GUIDELINES FOR PARTIAL DEPTH REPAIR IN CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

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Guidelines for Partial Depth Repair in Continuously Reinforced Concrete Pavement

Over the years, the Texas Department of Transportation (TxDOT) has improved design and construction practices of Continuously Reinforced Concrete Pavement (CRCP), which has resulted in good overall performance of CRCP in Texas. At the same time, the improved design and construction practices changed the type of distresses in CRCP. Typical punchout distresses that were once prevalent and required full-depth repairs, have become rare; rather, a substantial portion of distresses observed in CRCP built with the improved design and construction practices are partial depth distress (PDD). In PDD, the distress is confined to the top half of the slab, above longitudinal steel. The concrete below the longitudinal steel, or the approximate bottom half of the slab, remains in sound condition.

In CRCP, good load transfer at transverse cracks is provided by an adequate amount of longitudinal steel and aggregate interlock, which is responsible for good performance of CRCP in Texas. On the other hand, if load transfer is degraded or lost at transverse cracks or any transverse joints (construction joints or repair joints), CRCP performance could be severely compromised. In repairing PDD, it is strongly advisable to keep the continuity of the longitudinal steel so that a high level of load transfer is maintained at the transverse repair joints. Full-depth repair (FDR) requires cutting of longitudinal steel at the transverse repair joints and it's difficult to restore the continuity of longitudinal steel and load transfer capability at transverse repair joints. Accordingly, partial-depth repair (PDR) should be used for the repair of PDD, because it will keep the continuity of longitudinal steel, provide a high level of load transfer at transverse repair joints, and is more cost-effective than FDR. This document provides guidelines for the evaluation of CRCP distress to determine whether a distress is PDD, and for the proper repair procedures including repair material selection. This document does not address the repair of CPCD (Concrete Pavement Contraction Design.)

1. Evaluate CRCP Distress.

Typically there are two distress types in CRCP -- spalling and punchout. The primary difference between the two distress types is that spalling is a functional distress that does not negatively affect structural capacity of CRCP. On the other hand, punchout is a structural distress and if not repaired, will further deteriorate the pavement condition and ride quality. TxDOT has Specification Item 720 for the repair of spalling. For the full-depth repair of CRCP, TxDOT has Specification Item 361 and design standards "Full-Depth Repair for Concrete Pavement (FDR (CP)-05)." However, TxDOT does not have a specification item or design standards for PDR.

The first step to determine whether PDR is the optimum repair strategy is to evaluate the nature of the distress. More specifically, the depth of the distress must be determined. At the writing of this document, no non-destructive device is available that is easy to use and that can provide positive and accurate information on the extent of the distress in terms of the depth. Until such devices are developed and become available, sounding testing using a solid steel rod or a ball peen hammer might be the only feasible method to use. Areas yielding a dull sound are most probably areas experiencing PDD and should be considered as a candidate for PDR. This testing method has limitations in that it might not be applicable to thicker slabs.

Fortunately, CRCP distresses that extend to the depth of longitudinal steel and need PDR have unique appearances, and it could be possible to determine whether the distress needs PDR based on its appearances.

The unique features of PDD are:

1. Multiple longitudinal cracks with small spacing occurring between two closely spaced transverse cracks,
2. The distress occurred near tied longitudinal construction or longitudinal contraction joint, or under wheel path, and
3. There is no faulting at longitudinal joints.

If one of the features above is missing, the probability of the distress being PDD becomes smaller. Figures 1 through 6 illustrate typical partial depth distress. Note that the distresses meet all three features described above.

Figure 1. Partial depth distress near longitudinal construction joint

Figure 2. Partial depth distress under wheel path

In Figure 1, the distress is confined within two closely spaced transverse cracks. Note that there is no faulting at the longitudinal construction joint. The concrete within the distress fractured into smaller pieces and asphalt patching material was applied. In Figure 2, two longitudinal cracks occurred closely next to each other. Note that the two longitudinal cracks occurred within three closely spaced transverse cracks. No faulting is observed at the longitudinal construction joint.

