TECHNICAL MEMORANDUM 3 & 4

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To: 0-7147 Project Team	**Tech Memo No:** 0-7147 Technical Memorandum 3 & 4
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Subject: Task 3. Performance Evaluation of Special Pavement Sections, Task 4. Performance Evaluation of Experimental Sections	

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I. Introduction

The Texas Department of Transportation (TxDOT) has the most mileage of rigid pavement in the nation, which is, partly, a result of continuous improvements that have been made to rigid pavement design, materials, and construction. Since the structural behavior of rigid pavement is quite complicated, these improvements cannot be made solely based on theoretical work and quite often, test sections are built and monitored. In addition, it takes a while before any meaningful differences are noticed in rigid pavement behavior and performance. Accordingly, improvements in the design, material selection or construction technique of rigid pavement take lots of time and effort, including careful field experimental designs, and follow-up monitoring of the pavement conditions over a long period of time.

One of the reasons for TxDOT being the leader in the usage of rigid pavement as well as implementation of new or improved design and construction methods in the nation is that TxDOT is not afraid of trying new design concepts, new materials or innovative construction techniques, as long as they are technically sound. TxDOT also has an implementation program, which facilitates the implementation of research findings. Since the short-term and long-term monitoring of the implemented rigid pavement sections is a vital part of the whole rigid pavement improvement process, TxDOT sponsored rigid pavement database (RPDB) projects, whose primary objective is to monitor the behavior and performance of numerous sections built as test sections under research projects or sections built to evaluate the effectiveness of new techniques or materials. Examples of variables of interest investigated at TxDOT include:

1) Concrete placement temperature
2) Coarse aggregate type
3) Longitudinal steel percentage
4) Longitudinal bar size
5) Longitudinal steel depth
6) Post-tensioned prestress
7) Fast track construction
8) White topping
9) Concrete surface finishing
10) 2-lift construction
11) Use of recycled concrete aggregates
12) Roller compacted pavement

The performance of test sections that incorporated the above design/materials/construction techniques has been monitored under RPDB projects. Each RPDB project is 3 years long, with each RPDB project sponsored approximately every 10 years. The current project, 0-7147, is the third project sponsored since the year 2000. Since some of the test sections were built more than 30 years ago, it has been positively confirmed that some variables are not as important or critical as theoretical models indicate. For example, various test sections were built throughout Texas to investigate the effects of concrete placement temperature on long-term CRCP performance. Theoretical models indicated that CRCPs built in hot weather condition will have inferior performance due to high set temperature, which will result in larger crack widths and lower load transfer efficiency (LTE). However, CRCP sections built under the hot weather conditions did not show any performance issues. As a matter of fact, some sections built in hot weather conditions showed excellent performance. This finding nullifies the need for different steel designs based on expected concrete set temperatures, or shifting concrete placement at night, or incorporating Class F fly ash to control the concrete setting temperature, some of which were requirements at some point at TxDOT. On the other hand, national research studies still emphasize the importance of concrete setting temperature on CRCP design, and require changes in slab thickness and/or steel designs based on concrete placement temperature. Without adequate and thorough documentation of what TxDOT has done on this subject, future engineers at TxDOT may not know the truth about this, and might try to change CRCP designs or construction practices, which will unnecessarily complicate TxDOT operations and could increase construction cost and/or the time required to complete the projects. There are other examples, such as whether siliceous river gravel (SRG) could be used to minimize severe spalling problems by changing CRCP design, concrete mixing sequence, or using specific mix designs. TxDOT spent more than 20 years to address this issue, since TxDOT recognized that the use of local coarse aggregates for CRCP construction projects would be a win-win situation for both TxDOT and the construction industry. However, nothing has worked even though TxDOT tried almost every tool available. For all the efforts made by TxDOT to improve rigid pavement performance to be effectively utilized, the behavior and performance of all the test sections must be properly evaluated and properly documented, and the findings should be easily available to future TxDOT engineers.

The goal of this RPDB project is to exactly achieve those goals. In this RPDB project, test sections or test projects built over the years are grouped into 2 categories: one is called “Special Sections,” and the other “Experimental Sections.” Special sections are the pavements that incorporated non-traditional design/materials/construction that the TxDOT design standards or construction specifications do not normally cover. Experimental sections are those sections built to test the validity of the research findings. This Technical Memorandum summarizes the performance evaluations of special and experimental sections made by the research team under Tasks 3 and 4 up to July 2024. In that sense, this technical memorandum is interim in nature, since one more round of performance evaluations will be conducted in FY25, and the updated findings will be included in the final report.

II. Task 3: Performance Evaluation of Special Pavement Sections

The goal of this task is to document the condition and performance of 8 special pavement types built in Texas. Here, “the condition” means specifically visual condition observed by the research team, and “the performance” is defined as the product of pavement condition and time. Accordingly, for the condition and performance evaluations, no specific tasks were conducted other than periodic visual surveys.

Each special pavement section list below is characterized by unique design features, material compositions, and/or construction techniques, reflecting TxDOT's commitment to addressing specific roadway needs with tailored solutions. As discussed above, the evaluation focuses on monitoring the condition and performance of the following pavement types:

1. Fast Track CRCP (FT-CRCP)
2. Post-Tensioned Concrete Pavement (PTCP)
3. Bonded Concrete Overlay (BCO) & Unbonded Concrete Overlay (UBCO)
4. Whitetopping
5. Precast Concrete Pavement (PCP)
6. CRCP with 100% Recycled Concrete Aggregates (RCA)
7. Roller-Compacted Concrete Pavement (RCC)
8. CRCP with One-mat vs. Two-Mat Longitudinal Reinforcement Design

The above 8 pavement types are unique in that the usual rigid pavement design procedure, such as the 1993 AASHTO pavement design or the latest AASHTOWare, cannot be used to develop pavement designs, since these types were not included in the original AASHO Road Test. These pavement types were utilized or devised to address issues specific to the project site. For example, Fast Track CRCP was developed for the construction of intersections where traffic level is high, but few truck traffic. In this situation, building rigid pavement with traditional designs – concrete slab on stabilized base layer on treated subgrade – will take too much time, causing traffic delays at intersection areas at an intolerable level. Substitution of treated subgrade and stabilized base with an “equivalent” concrete slab could be a desirable alternative that could substantially expedite the construction. This need for the expedited construction resulted from an intersection construction in Houston, where the construction of rigid pavement at an intersection with traditional design/construction method caused so much traffic delay that the public contacted their congressman. The Houston District had to come up with a solution, and this “substitution” concept was adopted, even though the concept has never been officially tried. The Houston District came up with a 3-in concrete slab for 1-in ASB + 6-in CTB + 6-in lime treated subgrade. There is no document describing how 3-in equivalent concrete slab thickness was developed, which makes the performance evaluation of this FT-CRCP much more important. The same type of logic is applicable to the other special pavement sections.

A. Fast Track CRCP (FT-CRCP)

The nature of FT-CRCP and the reason for its applications were discussed previously, and the details of the sections and design standards are presented in Table 1 and Figure 1. As can be seen, all the FT-CRCP sections evaluated in this project are located in the Houston District.

Table 1 FT-CRCP Sections Information

District	Intersection		Construction Year	GPS Coordinates	Remark
Houston	Spring Cypress Rd	SH249	2002	30.013054, -95.589968	Crushed limestone used
	US59	SH 6	2001	29.598411, -95.621780	SRG used
	William Trace	SH 6	1993	29.592185, -95.604894	Limestone used
	JFK Blvd	BW8 Frontage Rd	1992	29.938902, -95.331258	Some cracks observed
	IH45 Frontage Rd	Greens Rd	1993	29.943800, -95.414535	Longitudinal crack observed

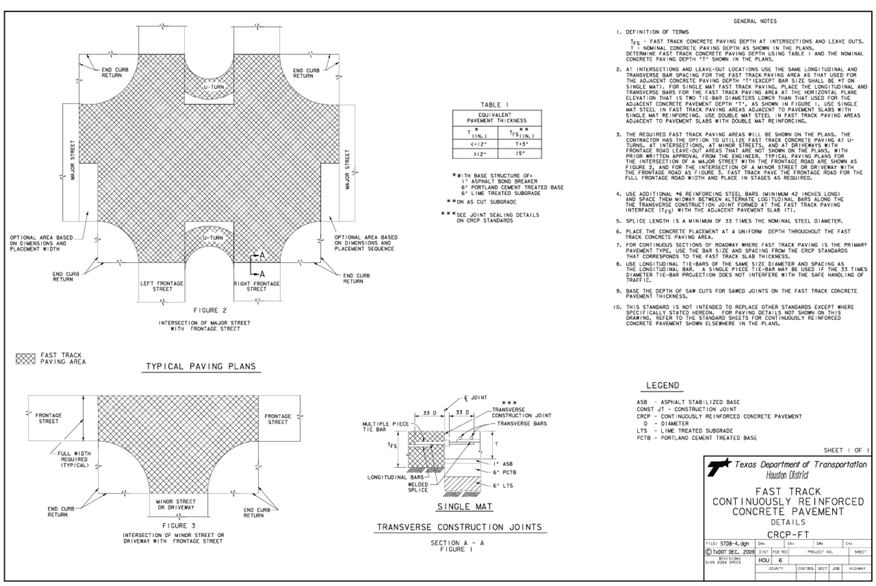


Figure 1 Design Standard for FT-CRCP (Houston District)

A summary of the visual evaluations of each section is presented.

