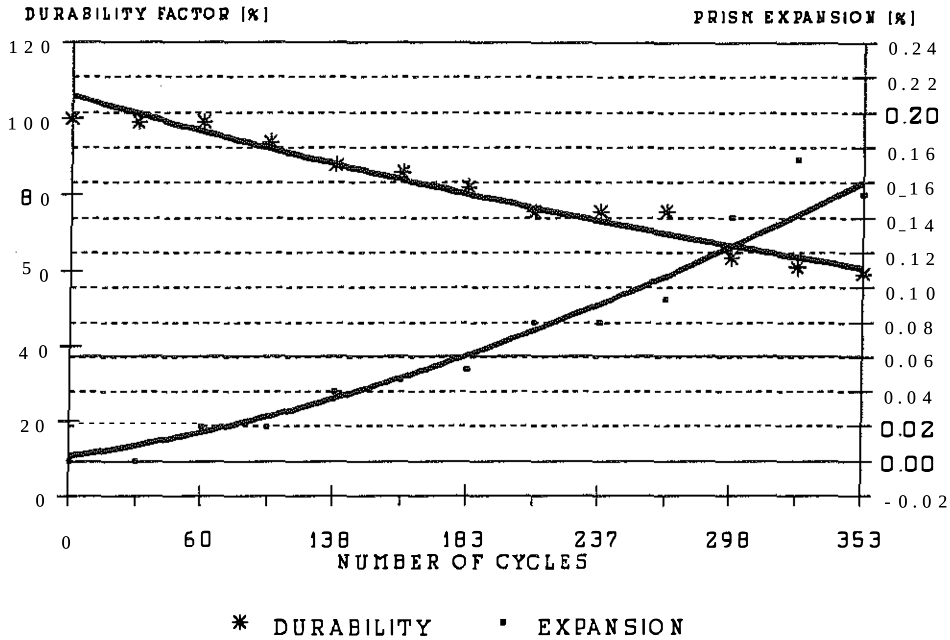
SPECIMEN NO. 4A



SPECIMEN NO 4B

PYRAMENT BLENDED CEMENT CONCRETE

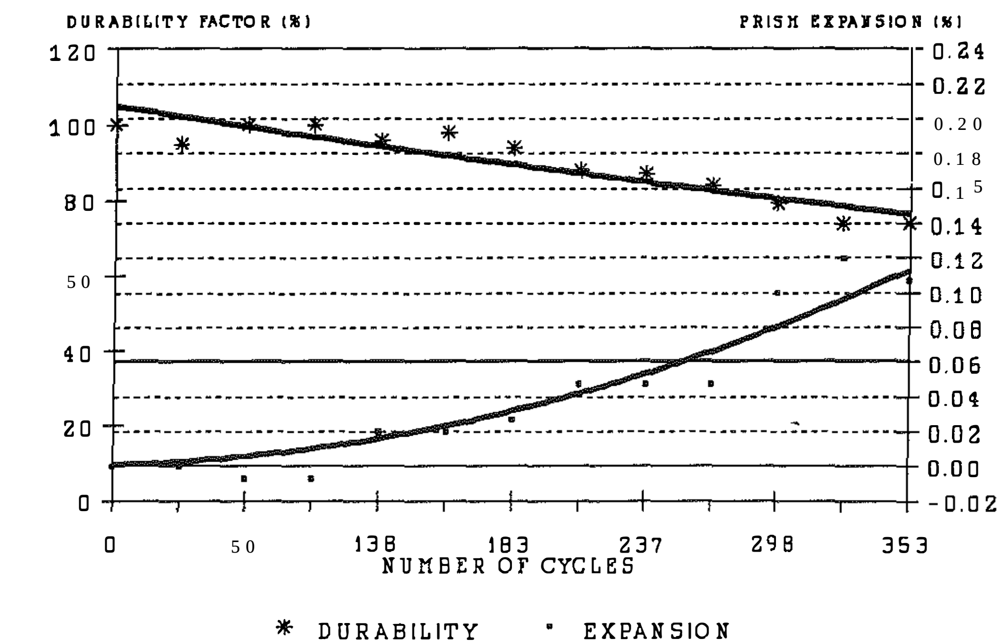
RESULTS OF FREEZE/THAW TESTS



SPECIMEN NO. 4C

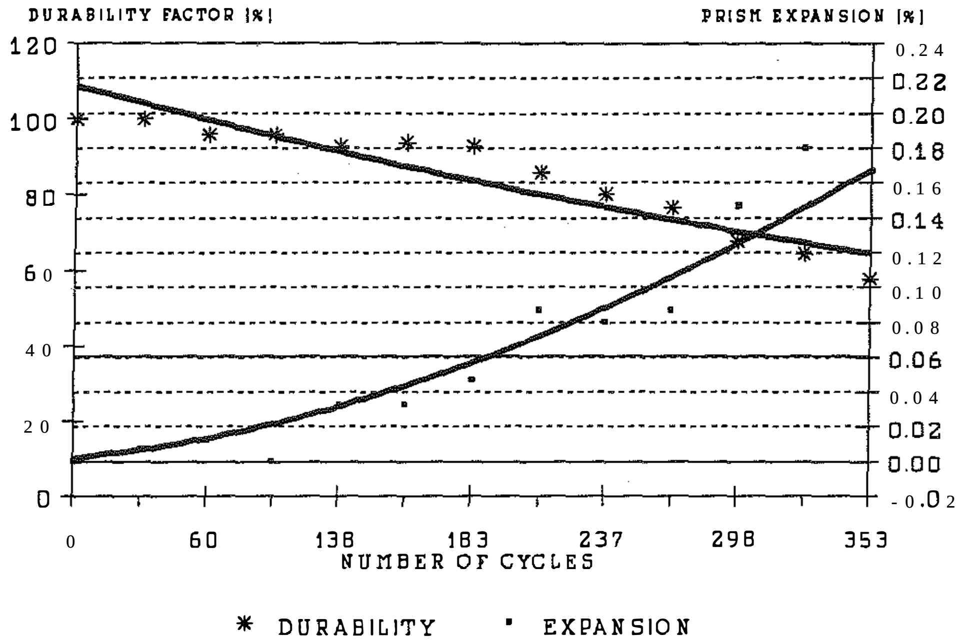
PYRAMENT BLENDED CEMENT CONCRETE

