

Research Report  
KTC 95-9

PERFORMANCE OF  
PYRAMENT CEMENT CONCRETE  
IN A HIGHWAY BRIDGE DECK

by

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16. Abstract  Pyrament Blended Cement (PBC) is a high performance cement that was developed by Lone Star Industries. Concrete that is 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. The objectives of this study were to evaluate the construction and performance of a full-depth bridge deck constructed of PBC concrete and to compare the data obtained to historical construction and performance properties of conventional, Class AA bridge deck concrete. This report provides information relative to construction activities, materials properties, and a summary of the three-year performance of the experimental bridge deck.					
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## EXECUTIVE SUMMARY

Pyrament Blended Cement (PBC) is a high performance cement that was developed by Lone Star Industries. Concrete that is 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 University of Kentucky Transportation Center (UKTC) to monitor construction activities and subsequent performance of the experimental bridge deck. The objectives of this study were to evaluate the construction and performance of a full-depth bridge deck constructed of PBC concrete and to compare the data obtained to historical 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, materials properties, and the three-year performance of the experimental bridge deck.

Construction activities, materials characteristics and initial performance of the experimental PBC concrete bridge have been described previously, [1]. The primary obstacle encountered during placement operations was a lack of time to properly finish the concrete deck. This resulted in very distinct differences in the surface texture throughout the experimental deck. Slump, air content, and temperature of the fresh concrete were monitored at various times during deck placement operations and were observed to be within allowable tolerances. The hardened PBC concrete was further evaluated in the laboratory relative to durability, compressive strength, modulus of elasticity, relative permeability to chloride ions, and air content.

Visual inspections of the experimental deck were conducted on a regular schedule as set forth in the study work plan. The first inspection of the experimental bridge deck confirmed the obstacles the concrete finishers faced in accomplishing their tasks due to the consistency and early stiffening of the PBC concrete. The deck was both smooth and quite rough, and had several uneven areas (dips or rolls). Shrinkage cracks were observed and charted by the inspector. Subsequent inspections determined that the length and width of these cracks increased in magnitude and new cracks were documented. The cumulative length of cracking was nearly 44.5 linear meters (146 linear feet).

Neither construction nor performance of the experimental PBC concrete bridge deck have been proven to be superior or even equivalent to that demonstrated by normal Class AA concrete. Workability and finishability of the PBC concrete were much more difficult when compared to these characteristics for Class AA concrete. Greater familiarity with the product by the contractor may have enhanced the outcome. Drying shrinkage cracking of the experimental PBC concrete is comparable to shrinkage cracking associated with conventional Class AA concrete bridge decks. The PBC concrete did exhibit higher compressive strengths and elastic moduli and had a high resistance to chloride ion penetration. However, the in-place cost of the experimental PBC bridge deck concrete was about fifty percent greater than the average cost of typical Class AA bridge deck concrete. Based upon information gained during this study, the use of PBC concrete in a full-depth bridge deck did not prove to be favorable to the use of Class AA concrete. Future use of PBC concrete in a full-depth bridge deck is not recommended.

## INTRODUCTION

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 17.24 MPa (2,500 psi) in four hours and achieve ultimate compressive strengths of over 82.74 MPa (12,000 psi). It is also reported that PBC concrete may be placed at temperatures as low as -17.8°C to -12.2°C (0°F to 10°F). Pyrament cement is a blend of 65 percent Portland cement, 30 percent fly ash, and five percent trade mark 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 University of Kentucky Transportation Center (UKTC) to monitor placement activities and subsequent performance of the experimental bridge deck. The objectives of this study were to evaluate the construction and performance of a full-depth bridge deck constructed of PBC concrete and compare construction and performance data obtained from the experimental deck concrete to 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 concrete, and monitoring of the bridge deck for the occurrence of shrinkage cracks. This report provides information relative to construction activities, materials testing, and observed performance of the experimental bridge deck. Also included is a brief comparison of the performance of the full-depth PBC bridge deck with typical performance of Class AA concrete that is normally used in full-depth bridge decks. Finally, the report provides recommendations relative to the future use of PBC for full-depth deck slabs.