- US 59 at SH 6 Section

The traffic at this intersection is quite high, which necessitated the use of FT-CRCP at this intersection. After more than 20 years, this section has mixed performance. The portion of FT-CRCP under US 59 (now IH 69) is excellent, with transverse cracks so tight. The reason is that this area is in the shade all the time, with minimum concrete temperature variations. On the other hand, the sections outside of the US 59 bridge experienced severe spalling (Figure 2). In this project, siliceous river gravel (SRG) was utilized as the coarse aggregate, which explains why severe spalling occurred. However, it should be noted that this spalling issue and resulting poor performance in terms of ride quality does not have anything to do with FT-CRCP system.

(a) (b)

Figure 2 Observed Spalling (SH6)

- IH 45 Frontage Road Section

The IH 45 Frontage Road section, previously reported to have tight longitudinal cracks, was revisited approximately 10 years later. The subsequent evaluation found that these cracks remained still tight (Figure 3), indicating that this crack could be superficial in nature to relieve warping and curling stresses. Other than the longitudinal cracks, there were no distresses, and after more than 30 years in service, the section is still in excellent condition.

(a) Overview

(b) Longitudinal Crack

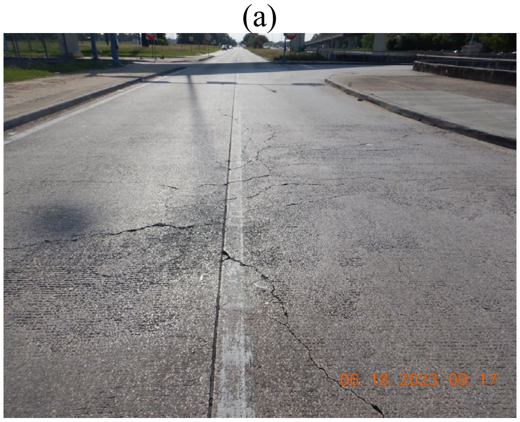
Figure 3 Overview of FT in IH45 Frontage Rd

- JFK Boulevard at BW 8 Section

This section is on the embankment area, and numerous cracks were observed, some of which have large crack widths. Also, most of the cracks with large widths are not of typical transverse crack shape, which implies that these cracks were not to relieve environmental stresses (temperature and moisture variations); rather, they are due to volume changes in the embankment materials. As previously reported, these soil movements led to significant cracking, necessitating full-depth repairs to restore the pavement's integrity (Figure 4).

(a)

(b)



(c)

(d)

Figure 4 Overview of FT-CRCP in JFK Blvd

- Overall Condition of Other Sections

Other FT-CRCP sections were generally found to be in excellent condition (Figure 5), showing minimal signs of distress. This overall good condition underscores the effectiveness of FT-CRCP in handling the demands of high-traffic environments, provided that initial construction and ongoing maintenance are managed effectively.

(a) Spring Cypress Rd (b) William Trace

Figure 5 Overview of other FT-CRCP in Houston

The detailed observations from these sections illustrate the varied responses of FT-CRCP to different environmental conditions and material choices. The use of SRG in the US 59 at SH 6 section, for example, underscores the need for careful consideration of aggregate selection to avoid spalling issues. In contrast, the proper maintenance of tight longitudinal cracks in the IH 45 Frontage Road section highlights the durability of FT-CRCP when subjected to high volumes of traffic over an extended period. The issues observed at JFK Boulevard at BW 8 also emphasize the impact of underlying soil conditions on pavement performance. Volumetric changes in the soil can lead to significant structural challenges, necessitating more intensive repair solutions such as full-depth replacements. In summary, while FT-CRCP sections generally exhibit excellent performance, the specific conditions at each site — including material selection and underlying soil properties — play an important role in their long-term durability.

B. Post Tension Concrete Pavement (PTCP)

Cast-in place Post-Tensioned Concrete Pavement (PTCP) is a specialized pavement type that aims at enhancing the structural capacity or reducing slab thickness of concrete pavement through the application of post-tensioning techniques. This method involves placing concrete and then applying tension to embedded tendons after the concrete has achieved a certain level of strength. The post-tensioning applies compressive stress to the concrete, which increases its ability to handle heavy loads or reduces required slab thickness.

In the Waco District, two sections of PTCP were constructed along IH 35. The first PTCP section – 6-in thick slab with 240-ft and 400-ft joint spacings, was built in 1985, with its performance quite excellent [1, 2]. However, it was removed and replaced with CRCP due to widening and realignment of the roadway, not because of any issues of the PTCP. The second section, constructed in 2008, features a 9-in thick PTCP slab and a length of 7 miles with individual slab lengths of 300-ft. This section, located at GPS coordinates [32.007939, -97.095398], was constructed to evaluate the viability of post-tensioning in concrete pavement, with a life-cycle cost as an evaluation criteria [3]. For this, a 14-in CRCP section was built at the same time frame in the south of this project. At this point, both PTCP and CRCP sections are performing well, and life-cycle comparisons are not feasible, primarily since it is not known how long the pavements will last. This task will probably need to be done in about 20 or 30 years. One challenge for the life cycle cost comparison is the initial construction cost. For various reasons, the bid price for PTCP for the selected contractor was $10/sy, which is of course not reasonable. The current research team talked to the contractor to obtain information on what the actual cost was; however, the contractor did not provide the information.

In this project, post-tensioning was applied in 2 phases. Figure 6 presents the application of initial post-tensioning.

Figure 6 Post-Tensioning Work

An evaluation conducted in June 2024 with TxDOT Maintenance Division revealed that the PTCP section remains in excellent condition, despite some observations of transverse and longitudinal cracks (as shown in Figure 7). Most of these cracks developed above the longitudinal and transverse pre-stressed tendons. It is quite similar to other cast-in-place concrete structures and pavement, where cracks usually develop along reinforcement from either differential settlement or Poisson's ratio effect.

(a) Longitudianal (b) Transverse

Figure 7 Observed Cracks & location of Steel

The evaluation included deflection measurements using the Falling Weight Deflectometer (FWD). The FWD testing was conducted in the southern part of PTCP NB & adjacent 14-in CRCP, which showed that the PTCP sections exhibit lower deflections when compared to the statewide average for 9-in CRCP (see in Figure 8). This result suggests that the PTCP effectively distributes loads and maintains structural integrity and/or better slab support in this project. Also, Load Transfer Efficiency (LTE) at transverse cracks was generally over 90% (see in Figure 9), demonstrating high load transfer capabilities. However, evaluating LTE at armor joints proved challenging due to the wide joint widths and difficulties in accurately positioning the loading plate.

