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U.S. Department of Transportation
Federal Highway Administration

TechBrief

NOVEMBER 2011 | FHWA-HIF-12-007

Jointed Full-Depth Repair of Continuously Reinforced Concrete Pavements

This TechBrief describes both conventional methods and an alternative method for making full-depth repairs in continuously reinforced concrete pavements. The alternative method, which does not utilize continuous longitudinal reinforcement in the repair area, is suitable for repairing a single lane (or two of three adjacent lanes), and results in repair areas that have performed well after several years.

Introduction

The South Carolina Department of Transportation (DOT) has developed a simple and innovative method for full-depth repair (FDR) of continuously reinforced concrete (CRC) pavements. This TechBrief presents some fundamental information about CRC pavement design and describes the methods that typically have been used for repair of CRC pavements. The principal focus of the TechBrief is the South Carolina experience with repair of CRC pavements using a jointed FDR technique.

A CRC pavement is a concrete pavement with continuous longitudinal steel reinforcement and no regularly spaced contraction or expansion joints. The only transverse joints used are non-active construction joints placed at the end of a day's paving. The continuous joint-free length of CRC pavement can extend to several miles, with breaks provided only at structures. CRC pavements develop a transverse cracking pattern with cracks generally spaced at about 2 to 6 ft (0.6 to 1.8 m). The cracking pattern is affected by the ambient weather condition at the time of construction, the amount of steel reinforcement, and concrete strength. The steel reinforcement, as shown in figure 1, induces the closely spaced cracking and then holds the cracks tightly closed. The higher the amount of steel used, the more closely spaced the cracks will be. Most of the cracks develop shortly after concrete placement; however, additional cracking may continue to develop over several years as a result of continued drying shrinkage of concrete, temperature variations, and traffic loading.

CRC pavements have an excellent record of performance in the United States. DOTs in several states, including Texas, Illinois, and Virginia, consider

Figure 1. Steel reinforcement in CRC pavement (staggered laps of longitudinal bars shown on right).

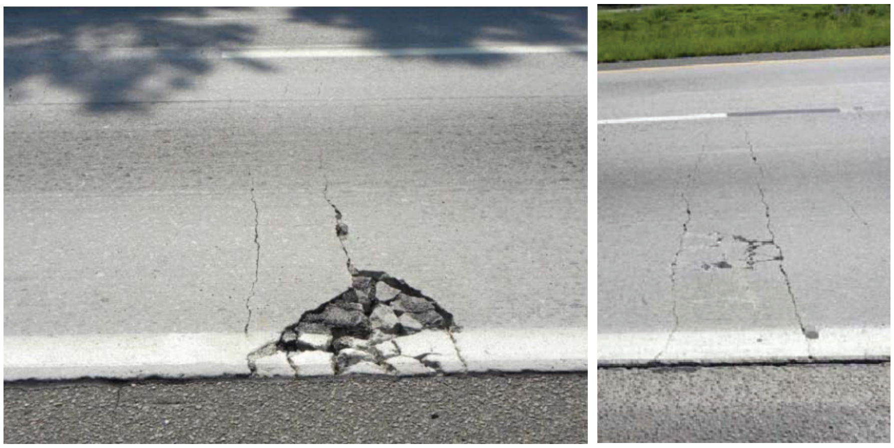

Figure 2. Punchout distress in CRC pavement.

CRC pavement as their primary concrete pavement alternative. When designed and constructed well, CRC pavements can provide a service life of 40-plus years with minimal maintenance. The maintenance that is needed in older CRC pavements is related to the development of punchout distress (figure 2), severely distressed/spalled cracks, and steel rupture. These distresses impact ride quality and safety. A common corrective action for these distress types is FDR. The repairs must be performed correctly; otherwise the likelihood of their early failure will be high.

Conventional Full-Depth Repair of CRC Pavements

Many agencies have developed standard techniques for performing FDR of CRC pavements. Most of the techniques are based on maintaining the continuity of the longitudinal steel within the patch area, as illustrated in figure 3. The steps involved in such FDRs are as follows:

1. Identify the repair boundary—most agencies require the repair to be full-lane width and at least 6 ft (1.8 m) in length.
2. Remove the damaged concrete.
   a. Sawcut along the repair area perimeter—full depth along the longitudinal edges and partial depth about 2 to 3 in. (50 to 75 mm) along the transverse edges, avoiding the longitudinal steel bars.
   b. Remove the interior damaged concrete by making a full-depth sawcut about 20 in. (0.5 m) from each transverse repair edge and lifting out the interior concrete. The breakout method for the interior concrete removal is not recommended as this method can damage the existing base.
   c. Remove the remaining concrete along the transverse edges by jack-hammering. This operation should result in about 20 in. (0.5 m) of longitudinal steel exposed at each transverse end to allow sufficient lap length for tying with new steel in the repair area. The recommended lap length for tying the longitudinal steel ranges from 25 to 30 times the steel diameter. Figure 4 shows the prepared area with exposed longitudinal steel bars.