## CONSTRUCTION AND TESTING ACTIVITIES

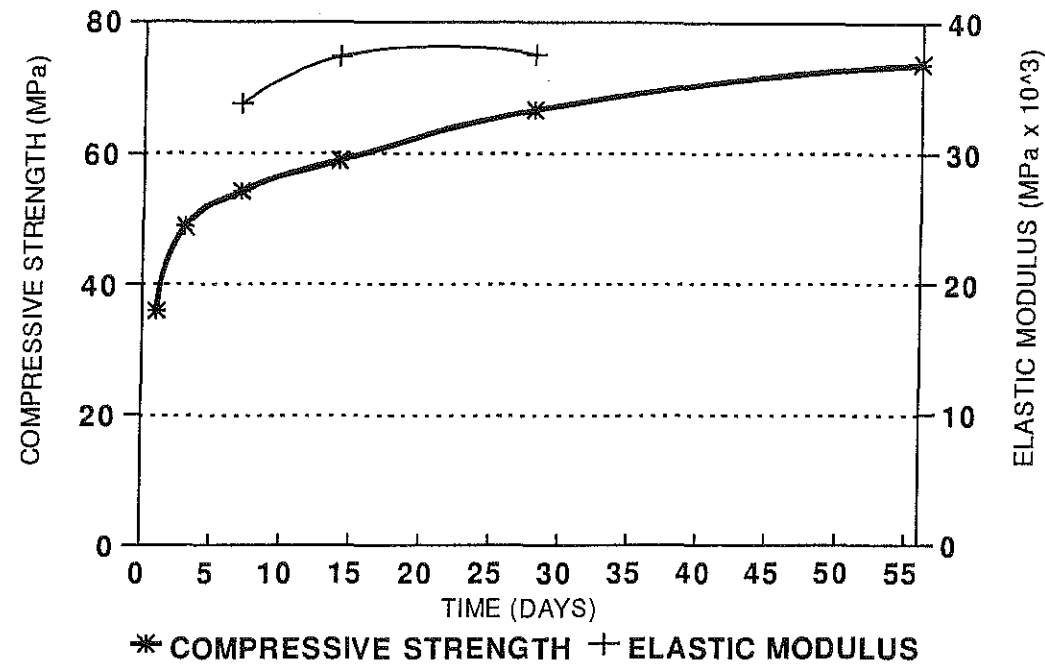
Construction activities and materials characteristics of the experimental PBC concrete bridge deck have been described in a previous report, [1]. Placement of the experimental bridge deck, located on County Route 8586 (Cooper Chapel Road) over McNeely Lake in Jefferson County, occurred on July 30, 1991. Some difficulties were encountered during the placement operations but these problems appeared to be remedied by making slight adjustments to the mixture. During placement of the approximately 118 cubic meters (154 cubic yards) of PBC concrete in the bridge deck, the primary obstacle encountered was the lack of time to properly finish the surface of the concrete deck. The concrete

finishers working the PBC concrete complained that there was insufficient time to provide the proper finish to the surface of the deck. The contractor's foreman stated that although a higher than normal slump tolerance expedited placement operations, the early stiffening of the PBC concrete made the deck extremely difficult to finish. Finishers sprayed water on the concrete's surface in an effort to lengthen the time necessary for proper finishing. The finishers also commented that the mixture was extremely sticky and contributed to the difficulties of providing proper finish. The result of the improper finish was borne out in the appearance of the deck after the curing period. The bridge deck had distinct differences in the surface texture throughout the length of the experimental deck. Some areas of the deck appeared quite smooth while other areas were exceptionally rough. Slump, air content, and temperature of the concrete were monitored at various times during the deck placement. The slump ranged from 114 mm to 203 mm (4.5 inches to 8.0 inches) and averaged 171 mm (6.75 inches). Air content of the fresh content ranged from 4.8 percent to 6.8 percent and averaged 5.8 percent. The temperature of the concrete was consistently around 29°C to 30°C (84°F to 86°F). All measurements of the properties of the fresh concrete were within the allowable tolerances specified in the Special Note for construction for the full-depth PBC concrete bridge deck. 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 hardened PBC concrete was evaluated for durability, compressive strength and static chord modulus of elasticity as a function of time, relative permeability to chloride ions, and air content. Concrete length-change prisms cast during placement did not perform well when evaluated for resistance to rapid freezing and thawing (ASTM C-666, Method B, Freezing in Air and Thawing in Water). The average Durability Factor for the 12 length-change prisms was 71 percent and the average expansion was 0.115 percent. The expansion of the prisms exceeded the permissible expansion (0.060 percent) allowed for length-change prisms containing aggregates for use in concrete pavements. The freeze/thaw test is a very severe test and the poor performance of the prisms during the test is generally indicative only of the resistance of the coarse aggregate to freezing and thawing.