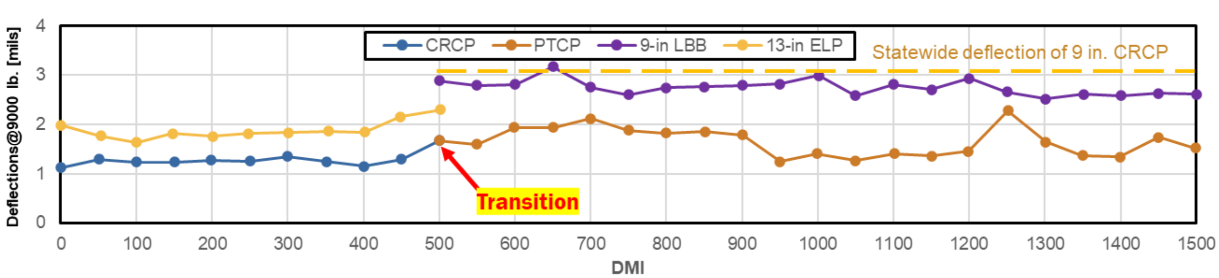


Figure 8 Deflections in PTCP Section

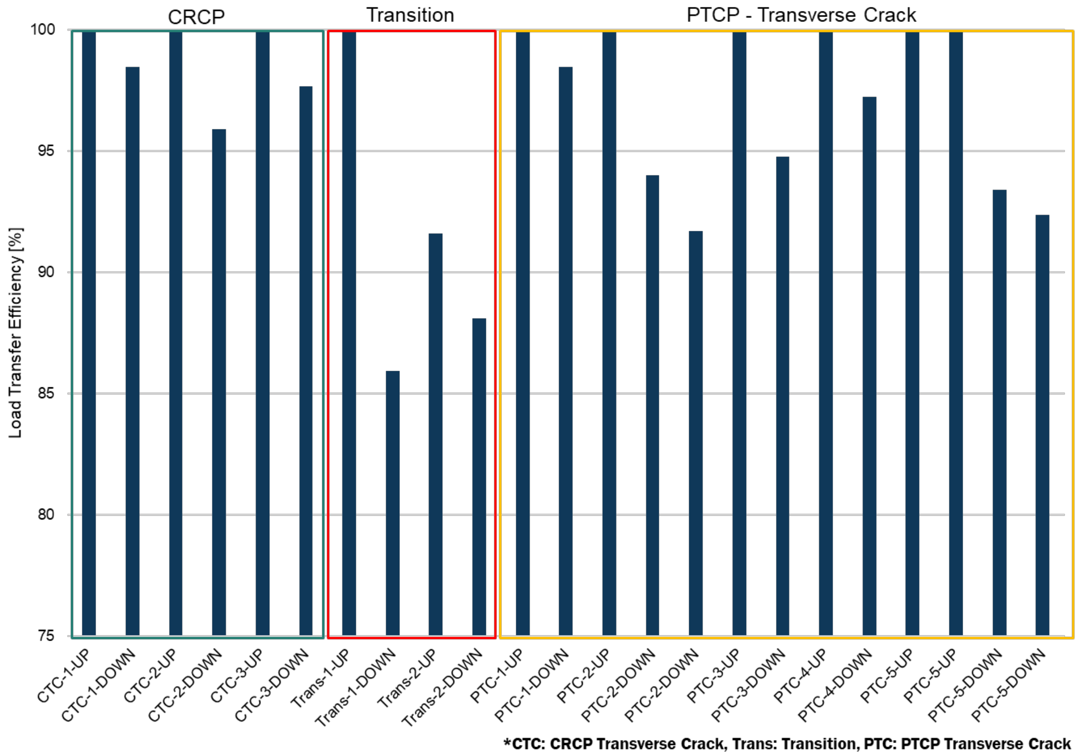
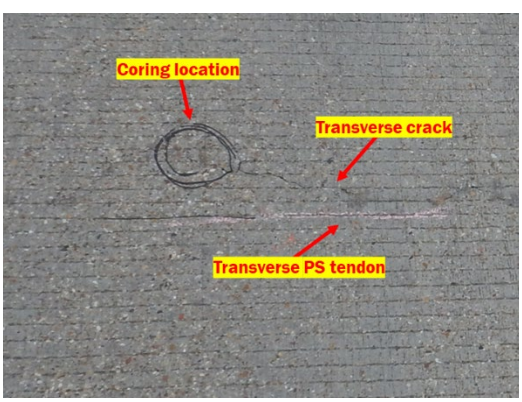


Figure 9 LTE at CTC, PTC, Transition in PTCP Section

To investigate the nature of the cracks, concrete cores were taken at few locations. As shown in Figure 10, core sample was taken away from both longitudinal and transverse tendons. These samples indicated that the cracks in the PTCP did not propagate to the full depth of the pavement, indicating that the cracks were either settlement cracks or due to warping/curling or a combination of both. Either way, it appears that post-tensioning helped to keep the crack from going through the slab.



(a) Longitudianal

(b) Transverse

Figure 10 Coring location & Core

Even though the condition of the PTCP throughout the project is quite satisfactory, there is an area in the northern part the project in northbound, where a half-moon shape crack developed, along with evidence of undersealing. (see Figure 11). It was observed that there is a drainage issue in this area.

(a) Longitudianal

(b) Transverse

Figure 11 Observed Distresses in PTCP section

Overall, the PTCP on IH 35 in Hillsboro continues to perform well, with cracks observed in only a few areas. Although not many, longitudinal & transverse cracks were found and most of cracks developed above longitudinal/transverse PS tendons. Field testing conducted during the construction indicated severe loss of prestress probably due to subbase friction, especially near the center portion of the 300-ft slab. Still, the pavement performs well under the applications of heavy, overweight trucks. This section provides a real-world fatigue testing and is expected to provide quite valuable fatigue damage information, which will hopefully provide a clear answer to questions regarding whether concrete pavement really fails due to fatigue damage of concrete, which is advocated by many researchers, or concrete pavement does not fail due to fatigue, as some researchers proclaim.

C. Bonded concrete overlay (BCO) & Unbonded concrete overlay (UBCO) sections

1) Bonded Concrete Overlays (BCO)

In bonded concrete overlay (BCO), the goal is for the existing and new slabs to function as a single, monolithic structure. Utilizing existing slabs saves costs and leverages the thickness to extend the pavement's life. This report evaluates the performance of two BCO sections:

- **US 75 in Sherman**

The first known bonded CRCP on JCP was placed on US 75 in Sherman in 2010 [4].The half-mile long JCP section on US 75 southbound that was selected for the rehabilitation is located just south of Exit 64. The 10-in JCP was completed in 1984. The roadway consisted of 10-in concrete slab with 15-ft joint spacing on 6-in flexible base and lime treated subgrade. Dowels were used at transverse joints for load transfer. The section has two 12-ft wide lanes in each direction, with 4-ft inside and 10-ft outside shoulders. Originally, shoulders were 1-in AC layer on 8-in flexible base. In 1998, tied concrete shoulders were retrofitted with 10-in JCP with matching 15-ft joint spacing on 6-in flexible base. When the pavement design was developed in the early 1980s for this section, the average annual daily traffic (AADT) was 11,000 and 20-year projected AADT (in 2004) was 16,200. The pavement was designed with 20-year design life with the above projected traffic. Actual ADT in 2004 was 55,000, which is more than 3-fold the projected design traffic for 2004.

From 2002 until 2010, the TxDOT Sherman Area Office spent on average between half a million and one million dollars per year for routine maintenance of the JCP in US 75. Repairs in this section required various lane closures for an average of 3 months per year. With the assumption that the same level of repairs would be needed for the next 20 years, the cost of maintenance was projected to be 10 to 20 million dollars, even without adjustments for inflation. Road user cost due to the lane closures for the next 20 years was estimated at over 70 million dollars.

Considering the financial constraints TxDOT was facing at that time, this level of cost was not acceptable and a better rehabilitation method that was cost-effective and that would provide a long-term good performance with minimal maintenance was needed. To explore different rehabilitation options for this roadway, a half-mile section with the worst condition was selected and detailed evaluations of the existing condition of the JCP were conducted with Falling Weight Deflectometer (FWD). The objective of the selection of the section in the worst condition was that, if the CRCP overlay works in this section, then the same overlay should work for the rest of the roadway. A total of 3 drops were made at each slab – upstream, mid-slab, and downstream. The deflections thus obtained are shown in Figure 12, which indicates unacceptably high deflections at a number of locations. The analysis showed quite poor structural conditions at some joints and cracks. Most large deflections were at transverse repair joints and cracks, while some were at transverse contraction joints, indicating poor slab support.

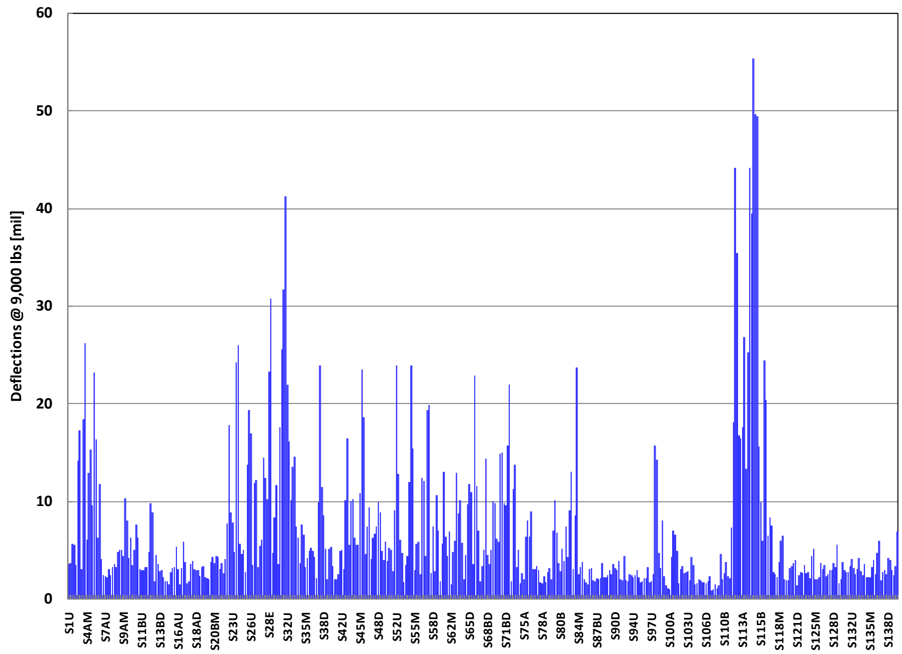


Figure 12 Deflections measured using FWD machine in US 75 in Sherman

Furthermore, there were two major issues in this pavement section: one is poor drainage and the other poor materials in the flex base. The plasticity index (PI) values of the base materials in this section were quite high, and the combination of high PI and poor drainage (high moisture content) was a primary cause for distress and a poor condition of the JCP.

Considering the importance of the section, which provides a major route between Oklahoma and Dallas area, and its poor pavement condition with high annual expenditures needed for repairs, a 7-in CRCP BCO was proposed. However, large deflections at contraction joints/repair joints/cracks were a major concern for CRCP bonded overlay, especially a potential for reflection cracking. No information was available regarding whether reflection cracking in CRCP from joint/crack movements in the existing JCP might compromise the performance of CRCP overlay. To address this uncertainty concerning a potential problem with reflection cracking, it was decided that 2-ft wide non-woven fabric be placed on transverse contraction joints and repair joints. This decision was based on neither past experience nor theoretical analyses. This decision was solely based on the engineering judgement of the pavement designer.