RESULTS OF FREEZE/THAW TESTS



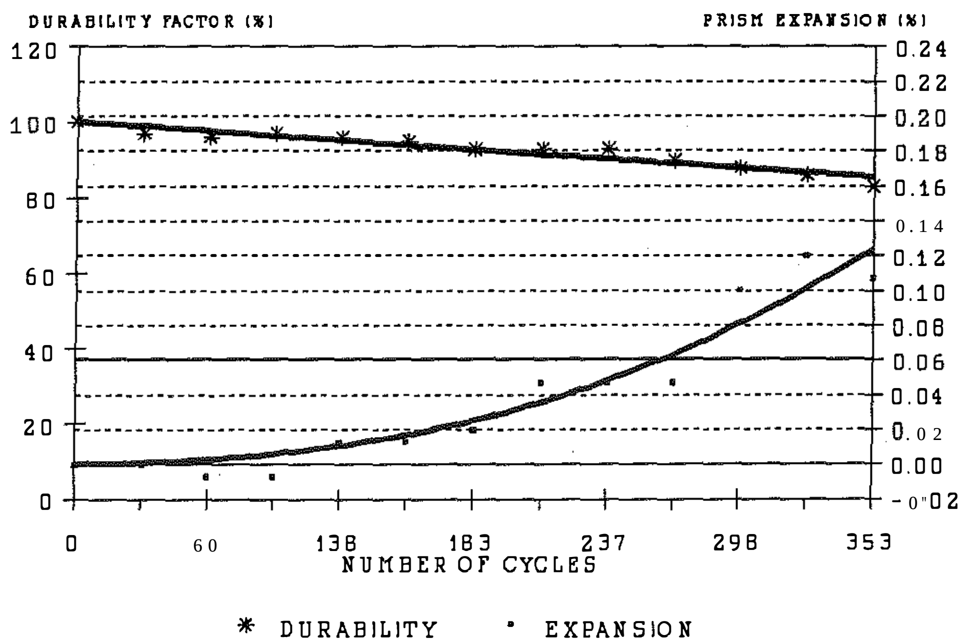
SPECIMEN NO 4D

PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS



SPECIMEN NO. 4E

PYRAMENT BLENDED CEMENT CONCRETE
RESULTS OF FREEZE/THAW TESTS



SPECIMEN NO 4F