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16. Abstract

This product introduces most transitions types of concrete pavement that consist of a variety of joint combinations and slab configurations. Transition area design often evolves around the placement and detailing of joints that are placed in concrete pavements to control cracking and to facilitate construction. They divide the pavement into practical construction increments, delineate traffic lanes, and accommodate slab movements. This project conducted a survey of Texas Department of Transportation (TxDOT) and other State Highway Association (SHA) practices and identified the best practices toward incorporating them into guidelines for design and construction of transition areas that will enable TxDOT engineers and designers to avoid the pitfalls of bad practices. In addition to the guidelines, the project also produced detail design sheets to illustrate the specifics in the form of standard sheets, which will be evaluated by TxDOT for implementation.

Guidelines address both design and construction of concrete pavements in transition areas with the joints and related details. The analysis of specific joint configurations associated with transitions was conducted with respect to stiffness of the joint, potential for permanent deformation, and slab restraint to translational movement at the joint. In the design guide, 13 most frequently constructed types of concrete pavement transitions are introduced and some of them have alternative designs as more options in the design guide. The design guide sheets provide the conceptual profile view or plan view drawing of each transition type of concrete pavement. The drawings address slab dimensions, joint types, and layouts of joints. Design guide sheets produce the design factors of each transition type such as joint reinforcing bar size and spacing when engineers choose a value from the list or input information manually with reference to recommended values. To help engineers, the key points of transition area design, important design options/factors, and construction issues are included. The guidelines provide a complete picture of the requirement for the design of a pavement transition for a variety of pavement types and terminal configurations that suitable for use.

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DESIGN AND CONSTRUCTION TRANSITION GUIDELINES FOR CONCRETE PAVEMENT

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CHAPTER I. INTRODUCTION

BACKGROUND

Transition area design often evolves around the placement and detailing of joints that are placed in concrete pavements to control cracking and to facilitate construction. They divide the pavement into practical construction increments, delineate traffic lanes, and accommodate slab movements. The three joint types that are commonly used in concrete pavement construction are contraction joints, construction joints, and isolation (i.e., expansion) joints. The first two joint types are used both transversely and longitudinally. Contraction joints are intended to control cracking while construction joints allow for interruption during placement or are used at planned joint locations such as longitudinal separations between adjacent lanes. Isolation joints allow anticipated differential horizontal and vertical movements (if no dowels are used) to occur between a pavement and immovable object or structure (relatively speaking). Isolation joints are not necessarily the same as expansion joints but often perform the function of an expansion joint and utilize full depth joint filler material. Proper jointing of concrete pavements is essential to ensure good performance since it is the primary key to avoiding random cracking. Load transfer across transverse joints is an important element of joint design. Closely spaced joints usually result in small openings at the joints that may result in increased aggregate interlock between panels. Spreading the joints farther apart typically results in a higher incidence of cracking plus wider openings of joints and diminished load transfer capability.

RESEARCH OBJECTIVE

The guidelines address the key factors to successfully designing and constructing concrete pavement transitions. These guidelines lead the user through a step-by-step process to obtain the best design possible for the given design conditions through the answers to questions about load transfer at joints and other joint details. The conceptual drawings are put into the guidelines, and the necessary details are provided to allow TxDOT personnel to specify the construction of pavement transitions. The drawings address slab dimensions, joint types, and layouts of joints. The guidelines also address transitions in the base materials to avoid restraint problems that would induce cracking or misalignment problems. In this manner, the guidelines also provide explanation of the situations that apply to each of the detail sheets.

RESEARCH APPROACH

The guidelines address both design and construction of concrete pavements in transition areas with the joints and related details. The analysis of specific joint configurations associated with transitions was conducted with respect to stiffness of the joint, potential for permanent deformation, and slab restraint to translational movement at the joint. The guidelines are made up of transition requirements, slab and jointing patterns with configurations details, design options, factors, and construction precautions. The guidelines provide a complete picture of the requirement for the design of a pavement transition for a variety of pavement types and terminal configurations suitable for use (see the appendix).

CHAPTER II. DESIGN CRITERIA

MAXIMUM JOINT SPACING

Joint spacing is the prime factor in constructing concrete pavement that is free of random cracks. Maximum joint spacing for jointed concrete pavement can be calculated based on subgrade strength and 'effective' thickness of the slab. The effective slab thickness takes into account all the other factors besides thickness that contribute stiffness or bending resistance to the slab. Continuously reinforced concrete pavement (CRCP) is characterized by longitudinal reinforcement that is spliced and continues for the full length of the pavement. There are sawn or formed longitudinal joints and transverse "cracks" that are designed to form naturally to relieve the stresses. CRCP does not contain transverse joint except at construction joints.

Subgrade Strength

Subgrade strength can be roughly divided into four categories: low, medium, medium high, and high strength relative to the k-value of the subgrade. Low is a $k < 100$ pound per cubic inch (pci) or California Bearing Ratio (CBR) < 3; medium is a $100 \leq k < 150$ pci or $3 \leq \text{CBR} < 5$; medium high is a $150 \leq k < 200$ pci or $5 \leq \text{CBR} < 10$; high is a $k \geq 200$ pci or $\text{CBR} \geq 10$. Figure 1 shows approximate subgrade strength based on soil classifications and bearing values (*1, 2*). It could be used in design as a reference when there is no tested value.

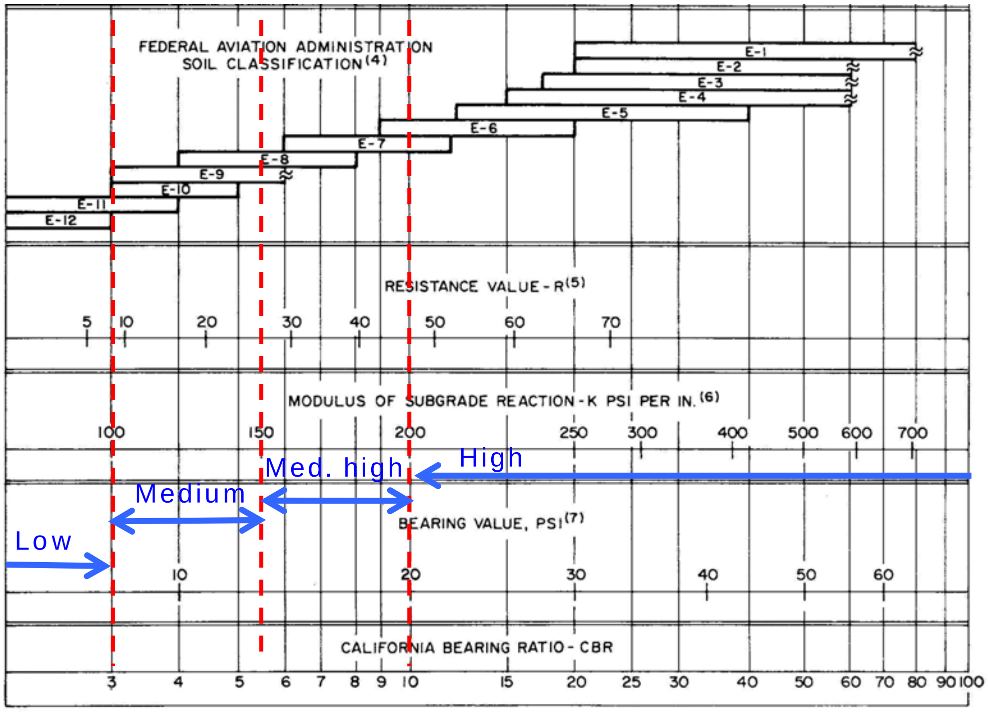

Figure 1. Approximate Relationship of Soil Classifications and Bearing Values (*1,2*).

Effective Slab Thickness

As a general concept, the ‘effective’ slab thickness is an equivalent single slab thickness typically varying as a function of the degree of bonding between the concrete slab and the subbase layer (*3*). Figure 2 shows the effective thickness by Equation 1 for unbonded concrete slabs and bases, which is a good assumption for concrete pavement systems incorporating a bond breaker.

$$h_e = \sqrt[3]{{h_c}^3 + \frac{E_b}{E_c}{h_b}^3} \tag{1}$$

Where, h_e = Effective thickness of combined slab (inch)
h_c = Thickness of concrete slab (inch)
h_b = Thickness of base (inch)
E_c = Elastic modulus of concrete (psi)
E_b = Elastic modulus of base (psi)

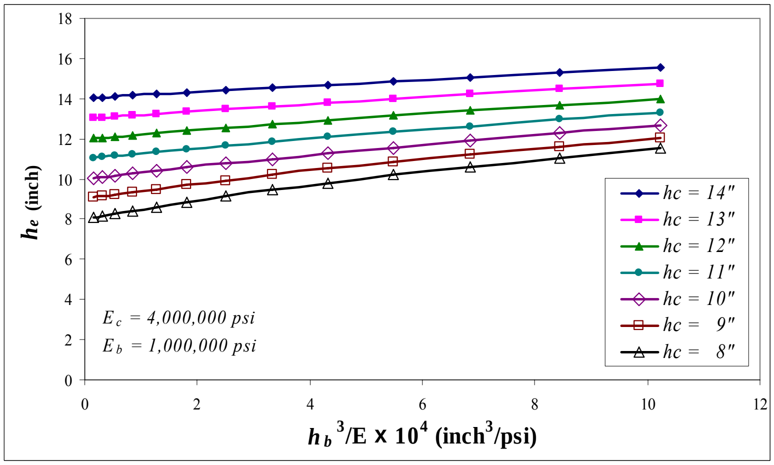

Figure 2. Effective Slab Thickness.

Maximum Joint Spacing

Maximum joint spacing (slab length) is a function of the actual slab thickness and the effective k-value immediately below the slab (*4*). The effective k-value depends on the subgrade k-value and the thickness and stiffness of the subbase layer. Table 1 shows the design k values affected by subbases.

Table 1. Design k-values for Untreated and Cement-treated Subbases (*4*).

Subgrade k value, pci	Untreated subbase k value, pci				Cement-treated subbase k value, pci			
	4 inch	6 inch	9 inch	12 inch	4 inch	6 inch	8 inch	10 inch
50	65	75	85	110	170	230	310	390
100	130	140	160	190	280	400	520	640
200	220	230	270	320	470	640	830	-

Figure 3 represents the examples of maximum joint spacing. To restrain cracking on concrete, drag length should not exceed 100 feet.

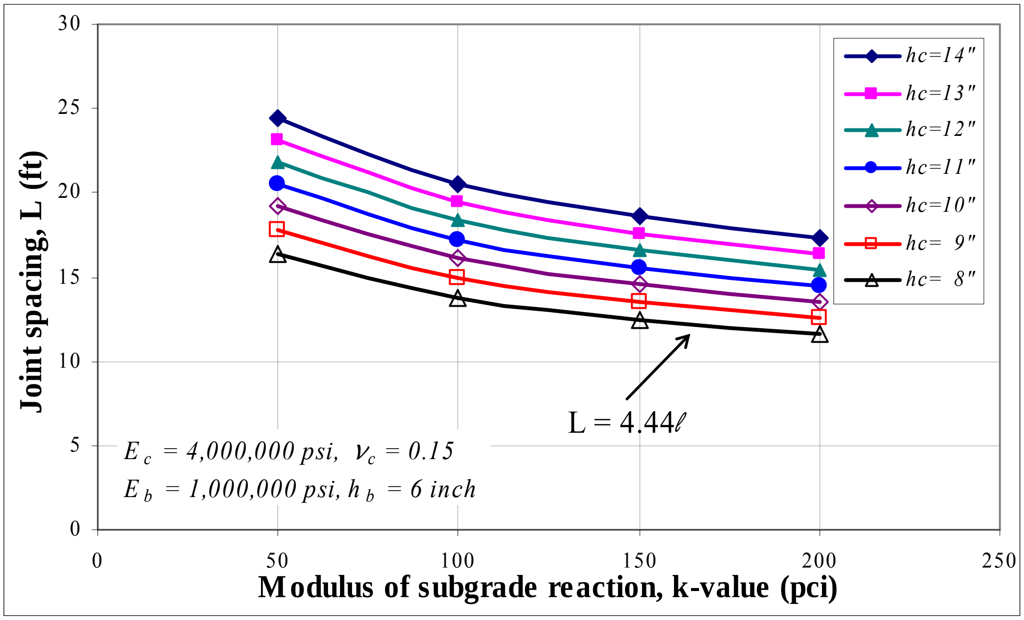

Figure 3. Maximum Joint Spacing and Slab Thickness Relationships (5).

MINIMUM DESIGN THICKNESS

In the design process for pavement transitions, appropriate criteria for design could be deflection based rather than fatigue damage based, as it would be for heavily trafficed pavement sections. Therefore, engineers should check minimum design thickness based on maximum allowable deflection. If the design thickness is not satisfied relative to the allowable slab deformation, load transfer using dowel bar or other load transfer devices should be considered (6). Table 2 shows examples of radius of relative stiffness (RRS) by Equation 2 for various concrete slabs' thickness, foundation modulus (k-value), and the elastic modulus of concrete. The RRS increases when concrete slab thickness or the elastic modulus of concrete increases. However, the RRS decreases when the subgrade k-value increases.

Radius of Relative Stiffness

$$\ell = \sqrt[4]{\frac{E_c h_e^{\,3}}{12(1-\nu^2)k}} \qquad (2)$$

Where, ℓ = Radius of relative stiffness (inch)
E_c = Elastic modulus of the concrete pavement layer (psi)
h_e = Effective thickness of combined slab (inch)
ν = Poisson's ratio
k = Foundation modulus (pci)

Table 2. Radius of Relative Stiffness.