The 7-in CRCP overlay was placed in two phases. In Phase 1, the concrete was placed on May 24, 2010, from 7 am to about 3 pm in the inside lane and 4-ft wide inside shoulder. After the concrete gained adequate strength and all the preparation for its opening to traffic was completed, the traffic was switched to the newly placed inside lane in mid-June of 2010. In Phase II, construction of the outside lane and 10-ft wide outside shoulder was carried out in mid-June, 2010. In Phase II, a decision was made to place concrete at night, since ambient temperature at daytime was quite high, which was considered as a potential issue for the overlay performance. While the construction operations in Phase I construction went flawlessly, there were issues with the concrete as well as the cleaning of the existing JCP surface prior to the overlay placement in Phase II construction. Some of the concrete delivered was quite dry, and some portion of the 7-in concrete overlay was removed and replaced.

In 2022, the AADT in the southbound of this section was 31,208 vehicles per day with 15% trucks, which is about 4,680 trucks per day in the southbound lanes, which is equivalent to approximately 2.4 million ESALs per year. In this estimation, an equivalent axle load factor of 1.4 was selected per truck; however, there are no WIM stations in this area with no information on truck weights. Actual ESAL numbers could be higher, considering overweight trucks recorded in Texas highways. As of 2023, there are 30 repairs done in the outside lane, but none in the inside lane. In other words, the difference in the performance for more than 13 years between inside and outside lanes is significant. Since the truck traffic is mostly in the outside lane, it could be construed that the truck traffic was the primary cause for the difference. Or it could have been the combination of truck traffic and construction quality that caused a big difference in the performance of inside and outside lanes. Moreover, the use of fabric does not explain the difference in the performance of the two lanes since fabric was placed in both lanes. However, the performance of the repairs of distresses in the outside lane, which consisted of removing deteriorated concrete in the overlay and non-woven fabric as well as cleaning reinforcing steel, followed by cleaning the surface of JCP and placing new concrete, has been excellent, indicating that the use of fabric was not needed to prevent or retard reflection cracking. Observations from the US 75 experimental project were: (1) bonded CRCP overlay on JCP could be a good rehabilitation option, (2) construction quality is an important factor for the good performance of bonded CRCP overlay on JCP, and (3) the use of non-woven fabric is not needed.

As for the condition of this pavement, numerous PCC patches were observed in the outside lane, attributed to construction issues as reported in 0-6590, even though a single distress was observed in the inside lane. As shown in Figure 13, PCC patches were in the outside lane only, with one location where a distress was in progress.

(a) PCC patches in outside lane (b) Distress in progress

Figure 13 PCC patches in outside lane and distress in progress

Additionally, drainage issues seem to be a pressing concern, as waterlogged areas were observed near the bridge as shown in Figure 14, which could eventually compromise the base support of the pavement.

(a) waterlogging beneath the bridge

(b) drainage in the side of the road pavement

Figure 14 Waterlogging under the bridge and drainage issue near the road pavement

- **Loop 286 in Paris**

In 2023, a bonded CRCP overlay was constructed over an approximately 0.85-mile section of Loop 286 in Paris, between US 82 and US 271, on the existing 9-inch CPCD. The overlay thickness was 5 inches. The original pavement structure, consisting of a 9-inch CPCD with a 1-inch ACP and an 8-inch flexible base, was placed in the late 1970s or early 1980s. Although the design life of this CPCD was 20 years, it served more than twice its intended lifespan.

Structural Evaluation

FWD testing was conducted before and after the BCO placement, showing substantial improvement in the structural condition of the existing CPCD. As depicted in Figure 15, FWD deflection measurements on the existing 9-inch JCP ranged from 4 mils to 20 mils. After the 5-inch CRCP overlay was applied, deflections at the same locations decreased to a range of 2 mils to 4 mils, ascertaining significant improvements in structural capacity of the pavement system.

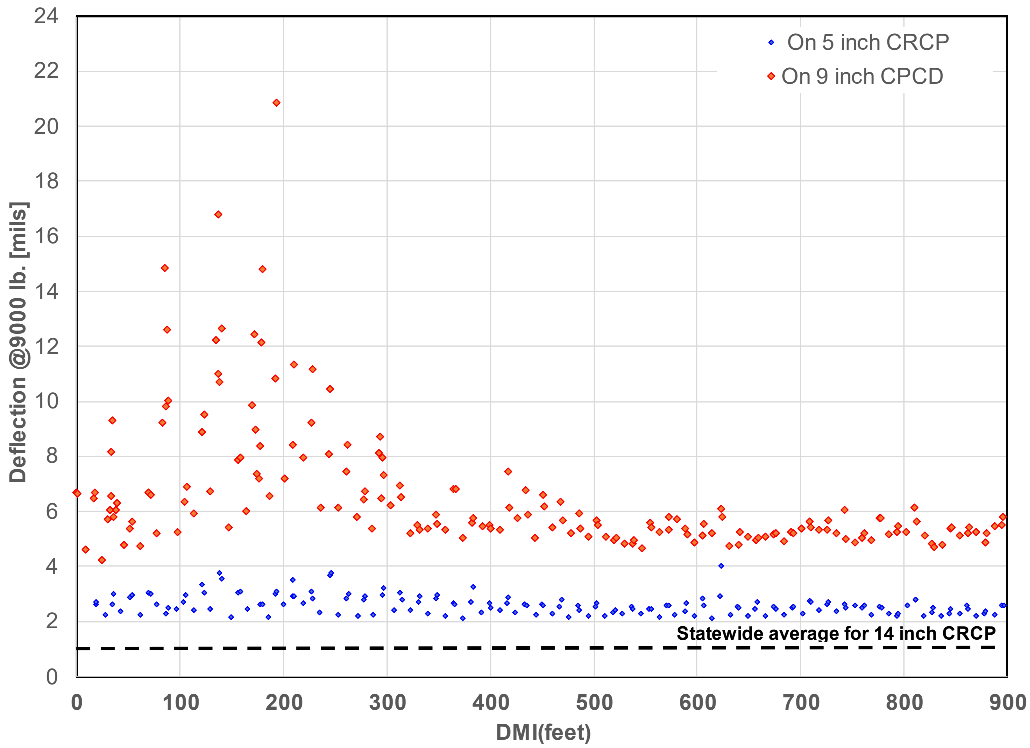


Figure 15 FWD deflection before and after Bonded CRCP overlay

Both the outside and inside lanes experienced bonding issues, traced back to the use of high slump concrete delivered during construction. Two prominent issues were observed: debonding and longitudinal cracks. Debonding was more common in the outside lane, whereas the inside lane had more longitudinal cracks along with debonding issues.

A field visit in March 2024 revealed the extent of longitudinal cracks, as shown in Figure 16. Settlement cracks were also observed in the inside lane, along with debonding near the longitudinal cracks, which was partly linked to the use of high slump concrete.

(a) (b)

Figure 16 Longitudinal cracks observed in the inside lane

The bonded CRCP overlay project on Loop 286 demonstrated a significant improvement in the structural condition of the existing JCP, as evidenced by reduced FWD deflections. However, issues with high slump concrete during construction led to debonding and longitudinal cracks, particularly in the inside lane. Addressing these issues in future projects will be crucial for ensuring the long-term performance of bonded overlays. Figure 17 shows typical transverse cracks observed in the field. Currently, there are no pressing issues regarding the pavement condition, but continued evaluations will be necessary to monitor the pavement's condition.

Figure 17 Transverse cracks

2) Unbonded Concrete Overlays (UBCO)

One method for rehabilitating severely deteriorated existing pavement is the use of Unbonded Concrete Overlay (UBCO). This involves placing a thin layer of asphalt concrete to minimize the impact of distress observed from the existing pavement. Compared to bonded concrete pavement, UBCO tends to break the bond with the existing pavement, making it more tolerant of minor material and construction imperfections in the existing pavement. However, this requires thicker slabs, which could be an issue where bridge clearances are not sufficient. However, because of the way UBCO is designed, UBCO is quite conservative pavement structure, and the UBCO performance in Texas has been quite good, as discussed in 0-6910 report [5]. The condition of UBCOs in Texas will be visually evaluated in FY 25, and the results will be included in the final report.

D. Whitetopping

Whitetopping is an advanced pavement rehabilitation technique that involves overlaying an existing asphalt pavement with a new layer of rigid pavement. This method has gained popularity due to its effectiveness in extending the life of deteriorating asphalt surfaces and enhancing their load-bearing capacity. Whitetopping is particularly beneficial in environments where pavements experience high traffic volumes and significant stop & go traffic, making it a versatile solution for a wide range of roadway applications.

The design concept of whitetopping involves making smaller size slabs to reduce the cracking potential due to bending stresses by traffic. Even though the current design life of Whitetopping in Texas is 10 years, many whitetopping projects in Texas have exceeded their design lifespan. A total of seven sections were evaluated, and the general section information is presented in Table 2. For this task, seven whitetopping sections constructed in Texas were evaluated. These sections were built at different times and feature various slab sizes.

Table 2 General Information of Whitetopping Projects

District	Location	GPS Coordinates		Slab Size [ft.]	Const. Year	Remark
		Latitude	Longitude			
Odessa	Loop 250 Frontage Rd	32.028332	-102.145395	3	2002	Intersection
Odessa	SH191 at Tanglewood Ln	31.891820	-102.341779	3	2002	Intersection
Abilene	SH36 at FM1750	32.436500	-99.712638	4	2003	Intersection
Brownwood	SH226 at SH279	32.106065	-99.165733	4	2003	Intersection
Childress	US287	34.256922	-99.517581	5		Intersection + Roadway
Paris	US69 at SH19	32.873533	-95.766126	6	2012	Intersection
Beaumont	FM1405	29.774139	-94.899551	6	2016	Roadway

The whitetopping section in Midland in the Odessa District was constructed in 2002, and during the evaluation, it was observed that slab slippage was a major issue. Figure 18 illustrates the extent of the observed distress, which may be due to the debonding between the concrete and asphalt layers, consistent with previous reports. During the field evaluations in the Midland section, lane widening was undersay, allowing for an observation of the side of the whitetopping as shown in Figure 17. It was observed that not all the saw-cut joints propagate through the slab; rather, saw-cut joints were popped every 6-ft rather than every 3-ft, which is the slab size. This indicates that the natural joint spacing for this whitetopping section could be 6-ft.

