CONCRETE RESURFACING OVERLAYS

FOR

TWO BRIDGE DECKS

by

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ABSTRACT

Two AASHO H-20 highway bridges in the Texas Highway Department system have received experimental resurfacing overlays of portland cement concrete. This paper describes the overlay operations, performance, and costs of the two installations. One deck, Colorado River bridge, was on a two-lane bridge with a 28 ft roadway 480 ft long (13,440 sq ft). The other, Bosque River bridge, was a two-lane bridge with a sidewalk. It was 400 ft long and had a total surface area of 16,000 sq ft.

One overlay was 1 5/8 in. thick and the other was 2 in. thick. Both were bonded with portland cement grout. Inspections, after opening to traffic, reveal reflective cracking and some unbonding, but the performance is generally good.

Key Words: Concrete, Overlay, Bridge, Bond, Delamination, Scarifier, Sand blast, Grout Cracking, Patch.

SUMMARY

Two experimental portland cement concrete bridge overlays have been placed for bridge resurfacing by the Texas Highway Department, (THD). One installation was in THD District 7 on Route 208 in Coke County, across the Colorado River at Robert Lee, Texas. The other was in THD District 2 on Spur 179 in Erath County across the Bosque River at Stephenville, Texas. The former was 1 5/8 in. thick overlay; the latter was 2 in. thick.

Both bridges were damaged lightly by scaling and severely by spalling and cracking. Each had developed numerous transverse cracks during some 22 years of service and there were some areas of serious checkerboard cracking between beams. The Colorado River bridge carried occasional heavy trucks with oil field equipment and with grain. The Bosque River bridge traffic was largely light traffic with farm supplies and produce providing the heavier loads.

Delamination was removed from both bridges with an air hammer. The Colorado River bridge deck was then cleaned by sand blasting whereas the Bosque River bridge was scarified with the McDonald Scabbler. Grout was brushed into the clean deck, and overlay was vibrated into place over the fresh grout. A vibrating screed was used for leveling and compacting the material on the Colorado River bridge, and internal vibrators followed by a pavement finishing machine were used on the Bosque River bridge. The Colorado River bridge overlay was placed in October 1969 by THD District 7 maintenance forces. The Bosque River bridge overlay was placed in November 1971 by THD District 2 maintenance forces

supplemented by contract forces for placement and finish of the overlay.

Both overlays have developed reflective cracks, and inspections have revealed several small areas of unbonding. The unbonded areas are generally, but not in all cases, over or very near cracked areas. Other areas of unbonding are attributed to overly thin grout from excessive mixing water or from spray blown back on the work during placement. A microscopic examination of slices across the interface of overlay and base concrete of cores from the bridges reveal relatively poor grouting on the Colorado River bridge, but good to excellent grouting on the Bosque River bridge. The latter showed cracked portions of aggregate and of mortar, caused by impacting blows of the scarifier, that had not been dislodged in the cleaning process. Those, no doubt, cause weaknesses in bond.

Both overlays have been in continuous service since installation and they are in good condition. The cost of the 13,440 sq ft overlay and patching on the Colorado River bridge was $0.92 per sq ft, and that of the 16,000 sq ft Bosque River bridge was $0.893 per sq ft for patching and overlay. An additional $5,800 ($0.363 per sq ft at overlay surface) was required to provide full depth deck replacement repairs in two locations on the Bosque River bridge.

IMPLEMENTATION

Deteriorated concrete bridge decks can be brought back to excellent serviceable condition by portland cement concrete overlays. The deck may have normal to above normal cracking for an effective overlay, but it should not have extensive checkerboard cracking as is sometimes found between beams. Repairs to severaly damaged decks are destined to short lives. A structural analysis of the bridge should be made to determine how much additional dead load that can be permitted, but the overlay should be about 2 in. thick.

The installation must be carefully planned and each worker must be thoroughly familiar with his job before an overlay is begun. It is of particular importance that cleaning and grouting be done well if the job is to be successful.

Air hammers and chipping tools have been used successfully in removing deteriorated concrete in delaminated and spalled areas. Sandblasting and scarifying with the Tennant machine and the McDonald scabbler have been used to remove relatively thin layers of surface material in preparation for the overlay. It has been found that bonding of the overlay to sandblasted surfaces is superior to that for surfaces prepared by the scarifying machines. Care must be taken with heavy jack hammers because they sometimes break through the deck. All rusty steel should be completely exposed and cleaned by sand blasting, or by other means if effective.

If a scarifier is used it must be followed by high pressure water jet, air jet, sand blast, vigorous stiff brooming, or combinations of these, to remove particles loosened but not dislodged by the scarifier. Close inspection is necessary to see that all such material is removed. If a scarifier is not used, the entire deck surface should be sand blasted to expose coarse aggregate and remove grease and soft surface mortar.

Patches may now be placed to bring the holes up to grade, but the shallower ones, up to 3 in. deep may be filled at the time of overlaying if desired. In preparation for patching, the bottom and sides of the hole should be scrubbed with grout and a layer of the grout (about 1/8 in. thick) should be left over the surface for bond. When the grout layer dries sufficiently to lose its stickiness and becomes crumbly when rubbed between fingers (it must not dry out to powder) the patch concrete should be compacted into place. The surface should be left rough to recieve the overlay and the patch should be wet cured. It must not be treated with a membrane curing compound, unless the compound is removed later, because it will prevent good bonding of the overlay. It will be ready to receive the overlay anytime after it is placed, but generally the overlay follows a day or more later.

The deck surface should be thoroughly clean, saturated surface dry, all equipment should be in place, and the work force should be ready before the grouting and overlay installation is begun. Grout is applied just ahead of the screed. It must be mixed or remixed just before placing to keep heavy particles from settling out. The thick cream consistency grout is thoroughly brushed into the surface with stiff brooms leaving a layer about 1/8 in. thick. The grout must be workable with the broom but it must not be soupy. When it dries to a crumbly consistency--it must not dry beyond the damp state--the overlay concrete is placed. Internal vibrators should be used just ahead of the screed.

The finish that is desired is applied behind the screed, and measures should be taken to prevent plastic shrinkage crack development. Wet mat curing or "air-tight" polyethylene sheeting should be applied as soon as possible for curing. Curing time requirements will depend on stiffness of the mix and curing temperature. A low slump type III cement concrete placed and cured in warm weather will be ready for traffic within 3 to 5 days, but additional curing may be given if traffic conditions permit.

Epoxy adhesive may be used instead of grout for bonding. It should be used in much the same manner as the cement grout, but recommendations of the manufacturer should be obtained before it is placed.

Mixes for grout and for overlay concrete are given in Appendix A of the report.

DISCLAIMER

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INTRODUCTION

Deteriorated concrete bridge decks are common practically every state highway department in the United States, (1, 2). Maintenance personnel are faced with costly budget items and traffic problems in providing repairs that are necessary to bring those bridge decks back to good serviceable conditions. The search has long been under way, and it continues today, for a method of repair that is sound, efficient, and economic.

Among promising methods of repair which have been tried on bridge decks is that of overlaying the old deck with a relatively thin layer of concrete, (3-8). Portland cement concrete overlays are attractive for this purpose because the material is durable, relatively inexpensive, and easy to place. An excellent review of construction techniques and test results on overlays is given by Felt (3).

Supplementing the information in Felt's report, among others, laboratory research conducted by the Texas Transportation Institute (TTI) for the Texas Highway Department (THD) showed that thin concrete overlays can be placed and cured on a vibrating base, that the overlay can be firmly bonded to the base concrete, and that the overlay adds to the flexural stiffness of the base concrete (9, 10). The laboratory program was supplemented by two experimental field installations of bonded portland cement concrete overlays. One of these was placed in 1969 and the other in 1971. Accounts of their installations and performances are given in the sections that follow.

Experimental Bridge Overlays

Cracking and spalling were extensive in both decks. Many of the cracks extended through the deck, and efflorescence could be clearly seen in some areas on the under side. Spalled areas, about 1 sq ft to some 15 sq ft in area, were scattered. Highway maintenance crews had made numerous patching and resurfacing repairs over spalled areas in the years prior to overlaying.

Portland cement concrete overlays were used on both bridges. The overlays were bonded to the old deck concrete by portland cement grout.

Route 208 (Colorado River Bridge at Robert Lee)

Description:

This AASHO H-20 bridge is located on State Route 208. It crosses the Colorado River at Robert Lee, Coke County, Texas. Two traffic lanes are carried on three continuous units, Fig. 1, over a total length of 480 ft. The 13,440 sq ft deck area, Fig. 2, had shallow surface scaling in spots, Fig. 3, and extensive isolated areas of spalling which extended below the top mat of steel in some spots, Figs. 4 and 5. Repair patches of concrete and mortar made with quick-setting cements and epoxy resins had been made from time to time, and the surface was rough. Cracking extended through the deck in some areas. The cracks were predominantly transverse, but they showed up in square patterns between beams in some locations on the bottom of the slab. Only a few longitudinal cracks were located, being difficult to see on the top surface. Those that were found were over beams.

An analysis of the structure showed that the supporting I-beams

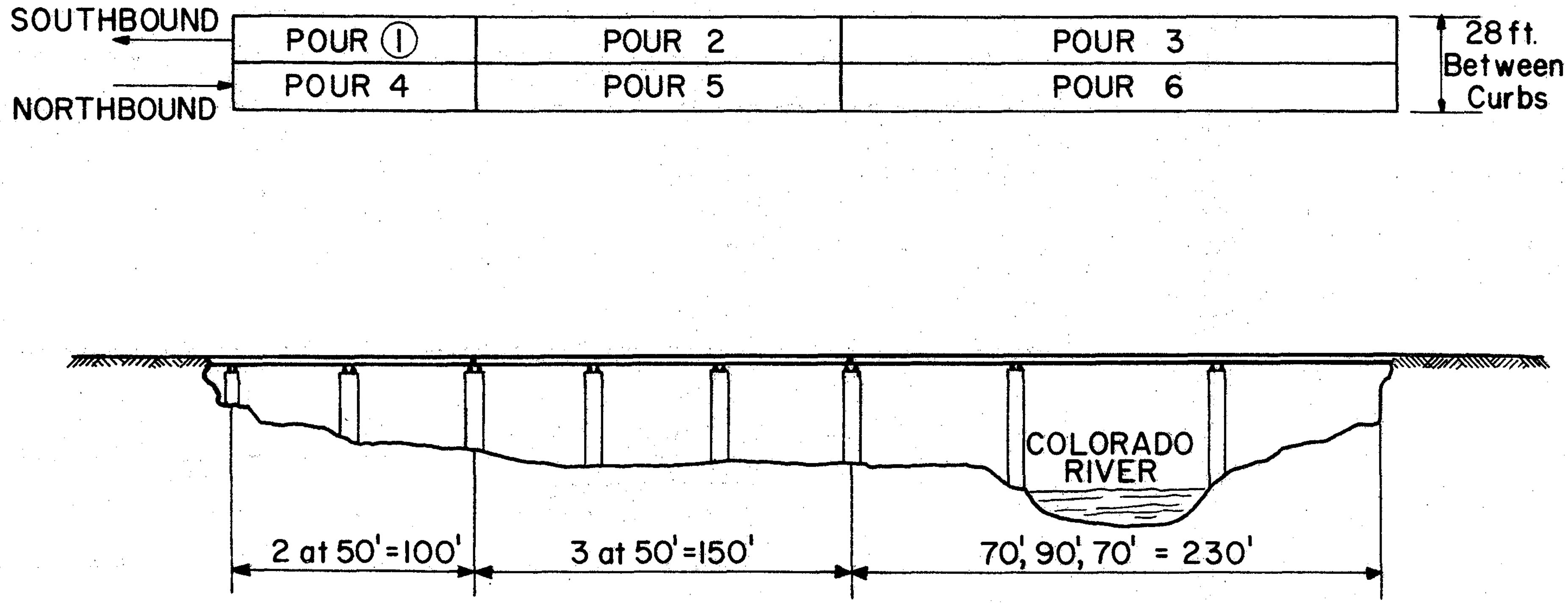


FIG. 1 BRIDGE ON TEXAS STATE ROUTE 208 IN COKE COUNTY, TEXAS SHOWING SEQUENCE OF PLACEMENT OF P.C. OVERLAY IN OCTOBER, 1970.

