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Research on Joint Sealant Materials to Improve Installation and Performance: Final Report

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Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration

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Research on Joint Sealant Materials to Improve Installation and Performance: Final Report

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16. Abstract

The objectives of this project were to 1) identify failure modes and their mechanisms in joint seals in Texas, and to 2) identify what needs to be done to minimize the failures and improve joint seal performance. To achieve these objectives efficiently, a factorial experiment was developed that included pavement age, shoulder and base type and climatic condition as independent variables. Field surveys were conducted to identify failure modes and their respective failure mechanisms in accordance with the factorial design developed. Field operations of joint seal installations were observed and contacts were made with joint seal contractors, other state DOT personnel as well as joint seal material producers. The findings from this study included (1) joint sealant performance period is much shorter than the current pavement design period, which is 30 years, (2) it is quite rare to observe pavement distresses that can be solely attributable to poor joint sealant condition, (3) there are other variables that have more significant effects on PCC pavement performance than joint seal condition, (4) most of the joint seal failures appear to be due to hardening of the sealant over time, or aging effect, (5) discrepancies exist between TxDOT requirements in design standards and field practice, and (6) continued concrete drying shrinkage increases joint width over time. It appears that the condition of joint sealant does not have substantial effects on overall performance of PCC pavement in Texas. This finding is in line with the findings in several state DOTs. However, joint sealing has its own merit, such as keeping incompressible materials out of the joints.

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Chapter 1 Introduction

The objective of joint sealing in Portland cement concrete (PCC) pavement is to minimize water and incompressible material getting into the joint. Adequate joint sealing also minimizes corrosion potential of dowels and tie bars by reducing entrance of water and de-icing chemicals. Intrusion of water into layers under the concrete slab through poorly sealed joints could degrade the durability of layers under the concrete slab, accelerating the deterioration of PCC pavement condition. Intrusion of water also increases the potential for freeze-thaw distress as well as D-cracking in concrete pavement. Even though these benefits of joint sealing are well known, there has been a controversy over whether these benefits are materialized in actual pavements. The primary cause for the controversy lies in the fact that current practice of sealing joints does not truly "seal" the joint throughout the performance or design period of concrete pavement, which is 30 years in Texas. Average effective life of joint sealing, based on field observations and opinions of engineers involved in PCC pavement design, construction and maintenance at a number of state DOTs, vary from seven to ten years, which would require re-sealing joints three to four times during the performance period of PCC pavement in Texas. However, re-sealing joints is rarely done, not only in Texas, but in northern states where one of the primary distresses in PCC pavement is joint deterioration due to freeze-thaw and D-cracking. Even some northern states, such as Wisconsin and Minnesota, do not seal joints where design sppeed is more than 45 miles per hour. The reason for not sealing joints is based on the field evidence made in Wisconsin that no difference in PCC pavement performance was observed in PCC pavement sections with joints sealed and not sealed (Shober 1997). According to Shober, the very worst performance resulted from partially sealed or filled joints. Based on the extensive field evidence in Wisconsin, Wisconsin DOT passed a policy in 1990 eliminating all PCC joint sealing in new construction and maintenance. Since then, whether to seal joints or not became a national issue.

In Texas, all joints in PCC pavements – contraction joints and longitudinal construction/warping joints in jointed concrete pavement (CPCD; concrete pavement, contraction design) or transverse construction joints and longitudinal construction/warping joints in continuously reinforced concrete pavement (CRCP) – have been sealed. Since stabilized base is used under concrete slab in Texas, disintegration of base material due to the water infiltrated through poorly sealed joints would not be as significant as for pavement with un-stabilized base. Due to mild weather condition, freeze-thaw damage or D-cracking in PCC pavement is quite rare in Texas. In addition, topography is quite flat in many parts of Texas and open ditch elevations are not much deeper than base elevations in many locations. When there is large rainfall, water ingress to the base and subgrade from open ditch is more pronounced than any water ingress through poorly sealed joints. All these make the controversy over seal or not seal more complicated in Texas.
In Texas, joint sealing has not been a serious issue, primarily because most of the concrete pavement built since 2001 has been continuously reinforced concrete pavement (CRCP), which requires sealing at longitudinal sawed contraction joint and longitudinal or transverse construction joints only. Lane mileage of CPCD has been decreasing in Texas. However, with a new CoTE requirement for CRCP, the usage of CPCD could increase in the future, especially in certain districts where the availability of coarse aggregate with a low CoTE is quite limited. Accordingly, the joint sealing issue could become important in the future in Texas. There are three elements associated with joint seal performance: (1) proper joint design, (2) quality of joint seal materials, and (3) proper installations.

Currently, joint design is dictated in the joint design standards, JS-14. Joint seal material quality is controlled by DMS-6310. Joint sealant installation is governed by Item 438. There are discrepancies between Texas Department of Transportation (TxDOT) requirements and actual practice, potentially compromising the effectiveness of joint performance. The discrepancies need to be identified and design standards or specifications revised or field practices modified.

This report consists of the following chapters:

Chapter 2 describes literature reviews on sealant performance evaluation methods as well as joint sealant installation practices in Texas.

Chapter 3 describes the field survey results to evaluate the performance of joint seals in PCC pavements in Texas. The field evaluations of joint seals in PCC pavements were conducted in accordance with a factorial experiment stipulated in the project agreement.

Chapter 4 presents field testing schemes and data analysis results to evaluate current TxDOT practices related to joint design, sealant materials and construction, and to identify areas that need to be improved. Gages were installed at two projects, one in SH 288 in the Dallas District and the other in FM 2253 in the Atlanta District, and data were downloaded and analyzed on a periodic basis.

Chapter 5 describes other states' practices in joint sealing, more specifically whether sealing is required. The performance of a seal-no seal test section in Texas was monitored and the findings are discussed in this chapter.

Chapter 6 describes the conclusions and recommendations.

Chapter 2 Evaluation Methods of Joint Seal Performance

There are different types of joint sealant failure, depending on the sealant material properties, joint movements and how sealants are installed. This chapter discusses failure types of joint sealant and evaluation methods for joint sealant condition.

2.1 Types of Joint Seal Damage

"Distress Identification Manual" for the long-term pavement performance program defines joint seal damage as any condition which enables incompressible materials or water to infiltrate the joint from the surface (Miller and Bellinger 2014). There are six types of joint seal damage described in the Manual, which is briefly discussed here. It is to be noted that, even though the term "joint seal damage" is used, some of the types are not directly related to joint seal damage; rather, they are consequences of the seal damage.

2.1.1 Adhesion failure (loss of bonding to the side of the joint)

Adhesion failure denotes the failure of the sealant to adhere to the concrete side surfaces of joints. The major causes for this type of failure include joint movements exceeding the ability of sealant to bond to concrete, uneven surface preparation, and weak bead configuration. Figure 2.1 illustrates the joint adhesion failure.

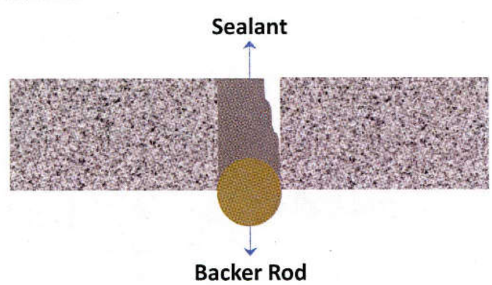


Figure 2.1 Adhesion failure

2.1.2 Cohesion failure (breakage within the sealants)

Cohesion failure occurs when sealant fails to hold together. Unlike the adhesion failure, which is a breakage between sealant and concrete, cohesion failure indicates breakages or cracks within sealant. Cracks can take place in either transverse or longitudinal directions. The major causes for this type of failure include presence of air voids in sealant, poor quality sealant, and/or improper multi-component sealant mixing. Figure 2.2 illustrates the joint cohesion failure.

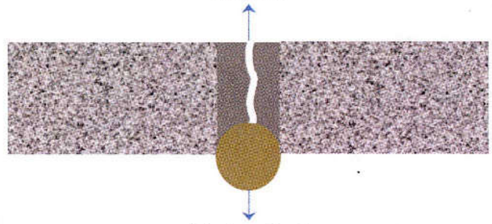


Figure 2.2 Cohesion failure

2.1.3 Torn or missing sealant

Torn or missing sealant is defined as the failure of sealant due to cohesive and adhesive failures, which includes displacements of sealant from its position. Major causes include improper surface preparation, poor quality of sealant, or inadequate shape factors of the joints.

2.1.4 Amount of incompressible material

When incompressible materials such as sand are infiltrated into poorly jointed seals, the expansion of concrete in hot weather could result in blowups, causing failure of rigid pavements. Incompressible material itself in a joint is not joint seal damage; rather, it is an indication of improper installation of joint seal or adhesion/cohesion damage to sealant.

2.1.5 Evidence of pumping

Pumping occurs when iwater intrudes through failed joints, cracks or along the pavement edges, and the infiltrated water carries fine particles from the foundation and shoulder of pavement, ejecting it onto the surface of pavement during traffic loading applications. Pumping becomes a serious problem when a larger amount of material is displaced, resulting in unsupported slab and eventual failure of the pavement (ASTM 1996).

2.1.6 Joint faulting

Joint faulting is the difference in the elevations across the joint between two slabs due to pumping or other causes. Joint faulting degrades riding quality of jointed concrete pavement (CPCD), especially when the average faulting is above 0.1 inches. With the use of dowels and stabilized base, faulting is substantially reduced. On the other hand, the absence of dowels or the use of non-stabilized base such as flexible base could cause faulting, even when the joint seal is properly functioning. Accordingly, joint faulting is not necessarily the evidence of a poor joint seal. However, poor joint seal performance could exacerbate a faulting problem.

2.2 Joint sealant type

There are two primarily different joint sealant types – liquid and preformed sealants. Liquid materials seal joints by adhering to the joint faces and are subjected to compression and tension.

The preformed materials are used for compression seals that operate only in compression and in expansion type joints (California Department of Transportation 2008).

The most widely used sealants in Texas are liquid type: silicon and asphalt sealants. Silicon is an inorganic polymer material and has resistance to moisture. Silicon also has good thermal stability, which makes it suitable material for outdoor application as sealant. Silicon is a cold-poured type sealant, possesses adequate adhesive and cohesive strength as well as lower temperature sensitivity, and is low modulus. It has as high as one hundred percent extension recovery and fifty percent compression recovery. Since silicone is virtually inert, it has good weathering characteristics as well. The cost of the silicon-sealant is high when compared to other cold-poured type sealants; however, it is known that its performance period is longer (Brown 1991; Dong et al. 2011). The curing time for silicon sealant is about 30 minutes and it develops a low elastic modulus, which allows good extension and compression recovery.

Asphalt sealant is a hot-poured type of sealant. Initially, hot poured asphalt was used as sealant since it was easily available, inexpensive, and of relatively acceptable quality. Installation of hot poured asphalt sealant requires high temperatures, usually from 350 to 400 °F to be placed properly in pavement joints. The temperature control should be a top priority to attain its desired properties. The cost and life span of the asphalt sealant is low when compared to the silicon sealant (Collins et al. 1986; Odum-Ewuakye and Attoh-Okine 2006).

Table 2.1 shows the joint sealant in the TxDOT DMS-6310 (Texas Department of Transportation 2012). It is noted that the current joint seal detail (JS-14) allows only Classes 5 and 8; in other words, hot-pour asphalt is not allowed per JS-14. Table 2.2 summarizes the materials and application requirements of the various classes.

Table 2.1 Class of joint sealants (Texas Department of Transportation 2012)

Class	Description
1	Two-component polyurethane, rapid curing, self-leveling
2	Two-component synthetic polymer, self-leveling
3	Hot-poured rubber
4	Low-modulus silicone, nonsag
5	Low-modulus silicone or polyurethane, self-leveling
6	Preformed seals
7	Low-modulus silicone, rapid curing, self-leveling
8	Low-modulus silicone or polyurethane, self-leveling, concrete only
9	Polymer-modified asphalt emulsion
10	Polymer-modified asphalt emulsion, nonsag

Table 2.2 Joint sealant applicability (Texas Department of Transportation 2012)

Features	Classes									
	1	2	3	4	5	6	7	8	9	
Material	Polyurethane	Synthetic Polymer	Asphalt	Silicone	Silicone or Polyurethane	Solid	Silicone	Silicone or Polyurethane	Asphalt Emulsion	
1- or 2-component	2[1]	2[1]	1	1	1	1	2[1]	1	1	1
Self-Leveling or Nonsag	SL	SL	N A	NS	SL	N A	SL	SL	SL	NS
Primer Required	Yes	No	No	No	No	No	Yes	No	No	No
Backer Rod Required	Yes	No	No	Yes	Yes[3]	No	Yes	Yes[3]	No	No
Joint Type[2]	H	ACS	AC	ACS	AC	CS	CSH	C	AC	AC

1. These materials must cure by chemical reaction and not by evaporation of solvent or fluxing of harder particles.
2. Joint Types: A = asphalt-to-concrete; C = concrete-to-concrete; S = steel or armored; H = header-type. Use with joint types other than the ones listed only after evaluating the sealant for the proposed application.
3. Unless otherwise shown on the plans.

2.3 Evaluation of Joint Sealant Condition

As discussed earlier, there are six items related to joint seal damage, some of which are the results of the others. Accordingly, quantifying joint sealant condition numerically is not a simple task. Also, to make quantified joint sealant condition more meaningful, the quantified value should have a close correlation with pavement performance. At this point, no joint sealant condition evaluation system exists that correlates with pavement condition. In this report, the most widely used system is discussed. In this system, the joint sealant condition is quantified by the following equation:

$$\mathbf{SCN = 1(L) + 2(M) + 3(H)}$$

where, SCN = sealant condition number
L = number corresponding to low severity sealant condition
M = number corresponding to medium severity sealant condition
H = number corresponding to high severity sealant condition

SCN can be determined for each joint, and how L, M and N are determined is as follows. For each joint, the values of two variables – water infiltration and stone intrusion – are determined. For water infiltration, total percentage of joint seal length that allows water to enter into joint through adhesive and cohesive failures is determined in accordance with the equation below (Evans et al. 1999).

$$\% L = (L_f/L_{tot}) \times 100$$

where: % L = percent length of the joint allowing water infiltration
L_f = length of the joint sealant that allows the infiltration of water
L_{tot} = length of the joint sealant evaluated

Once % L is determined, the water infiltration is rated using the following criteria:

- **No** water infiltration: % L = 0 % < % L < 1 %
- **Low** severity water infiltration: 1 % < % L < 10 %
- **Medium** severity water infiltration: 10 % < % L < 30 %
- **High** severity water infiltration: % L > 30%

Stone intrusion is rated using the following criteria:

- **No**: no stones or sands at all
- **Low**: occasional stones or sands stuck to the top of the sealant (or material embedded on the surface of the sealant/channel interface).
- **Medium**: sand or debris stuck to sealant and some debris deeply embedded in the sealant.
- **High**: much sand and debris stuck to and deeply embedded in the sealant or filling the joint.

For example, if a joint has 20% water infiltration (Medium) and occasional stones or sands stuck to the top of the sealant (Low), an SCN of 3 is obtained for the joint (1*(1) + 2*(1) + 3*(0)). It is noted that SCN varies from 0 to 6. For SCN to be zero, the rates should be "No" for both water infiltration and stone intrusion. For SCN to be 6, the rates should be "High" for both water infiltration and stone intrusion.

The rating system discussed can be quite subjective, and does not appear to be directly related to pavement performance. For example, level of stone intrusion may not have any impact on pavement performance if joint movements are small with small joint spacing and stones are of small size.

Figures 2.3, 2.4, and 2.5 show the examples of each "Low, Medium, and High" in terms of stone intrusion, respectively.

Figure 2.3 Low level of stone intrusion

Figure 2.4 Medium level of stone intrusion

Figure 2.5 High level of stone intrusion

In general, more than 10 joints are evaluated, and the joint sealant conditions are quantified as discussed above. Based on the SCN, seal rating (SR) is derived at three levels, which are "Good (SCN: 0-1)", "Fair (SCN: 2-3)", and "Poor (SCN: 4-6)".

To determine SCN and SR, the methods described above were applied to FM 2499 in Denton County in the Dallas District and the results are shown in Table 2.3. SCN and SR were derived for all the sections surveyed in Texas and the information is included in Appendix I along with the pavement details.

Table 2.3 Example of SCN and SR evaluation

FM 2499 [Denton County, Dallas]	TCJ-1	TCJ-2	TCJ-3	TCJ-4	TCJ-5	TCJ-6	TCJ-7	TCJ-8	TCJ-9	TCJ-10	TCJ-11	TCJ-12	TCJ-13	TCJ-14	TCJ-15
1. Adhesion failure [in]	72	29	-		-	-	-	72	-			72			
2. Cohesion failure [in]	-	-	-		-	-	-	-	-			-			
3. Torn or missing sealant [in]	72	72	-	101	-	58	20	72	-	108		-		144	
[% T or M = L_{tm}/L_{tot}*100%]	50%	50%	0%	70%	0%	40%	14%	50%	0%	75%	0%	0%	0%	100%	0%
4. Amount of incompressible material	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
5. Evidence of pumping	-	-	-		-	-	-	-	-			-			
6. Joint faulting	-	-	-		-	-	-	-	-			-			
7. Water infiltration	144 in.	101 in.	0 in.	101 in.	0 in.	58 in.	20 in.	144 in.	0 in.	108 in.	0 in.	72 in.	0 in.	144 in.	0 in.
[% L = L_f/L_{tot}*100%]	100%	70%	0%	70%	0%	40%	14%	100%	0%	75%	0%	50%	0%	100%	0%
Water infiltration Severity ratings	HIGH	HIGH	NO	HIGH	NO	HIGH	MED	HIGH	NO	HIGH	NO	HIGH	NO	HIGH	NO
8. Stone/Debris Retention Severity Rating															
	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Seal Condition Number (SCN)	4	4	1	4	1	4	3	4	1	4	1	4	1	4	1
Seal Rating (SR)	Poor	Poor	Good	Poor	Good	Poor	Fair	Poor	Good	Poor	Good	Poor	Good	Poor	Good

2.4 Sealant Installation Practice in Texas

This section provides the current practice of joint sealant installations in Texas. For a number of operations and equipment related to sealing joints, current TxDOT specifications Item 438 "Cleaning and Sealing Joints and Cracks (Rigid Pavement and Bridge Decks)" references the manufacturer's recommendations. Accordingly, variations exist in joint sealing operations, depending on the manufacturer of the sealant and equipment. Typical operations in Texas are discussed in this section.

2.4.1 Joint preparation

1st Step: Saw cut

Figure 2.6(a) shows the first saw cut to the one-third pavement depth. A wet saw is usually applied in this step. Figure 2.6(b) illustrates the second saw cut, which is to provide sealant reservoir.

a. The first saw cut (wet)	b. The second saw cut (dry)

Figure 2.6 Saw cut operations

2nd Step: Sand blasting and air blasting

After saw cutting, joint interfaces are sandblasted to remove the residuals in the interfaces of joint as shown in Figure 2.7(a). Figure 2.7(b) shows the joint cleaning procedure using compressed air. The compressed air must be free of moisture and oil. The joint interfaces are supposed to be checked for cleanliness. If there are any dust or remaining concrete particles, then the joint must be re-blasted and blown clean. To ensure cleanliness, it is recommended that each joint interface be wiped clean with a clean rag without solvents to remove any dust remaining after sandblasting. However, this recommendation is rarely followed.

a. Sand blasting | b. Air blasting

Figure 2.7 Sand blasting and air blasting

2.4.2 Backer rod installation

The backer rod plays a role as a bond breaker, preventing the sealant from bonding to the bottom of the joint and preventing the flow of the material through the joint itself. Backer rods consist of cylinders of compressible material, which holds the fluid sealant in place in open joints. Backer rods also prevent "three-face bonds" in the joints. This enhances the performance of joint sealant by minimizing stresses in the sealants. It should be noted that TxDOT "Concrete Paving Details Joint Seals (JS-14)" does not require a backer rod at longitudinal sawed contraction joints or longitudinal/transverse construction joints, which violates the principle of avoiding three-face bonds. However, backer rods were installed in all the joint sealing operations observed. The size of the backer rod must be at least 25% greater than the joint reservoir width (Texas Department of Transportation 2012). Figure 2.8(a) shows a backer rod installation at longitudinal sawed contraction joint and Figure 2.8(b) illustrates a close-up view after backer rod installation.

a. Backer rod installation | b. Close-up view after backer rod installation

Figure 2.8 Backer rod installation

2.4.3 Sealant installation

Sealant is installed in one direction only and from the bottom of the joint up. Figure 2.9 illustrates the sealant installation operation.

Figures 2.10(a) and (b) show sealant not properly installed. The tip of the sealant nozzle was not properly located, with the resulting poor sealant installation.

Figure 2.9 Sealant installation

a. Backer rod installation	b. Close-up view after backer rod installation

Figure 2.10 Inadequate sealant installation

Chapter 3 Evaluation of Joint Seal Performance in Texas PCC Pavement

3.1 Factorial Design of Field Survey

The objective of this field survey was to evaluate the performance of joint seals in PCC pavements in Texas. The research team performed field evaluations of joint seals in PCC pavements in accordance with a factorial experiment stipulated in the project agreement.

A total of 61 sections were selected for joint sealant condition evaluations. Those sections were selected based on pavement type and age, environmental condition, and base and shoulder type; these selections ensure the inclusion of all environmental conditions in Texas as well as pavements with various structures and ages. Efforts were made to develop a balanced factorial experiment. Tables 3.1, 3.2, and 3.3 show the pavement details for the selected sections under "Pavement Age". Figure 3.1 shows the lane mile information for CPCD, including a few JRCP in Texas based on the 2013 TxDOT Pavement Management Information System (PMIS). According to the 2013 PMIS, the Dallas, Beaumont, and Houston Districts have the most CPCD in Texas. Therefore, the most candidate sections for sealant condition survey were located in those three Districts. There were no CPCD sections in Abilene, Austin, San Antonio, Corpus Christi, Brownwood, or El Paso Districts, which indicates that CPCD has been rarely constructed in a "dry-no freeze" zone.

Figure 3.2 shows the location of the test sections for joint sealant condition survey. As discussed earlier, since most of the CPCD sections are located in the Dallas, Beaumont, and Houston Districts, the sections investigated are also in these Districts.

Table 3.1 Pavement details (less than 10 years)

Pavement Age: Less than 10-Y							Reference Marker								Construction		
NO	District	County	Highway	CSJ	P_Age	P_Type	Begin	End	Section Length[mile]	T [in]	Shoulder	Base	Subgrade	Letting Year	Begin	End	Comments
1	DAL	DALLAS	MH	8050-18-042	5	CPCD			2.427	10	Mono Curb	4-in ASB [TY-B]	6-in LTS	2005	02/09/2005	01/27/2009	Widening Project
2	BMT	JEFFERSON	FM 364	0786-01-070	9	CPCD	RM 446+0.85	449+0.54	2.647	12	Tied Concrete	1-in AC+6-in CSB	6-in LTS	2003			
3	DAL	DALLAS	MH	8043-18-005	7	CPCD			2.011	8	Mono Curb	4-in ASB [TY-B]	24-in LTS	2005			
4	BRY	BRAZOS	BS 6-R	0050-01-060	5	CPCD	RM 415+0.657	RM 417+0.493	1.835	8	TY-II Curb	1.5-in Bond Breaker	Existing CPCD	2004	08/10/2004	02/04/2009	
5	DAL	DENTON	FM 2499	2681-01-015	6	CPCD	RM 246+0.7	RM 249+0.432	2.722	8	Curb	4-in ASB [TY-B]	6-in LTS	2006	07/06/2006	05/23/2008	
6	DAL	COLLIN	SH 78	0281-02-060	4	CPCD	RM 264+0.774	RM 272+0.425	7.767	9	TY-I Curb	4-in ASB	12-in LTS	2009	08/11/2009		Widening Project
8	BMT	ORANGE	BU 90-Y	0028-15-040	9	CPCD	RM 439+0.126	RM 440+0.746	1.599	10	TY-P Mono Curb	1-in AC+6-in CSB	6-in LTS	2001	07/11/2001	09/19/2005	
9	WAC	MCLENNAN	FM 933	0209-07-031	5	CPCD	RM 353+0.740	RM 357+0.603	3.865	10	TY-II Mono Curb	6-in ASB [TY-B]	No Info.	2005	03/09/2005	12/03/2009	
10	WAC	MCLENNAN	FM 1695	2506-01-021	5	CPCD	RM 358+0.462	RM 359+0.852	2.314	10	TY-P Mono Curb	3-in ASB [TY-B]	8-in LTS	2004	07/08/2004	06/02/2009	Unable to access
11	DAL	DALLAS	IH 35E	0196-03-106	7	CPCD.	RM 445+0.242	RM 446	0.758	11	Tied Concrete	4-in ASB [TY-B]	6-in LTS	2005	06/08/2005	01/09/2007	Unable to access
12	DAL	DENTON	IH 35E	0196-01-093	8	CPCD	RM 463+0.698	RM 464+0.966	1.384	10	Tied Concrete	4-in ASB [TY-B]	6-in CTS	2004	11/10/2004	01/17/2006	Ovarlaid with AC
13	TYL	HENDERSON	SH 198	1668-01-013	2	CPCD	RM 303A+0.127	RM 304+0.109	0.972	9	TY-II Mono Curb	4-in ASB	6-in LTS	2010	07/08/2010		Reconstruction
14	DAL	COLLIN	US 75	0047-06-132	5	CPCD	RM 247+0.034	RM 248	0.966	10	Tied Concrete	2.5-in ASB [TY-B]	8-in LTS	2008	06/11/2008	10/23/2009	Widening Project
15	DAL	COLLIN	SH 289	0091-05-049	7	CPCD	RM 254	RM 254+0.6005	0.6005	12	Curb	2-in ASB [TY-B]	6-in LTS	2006	05/09/2006	11/19/2007	Widening Project
16	DAL	DENTON	IH 35E	0196-02-098	10	CPCD	RM 446	RM 446+0.534	0.534	11	Tied Concrete	4-in ASB [TY-B]	6-in LTS	2003	08/05/2003	06/28/2004	Unable to access
17	DAL	DENTON	SH 121	3547-01-008	7	CPCD	RM 273+0.163	RM 274+0.676	1.244	11	Tied Concrete	4-in ASB	6-in LTS	2002	02/04/2003	11/07/2007	Ramp Widening
18	DAL	DENTON	SH 121	3547-01-008	7	CPCD				10	TY-II Mono Curb	4-in ASB	6-in LTS				1st Frontage Rd [CPCD]
19	DAL	DENTON	SH 121	3547-01-008	7	CRCP				8	TY-II Mono Curb	2-in ASB	6-in LTS				Unable to access
20	DAL	DENTON	IH 35	0195-03-062	9	CPCD	RM 467+0.473	RM 469+0.788	0.706	9	TY-II Mono Curb	4-in ASB	8-in LTS	2003	01/09/2004	07/20/2005	U-Turn Lane
21	DAL	DENTON	IH 35	0195-03-062	9	CRCP	RM 467+0.473	RM 469+0.788		10	Tied Concrete	6-in ASB [TY-B]	8-in LTS	2003	01/09/2004	07/20/2005	Ovarlaid with AC
22	DAL	DALLAS	IH 20	2374-04-064	2	CPCD	RM 457+0.567	RM 458+0.324	0.758	9	TY-II Mono Curb	4-in ASB	8-in LTS	2010	06/04/2010		Unable to access
23	DAL	DALLAS	US 67	0261-02-065	3	CRCP	RM 16+0.705	RM 17+0.262	0.557	8	Tied Concrete	6-in ASB [TY-B]		2008	09/09/2009		Widening Project [CRCP]
24	DAL	ELLIS	US 287	0172-05-095	11	CPCD	RM 490+0.178	RM 491+.584	1.406	8	Curb	4-in ASB	12-in Flex Base	2002	08/07/2002	08/28/2003	US 287 [CPCD]
25	PAR	GRAYSON	US 75	0047-18-055	7	CRCP	RM 203+0.309	RM 204+0.122	0.813	10	Curb	4-in ASB [TY-B]	6-in LTS	2005	12/02/2005	03/31/2007	US 75 West Frontage Rd
26	PAR	GRAYSON	US 75	0047-18-055	7	CPCD				10	Curb	4-in ASB [TY-B]	6-in LTS				Unable to access
27	BMT	ORANGE	BU 90-Y	0028-15-040	9	CPCD	RM 440+0.746	RM 439+0.147	1.599	10	TY-P Mono Curb	1-in AC+6-in CSB	6-in LTS	2001	07/11/2001	09/19/2005	
28	TYL	SMITH	LP 323	1790-02-027	6	CPCD	RM 676+0.797	RM 678+0.537	1.74	12	TY-II Mono Curb	4-in ASB	6-in CTS	2003	09/10/2003	04/30/2008	
29	LBB	LUBBOCK	US 82	0053-1-090	3	CRCP	RM 308+1.996	RM 310+1.436	1.049	13	Tied Concrete	6-in ASB	6-in Flex Base	2011			
30	HOU	MONTGOMERY	FM 1488	0523-10-033	4	CRCP				11	Tied Concrete	1-in AC+6-in CSB	6-in LTS				

Table 3.2 Pavement details (10 to 20 years)

Pavement Age: 10-Y to 20-Y							Reference Marker								Construction		
NO	District	County	Highway	CSJ	P_Age	P_Type	Begin	End	Section Length[mile]	T[in]	Shoulder	Base	Subgrade	Letting Year	Begin	End	Comment
31	Dallas	Denton	IH 35E FR [NB]	0196-02-098	10	CPCD				11	Tied Concrete	4-in ASB [TY-B]	6-in LTS			2004	
32-1	Beaumont	Liberty	US 90 EB	0028-03-081	14	CPCD	RM 847			10	Tied Concrete	Ex. 6-in ACP				2000	
32-2	Beaumont	Liberty	US 90 WB			CPCD	RM 847				Asphalt					Older than 20-Y	
33	Dallas	Dallas	SL 12	0581-01-090	15	CPCD				9	Curb	4-in ASB [TY-B]	8-in LTS			1999	
34	Dallas	Collin	SH 289	0091-05-029	15	CPCD				9	Curb	2-in ASB	6-in LTS			1999	Not Clear
35	Dallas	Collin	US 75	0047-06-104	16	CPCD				9	Tied Concrete	-	-			1998	
36	Dallas	Navarro	IH 45	0093-01-064	17	CPCD				12	Tied Concrete	2-in AC Level Up	Ext. 10-in CPCD			1997	
37	Dallas	Navarro	IH 45	0093-01-064	17	CRCP				12	Tied Concrete	4-in ASB	6-in LTS			1997	
38-1	Beaumont	Jefferson	FM 364 NB	0786-01-062	18	CPCD				10	Tied Concrete	6-in CSB	6-in LTS			1996	
38-2	Beaumont	Jefferson	FM 364 SB	0786-01-062	18	CPCD				10	Tied Concrete	6-in CSB	6-in LTS			1996	
38-3	Beaumont	Jefferson	FM 364 SB	0786-01-062	18	CPCD				10	Tied Concrete	6-in CSB	6-in LTS			1996	
39	Dallas	Collin	US 380	0135-02-030	20	CPCD				9	Curb	4-in ASB	6-in LTS			1994	
40	TYL	VAN ZANDT	SH 19	0108-02-025	11	CPCD	RM 285+0.805	RM 286+0.473	0.737	9	TY-II Curb	4-in ASB		2001	05/02/2001	06/11/2003	
41	Dallas	ELLIS	US 287	0172-05-095	11	CPCD	RM 490+0.178	RM 491+.584	1.406	8	Curb	4-in ASB	12-in Flex Base	2002	08/07/2002	08/28/2003	Not Clear
42	Laredo	Webb	IH 35		12	CRCP				9	Tied Concrete	AC Level Up				2002	

Table 3.3 Pavement details (older than 20 years)

Pavement Age: Older than 20-Y							Reference Marker								Construction		
NO	District	County	Highway	CSJ	P_Age	P_Type	Begin	End	Section Length[mile]	T[in]	Shoulder	Base	Subgrade	Letting Year	Begin	End	Comments
43	Beaumont	Chambers	IH 10	0508-03-062	22	CPCD				14	Tied Concrete	1-in Bond Breaker	Existing CPCD			1992	No Dowel
44	Dallas	Collin	SH 289	0091-05-025	25	CPCD	RM 242+1.8	RM 254+1.2		9	Curb	6-in ASB	6-in LTS			1989	
45	Dallas	Denton	IH 35	0195-02-035	26	CPCD				11	Tied Concrete	2-in AC Level up	10-in Ex. CPCD			1988	
46	Lubbock	Swisher	IH 27	0306-03-023	26	CRCP				9	Tied Concrete	4-in ASB				1988	
47	Dallas	Denton	SL 288	2250-02-002	27	CPCD				9	Curb	4-in ASB	8-in LTS			1999	
48	Dallas	Dallas	IH 20	0014-30-020	30	CPCD	RM 482+0.0	RM 496+0.0		12	Tied Concrete	-	-			1984	
49	Dallas	Dallas	US 80	0095-02-061	30	JRCP	-			11	AC	6-in ASB	8-in LTS			1984	
50	Dallas	Dallas	SH 66	0009-03-017	37	CPCD	RM 596+0.0	RM 606+1.6		9	Curb	-	6-in LSS			1977	
51	Wichita Falls	Montague	US 287	0013-05-017	42	CRCP				8	AC	4-in ASB				1972	
52	Dallas	Denton	US 380	0314-09-023	43	CPCD				8	2-Coarse Surf. Treatment	6-in LSB				1971	Overlaid with AC
53	Dallas	Navarro	SH 31	0163-02-019	44	CPCD				9	AC	6-in SCB	6-in LTS			1970	Overlaid with AC
54	Dallas	Dallas	SH 356	0092-07-032	47	CPCD	-			10	Curb	None	6-in LTS			1967	
55	Beaumont	Hardin	SH 326	0601-01-022	47	JRCP	-			8	Curb	4-in CSB				1967	
56	Beaumont	Jefferson	US 90	0028-07-024	50	JRCP	-			10	Curb	4-in Flexible Base	6-in LTS			1964	Reconstructed
57	Beaumont	Chambers	SH 124	0368-01-033	52	CPCD	RM 478+0.0	RM 480+0.1		10	Curb	9-in Comp. Roadbed Treatment	-			1962	No Dowel
58	Beaumont	Jefferson	SH 73	0508-03-009	52	CPCD				10	Curb	6-in LSB	No Info.			1962	Overlaid with AC
59	Beaumont	Jefferson	IH 10 FR	0028-13-018	54	CPCD	RM 851+0.0	RM 855+0.1		9	Curb	6-in LSB				1960	
60	Beaumont	Jefferson	SH 347	0667-01-028	54	CRCP	RM 458+0.6	RM 458+1.3		7	Curb	6-in Flex. Base	-			1960	Overlaid with AC
61	Beaumont	Jefferson	US 87	0306-03-023	63	JRCP				9	Curb	No Info.				1951	

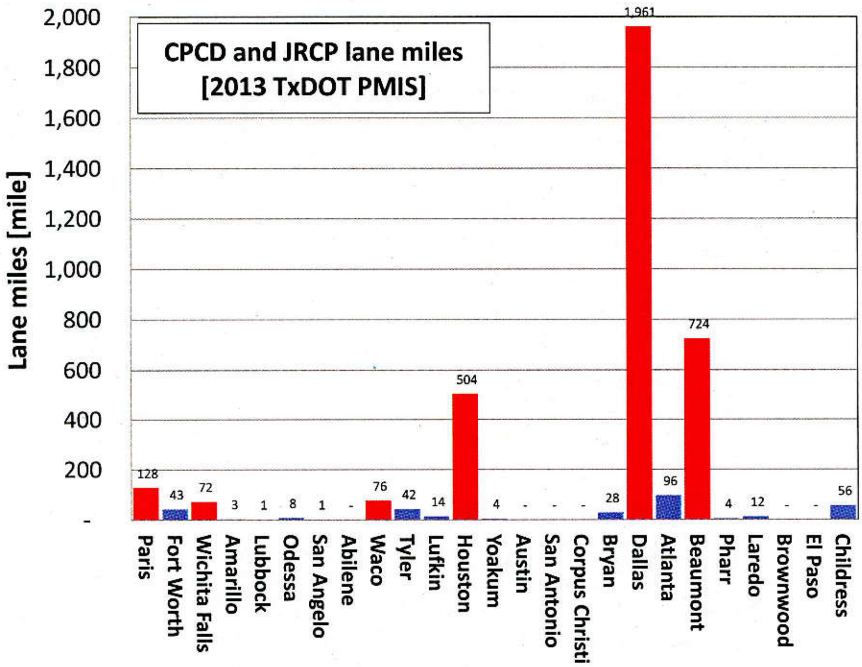


Figure 3.1 CPCD and JRDP lane miles District wide

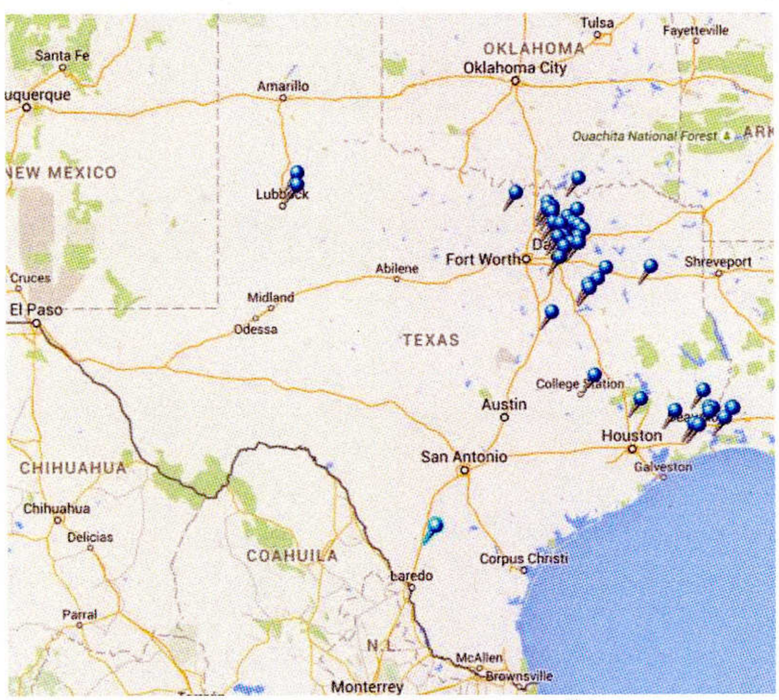


Figure 3.2 Investigated sections for joint sealant condition survey

3.2 Condition Survey Result of Joint Sealant with Pavement Type

Field surveys were planned for all 61 sections. These sections consisted of three types of rigid pavement, CPCD, JRCP, and CRCP. Nine sections were not investigated due to heavy traffic and safety concerns, and two sections were under construction or reconstructed. Accordingly, field surveys were conducted for the remaining 50 sections.

Table 3.4 shows the number of planned and conducted survey sections with different pavement ages. There are 24 CPCD and six CRCP sections with pavement age less than 10 years; detailed sealant surveys were conducted for only 21 sections. For pavement sections with 10 to 20 years of service, 14 sections were surveyed, and 15 pavement sections with more than 20 years old were investigated. In this chapter, discussions are provided for selected sections only, and the information of the sections not included in this chapter are included in Appendix I.

Table 3.4 Pavement type and age

	Age						Total	
	Less than 10		10 to 20		More than 20			
	Planned	Surveyed	Planned	Surveyed	Planned	Surveyed	Planned	Surveyed
CPCD	24	17	10	12	13	11	47	40
JRCP	-	-	-	-	3	2	3	2
CRCP	6	4	2	2	3	2	11	8
Total	30	21	12	14	19	15	61	50

3.2.1 Pavements with age less than 10 years

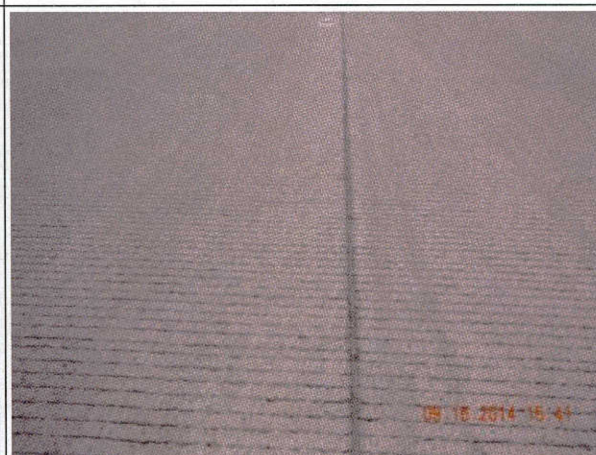
3.2.1.1 Sealant condition in CRCP

Figure 3.3 shows a typical sealant condition in CRCP where the pavement age is less than 10 years old. The NO at the end of the figure label indicates the project number in Tables 3.1 through 3.3. This pavement was built in 2011 in the Lubbock District. As shown in Figures 3.3(b) and (c), although the pavement is only three years old, minor distress in the form of chipping occurred due to inadequate saw cuts in longitudinal construction joints. On the other hand, the condition of the sealant at longitudinal contraction joint was excellent, as shown in Figure 3.3(d).

a. Overall pavement condition

b. Longitudinal construction joint #1

c. Longitudinal construction joint #2



d. Longitudinal contraction joint

Figure 3.3 Sealant condition on US 82-LBB [NO. 29]

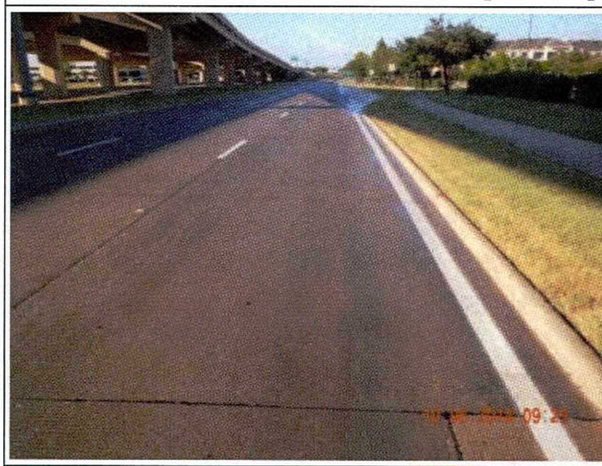
3.2.1.2 Sealant condition in CPCD

Figures 3.4(a) and (b) show the overall pavement condition and localized missing sealant on SH 121 NB in the Dallas District. The pavement construction was started in 2003 and finished in 2007.

It was a rainy day when the section was surveyed. Water was observed in the joint areas where joint sealant was missing, which indicates that the areas seem to serve as a reservoir for rainwater. It also indicates that it is difficult for rainwater to permeate into the pavement base layer through joints even when joint sealant is missing. Figures 3.4(c) and (d) show the pavement condition on SH 121 SB. It is observed that water stayed at the joint even though sealant was missing. The overall condition of the pavement was quite good.

a. Overall condition on SH 121 NB [NO. 17]

b. Missing sealant [NO. 17]



c. Overall condition on SH 121 SB [NO. 18]

d. Missing sealant [NO. 18]

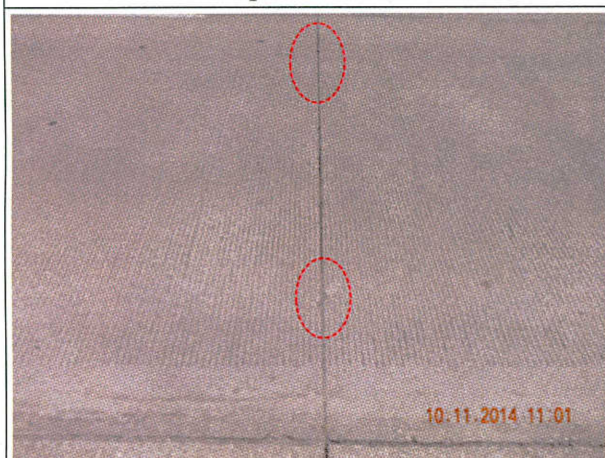
Figure 3.4 Sealant condition on SH 121-DAL [NO. 17 and NO. 18]

Figure 3.5 shows the adhesion failure in the wheel paths on US 90 Business Rd in the Beaumont District. This section was completed in 2005. It is observed that the adhesion failure occurred near the wheel paths. The cause for the adhesion failure of sealant near the wheel paths is not known.

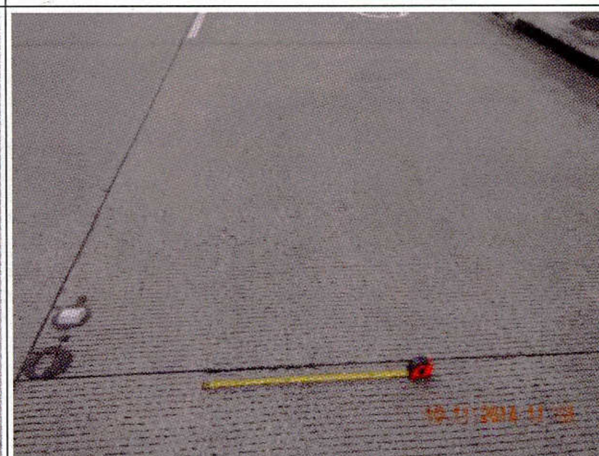
The field survey results show that sealant condition has been satisfactory in pavements less than 10 years old.

a. Overall pavement condition

b. Longitudinal joint



c. Transverse contraction joint



d. Missing sealant at wheel path

Figure 3.5 Sealant condition on US 90 BR-BMT [NO. 27]

3.2.2 Pavements with age between 10 and 20 years

3.2.2.1 Sealant condition in CRCP

Figures 3.6(a) and (b) show the sealant condition at longitudinal contraction joint on IH 35 in Webb County, Laredo District, which was built in 2002, showing adhesion failure, missing sealant, and spalling. However, distresses related to sealant issues were not observed. On the other hand, as shown in Figures 3.6(c) and (d), partial depth distresses were observed. This type of partial depth distress occurs when delamination exists at the depth of longitudinal steel. One of the reasons for delamination is an increased stress around longitudinal steel due to the applications of heavy wheel loading. The SCN of this section was estimated to be close to 0, which indicates a good sealant condition. The distress observed here is not related to the sealant condition.

a. Longitudinal contraction joint #1

b. Longitudinal contraction joint #2

c. Partial depth distress #1

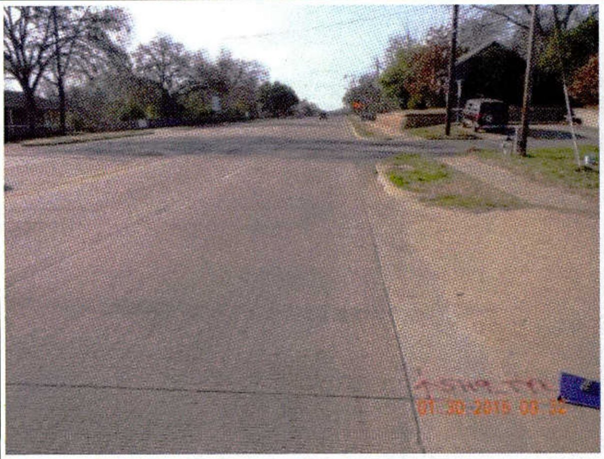
d. Partial depth distress #2

Figure 3.6 Sealant condition on IH 35-LRD [NO. 42]

3.2.2.2 Sealant condition in CPCD

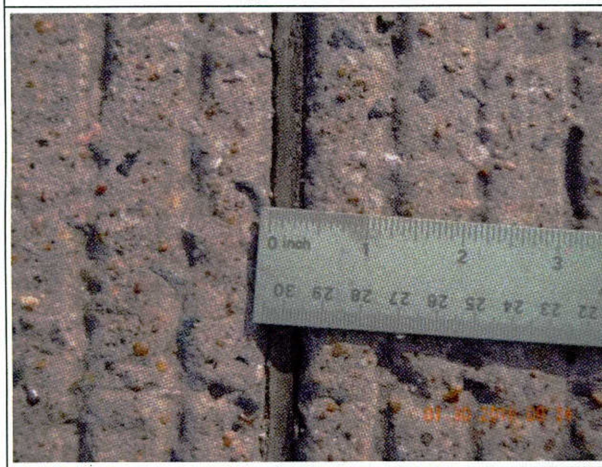
1) SH 19, Tyler District

SH 19 was built in May, 2003 with a 9-in CPCD over 4-in asphalt stabilized base in Van Zandt County, Tyler District. Figure 3.7(a) shows the overall pavement condition on SH 19. Figures 3.7 (b) and (c) show the transverse contraction joint and joint width, respectively. As shown in these two figures, adhesion failures were observed at transverse joints. Figure 3.7 (d) presents the longitudinal joint condition. Even though the pavement was 12 years old at the time of the condition survey, the overall joint condition was good.



a. Overall pavement condition

b. Transverse contraction joint



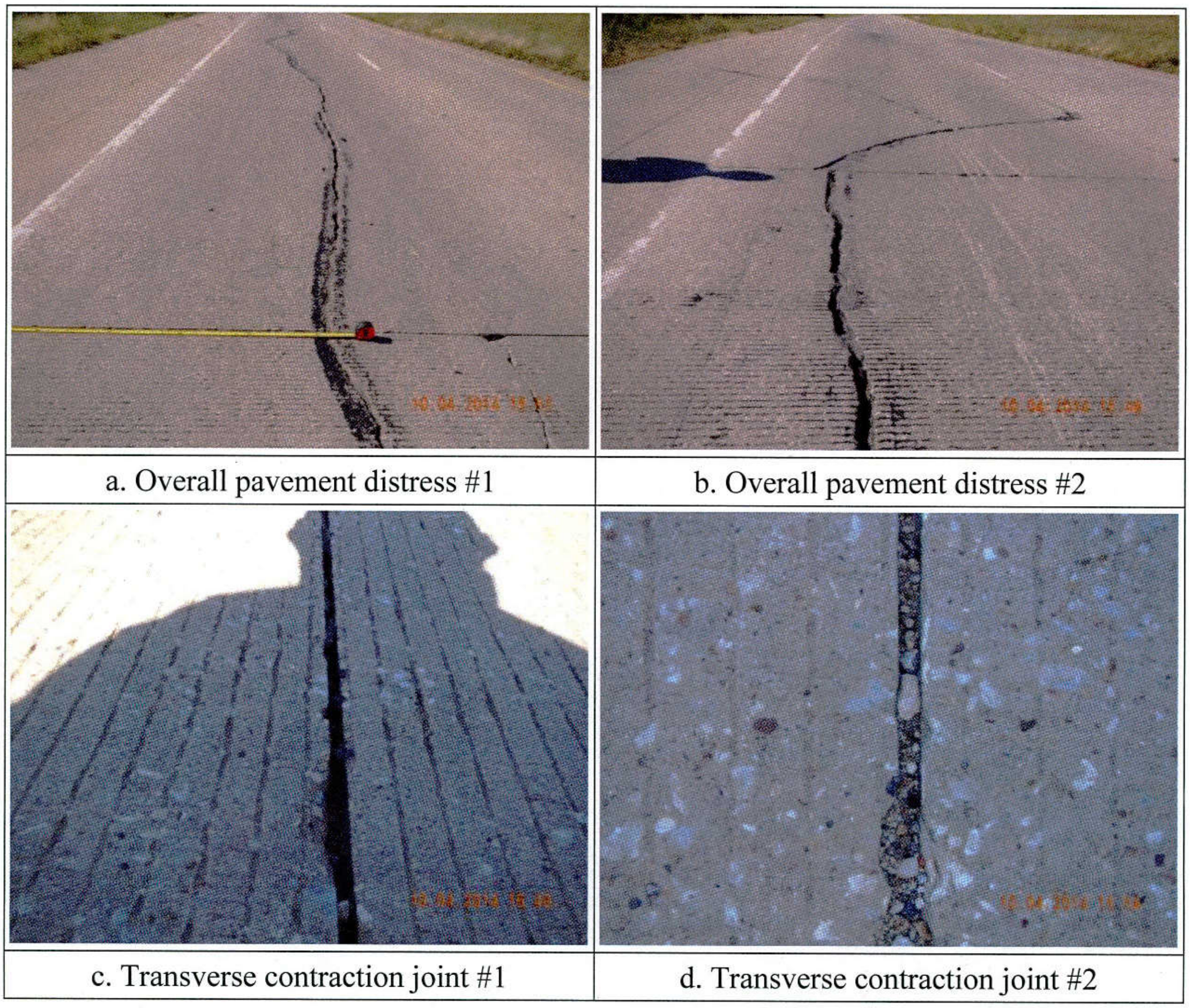
c. Joint width

d. Longitudinal construction joint

Figure 3.7 Sealant condition on SH 9-TYL [NO. 40]

2) SL 288, Dallas District

Figure 3.8 shows the pavement condition on SL 288 in the Dallas District, which was built in 1999 with a 9-in CPCD. The survey was conducted on 14 October, 2014. This section was constructed with a 4-in. ASB (asphalt stabilized base) and 8-in. lime treated subgrade (LTS). Significant pavement distress was observed in the form of wide longitudinal cracks as shown in Figures 3.8(a) and (b). Most of the sealant in the transverse contraction joints were missing. However, the overall condition of the joints was good. The SCN was estimated to be at about 6, which implies the worst sealant condition. It implies a rather poor correlation between SCN and overall joint condition.



a. Overall pavement distress #1

b. Overall pavement distress #2

c. Transverse contraction joint #1

d. Transverse contraction joint #2

Figure 3.8 Sealant condition on SL 288-DAL [NO. 47]

3) FM 364, Beaumont District

FM 364 in the Beaumont District was built in 1996 with a 10-in CPCD. The section was surveyed on 11 October, 2014. Figure 3.9 illustrates the typical section from the planset. Even though it can be postulated that the joints in both northbound and southbound lanes must have been installed by the same contractor using the same type of sealant, a significant difference exists in the performance of joints between north and southbound lanes as shown in Figure 3.10. Joint sealant condition on northbound lanes was good as shown in Figures 3.10(a) and (b). On the other hand, as can be seen in Figures 3.10(c) and (d), the condition on southbound lanes was relatively poor. At this point, the cause(s) for this difference in joint sealant condition between northbound and southbound lanes is not known. Figure 3.10(d) illustrates that once the joint movements occur due to faulting or transverse cracks near the joint, sealant adhesion failure could occur, resulting in missing sealant. In other words, it appears that sealant missing is the results of slab cracking, not the other way around.

