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THE CONSTRUCTION OF A PYRAMENT BRIDGE DECK OVERLAY

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CONSTRUCTION REPORT

Under the Supervision
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16. ABSTRACT <p>The Oklahoma Department of Transportation (ODOT) has been using High Density Portland Cement (HDPC) overlays on reconstruction of bridge decks since 1977. At the time of introduction, the HDPC (Iowa method) was considered the best method to prevent or minimize bridge deck deterioration. Although many of the overlays have performed well, some have experienced severe cracking and delamination within ten years of service.</p> <p>Pyrament was chosen to be evaluated on a two inch bridge deck overlay as part of a bridge deck rehabilitation project. The performance of the overlay will be compared to the presently used HDPC overlays.</p> <p>Pyrament is a rapid setting, low permeability, high strength concrete developed by Lonestar Industries. Pyrament cement is a blend of 65% Portland cement, 30% fly ash, and 5% trademark additive. The 4-hour and 28-day compressive strengths were 2700 psi and 9600 psi respectively.</p> <p>Proper curing of Pyrament was found to be critical. Phase I of the project developed severe shrinkage cracking. Five percent of the Phase I overlay had to be replaced due to shrinkage cracking accompanied by delaminations. The curing procedures in Phase II were changed to resin curing compound, fogging, wet burlap, cotton blankets, and plastic all kept in place for 24 hours. The Phase II overlay shows no signs of cracking.</p> <p>The overlay will be tested annually and a performance report will be written in 1993.</p>			
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BACKGROUND

High Density Portland Cement Concrete Overlays

The Oklahoma Department of Transportation (ODOT) has been using High Density Portland Cement (HDPC) overlays for constructing decks on new bridge structures since 1974. In 1977, ODOT began using HDPC overlays on reconstruction projects as well. At the time of introduction, the HDPC or low-slump concrete was considered the best method to prevent or minimize spalling and delamination resulting from the corrosion of reinforcing steel. The HDPC overlay provides a dense, protective layer with reduced permeability. Additional benefits included high strength and good freeze-thaw durability utilizing air entraining additives. Although many of the overlays have performed well, some have experienced severe cracking and areas of delamination within ten years of service.

Since the introduction of HDPC overlays, concrete additives have been developed which can produce a stronger concrete, further reduce permeability, and provide a faster cure or set time. A wide range of additives are available which control water requirements, set time, workability, and strength. These additives are quite sensitive in their application. This has made engineers cautious to specify "specialty" concrete in a generic sense. However, commercial products are emerging that have proven track records of providing concrete with given characteristics and limited risk. The Bridge Division of ODOT is interested in applying this technology to improve the performance of bridge deck overlays. Thus, Pyrament was chosen to be evaluated on a two inch bridge deck overlay.

What is Pyrament?

Pyrament is a rapid setting, low permeability, high strength concrete developed by Lonestar Industries. Pyrament cement is a blend of 65% Portland cement, 30% fly ash, and 5% trademark additive. The mix design used for the bridge deck overlay is shown below in Table 1. The aggregate gradations are shown in Tables 2 and 3.

Pyrament has many characteristics which are attractive for use on a bridge deck overlay. It can obtain a compressive strength of 2500 psi in four hours and an ultimate strength of over 10,000 psi. It has good freeze-thaw durability due to low permeability. The manufacturer reports it can be placed in cold weather with temperatures as low as 0 to 10 degrees Fahrenheit.

<u>ONE CUBIC YARD WEIGHTS</u>	
Pyrament XT Bridge Overlay	
Stone Size/Designation: 3/4" Bridge Mix	
3" - 5" Slump Range	
Pyrament XT	700 lbs.
Sand	1,130 lbs.
Stone	2,138 lbs.
Water	189 lbs.

Table 1. Pyrament Mix Design

COARSE AGGREGATE

Source: Dolese Bros. Co.
Richards Spur, Oklahoma

L. A. Abrasion: 25.0%
Specific Gravity: 2.66
Absorption: 0.9%
Na₂SO₄ Soundness: 8.0%
MgSO₄ Soundness: 3.4%

TYPICAL GRADATION

Richards Spur 3/4" Bridge Mix

<u>Sieve Size</u>	<u>Percent Passing</u>	<u>Specification</u>
3/4"	100	100
1/2"	64.6	60 - 70
3/8"	43.0	35 - 45
# 4	6.1	5 - 10
# 8	0.9	0 - 5

Table 2. Pyrament Coarse Aggregate Gradation.

FINE AGGREGATE

Source: The Dolese Company
Dover, Oklahoma

Designation: ASTM C-33 Concrete Sand

Specific Gravity: 2.64
Absorption: 0.6%

TYPICAL GRADATION

Dover Concrete Sand

<u>Sieve Size</u>	<u>Percent Passing</u>	<u>AASHTO Specification</u>
3/8"	100	100
# 4	97.8	95 - 100
# 8	94.0	80 - 100
# 16	74.6	50 - 85
# 30	42.9	25 - 60
# 50	19.2	10 - 30
#100	4.0	2 - 10
#200	1.9	0 - 3

Table 3. Pyrament Fine Aggregate Gradation.

PROJECT SELECTION

The project selected by the ODOT Bridge Division was an interstate rehabilitation project located on I-40 in Oklahoma City. The bridge is a slab span structure with four spans (38'-57'-57'-38') with a total bridge length of 187.5 feet. (Figure 1) The bridge was originally constructed in 1962 and at the time of rehabilitation it contained an asphalt overlay. The bridge is located in an urban area with an Average Daily Traffic (ADT) of 50,000. The project location is illustrated in Figure 2.

The project included widening of the existing deck prior to the placement of the Pyrament overlay. The deck was widened ten feet on both the north and south ends of the structure. Also the structure was widened eight feet in the center in order to join the two structures. The final dimensions of the finished structure were 187.5 feet long by 114 feet wide with bridge deck area of 21,375 square feet. The deck widening is illustrated in Figure 3.

