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CONCRETE PAVEMENT GUIDE
PART 3: PRESERVATION STRATEGIES
CHAPTER 380 – CONTINUOUSLY REINFORCED CONCRETE PAVEMENT FULL-DEPTH REPAIR

This chapter discusses the design and construction processes used in the full-depth repair (FDR) of CRCP, providing guidelines and criteria to replace localized areas of deteriorated pavement with reinforced concrete.

380.1 PURPOSE AND DESCRIPTION

Full-depth repair (FDR) of continuously reinforced concrete pavement (CRCP) is used to restore localized areas of damage when normal maintenance repairs can no longer be applied. FDR involves the full-depth, full-lane-width removal of a deteriorated CRCP area and replacement with RSC or conventional concrete that meets the durability and opening-time demands of the project. Underlying base repair may also be required with FDR, separated from the RSC pavement by a polyethylene bond breaker.

CRCP-FDR can extend pavement service life, delaying the need for costly overlays or total pavement reconstruction while addressing ride quality and safety issues. For FDR to be most effective, it must be engineered and constructed properly at the right time in the pavement life cycle. If the window of opportunity is missed, pavement distress will increase at an accelerated rate and FDR will be ineffective.

CRCP-FDR is currently a nonstandard strategy in the process of being standardized for the revised 2015 Standard Specifications. In the interim, a nonstandard special provision and construction details are available from the Office of Concrete Pavement in the Headquarters Division of Maintenance or by submitting a nonstandard special provision (nSSP) request to: nssp.submittals@dot.ca.gov.

Figure 380-1: Typical CRCP punchout distress (FHWA)
380.1.1 Background

CRCP is constructed with longitudinal and transverse reinforcing bars and no transverse joints. The reinforcement bars in the longitudinal direction keep the transverse cracks tight and additional transverse bars are used also in the transverse direction to hold the longitudinal steel in place. The longitudinal steel and aggregate interlock provide good load transfer at transverse cracks or construction joints.

CRCP is designed to crack in the transverse direction to relieve stress, so transverse cracks are not considered distress. The longitudinal bars in CRCP typically keep the transverse cracks tight from 0.02” to 0.04”. If transverse cracks widen, water will readily infiltrate the crack and erode underlying support. Associated high deflections under repetitive heavy traffic loads can cause the reinforcement bars to rupture, resulting in faulting and punchouts (see Figure 380-1).

CRCP is designed to have $\leq 10$ punchouts per mile at the end of its design life. Punchouts can be caused by poor concrete consolidation around reinforcing steel that prevents adequate bonding, which can cause large crack spacing from 10’ to 14’ that sometimes leads to transverse crack widening and increased tensile stress in the reinforcement. If the reinforcement ruptures, the transverse crack will open and close freely, losing most load transfer, allowing water infiltration, and compromising CRCP performance. Typically, the steel reinforcement ruptures first in the outside lane, placing more stress on the inner bars as rupture progresses from the outside inward.

380.2 Appropriate Use

FDR and base replacement should be considered to address CRCP distress caused by excessive wheel loading, pumping, and inadequate CRCP structural capacity from deficient concrete thickness or underlying support). CRCP distress such as longitudinal cracks, wide transverse cracks, and faulting are precursors to punchout failures. The punchout severity and extent should be evaluated using the criteria in Table 380-1 to identify FDR or other potential CRCP pavement strategies.

<table>
<thead>
<tr>
<th>APCS Distress Type</th>
<th>Severity</th>
<th>Extent (per lane-mile)</th>
<th>Recommended Primary Strategy*</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRCP Punchouts</td>
<td>Low</td>
<td>1</td>
<td>None</td>
<td>APCS Manual, Ch. 380</td>
</tr>
<tr>
<td>(Count $\geq 1$)</td>
<td>Medium</td>
<td>2–5</td>
<td>Full-depth repair</td>
<td>Ch. 380, 370</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>&gt; 10</td>
<td>Lane replacement, HMAOL, Unbonded concrete overlay</td>
<td>Ch. 400, 370, 420</td>
</tr>
</tbody>
</table>

If CRCP distress is not repaired, increased deterioration will occur, further reducing ride quality.

Where to replace underlying base is determined based on the condition of the pavement structure being repaired. Pavement distress indicators of deteriorated underlying base include:

- Cracking with settlement $> \frac{1}{4}”$
- Pumping
- Spalling $> 2\text{ft}^2$ total or $> 2”$ wide over 75% of the crack length

Removing and replacing the existing base affects the initial cost, duration, and ongoing maintenance demands of the project. Replacing underlying base in good condition will unnecessarily increase the construction time and material costs, while performing only concrete FDR when the treated base is deteriorated will lead to early repair failure and increased costs for additional repairs.
380.3 MATERIALS

FDR uses concrete bases, polyethylene bond breaker, bar reinforcement, and RSC materials to repair CRCP. HMA should only be considered for temporary CRCP repairs. Bituminous materials are not recommended for permanent repairs of concrete pavement because they allow excessive horizontal movement, provide no load transfer across transverse joints, and may lead to rapid deterioration.

