IMPLEMENTATION OF COMPOSITE PAVEMENT SYSTEMS

Texas DOT Two-Lift Concrete Pavement Construction Project: Frontage Road Along SB U.S. 59




Prepared By:

Applied Pavement Technology, Inc.
115 West Main Street, Suite 400
Urbana, IL 61801
217-398-3977
www.appliedpavement.com

March 2019

IMPLEMENTATION OF COMPOSITE PAVEMENT SYSTEMS

Texas DOT Two-Lift Concrete Pavement Construction Project: Frontage Road Along SB U.S. 59

Mark B. Snyder
Consultant
Bridgeville, PA

Kurt D. Smith
Applied Pavement Technology, Inc.
115 West Main Street, Suite 400
Urbana, Illinois 61801

Andy Naranjo
Texas Department of Transportation
125 E. 11th Street
Austin, TX 78701

Prepared By:

Applied Pavement Technology, Inc.
115 West Main Street, Suite 400
Urbana, IL 61801
217-398-3977
www.appliedpavement.com

March 2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TEXAS DOT TWO-LIFT CONCRETE PAVEMENT CONSTRUCTION PROJECT: FRONTAGE ROAD ALONG SB U.S. 59

Introduction

The Strategic Highway Research Program 2 (SHRP2) R21 project, Composite Pavement Systems, focused on the design and construction of renewable composite pavements using either a hot-mix asphalt (HMA) wearing course or a portland cement concrete (PCC) surface over an underlying structural concrete layer (i.e., either HMA/PCC or PCC/PCC designs). These composite pavement systems are promising technologies for providing sustainable, long-lasting roadways that can be rehabilitated with minimal disruption to the traveling public.

Under the SHRP2 Implementation Assistance Program (IAP), the Federal Highway Administration (FHWA), working in collaboration with the American Association of State Highway and Transportation Officials (AASHTO), administered a series of activities aimed at fostering the implementation of composite pavement systems:

- Provision of technical assistance and support to State Highway Agencies (SHAs) in the planning, design, and construction of new composite pavement systems.
- Development of a workshop on the design and construction of new composite pavement systems and delivery of that workshop to interested SHAs.
- Sponsorship of a multi-state showcase event promoting new composite pavement systems and featuring a visit to a nearby project.
- Conduct of a multi-state peer exchange providing a forum for SHAs to share their knowledge of and experience with new composite pavement systems.
- Provision of technical outreach through technical presentations on new composite pavement systems at national conferences and events.

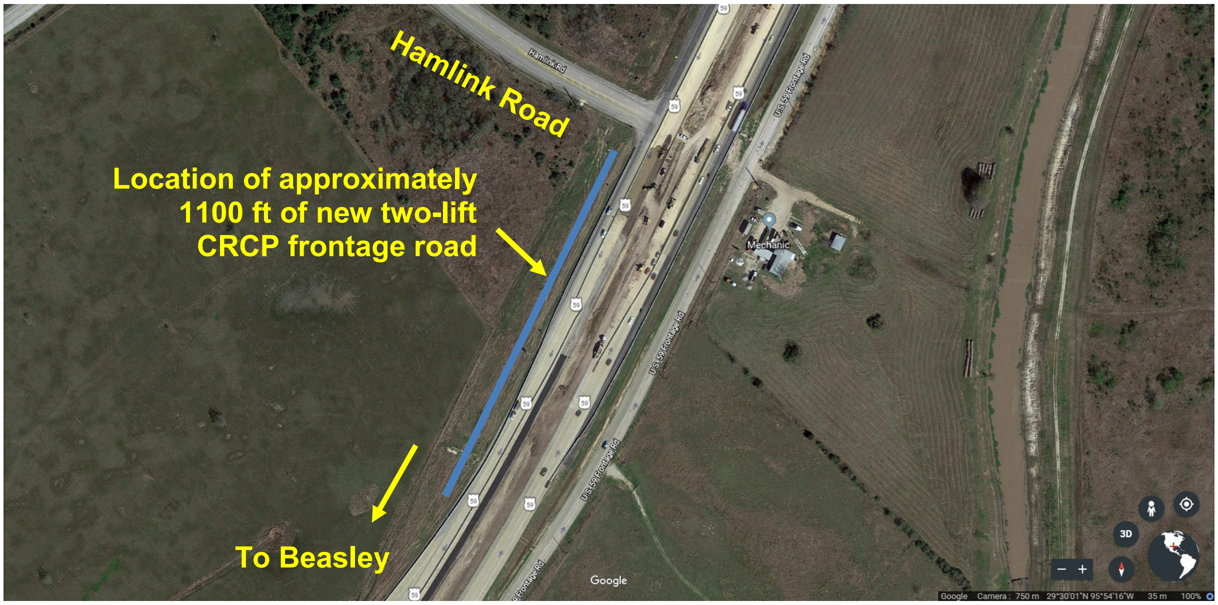
As part of this implementation effort, the Texas Department of Transportation (TxDOT) expressed interest in the construction of a two-lift (wet-on-wet) continuously reinforced concrete pavement (CRCP). TxDOT's interest in two-lift paving focused on examining the potential benefits of using concrete with a lower coefficient of thermal expansion (CTE) in the top portion of the pavement to reduce thermal stresses and improve pavement performance.

This report documents the construction of a two-lift continuously reinforced concrete pavement on a frontage road along southbound U.S. 59 near Beasley, Texas on the nights of April 7 and April 13, 2017. Appendix A provides the two-lift special specification used in the project while Appendix B presents selected project plan documents.

Project Overview

The two-lift pavement was constructed as a part of the frontage road constructed along the southbound lanes of U.S. 59 near Beasley, located south of Houston. Placement included approximately 1,100 lineal ft (335 m) of 36-ft (11-m) wide, two-lift continuously reinforced concrete pavement (CRCP) located between Hamlink Road and Beasley (see figure 1), approximately between Stations 1431 and 1442. The pavement was placed in two construction events, with a 20-ft (6.1-m) wide pavement (consisting of a 12-ft [3.7-m] outside travel lane and 8-

ft [2.4-m] paved outside shoulder) placed over the 1,100-ft (335-m) long project on April 7 and a 16-ft (4.9-m) wide pavement (consisting of a 12-ft [3.7-m] inside travel lane and 4-ft [1.2-m] paved inside shoulder) placed over the 1,100-ft (335-m) long project on April 13. The two placements were tied together using couplers on the transverse reinforcing steel, as described later.



(see Acknowledgments on last page)

Figure 1. Project location.

Mix Design

The TxDOT mix design requirements for the bottom and top lifts are shown in table 1.

Table 1. Concrete mix designs used in two-lift CRCP.

Material	Bottom Lift	Top Lift
Cement (lb/yd^3)	375 (Type I/II)	350 (Type I/II)
Fly Ash (lb/yd^3)	125 (Class F)	150
Grade 2 Coarse Aggregate, SSD (lb/yd^3)	1,805	1,760
Natural Fine Aggregate, SSD (lb/yd^3)	1,090	1,120
Fine Recycled Concrete Aggregate, SSD (lb/yd^3)	256	263
Water (lb/yd^3)	218	218
Chemical Admixtures	[1, 2, 3]	[1, 2, 3]
Theoretical unit weight (lb/ft^3)	143.2	143.0
Design w/cm ratio (max)	0.44	0.44
Design air content (%)	4.0	4.0
Design compressive strength @ 28 days (lb/in^2)	4,000	4,000
Target compressive strength @ 7 days (lb/in^2)	3,250	2,850

[1] Air-entrainer = BASF MasterAir EA90.
[2] Type A Water-Reducer = BASF Polyheed 900.
[3] Type D Water-reducing retarder = BASF Pozzolith 300R

Concrete in the lower lift was designed to have a CTE of more than 5.5 x 10^{-6} in/in/°F (9.9 x 10^{-6} mm/mm/°C) while the concrete in the top lift was designed to have a CTE of less than 5.5 x 10^{-6} in/in/°F (9.9 x 10^{-6} mm/mm/°C).

Pavement Design Considerations

The pavement cross-section is shown in figure 2. The 10-inch (254-mm) total PCC thickness is comprised of a nominal 7-inch (178-mm) bottom lift and a nominal 3-inch (76-mm) top lift. The longitudinal steel consists of No. 6 bars (0.75-inch [19-mm] diameter) placed on 7-inch (178-mm) spacings and centered approximately 5 inches (127 mm) above grade (at the approximate mid-depth of the composite section). The longitudinal steel rests on the transverse steel, which consists of No. 5 bar (0.625-inch [16 mm] diameter) that are placed 48-inch (1219 mm) spacings. The 10-inch (254-mm) composite pavement section is placed over a 1-inch (25 mm) asphalt bondbreaker interlayer, a 6-inch (152-mm) cement-treated base, 6 inches (152 mm) of lime-treated subgrade soil, and the natural subgrade soil. The resulting total pavement thickness is 23 inches (584 mm) of new and improved materials over natural subgrade.