Standard test cylinders were cast during the placement operations. Compression tests were performed at 27 hours, three, seven, 14, 28 and 56 days. Figure 1 illustrates the strength gain of the PBC concrete as a function of time. The PBC concrete easily achieved the required 51.71 MPa (7,500 psi) compressive strength at 28 days. The average 28-day compressive strength of specimens cast by UKTC personnel was 66.74 MPa (9,680 psi). Tests indicated a static chord modulus of elasticity of about  $37.92 \times 10^3$

## STRENGTH DEVELOPMENT PYRAMENT CEMENT CONCRETE



**Figure 1.** *Strength development properties of the PBC concrete mixture.*

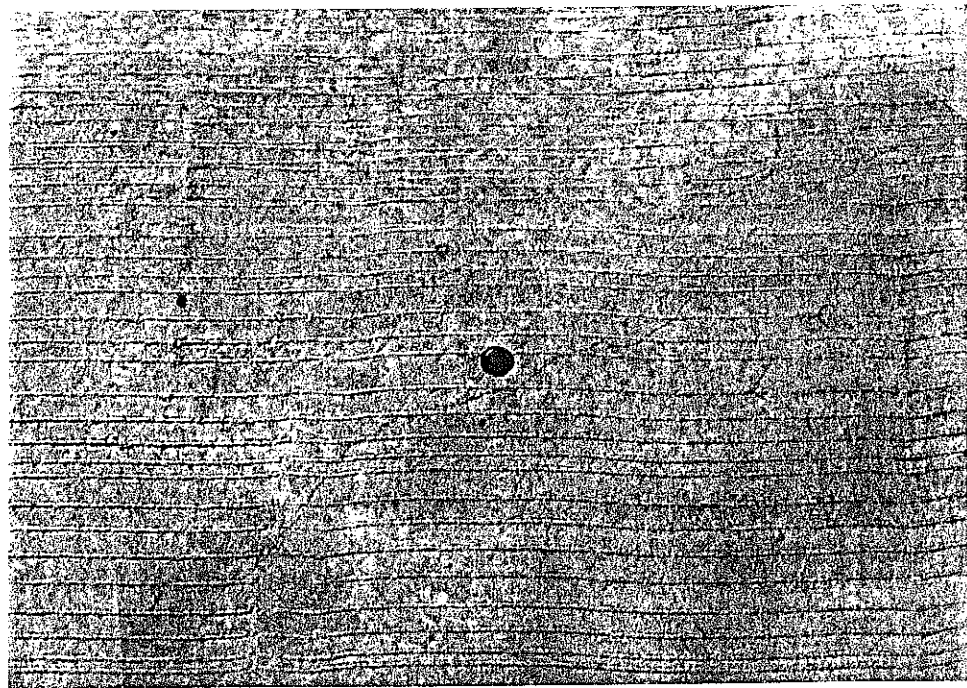
MPa ( $5.5 \times 10^6$  psi) at 28 days. The chloride ion permeability of three PBC concrete cores was rated as very low when evaluated in accordance with ASSHTO T 277, [2]. The air content of three core specimens obtained from the experimental PBC concrete bridge deck averaged 8.0 percent, exceeding the maximum air content of 7.0 percent allowed in the Special Note for construction for the experimental PBC concrete bridge deck.

### 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. Visual inspections were scheduled to be performed weekly for the first month after placement. However, the deck remained cluttered during this period and it was impossible to inspect the deck properly. The first detailed visual inspection of the experimental deck was performed on August 30, 1991, approximately