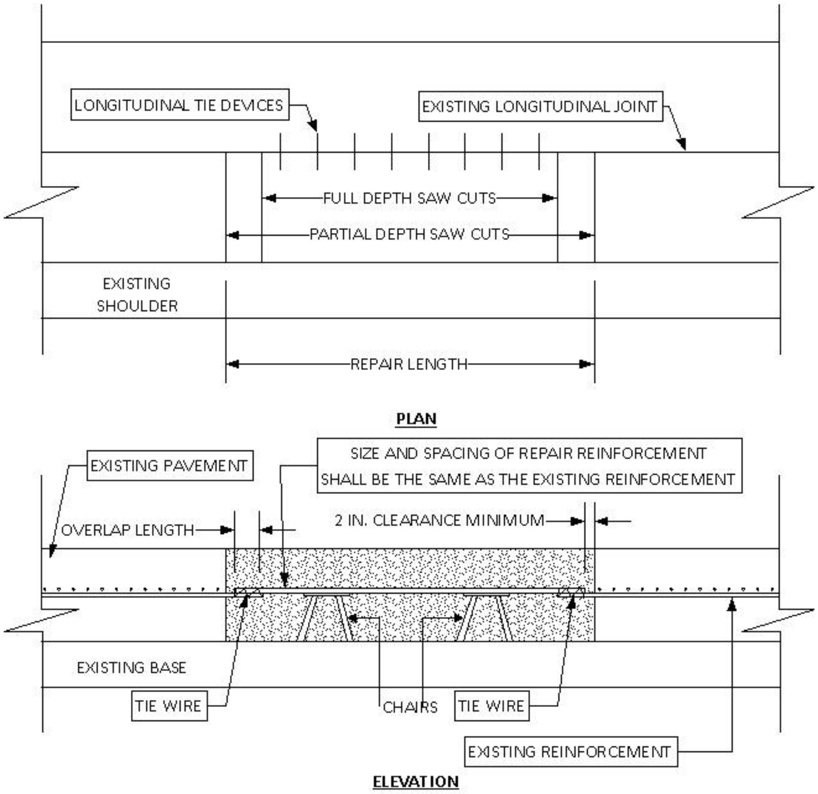

Figure 3. Schematic of conventional CRC pavement FDR.

3. Restore the base if it is damaged during the concrete removal operation.

4. Install longitudinal steel in the repair area, tying at each end to the exposed original steel. The new steel should be the same size (diameter) and grade (usually Grade 60) as the original steel. Some agencies require supplemental steel bars to be used in the repair area.

Figure 4. Prepared repair area with exposed longitudinal steel bars.

5. Place concrete in the repair area—finish the concrete, provide surface texture, and apply curing treatment.

6. Open to traffic—typically within 6 to 12 hours, as dictated by lane closure requirements.

The conventional FDR method as described above has shown mixed levels of performance, especially when repairs were performed under short lane-closure requirements. Many FDRs have failed within 1 to 5 years, creating a need to keep extending the repair area with subsequent repairs. Typical examples of failed conventional FDR of CRC pavements are shown in figure 5.

Failures have typically been due to the following:

1. Inability to adequately restore the base under the exposed steel after concrete removal.

2. Poor quality concrete—the time required to jackhammer the end concrete area limits the time available to properly place and finish the repair concrete.

3. Poor steel lapping practices.

To address some of the shortcomings of the conventional FDR technique, several Texas DOT districts have modified the technique as follows (Texas DOT):

1. Perform a full-depth sawcut along the transverse edges of the repair area.

2. Remove all damaged concrete using the lift-out method, minimizing any hand removal of the concrete.

3. Drill holes in the transverse sawcut faces for installing tie bars.

4. Install tie bars in the drilled holes and epoxy-grout the bars.

5. Connect the tie bars with the repair area longitudinal bars corresponding to the tie bar spacing.

Figure 5. Failed FDRs on CRC pavements.