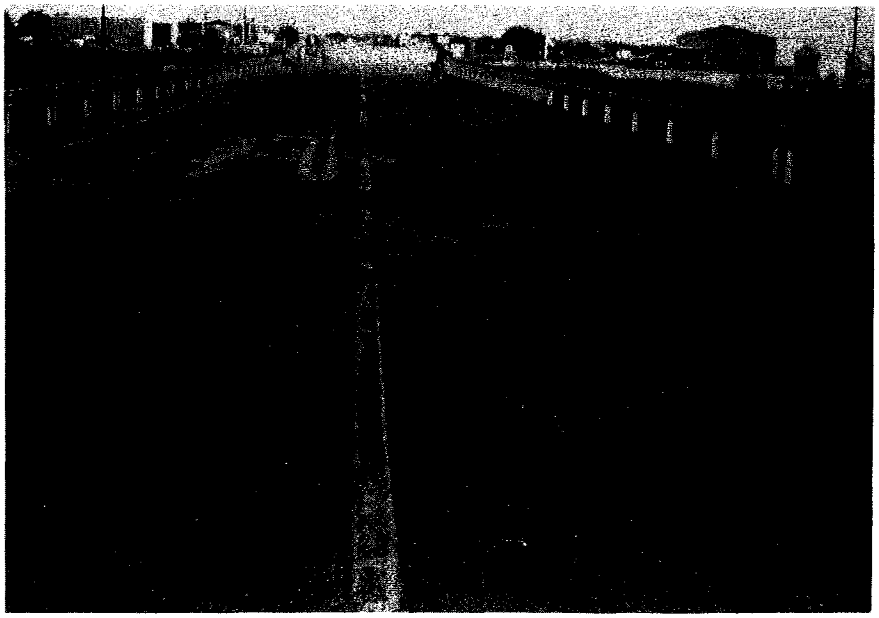


Figure 2. General View of the Deck before Repair Colorado River Bridge.

Figure 3. Scaled Deck

Colorado River Bridge.

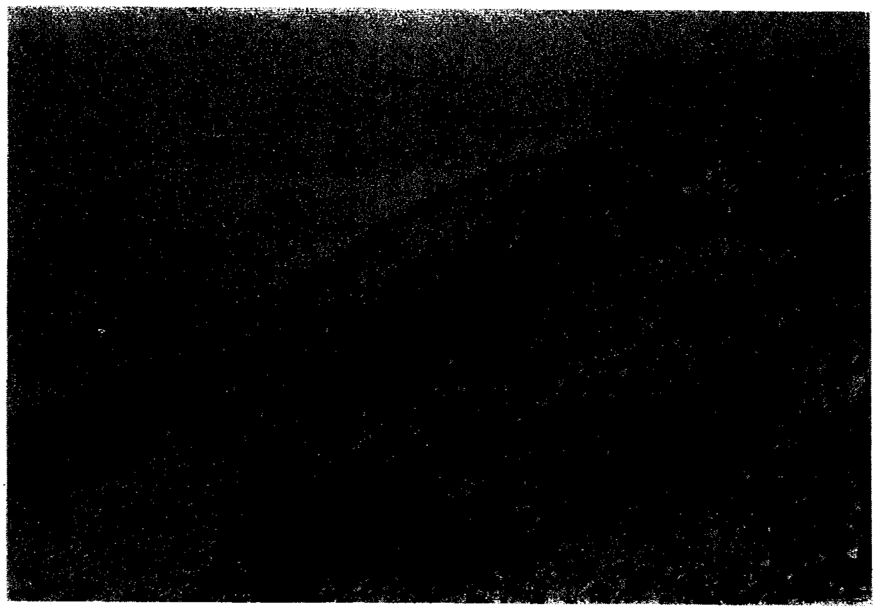


Figure 4. Spalled Area

Colorado River Bridge.

Figure 5. Corroded Steel in Spalled Area

Colorado River Bridge.

were capable of carrying a 1 5/8 in. thick overlay without shoring during placement. A portland cement concrete resurfacing overlay was designed to provide a smooth riding surface, to seal some of the major cracks, and to add stiffness to the longer spans. Spalled areas and pot holes were to be patched prior to overlaying. The work was performed by THD District 7 personnel; TTI provided technical assistance in producing job specifications, Appendix B, furnishing advice on the job about installation procedures, and made inspections after the overlay was put into service.

Surface Preparation: (Colorado River Bridge)

The deck was inspected for delamination and other concrete defects before any repairs were made. Delaminated areas were located by a sounding rod, and they were then routed out with air hammers, Figs. 5 and 6.

Following removal of debris created by the routing operation, exposed rusted steel and surfaces of depressions routed out by jack hammers were cleaned by sand blasting. All loose material was then removed. Compressed air was used to remove small particles and dirt. Sides and bottom surfaces of holes deeper than about two in. were then coated with grout which was thoroughly broomed in, to leave a layer about 1/8 in. thick over the entire coated surface. While the grout was still damp, concrete was compacted into the holes to bring them up to grade. The grout and concrete used in the holes was the same as that used for the overlay which is described below. The patch concrete was cured under wet mats until the deck surface was

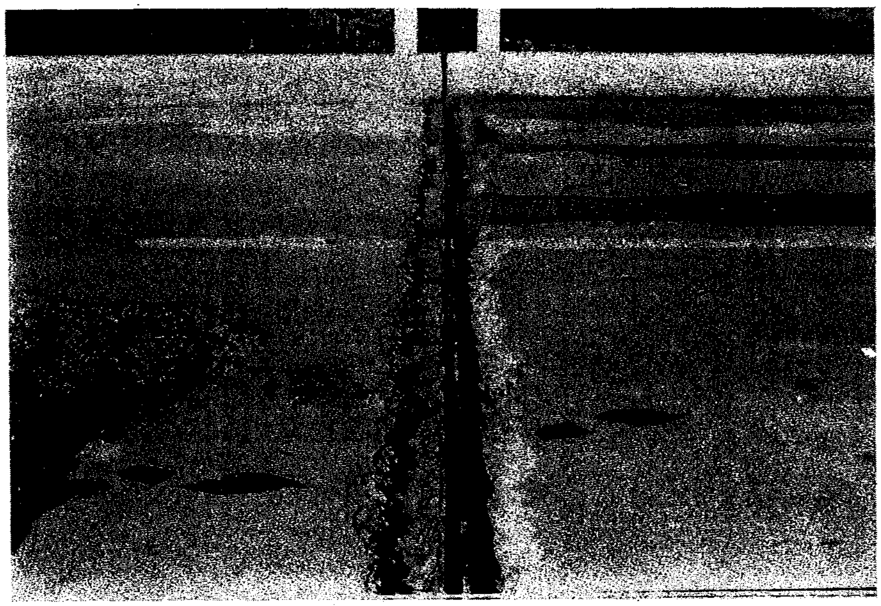


Figure 6. Preparation at Construction Joints Prior to Overlay Colorado River Bridge.

prepared for overlay, a period of two to four days.

The entire deck was sandblasted, Fig. 7, after the patching operation, to remove surface oils and mortar and to expose the coarse aggregate for bonding to the overlay. The deck was then swept clean with brooms and air to remove debris and dirt. It was not flushed nor wet down with water ahead of the grout. Side forms and screed rails were then set for placement of a 12 ft wide overlay strip extending from the longitudinal center line of the bridge toward the curb. A 2 ft wide strip was left adjacent to the curb because the screed was not long enough to cover the entire 14 ft wide lane. That strip was hand placed after the center 24 ft, 2-12 ft lanes, had been completed.

Bond Course-Grout: (Colorado River Bridge)

Portland cement grout made with Type III cement, sand, and water, Appendix A, was used for bonding the overlay concrete to the old concrete deck.

The grout was mixed in a mortar mixer located at the job site. It was delivered by wheel barrows and dumped just ahead of the overlay, Fig. 8. It was manually broomed into the old concrete with stiff brooms. The deck was damp from rains but the surface was dry when the grout was applied. The weather was hot, dry, and windy during the placement, and water sprays were installed along side rails to prevent rapid evaporation of mixing water from the concrete after it was placed. During most of the placement period, the spray had to be cut back to almost ineffectual levels because cross winds blew it over

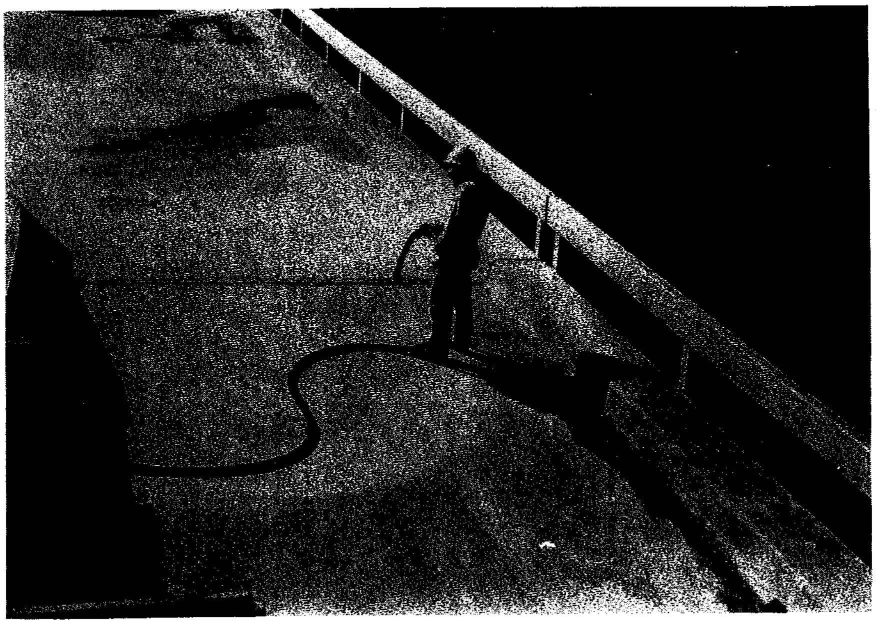


Figure 7. Sandblasting the Deck

Colorado River Bridge.

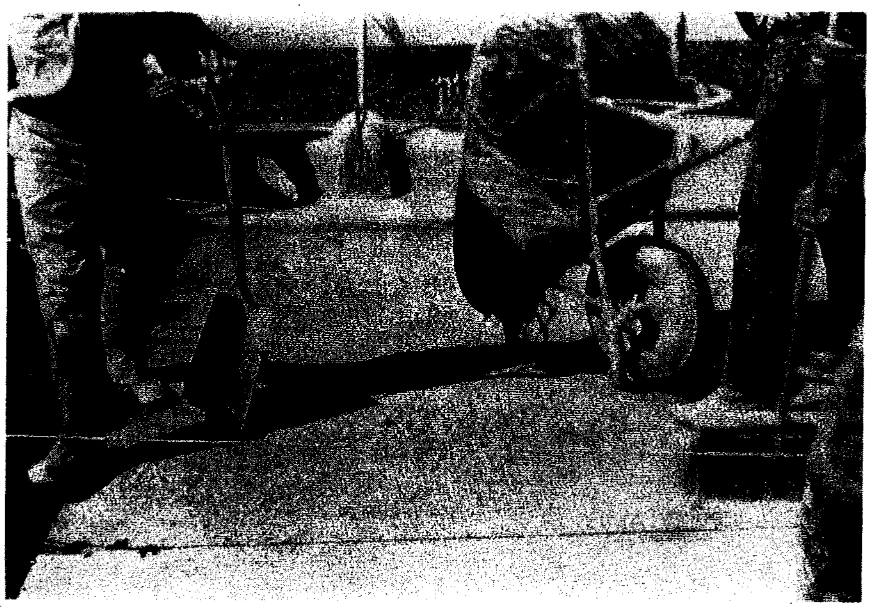


Figure 8. Applying Grout Just Ahead of the Screed Colorado River Bridge.

the slab and deposited it there. This was a continuous source of trouble during the work.

When the grout dried out enough to change from a sticky consistency to a damp condition which would crumble when rolled between ones fingers, the overlay was placed. Because of the atmospheric condition on this job, the grout could be spread about 5 ft ahead of overlay placement without excessive loss of moisture.