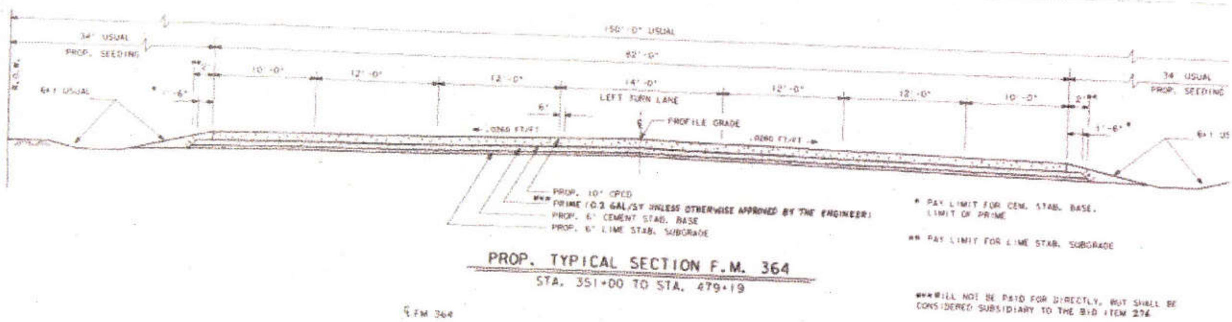


Figure 3.9 Typical section of FM 364-BMT

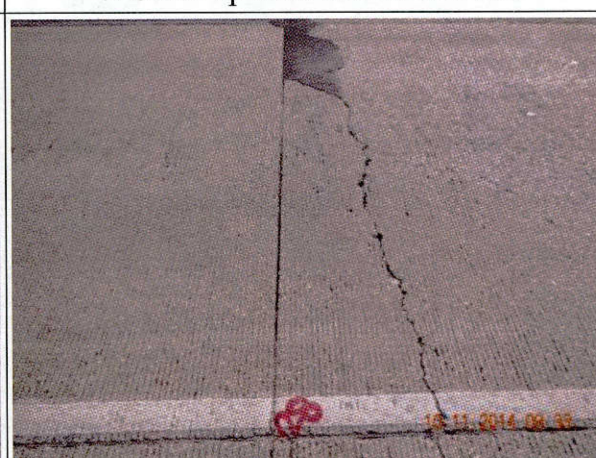
	
a. Overall condition on FM 364 NB	b. Close-up view on FM 364 NB
	
c. Missing sealant on FM 364 SB	d. Joint crack on FM 364 SB

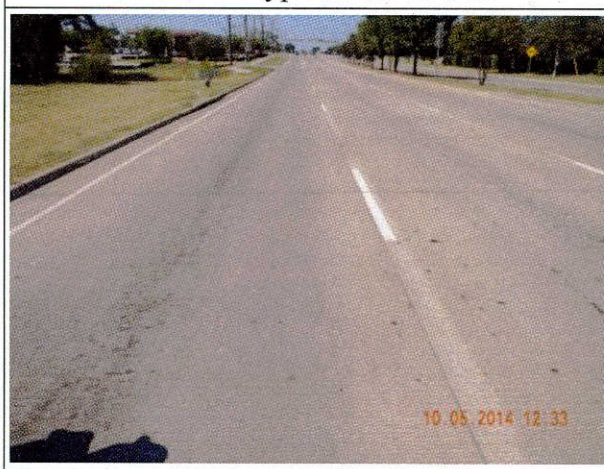
Figure 3.10 Sealant condition on FM 364-BMT [NO. 38]

4) US 380, Dallas District

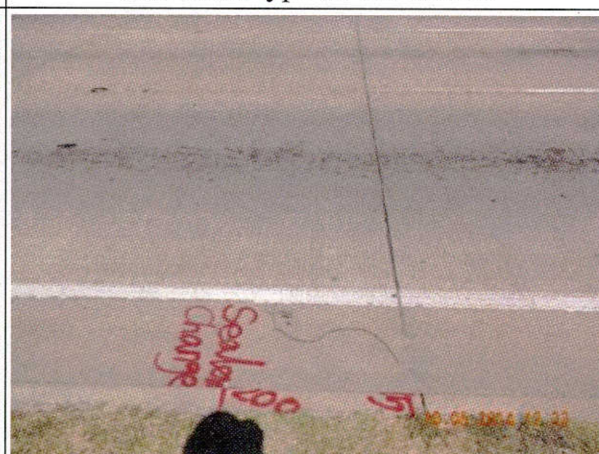
US 380, built in 1994 with a 9-in CPCD in the Dallas District, was investigated on 5 October, 2014. As shown in Figures 3.11(a) and (b), two types of sealant were applied when the resealing was conducted. As can be seen Figure 3.11(a), no missing sealant or adhesion failure was observed where the sealant type #1was used. On the other hand, as shown in Figure 3.11(b), missing sealant and adhesion failures were observed where the sealant type #2 was used. However, field survey results show that the overall joint and pavement condition was good regardless of sealant types, as shown in Figure 3.11(c). This result implies that the SCN and seal rating (SR) of joints may have a weak correlation with pavement performance. In other words, the mean of SCN and SR indicates only the condition of the joint sealant, not necessarily the performance of joints or pavement.

a. Sealant type #1 on US 380

b. Sealant type #2 on US 380



c. Overall pavement condition on US 380



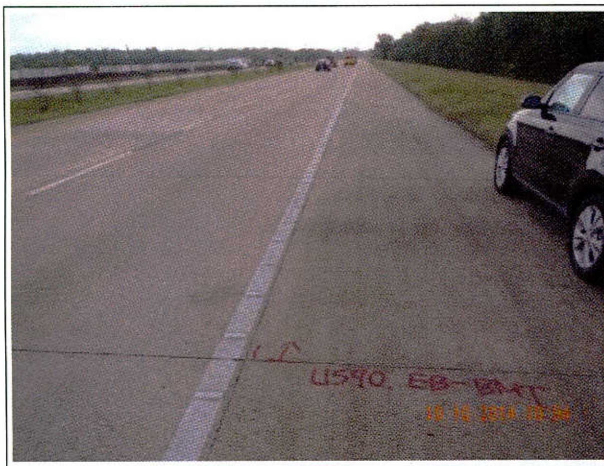
d. Sealant type change at 15th joint

Figure 3.11 Sealant condition on US 380-DAL [NO. 39]

5) US 90 EB, Beaumont District

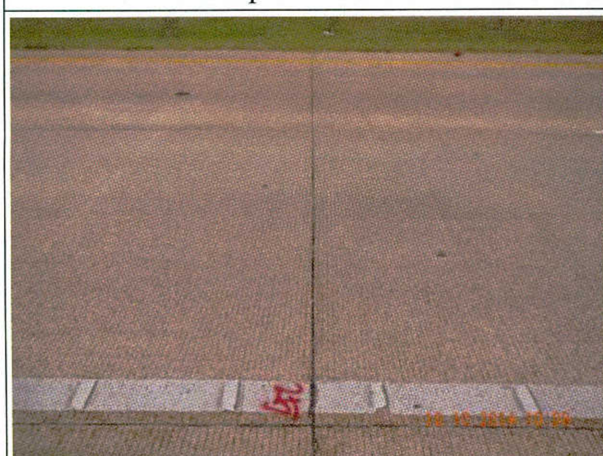
US 90 EB was built in 2000 with a 10-in CPCD. The overall pavement condition including joint condition was very good except for a few missing sealants within the surveyed section. Figure 3.12(a) shows the overall pavement condition. Figures 3.12(b) and (c) show the condition of a typical transverse contraction joint. The misaligned dowel bar was observed as shown in Figure 3.12(d). However, there were no structural distresses observed in the span of 14 years in this area, which implies that one or two misaligned dowel bars may not affect the transverse contraction joint performance in CPCD.

Figures 3.13(a), (b), (c), and (d) show the missing sealants on US 90 WB. It appears that diamond grinding operation caused extrusion of the sealant.



a. Overall pavement condition

b. Transverse contraction joint #1



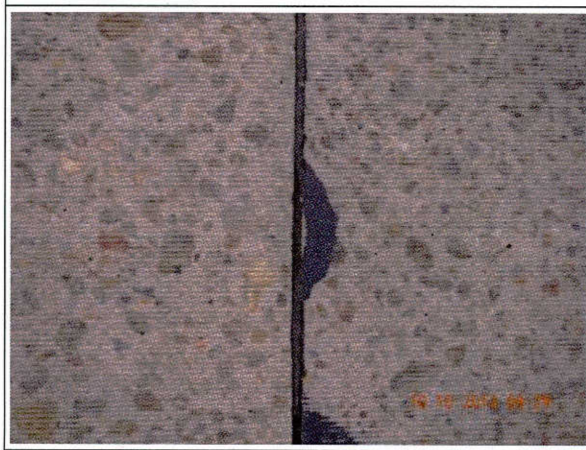
c. Transverse contraction joint #2

d. Misaligned dowel bar

Figure 3.12 Sealant condition on US 90 EB-BMT [NO. 32]

a. Missing sealant on US 90 WB #1

b. Missing sealant on US 90 WB #2



c. Missing sealant on US 90 WB #3

d. Missing sealant on US 90 WB #4

Figure 3.13 Sealant condition on US 90 WB-BMT [NO. 32]

3.2.3 Pavements with age more than 20 years

3.2.3.1 Sealant condition in CRCP

Figure 3.14 shows a typical sealant condition in CRCP built more than 20 years ago. Figures 3.14(a) and (b) present the overall pavement as well as joint conditions at longitudinal contraction and construction joints, respectively. This pavement on IH 27 is in the Lubbock District and built in 1988. Figures 3.14(c) and (d) show missing sealant at longitudinal contraction joints. Even though it is not known how long the sealant has been missing, no significant distresses related to missing sealants were observed.

Field survey results on CRCP indicate that, regardless of pavement ages, joint or pavement performance does not appear to be affected by the condition of sealants.

a. Overall pavement condition

b. Longitudinal construction joint

c. Longitudinal contraction joint #1

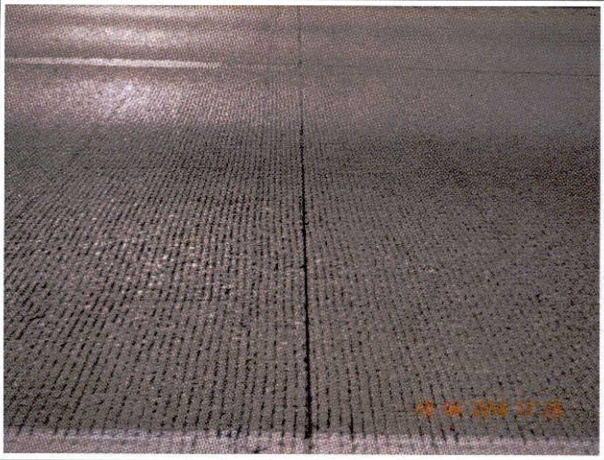
d. Longitudinal contraction joint # 2

Figure 3.14 Sealant condition on IH 27-LBB [NO. 46]

3.2.3.2 Sealant condition in CPCD

1) IH 35, Dallas District

Figure 3.15 shows the pavement condition on IH 35 in Denton County, Dallas District. In 1988, this section was overlaid with 11-in CPCD over 2-in asphalt interlayer, on top of existing 10-in CPCD. The original CPCD was built in 1960, which means that the 10-in CPCD provided 28 years of service before the unbounded overlay was applied. The condition of transverse contraction joints was in a good condition except for a few joints. A missing sealant was observed in the wheel paths as shown in Figure 3.15(b) and spalling was observed as shown in Figure 3.15(c). Also, an asphalt concrete patch was applied at large spalled areas in transverse contraction joints, as shown in Figure 3.15(d).



a. Condition of transverse contraction joint

b. Missing sealant in wheel path

c. Spalling in wheel path

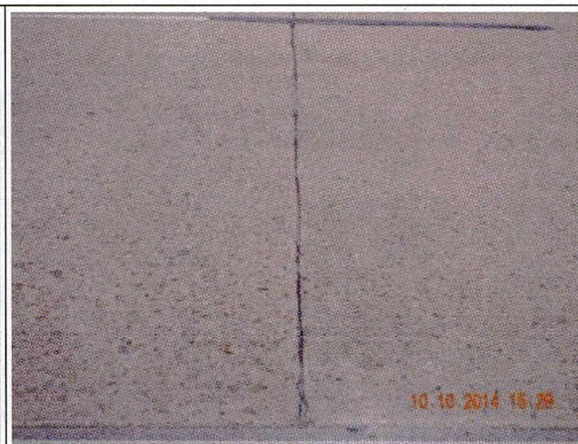
d. AC patch in wheel path

Figure 3.15 Sealant condition on IH 35-DAL [NO. 45]

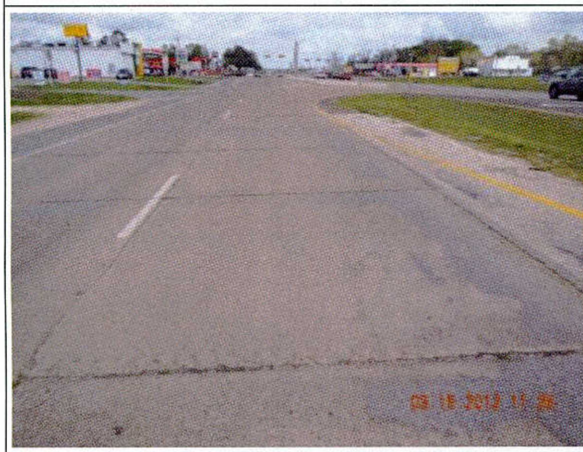
2) SH 124, Beaumont District

SH 124 in Chambers County, Beaumont District was built in 1962 with a 10-in CPCD. The age of the pavement when the condition survey was conducted was 52 years. Dowel bars were not used in this section. Diamond grinding was done to correct joint faulting as shown in Figures 3.16(a) and (b), which also shows missing sealants. When the section was surveyed in 2012 for the rigid pavement database project (0-6274), severe faulting was observed as illustrated in Figures 3.16(c) and (d). It appears that diamond grinding was applied to correct faulting and diamond grinding might have caused the breakage of sealants.

a. Overall condition on SH 124



b. Diamond grinding



c. Pavement condition in 2012

d. Joint faulting in 2012

Figure 3.16 Sealant condition on SH 124-BMT [NO. 57]

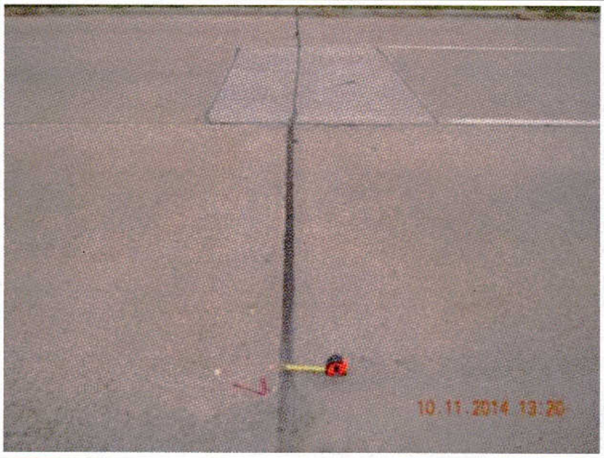
3.2.3.3 Sealant condition in JRCP

1) US 87, Beaumont District

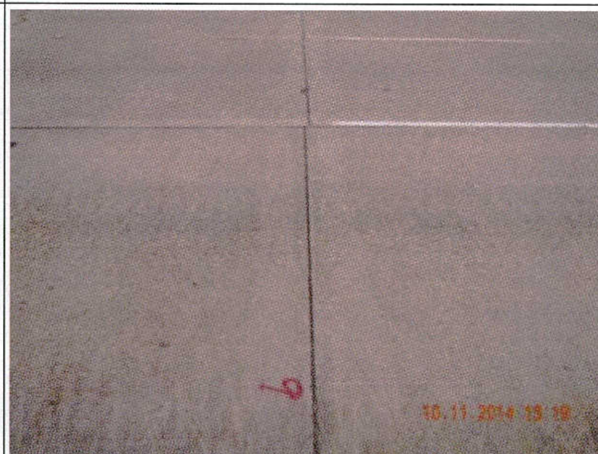
US 87 was built in 1951 with a 9-in JRCP in Jefferson County, Beaumont District. The age of pavement when the condition survey was conducted was 63 years. Figure 3.17(a) shows the overall pavement condition on US 87. Several concrete patches were installed at transverse expansion joints. In addition, transverse cracks occurred in most JRCP slabs and were sealed as shown in Figure 3.17(b). Figures 3.17(c) and (d) show the transverse expansion joint condition.

a. Overall condition on US 87

b. Transverse crack on US 87



c. Sealant condition #1 on US 87

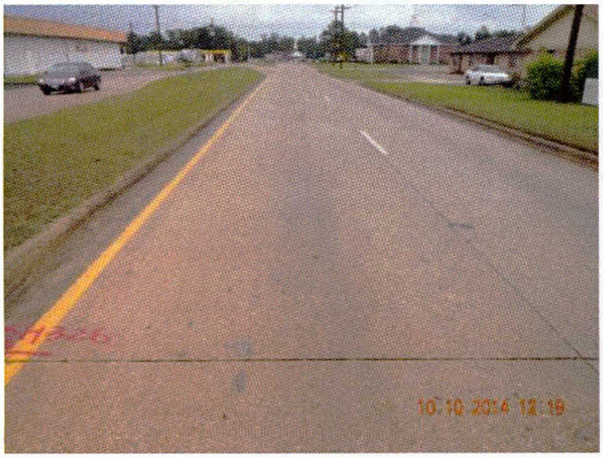


d. Sealant condition #2 on US 87

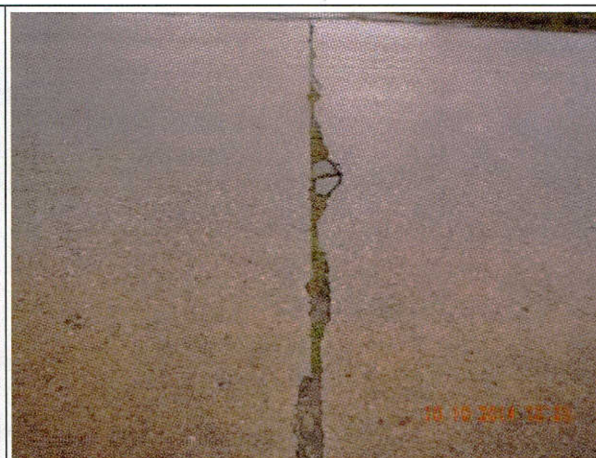
Figure 3.17 Sealant condition on US 87-BMT [NO. 61]

2) SH 326, Beaumont District

SH 326 was constructed in 1967 with 10-in JRCP over 4-in cement stabilized base. The field survey was conducted on October, 2014. As shown in Figure 3.18, sealant was not present at all joints. Minor spalling was observed at some joints as shown in Figures 3.18(b) and (c), which might have occurred due to missing sealants, resulting in 'a high severity rating related to water infiltration criteria.' All the joints were also filled with dirt or other materials, which implies that the number affecting the SCN in terms of incompressible material is 'a high severity debris or stone retention rating.' Because of these two criteria for estimating the SCN, the SCN was estimated at 6.

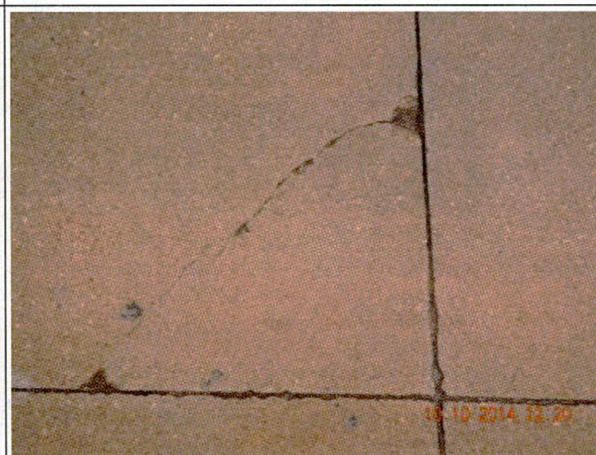


a. Overall condition



b. Expansion joint

c. Spalling



d. Corner break

Figure 3.18 Sealant condition on SH 326-BMT [NO. 55]

3.2.4 Summary of pavement age effect on joint sealant performance

Figure 3.19 shows the SCN result for CRCP. The SCNs for all the sections with pavement age less than 20 years are 0 and the other two sections with pavement age more than 20 years are 1 and 2. The results show that joint sealants have been maintained in a good condition. In CRCP, whether longitudinal contraction/construction joints or transverse construction joints, concrete movements are severely restricted by reinforcements. It appears that small concrete movements attributed to the good sealant performance.

Figures 3.20(a), (b), and (c) show the SCN results of CPCD sections. It was noticed that joints in several sections were resealed when the pavement ages were more than 10 years. Accordingly, estimation of the current SCN in terms of joint age was not feasible.

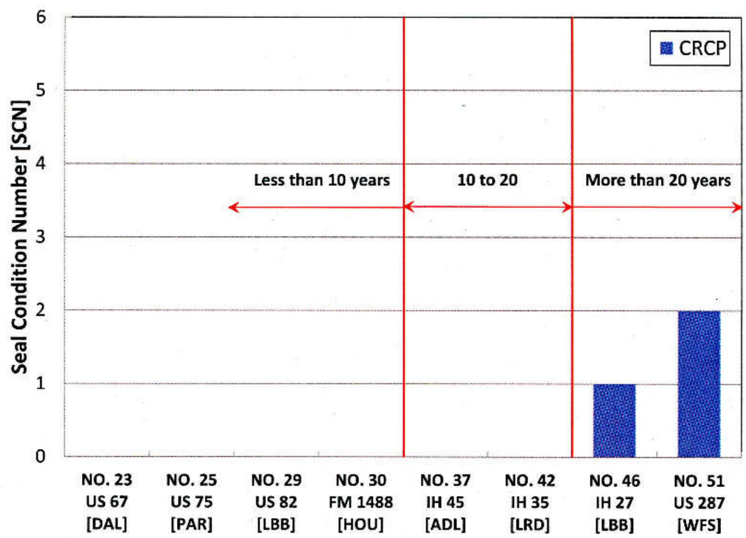
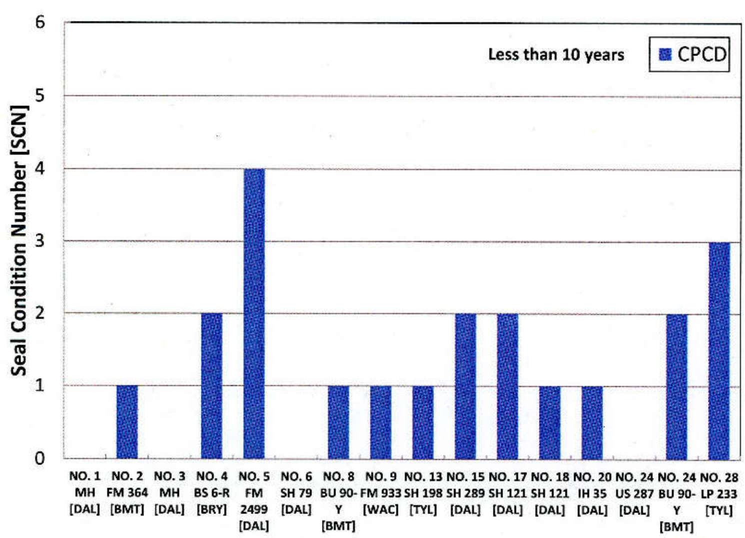
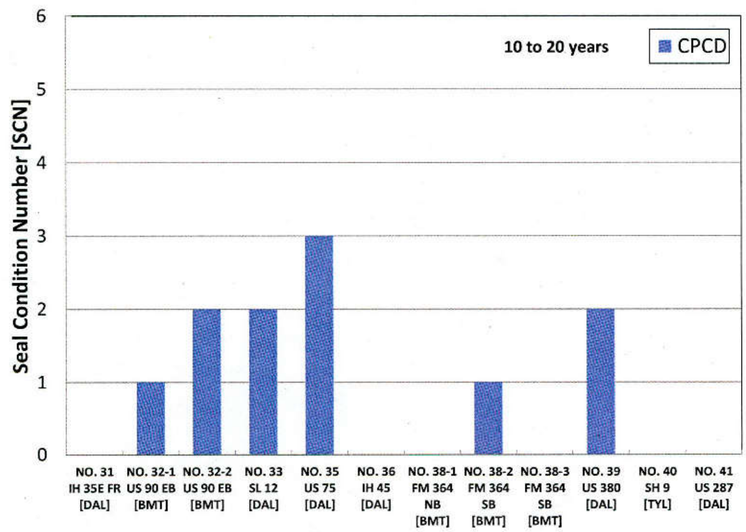


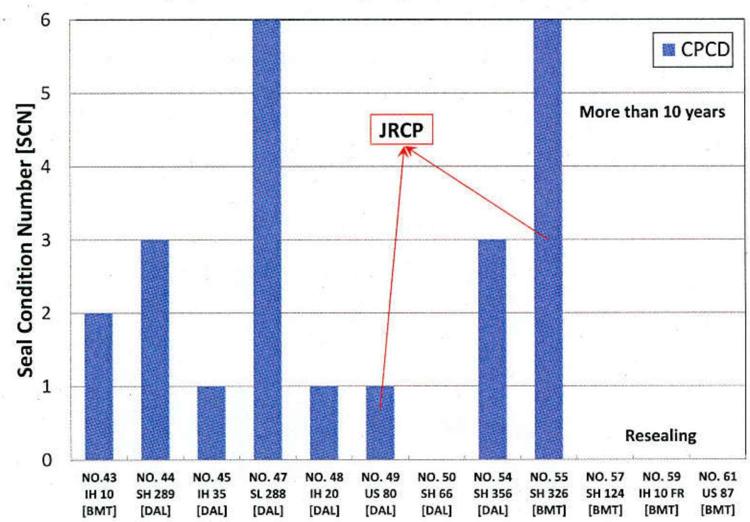
Figure 3.19 CRCP seal condition number [SCN]



(a) Pavement age (less than 10 years)



(b) Pavement age (10 to 20 years)



(c) Pavement age (more than 20 years)

Figure 3.20 CPCD seal condition number [SCN]

Compared with older CPCD sections, sealant conditions were relatively good for the pavement sections with less than 10 years of service. Even though there appears to be a positive correlation between sealant conditions and pavement age in CPCD, no significant correlation was observed between sealant condition and pavement condition. On the other hand, field survey results show that once joint movements appear to be excessive due to cracking near a joint or faulting, it appears that the sealant failure such as adhesion failure and torn or missing sealant developed. In other words, the sealant conditions are highly influenced by joint movements.

3.3 Condition Survey Result of Joint Sealant with Geographic Regions

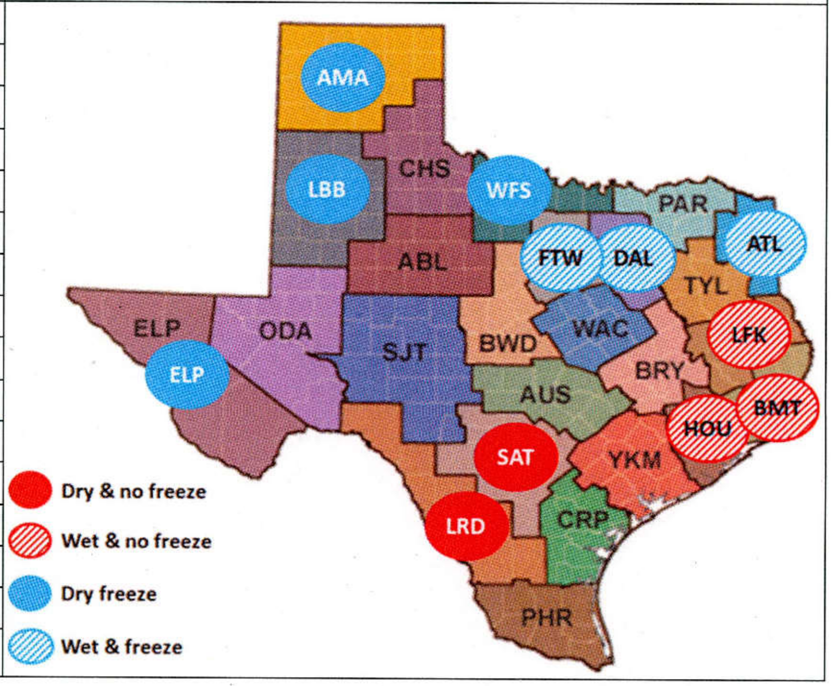
Texas was divided by four different regions based on temperature and rainfall to identify their effect on sealant performance. They are wet-no freeze, wet-freeze, dry-no freeze, and dry-freeze zones. Table 3.5 shows the number of surveyed sections for each geographical location.

Even though the number of sections selected in this study is not sufficient for valid statistical analysis, comparisons of the seal performance of sections in the four regions (Table 3.5) indicated no significant differences.

Table 3.5 Geographic locations

	Districts	Total
Wet-no freeze	Beaumont	13
	Lufkin	-
	Houston	1
	Bryan	1
Wet freeze	Atlanta	-
	Tyler	3
	Dallas	26
	Paris	1
	Waco	1
Dry-no freeze	Laredo	1
	San Antonio	-
Dry freeze	El Paso	-
	Lubbock	2
	Amarillo	-
	Wichita Falls	1
Total		50

Geographic map



3.4 Base type

Currently, two types of base are utilized in Texas – (1) 4-in asphalt stabilized base or (2) 1.0-in asphalt stabilized base over 6-in cement stabilized base. However, different base types have been used in the past in Texas. Table 3.6 shows the number of sections with different base types in the sections surveyed. The pavement base types consist of 27 asphalt stabilized bases, 8 cement stabilized bases, and the other 15 bases such as existing roadbed or AC level up for unbonded concrete overlay.

Detailed statistical analysis was not conducted to identify base type effect on joint seal or pavement performance, primarily due to the insufficient number of sections to account for various factors such as pavement age, geographical location, and shoulder type. However, cursory analysis of field survey results show that the pavement base type does not have an effect on sealant condition.

Table 3.6 Pavement base type

	Age			Total
	Less than 10	10 to 20	Older than 20	
Flexible Base	-	-	2	2
ASB	16	7	4	27
CSB	4	3	1	8
Others	1	4	8	13
Total	21	14	15	50

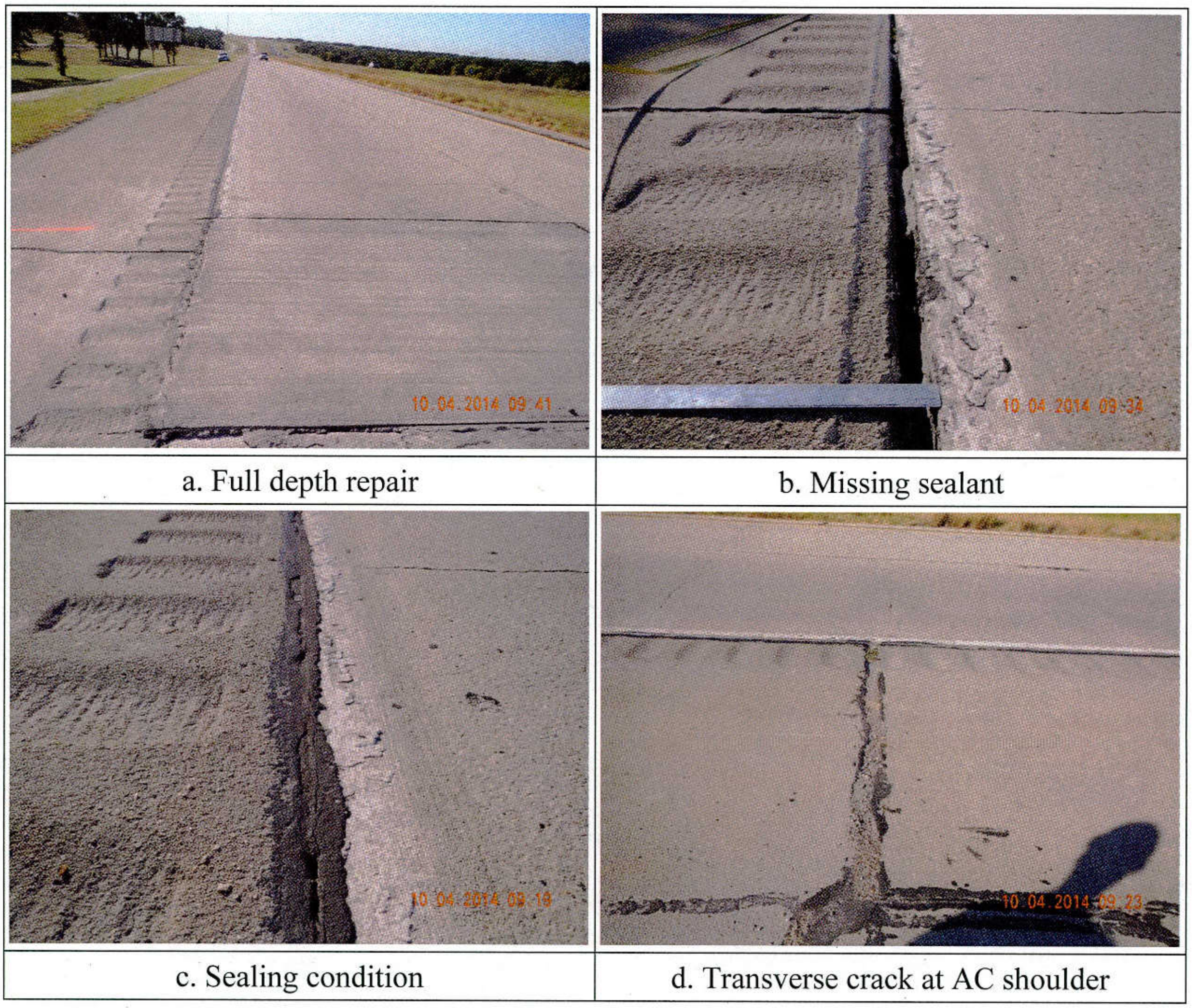
3.5 Shoulder type

Joint seal conditions of pavements with asphalt shoulder or tied-concrete shoulder were compared to identify the effect of shoulder type on sealant condition and pavement performance. All the sections with pavement age less than 20 years had tied-concrete shoulder or curb, primarily due to the implementation of TxDOT policy of using tied-concrete shoulder in the late 1980s. Due to this limitation, all the sections with asphalt shoulder were pavements older than 20 years. Table 3.7 shows the distribution of surveyed sections in terms of the shoulder type and pavement ages.

Table 3.7 Shoulder type

	Age			Total
	Less than 10	10 to 20	Older than 20	
Asphalt	-	-	3	3
Concrete	6	9	4	19
Curb	15	5	8	28
Total	21	14	15	50

US 287 built in 1972 in the Wichita Falls District was investigated as shown in Figure 3.21. There were numerous Portland cement concrete patches (PCPs) observed as shown in Figure 3.21(a). This pavement was built with asphalt shoulder. Joint separations between outside lane and asphalt shoulder and resulting pumping were observed as shown in Figure 3.21(b). This magnitude of lane separation will allow water to get into layers under the concrete slab, degrading the durability of the slab support and causing pavement distress. Figure 3.21(c) shows sealing with hot pour asphalt to prevent gaps at a joint. Cracking was also observed in the asphalt shoulder as shown in Figure 3.21(d), which could allow rain water to get into the pavement system. It is important to keep the joints between concrete main lanes and asphalt shoulders as tight as possible in order to prevent or minimize water infiltration. Since there are no good means available to keep the concrete lanes and asphalt shoulders tight, the best option would be to keep the joints sealed.



a. Full depth repair	b. Missing sealant
c. Sealing condition	d. Transverse crack at AC shoulder

Figure 3.21 Sealant condition on US 287-WFS [NO. 51]

3.6 Summary

This chapter described the work performed to evaluate joint seal performance in Texas, along with identifying correlations between joint seal condition and pavement performance. A factorial experiment was developed that included pavement age, pavement type, base type, shoulder type and climatic condition as investigative variables. A total of 61 sections were selected and field evaluations conducted on 50 sections. Due to the number of independent variables included as well as the skewed nature of the dataset (for example, shoulder type and pavement age are compounded), as is usually the case in the analysis of historical data in pavement performance investigations, a complete data analysis was not feasible. However, valuable information was obtained, which can be summarized as follows:

1) Overall joint conditions in CPCD were good regardless of the joint sealant condition. Seal condition number (SCN) and seal rating (SR) do not appear to have a positive correlation with joint or pavement performance.
2) In general, no close correlations were observed between joint sealant condition and pavement performance, which agrees with the findings from other states. This does not necessarily mean no need for joint sealing. Instead, this means that there are other factors that have more significant effects on PCC pavement performance than joint sealing.
3) Currently, there are no good methods for the evaluation of joint seal condition. The most widely used method that was adopted in this study has limitations. For example, missing sealant is automatically assumed to contribute to water infiltration. However, standing water was observed where joint sealant was missing. Also, determining stone intrusion is quite subjective, which could result in variations of the evaluation results.
4) Missing sealants at longitudinal contraction joints does not seem to negatively affect the pavement performance. It appears that tight widths of the joints by tie bars and transverse steel in case of CRCP keep the joints closed, preventing water or incompressible materials from getting into the joints.
5) Sealant adhesion failures in CPCD were observed where joint movements appeared to be excessive due to faulting or cracks near joints. In Texas, the use of dowels and a stabilized base is required by design standards and pavement design guide, both of which minimize faulting or cracks. It is expected that adhesion failures in CPCD will be minimal if sealant is properly installed and CPCD is designed and built in accordance with TxDOT standards and specifications.
6) Even though no good correlations were observed between joint seal condition and pavement performance, separation of asphalt shoulder from concrete main lanes could adversely affect pavement performance. Efforts should be made to keep the longitudinal joints sealed to prevent water infiltration.

Chapter 4 Field Testing for Joint Movement Evaluation

4.1 Introduction

One of the objectives of this research project was to evaluate current TxDOT practices in design, materials, and installation of joint seal, with the ultimate goal of improving current design standards and specifications. Two factors that should be considered for proper joint design are: 1) the movement of concrete slab, and 2) extension and contraction capabilities of the sealant.

One step to improving joint design standards was to evaluate joint movements. During the PMC meeting on February 27, 2015, suggestions were made to measure joint movements from the setting of concrete. Also suggested was that a CPCD with concrete that contains siliceous river gravel (SRG) as coarse aggregate be selected for the measurements. Those suggestions were based on the Minnesota DOT's stipulations of installing sealant after four years of concrete placement, since the measurements of the concrete movements indicated concrete continued to shrink over four years after placement.

The research team installed concrete displacement gages, called crackmeters, at two projects: one on SH 288 in the Dallas District and the other on FM 2253 in the Atlanta District. Both were CPCD. The project on SH 288 was old CPCD, while the one on FM 2253 was a new construction. Gages were installed on December 3, 2014 at SH 288 and on September 10 and 11, 2015 at FM 2253.

In this chapter, field testing conducted to measure joint movements and the analysis of data collected up to this point are described.

4.2 Joint Movements on SH 288 in the Dallas District (Existing CPCD)

The test section is located on SH 288 in Denton County, Dallas District. GPS coordinates and the map of the test location are presented in Figure 4.1. The cover page and typical sections of this project are shown in Figure 4.2. This section was built in 1987 with 9-in. CPCD on 4-in. asphalt stabilized base over 8-in. lime treated subgrade.

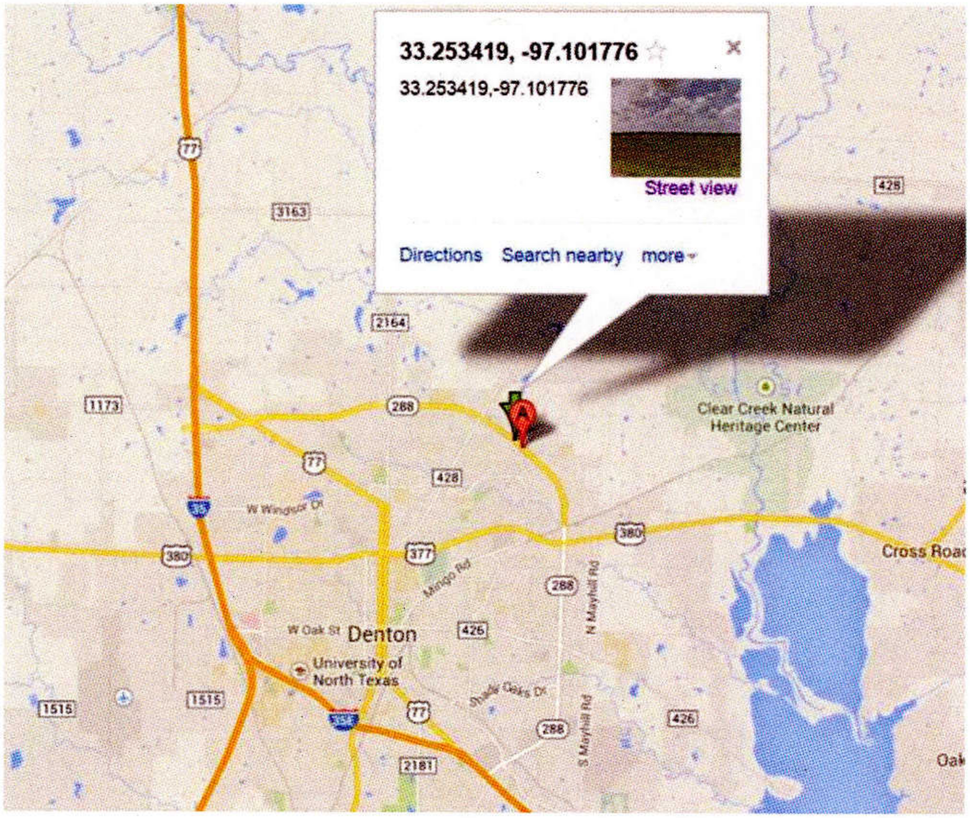


Figure 4.1 Test location

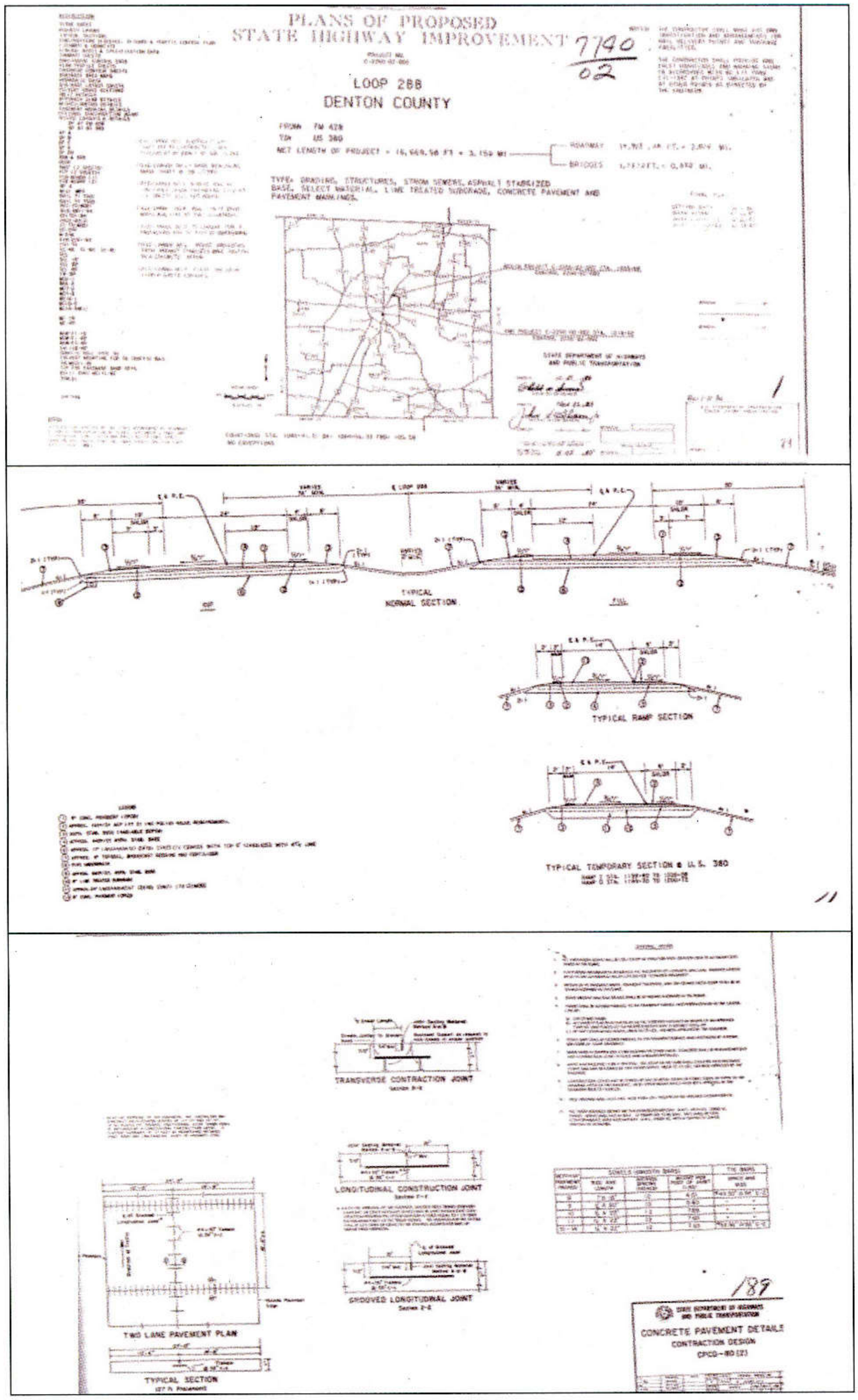


Figure 4.2 Planset of SH 288

4.2.1 Gage installation plan and procedure

Figure 4.3 shows the gage installation plan. Three crackmeters were installed in a longitudinal direction at different depths (top-middle-bottom) to measure horizontal joint movements. Two crackmeters were installed in a vertical direction at the top of the slab to measure vertical slab movements. Gage protection boxes were placed to protect the gages. Two joints were selected for this testing. Figure 4.4 shows selected joints where gages were installed.

Gages were installed on Dec 3, 2014. The intent was that the joint movements would be monitored from winter to summer, with the objective of quantifying maximum annual joint movements. Figure 4.5 illustrates the sequence of gage installations.

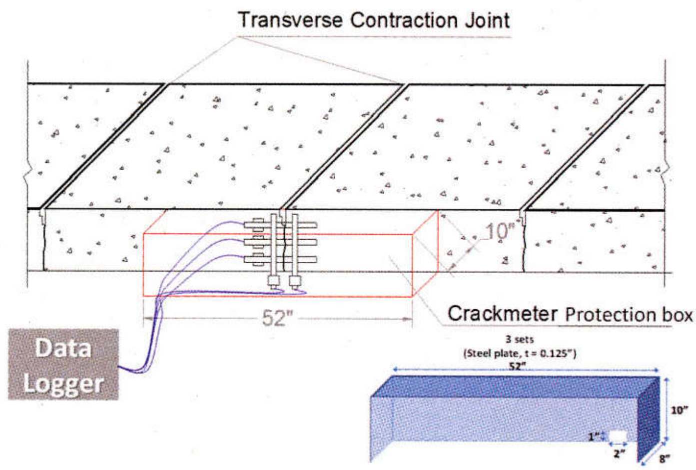


Figure 4.3 Crackmeter installation plan

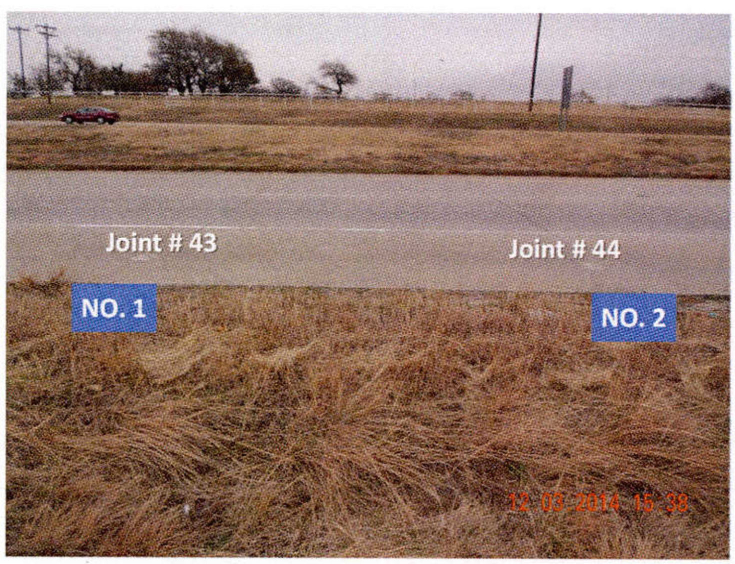


Figure 4.4 Selection of gage installation on SH 288

Figure 4.5 Gage installation procedures and data logger installation on SH 288

4.2.2 Joint condition

Figure 4.6 shows the condition of one joint in CPCD. As shown in the figure, CPCD slab thickness is 9-in with asphalt base thickness of 4-in. Saw-cut depth was about 2.5-in, which is a little deficient; however, a crack developed under the saw cut. The overall condition of the joint was good.