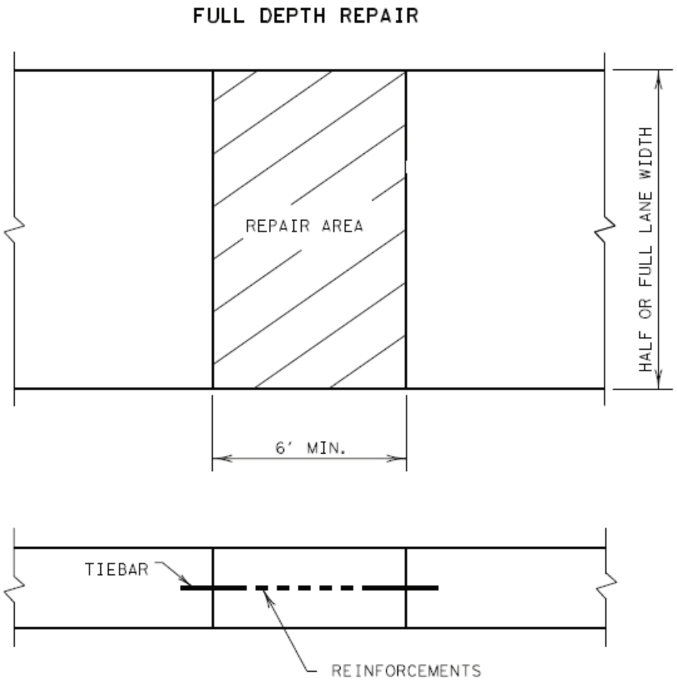

Figure 6. Plan and cross section of the Texas FDR of CRC pavements.

6. Follow through with concrete placement, finishing, and curing, as with the conventional technique.

The Texas method, illustrated in figure 6, shortens the time for preparing the repair area and allows for restoration of the base within the entire repair area. However, the performance of this alternate FDR method has also been mixed, primarily because the tie bars across the full-depth sawcut transverse edges of the repair area do not provide adequate load transfer under heavy truck loading.

Jointed Full-Depth Repairs: The South Carolina Experience

The South Carolina DOT has developed a simpler, innovative FDR method for repairs of CRC pavements performed along a single lane. Under this approach, no effort is made to maintain continuity of the longitudinal steel. This method is similar to the Texas method, except, instead of using epoxy-grouted tie bars at the transverse edges of the repair area, the South Carolina DOT approach uses epoxy-grouted conventional dowel bars to provide adequate load transfer; and longitudinal steel continuity is not attempted. This is, in essence, the method typically used by DOTs throughout the United States for FDR of jointed concrete pavements.

In addition to providing proper load transfer across the transverse edges of the repair area, since the repair is applied to a single lane of a roadway having two or more lanes, there is no concern regarding any movement of the two free ends of the CRC pavement in the repair area. This repair option is not recommended for repairs across all lanes of a CRC pavement as this would compromise the normal functioning of the CRC pavement. The key details of the South Carolina method are as follows:

1. Repairs are full-lane width and in a single lane, typically in the outside lane of a two-lane, one-direction roadway. However, a few repairs have been carried out in two lanes of a three-lane roadway (sections of I-77).

2. The repair area perimeter cuts are made full depth.

3. Longitudinal steel continuity is not maintained in the repair area. In fact, longitudinal steel is not used in the repair area.

4. Similar to the conventional FDRs described above, tie bars are not used along the centerline longitudinal joint for patches less than 16 ft (4.9 m) in length. For longer patches, longitudinal tie bars are spaced nominally at 30-in. (760-mm) intervals, but the spacing may be varied to avoid existing cracking in the adjacent lane and to be at least 15 in. (400 mm) away from the transverse joints at each end of the repair area.

5. Dowel bars are placed at mid-depth at a nominal spacing of 12 in. (300 mm) starting and ending about 12 in. from the corners of the repair area. The dowel bar spacing is adjusted to miss any longitudinal steel in the existing pavement.

6. Intermediate transverse joints are required for repair lengths greater than 16 ft (4.9 m). Dowel baskets are used at these intermediate joints, with dowels spaced at 12 in. (300 mm). The intermediate joints are sawed to a depth of one-third the depth of the repair area and sealed.

The details of the South Carolina DOT method are shown in figure 7.