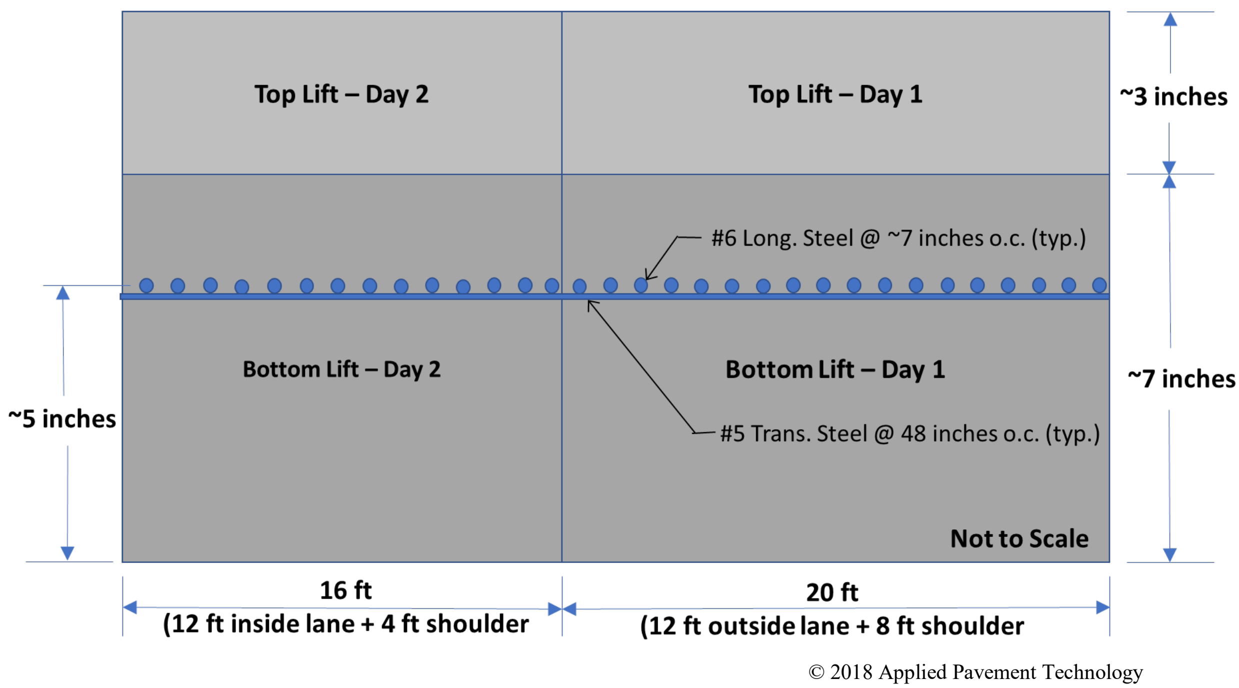


Figure 2. Two-lift concrete composite pavement cross-section.

A 20-ft (6.1-m) width of pavement, comprising the outside lane and shoulder, was placed on the night of April 7, 2017, while the 16-ft (4.9-m) inside lane and shoulder were placed on the night of April 13, 2017. The top lift covers but does not encapsulate the bottom lift because of the need to carry the transverse reinforcing steel across the entire pavement width; transverse steel couplers were placed nearly flush with the planned vertical plane of the lower lift of concrete prior to paving.

Construction Process

The following provides a summary of the two-lift concrete composite pavement construction process observed on the nights of April 7 and 13, 2017. Observed features and processes included reinforcing steel arrangement and support, materials stockpiling and mixture production facilities, concrete transport and placement, paving, materials testing, finishing and texturing, and curing. The research team did not observe subgrade preparation, base placement, or steel placement; the information concerning these topics that is presented in this report is based on information obtained from project personnel.

Subgrade Preparation

Preparation of the lime-treated subgrade was conducted in accordance with Item 260, *Lime Treatment (Road-Mixed)*. This section of the Texas DOT Standard Specifications (2014) describes materials, equipment, and construction procedures for subgrade preparation and the mixing and compaction of lime, water and subgrade or base materials in the roadway. Lime stabilization was performed to a depth of 6 inches (152 mm) with required compaction of at least 95 percent of maximum density at a moisture content that is within -1 to +2 percent of optimum. It is likely that at least lower levels of the subgrade are saturated, as indicated by the presence of standing water in ditches along the new roadway (see figure 3).

Figure 3. Typical wet ditch conditions along north side of project roadway near west end.

Base Placement

After the completion of lime-stabilization of the subgrade surface, 6 inches (152 mm) of cement-treated base was constructed in accordance with Item 275 *Cement Treatment (Road-Mixed)*. This section of the Texas DOT Standard Specifications (2014) describes materials, equipment and construction procedures for the mixture and compaction of cement, water and base materials in the roadway. Compaction is achieved in density control to at least 95 percent of the maximum density.

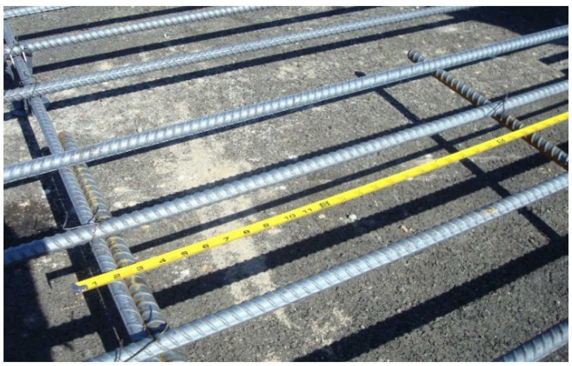
Following placement of the cement-treated base, a 1-inch (25-mm) layer of asphalt concrete was placed as a bondbreaker interlayer material.

Steel Placement

Reinforcing steel was placed just prior to each night of paving. Primary transverse steel reinforcing, comprising bare No. 5 (0.625-inch [16 mm] diameter) Grade 60 deformed steel reinforcing bars, was placed on 48-inch (1219-mm) centers and extends across the full width of paving. These bars were supported approximately 4 inches (102 mm) above the asphalt concrete interlayer (clear distance) by plastic chairs placed at intervals of between 35 and 42 inches (889 and 1067 mm) laterally across the pavement (see figures 4a and 4e).

a. Steel placement overview, April 7 (Day 1), looking south.

b. Longitudinal steel, No. 6 bars at 7-inch (178-mm) spacings.



c. Transverse steel, No. bars at 48-inch (1219-mm) spacings.

d. Transverse tie bar coupler between lanes.

e. Steel placement overview, April 13 (Day 2), looking south.

f. Coupled transverse reinforcement and tie bars (Day 2).

g. Example of concrete loss near some transverse steel couplers.

h. Construction header and reinforcing (transverse construction joint).

Figure 4. Reinforcing steel configuration and assembly.

Longitudinal steel comprising bare No. 6 (0.75-inch [19-mm] diameter) Grade 60 deformed steel reinforcing bars were placed on and tied to the transverse steel (resulting in placement of the longitudinal steel approximately at the planned mid-depth of the composite 10-inch [254-mm] concrete pavement) on approximately 7-inch (178-mm) centers (see figure 4b), with a distance of 3 to 4 inches (76 to 102 mm) from the pavement or joint edges to the first bar. Longitudinal steel lap lengths ranged from 24 inches (610 mm) to several feet and varied with bar length (which also varied). Lap locations were supposed to be staggered a minimum of 25 inches (635 mm) (see figure 4e) such that no more than one-third of the longitudinal steel would be spliced in any given 12-ft (3.7-m) width and 2-ft (0.61 m) pavement length; however, higher amounts of steel were spliced in some areas where excessively long bars were not cut, resulting in very long lap lengths.

Additional No. 5 (0.625-inch [16-mm] diameter) bars, approximately 48 inches (1219 mm) long, were placed on top of and tied to the longitudinal steel between the primary transverse steel bars and were centered on the lane-shoulder joint locations, effectively creating a 24-inch (610-mm) tie bar spacing (see figures 4a, 4e and 4f). Half-length (24-inch[610-mm]) No. 5 (0.625-inch [16-mm] diameter) tie bars were also placed below and tied to longitudinal bars in between transverse bars at the longitudinal construction joint between travel lanes (see figure 4a).

The ends of all transverse steel along the longitudinal construction joint between the two travel lanes were threaded. Threaded steel couplers were installed on each transverse bar for the first night of paving and were positioned such that the plugged end of the coupler was flush with or slightly recessed from the planned edge of concrete (see figure 4d). After passage of the paver on the first night, the coupler ends were exposed using probing techniques and/or water flushing. In some cases, this process resulted in significant damage to the joint face (see figure 4g).

Prior to the second night of paving, the coupler plugs were removed and 24-inch (610 mm), No. 5 (0.625-inch [16-mm] diameter) threaded deformed bars were attached to the couplers to provide tie bars across the longitudinal construction joint and to provide a tied lap connection between transverse reinforcing steel in the two lanes (see figures 4e, 4f and 4g).

The project plans for transverse construction joint headers called for the use of one 50-inch (1270-mm), No. 6 (0.75-inch [19-mm] diameter) threaded deformed bar and coupler for every longitudinal bar in the pavement, plus an additional 50-inch (1270-mm), No. 6 (0.75-inch [19-mm] diameter) and coupler on 14-inch (356-mm) centers, but it appeared that the actual bars used were only approximately 30 inches (762 mm) long (see figure 4h). An additional transverse steel bar was provided for supporting the extra longitudinal bars at the header.

Mix Production

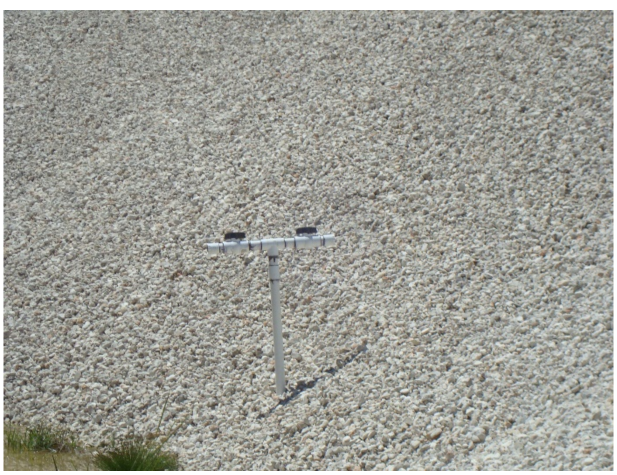
Concrete mixes were wet-batched at separate facilities. Concrete for the 3-inch (76-mm) top lift (featuring a lower CTE) was produced in a double-drum batch plant (see figures 5a and 5b) located near Beasley. The facility appeared to be well-managed and maintained with clean aggregate sources in well-separated, moisture-controlled stockpiles (see figures 5c, 5d and 5e) and a truck washout facility (figure 5f).

a. Top-lift concrete batch plant.

b. Top-lift batch plant – side view.

c. Aggregate loading bins and conveyors.

d. Coarse aggregate stockpile.



e. Aggregate stockpile sprayer.

f. Truck wash-out facility.

