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| 16. Abstract<br><br><p>This report describes two punchout repairs made in a continuously reinforced concrete pavement (CRCP) using precast portland cement panels. The two repairs, one 12 foot by 12 foot, the other 6 foot by 6 foot, were completed and opened to traffic in one afternoon.</p> <p>This technique provides a rapid method of repair that produces a repair that is structurally as good or better than the surrounding pavement. With a trained crew, the repair time can be reduced and thus reducing lane closure time. Since lane closure time is a critical consideration in high volume highways, this method will be cost effective in those areas.</p> |  |  |  |  |           |
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POLYMER CONCRETE FOR PRECAST REPAIR OF CONTINUOUSLY REINFORCED  
CONCRETE PAVEMENT ON IH 30, NEAR MT. PLEASANT

by

Alvin H. Meyer  
B. Frank McCullough  
David W. Fowler

Research Report Number 246-1

Research Project 3-18-79-246  
Polymer Concrete for Concrete Pavement Rehabilitation

conducted for

Texas  
State Department of Highways and Public Transportation

in cooperation with the  
U. S. Department of Transportation  
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH  
BUREAU OF ENGINEERING RESEARCH  
THE UNIVERSITY OF TEXAS AT AUSTIN

August 1981

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## PREFACE

This is the first report in a series of reports that describes the work done in Research Project 3-18-79-246, "Polymer Concrete For Precast Repair of Continuously Reinforced Concrete Pavement on IH 30, near Mt. Pleasant." The report deals with the repair of CRC pavements using polymer concrete.

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August 1981

## ABSTRACT

This report describes two punchout repairs made in a continuously reinforced concrete pavement (CRCP) using precast portland cement panels. The two repairs, one 12 foot by 12 foot, the other 6 foot by 6 foot, were completed and opened to traffic in one afternoon.

This technique provides a rapid method of repair that produces a repair that is structurally as good or better than the surrounding pavement. With a trained crew, the repair time can be reduced and thus reducing lane closure time. Since lane closure time is a critical consideration in high volume highways, this method will be cost effective in those areas.

## SUMMARY

Rapid structural repairs of high volume highways is an increasingly critical problem. Lane closure required for repairs causes traffic congestion and creates a safety hazzard for the traffic and the workmen in the repair area. Additionally, time delays due to lane closure represent a significant cost to the user.

This report describes a rapid repair techinque using precast portland cement concrete panels and polymer concrete (PC) to repair two punchouts in a continuously reinforced concrete pavement (CRCP). The repairs were completed and the lane reopened to traffic in one afternoon, even though the maintenance crew was unfamiliar with the techniques involved.

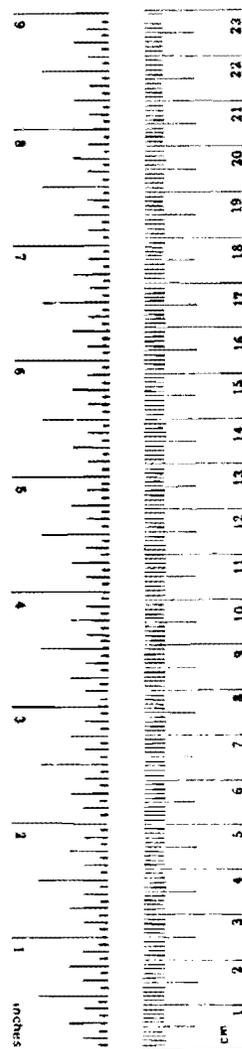
## IMPLEMENTATION

These were the first known precast panel repairs in continuously reinforced concrete pavement. Precast panels have performed well in other types of pavements and should perform well in CRCP. However, it is recommended that the implementation of this technique be made in a deliberate and controlled manner until more data is generated to evaluate long-term performance.

## METRIC CONVERSION FACTORS

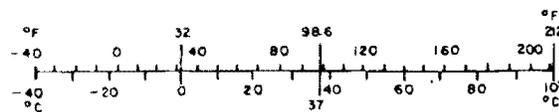
### Approximate Conversions to Metric Measures

| Symbol                     | When You Know             | Multiply by                      | To Find                | Symbol          |
|----------------------------|---------------------------|----------------------------------|------------------------|-----------------|
| <b>LENGTH</b>              |                           |                                  |                        |                 |
| in                         | inches                    | 2.5                              | centimeters            | cm              |
| ft                         | feet                      | 30                               | centimeters            | cm              |
| yd                         | yards                     | 0.9                              | meters                 | m               |
| mi                         | miles                     | 1.6                              | kilometers             | km              |
| <b>AREA</b>                |                           |                                  |                        |                 |
| in <sup>2</sup>            | square inches             | 6.5                              | square centimeters     | cm <sup>2</sup> |
| ft <sup>2</sup>            | square feet               | 0.09                             | square meters          | m <sup>2</sup>  |
| yd <sup>2</sup>            | square yards              | 0.8                              | square meters          | m <sup>2</sup>  |
| mi <sup>2</sup>            | square miles              | 2.6                              | square kilometers      | km <sup>2</sup> |
|                            | acres                     | 0.4                              | hectares               | ha              |
| <b>MASS (weight)</b>       |                           |                                  |                        |                 |
| oz                         | ounces                    | 28                               | grams                  | g               |
| lb                         | pounds                    | 0.45                             | kilograms              | kg              |
|                            | short tons<br>(2000 lb)   | 0.9                              | tonnes                 | t               |
| <b>VOLUME</b>              |                           |                                  |                        |                 |
| tsp                        | teaspoons                 | 5                                | milliliters            | ml              |
| Tbsp                       | tablespoons               | 15                               | milliliters            | ml              |
| fl oz                      | fluid ounces              | 30                               | milliliters            | ml              |
| c                          | cups                      | 0.24                             | liters                 | l               |
| pt                         | pints                     | 0.47                             | liters                 | l               |
| qt                         | quarts                    | 0.96                             | liters                 | l               |
| gal                        | gallons                   | 3.8                              | liters                 | l               |
| ft <sup>3</sup>            | cubic feet                | 0.03                             | cubic meters           | m <sup>3</sup>  |
| yd <sup>3</sup>            | cubic yards               | 0.76                             | cubic meters           | m <sup>3</sup>  |
| <b>TEMPERATURE (exact)</b> |                           |                                  |                        |                 |
| °F                         | Fahrenheit<br>temperature | 5/9 (after<br>subtracting<br>32) | Celsius<br>temperature | °C              |



### Approximate Conversions from Metric Measures

| Symbol                     | When You Know                     | Multiply by          | To Find                   | Symbol          |
|----------------------------|-----------------------------------|----------------------|---------------------------|-----------------|
| <b>LENGTH</b>              |                                   |                      |                           |                 |
| mm                         | millimeters                       | 0.04                 | inches                    | in              |
| cm                         | centimeters                       | 0.4                  | inches                    | in              |
| m                          | meters                            | 3.3                  | feet                      | ft              |
| m                          | meters                            | 1.1                  | yards                     | yd              |
| km                         | kilometers                        | 0.6                  | miles                     | mi              |
| <b>AREA</b>                |                                   |                      |                           |                 |
| cm <sup>2</sup>            | square centimeters                | 0.16                 | square inches             | in <sup>2</sup> |
| m <sup>2</sup>             | square meters                     | 1.2                  | square yards              | yd <sup>2</sup> |
| km <sup>2</sup>            | square kilometers                 | 0.4                  | square miles              | mi <sup>2</sup> |
| ha                         | hectares (10,000 m <sup>2</sup> ) | 2.5                  | acres                     |                 |
| <b>MASS (weight)</b>       |                                   |                      |                           |                 |
| g                          | grams                             | 0.035                | ounces                    | oz              |
| kg                         | kilograms                         | 2.2                  | pounds                    | lb              |
| t                          | tonnes (1000 kg)                  | 1.1                  | short tons                |                 |
| <b>VOLUME</b>              |                                   |                      |                           |                 |
| ml                         | milliliters                       | 0.03                 | fluid ounces              | fl oz           |
| l                          | liters                            | 2.1                  | pints                     | pt              |
| l                          | liters                            | 1.06                 | quarts                    | qt              |
| l                          | liters                            | 0.26                 | gallons                   | gal             |
| m <sup>3</sup>             | cubic meters                      | 35                   | cubic feet                | ft <sup>3</sup> |
| m <sup>3</sup>             | cubic meters                      | 1.3                  | cubic yards               | yd <sup>3</sup> |
| <b>TEMPERATURE (exact)</b> |                                   |                      |                           |                 |
| °C                         | Celsius<br>temperature            | 9/5 (then<br>add 32) | Fahrenheit<br>temperature | °F              |