380.3.1 Base Replacement Materials

Rapid strength concrete base (RSCB) or lean concrete base rapid setting (LCBRS) is used to replace existing base under CRCP-FDR. RSCB is RSC that complies with Section 90-3 of the Standard Specifications, although it must be placed separately from the RSC pavement surface using a polyethylene bond breaker. RSCB is the preferred material for any necessary repairs to the underlying base layer. Using RSCB instead of LCBRS can simplify the construction operation and add strength to the pavement structure.

380.3.2 Base Bond Breaker

Base bond breaker is a material used to reduce friction between concrete pavement and base material that can lead to cracking. The bond breaker allows the pavement structure layers to move independently, reducing reflective cracking and providing flexibility for concrete curling due to temperature differences between the top and bottom of the pavement surface.

For CRCP-FDR, a white, opaque polyethylene film that complies with the specifications for base bond breaker no. 3 under SSP 36-2 must be installed on top of the base layer before the RSC pavement surface is placed.

380.3.3 Reinforcement Bars

CRCP-FDR uses both longitudinal and transverse steel bars for reinforcement continuity at the construction joints. Deformed steel bars that meet the requirements in Section 52 of the 2010 Standard Specifications are used. The use of epoxy-coated reinforcement is not typically necessary for CRCP, except in areas where corrosion is known to be a problem because of the presence of salts. Epoxy coating should be used where the pavement is within 1/2 mile from a saltwater body or in high desert and mountain climate regions. The pavement climate regions map is available on the Pavement website at: http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement_Engineering/PDF/Pavement_Climateregions_100505.pdf

380.3.4 Rapid Strength Concrete

RSC is typically used for FDR because of the need for high early strength before opening to traffic. Standard Specification Section 90-3 allows the contractor to design the concrete mix depending on available curing time. Generally, 4 types of concrete mixes are used for FDR (see Table 380-2).

<table>
<thead>
<tr>
<th>Typical Curing Time (hours)</th>
<th>Concrete Mix Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2–4</td>
<td>Specialty high early strength cement mixes. The cement may be portland, non-portland, or blended.</td>
</tr>
<tr>
<td>4–6</td>
<td>In addition to specialty cements, Type III portland cement with non-chloride accelerators and high-range water-reducing admixture may be used if shrinking and early age cracking requirements are met.</td>
</tr>
<tr>
<td>&lt; 24</td>
<td>Type II portland cement with non-chloride accelerators</td>
</tr>
<tr>
<td>≥ 24</td>
<td>Conventional*</td>
</tr>
</tbody>
</table>

*Note: Preferred for lower cost and superior performance when strength can be attained before traffic opening.
The use of calcium chloride (CaCl₂) accelerators to achieve rapid strength is not allowed since they can double the rate of steel corrosion and concrete shrinkage, resulting in excessive pavement cracking.

Although RSC repair materials can provide effective solutions for early opening to traffic, there are also associated performance concerns. For example, NCHRP Report 540 about early-opening-to-traffic (EOT) RSC mixtures noted that many such mixes contain higher cement contents and multiple admixtures, which can lead to increased shrinkage, altered microstructure, and unexpected interactions. Furthermore, the study noted:

- Durable 6 to 8-hour and 20 to 24-hour EOT repairs can be constructed, but the 6- to 8-hour EOT concrete materials are more prone to durability-related problems, heightening the risk of premature failure.
- Difficulty in achieving an adequate entrained air-void system was associated with EOT concrete, resulting in paste freeze-thaw deterioration and deicer scaling.
- Increasing cement content does not necessarily increase concrete strength, and may adversely affect the durability of the RSC mixture.
- Increased problems may result from interactions between the various mixture constituents. Extensive testing should be conducted on the actual job mixture during the mix design stage.

If the available traffic window allows a slower setting mixture, contact the Office of Concrete Pavement in the Headquarters Division of Maintenance or submit a non-standard special provision (nSSP) request to: nssp.submittals@dot.ca.gov.

### 380.4 Design

FDR performance can be improved with proper design, considering issues such as concurrent pavement work, repair locations and boundaries, and traffic control.

#### 380.4.1 Order of Work

The order of CRCP work is important to mitigate any unintentional spalling or damage to adjacent pavement from FDR work. Isolated FDR should be done concurrently or before spall repairs of cracks or joints. Grinding and joint sealing should be the last CRCP work performed, if applicable.