Figure 3. Partial depth distress under wheel path with fractured concrete

Figure 4. Partial depth distress under wheel path

Figure 3 shows that the distress occurred under the wheel path and the surface of the concrete has been fractured into smaller pieces. Note that there is no faulting at the longitudinal construction joint. Figure 4 shows similar traits, with fractured pieces and no faulting at the longitudinal warping joint.

Figure 5. Partial depth distress under wheel path

Figure 6. Partial depth distress under wheel path

Figure 5 meets all three features described on page 3. Note the whitish material at the second transverse crack from the right. This material is calcium carbonate and is observed at PDD quite often. Figure 6 also shows no faulting at the longitudinal warping joint and several longitudinal cracks.

TxDOT initiated a research project in September 2010 to further investigate effective repair of concrete pavement, and this document will be modified as the findings from the study become available.

2. Determine Repair Boundaries.

Once the distress has been determined as a PDD, the boundary of the repair area has to be established. Unlike full depth distress, PDD is normally confined longitudinally by transverse cracks. Transversely, the boundary should contain all longitudinal cracks or fractured concrete. Accordingly, about 2 to 3 inches outside of the transverse cracks that confine the distress area can be the limit of PDR in the longitudinal direction. Repair limits for transverse direction must be beyond the distress area. Taking 1-in diameter cores can provide more definite information on the repair limits in the transverse direction. In addition, repair areas shall not be closer than 6-in to any other transverse crack or joint. The minimum size of the repair area should be 1-ft in both longitudinal and transverse directions. The boundaries thus determined are clearly marked for saw cutting operation as shown in Figures 6 and 7. The repair boundaries should be straight for the ease of saw cutting.

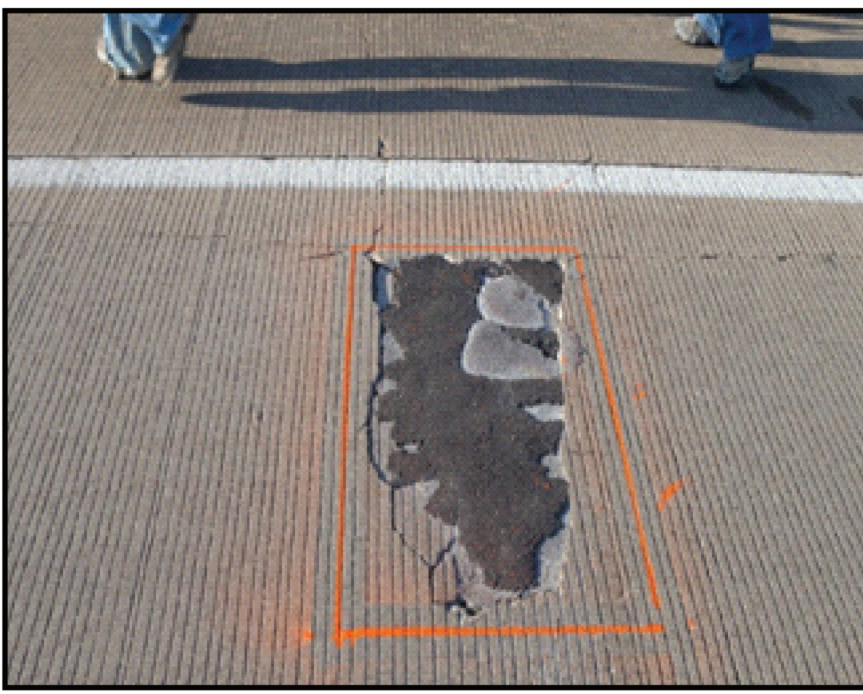


Figure 7. Boundary of PDR straight and clearly marked

Figure 8. Saw cut operation

3. Saw Cut and Remove Concrete.

Repair boundaries are saw cut to a maximum of one-third of the slab depth if the slab thickness is less than 14 inches. In Texas, longitudinal steel is placed approximately at mid-depth for slabs not greater than 13 inch thick, and the saw cut should never be close to the mid-depth since it increases the potential for cutting longitudinal steel. For slabs 14 to 15 inches thick, the saw cut depth should be a maximum of 4 inches. Saw cut depth should be deep enough to avoid a feathered shape in the existing concrete, but not deep enough to cut longitudinal steel.