Figure 5. Mix production facilities for top-lift concrete.

Concrete for the 7-inch (178-mm) bottom lift (featuring a higher CTE) was produced in a single-drum Johnson-Ross plant at a location in Rosenberg, TX about 10 to 15 minutes away from the paving site (see figures 6a and 6b). Aggregate stockpiles, handling, and storage generally appeared to be adequate (see figures 6c, 6d, and 6f), although the coarse aggregate appeared to be unwashed (see figure 6e).

Weather Conditions

The weather conditions described below are as reported for Sugarland Municipal Airport, which is located approximately 20 mi (32 km) northeast of the project site. They are qualitatively representative of conditions observed at the project site:

- Night 1: Two-lift concrete paving operations began at approximately 9:00 p.m. on April 7, 2017 and concluded around 8:00 a.m. on April 8, 2017. Paving began under mostly clear conditions with an ambient air temperature of approximately 69 °F (21 °C), 52 percent relative humidity (RH), and winds from the south at about 9 mi/hr (14 km/hr). Temperatures and winds decreased overnight to lows of approximately 57 °F (14 °C) and no wind with 93 percent RH between 5:00 a.m. and 7:00 a.m., at which point temperatures and winds began to increase and humidity began to decrease under continued clear conditions. Post-construction conditions on April 8 featured mostly sunny conditions with a high temperature around 81 °F (27 °C), southerly winds between 15 and 20 mi/hr (24 and 32 km/hr), and relative humidity decreasing to a low of around 42 percent during the warmest temperatures.
- Night 2: Two-lift concrete paving operations began at approximately 8:00 p.m. on April 13, 2017 and concluded around 5:00 a.m. on April 14, 2017. Paving began under mostly clear conditions with an ambient air temperature of approximately 74 °F (23 °C), 71 percent relative humidity (RH), and winds from the southeast at about 15 mi/hr (24 km/hr). Temperatures and winds decreased overnight to lows of approximately 63 °F (17 °C) and no wind with 100 percent RH at about 3:00 a.m., after which conditions gradually increased to a temperature of 67 °F (19 °C), an RH of 93 percent, and winds out of the east at 7 mi/hr (11 km/hr) by the time paving was completed. Post-construction conditions on April 14 featured sky conditions ranging from sunny to cloudy with a high temperature around 81 °F (27 °C), southeasterly winds between 9 and 14 mi/hr (14 and 23 km/hr), and relative humidity decreasing to a low of around 53 percent during the warmest temperatures.

Concrete Transport and Placement

Concrete for both top and bottom lifts was transported using end-dump trucks. To avoid possible job site confusion, trucks transporting bottom-lift concrete were flagged with red ribbon (see figure 7) while white ribbon was used to mark trucks transporting top-lift concrete. Bottom and top lift concrete batches were prepared and delivered at a ratio of about 2.5-to-1 because of the much higher demand for concrete for the thicker bottom lift. All concrete was placed on grade or on the lower lift using a side-loading belt placer (see figure 8).

Per TxDOT Item 360 (Concrete Paving), the time limit for discharging non-agitated concrete from trucks is 45 minutes. Batch ticket summaries indicate that the time between bottom-lift concrete truck departure and concrete placement was often between 45 and 60 minutes; top-lift concrete truck times were always less than 45 minutes.

a. Bottom-lift concrete batch plant.

b. Coarse aggregate stockpile.

c. Fine aggregate stockpile and end loader.

d. Aggregate bins and conveyors.

e. Close-up of coarse aggregate.

f. Aggregate storage and handling - general.

Figure 6. Mix production facilities for bottom-lift concrete.

Figure 7. Transport truck for bottom-lift concrete (note red flagging on side mirror).

Figure 8. Concrete dump truck discharging load into conveyor for placement machine.

Concrete Paving Operations

Rao et al. (2013) state that the bottom concrete lift can be paved using conventional paving equipment and procedures, with no special consideration for ride quality or surface texture, and that the top lift should be placed within 15 to 90 minutes (ideally no more than 60 minutes) after placement of the bottom lift. Specifications for this project required that the top lift be placed no more than 60 minutes after placement of the bottom lift unless the bottom lift contained a set-retardant (which was reported to be the case for this project), in which case the time limit was extended to 90 minutes. Field notes for this project indicate that the 90-minute limit was exceeded at the beginning of the second night of paving.

Paving proceeded from north to south on the first night of paving, and from south to north on the second night. The following sections describe placement and finishing of the bottom and top lifts of concrete for this project.

Bottom Lift

The bottom lift concrete was placed using dual-stringline paving techniques, a Gomaco Model PS-48 Placer-Spreader (see figure 9a), paving was performed using a CMI SF 350 4-track slip form paving machine (see figure 9b). Minor bull and hand float work was performed behind the paver to correct surface imperfections, but no significant finishing or texture was applied to the surface of the bottom lift. Evaporative retardant between the first and second lifts was not permitted.

Top Lift

The top lift concrete was generally placed within 90 minutes of placement of the bottom lift concrete. The equipment used to place the top lift was similar to that used for the bottom lift (see figures 9c and 9d).

a. Bottom lift placer-spreader.

b. Bottom-lift paving.

c. Top lift placer-spreader.

d. Top lift placer-spreader.

Figure 9. Paving equipment and operations.

Finishing, Texturing and Curing

On the first night only, transverse rebar couplers along the longitudinal construction joint between travel lanes were exposed using hand excavation or water flushing techniques (see figure 10a). This was done immediately behind the top lift paving operation.

The top lift was finished and textured in several steps. Hand work was performed using bull floats and hand floats, as required (figure 10b). A PVC tube float was suspended diagonally from a CMI self-propelled construction bridge and used to uniformly float the entire pavement surface (see figure 10c). The bridge also included a rear-mounted turf drag, which was used to provide longitudinal macrotexture to the entire pavement surface after the completion of floating (see figure 10d).

a. Exposed rebar couplers.

b. Hand work behind paver near header.

c. Tube float finishing.

d. Turf drag texturing.

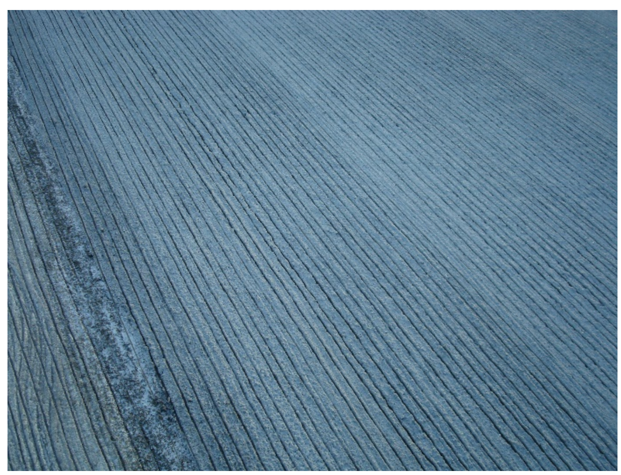
Figure 10. Surface finishing operations.

The tube float-turf drag cart was followed by a texture-cure cart that provided longitudinal tining and white pigmented spray cure (see figures 11a through 11d). The curing compound was required to confirm to ASTM C 309 Type 2 Class A and was placed in two coats at a coverage rate not exceeding 180 ft^2/gal (4.4 m^2/L), with the first coat placed within 10 minutes of tining and "as soon as the free moisture has disappeared" and the second coat within 30 minutes of tining. Curing was to be maintained for at least 3 days, but curing was effectively much longer on this project because it was not to be opened to traffic for several months.

a. Tining and curing the pavement surface.

b. Rake for longitudinal tining.

c. Curing compound transport container.



d. Final surface with turf-drag texture, tining and curing compound.

Images a-d: © 2017 Mark Snyder

Figure 11. Tining and curing operations.

Joint Sawing and Sealing

The longitudinal lane-shoulder joints were to be sawed to approximately D/3 + 1/2 inch (13 mm) "as soon as possible without damage to the pavement" (see figure 12). A joint sealant reservoir measuring 0.62 inches (16 mm) deep and 0.25 inches (6 mm) wide was provided (by additional saw cut, if necessary) in all longitudinal construction and contraction joints prior to installing joint sealant. Sealant material was specified to be TxDOT DMS-6310 Class 5 or 8 (low-modulus silicone or polyurethane, self-leveling).

Figure 12. Lane-shoulder joint sawed in concrete placed on first night of paving.

Testing and Instrumentation

The 7-day target compressive strength for the bottom lift concrete was 3200 lb/in^2 (22.1 MPa), with a 28-day target of 4000 lb/in^2 (27.6 MPa). The 7-day target compressive strength for the top lift was 2750 lb/in^2 (19.0 MPa).