Thickness, h_e (inch)	k-value (pci)	Elastic modulus of concrete, E_c (psi)		
		3,000,000	3,500,000	4,000,000
8	50	40.2	41.8	43.2
	100	33.8	35.2	36.4
	150	30.6	31.8	32.8
	200	28.4	29.6	30.6
9	50	43.9	45.7	47.2
	100	37.0	38.4	39.7
	150	33.4	34.7	35.9
	200	31.1	32.3	33.4
10	50	47.6	49.4	51.1
	100	40.0	41.6	43.0
	150	36.1	37.6	38.8
	200	33.6	34.9	36.1
11	50	51.1	53.1	54.9
	100	43.0	44.6	46.2
	150	38.8	40.3	41.7
	200	36.1	37.5	38.8
12	50	54.5	56.7	58.6
	100	45.9	47.7	49.3
	150	41.4	43.1	44.5
	200	38.6	40.1	41.4
13	50	57.9	60.2	62.2
	100	48.7	50.6	52.3
	150	44.0	45.7	47.3
	200	40.9	42.5	44.0
14	50	61.2	63.6	65.8
	100	51.5	53.5	55.3
	150	46.5	48.3	50.0
	200	43.3	45.0	46.5

Corner Deflection Based on Westergaard Equation

Figure 4 represents the examples of corner deflections by Equation 3 for various concrete slabs' thickness and foundation modulus (7). The corner deflection decreases when concrete slab thickness or foundation modulus increases.

$$\delta = \frac{P}{k\ell^2}\left[1.1 - 0.88\left(\frac{a\sqrt{2}}{\ell}\right)\right] \qquad (3)$$

Where, δ = Corner deflection (inch)
P = Wheel load (lb)
k = Foundation modulus (pci)
ℓ = Radius of relative stiffness (inch)
a = Radius of circular load (inch)

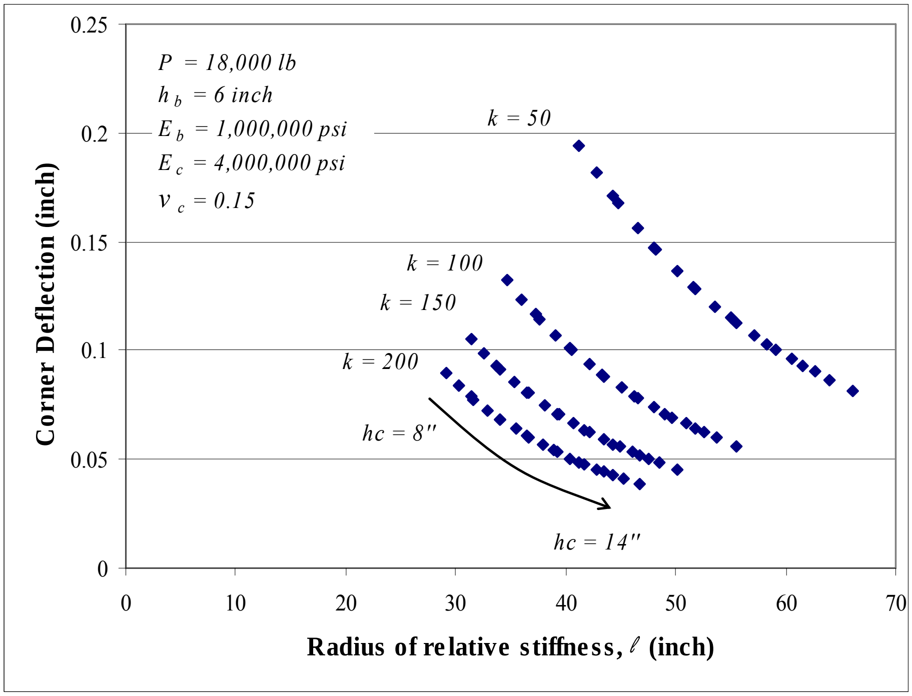

Figure 4. Corner Deflection.

Pavement Deflection Criteria

The maximum deflection allowed was based on the subgrade type strength and its elastic characteristics relative to the maximum strain associated with its elastic range of strain. In like manner, the maximum allowable stress that can be tolerated by the native subgrade is based on the elastic-plastic characteristics of the subgrade. These concepts are illustrated in Figure 5, which is a typical, generic plot of stress vs. strain under monotonic loading for a soil.

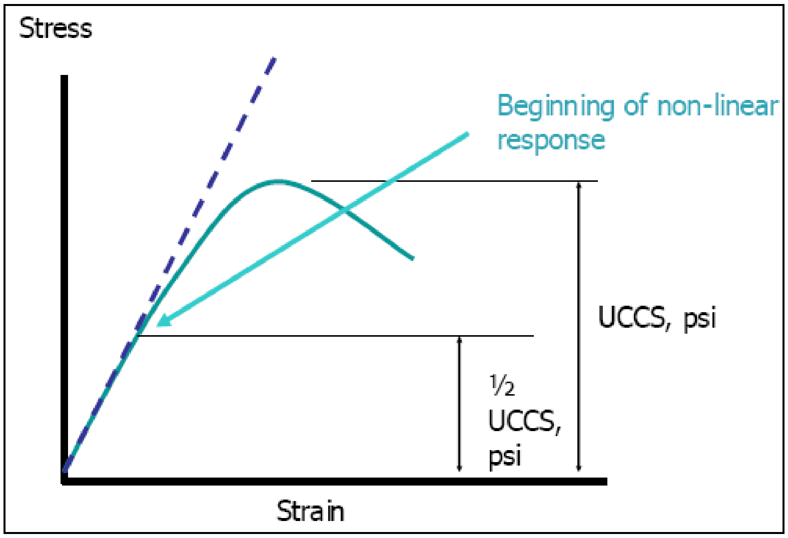

Figure 5. Typical Stress-Strain Response in Subgrade Soil (8).

Note that up to a stress of about one-half of the ultimate, unconfined compressive stress (UCCS) at failure, the stress-strain response is typically linear; and if a cyclic load or stress were applied up to about 0.5 UCCS of the subgrade, the strain is typically fully recoverable for each application of load or stress. The rate of permanent deformation accumulation is assumed to occur at an unacceptable rate if the cyclic stress exceeds about 0.5 UCCS. At this point, each load or stress cycle results in a permanent or non-recoverable strain. Over time and loading, this cumulative strain grows resulting in a loss of support under the slab. Loss of subgrade support is a parameter that may affect pavement performance and is a causative factor related to joint faulting and corner cracking. Based on this approach, the pavement structure is designed so that stresses induced in the subgrade under traffic loading would not exceed 0.5 of the UCCS.

Dimensionless Deflection

For design purpose, it is useful to refer to slab deflection in a dimensionless format to gain the widest possible generality. Figure 6 shows examples of dimensionless deflection using Equation 4 for various concrete slabs' thickness and subbase modulus (8).

$$d^* = \frac{\delta k \ell^2}{P} \quad \Rightarrow \quad \delta \cdot k = \frac{P \cdot d^*}{\ell^2} \le 10 \text{ psi limit } (\approx \frac{1}{2} \text{UCCS}) \qquad (4)$$

Where, d^* = Dimensionless deflection
δ = Westergaard corner deflection (inch)
k = Foundation modulus (pci)
ℓ = Radius of relative stiffness (inch)
P = Wheel load (lb)

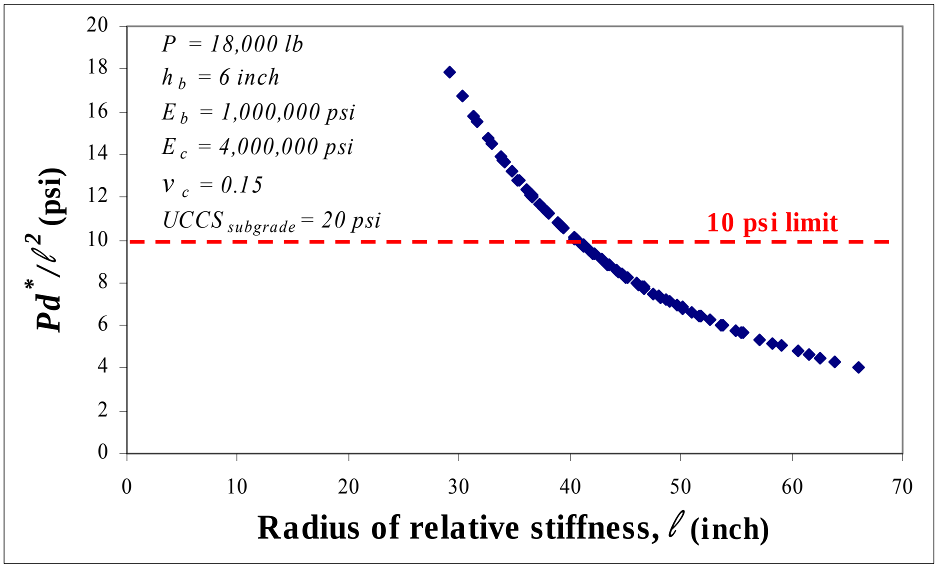

Figure 6. Deflection Limit.

In the case of the example in Figure 7, 9 inches is the minimum effective slab thickness without load transfer to restrict average allowable deflection, generally 0.1 inch. However, if statistical variation of the factors affecting the design is considered, the allowable minimum thickness would be increased as subsequently elaborated.

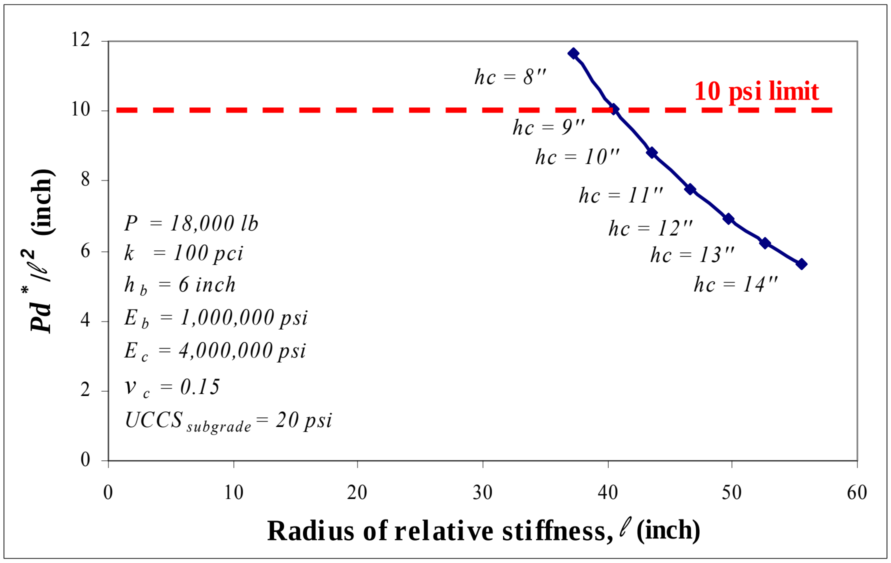

Figure 7. Example of the Deflection Limit.

MINIMUM LOAD TRANSFER EFFICIENCY

When design thickness is not sufficient to restrict deflection to the maximum allowable level, load transfer must be adjusted accordingly. Load transfer efficiency (LTE) depends on slab thickness and dowel bar size and spacing. Therefore, dowel bar size and spacing would be selected according to the relationship between joint stiffness, slab thickness, and the minimum or desirable level of LTE.

Deflection with LTE

Figure 8 shows the variation of the mean corner deflection with LTE according to Equation 5 for various concrete slab thicknesses. Figure 9 shows the design corner deflection after considering statistical variation of the design factors (*8*). The deflection variance (*Var[δ]*) is useful to determine a measured level of reliability against slab failure due to permanent subgrade deformation through Equation 6 (*8*). Assuming the deviation of slab deflection at the critical load location on the slab is normally distributed about the mean, Z_R can be selected for a given level of reliability from a normal standard deviate table (i.e., Z_R for a 95 percent reliability = 1.645). Figures 8 and 9 show the increment of deflection based on 95 percent confidence interval (CI).

$$\delta = \frac{\delta}{1 + LTE} \tag{5}$$

$$\delta_{CI} = \bar{\delta} + Z_R (SD_\delta) \tag{6}$$

Where, δ = Corner deflection with load transfer (inch)

δ = Mean corner deflection by corner loading (inch)

LTE = Load transfer efficiency (%)

δ_{CI} = Corner deflection with confidence interval (inch)

Z_R = Normal standard deviate (reliability factor)

SD_{δ} = Deflection standard deviation (inch) = $\sqrt{VAR[\delta]}$

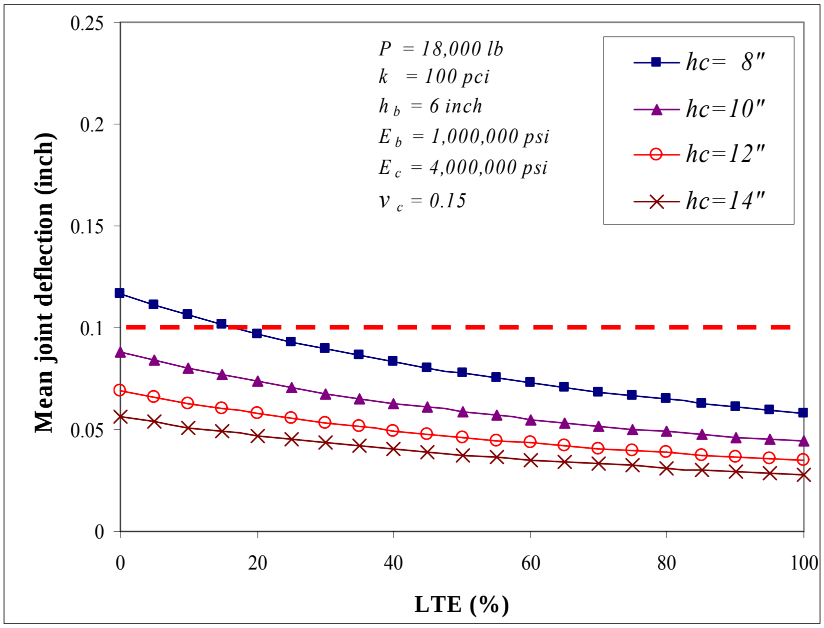

Figure 8. Mean Joint Deflection with LTE.