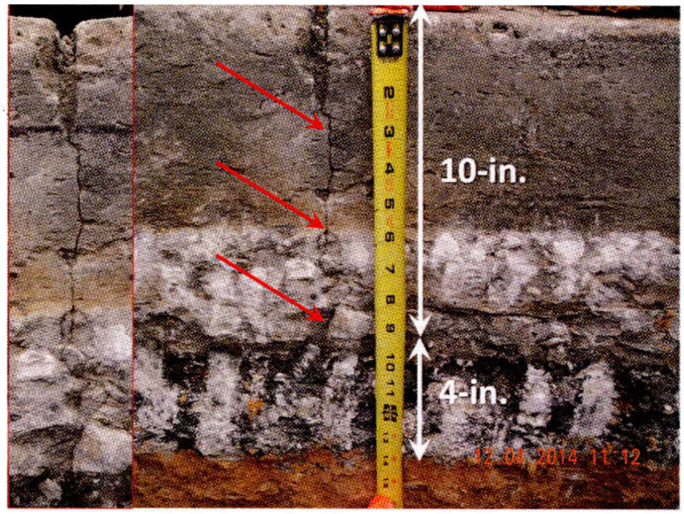
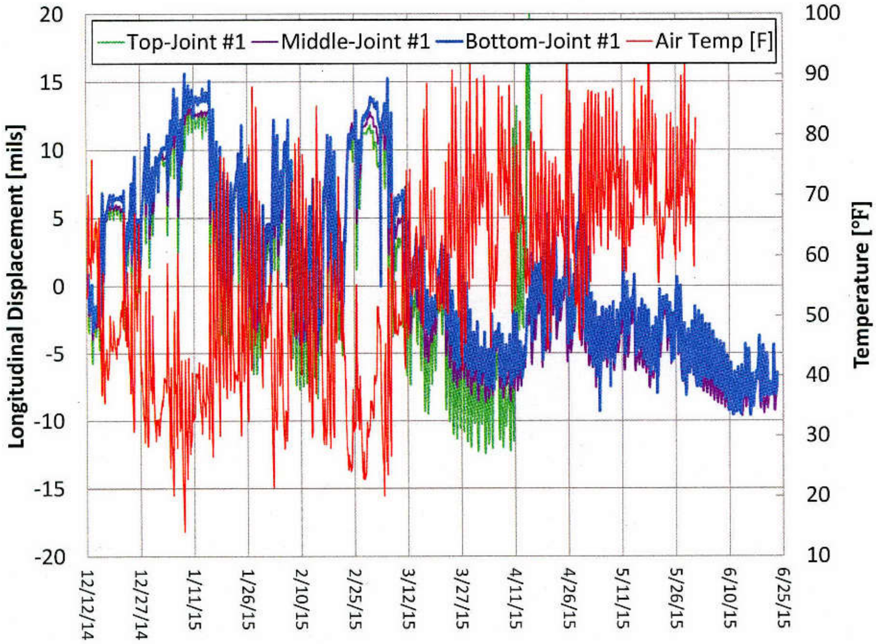


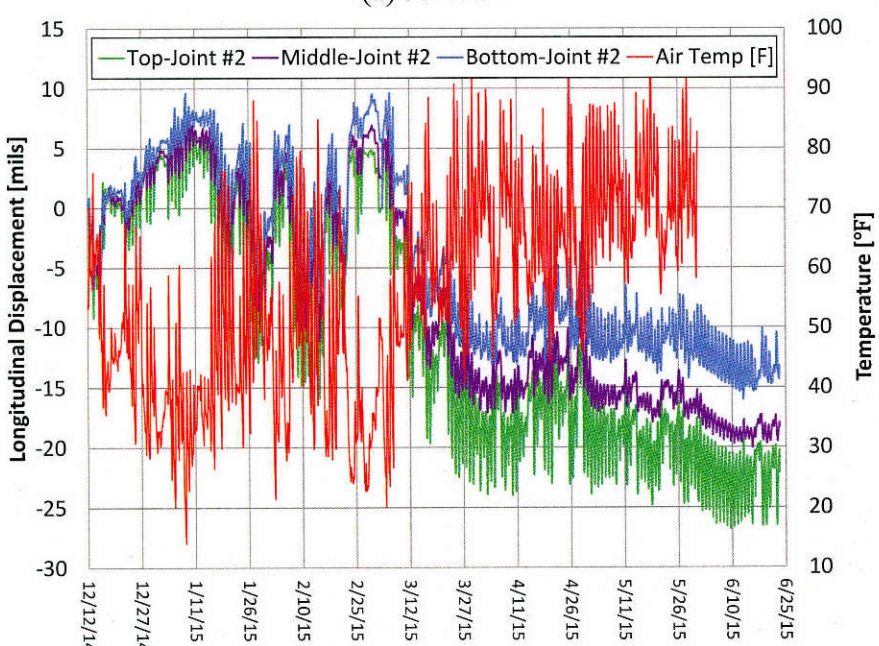
Figure 4.6 Joint condition on SH 288

4.2.3 Joint movements in longitudinal direction

As discussed earlier, three crackmeters were installed in a longitudinal direction at two adjacent joints (#1 and #2). Figures 4.7(a) and 4.7(b) show horizontal slab movements in a longitudinal direction (more precisely, horizontal portion of the overall slab movements) at Joint #1 and Joint #2, respectively, at three different depths with temperature changes from the beginning of the gage installations to March, 2015. The figures show a general trend – as temperature goes down, joint width increases, and vice versa. Figures 4.8(a) and 4.8(b) illustrate the relationship between air temperature and horizontal slab movements for a 24 hour period between March 24th and 25th, 2015, at Joint #1 and Joint #2, respectively. They show curling behavior of the slab – as temperature went up, joint width decreased at the top, while at the bottom, the crack width actually increased. The slope between temperature and slab movements at the top at Joint #1 is 0.18 mils/°F while that at Joint #2 is 0.26 mils/°F. The difference is 0.08 mils/°F, or about 40 %. This difference could be due to a number of factors, such as the degree of aggregate interlock at the joint and different base friction characteristics at the two joint areas. For the development of a criteria for joint sealant extension capability, the larger value could be used. Assuming 100 °F variations in air temperature between summer and winter, the extension of sealant from summer to winter would be 0.026 inches. Since the width of the joint during initial cut is 5/8 inches (0.375 inches), the tensile strain of the sealant would be 0.069 in/in. Current TxDOT DMS-6310 requires that Class 5 joint sealant meet 150 % extension at 24 hours, which is equivalent to 1.5 in/in strain. Accordingly, the current requirement of 150 % extension is more than adequate to prevent cohesive failures, even though it is not known whether aged sealant will meet the requirement of 150 % extension. It should be noted that the assumption made in the evaluations of the adequacy of current TxDOT DMS-6310 requirements for extension includes (1) slab was placed in hot summer and (2) concrete stresses in the concrete near the joints due to temperature variations are negligible.

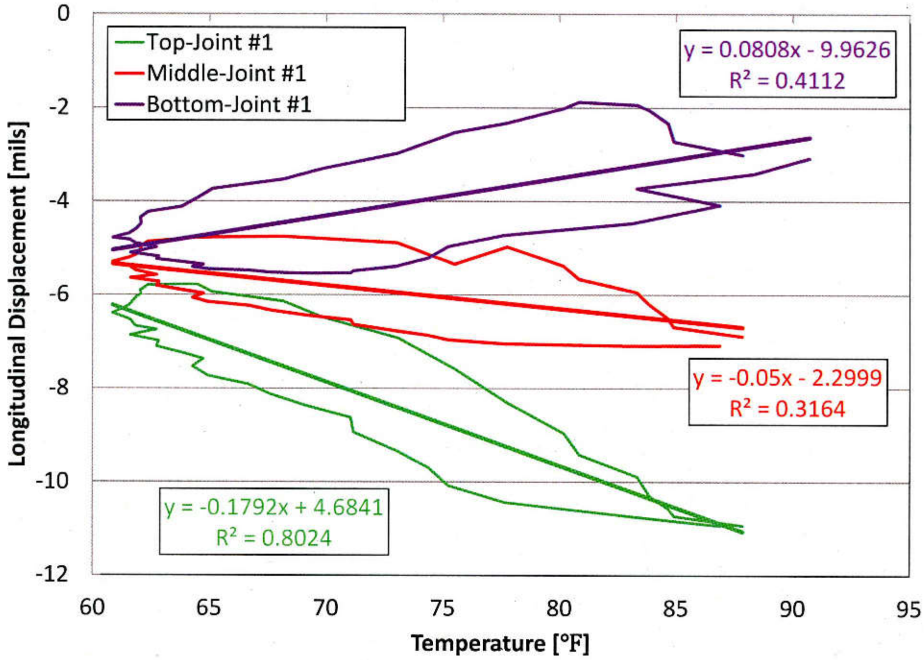


(a) Joint #1

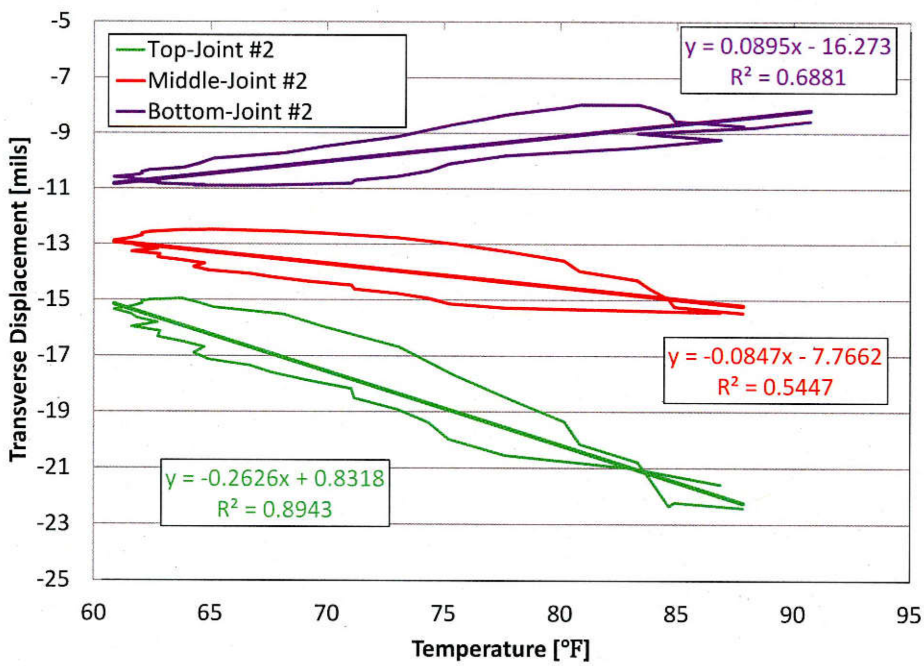


(b) Joint #2

Figure 4.7 Slab displacement in transverse direction on SH 288



(a) Joint #1



(b) Joint #2

Figure 4.8 Air temperature vs transverse displacement on SH 288

4.2.4 Joint movements in vertical direction

Two crackmeters were installed in a vertical direction at Joint #2. Figure 4.9 shows vertically installed crackmeters at each slab near the joint. Figure 4.10(a) presents the vertical movements at both slabs. As shown in horizontal movements, curling behavior due to temperature variations was observed. Daily vertical movements were as large as 35 mils, observed on March 27, 2015, which is much larger than observed at pavement edge in CRCP. Figure 4.10(b) shows the detailed vertical movement behavior during a two-week period. Vertical movements at both sides of the joint are very close to each other, and curling behavior is clearly demonstrated. This curling behavior supports the idea of "avoid adhesion at three sides," which justifies the placement of backer rod. Figure 4.11 shows the relationship between air temperature and vertical slab displacement. On average, one mil per °F was obtained.

However, the gage protection boxes were destroyed during the full depth repair (FDR) for adjacent CPCD slabs as shown in Figure 4.12. The gage analysis results showed that the protection boxes were broken on April 16, 2015, and data obtained since that point were not reasonable.

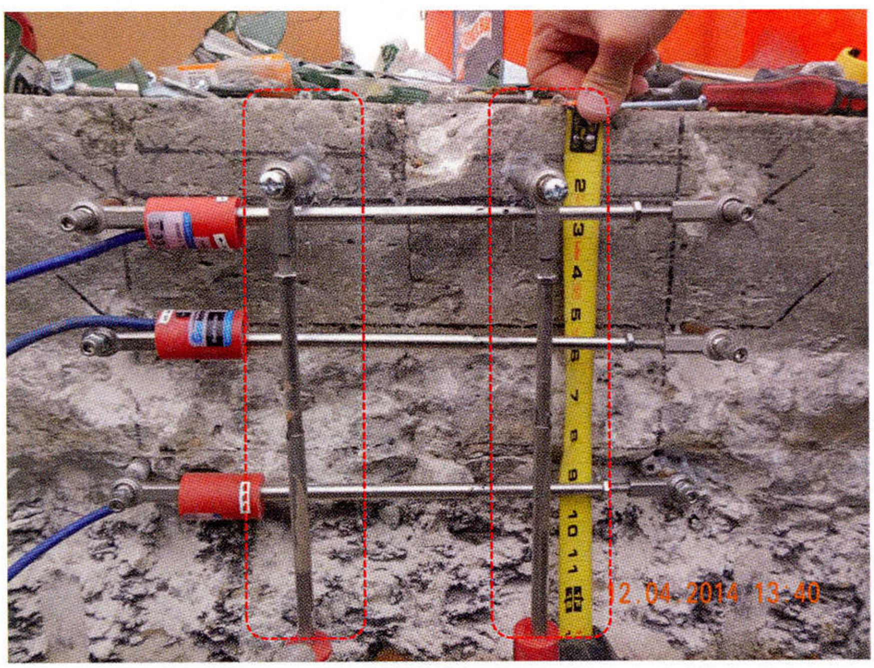
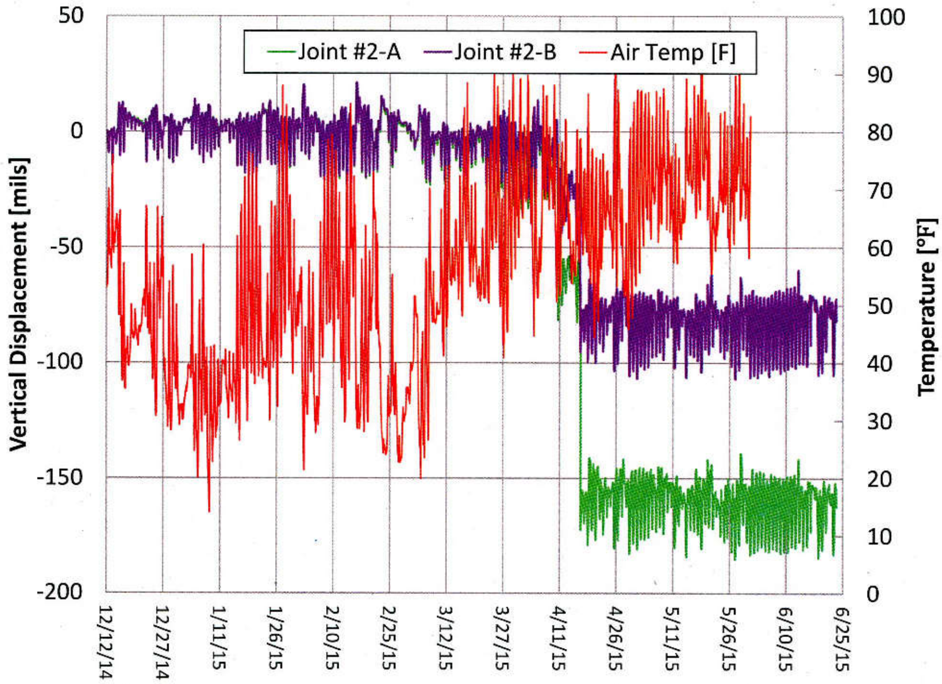
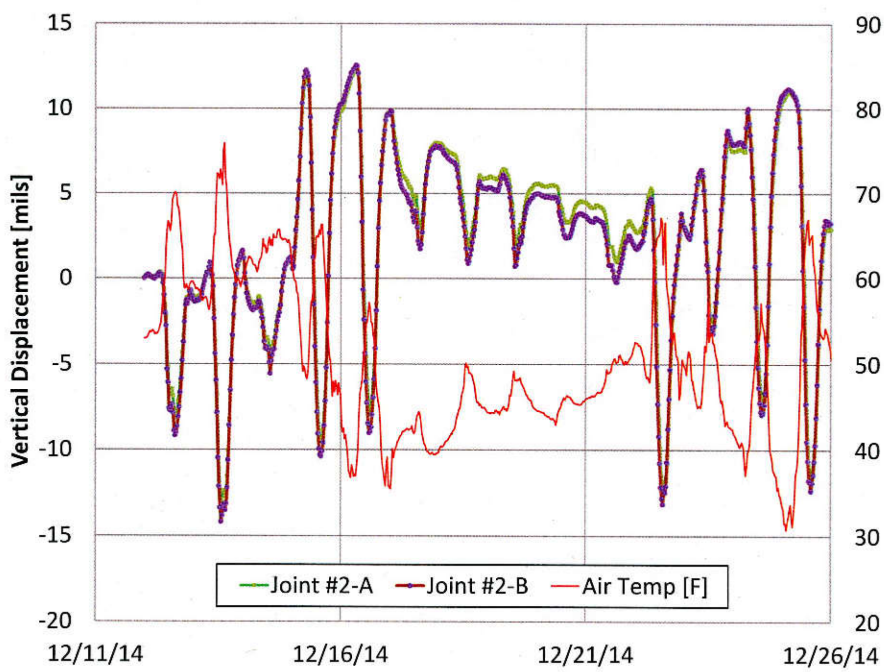


Figure 4.9 Vertically installed crackmeters on SH 288



(a) Vertical movement



(a) Vertical movement (12/11/2014 ~ 12/26/214)

Figure 4.10 Vertical movement at each joint

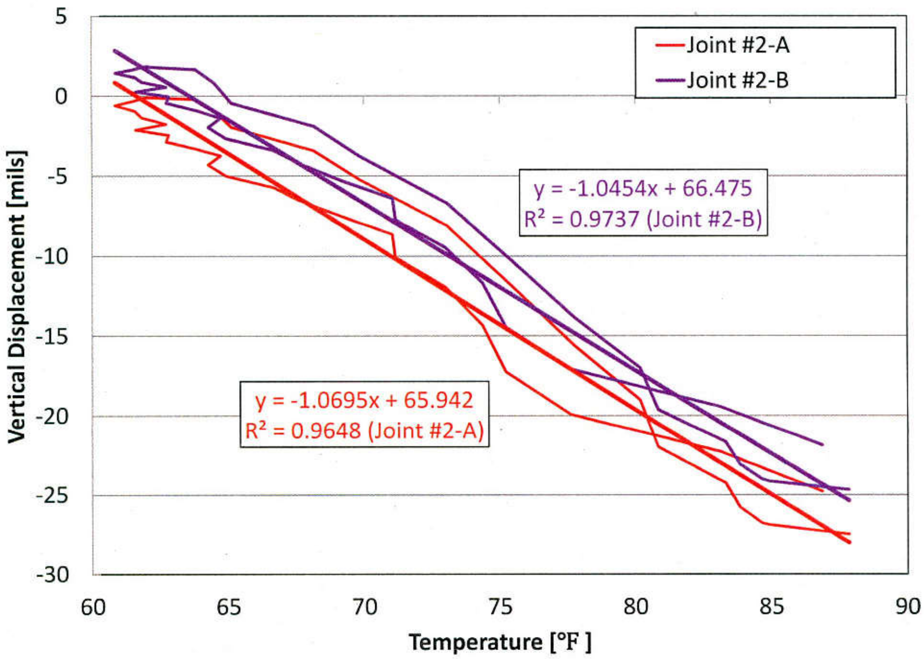


Figure 4.11 Air temperature vs vertical displacement on SH 288

Figure 4.12 Destroyed gages during the FDR on SH 288

4.3 Joint Movement on FM 2253 in the Atlanta District (New CPCD)

Portland cement concrete undergoes continued drying shrinkage, and joint widths will also continue to increase. Accordingly, the installation of joint sealant during PCC pavement construction might induce excessive strain in joint sealants. Minnesota DOT contemplated delaying joint sealant installation until sufficient concrete drying shrinkage took place. To evaluate the potential benefit of delaying sealing operations, field testing was conducted to investigate the effects of concrete drying shrinkage on the increase in joint width.

4.3.1 Drying shrinkage testing

Figure 4.13 represents the schematic for drying shrinkage test prisms. Two different sizes of prism, one 14-in×4-in×4-in and one 7-in×4-in×4-in, were prepared to evaluate the size effect. Vibrating wire strain gages (VWSGs) were installed at the center of the concrete prisms to monitor concrete strain changes. Relative humidity (RH) sensors were installed outside of concrete prisms to monitor ambient RH and temperature variations.

Figure 4.14 illustrates the casting procedure of drying shrinkage prisms. A double layer of polyethylene sheets was installed to minimize frictional stresses, at the bottom of prisms as shown in 4.14(d). To investigate the effects of curing compound on drying shrinkage of concrete, one half of the specimens were fully covered with curing compound, while the other half were left without curing compound. The accurate application rate of curing compound on those specimens was not obtained due to the difficulty of measuring the weight of curing compound precisely. Figure 4.14(e) shows the drying shrinkage box, which can minimize the effect of temperature change between two sets of prisms due to sunshine.

Concrete was placed on September 10, 2015 in the main lane as shown in Figure 4.15, and the drying shrinkage prisms were also made with the concrete obtained from CPCD construction, which contained siliceous river gravel as coarse aggregate.

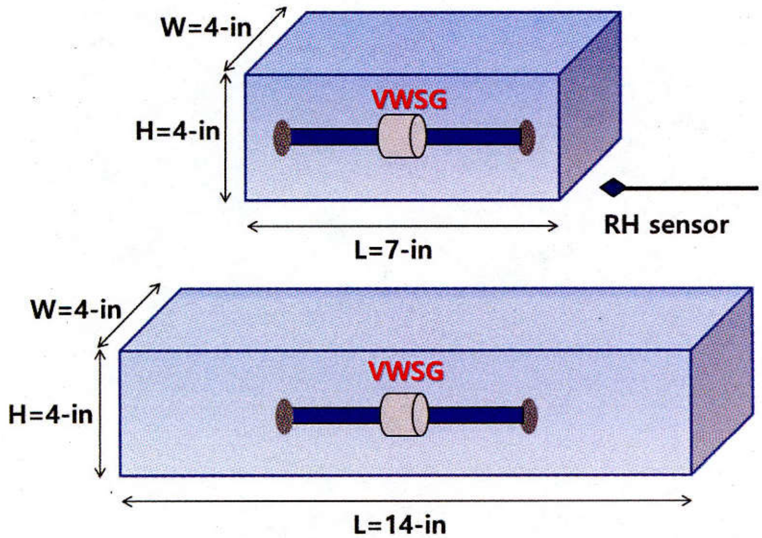
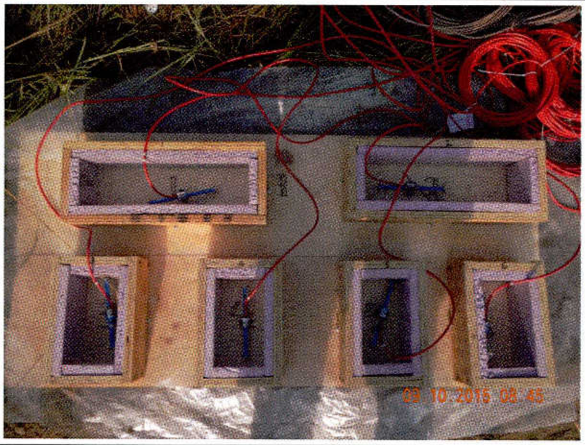
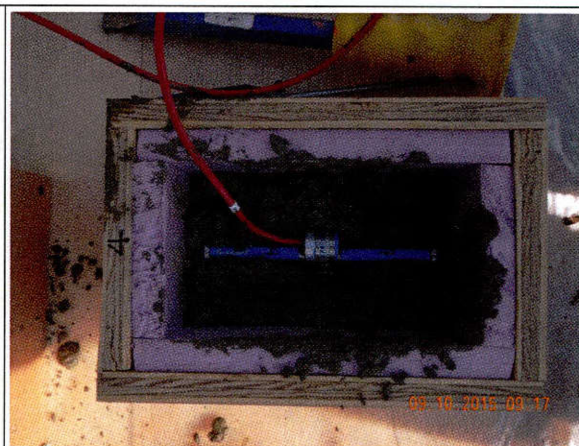


Figure 4.13 Schematic of drying shrinkage testing

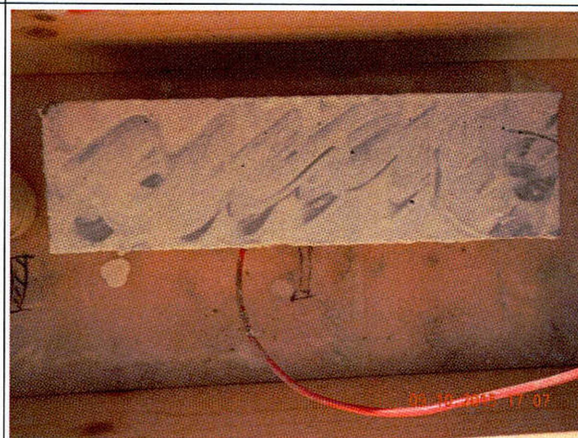


(a) Drying shrinkage prisms



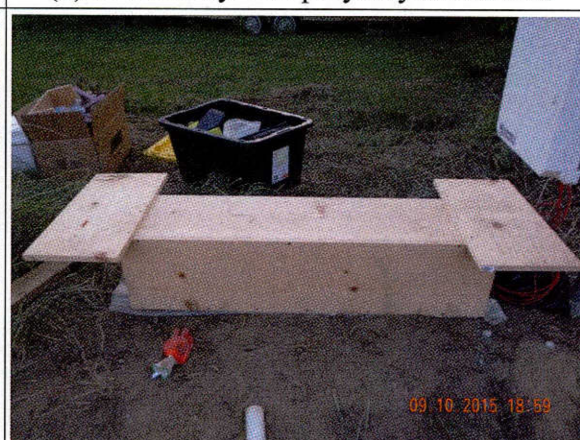
(b) Embedded VWSG

(C) Curing compound applicatiom



(d) Double layer of polyethylene sheets

(d) Fully coated prism with curing compound



(e) Drying shrinkage testing box

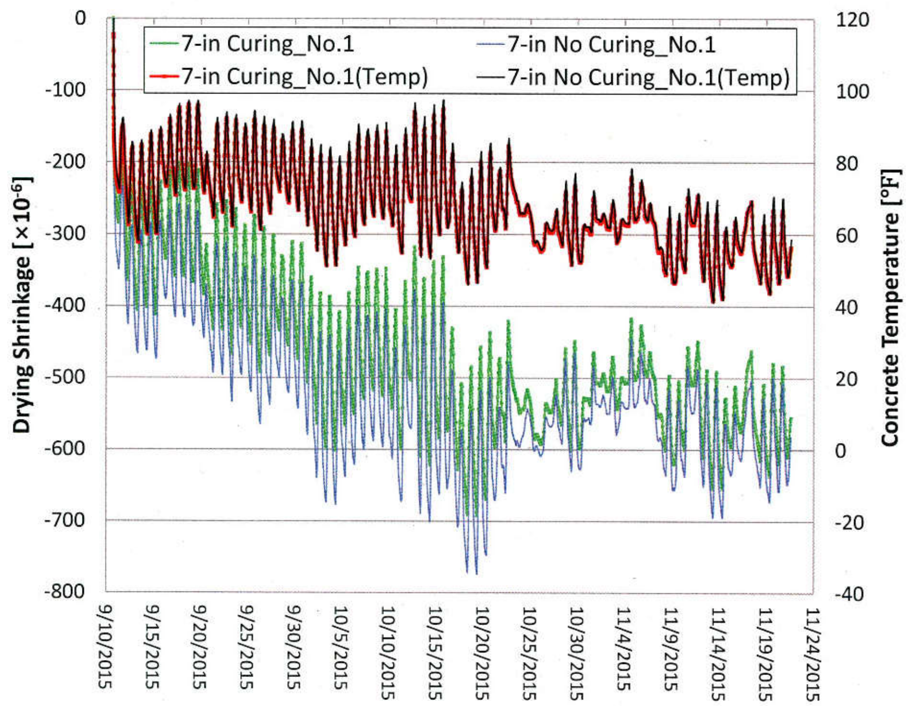
Figure 4.14 Drying shrinkage testing on SH 288

Figure 4.15 Concrete placement on FM 2253

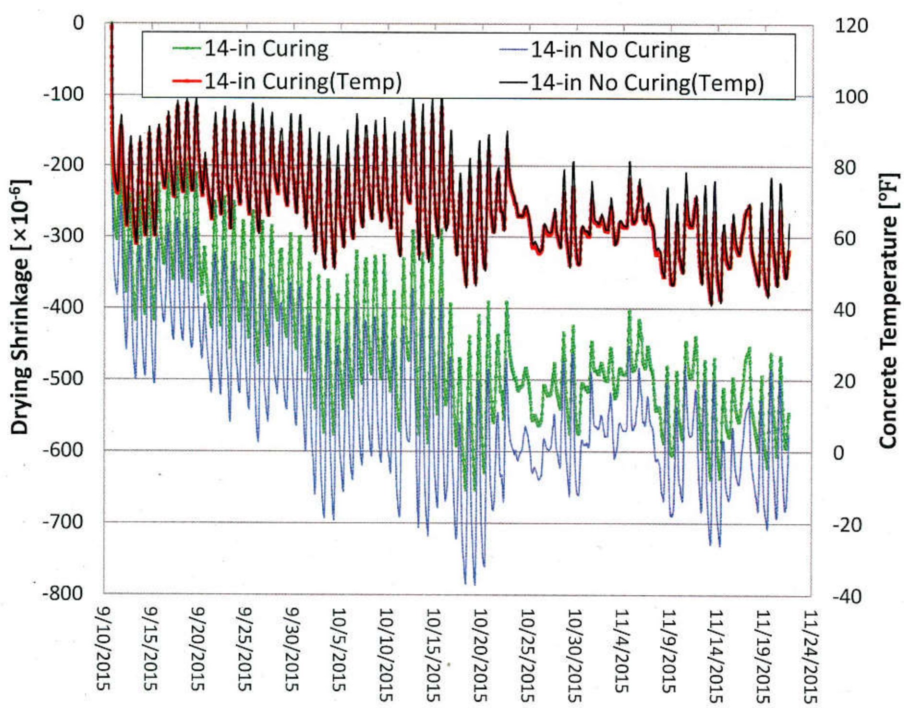
Data was collected on November 21, 2015, 70 days after concrete placement. Figures 4.16(a) and (b) illustrate a comparison of the drying shrinkage for 7-in and 14-in prisms, respectively, with curing and no curing compounds. Since concrete temperatures for both prisms are assumed identical, the variations in concrete strains from specimens with and without curing compounds should be the effect of curing compounds.

Drying shrinkage values of prisms with no curing compound were larger than those of prisms with curing compound applied, regardless of prism size. Figures 4.17(a) and (b) show concrete strain variations as a function of time for 7-in and 14-in specimens, respectively. The data was obtained for the 16 hours after starting measurement of drying shrinkage. As shown in these graphs, when no curing compound is applied, the gradients of the lines of prisms with no curing compound are larger than those of prisms with curing compound, which implies that the large amount of moisture evaporation resulted in greater drying shrinkage of concrete. If drying shrinkage is ignored in 7-in prism with curing compound, 6.43×10^{-6}/°F can be considered as a coefficient of thermal expansion (CoTE) of concrete; this result is within a reasonable range of the CoTE of the concrete used in this project.

Figure 4.18 shows the concrete strain versus concrete temperature over time, and indicates a larger drying shrinkage of concrete specimens with no curing compound.

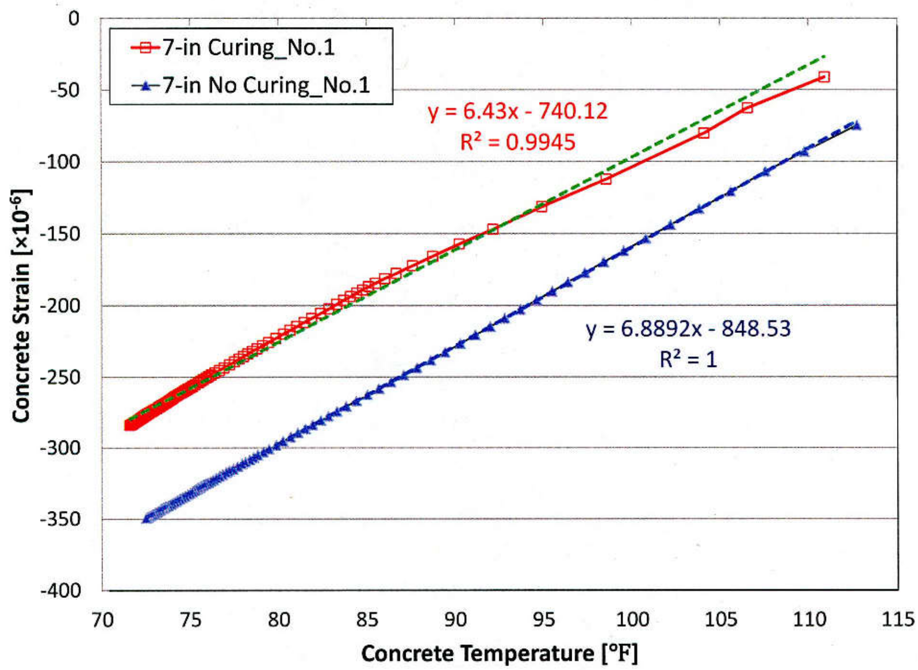


(a) 7-in prisms

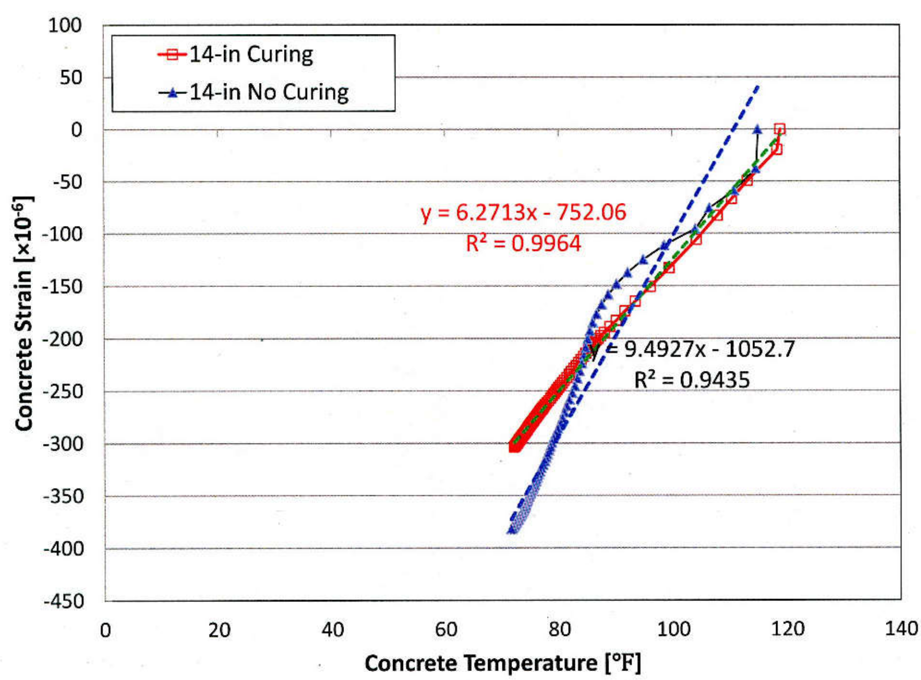


(b) 14-in prisms

Figure 4.16 Drying shrinkage results

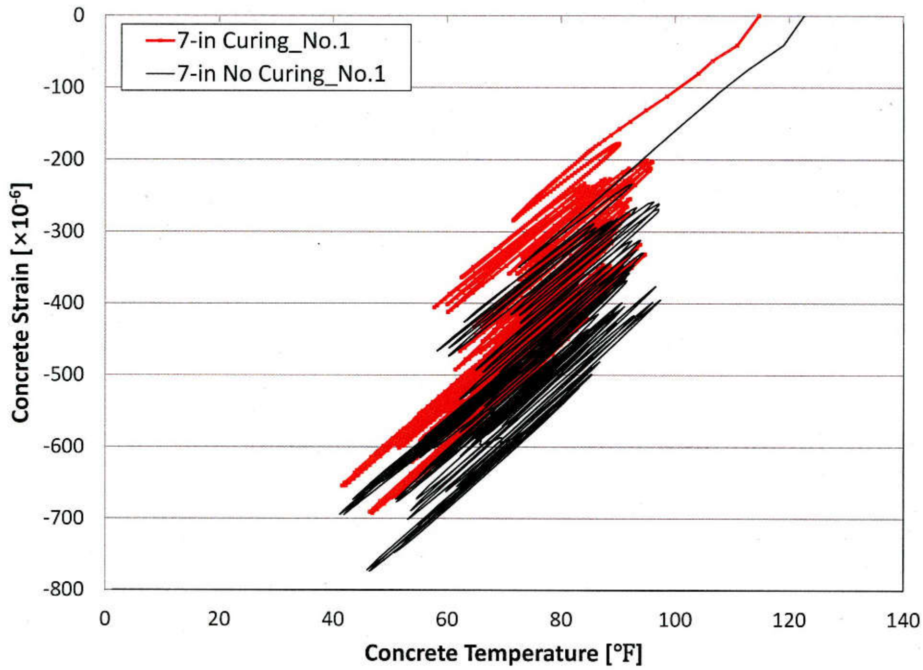


(a) 7-in prisms

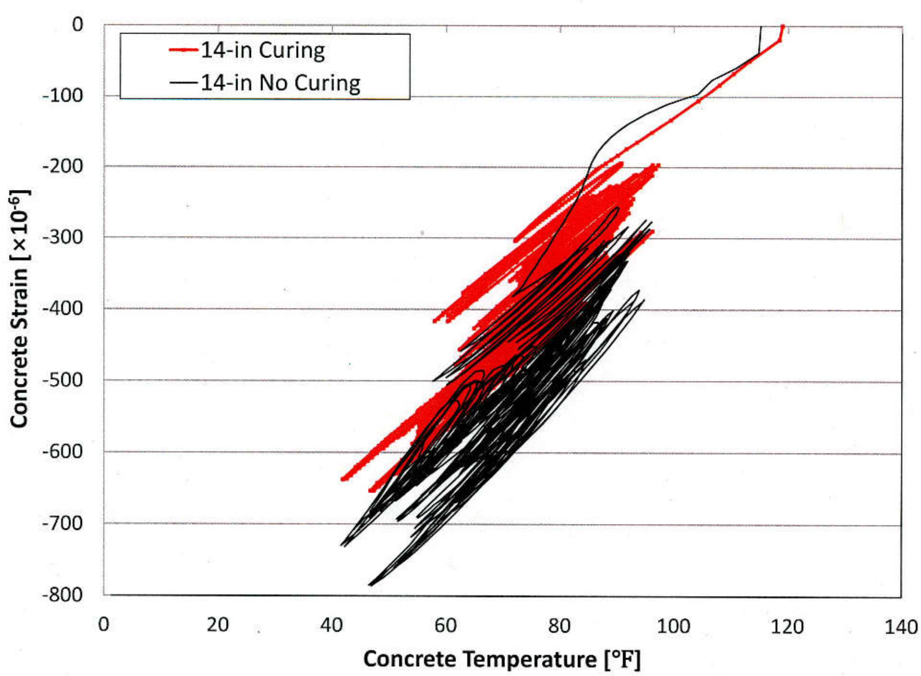


(b) 14-in prisms

Figure 4.17 Concrete strain change vs temperature variation during 16 hours after casting



(a) 7-in prisms



(b)14-in prisms

Figure 4.18 Concrete strain vs concrete temperature

4.3.2 Joint movements

Figure 4.19 shows joint condition after one day of concrete placement, which was September 11, 2015. It shows quite shallow saw cut depth at the edge of the slab. The cut is shallow because the concrete was placed with forms, and the saw cut operation was stopped a few inches away from the form. However, the saw cut depth was adequate through the joint except at the edge of pavement as shown in Figure 4.20. Figure 4.19 shows a crack already developed at the bottom of the saw cut.

Figure 4.19 Joint condition before gage installation

Figure 4.20 Sawcut at pavement edge

4.3.3 Joint displacement measurement

4.3.3.1 Gage installation

Figure 4.21 illustrates the crackmeter installation procedure to measure the joint displacement due to drying shrinkage and temperature change. The gages were installed on September 11, 2015, one day after concrete placement.

4.3.3.2 Joint displacement in longitudinal direction

Figure 4.22(a) shows joint displacements at Joint 1 (J1). Joint displacements increased over time at early ages. However, after October 23, joint width actually decreased even though temperature decreased. There was more than three inches of rain on October 23, 2015 in this area and swelling of concrete appears to cause the decrease in joint width. On the other hand, the joint width at Joint 2 (J2) gradually increased as shown in Figure 4.22(b). Even though the decrease in joint width due to the swelling of concrete is observed on October 23, the overall trend of joint width over time was as expected – as temperature went down, joint width increased. Even though these two joints were only 15-ft apart, their behaviors were quite different, as noticed in the joints on SH 288 discussed earlier. This provides important information on joint behavior in CPCD, which is that joint behavior is not uniform among joints; rather, there is a large variability in joint movements among joints. The exact cause for this heterogeneity in joint behavior among joints is not known; however, it is postulated that a number of factors such as variations in base friction, condition of dowel bar (alignment and bonding condition with concrete), and the condition of the crack under the saw cuts, all affect joint movement behavior. This large variability in joint movement behavior makes the joint analysis and design more complicated. It is reasonable to be conservative in the design of any engineering structures if large variability is known to exist. However, in the case of joint design, joint movement data for a large number of joints is quite a challenge.

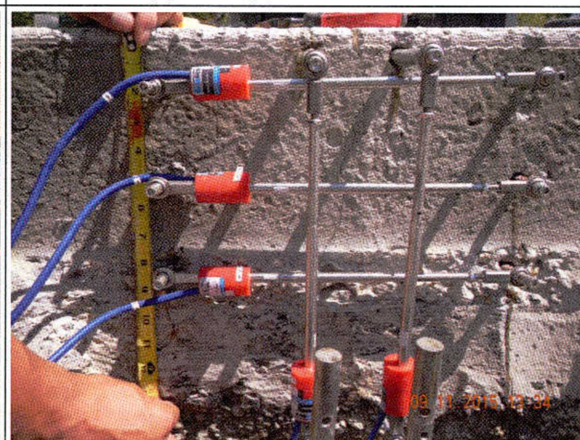
To investigate the effects of drying shrinkage of concrete on the variations of joint widths over time, joint displacement data was analyzed at a fixed temperature of 70 °F, thus eliminating the effects of temperature variations. Figure 4.23 illustrates the analysis results at both joints. In Joint 1, overall decrease in joint width was observed. On the other hand, in Joint 2, joint width increased over time. Actual increase in joint width at Joint 2 was about twice as large as that in Joint 1, which confirms the heterogeneous nature of joint movements at transverse contraction joints in CPCD. Figure 4.24 shows the adjacent joint condition, showing 1/8-in (125 mils) width of a crack. This value of 125 mils is even larger than the data obtained in Joint 2, which confirms large variabilities in joint movements among joints.

Figure 4.25 shows the analyzed joint shapes at Joint #2 from the crackmeter displacement results at one day and five weeks after concrete placement. Data was analyzed at 7 am on both days to minimize temperature effects. In this analysis, it was assumed that the initial width of joint was 1/8-in (125 mils) and the joint shape was rectangular at 7 am in the morning after one-day curing, with no built-in curling at that point. Figure 4.25 shows an increase in joint width as well as curling of the concrete slabs. Over five week period, joint widths at the top and bottom of the slab increased by about 78% and 62%, respectively. A vertical displacement was measured at 36 mils due to curling effect. It is expected that concrete will continue to shrink, increasing joint width. Whether the current extension requirement for joint sealant in TxDOT DMS-6310 is adequate will depend on how much additional drying shrinkage will take place. It is difficult to obtain information on the variations in joint width from the setting of fresh concrete. It is strongly recommended that TxDOT continue to collect data from this experiment and analyze data for the refinement of the requirements in DMS-6310.

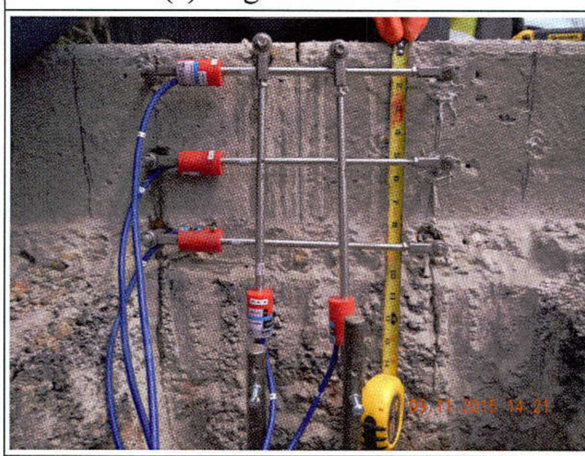
(a) Concrete break

(a) Completed soil work

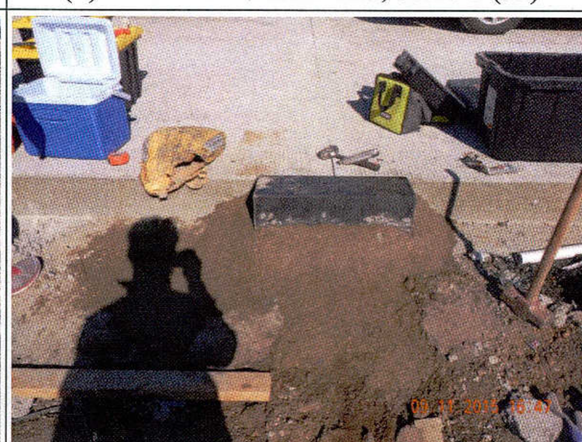
(c) Gages installation



(d) Installed crackmeters, Joint 1 (J1)

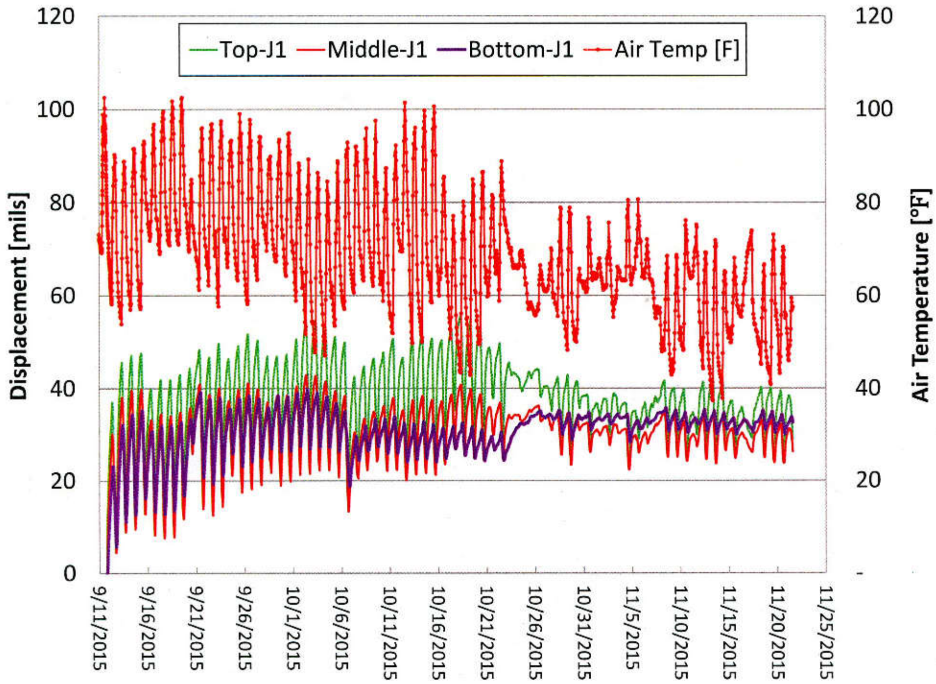


(e) Installed crackmeters, Joint 2 (J2)

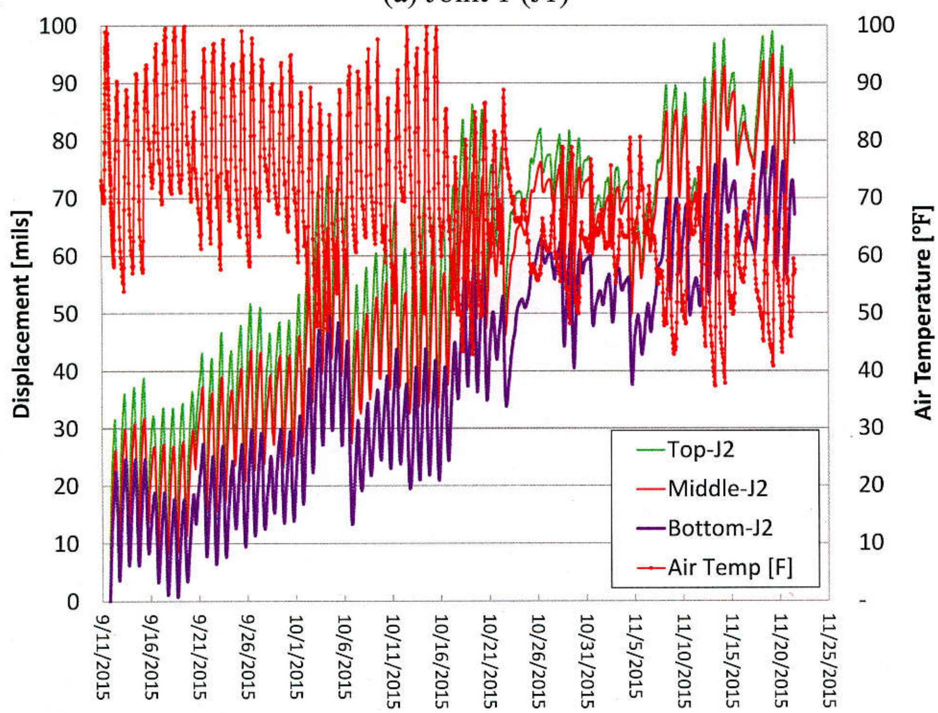


(f) Gage protection box

Figure 4.21 Sawcut at pavement edge

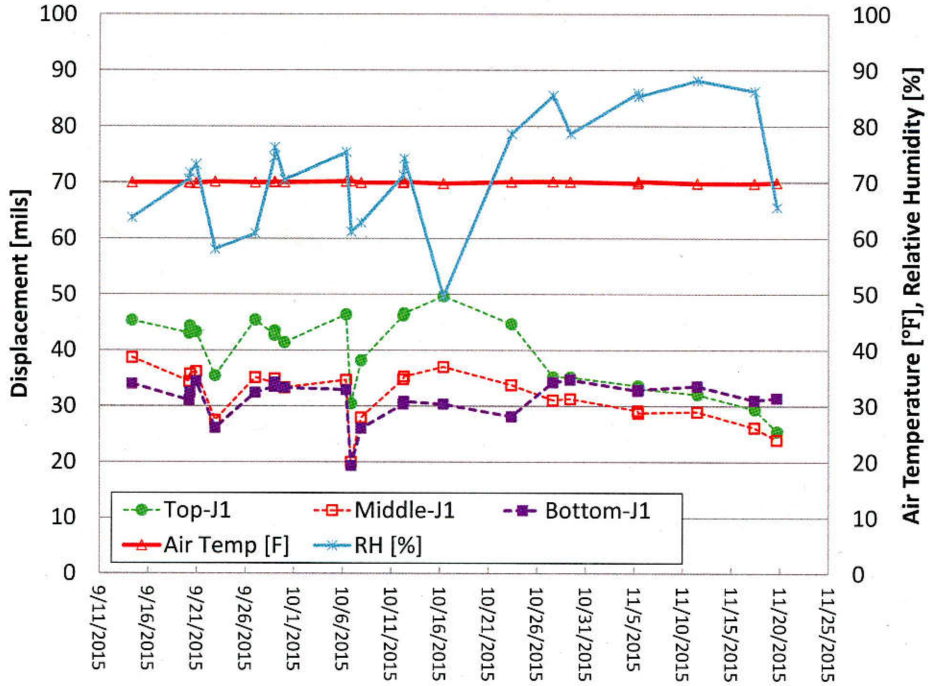


(a) Joint 1 (J1)

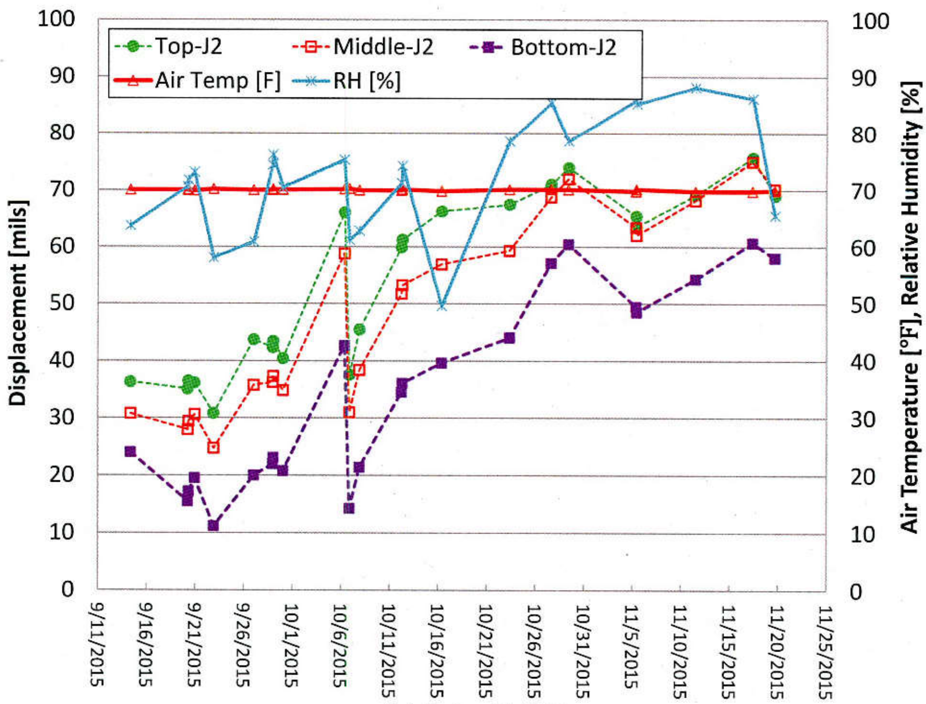


(b) Joint 2 (J2)

Figure 4.22 Joint displacement in transverse direction on FM 2253



(a) Joint 1 (J1)



(b) Joint 2 (J2)

Figure 4.23 Joint displacement at a constant temperature (70 °F)

Figure 4.24 Crack width at Joint on FM 2253

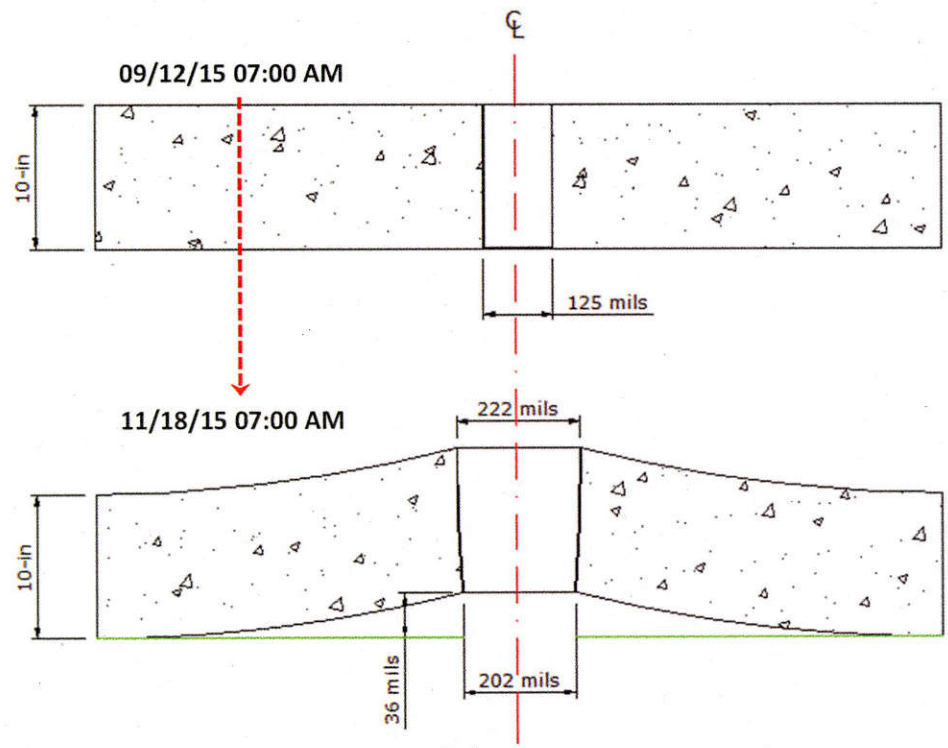
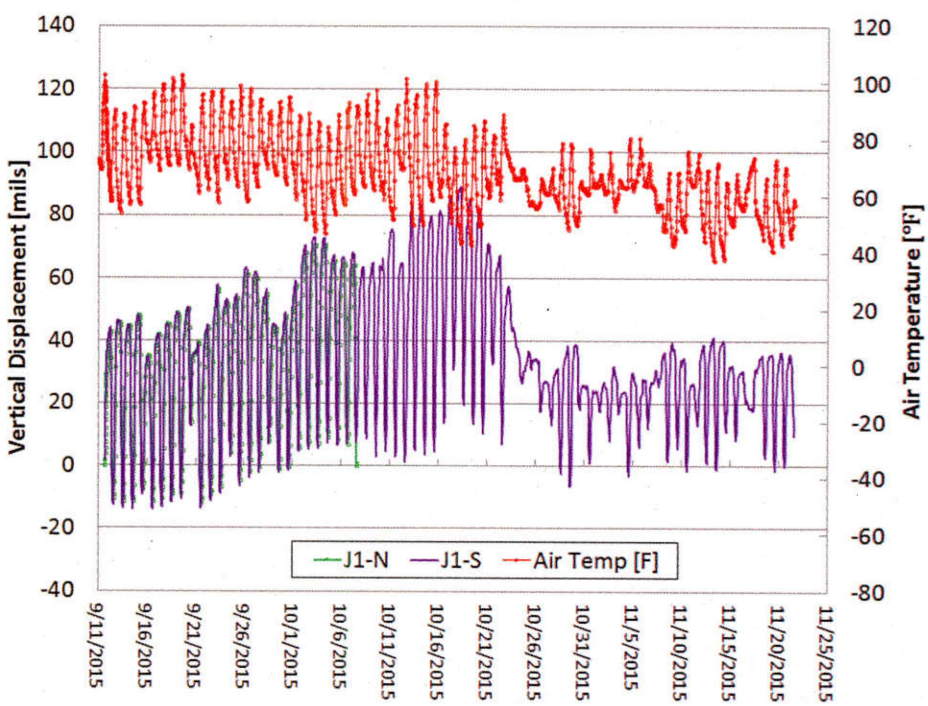


Figure 4.25 Actual joint shape at Joint #2

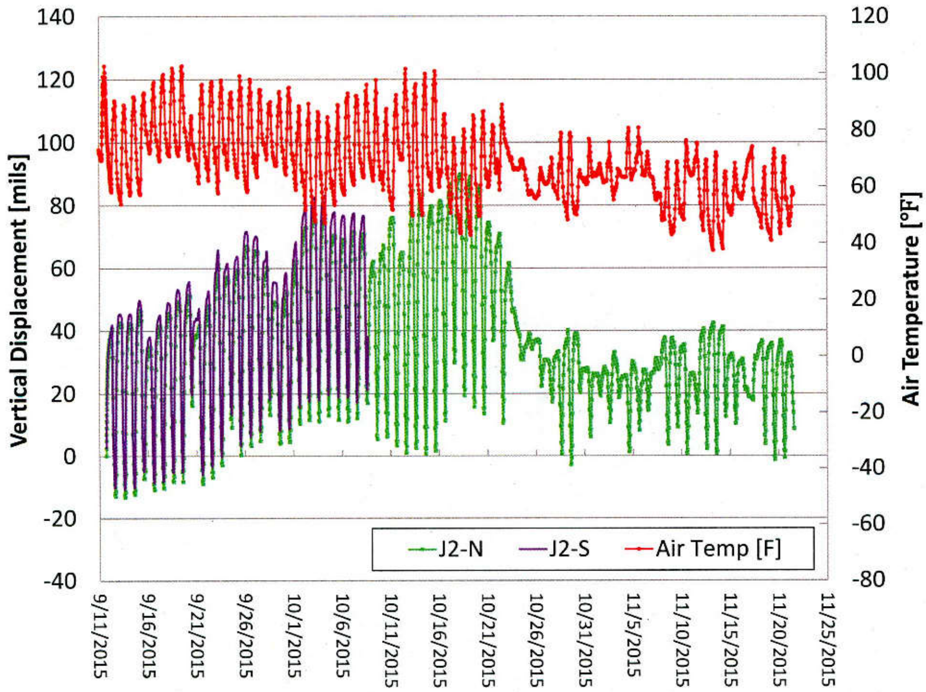
4.3.3.3 Joint displacement in vertical direction on FM 2253

As described earlier, the crackmeters were also installed vertically to measure the curing behavior as temperature change.