Contractor, TxDOT, and University of Texas (UT) staff performed concrete material sampling and testing during placement of both the bottom and top lifts. Testing of plastic (fresh) concrete included mixture slump, temperature and air content. All three organizations cast cylinders for compressive strength testing while the UT team also cast additional cylinders and beams for determination of elastic modulus, coefficient of thermal expansion, and flexural strength. Photos of the field testing and preparation of test specimens are presented in figure 13. Results of these tests are described in the following sections.

a. Mixture sampling.

b. Mixture temperature measurement.

c. Air content test.

d. Preparation of test cylinders.

e. Concrete test cylinders.

f. UT test beams and cylinders.

Figure 13. Field sampling, testing and preparation of test specimens.

Mixture Temperature, Slump and Air Content

Table 2 presents mixture temperature, slump and air content measurements for each lift on each paving night, as reported by the contractor, TxDOT, and UT. All reported values fall within acceptable job control values, which are also presented in the table.

Table 2. Summary of plastic (fresh) concrete test results.

Top Lift							
	Test Location	**Mix Temp, °F**	**Avg. Mix Temp, °F**	**Slump, in**	**Avg. Slump, in**	**Air Content, %**	**Avg. Air Content, %**
Job Control Req'ments		40 – 95		Target 3.0, maximum 6.5		2.5 – 5.5 (target 4.0)	
Contractor	NR	70 (x2)	73	2 (x2)	2	4.2 (x2)	3.8
	NR	75 (x2)		2 (x2)		3.5 (x2)	
TxDOT	NR	NR	NR	NR	NR	NR	NR
	NR	NR		NR		NR	
Univ – Tx	Apr 7 Start+100 ft	NR		1.00		3.0	
	Apr 7 Start+600 ft	NR	NR	3.00	2.1	3.0	3.0
	Apr 7 End - 100 ft	NR		2.25		3.0	
	Apr 13 Start+100 ft	NR		1.75		3.0	
	Apr 13 End–600 ft	NR	NR	2.50	2.3	3.0	3.0
	April 13 End–100 ft	NR		2.50		3.0	
Bottom Lift							
	Test Location	**Mix Temp, °F**	**Avg. Mix Temp, °F**	**Slump, in**	**Avg. Slump, in**	**Air Content, %**	**Avg. Air Content, %**
Contractor	NR	70 (x2)	72	NR	NR	4.2 (x2)	3.8
	NR	75 (x2)		NR		3.5 (x2)	
TxDOT	NR	69	68	NR	NR	4.6	4.1
	NR	68		NR		3.7	
Univ – Tx	Apr 7 Start+100 ft	NR		1.50		3.5	
	Apr 7 Start+600 ft	NR	NR	2.50	1.92	4.0	3.7
	Apr 7 End - 100 ft	NR		1.75		3.5	
	Apr 13 Start+100 ft	NR		0.50		4.0	
	Apr 13 End–600 ft	NR	NR	1.50	1.0	4.0	4.0
	April 13 End–100 ft	NR		1.00		4.0	

NR = Not Reported or Not Performed

Compressive Strength

Table 3 presents compressive strength test results for each lift on each paving night, as reported by the contractor, TxDOT, and UT. All reported values fall within acceptable job control values and design strength values, which are also presented in the table.

Table 3. Summary of compressive strength test results.

Top Lift							
	Test Location	**f'_c, lb/in^2 (4 days)**	**Avg f'_c, lb/in^2 (4 days)**	**f'_c, lb/in^2 (7 days)**	**Avg f'_c, lb/in^2 (7 days)**	**f'_c, lb/in^2 (28 days)**	**Avg f'_c, lb/in^2 (28 days)**
Job Control or Design Req'ments				2750 min.		4000 min.	
Contractor	Apr 7 1443+00	NR	NR	NR	NR	NR	NR
	Apr 13 1443+50	3692, 3744	3720	4235, 4175	4210	6379, 6411	6400
TxDOT	Apr 7 1443+00	NR	NR	NR	NR	NR	NR
	Apr 13 1443+50	NR		3881, 4351	4120	NR	
Univ – Tx	Apr 7 Start+100 ft	NR	NR	NR	NR	6311, 6549, 6989, 6239	6522
	Apr 7 Start+600 ft	NR		NR		6004, 5836, 5947	5862
	Apr 7 End - 100 ft	NR		NR		6152, 5672, 5752, 5990, 6114	5936
	Apr 13 Start+100 ft	NR	NR	NR	NR	6851, 6265, 5969	6362
	Apr 13 End–600 ft	NR		NR		6389, 6439, 6331, 6474, 6140	6355
	April 13 End–100 ft	NR		NR		6373, 6251, 6409, 6519, 6556	6441
Bottom Lift							
	Test Location	**f'_c, lb/in^2 (4 days)**	**Avg f'_c, lb/in^2 (4 days)**	**f'_c, lb/in^2 (7 days)**	**Avg f'_c, lb/in^2 (7 days)**	**f'_c, lb/in^2 (28 days)**	**Avg f'_c, lb/in^2 (28 days)**
Job Control or Design Req'ments				3200 min.		4000 min.	
Contractor	Apr 7 1443+00	3738, 3852	3800	4339, 4531	4440	5934, 5587	5760
	Apr 13 1443+50	NR	NR	NR	NR	NR	NR
TxDOT	Apr 7 1443+00	NR	NR	4464, 4227	4350	NR	NR
	Apr 13 1443+50	NR		NR	NR	NR	
Univ – Tx	Apr 7 Start+100 ft	NR	NR	NR	NR	5021, 5929, 5903, 5877, 5759	5867
	Apr 7 Start+600 ft	NR		NR		5242, 5294, 5637, 5719, 5564	5491
	Apr 7 End - 100 ft	NR		NR		5748, 5882, 6147	5926
	Apr 13 Start+100 ft	NR	NR	NR	NR	5737, 5839, 5602, 6645, 5976	6015
	Apr 13 End–600 ft	NR		NR		5771, 5764, 5757	5764
	April 13 End–100 ft	NR		NR		6122, 5804, 5884, 6023, 5797	5926

NR = Not Reported or Not Performed

Modulus of Elasticity

The University of Texas team performed 28-day modulus of elasticity testing on cylinders cast for the bottom and top lifts. The results of these tests are summarized in table 4. The test results indicate fairly uniform concrete elastic modulus in both the top and bottom lifts on both days of paving, with an average 28-day elastic modulus of approximately 4.4 million lb/in^2 (30,340 MPa).

Table 4. Summary of elastic modulus testing.

Test Location	E_c, ksi (Specimen 1, 28 days)	E_c, ksi (Specimen 2, 28 days)	Avg E_c, ksi by sample location, date (28 days)	Avg E_c, ksi by lift and placement date (28 days)
Top Lift				
Apr 7 Start+100 ft	4601	4475	4538	4335
Apr 7 Start+600 ft	4124	4124	4124	
Apr 7 End - 100 ft	4089	4597	4343	
Apr 13 Start+100 ft	4368	4558	4463	4491
Apr 13 End–600 ft	4621	4532	4577	
April 13 End–100 ft	4415	4453	4434	
Bottom Lift				
Apr 7 Start+100 ft	4391	4388	4389	4330
Apr 7 Start+600 ft	4304	4480	4392	
Apr 7 End - 100 ft	4384	4033	4208	
Apr 13 Start+100 ft	4450	4341	4395	4395
Apr 13 End–600 ft	4401	4378	4389	
April 13 End–100 ft	4328	4473	4401	

Flexural Strength

The University of Texas team performed 7-day flexural strength test on concrete beams cast during placement of the top and bottom lifts on each day of paving. The results of these tests are summarized in table 5. These results were more variable than the compressive strength test results, but average strength in both layers on both days of placement was approximately 640 lb/in^2 (4.4 MPa), which represents a very good 7-day strength.

Table 5. Summary of flexural strength testing.

Test Location	M_r, lb/in^2 (Specimen 1, 7 days)	M_r, lb/in^2 (Specimen 1, 7 days)	M_r, lb/in^2 (Specimen 1, 7 days)	Avg M_r, lb/in^2 by sample location, date (7 days)	Avg M_r, lb/in^2 by lift and placement date (7 days)
Top Lift					
Apr 7 Start+100 ft	679	706	673	686	646
Apr 7 Start+600 ft	577	581	692	617	
Apr 7 End - 100 ft	673	623	614	637	
Apr 13 Start+100 ft	702	674	558	645	651
Apr 13 End–600 ft	688	674	619	660	
April 13 End–100 ft	623	632	688	648	
Bottom Lift					
Apr 7 Start+100 ft	702	727	719	716	632
Apr 7 Start+600 ft	531	547	535	538	
Apr 7 End - 100 ft	600	660	669	643	
Apr 13 Start+100 ft	660	632	642	645	646
Apr 13 End–600 ft	689	739	762	730	
April 13 End–100 ft	360 (outlier)	590	535	563	

Coefficient of Thermal Expansion (CTE)

CTE is a measure of the extent a material expands or contracts due to changes in temperature. For concrete, CTE values are heavily influenced by the coarse aggregate type and volume.

The University of Texas team performed CTE tests on concrete cylinders cast during the placement of both lifts on both days of paving. Results of these tests are presented in table 6 and show that the average CTE of the top lift was approximately 4.32 x 10^{-6} in/in/°F (7.78 x 10^{-6} mm/mm/°C) while the average CTE of the bottom lift was approximately 6.31 x 10^{-6} in/in/°F (11.34 x 10^{-6} mm/mm/°C). These values conform with the stated goal of having a low (less than 5.5 x 10^{-6} in/in/°F [9.9 x 10^{-6} mm/mm/°C]) in the top layer and a high CTE (greater than 5.5 x 10^{-6} in/in/°F [9.9 x 10^{-6} mm/mm/°C]) in the bottom layer.