Overlay: (Colorado River Bridge)

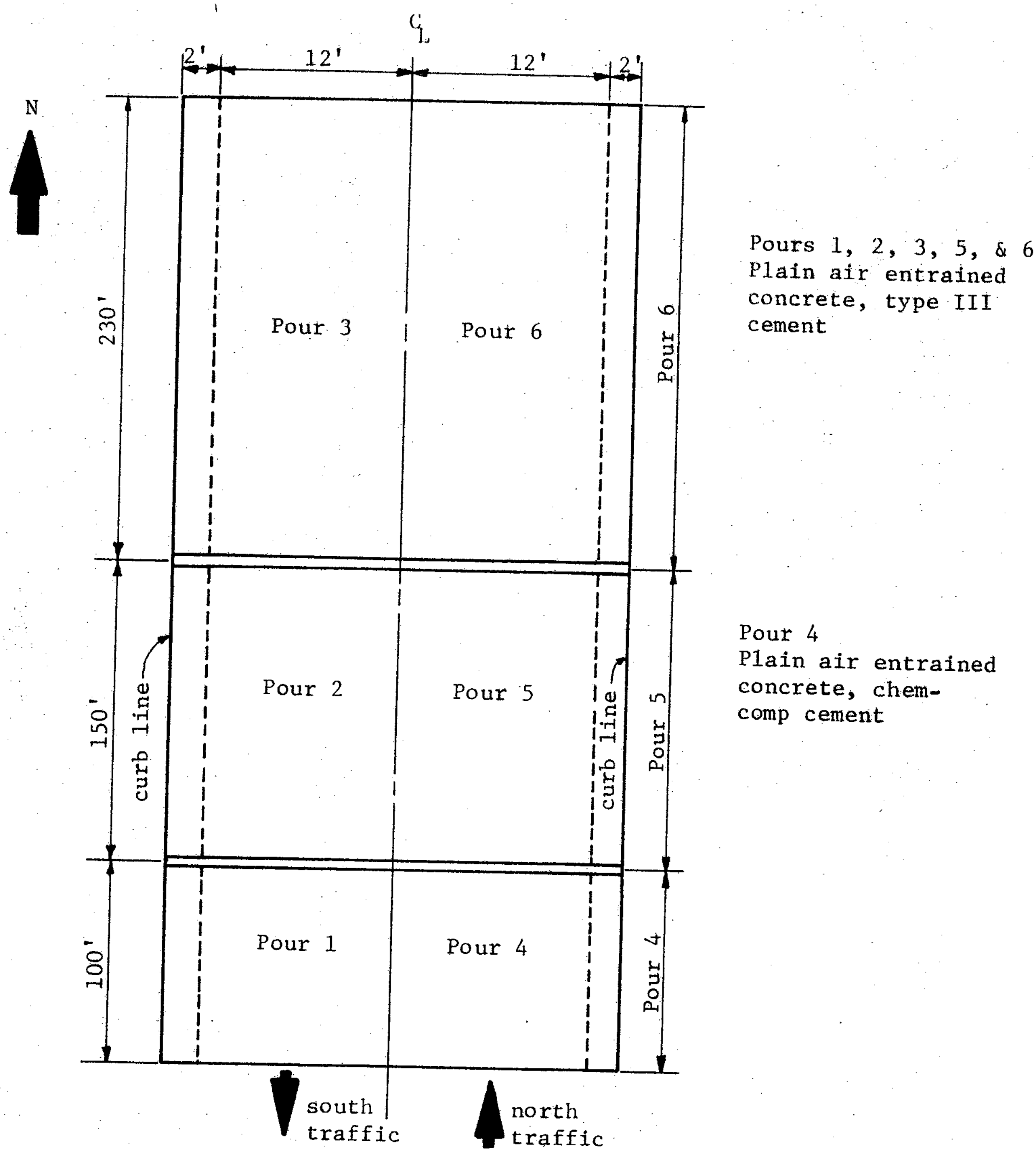
The mix design for the overlay concrete is shown in Appendix A. Type III cement was used everywhere except for pour 4, Fig. 9, which used shrinkage compensating cement. The aggregates were from a local pit. Properties of the material are given in Table I. Mixing was done on the job site and the concrete was delivered in a front end loader. Only the vibrating screed, Fig. 10, was used for compaction. The screed was followed by wood float finishing.

Pours 1, 2, 3, and 6 were cured 7 days under wet cotton mats, and pours 4 and 5 were cured 7 days under polyethylene sheeting. The Chem Comp cement concrete, pour 4, was flushed with water beneath the membrane to provide added moisture for curing. The bridge was opened to traffic immediately after curing mats were removed. Two coats of a mixture of equal volumes of boiled linseed oil and kerosene were sprayed on the deck after it had dried four days.

The overlay cylinder strength at 28-day age was 5636 psi, average of 3 cylinders. The two-beam average beam break was 763 psi at 3 days, 773 psi at 7 days, and 935 psi at 28 days. The secant modulus at ½ compressive strength was 5870 ksi at 28 days.

Follow-up Inspections:

Plastic shrinkage cracking developed over a portion, about 100 sq ft of pour 1 before curing mats were placed. Two months after the overlay was opened to traffic, an inspection of the surface revealed transverse reflective cracking over some supports, but the cracks were narrow. At that time there was no cracking found in the shrinkage compensating cement, Chem Comp, concrete, pour 4.



Note: The 2-ft wide strips adjacent to curb lines were hand placed after pours 1-6 were in place.

Figure 9. Schedule of Pours - Spur 179 Bridge at Robert Lee, Texas

TABLE I. PROPERTIES OF OVERLAY CONCRETE, ROUTE 208, COLORADO RIVER BRIDGE AT ROBERT LEE, TEXAS

Pour Number	Slump (in.)	Air (%)	Cement Type	Cylinder Age (days)	Cylinder Strength (psi)	Beam 7-day (psi)	Modulus of Elasticity* (ksi)	Curing Condition
1	2 1/2	5	III	21	3380		4830	7-day wet mat
	2 1/2	4.3		56	3300		4470	
	3 1/2	4.2						
2	2 1/2	4.3	III					7-day wet mat
	3	4.9						
	4	5.2						
3	4	6.8	III		----	668		7-day wet mat
	3 3/4	5.3						
	3 1/2	5.2						
4	4	7.8	Chem-	15	3600	662	4900	7-day poly sheet
	3 1/4	6.5	Comp	50	4570		4700	
	3	5.3						
5	4	6.0	III			592		7-day poly sheet
	3 1/2	4.8						
	3	4.4						
6	3	5.5	III			845		7-day wet mat
	4 1/2	4.5						
	2 3/4	4.7						

* Slope of the straight line from zero to 1/2 cylinder strength in the compressive stress-strain diagram.

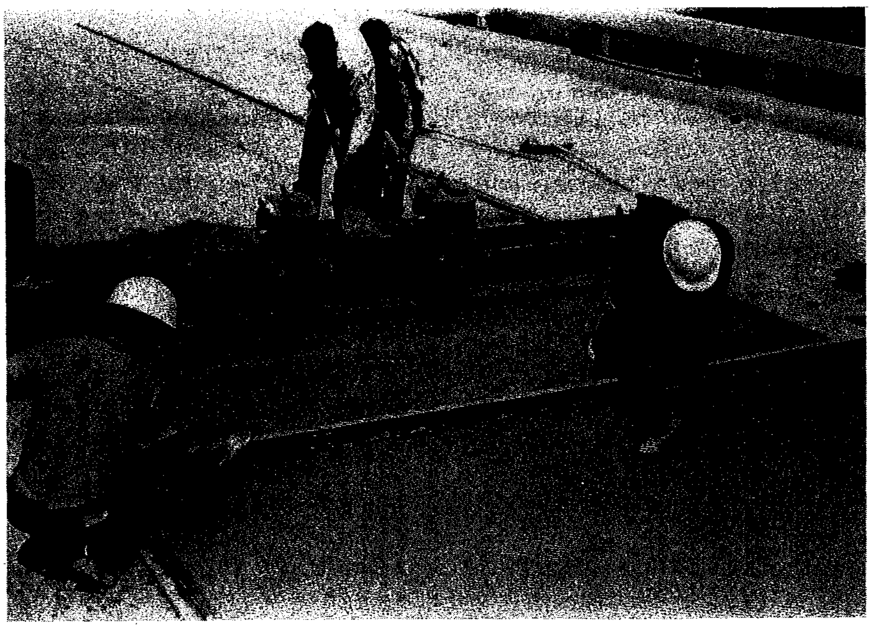


Figure 10. Vibrating Screed and Finishing Colorado River Bridge.

At four months age a check for delamination was made with the TTI delamination detector (11). One area about 12 ft square in pour 2, N-W corner by the curb line, gave signals which indicated that there were three or four small spots of delamination. That particular area was troublesome during grouting because water from the fog spray nozzles was blown to the deck by gusting winds. In a later inspection when cores were taken, the overlay in that area readily parted from the base slab revealing either no grout or a powdery material which presumably was extremely wet grout at placement.

After 19 months in service, the overlay was again inspected. That inspection consisted of making a record of delamination found by the TTI delamination detector (11), visual inspection for cracks, coring to determine the condition of the overlay and base material, and pipe cap tests, Fig. 11, to determine the tensile strength of the bond between the overlay and the base material. A two-in. diameter coring bit was used for the cores and the pipe-cap tests. Fig. 12 gives general locations of cracks, delaminations, and cores.

A number of very narrow areas one ft. long were delaminated at longitudinal cold joints along the center of the roadway and two ft. from each curb. Two delaminated areas about 3 in. to 6 in. wide extended almost the full width of the 12 ft wide pour number 6. Both lay along transverse cracks in the overlay, one being reflected from a construction joint in the deck, and the other from a full depth crack. The delaminated area in pour 2, found in the earlier inspection, appeared to be about the same size as it was when discovered. Six small

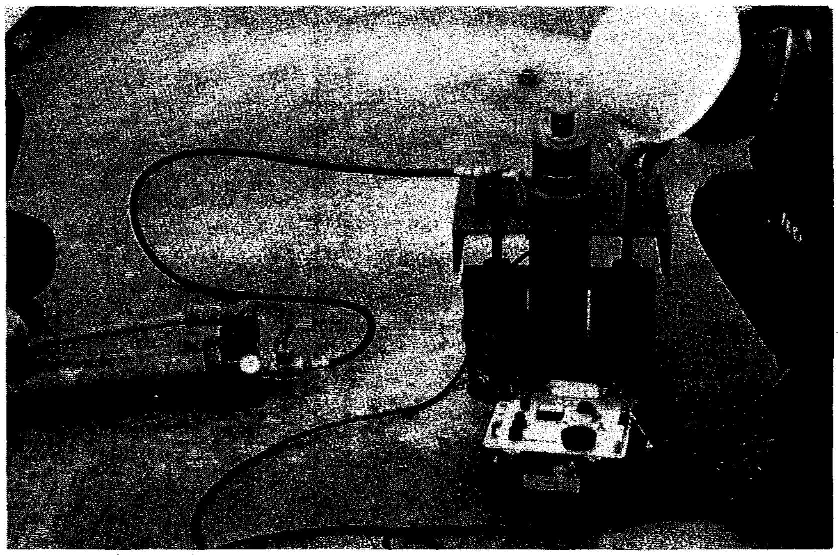


Figure 11. Pile Cab Test.

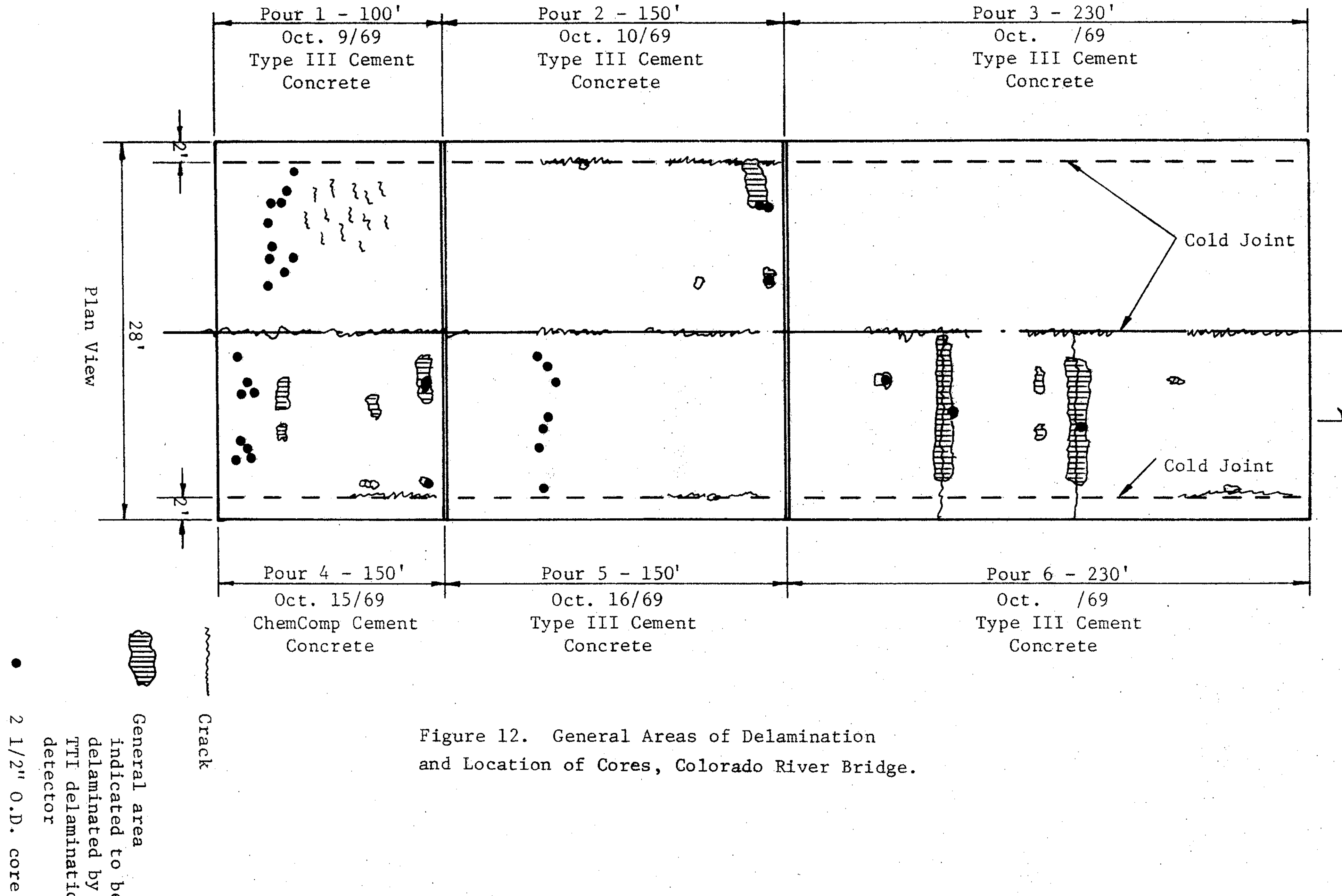


Figure 12. General Areas of Delamination and Location of Cores, Colorado River Bridge.

areas of delamination were found in pour 4, the first trouble that had been found in the shrinkage compensating cement material.

