JULY 2018 FHWA-HIF-18-050

Tech Brief

Precast Concrete Panels for Rapid Full-Depth Repair of CRC Pavement to Maintain Continuity of Longitudinal Reinforcement

INTRODUCTION

This Tech Brief describes a recently implemented method for rapid overnight full-depth repairs of continuously reinforced concrete (CRC) pavements using precast concrete panels. This method, developed by the Illinois Tollway, uses continuous longitudinal reinforcement throughout the repair area to make the method applicable for repairing multiple lanes or large areas, as well as for isolated repairs for long-term performance with minimal impact to traffic. The Illinois Tollway has successfully utilized this method for a high traffic-volume expressway in the Chicago metropolitan area.

CRC pavements contain continuous longitudinal steel reinforcement with no transverse contraction or expansion joints, except as required at end-of-day construction, at bridge approaches, and at transitions to other pavement types or structures. The longitudinal steel reinforcement induces closely spaced cracks and then holds the cracks tight. The transverse cracks are spaced at about 2 to 6 ft (0.6 to 1.8 m) and have narrow crack widths of less than 0.02 inches (0.5 mm), which helps to maximize the aggregate interlock at the crack locations.

The Illinois Tollway first started building CRC pavements in 2004, when a new capital program converted all manual toll collection at plazas to electronic methods (open-road tolling) to eliminate traffic backups. Most of the toll plazas on the system were reconstructed using CRC pavements. At that time, the Tollway also began reconstructing and widening corridors with CRC pavements capable of carrying heavier traffic loads. The CRC pavements at the open-road toll plazas included the installation of treadle frames and loop detectors, which eventually will be upgraded. To address these upgrades and future distresses, the Illinois Tollway decided to develop a precast concrete panel (PCP) system for rapid and long-lasting repair of CRC pavements.

The Illinois Tollway currently consists of 294 median miles of interstate and expressway pavements in northeastern Illinois, mainly in the Chicago metropolitan area. One of the initial projects in ongoing capital improvement programs included the reconstruction and widening of a 5-mile section of I-80/I-294 known as the Tri-State Tollway corridor south of Chicago and just west of the Indiana/Illinois border. This section of the Tollway system has more than 88,000 annual average daily traffic (AADT), with about 22 percent commercial trucks.

U.S. Department of Transportation
Federal Highway Administration

The reconstruction of this section of I-80/I-294 CRC pavement during 2004 and 2005 included four lanes in each direction with a 12-inch (300-mm) CRC pavement built over a 4-inch (100-mm) asphalt stabilized base over a 12-inch (300-mm) unbound aggregate base.

This pavement section remains in excellent condition; however, a retrofitted weigh-in-motion (WIM) system in all four lanes at one location in the westbound direction resulted in the saw cutting of the longitudinal steel reinforcement in the CRC. This ultimately resulted in localized failure of the CRC pavements in all four lanes, as well as within an adjacent CRC ramp lane. The Tollway needed a repair strategy that would have minimal impact to traffic while maintaining a safe work zone for the contractor and traveling public. Figure 1 shows the distressed pavement before implementation of the full-depth CRC repairs using PCP described in this Tech Brief.

Figure 1. Photo. Distressed section of I-80/I-294 CRC pavement.

It was the Tollway's desire to design a generic PCP system for repair of CRC pavements that would maintain the continuity of the longitudinal steel and provide for load transfer at construction joints. To maintain the continuity of the longitudinal steel reinforcement within any CRC repair area, the longitudinal bars within the existing CRC pavement must be located and effectively overlapped with longitudinal steel bars in the PCP panel. The Tollway designed the steel bar overlap to be accommodated using narrow-width overlap zones in gaps between the existing CRC pavement and the PCP panels or between series of panels. The Tollway's design allows repairs across multiple lanes at any location. A detailed description of single-lane repair of a CRC pavement with conventional cast-in-place concrete and no continuity of the longitudinal reinforcement is available in Federal Highway Administration (FHWA) Tech Brief HIF-12-007, Jointed Full-Depth Repair of Continuously Reinforced Concrete Pavement.

The Tollway established generic plans and specifications for the CRC repair system using PCP panels. The designer's responsibility was to identify the specific transverse boundaries of the distressed areas that required a PCP repair in each lane. The contractor's responsibility was to develop the detailed design of each precast panel and an installation plan for Tollway approval. The contractor was also responsible for surveying the repair areas to determine the widths, lengths, and number of CRC precast panels for each repair area.