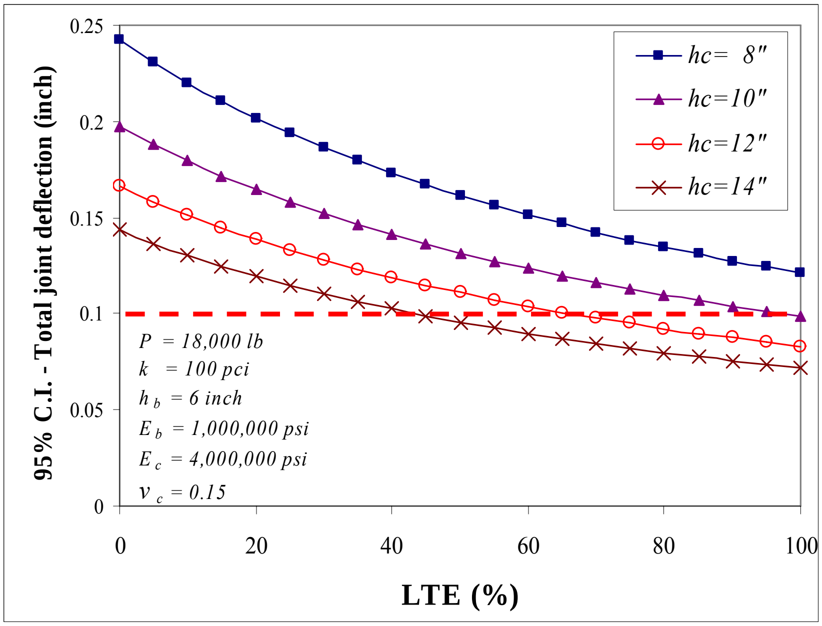

Figure 9. Design Joint Deflections with LTE at 95 Percent Reliability.

Figure 10 shows an example analysis for an 11 inch slab that has a mean deflection less than 0.1 inch. However, the 0.1 inch-deflection criteria can be met with 79 percent LTE at 95 percent reliability (*9*).

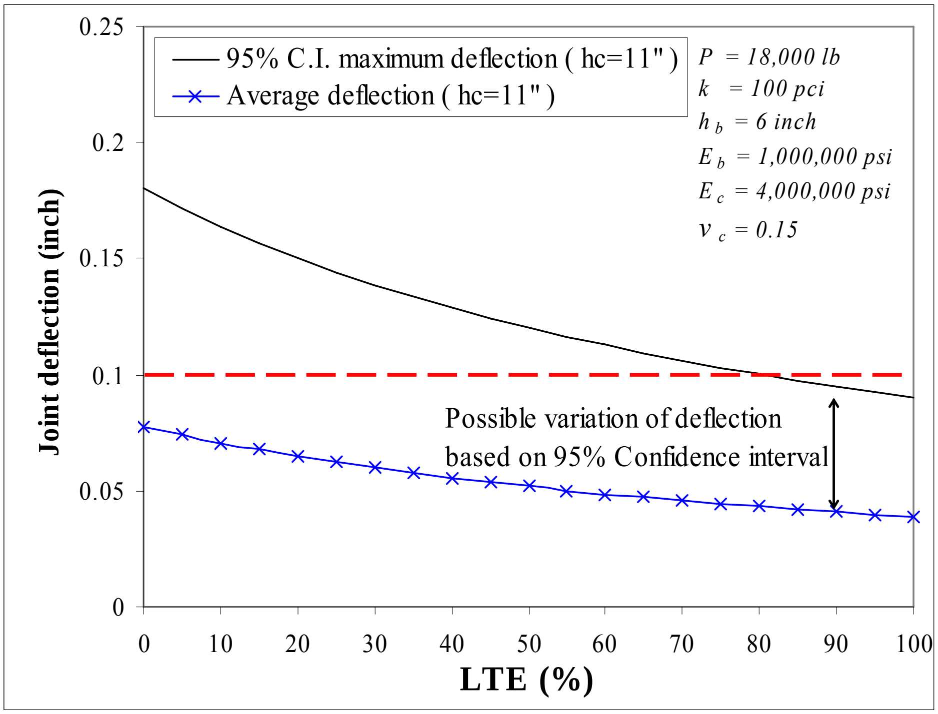

Figure 10. Design Deflection Variation with LTE at 95 Percent Confidence Interval.

Joint Stiffness

Stiffness of a doweled joint depends on diameter and spacing of dowel and aggregate interlocking. Joint stiffness can be calculated using Equations from 7 to 15 and dowel bar size selected using Table 3 (*10*).

$$J = J_D + J_{AI} \qquad (7)$$

Where, J = Total joint stiffness
J_D = Joint stiffness of dowel bars
J_{AI} = Joint stiffness of aggregate interlock

$$J_D = \frac{D}{sk\ell} \qquad (8)$$

$$D = \frac{1}{\frac{1}{DCI} + \frac{1}{12C}} \qquad (9)$$

$$DCI = \frac{4\beta^3 E_d I_d}{(2+\beta w)} \tag{10}$$

$$\beta = \sqrt[4]{\frac{Kd}{4E_d I_d}} \tag{11}$$

Where, K = Modulus of dowel support, 1,500,000 (pci)
d = Diameter of dowel (inch)
E_d = Young's modulus of dowel, 30,000,000 (psi)
I_d = Moment of inertia of dowel bar cross-section (inch^4) = $\frac{\pi d^4}{64}$
w = Joint or crack opening (inch)

$$C = \frac{E_d I_d}{w^3(1+\phi)} \tag{12}$$

$$\phi = \frac{12 E_d I_d}{G_d A_z w^2} \tag{13}$$

Where, G_d = Shear modulus of dowel bar (psi) = $\frac{E_d{}^4}{2(1+v_d)}$
v_d = Poisson's ratio of dowel, 0.3
A_z = Effective cross-section area of dowel (inch^2) = $0.9 \times \frac{\pi d^2}{4}$

$$J_{AI} = \frac{Agg}{k\ell} \tag{14}$$

$$\log\left(\frac{Agg}{k\ell}\right) = ae^{-e^{\frac{-(x-b)}{c}}} + de^{-e^{\frac{-(s-e)}{f}}} + ge^{-e^{\frac{-(x-b)}{c}}} \times e^{-e^{\frac{-(s-e)}{f}}} \tag{15}$$

Where, a = -4
x = 0.039
b = -11.26
c = 7.56
d = -28.56
$s = 0.0312 h_e^{1.4578} \cdot e^{-0.039cw}$
h_e = Effective thickness of combined slab (inch)
cw = Crack width (mils = inch×10^3)
e = 0.35
f = 0.382
g = 56.26

Table 3. Joint Stiffness.

Thickness, h_e (inch)	**k-value (pci)**	**Dowel size (inch)**							
		1	**1 1/8**	**1 1/4**	**1 3/8**	**1 1/2**	**1 5/8**	**1 3/4**	**1 7/8**
8	50	38.8	47.9	57.7	68.4	79.8	91.9	104.8	118.4
	100	23.1	28.5	34.3	40.7	47.4	54.7	62.3	70.4
	150	17.0	21.0	25.3	30.0	35.0	40.3	46.0	51.9
	200	13.7	16.9	20.4	24.2	28.2	32.5	37.1	41.9
9	50	35.6	43.8	52.8	62.6	73.0	84.1	95.9	108.4
	100	21.2	26.1	31.4	37.2	43.4	50.0	57.0	64.4
	150	15.6	19.2	23.2	27.5	32.0	36.9	42.1	47.6
	200	12.6	15.5	18.7	22.1	25.8	29.8	33.9	38.3
10	50	32.9	40.5	48.8	57.8	67.5	77.7	88.6	100.1
	100	19.5	24.1	29.0	34.4	40.1	46.2	52.7	59.6
	150	14.4	17.8	21.4	25.4	29.6	34.1	38.9	43.9
	200	11.6	14.3	17.3	20.5	23.9	27.5	31.3	35.4
11	50	30.6	37.7	45.5	53.8	62.8	72.4	82.5	93.2
	100	18.2	22.4	27.0	32.0	37.4	43.0	49.1	55.4
	150	13.4	16.6	20.0	23.6	27.6	31.8	36.2	40.9
	200	10.8	13.3	16.1	19.0	22.2	25.6	29.2	33.0
12	50	28.7	35.3	42.6	50.4	58.8	67.8	77.3	87.3
	100	17.1	21.0	25.3	30.0	35.0	40.3	46.0	51.9
	150	12.6	15.5	18.7	22.1	25.8	29.8	33.9	38.3
	200	10.1	12.5	15.1	17.8	20.8	24.0	27.3	30.9
13	50	27.0	33.3	40.1	47.5	55.4	63.9	72.8	82.3
	100	16.1	19.8	23.9	28.3	33.0	38.0	43.3	48.9
	150	11.9	14.6	17.6	20.9	24.3	28.0	32.0	36.1
	200	9.6	11.8	14.2	16.8	19.6	22.6	25.8	29.1
14	50	25.5	31.5	38.0	44.9	52.4	60.4	68.9	77.8
	100	15.2	18.7	22.6	26.7	31.2	35.9	41.0	46.3
	150	11.2	13.8	16.7	19.7	23.0	26.5	30.2	34.2
	200	9.0	11.1	13.4	15.9	18.6	21.4	24.4	27.5

Dowel bar length = 18 inch, Average dowel bar spacing = 12 inch, Modulus of concrete, E_c = 4,000,000 psi

Load Transfer Efficiency

LTE can be calculated by Equation 16 using joint stiffness and the relationship between the joint stiffness and the load transfer efficiency as represented in Figure 11 (*11*). In Figure 11, LTE increases very rapidly up to approximately 85 percent. However, LTE gradually approaches 100 percent as joint stiffness increases from a J value of 10 to 1000.

$$LTE = \frac{1}{1 + Log^{-1}\left[\dfrac{0.214 - 0.183\left(\dfrac{a}{\ell}\right) - Log(J)}{1.180}\right]} \tag{16}$$

Where, J = total joint stiffness and
a = loaded radius.

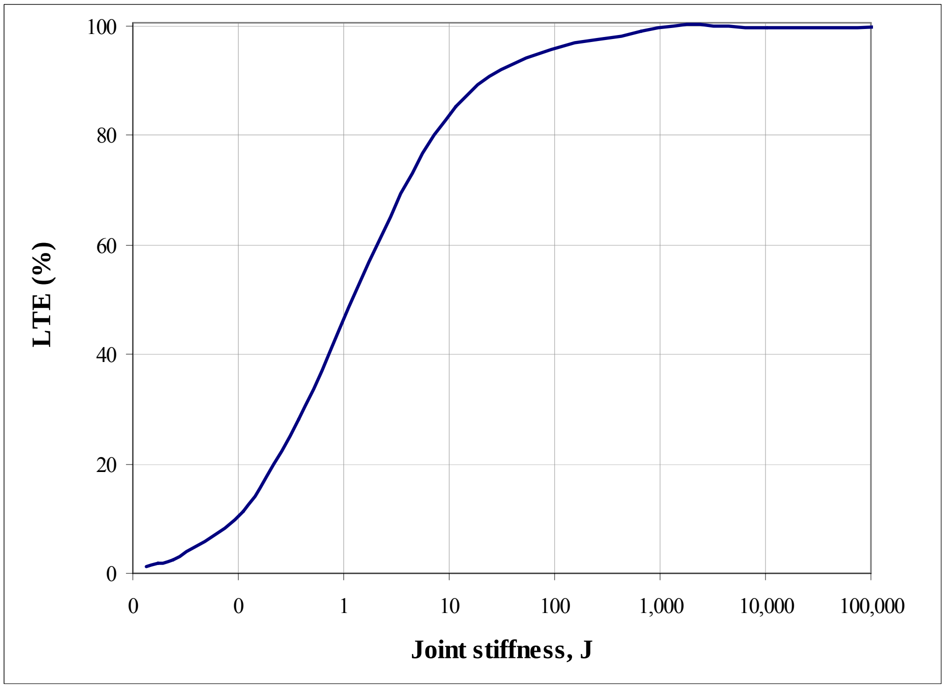

Figure 11. Relationship between the Joint Stiffness and the LTE.

CHAPTER III. GUIDE TO USING TRANSITION DESIGN SPREADSHEET

EXCEL SPREADSHEET GENERAL FORMATS

Insert the title of the transition on the top of each page. Plane view and x-section box is the conceptual profile view or plan view drawing for the selected transition. Table 4 explains the classification and notations of the joint types shown in the details. For example, *Longitudinal tied contraction joint* will be designated as *Longitudinal Type A (Tied)*; *Transverse construction joint with deformed bar* would be *Transverse Type B (DB)*; and *Transverse isolation joint with wide flange* will be *Transverse Type C (WF)*.

Table 4. Classification and Notations of Joint Types.

Type	Joint Description
A	Contraction joint
B	Construction joint
C	Isolation joint

Modifier	Abbreviation
With smooth dowel	SD
With deformed bar	DB
Tied	
Thickened edge	TE
Wide flange	WF
Sleeper slab	SS
Tapered	

There are key points of transition design and important options/factors for design consideration. They are associated with the inputs and outputs relative to each transition type. Choose a value from the provided list or input manually with reference to recommend values. When the design factors are same as a previous transition type, omit the repeated factors. Construction issues are key points of transition construction and important issues for construction during construction.

EXCEL SPREADSHEET FOR EACH TRANSITION TYPE

There are 13 types of transitions, and some of them have alternative designs as suggested options in the design guide spreadsheet. These designs do not replace or supersede any previously used transition.

CRC Pavement to CRC Pavement Thickness Transition

This is a transition of two continuously reinforced concrete (CRC) pavement segments that have different thicknesses. Dowels/tie bars are drilled and epoxied into the existing pavement to transition to the new pavement. The tapered transition area should be at least 20 ft, and lap splice length of the steel bars should be 33 times the steel bar diameter. The reinforcing steel splice is made in the thickness transition area if one is present. Thickness transition can taper over a distance 20 ft or greater.