#### 380.4.2 Repair Locations and Boundaries

Visual surveys are needed to identify FDR locations and estimate quantities during preliminary and final project design, and to verify locations and boundaries during construction. Identifying definitive repair boundaries is critical to completing a project quickly and ensuring good repair performance. Ensuring that all deterioration is included within the repair boundaries minimizes the need for additional, unplanned saw cutting and concrete removal work. Using the criteria in Section 380.2, project designers should also consult with the district maintenance engineer and area field personnel when selecting CRCP areas for replacement. If existing spalls are deeper than 1/3 the pavement thickness, FDR should be used as the repair strategy.

The pavement management system contains a visual record of every mainline concrete slab in the state, accessible online through the iVision software program at [https://ivision.fugro.com/CaliforniaSH/#/Login](https://ivision.fugro.com/CaliforniaSH/#/Login). Visual and distress data are scheduled for collection biannually, so the available information can provide approximate pavement conditions but may not reflect the most current conditions, which should be verified with a field review to identify unrecorded or recent distress and potential failure mechanisms, such as issues with surrounding terrain or drainage conditions.
It may be possible to effectively survey the traveled way from median and outside shoulder areas during non-peak daytime hours. Blank slab replacement field review forms included in Appendix 320-1 can be adapted for CRCP-FDR use.

A follow-up field evaluation should be performed during PS&E or construction as close as possible to the scheduled repair work so any additional deterioration that developed since the latest estimate is repaired. The FDR area must be the full lane width between longitudinal joints and at least 6’ long to minimize rocking, pumping, and pavement breakup.

The FDR boundary should not be too close to an existing transverse crack or construction joint to avoid adjacent distress. If the FDR boundary is within 1.5’, extend the repair to the nearest transverse crack or construction joint.

380.4.3 Traffic Control
Various traffic control alternatives may be considered for CRCP-FDR depending on the project location, size, and amount of repair work:

- Continuous lane closure
- Weekend closure
- Nighttime closure

Exposure of full-depth saw cut repair areas to traffic is limited to ≤ 7 days between sawing and concrete removal operations to avoid adjacent pavement cracking. Traffic is not allowed on completed CRCP-FDR areas until RSC materials have cured and achieved a minimum flexural strength of 400 psi determined under CT 524.

380.5 Construction
Some key but limited information about FDR construction is summarized in this section. Refer to the Construction Manual for more details about FDR construction procedures.

FDR requires the following individual construction processes:

- Concrete sawing and removal (see Section 380.5.1)
- Cleaning
- Placing reinforcement bars (see Section 380.5.2)
- Placing no. 3 bond breaker and RSC
- Finishing and Curing (see Section 380.5.3)

380.5.1 Concrete Sawing and Removal
Concrete sawing for FDR can be accomplished by the following saw cutting procedures:

- Smooth-faced: the transverse joint is sawed to its full depth. No aggregate interlock is obtained with this procedure.

- Rough-faced: a diamond-bladed saw is used to outline the repair boundaries by making a partial-depth saw cut above the longitudinal bars. The pavement is removed by chipping or other methods below the partial saw cut. Chipping results in a rough face with aggregate interlock between the new repair and the existing pavement, analogous to a spall repair interface.
The repaired area must be at least 6’ long and extend the full lane width between longitudinal joints (see Figure 380.2). Rough-faced, partial-depth saw cuts are made around the outer perimeter of the FDR area. Smooth-faced full-depth saw cuts are made 26” inside the outer perimeter of the existing CRCP that will typically be removed using the lift-out method to avoid damaging the pavement, base, and reinforcing bars remaining in-place (see Figure 380-3). Between the full and partial-depth saw cuts, existing concrete is chipped or otherwise removed to the full pavement depth, exposing the reinforcement bars so they can be lap spliced with replacement FDR bar reinforcement.

If the existing base is being replaced, a full-depth saw cut around the removal area is also required for any type of cement treated or concrete base material.

Exposure of full-depth saw cut repair areas to traffic is limited to ≤ 7 days between sawing and concrete removal operations to avoid adjacent pavement cracking.

380.5.2 Bar Reinforcement
Reinforcement bar continuity is critical to FDR performance. A short tied lap splice is used to join the existing longitudinal bars to the new longitudinal bars. A lap length of 26” is typically effective to re-establish longitudinal bar continuity for tensile strength. Tie bars are installed to provide adequate reinforcement across longitudinal construction joints. Refer to Figure 380-2 for placement details.

![Figure 380-2: Partial and full-depth saw cuts in the repair area](image)

![Figure 380-3: Concrete removal using lift-out method](image)
380.5.3 *Finishing and Curing*

Saw cuts are not required at longitudinal construction joints except where existing joint seals are being replaced in desert and mountain climate regions.