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## Chapter 1

### INTRODUCTION

One of the objectives of this research study is to develop repair procedures for repairing punchouts in CRC pavements by using polymer concrete. This report describes a field test using procedures developed in Research Study 3-8-75-177 using polymer concrete as the bonding agent. The background and design portions of this report are taken from Research Report 177-15 (Ref 1)\* and are presented here for clarity and completeness.

It is important that repair of punchouts and other severe defects in continuously reinforced concrete pavements (CRCP) be performed in minimal time, be structurally sound, and be economical. This is of particular importance on CRCP which are used primarily for high volume roadways where hazards due both to defects and their repair are great.

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\*Numbers in parentheses refer to items in the References contained at the close of this report.

## Chapter 2

### BACKGROUND

CRC pavements were developed to reduce many maintenance problems encountered principally at joints in concrete pavements. Longitudinal reinforcing steel was incorporated throughout the length of the pavement to keep transverse cracks tightly closed. Thus, CRCP is constructed without transverse joints for contraction or expansion. However, it was found through experience that CRCP exhibited a wide variety of structural responses and maintenance on some sections was required sooner than anticipated.

From past surveys of in-service CRC pavements, six distinct distress patterns have been identified. These are transverse cracking, radial cracking, longitudinal cracking, spalling, pumping, and punchouts (Ref 5). The most serious manifestations of these distresses are punchouts, where portions of the pavement become detached and ejected or depressed, leaving a pothole. In addition to posing a hazard to vehicular operation, punchouts may lead to further deterioration of the surrounding concrete and subbase through impact loading, and water penetration. Thus, repair of distress on CRCP warrants prompt attention and, also, immediate restoration of service, since CRCP is generally used in locations with high traffic volumes.

### PRECAST JOINTED CONCRETE PAVEMENT REPAIR

The repair of concrete pavements using precast concrete slabs is not a new idea in the United States. Previous precast repair work has been performed on jointed concrete pavements. Several of the repair methods reported in the literature are briefly summarized below.

A test program to evaluate precast and cast-in-place repair of joints in jointed reinforced concrete pavements was begun in Michigan in 1971 (Ref 9). The precast slabs used in this program were 8 or 9 inches (203 and 229 mm) thick, 12 feet (3.66 m) wide, and from 6 to 12 feet (1.83 to 3.66 m) long. The slabs were cast to standard sizes at a maintenance yard, transported to

the repair sites, and installed on grout beds struck-off to the proper height. The repairs were constructed with and without dowel bars along the transverse edges for load transfer. Greased dowel bars were installed by drilling holes into the vertical faces of the adjacent pavement at middepth and then inserting the bars into the holes prior to slab placement. As asphaltic filler board was placed along the transverse edges. After the slab was placed, the dowel bars were welded to a steel plate cast into the end of the slab. The joints at the edges of the slab were then sealed with a hot-poured rubber-asphalt sealant. The procedure used in these precast repairs resulted in average lane closure times of two hours and forty minutes for doweled slabs and one hour and twenty-five minutes for undoweled slabs. Repair costs in 1971 and 1972 for these precast slab repairs were \$41 and \$52 per square yard, respectively.

In 1972, the Florida Department of Transportation used precast slabs to replace fractured jointed concrete pavement slabs (Ref 4). The 12 x 20 foot (3.66 x 6.10 m) slabs were cast and cured at a maintenance yard, transported to the repair site, placed in the prepared area one-half inch (12.7 mm) below in the elevation of the pavement surface, and raised to grade by slab jacking with pressurized grout, and then pressed fiberboard with a rubberized asphalt sealant was placed around the edges. This work was performed at night and as many as four slabs were replaced during an eight-hour worknight. The cost of the repair in 1972 was \$35 per square yard.

In 1974, the California Department of Transportation repaired a 30-foot (9.14 m) long portion of concrete pavement on the Ventura Freeway (Ref 8) with two precast slabs. The two slabs were 12.3 and 17.4 feet (3.75 and 5.31 m) long, 11.4 feet (3.47 m) wide, and 8 inches (203 mm) thick. The slabs were cast in an area close to the repair site and placed on a prepared grout bed, and the remaining space at the edges of the slabs were filled with concrete grout. The total cost of the repair was under \$3,000, or approximately \$75 per square yard.

An experiment was begun in 1974 by the Virginia Department of Highways and Transportation to evaluate repair of concrete pavement with partial-depth precast slabs (Ref 3). The slabs were 2 inches (51 mm) thick and ranged from

1 x 1 foot to 2 x 3 feet (.3 x .3 m to .61 x .91 m). Some of the slabs were formed with a hydraulic press and others were more conventionally cast, using metal fibers. Deteriorated areas were prepared by cutting a 2.5-inch (64-mm) deep portion of pavement with a Klarcrete cutting machine. Some of the pre-cast panels were cut to size at the repair site with a bench type masonry saw. The slabs were seated in a bed of epoxy grout. The average installation time per patch on this project was 77 minutes. This was not the total lane closure time. The average cost of the hydraulic pressed precast slab repairs was \$25 per square foot.

The New York State Thruway Authority used prestressed precast concrete slabs as large as 13 x 30 x .75 feet (3.96 x 9.14 x .23 m) to replace deteriorated portions of a jointed concrete pavement in 1974 (Ref 7). The steam cured slabs developed a 5,000-psi (35,500-kPa) compressive strength in three days. The slabs were transported to the site and installed overnight. As much as 120 square yards of replacement were completed per night.

#### PRECAST METHOD APPLIED TO CRCP

The application of the precast concept to repair of CRCP has an additional complicating factor over precast repair of jointed concrete pavements. These complications arise from the necessity to maintain steel continuity in the CRC pavements. In terms of volume change stress, restraint of the steel at the end of a reinforced concrete slab induces significant stress increases over the unrestrained condition. These stresses may become destructively excessive and must be accounted for in design. In short, the precast repair methodology as applied to CRCP, illustrated in Fig 1, consists of replacing the deteriorated pavement with a precast slab, anchoring the steel at the ends of the repair, and then filling the space around the steel connections with a fast-setting cast-in-place material.