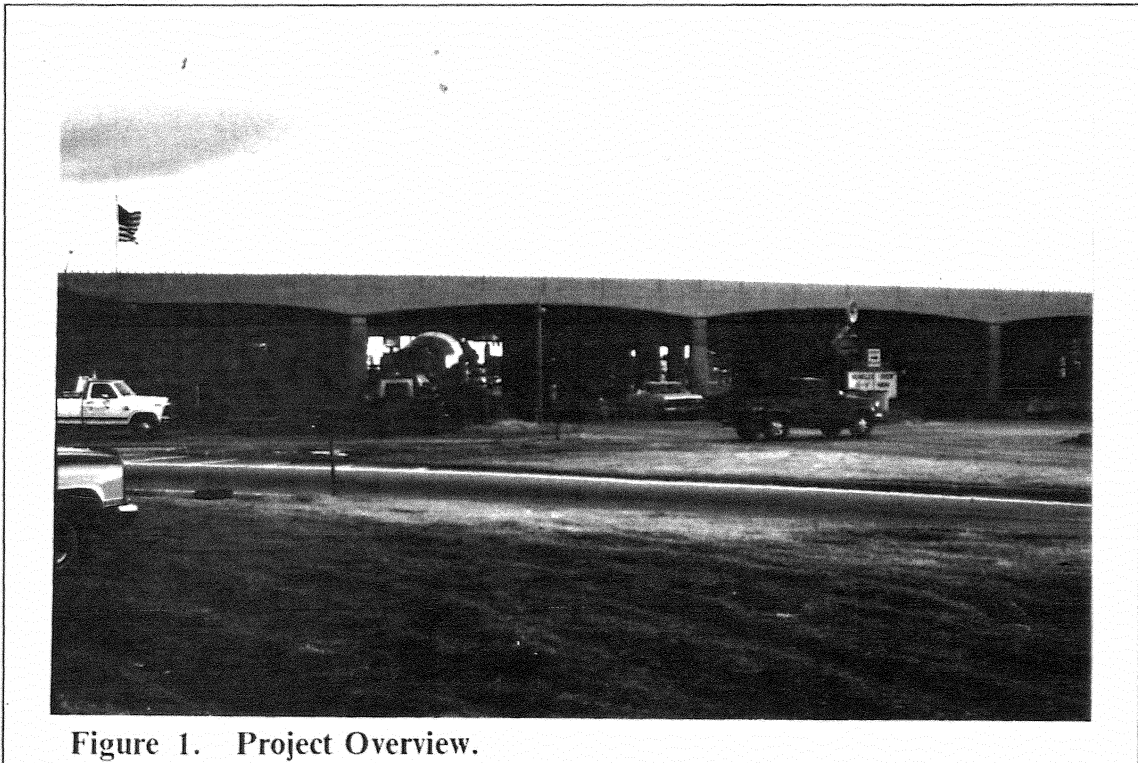


Figure 1. Project Overview.

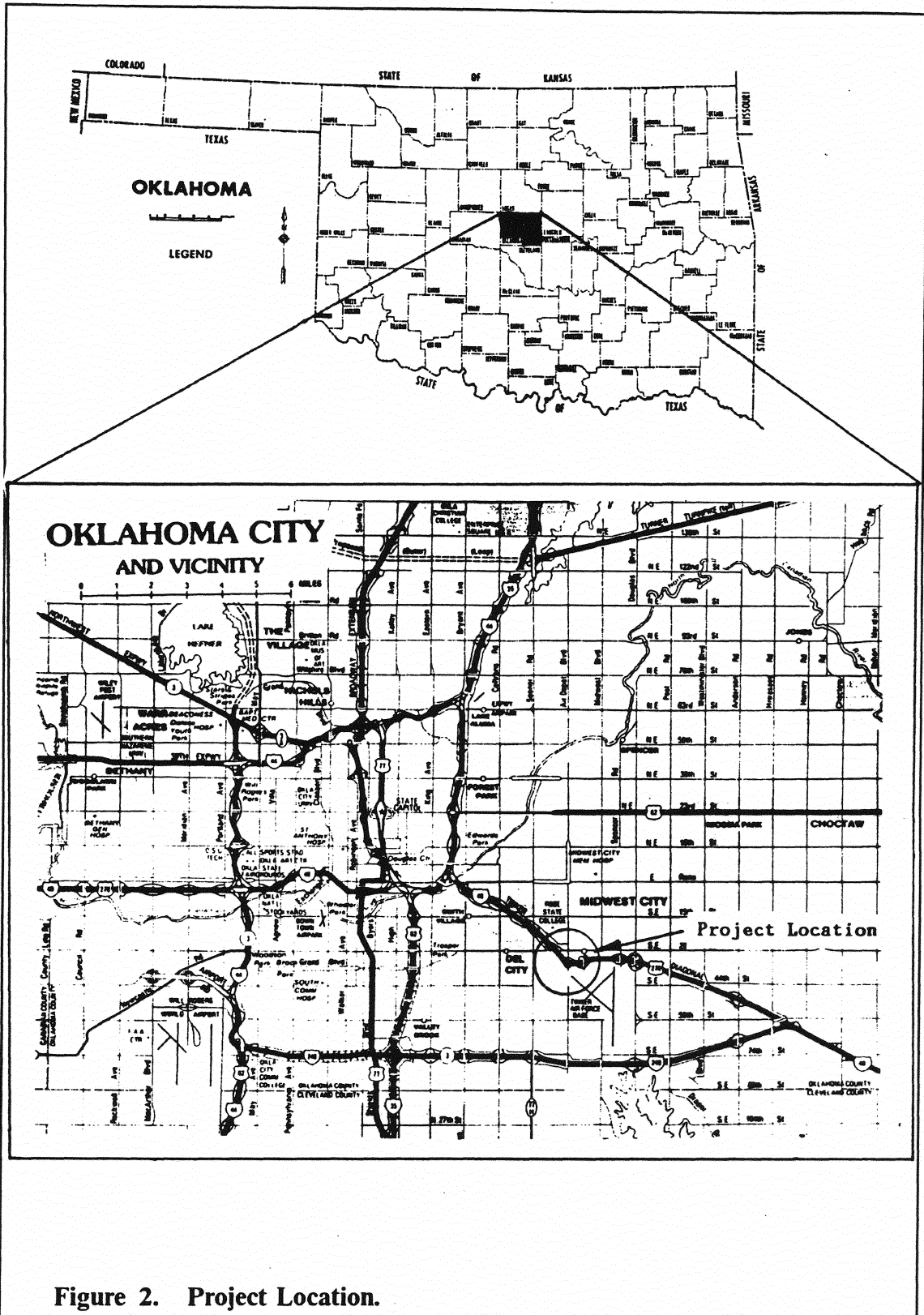
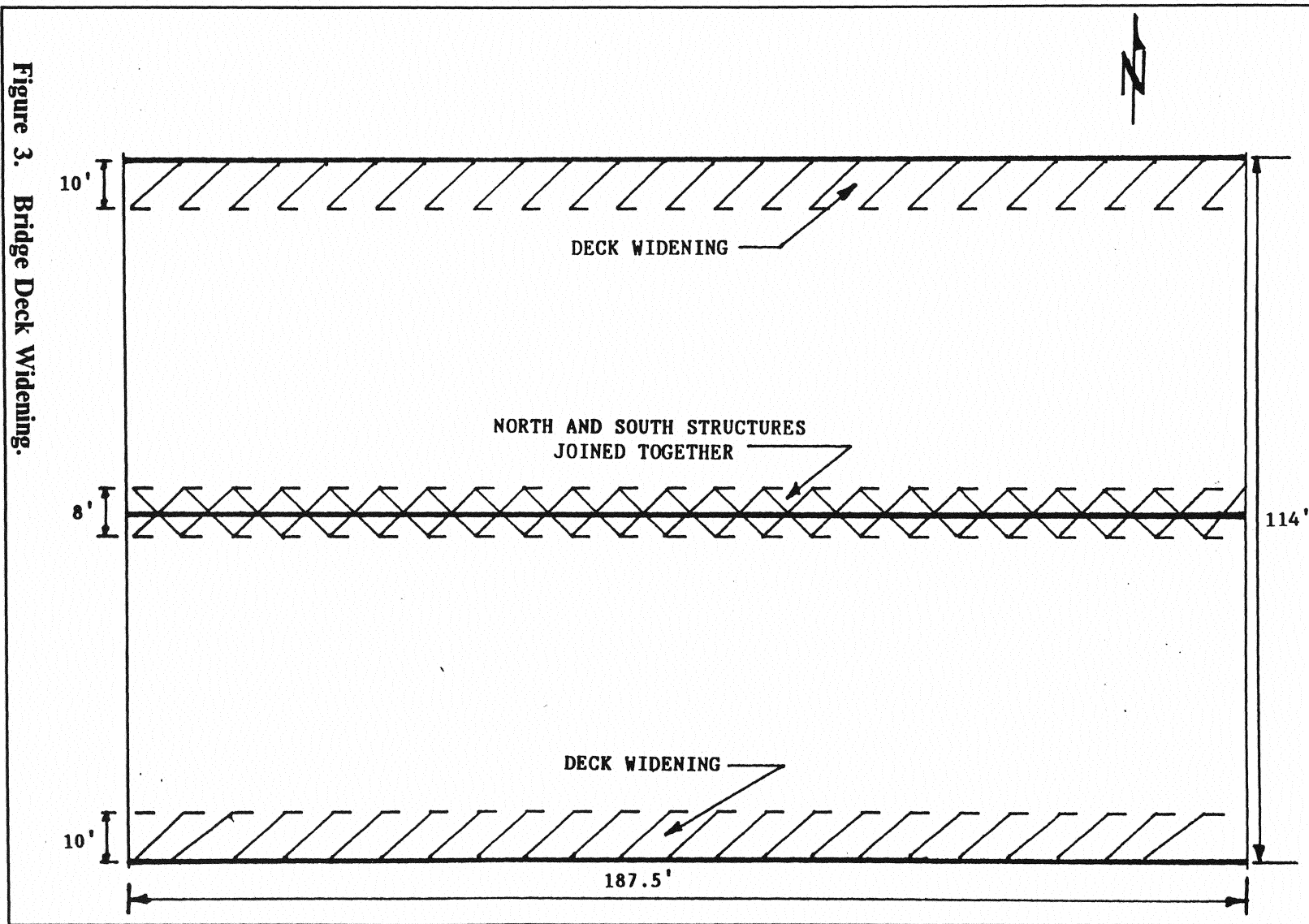