Case Study: I-20 CRCP

The first production use of the jointed FDR method in South Carolina was along sections of I-20, near Aiken. Project details are as follows:

Original CRC Pavement

- Construction date: 1969–70.
- Pavement thickness: 8 in. (200 mm).
- No. of lanes: Two in each direction; asphalt concrete (AC) shoulders.
- Longitudinal steel reinforcement: No. 5 bars at 6-in. (150-mm) spacing.
- Transverse steel reinforcement: No. 4 bars at 30-in. (760-mm) spacing.
- Base type: Cement-stabilized earth base, 5 in. (130 mm) thick (using select soil-clay mixture).

Jointed FDRs (outside lane only)

- Repairs performed: 1985 and 1993.
- Dowel bars: 1.25-in. (32-mm) diameter, 18-in. (0.5-m) length, 12-in. (300-m) spacing.

Subsequent Rehabilitation

The eastbound lanes of I-20, incorporating the FDRs, were overlaid during 1997–98 with AC about 5 in. (125 mm) thick, reportedly due to poor ride along these sections. During 2005, an AC overlay 5 in. (125 mm) thick was placed over the westbound lanes incorporating the jointed FDRs. The AC overlays incorporated a layer of open-graded friction course 1 in. (25 mm) thick.

Performance to Date

The jointed FDRs with the AC overlay are performing well, based on a windshield survey performed during August 2010. Very few joints of the FDR had reflected to the surface of the AC overlay. The reflected cracking was of low severity, and the AC was not deteriorated at the cracks. There did not appear to be any loss of AC material or vertical displacement at the few crack locations that were observed. This good performance of the AC overlay is due to lack of any horizontal movement at the repair joint locations and good load transfer effectiveness due to the use of dowels at the joints. The ride at posted operating speed was good.

Case Study: I-95 CRCP

The jointed FDR method was also used along sections of I-95. Project details are as follows:

Original CRC Pavement

- Construction date: 1973–74.
- Pavement thickness: 8.5 in. (215 mm).

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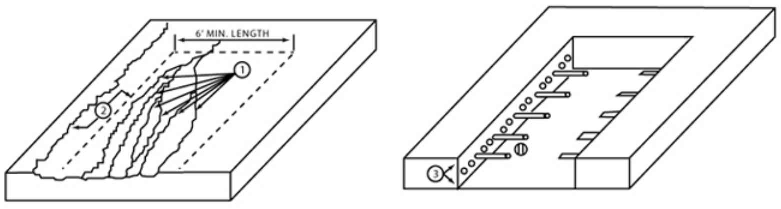
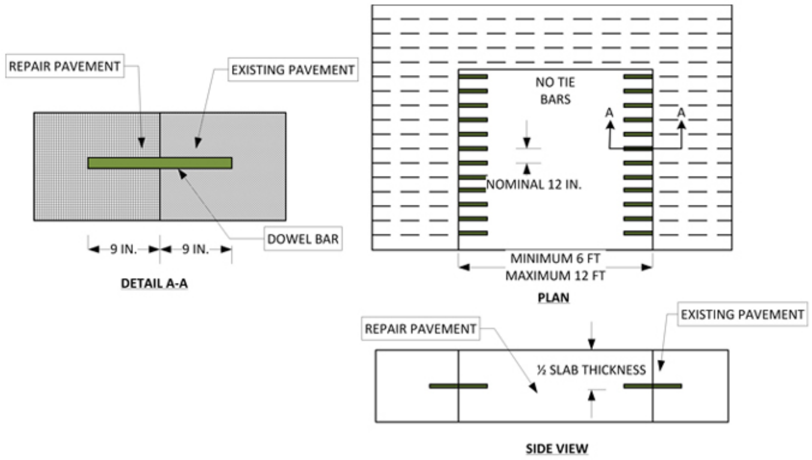
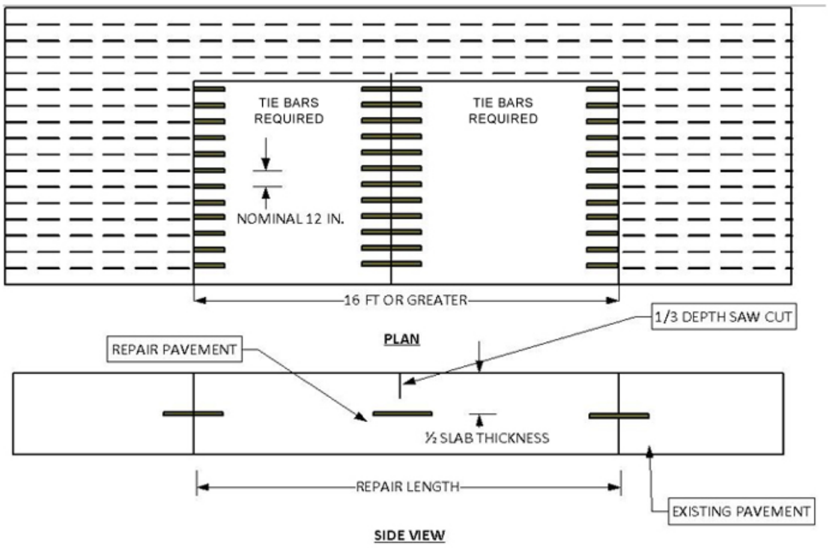