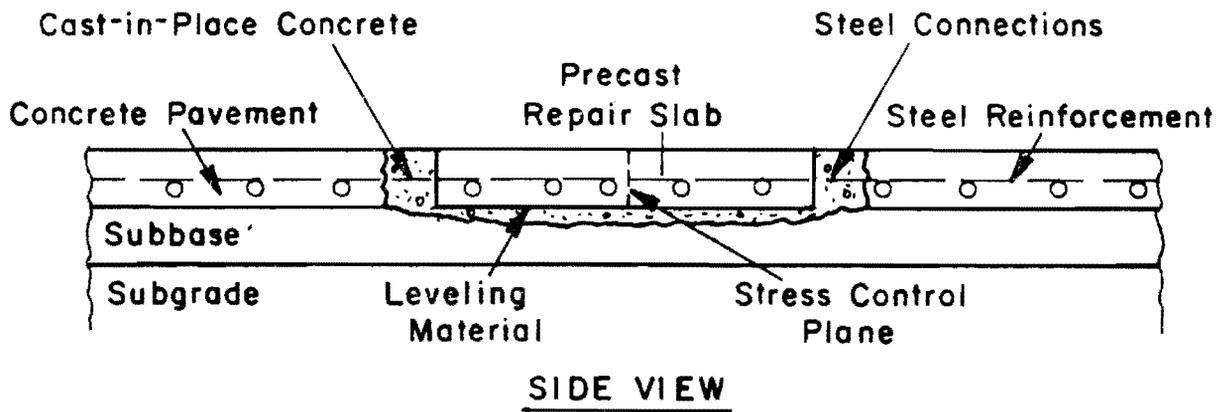
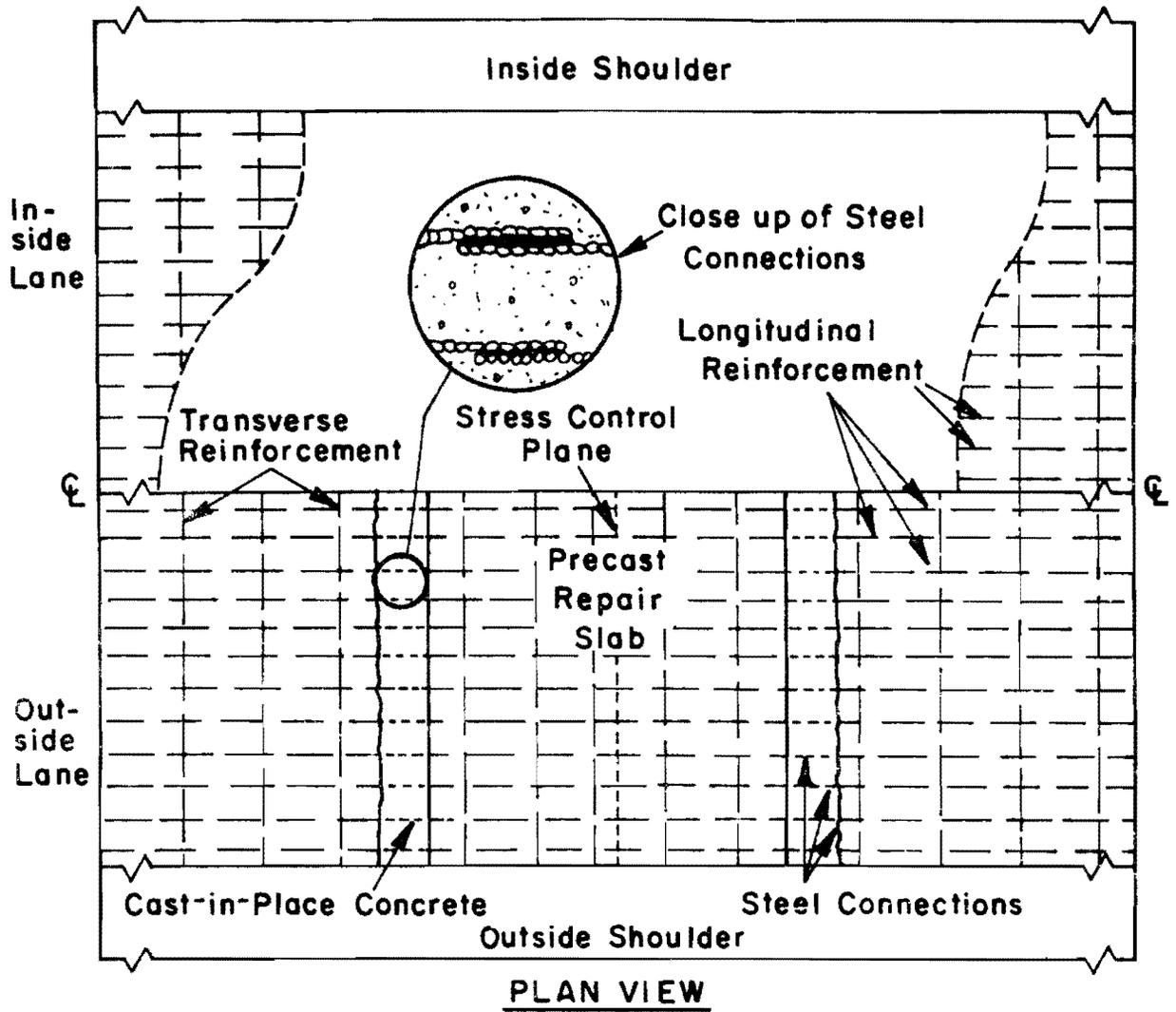


Fig 1. Precast repair methodology applied to CRCP.  
(After Ref 1).

## Chapter 3

### FACTORS AFFECTING DESIGN OF CRCP REPAIRS

The structural response of CRCP is composed of a complex set of interacting elements. When the normal continuity of this pavement type is disrupted, as is the case when full depth repairs are performed, the resulting discontinuities add to the complexity. To rationally design a repair, these factors and their influence must be anticipated and analyzed. Structural response is not the only factor affecting design of repairs. Two other factors which should be considered are the dimension of CRCP and preparation of the deteriorated area.

Size compatibility of separately constructed structural elements is an important consideration in all engineered construction. This is of prime importance to precast repair slabs which must form a smooth riding surface with adjacent pavement. The dimensions of CRCP which influence prefabrication of repair slabs include overall size and shape, reinforcement dimensions, and dimensions of deteriorated areas.

#### PREPARATION OF DETERIORATED AREA

Preparation of the deteriorated area includes removal of concrete and removal of damaged subbase.

The removal of concrete should include all deteriorated or damaged concrete, be performed as quickly as possible, minimize disturbance to the surrounding concrete and subbase, and be made to the proper dimensions. It is important that the concrete be excavated back to sound material. Experience with portland cement concrete patches has shown that there is a tendency for the areas adjacent to the patches to fracture, rock, become dislodged, and require replacement.

Time is an important element of highway repairs. The quicker the concrete is removed, the longer the time is available for installation and curing of the repair before traffic must be returned to the area.

Detrimental effects to the surrounding pavement structure during removal of concrete should be minimized. With some of the impact tools used for this purpose, damage to the surrounding concrete may be unavoidable. In this case, the repair design should be made so as to lessen the effects of the concrete removal equipment as much as possible.

It is important that steel continuity in CRC pavements be maintained. The concrete removal equipment should be capable of removing the concrete from around the steel reinforcement to provide for steel connections. The disruption of steel continuity resulting from cutting of the steel should be for only a brief period since temperature variations will create movements in the slab ends which may be destructive to the adjacent lane and also the repair.

Determination should be made of the cause of pavement failure. Many times it is not possible to determine the cause from inspection of the surface. Observation of the area during concrete removal operations may help in the identification. If possible, corrective steps should be taken to prevent similar failure of the repair.

During the preparation of the area to be repaired, the lane being repaired should be blocked off in a positive manner to protect workmen from vehicular traffic.

#### DESIGN RECOMMENDATIONS

Recommendations on the design of precast slab elements are presented in this section. The elements of precast repair slab discussed are slab dimensions, steel reinforcement, lift connections, weakened plane, and steel anchorage. The recommendations presented here are composite for Texas conditions. Adaptations to specific conditions for other areas may be necessary.

Slab Dimensions. The slab thickness should be reduced 0.2 to 0.25 inch (5.08 to 6.35 mm) less than the depth of the pavement being repaved, unless other knowledge indicates otherwise.

The width of the slab should be 0.5 to 1.0 inch (12.7 to 25.4 mm) less than the full lane width. This will depend upon the treatment of the inside

edge adjacent to the next lane and the edge next to the shoulder.