Figure 2. Project Location.

Figure 3. Bridge Deck Widening.



DESCRIPTION OF CONSTRUCTION

Phase Construction

The bridge deck rehabilitation project was split into two phases. During the first phase, traffic was channeled from three lanes each direction into two lanes each direction. The two lanes were diverted to the center of the structure so the ten foot widening could be constructed on both the north and south ends. Upon completion of the widening, the Pyrament overlay was placed on the northernmost 26 feet and the southernmost 26 feet.

During the second phase traffic was maintained at two lanes each direction. The two lanes were diverted to the outside lanes where the new Pyrament overlay was in place. Upon completion of the widening, the Pyrament overlay was placed on the remainder of the structure. Figure 4 illustrates the the sequencing of each Pyrament overlay placement. The May and June placement dates were part of Phase I, while the August placement dates were part of Phase II.

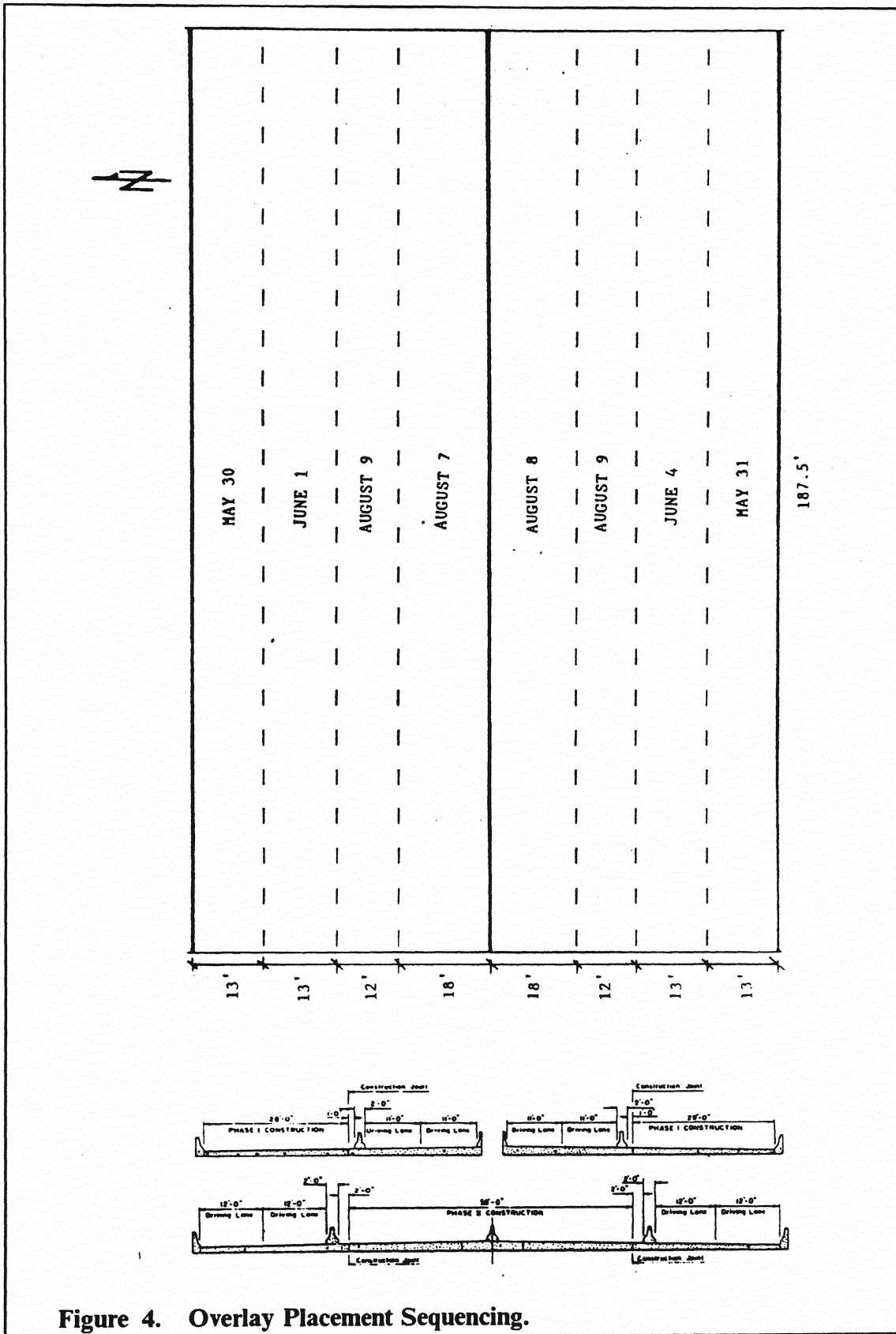


Figure 4. Overlay Placement Sequencing.

Deck Preparation

To ensure the best performing overlay possible, proper bridge deck preparation procedures must be implemented. The deck preparation procedures for this project included scarification, bridge deck testing, removal of deteriorated concrete, patching, sandblasting, and wetting the surface.

The project specification required the bridge deck be scarified a minimum of one-half inch. This scarification included the widened sections of the deck which contained new concrete. In most areas of the deck 1 1/2 to 2 1/2 inches of concrete was removed. It was difficult to obtain only one-half inch removal with the large milling machine used on this project. During Phase I the contractor had difficulty in maintaining the proper grade resulting in scarification depths as great as three inches.