DESIGN APPROACH

The existing CRC pavements for westbound I-80/I-294 and for most of the rest of the Tollway system are designed with 12-inch (300-mm) slab thickness, with 0.8 percent steel content using No. 7 size longitudinal bars at a 3.5-inch (90-mm) depth below the surface, and with No. 4 transverse support bars every 4 ft (1.2 m). Figure 2 shows the multiple lane repair areas for this project.

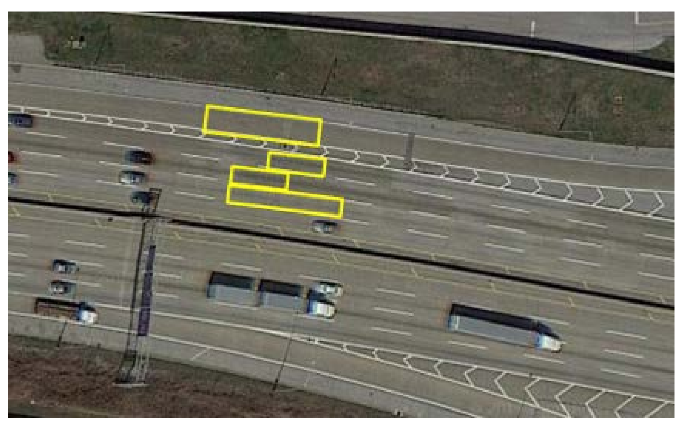

Figure 2. Photo. Repair areas along a section of I-80/I-294 CRC pavement.

The Tollway's generic repair system incorporated the following features:

- Continuity of the longitudinal steel through the repair areas, matching the steel content of 0.8 percent in the existing pavement. This was done using No. 10 deformed bars in the precast concrete panels. The spacing of the deformed bars varied from 13.0 to 13.5 inches (330 to 343 mm), depending on the lane width of the repair area. The spacing of the bars was selected to ensure the amount of steel reinforcement in the overlap zones and within the precast panels matched or exceeded the amount of longitudinal reinforcement in the existing CRC pavement. Two types of splice zones were used to maintain steel continuity. The first splice zone detail was developed to maintain continuity between the original CRC pavement and the CRC precast panel. This detail was for locations where a precast panel was placed next to an existing CRC pavement at the ends of the repair area. The second splice zone detail was developed for connections between precast panels where multiple precast panels were placed in sequence within a repair area.

- Load transfer at all repair area transverse construction joints. The No. 10 deformed bars continuing through the transverse construction joints were considered adequate for maintaining load transfer across these joints.

Splice Zone Details

The transverse splice zones were designed to be full lane width and 18 inches (450 mm) long. To maintain continuity of the longitudinal steel bars from the existing CRC pavement into the repair area precast panels, it was determined that the overlap length for No. 10 bars, using either ultra-high-performance concrete (UHPC) or an approved high early-strength concrete (HESC) in the splice zone gap, would need to be a minimum of 14 inches (355 mm). A full-depth temporary (dummy) precast panel was used to cover the splice zone gap during the night of panel placement. During the next night, the temporary precast panel was removed, and the gap was filled with a fiber-reinforced UHPC or an approved HESC. This process allowed overnight panel installation with no impact to the daytime peak hour traffic.

Steel Connection at Existing CRC Pavement

The repair design required the use of 32-inch (810-mm) long No. 10 bars to be embedded 16 inches (406 mm) into 2.0-inch (50-mm) diameter holes predrilled into the existing CRC pavement at each end of the repair area. This resulted in availability of 16 inches of the bars for overlap with bars extending from the precast panels. An epoxy adhesive for embedding the dowels was specified to meet ASTM C881 requirements for class and grade at the ambient air temperature expected during construction. The predrilled holes were centered below the longitudinal reinforcement bars in the existing CRC pavement. The spacing of the embedded deformed bars varied from 13.0 to 13.5 inches (330 to 343 mm), depending on the lane width of the repair area.

Panel Design and Reinforcement

The PCP panels were fabricated with No. 10 deformed epoxy-coated longitudinal bars, placed at mid-depth of each panel and spaced at 13.0 inches (330 mm) on center for panel widths of less than 13.5 ft (4.1 m) or 13.5 inches (343 mm) on center for panel widths of 13.5 ft (4.1 m) or greater. The longitudinal bars in each PCP panel were fabricated with threaded couplers at each end, as shown in figure 3. This was done to simplify the design of the temporary panels that would be used to cover the overlap zone gaps at the end of the first night of panel placement. The use of the couplers allowed the bars to be extended into the overlap zone on the night that the overlap zones would be backfilled with either UHPC or HESC.