Design Factors

- Slab thickness – Choose one from 8 inch to 15 inch.
- The steel bar size and spacing are automatically decided by TxDOT CRCP standard design when slab thickness is chosen. Moreover, engineers also can input steel bar size and spacing manually if properties are different than standard. Table 5 shows the TxDOT standard design values for CRC pavement.

Table 5. TxDOT Standard Design for CRC Pavement.

Slab Thickness (inch)	Reinforce Bar No.	Bar Diameter (inch)	Spacing (inch)
8	#6	0.75	9
9	#6	0.75	8
10	#6	0.75	7
11	#6	0.75	6.5
12	#6	0.75	6
13	#6	0.75	5.5
14	#6	0.75	9.5 double
15	#6	0.75	8.5 double

- Lap splice length – Automatically calculated by 33 times the steel bar diameter.

CRC Pavement to CRC Pavement Construction Joint Transition

This is a transition detail between CRC pavement segments. For design purposes, the wheel path is assumed to be 3-ft wide and 1 ft from the longitudinal edge. As a minimum, three 36-inch deformed bars should be drilled and epoxied in each wheel path to provide for additional load transfer. If more than 6 months transpire before placing the adjacent CRC pavement, joint type should be the transverse isolation joint with deformed bar (Type C [DB]) that includes an expansion joint filler material (such as preformed bituminous fiber) to minimize damage due to differential thermal movement. It is important to achieve proper consolidation of the concrete behind the header during construction.

Design Options/Factors

1. Additional deformed bars provide load transfer across the header joint in the wheel path.
2. Design analysis entails determination of additional load transfer bar size, spacing, and length:

$$\text{Number of additional load transfer bars} = \frac{Slab\ width}{required\ bar\ spacing} \qquad (17)$$

   Where, r*equired bar spacing* is the maximum bar spacing that is required to achieve the design J factor. Design J factor is the sum of aggregate J factor, reinforcing steel J factor, and load transfer bar J factor.
3. As a minimum, three additional deformed bars should be placed in each wheel path.

Input Design Factors

- Aggregate type – Choose one from crushed limestone or river gravel. Aggregate type affects the expected joint opening; river gravel causes about a 30 percent larger joint opening than crushed limestone because river gravel has a higher coefficient of thermal expansion.
- Steel bar size – Automatically decided by TxDOT CRCP standard design when choosing slab thickness. Moreover, the engineer also can input steel bar size and spacing manually if properties are different than the standard.
- Subbase thickness – The engineer can try various subbase thicknesses using the design guide spreadsheet. Minimum design LTE would be changed by the subbase thickness, and it will affect the load transfer bar size and spacing.
- Subbase modulus – Input by the engineer referring to recommended values. Table 6 provides guidelines for the modulus of elasticity selection.

Table 6. Modulus of Elasticity for Various Base Types (*9*).

Base type	Modulus of Elasticity (psi)
Fine-grained soils	3000 - 40,000
Sand	10,000 - 25,000
Aggregate	15,000 - 45,000
Lime-stabilized clay	20,000 - 70,000
Asphalt-treated base	300,000 - 600,000
Cement-treated base	1000 × (500+compressive strength)
Lean concrete base	1000 × (500+compressive strength)

- Subgrade strength – Input by the engineer referring to the recommended value. Table 7 shows the guidelines of design k-value and CBR for subgrade strength.

Table 7. Design k-Value and CBR for Subgrade Strength Based on Soil Classification (*3*).

Classification	Modulus of Subgrade Reaction (k-value), pci	California Bearing Ratio
Low	$k \leq 50$	$CBR \leq 2$
Med-low	$50 < k \leq 100$	$2 < CBR \leq 3$
Medium	$100 < k \leq 150$	$3 < CBR \leq 5$
Med-high	$150 < k \leq 200$	$5 < CBR \leq 10$
High	$200 < k$	$10 < CBR$

- Subgrade UCCS – Input by the engineer referring to the subgrade unconfined compressive strength recommended value. Table 8 shows the guidelines for subgrade unconfined compressive strength.

Table 8. Approximate Subgrade Parameter Based on Soil Classification (*4*).

Classification	Approximate Resilient Modulus at a Deviatoric Stress of 6 psi, psi	Approximate Unconfined Compressive Strength, psi
Stiff, fine-grained	12340	33
Medium, fine-grained	7675	23
Soft, fine-grained	3018	13
Very soft, fine-grained	1000	6

- Regional classification – As shown in Figure 12, the engineer chooses one region based on the district of interest (see Table 9). Twenty-five TxDOT districts were used for regional classification, and they were grouped into five zones from southeast to northwest based on air temperature, annual precipitation, and maximum depth of frost penetration contour data. In the case of a transverse construction joint with deformed bar (Type B [DB]), zone 1 allows for a joint opening width of 0.13 inch using crushed limestone aggregate type. Zones 2, 3, 4, and 5 have 5, 10, 15, and 20 percent larger values respectively than zone 1 because of higher temperature range variations.

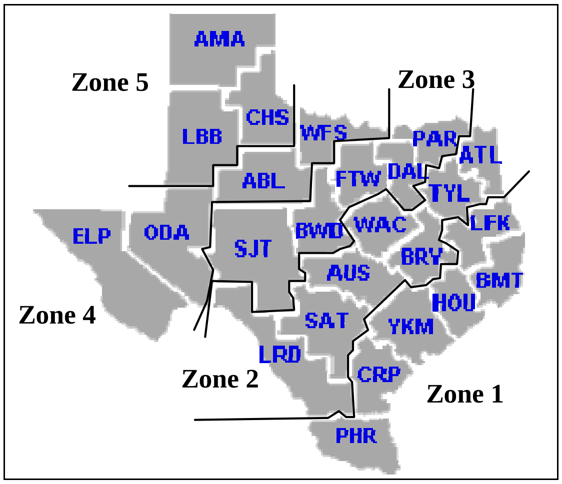

Figure 12. Regional Classification Map Based on 25 TxDOT Districts (*6*, *12*).

Table 9. Regional Classification Based on 25 TxDOT Districts.

Zone	TxDOT District		Zone	TxDOT District	
1	BMT	Beaumont	3	BWD	Brownwood
	CRP	Corpus Christi		DAL	Dallas
	HOU	Houston		FTW	Fort Worth
	LFK	Lufkin		PAR	Paris
	PHR	Pharr		SJT	San Angelo
	YKM	Yoakum	4	ABL	Abilene
2	ATL	Atlanta		ELP	El Paso
	AUS	Austin		ODA	Odessa
	BRY	Bryan		WFS	Wichita Falls
	LRD	Laredo	5	AMA	Amarillo
	SAT	San Antonio		CHS	Childress
	TYL	Tyler		LBB	Lubbock
	WAC	Waco			

- Traffic level – Chosen from one of three traffic levels. Since traffic level affects the design year of pavement, loads transfer efficiency would drop with time and equivalent single axle load (ESAL). Table 10 shows load transfer efficiency changes from the initial 100 percent LTE by traffic level increase.

Table 10. Load Transfer Efficiency for Traffic Levels.

Traffic Level, ESAL	Load Transfer Efficiency of Joint (%)
Low, 20 million	92
Medium, 40 million	84
High, 80 million	70

- Expected joint opening – Automatically calculated by aggregate type and regional choice using Equation 18. Joint opening is highly related with aggregate load transfer efficiency.

$$\text{Joint opening} = L \cdot CoTE \cdot \Delta T \tag{18}$$

Where, L = PCC slab length (inch)
$CoTE$ = Coefficient of Thermal Expansion (10^{-6}/°F)
Crushed limestone is 4, and river gravel is 6.
ΔT = Temperature gap between set temperature and lowest temperature

- Wheel path center from longitudinal joint – Input by the engineer to specify addition deformed bar location.

Output Design Factors

- Radius of relative stiffness, ℓ – Automatically calculated by Equation 2; it is related with deflection, J-factor, and load transfer efficiency.
- Minimum design LTE – Load transfer efficiency that needs to be satisfied for allowable deflection limit based on current design properties.
- Current LTE – Load transfer efficiency of current design without dowel or reinforcing steel bar.
- Additional bar size - spacing – Dowel or reinforcing steel bar size and spacing would be recommended together to increase current LTE over minimum design LTE. Choose any one combination of size and spacing from available multiple outputs. When “Needless” is indicated, no load transfer device is needed. “Redesign!” is shown, the load transfer device cannot increase the current LTE enough over the minimum design LTE. Other input parameters need to be tried until the design criterion is met, or “Needless” in the case of “Redesign!”
- Additional bar length – 36 inches is the recommended minimum length of the additional reinforcing bar. Engineers could change this length based on field conditions.
- Current + add bar LTE – Load transfer efficiency after dowel or reinforcing steel bar placing. It depends on the additional bar properties and will be larger than the minimum design LTE when design is appropriate.

CRC Pavement to Jointed Concrete Pavement (JCP) Transition

This is the transition detail between CRC pavements and jointed concrete pavement. Three options are recommended.

Option 1 details a sleeper slab with I-beam. A 2 inch poly foam compression seal is inserted at the end of the CRC pavement based on an expected end movement. A 6 inch wide I-beam is tied to the jointed concrete slab by 0.75 inch diameter, 8 inch studs at 18 inch centers. The sleeper slab length would be 60 inch, with various thicknesses based on the subgrade condition.

Option 2 is using a wide flange with dowels instead of the I-beam and sleeper slab. This design option can be applied effectively between previously placed CRC pavement and the new jointed concrete slab since a sleeper slab is not involved. It uses the same type of compression seal as with option 1 to allow CRC pavement movement. Wide flange width was recommended as 4 inch, but it can be varied based on field conditions. The same size and spacing studs with option 1 are used to tie on the jointed concrete slab. Dowel size and spacing would be determined by design to achieve appropriate LTE between CRCP and JCP.

Option 3 uses a 240-ft long gradually reduced reinforcing steel design from the end of the CRC pavement. The 120 ft section, including the terminal end is reinforced at 30 percent of the design steel content and the next 120 ft at 60 percent of the design steel content. This section is saw cut at 6 ft (or the designed) intervals to induce a uniform crack pattern. Spacing at 12 ft are saw cut in the 30 percent reinforced zone, with the option of providing dowels to compensate for the expected wider openings.

Design Options/Factors

1. Design analysis entails determination of dowel bar size and spacing. The number of dowel bars can be calculated by the dividing slab width by the required bar spacing. Where, the required bar spacing is the maximum bar spacing that is required to achieve the design J factor. Design J factor is the sum of the aggregate J factor and load transfer bar J factor.
2. Reinforcing steel content is gradually reduced through the transition to distribute the movement of the terminal joint over the joints/cracks in the transition zone (Option 3).
3. Transition zone saw cuts are a minimum 1 inch deep and are used to induce the crack pattern at dowel bar locations (Option 3).
4. The additional load transfer dowels are placed in the wheel paths, with a minimum of 3 bars per wheel path (Option 3).
5. On the saw cut joints in the 30 percent or 60 percent of the design steel zones, provide additional dowels as needed to provide load transfer (Option 3).
6. Design crack spacing in the 60 percent zone is a function of the steel content (Option 3).

Input Design Factors

- Terminal joint movement – Automatically calculated by aggregate type and regional choice using Equation 18.
- Sleeper slab thickness – Matching the subbase thickness is recommended but manually input based on subgrade condition (Option 1).
- Sleeper slab length – 60 inch is the recommended length (Option 1).
- Design JCP slab length – Same as joint spacing. Normally 15 ft is slab length but should be smaller than 4.44ℓ based upon slab curling/warping behavior.
- Expected joint opening of JCP – Automatically calculated by aggregate type and regional choice.
- Wide flange width – 4 inch is the recommended width, but it could be changed based on field conditions (Option 2).
- 60 percent transition zone saw cut spacing – 6 ft is the recommended spacing, but it could be changed based on steel content (Option 3).
- 30 percent transition zone saw cut spacing – 12 ft to 15 ft is the recommended spacing, but it could be changed based on subbase type (Option 3).

Output Design Factors

- JCP slab length – Checks JCP slab length against 4.44ℓ; indicates "Redesign!" when design JCP slab length is larger than 4.44ℓ.
- JCP aggregate-based LTE – Aggregate interlocking (A.I.) LTE of current design.
- JCP dowel size - spacing – Dowel size and spacing combinations together that would increase current LTE over the minimum design LTE. Choose any one combination of size and spacing from available multiple outputs.
- JCP dowel length – 18 inch is standard for TxDOT design. JCP Aggregate + Dowel LTE – Load transfer efficiency based on dowel and A. I. The dowel LTE depends on the dowel bar properties.
- CRCP to JCP dowel size - spacing – Dowel size and spacing that would increase current LTE over the minimum design LTE. Choose any one combination of size and spacing from multiple outputs (Option 2).
- CRCP to JCP dowel length – 18 inch is standard for TxDOT design (Option 2).
- CRCP to JCP LTE – Load transfer efficiency with dowel included; depends on the dowel bar properties (Option 2).
- 30 percent transition zone LTE without dowel – A. I. only LTE of current (Option 3).
- 30 percent transition zone dowel size - spacing – Dowel size and spacing combination that would increase current LTE. Choose combination of size and spacing from multiple choices (Option 3).
- 30 percent transition zone dowel length –18 inch is standard for TxDOT design.
- 30 percent transition zone LTE with dowel – Dowel-based LTE; depends on the dowel bar properties (Option 3).

Construction Issues

1. Dowel alignment is critical for doweled options.
2. Wide flange design and reinforcing steel transition design are experimental until sufficient experience using them has been gained (Options 2 and 3).
3. Saw cuts need to be made soon as possible after initial setting of the CRC pavement (Option 3).

CRC Pavement to Flexible Pavement Transition

This is the transition between CRC pavement and asphalt concrete pavement. Two options are available.

Option 1 uses a tapered slab between CRC pavement and flexible pavement. A beveled edge should be placed at the end of the tapered section to minimize crack reflection at that point in the flexible pavement. Treated subbase needs to be extended into the flexible pavement section for a distance of at least 5 ft.