Once the saw-cut is completed, remove the concrete using jackhammers with a maximum weight of 37.5 lbs. Start the removal of concrete at the center portion of the repair area and proceed toward the repair boundaries as shown in Figure 9. If the removal of concrete is difficult, additional saw cutting the distressed concrete into smaller pieces can facilitate the removal operation. In addition to using jackhammers, small hammers with spade bits can be useful for removing concrete near repair boundaries. Experience shows that careful removal of the concrete pieces using jackhammers with a maximum weight of 37.5 lbs and small hammers with spade bits won't damage the surrounding concrete.

After the removal of the concrete, the condition of the remaining concrete should be closely inspected for any damages that could have occurred during the concrete removal operation. Any damaged concrete should be removed with care not to cause further damage to existing concrete.

Figure 9. Removing concrete using a jackhammer

Figure 10. Large amount of fine materials at the bottom of the PDD

4. Install Hook-Bar.

If each length of the repair boundaries is equal to or greater than 3 ft, install hook bars in 1 ft spacing in both longitudinal and transverse directions. The hook bars shall be #5 bars with the length equal to a half slab thickness, meeting the requirements of Item 440, "Reinforcing Steel." Drill vertical holes at 2-in depth for hook bars. Clean the holes with oil-free compressed air. Inject Type III, Class A or Class C epoxy material to the holes and insert hook bars. The amount of the epoxy should be just enough to fill the holes after hook bars are inserted, but not excessive.

5. Clean Repair Area.

Once the concrete removal is complete, the surfaces of the repair area, both vertical faces and the bottom area, should be thoroughly cleaned. Due to the nature of the distress and concrete removal operations, there will be a large amount of fine materials within the PDD area that were generated by the abrasion actions of concrete pieces under traffic wheel loading; this is shown in Figure 10. These fine materials must be completely removed to provide a good bonding between the repair materials and existing concrete. Experience shows that good bonding between repair materials and existing concrete surface is essential to the good performance of PDR. If a good bonding is not achieved, the effectiveness of PDR will be limited and further distress will result.

First, apply compressed oil-free air to remove fine materials. Then, apply sandblasting to remove remaining fine materials and fractured pieces on the repair surface. In many cases, reinforcing steel will be exposed as shown in Figure 10. Use sandblasting to remove any cement paste from reinforcing steel. Finally, clean the repair area and exposed reinforcing steel using compressed air.

6. Prepare Repair Materials.

The selection of repair materials should be based on (1) how soon the repaired section should be open to traffic and (2) ambient temperature condition during repairs. If the ambient temperature is low, such as lower than 60 ºF, PDR should be postponed until ambient temperature becomes more favorable (higher than 60 ºF). If PDR must be done when the ambient temperature is much lower than 60 ºF, temporary patching with asphalt materials should be considered.

If the repaired area should be open to traffic as soon as possible, for example within 3 to 4 hours after repair material placement, the use of proprietary materials with the capability of achieving high early strength should be considered. There are several different proprietary material types available. They include cementitious and polymeric materials. In general, polymer-based materials are more expensive than proprietary or general cementitious materials, even though polymer-based materials provide higher early strength than cementitious materials. Also, polymer-based materials have a larger coefficient of thermal expansion (CoTE) than Portland cement concrete (PCC) materials, which is not desirable in achieving good bond between repair materials and existing concrete. There are a number of different types of proprietary cementitious materials available for PDR; contact Rigid Pavement and Concrete Materials Branch of CSTMP for the selection of optimum repair materials. The volume change potential of PDR materials due to temperature variations has substantial effects on PDR performance. The use of coarse aggregate that provides lower CoTE and modulus of elasticity will be ideal for PDR. If at all possible, crushed limestone should be used, as it will give low CoTE and modulus of elasticity regardless of the coarse aggregate type used in the existing pavement. Compatibility in material properties between repair materials and existing concrete should not be a concern.