The required slab dimensions for a precast repair are shown in Fig 2. The length of a precast repair slab may be determined with the following equation:

$$L_S = L_R - 2L_{AZ} \quad (1)$$

where

$L_S$  = length of precast repair slab, in.,

$L_R$  = total length of repair, in., and

$L_{AZ}$  = length of steel anchorage zone, 8 to 10 in. (203 to 254 mm).

The width of the precast slab may be determined by

$$W_S = W_R - X \quad (2)$$

where

$W_S$  = width of precast repair slab, in.,

$W_R$  = width of repair = lane width, in., and

$X$  varies according to edge treatment, 0 to 1 in. (25.4 mm).

The recommended thickness of a precast repair slab, shown in Fig 3, is

$$D_S = D_P - 0.25 \quad (3)$$

where

$D_S$  = depth of precast repair slab, in., and

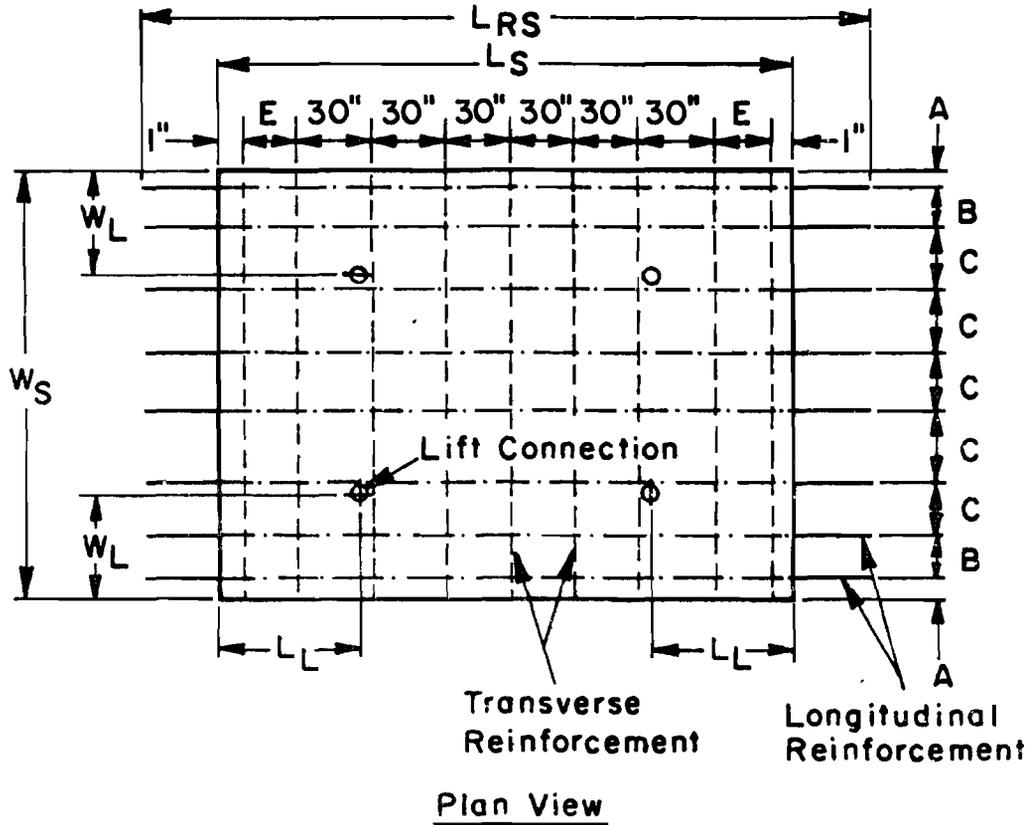
$D_P$  = CRCP depth, in.

Steel Reinforcement. The same type of steel reinforcement used in the pavement to be repaired should be used in the repair slab. The exception to this rule is for CRCP constructed with smooth welded wire fabric. In this case, the use of deformed wire should be considered. Deformed reinforcing steel should be used for all precast repair slabs. Guidelines to the steel reinforcement used in 70 to 90 percent of the CRC pavements constructed in Texas between 1959 and 1970 are listed in Table 1.

The recommended dimensions and placement of reinforcement in a precast repair slab are shown in Fig 2. The spacing, grade, and diameter of longitudinal steel reinforcement are controlled by the steel present in the existing CRCP. The length of the longitudinal reinforcing steel is

### TRANSVERSE REINFORCEMENT

E = variable spacing to accommodate the transverse steel spacing



### SLAB DIMENSIONS

$$L_S = \text{precast slab length} = L_R - 2SL_{AZ}$$

$$L_R = \text{length of repair (not shown)}$$

$$L_{AZ} = \text{length of steel anchorage zone (not shown)}$$

$$L_L = \text{distance to lift connection} = L_S/4$$

$$W_S = \text{precast slab width} = W_R - X$$

$$W_R = \text{width of repair} = \text{lane width (not shown)}$$

$$X = \text{varies for edge treatment, 0 to 1 inch}$$

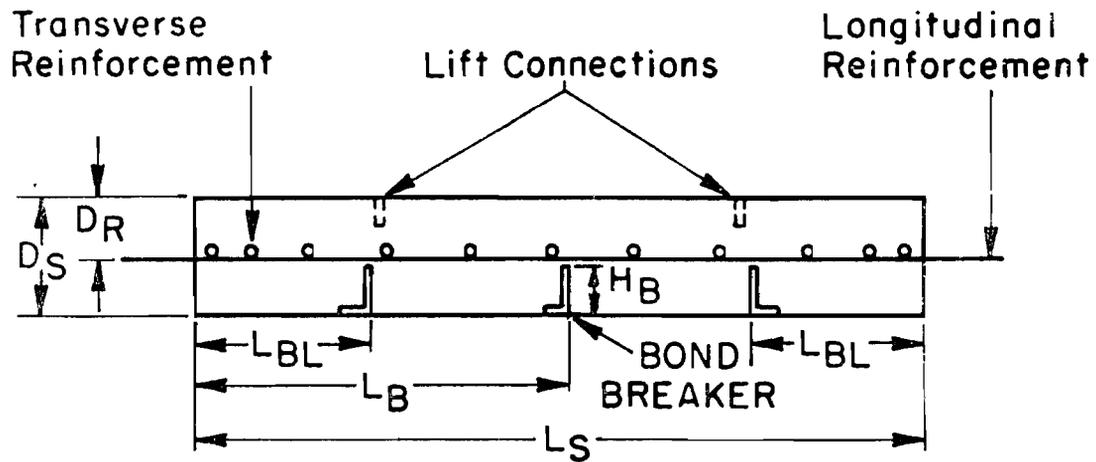
$$W_L = \text{distance to lift connection} = W_S/4$$

### LONGITUDINAL REINFORCEMENT

$$L_{RS} = \text{length of longitudinal reinforcement} = L_R - 6 \text{ inches}$$

$$A, B, C = \text{longitudinal steel spacing of pavement, see Table 1}$$

Fig 2. Guidelines for dimensions of precast repair slabs for Texas. (After Ref 1).

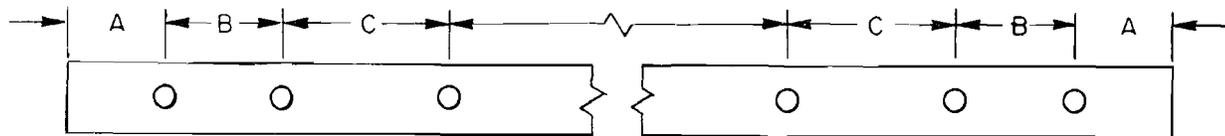


- $D_S$  = slab depth =  $D_p - 0.25$  inch  
 $D_R$  = depth of longitudinal reinforcement =  $D_p/2$   
 $L_S$  = precast slab length, Fig 1  
 $L_B$  = distance to bond breaker =  $L_S/2$  when  $L_S > 7$  feet  
 $L_{BL}$  = distance to bond breaker -  $(L_S/4) - 1$  inch when  $L_S > 14$  feet  
 $H_B$  = height of bond breaker, Fig 4

Fig 3. Guidelines for dimensions of precast repair slabs for Texas.  
(After Ref 1).