Aside from the plastic shrinkage cracking in pour 2, referred to earlier, most of the cracks were reflected from old deck cracking or they occurred along cold joints. About the same pattern of cracking was found during this 19 month survey as was found about 3 months after the overlay was placed. There were more visable cracks in areas where cracks were evident in the bottom of the slab and cracks at cold joints were wider.

Eight cores were taken to determine the condition of the original deck and the overlay concrete. All were taken from areas where delamination was indicated by the detector or from an area over cracked concrete. All of these cores, except one, broke at the bond line.

A microscopic examination of slices cut from the overlay showed numerous entrapped air voids indicating inadequate compaction. The line of bonding grout varied in thickness from zero to about 0.08 in. Cores from the delaminated area of pour 2, referred to earlier, were covered with a powder or very thin porous grout with no strength. One core in that area, pour 2, revealed a delamination 1/2 in. below the bond line in the old concrete.

In the pipe-cap tests an annular ring was drilled through the overlay and to a depth of about one in. into the old concrete. A pipe cap was then bonded to the top of the cylinder which was still held in place by the unbroken concrete at the bottom of the annular cut. The pipe cap was then connected to a hydraulic jack through a calibrated load cell. An upward force was applied to the core until it broke away from the slab. Of the thirteen tests performed in this manner ten separations occurred at the bond line, two in the overlay material, and one in the base slab. Tensile bond strengths were generally low, the lowest being 14 psi and the highest 220 psi. Six of the 13 had strengths less than 100 psi, see Table II. These values are much lower than strengths obtained by similar tests on laboratory specimens. The primary reasons for the low strengths can be attributed to poor distribution of bonding grout, as revealed in the core samples, and possibly to low grade surface concrete.

TABLE II. TENSILE BOND STRENGTH BY PIPE CAP TEST, COLORADO RIVER BRIDGE OVERLAY

Specimen Number	Pour Location	Tensile Bond Strength, psi	Remarks
1	1	97	Separation at bond line
2	1	66	Separation at bond line
3	1	158	Separation at bond line
4	1	158	Separation at bond line
5	4	113	Separation in old concrete
6	4	50	Separation at bond line
7	4	176	Separation at bond line
8	4	145	Separation at bond line
9	4	74	Separation at bond line
10	5	32	Separation at bond line
11	5	220	Separation in overlay concrete
12	5	14	Separation at bond line
13	5	195	Separation in overlay concrete

* See Figure 11 for locations on the bridge.

Spur 179 Bridge at Stephenville

Description:

This 23-year-old AASHO 20-44 bridge is located at Stephenville, Texas in Erath County. It carries spur 179 across the Bosque River on the outskirts of Stephenville. The bridge is 400 ft long and 40 ft wide with two traffic lanes and a sidewalk. There are five simple I-beam spans 40 ft long and one continuous I-beam unit with 4 spans of 40, 60, 60, and 40 ft. The plan is shown in Fig. 13. In addition to busy passenger vehicle traffic, it carries trucks with farm and ranch supplies and produce as well as local business freight.

The bridge has been carrying traffic since 1948. De-icing salt was first used on the deck in 1961. Between 1961 and 1969 about two 50 pound applications of salt were applied annually. No salt has been applied since 1969.

Isolated spalls, Fig. 14, have been patched from time to time, and two full depth deck replacement patches of Fast-Fix[1] concrete were made just prior to the overlay repair. Transverse cracks extending through the deck were present in a number of places. Two areas of checkerboard cracks were visible on the bottom of the deck between the steel I-beams, but this cracking was not considered to be serious enough to replace that part of the deck.

A two-inch thick plain concrete overlay was planned by THD

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1. Fast-Fix is the trade name of the quick setting cement, supplied by The Western Company, Richardson, Texas, used to make a rapid setting concrete which was used for full depth deck repairs on this bridge.

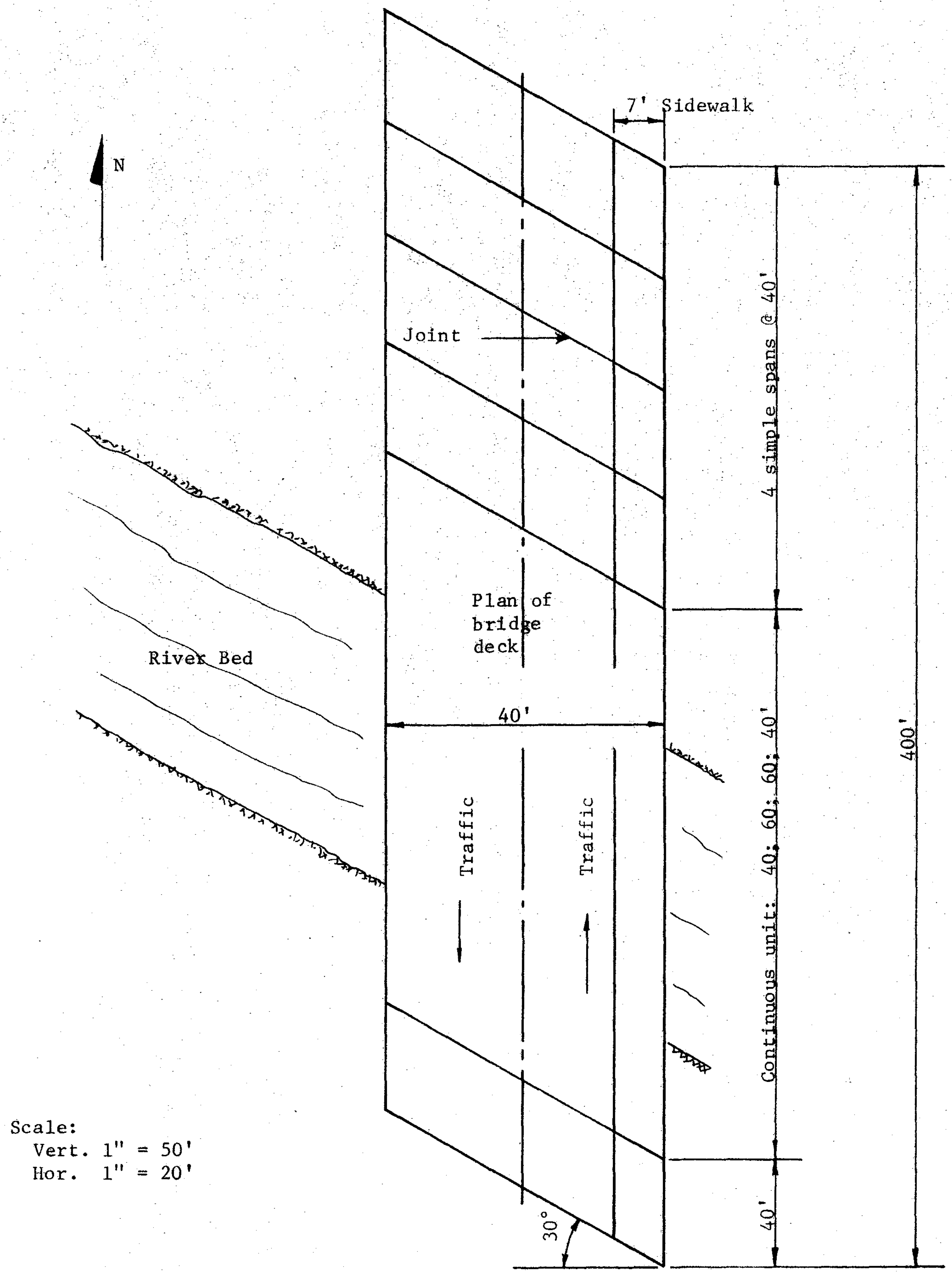


Figure 13. Bosque River bridge, Spur 179, Stephenville, Texas.

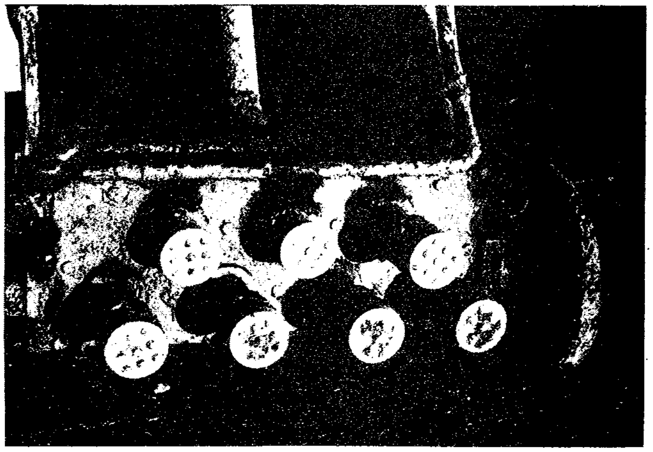
Figure 14. Delamination of Bosque River Bridge.

maintenance personnel to provide stiffness over cracked portions, to fill in spalled areas, and to provide a smooth riding surface. The deck was prepared and the grout was placed by THD District 2 personnel, the overlay was placed and finished by contract and it was cured by THD personnel. TTI provided technical assistance in preparing specifications, Appendix C, and in periodic inspections of the finished overlay.

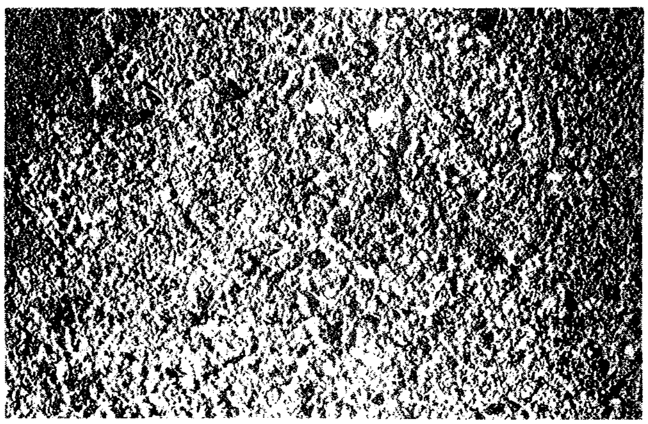
Surface Preparation: (Bosque River Bridge)

The deck was inspected for delamination and other concrete defects before any repairs were made. Delaminated areas, located by sounding, and spalled areas were routed out with air hammers in the same way as for the Colorado River bridge described earlier, Fig. 5. Edges of delaminated areas were cut back about two in. into sound material. The reinforcing steel that was uncovered when defective concrete was broken out was generally rusty, and the two in. cut into sound material did not uncover more than an occasional unrusted rod.

A scarifier, McDonald Scabbler (12), followed the jack hammers to remove the top surface of the entire deck, including sound portions as well as those areas that had been routed out. The rusty exposed steel was then sandblasted to remove rust. Debris left by the Scabbler and sandblaster was blown from the deck which was then flushed with water to remove dust and fine particles left by the air jet. Fig. 15 shows the impacting faces of the Scabbler, and the surfaces of the original concrete and the Fast-Fix concrete that had been subjected to the Scabbler.



a) Impacting heads



b) Scarified Original Deck Concrete

c) Scarified Fast-Fix Concrete

Figure 15. McDonald Scabbler and Scabbler Scarified **Concrete.**

Bond Course - Grout: (Bosque River Bridge)

The grout mix used for this overlay was identical to that used on the Colorado River bridge, Appendix A. It was mixed in small batches in a mortar mixer and was delivered to the deck in a front end loader.

The original plans called for the use of an epoxy adhesive over one-half of the bridge so that the field performance of epoxy bond could be compared with that of grout bond. The epoxy was not used because of unfavorable, cool and rainy, weather conditions when the job was scheduled to begin.

The grout was manually scrubbed into the damp scarified surface with stiff bristle brooms just ahead of the overlay. When it dried to a damp condition, enough to lose its stickiness, the overlay was applied.