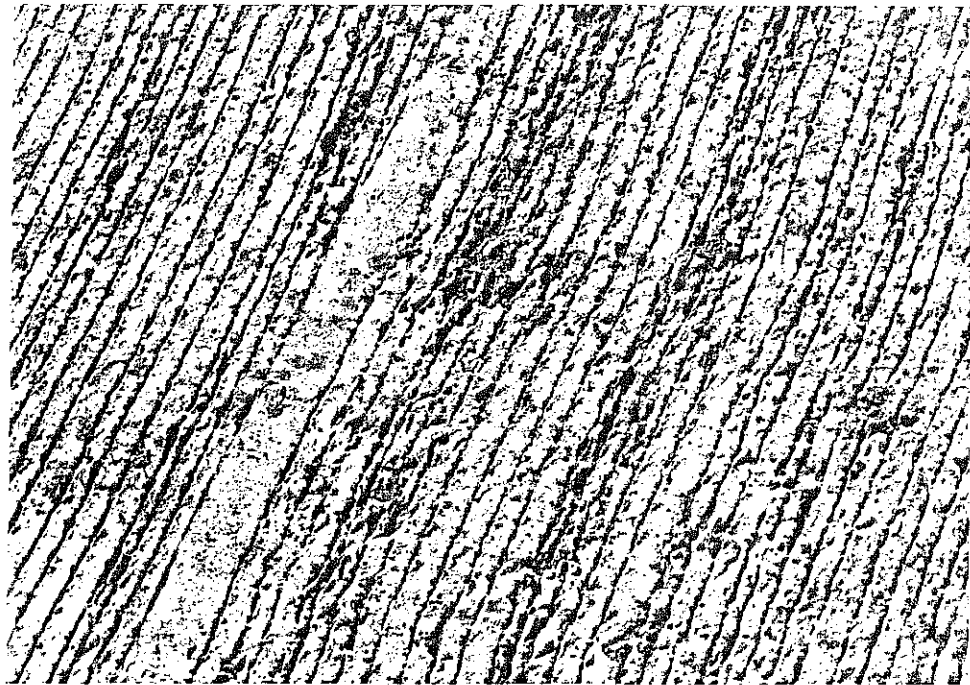
28 days after placement. The bridge deck was surveyed from above, on the surface, and below. The lack of adequate time to provide a proper finish to the deck was readily apparent when observing the surface of the deck. As shown in Figures 2 and 3, the tyned depths were very inconsistent. Some areas of the experimental deck were quite smooth, almost slick, while other areas of the deck's surface exhibited deep grooves. Aggregates near the surface were displaced in the deeply tyned areas causing these areas of the bridge deck to be extremely rough. The surface of the deck also was observed to be generally uneven. As seen in Figure 4, the surface of the deck exhibited numerous dips or rolls.

Six shrinkage cracks were observed during the 28-day inspection. The cumulative length of the cracks was 9.24 linear meters (30.3 linear feet). A diagram, or grid sheet, was created during the 28-day inspection to map the location of developing and propagating shrinkage cracks. A grid sheet detailing the propagation shrinkage cracks during subsequent visual inspections is depicted in Figure 5. In addition to shrinkage cracks, there were numerous microcracks observed throughout the deck as illustrated in Figure 6. The microcracks did not extend through the full depth of the slab and do not appear on the grid.