TABLE 1. GUIDELINES FOR CRCP CONSTRUCTED IN TEXAS BETWEEN 1959 AND 1970<sup>1</sup>  
(After Ref 1)

| Pavement Thickness, in. | 0.5 Percent Longitudinal Steel<br>High Yield, 60 ksi, Deformed Steel Bars |                   |         |         |                   |        |        | 0.6 Percent Longitudinal Steel<br>Hard Grade, 50 ksi, Deformed Steel Bars |                   |        |        |                   |        |        |
|-------------------------|---|-------------------|---------|---------|-------------------|--------|--------|---|-------------------|--------|--------|-------------------|--------|--------|
|                         | Bar No.   | 24-Foot Placement |         |         | 12-Foot Placement |        |        | Bar No.   | 24-Foot Placement |        |        | 12-Foot Placement |        |        |
|                         |   | A*, in.           | B*, in. | C*, in. | A, in.            | B, in. | C, in. |   | A, in.            | B, in. | C, in. | A, in.            | B, in. | C, in. |
| 8                       | 5   | 3                 | 6       | 7.5     | 3                 | 5.25   | 7.5    | 5   | 3.5               | 4      | 6.5    | 3                 | 4      | 6.5    |
| 7                       | 5   | 3                 | 5       | 8.5     | 4                 | 8.5    | 3.5    | 5   | 3                 | 6      | 7.5    | 3                 | 5.25   | 7.5    |
| 6                       | 4   | 3                 | 4.5     | 7       | 3                 | 6      | 7      | 5   | 3                 | 5      | 8.5    | 4                 | 8.5    | 8.5    |



\* A, B AND C ARE STEEL SPACING DIMENSIONS, AS SHOWN ABOVE.

<sup>1</sup>These dimensions will vary slightly for projects designed and constructed by the Houston Urban Office

1 in. = 25.4 mm

1 psi = 6.89 kPa

1 ft = .305 m

$$L_{RS} = L_R - Y \quad (4)$$

where

$$\begin{aligned} L_{RS} &= \text{length of longitudinal steel reinforcement, in.,} \\ L_R &= \text{length of repair, in.} \\ Y &= 6 \text{ in. (152 mm) to } 2L_{AZ}, \text{ in., depending on steel} \\ &\quad \text{anchorage, and} \\ L_{AZ} &= \text{length of steel anchorage zone, in.} \end{aligned}$$

The depth of the longitudinal steel reinforcement should be the same as in the pavement being repaired. In Texas this distance should be

$$D_R = D_P/2 \quad (5)$$

where

$$\begin{aligned} D_R &= \text{distance from the surface of the slab to the centroid} \\ &\quad \text{of the longitudinal steel reinforcement, in., and} \\ D_P &= \text{depth of pavement to be repaired, in.} \end{aligned}$$

The transverse steel reinforcement should consist of No. 4, grade 60, steel reinforcing bars unless deformed wire fabric is used. The transverse spacing should be 30 in. (76.2 cm), varying at the ends of the slab as required. The length of the transverse steel reinforcement should be

$$L_{TR} = W_S - 3.0 \quad (6)$$

where

$$\begin{aligned} L_{TR} &= \text{length of transverse reinforcement, in., and} \\ W_S &= \text{width of precast repair slab, in.} \end{aligned}$$

The transverse reinforcement should be positioned on top of the longitudinal reinforcement.

Lift Connections. The positions of threaded inserts for lifting connections are shown in Fig. 2. The distance from the edge of the slab to the lift points should be

$$W_L = W_S/4 \quad (7)$$

where

$$\begin{aligned} W_L &= \text{distance to lift point along transverse edge, in., and} \\ W_S &= \text{width of precast repair slab, in.} \end{aligned}$$

$$\text{and } L_L = L_S/4 \quad (8)$$

where

$$\begin{aligned} L_L &= \text{distance to lift point along longitudinal edge, in., and} \\ L_S &= \text{length of precast repair slab, in.} \end{aligned}$$

It should be noted that in addition to the threaded inserts there are several other types of lift mechanisms available from commercial sources. Some of these may offer advantages over the threaded type of insert.

Weakened Plane. For precast repair slabs longer than 7 feet (2.13 m), a weakened plane, formed with a bond breaker made out of 28-gage galvanized metal, should be oriented in the middle of the slab. The dimensions and details of bond breakers for varying pavement thicknesses are shown in Fig 4. The distance from the end of the slab to the bond breaker is

$$L_B = L_S/2 \quad (9)$$

where

$$\begin{aligned} L_B &= \text{distance from end of slab to bond breaker, in., and} \\ L_S &= \text{length of precast repair slab, in.} \end{aligned}$$

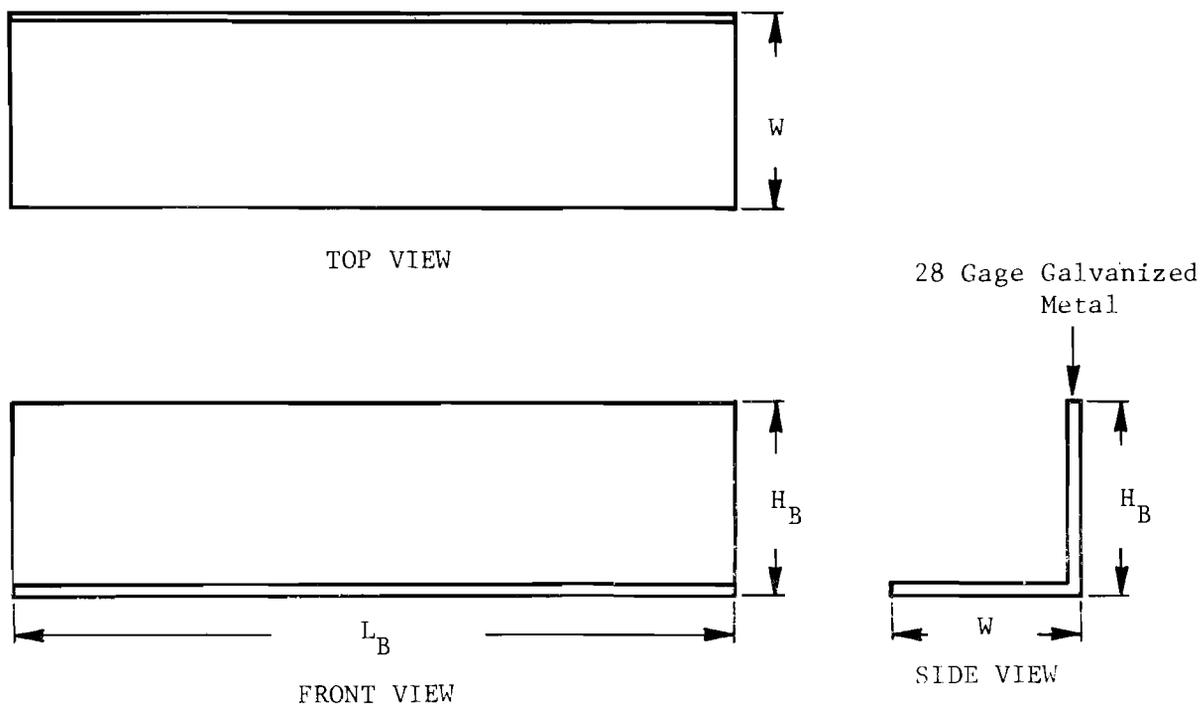
Precast slabs longer than 14 feet (4.26 m) will require two additional weakened planes. These bond breakers are positioned near the quarter points of the slab length and should not interfere with the lifting hardware positioned there. The distance from the end of the slab to these bond breakers is

$$L_{BL} = L_S/4 - 1 \quad (10)$$

where

$$\begin{aligned} L_{BL} &= \text{distance from end of slab to additional bond breakers} \\ &\quad \text{for slabs longer than 14 feet (4.26 m), in., and} \\ L_S &= \text{length of precast repair slab, in.} \end{aligned}$$

Steel Anchorage. The use of prepositioned steel reinforcement in the precast slab aligned with the reinforcement in the CRC pavement is recommended. Positive steel connections, made with individual lap welds, weld transfer plates, or cable clamps appear to offer the best anchorage regardless of the cast-in-place concrete to be placed around them. The length of the steel anchorage zone should be greater than 6 inches (152 mm) and less than 12 inches (305 mm). A 10-inch (254-mm) long anchorage zone should be adequate for the above connections.