Bridge deck testing was performed after the completion of scarification. The Research Division of ODOT performed halfcell testing (ASTM C-876), delamination (chain-drag) testing, and chloride content testing (AASHTO T260). The results of the tests were used to determine which areas of the bridge deck contained deteriorated concrete and required removal before the overlay placement. The areas of high halfcell potentials corresponded with areas of delamination and high chloride contents. The results of this testing are illustrated in Figures 5 and 6. Areas of delamination and high halfcell readings corresponded to areas of the deck where the old structures' gutterline existed. These were predictable because salt water from deicers tends to settle in the gutters of bridge decks. The result of salt water ponding in the gutters is the eventual corrosion of the reinforcing steel.

Removal of deteriorated concrete areas was performed after the bridge deck survey was complete. Removal was performed using concrete saws to outline the deteriorated areas and jackhammers were used to remove the concrete. In most cases the concrete was removed to a depth just below the top mat of reinforcing steel.

Patching of the removal areas was performed using Pyrament as the patching material. All of the deep removal areas (greater than 3 inches) were patched in Phase I of the project. This left some shallow removal areas unpatched prior to the placement of the overlay. All removal areas were patched during Phase II. This was done in an effort to provide a more uniform depth overlay.

Sandblasting of the bridge deck was required after patching and prior to the placement of the overlay. This was to remove dirt, grease, and oil to ensure a clean concrete surface to obtain a good bond with the overlay.

The manufacturer recommended the existing bridge deck be in a saturated, surface dry condition prior to the placement of the overlay. The deck was saturated by rainfall during Phase I. Puddles of water had to be off the deck before the laydown began. The weather was dry during Phase II and the deck was flooded using a water truck the night before overlay placement.

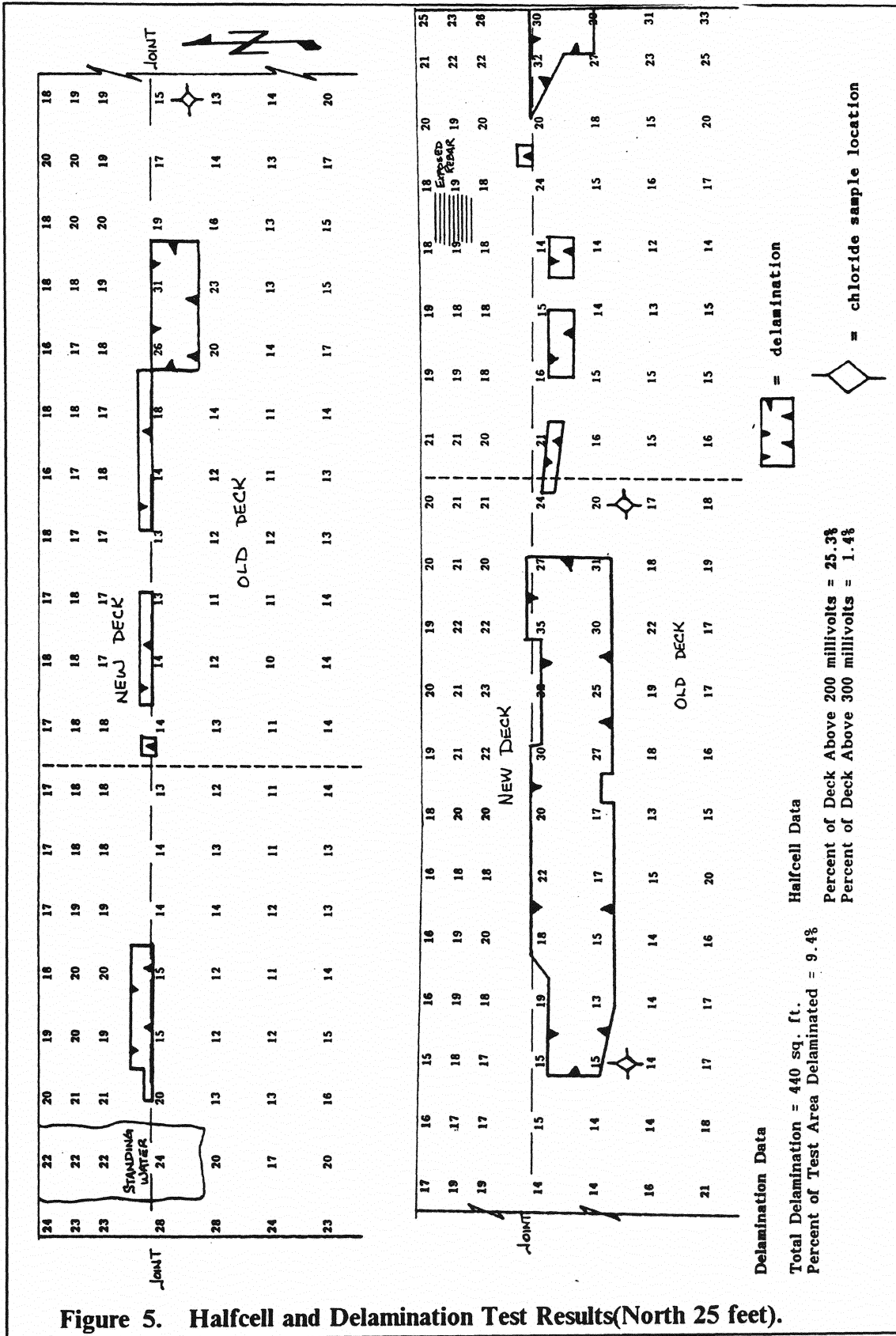
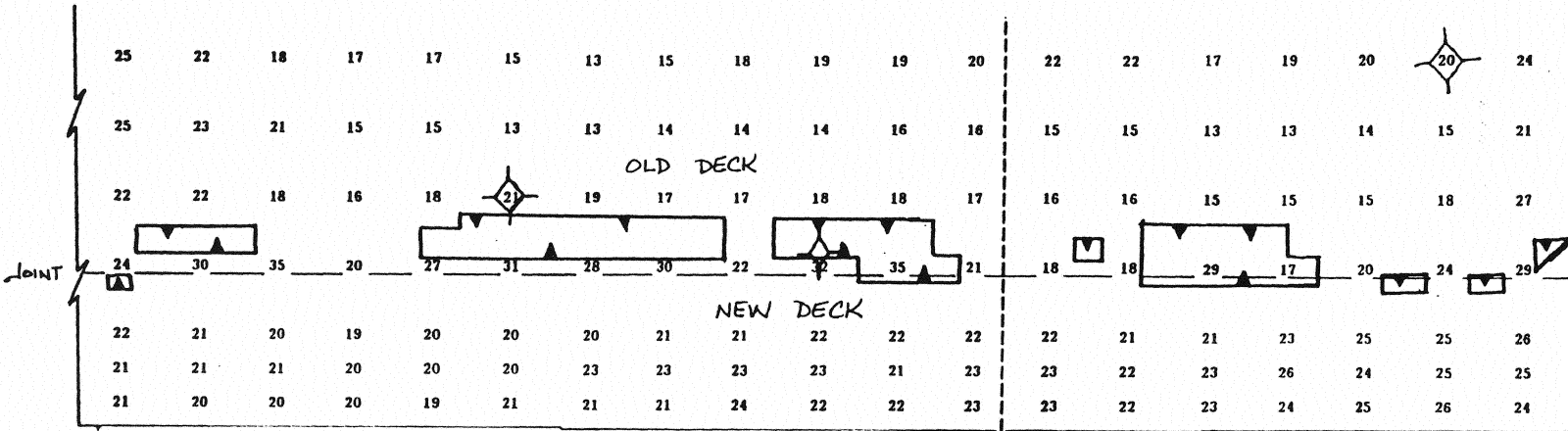
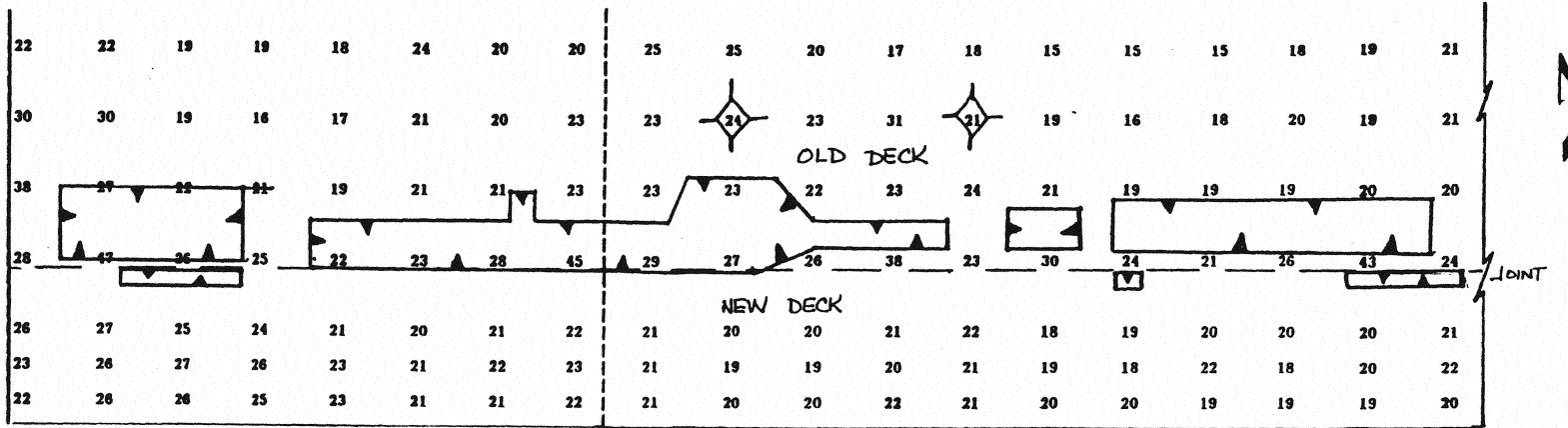