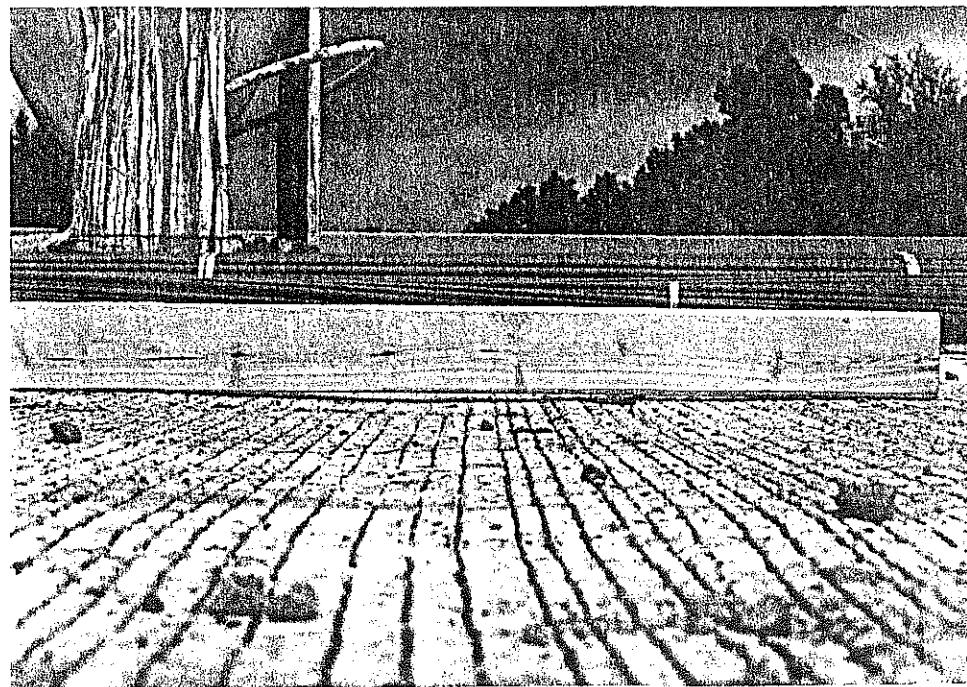


**Figure 2.** *Some areas of the bridge deck were improperly tyned due to the rapid hardening of the experimental PBC concrete.*





**Figure 3.** *Some areas of the bridge were deeply tyned, dislodging