Overlay: (Bosque River Bridge)

The overlay for this bridge was essentially the same as that on the Colorado River bridge, Appendix A. Type III cement was used throughout, and a maximum slump of 2 in. was specified but it varied between 3 and 4 ins. No patching, except for the full thickness Fast-Fix mentioned earlier, preceded the overlay. The holes were filled with overlay concrete as the resurfacing advanced.

The concrete, mixed and delivered in transit mix trucks, was dumped as needed just ahead of the finishing machine where it was compacted by internal vibrators. A paving machine finisher smoothed and textured the surface. The full width slab was overlaid in one pass with hand work being done at curbs to keep up with the finishing machine. The 16,000 sq ft of overlay was placed on November 17 and 18, 1971.

Attempted fogging was largely ineffective because the nozzle could not be located to take advantage of the wind. The overlay was cured under plastic sheeting for 5 days and then it was opened to traffic. The material had a 3-day beam strength of 763 psi and a 28-day cylinder strength of 5970 psi.

Follow-up Inspection: (Bosque River Bridge)

The north bound traffic lane of the overlay was inspected on May 16, 1972, six months after its installation. It was checked visually for cracks and general condition. Further inspection for bond and for condition of materials was made through a study of 27 cores, six of which were used for pipe cap tests.

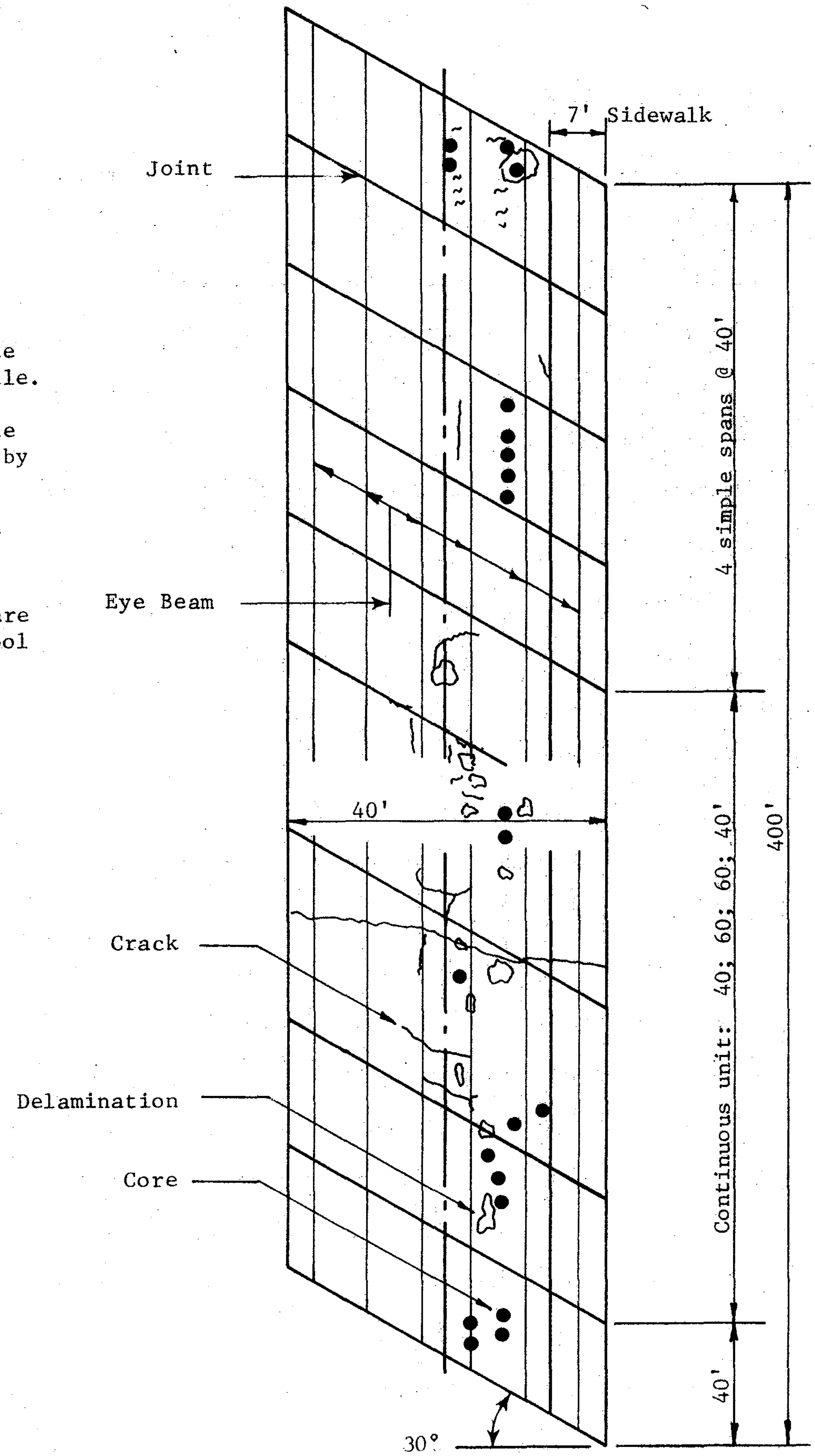
Numerous short diagonal cracks were found in the overlay at the north end of the bridge over the full depth slab replacement material, Fast-Fix concrete. These cracks looked very much like plastic shrinkage cracks, but they were not seen when the curing mats were removed, five days after placement. Four cores were taken through the overlay material over those cracks. Two of them were cracked completely through the overlay, another about 3/4 through, and the other to 1/2 of its depth. No other cracking of this particular kind was found, but there were a number of transverse and longitudinal cracks. Most of these were found at or in the vicinity of two cold joints in the continuous unit, Fig. 16. One of those joints was on a skew angle and it was accompanied by extensive

Plan of Spur 179 bridge across Bosque River at Stephenville.

Cores taken from the deck are indicated by the symbol ●

Cracks are shown by the symbol

Delaminated areas are bounded by the symbol



Scale:
Vert. 1" = 50'
Hor. 1" = 20'

Figure 16. Deck plan of Bosque River Bridge showing locations of cracks, delaminations, and cores.

cracking on the bottom of the slab as well as on the top of the overlay. Cracks at both locations appear to have developed first over the two central longitudinal steel beams, progressing either, or both, diagonally or transversely to meet cracks extending from the adjacent beam.

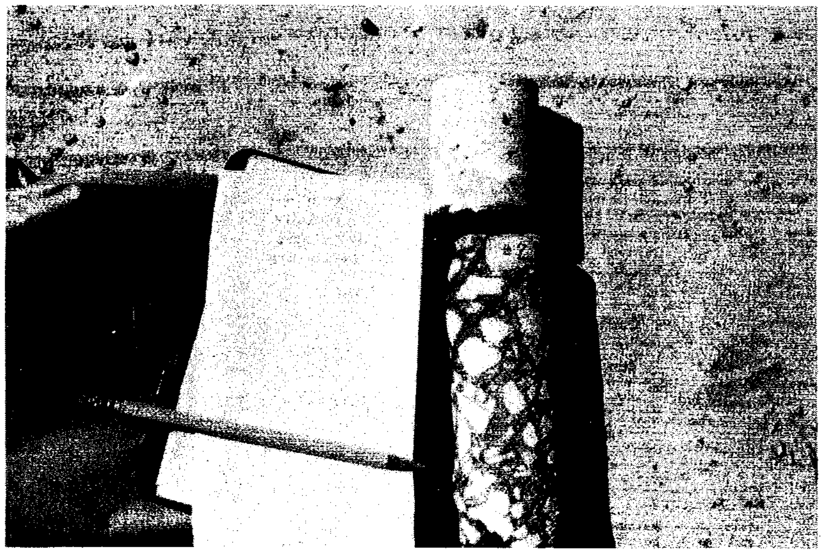
Several delaminated (unbonded) areas were detected by sounding with a chain drag. All except two small areas were located in either the continuous unit or in the area of the full depth Fast-Fix concrete at the north end of the bridge, Fig. 16. There were no cracks surrounding the unbonded areas.

Twenty-seven cores, 21 two in. diameter and 6 four in. diameter, were taken from the deck during this inspection, Fig. 16. Of the twenty-one 2 in. diameter cores, six were used for pipe cap tensile bond tests. The remaining 2 in. cores and the six 4 in. diameter cores were visually inspected for the condition of the materials and bond. A schedule of the cores is given in Table III. Eleven of the 2 in. and one of the 4 in. cores broke at the bond line during drilling. See Fig. 17 as an example. Surfaces at the bond line of cores broken in drilling were so badly worn by twisting against each other that the bonded surfaces were destroyed, Fig. 18. One 4 in. core, number 27 taken from span 9, had an old delamination one in. below the bond line. Two specimens cored through visual cracks in the overlay, in addition to the four taken in Fast-Fix concrete, were cracked completely through the overlay. No cracks could be found in the base slab concrete of those cores.

Six compression cylinders, 2 each from overlay concrete, original deck concrete, and Fast-Fix concrete, were cut from the 2 in. diameter

TABLE III. SCHEDULE OF CORES TAKEN FROM THE BOSQUE RIVER BRIDGE, TEXAS ROUTE 208, AT STEPHENVILLE, TEXAS (All were taken from the north bound traffic lane)

Core Number	Core Diameter (in.)	Span	Comments
1	2	1	
2	2	1	
3	2	1	Drilled through crack in overlay; cracked through overlay
4	2	1	Drilled through crack in overlay; cracked through overlay
5	2	1	Drilled through crack in overlay; cracked 1/2 overlay depth
6	2	1	Drilled through crack in overlay; cracked 3/4 overlay depth
7	4	1	
8	2	3	
9	2	3	Pipe cap test
10	2	3	Pipe cap test
11	2	3	Pipe cap test
12	2	3	
13	2	6	
14	2	6	Drilled through crack in overlay; cracked through overlay
15	2	6	
16	2	8	
17	2	8	
18	2	8	Pipe cap test
19	2	8	
20	2	8	Pipe cap test
21	2	8	
22	2	8	Pipe cap test
23	4	9	Drilled through crack in overlay; cracked through overlay
24	4	9	
25	4	9	
26	4	9	
27	4	9	



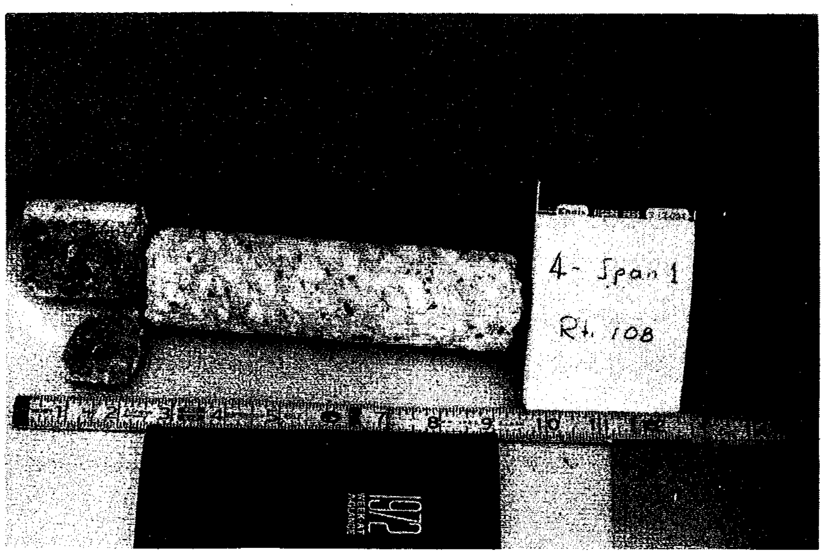


Figure 17. Two-in. Cores from Bosque River Bridge Showing Breaks at Bond Line. Also, note Cracked Overlay in 4-Span 1 Specimen.

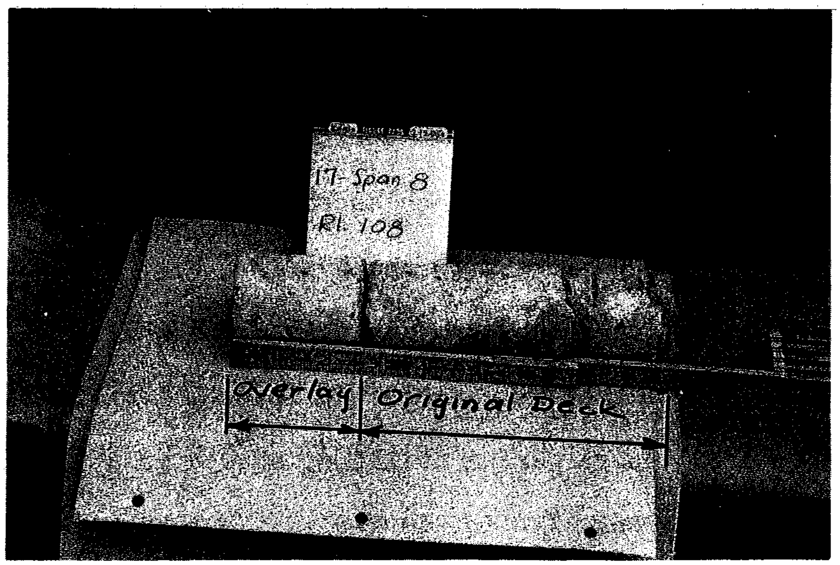


Figure 18. Two-in. Dia. Core from Bosque River Bridge Showing Abrasion at Interface at Overlay and Slab Due to Grinding When Overlay Broke Loose During Drilling.

cores. Since it was not possible to have the desired ratio of length-to-diameter in these specimens, they were cut to make the length very nearly equal to the diameter. After the ends were squared and ground they were tested to failure in compression. All were tested in a dry condition. Strengths, from these tests, Table IV, are highest for the overlay material.