Table 6. Summary of CTE testing.

Construction Date	Specimen 1 ($\times 10^{-6}$ in/in/°F)	Specimen 2 ($\times 10^{-6}$ in/in/°F)	Average ($\times 10^{-6}$ in/in/°F)
Top Lift			
April 7	4.463	4.178	4.32
April 13	4.403	4.263	4.33
Bottom Lift			
April 7	6.310	6.323	6.32
April 13	6.172	6.427	6.30

Embedded Instrumentation

The University of Texas team installed temperature-logging "iButtons" near the pavement edge at each of the locations listed in tables 3, 4 and 5. Figure 14 presents photos of an example instrument mounting just prior to and just after paving.

a. Sensors before paving

b. Sensors after paving

Images a-b: © 2017 Mark Snyder

Figure 14. Photos of UT temperature logging sensors before and after placement of the lower paving lift.

Construction Observations

A few observations from the construction of the two-lift CRCP project over the two separate nights of paving are summarized below:

- On the first night of paving, a drum liner from the concrete mixer got introduced into the concrete and was deposited on grade but was removed ahead of the paver (see figure 15).
- Some areas of the longitudinal construction joint face along the night 1 placement showed signs of poor consolidation, shrinkage cracking, and excessive damage as a result of locating the reinforcing steel couplers (see figure 16). In addition, the paver hit several of the couplers that caused some alignment issues (see figure 16c).

Figure 15. Drum liner from concrete mixer.

a. Excessive loss of concrete at steel coupler.

b. Consolidation issues and shrinkage cracking at longitudinal construction joint.

c. Shrinkage cracking and concrete loss at couplers along longitudinal construction joint.

d. Consolidation problem and concrete loss at coupler along longitudinal construction joint.

Figure 16. Longitudinal construction joint defects in first night paving.

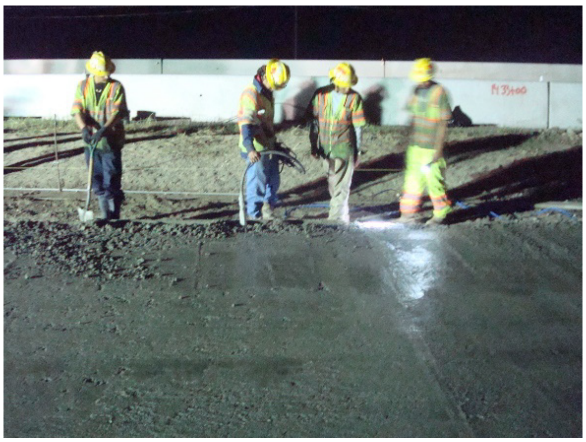
- On the second night of paving, “tar paper” was placed over areas of the asphalt interlayer that were damaged during the first night paving operations, as shown in figure 17. This was done to provide a smoother interface plane under the CRCP and to prevent the CRCP from interlocking with the asphalt.

Figure 17. “Tar paper” covering paver track damage to asphalt interlayer.

- There were several difficulties at the beginning of the second night of paving. It was difficult to get the first (lower lift) paver up the hill and onto the header and the east track lifted in the air about 12 inches (305 mm) before settling in. There also appeared to be insufficient volume of concrete (or inadequate spreading) during the first 50 ft (15 m) of lower lift paving, which left exposed rebar behind the paver (see figures 18a and 18b). This required a significant amount of hand work to cover the steel (figure 18c). Additional fill was eventually accomplished with top lift material (figure 18d). There was a delay of approximately 2 hours before the second lift of paving was placed in this area.
- The bottom lift paver experienced continual difficulties with one of the vertical string line sensors throughout the second night, which resulted in frequent lifting of the east front track and resulting irregularities in the paving surface. The paving crew would sometimes manually manipulate the sensor to effect a correction when the track was lifting.

a. Exposed steel, start of night 2 paving.

b. Exposed steel, start of night 2 paving.



c. Hand work to fill low edge areas.

d. Filling low bottom lift areas with top lift.

Figure 18. Exposed rebar and hand work, south end of night 2 bottom lift paving.

- Approximately 275 ft from the south end (start of 2nd night paving) it was noted that an oily material was leaking from the top lift spreader (see figure 19); this continued indefinitely.

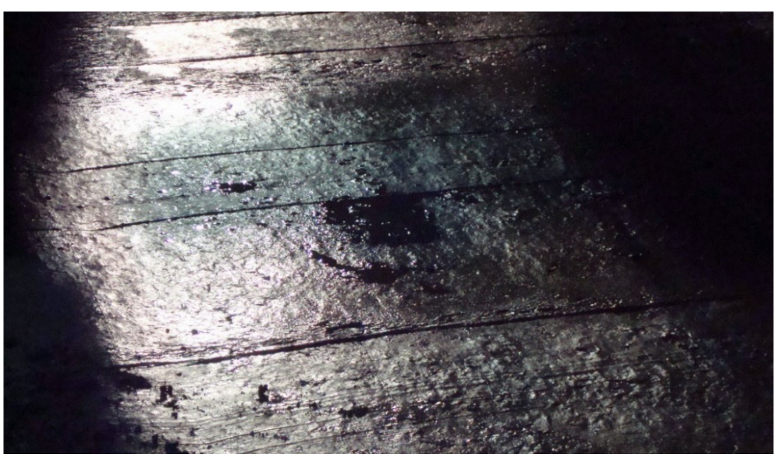


Figure 19. Oil leaked on pavement surface from top lift spreader at approximately Station 1433+75, night 2.

- The top lift paver frequently left a rough outside (east) edge on night 2 (see figure 20). This required significant hand work for correction.

a. Example of rough top surface edge in top surface paving, night 2.

b. Example of rough top surface edge in top surface paving, night 2.

Images a-b: © 2017 Mark Snyder

Figure 20. Exposed rebar and hand work, south end of night 2 bottom lift paving.

- The tining operations experienced some problems on night 2, including some localized areas where tining intersected the shoulder edge (rather than maintaining a few inches of non-tined surface) and one area where the tining was exceptionally deep. These conditions are both documented in figure 21. These problem areas notwithstanding, the tining on night 2 was generally straighter (less "wavy") than the tining on the first night of paving.

a. Tining intersecting shoulder pavement edge, night 2.

b. Deep, wandering tining near north end of night 2 paving.

Images a-b: © 2017 Mark Snyder

Figure 21. Tining problems on second night of paving.

- The difficulties documented above are not representative of the overall quality of paving, which was generally considered to be very good. The final finished pavement appeared to be quite acceptable at the end of the second night of paving, as illustrated in figure 22.

a. Overview of finished pavement, looking south.

b. Overview of finished pavement, looking north.

Figure 22. Overview of finished project immediately after construction.

Summary

This 1100-ft (335-m) two-lift CRCP was constructed as part of a frontage road along the southbound lanes of U.S. 59 near Beasley, Texas. It included two 12-ft (3.7-m) travel lanes, an 8-ft (2.4-m) outside shoulder and a 4-ft (1.2-m) inside shoulder. The concrete in the lower lift was designed to have a CTE of more than 5.5 x 10^{-6} in/in/°F (9.9 x 10^{-6} mm/mm/°C) while the concrete in the top lift was designed to have a CTE of less than 5.5 x 10^{-6} in/in/°F (9.9 x 10^{-6} mm/mm/°C).

The outer lane and outside shoulder were paved from north to south on April 7, 2017; the inside lane and inside shoulder were paved from south to north on April 13, 2017. Weather during placement was generally suitable for paving, with mostly clear skies and temperatures ranging from the upper 50s to lower 70s °F (15 to 21 °C), with 50 to 100 percent RH and winds generally calm to 10 mi/hr (16 km/hr) (slightly higher at the beginning of the first night). Table 7 presents a brief summary of key project information.

Overall Observations

A summary of some of the overall observations pertaining to the construction of the two-lift CRCP pavement are presented below:

- The Beasley plant (top lift concrete) appeared to be newer and well-managed, with clearly separated stockpiles of clean material. The Rosenberg plant (bottom lift concrete) was older and was reported to have been recently brought out of retirement. Some of the coarse aggregate at this site appeared to be wet and unwashed (containing fines).
- The use of white and red ribbons on haul truck mirrors (for top and bottom lift concrete, respectively) was effective in ensuring that the correct mixture was delivered to the correct paver in the field.

- The time between top and bottom lift placements was generally between 60 and 90 minutes, which complied with project specifications because of the use of a retarder in the lower lift. However, there were some areas (e.g., the start of night 2) where the time between placements was as much as 2 hours. In such cases, the lower lift concrete still appeared to be “fresh” and unlikely to result in interface debonding.

Table 7. Summary of two-lift concrete pavement details.