Figure 4.26(a) and (b) illustrate the joint displacements in the vertical direction at Joint 1 and Joint 2, respectively. The joint displacement in the vertical direction increased up to 85 mils within the 42 days age for both Joint 1 and Joint 2, and decreased with temperature drop and swelling effect due to rain after the 42 days of concrete placement, which was on October 23, 2015. Figure 4.27 shows the relative humidity (RH) variation with time. The graph clearly indicates that it was rainy on October 23, 2015, and the RH of air has maintained quite high until November 21, 2015.



(a) Joint 1 (J1)



(b) Joint 2 (J2)

Figure 4.26 Joint displacement in vertical direction on FM 2253

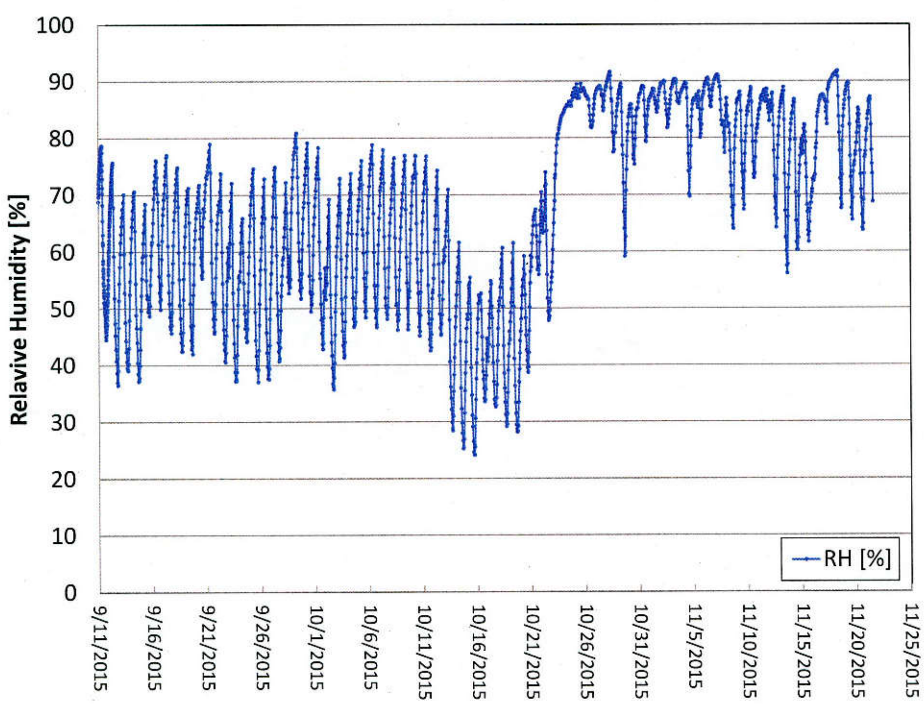


Figure 4.27 Relative humidity (RH) on FM 2253

4.4 Summary of Joint Movement

To evaluate joint movements at transverse contraction joints in CPCD, two projects were selected and gages were installed at two transverse contraction joints in each project. One is on SH 288 in the Dallas District and the other is on FM 2253 in the Atlanta District.

The analysis of data obtained indicates the following:

1) Large variabilities exist in joint movements among transverse contraction joints. Quite different joint movements were obtained in two adjacent contraction joints.
2) Whether the current extension requirement for joint sealant in TxDOT DMS-6310 is adequate will depend on how much additional drying shrinkage will take place. It is difficult to obtain information on the variations in joint width from the setting of fresh concrete. It is strongly recommended that TxDOT continue to collect data from this experiment and analyze data for the refinement of the requirements in DMS-6310.
3) Concrete slabs at transverse joints exhibit not only axial behavior in the longitudinal direction, but curling behavior as well, which makes joint shape analysis quite complicated. With the continued drying shrinkage of concrete near the slab surface along with the curling behavior due to temperature variations along the slab depth, sealant will experience more strains at the top, and the aging effect of sealant will be more pronounced at the top as well. Consequently, adhesion or cohesion failures might initiate at the top, if they occur.
4) Concrete swells when wet from rain, resulting in the decrease in joint width. However, subsequent drying once rain stops continues to increase joint width.

Chapter 5 Seal and No Seal

5.1 Introduction

Currently, many state highway agencies require joint sealing for jointed concrete pavement. Joint sealing is commonly believed to be beneficial to concrete pavement performance in two ways: 1) Sealed joints are believed to reduce water infiltration into the pavement base so that joint distresses related to pumping, corner break, and freeze-thaw damage can be reduced. 2) Sealed joints are also believed to reduce the infiltration of incompressible materials, which could prevent spalling and blowups (Hall and Crovetti 2000). However, several state highway agencies have decided not to seal joints based on their observations in CPCD performance with sealed and unsealed joints, along with the cost factor (Hall and Crovetti 2000). Wisconsin DOT presented quite powerful arguments regarding why transverse contraction joints should not be sealed (Shober 1997). Since then, whether to seal transverse contraction joints or not has become a national issue with varying opinions and no consensus among pavement engineers.

The Seal/No Seal (SNS) Group was formed to respond to the age-old industry question about the value of sealing concrete pavement joints. There is increased interest in eliminating joint sealing to reduce initial construction cost. However, there is a lack of data or evidence on sealant effectiveness and the long-term performance. Life cycle cost (LCC) analysis data doesn't exist that could provide positive evidence on the benefits of sealing (Seal/No Seal Group 2012). It appears that, at least in Texas, the condition of joints does not have as significant effects on CPCD performance as other design and construction variables, such as joint spacing, slab thickness, use of dowels, and the slab supporting condition. Also, any distresses resulting from joint sealing issues in Texas are limited to minor spalling or chipping of the concrete, which is not structural distress and quite often overlooked as minor nuisance by both pavement engineers and motorists. It is primarily because freeze-thaw or D-cracking of concrete at joints is quite rare in Texas and water intrusion through transverse contraction joints is not a serious issue in Texas, partly due to the use of stabilized base. In addition, topography is quite flat in many parts of Texas and open ditch elevations are not much deeper than base elevations in many locations. When there is large rainfall, water ingress to the base and subgrade from open ditches is more pronounced than any water ingress through poorly sealed joints. All these make the controversy over whether to seal or not seal more complicated in Texas.

In Europe prior to 1979, several countries authorized the use of unsealed joints in highways and other main roads (Burke Jr and Bugler 2002). The 16th World Congress of the Permanent International Association of Road Congresses (PIARC) in 1979 recommended transverse joints can be unsealed if 1) traffic is light, 2) traffic is heavy but dry climate, and 3) traffic is heavy and wet climate, but dowelled joint, when the joint spacing is from 4 to 6 meters (13.3-ft to 20-ft). At that time, the observations of unsealed pavements in Austria, Denmark, Belgium, France, Netherlands, Spain and Switzerland were less than 10 years old, and conclusive opinions were not made. However, Germany had 600 miles of unsealed pavements with ages up to 20 years. In

2001, a brief enquiry was made to pavement authorities of European countries to obtain information on the performance of unsealed joints. It found that no country adopted unsealed jointed pavements as a national standard. Germany, which has the most unsealed pavement in Europe, concluded that control of subsurface water is a critical aspect affecting the long-term performance of concrete pavements.

In Texas, joint sealing has not been a serious issue, primarily because most of the concrete pavement built since 2001 has been continuously reinforced concrete pavement (CRCP), which requires sealing at longitudinal sawed contraction joints and longitudinal or transverse construction joints only. Lane mileage of CPCD has been decreasing in Texas. However, with a new CoTE requirement for CRCP, the usage of CPCD could increase in the future, especially in certain districts where the availability of coarse aggregate with a low CoTE is quite limited.

In this chapter, other highway agencies' experiences on seal/no seal are described. Field survey results on the sections with seal/no seal in Texas is also presented.

5.2 State Agencies' Practices

5.2.1 California Department of Transportation

The California Department of Transportation (Caltrans) followed the practice of unsealed joints in concrete pavements in the past; however, further research on this topic suggested the sealing of joints in concrete pavements. From the early 1990s Caltrans started using joint sealing as a standard practice (American Concrete Pavement Association 2010; Burke Jr and Bugler 2002).

5.2.2 North Dakota Department of Transportation

The North Dakota Department of Transportation (NDDOT) evaluated the practice of unsealed joints in concrete pavements in 2009 (Dunn et al. 2009). The project included test sections (unsealed joints) and controlled sections (sealed joints) at four locations in North Dakota. The design at both test and controlled section was joint width of 1/8-in, saw cut depth of one-third of slab thickness of pavement. Most of the test sections were 2,000 ft long and the control section was 1,000 ft long. Over the 10-year performance, analysis showed a major distress in the form of spalling and corner cracks at joints in unsealed sections. Joints in shoulders were filled with incompressible materials, while joints in driving lanes were free of incompressible materials due to differential air pressure formed by the vacuum of traffic (Dunn et al. 2009).

Figure 5.1 shows the locations of test and control sections in the NDDOT. Based on the research findings, the NDDOT decided to seal joints and use a drainable base layer.

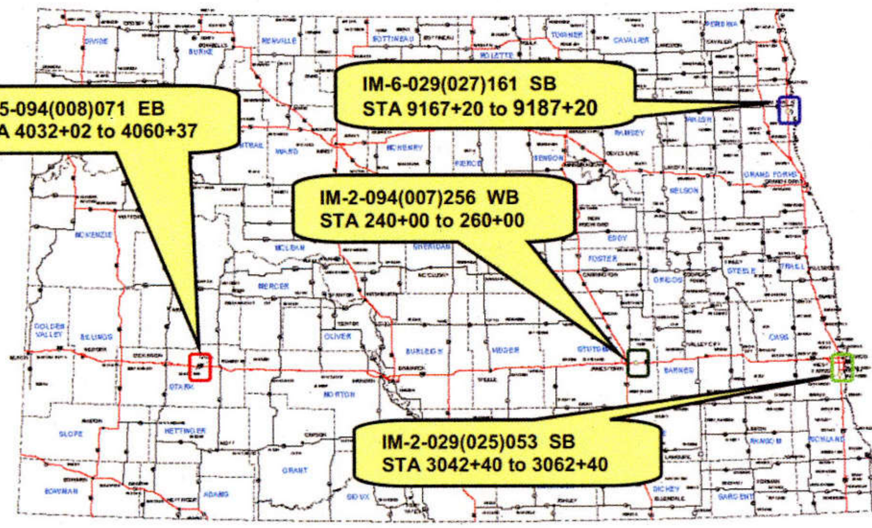


Figure 5.1 Seal/No Seal test location in North Dakota (Dunn et al. 2009)

5.2.3 Wisconsin Department of Transportation

The Wisconsin Department of Transportation (WisDOT) has been studying the effect of PCC joint and crack sealing in total pavement performance for over 50 years. By 1984, it was concluded that pavements with unsealed joints had better performance than pavements with sealed joints in terms of distress, ride, and materials integrity. In 1990, WisDOT passed a policy eliminating all PCC joint sealing for new construction and maintenance (Shober 1997).

Based on the research, the following recommendations were made: 1) PCC pavement contraction joints should be left unsealed and sawed as narrowly as possible and 2) highway research must focus and concentrate upon user needs, which means that the pavement performance should be the primary evaluation criteria. However, most of the unsealed sections showed only short-term performance (aged up to 10 years). Research study investigated the performance of the following unsealed sections:

1. USH 51 Marathon County (dowels) 1974
2. USH 18/151 Iowa County (no dowels) 1983
3. STH 16/190 Waukesha County (no dowels) 1983
4. STH 29 Brown County (doweled and non-doweled) 1988
5. STH 164 Waukesha County (no dowels) 1988

In the above test sections, two were eight years old, two were 13 years old, and the USH 51 was 22 years old.

Based on the extensive evaluations, the following conclusions were made (Shober 1997).

1) Joint sealing has no significant effect on pavement ride quality.
2) Joint sealing appears to have no observable effect on bridge encroachment.
3) Joint sealing has no significant effect on material integrity.

Shober presented the following explanations for why joint sealing does not improve pavement performance, as has been promoted in the paving industry for so long.

1) Stress concentrations – Even joints that are well-sealed at the beginning will deteriorate over time, allowing incompressible materials to get in to the joints at discrete locations. When concrete temperature goes up, the concrete at those areas with incompressibles at the joint will experience localized spalling. When joints are not sealed with a narrow joint width, joints might be filled with incompressibles; however, concrete stresses when the concrete expands due to temperature increase will be uniformly distributed throughout the slab widths, minimizing compressive stresses in concrete resulting in almost no distress.
2) Incompressible locations – In unsealed joints, incompressibles are not located near the top of the joint, so there is no stress at the top joint edge. In addition, no large incompressibles get into the narrow joint to cause stress concentrations.
3) Construction and maintenance – Since sealant is effective for about five to 10 years, in order to truly have a sealed system, re-sealing joints is required. Re-sealing will result in a wide joint reservoir and can affect ride.
4) Funneling water – Wisconsin's narrow and unsealed joints are quite impermeable in warm weather. On the other hand, a truly sealed system will soon begin to have sealant failures, resulting in a funneling effect which allows more water to enter the joint than would occur with a narrow and unsealed joint.

5.2.4 Illinois Department of Transportation

A test section was constructed to evaluate transverse joint sealant effectiveness on SR 59 near Joliet, Illinois. Test sections consisted of eight sealed sections and two unsealed sections. Hot pour and silicon sealants were installed with a single saw cut. The pavement was constructed with 9.75-in thick and dowelled on a 15-ft joint spacing.

The purposes of the experiment were 1) to determine the cost effectiveness of sealing transverse joints in overall pavement performance, 2) to establish actual construction costs for future life cycle costs analysis, 3) to document the construction process, site factors, material properties, and establish base line performance measurements, and 4) to provide additional information for future national or regional joint sealant evaluations (American Concrete Pavement Association 2010).

Figure 5.2 shows the location of test sections. Test sections were opened to traffic on November 3, 2009. The performance information has not been published yet.

Figure 5.2 Seal/No Seal test location in Illinois (American Concrete Pavement Association 2010)

5.3 LTPP Test Section in Texas

An LTPP section of significance is located on US 90 eastbound in the Jefferson County, Beaumont District (GPS coordinates: 30.042605, -94.371218, LTPP section ID: 484143 and 48B410). This section was categorized in 'Wet and Non-Freeze' climatic region in the LTPP sections. This section was built in October 01, 1970 with 10.4-in thick jointed reinforced concrete pavement (JRCP) on 4.5-in cement treated base (CSB) over 5.5-in lime treated subgrade (LTS). Expansion joint spacing was 60-ft 6-in, with three contraction joints between expansion joints.

According to the LTPP database webpage (Federal Highway Administration 2015), data has been collected since January 1, 1987, which indicates that the current pavement condition related to joint sealant presents 28 years of pavement performance. Figure 5.3 shows a captured image from the LTPP InfoPave^{TM} webpage.

Field performance survey was conducted on January 29, 2015. A total of 26 expansion joints were investigated; fourteen joints in the unsealed section and twelve joints in sealed section, as shown in Figure 5.4.

Figure 5.5(a) shows the overall pavement condition of both the sealed and unsealed sections. Figures 5.5(b) and (c) show the typical condition of expansion and contraction joints, respectively, in the unsealed section. Overall performance of unsealed joints has been excellent. Figure 5.5(d) shows the expansion joint between the unsealed and sealed sections. Figures 5.5(e) and (f) show the typical condition of expansion and contraction joints, respectively, in the sealed section.

The field survey result showed no significant difference in either joint or pavement performance between the sealed and unsealed sections. However, this is just one section with relatively low traffic, and the findings in this section should not be interpreted as sealing having no effect on joint or pavement performance.

Tables 5.1, 5.2, 5.3, and 5.4 present the information recorded in the LTPP data base. The information includes the climatic and traffic information, pavement distresses, international roughness index (IRI), deflection at 9,000 lbs, and the load transfer efficiency (LTE). As shown in Table 5.3, the average deflection at 9,000 lbs was measured as 24 mils, which is quite large for PCC pavement and almost ten times that of 10-in CRCP average deflection (Choi et al. 2013).

Basic Section Overview (48-4143)

State/ Province	Texas	**GPS- Lat., Long. (Degrees)**	30.0426, -94.37099	**Date of Construction**	01-Oct-1970
County	JEFFERSON	**Functional Class**	Rural Principal Arterial - Other	**Date Included in LTPP**	01-Jan-1987
Route, Direction	U. S.-90, East Bound	**No. of Lanes**	2	**LTPP Monitoring Status**	ACTIVE
Mile Post		**Climatic Zone**	Wet, Non-Freeze	**Region (Code and Description)**	3- Southern

LTPP Section History and Pavement Structure

LTPP Section M&R History				Layer Information				Strength or Stiffness Measures (Multiple)	
Experiment Number	**Construction Number (CN) and Max Layer Number**	**CN Event (M&R) Date**	**CN Event (Code and Description)**	**Layer Number**	**Layer Type**	**Thickness (in.)**	**Material Code Description**	**Test Results (Abbr,Unit)**	**Other (Abbr,Unit)**
GPS-4	CN1 (Layer Max =4)	Jan-1987		1	Subgrade (untreated)		102-Fine-Grained Soils: Lean Inorganic Clay		
				2	Bound (treated) subbase	5.5	338-Lime-Treated Soil		
				3	Bound (treated) base	4.5	331-Cement Aggregate Mixture		
				4	Portland cement concrete layer	10.4	5-Portland Cement Concrete (JRCP)		

Figure 5.3 Basic information of US 90

a. Overall pavement condition

b. Expansion joint in No Seal section

c. Contraction joint in No Seal section

d. Limit between Seal and No Seal

e. Expansion joint in Seal section

f. Contraction joint in Seal section

Figure 5.4 Joints conditions on US 90

a. Overall pavement condition (No Seal)

b. Overall pavement condition (Seal)

a. Distress in No Seal section (1)

b. Distress in No Seal section (2)

c. Distress in Seal section (1)

d. Distress in Seal section (2)

Figure 5.5 Distresses at Sealed and No Sealed sections

Table 5.1 Climatic and traffic information

Time (Year)	Climate (Virtual Weather Station (VWS) Data)				Traffic Estimate				
					SHA Data			Monitored Data	Computed Data
	Annual Average Precipitation (mm)	Annual Average Temperature (deg C)	Annual Average Freeze Index (deg C deg days)	Annual Average Humidity Min-Max (%)	Annual Average Daily Traffic (AADT)	Annual Average Daily Truck Traffic (AADTT)	18-Kip ESAL (KESAL)	Annual Average Daily Truck Traffic (AADTT)	18-Kip ESAL (KESAL)
1970	1382.1	19.9	1		1053	140	43		
1971	1108.5	20.4	0		1082	144	44		
1972	1421.3	19.8	0		1141	133	41		
1973	1993.4	19.6	4		1144	129	39		
1974	1459	20.1	0		1095	149	44		
1975	1508.2	19.9	0		1261	149	74		
1976	1312.3	18.9	0		1170	153	81		
1977	1320.6	20.1	1		1280	158	83		
1978	1116.2	19.3	2		1589	218	113		
1979	1997.2	18.8	6		1609	238	131		
1980	1467.7	19.6	0		1625	275	157		
1981	1354.7	19.9	1		1950	302	172		
1982	1458.4	20.2	6		1755	290	161		
1983	1975.4	18.9	25		1950	205	101		
1984	1306.9	20.1	2	59-96	1852	252	150		
1985	1331.8	19.9	8	58-97	1592	191	81		
1986	1780.5	20.3	0	55-95	1528	185	84		
1987	1611.2	19.4	0	52-96	1690	243	103		
1988	1016.9	19.9	0	51-95	1495	247	92		
1989	1482.3	19.5	23	55-94	1560	251	79		
1990	1375.2	20.8	9	55-96	1860	187	50	151	
1991	2038.7	20.3	0	58-95	1825	154	42	163	
1992	1510.7	19.7	0	57-97	1951	179	48	212	
1993	1487.5	19.6	0	56-96	1919	175	46	205	
1994	1668.4	20.2	0	58-96	1855	100	32		
1995	1680.7	20.3	0	57-97	2065	111	33	310	
1996	1301.1	20.2	7	61-97	2415	130	44	269	
1997	1186.6	19.3	2	58-96		275	58	380	
1998	1694.9	21.3	0	60-96		328	64	389	
1999	1019.1	21	0	53-96		291	62	346	
2000	1032	20.9	0	53-95		300	64	380	111
2001	2330.1	20.4	0	57-97		358	69	449	
2002	1573.3	20.3	0	60-97		369	71	439	
2003	1555.9	20.2	0	57-96		380	74	455	
2004	1457.5	14.5	1	57-95		338	72	169	77
2005	827.3	19.3	0	48-90		403	78	500	
2006	1965	20.5	0	49-92		415	80	546	
2007	1365.9	20.5	0	52-92		427	83	493	
2008	1495.5	20.4	0	50-93		380	81	290	
2009	1212.3	20.5	0	54-96				221	
2010	1039.5	20	4	52-96				61	
2011	1008.1	20.8	6					284	
2012	1442.8	21.3	0					295	

Table 5.2 Pavement performance history (Distresses-484143)

Survey Date and CN Event Date	CN Event Description	JPCP Distress (Sum of all severity - Low, Medium, High)					Longitudinal Crack Length Severity		
		Fatigue (m^2)	Faulting (mm)	Spalling of Trans. Joints (Count)	Transverse Cracking (Count)	Corner Breaks (Count)	Low (mm)	Medium (mm)	High (mm)
03/07/1990				7	0	0	0	0	0
02/27/1991				7	0	0	0	0	0
07/11/1991				13	0	0			
03/23/1992				2	0	0	0	0	0
04/03/1992				13	0	0			
02/26/1993				8	0	0	0	0	0
04/29/1993			0.7	15	0	0			
01/10/1995			0.7	21	0	0			
02/25/1995				6	0	0	5	0	0
04/10/1995			0.6	21	0	0			
06/08/1995			0.4	20	0	0			
07/09/1997			0.8	21	0	0			
09/25/1997			0.8	21	0	0			
05/14/1998			0.6	16	0	0			
08/29/2000			1.1	17	0	0			
02/22/2001				3	0	0			0
01/06/2003				4	1	0		0	0
07/25/2003			0.9	16	0	0			
02/02/2011			0.6	16	0	1			
06/26/2013			1	16	0	1			

Table 5.3 Pavement performance history (IRI and structural condition-484143)

and CN Event Date	CN Event Description	Profile	Deflection			
		International Roughness Index (IRI) Section Average (m/km)	Avg Deflection (9-Kip, wheel load) at 0" from Load Plate (microns)	Avg Deflection (9-kip, wheel load) farthest sensor (60" or 72") from Load Plate (microns)	Load Transfer Efficiency of Transverse Joints (%)	
					Approach	Leave
04/13/1990		2.227				
07/24/1990			58	35	95	96
04/08/1991		2.293				
09/26/1991					82	85
11/02/1992		2.211				
11/18/1993			67	41	86	82
12/16/1993		2.232				
01/18/1994			65	40	81	79
02/15/1994			67	40	80	79
03/22/1994			66	40	87	89
04/19/1994			65	39	90	92
04/21/1994		2.247				
05/19/1994			69	44	95	95
06/29/1994			65	38	95	96
07/11/1994			66	39	94	96
07/13/1994		2.352				
08/09/1994			66	39	93	94
09/12/1994			63	37		
10/26/1994		2.349				
11/07/1994			63	38	92	91
12/12/1994			62	36	86	81
01/10/1995			61	36	87	84
01/17/1995		2.206				
02/13/1995			63	37	84	80
03/06/1995			61	36	89	88
04/10/1995			63	37	89	93
04/20/1995		2.306				
05/09/1995			63	37	95	94
06/05/1995			64	37	95	95
06/28/1995		2.364				
02/26/1996			63	37	96	95
11/19/1996			63	37	90	90
12/17/1996			64	37	85	84
01/07/1997		2.181				
01/28/1997			66	38	81	81

and CN Event Date	CN Event Description	Profile	Deflection			
		International Roughness Index (IRI) Section Average (m/km)	Avg Deflection (9-Kip, wheel load) at 0" from Load Plate (microns)	Avg Deflection (9-kip, wheel load) farthest sensor (60" or 72") from Load Plate (microns)	Load Transfer Efficiency of Transverse Joints (%)	
					Approach	Leave
02/18/1997			62	36	82	84
03/25/1997			63	37	93	97
04/08/1997		2.256				
04/24/1997			64	37	92	92
05/18/1997			63	37	94	94
06/27/1997			62	36	93	95
07/09/1997			61	36	92	95
08/19/1997			63	36	96	93
08/20/1997		2.322				
09/25/1997			64	36	90	90
10/01/1997		2.309				
06/17/1999			60	36	91	93
12/07/1999		2.292				
10/23/2001		2.311				
07/25/2003			61	37	95	94
02/28/2004		2.322				
02/02/2011			67	39	78	81
12/08/2011		2.346				
08/07/2014		2.408				

Table 5.4 Pavement performance history (Distresses – 48B410)

Survey Date and CN Event Date	CN Event Description	AC Distress (Sum of all severity - Low, Medium, High)				JPCP Distress (Sum of all severity - Low, Medium, High)				Longitudinal Crack Length Severity		
		Fatigue (m2)	Longitudinal Cracking (WP, NWP) (Length,m)	Transverse Cracking (Count)	Rutting (mm)	Faulting (mm)	Spalling of Trans. Joints (Count)	Transverse Cracking (Count)	Corner Breaks (Count)	Low (mm)	Medium (mm)	High (mm)
09/05/1989							1	0	0			
06/29/1990							5	0	0			
Dec-1990	2-Transverse Joint Sealing (linear ft.), 3-Lane-Shoulder Longitudinal Joint Sealing (linear ft.)											
02/27/1991					3		8	0	0	0	0	0
07/11/1991							5	0	0			
03/23/1992					1		5	0	0	0	0	0
04/03/1992							6	0	0			
02/26/1993					3							
04/29/1993						0.5	6	0	0			
02/25/1995					4							
06/08/1995						0.5	6	0	0			
05/14/1998						0.4	9	0	0			
08/29/2000						1.1	9	0	0			
02/22/2001							2	0	0	0	0	0

Chapter 6 Conclusions and Recommendations

The objectives of this project were to 1) identify failure modes and their mechanisms in joint seals in Texas, and to 2) identify what needs to be done to minimize the failures and improve joint seal performance. To achieve these objectives efficiently, a factorial experiment was developed that included pavement age, shoulder and base type and climatic condition as independent variables. Field surveys were conducted to identify failure modes and their respective failure mechanisms in accordance with the factorial design developed. Field operations of joint seal installations were observed and contacts were made with joint seal contractors, other state DOT personnel, as well as joint seal material producers.

The relationship between joint sealant failure and PCC pavement performance was analyzed based on the sealant condition survey results. The findings from this study can be summarized as follows:

A. General Conclusions

1. Joint sealant performance period is much shorter than the current pavement design period, which is 30 years. On average, joint sealant performance period is less than 10 years. Re-sealing of joints is quite rare, not only in Texas but in other states as well.
2. It is quite rare to observe pavement distresses that can be solely attributable to poor joint sealant condition. More specifically, there are test sections in Beaumont built with and without sealing. From a practical standpoint, there was no difference in pavement performance between the two sections.
3. There are other variables that have more significant effects on PCC pavement performance than joint seal condition. They include slab thickness, joint spacing, dowel bar alignment and bonding condition with concrete, and the durability of slab support. Negligible effect of joint seal condition on overall pavement performance does not necessarily mean the insignificance of joint seal effect. Other factors have larger effects and joint seal condition effect might have been masked.
4. Most of the joint seal failures appear to be due to hardening of the sealant over time, or an aging effect. Currently, there is no criteria established for long-term aging of sealant. Further effort will be needed in this area; however, aging of sealant is a very difficult topic, and should be addressed in a national level study, not by TxDOT.
5. No conclusive findings were made in this study that would support resolving sealing or no sealing issue.

B. Discrepancy between TxDOT Requirements and Field Operations

1. TxDOT Design Standards JS-14 do not require backer rod at longitudinal sawed contraction joint or longitudinal/transverse construction joints. However, joint seal subcontractors always install backer rods in those joints without exception. They cited

avoiding a three-face contact between sealant and concrete surfaces as a primary reason for installing backer rod.

2. TxDOT JS-14 allows only silicone material for joint sealant in concrete pavement. However, hot pour materials are also used for joint sealant in concrete pavement, especially in re-sealing operations.

C. Joint Movements

1. Large variabilities exist in joint movements among transverse contraction joints. Quite different joint movements were obtained in two adjacent contraction joints.
2. Whether the current extension requirement for joint sealant in TxDOT DMS-6310 is adequate will depend on how much additional drying shrinkage will take place. It is difficult to obtain information on the variations in joint width from the setting of fresh concrete. It is strongly recommended that TxDOT continue to collect data from this experiment and analyze data for the refinement of the requirements in DMS-6310.
3. Concrete slab at transverse joints exhibits not only axial behavior in the longitudinal direction, but curling behavior as well, which makes joint shape analysis quite complicated. With the continued drying shrinkage of concrete near the slab surface along with the curling behavior due to temperature variations along the slab depth, sealant will experience more strains at the top while the aging effect of sealant will be more pronounced at the top as well. Consequently, adhesion or cohesion failures might initiate at the top, if they occur.
4. Daily and annual variations of joint movements are quite small, and there is no reason for larger joint width as a joint seal reservoir. In addition, concrete keeps shrinking, with resulting increase in joint width. Accordingly, joint width at transverse contraction joints can be reduced to 1/8-in, with one cut only, which will reduce the time and cost involved in joint installations.
5. Concrete swells when wet from rain, resulting in the decrease in joint width. However, subsequent drying once rain stops continues to increase joint width.

D. Joint Condition Evaluation Method

1. Currently, there are no good methods for the evaluation of joint seal condition. The most widely used method that was adopted in this study has limitations. For example, missing sealant is automatically assumed to contribute to water infiltration. However, standing water was observed where joint sealant was missing. Also, determining stone intrusion is quite subjective, which could result in variations of the evaluation results.

2. Overall joint conditions in CPCD were good regardless of the joint sealant condition. Seal condition number (SCN) and seal rating (SR) do not appear to have a positive correlation with joint or pavement performance.

3. Missing sealant at longitudinal contraction joints does not seem to negatively affect the pavement performance. It appears that tight widths of the joints by tie bars and transverse steel in the case of CRCP keep the joints closed, preventing water or incompressible materials from getting into the joints.
4. Sealant adhesion failures in CPCD were observed where joint movements appeared to be excessive due to faulting or cracks near joints. In Texas, the use of dowels and a stabilized base is required by design standards and pavement design guide, both of which minimize faulting or cracks. It is expected that adhesion failures in CPCD will be minimal if sealant is properly installed and CPCD is designed and built in accordance with TxDOT standards and specifications.
5. Even though no good correlations were observed between joint seal condition and pavement performance, separation of asphalt shoulder from concrete main lanes could adversely affect pavement performance. Efforts should be made to keep the longitudinal joints sealed to prevent water infiltration. Hot pour materials that have low modulus should be selected for the sealing of longitudinal joints between concrete main lane and asphalt shoulder.

It appears that the condition of joint sealant does not have substantial effects on overall performance of PCC pavement in Texas. This finding is in line with the findings in several state DOTs, such as Wisconsin and Minnesota. However, joint sealing has its own merit, such as keeping incompressible materials out of the joints. Even though the performance period of joint sealant is in the range of 10 years or less, which means joint sealant cannot keep water from getting into joints once the pavement reaches 10 years of service, sealants still can keep the incompressible materials out of joints.

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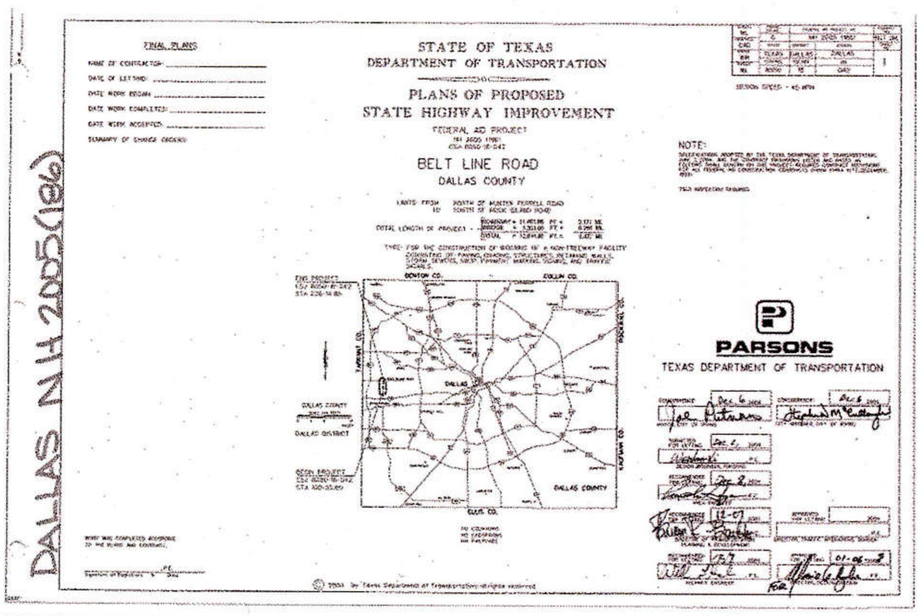
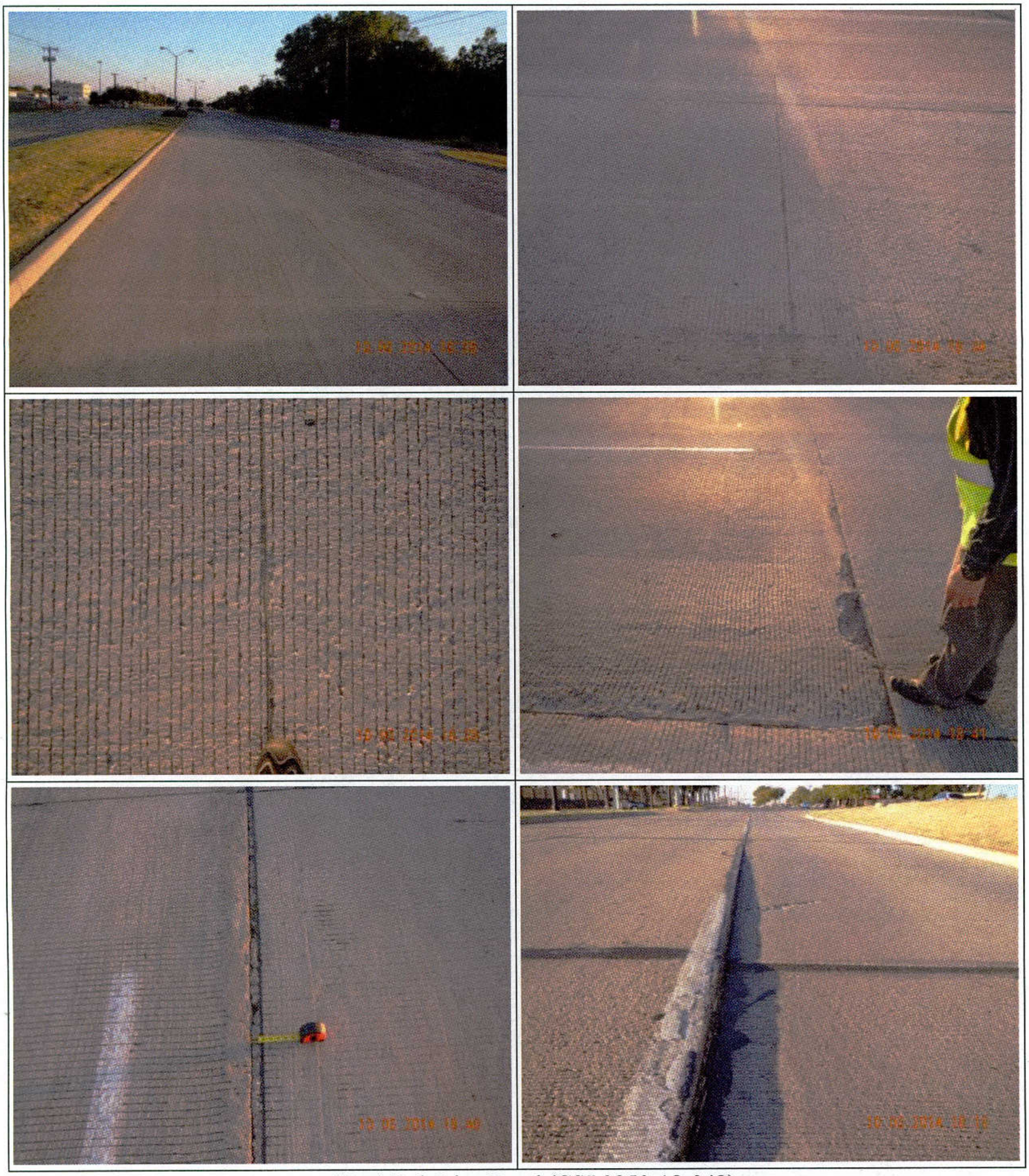
Appendix I Sealant Survey Information

No. 1 Belt Line Rd, Dallas District

Attribute	Information	Special Note
CSJ	8050-18-042	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	2009	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Mono curb	
Base Type	4-in. ASB [TY-B]	
Subgrade Type	6-in. LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details	CPCD-94	

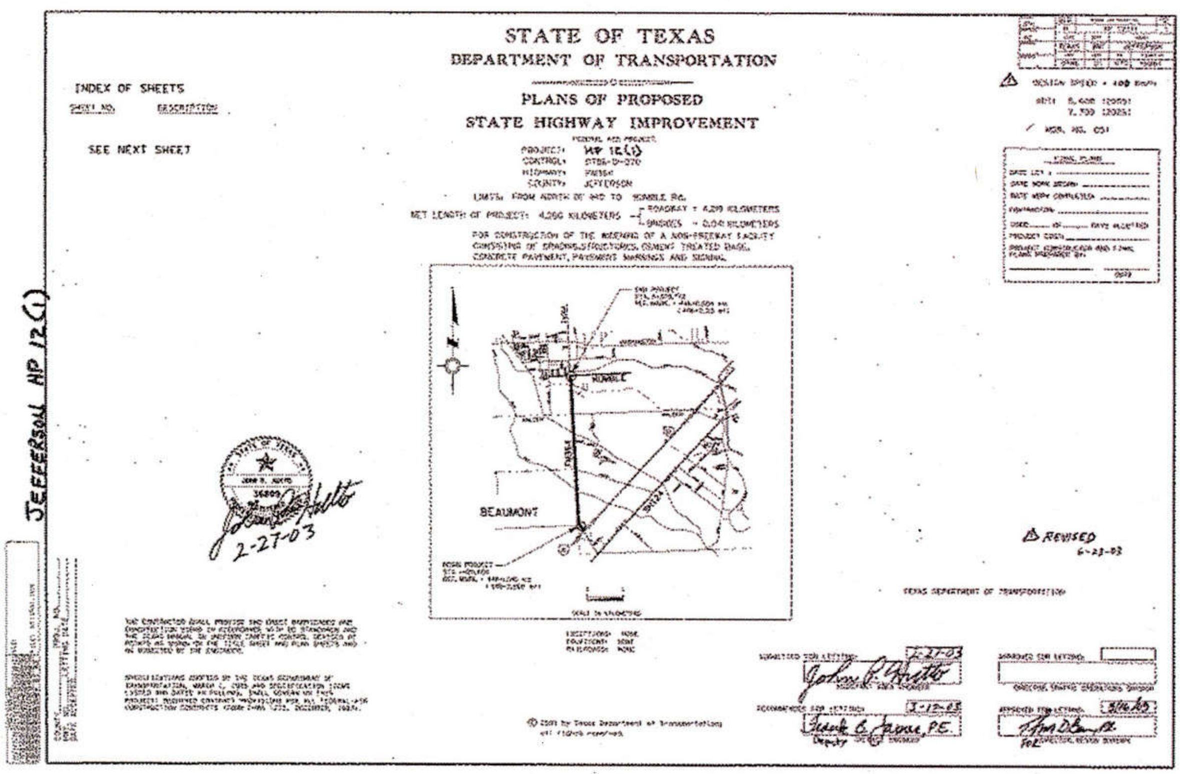




No.1 Belt Line Road (CSJ 0850-18-042)

No. 2 FM 364, Beaumont District

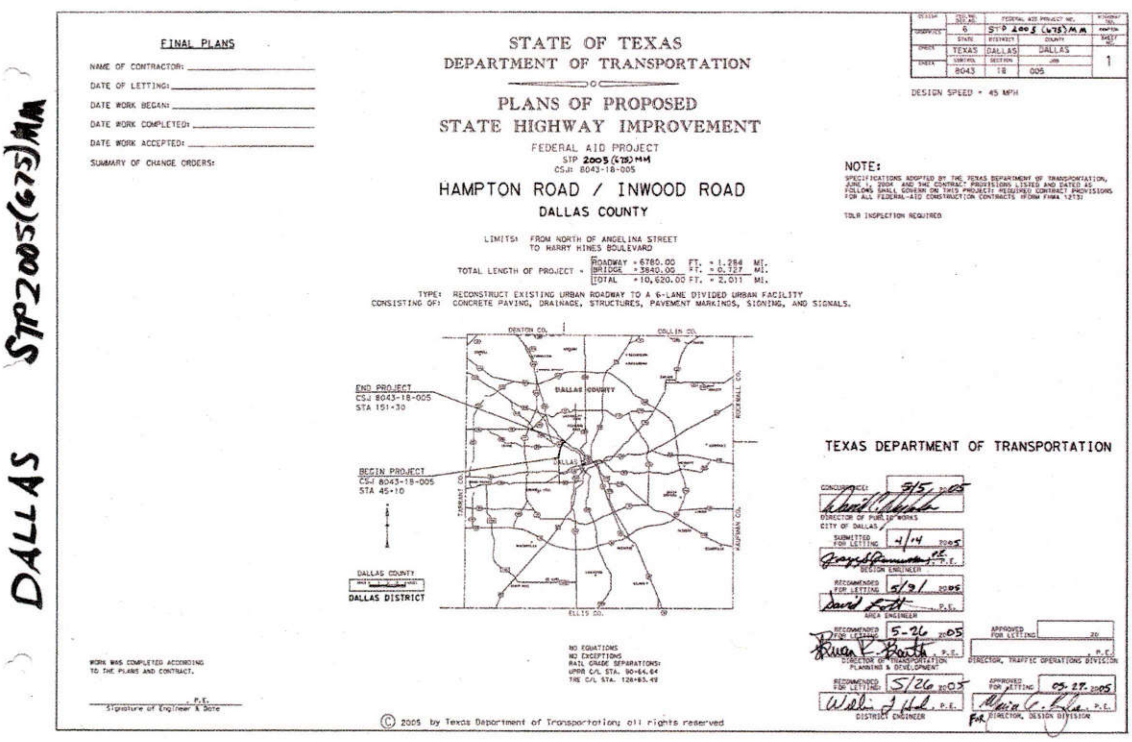
Attribute	Information	Special Note
CSJ	0786-01-070	
County	Jefferson	
Reference Marker	RM 446+0.85 - 449+0.54	
GPS Coordinates		
Construction Year	2005	
Pavement Type	CPCD	
Slab thickness	12-in.	
Shoulder Type	Tied Concrete	
Base Type	1-in AC+6-in CSB	
Subgrade Type	6-in. LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.2 FM 364 (CSJ 0786-01-070)

No. 3 Inwood Rd, Dallas District

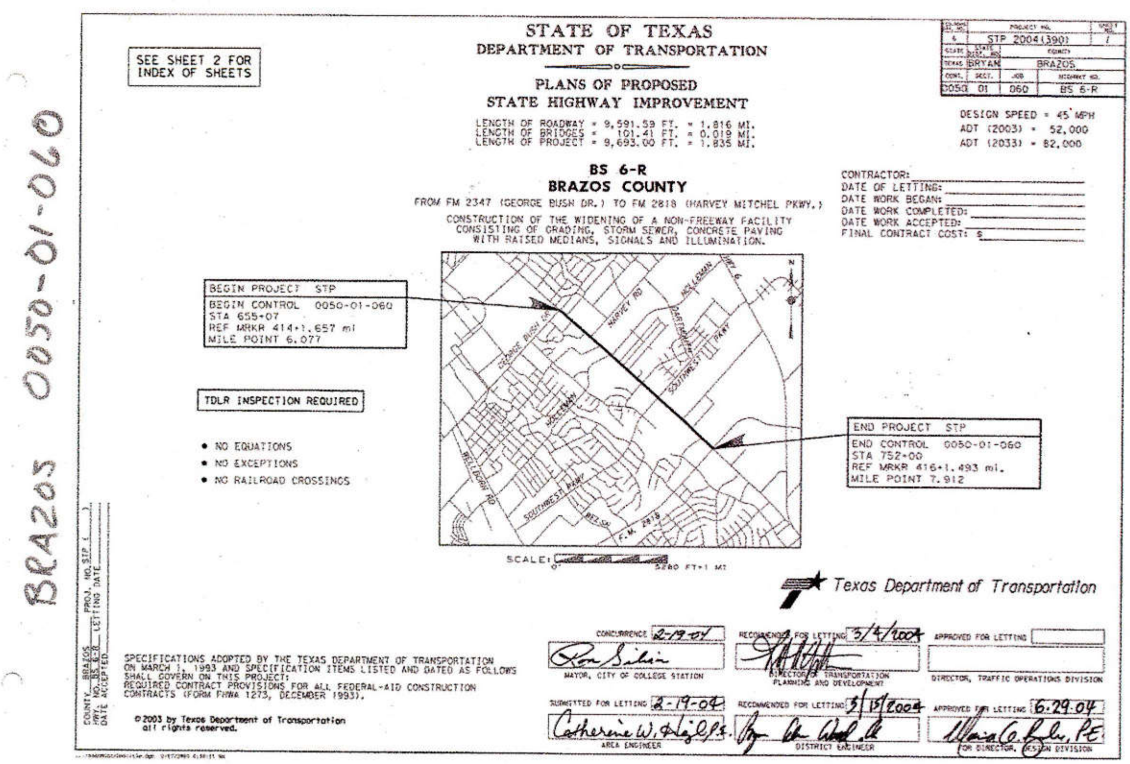
Attribute	Information	Special Note
CSJ	8043-18-005	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	2007	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type	Mono Curb	
Base Type	4-in ASB [TY-B]	
Subgrade Type	24-in. LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.3 Inwood Rd (CSJ 8043-18-005)