Figure 18 Sliding in WT section in Odessa

Figure 19 Edge Cross Section View of WT in Midland at Sawcut Location

In the Abilene section, numerous diamond cracks were observed as shown in Figure 20. The cause of these cracks is likely due to the joints being located in the wheel path. This distress is similar to what was observed in the Whitetopping project in Minnesota. The extent of the cracking worsened over time, and it is believed that these diamond cracks will compromise the long-term performance of whitetopping.

Figure 20 Diamond Crack in WT Section in Abilene

In the Cross Plains section in the Brownwood District, as shown in Figure 21, it was observed that cracks did not propagate at the all saw-cut joints, as observed in the Midland section. Some suggest that the lack of crack propagation is due to insufficient saw-cut depth. However, in the Cross Plains section, the saw-cut depth is one-third of the slab thickness, which should be sufficient. Despite this, some joints did not cracked. This indicates that the 4-ft joint spacing applied in this whitetopping project is also somewhat smaller than needed. Based on the information from the Midland and Cross Plains sections, it can be concluded that slab sizes of 3-ft and 4-ft are smaller than needed for whitetopping design, and the current TxDOT design of 6-ft by 6-ft appears to be adequate.

Figure 21 Edge Cross Section View of Whitetopping Project in Cross Plains

The whitetopping section constructed at the intersection in Chillicothe in the Childress District was evaluated and found to be in quite good condition. This section, constructed with a slab size of 5-ft by 5-ft, showed only one diagonal crack and FDR each, and one distress was observed at the transition to CRCP. However, the overall condition was notably good, with no sliding observed. The overview and observed distresses are shown in Figure 22.

(a)

(b)

(c)

(d)

Figure 22 Whitetopping section in Chillicothe

As part of the 5-5482 implementation project [6], two whitetopping sections were constructed in the early 2010s. These sections were designed using the newly developed mechanistic-empirical design procedures from TxDOT Research Project 0-5482 [7]. The section at Loy Lake was replaced with CRCP, making it unavailable for evaluation. However, the whitetopping section located at US 69 and SH 19 in Emory, a 7-in thick slab with 6-ft by 6-ft joint spacing, was evaluated, and it has now reached its design life of 10 years. Despite heavy truck traffic, the section is in good condition. Additionally, only one diagonal crack was found during the evaluation, as shown in Figure 23. This suggests that the design procedures used for this section were effective in ensuring long-term performance.

(a) Overview (b) Diagonal Crack

Figure 23 WT project in Emory

Lastly, an interesting whitetopping project was evaluated at FM1405 in Beach City, in the Beaumont District, with GPS coordinates 29.727999, -94.916286. This section is the only whitetopping project constructed on a regular roadway rather than at an intersection. The pavement is 6-in thick, slab size is 6-ft by 6-ft, and the entire section is approximately 3.3 miles long. The overall performance observed during the field evaluation was quite good as shown in Figure 24. As shown in Figure 25, however, in the northern part of the section near the railway, some distresses, including various types of cracks, were observed. These distresses were limited to the area near the railway, and no significant distress was observed elsewhere. The potential cause of the distress is attributed to the construction on an embankment, where volume changes in the subgrade likely led to the observed issues.

Figure 24 Whitetopping in FM1405

(a) (b)

Figure 25 Observed Distresses in FM1405

Whitetopping has proven to be an effective pavement rehabilitation technique, particularly in areas with high traffic volumes and stop-ang-go traffic patterns, significantly extending the life of deteriorating asphalt surfaces and enhancing load-bearing capacity. Its performance has been shown to exceed the design life of 10 years. The evaluation of seven whitetopping sections in Texas, constructed at different times and with various slab sizes, demonstrates the versatility and durability of this method. Although some sections exhibited specific types of distress, the overall performance was notably good, with minimal issues such as slippage and cracking in most areas. These findings suggest that when whitetopping is properly designed (6-ft joint spacing with proper slab thickness) and implemented, it provides a robust and long-lasting solution for deteriorated asphalt pavements especially at intersections.

E. Precast Concrete Pavement (PCP)

PCP (Precast Concrete Pavement) has advanced over the past 15 years and is being used in many states. In the United States, PCP technology is being developed for its benefits in full-panel replacements and continuous applications such as rehabilitating longer lengths or wider areas. In this task, the evaluation of PCP was conducted on two individual sections.

The first section, shown in Figure 26, is located on the northbound of IH 35 frontage road between Airport Road and SH 195 in Georgetown, with GPS coordinates [30.687526, -97.656608]. This section utilized the CTR method developed by UT Austin [8]. The CTR method involves applying post-tensioning to precast slabs, which is different from the most widely used method of PCP, where no post-tensioning is applied. The thickness of the pre-cast panels was 8-in. During the section evaluation, joint faulting and longitudinal cracks were observed, which were also mentioned in previous reports. Additionally, small cracks were observed at the slab edges, as shown in Figure 27. However, due to the relatively low traffic volume in this section, these small cracks do not cause significant problems. The value of this section is quite limited since the traffic volume is so low, and no conclusions could be made whether this technology could be a viable option for highways with heavy truck traffic, which is unfortunate. In the future, it is advised that special sections are placed at roadways with heavy truck traffic, with the idea that failure could occur and repairs would be needed. The bottom line is that we learn more from failures and successes.

Figure 26 PCP section in Georgetown

Figure 27 Edge Crack in PCP Section in Georgetown

The second section, shown in Figure 28, is located between SH97 and SH72 in Fowlerton in the San Antonio District, with GPS coordinates [28.496680, -98.801147]. This section, built in April, 2016 with 12-in slab thickness and 8-ft joint spacing, used the dowel bar installation method, a common approach for PCP [9]. No noticeable distress was found in this section. However, some minor slipping was observed at the ends of a few slabs and FDR was conducted, which does not significantly affect the overall structural performance. The traffic in this intersection is not high, even though most of the traffic appears to be trucks, and continued monitoring of this section is recommended.

Figure 28 PCP section in Fowlerton

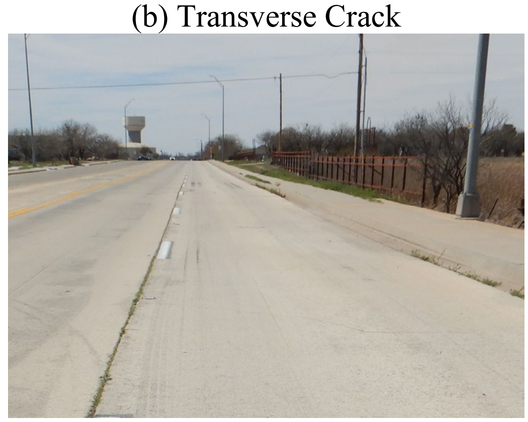
F. Roller Compacted Concrete Pavement (RCCP)

RCCP, which has recently raised selection of concrete pavement type, is currently under study. This type of pavement has a lower water-cement ratio compared to conventional concrete and uses rollers instead of vibration to compact the concrete. Dowel bars are not used in this pavement structure. Two sections were evaluated for this study. The first section is located on Grape Creek Road and 50th Street in San Angelo and was constructed in 2011 and 2012. Despite being open to traffic for a relatively short period, this section has experienced undulation (see Figure 29(d)), longitudinal cracks, and joint faulting. As shown in Figures 29(a) and (b), this indicates inadequate load transfer due to the lack of dowel and tie bars and poor aggregate interlock at the joints, resulting in faulting and transverse cracks. Additionally, as seen in Figure 29(c), severe spalling was observed in some areas, even though the severe spalling doesn't appear to be the use of SRG, as in CRCP in the Houston District. Overall condition appears to be adequate, even though the traffic is typical of residential areas, and no positive conclusions could be made regarding whether RCCP is a good pavement type for major highways.

(a) Faulting

(b) Transverse Crack

(c) Spalling



(d) Undulation

Figure 29 Observed Distresses in RCCP section in San Angelo

Another RCCP section evaluated was the pavement at US 83 and RM 337 in Leakey in the San Antonio District. The visual condition survey indicated that longitudinal & transverse cracks were present in several locations as shown in Figure 30. Also, surface defects and small spalling were observed. Moreover, the primary issues were noise and reduced ride quality due to faulting at joints. The noise and deterioration of ride quality were significant enough to cause some complaints from nearby residents. One of the advantages of RCCP is stated that the smaller crack width due to the lower drying shrinkage of the PCC mix allows for excellent aggregate interlock at the joints. However, that advantage was not evident in this project. The traffic level in this project is really low, and the performance issues here – cracking and faulting – show that RCCP is not ready for implementation for mainlanes on major highways.