aggregates in the experimental PBC deck.*



**Figure 4.** *The surface also contained several dips or rolls as a result of finishing difficulties.*

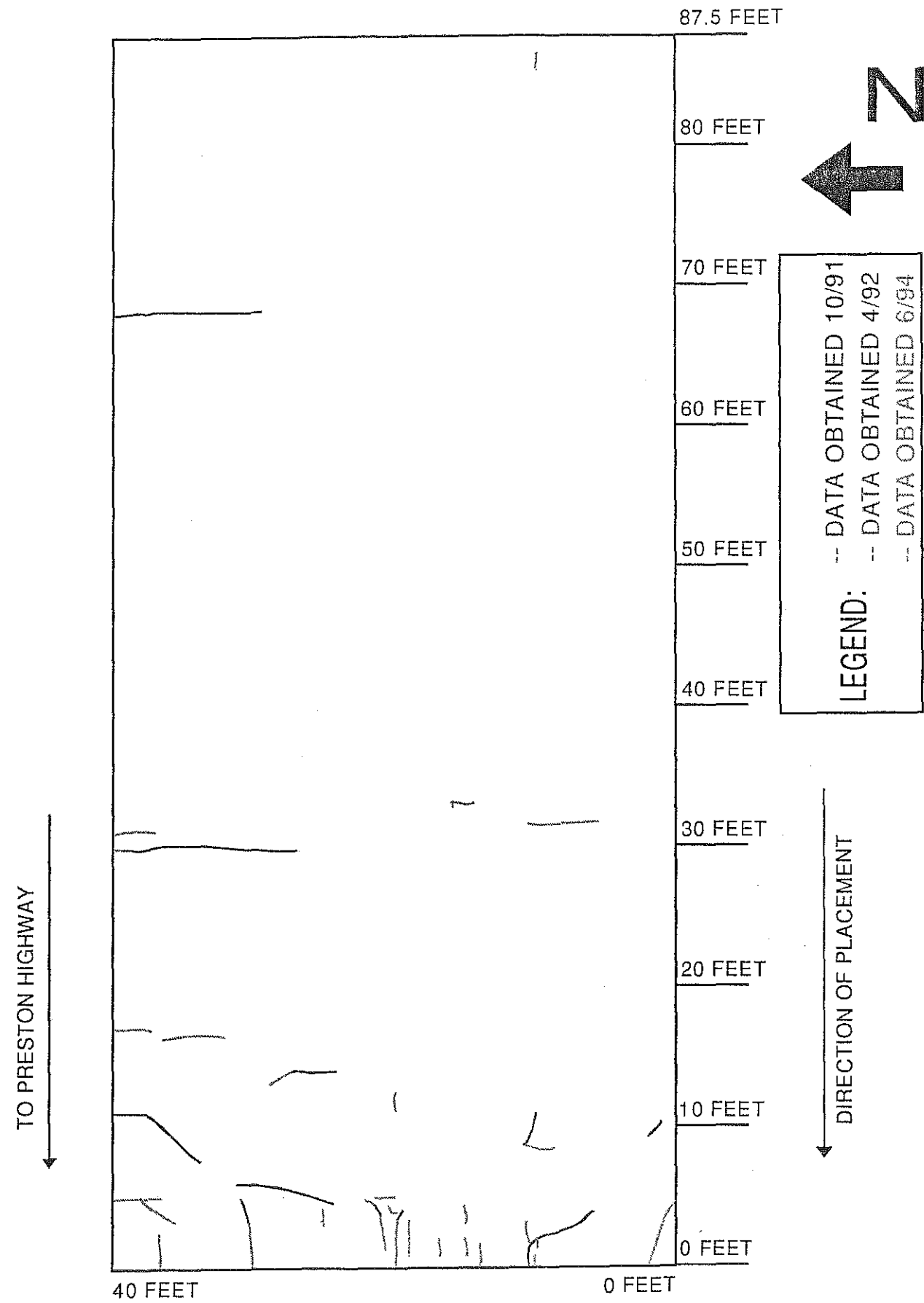
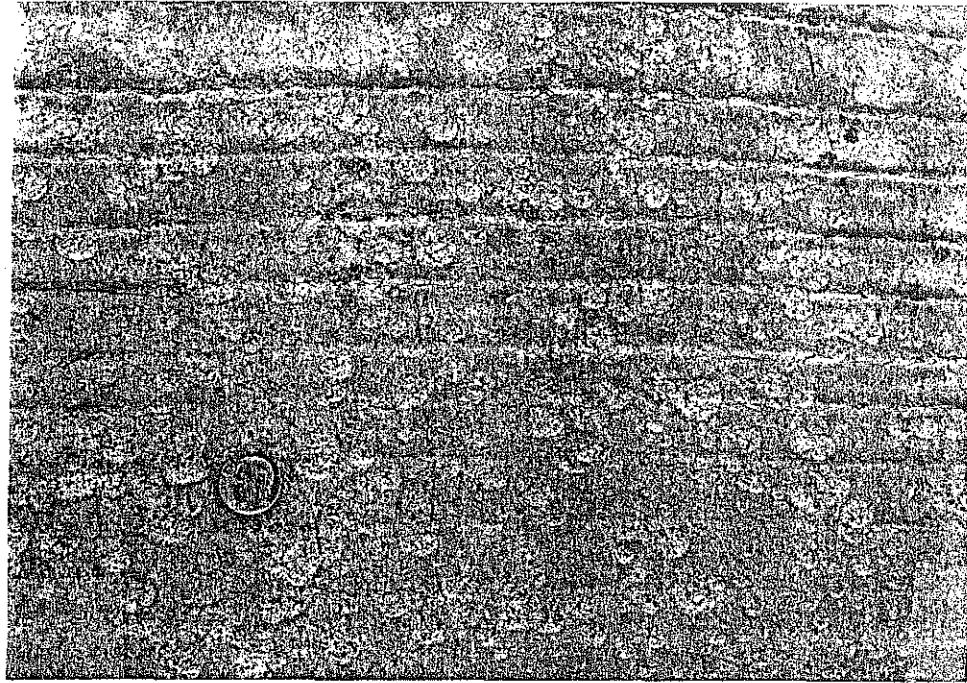