No. 4 BS 6 –R, Bryan District

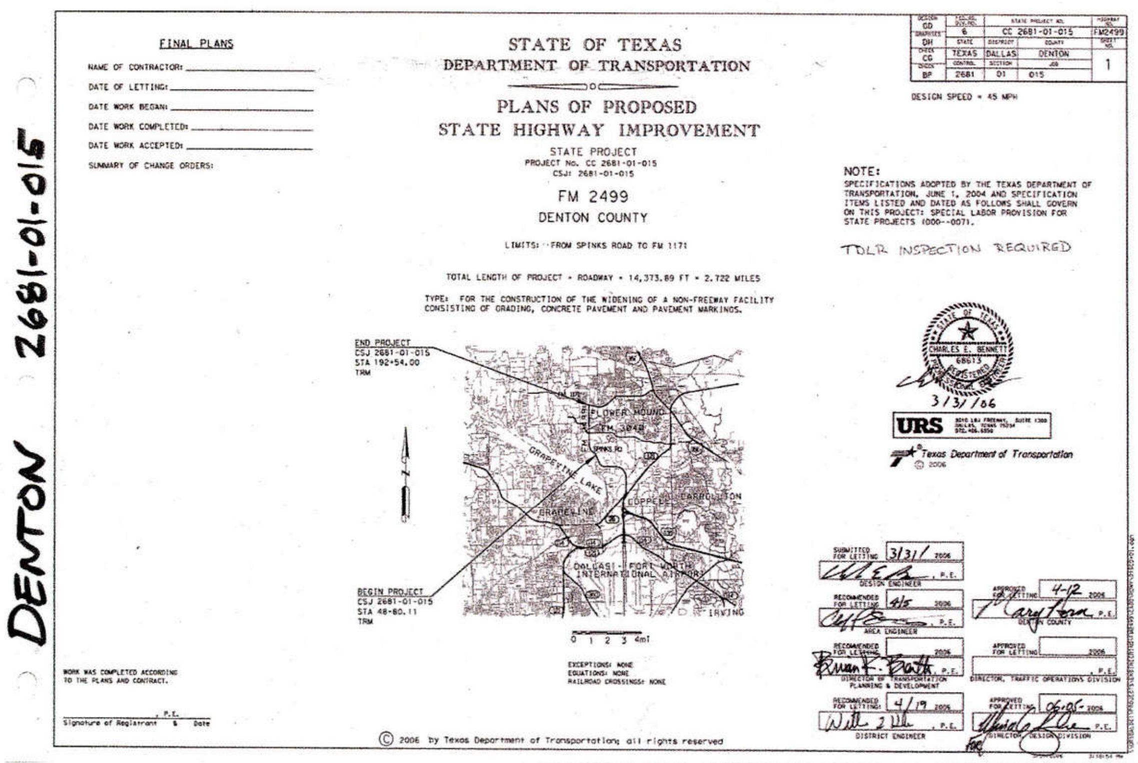
Attribute	Information	Special Note
CSJ	0050-01-060	
County	Brazos	
Reference Marker	RM 415+0.657 - RM 417+0.493	
GPS Coordinates		
Construction Year	2009	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type	TY-II Curb	
Base Type	1.5-in Bond Breaker	
Subgrade Type	Existing CPCD	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.4 BS 6-R (CSJ 0050-01-060)

No. 5 FM 2499, Dallas District

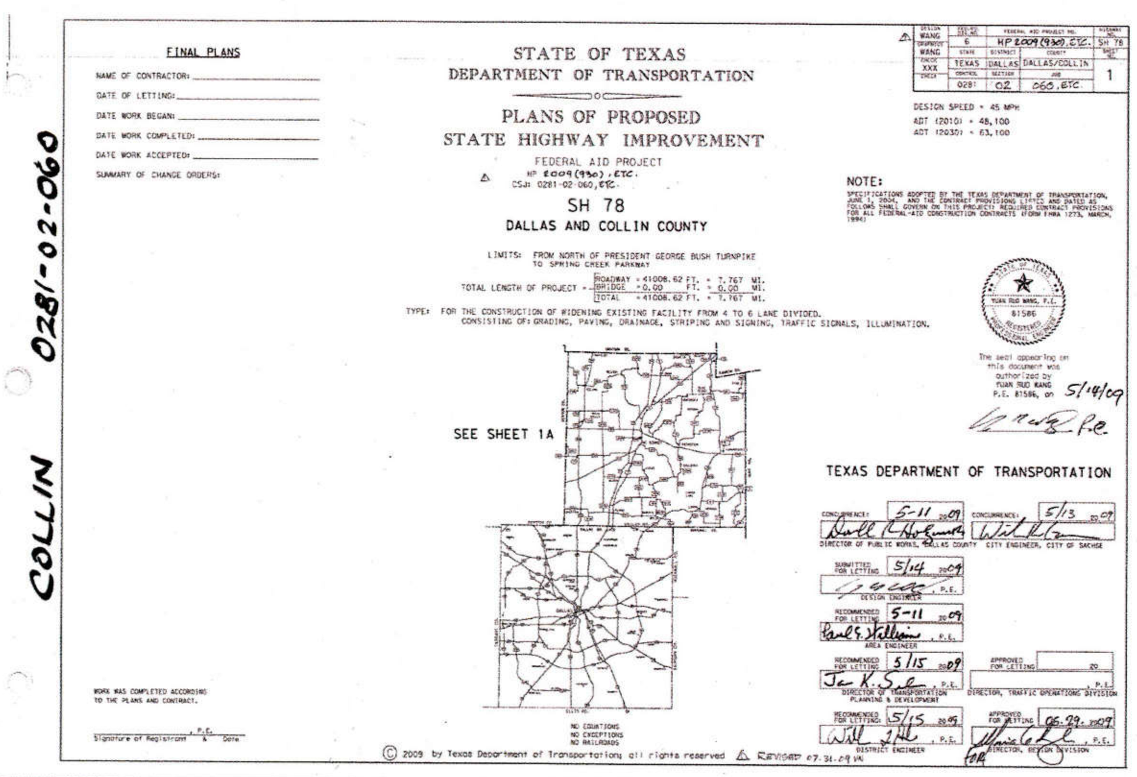
Attribute	Information	Special Note
CSJ	2681-01-015	
County	Denton	
Reference Marker	RM 246+0.7 - RM 246+0.7	
GPS Coordinates		
Construction Year	2008	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type	Curb	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in. LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

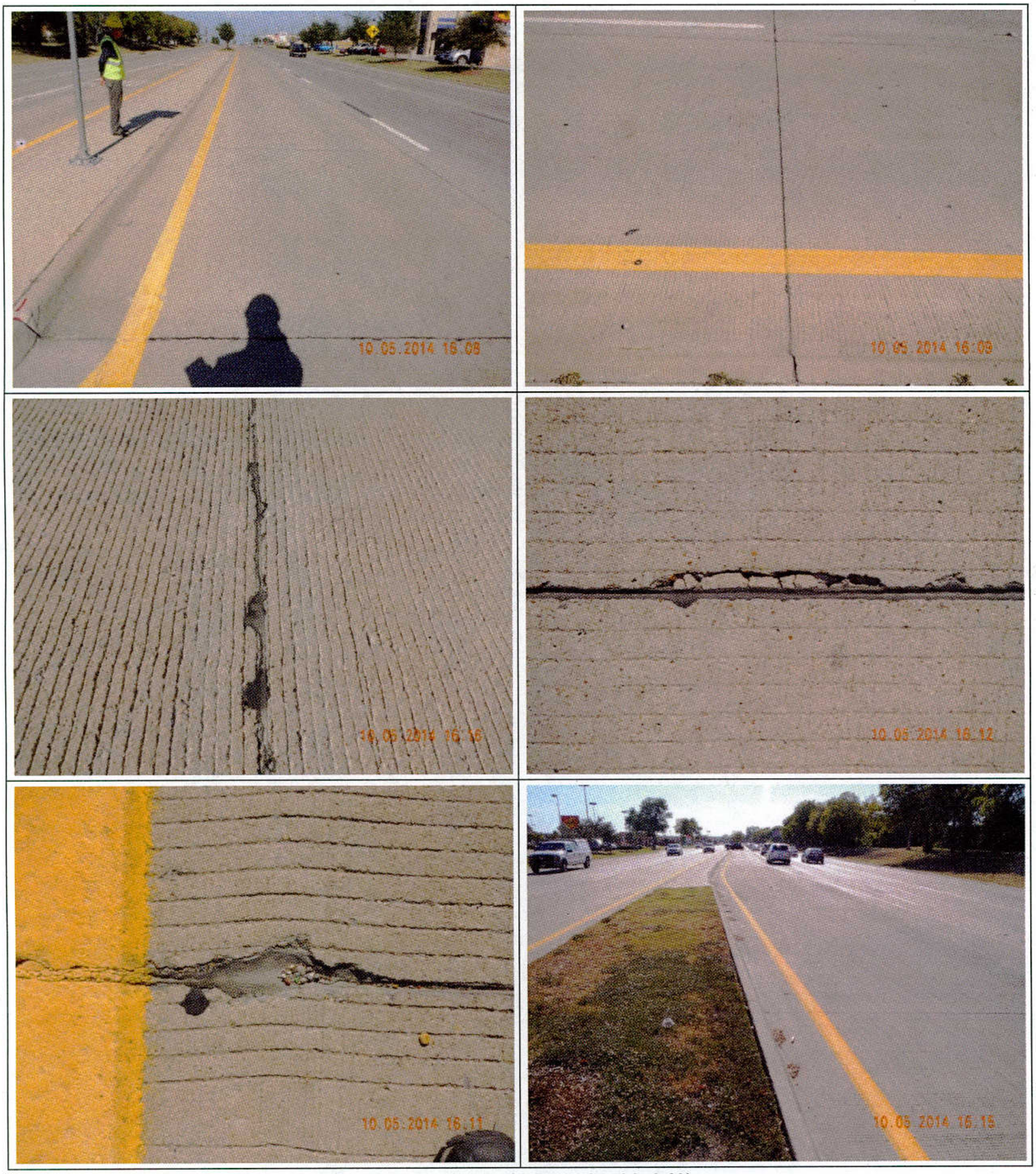


No.5 FM 2499 (CSJ 2681-01-015)

No. 6 SH 78, Dallas District

Attribute	Information	Special Note
CSJ	0281-02-060	
County	Collin	
Reference Marker	RM 264+0.774 - RM 272+0.425	
GPS Coordinates		
Construction Year	2011	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	TY-I Curb	
Base Type	4-in ASB	
Subgrade Type	12-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

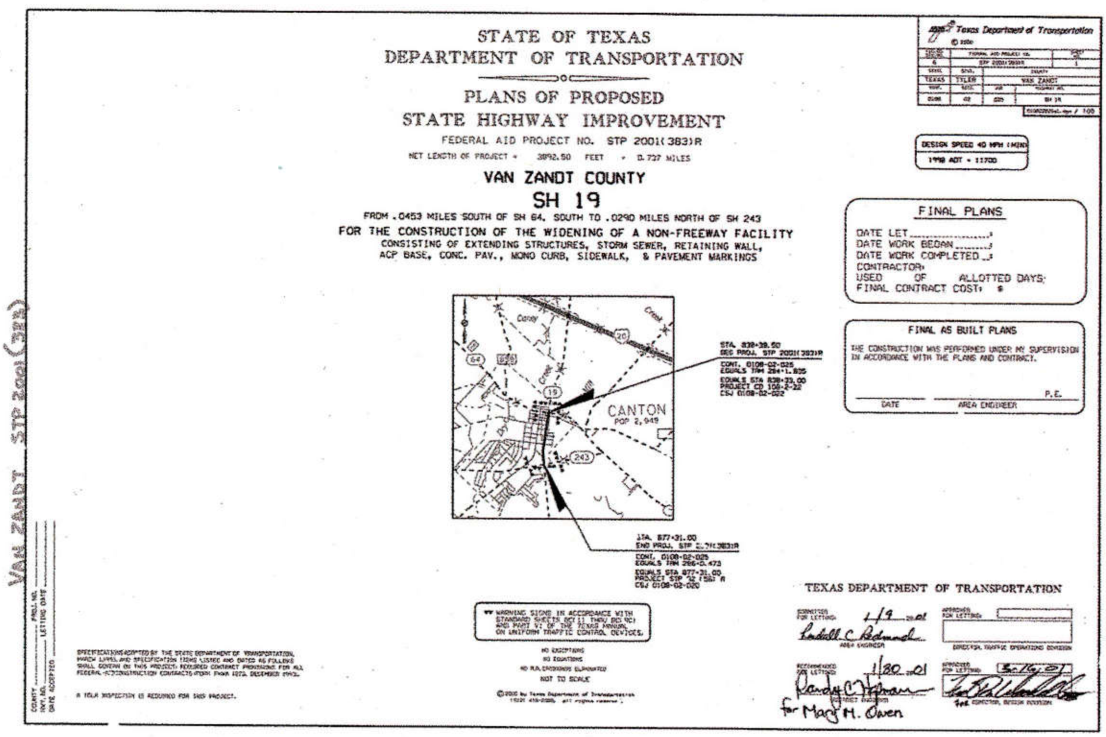




No.6 SH 78, (CSJ 0281-02-060)

No. 7 SH 19, Tyler District

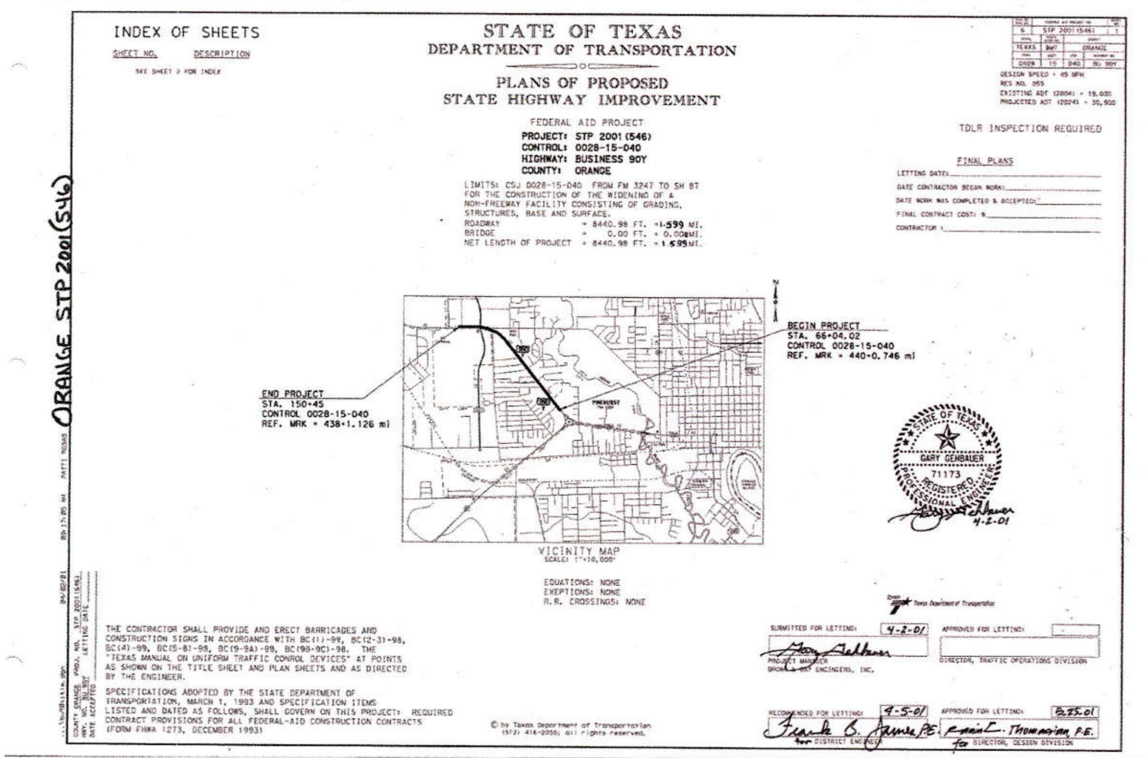
Attribute	Information	Special Note
CSJ	0108-02-025	
County	Van Zandt	
Reference Marker	RM 285+0.805 - RM 286+0.473	
GPS Coordinates		
Construction Year	2003	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	TY-I Curb	
Base Type	4-in ASB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.7 SH 19, (CSJ 0108-02-025)

No. 8 BU 90-Y, Beaumont District

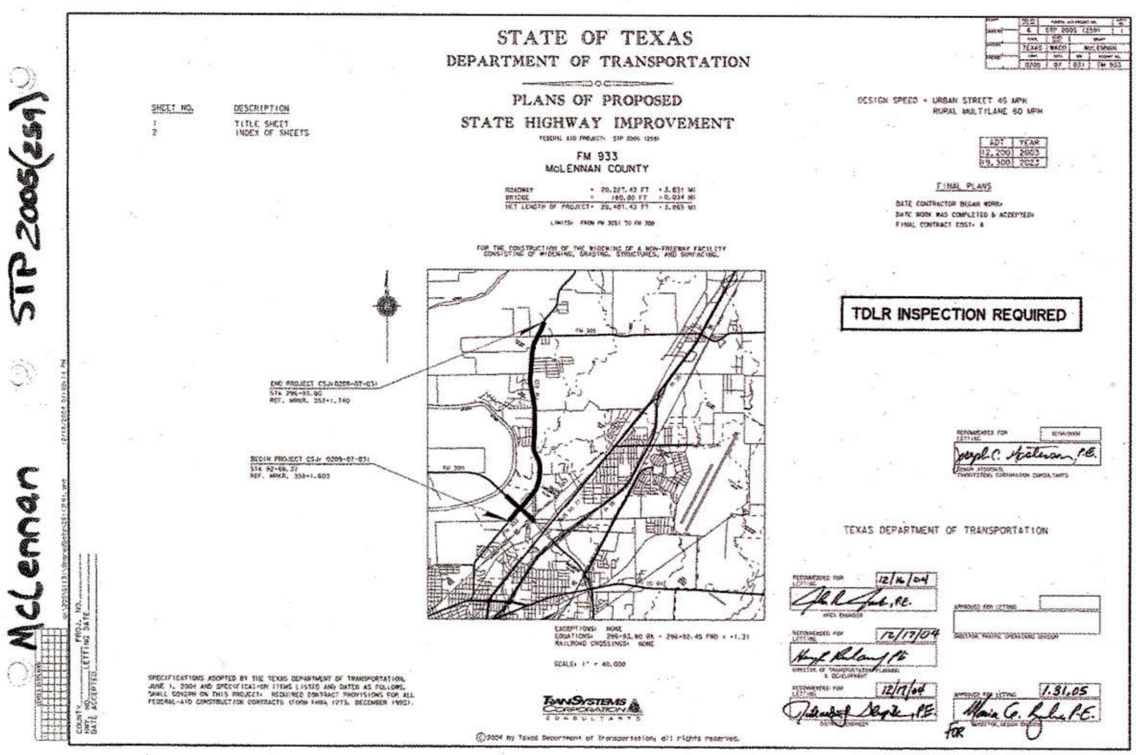
Attribute	Information	Special Note
CSJ	0028-15-040	
County	Orange	
Reference Marker	RM 439+0.126 - RM 440+0.746	
GPS Coordinates		
Construction Year	2005	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	TY-P Mono Curb	
Base Type	1-in AC+6-in CSB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.8 BU 90-Y, (CSJ 0028-15-040)

No. 9 FM 933, Waco District

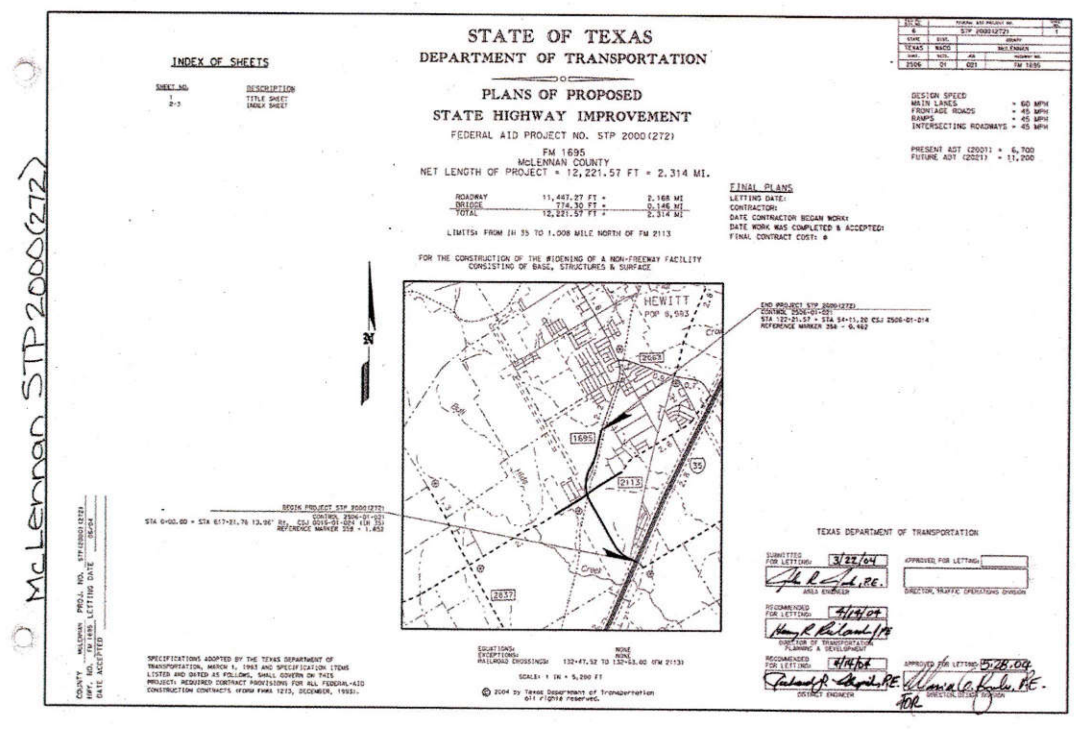
Attribute	Information	Special Note
CSJ	0209-07-031	
County	McLennan	
Reference Marker	RM 353+0.740 - RM 357+0.603	
GPS Coordinates		
Construction Year	2009	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	6-in ASB [TY-B]	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.9 FM 933, (CSJ 0209-07-031)

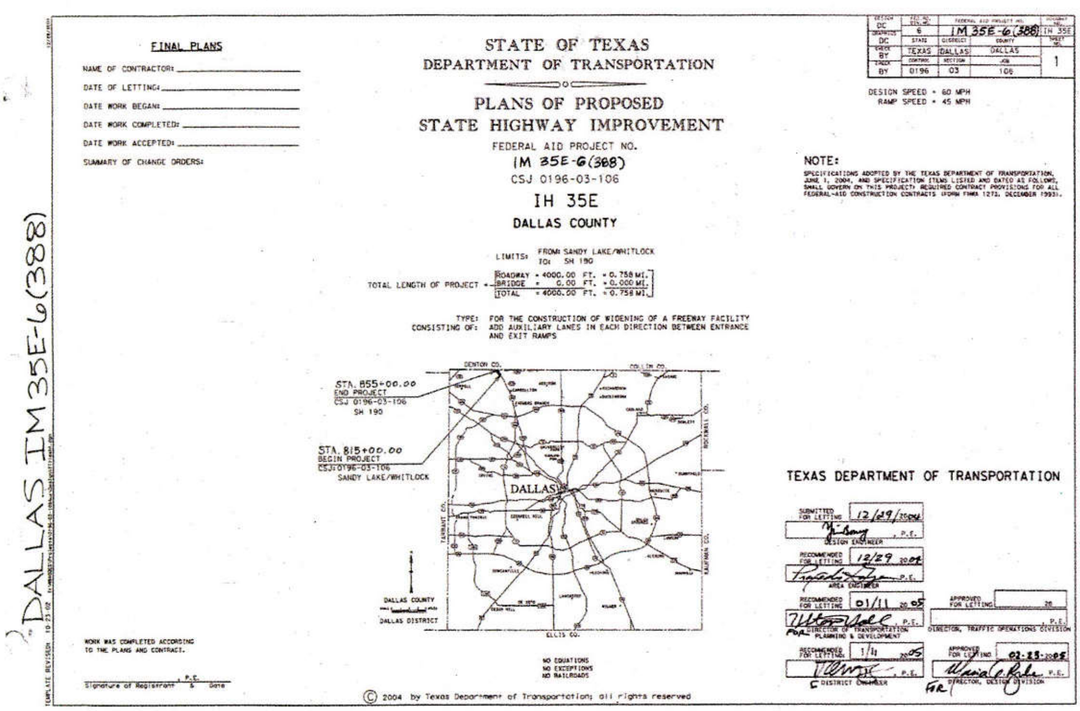
No. 10

Attribute	Information	Special Note
CSJ	2506-01-021	
County	McLennan	
Reference Marker		
GPS Coordinates		
Construction Year	2009	
Pavement Type	CPCD	
Slab thickness	10-in	
Shoulder Type		
Base Type	3-in Type B, AC Bond Breaker	
Subgrade Type	8-in LTS	
Drainage Type	Flat bottom Ditch	
Coarse Aggregate Type		
Con. Pavement Details		



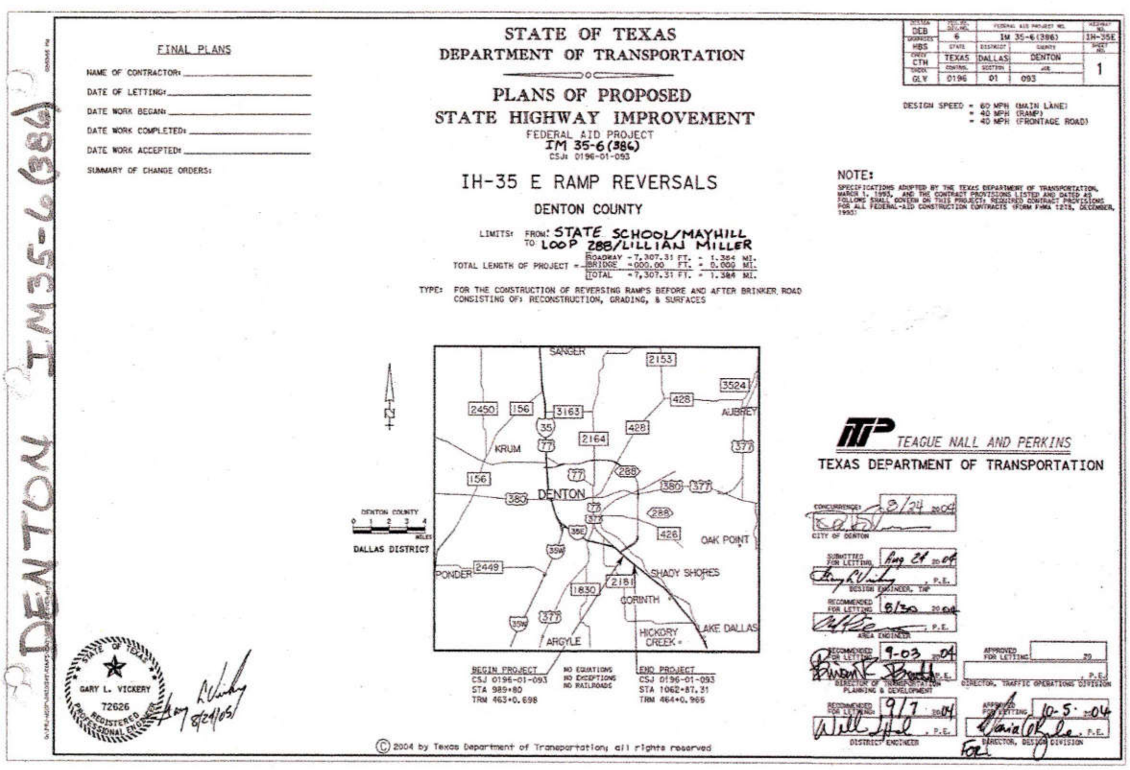
No. 11 IH 35E, Dallas District

Attribute	Information	Special Note
CSJ	0196-03-106	
County	Dallas	
Reference Marker	RM 445+0.242 - RM 446	
GPS Coordinates		
Construction Year	2007	
Pavement Type	CPCD	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 12 IH 35E, Dallas District

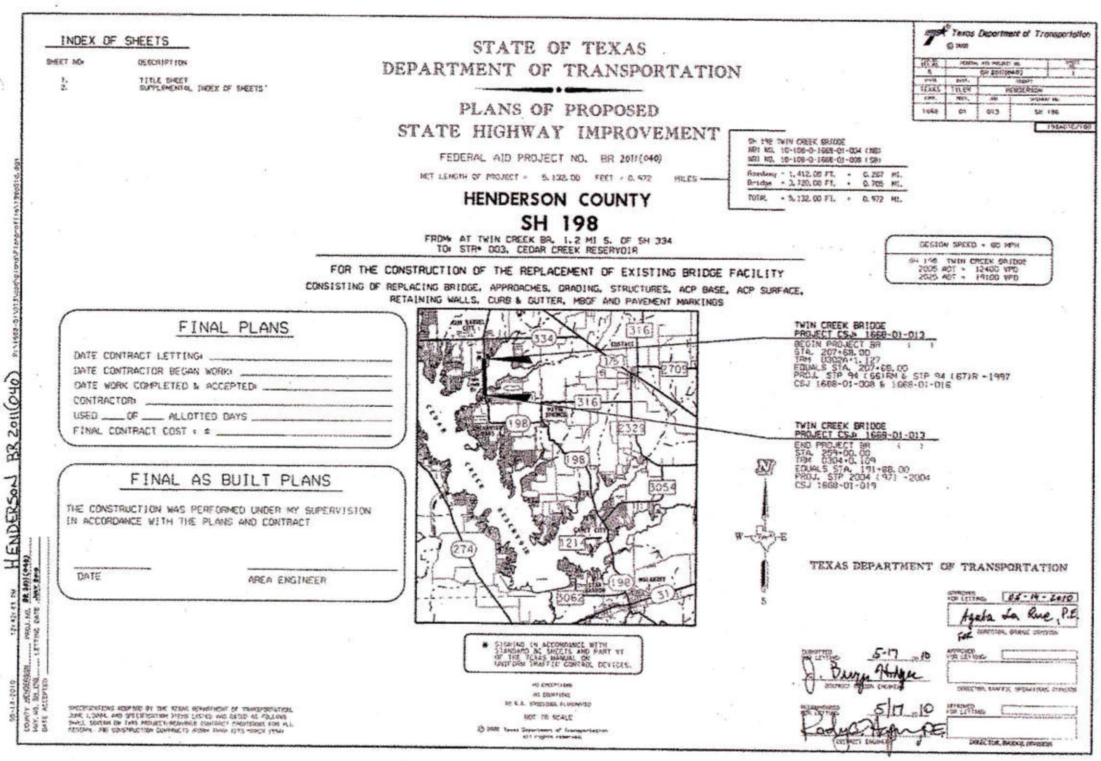
Attribute	Information	Special Note
CSJ	0196-01-093	
County	Denton	
Reference Marker	RM 463+0.698 - RM 464+0.966	
GPS Coordinates		
Construction Year	2006	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in CTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.12 IH 35E, (CSJ 0196-01-093)

No. 13 SH 198, Tyler District

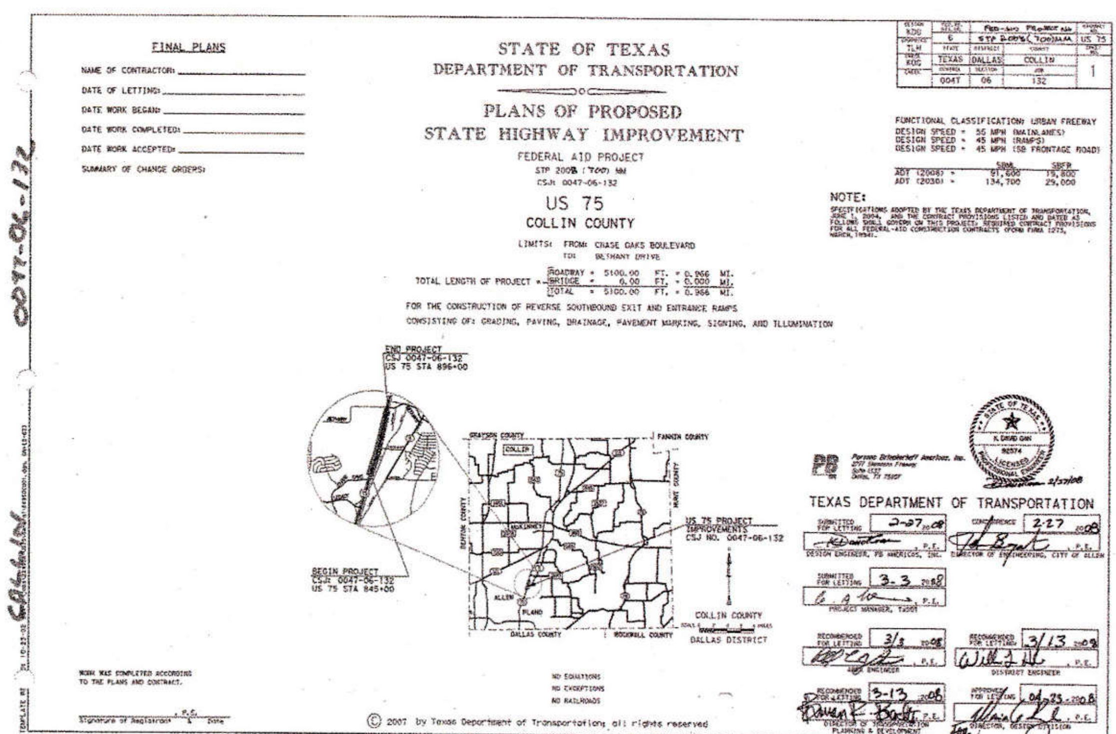
Attribute	Information	Special Note
CSJ	1668-01-013	
County	Henderson	
Reference Marker	RM 303A+0.127 - RM 304+0.109	
GPS Coordinates		
Construction Year	2012	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	4-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.13 SH 198, (CSJ 1668-01-013)

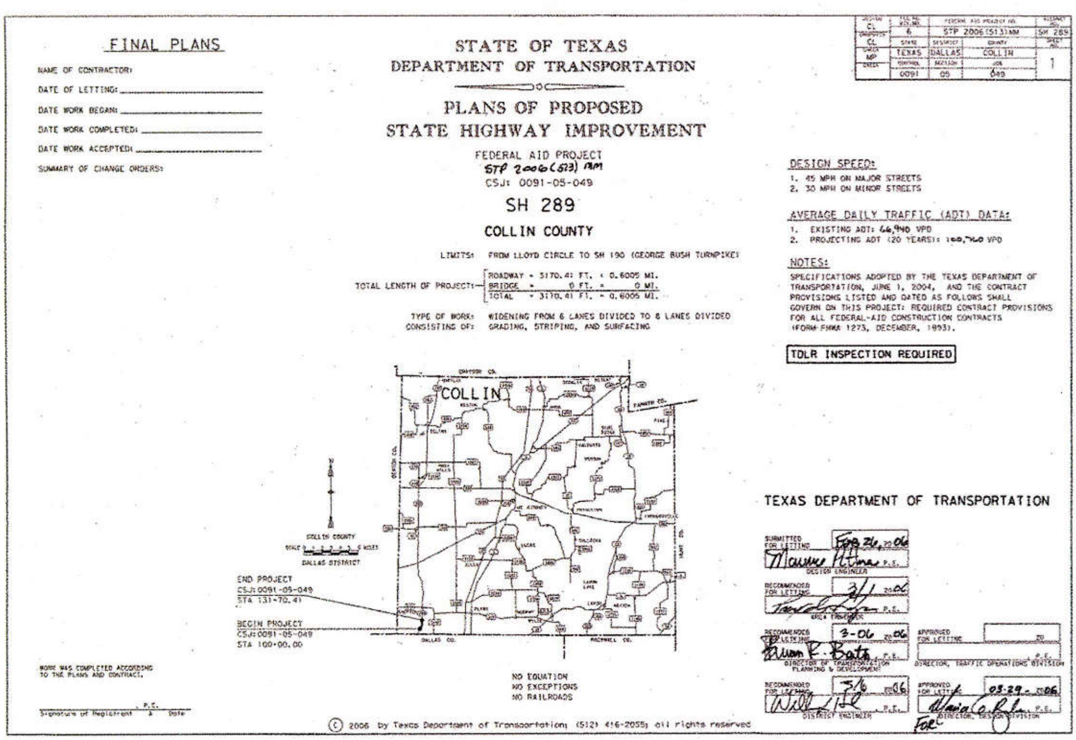
No. 14 US 75, Dallas District

Attribute	Information	Special Note
CSJ	0047-06-132	
County	Collin	
Reference Marker	RM 247+0.034 - RM 248	
GPS Coordinates		
Construction Year	2009	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Tied Concrete	
Base Type	2.5-in ASB [TY-B]	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 15 SH 289, Dallas District

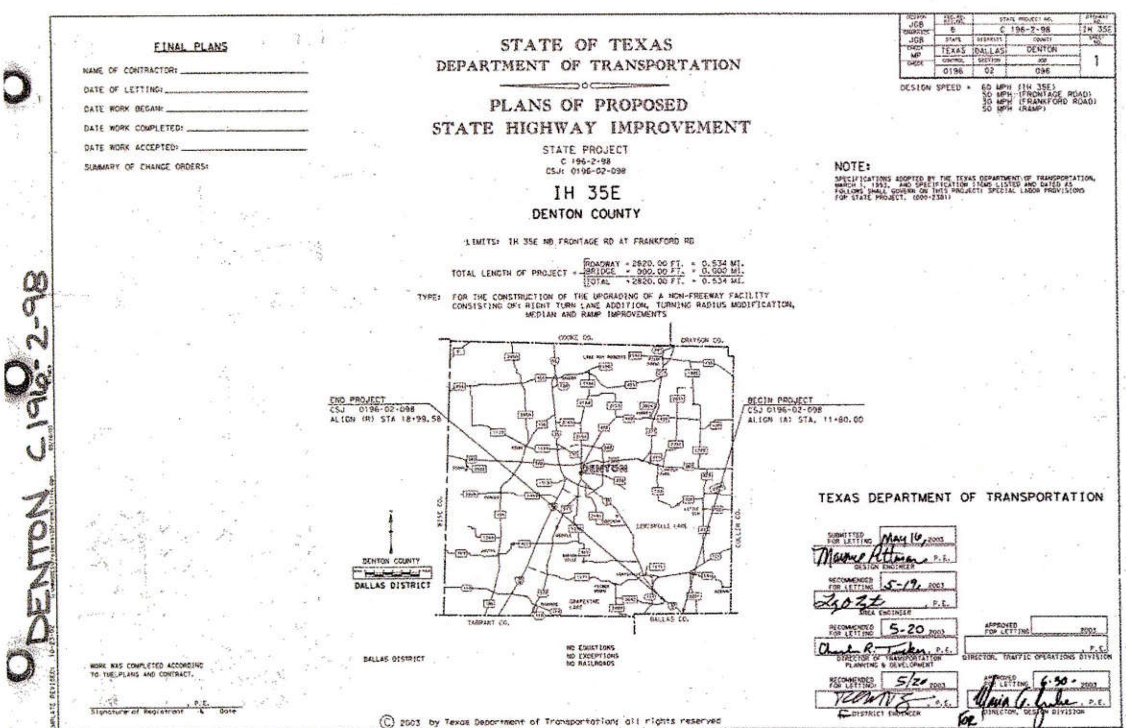
Attribute	Information	Special Note
CSJ	0091-05-049	
County	Collin	
Reference Marker	RM 254 - RM 254+0.6005	
GPS Coordinates		
Construction Year	2007	
Pavement Type	CPCD	
Slab thickness	12-in.	
Shoulder Type	Curb	
Base Type	2-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.15 SH 289, (CSJ 0091-05-049)

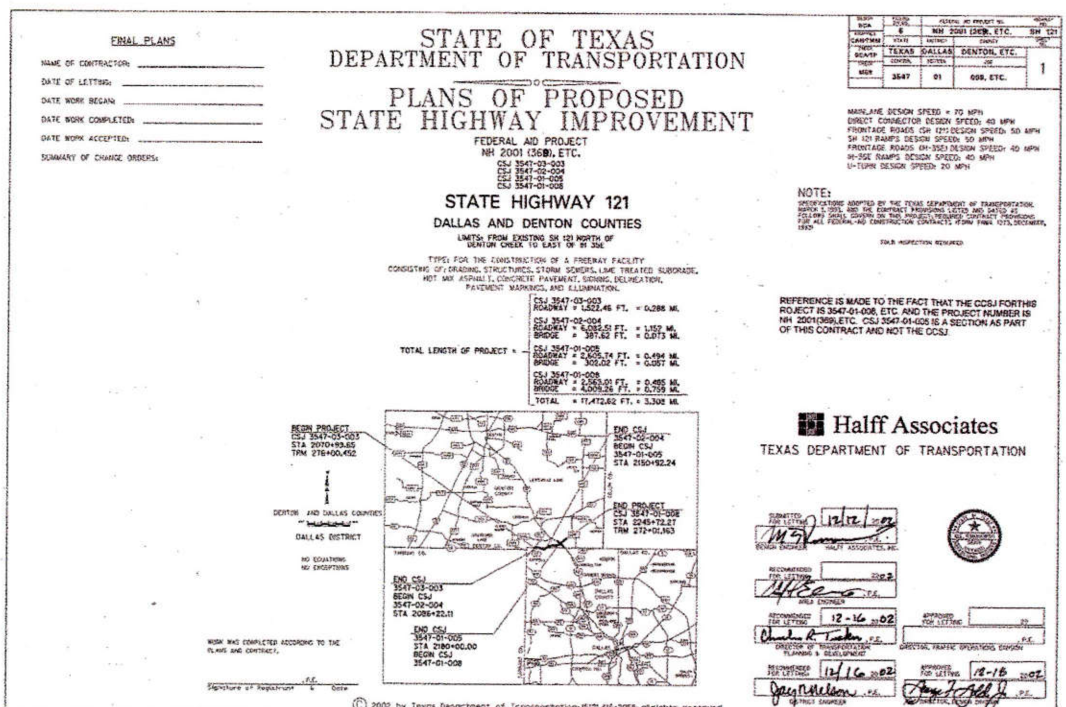
No. 16 IH 35E, Dallas District

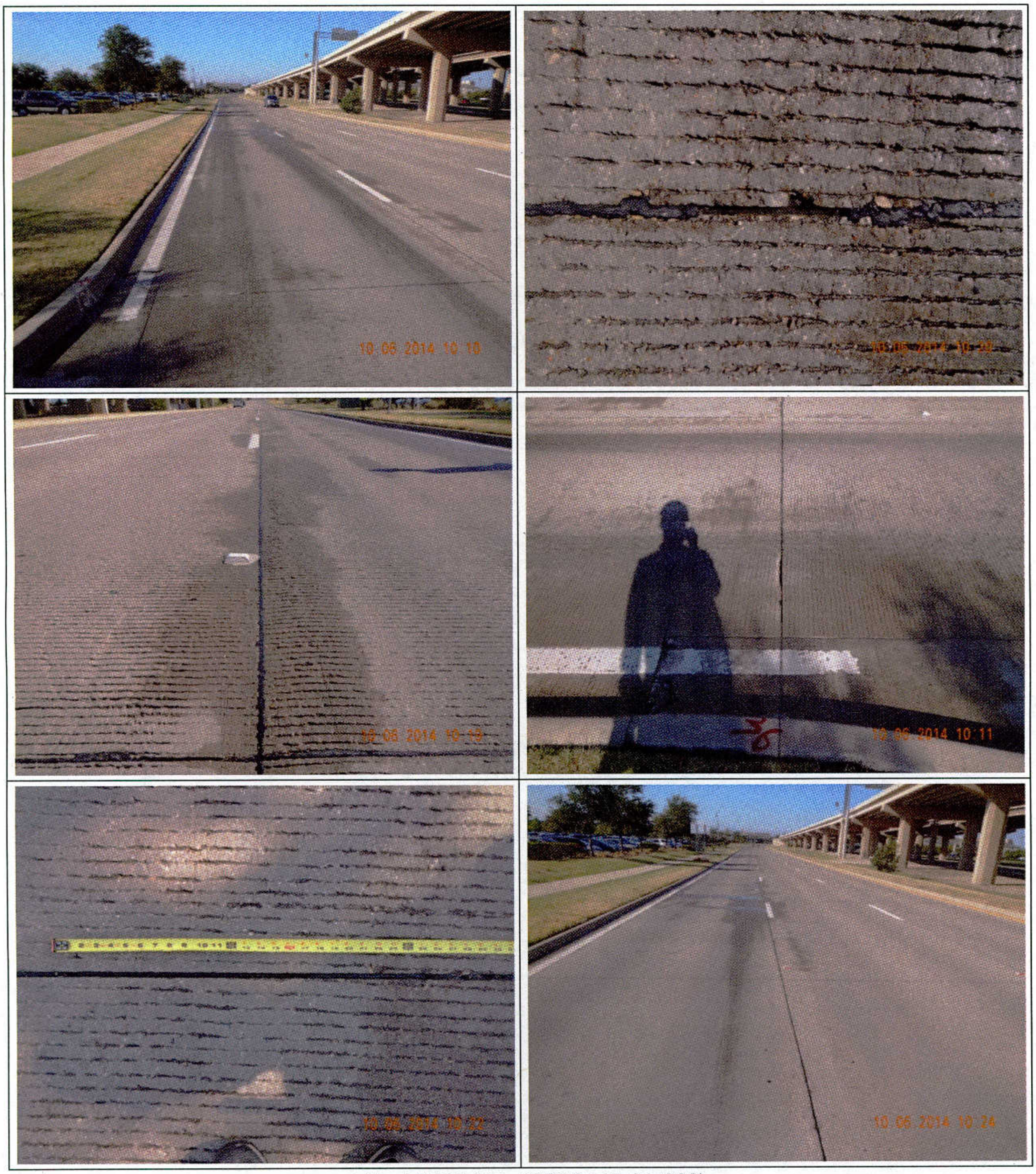
Attribute	Information	Special Note
CSJ	0196-02-098	
County	Denton	
Reference Marker	RM 446 - RM 446+0.534	
GPS Coordinates		
Construction Year	2004	
Pavement Type	CPCD	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 17 SH 121, Dallas District

Attribute	Information	Special Note
CSJ	3547-01-008	
County	Denton	
Reference Marker	RM 273+0.163 - RM 274+0.676	
GPS Coordinates		
Construction Year	2007	
Pavement Type	CPCD	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

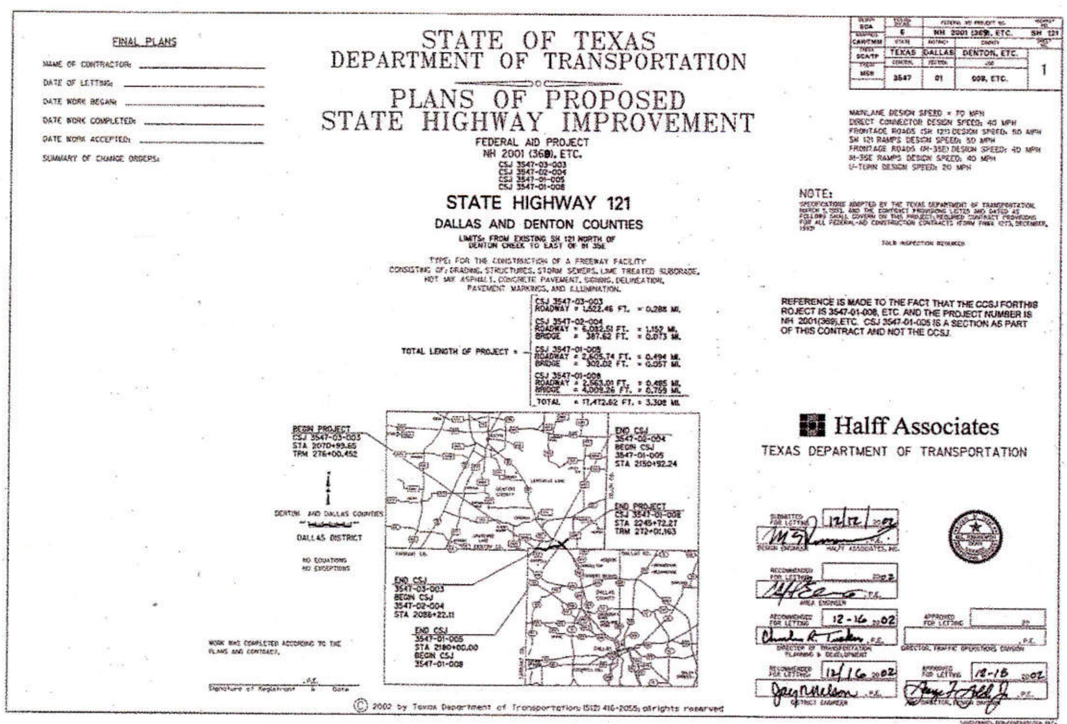


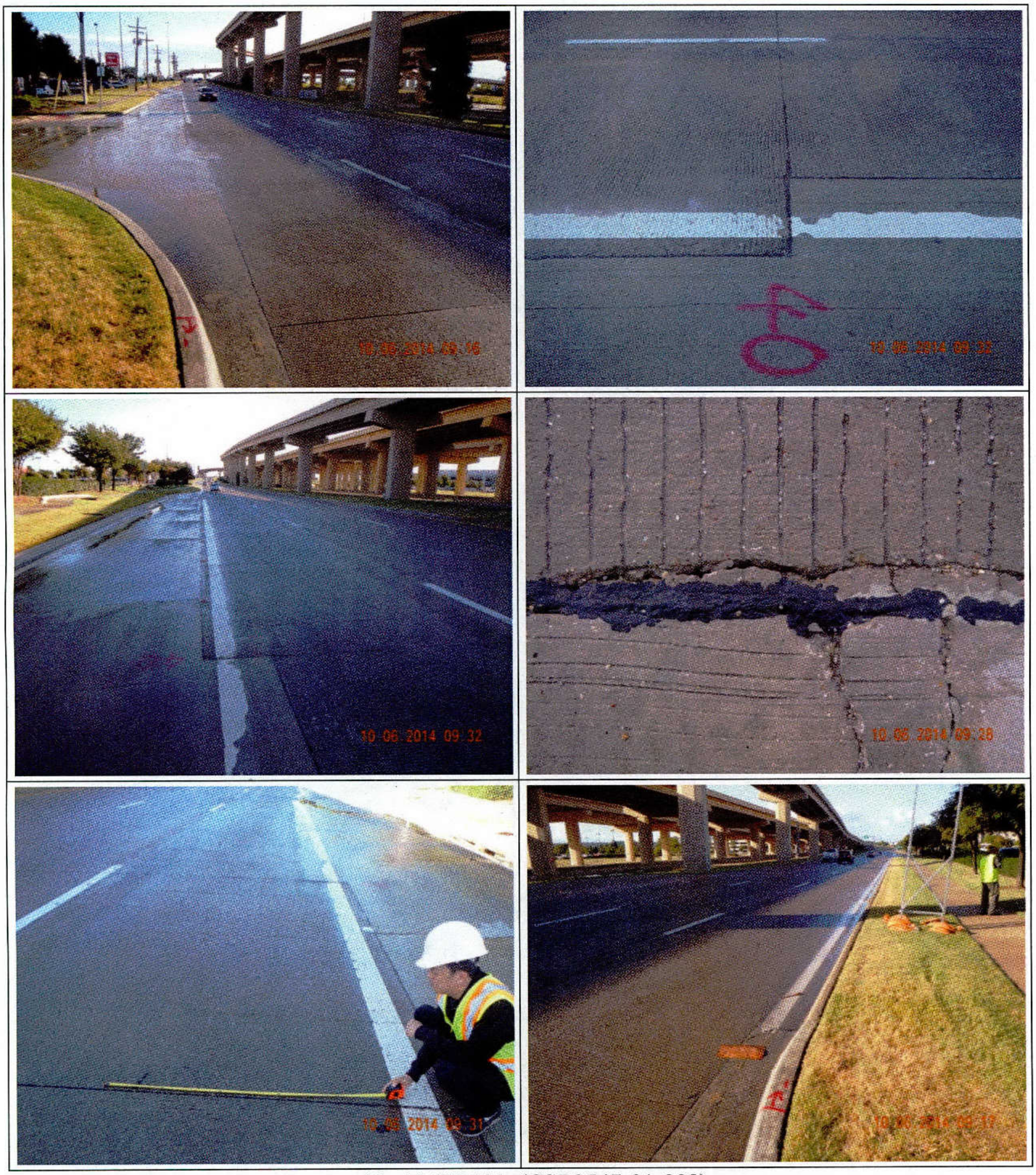


No.17 SH 121, (CSJ 3547-01-008)