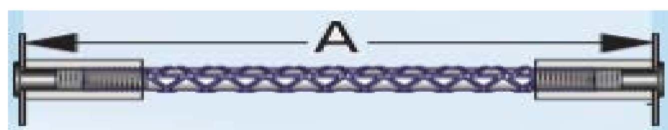

Figure 3. Illustration. Longitudinal reinforcement (No. 10 bars) in PCP panel threaded at both ends with couplers attached. Note: A = panel length, typically 10 ft-7.75 inches (3.2 m).

The design thickness of the PCP panels was 11.5 inches (292 mm), thinner by 0.5 inch (12 mm) than the adjacent CRC pavement. Panel length was typically 10 ft-7.75 inches (3.2 m). Leveling hardware included during fabrication near each corner of the PCP panels allowed the panels to be adjusted with leveling bolts to the desired elevation, leaving a gap of no more than 0.5 inch (12 mm) under the PCP panel to be filled with a high early-strength grout. If there was not sufficient time for the under-panel grouting on the night of panel placement, the PCP panels would remain on the base until a subsequent night, when leveling bolt adjustments would be made. The plan view of a typical repair area with multiple PCP panels is shown in figure 4.

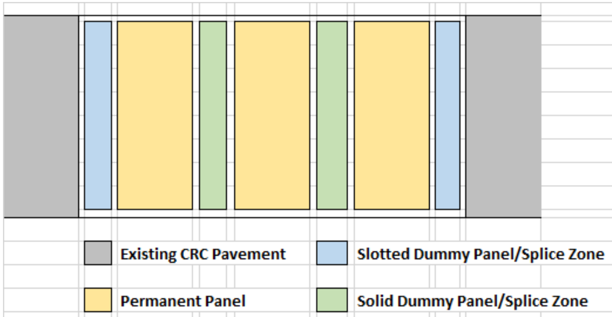

Figure 4. Illustration. Plan view of a repair area with multiple PCP panels.

Repair Plans and Specification

The Tollway plans and specification for the repair work included detailed notes on panel fabrication and panel installation, such as the requirements for all materials, shop drawings, fabrication of panels, quality control during fabrication/placements, preplacement meetings, tolerances for removals/placements, smoothness on finished surfaces, and criteria for opening to traffic. The material requirements applied to the fabrication of all panels using standard concrete, grout material for the under-panel grouting of all voids under CRC precast panels set on leveling bolts, and the splice zone backfill using UHPC or HESC. The specification for the UHPC material required the use of a modified proprietary UHPC product or an approved equivalent. The proprietary UHPC product was modified so that the ultimate 28-day compressive strength was reduced to less than 20,000 psi (138 MPa) while early age strength was increased so that a compressive strength of 2,500 psi (17 MPa) could be obtained within 4 hours. These modifications allowed the splice zone backfills to be completed during nighttime lane closures and for the repaired pavement section to be opened to traffic before 6:00 am the next morning.

INSTALLATION OF CRC PRECAST REPAIR SYSTEM

Tollway inspectors visited the precast plant to inspect the contractor’s fabricated panels and ensure the panels complied with the shop drawings. Once the panels were cleared for shipment and the Tollway approved the installation techniques for the precast panels for the I-80/I-294 project, overnight installation of the panels was authorized to begin in October 2017. Pavement removal and precast panel installation was done one lane at a time, starting in the outside ramp lane and then proceeding with lanes 4, 3, and 2, respectively. The accelerated cast-in-place patching in lane 1 and within the gore area was completed on weekends after all precast repairs were placed. The steps for the repairs in each lane were as follows:

Night One

1. The closure of traffic started at 9:00 pm. Two traffic lane closures existed between 9:00 pm and midnight. The third lane was closed at about midnight to allow for only one lane of live traffic until 5:00 am. During the repair of the CRC ramp pavement, only one mainline traffic lane had to be closed during the nighttime hours.
2. The full-depth repair boundaries within the repair area were identified and marked for the full-depth saw cut locations.
3. Full-depth saw cuts were made along the repair area perimeter. Additional interior full-depth saw cuts were made within the repair area to make removal of the interior concrete easier the following night.
4. All traffic lanes were reopened to commuter traffic by 5:00 am.