Figure 5. Halfcell and Delamination Test Results(North 25 feet).

Figure 6. Halfcell and Delamination Test Results (South 25 feet).





Delamination Data

Total Delamination = 442 sq. ft.
 Percent of Test Area Delaminated = 9.6%

Halfcell Data

Percent of Deck Above 200 millivolts = 66.5%
 Percent of Deck Above 300 millivolts = 4.1%
 Percent of Deck Above 350 millivolts = 1.1%
 Percent of Deck Above 400 millivolts = 0.2%

 = delamination

 = chloride sample location

Placement

The placement of the Pyrament began by trucking the concrete from a local ready-mix plant located approximately five miles from the bridge. The mix design used on this project allowed the concrete 90 minutes workability time. The truck loadings reached a maximum six cubic yards during Phase I. This resulted in some difficulty unloading the concrete before its workability time had expired. Thus, the truck loads were limited to four cubic yards during Phase II.

The concrete trucks were backed on to the deck and unloaded directly in front of the finishing machine. Various tests were run on each truck load. These included slump, air content, and compressive strength cylinders. During the laydown it was noticed the best procedural efficiency occurred when the slump was maintained at the high end of the two to six inch allowable range. When the slump was at the low end of the range the concrete had a tendency to set up too fast.

A Bidwell finisher with two vibrating screeds was used to finish the Pyrament overlay. This particular finisher was used on many of Oklahoma's interstate bridges which contain low slump high density concrete overlays. It was noted during Phase I the vibrating screeds were not adequately consolidating the overlay in areas where the depth was in excess of four inches. Thus in Phase II, all removal areas were patched in order to eliminate the deep areas and obtain a uniform depth overlay.

The manufacturer recommended an evaporation retardant be used to aide in obtaining a smooth finished surface. The evaporation retardant was placed using hand held spray cans and applied between the finishers' screeds and directly behind the second screed. This application made it much easier to obtain a smooth finish. In instances where the evaporation retardant was not applied the concrete surface became sticky and difficult to hand finish.

A tine finish was applied to the overlay once the concrete was floated to a smooth finish. The tine finish was applied using a hand rake. A scaffold was tied to the finishing machine so the tine could be applied immediately.

Curing

The proper curing of Pyrament is extremely important. The project specification required the overlay be cured using linseed emulsion then covered with wet blankets and plastic. The blankets and plastic were kept in place for 24 hours.

The above curing procedures were used during the Phase I portion of the project. At times the contractor was delayed in placing the cotton blankets. This resulted in the overlay setting up before the blankets were placed. The Phase I overlay developed severe shrinkage cracking 24 hours after placement. The cracks were Y-shaped in formation and some migrated to full depth (Figure 7). It was also noted portions of the overlay were not consolidated at the interface with the bridge deck. This was especially evident in areas where the overlay was greater than four inches thick.

The cracking problems in Phase I had to be addressed before Pyrament could be used in Phase II. It was discovered between phases that linseed had never been used on Pyrament as a curing agent. The manufacturer recommended a resin curing compound be used in Phase II. In addition to a resin compound, the wet blankets would be placed immediately behind the application of the resin compound.

The Phase II curing procedures included resin curing compound, fogging the surface with a light water mist, placement of burlap, cotton blankets, and plastic all kept in place for 24 hours. The fogging and placement of burlap were steps added by the contractor during construction. This resulted in maintaining a good finished surface since the burlap weight was less than that of the cotton. If the cotton blankets were placed directly on the wet concrete surface the tine finish could be disturbed.

Silane Application

The ODOT specification requires the application of silane to all bridge deck surfaces. One of the reported benefits of Pyrament is reduced permeability. To best monitor this characteristic, only the northwest quadrant of the bridge was treated with silane. The test results for the untreated area and the treated area will be compared to determine if silane application is necessary.

Cost

The Pyrament overlay was bid at \$37.00 per square yard in place. ODOT's HDPC overlays have been averaging approximately \$30.00 per square yard in place. These costs include scarification, deteriorated concrete removal, and overlay placement along with any other incidental costs. The material cost for the Pyrament concrete was \$235.05 per cubic yard. This compares with a cost of \$51.50 per cubic yard of 3500 psi Portland cement concrete.