Dimensions:

| Pavement Thickness, in. | Height of Bond Breaker, $H_B$ , in. | Width of Bond Breaker, $W$ , in. |
|-------------------------|-------------------------------------|----------------------------------|
| 6                       | 2                                   | 2                                |
| 7                       | 2.50                                | 2.50                             |
| 8                       | 2.75                                | 2.75                             |
| 10                      | 3.25                                | 3.25                             |

$L_{BB}$  = length of bond breaker, in.

$$L_B = W_S - 3.0 \quad \text{in.} = 25.4 \text{ mm}$$

where  $W_S$  = width of precast repair slab, in.

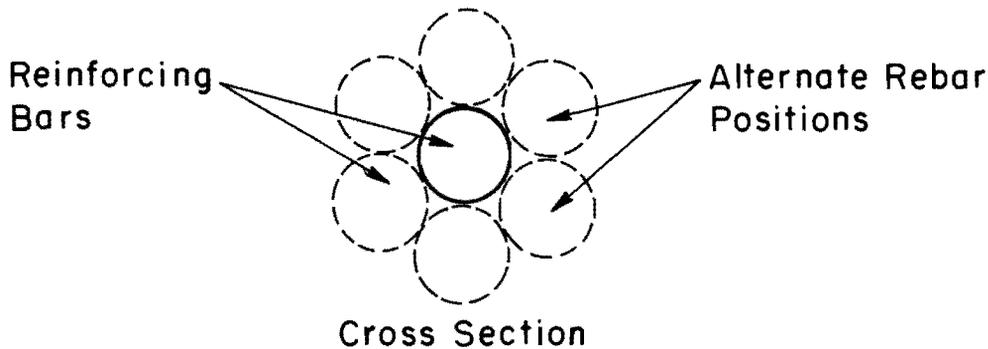
Fig 4. Recommended dimension for bond breakers in precast repair slabs longer than 7 ft (2.13 m) (after Ref 1).

The use of polymer concrete in the steel anchorage zones is highly recommended. This material not only offers excellent bond characteristics with steel, it is capable of penetrating, filling the voids, and strengthening the concrete in the adjacent pavement. The use of a combination positive/passive steel connection is possible with this material due to its superior bond with steel. In addition, the length of the anchorage zone can be reduced. Positive steel connections should be made 8 to 10 inches (203 to 254 mm) long. Guidelines for the steel anchorage zone are shown in Fig 5.

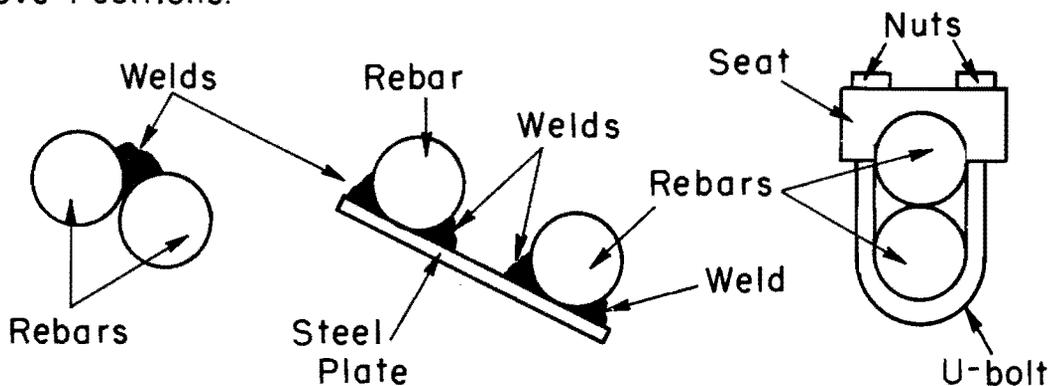
#### SLAB PREPARATION

The following steps are recommended for the preparation of precast repair slabs for CRCP:

- (1) Select convenient area to cast slabs.
- (2) Construct forms:
  - (a) the width between the parallel sides of the form should be equal to  $W_S$ , determined from Eq 2 with X equal to 1.0;
  - (b) the length between end pieces should equal  $L_S$  in Eq 1 with  $L_{AZ}$  equal to 10; and
  - (c) forms should be constructed in accordance with Item 420.0 of the Standard Specifications (Ref 10).
- (3) Place polyethylene sheets on the ground over the casting bed. The sheets should have a minimum thickness of 4 mm (0.004 in.).
- (4) Assemble forms over the polyethylene sheets.
- (5) For slabs longer than 7 feet (2.13 m), insert and secure bond breakers as shown in Figs. 3 and 4.
- (6) Place longitudinal reinforcement:
  - (a) determine length of rebars with Eq 4 with  $Y = 5$ ;
  - (b) cut rebars;
  - (c) place rebars in forms and position according to steel spacing in CRCP, Table 1; and
  - (d) support rebars on metal or plastic chairs. Do not use wood or cinder blocks.
- (7) Place transverse reinforcement:
  - (a) position transverse reinforcement on top of the longitudinal reinforcement according to spacing shown in Fig 2; and
  - (b) tie steel together at intersections.



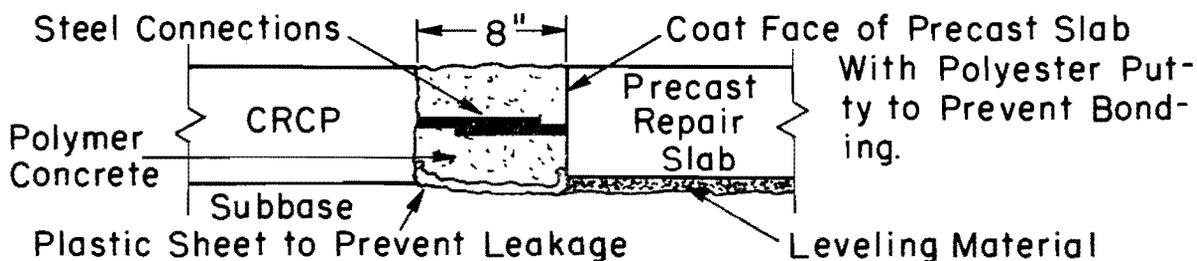
Align Corresponding Rebars as Close as Possible in One of the Above Positions.