Night Two

1. Two traffic lanes were closed at about 9:00 pm, and the third one was closed at midnight.
2. Concrete pavement from the repair area was removed. The contractor used the lift out method to start the concrete removal and then removed the bulk of the repair area pavement using an excavator. No damage or spalling to the surrounding pavements that remained was observed.
3. Following the damaged pavement removal, the repair area was prepared for the installation of the CRC precast panels as follows:
   a. Any disturbed or damaged base within the removal area was restored. An asphalt stabilized base existed below the CRC pavement. Bond between the CRC pavement and underlying asphalt stabilized base was not broken at all locations, and some isolated areas of asphalt stabilized base were removed with the concrete pavement. A dense graded coarse aggregate was placed and compacted to fill voids in the base.
   b. The required locations for the deformed dowel bars to be inserted were marked on the transverse vertical faces at each

end of the removal area. Using a gang drill, 2-inch (50-mm) diameter holes were drilled 16 inches (400 mm) into the existing CRC pavement at both ends of the removal area. At this project, some of the horizontal holes that were too close to the longitudinal joints had to be hand drilled and the locations of the holes slightly adjusted to avoid longitudinal tie bars that were not accounted for in the design drawings.

c. The predrilled holes were air blasted, and then the No. 10 deformed bars were inserted into each drilled hole using epoxy.
d. All vertical surfaces around the perimeter of the removal area were air blasted, and form oil was applied on the vertical surfaces of the repair area to prevent any bedding grout used under the permanent panels or for splice zone backfilling material to bond to saw cut faces of the existing concrete pavements surrounding the repair area.
e. Once the base had been restored and compacted, 1.5-inch (38-mm) diameter foamed backer rods were nailed into the exposed base along the expected perimeter of each precast panel. It is important that the backer rods are continuous so that the bedding grout remains confined within the bottom area of the panels and does not flow into the splice zone gap or into the longitudinal joint gaps.
f. Four steel plates were placed on the prepared base where the leveling bolts of each CRC precast panel would be located. Initially, the plates were designed to be only 4 inches by 4 inches (10 mm by 10 mm), which resulted in a few issues with placement accuracy. The plates were changed to 12 inches by 12 inches (300 mm by 300 mm) for the remaining panel placements.

4. All temporary and permanent precast panels were set within the removal area in sequence, starting at the end of the repair area that was upstream of the traffic flow. All panels were set with a joint gap between panels or between existing concrete and panels of no more than 0.5 inch. (12 mm).

The details for precast panel placement within any repair area were as follows:

a. The slotted temporary splice zone precast panel was first placed adjacent to existing CRC pavement over the embedded deformed bars. After placing the first temporary panel, all remaining temporary and permanent panels were placed in sequence with all joint gaps being within the specified tolerance of 0.25 inch ± 0.25 inch (6 mm ± 6 mm).
b. As each permanent precast panel was placed over the base (see figure 5), the leveling bolts on the panel were adjusted so that every corner of the precast panel was flush with or no more than 0.25 inch (6 mm) higher than any surrounding existing concrete. Also, after each permanent panel was placed, the threaded couplers in the panels were covered with duct tape to prevent the bedding grout that might seep through a broken backer rod from filling the openings in the couplers.

Figure 5. Photo. Permanent precast panel placement showing corner leveling bolts.

c. After all panels were placed and leveled, each temporary precast panel was lifted to allow for leveling sand to be placed over the base so that, when the temporary panel was reset, the surface of the panel was within 0.25 inch (6 mm) of the surrounding concrete pavement or adjacent permanent panel. All temporary panels were designed 0.5 inch (12 mm) thicker than permanent precast panels, and the thickness of the leveling sand was not allowed to exceed 0.25 inch (6 mm). Figure 6 shows the first slotted temporary panel being reset between the existing pavement and the first permanent panel in the ramp lane.

Figure 6. Photo. Resetting of the slotted temporary panel.

d. Incompressible shims approved by the engineer were hammered into each transverse and longitudinal joint to maintain horizontal alignment of the precast panels and to prevent any movement of the panels when opened to traffic the next morning.
e. Batching equipment and pumps were set up on-site to apply the bedding grout to fill the gap beneath the permanent precast panels. The bedding grout was applied using the grout port holes. Any bedding grout material that seeped into a splice zone was removed by the contractor the following night. All lifting insert holes and grout ports of the permanent panels were backfilled with an approved grout material.
f. After the bedding grout reached the cure time required to obtain a compressive strength of 300 psi (2 MPa), the repair area and other adjacent lanes that were closed were opened to traffic, typically no later than 5:00 am.