Item	Details
General Project Information	• Two-lift wet-on-wet composite concrete pavement • Location: Both lanes of a frontage road parallel to southbound U.S. 59 near Beasley, Texas • Length: 1,100 ft (335 m), consisting of two 12-ft (3.6-m) lanes, an 8-ft (2.4-m) outside shoulder and a 4-ft (1.2-m) inside shoulder
Pavement Design and Materials Information	• 10-inch (254-mm) thick CRCP − Top lift: 3-inch (75 mm) thick portland cement concrete containing coarse aggregate with coefficient of thermal expansion less than 5.5 x 10^{-6} inch/inch/˚F (9.9 x 10^{-6} mm/mm/˚C) − Bottom lift: 7-inch (178-mm) thick portland cement concrete containing coarse aggregate with coefficient of thermal expansion greater than 5.5 x 10^{-6} inch/inch/˚F (9.9 x 10^{-6} mm/mm/˚C) • Reinforcement placed at mid-depth of total slab thickness − Longitudinal: #6 bars at 7-inch (178-mm) spacings − Transverse: #5 bars at 48-inch (1219-mm) spacings • Foundation: 1-inch (25 mm) asphalt bondbreaker interlayer, 6-inch (152-mm) cement-treated base, 6-inch (152-mm) lime-treated subgrade soil
Construction Information	• Construction Dates: April 7, 2017 and April 13, 2017 • Weather Conditions: 50s to lower 70s °F (15 to 21 °C), with 50 to 100% RH and winds generally calm to 10 mi/hr (16 km/hr). • Nighttime paving

- Some areas of the longitudinal construction joint face (first night placement) showed signs of poor consolidation, shrinkage cracking, and excessive loss of concrete around rebar couplers.
- The bottom lift paver experienced chronic control problems on the second night of paving, which caused one track to lift and resulting pavement surface irregularities that had to be corrected by hand or with additional concrete from the top lift paving operation.
- The top lift paver frequently left a rough shoulder edge on the second night of paving, which required hand work to repair.
- There was some exceptionally deep tining and some errant tining (intersecting the pavement edge) in localized areas (not widespread) on the second night.
- The overall quality of construction appeared to be good considering the various challenges that were encountered.

Field Testing Results

Field testing and test specimens were prepared by the contractor, TxDOT, and the University of Texas and presented in tables 2 through 6. Some relevant observations on the testing results:

- The concrete mixture temperature measurements ranged from 68 to 73 °F (20 to 23 °C), well within the acceptable range of 40 to 95 °F (4 to 35 °C).
- The top lift slump measurements ranged from 2 to 2.3 inches (51 to 58 mm), while the bottom lift slump measurements ranged from 1 to nearly 2 inches (25 to 51 mm).
- The air content measurements for both layers ranged from 3.0 to 4.1 percent, generally slightly lower than the 4.0 percent target value, but well within the acceptable range of 2.5 to 5.5 percent.
- Compressive strength test results were all well above job control values (2750 lb/in^2 [19.0 MPa top lift and 3200 lb/in^2 [22.1 MPa] bottom lift at 7 days) and specified values (4000 lb/in^2 [27.6 MPa] at 28 days). Seven-day strengths exceeded 4000 lb/in^2 (27.6 MPa) and 28-day strengths were 5500 to 6500 lb/in^2 (37.9 to 44.8 MPa).
- The modulus of elasticity (28-day) values were approximately 4.4 million lb/in^2 (30,340 MPa). There was no specified requirement for this test.
- The flexural strength test values (7-day) averaged approximately 640 lb/in^2 (4.4 MPa). There was no specified requirement for this test.
- The CTE of the top lift averaged approximately 4.32 x 10^{-6} in/in/°F (7.78 x 10^{-6} mm/mm/°C) while the average CTE of the bottom lift was approximately 6.31 x 10^{-6} in/in/°F (11.34 x 10^{-6} mm/mm/°C). These values conform with the stated goal of having a low (less than 5.5 x 10^{-6} in/in/°F [9.9 x 10^{-6} mm/mm/°C]) in the top layer and a high CTE (greater than 5.5 x 10^{-6} in/in/°F [9.9 x 10^{-6} mm/mm/°C]) in the bottom layer.

References

Rao, S., M. Darter, D. Tompkins, M. Vancura, L. Khazanovich, J. Signore, E. Coleri, R. Wu, J. Harvey, and J. Vandenbossche. 2013. *Composite Pavement Systems, Volume 2: PCC/PCC Composite Pavements*. SHRP2 Report S2-R21-RR-3. Transportation Research Board, Washington, DC. http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R21-RR-3.pdf.

APPENDIX A – SPECIAL SPECIFICATION 3018: TWO-LIFT CONCRETE PAVEMENT

Special Specification 3018
Two-Lift Concrete Pavement

1. DESCRIPTION

Construct two-lift concrete pavement.

This Specification references and incorporates current special provisions to the following Items.

- Item 360, "Concrete Pavement"
- Item 420, "Concrete Substructures"
- Item 421, "Hydraulic Cement Concrete"

The Contractor must comply with Item 360, "Concrete Pavement," unless otherwise specified herein.

2. MATERIALS

Furnish materials in accordance with Item 360, "Concrete Pavement," and Item 421, "Hydraulic Cement Concrete," unless otherwise noted in this Specification.

2.1. **Bottom-Lift Concrete.** Use a coarse aggregate that produces a concrete with a coefficient of thermal expansion greater than 5.5 microstrain/°F.

2.2. **Top-Lift Concrete.** Use a coarse aggregate that produces a concrete with a coefficient of thermal expansion of 5.5 microstrain/°F or less.

3. EQUIPMENT

Provide equipment in accordance with Item 360, "Concrete Pavement." Provide enough concrete mixing, delivery, and paving equipment to meet the requirements of this Specification.

4. CONSTRUCTION

Construct two-lift concrete pavement by paving two (2) individual layers of concrete with thicknesses shown on the plans, such that the result is wet-on-wet placement. Construct the pavement in accordance with Item 360, "Concrete Pavement," unless otherwise noted in this Specification.

4.1. **Paving and Quality Control Plan**. Submit a paving and quality control plan for approval before beginning pavement construction operations. Include details of all operations in the concrete paving process, including methods to construct transverse joints, methods to consolidate concrete at joints, longitudinal construction joint layout, sequencing, curing, lighting, early opening, leave-outs, sawing, inspection, testing, construction methods, other details, and a description of all equipment. List certified personnel performing the testing. Include details of the concrete delivery plan to keep track of concrete delivery for the bottom and top-lifts. Submit revisions to the paving and quality control plan for approval.

4.2. **Job-Control Testing.** Perform job-control testing in accordance with Section 360.4.2, "Job-Control Testing." Perform job-control testing on the bottom and top lifts of the two-lift concrete pavement.

4.3. **Bottom Lift of Two-Lift Concrete Pavement.** Provide concrete for the bottom lift capable of supporting the top-lift concrete with minimal intermingling of the two (2) layers at the time of placement.

4.4. **Top Lift of Two-Lift Concrete Pavement.** Time the placement of the top lift to ensure a wet-on-wet placement. Place the top lift no more than 60 min. after placement of the bottom lift. If the bottom lift contains a set retarding chemical admixture, this time may be extended to 90 min.; however, the bottom-lift concrete should still support the top-lift concrete with minimal intermingling of the two (2) layers at the time of placement.

4.5. **Longitudinal Contraction Joint.** Saw cut and seal longitudinal contraction joints as shown on the plans, except use the following equation to determine saw cut depth:

Saw cut depth = T/3 + 1/2 in.

where

T = pavement thickness, in.

5. MEASUREMENT

5.1. **Two-Lift Concrete Pavement.** Two-lift concrete pavement will be measured by the square yard of surface area in place. The surface area includes the portion of the pavement slab extending beneath the curb.

5.2. **Curb.** Curb on concrete pavement will be measured by the ft. in place.

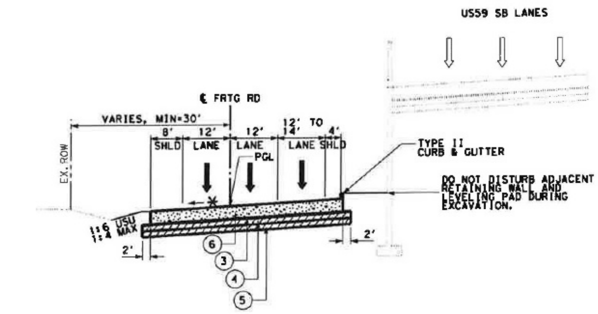
6. PAYMENT

These prices are full compensation for materials, equipment, labor, tools, and incidentals.

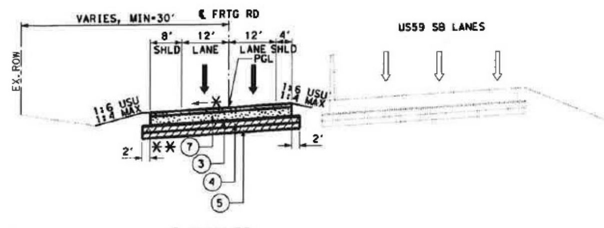
6.1. **Two-Lift Concrete Pavement.** The work performed and materials furnished in accordance with this Specification and measured as provided under “Measurement” will be paid for at the adjusted unit price for “Two-Lift Concrete Pavement” of the type and depth specified as adjusted in accordance with Section 360.6.2., “Deficient Thickness Adjustment.”

6.2. **Curb.** The work performed and materials furnished in accordance with this Specification and measured as provided under “Measurement” will be paid for at the unit price bid for “Curb” of the type specified.

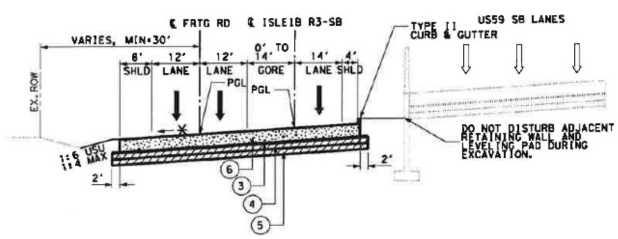
APPENDIX B – PROJECT PLAN DOCUMENTS



℄ FRTG RD
℄ FRTG RD STA 1420+39.80 TO STA 1424+75.11
N.T.S.



℄ FRTG RD
℄ FRTG RD STA 1429+02.53 TO STA 1442+07.17
N.T.S.



℄ FRTG RD
℄ FRTG RD STA 1424+75.11 TO STA 1429+02.53
N.T.S.