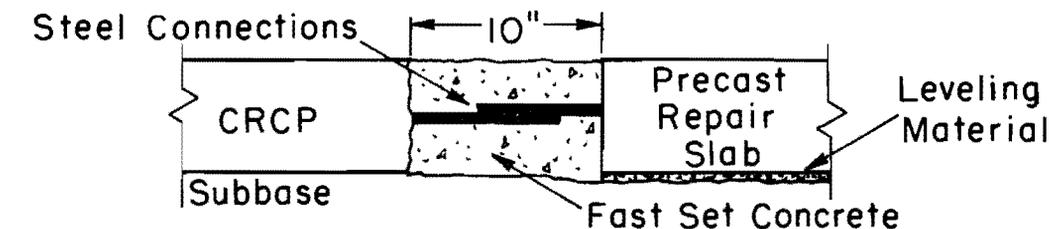
Lap Welded Bars

Unaligned Bars  
Welded Using Steel Plate

Cable Clamped Bars



Side View of Anchorage Zone With Polymer Concrete Filler



Side View of Anchorage Zone With Fast Set Concrete Filler

1 in. = 25.4

Fig 5. Guidelines for steel anchorage. (After Ref 1).

- (8) Place lift connections:
  - (a) position lift connections at the positions shown in Fig 2; positions may be calculated with Eqs 7 and 8;
  - (b) align top of lift connection with surface of precast slab; and
  - (c) insert movable plugs into threads to prevent entrance of foreign material.
- (9) Concrete mix should conform to Item 366 (Ref 10), use same coarse aggregate as existing concrete.
- (10) Cast concrete beam specimens as outlined in State Department of Highways and Public Transportation Bulletin C-11 (Ref 2).
- (11) Place and vibrate concrete in accordance with Item 366 (Ref 10).
- (12) Strike concrete off to the proper elevation. Do not overwork.
- (13) Create a skid resistant surface texture with a burlap drag or stiff-bristled hand broom as specified in Item 360.8 (Ref 10).
- (14) Cure the concrete with a curing membrane or wet mat as specified in Item 360.9 (Ref 10).
- (15) Remove forms:
  - (a) allow concrete to cure a minimum of 72 hours before removing forms; and
  - (b) do not damage concrete surfaces or edges.
- (16) Do not lift slabs until concrete has reached the strengths listed in Table 2.

#### SLAB TRANSPORTATION

Handling and transportation of large concrete slabs may result in chipping of edges or scuffing of the surface texture. Prevention of damage to precast slabs and safety of workmen are the principal considerations for the transport operation.

Precast repair slabs may be lifted with a simple mechanism consisting of four swivel lift plates attached to the slab with threaded inserts.

Analysis shows that stress levels for the 1/4 span placement of the lift points resulted in low stresses and compression in the bottom fiber. Compression in the lower slab fiber is important to prevent slabs with weakened planes from prematurely cracking due to the loss of bond.

TABLE 2. REQUIRED MEAN FLEXURAL STRENGTH FOR LIFTING  
 PRECAST SLAB WITH LIFT POINT PLACED AT 1/4 SPAN  
 (After Ref 1)

| Slab Size,<br>ft | Standard<br>Deviation<br>of Concrete<br>Strength,<br>psi | Required Mean<br>Flexural Strength,<br>psi |
|------------------|--|--|
| 12 x 6           | 20   | 180  |
|                  | 40   | 215  |
|                  | 60   | 250  |
| 12 x 12          | 20   | 270  |
|                  | 40   | 310  |
|                  | 60   | 345  |
| 12 x 14          | 20   | 345  |
|                  | 40   | 380  |
|                  | 60   | 420  |
| 12 x 20          | 20   | 500  |
|                  | 40   | 540  |
|                  | 60   | 580  |

$$1 \text{ ft} = 0.305 \text{ m} \quad 1 \text{ psi} = 6.89 \text{ kPa}$$

TABLE 3. APPROXIMATE WEIGHT OF PRECAST CONCRETE SLABS  
(After Ref 1)

| Slab Width, ft | Slab Length, ft | Slab Thickness, in. | Approximate Weight,* lb |
|----------------|-----------------|---------------------|-------------------------|
| 12             | 4               | 6                   | 3,600                   |
|                |                 | 8                   | 4,800                   |
|                |                 | 10                  | 6,000                   |
| 12             | 6               | 6                   | 5,400                   |
|                |                 | 8                   | 7,200                   |
|                |                 | 10                  | 9,000                   |
| 12             | 12              | 6                   | 10,800                  |
|                |                 | 8                   | 14,400                  |
|                |                 | 10                  | 18,000                  |
| 12             | 14              | 6                   | 12,600                  |
|                |                 | 8                   | 16,800                  |
|                |                 | 10                  | 21,000                  |
| 12             | 20              | 6                   | 18,000                  |
|                |                 | 8                   | 24,000                  |
|                |                 | 10                  | 30,000                  |

\*Based on unit weight of  $150 \text{ lb/ft}^3$  ( $2403 \text{ kg/m}^3$ )

1 ft = 0.305 m      1 in. = 25.4 mm      1 lb = 2.205 kg

The following procedures are recommended for transportation of precast repair slabs to the repair site.

- (1) Allow concrete to attain the mean concrete strengths listed in Table 2.
- (2) Bolt swivel lift plates to lift connections.
- (3) Lift slab with movable lifting equipment. The approximate weight for a range of precast concrete slabs is presented in Table 3.
- (4) Place slab on transport vehicle:
  - (a) use a flat bed truck so that the bottom surface of the slab is in full contact with the truck bed;
  - (b) for more than one slab, place 2 x 8 wood runners spaced 24 in. center-to-center between the slabs;
  - (c) secure the slabs to the truck to prevent movement during transportation.
- (5) Remove lifting hardware.
- (6) Drive to repair location.
- (7) Reinsert lifting hardware and remove slabs from vehicle.

#### INSTALLATION PROCEDURE

The following procedure is recommended for the removal of deteriorated pavement and placement of a precast repair slab.

- (1) Block off traffic in lane to be repaired. A positive protection device, such as a portable crash cushion (Ref <sup>4</sup>), should be used in addition to common signing practices.
- (2) Determine length of unsound pavement;
  - (a) estimate length of unsound pavement;
  - (b) select length based upon lengths of prepared slabs or based upon deterioration and cast repair slab to size;
  - (c) include length of steel anchorage zones.
- (3) Mark saw cut lines:
  - (a) mark length of precast repair slab on outside edge of pavement;
  - (b) measure and mark length of steel anchorage zones along edge of pavement;
  - (c) construct a line across the pavement perpendicular to the edge using the 3-4-5 or 5-12-13 right triangle methods;
  - (d) mark parallel lines at other marks on outside of pavement; and
  - (e) use a permanent type water resistant marker.

- (4) Perform saw cuts:
  - (a) make cuts on end lines  $2\frac{1}{2}$  in. (63.5 mm) deep, avoid cutting longitudinal reinforcing steel;
  - (b) make cuts to within  $\frac{1}{2}$  in. (12.7 mm) of concrete depth along the two inside transverse lines, cutting the steel; and
  - (c) make other cuts as required to dislodge deteriorated concrete.
- (5) Remove concrete from around steel in steel anchorage zone:
  - (a) use jackhammer or pavement breaker attachment on backhoe;
  - (b) do not damage reinforcing steel;
  - (c) leave vertical face on concrete at ends of the repair; and
  - (d) remove any transverse steel in anchorage zone.
- (6) Dislodge remaining deteriorated concrete from shoulder and adjacent pavement with an air hammer.
- (7) Remove deteriorated pavement:
  - (a) expose reinforcing steel on deteriorated portions by chipping away concrete, attach lifting chains at these points, and lift sections from pavement, or, drill holes into deteriorated concrete and place key lifting bolts to remove concrete;
  - (b) place debris in dump truck;
  - (c) minimize damage to subbase course; and
  - (d) remove all broken concrete and debris from area.
- (8) Repair subbase course as required.
- (9) Prepare leveling course:
  - (a) set up track-screed assembly;
  - (b) adjust screed to align precast slab with adjacent CRCP surface;
  - (c) place concrete grout on surface of subbase; and
  - (d) strike grout off with transverse and longitudinal movements of screed.
- (10) Position precast slab into repair:
  - (a) attach lifting devices to slab;
  - (b) lower slab into position;
  - (c) keep slab level while lowering into position;
  - (d) adjust position while lowering with hands or prying tools.