Night Three

1. Two traffic lanes were closed at about 9:00 pm, and the third one was closed at midnight.
2. The UHPC splice zone backfill mixer and other equipment were set up near the work zone and prepared for UHPC production.
3. All temporary precast panels were lifted and removed from the splice zones. The incompressible shims were removed as necessary to allow for easy lift out of the temporary panels.
4. The splice zones were prepared for UHPC backfill as follows:
   a. Any hardened overflow bedding grout material that seeped into the splice zone was removed.
   b. Leveling sand that was placed under temporary precast panels was removed, and the base was restored if damaged.
   c. All protective duct tape over couplers embedded within the permanent precast panels was removed, and the No. 10 threaded reinforcement bars were inserted into each of the couplers. Because of the length of threading on the bars and because the length of the splice zones had to be reduced slightly to accommodate the adjusted precast panel lengths, the overall length of the bars had to be shortened slightly to fit within the 18-inch (450-mm) long splice zones. This resulted in reducing the overlap of the splice zone longitudinal bars from 14 inches (355 mm) to about 13 inches (330 mm). Figure 7 shows the splice zone with the threaded No. 10 bars in the splicers of the permanent precast panels.

Figure 7. Photo. A splice zone with the threaded No. 10 bars in the precast panel splicers.

   d. Backer rods or polyurethane foam were used as gaskets to fill joint gaps that surrounded each splice zone so that the UHPC material did not seep into the longitudinal joints.
5. The UHPC material was produced and placed within each splice zone in accordance with the manufacturer's specifications and finished flush with the adjacent pavements or panels. Figure 8

shows the placement of the material within a prepared splice zone. Placement of UHPC within the splice zones was completed no less than 4 hours before the work zone was to be reopened to traffic. Two of the five splice zones for the ramp lane repairs were backfilled with an experimental proprietary steel fiber-reinforced high-early-strength concrete material. Compressive strength for the UHPC averaged about 4,000 psi (27 MPa) at 4 hours, and compressive strength for the HESC averaged about 6,300 psi (43 MPa) at 3 hours. Since the UHPC product was very flowable, the backfilled splice zones had to be confined at the surface with plywood cover to provide a flush surface, as the pavements had a 1.5 percent cross slope. The HESC did not require surface confinement when placed within the splice zones and was relatively easier for the contractor to produce on-site and place.

Figure 8. Photo. UHPC placement into the splice zone.

6. Once the last splice zone backfill material reached either the minimum compressive strength of 2,500 psi (17 MPa) or a 4-hour cure time, the work zone was reopened to traffic. The reopening occurred no later than 5:00 am.

Night Four or Later
The last step for the contractor to carry out was to diamond grind 100 percent of the repaired area of the CRC pavement to provide for good rideability. The diamond grinding occurred during nighttime hours after most of the pavement repair or rehabilitation work was completed. Figure 9 shows the repaired ramp lane as of mid-February 2018.

Figure 9. Photo. Completed repair of the ramp lane.

PERFORMANCE TO DATE

The CRC precast repair area on the I-80/I-294 Tollway project was observed immediately after the installation work was completed in October 2017, then in mid-December 2017 and in mid-February 2018. The repairs have been exposed to extremely high truck traffic and cold temperatures over the 4-month observation period. The only distresses seen so far are micro shrinkage cracks that were observed the morning after placement in a few of the splice zone backfills, with both the UHPC product and with the HESC product. The cracks are hardly observable and have not propagated or widened since placement occurred. Also, slight debonding and separation of the backfill material from one of the vertical faces of the adjacent precast panel has been observed at most splice zones.

No settlement of the precast panels had been observed, and the rideability of the repair area surfaces remains excellent. The transverse cracking in the existing CRC pavements that are adjacent to the repair areas appears to be unaffected. No widening of these cracks is evident, and no new cracking has been observed in the adjacent existing CRC pavement.

SUMMARY

For rehabilitation or patching of CRC pavements of two lane widths or more, where the need for overnight replacement exists in all adjacent lanes from edge to edge of a multilane roadway, the Illinois Tollway's generic CRC precast system can be applied to maintain the continuity of longitudinal steel throughout the repair area and to ensure adequate load transfer at construction joints. If the location for an overnight repair is isolated within a single lane, then a precast system that is typically used for jointed plain concrete pavements and that does not maintain continuity of the longitudinal steel may be used to provide a long-term repair.

REFERENCES

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In figure 2, the original map is the copyright property of Google® Earth™ and can be accessed from https://www.google.com/earth. The map overlays showing the pavement repair areas were developed as a result of this research project.

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