Once the material is selected, a mix design has to be developed. For Class HES concrete, refer to Item 421 for the mix design development. For other proprietary materials, consult the manufacturer's instructions. During the trial mix design, a maturity curve can be developed in accordance with Test Method Tex-426-A, “Estimating Concrete Strength by the Maturity Method.” The maturity curve can be used to determine when PDR is ready to open to traffic without performing strength testing.

The frequency of PDD is usually sporadic and, compared with full-depth distress, the size of PDD is small. Accordingly, the quantity of the repair materials needed for PDR is relatively small. Ready mix trucks or other large mixing equipment cannot mix small quantity materials efficiently. Also, the setting time of the repair materials is shorter than normal PCC materials. Accordingly, it will be more efficient if the materials are mixed at the job site in a small drum or paddle-type mixer. This will require the preparation of the components of repair materials in advance in separate containers, bringing and mixing them at the job site. Figure 11 shows the mixing of the previously prepared repair material components at the job site in a small mixer.

7. Place Repair Material.

Before placing repair materials, wet the surfaces of the repair area without leaving excess water at the bottom of the repair area. Start placing repair materials in the middle of the repair areas and pushing toward the edges. Place repair materials in the repair area a little bit higher than the pavement surface to allow for the reduction of volume during consolidation. Consolidate the repair materials using an internal vibrator. It is important to remove entrapped air and consolidate the repair materials as well as possible without over-vibrating, which might cause segregation problems.

If a maturity curve was developed during the mix design stage, there are two options to estimate the maturity of repair materials for the determination of the time for opening to traffic. One is to embed thermo-couple wire in the repair material. In this case, place one end of the thermo-couple in the center portion of PDR and connect the other end to the maturity meter. To minimize the interference with finishing operations, embedding the thermo-couple can be done just after screeding and finishing, and before the application of curing compounds. The other option is to make a cylinder and place a thermo-couple in the center position of the cylinder and attach the other end of the thermo-couple to a maturity meter. Place the cylinder near the repair site.

If a maturity curve was not developed during the mix design stage, make a minimum of six 4-by-8 cylinders and cure them at the job site.

Figure 11. Mixing of prepared repair materials at the job site

The surface area of PDR is relatively small, and the usual requirements for surface finish in normal concrete pavement are not applicable. The use of 2-by-4 is appropriate for screeding and finishing. Start at the center of the repair and move toward the boundaries of the repair to enhance the bonding between repair materials and the repair surface of the existing concrete.

Figure 12. Application of sufficient curing compound

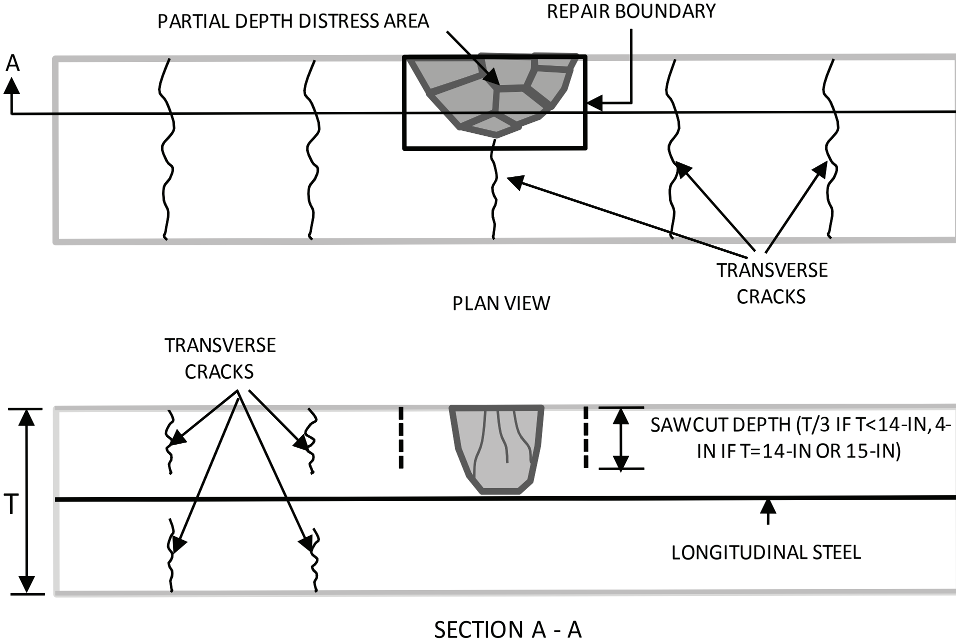
8. Provide Optimum Curing.