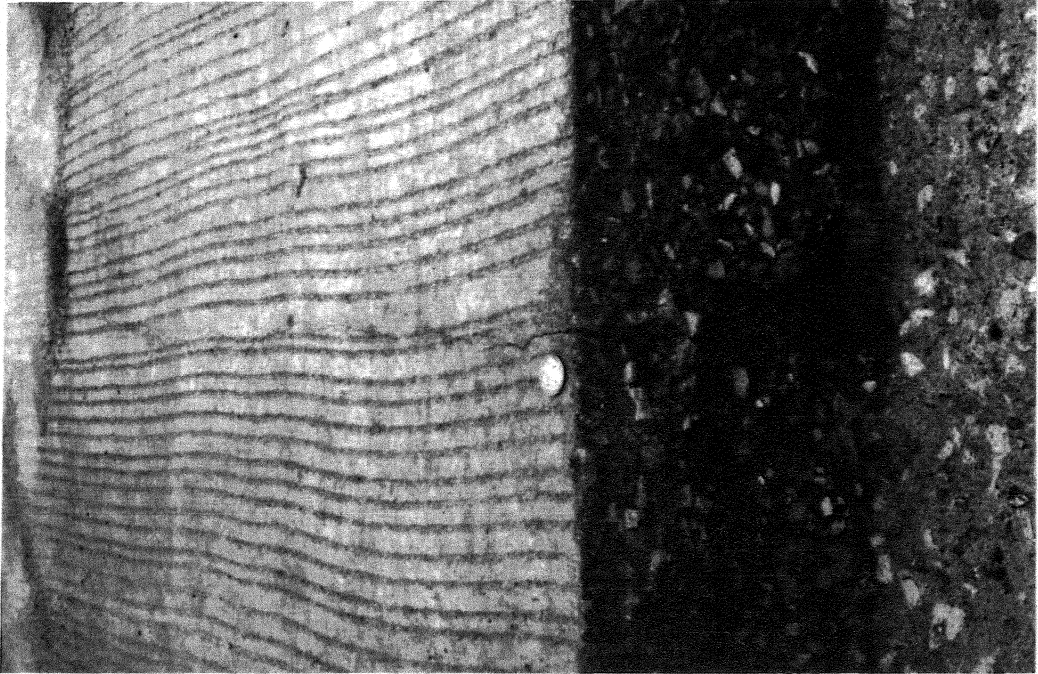


Figure 7. Full Depth Crack (24 Hours After Placement).

Repaired Areas

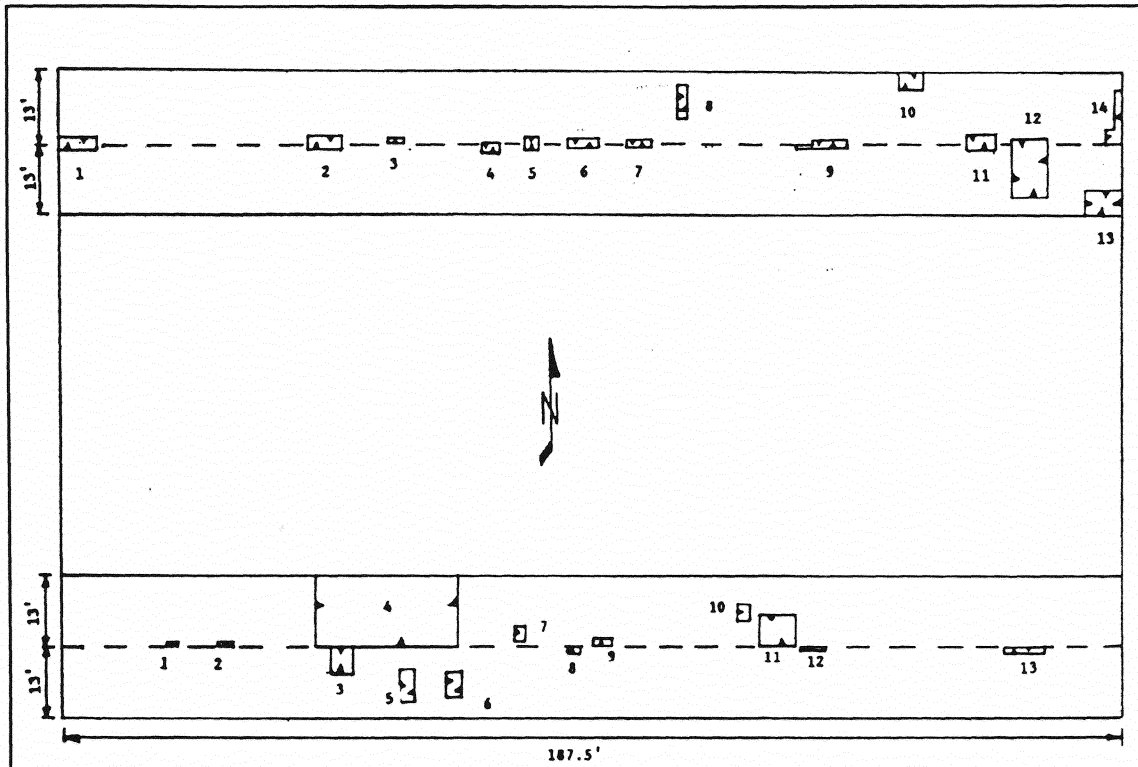
The problem of how to repair the cracked areas of the Pyrament overlay had to be addressed after the overlay was in place. The Research Division of ODOT performed a delamination (chain-drag) survey of the new overlay. The results of this survey were compared to a crack map of the overlay to determine which areas of the overlay had to be removed.

The delamination survey indicated all delaminated areas were located in the Phase I portion of the overlay. This consisted of the northernmost 26 feet and the southernmost 26 feet of the bridge deck. The northernmost 26 feet contained 14 delaminated areas totalling 216 square feet. The southernmost 26 feet contained 13 delaminated areas totalling 478 square feet. The total delaminated area was 694 square feet which is 7% of the Phase I overlay or 3.2% of the entire bridge deck. The locations of the delaminated areas are illustrated in Figure 8. Photographs of the cracking are shown in Figures 9 and 10.

Each of the delaminated areas contained shrinkage cracks. Figure 8 indicates almost all of the delaminated areas were located along the longitudinal construction joints separating each days overlay placement. The construction joints are illustrated with a dashed line. The two construction joints were located in the old bridge deck gutter. There were many areas of concrete removal along the old gutter which resulted in the overlay being the thickest in these areas. As mentioned earlier in this report, the vibrating screeds of the finishing machine did not fully consolidate the overlay when depths were greater than four inches. Voids at the overlay/deck interface combined with the shrinkage cracks would cause problems in the future and needed to be removed.

The delaminated areas indicated in Figure 8 were removed and replaced with Pyrament. A concrete saw was used to outline each area and jackhammers were used to remove the concrete. The delaminated areas were easily removed due to lack of consolidation and bonding at the bottom of the overlay. However, the contractor had difficulty removing areas just outside the delaminated areas which indicated there was excellent bonding and consolidation where there were no delaminations. Pyrament was placed in the removed areas and vibrated and finished by hand.

A number of shrinkage cracks were still present in the Phase I portion of the overlay. No delaminations were detected in these areas. ODOT wanted to take every precaution to seal the overlay to obtain longer service life. A methyl methacrylate sealer was used to seal each of the shrinkage cracks. Five sample cores were taken to ensure the methyl methacrylate was penetrating and sealing the cracks. The cores indicated the methyl methacrylate had penetrated the cracks to depths ranging from one to three inches.