Figure 5. Grid sheet detailing propagation of shrinkage cracks.

SCALE: 1.0 INCH = 1.0 FOOT



**Figure 6.** Numerous microcracks were observed on the surface of the PBC concrete bridge deck.

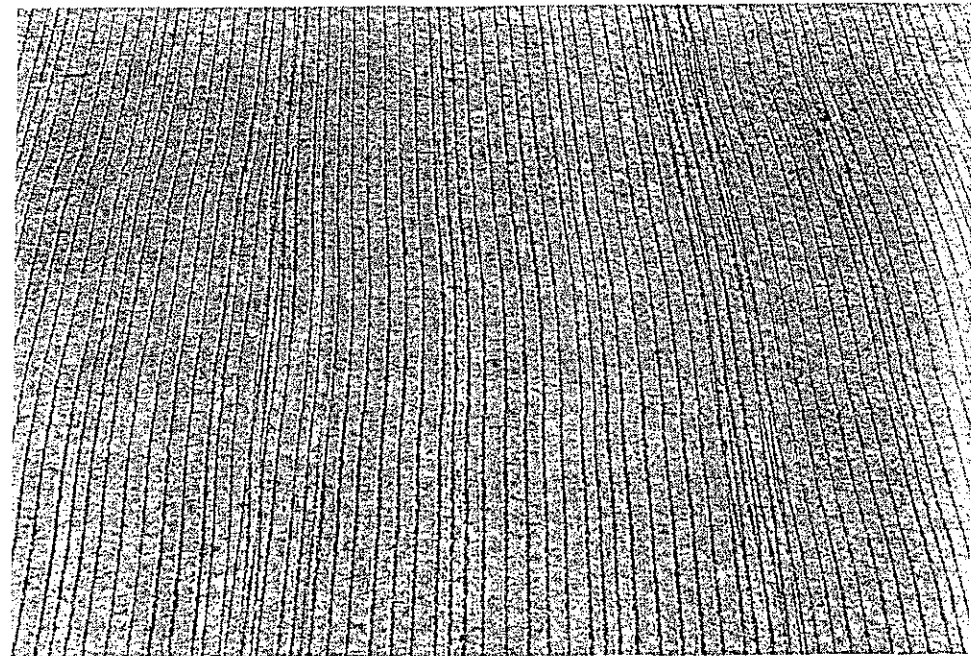
Subsequent visual inspections of the experimental PBC concrete bridge deck were performed biannually for two additional years. The length of the shrinkage cracks increased significantly during the period from the initial inspection to the March, 1992 inspection. Also, two new cracks were observed during the March, 1992 inspection. The cumulative total length of cracking increased from 9.24 linear meters (30.3 linear feet) to 23.07 linear meters (75.7 linear feet). Progression of the cracks was detailed on the crack grid sheets during each inspection. Inspections performed in September, 1992 and March, 1993 detected no new cracking and very little change in the shrinkage cracks already documented. The cumulative length of cracking was approximately 26.52 linear meters (87 linear feet).

The last inspection of the experimental PBC bridge deck occurred in June, 1994. The inspection revealed that existing cracks had expanded significantly. In addition, several new cracks were observed. The cumulative length of cracking increased to approximately 44.50 linear meters (146 linear feet). This was an increase of 17.98 linear meters (59 linear feet) during the 15 months since the previous inspection. It is suspected the significant increase in magnitude of the cracking may be due to the unusually harsh Winter between the last two inspections. During the Winter of 1993 - 1994, according

to the Jefferson County Roads Department, the experimental bridge deck received about 14 applications of salt, which is an unusually high amount.

#### COMPARISON TO CONVENTIONAL CLASS AA CONCRETE

Construction and performance aspects of the experimental PBC concrete deck were compared to construction and performance typical of conventional Class AA bridge deck concrete. Placement and finishing operations relative to the PBC concrete were much more demanding when compared to Class AA concrete due to a drastic decrease in set time. The concrete workers had only a limited time to work with the concrete. Eventually, the finishers sprayed water on the surface in an attempt to aid finishing operations. The resulting surface characteristics of the experimental deck were not consistent, having nearly slick areas in some places and very rough areas in other spots. Greater familiarity with the experimental product may have enhanced the final product produced by the concrete finishers. Figure 7 illustrates a desirable deck finish obtained on a bridge deck containing conventional Class AA concrete.



**Figure 7.** *Surface finish and texture of a conventional Class AA concrete bridge deck.*

Drying shrinkage cracking of the experimental PBC concrete also proved to be a problem, but may be no worse than that observed with conventional Class AA concrete bridge decks. The overall performance of the experimental PBC concrete bridge deck was not proven to be any greater than that demonstrated by normal Class AA concrete with the notable exceptions of the higher compressive strengths and elastic moduli, and the very low chloride ion permeability. However, the low chloride ion permeability provided by the mixture is diminished when the deck exhibits full-depth cracking.

The in-place concrete costs associated with the experimental PBC concrete bridge construction (includes superstructure and integral end bents) were about 150 percent greater than those associated with a conventional Class AA concrete bridge deck. The cost of in-place concrete for the experimental PBC concrete bridge was \$585.58 per cubic meter (\$450.00 per cubic yard). Although a direct cost comparison between the experimental PBC concrete and conventional Class AA concrete was not available, the average cost for in-place Class AA concrete bridge deck construction in Kentucky during 1991 was \$383.01 per cubic meter (\$292.83 per cubic yard).