Option 2 uses an elastomeric concrete joint to resist not only horizontal movement but also vertical movement between the jointed concrete slab and the flexible pavement section. This option also needs a treated subbase extension into the flexible pavement section at least 5 ft. A sleeper slab or wide flange joint type should be constructed between the CRC and flexible pavement for both options. Dowel size and spacing for wide flange joint design would be determined by design to achieve the appropriate LTE between CRC and jointed concrete (JC) pavement.

Design Options/Factors

1. The stiffness of the treated subbase, the maximum allowable differential deflection between the concrete and asphalt pavements, and the thickness of the tapered slab end (Option 1).
2. Design analysis considers the maximum differential deflection between the concrete and asphalt pavements based on the strength of a 6 inch cement treated base.
3. The stiffness of the treated subbase and the maximum allowable differential deflection between the concrete and asphalt pavements (Option 2).

Input Design Factors

- Taper slab length – 5 ft is the recommended length, but it could be changed based on field conditions (Option 1).
- Elastic modulus of elastomeric concrete – Input by the engineer referring to the recommended value. Table 11 shows the guidelines for the elastic modulus of elastomeric concrete (Option 2).

Table 11. Properties of Elastomeric Concrete.

Brand name Manufacturer	Compressive Strength ASTM D 695	Tensile Strength ASTM D 638	Elastic Modulus (psi)
Pro-Crete CAPITAL SERVICES	2800 psi	900 psi	3.02×10^6
Delcrete™ D.S. BROWN	800 psi	600 psi	1.61×10^6
Pro-Crete NH CAPITAL SERVICES	4200 psi	2250 psi	3.69×10^6

- Elastomaric concrete joint width – 1 inch is the recommended width, but it could be changed based on field conditions (Option 2).
- Elastomeric concrete joint movement – Automatically calculated by aggregate type and regional choice based on expected joint opening (Option 2).

Output Design Factors

- CRC pavement to jointed slab aggregate LTE only – LTE between CRC pavement and jointed concrete pavement by aggregate interlocking only.
- CRC pavement to jointed slab LTE – Dowel based LTE; depends on the dowel bar properties.
- Maximum jointed slab length– Jointed concrete slab length beyond tapered section. It is automatically calculated by subtracting tapered slab length from 4.44ℓ (Option 1).
- T_T – Thickness of the tapered slab. If not input, it will be defaulted to half of the concrete slab thickness (Option 1).
- T/4 –A quarter of thickness (Option 1).
- Maximum slab length –Maximum allowable concrete slab length. It is automatically calculated by 4.44ℓ (Option 2).

Construction Issues

1. Compaction of hot mixed asphalt (HMA) and subgrade materials to 100 percent and 95 percent density, respectively.
2. Subgrade may be either cement or lime stabilized.
3. The tapered section should be rough finished with a beveled edge (Option 1).
4. Order of placement of the Portland cement, flexible, and elastomeric concrete (Option 2).

Jointed Concrete Pavement to Flexible Pavement Transition

The transition of jointed concrete pavement to flexible pavement is basically identical with the transition of CRC to flexible pavement. The concrete pavement joint type is type B (SD) because the joint opening between JC pavement segments would be less than the joint opening between the CRC and the JC slab. Design options/factors and construction issues are the same as the transition between CRC and flexible pavements.

Jointed Concrete Pavement to Jointed Concrete Pavement Transition

The transition between two jointed concrete pavements that have different thicknesses involves a tapered section that is approximately 15 ft in length but should be less than 4.44 ℓ. Transverse Type B (SD) is used at the end of the tapered transition. Match the transition at the ends in construction.

CRC Pavement to Bridge Approach Slab Transition

The transition of a CRC pavement to a bridge approach slab is basically identical with the transition of a CRC to a jointed concrete pavement. The first contraction joint of the jointed concrete pavement is changed to the construction joint between the jointed concrete slab and bridge approach slab. Design options/factors and construction issues are the same with the transition of CRC pavements to jointed concrete pavement.

JC Pavement to Bridge Approach Slab Transition

Two construction joints are used at the end of the JC pavement to reduce the crack opening at the joint between the jointed concrete slab and bridge approach slab. Moreover, a treated subbase is used throughout the transition area to reduce different settlement of the jointed concrete slab.

Design Options/Factors

The stiffness of cement treated base and the maximum allowable differential deflection between the concrete and bridge approach slab.

- Bridge approach slab thickness – When the bridge approach slab thickness is longer than the jointed concrete slab thickness.
- JCP to bridge slab minimum design LTE – Calculate the minimum design load transfer efficiency between the jointed concrete slab and bridge slab.

Stabilized subgrade may be either cement or lime treated.

Intersection Transition

Three options are recommended based on the orientation of the continuously paved lanes. Options 1 and 2 are appropriate when the frontage road would be paved continuously through the intersection and the cross road is isolated from the frontage road in the intersection. Option 3 is for continuous paving of the cross road and isolation of the frontage road. A wide flange, sleeper slab, or thickened edge joint types are applied for the isolation sections. In the special area where the two directional pavement segments overlap, a transverse contraction joint with reinforcing steel bar (header joint) is employed if the paving is interrupted. The longitudinal construction joint between CRC pavement and the turning radius will be tied with deformed bars. The thickened edge isolation joint type is used on the other directional edge of the turning radius to avoid restriction of the CRC pavement end movement while reducing deflection. The 2 ft supplementary slab is doweled at the corner of turning radius to prevent corner cracking. Option 1 is recommended when the intersection length between the inside longitudinal joints is larger than 500 ft; if it is less than 500 ft, option 2 is recommended.

Design Options/Factors

1. Conflicting road pavement should be isolated from the continuously paved road to avoid lateral restraint caused by differential directional movement.
2. Use of a wide flange, sleeper slab, or thickened edge.

Design Factors

- Expected joint opening of CRCP – CRCP LTE analysis is required for the transverse contraction joint (Type B [DB]) with the special area.
- Wide flange joint dowel bar size can be determined using the CRC pavement to JC pavement transition spreadsheet if needed.

Construction Issues

1. Use of wide flange, sleeper slab, or thickened edge between frontage road and cross road.
2. Route traffic to facilitate construction of the jointing plan, but avoid additional transverse (i.e., header) joints in this region, if possible.

Overlay – Unbonded, Bonded, AC Overlay Transition

A 20 ft tapered overlay is used to transition an asphalt concrete (AC) overlay to a concrete slab. Tack coat application before the overlay promotes bonding between the AC overlay and the PCC slab. A stress-absorbing membrane interlayer can also be used to minimize the reflection cracking in the AC overlays. On the other hand, the transverse construction joint of bonded overlay needs to be matched with the transverse joint in the existing pavement.

Design Options/Factors

Consider a stress-absorbing membrane interlayer to minimize reflection cracking in AC overlays as a design option.

- Tapered overlay length – 20 ft is the minimum recommended length, and it can be increased based on the overlay thickness.

Construction Issues

1. Use of a tack coat between the PCC slab and AC overlay.
2. Construction joint of bonded or unbonded overlay needs to be matched with transverse joint of existing pavement.

CRC Bonded Overlay to CRC Pavement Transition

The transition between the bonded CRC pavement overlay and the new CRC pavement involves a double layer of steel when the thickness is more than 13 inches based on TxDOT's CRC pavement design standard; use a single layer of steel bar for thicknesses less than 13 inches. Employ additional reinforcing bars between the bonded overlay and the new CRC pavement if load transfer efficiency is not sufficient. A minimum lap splice length of steel bars should be 33 times of larger steel bar diameter between the bonded overlay and the new CRC pavement. Use a CRC pavement to CRC pavement thickness transition slab when bonded overlay thickness is different from new CRC pavement.

Design Options/Factors

1. Use reinforcing bar when subgrade strength is insufficient.
2. A double layer of steel pavement design would be applied when the CRC pavement thickness is over 13 inches.
3. If the combined thickness of overlay and old CRC pavement is different than the new pavement, refer to CRC pavement to the CRC pavement thickness transition.

Reinforcing bar alignment is critical through the transition zone in construction.

Drop Inlet/Drainage Box Transition

Drop inlet or drainage box structures should be isolated from the pavement structure because they are relatively fixed. A doweled transverse construction joint is used between the structure and the pavement, but no dowel is used for longitudinal construction joints. A transverse contraction joint should match inlets corners to prevent diagonal random cracking in the pavement.

Design Options/Factors

1. Drop inlet should be blocked out wide enough to allow for the isolation joint.
2. Only dowel the transverse construction joints.

Dowels need to be properly aligned in construction.

Gore Area/Ramp Transition

Gore area termination should be at least 2 ft wide to allow for construction. The transverse contraction or construction joint should be matched at the end of the gore area to prevent diagonal random crack propagation into the ramp pavement. Thickness transition, if needed, would be completed before this transverse contraction. The transition area would extent over a distance of 20 ft.

Design Options/Factors

1. Length and width of gore area.
2. Minimum 2 ft wide and squared off where main lane and ramp meet; match a contraction joint with the squared off face in construction.

CHAPTER IV. CONCLUSION

The design guidelines for concrete pavement transitions addressed the key factors to successfully design and construct transitions. These guidelines provide information about reinforcing and dowel bar design at joints and other joint details. The analysis of specific joint configurations associated with transitions was conducted with respect to stiffness of the joint, potential for permanent deformation, and slab restraint to translational movement at the joint.

The design guide sheets provide the conceptual profile view or plan view drawing of each transition type of concrete pavement. The drawings address slab dimensions, joint types, and layouts of joints. Design guide sheets produce the design factors of each transition type such as joint reinforcing bar size and spacing when engineers choose a value from the list or input information manually with reference to recommended values. To help engineers, the key points of transition area design, important design options/factors, and construction issues are included.

The guidelines provide a complete picture of the requirement for the design of a pavement transition for a variety of pavement types and terminal configurations that are suitable for use. In future work, proposed transition designs need to be constructed and monitored in the field to improve the transition area design and performance.

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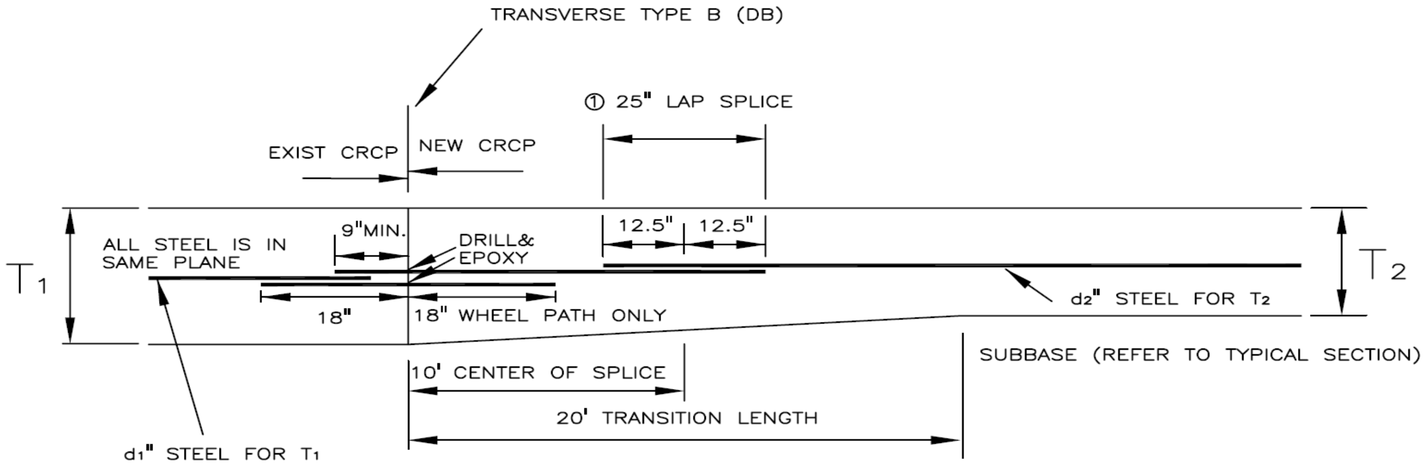
APPENDIX: DESIGN GUIDE SHEETS