(a) Faulting & Cracks

(b) Transverse Crack & Surface Defects

Figure 30 Observed Distresses in RCCP Section in Leakey

Lastly, an evaluation was conducted on a section of RCCP constructed at the rest area on IH 20 in Ranger. As shown in Figure 31(a), the overall performance of the section appeared to be good, but some distresses were found. Figures 31(b) and (c) show longitudinal and transverse cracks, and it was noted that one longitudinal crack already had been repaired. Interestingly, most of the cracks occurred near saw-cut joints. No in-depth evaluation was conducted to identify the cause(s) of these cracks; however, it is hypothesized that these cracks were due to poor jointing practices – law-sawcut and/or deficient saw-cut depth. However, since this is a rest area not related to driving quality, these issues are unlikely to affect its usability.

(a) Overview

(b) Longitudinal Crack

(c) Transverse Crack

(d) Longitudinal Crack Repair

Figure 31 RCCP section in Ranger Rest Area

Based on the evaluation of RCC pavements conducted in this investigation, the following recommendations are made:

1) The use of RCCP on major highway lanes is not recommended until new material design/construction methods that ensure good load transfer at transverse joints and no faulting are developed and proven to work.

2) Construction and material specifications that promote the compaction of RCC materials in RCCP should be developed.

3) RCCP may be a good candidate for rest areas or ports where riding quality is not critical.

G. CRCP with 100% Recycled Concrete Aggregates (RCA)

In the mid-1990s, TxDOT conducted a reconstruction project for a CRCP section using 100% recycled materials over a span of more than 5.8 miles. This section is located on IH 10 in Houston, between IH 45 and Loop 610 West, with GPS coordinates [29.77763, -95.411335]. Reportedly, no virgin aggregates were used in this project. Instead, crushed concrete obtained from then existing IH 10 in the same location and also other projects was used for both coarse and fine aggregates. The original aggregate in the recycled concrete was SRG, which was reported to be prone to spalling.

The current condition of this section is excellent, with some repairs made to address spalling and large FDR noted (Figure 32). Despite being in operation for almost 30 years and experiencing heavy truck traffic as well as submerged in the water several times, the evaluation of this section indicates that the use of 100% recycled materials resulted in satisfactory performance. Based on the early-age performance of this section, TxDOT made changes to Item 421 in 2004 Construction Specifications, which allowed the use of RCA for coarse aggregates for Class P concrete. The long-term good performance of this project suggests that the changes made in Item 421 were a good decision.

(a) Overview

(b) Detailed view

(c) FDR #1

(d) FDR & Spalling Repair

Figure 32 CRCP with RCA Section on IH10 in Houston

H. CRCP with 1 mat vs. 2 mat Longitudinal Reinforcement Design

This section was evaluated due to its unique features, even though it was not in the original evaluation list. It is located on IH 35 near the Hill County Safety Rest Area in the Waco District. Both north- and south-bound sections were constructed with 14-inch CRCP from 1999 to 2003, but the reinforcement designs were different. The southbound section was built with a single mat of #7 bars, while the northbound section was constructed with a double mat of #6 bars. The steel percentages were pretty much identical at 0.68 %.

Numerous distresses were observed in the southbound direction, with significant repairs already carried out, as shown in Figure 33. In contrast, the condition of the northbound section is almost perfect, with no repairs. Traditionally, TxDOT always placed longitudinal steel at mid-depth, regardless of slab thickness. When the slab is not large, the mid-depth placement of steel worked quite well, since the distance between slab surface and longitudinal steel is not excessive, ensuring the ability of steel in restraining concrete volume changes near the concrete surface, resulting in small transverse crack spacing and tight crack widths. However, as slab thickness becomes large, placing longitudinal steel at mid-depth resulted in large crack spacing due to the diminished ability of longitudinal steel in restraining concrete volume changes near the slab surface, which also resulted in larger crack widths and a higher potential for horizontal cracking at the depth of longitudinal steel. At the time this section was built, no consideration was paid to this aspect, primarily due to the absence of knowledge of the interactions between steel and concrete. Horizontal cracking was observed in the one-mat section in 1999, and it was the first horizontal crack ever observed in CRCP. TxDOT Research Project 0-7026 validated the hypothesis of horizontal cracking mechanism, which includes the placement of longitudinal steel farther away from the slab surface promotes warping and curling behavior while minimizing axial slab behavior, thus increasing horizontal cracking potential for thick CRCP with steel placed at mid-depth. The vast difference in the performance of identical pavement structures except for steel designs, built by the same contractor at the same time-frame using the same materials, with both pavement structures subjected to identical environmental conditions and comparable truck traffic (as a matter of fact, northbound truck traffic is much heavier than in the southbound), clearly indicates the significant effects of steel designs on CRCP behavior and long-term performance. In this project, distresses caused by initial horizontal cracking occurred in 2008 and 2009, about 9 or 10 years after the construction. The same type of distresses is observed on IH 35 just north of Temple, and forensic evaluations will be conducted in FY 25. These distresses are serious ones, which should be properly addressed. The findings of the forensic evaluations will be included in the final report, if the findings are available in time for the report preparation.

(a) One-mat (b) Two-mat

Figure 33 Different pavement conditions between one and two mat sections

III. Task 4: Performance Evaluation of Experimental Section

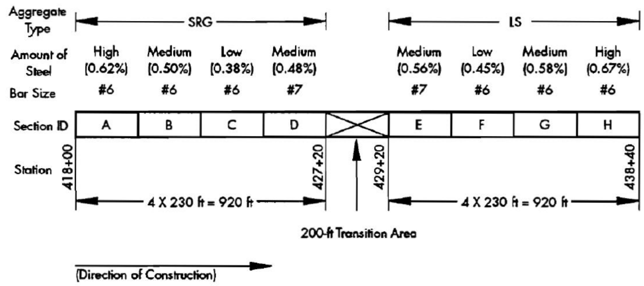
Over the years, TxDOT has invested in research aimed at improving the performance of rigid pavements, with various projects conducted with different objectives. These experimental sections represent the issues in rigid pavements TxDOT faced at that time and the continued monitoring and documentation of the performance of those sections will provide valuable information for TxDOT in improving rigid pavement-related operations.

A. Section Built Under TxDOT Research Project 0-1244

TxDOT Research Project 0-1244 had multiple objectives, including investigating (1) the effects of concrete set temperature on CRCP performance, (2) coarse aggregate effects on spalling, and (3) the effects of longitudinal steel amount on CRCP behavior and performance with different coarse aggregate types. Under this project, four CRCP experimental sections were constructed in the Houston District [10]. These sections are located on IH 45 in Spring Creek, Beltway 8 (BW 8) frontage road, and two locations on SH 6. Among the four sections, the two on SH 6 were overlaid with hot mix asphalt in the mid-2000s due to severe spalling problems. The other two experimental sections (one on IH 45 in Spring Creek and the other on the BW 8 frontage road) are in good condition except for spalling problems in sections containing siliceous river gravel (SRG) as coarse aggregate. The IH 45 section used to be inside shoulder, which allowed the performance evaluations; however, the test section was converted to HOV lane and is not available for performance monitoring. Accordingly, field evaluations were conducted at BW 8 section only.

The section on BW8 is located on the eastbound frontage road of Beltway 8, east of Antoine Rd. The GPS coordinates for this test section are [29.937122, -95.482736]. This section was placed on November 24 and 25, 1989. As of the writing of this technical memorandum, this section is almost 35 years old, exceeding its design life by 5 years, still with no structural distresses. Two types of coarse aggregate (SRG and limestone (LS)) and four different reinforcement designs (low, two mediums, and high) were used and selected. Figure 34 illustrates the overview and plans of the test sections, respectively. This section is a 10-in CRCP with a 1-in bond breaker over a 6-in cement-stabilized base (CTB). For the concrete mixtures, both the SRG and LS sections used 5.2-sack cement with a 25% replacement of fly ash. The water-to-cement ratio was 0.44 and 0.45 for the SRG and LS sections, respectively.

(a) Overview



(b) Layout

Figure 34 Section in BW 8 Frontage Rd

This section provided an excellent opportunity to investigate the effects of coarse aggregate type and steel percentages. It is quite difficult to investigate the effects of longitudinal steel amounts on CRCP performance in typical CRCP projects because CRCPs are constructed with a fixed steel amount per design standards, resulting in little variation in the amount of longitudinal steel within a project. A series of field investigations revealed that there was not a single punchout distress found in either the LS or SRG sections. However, there was a significant difference in the surface condition between these two different coarse aggregate types; while the SRG section had numerous severe spalling and spalling repairs, the general condition of the LS section was near perfect, with tight crack widths and no spalling. Figure 35 shows the general surface condition of both SRG and LS sections, repairs of severe spalling shown in the SRG section while excellent surface condition in the LS section. In Figure 36, it is important to note that another spalling begins to develop right next to the existing deep spalling repair. This means that spalling can continue to occur over time, even after more than 30 years, which implies that fatigue damage at the interfaces between SRG surface and surrounding mortar due to continued volume changes from temperature and moisture variations is partly responsible for severe spalling. It also should be noted that severe spalling was much less in the SRG subsection with larger amount of steel, and most serious severe spalling occurred in the SRG section with low amount of longitudinal steel. This again implies that “large volume changes or slab movements” – either by lower amount of steel and/or larger temperature and moisture variations – are responsbile for severe spalling. Obviously, since no spalling was observed in the LS section regardless of steel amounts used, severe spalling is related to coarse aggregate characteristics, including but not limited to, surface texture, shape, thermal conductivity, and coefficient of thermal expansion. Efforts were made in TxDOT research projects to identify mechanisms for severe spalling; however, the findings indicate a challenging nature of this issue, primarily due to the quite complex nature of severe spalling mechanisms as well as difficulties in implementing the findings at TxDOT in terms of construction/materials specifications or design standards that could be applicable to all environmental conditions during CRCP construction in Texas.