① 14"CONT REINF CONC PAV
② NOT USED
③ 1"ASPHALT BOND BREAKER
④ 6"CEMENT STAB BASE
⑤ 6"LIME TRT SUBGRADE
⑥ 10"CONT REINF CONC PAV
⑦ 10" TWO LIFT CONC PAV

NOTES:

1. SEE ROADWAY PLAN AND PROFILE SHEETS FOR LIMITS OF PAY FOR PAVEMENT ITEMS AND PROPOSED SSTR AND SSCB.
2. SEE STORMWATER POLLUTION PREVENTION PLAN FOR BLOCK PLACEMENT LIMITS.
3. SEE MOW STRIP STANDARDS FOR FURTHER DETAILS.

✻ SLOPE VARIES. SEE SUPERELEVATION SHEET DIAGRAMS AND TABLE SHEET

✻✻ SEE 10 IN. CRCP TWO LIFT CONCRETE PAVEMENT SHEET FOR DETAILS.

STATE OF TEXAS
GLENN C. LAZARO
113746
LICENSED PROFESSIONAL ENGINEER

09/21/2015

The seal appearing on this document was authorized by Glenn C. Lazaro, P.E. 113746
Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act.

TEXAS DEPARTMENT OF TRANSPORTATION
® 2013 TxDOT

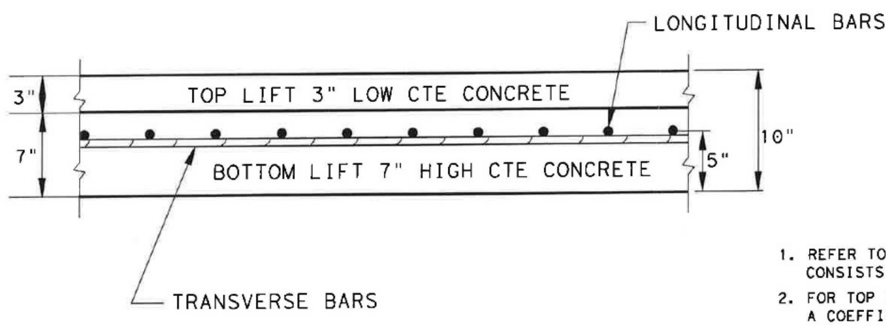
RAMP & FRONTAGE ROAD PROPOSED TYPICAL SECTION

SCALE: N.T.S.
SHEET 3 OF 3

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			2021
STATE	DIST.	COUNTY	
TEXAS	HOU	FORT BEND	
CONT.	SECT.	JOB	HIGHWAY NO.
0089	09	058,etc	US59

DATE: $DATE$
FILE: $FILEL$

DATE:
FILE:



TWO LIFT CONCRETE PAVEMENT

TYPICAL SECTION

GENERAL NOTES

1. REFER TO CRCP(1)-13 STANDARD FOR THE CRCP DETAILS. TWO LIFT PAVING CONSISTS OF TWO LAYERS OF CONCRETE PLACED WET ON WET.
2. FOR TOP LIFT CONCRETE, USE COARSE AGGREGATES TO PRODUCE CONCRETE WITH A COEFFICIENT OF THERMAL EXPANSION (CTE) NOT MORE THAN 5.5×10^{-6} IN/IN/°F.
3. FOR BOTTOM LIFT CONCRETE, USE COARSE AGGREGATES TO PRODUCE CONCRETE WITH A COEFFICIENT OF THERMAL EXPANSION (CTE) MORE THAN 5.5×10^{-6} IN/IN/°F.

STATE OF TEXAS
GLENN C. LAZARO
113746
LICENSED
PROFESSIONAL ENGINEER

09/21/2015

The seal appearing on this document was authorized by Glenn C. Lazaro, P.E. 113746
Alteration of a sealed document without proper notification to the responsible engineer is an offense under the Texas Engineering Practice Act.

Texas Department of Transportation

10 IN. CRCP
TWO LIFT CONCRETE PAVEMENT

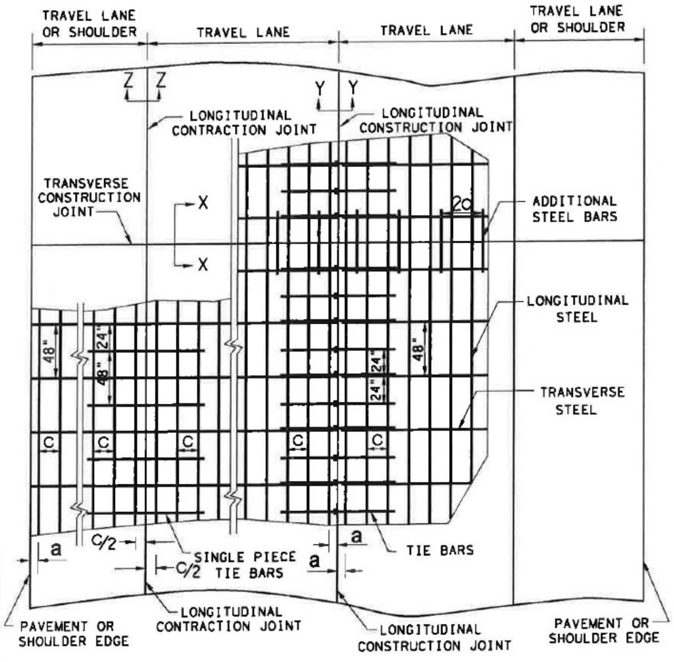
FILE:	DN: TxDOT	CK: AN	DW: HC	CK:
© TxDOT	CONT	SECT	JOB	HIGHWAY
	0089	09	058, etc	US59
	DIST	COUNTY		SHEET NO.
	HOU	FORT BEND		2023

TABLE NO. 1 LONGITUDINAL STEEL

SLAB THICKNESS AND BAR SIZE		REGULAR STEEL BARS	FIRST SPACING AT EDGE OR JOINT	ADDITIONAL STEEL BARS AT TRANSVERSE CONSTRUCTION JOINT (SECTION X-X)	
T (IN.)	BAR SIZE	SPACING c (IN.)	SPACING a (IN.)	SPACING 2 x c (IN.)	LENGTH L (IN.)
7.0	#5	6.5	3 TO 4	13	50
7.5	#5	6.0	3 TO 4	12	50
8.0	#6	9.0	3 TO 4	18	50
8.5	#6	8.5	3 TO 4	17	50
9.0	#6	8.0	3 TO 4	16	50
9.5	#6	7.5	3 TO 4	15	50
10.0	#6	7.0	3 TO 4	14	50
10.5	#6	6.75	3 TO 4	13.5	50
11.0	#6	6.5	3 TO 4	13	50
11.5	#6	6.25	3 TO 4	12.5	50
12.0	#6	6.0	3 TO 4	12	50
12.5	#6	5.75	3 TO 4	11.5	50
13.0	#6	5.5	3 TO 4	11	50

TABLE NO. 2 TRANSVERSE STEEL AND TIE BARS

SLAB THICKNESS (IN.)	TRANSVERSE STEEL		TIE BARS AT LONGITUDINAL CONTRACTION JOINT (SECTION Z-Z)		TIE BARS AT LONGITUDINAL CONSTRUCTION JOINT (SECTION Y-Y)	
	BAR SIZE	SPACING (IN.)	BAR SIZE	SPACING (IN.)	BAR SIZE	SPACING (IN.)
7.0 - 7.5	#5	48	#5	48	#5	24
8.0 - 13.0	#5	48	#6	48	#6	24

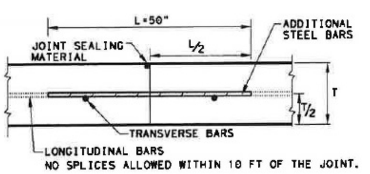


TYPICAL PAVEMENT LAYOUT

PLAN VIEW (NOT TO SCALE)