Transition Type: **CRC PAVEMENT TO CRC PAVEMENT THICKNESS TRANSITION**

Plan View & X-Section



Design Options/ Factors

1. The reinforcing steel splice is made in the thickness transition area if one is present.

Design Factors

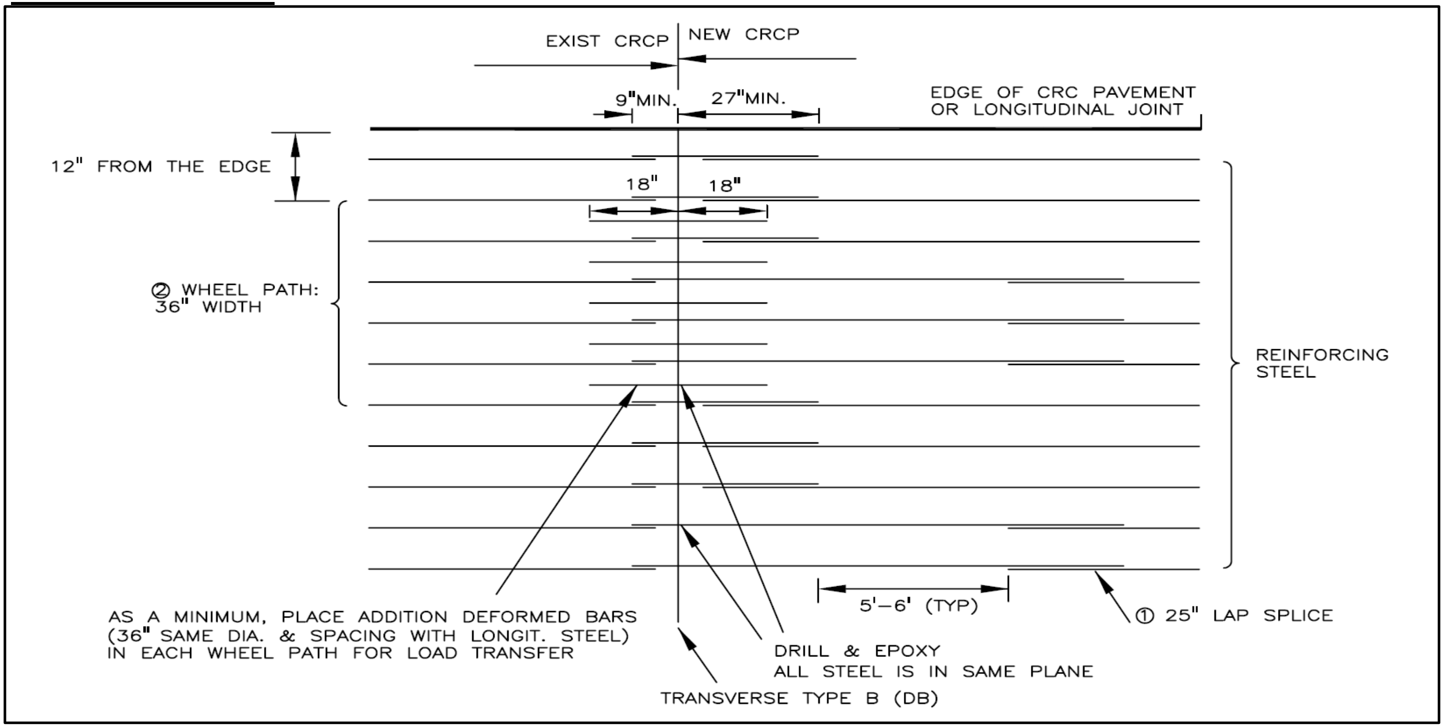
T_1 slab thickness (in.)	d_1 Steel bar size	d_1 Steel bar space (in.)	T_2 slab thickness (in.)	d_2 Steel bar size	d_2 Steel bar space (in.)	Lap splice length (in.)
10 ▼	#6 - 0.75 in.	7	8 ▼	#6 - 0.75 in.	9	25

Construction Issues

1. Thickness transition can be done over distance greater than 20 ft.

Transition Type: **CRC PAVEMENT TO CRC PAVEMENT (OPTION 1)**

Plan View & X-Section



Design Options/ Factors

1. Additional deformed bar provides load transfer across the header joint in the wheel path.
2. Design analysis entails determination of additional load transfer bar size and spacing.
   # of additional load transfer bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + reinforcing steel J factor + load transfer bar J factor
3. As a minimum, 3 additional deformed bars should be placed in each wheel path.

Input Design Factors

Conc. slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	150	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening (in.)	Wheel path center from long. joint (in.)
HOU	High - 80	0.14	30

Output Design Factors

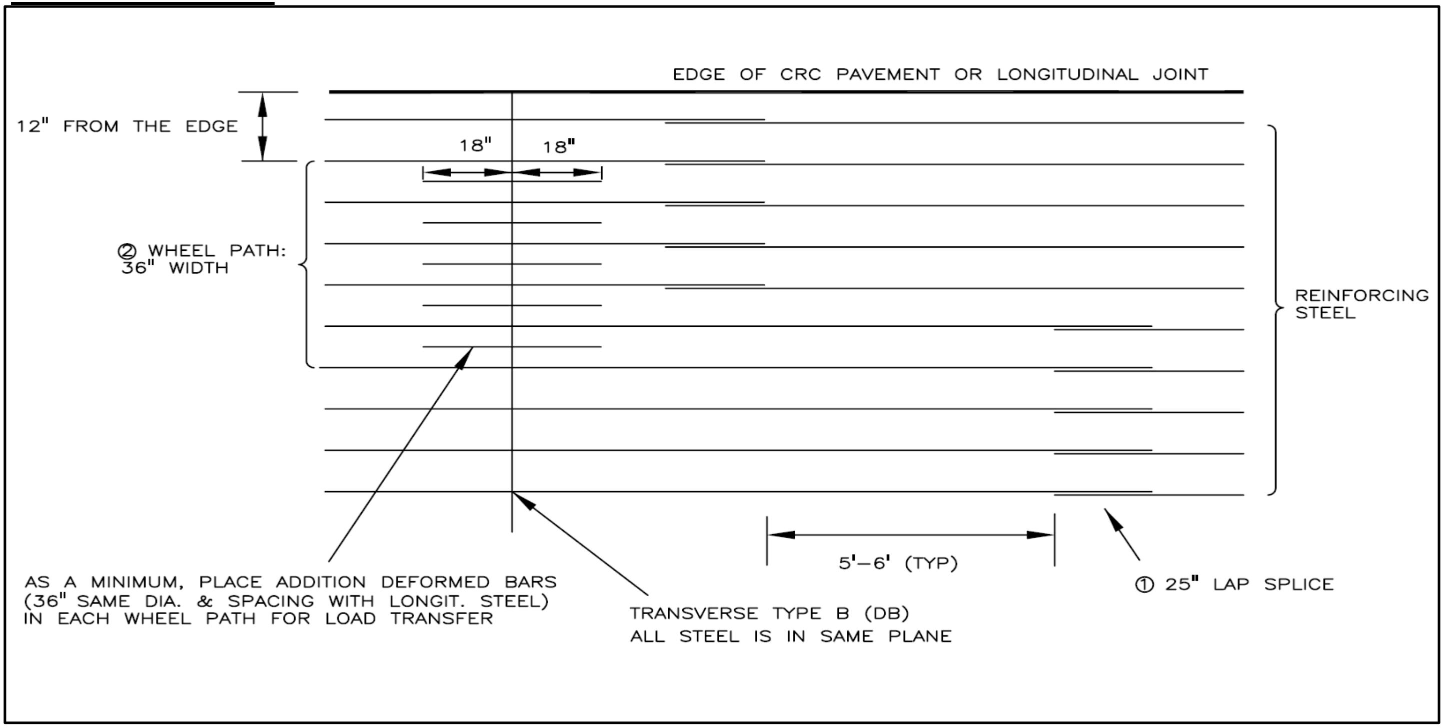
Radius of Relative Stiffness, ℓ (ft)	Minimum Design LTE (%)	Current LTE (%)	Additional bar size - spacing	Additional bar length (in.)	Current+Add bar LTE (%)
3.3	57.0	60.9	Needless	36	60.9

Construction Issues

1. It is important to achieve proper consolidation of the concrete behind the header.
2. If more than 6 months transpire before the adjacent concrete is placed, an expansion joint filler (i.e., preformed bituminous fiber material) should be used in the Transverse Type C (DB) joint.

Transition Type: **CRC PAVEMENT TO CRC PAVEMENT (OPTION 2)**

Plan View & X-Section



Design Options/ Factors

1. Additional deformed bar provides load transfer across the header joint in the wheel path.
2. Design analysis entails determination of additional load transfer bar size and spacing.
   # of additional load transfer bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + reinforcing steel J factor + load transfer bar J factor
3. As a minimum 3, additional deformed bars should be placed in each wheel path.

Input Design Factors

Conc. slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Gravel	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening (in.)	Wheel path center from long. joint (in.)
AMA	High - 80	0.29	36

Output Design Factors

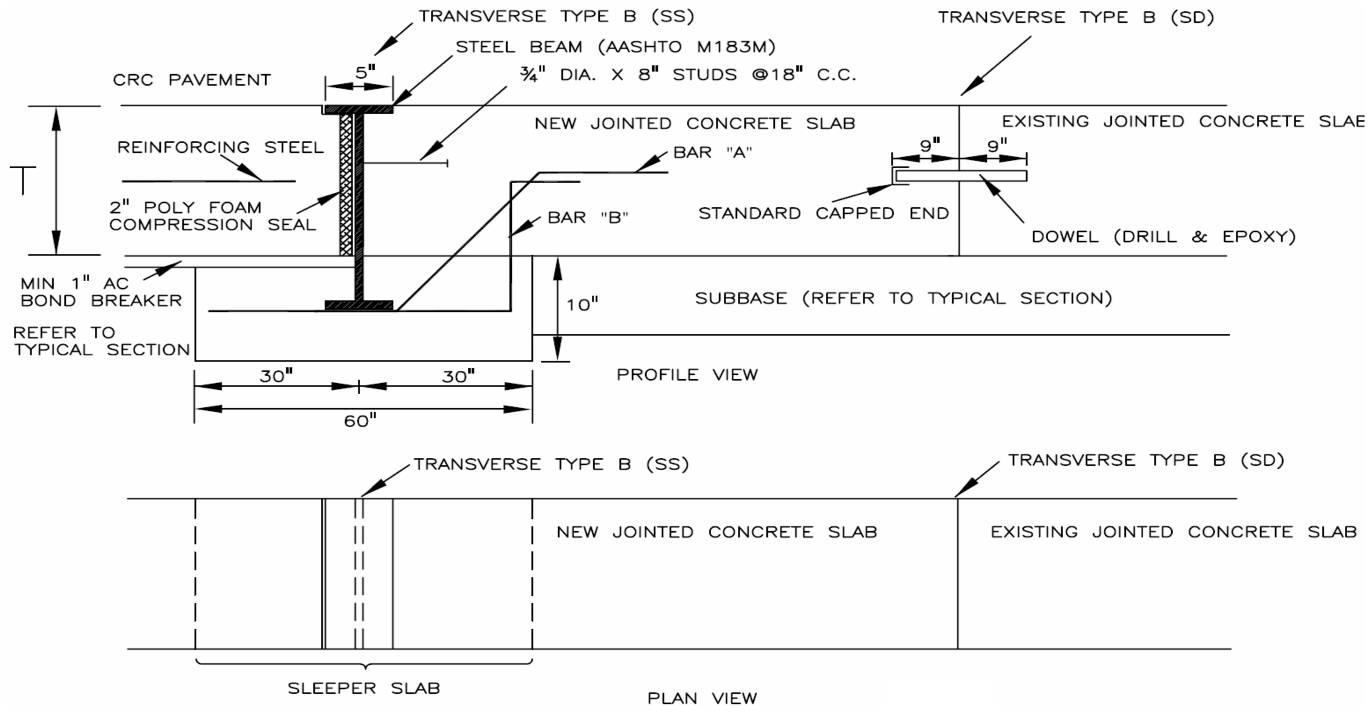
Radius of Relative Stiffness, ℓ (ft)	Minimum Design LTE (%)	Current LTE (%)	Additional bar size - spacing	Additional bar length (in.)	Current+Add bar LTE (%)
3.6	22.0	62.2	Needless	36	62.2

Construction Issues

1. It is important to achieve proper consolidation of the concrete behind the header.
2. If more than 6 months transpire before the adjacent concrete is placed, an expansion joint filler (i.e., preformed bituminous fiber material) should be used in the Transverse Type C (DB) joint.

Transition Type: **CRC PAVEMENT TO JOINTED CONCRETE PAVEMENT (OPTION 1)**

Plan View & X-Section



Design Options/ Factors

1. Design analysis entails determination of dowel bar size and spacing.
   # of dowel bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + dowel bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	Sleeper slab thickness (in.)	Sleeper slab Length (in.)	Design JCP slab length (ft)	Expected joint opening of JCP (in.)
HOU	High - 80	0.86	10	60	15	0.14

Output Design Factors

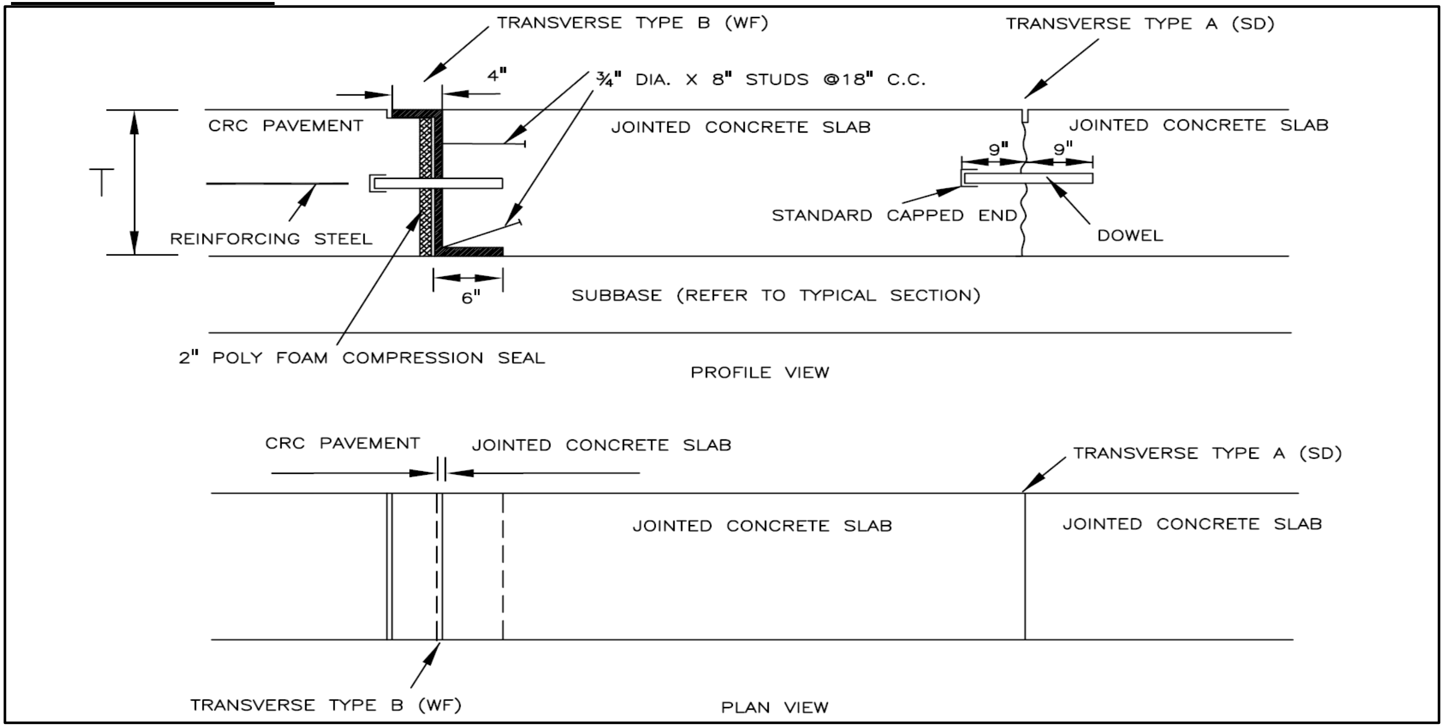
Radius of Relative Stiffness, ℓ (ft)	JCP slab length (ft)	Minimum Design LTE (%)	JCP Aggregate LTE only (%)	JCP dowel # - spacing	JCP Dowels length (in.)	JCP Aggregate + Dowel LTE (%)
3.6	15	22.0	1.0	#8 - 12 in.	18	62.5