Repair materials used for PDR have relatively lower water-cement ratio than normal PCC materials. Keeping the water in the repair materials is of utmost importance in providing optimum curing. Non-optimum curing practice in PDR will result in poor performance of PDR, because (1) PDR has a larger surface to volume ratio than normal PCC pavement and thus is prone to moisture loss resulting in shrinkage, (2) volume changes due to moisture loss at the early ages will degrade the bond between repair materials and the repair surface of existing pavement, and (3) water-cement ratio of repair materials is low and any loss will reduce the potential for full hydration of cementitious materials. Optimum curing is achieved by the application of curing compounds as soon as the tining operation is complete. Since the PDR is a small area, tining may not be needed, or if tining is provided, it can be done as soon as the surface of the repair area is screeded and finished. Since there is almost no bleeding in the repair materials, there is no need to wait until bleeding stops. Provide curing compounds in a much greater amount than required in Item 360 and apply uniformly. Figure 12 shows the surface of the repair area after sufficient curing compounds were applied. Once the curing compounds are dried and not sticky anymore, place a blanket that will completely cover the repair area and apply water to keep the blanket wet continuously until the PDR area is open to traffic.

9. Open To Traffic.

When the strength of the repair material meets the opening to traffic strength requirement, which is 2,600 psi compressive strength, the PDR section can be open to traffic. If the maturity curve was developed during the mix design stage and thermo-couple was placed in the PDR or in a cylinder, read the maturity readings to estimate the compressive strength of in-situ repair material. When the maturity reading indicates the in-situ strength achieved is greater than 2,600 psi, PDR is ready to open to traffic.

If a maturity curve was not developed, break the cylinders at appropriate intervals to estimate the in-situ strength of the repair material. When the estimated strength of repair material is greater than 2,600 psi, remove the wet-mat. The section is ready for opening to traffic.



GENERAL NOTES

(1) MINIMUM SIZE OF PARTIAL DEPTH REPAIR AREA SHOULD BE 12-IN IN BOTH LONGITUDINAL AND TRANSVERSE DIRECTIONS.

(2) REPAIR BOUNDARIES SHOULD ENCOMPASS ALL DISTRESSED AREAS. TRANSVERSE REPAIR BOUNDARIES SHOULD BE 2 TO 3 INCHES AWAY FROM ANY DISTRESSED AREA. LONGITUDINAL REPAIR BOUNDARY SHOULD BE 2-IN BEYOND THE EXTENT OF DISTRESS AREA.

(3) SAW-CUT AT REPAIR BOUNDARIES SHOULD BE STRAIGHT AND VERTICAL TO PROVIDE A VERTICAL SURFACE AND SQUARE CORNERS.

(4) SAW-CUT DEPTH SHOULD BE ONE-THIRD OF SLAB THICKNESS FOR SLABS WITH 13-IN THICK OR LESS, OR 4-IN FOR SLABS WITH 14-IN AND 15-IN SLAB THICKNESS. SAW-CUT OPERATION SHOULD NEVER CUT THE LONGITUDINAL STEEL.