(a) SRG Section (b) Limestone Section

Figure 35 General surface conditions

Figure 36 Developing Spalling over time

In addition, as shown in Figure 37, a large full-depth repair was made three years ago. However, it was discovered that the width of one transverse repair joint was quite large, and tie bars at a repair joint were pulled out, as displayed in Figure 38(b). It is believed that the high coefficient of thermal expansion of the existing slab with SRG, along with lower steel amount and large crack spacing in the existing CRCP, caused the tie bars to be pulled out from the repaired section. This implies that there was debonding between tie bars and newly placed concrete in the repaired section. However, it is not known whether the debonding occurred while the repair concrete was still gaining strength. Regardless of what happened here, it shows the tie bar length was not adequate. To obtain more detailed information on the behavior of repair joints in this area, the research team discussed potentially installing gages to investigate the slab behavior here.

However, that would be out of the scope of this research project, even though the data will provide valuable information that could help TxDOT in improving reinforcement details in new construction and repairs of CRCP. Additionally, during the evaluation period, the weather was cold, which contributed to the widening of the joint due to shrink of concrete. Furthermore, the section was evaluated once more during the summer, and it was found that the joints had closed due to the warmer weather (see Figure 39), indicating that the slabs here moved more than expected. This large slab movement is indirect evidence that the bonding between tie bars and repair concrete was broken.

Figure 37 FDR in BW 8 Section

(a) Repair joint condition in winter

(b) Popped up tie bar

Figure 38 Repair Joint in BW 8 Section

Figure 39 Closed repair joint in summer in BW 8 Section

The crack spacing in the inside lane of the SRG section was also investigated. Figure 40 shows the correlation between the steel percentage and average crack spacing in the SRG sections. Among these, Section A had the highest steel percentage, while Section C had the lowest. A interesting finding from the field evaluation was that Section A exhibited smaller crack spacing and less spalling. This observation, mentioned in previous reports, suggests that a larger amount of steel restrained concrete movement more effectively, thereby causing more transverse cracks and reducing the occurrence of spalling. Conversely, in Section C, the lower amount of steel did not adequately restrain concrete volume changes, leading to larger slab movements and crack spacing, and eventually spalling.

The findings of this section confirm the relationship between longitudinal steel amount and crack spacing, or the degree of restraints on concrete volume changes affected by steel amounts. On the other hand, using different steel designs may not work to address severe spalling problems when SRG (that was used in this project) is used as coarse aggregate, since severe spalling was observed even in Section A where the largest amount of longitudinal steel was used, even though its frequency was smaller than that in Section C where the longitudinal steel amount was low.

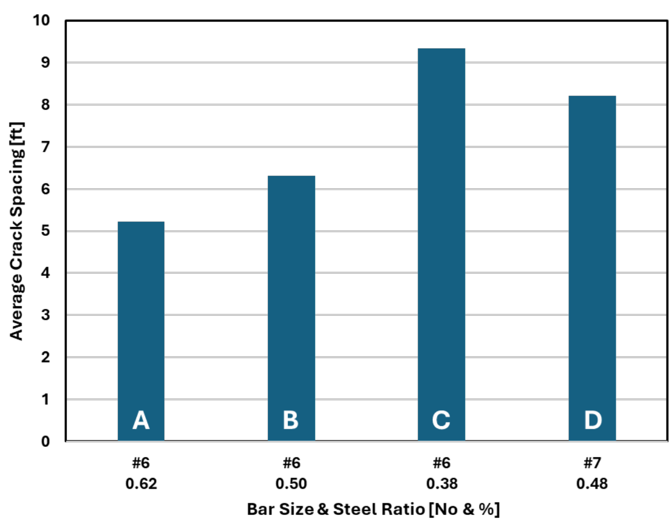


Figure 40 Average crack spacing of SRG section

B. *Section Built Under TxDOT Research Project 0-3925*

In the 0-3925 project, the effects of several experimental variables on the crack spacing distributions and performance of CRCP were investigated [11]. These variables included aggregate type (SRG, LS, and blended), number of steel mats, curing method (standard, double coating, and poly sheeting), saw cut, and paving time (day and night). The section was constructed on US 290 westbound and eastbound in the Houston District near Hempstead in the summer of 1995. It comprises three subsections—named US290SPS-1E, US290-2E, and US290-3W. The GPS coordinates for the sections are: US290SPS-1E at 30.093863, -96.035228; US290-2E at 30.083399, -96.004187; and US290-3W at 30.082612, -96.001003. All these test sections were in the outside lane.

- US290SPS-1E

The first half (500-ft) of the US290SPS-1E section introduced early-entry saw cuts with an almost consistent spacing (6-ft) at the initial construction stage, while the rest of the section did not. This early-entry saw cuts, or called active crack control, were implemented as TxDOT's efforts to utilize locally available SRG aggregates in Houston for CRCP. The initial thought was that, this active crack control would induce so many transverse cracks, resulting in smaller crack spacing, smaller slab movements, and thus lowering the potential for severe spalling. The depth of the early-entry saw was 1-in. Figure 41 shows an overview of the section, with transverse active crack control in this test section. This section shows the presence of spalling at the saw cut joints or transverse cracks as shown in Figure 42. However, the spalling here is not a typical type; rather, it appears due to the early-entry saw-cuts having caused damage along interfaces between SRG surface and surrounding mortar. SRG used in Houston area has quite hard, and saw-cutting while concrete is gaining strength at early ages could disrupt the bonding between SRG surface and mortar, resulting in distress resembling spalling as shown in Figure 42. The uncut section also began to show clear signs of early-age spalls at almost every transverse crack as shown in Figure 43, even though there were more chipping than spalling. The findings in this section are that active crack control appears to help mitigate severe spalling observed in CRCP with SRG in Houston.

Figure 41 Overview of US290SPS-1E

Figure 42 Spalling in US290SPS-1E

Figure 43 Uncut section in US290SPS-1E

- US290-2E

This section was constructed at different times of the day (night and morning) to examine the effect of construction time/temperature variables. However, both sections, with SRG used, showed very similar crack spacing distributions. As reported in previous studies, over 80-90% of the cracks in both sections had crack spacing less than 4 feet. Additionally, as shown in Figure 44, there were many longitudinal cracks almost parallel to the longitudinal saw cut joint, resulting in large FDR as shown in Figure 45. This is most likely because the longitudinal saw cut was introduced too late or at an inappropriate depth. Several longitudinal cracks were also found in the main lanes. However, despite the very narrow transverse crack spacing and significant heavy truck traffic, the US290-2E section did not exhibit any punchout distress after almost 30 years of service, which indicates negligible effects of concrete set temperature on CRCP performance.

Figure 44 Longitudinal crack in US290-2E Section

Figure 45 Large FDR in US290-2E Section

- US290-3W

Unlike US290SPS-1E and US290-2, this section used LS instead of SRG as coarse aggregates. The crack spacing was generally larger than that of US290SPS-1E and US290-2. The use of LS appears to have resulted in much larger crack spacing, which is the case statewide. In terms of pavement distress, this section performed much better than US290SPS-1E and US290-2E as shown in Figure 46. No spalling or punchouts were observed.

Figure 46 Overview of US290-3W Section

The findings in this section clearly demonstrate significant effects that coarse aggregates have on the performance of CRCP, especially severe spalling. Whether active crack control could prevent severe spalling when SRG is used is still unknown, since the inference space is quite small and early-age CRCP behavior affected by active crack control was not investigated. If TxDOT intends to pursue this idea of using SRG in CRCP in Houston area, further evaluations with CRCP slab micro-behavior as affected by active crack control are recommended, even though it is not known whether the findings will provide positive information on the use of SRG in Houston.

C. Section Built Under TxDOT Research Project 0-4826

The main objective of Project 0-4826 was to investigate effective methods for preventing or minimizing spalling distresses in CRCP when SRG is used as coarse aggregate [12]. This project is another indication that TxDOT genuinely tries to maximize the use of locally available aggregates. A 12-in CRCP was constructed in November 2005 on SH 288 in the Houston District with various curing methods, mix designs (fly ash content), and batching sequences. The GPS coordinates for this section are [29.506624, -95.388193]. Approximately 10 years after the last evaluation, there is no punch-out distress in this section, as reported in previous studies. However, spalling distresses and later-age cracks have persistently been identified, and in some sections, crack spacing was too small, leading to distresses depicted in Figure 47.

(a) (b)

Figure 47 Observed distresses in 0-4826 Section

The 2022 PMIS condition score for this section was 66 points, and the pavement was only 15 years old. Field condition surveys revealed that all sections were experiencing spalling distresses. In other words, regardless of batching sequence, mix design, and curing method attempted in this study, every section had spalling distresses, with varying degrees in their severities. Since it is found that spalling is a long-term distress at its making, long-term evaluations of this section would be ideal. However, this section was replaced with another CRCP in July 2023 to provide a room for interchanges in this area.