Construction Issues

1. Dowel alignment is critical for doweled options.

Transition Type: **CRC PAVEMENT TO JOINTED CONCRETE PAVEMENT (OPTION 2)**

Plan View & X-Section



Design Options/ Factors

1. Design analysis entails determination of dowel bar size and spacing.
   # of dowel bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + dowel bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	Wide flange width, Wwf (in.)	Design JCP slab length (ft)	Expected joint opening of JCP (in.)
HOU ▼	High - 80 ▼	0.86	4	15	0.14

Output Design Factors

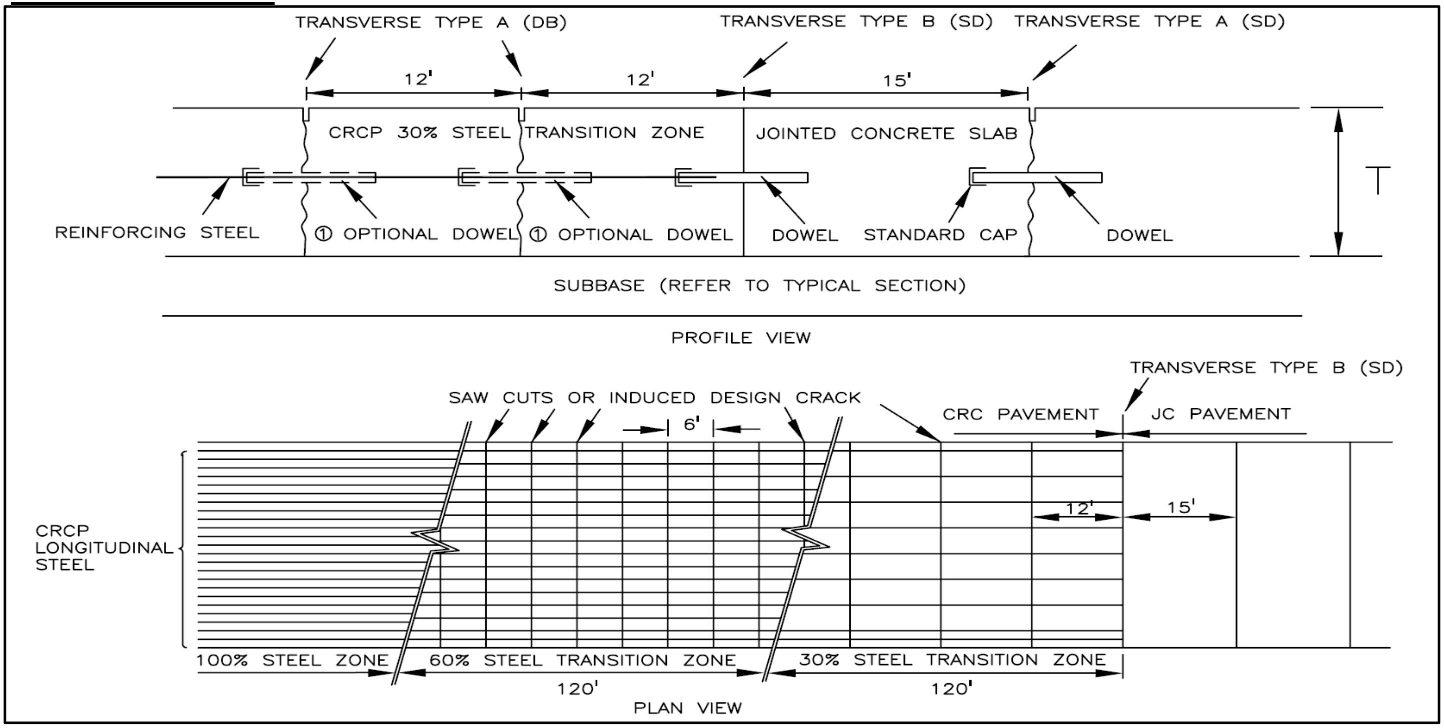
Minimum Design LTE (%)	CRCP to JCP dowel size -spacing	CRCP to JCP Dowels length (in.)	CRCP to JCP LTE (%)	JCP slab length (ft)	JCP dowel size - spacing	JCP Dowels length (in.)	JCP Aggregate + Dowel LTE (%)
22.0	#8 - 12 in. ▼	18	60.8	15	#8 - 12 in. ▼	18	61.7

Construction Issues

1. Dowel alignment is critical for doweled options.
2. This design is experimental until sufficient experience using it has been gained.
3. Sleeper slab is not required with this design.

Transition Type: **CRC PAVEMENT TO JOINTED CONCRETE PAVEMENT (OPTION 3)**

Plan View & X-Section



Design Options/ Factors

1. Reinforcing steel is gradually reduced through the transition to distribute the movement of the terminal joint over the joints/cracks in the transition zone.
2. Transition zone saw cuts are a minimum 1 inch deep and are used to induce the crack pattern at dowel bar locations.
3. The additional load transfer dowels are placed in the wheel paths; min 3 bars per wheel path.
4. Joints with 30 percent or 60 percent steel; provide additional load transfer dowels as needed to provide load transfer.
5. Design crack spacing with 60 percent steel is a function of the percent steel, but saw cut interval should not be less than three times the ℓ-value.

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	21	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	60% transition zone saw cut spacing (ft)	30% transition zone saw cut spacing (ft)	Design JCP slab length (ft)	Expected joint opening of CRCP to JCP (in.)
HOU ▼	High - 80 ▼	0.86	6	12	15	0.14

Output Design Factors

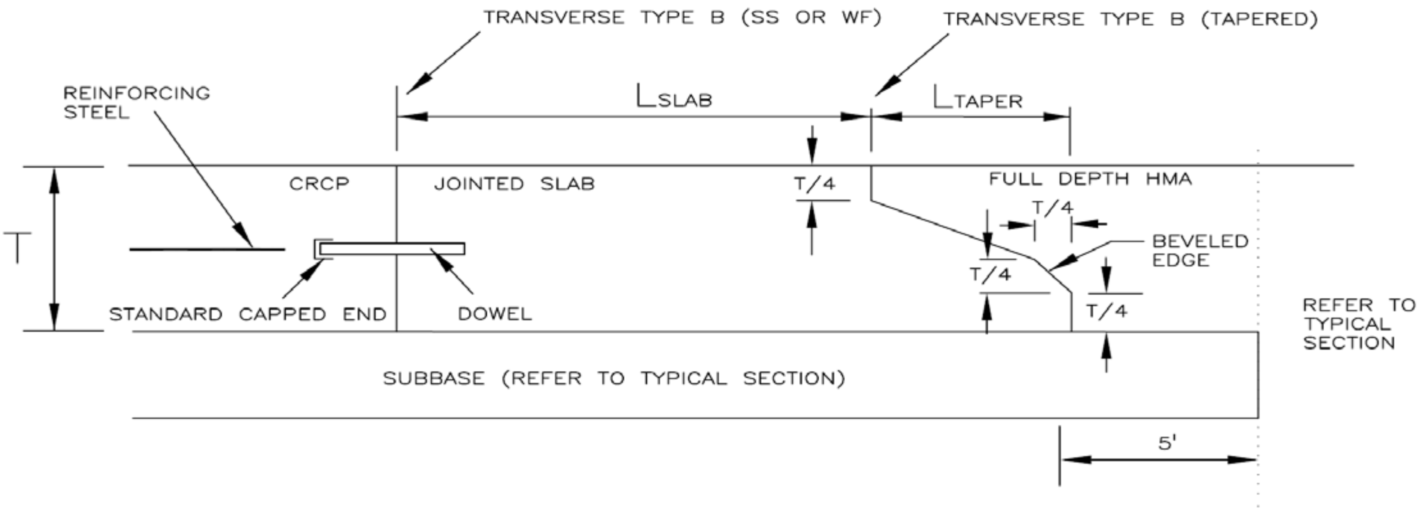
Minimum Design LTE (%)	30% transition zone LTE without dowel (%)	30% transition zone dowel size -spacing	30% transition zone dowel length (in.)	30% transition zone LTE with dowel (%)	JCP slab length (ft)	CRCP to JCP Dowel size -spacing	CRCP to JCP Dowels length (in.)
22.0	51.7	Needless ▼	18	51.7	15	#8 - 11 in. ▼	18

Construction Issues

1. Saw cuts need to be made soon after as possible initial setting of the concrete.
2. This design is experimental until sufficient experience using it has been gained.
3. Dowel alignment is critical through the 30 percent steel transition zone.

Transition Type: CRC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 1)

Plan View & X-Section



Design Options/ Factors

1. The stiffness of treated subbase, the maximum allowable differential deflection between the concrete and asphalt pavements, and the magnitude of T_T.
2. Design analysis considers the maximum differential deflection between the concrete and asphalt pavements based on the strength of the 6 inch cement treated base or the thickness of T_T.

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement of CRCP (in.)	Taper slab length, L_{TAPER}(ft)
HOU ▼	High - 80 ▼	0.86	5

Output Design Factors

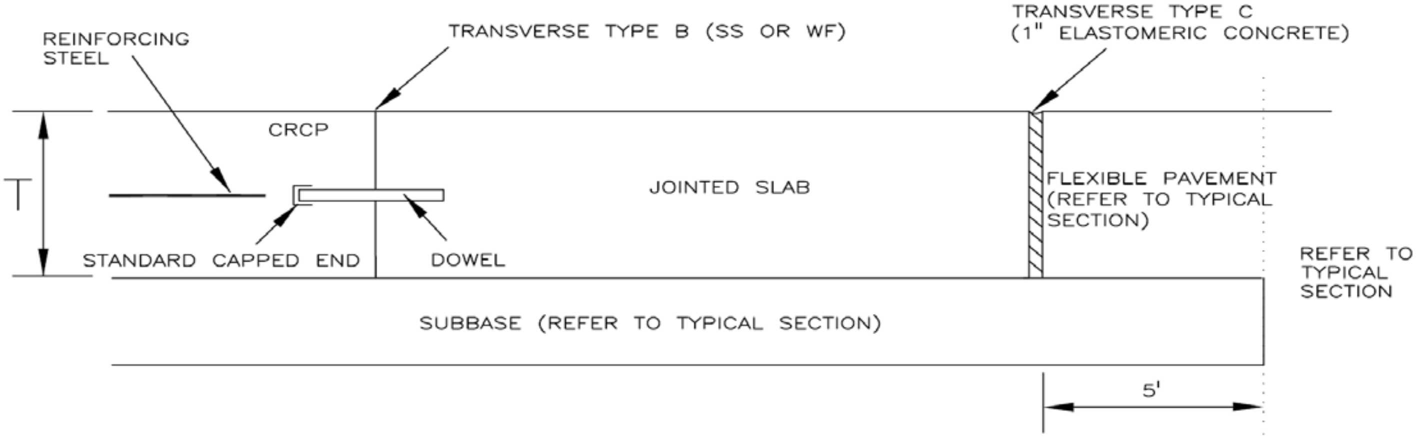
Minimum Design LTE (%)	CRCP to JC slab Aggregate LTE only (%)	CRCP to JC slab Dowel size -spacing	CRCP to JC slab Dowels length (in.)	CRCP to Jointed slab LTE (%)	Max. slab length on top, L_{SLAB} (ft)	T_T (in.)	T/4 (in.)
22.0	0.9	#8 - 9 in. ▼	18	62.3	11	5	2.5

Construction Issues

1. Compaction of hot mixed asphalt and subgrade materials to 100 percent and 95 percent density, respectively.
2. The tapered section should be rough finished with a beveled edge.
3. Subgrade may be either cement or lime stabilized.

Transition Type: **CRC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 2)**

Plan View & X-Section



Design Options/ Factors

1. The stiffness of treated subbase and the maximum allowable differential deflection between the concrete and asphalt pavements.
2. Design analysis considers the maximum differential deflection between the concrete and asphalt pavements based on the strength of the 6 inch cement treated base.