No. 18 SH 121, Dallas District

Attribute	Information	Special Note
CSJ	3547-01-008	
County	Denton	
Reference Marker		
GPS Coordinates		
Construction Year		
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	4-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

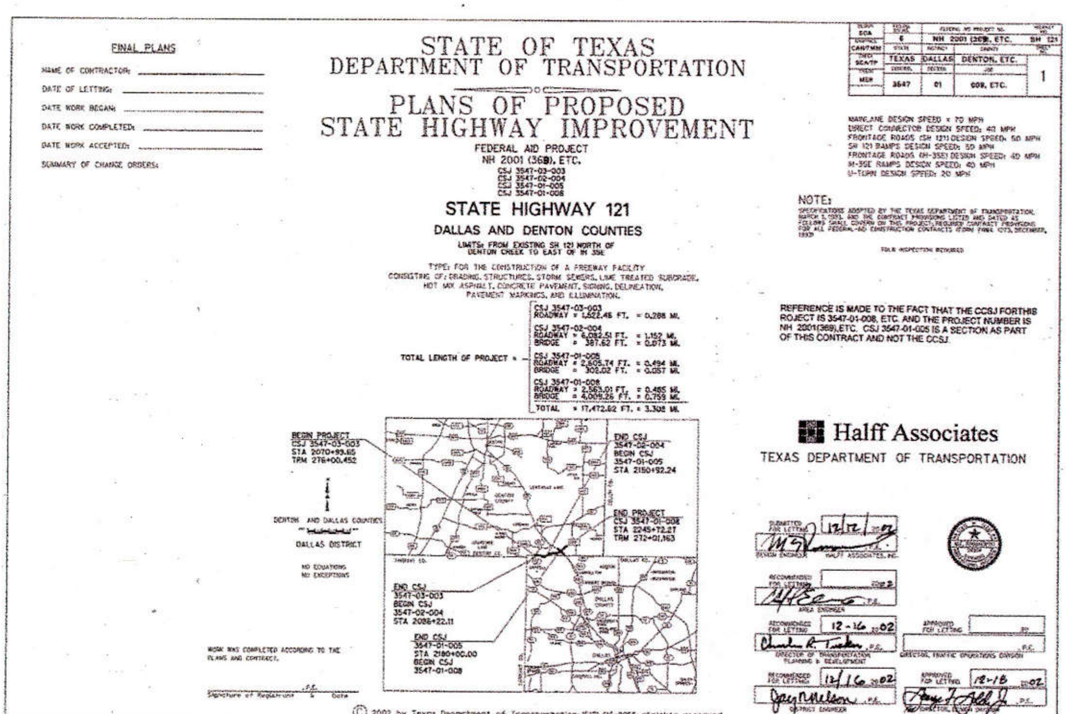




No.18 SH 121, (CSJ 3547-01-008)

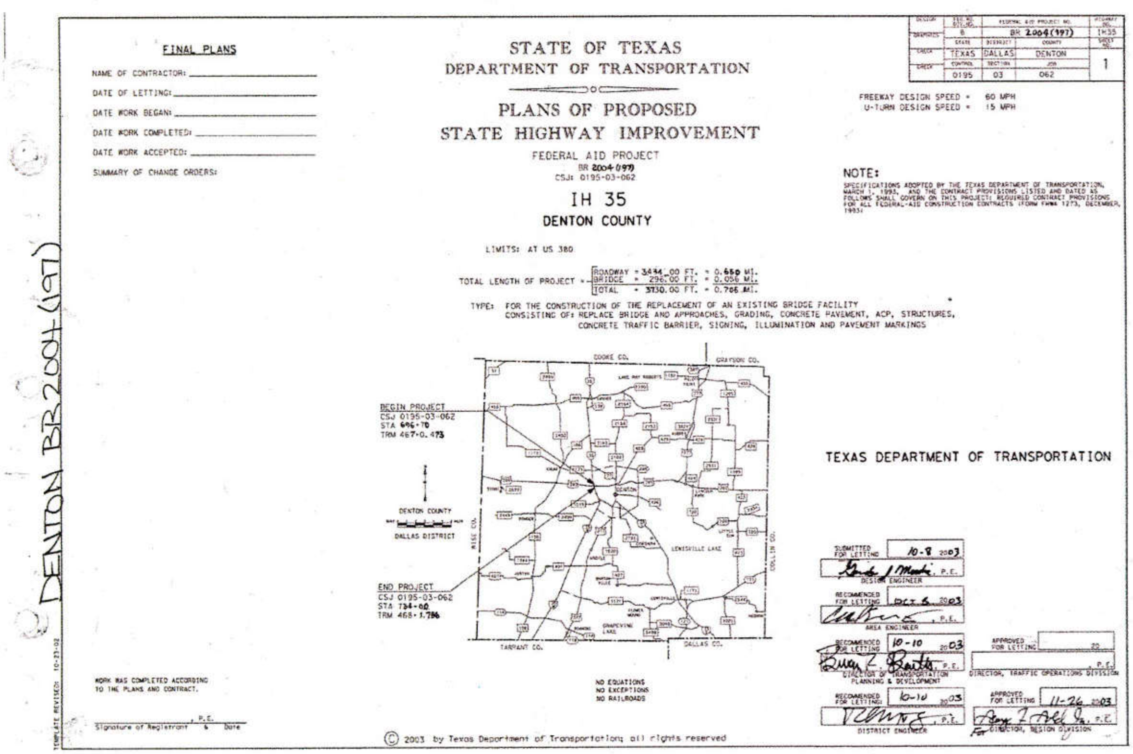
No. 19 SH 121, Dallas District

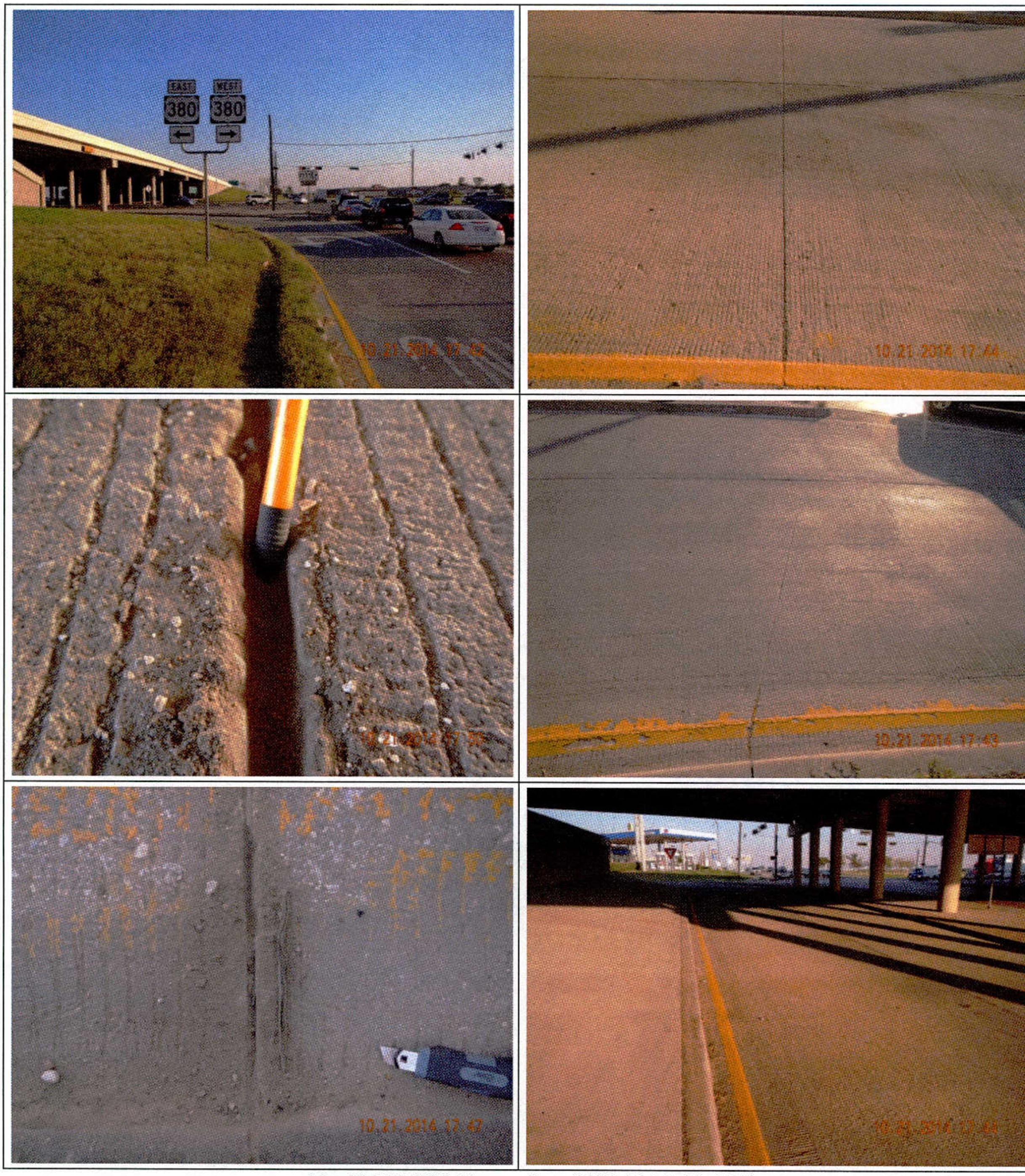
Attribute	Information	Special Note
CSJ	3547-01-008	
County	Denton	
Reference Marker		
GPS Coordinates		
Construction Year		
Pavement Type	CRCP	
Slab thickness	8-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	2-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 20 US 380 U-Turn Ln, Dallas District

Attribute	Information	Special Note
CSJ	0195-03-062	
County	Denton	
Reference Marker	RM 467+0.473 - RM 274+0.676	
GPS Coordinates		
Construction Year	2005	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	4-in ASB	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

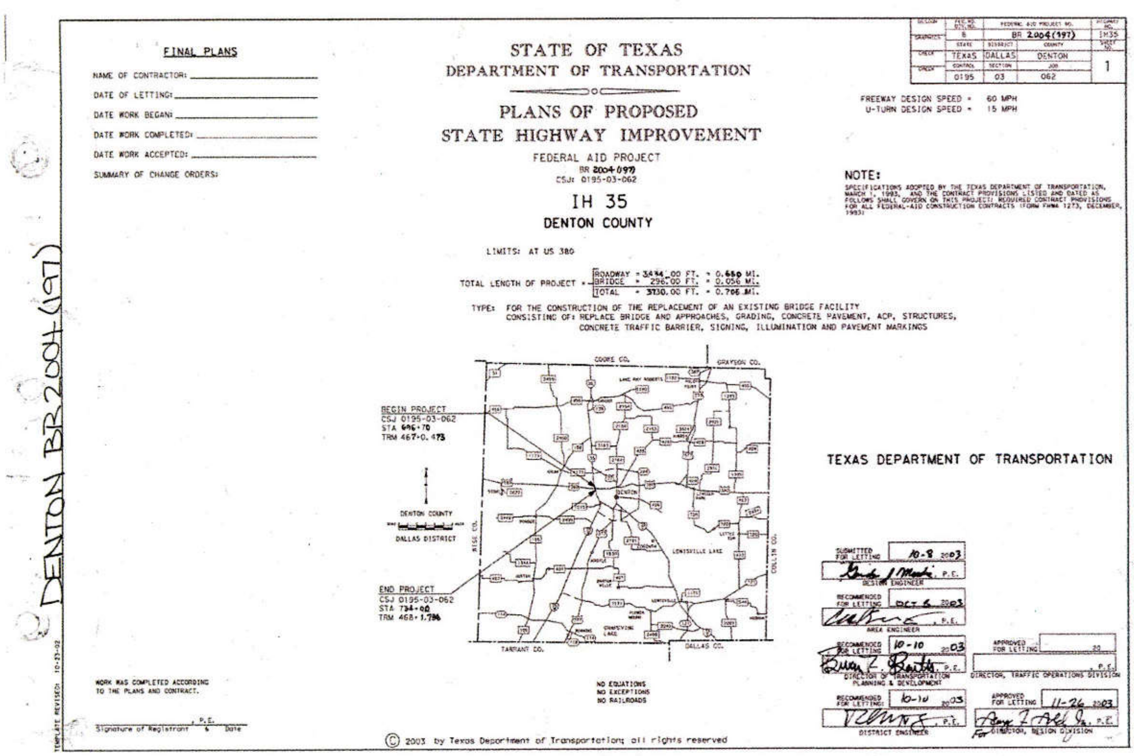




No.20 US 380 U-turn Ln, (CSJ 0195-03-062)

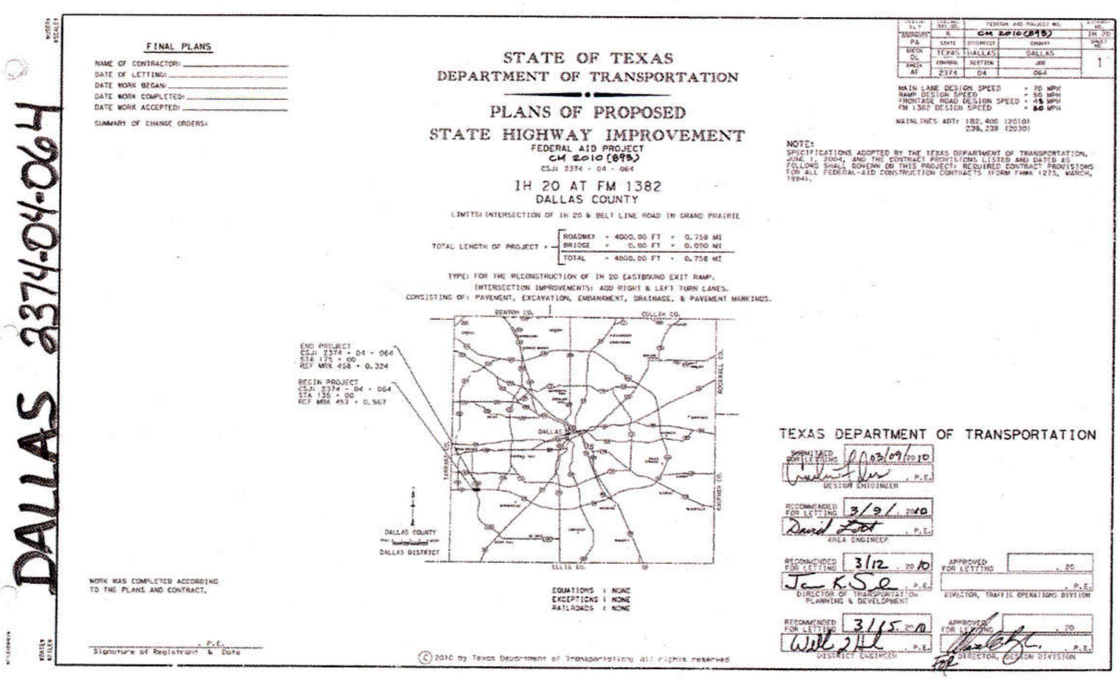
No. 21 IH35E, Dallas District

Attribute	Information	Special Note
CSJ	0195-03-062	
County	Denton	
Reference Marker	RM 467+0.473 - RM 274+0.676	
GPS Coordinates		
Construction Year	2005	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Tied Concrete	
Base Type	6-in ASB [TY-B]	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



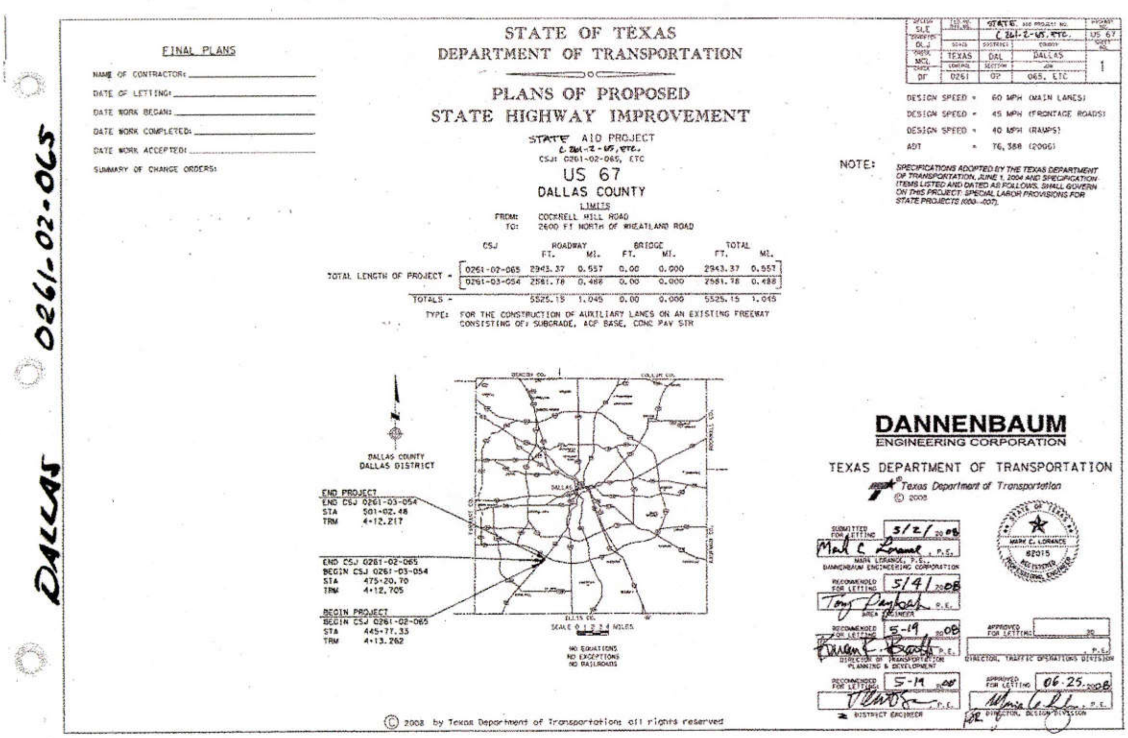
No. 22

Attribute	Information	Special Note
CSJ	2374-04-064	
County	Dallas County	
Reference Marker		
GPS Coordinates		
Construction Year	2012	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type		
Base Type		
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 23 US 67, Dallas District

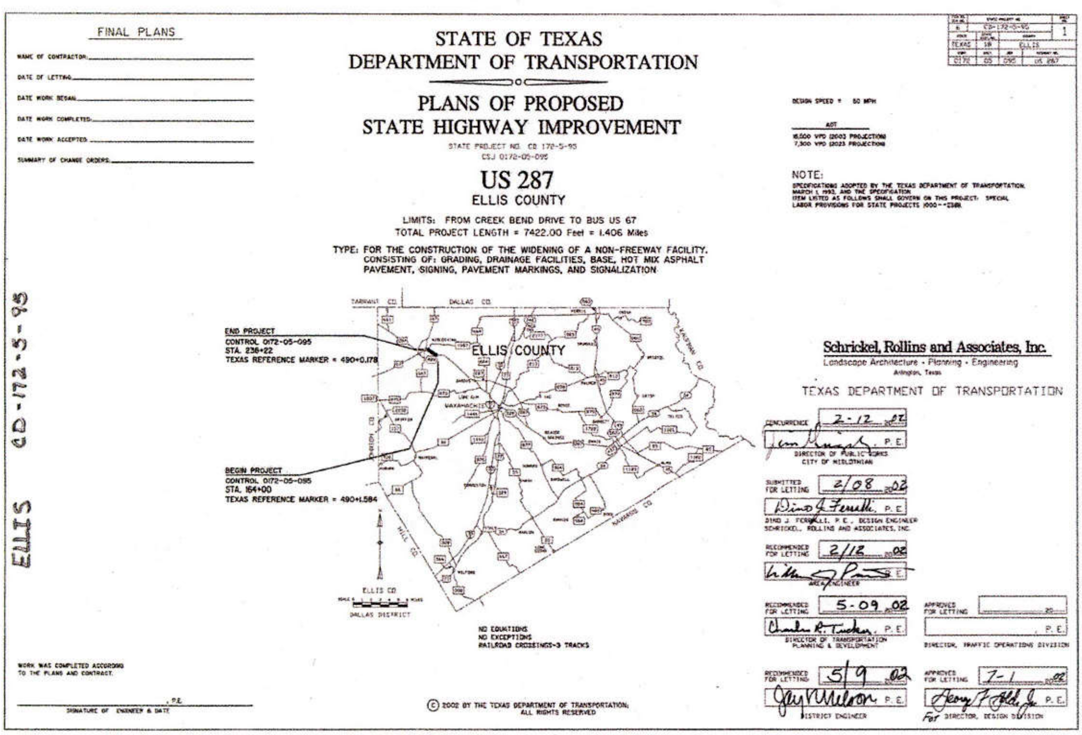
Attribute	Information	Special Note
CSJ	0261-02-065	
County	Dallas	
Reference Marker	RM 16+0.705 - RM 17+0.262	
GPS Coordinates		
Construction Year	2010	
Pavement Type	CRCP	
Slab thickness	8-in.	
Shoulder Type	Tied Concrete	
Base Type	6-in ASB [TY-B]	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.23 US 67, (CSJ

No. 24 US 287, Dallas District

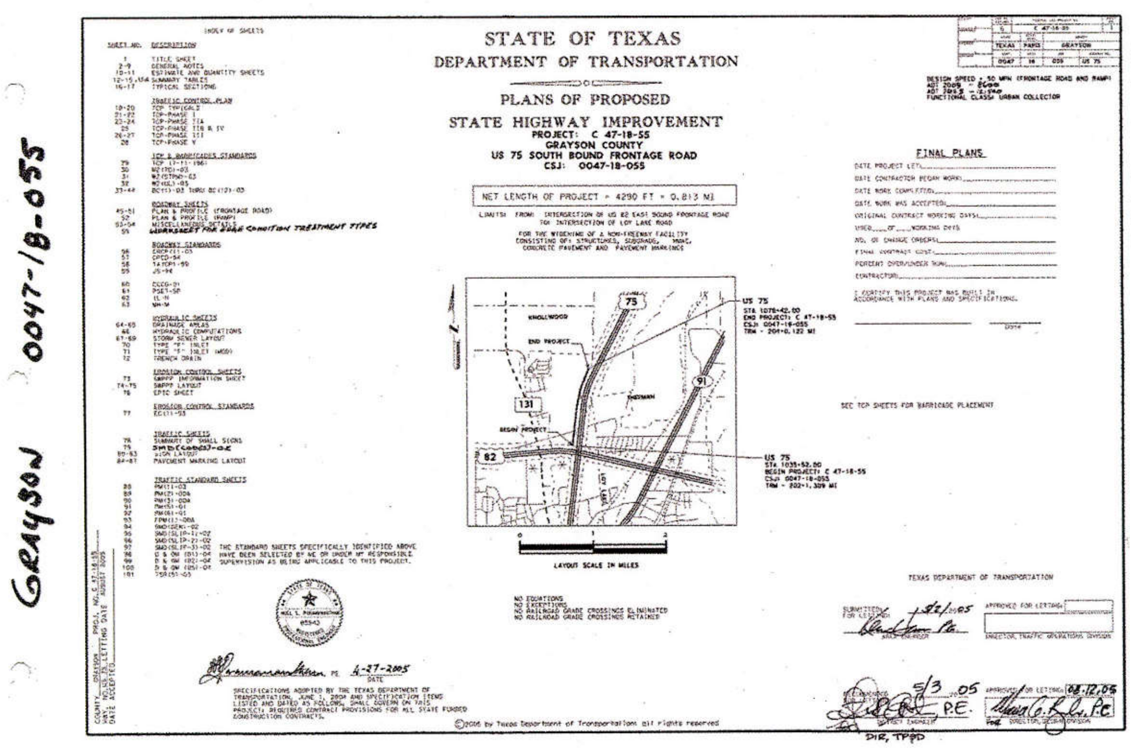
Attribute	Information	Special Note
CSJ	0172-05-095	
County	Ellis	
Reference Marker	RM 490+0.178 - RM 491+.584	
GPS Coordinates		
Construction Year	2003	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type	Curb	
Base Type	4-in ASB	
Subgrade Type	12-in Flex Base	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.24 US 287, (CSJ 0172-05-095)

No. 25 US 75, Paris District

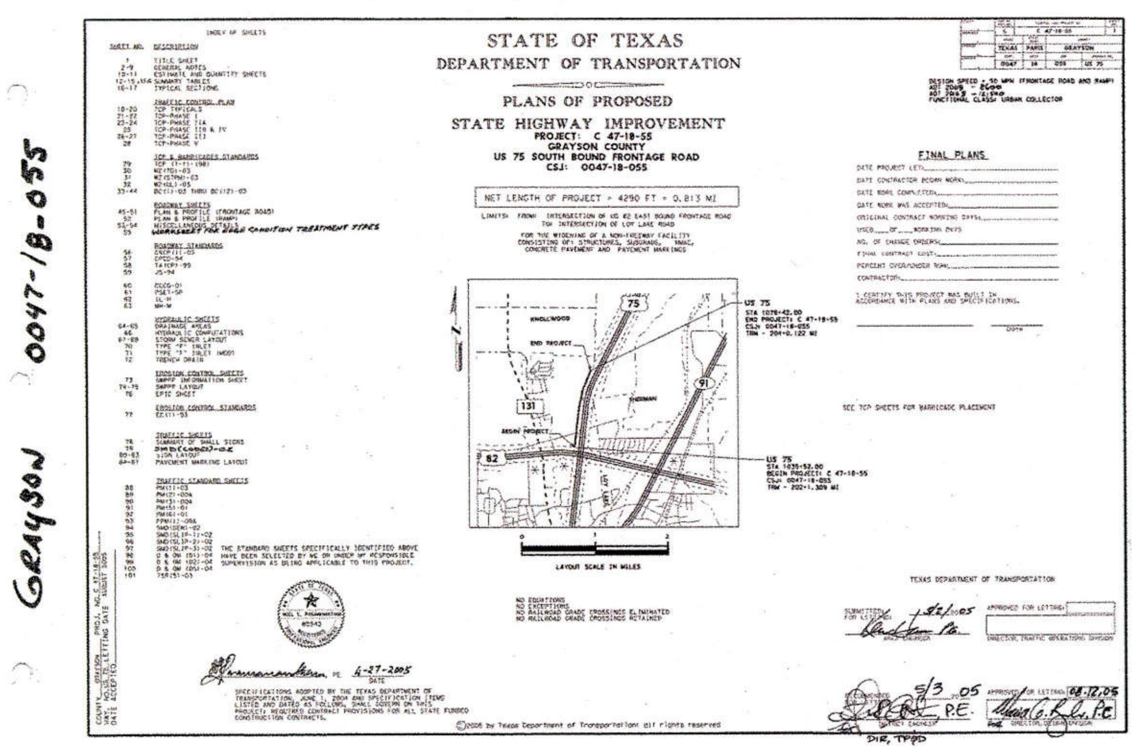
Attribute	Information	Special Note
CSJ	0047-18-055	
County	Grayson	
Reference Marker	RM 203+0.309 - RM 204+0.122	
GPS Coordinates		
Construction Year	2007	
Pavement Type	CRCP	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.25 US 75, (CSJ 0047-18-055)

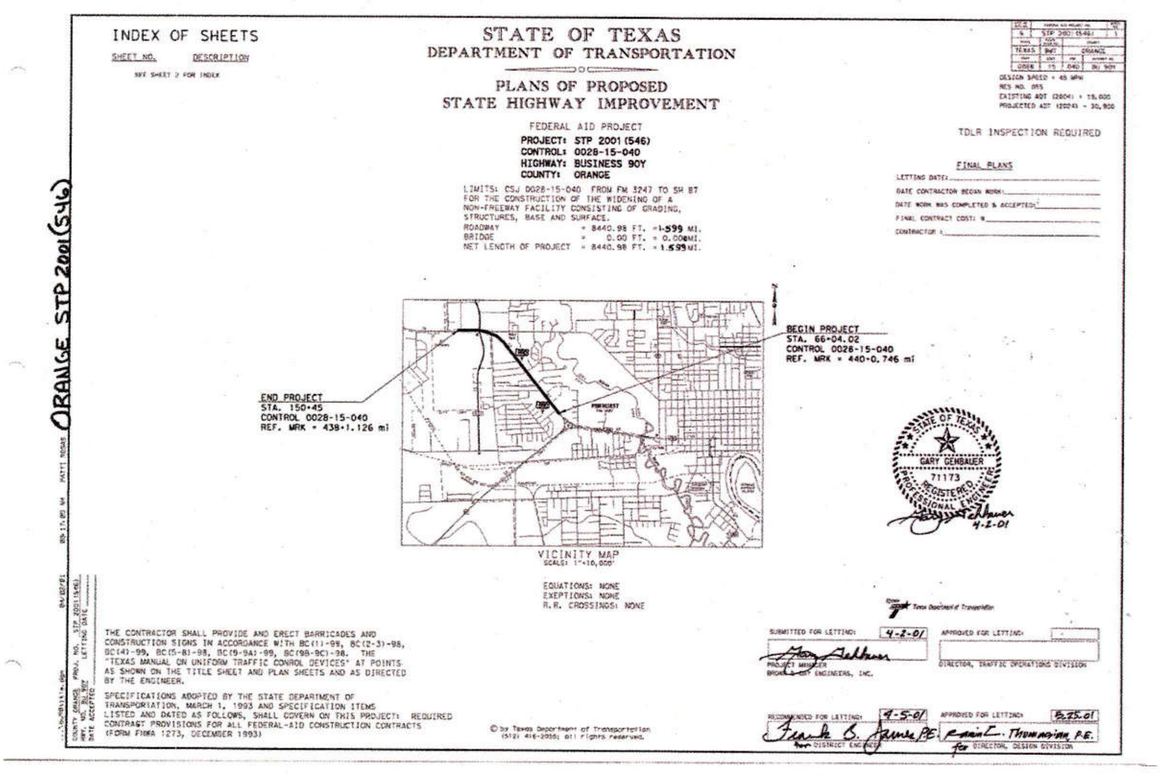
No. 26 US 75, Paris District

Attribute	Information	Special Note
CSJ	0047-18-055	
County	Grayson	
Reference Marker		
GPS Coordinates		
Construction Year		
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 27 BU 90-Y, Beaumont District

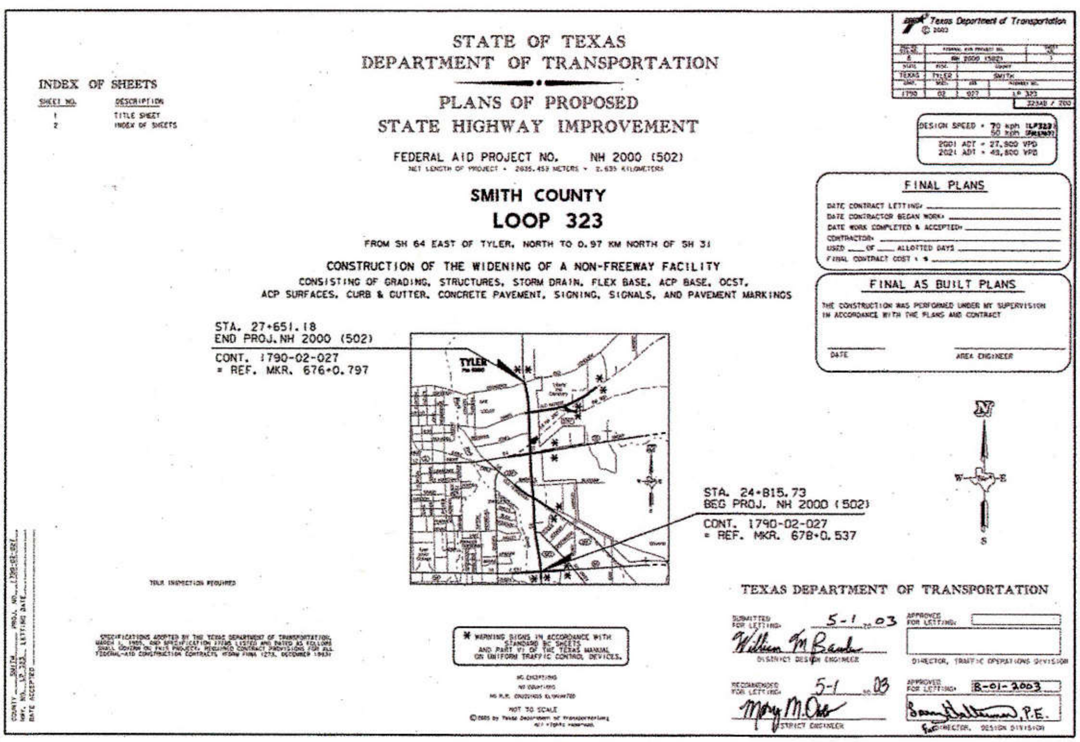
Attribute	Information	Special Note
CSJ	0028-15-040	
County	Orange	
Reference Marker	RM 440+0.746 - RM 439+0.147	
GPS Coordinates		
Construction Year	2005	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	TY-P Mono Curb	
Base Type	1-in AC+6-in CSB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

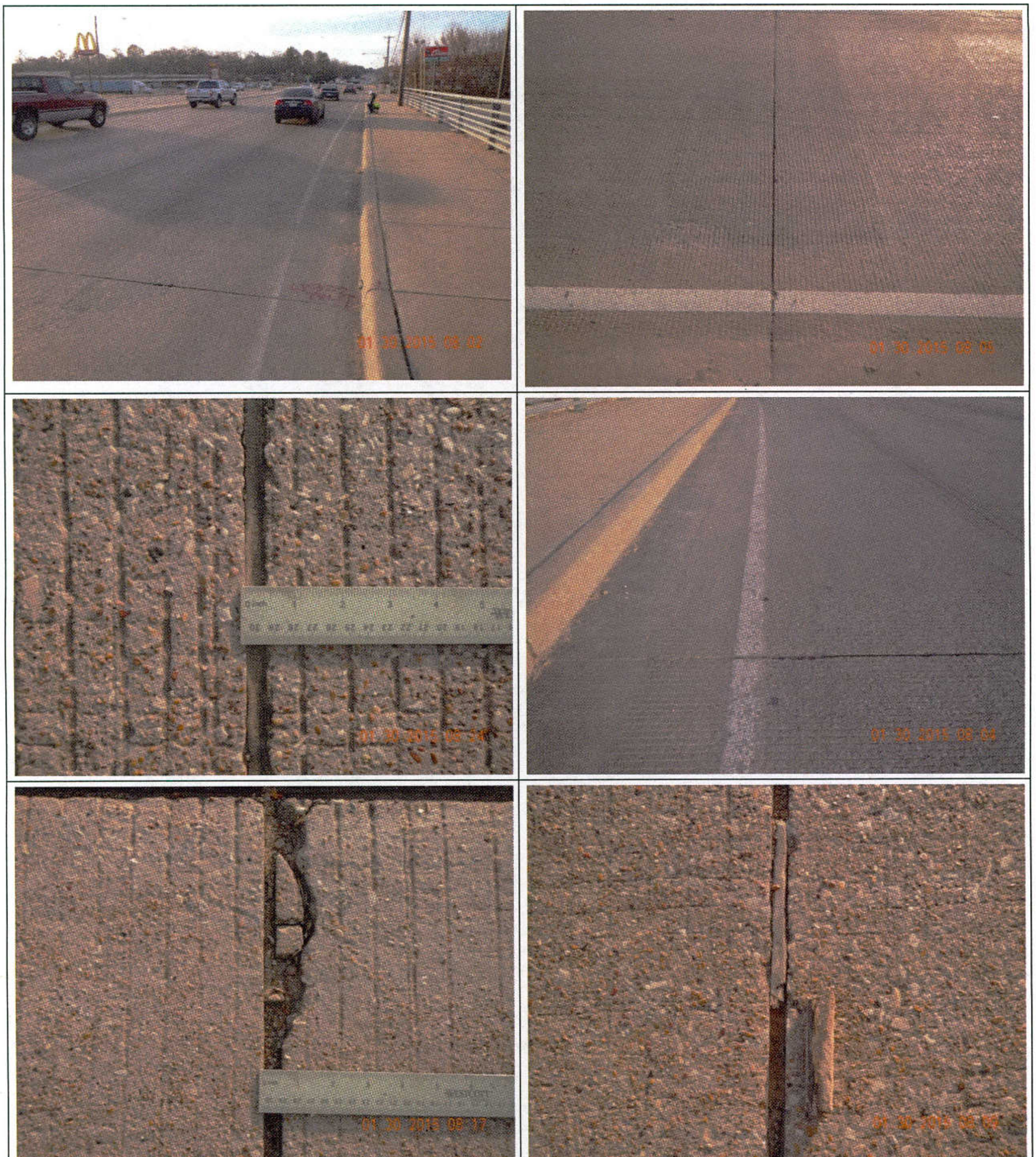


No.27 BU 90-Y, (CSJ 0028-15-040)

No. 28 LP 323, Tyler District

Attribute	Information	Special Note
CSJ	1790-02-027	
County	Smith	
Reference Marker	RM 676+0.797 - RM 678+0.537	
GPS Coordinates		
Construction Year	2008	
Pavement Type	CPCD	
Slab thickness	12-in.	
Shoulder Type	TY-II Mono Curb	
Base Type	4-in ASB	
Subgrade Type	6-in CTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		





No.28 LP 323, (CSJ 1790-02-027)

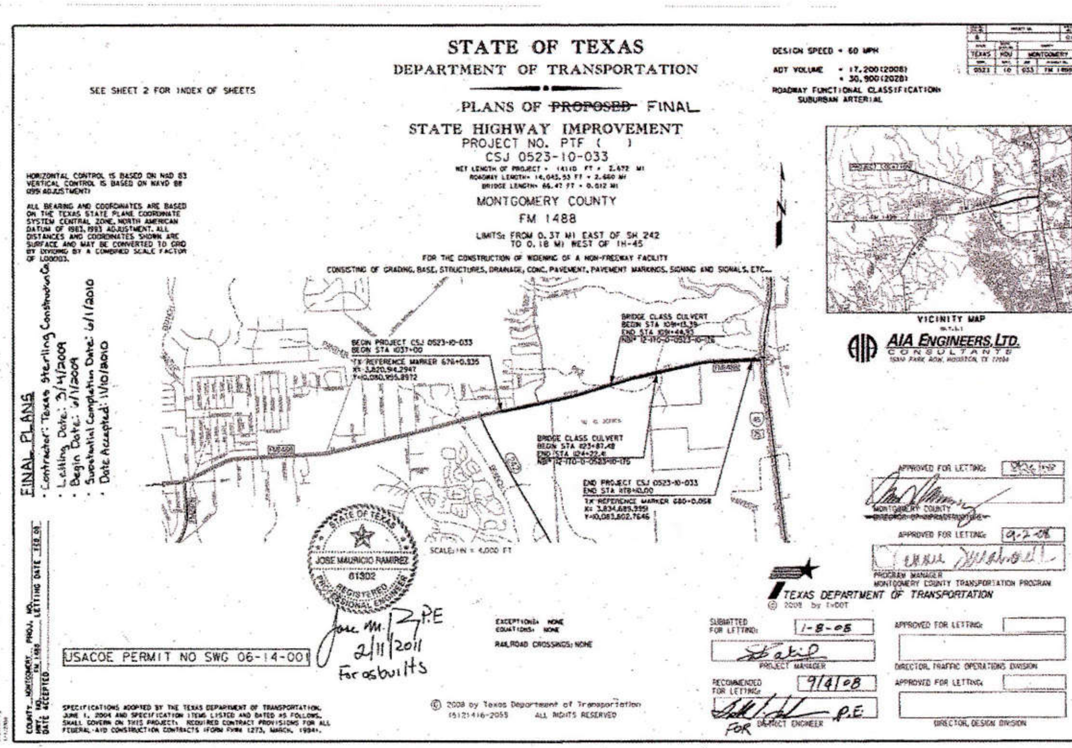
No. 29 US 82, Lubbock District

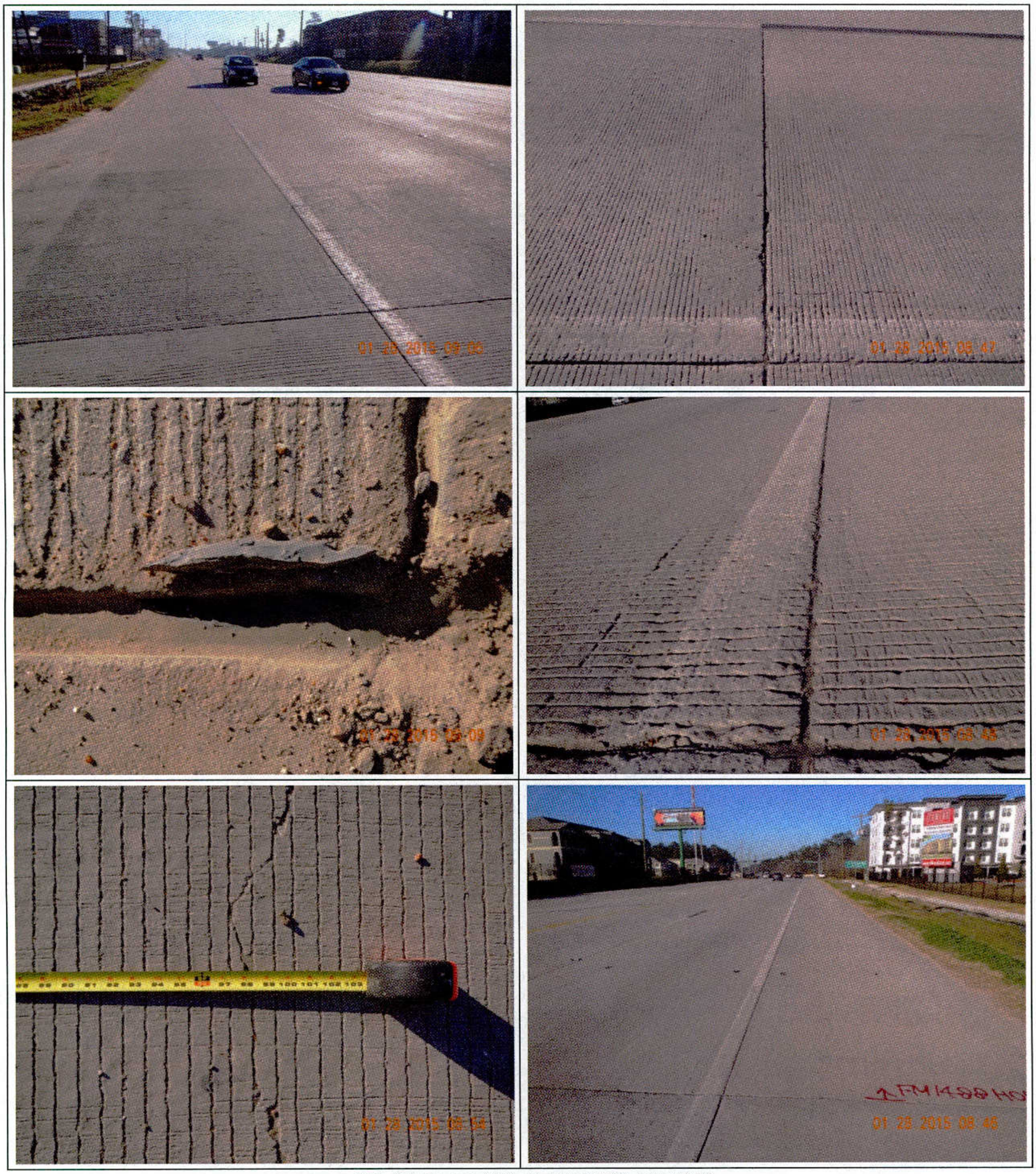
Attribute	Information	Special Note
CSJ	0053-1-090	
County	Lubbock	
Reference Marker	RM 308+1.996 - RM 310+1.436	
GPS Coordinates		
Construction Year	2013	
Pavement Type	CRCP	
Slab thickness	13-in.	
Shoulder Type	Tied Concrete	
Base Type	6-in ASB	
Subgrade Type	6-in Flex base	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

No.29 US 82, (CSJ 0053-1-090)

No. 30 FM 1488, Houston District

Attribute	Information	Special Note
CSJ	0523-10-033	
County	Montgomery	
Reference Marker		
GPS Coordinates		
Construction Year		
Pavement Type	CRCP	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	1-in AC+6-in CSB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

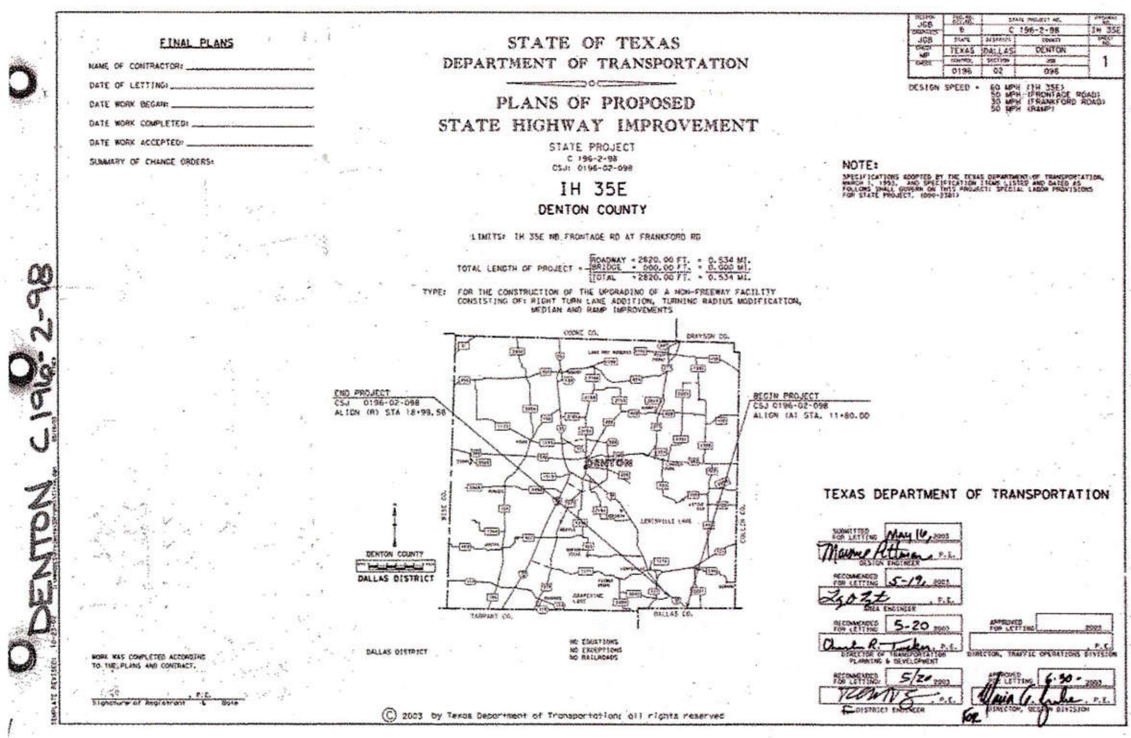




No.30 FM 1488, (CSJ 0523-10-033)

No. 31 IH 35E FR [NB], Dallas District

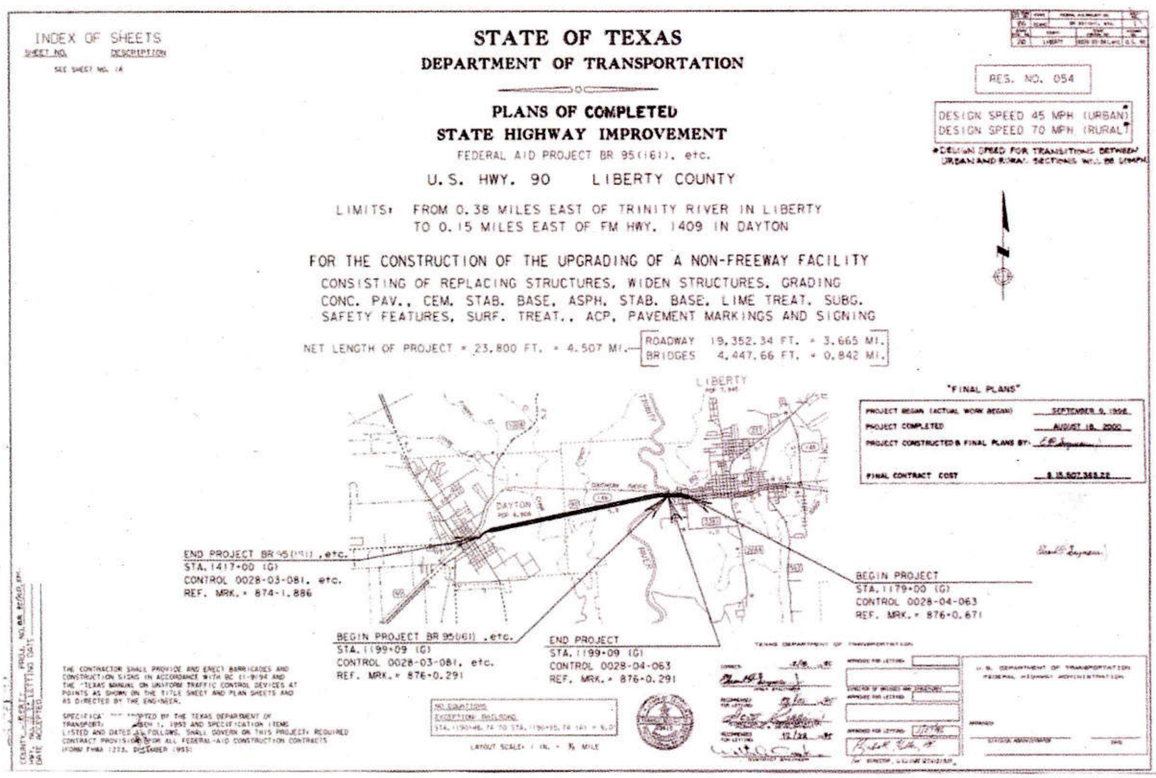
Attribute	Information	Special Note
CSJ	0196-02-098	
County	Denton	
Reference Marker	RM 308+1.996 - RM 310+1.436	
GPS Coordinates		
Construction Year	2004	
Pavement Type	CPCD	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB [TY-B]	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.31 IH 35E FR [NB], (CSJ 0196-02-098)

No. 32-1 US 90 EB, Beaumont District

Attribute	Information	Special Note
CSJ	0028-03-081	
County	Liberty	
Reference Marker	RM 847	
GPS Coordinates		
Construction Year	2010	
Pavement Type	CPCD	
Slab thickness		
Shoulder Type	Tied Concrete	
Base Type		
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.32 US 90 EB, (CSJ 0028-03-081)

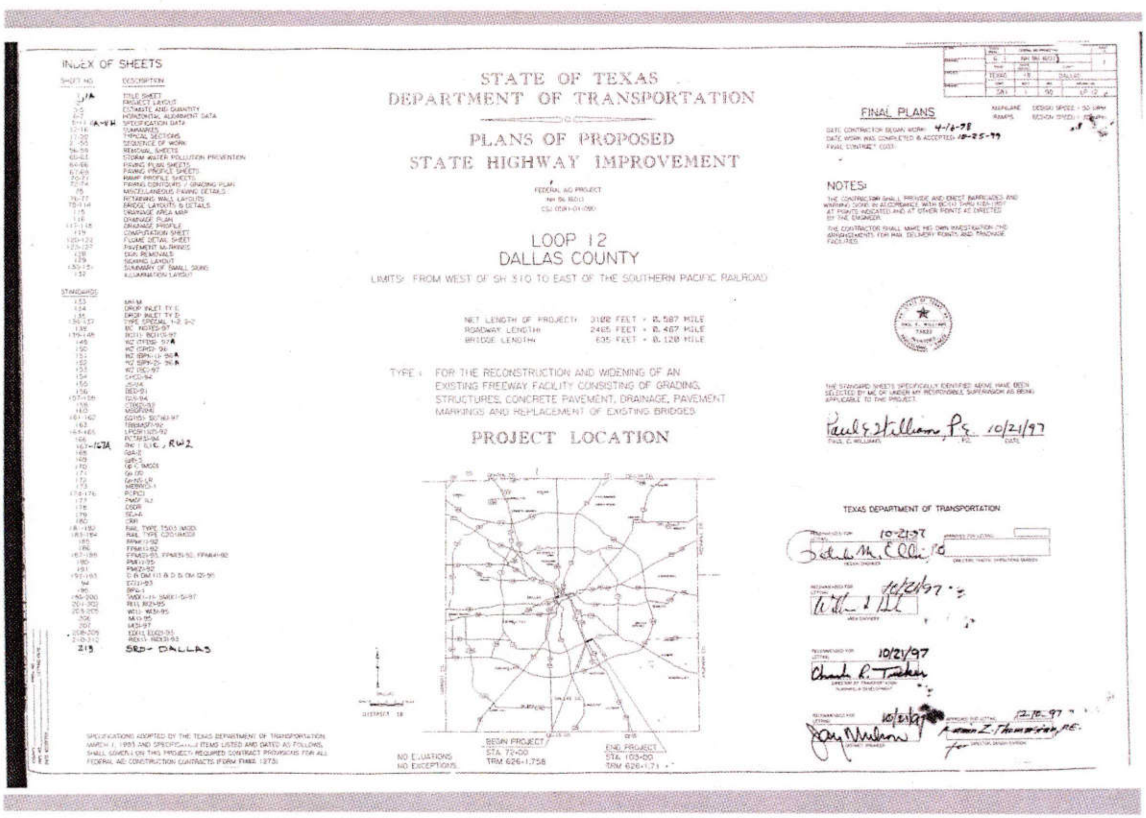
No. 32-2 US 90 WB, Beaumont District

Attribute	Information	Special Note
CSJ	0028-03-???	
County	Liberty	
Reference Marker	RM 847	
GPS Coordinates		
Construction Year		
Pavement Type	CPCD	
Slab thickness		
Shoulder Type	Asphalt Shoulder	
Base Type		
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

No.32 US 90 WB, (CSJ 0028-03-???)