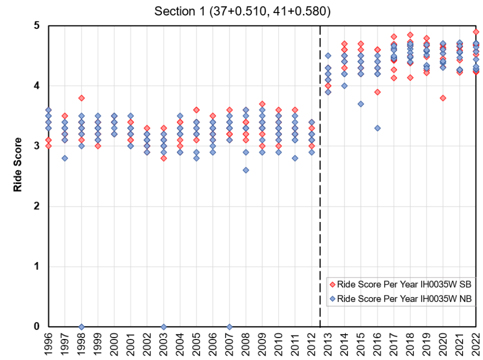
D. Section Built Under TxDOT Research Project 5-9046

Diamond grinding (DG) is a pavement preservation technique that involves using diamond-tipped blades to remove a thin layer of the surface of concrete pavements. This process restores the pavement to a smooth condition, improves skid resistance, reduces noise, and extends the pavement's life. It is particularly effective in addressing surface irregularities, such as faulting at joints and cracks, and can enhance the overall ride quality of the roadway. Diamond grinding is widely used in maintaining highways and airport runways, providing an efficient and cost-effective solution for prolonging pavement performance and safety.

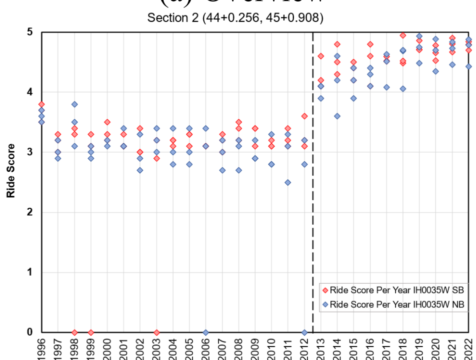
The TxDOT research project 5-9046-01 discusses the diamond grinding rehabilitation of existing CRCP sections on IH35W in the Fort Worth District [13]. The grinding operation used a 4-foot-wide fixed-type grinding blade assembly to achieve a smoother post-grinding profile. Field data collection involved measurements of pavement surface properties before and after the grinding operation, focusing on surface macro texture, skid resistance, surface roughness, and pavement noise. The research examined different pre-existing surface conditions and traffic levels on the effectiveness of diamond grinding. The rehabilitation was completed on August 2, 2012.

In this task, PMIS data was analyzed for these test sections. The research team evaluated the changes in pavement conditions after diamond grinding on three different original surface types (Carpet Drag, Burlap Drag, Transverse Tining). Figure 48 shows the changes in ride scores over time. The dataset included both pre-rehabilitation and post-rehabilitation periods. The PMIS analysis results indicated that the ride scores for all three sections increased. Another notable point is that after DG, the ride scores did not decrease over time, suggesting that there is no significant change in the pavement profiles after diamond grinding. This comparative analysis confirmed that ride scores consistently improved following diamond grinding rehabilitation.

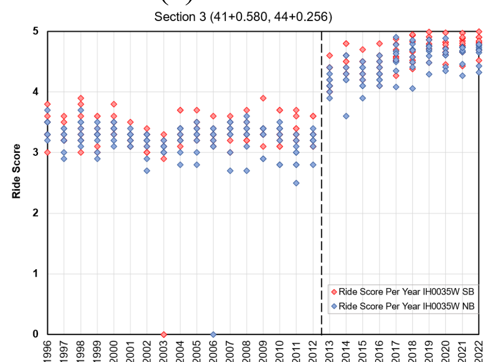
(a) Overview



(b) Section #1



(c) Section #2



(d) Section #3

Figure 48 Ride Scores over time on IH35W in FTW

However, Figure 49, which illustrates the surface condition in June, 2024, shows the marked difference in the surface condition between along wheel paths and at shoulder – the macro texture geenerated by DG disappeared under the wheel loading. It is not known whether the loss of macro texture would result in lower skid numbers, since micro textures still remain under wheel paths. Evaluation of the effectiveness of DG on preserving skid resistance is quite complicated and is beyond the scope of this research study, and no further evaluations were performed.

(a) Wheel Path

(b) Near Shoulder

Figure 49 Surface Texture of Diamond Grinding Section on IH35 W

E. Section Built Under TxDOT Research Project 0-7026

In Texas, a new type of distress was identified in relatively thick CRCPs. The major feature of this distress is partial depth distress. The horizontal cracks occurred at the depth of longitudinal steel, with large crack spacings and wide crack widths. To address this issue, TxDOT conducted research project 0-7026. The objective of this project was to improve the performance of CRCP by identifying optimum steel depths for thick CRCP [14].

A total of four sections were constructed between 2020 and 2022. During field evaluations, notable distresses were not observed. However, there was a significant difference in crack spacing and crack width. Particularly in the upper depth section, the crack spacings and widths were quite small. Figure 50 illustrates a close view of the mid-depth and upper depth sections on IH35 in Hillsboro in the Waco District. Even though it is not clearly shown in Figure 50 due to the resolution and contrast of the pictures, placing longitudinal reinforcement at above the mid-depth effectively restrains the movement of concrete, resulting in smaller crack spacing and crack width. Conversely, the general section, where the reinforcement was placed at mid-depth, shows large crack spacing and crack width, indicating less restraints on concrete volume changes by longitudinal steel and potentially higher probability of horizontal cracking.

(a) General Subsection

(b) Upper-depth Subsection

Figure 50 0-7026 Section on IH35 in Hillsboro

Another section, the section on US62 in El Paso, was also investigated. This section had three subsections: the general mid-depth subsection, the upper-depth subsection, and the upper-depth subsection with low CoTE.

Investigations were conducted at the outermost lane where the gauges were installed. It was still closed to traffic when the evaluation was made in (month and year) and no distresses were found. Figure 51 shows the average crack spacing for each subsection. Similar to the Hillsboro section, the upper-depth subsection showed smaller crack spacing, indicating that the longitudinal steel more effectively restrains the movement of concrete. Another interesting finding was observed in the upper-depth low CoTE subsection. Despite having a lower steel ratio than the other 2 subsections, it exhibited nearly similar crack spacing to the upper-depth subsection. This finding further supports the proposition that if the longitudinal steel is placed at an optimal depth, CRCP slab movement behavior could be properly controlled, thus providing optimum CRCP performance with lower longitudinal steel amount. This proposition cannot be lightly considered, since it is a quite bold idea. Fortunately, TxDOT will have a new research project that will start this September, where CRCP behavior will be investigated as affected by various steel configurations. The findings from that study are expected to shed lights on this important issue.

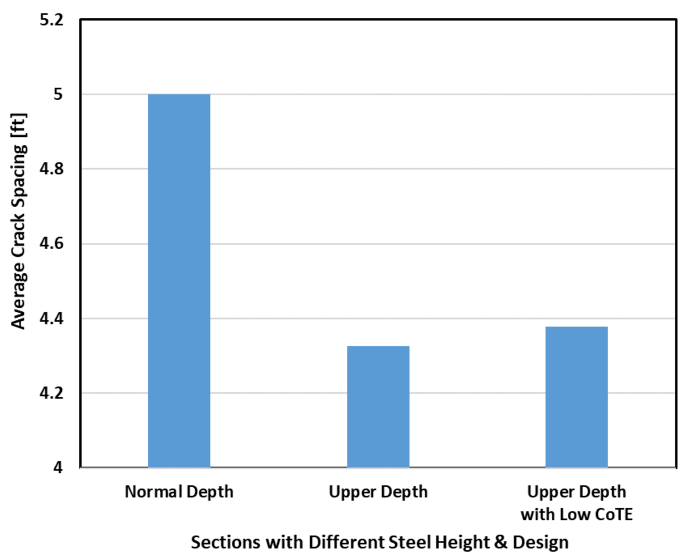


Figure 51 Crack spacing on US62 in El Paso

IV. Conclusion

TxDOT has historically invested substantial time and resources into improving the performance of rigid pavements, and Texas holds the distinction of having the most rigid pavement lane mileage in the United States. The 0-7147 research project entitled "Project Level Performance Database for Rigid Pavements in Texas, Phase III" aims to evaluate various types of rigid pavements constructed in Texas and create a comprehensive database to analyze their performance and economic benefits.

This Technical Memorandum summarized the performance evaluations of special and experimental sections made by the research team under Tasks 3 and 4 up to July 2024. In that sense, this technical memorandum is interim in nature, since one more round of performance evaluations will be conducted in FY25, and the updated findings will be included in the final report.

Evaluations of special sections revealed that almost all the sections performed well, validating the technical worthiness of the special features evaluated. Based on these results, TxDOT may want to develop or modify design standards and special specifications or special provisions, so that the technology evaluated in the special sections could be easily implemented.

The performance of experimental sections varied quite a lot, signifying potential discrepancies between results from theoretical models and actual pavement behavior and performance. This is not surprising, considering quite complicated nature of CRCP behavior, especially the interactions among longitudinal steel, concrete materials, and environmental conditions. One good finding is that concrete setting temperature does not have significant effects on the long-term performance of CRCP, making TxDOT CRCP construction operations less restrictive.

In summary, 0-7147 research project is a significant study that highlights the current state and future directions for rigid pavements in Texas. Continuous monitoring and data analysis will enable the improvements in pavement designs and construction/maintenance, enhancing the potential for improved performance of rigid pavements in Texas and beyond.

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