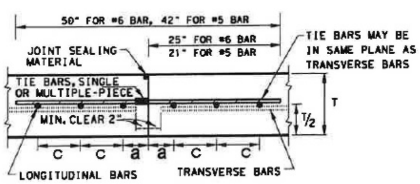
GENERAL NOTES

1. DETAILS FOR PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE SHOWN ELSEWHERE IN THE PLANS. PAVEMENTS WIDER THAN 100 FT. WITHOUT A FREE LONGITUDINAL JOINT ARE NOT COVERED BY THIS STANDARD.
2. USE COARSE AGGREGATES TO PRODUCE CONCRETE WITH A COEFFICIENT OF THERMAL EXPANSION (CTE) NOT MORE THAN 5.5 X 10^{-6} IN/IN/°F.
3. ALL THE REINFORCING STEEL AND TIE BARS SHALL BE DEFORMED STEEL BARS CONFORMING TO ASTM A 615 (GRADE 60) OR ASTM A 996 (GRADE 60) OR ABOVE. STEEL BAR SIZES AND SPACINGS SHALL CONFORM TO TABLE NO. 1 AND TABLE NO. 2.
4. WHEN LOW CTE CONCRETE (NOT MORE THAN 4.0 X 10^{-6} IN/IN/°F) IS PRODUCED, TABLE NO. 1A MAY BE USED FOR LONGITUDINAL STEEL AS APPROVED BY THE ENGINEER.
5. STEEL BAR PLACEMENT TOLERANCE SHALL BE +/- 1 IN. HORIZONTALLY AND +/- 0.5 IN. VERTICALLY. CALCULATED AVERAGE BAR SPACING (CONCRETE PLACEMENT WIDTH / NUMBER OF LONGITUDINAL BARS) SHALL CONFORM TO TABLE NO. 1 OR TABLE NO. 1A.
6. PAVEMENT WIDTHS OF MORE THAN 15 FT. SHALL HAVE A LONGITUDINAL JOINT (SECTION Z-Z OR SECTION Y-Y). THESE JOINTS SHALL BE LOCATED WITHIN 6 IN. OF THE LANE LINE UNLESS THE JOINT LOCATION IS SHOWN ELSEWHERE ON THE PLANS.
7. THE SAW CUT DEPTH FOR THE LONGITUDINAL CONTRACTION JOINT (SECTION Z-Z) SHALL BE ONE THIRD OF THE SLAB THICKNESS (T/3).
8. WHEN TYING CONCRETE GUTTER AT A LONGITUDINAL JOINT, THE TIE BAR LENGTH OR POSITION MAY BE ADJUSTED. PROVIDE 3 IN. OF CONCRETE COVER FROM THE BACK OF GUTTER TO THE END OF TIE BAR.
9. REPLACE MISSING OR DAMAGED TIE BARS WITHOUT ADDITIONAL COMPENSATION BY DRILLING MIN. 10 IN. DEEP AND GROUTING TIE BARS WITH TYPE III, CLASS C EPOXY. MEET THE PULL-OUT TEST REQUIREMENTS IN ITEM 361.
10. OMIT TIE BARS LOCATED WITHIN 18 IN. OF THE TRANSVERSE CONSTRUCTION JOINTS (SECTION X-X). USE HAND-OPERATED IMMERSION VIBRATORS TO CONSOLIDATE THE CONCRETE ADJACENT TO ALL FORMED JOINTS.
11. LONGITUDINAL REINFORCING STEEL SPLICES SHALL BE A MINIMUM OF 25 IN. STAGGER THE LAP LOCATIONS SO THAT NO MORE THAN 1/3 OF THE LONGITUDINAL STEEL IS SPLICED IN ANY GIVEN 12-FT. WIDTH AND 2-FT. LENGTH OF THE PAVEMENT.
12. THE DETAIL FOR THE JOINT SEALANT AND RESERVOIR IS SHOWN ON STANDARD SHEET "CONCRETE PAVING DETAILS, JOINT SEALS."



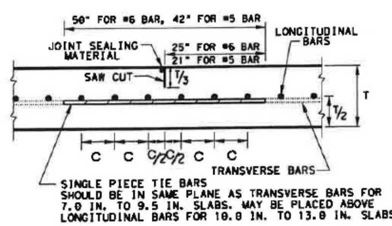
TRANSVERSE CONSTRUCTION JOINT

SECTION X - X



LONGITUDINAL CONSTRUCTION JOINT

SECTION Y - Y



LONGITUDINAL CONTRACTION JOINT

SECTION Z - Z

SHEET 1 OF 2

Texas Department of Transportation — Design Division Standard

CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

ONE LAYER STEEL BAR PLACEMENT

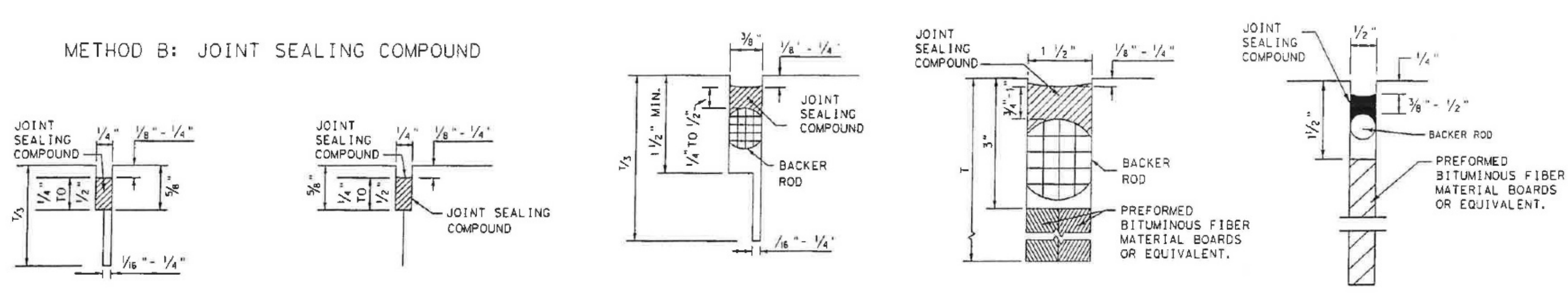
T = 7 to 13 INCHES

CRCP(1)-13

FILE: crcp113.dgn	DN: TxDOT	CK: AN	DW: HC	CK: RM
© TxDOT October 2013	CONT	SECT	JOB	HIGHWAY
REVISIONS	0089	09	058,etc	US59
10/10/2011 ADD ON NOTE; 04/09/2013 REMOVE 6" AND 6.5" ADD CTE REQUIREMENTS	DIST	COUNTY		SHEET NO.
	12	FT BEND		2276

DATE: $DATE$ FILE: $FILE$

METHOD B: JOINT SEALING COMPOUND



LONGITUDINAL SAWED CONTRACTION JOINT

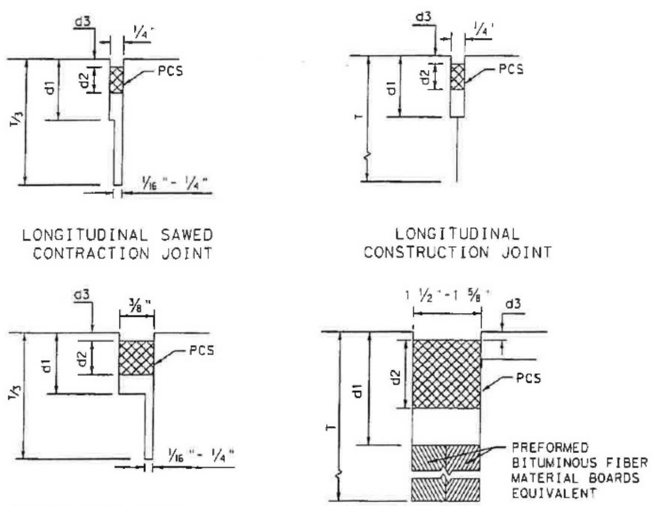
LONGITUDINAL OR TRANSVERSE CONSTRUCTION JOINT

TRANSVERSE SAWED CONTRACTION JOINT

TRANSVERSE FORMED EXPANSION JOINT

FORMED ISOLATION JOINT

METHOD A: PREFORMED COMPRESSION SEALS (PCS) (DMS-6310 CLASS 6)



TRANSVERSE SAWED CONTRACTION JOINT

TRANSVERSE FORMED EXPANSION JOINT

GENERAL NOTES

1. UNLESS OTHERWISE SHOWN IN THE PLANS, EITHER METHOD "A" OR METHOD "B" MAY BE USED.
2. THE LOCATION OF JOINTS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
3. THE JOINT RESERVOIR FOR SEALANT OR PCS SHALL BE SAWED UNLESS OTHERWISE SHOWN ON THE PLANS FOR THE LONGITUDINAL AND TRANSVERSE CONSTRUCTION JOINTS AND THE SAWED JOINTS.
4. DIMENSIONS d1, d2, AND d3 SHOWN IN METHOD A SHALL BE IN ACCORDANCE WITH THE PREFORMED COMPRESSION SEAL MANUFACTURER'S RECOMMENDATION.
5. REFER TO DMS-6310 "JOINT SEALANTS AND FILLERS" FOR THE CLASSIFICATIONS.
6. FOR SAWED LONGITUDINAL JOINT, LONGITUDINAL OR TRANSVERSE CONSTRUCTION JOINT, USE JOINT SEALANT CLASS 5 OR 8 UNLESS OTHERWISE SHOWN ON THE PLAN OR APPROVED.
7. FOR TRANSVERSE SAWED CONTRACTION, TRANSVERSE FORMED EXPANSION JOINT, AND ISOLATION JOINT USE JOINT SEALANT CLASS 5 OR 8 AT NEW JOINTS. USE JOINT SEALANT CLASS 4, 5, 7, OR 8 FOR MAINTAINING EXISTING JOINTS.
8. THE JOINTS SHALL BE CLEANED IN ACCORDANCE WITH THE ITEM 438 "CLEANING AND SEALING JOINTS" OR ITEM 713 "CLEANING AND SEALING JOINTS AND CRACKS (CONCRETE PAVEMENT)".
9. ISOLATION JOINTS ACCOMMODATE HORIZONTAL AND VERTICAL MOVEMENTS THAT OCCUR BETWEEN A PAVEMENT AND A STRUCTURE. ISOLATION JOINTS MAY BE USED FOR BRIDGE ABUTMENTS, INTERSECTIONS, CURB AND GUTTER, OLD AND NEW PAVEMENTS, OR AROUND DRAINAGE INLETS, MANHOLES, FOOTINGS AND LIGHTING STRUCTURES.

Texas Department of Transportation — Design Division Standard

CONCRETE PAVING DETAILS

JOINT SEALS

JS-14

FILE: js14.dgn | DN: TxDOT | CK: HC | DW: HC | CK: AN
©TxDOT: DECEMBER 2014 | CONT 0089 | SECT 09 | JOB 058,etc | HIGHWAY I-69US 59
REVISIONS | DIST HOU | COUNTY FORT BEND | SHEET NO. 317

DATE: 3/26/2015 12:56:11 PM
FILE: H:\cdD\0089_09_058\STANDARDS\Roadway\js14.dgn

ACKNOWLEDGMENTS

The original map on page 2 is the copyright property of Google and can be accessed from https://www.google.com/maps/. The map overlays were developed as a result of this research project. The map overlays on page 2 include a line along the highway showing the new frontage road location with arrows and text emphasizing showing that it is between Beasley and Hamlink Road.