Traffic is not allowed on completed CRCP-FDR areas until RSC materials have cured and achieved a minimum flexural strength of 400 psi determined under CT 524.

### 380.6 PLANS, SPECIFICATIONS, AND ESTIMATING

CRCP-FDR is currently a nonstandard strategy in the process of being standardized for the 2015 Revised Standard Specifications. In the interim, the current construction detail plans and nonstandard special provisions (nSSP) for CRCP-FDR are available from the HQ Maintenance Pavement Program Office of Concrete Pavement and Pavement Foundations or by submitting a nonstandard special provision (nSSP) request to: nssp.submittals@dot.ca.gov.

#### 380.6.1 Plans

A complete set of FDR plans requires these sheets:

1. Title sheet showing limits of project
2. Typical cross sections showing existing pavement widths and thicknesses
3. Quantity sheets specifying the type and amount of work.
   - Locations of FDR and other work should be tabulated in the quantity tables rather than shown on layout sheets, even if layout sheets are provided for other work. Include the following note: “Locations shown for full-depth repair and replacing underlying base in quantity tables are approximate. Final locations will be determined by the Engineer.”
4. Construction details for unique items of work not addressed on other plan sheets
5. Standard plans listed in Table 320-5:

<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Plan</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie Bar Details</td>
<td>P15</td>
<td>Use to show tie bar tolerances only. Tie bar placement details are included in the FDR construction detail.</td>
</tr>
<tr>
<td>Joint Sealing</td>
<td>P20</td>
<td>Use when existing longitudinal joint seals need to be replaced due to FDR work, typically in desert and mountain climate regions.</td>
</tr>
</tbody>
</table>

#### 380.6.2 Specifications

The nSSP for CRCP-FDR includes requirements for removing existing concrete pavement, cleaning and preparing the excavation, placing base bond breaker, bar reinforcement, and RSC. When CRCP-FDR and other pavement repairs are included in a project, include order of work provisions when applicable (see Section 380.4.1 for recommendations).

Existing base removal specifications are in SSP 28-15 “Replace Base,” which also includes payment for the RSCB or LCBRS replacement material and placement. SSP 28-15 must be used together with the appropriate materials specifications in SSP 28-3 for RSCB or 28-4 for LCBRS.

**SSP 36-2** is used for polyethylene film base bond breaker no. 3 and payment is included in the nonstandard bid item for CRCP-FDR.
Table 380-4: Specifications for CRCP Full-Depth Repair Work

<table>
<thead>
<tr>
<th>Item Code</th>
<th>Description</th>
<th>2010 and 2015 Standards</th>
<th>Special Provisions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonstandard</td>
<td>CRCP Full-Depth Repair (FDR) with RSC</td>
<td></td>
<td>nSSP*</td>
<td>For FDR work with RSC. Includes payment for no. 3 base bond breaker and bar reinforcement.</td>
</tr>
<tr>
<td>Nonstandard</td>
<td>CRCP Full-Depth Repair (FDR) with Concrete</td>
<td></td>
<td>nSSP*</td>
<td>For FDR work with adequate curing time for conventional cementitious materials.</td>
</tr>
<tr>
<td>Not used</td>
<td>Base Bond Breaker</td>
<td></td>
<td>36-2</td>
<td>Should be included for all FDR work. Specifies bond breaker materials and placement requirements.</td>
</tr>
<tr>
<td>280200</td>
<td>Replace Base</td>
<td></td>
<td>SSP 28-15</td>
<td>Should be included for most FDR work.</td>
</tr>
<tr>
<td>410097</td>
<td>Drill and Bond (Tie Bar)</td>
<td>41-10</td>
<td></td>
<td>Use for each tie bar at longitudinal construction joints for FDR.</td>
</tr>
<tr>
<td>Various</td>
<td>Seal Joint</td>
<td>41-5</td>
<td></td>
<td>Use when existing longitudinal joint seals need to be replaced because of FDR. Match the existing joint seal material.</td>
</tr>
</tbody>
</table>

*nSSPs must be approved by the HQ Division of Maintenance Pavement Program Office of Concrete Pavement/Foundations.

380.6.3 Cost Estimating

The quantity of CRCP full depth repair is measured and paid for by the square yard based on the authorized concrete repair area. CRCP-FDR payment includes removing existing concrete pavement, cleaning and preparing the excavation, placing no. 3 base bond breaker, bar reinforcement, and RSC. Replace base, drill and bond tie bars, and seal joint work is paid for separately using the standard individual bid items.

REFERENCES

1. “Continuously Reinforced Concrete Pavement (CRCP), Chapter 2 – Publication Number HRT-05-081, October 2005, a publication of FHWA.