DELIMITATIONS NORTHERN 26 FEET		
NUMBER	DIMENSIONS (FEET)	AREA (SQ. FT.)
1	7.0 x 2.0 =	14.00
2	6.0 x 2.2 =	13.20
3	3.5 x 1.3 =	4.55
4	2.8 x 1.5 =	4.20
5	2.8 x 2.3 =	6.44
6	5.6 x 1.7 =	9.52
7	4.7 x 1.2 =	5.64
8	1.7 x 7.2 =	12.24
9	3.0 x 0.8 =	2.40
	5.9 x 1.8 =	10.62
10	4.7 x 3.2 =	15.04
11	5.6 x 2.6 =	14.56
12	6.3 x 9.6 =	60.48
13	4.8 x 7.0 =	33.60
14	12.0 x 0.5 =	6.00
	2.3 x 1.5 =	3.45
TOTAL =		215.94

DELIMITATIONS SOUTHERN 26 FEET		
NUMBER	DIMENSIONS (FEET)	AREA (SQ. FT.)
1	1.5 x 0.9 =	1.35
2	3.4 x 1.0 =	3.40
3	5.3 x 4.7 =	24.91
4	24.7 x 13.3 =	328.51
5	2.7 x 6.8 =	18.36
6	2.8 x 5.6 =	15.68
7	2.8 x 2.5 =	7.00
8	2.4 x 2.3 =	5.52
9	3.5 x 1.8 =	6.30
10	2.7 x 3.0 =	8.10
11	7.3 x 6.3 =	45.99
12	4.0 x 0.8 =	3.20
13	7.6 x 1.3 =	9.88
TOTAL =		478.20

Figure 8. Repaired Area Locations.

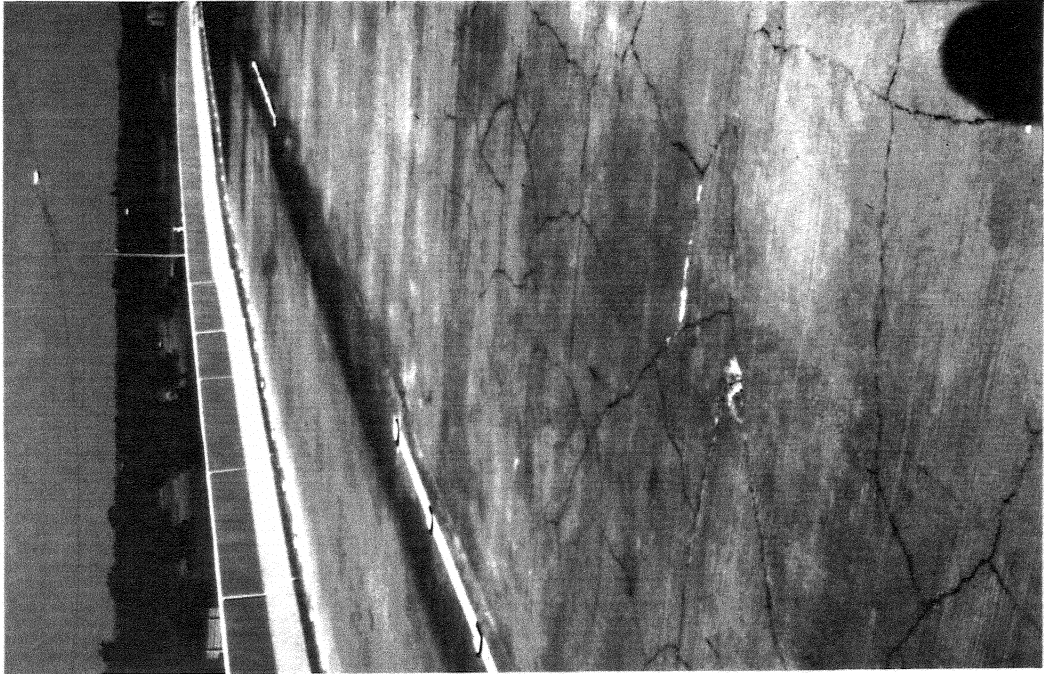


Figure 9. Severely Cracked Section.



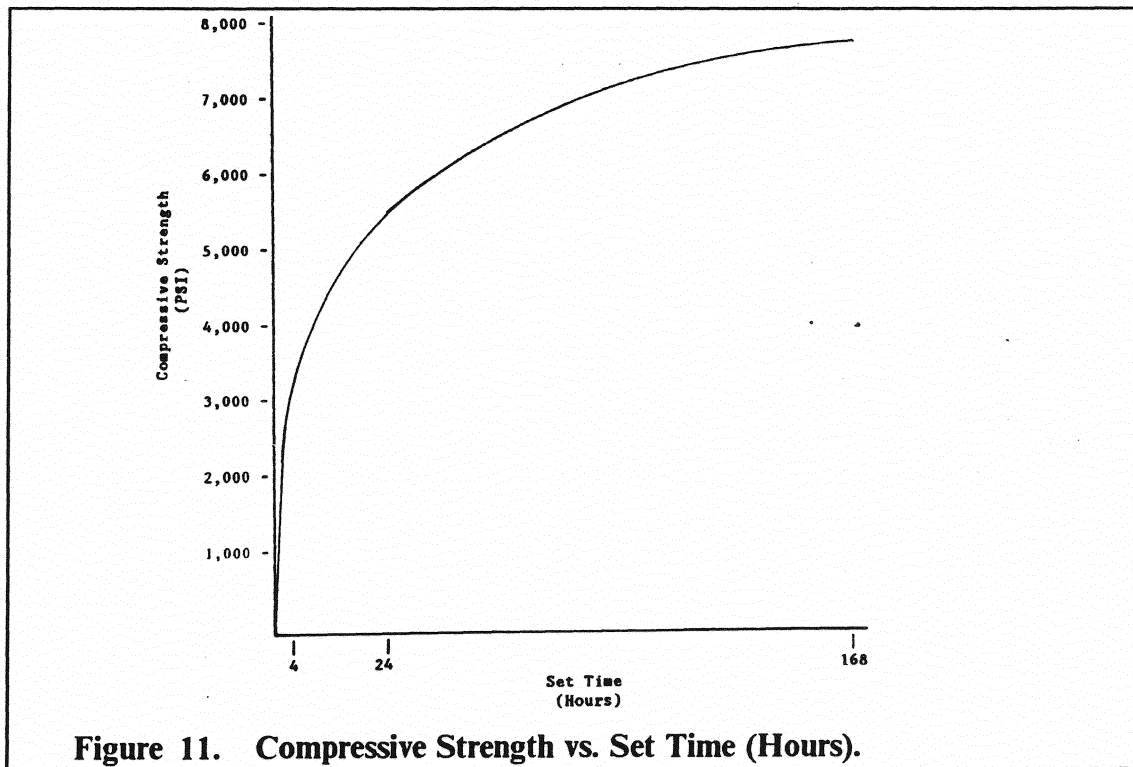
Figure 10. Severely Cracked Section(close-up).