#### SUMMARY

Construction activities, materials characteristics and three-year performance of an experimental PBC concrete bridge have been described herein. The primary hindrances encountered during placement of the experimental PBC bridge deck were stickiness of the mixture and lack of time necessary to provide a proper finish. This resulted in distinct differences in the surface texture of the experimental deck. Some areas of the deck were quite smooth while other areas were markedly rough. Slump, air content, and temperature of the fresh concrete were monitored at various times during the deck placement and were observed to be within allowable tolerances. The PBC concrete was characterized relative to durability, compressive strength, modulus of elasticity, relative permeability to chloride ions, and air content.

The PBC concrete easily achieved the required 51.71 MPa (7,500 psi) compressive strength at 28 days. The average 28-day compressive strength of specimens cast by UKTC personnel was 66.74 MPa (9,680 psi). The PBC concrete had a static chord modulus of elasticity of about  $37.92 \times 10^3$  MPa (5.5 million psi) at 28 days. The chloride ion permeability of the PBC concrete was rated as "very low." The average air content of core specimens obtained from the experimental PBC concrete bridge deck was 8.0

percent, exceeding the maximum air content specified in the Special Note for construction for the experimental PBC concrete bridge deck.

Visual inspections of the experimental deck were conducted on a regular schedule set forth in the study work plan. The initial inspection after the seven-day curing period revealed the contractor had covered much of the deck with equipment and supplies. Because the deck was used as a staging area, the first detailed inspection did not occur until the deck was 28-days old. The first inspection of the experimental bridge deck confirmed the difficulties the concrete finishers had in performing their duties due to the consistency and early hardening of the PBC concrete. The deck was both smooth and quite rough, and had several uneven areas (dips or rolls). Six drying shrinkage cracks were observed and charted by the inspector during this inspection. Subsequent inspections determined that the length and width of these cracks increased and new cracks were documented. The cumulative length of cracking after a three-year period was nearly 44.5 linear meters (146 linear feet).

Construction and performance of the experimental PBC concrete deck were compared to the construction and performance of conventional Class AA bridge deck concrete. Placement and finishing operations relative to the PBC concrete were much more demanding when compared to Class AA concrete due to a drastic decrease in set time. Greater familiarity with the experimental product may have enhanced the final result. Drying shrinkage cracking of the experimental PBC concrete also proved to be a problem, but most likely was no worse than shrinkage cracking associated with conventional Class AA concrete bridge decks. The overall performance of the experimental PBC concrete bridge deck did not prove to be any greater than that demonstrated by normal Class AA concrete. The PBC concrete did have higher compressive strengths and elastic moduli and a very high resistance to chloride ion penetration. However, the advantage of increased resistance to chloride penetration is significantly diminished when the concrete exhibits significant shrinkage cracking. The in-place concrete costs associated with the experimental PBC concrete bridge construction (includes superstructure and integral end bents) were about 150 percent greater than costs associated with a conventional Class AA concrete bridge deck. The cost of in-place concrete for the experimental PBC concrete bridge was \$585.58 per cubic meter (\$450.00 per cubic yard). This compares to a 1991 average cost of \$383.01 per cubic meter (\$292.83 per cubic yard) for Class AA concrete bridge construction.

## CONCLUSIONS AND RECOMMENDATIONS

Reported herein is a summary of all data collected throughout the three-year study, including performance documentation. This report also presents comparisons of the placement and performance histories of conventional Class AA concrete and the experimental PBC bridge deck concrete. The overall construction and performance aspects of the experimental PBC concrete bridge deck did not prove to be better than those of conventional Class AA concrete. Workability and finishability of the PBC concrete was much more difficult when compared to Class AA concrete. Greater familiarity by the contractor with the product may have enhanced the results. Drying shrinkage cracking of the experimental PBC concrete is comparable to shrinkage cracking associated with conventional Class AA concrete bridge decks. The PBC concrete did exhibit higher compressive strengths and elastic moduli and had a high resistance to chloride ion penetration. The in-place cost of the PBC concrete was \$585.58 per cubic meter (\$450.00 per cubic yard). This compares to a 1991 average cost of \$383.01 per cubic meter (\$292.83 per cubic yard) for Class AA concrete bridge construction. The cost of the experimental PBC concrete is significantly more than that of normal Class AA concrete. Considering all aspects, the use of PBC concrete in a full-depth bridge deck was not proven to be advantageous to the use of Class AA concrete. Future use of PBC concrete in full-depth bridge decks is not recommended.

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