Tensile bond strengths from six 2 in. specimens from the Bosque River bridge are shown in Table V. In each specimen, a residue of mortar from the base slab broke away with the overlay, Fig. 19. Some of the residue was small pieces of broken aggregate, which is discussed later. All specimens that were collected intact, i.e., not having the interface ground away during drilling, showed grout layers varying in thickness from about 1/16 in. to 1/8 in., but there were no powdery interfaces such as were found in the Colorado River bridge cores.

Tests of tensile bond strength of 2 in. overlay bonded with grout to a new base concrete and an old base concrete was made to see if there would be wide differences under laboratory conditions. New concrete cubes, 7 in. on a side, were made for this purpose, and they were tested 9 days after overlaying. A slab on grade about 25 years old was used for the old concrete. The slab had served as an apron at an airplane hanger at the Texas A&M Research Annex, and it was still in place. Overlays made of four different concretes were bonded to the sand-blasted surface of the slab and tested for tensile bond at 19 months age. Three of the overlays were bonded with grout, while the fourth,

TABLE IV. COMPRESSIVE STRENGTHS OF CORES TAKEN FROM THE BOSQUE RIVER BRIDGE

Specimen Number	Diameter (in.)	Length (in.)	Compressive Strength (psi)	Material
1	1.95	2.05	3230	Overlay Concrete
2	1.95	2.10	3013	Overlay Concrete
3	1.95	2.05	2040	Original Deck
4	1.95	2.00	2126	Original Deck
5	1.95	2.25	1942	Fast-Fix Concrete
6	1.95	2.20	Void	Fast-Fix Concrete

TABLE V. TENSILE BOND STRENGTH BY PIPE CAP TEST BOSQUE RIVER BRIDGE OVERLAY AND OF OTHER OVERLAYS

Concrete base for the 2-in. thick overlays used to develop the tensile bond strength, by pipe cap test, shown in table, psi.

Line Number	Bosque River Bridge	25 Year Old Slab on Grade				New Concrete Cube			Colorado River Bridge*
		Plain Concrete	Chem-Comp	Chopped Wire Reinforced	SM 100 Concrete	Grout Bond	Epoxy Bond	No bond Material	
1	20	153	132	165	111	271	145	258	97
2	40	153	174	140	490	271	174	105	66
3	77	97	210	200	405	268	105	197	158
4	118	179	129	200	250				158
5	94								113
6	56								50
7									176
8									145
9									74
10									32
11									220
12									14
13									195
Average	67	145	161	176	314	268	141	187	115

* Values from Table II

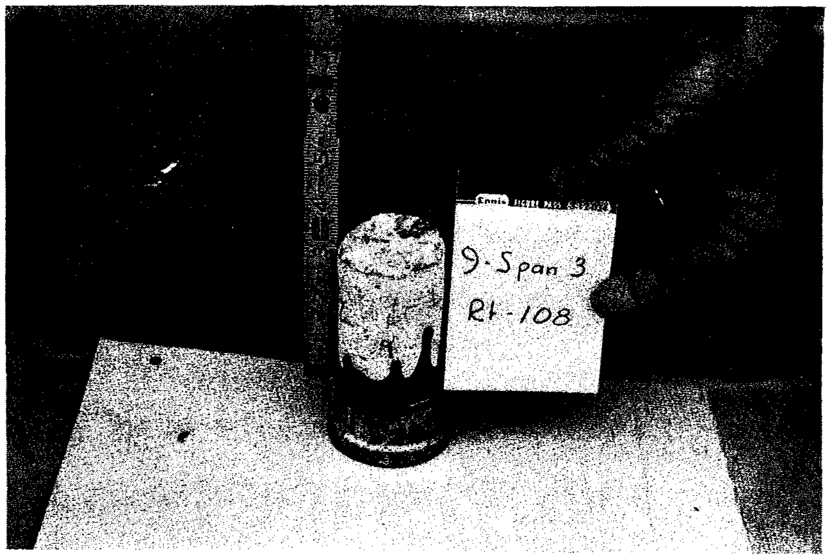


Figure 19. Pipe Cap Test Specimens, Bosque River Bridge. Lighter Color material on the Bonded Faces Broke Away From the Original Deck; Darker Material is Bonding Grout.

a latex modified concrete, was bonded with its own mortar. Results of the test are given in Table V. The cubes were sand-blasted, grouted, and overlayed in the same way as the slab except that an epoxy adhesive was included for one set of the cubes. The results of the tensile bond test are given in Table V.

In order to get information with which shear bond and tensile bond could be compared, tests were made on laboratory specimens. Identical cubes, 7 in. on a side, were prepared by sand-blasting the top surface. Six of these were grouted and overlaid with concrete, another set of 6 were overlaid with concrete without grout, and the third set of 6 specimens were overlaid with concrete applied to epoxy adhesive. At 7-day age two in. pipe cap tensile bond tests were made on 3 of each set and shear bond tests (13) were made on 3 of each set. The bond strength of each specimen is given in Table VI and a plot of the values is shown in Fig. 20. The linear curve through the plotted points shows that the shear bond strength is about 2.5 times the tensile bond strength for these particular specimens. This particular ratio would not be valid for all bonded overlays, but it gives a rough idea of relative values. From it one can see that a tensile bond at about 75 psi is roughly equivalent to a shear bond strength of 200 psi in these specimens. A tensile bond of approximately 25 psi will be adequate to develop the nominal 64 psi required (10) for traffic induced shear.

The bond strength of the Bosque River Bridge overlay is significantly lower than any other. By visual inspection of cores, the grout for this bridge appears to be of a better quality and to have better distribution

TABLE VI. COMPARISON OF BOND STRENGTHS IN TENSION WITH THOSE IN SHEAR

Tensile bond on 2 in. diameter specimens; shear bond on 7 in. cubes.

Specimen Number	Bonding Agent	Tensile Bond (psi)	Shear Bond (psi)
1	Grout	271	712
2	Grout	271	592
3	Grout	263	690
4	Epoxy	145	245
5	Epoxy	174	296
6	Epoxy	105	316
7	None	258	622
8	None	105	694
9	None	197	388

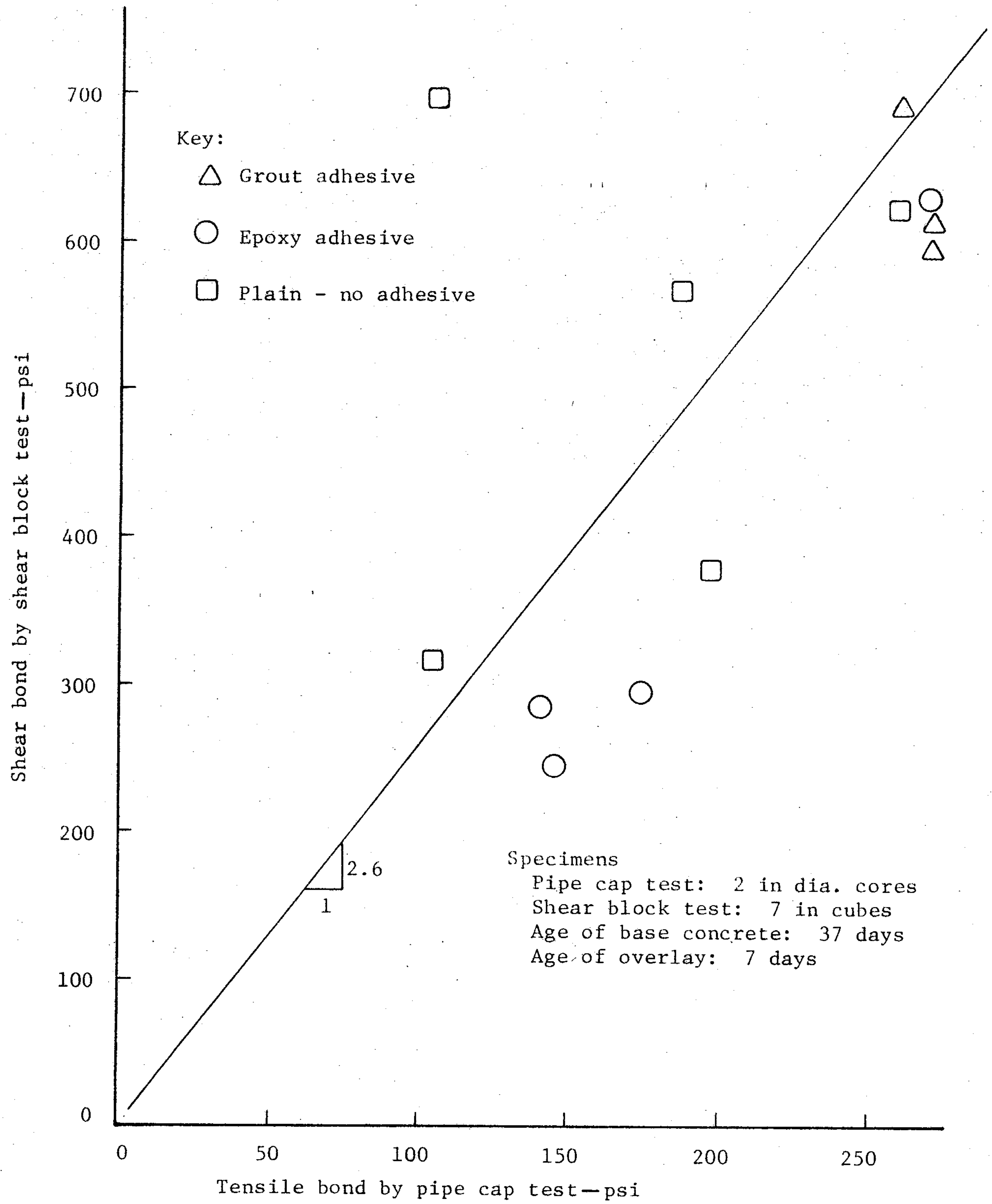


Figure 20. Relationship between tensile bond (pipe cap test) and shear bond (shear block test) for overlays bonded to laboratory specimens.

than that of the Colorado River bridge overlay. The discussion which follows on the scarified surface preparation might help to explain the difference in bond.

The bond of plain concrete overlay on the 25 year old slab on grade with grout bond, 145 psi, is much lower than that of the new concrete at 260 psi. All of the bond values for the slab on grade are high, however. A good surface cleaned well by sandblasting will provide good bond if the grout is prepared and placed properly.

Some of the Bosque River bridge cores were cut into slices across the bond line and the slices were then polished for study under an optical microscope. The grout showed up well in that study and it appeared to be sound and firmly fixed to both the old and the new concretes. Its very dark shade, that of a rich mortar, at the top of the old concrete gradually blended in with the lighter shade of the overlay concrete.

A number of aggregates at the top surface of the old concrete were shattered, and the cracks in those stones, discernable to the naked eye, were easily seen through a reading glass. Fig. 21, micro photographs, show broken aggregate and crushed mortar at the top of the original deck. Those stones were exposed to the blows of the scarifier when the deck was being prepared, and they were crushed under the impacting hammers of that machine. In some areas the mortar matrix of the old material showed cracks parallel to the surface. Those isolated cracks were presumably caused by the scarifier when its hammers impacted the mortar.