No. 33 SL 12, Dallas District

Attribute	Information	Special Note
CSJ	0581-01-090	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	1999	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type	4-in ASB [TY-B]	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



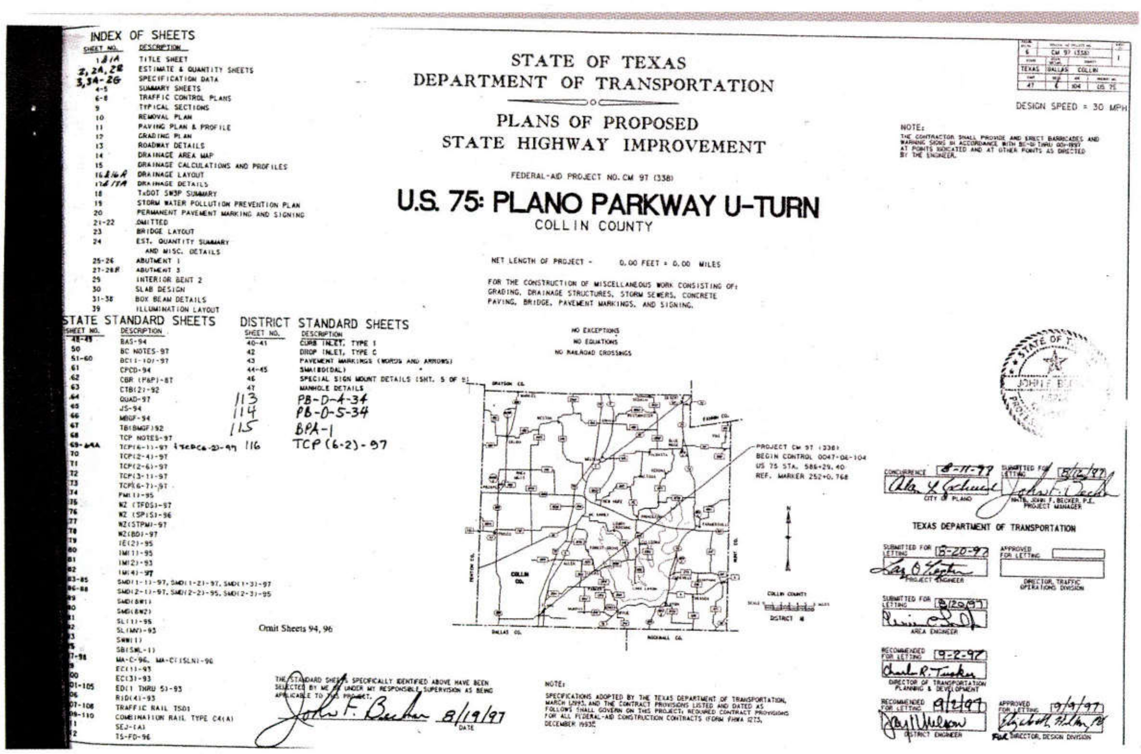
No.33 SL 12, (CSJ 0581-01-090)

No. 34 SH 289, Dallas District

Attribute	Information	Special Note
CSJ	0091-05-029	
County	Collins	
Reference Marker		
GPS Coordinates		
Construction Year	1999	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type		
Base Type	2-in Asphalt Stabilized Base	
Subgrade Type	8-in LTS 6-in 4% Lime Treate d	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

No. 35 US 75 FR, Dallas District

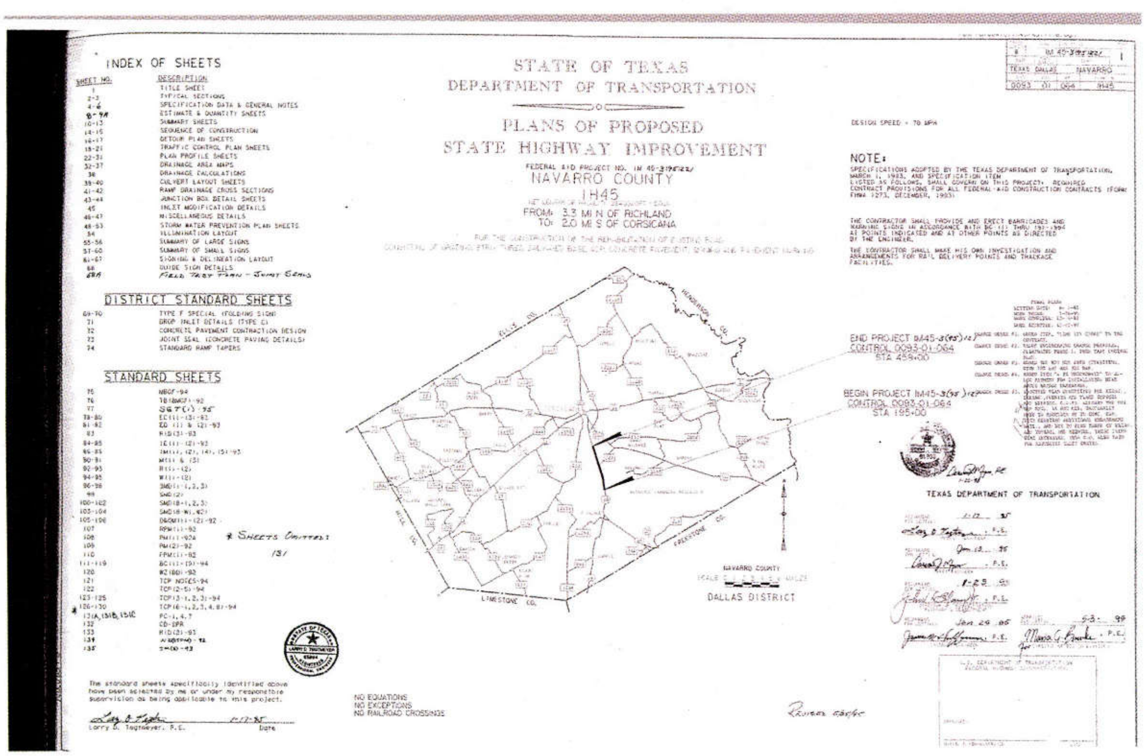
CSJ	0047-06-104	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	1998	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Tied Concrete	
Base Type		
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.35 US 75, (CSJ 0047-06-104)

No. 36 IH 45, Dallas District

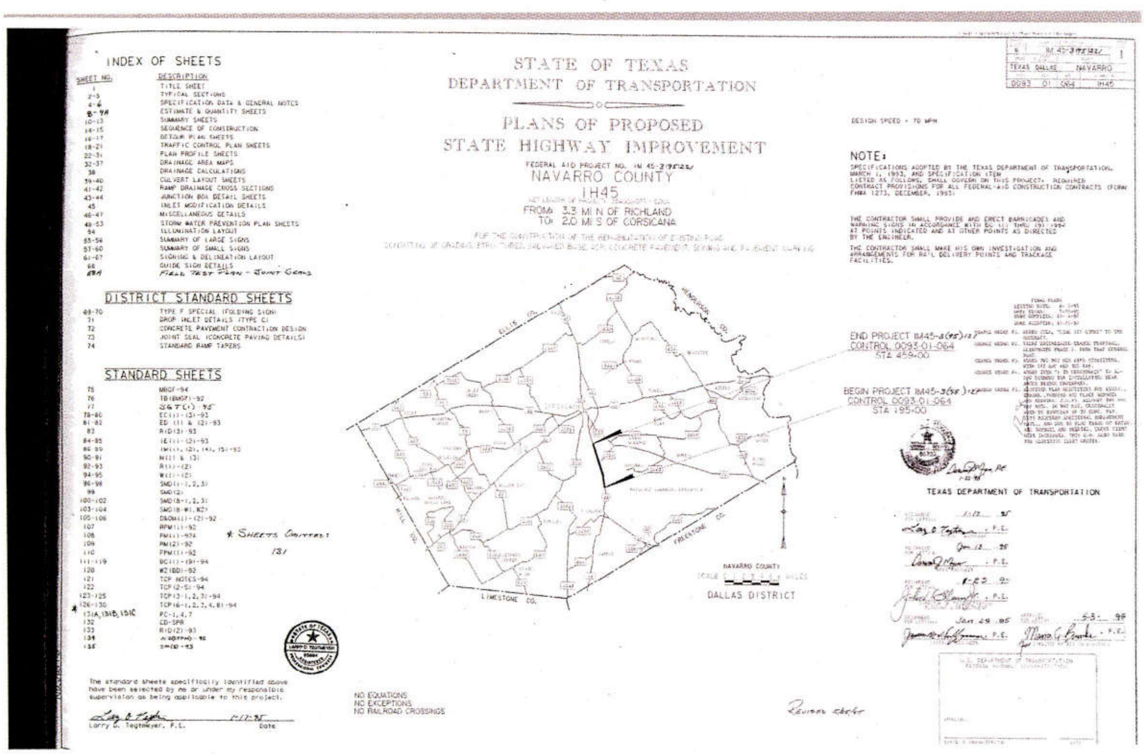
Attribute	Information	Special Note
CSJ	0093-01-064	
County	Navarro	
Reference Marker		
GPS Coordinates		
Construction Year	1997	
Pavement Type	CPCD	
Slab thickness	12-in.	
Shoulder Type	Tied Concrete	
Base Type	2-in AC Level Up	
Subgrade Type	Ext. 10-in CPCD	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.36 IH 45, (CSJ 0093-01-064)

No. 37 IH 45, Dallas District

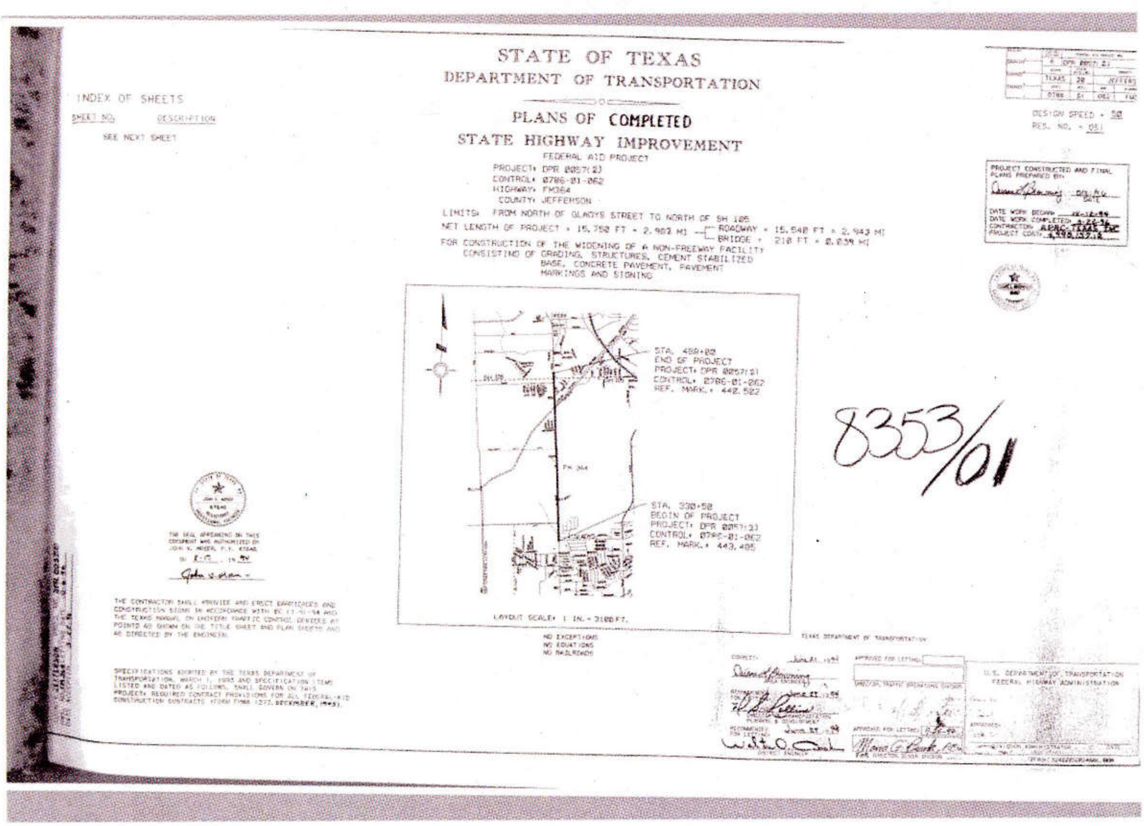
Attribute	Information	Special Note
CSJ	0093-01-064	
County	Navarro	
Reference Marker		
GPS Coordinates		
Construction Year	1997	
Pavement Type	CRCP	
Slab thickness	12-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.37 IH 45, (CSJ 0093-01-064)

No. 38 FM 364 NB, Beaumont District

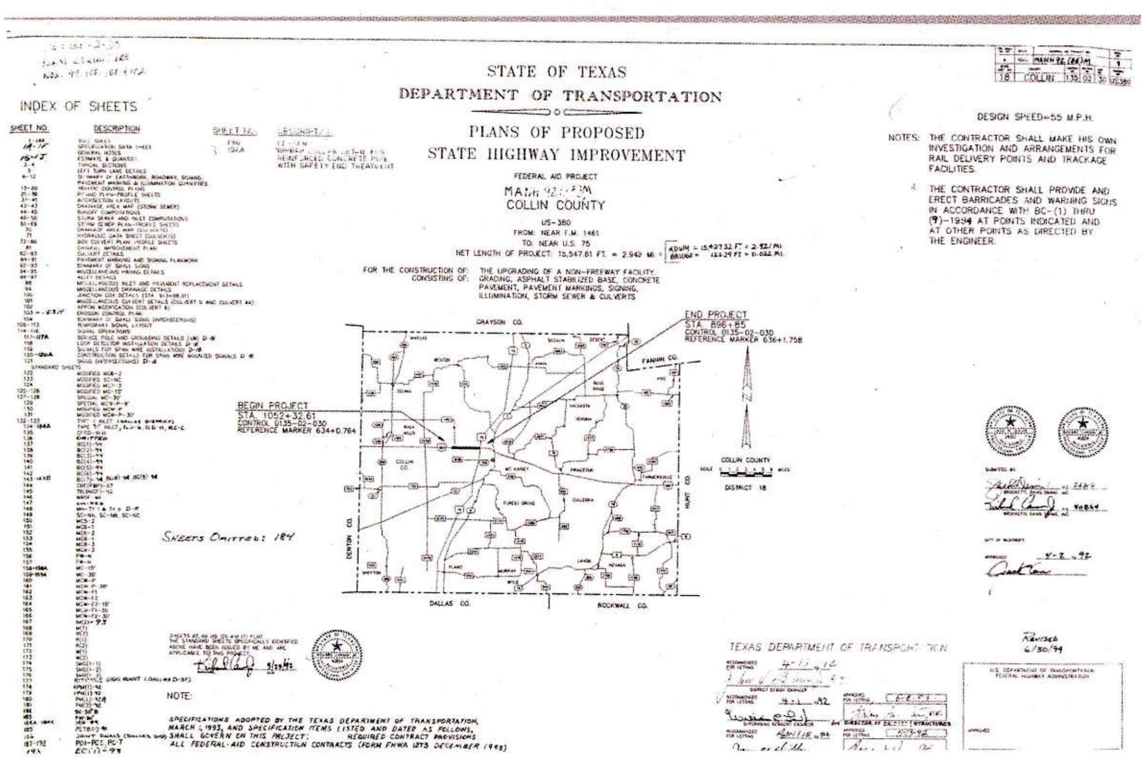
Attribute	Information	Special Note
CSJ	0786-01-062	
County	Jefferson	
Reference Marker		
GPS Coordinates		
Construction Year	1996	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Tied Concrete	
Base Type	6-in CSB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.38 FM 364 NB, (CSJ 0786-01-062)

No. 39 US 380, Dallas District

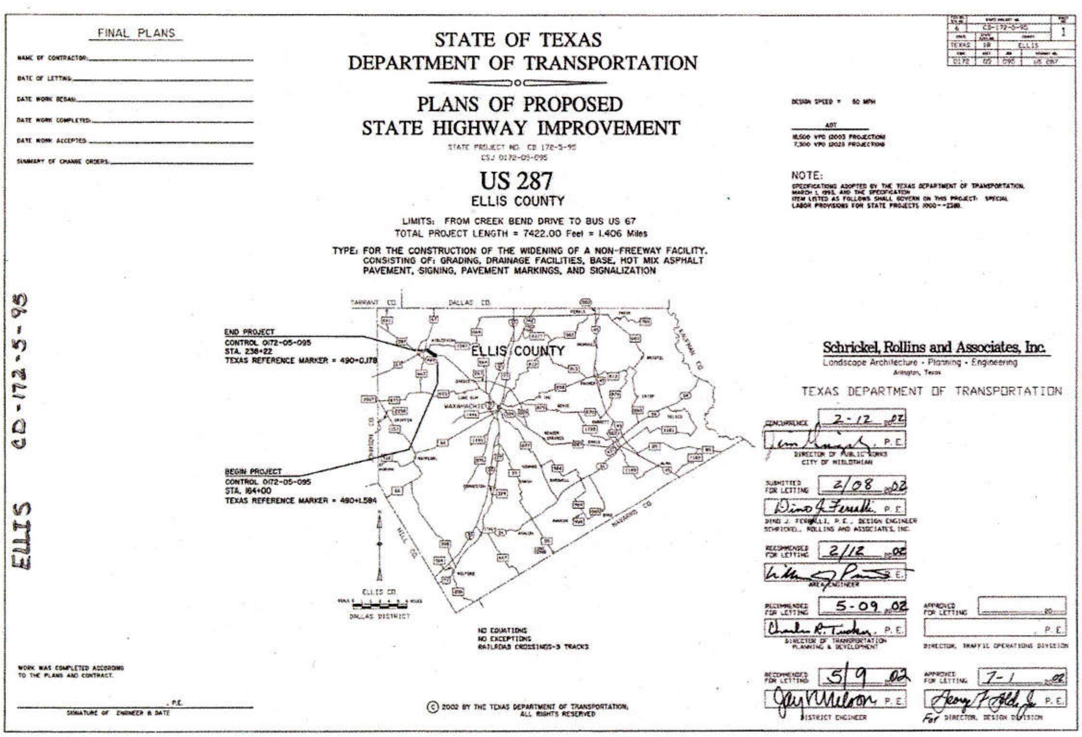
Attribute	Information	Special Note
CSJ	0135-02-030	
County	Collin	
Reference Marker		
GPS Coordinates		
Construction Year	1994	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	TY-II Curb	
Base Type	4-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.39 US 380, (CSJ 0135-02-030)

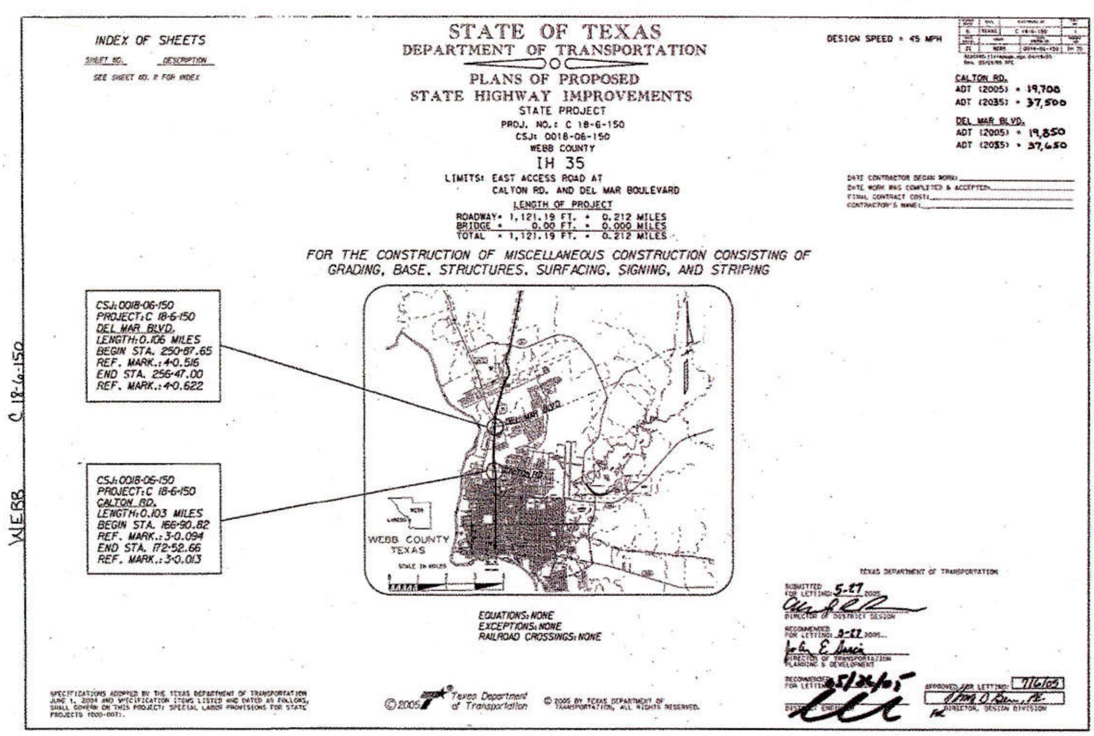
No. 41

Attribute	Information	Special Note
CSJ	0172-05-095	
County	Ellis	
Reference Marker		
GPS Coordinates		
Construction Year	2003	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type		
Base Type	4-in ACP	
Subgrade Type	12-in Flexible Base	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 42 IH 35, Laredo District

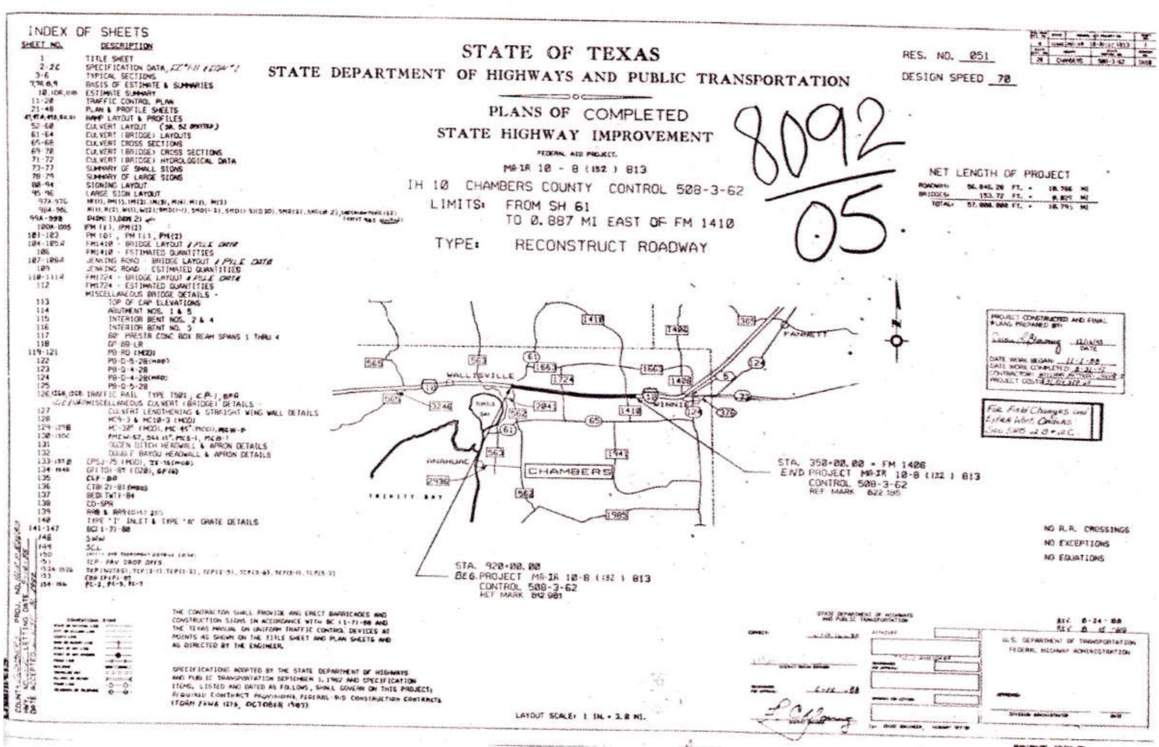
Attribute	Information	Special Note
CSJ		
County	Webb	
Reference Marker		
GPS Coordinates		
Construction Year	2002	
Pavement Type	CRCP	
Slab thickness	9-in.	
Shoulder Type	Tied Concrete	
Base Type	Existing AC	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.42 IH 35

No. 43 IH 10, Beaumont Distrct

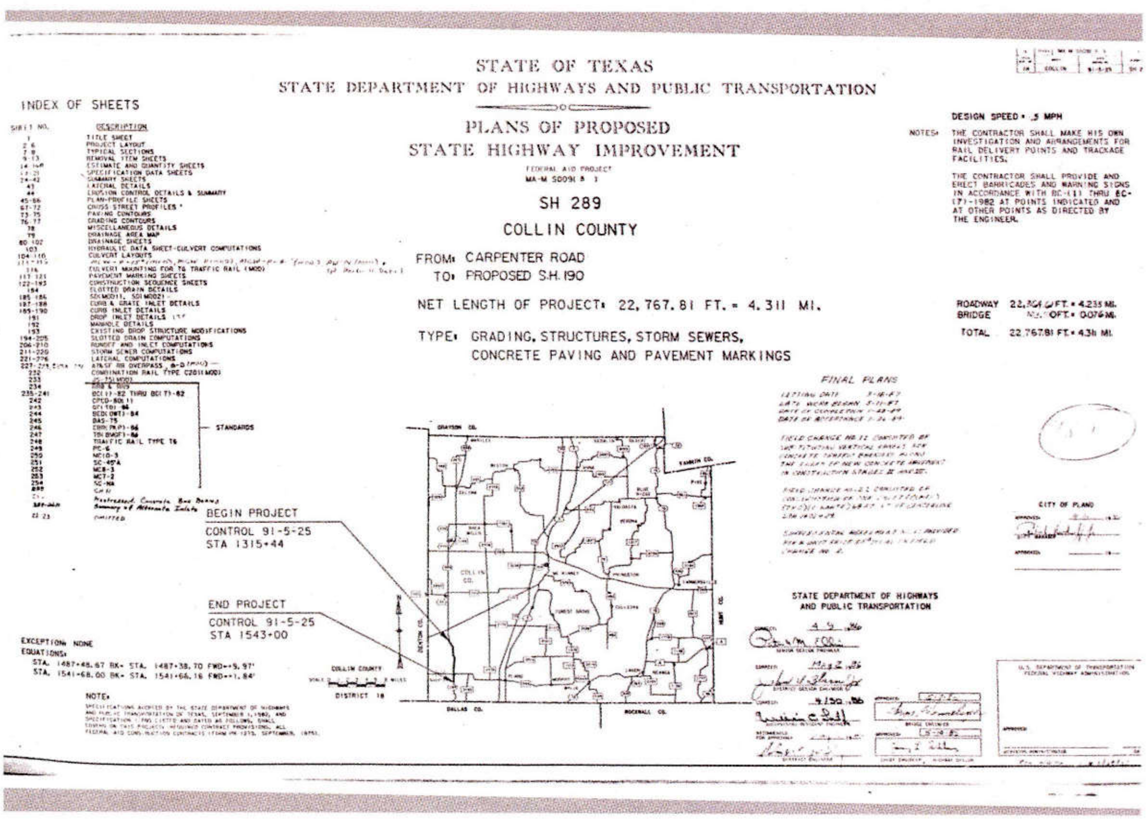
Attribute	Information	Special Note
CSJ	0508-03-062	
County	Chambers	
Reference Marker		
GPS Coordinates		
Construction Year	1992	
Pavement Type	CPCD	
Slab thickness	14-in.	
Shoulder Type	Tied Concrete	
Base Type	1-in Bond Breaker	
Subgrade Type	Existing CPCD	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

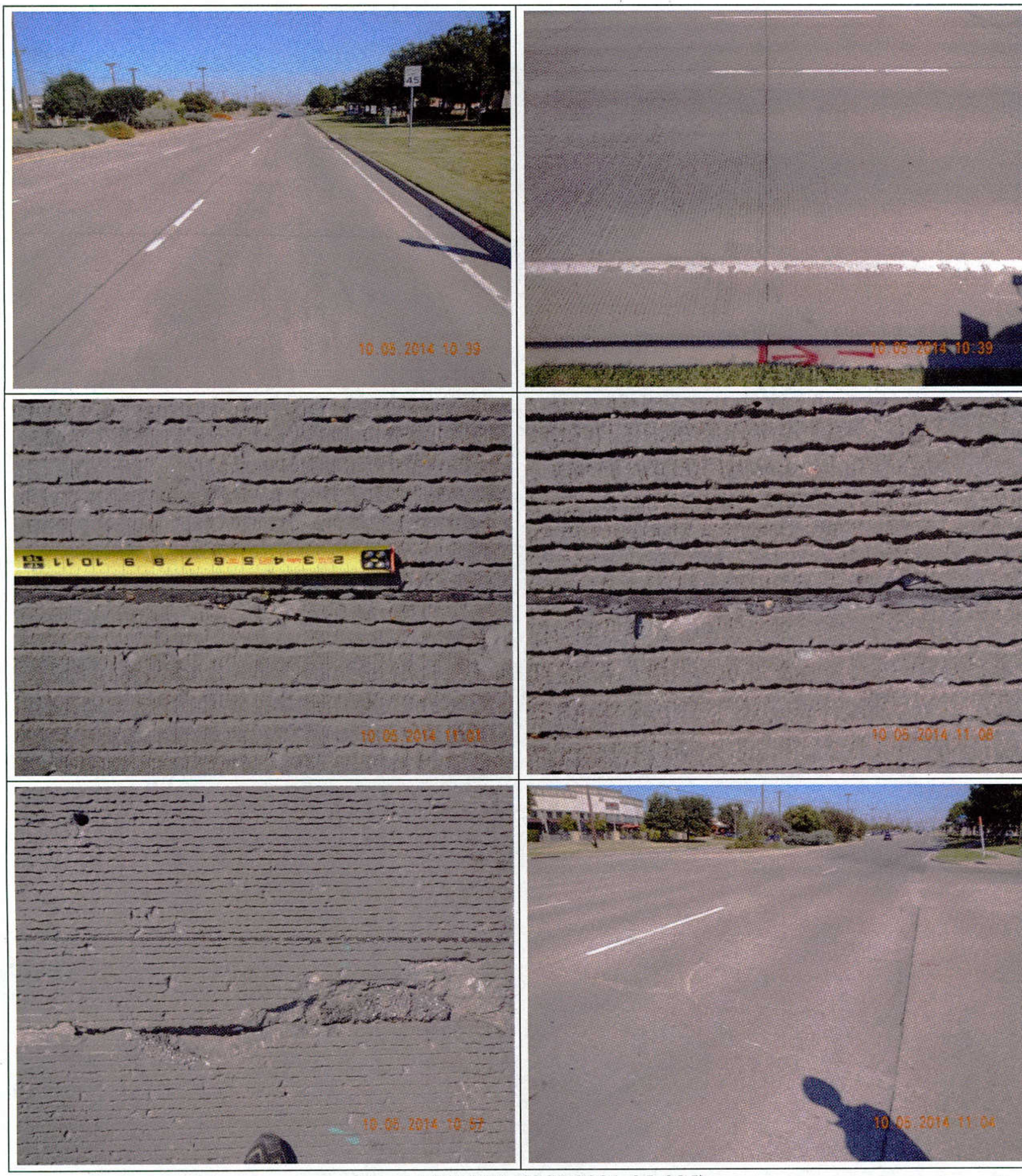


No.43 IH 10, (CSJ 0508-03-062)

No. 44 SH 289, Dallas District

Attribute	Information	Special Note
CSJ	0091-05-025	
County	Collin	
Reference Marker	RM 242+1.8 - RM 254+1.2	
GPS Coordinates		
Construction Year	1989	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type	6-in ASB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

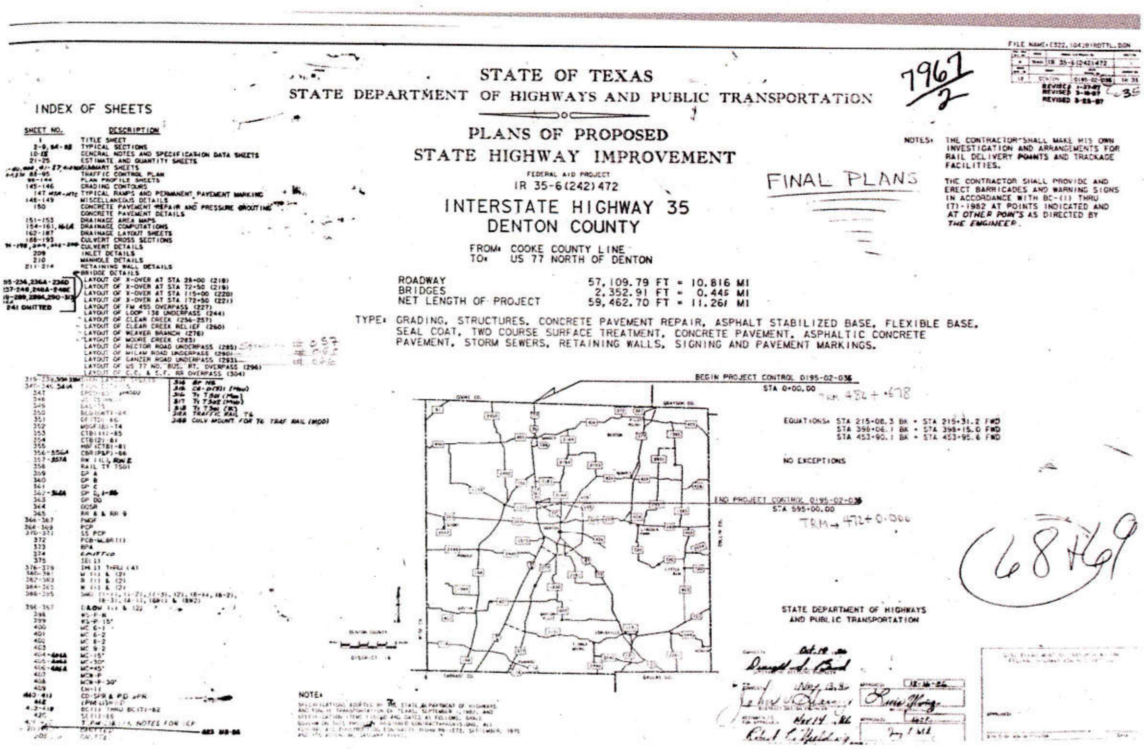




No.44 SH 289, (CSJ 0091-05-025)

No. 45 IH 35, Dallas District

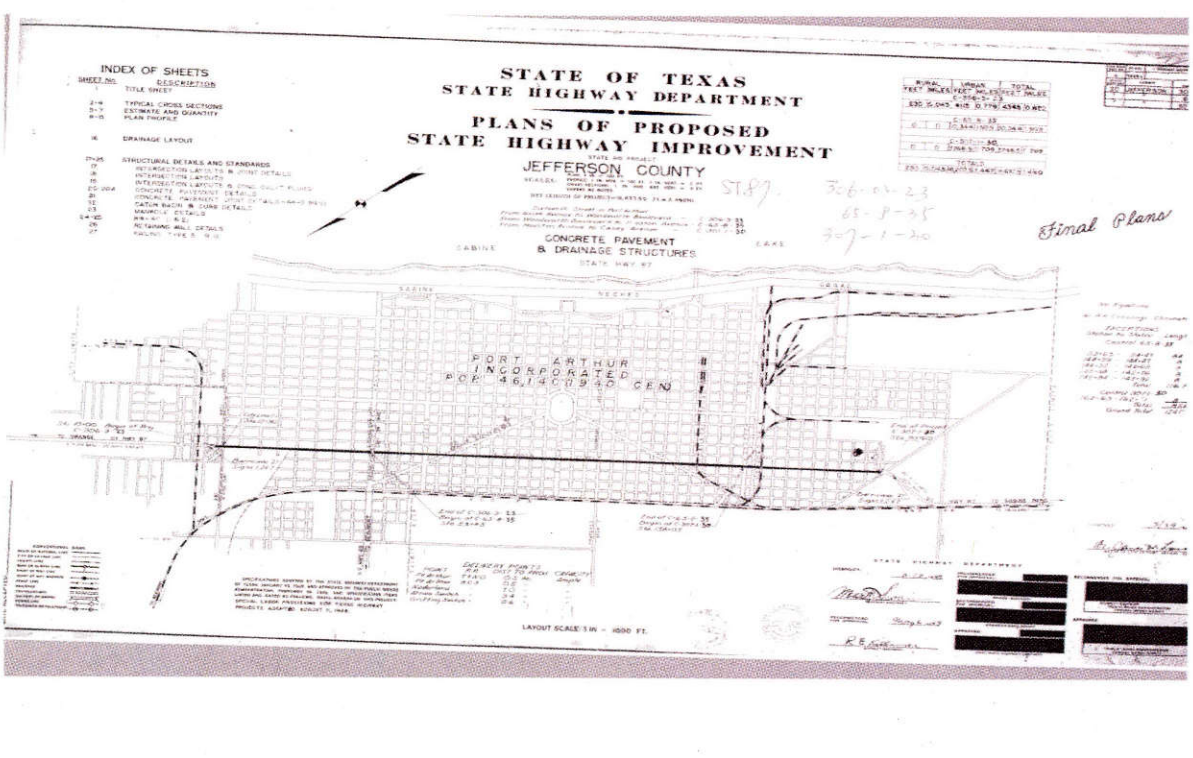
Attribute	Information	Special Note
CSJ	0195-02-035	
County	Denton	
Reference Marker		
GPS Coordinates		
Construction Year	1988	
Pavement Type	CPCD	
Slab thickness	11-in.	
Shoulder Type	Tied Concrete	
Base Type	2-in AC Level up	
Subgrade Type	10-in Ex. CPCD	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

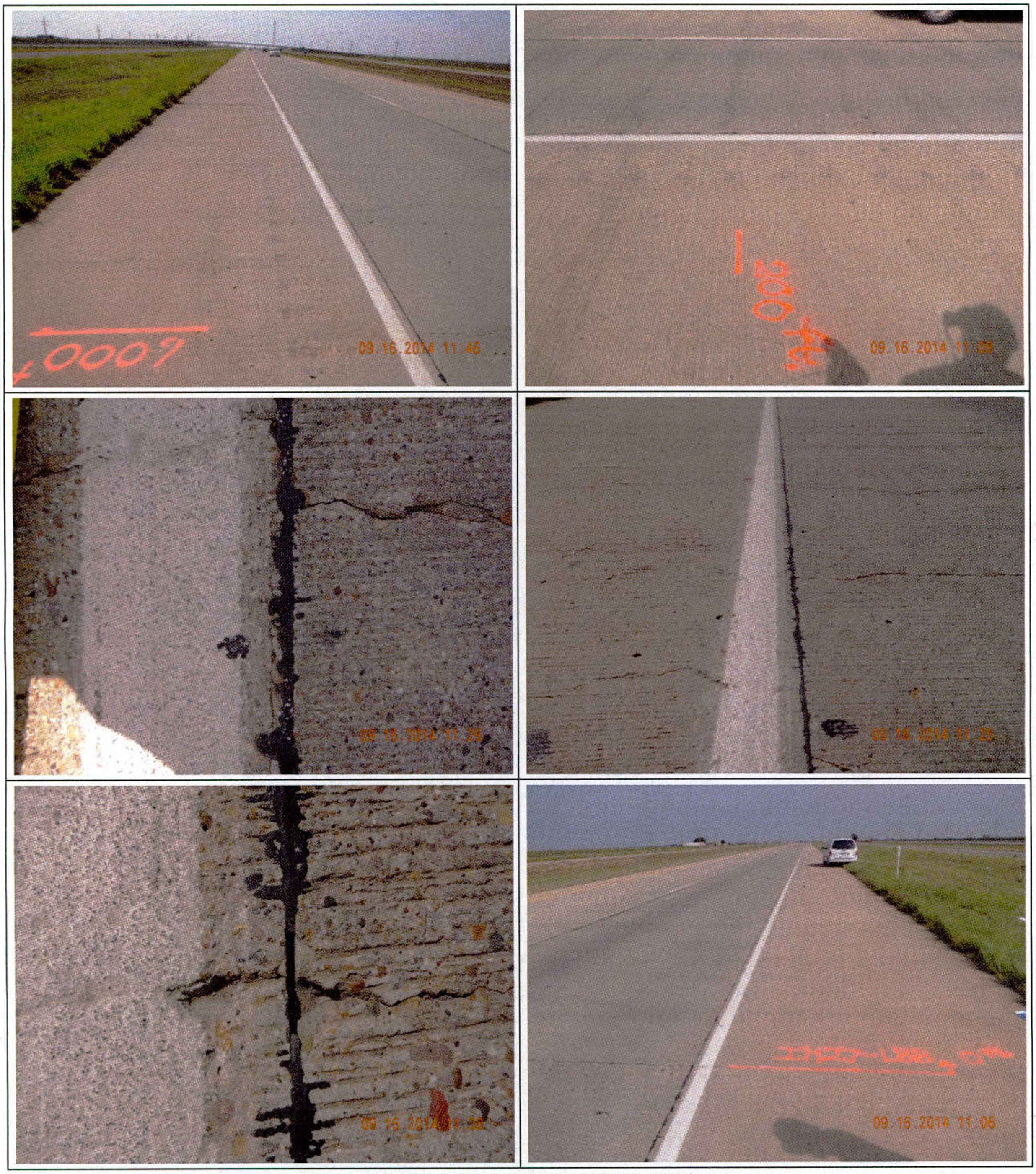


No.45 IH 35, (CSJ 0195-02-035)

No. 46 IH 27, Lubbock District

Attribute	Information	Special Note
CSJ	0306-03-023	
County	Swisher	
Reference Marker		
GPS Coordinates		
Construction Year	1988	
Pavement Type	CRCP	
Slab thickness	9-in.	
Shoulder Type	Tied Concrete	
Base Type	4-in ASB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

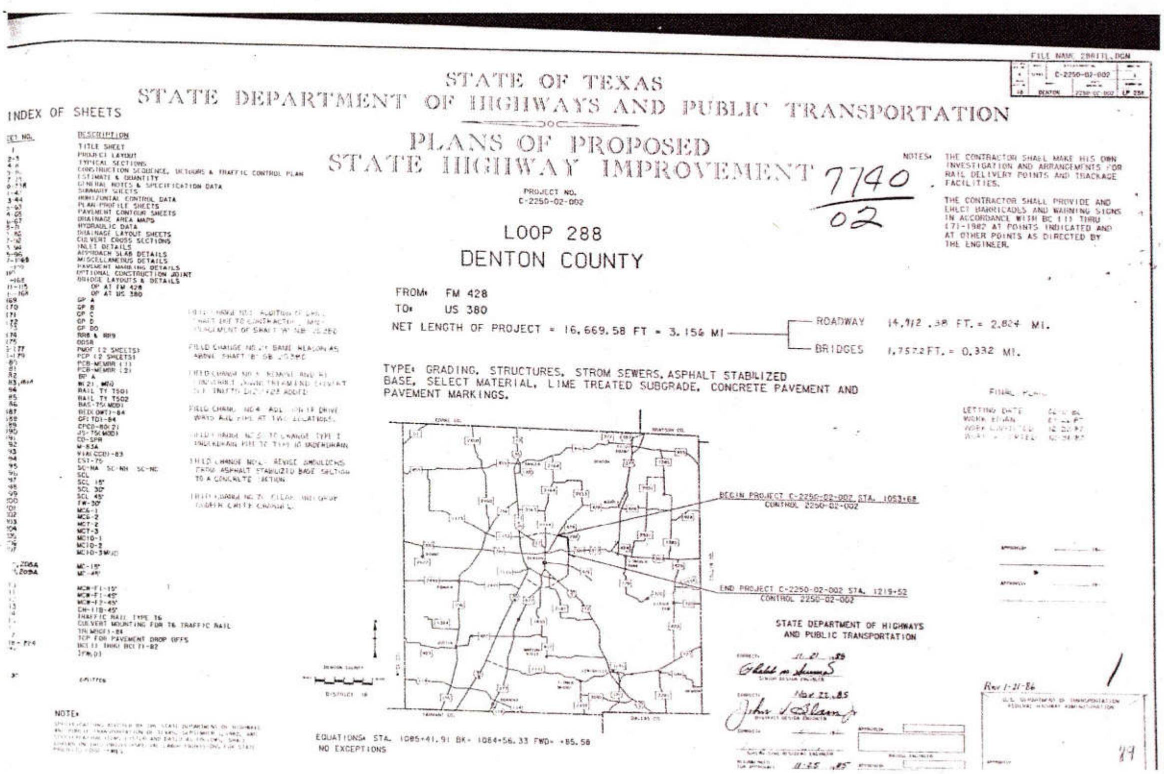




No.46 IH 27, (CSJ 0306-03-023)

No. 47 SL 288, Dallas District

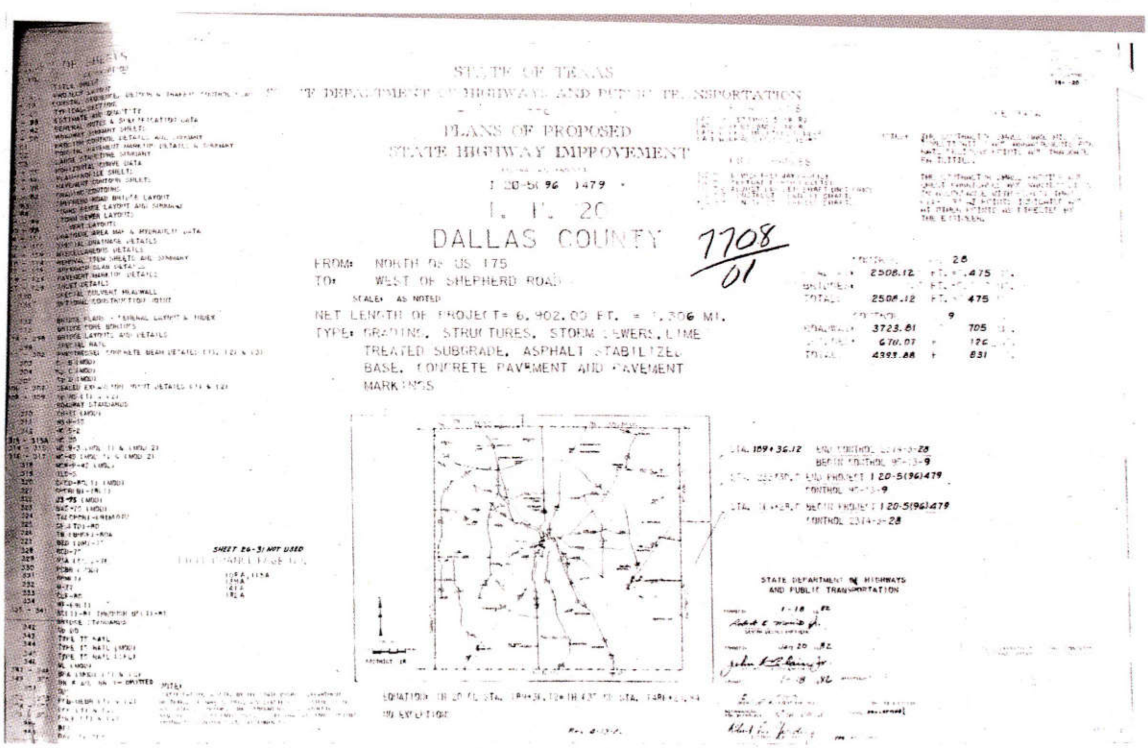
Attribute	Information	Special Note
CSJ	2250-02-002	
County	Denton	
Reference Marker		
GPS Coordinates		
Construction Year	1999	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type	4-in ASB	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

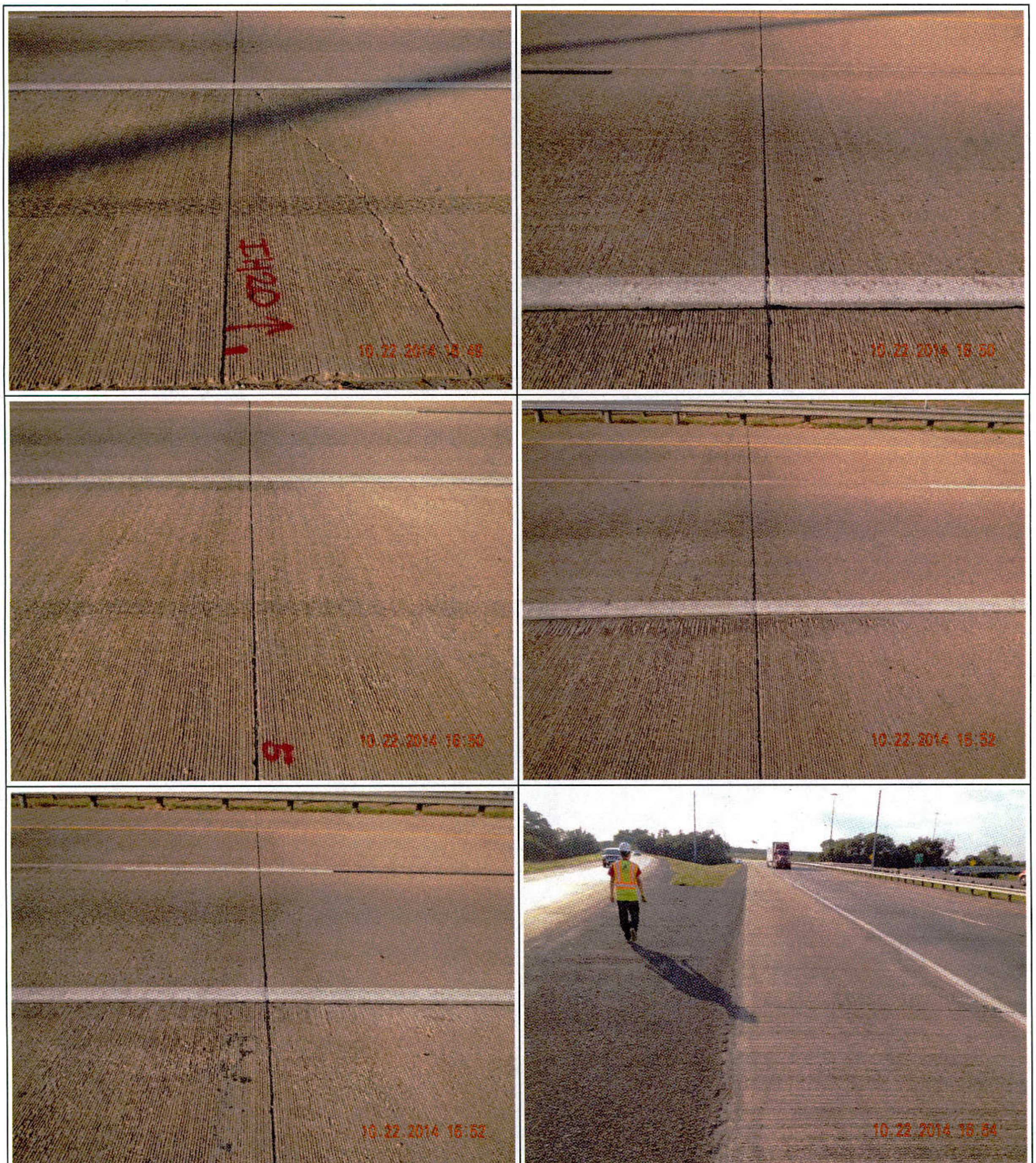


No.47 SL 288, (CSJ 2250-02-002)