Texas Department of Transportation
Construction Division (Pavements)

PARTIAL DEPTH REPAIR FOR

CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

FILE:	DN: TxDOT	CK:			
© TxDOT September 1994	DISTRICT	FEDERAL AID PROJECT			SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY

SPECIAL SPECIFICATION
XXXX
Partial Depth Repair of Concrete Pavement

1. Description. Repair concrete pavement to partial depth in accordance with the details shown on the plans and the requirements of this Item.

2. Materials. Provide materials that meet the pertinent requirements of the following:

- Item 360, "Concrete Pavement"
- Item 421, "Hydraulic Cement Concrete"
- Item 440, "Reinforcing Steel"
- DMS 6100, "Epoxies and Adhesives."

If material in Item 421 does not meet the strength requirement, provide material that meets the requirements in DMS-4655, "Rapid-Hardening Cementing Materials for Concrete Repair"

3. Equipment. Provide tools and equipment necessary for proper execution of the work that meet the pertinent requirements of the following:

- Item 360, "Concrete Pavement"
- Item 429, "Concrete Structure Repair"

In addition, provide following equipment:

A. Drill. Use a maximum 40 lb. hydraulic drill with tungsten carbide bits.
B. Air Compressor. Provide compressor capable of delivering air at 120 cu. ft. per minute and with a minimum 90 psi nozzle pressure.

4. Construction. Obtain approval for all materials and methods of application at least 2 weeks before beginning any repair work. Repair locations will be indicated on the plans or by the Engineer.

A. Remove Concrete. Use jackhammer and other equipment to remove concrete from repair area designated by the Engineer. Use caution not to damage the sound concrete during this operation. Make sure that all loose concrete materials are removed. Obtain approval of the completed concrete removal before proceeding to drilling

B. Drill Holes. Use drilling operations that do not damage the surrounding concrete. Drill holes in a slab vertically at the depth shown on the plans. Ensure that the holes diameters are no more than 1/8 in. larger than tie bar diameter.

C. Clean Holes. Clean holes with oil-free and moisture-free compressed air and a wire brush to remove all cuttings, dust, and other deleterious material. Check the compressed air stream purity with a clean white cloth. Insert the nozzle to the bottom of the hole to force out all dust and debris. Alternate use of the wire brush and compressed air as necessary until all loose material has been removed.

D. Insertion of Epoxy Material and Tie Bar. Inject epoxy material into hole at adequate amount so that there will be no excess epoxy material on the surface of existing concrete when a tie bar is inserted fully to the depth of the hole. Place the tie bars into the hole. Remove any excess epoxy material from the concrete that comes out when a tie bar is fully inserted.

E. Surface Cleaning. Clean the area to be repaired by abrasive blasting or other approved methods. Remove all loose particles, dirt, deteriorated concrete, or other substances that would impair the bond of the repair material. Follow this with a high-pressure air blast for final cleaning.

F. Repair Material Application. Mix, place, cure, and test concrete to the requirements of Item 360, “Concrete Pavement,” and Item 421, “Hydraulic Cement Concrete.” Broom-finish the concrete surface unless otherwise shown on the plans. Match the grade and alignment of existing concrete pavement. For repair areas to be opened to traffic before 72 hr., use curing mats to maintain a minimum concrete surface temperature of 70°F when air temperature is less than 70°F.

G. Repairs. Repair damages to concrete pavement caused by Contractor’s operation without any additional compensation. Perform repairs as directed.

5. Measurement. This Item will be measured by the square foot, in place, as measured on the surface of the completed repair.

6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Partial Depth Repair of Concrete Pavement.” This price shall be full compensation for furnishing all materials, tools, equipment, labor, and incidentals necessary to complete the work. No payment will be made for extra work required to repair damage to the adjacent pavement that occurred during concrete removing or cleaning operations.

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