DISTRESSED CRCP

CRCP PATCH AREA



PATCH LENGTHS 6 FT TO 12 FT



PATCH LENGTHS 16 FT OR GREATER

Figure 7. Details of the South Carolina jointed FDR of CRC pavement.

- No. of lanes: Two in each direction; AC shoulders.
- Longitudinal steel reinforcement: No. 5 bars at 6-in. (150-mm) spacing.
- Transverse steel reinforcement: No. 4 bars at 30-in. (800-mm) spacing.
- Base type: Cement-stabilized earth base (using select soil-clay mixture), 5 in. (125 mm) thick.

Jointed FDRs (outside lane only)

- Repairs performed: 2005 and some subsequently.
- Dowel bars: 1.25-in. (32-mm) diameter, 18-in. (0.5-m) length, 12-in. (300-mm) spacing.
- Additional treatment: The riding surfaces of the repair areas were ground after completion of the FDRs.

Performance to Date

Overall, the jointed FDRs are performing well, based on a windshield survey performed during August 2010, as shown in figure 8. The CRC pavement still had a bare concrete surface. The overall ride was good, including over the FDR areas. The repair areas included single panel repairs (up to a length of about 18 ft [5.5 m]) as well as multiple panel repairs with intermediate joints at 15-ft (4.57 m) spacing, incorporating dowel baskets. One repair area was more than 250 ft (76.2 m) long with 18 panels—each of 16 panels was 15 ft (4.6 m) long and two panels at one end were each 9 ft (2.7 m) long. The repair area joints were in good condition and sealed. There was no noticeable faulting at the repair area joints. There did not appear to be any adverse effect on the cracking in the inside CRC lane. The inside lane cracks within the outside lane repair areas appeared to be tight. A few of the repair panels exhibited single transverse mid-panel cracking. The cracking was about 0.04 to 0.08 in. (1 to 2 mm) wide as observed from the shoulder. Some repair panels were observed to exhibit mid-panel longitudinal cracking, as shown in figure 9. The repair panel cracking at these few isolated areas was reportedly due to poor base/subbase condition at these locations.

Figure 8. Views of the I-95 jointed FDRs.

Figure 9. Longitudinal cracking at a jointed FDR location.

Summary

There has been more than 10 years of good experience with the application of jointed FDR of CRC pavement in South Carolina. This good performance is limited to the application of the repairs in the outside lane only of a two-lane roadway or in two adjacent lanes of a three-lane roadway. It appears that as long as one lane of a two- or three-lane roadway is not patched (opened up) in the areas adjacent to the FDRs, the expansion/contraction in the repair areas is held in check by the tie-in with the remaining CRC lane. Therefore, based on the South Carolina experience, the normal functioning of the CRC pavement adjacent to the jointed FDR areas has not been compromised. This method also should perform well in other climatic areas as long as there is at least one lane that is not repaired adjacent to the jointed FDR areas.

It is again emphasized that this technique has not been applied to the repair of all lanes of a CRC pavement at a given location. Such applications would leave the CRC pavement unrestrained at the transverse faces of the FDR and subject to damaging daily and seasonal movements.

Reference

Texas DOT Web site for CRCP repair details: http://onlinemanuals.txdot.gov/txdotmanuals/pdm/fulldepth_repair.htm#1002920.

Acknowledgment

The support of Andy Johnson, Ph.D., P.E., State Pavement Design Engineer, South Carolina Department of Transportation, in the preparation of this TechBrief is greatly appreciated.

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Research—This TechBrief was developed by Shiraz Tayabji, Ph.D, P.E. (Fugro Consultants) as part of FHWA's ACPT product implementation activity. The TechBrief is based on research cited within the document.

Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to FHWA's field offices.

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Key Words—continuously reinforced concrete pavement, full-depth repair, cracking

NOVEMBER 2011

FHWA-HIF-12-007