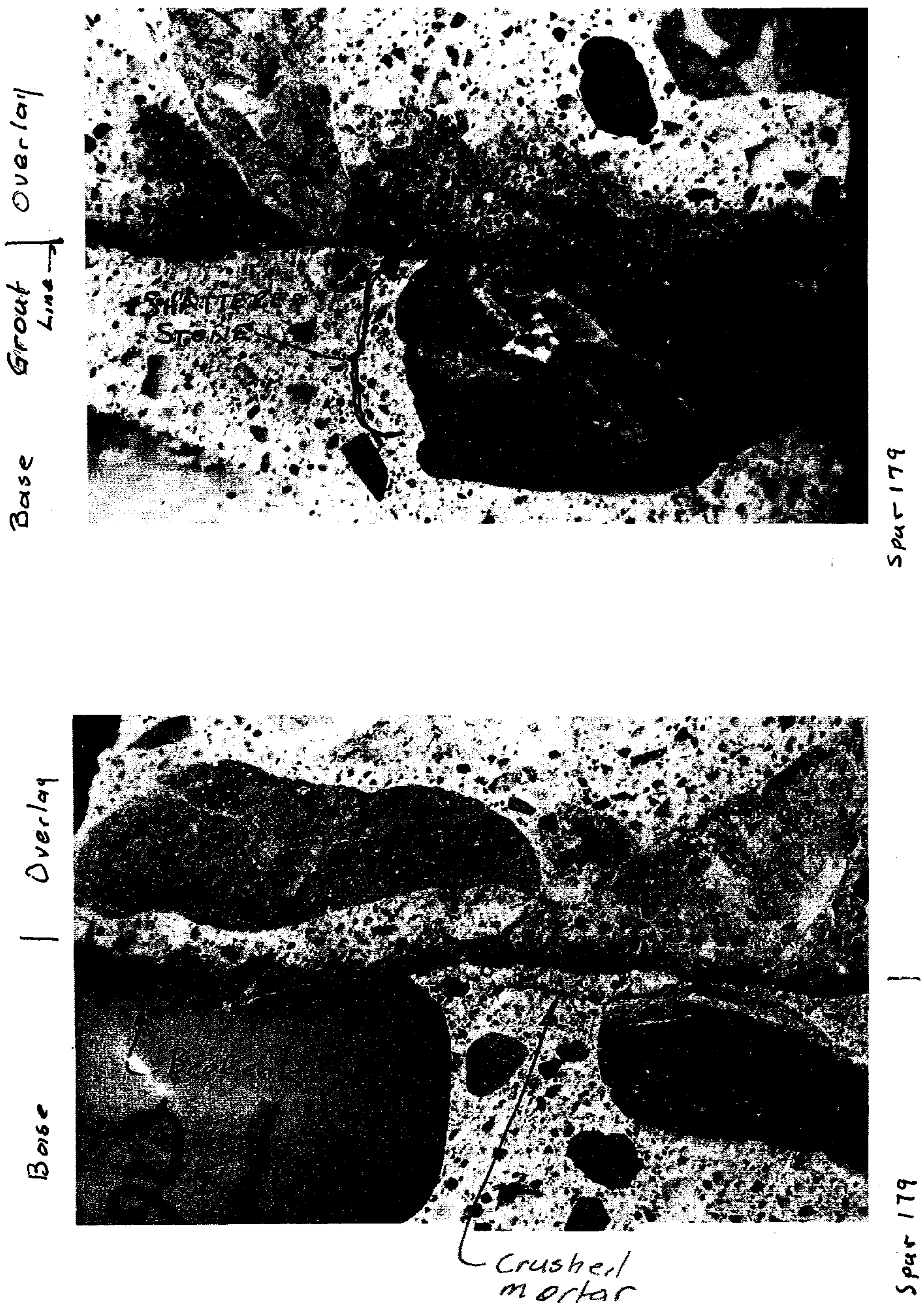


Figure 21. Microscopic Views, 10X, of Shattered Stone and Crushed Mortar at the Top Surface of the Old Deck of the Basque River Bridge.

After the crushed aggregates and mortar were found in the Bosque River bridge material, two old cores which had been retained from the Colorado River bridge overlay were sliced and studied. No crushed material was found in those slices.

Discussion:

The experience gained through the installation of the two experimental concrete overlays emphasizes the importance of preparation of the deck and training of the crew. The well prepared deck provides a sound base from which the repair may be made. A well trained crew insures a well executed repair operation which helps to insure a successful job. Recommended minimum requirements for thin concrete overlays and patches are given in Appendix D.

The decision on whether overlay repairs are needed is one that must be based on knowledge gained through experience in highway maintenance. It is a matter of judgement, and a number of factors must be considered in arriving at a decision. Those factors include condition of the deck, traffic handling, relative costs of various proposed solutions and availability of funds, personnel, and equipment.

The condition of the deck is very important, and it should be kept in mind that the thin overlay is a repair and not a rebuilding. If the deck is cracked so badly that the bottom mat of reinforcing steel is not well bonded to act integrally with the concrete which is still sound, then a thin overlay will not solve the problem. Such a condition will require full depth replacement of the slab in the affected area. Nominal cracking in either or both transverse and longitudinal directions can be tolerated. Surface roughness due to scaling and spalling can be remedied by a thin overlay, and such an overlay will add to the stiffness of the deck.

Laboratory experiments (15) have shown that corrosion can occur in mortar with as low as 2% (by weight of cement) calcium chlorides. Spellman and Stratfull (16) have shown that chlorides penetrate concrete whether it is cracked or not.

If non-rusty steel was originally installed it will remain without rust unless the concrete environment is corrosive or unless pores and cracks in the concrete permit corrosives to reach the steel. The continuation of corrosion implies continued spalling, which would be just as destructive to a new overlay as it is to the old concrete. Decks that have been subjected to de-icing salts have the higher salt concentration in the top region of the slab. If the salt content of that material is high enough to provide a corrosive environment for reinforcing steel, it should be removed before the overlay is applied. Such removal greatly increases the cost of preparation, especially if removal extends below the top mat of steel.

Areas where concrete has been removed to a depth deeper than the top mat of steel probably should be patched ahead of the overlay placement. There is no evidence to show that the hole cannot be filled with overlay concrete during the overlay operation, but if it is done separately there is more time and a better opportunity to compact the concrete under and around exposed steel. If no material is removed below the steel, the hole can be patched and overlaid in the same operation. A bonding agent and good compaction must be used in either case.

Adequate preparation of the deck requires the removal of all deteriorated concrete and all concrete, sound or deteriorated, covering rusty steel. A sound concrete overlay can last only as long as the base to which it is bonded. For that reason all deteriorated material must be removed. The inspections made after the overlays reported here were installed showed that in two areas delamination was either not detected prior to the overlay installation, or it developed later. It is probable that it was not found in the pre-overlay inspection. The delamination was below the top mat of steel in both cases.

The air hammers used in removing deteriorated concrete for these two overlays serve well, but they should be supplemented with chipping tools to handle the lighter material and for dressing. In one spot the heavy air hammer broke through the deck. Although sawed edges are recommended by some (17) for preparing patch areas no sawing was done here. All holes were dressed with the air hammer to produce vertical edge walls where the depth was about an inch or more. And, since the overlay was applied over the original deck, there were no feather edges to the system. If the patch alone is made with no overlay, sawed edges, as recommended in the Concrete Primer of the Bureau of Reclamation (17), possibly would be more durable than feather edged patches.

The decks appeared to be well cleaned by both sand-blasting and scarifying with the Scabbler. The scarified surface had about 1/8 to 1/4 inch thickness of cover removed whereas there was much less removed by sand-blasting. The sand-blasted surface was not nearly as rough as the scarified surface, but a very rough surface is not a requirement for good bond of an overlay. The past overlay inspections revealed that much of the scarified surface was crushed--shattered stones and crushed mortar--whereas no such damage was found from sand-blasting.

After the damage was found in the Bosque River bridge surface, bridges in THD District 5 on US 87 that had been overlaid with epoxy surfacing were cored to study the effect of Tennant machine preparation on one bridge and diamond sawcutting on another. The sliced cores of Tennant machine prepared surface showed some surface damage, Fig. 22, but it was not as extensive as that resulting from the Scabbler. The surface scarified with the diamond blade saws showed no damage in slices cut from the cores.

No tests were made to determine the effect of the various surface flaws, if any, on either tensile bond or shear bond strength of overlays placed on them. It is reasonable to expect reduced bond of either kind of overlays placed on damaged surfaces, but whether or not the reduction is serious is not known. It should be investigated not only for bond strength but also for bond life and for durability of the overlay system.

Pull-off tests of caps bonded directly to scarified surfaces and to scarified surfaces sealed with epoxy have been made by the California Division of Highways.[1] Surfaces scarified by the Tennant machine and the Scabbler had lower pull-off strengths than those finished only by sandblast, whipblast, or brooming. Felt (3) warned of inferior bond when partially loosened sand grains are not removed. It is probable that much of the material that is crushed but not dislodged by the scarifier can be removed by other means prior to overlaying. Methods should be sought for that purpose.

There is no complete record of service life of overlays. Gillette (5) gives information on systems as old as 10 years on highway and airfield pavements, but it is not yet known what kind of preparation will serve best and the longest.

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[1]"Pull-off Tests on Scarified Bridge Deck Surfaces," by Bruce J. Gunderson, 12-69 (Received by letter July 25, 1972, from Mr. Guy D. Mancarti, 95807) Calif. Div. of Highways, P. O. Box 1499, Sacramento, Calif.

Figure 22. Damage on Surface Scanified by Tennant Machine, 15X.

There have been no problems of bonding with grout as long as it is mixed and placed properly. The 1/8 inch thick layer used in the installations reported has worked well when applied to a surface with no free standing water, brushed into the surface, and covered when damp. The cores showed that the grout layer was too thin or nonexistent in some spots, it was powder in some spots, and it was excellent in some spots. The powder found in some areas was caused by too much water in the grout from mixing or from being placed on a wet surface. Tracking from tires and boots in the grouted area should be avoided. When they occur the tracks should be rebroomed to bring the grout back to its proper level. The problems mentioned here can be easily solved or eliminated by close job control.

Two major problems were encountered in overlay placement, and both of those can be avoided by good planning. In one area on the Colorado River bridge the vibrators on the screed were not working correctly and a small portion of the overlay was probably not well compacted because of that. From the experience on both of the installations it was found that internal vibrators as principal or standby compactors are vital. They should always be on hand, and they should always be used ahead of the strike off machine. The other problem was that of getting the overlay covered before plastic shrinkage cracks developed. Fog systems should be available for use during periods when the moisture content of the atmosphere is low and especially during windy weather. And, membrane curing compound should always be used if curing mats cannot be applied before surface drying sets in.

Aside from the preparation of the deck to receive the grout and the overlay all of the problems mentioned can be avoided by careful planning and job control. Each of the overlay installations reported here were the first experience of that kind for the crews doing the work. Planning and job execution will be improved from the experience gained in these two installations.

Costs:

The complete overlay installation on the Colorado River bridge was made by Department personnel at a total cost of $0.92 per sq ft of the 13,440 square feet covered. The Bosque River bridge was prepared for the overlay by Department forces but the overlay placement and finishing was contracted. The overall cost of the repair on this 16,000 sq ft surface was $1.256 per sq ft and it was broken down as follows:

Scarifying	$ 3,300
Fast-fix full depth deck replacement patches	$ 5,800
Grout	$ 900
Overlay (including finish and cure)	$ 6,500
Traffic control and miscellaneous	$ 3,600
Total job cost	$20,100
Total repaired area	16,000 sq. ft.

Conclusions:

1. Deteriorated decks of concrete bridges can be brought back to serviceable condition with thin (about 2 in. thick) bonded concrete overlays.
2. Highway district maintenance crews can apply the concrete overlay, however, close control must be exercised over the work crew to insure proper installation.
3. Some scarifiers leave crushed stone and crushed mortar embedded in the deck.
4. Portland cement grout provides good bond between the overlay and the clean deck when properly applied.
5. Full depth cracks in the deck slab will reflect through the overlay.
6. The overlay should be used to correct deteriorated conditions caused by spalls and scaling; not to correct extensive checkerboard cracking from vehicle loads.
7. The cost of a 1 5/8 in. thick overlay placed on a sand blasted surface in 1969 was $0.92 per sq ft. The cost of a 2 in. thick overlay placed on a surface prepared with a McDonald Scabbler in 1971 was $1.256 per sq ft which includes $0.363 per sq ft for portions of full depth replacement, a cost not involved in the 1 5/8 in. overlay installation.

Recommendations:

Because of some of the problems encountered in the two installations reported here, the following recommendations are offered:

1. Do not place a thin concrete overlay over a portion of deck that is badly beaten up by wheel loads. Where the concrete has extensive checkerboard cracking on the underside between beams very serious consideration should be given to complete replacement of the deck in that area.
2. Determine if the crushed material left embedded in the deck by scarifiers is detrimental to performance of the overlaid structure. If it is, then find out how the crushed material can be removed at a minimum cost, or use other methods of preparation of the deck.
3. Make a thorough investigation to locate deteriorated concrete, including delamination, before any repairs are begun. Make another thorough investigation after all deteriorated material found in the first investigation is removed. The TTI delamination detector would be very useful and quick for such work.

Make a thorough investigation with the TTI delamination detector after the overlay is finished, and periodically repeat it, say every two years. Keep a history of the overlay installation, cost, and service performance and plan future overlay operations on the accumulated records of installations. Also, develop modifications and changes suggested by these records.

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APPENDICES

APPENDIX A

APPENDIX A: Mixes

GROUT MIX, Points by weight

1 - Cement
3/4 - Sand (saturated, surface dry)
1/2 - Water
Air - None
Mix to thick creamy consistency.

OVERLAY MIX, lbs./cu. yd.