- (11) Anchor steel at end of slab following anchorage strategy.
- (12) Place cast-in-place concrete in anchorage zones.
- (13) Fill sides around precast slab;
  - (a) place grout along inside edge of slab; and
  - (b) place bituminous mixture along outside edge of slab between bituminous shoulder; use grout if repair is adjacent to portland cement concrete shoulder or another lane.

## Chapter 4

### FIELD INSTALLATION

Using the procedure described in previous sections, two punchouts in the eastbound lane of IH 30 near Mt. Pleasant, Texas were repaired. This is the first known application of a precast slab repair to CRCP in this country. The existing pavement is an 8-in. thick surface course with #5 longitudinal bars on 7 1/2-in. centers with #4 transverse bars on 30-in. centers. The base course is a cement-treated soil material.

One of the repair areas was full-lane width (12 feet) by 12 feet long. The other was half-lane width (6 feet) by 6 feet long. The repair areas were outlined and saw cuts were made about 3 inches deep (Fig 6). A jack hammer was used to break up the concrete around the periphery of the repair to expose about 8 inches of the longitudinal steel. A cutting torch was used to cut the steel. The concrete was then removed from the repair area. A wood form was placed on the shoulder side of the repair to give a straight edge for alignment of the precast slab. Figure 7 illustrates the repair area ready to receive the precast panel.

The repair slabs were formed and cast in the SDHPT maintenance yard at Mt. Pleasant and were allowed to cure for seven days before placement in the pavement. The slabs were transported to the job site on a flat bed trailer, and a crane was used to place the slabs on a mortar bed. Beams with adjustable leveling shoes were used to get the slabs in final position (Figs 8, 9, and 10).

With the slab in final position, the longitudinal steel was connected using two different methods. For the larger repair, the steel connections were welded. U-bolts were used for the connections on the smaller repair. For these repairs, the alignment between the existing longitudinal steel and pre-cast panel steel was very good, and no special connections were required.

After the steel connections were made, the voids between the precast slab and the existing pavement were filled with polymer concrete. Two



Fig 6. Repair area showing punchout



Fig 7. Repair area ready to receive precast slab.

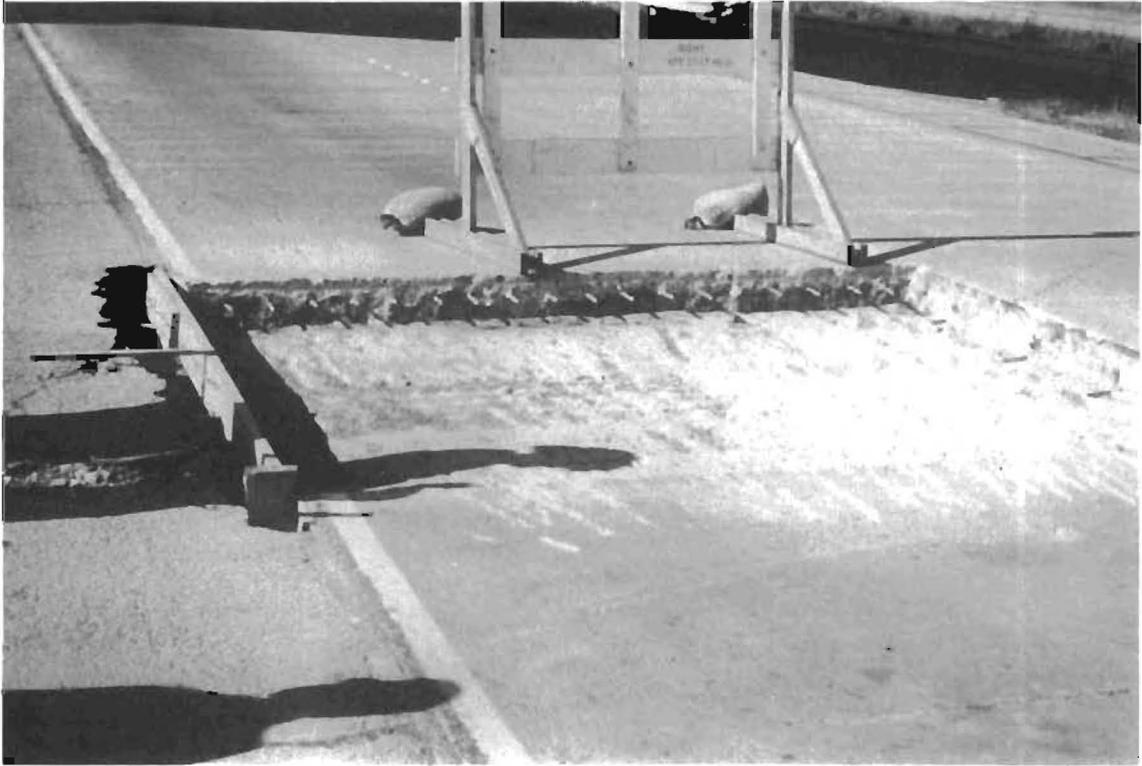


Fig 8. Work area during repair.



Fig 9. Work area showing bedding grout.



Fig 10. Precast repair showing leveling beams.

polymer concrete systems were used. A pre-packaged, commercially-available product manufactured by the Rohm and Haas Company under the trade name Plexi-Crete<sup>R</sup> was used for the small repair. A monomer developed by Drs. Fowler and Paul at the University of Texas at Austin was used for the larger repair. Both systems are methyl methacrylate-based and well-documented in previous research.

The set-time for the polymer concrete is normally about 30 minutes. Due to low ambient temperatures during the Mt. Pleasant repairs (50 to 70°F), the set times were 45 minutes to an hour. Once the polymer concrete has set, the repair can be opened to traffic, assuming no repairs are needed on the shoulder. In these repairs, a void was left at the shoulder and these voids were filled with cold mix asphalt concrete and compacted. The repairs were then opened to traffic. Figures 11 and 12 illustrate the completed repairs. Total time for both repairs was less than 12 hours.

The repairs were made in November, 1979, and, to date, are performing in excellent fashion.



Fig 11. Completed 12' x 12' precast panel repair.



Fig 12. Completed 6' x 6' precast repair.

## Chapter 5

### CONCLUSIONS AND RESEARCH NEEDED

#### CONCLUSIONS

Although some unanswered questions remain, the following conclusions can be drawn:

- (1) Repair of CRCP with precast panels is a viable alternative.
- (2) Repairs can be made with less than a 6-hour lane closure.
- (3) The method is cost effective when user delay costs are included (less than one day versus three to seven days for conventional repairs).

#### RESEARCH NEEDED

- (1) Refinement of repair technique--it appears feasible that with a trained crew the lane closure time could be reduced to less than four hours for a single repair.
- (2) A complete factorial experiment to evaluate pertinent variables; for example, laboratory tests indicate that when polymer concrete is used, the steel may not need to be connected.
- (3) Evaluate long-term performance.

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B. Frank McCullough is a Professor of Civil Engineering at The University of Texas at Austin, and is Director of the Center for Transportation Research. He has strong interests in pavements and pavement design and has developed design methods for continuously reinforced concrete pavements currently used by the State Department of Highways and Public Transportation, U.S. Steel Corporation, and others. He has also developed overlay design methods now being used by the FAA, U.S. Air Force, and FHWA. During nine years with the State Department of Highways and Public Transportation he was active in a variety of research and design activities. He worked for two years with Materials Research and Development, Inc., in Oakland, California, and for the past nine years for The University of Texas at Austin. He participates in many national committees and is the author of over 100 publications that have appeared nationally.



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