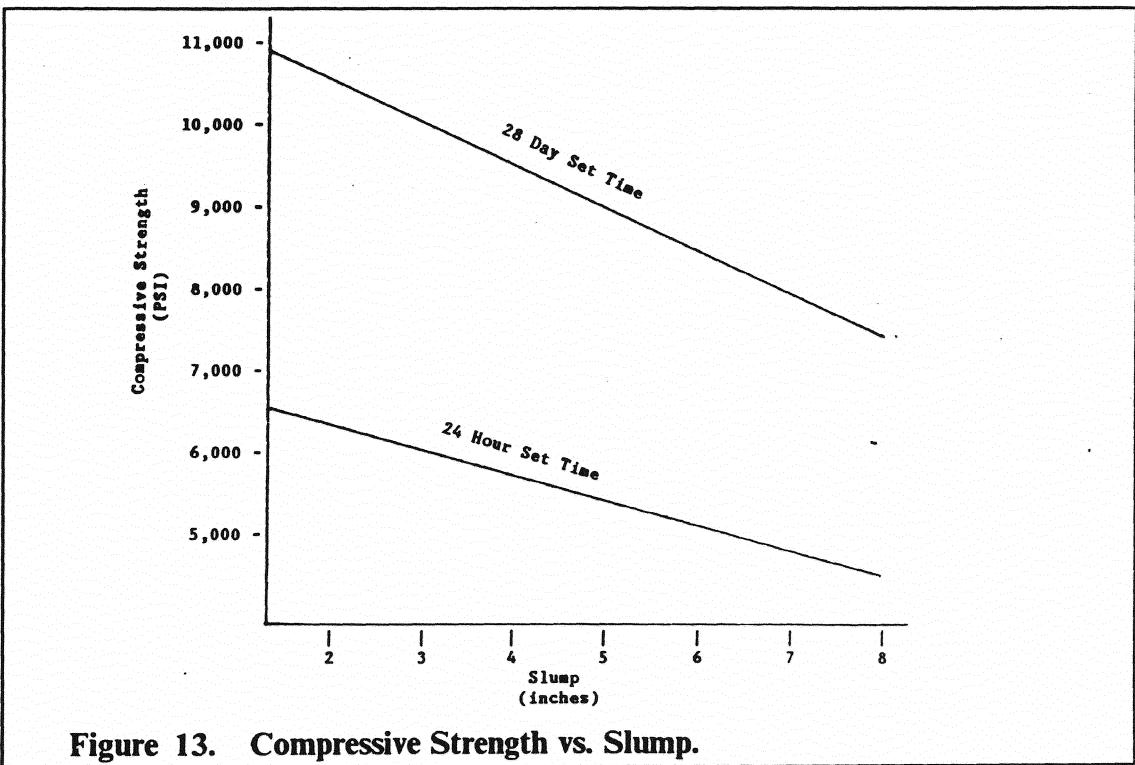
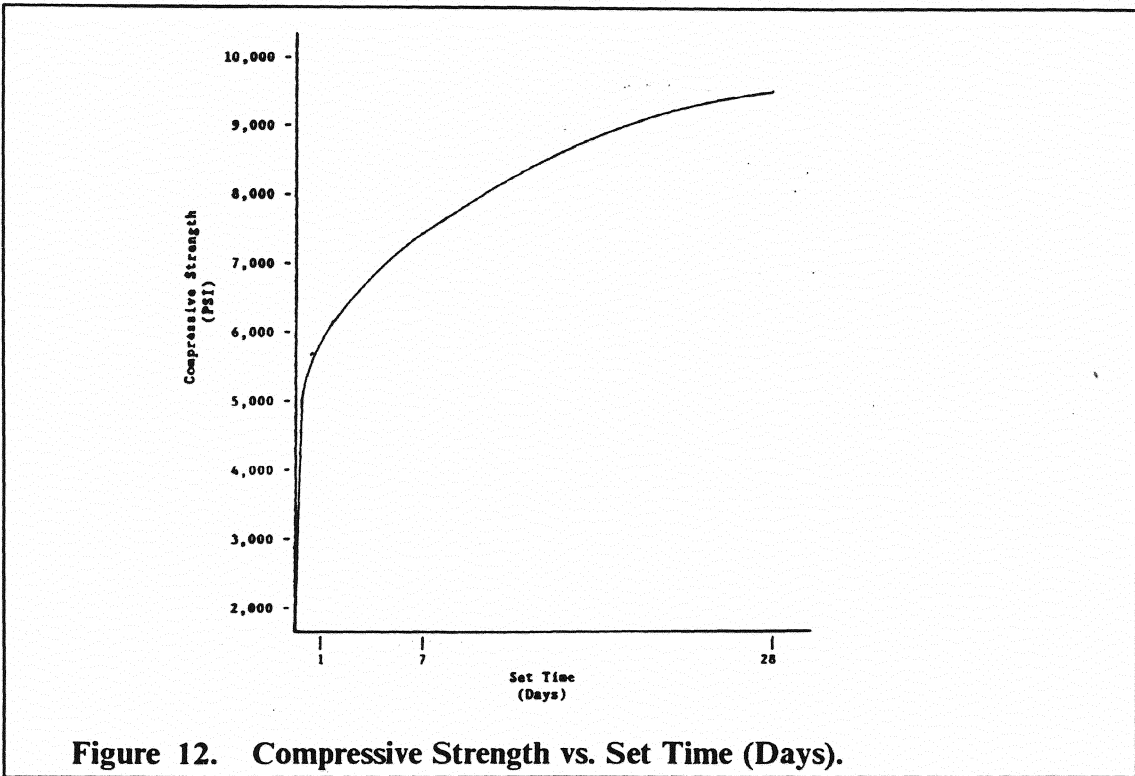
TESTING

Compressive Strength

Compressive strength cylinders were made during the Pyrament overlay placement. The cylinders were tested at 4 hour, 24 hour, 7 day, and 28 day set times. The project specification required a minimum 4 hour compressive strength of 2500 psi and a minimum 28 day compressive strength of 8000 psi. The 4 hour compressive strengths ranged from 2550 psi to 3200 psi with an average of 2700 psi. The 28 day compressive strengths ranged from 7660 psi to 11,050 psi with an average of 9600 psi. The Pyrament compressive strengths over time are illustrated in Figures 11 and 12. The test cylinder results indicate the Pyrament obtained the necessary compressive strengths on this project.

Slump tests were performed on each concrete truckload in which cylinders were made. As expected, the compressive strength of Pyrament decreased as the slump increased. Figure 13 illustrates the relationship between slump and compressive strength for the Pyrament at 24 hour set time and at 28 day set time. The strength requirements were still easily met at the upper slump specification limit of six inches. Construction procedures were simplified when the Pyrament could be placed with five inch slump instead of a two inch slump.





Future Testing

Annual testing will be performed on the bridge deck containing the two inch Pyrament overlay. The testing will begin six months after the completion of construction and continue each year late in the spring. This testing will include halfcell testing, delamination (chain-drag) testing, chloride sampling tests, permeability testing, and visual survey to include crack mapping.

DISCUSSION

This project clearly illustrated that proper curing of the Pyrament overlay was critical. The curing procedures used in Phase I were linseed application, wet cotton blankets, and plastic covering, all kept in place for 24 hours. In most instances the overlay surface was hard before the wet cotton blankets were placed by the contractor. The amount of shrinkage cracking that developed in Phase I nearly caused the termination of Pyrament for the Phase II overlay.

The Phase II overlay used a resin curing agent, fogging, wet burlap, wet cotton blankets, and plastic covering, all kept in place for 24 hours. The truck loadings were limited to four cubic yards. All areas where deteriorated concrete was removed from the old deck were patched prior to the overlay to obtain the most uniform depth overlay possible. The above procedures resulted in the Phase II overlay being successful with no crack development.

The compressive strength of the Pyrament concrete exceeded the specification requirements of 2500 psi after 4 hours and 8000 psi after 28 days. This held true for slumps ranging from two to six inches. The compressive strength results indicate Pyrament overlays can be opened to traffic after 24 hours curing. This quality is beneficial for rapid urban interstate bridge deck rehabilitation.

Even though the Phase I overlay developed severe shrinkage cracking due to improper curing, adjustments were made during Phase II to indicate that Pyrament can be used for bridge deck overlays. The Pyrament overlay cost 23% more than HDPC overlays. This may be a small price to pay for the ability to open traffic to a new overlay after 24 hours.