Gravel (max. size 1/2 in.)	1846
Sand	1142
Cement	664
Water (to produce 2 in. slump)	280 (approx.)
Air	6%

APPENDIX B

SPECIFICATIONS FOR COLORADO RIVER BRIDGE OVERLAY

RECOMMENDED SPECIFICATIONS FOR COLORADO RIVER BRIDGE OVERLAY

The following information was supplied to the Texas Highway Department concerning a 1 1/2" overlay on a bridge deck surface. Changes may be required to adapt to other installations.

This information is intended for use as a guide only.

A. Preparation of Deck

1. Remove all unsound concrete to leave only sound, undelaminated material.

2. Sandblast the deck to expose coarse aggregate; clean any exposed steel; and remove spots of oil, grease, and other contaminants which might be detrimental to bonding of overlay to old concrete.

3. Clean all steel exposed by deterioration or by operations in 1 and 2.

4. Sweep the deck clean of debris and dust.

B. Fill Holes After Removal of Unsound Concrete

1. Thoroughly clean and dry the holes.

2. Thoroughly work grout into the dry base concrete in and around the hole. A stiff brush serves well for this purpose. The brush marks should not be higher than 1/8 inch when this operation is finished; on the average, the thickness of the grout will be about 1/16 inch.

3. When the grout dries to a damp condition, fill the hole with overlay concrete to the level of the deck surface. This concrete must be thoroughly packed to leave no void space and to insure good bonding to the base material.

C. Provide Grout Bonding Agent on Deck

1. Thoroughly clean and dry the deck.

2. Work grout into the deck thoroughly by broom or brush. Broom marks should not be higher than 1/8 inch, and the average thickness should be about 1/16 inch. Do not work so far ahead of the overlay operation that the grout will dry out.

3. When the grout dries to a damp condition the overlay concrete should be applied.

D. Place Reinforcing

(See sketch.)

E. Place Overlay Concrete

1. Place overlay concrete when the grout has dried to a damp condition.

2. Compact the overlay concrete with a vibrating screed so that the concrete flows to leave no voids.

3. Finish the overlay surface. No additional water should be added to the concrete for finishing purposes.

4. Wet cure the overlay six days under wet mats.

MATERIALS

A. For the bridge overlay, both Type III and shrinkage compensating cements were used in the overlay mix. The shrinkage compensating cement was Chem. Comp. Cement, El Toro brand, obtained from Southwestern Portland Cement Company, P. O. Box 1547, Odessa, Texas 79760.

B. Aggregates - Natural Sand and Gravel

Use THD concrete sand for grout and for concrete.

Gravel gradation:

Size	% Retained
3/4	0
1/2	15
3/8	25
#4	58
#8	2

C. Air-Entrainment Agent

Sufficient entrainment agent to produce 6% air content.

D. Reinforcing Steel (not applicable)

(See sketch.)

E. Mixes - Grout (parts by weight)

1 part cement (Type III), 3/4 part saturated surface dry sand, 0.5 lb water per pound of cement.

Overlay

(Mix is same for Type III and shrinkage compensating cement.)

Weights Per Cubic Yard Concrete

Gravel	1846 lb	(saturated surface dry)
Sand	1142 lb	" " "
Cement	664 lb	
Water	285 lb	(2-2 1/2 slump desired)

Air-entraining agent to produce 6% air.

APPENDIX C

SPECIFICATIONS FOR BOSQUE RIVER BRIDGE OVERLAY

BOSQUE RIVER BRIDGE - RECOMMENDED SPECIFICATIONS FOR CONCRETE OVERLAY

It is essential that the damaged deck be conditioned to receive the overlay. That overlay must be of high quality material and workmanship, and it must be adequately bonded to the base slab. Every phase of the repair operation must be carefully executed if the work is to be successful.

Preparation of the deck to receive patches and overlay requires removal of all loose and deteriorated concrete, and the steel must be cleared of rust and loose scale. Material containing oil and grease must be removed to permit good bond between new and old concrete. Care should be taken to prevent surface contamination from blasting sand and from oil and grease from tools and machines.

PATCHES

Holes and spalled areas extending below the top steel, a depth of about 3 in., should be patched before the overlay is applied. This allows for early shrinkage of the deeper material before the overlay is applied, and permits a greater compaction effort sometimes required in such areas. These areas are prepared for the patch by first removing all loose material. The chipping hammer is used in small areas, but if deep spalling covers a wide area, a concrete scarifier works well in removing deterioration. The chipping hammer, on the scarifier, should be followed by a high pressure water jet or sandblasting, or both. This removes small loose particles and cleans exposed steel. All dust should then be removed.

The base concrete should be sprinkled or flushed with water in preparation to receive the portland cement grout, but the surface must be dry when the grout is applied. This is to prevent the old concrete from soaking up water needed to hydrate the patch material. The old concrete to which epoxy is applied, however, must be thoroughly dry--it should not be wet down. Manufacturers' recommendations in the use of epoxy must be carefully followed.

Patches bonded with grout:

The sound concrete should be coated with a cement grout thoroughly worked into all surfaces, including vertical edges. The grout, a mixture of portland cement, water, and concrete sand, see attached sheet, should be worked in with a stiff brush or broom to leave a thickness of about 1/8 in. over the area to be filled. When the grout becomes damp dry, a low slump, 1 in. maximum, air-entrained concrete mix should be thoroughly compacted in the area to bring it up to the level of the top surface of the deck. Care must be taken to see that this concrete is worked under and around exposed steel and in other areas which might present difficulty. It should be rammed into place, if necessary, to force it into all areas. The surface should be given a rough finish, and no curing compounds should be used on it. It should be cured under impervious matting for about 12 hours to prevent loss of moisture. The overlay may then be applied.

Patches bonded with epoxy:

Epoxy may be used to bond the concrete patch instead of using cement grout. The preparation is the same for both but the surface must be thoroughly dry to receive the epoxy, and manufacturers' instructions must be closely followed for good results.

Overlay:

Removal of loose and damaged concrete on the deck proper may precede or it might follow the patching outlined above. Scarifiers, such as the Tennant machine, have been used in some operations. In others, hand tools such as light air hammers have worked well. Some operations have followed the scarifier with a high pressure water jet to remove loosened material. Air hammering should be used only over areas where damaged material is to be routed out. The entire surface should then be thoroughly sandblasted and all dust and loose material should be removed to provide a clean deck. After cleaning, side forms are set and a vibrating screed mounted for compacting and finishing.

Grout:

The surface of dry concrete should be dampened to prevent it from removing moisture from the grout. No free water, however, should be on the surface when grout is applied. Grout should be thoroughly worked into the roughened, clean surface to about 1/8 in. thickness, ahead of the overlay placement operation.

In order to compare the effectiveness of grout as a bonding agent with that of epoxy as a bonding agent, it is recommended that about half of the length of the overlay be bonded with grout, and the remainder be bonded with epoxy.

Epoxy:

For those sections where epoxy is to be used to bond the overlay, the concrete surface should be dry and the instructions of the manufacturers should be carefully followed in both preparation and application.

Placing overlay:

Low slump, air-entrained overlay concrete, a seven sack mix with 1/2 in. maximum size aggregate, is placed over the bonding agent and compacted to 2 inch thickness with the vibrating screed. Additional compaction should be applied by tamping if the screed does not provide the effort necessary for thorough compaction. The surface should be finished by burlap drag, broom, or float to the texture desired.

Curing overlay:

Plastic shrinkage should be prevented by using water spray or monomolecular film or both prior to applying mats for curing. The overlay should be cured under wet or impervious matting until the specified compressive strength is attained. After removal of the mats and after drying, it should receive two coats of a mixture of boiled linseed oil and kerosene (or mineral spirits), 50% each by volume, at the rate of about one gallon per 40 square yards of surface. It can be opened to traffic after the linseed oil dries.

Tests

Slump: Maximum slump shall be 2 in.

Air content: The air content shall be 6% $\pm$ 1%.

Compressive strength: 2500 psi before being opened to traffic.

Grout mix (parts by weight)

1 part cement

3/4 part saturated surface dry sand

1/2 part water

Mix to a thick creamy consistency.

Epoxy

Prepare to meet manufacturers specifications.

Overlay mix (weight per cubic yard of concrete)

Gravel 1846 lb saturated surface dry

Sand 1142 lb saturated surface dry

Cement 664 lb Type III

Water 285 lb to produce 2 inch slump

Entrained air 6%.

Aggregate gradation

Sand - must meet THD gradation for concrete sand

Gravel - size % retained

size	% retained
3/4	0
1/2	15
3/8	25
#4	58
#8	2

APPENDIX D

RECOMMENDED MINIMUM REQUIREMENTS FOR THIN CONCRETE OVERLAYS AND PATCHES

RECOMMENDED MINIMUM REQUIREMENTS FOR THIN CONCRETE OVERLAYS AND PATCHES

NOTE: The recommendations which follow are considered to be minimum requirements for the usual problems encountered in installing bonded thin, about 2 in. thick, concrete overlays on concrete bridge decks. Additional requirements to fit the particular situation not covered below should be developed as needed.

LABOR: Personnel are required to remove unsound concrete, to uncover rusty steel, to remove rust from steel exposed before and after preparation, scarify the deck, clean the deck, apply bonding material, mix, place and cure patch and overlay concrete, and to take care of special provisions in specifications.

MATERIALS:

Grout: A mixture of one part (wgt) of portland cement with 3/4 parts of saturated surface dry sand passing #8 sieve and 1/2 (approx.) parts water mixed to a thick creamy consistency.

Epoxy: Only that which has a proven record of good service should be used for bonding agent. The recommendations of the manufacturer should be followed in applying it.

Overlay Concrete: (Wgt per cubic yard of Concrete)

Gravel: 1846 lb saturated surface dry.

Sand: 1142 lb saturated surface dry.

Cement: 664 lb, Type III

Water: 285 lb (Approx.) to produce 2 in. slump.

Entrained Air: 6 per cent.

Aggregate Gradation:

Sand: Meet THD gradation for concrete sand.

Gravel:

Size	% retained
3/4	0
1/2	15
3/8	25
#4	58
#8	2

LOCATING UNSOUND CONCRETE: All unsound concrete should be located and marked for removal. Trained personnel with the TTI delamination detector, sounding hammer, or chain drag should be used to locate the material to be removed.

REMOVAL OF UNSOUND CONCRETE: All unsound concrete must be removed. Removal should extend into sound concrete to insure that no poor concrete remains in place. Air hammers, chipping hammers, and saws may be used for removal.

CLEANING STEEL: All rusty steel should be uncovered and the rust should be removed by sand blasting. If the steel is loose (not bonded), it should be exposed all the way around so that it will be encased in new concrete when the patch or overlay is placed.

CLEANING THE DECK SURFACE: The deck must be thoroughly cleaned to remove oil, grease, and other contaminants. Loose and unsound surface mortar and aggregates, too, must be removed. Sandblasting is the preferred method of doing this. Scarifying machines such as the Tennant machine and the McDonald Scabbler should be used only when it is necessary to remove more than about 1/16 inch of surface material.

The deck must be thoroughly cleaned of dust and debris following sandblasting and scarifying. Particular attention must be given to removal of dust to be sure that no film of either wet or dry loose fine material remains.

APPLYING BONDING AGENT: Either epoxy resin or cement grout may be used to bond the new concrete to the old concrete. The surface must be clean and free of dust and debris for either of the bonds. Epoxy bond requires a dry concrete base unless special resins are used. The old surface should be saturated surface dry when grout is used. Traffic must be kept off the clean surface. Grouted surfaces should not be tracked.

Epoxy: Apply epoxy ahead of the fresh concrete according to recommendations of the manufacturer of the material.

Grout: Thoroughly brush the grout into surfaces to be patched or overlaid. A stiff broom should be used, and the average thickness of the grout should be approximately 1/8 in. when it is worked in. Care must be taken to see that it is worked in thoroughly; that it is not too thick (corners and depressions should be carefully treated); and that the grout is well mixed. The concrete should be placed on the grout after it has dried to a damp condition, not a dry condition.

CONCRETE PLACEMENT: Place concrete for patches and overlay on only properly prepared bases over untracked epoxy or grout bonding agent. The concrete must be worked into corners, depressions, and around exposed steel. Internal vibrators should be used and they may be supplemented by surface vibrators. If necessary for stiffer mixes, compaction with a ram in addition to internal vibration might be necessary.

Overlay concrete may be finished with a pavement finisher or by vibrating screed. Texture should be provided as called for by THD.

Patch concrete must be finished rough in order to receive the overlay and to bond well. No curing compound is to be used on patch concrete which will be followed by an overlay.

CURING: Wet mat cure is preferable for both patch and overlay concrete but polyetheylene sheeting may be used if it is kept air tight. Patches should not be overlaid before the patch concrete has set up. If epoxy is to be used for a bonding agent, the patch concrete must be thoroughly cured and dried unless a non-water sensitive epoxy is used. Grout may be applied as soon as the surface is damp-dry.

The overlay must be cured until the concrete has the test beam strength specified for bridge deck concrete.