No. 48 IH 20, Dallas District

Attribute	Information	Special Note
CSJ	0014-30-020	
County	Dallas	
Reference Marker	RM 482+0.0 - RM 496+0.0	
GPS Coordinates		
Construction Year	1984	
Pavement Type	CPCD	
Slab thickness	12-in.	
Shoulder Type	Tied Concrete	
Base Type		
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

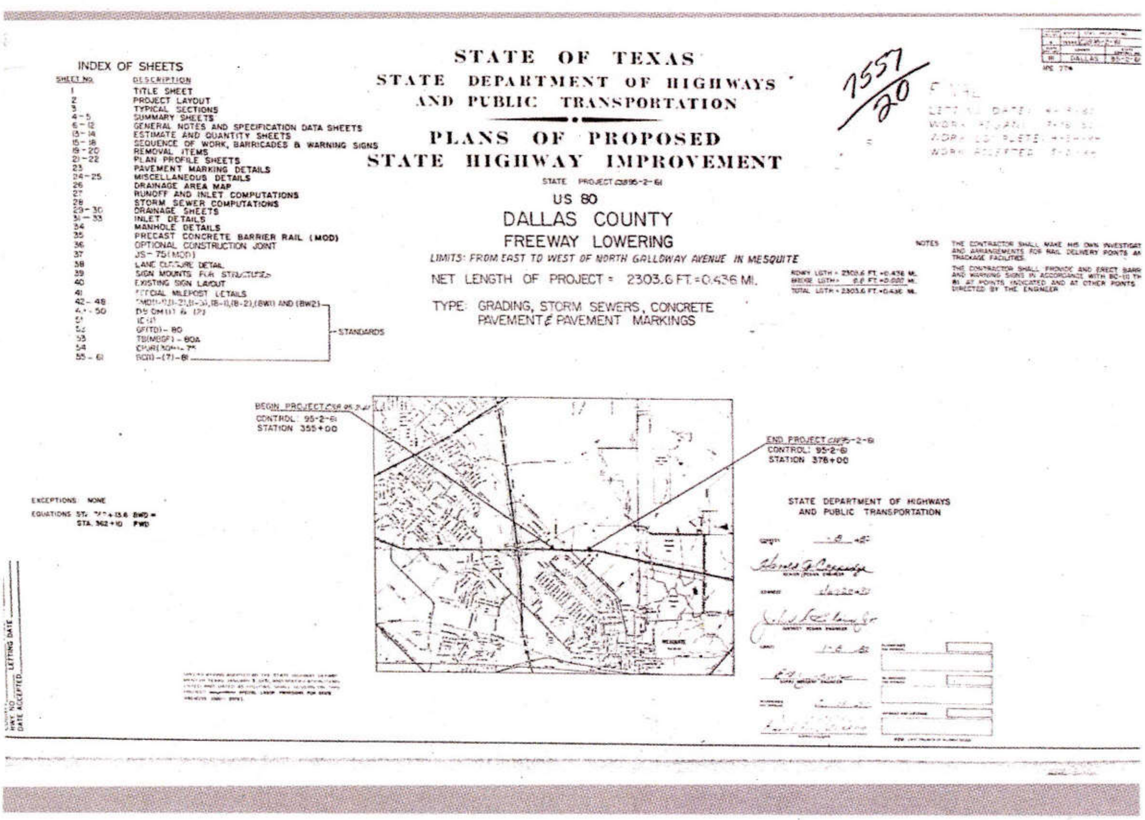




No.48 IH 20, (CSJ 0014-30-020)

No. 49 US 80, Dallas District

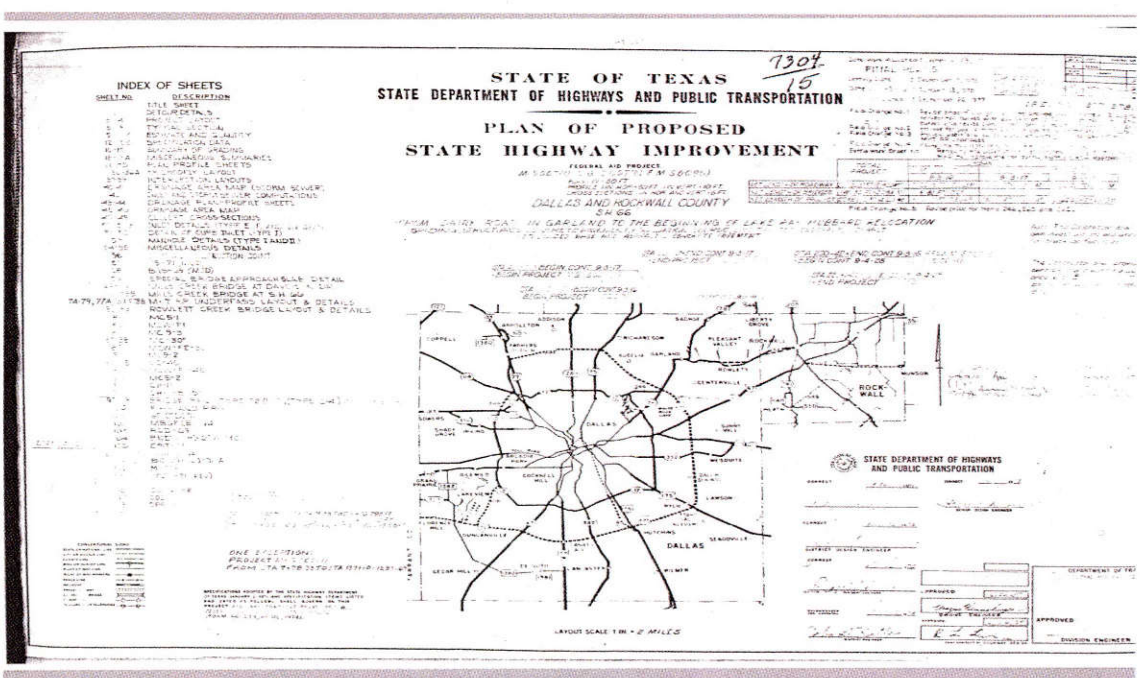
Attribute	Information	Special Note
CSJ	0095-02-061	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	1984	
Pavement Type	JRCP	
Slab thickness	11-in.	
Shoulder Type	AC	
Base Type	6-in ASB	
Subgrade Type	8-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.49 US 80, (CSJ 0095-02-061)

No.50 SH 66, Dallas District

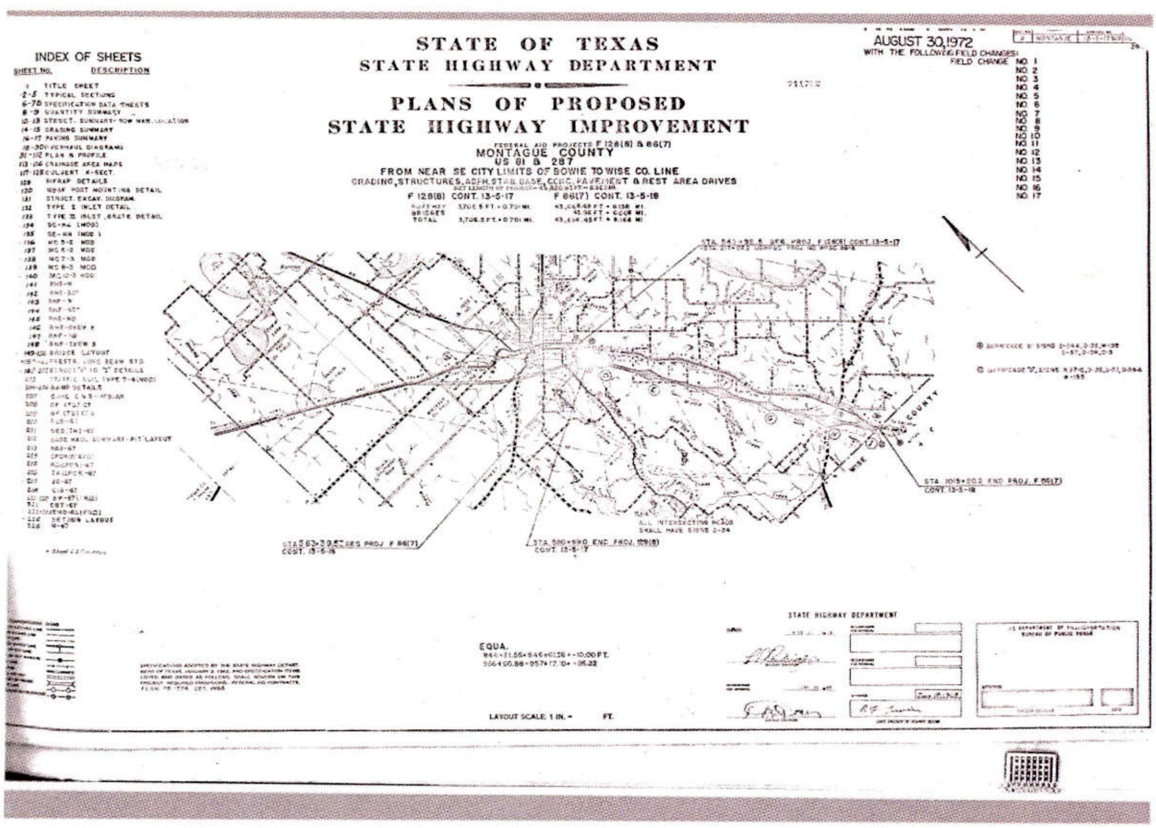
Attribute	Information	Special Note
CSJ	0009-03-017	
County	Dallas	
Reference Marker	RM 596+0.0 - RM 606+1.6	
GPS Coordinates		
Construction Year	1977	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type		
Subgrade Type	6-in LSS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

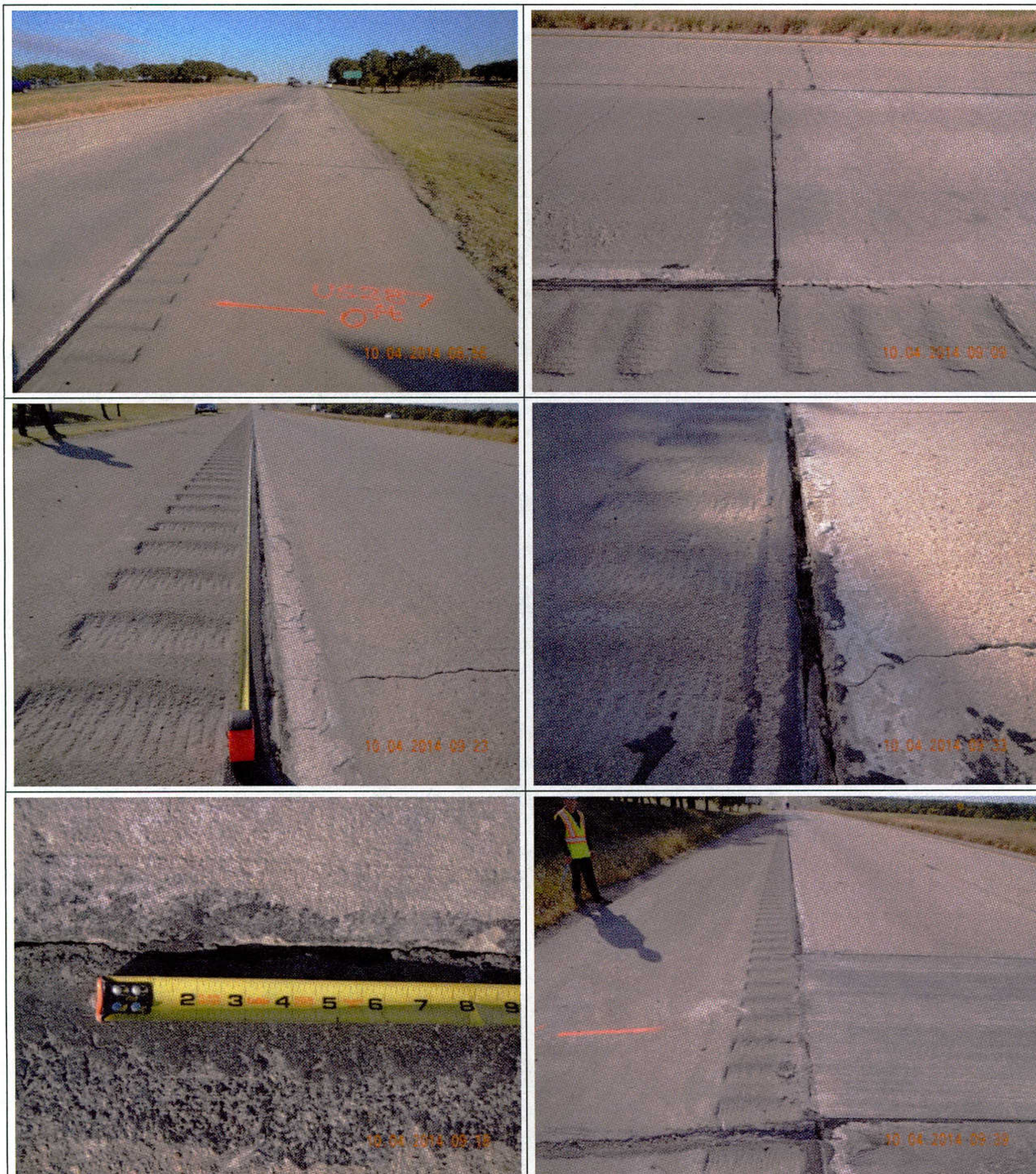


No.50 SH 66, (CSJ 0009-03-017)

No. 51 US 287, Wichita Falls District

Attribute	Information	Special Note
CSJ	0013-05-017	
County	Montague	
Reference Marker		
GPS Coordinates		
Construction Year	1972	
Pavement Type	CRCP	
Slab thickness	8-in.	
Shoulder Type	AC	
Base Type	4-in ASB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		





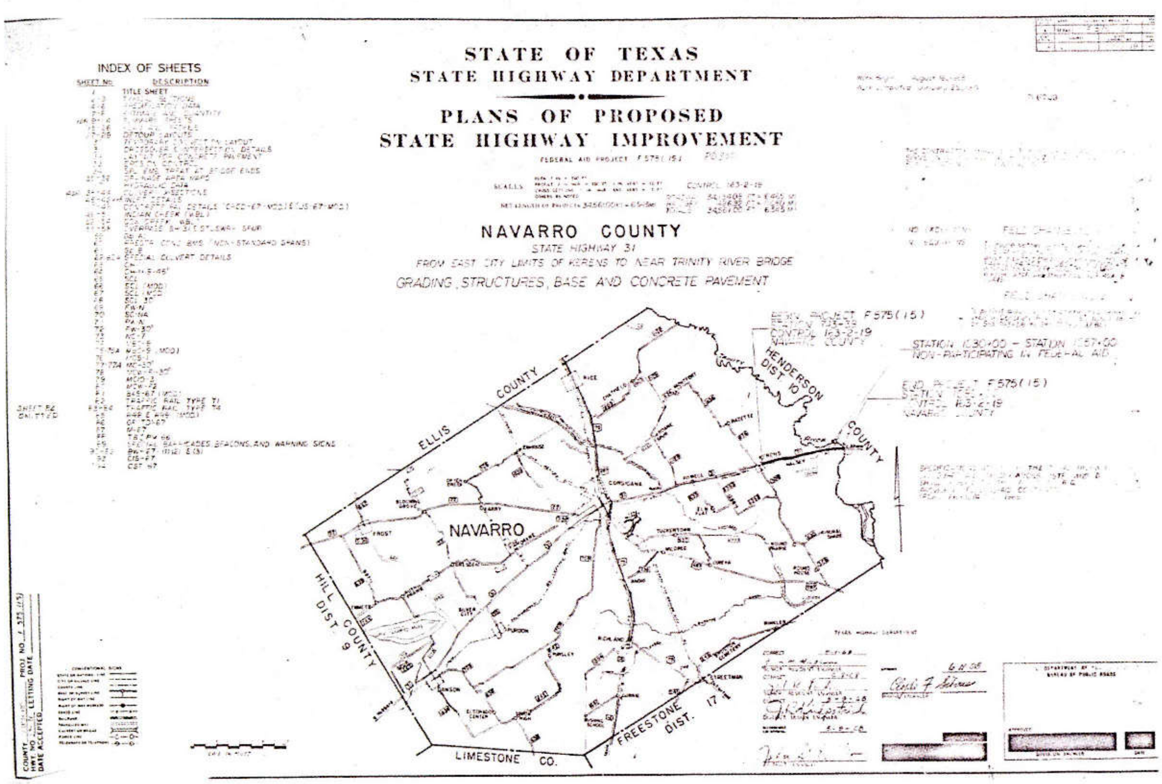
No.51 US 287, (CSJ 0013-05-017)

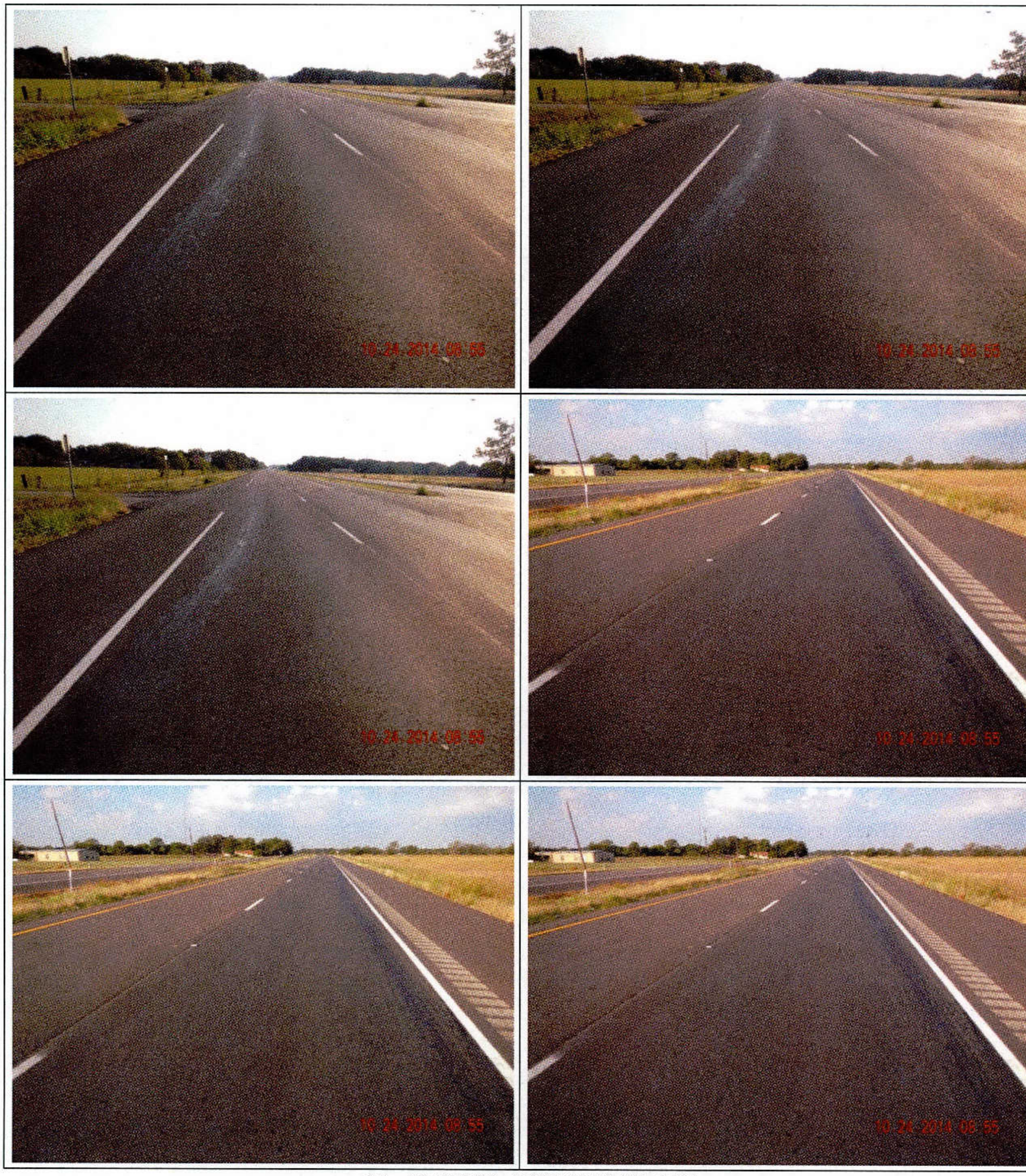
No. 52 US 380, Dallas District

Attribute	Information	Special Note
CSJ	0314-09-023	
County	Denton	
Reference Marker		
GPS Coordinates		
Construction Year	1971	
Pavement Type	CPCD	
Slab thickness	8-in.	
Shoulder Type	2-Coarse Surf. Treatment	
Base Type	6-in LSB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

No. 53 SH 32, Dallas District

Attribute	Information	Special Note
CSJ	0163-02-019	
County	Navarro	
Reference Marker		
GPS Coordinates		
Construction Year	1970	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	AC	
Base Type	6-in SCB	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		

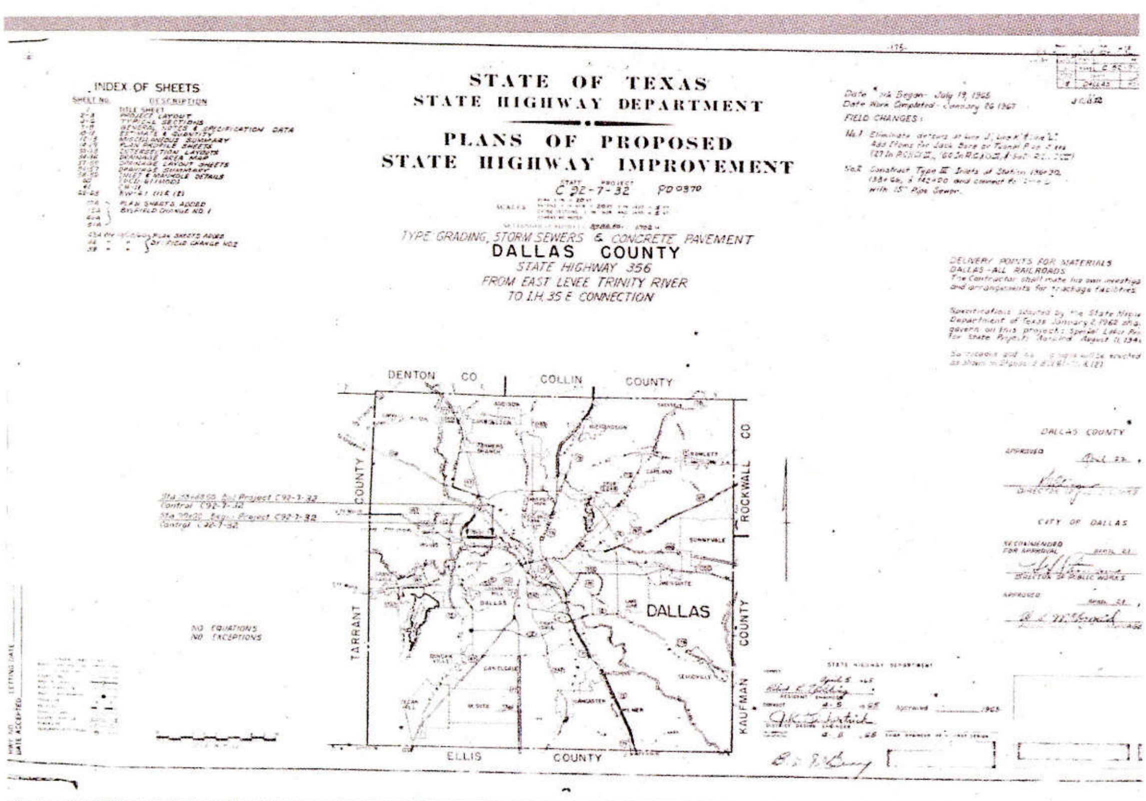




No.53 SH 32, (CSJ 0163-02-019)

No. 54 SH 356, Dallas District

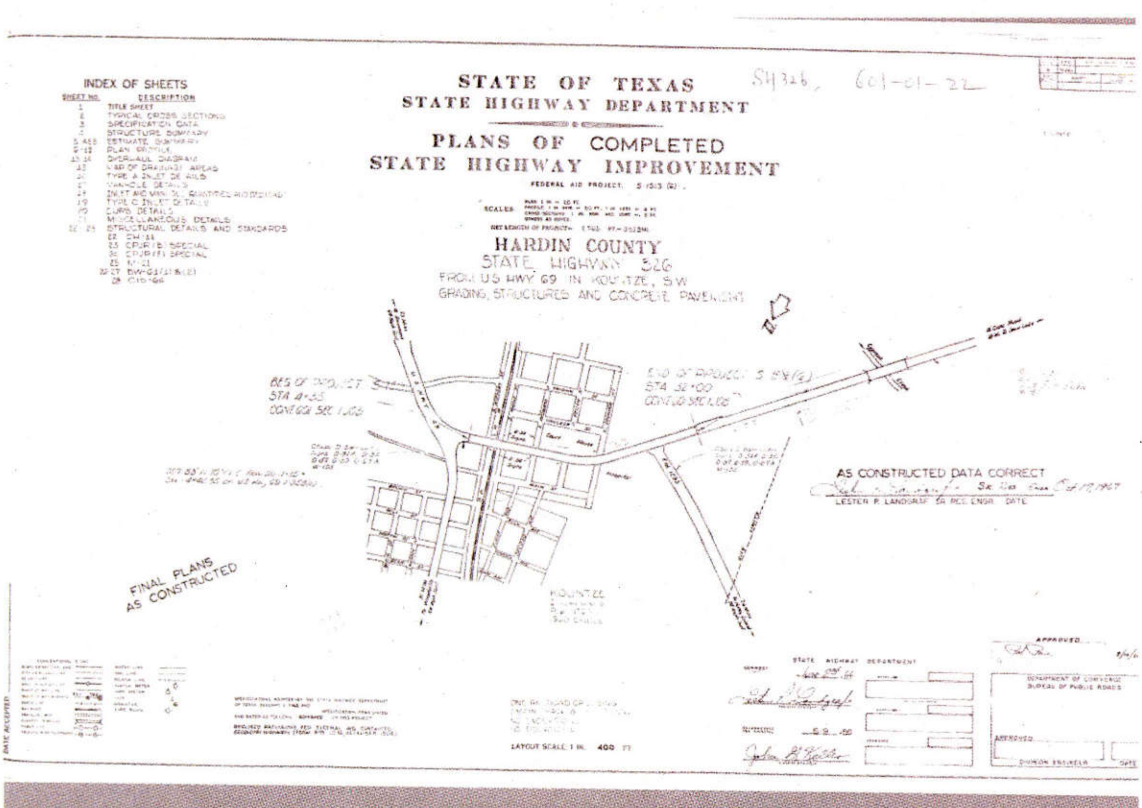
Attribute	Information	Special Note
CSJ	0092-07-032	
County	Dallas	
Reference Marker		
GPS Coordinates		
Construction Year	1967	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	None	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.54 SH 356, (CSJ 0092-07-032)

No. 55 SH 326, Beaumont District

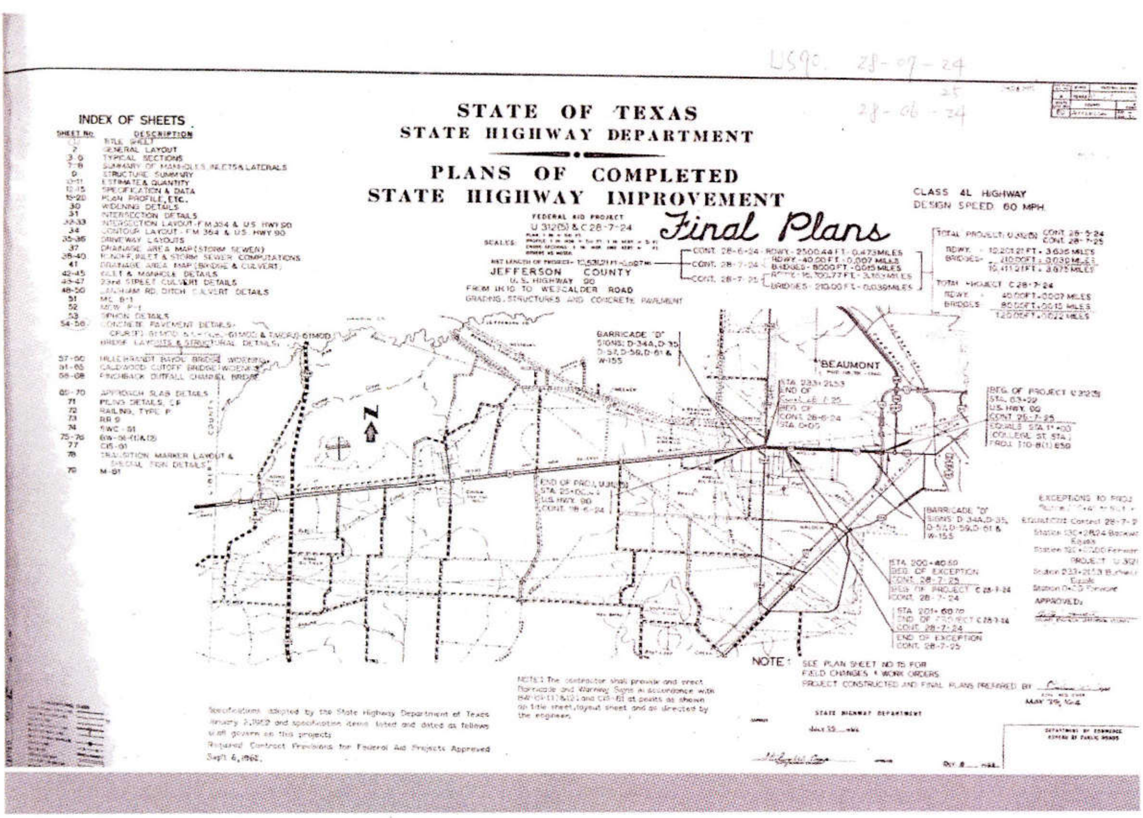
Attribute	Information	Special Note
CSJ	0601-01-022	
County	Hardin	
Reference Marker		
GPS Coordinates		
Construction Year	1967	
Pavement Type	JRCP	
Slab thickness	8-in.	
Shoulder Type	Curb	
Base Type	4-in CSB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.55 SH 326, (CSJ 0601-01-022)

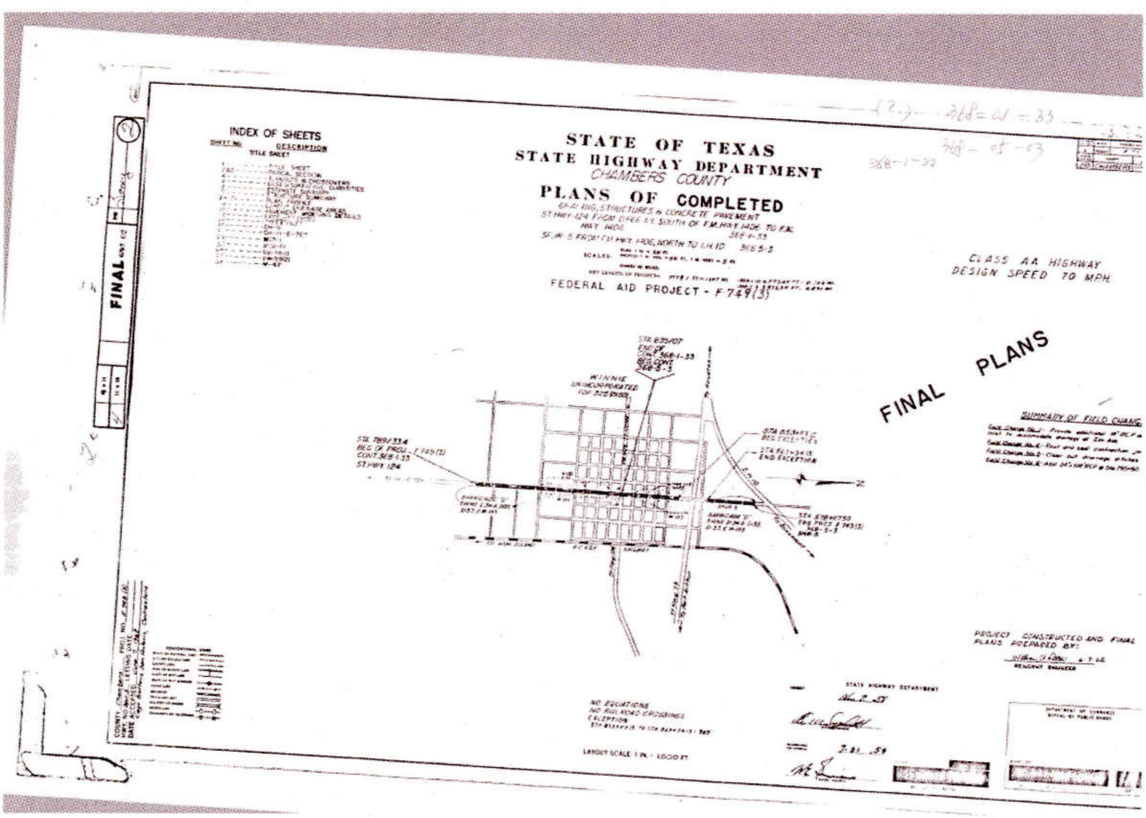
No. 56 US 90, Beaumont District

Attribute	Information	Special Note
CSJ	0028-07-024	
County	Jefferson	
Reference Marker		
GPS Coordinates		
Construction Year	1964	
Pavement Type	JRCP	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	4-in Flexible Base (Cement St abilized)	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 57 SH 124, Beaumont District

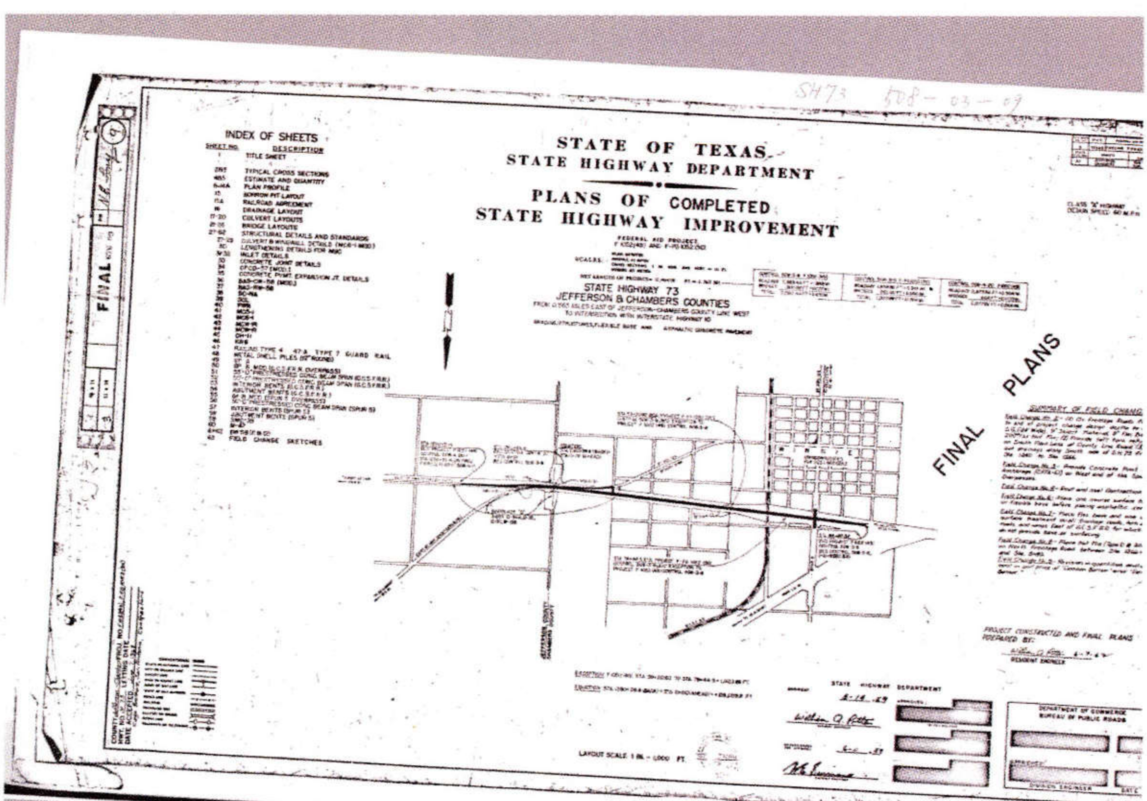
Attribute	Information	Special Note
CSJ	0368-01-033	
County	Chambers	
Reference Marker	RM 478+0.0 - RM 478+0.0	
GPS Coordinates		
Construction Year	1962	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	9-in Comp. Roadbed Treatment	
Subgrade Type	6-in LTS	
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.57 SH 124, (CSJ 0368-01-033)

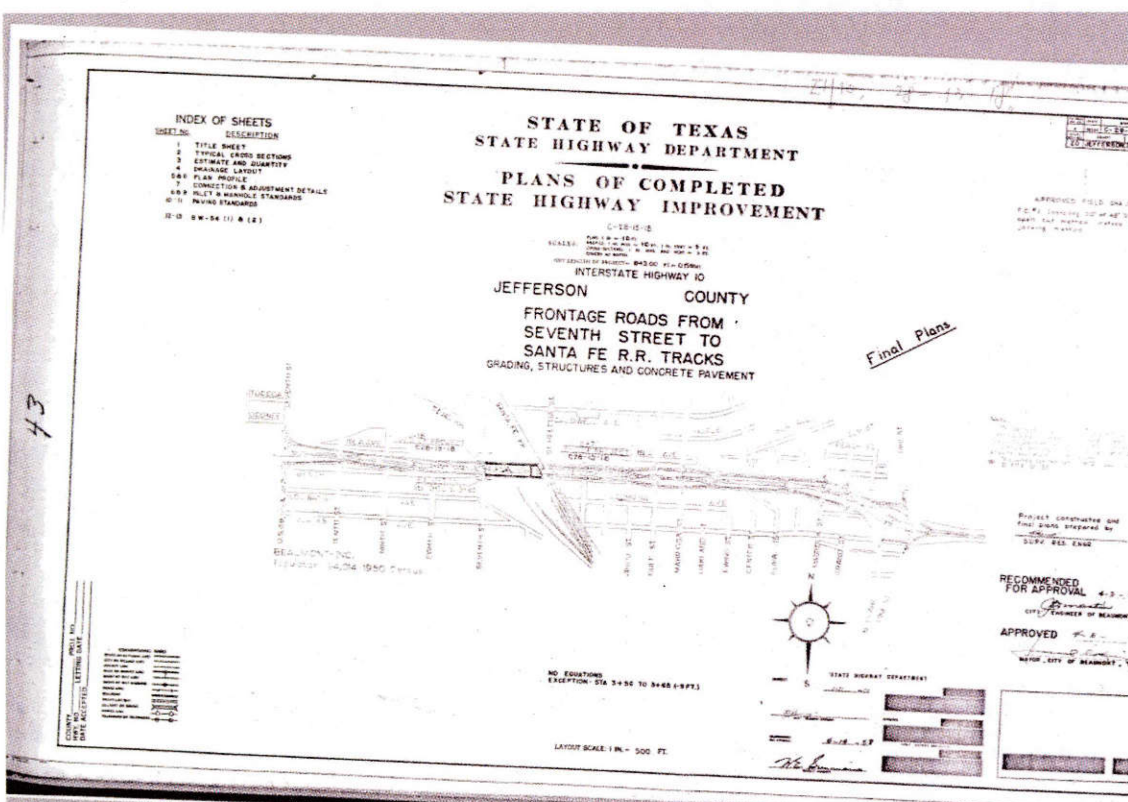
No. 58 SH 73, Beaumont District

Attribute	Information	Special Note
CSJ	0508-03-009	
County	Jefferson	
Reference Marker		
GPS Coordinates		
Construction Year	1962	
Pavement Type	CPCD	
Slab thickness	10-in.	
Shoulder Type	Curb	
Base Type	6-in LSB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 59 IH 10 FR, Beaumont District

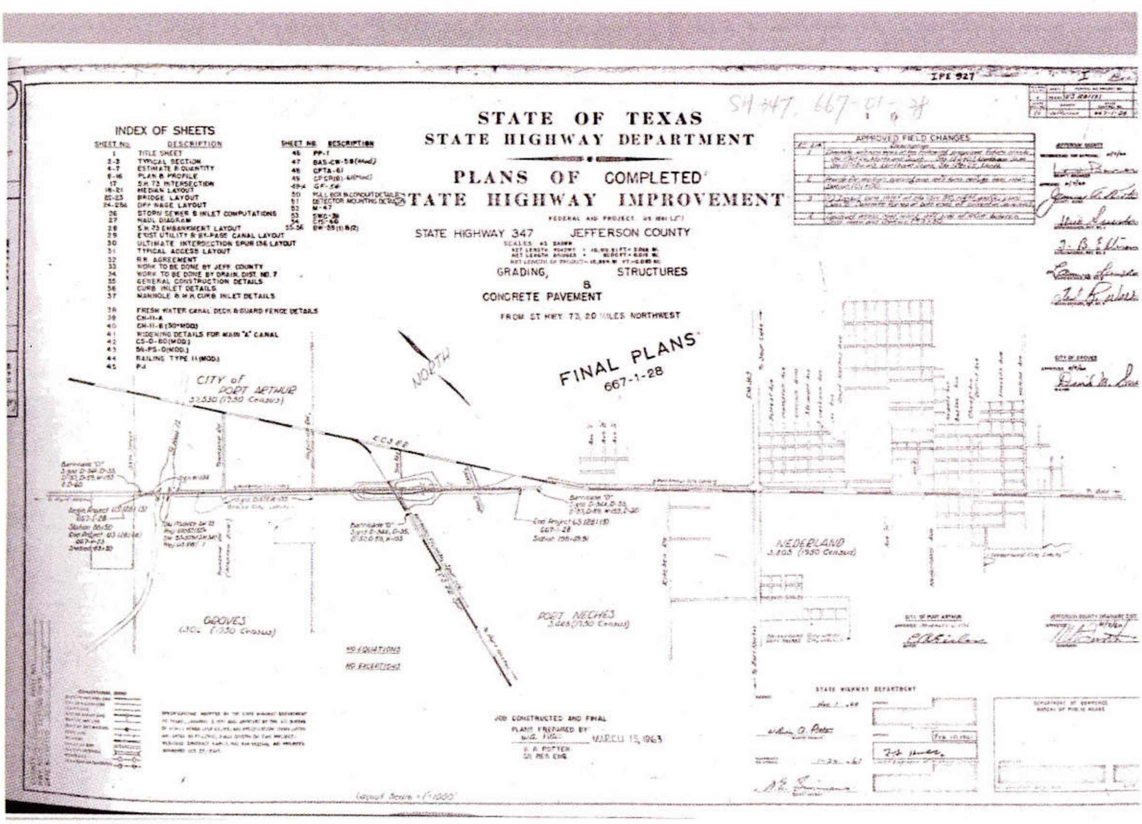
Attribute	Information	Special Note
CSJ	0028-13-018	
County	Jefferson	
Reference Marker	RM 851+0.0 - RM 855+0.1	
GPS Coordinates		
Construction Year	1960	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type	6-in LSB	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No.59 IH 10 FR, (CSJ 0028-13-018)

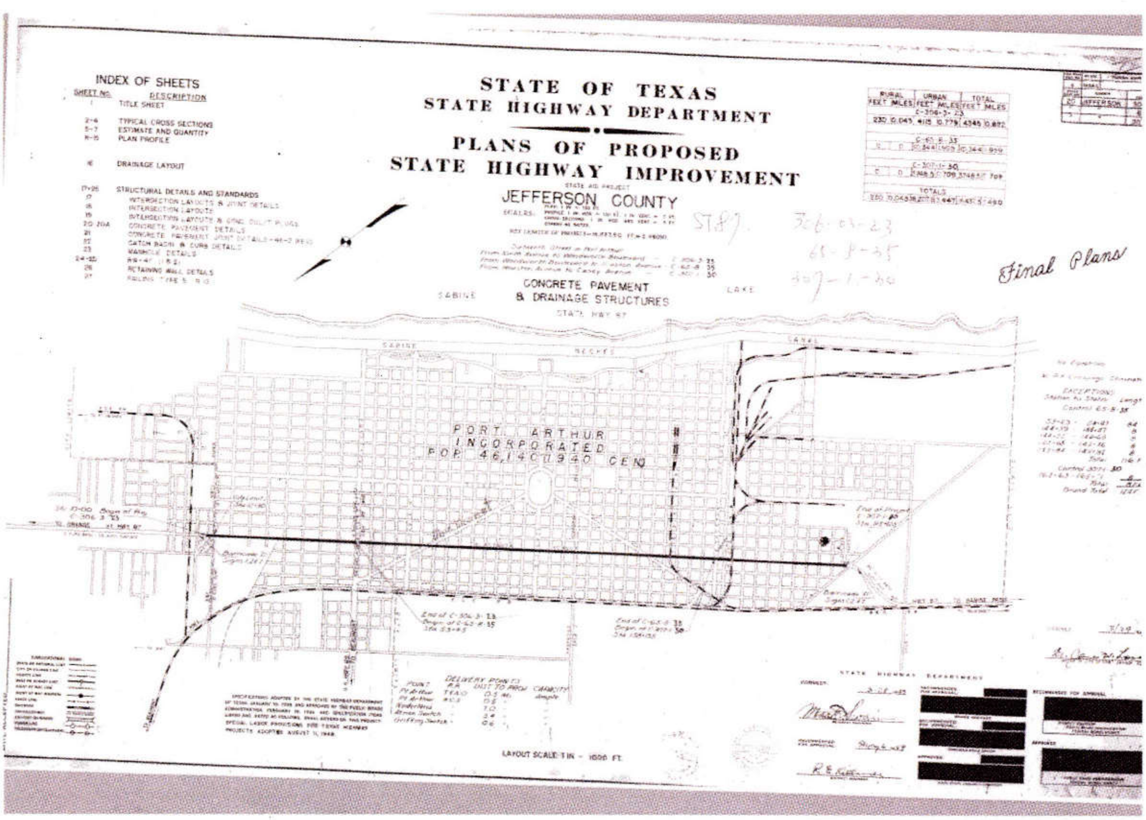
No. 60 SH 347, Beaumont District

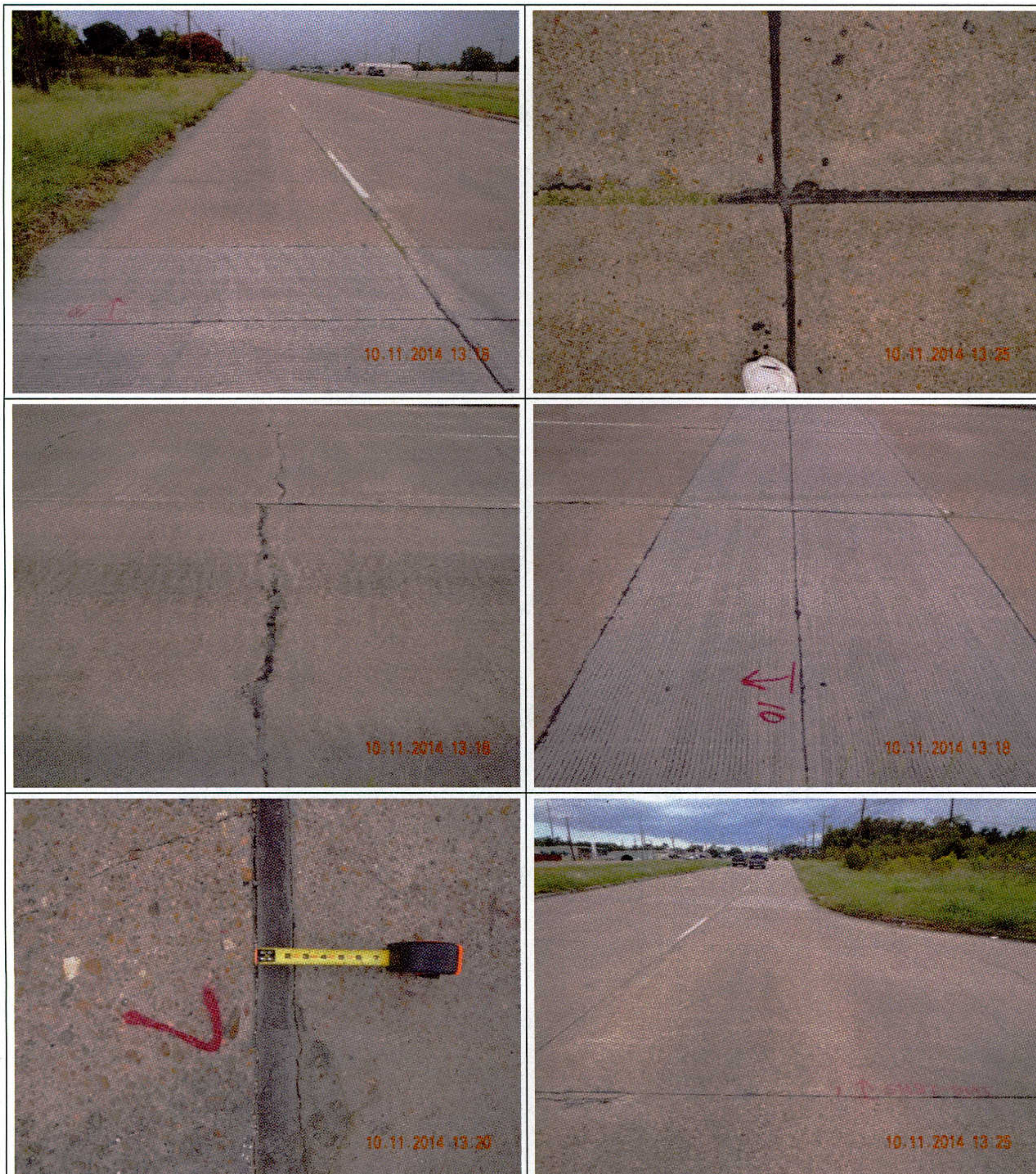
Attribute	Information	Special Note
CSJ	0667-01-028	
County	Jefferson	
Reference Marker	RM 458+0.6 - RM 458+1.3	
GPS Coordinates		
Construction Year	1960	
Pavement Type	CRCP	
Slab thickness	7-in.	
Shoulder Type	Curb	
Base Type	6-in Flex. base	
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		



No. 61 US 87, Beaumont District

Attribute	Information	Special Note
CSJ	0306-03-023	
County	Jefferson	
Reference Marker		
GPS Coordinates		
Construction Year	1951	
Pavement Type	CPCD	
Slab thickness	9-in.	
Shoulder Type	Curb	
Base Type		
Subgrade Type		
Drainage Type		
Coarse Aggregate Type		
Con. Pavement Details		





No.61 US 87, (CSJ 0306-03-023)

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