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement of CRCP (in.)	Elastic modulus of Elastomeric concrete (psi)	Elastomeric concrete joint width (in.)	Elastomeric concrete joint movement (in.)
HOU	High - 80	0.86	3,000,000	1.0	0.14

Output Design Factors

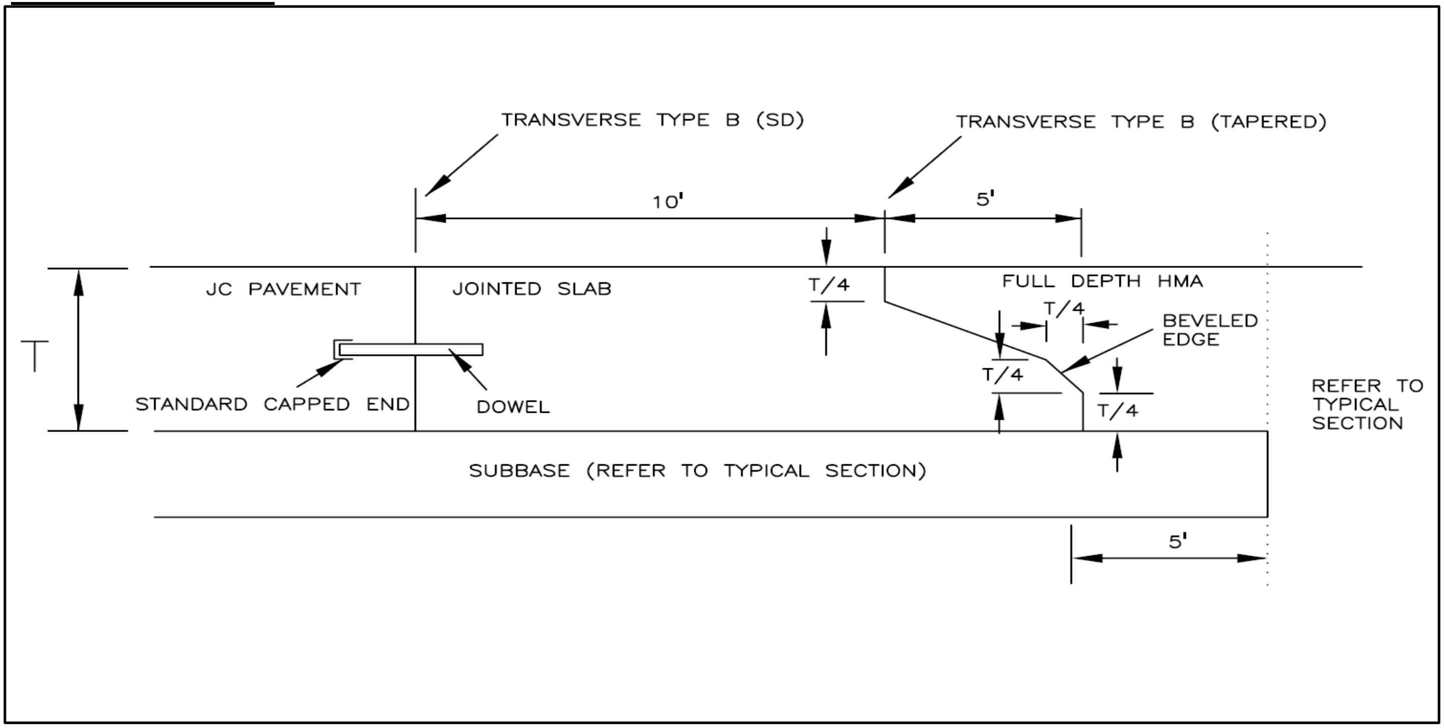
Minimum Design LTE (%)	CRCP to JC slab Aggregate LTE only (%)	CRCP to JC slab Dowel size -spacing	CRCP to Jointed slab Dowels length (in.)	CRCP to Jointed slab LTE (%)	Maximum slab length (ft)
22.0	0.9	#8 - 9 in.	18	62.3	16

Construction Issues

1. Compaction of hot mixed asphalt and subgrade materials to 100 percent and 95 percent density, respectively.
2. Order of placement of the Portland cement, HMA, and elastomeric concrete.
3. Subgrade may be either cement or lime stabilized.

Transition Type: **JOINTED CONCRETE PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 1)**

Plan View & X-Section



Design Options/ Factors

1. The stiffness of treated subbase, the maximum allowable differential deflection between the concrete and asphalt pavements, and the magnitude of T_T.
2. Design analysis considers the maximum differential deflection between the concrete and asphalt pavements based on the strength of the 6 inch cement treated base or the thickness of T_T.

Input Design Factors

Slab thickness (in.)	Aggregate type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
10	Limestone ▼	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement of JCP (in.)	Taper slab length, L_{TAPER}(ft)
HOU ▼	High - 80 ▼	0.04	5

Output Design Factors

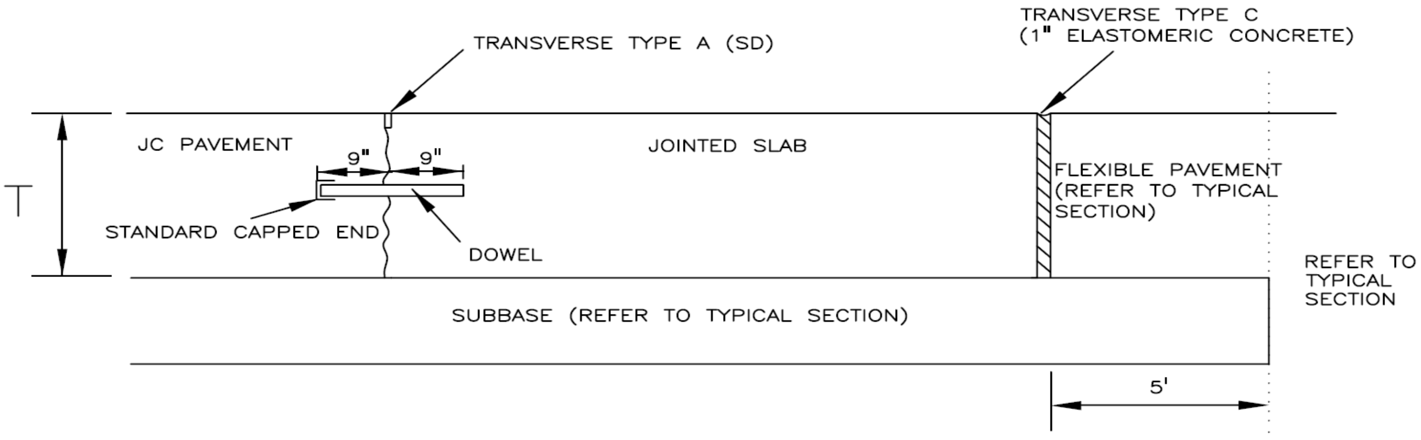
Minimum Design LTE (%)	JCP to Jointed slab Aggregate LTE only (%)	JCP to Jointed slab Dowel size -spacing	JCP to Jointed slab Dowels length (in.)	JCP to Jointed slab LTE (%)	Max. slab length on top, L_{SLAB} (ft)	T_T (in.)	T/4 (in.)
22.0	31.7	Needless ▼	18	31.7	11	5	2.5

Construction Issues

1. Compaction of hot mixed asphalt and subgrade materials to 100 percent and 95 percent density, respectively.
2. The tapered section should be rough finished with a beveled edge.
3. Subgrade may be either cement or lime stabilized.

Transition Type: JOINTED CONCRETE PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 2)

Plan View & X-Section



Design Options/ Factors

1. The stiffness of treated subbase and the maximum allowable differential deflection between the concrete and asphalt pavements.
2. Design analysis considers the maximum differential deflection between the concrete and asphalt pavements based on the strength of the 6 inch cement treated base.

Input Design Factors

Slab thickness (in.)	Aggregate type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
10	Limestone	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement of JCP (in.)	Elastic modulus of Elastomeric concrete (psi)	Elastomeric concrete joint width (in.)	Elastomeric concrete joint movement (in.)
HOU	High - 80	0.86	3,000,000	1.0	0.09

Output Design Factors

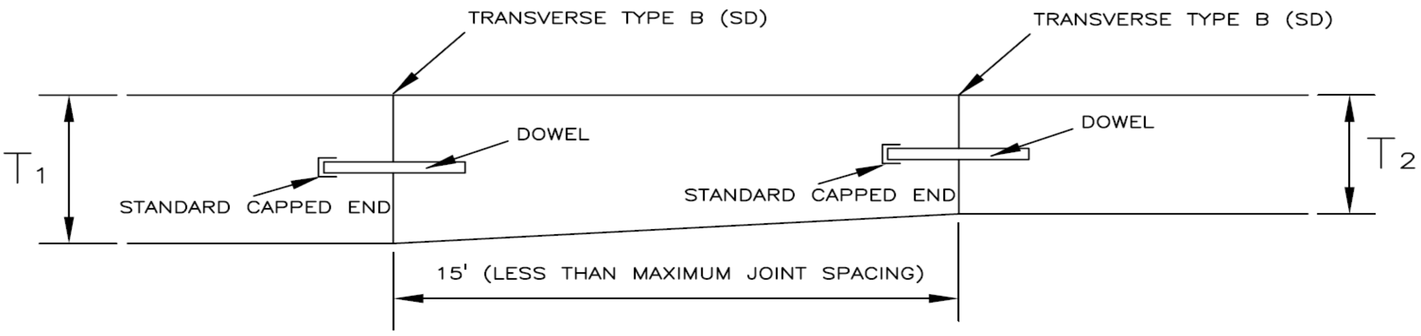
Minimum Design LTE (%)	JCP to Jointed slab Aggregate LTE only (%)	JCP to Jointed slab Dowel size -spacing	JCP to Jointed slab Dowels length (in.)	JCP to Jointed slab LTE (%)	Maximum slab length (ft)
22.0	0.9	#8 - 11 in.	18	61.3	16

Construction Issues

1. Compaction of hot mixed asphalt and subgrade materials to 100 percent and 95 percent density, respectively.
2. Order of placement of the Portland cement, HMA, and elastomeric concrete.
3. Subgrade may be either cement or lime stabilized.

Transition Type: **JOINTED CONCRETE PAVEMENT TO JOINTED CONCRETE PAVEMENT**

Plan View & X-Section



Design Options/ Factors

1. Length of the transition should be less than 4.44 ℓ.

Input Design Factors

T1 slab thickness (in.)	T2 slab thickness (in.)	Aggregate type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)	Taper slab length (ft)
12	10	Limestone	6	1,000,000	100	20	15

Regional classification	Traffic level (Million ESAL)	Expected joint opening of T1 slab (in.)	Design T_1 slab length (ft)	T1 slab dowels length (in.)	Expected joint opening of T2 slab (in.)	Design T_2 slab length (ft)	T2 slab dowels length (in.)
HOU	High - 80	0.04	15	18	0.04	15	18

Output Design Factors

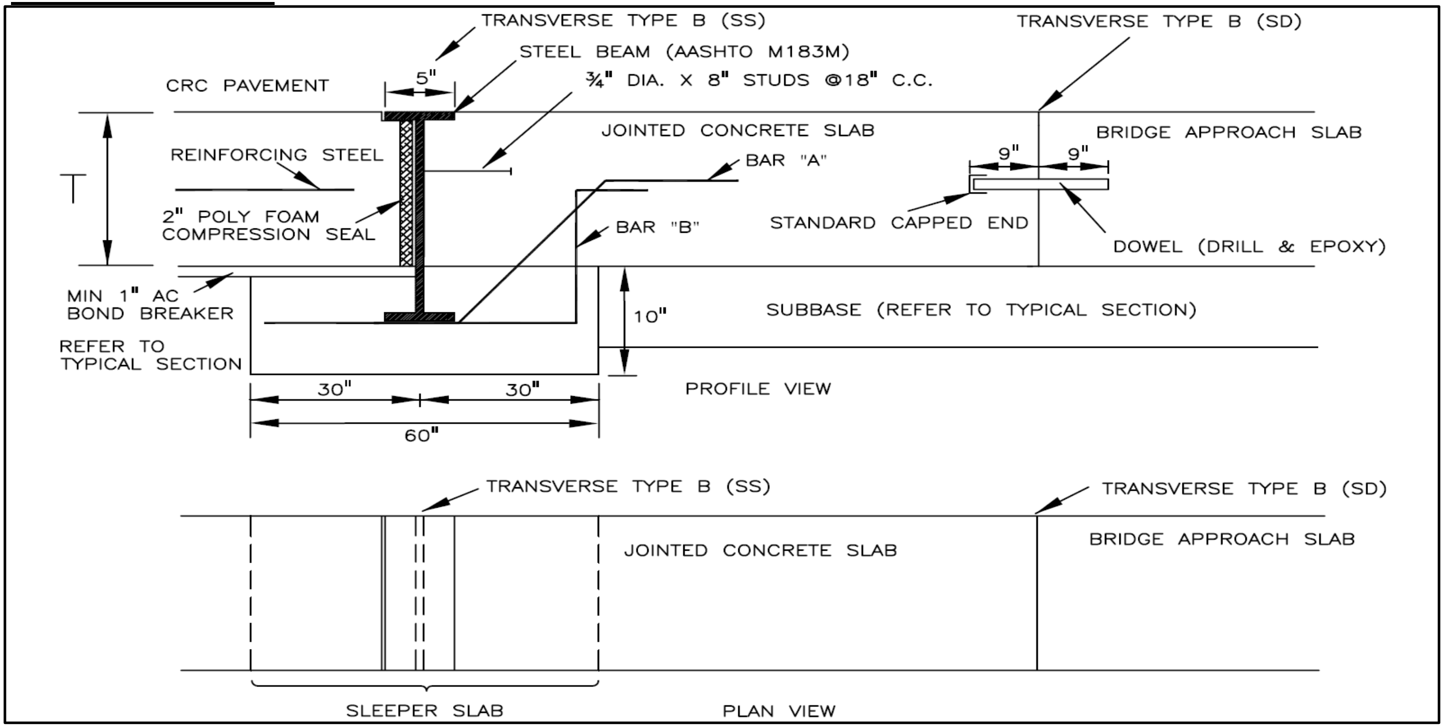
T_1 slab minimum design LTE (%)	T_1 slab length (ft)	T1 slab Dowel size - spacing	T_1 slab LTE (%)	T_2 slab minimum design LTE (%)	T_2 slab length (ft)	T2 slab Dowel size - spacing	T_2 slab LTE (%)
4.0	15	Needless	52.1	22.0	15	Needless	31.7

Construction Issues

1. Matching the transition at the ends.

Transition Type: **CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 1)**

Plan View & X-Section



Design Options/ Factors

1. Design analysis entails determination of dowel bar size and spacing.
   # of dowel bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that are required to achieve the design J factor
   Design J factor = Aggregate J factor + dowel bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	Sleeper slab thickness (in.)	Sleeper slab Length (in.)	Design JCP slab length (ft)	Expected joint opening of JCP (in.)
HOU ▼	High - 80 ▼	0.86	10	60	15	0.09

Output Design Factors

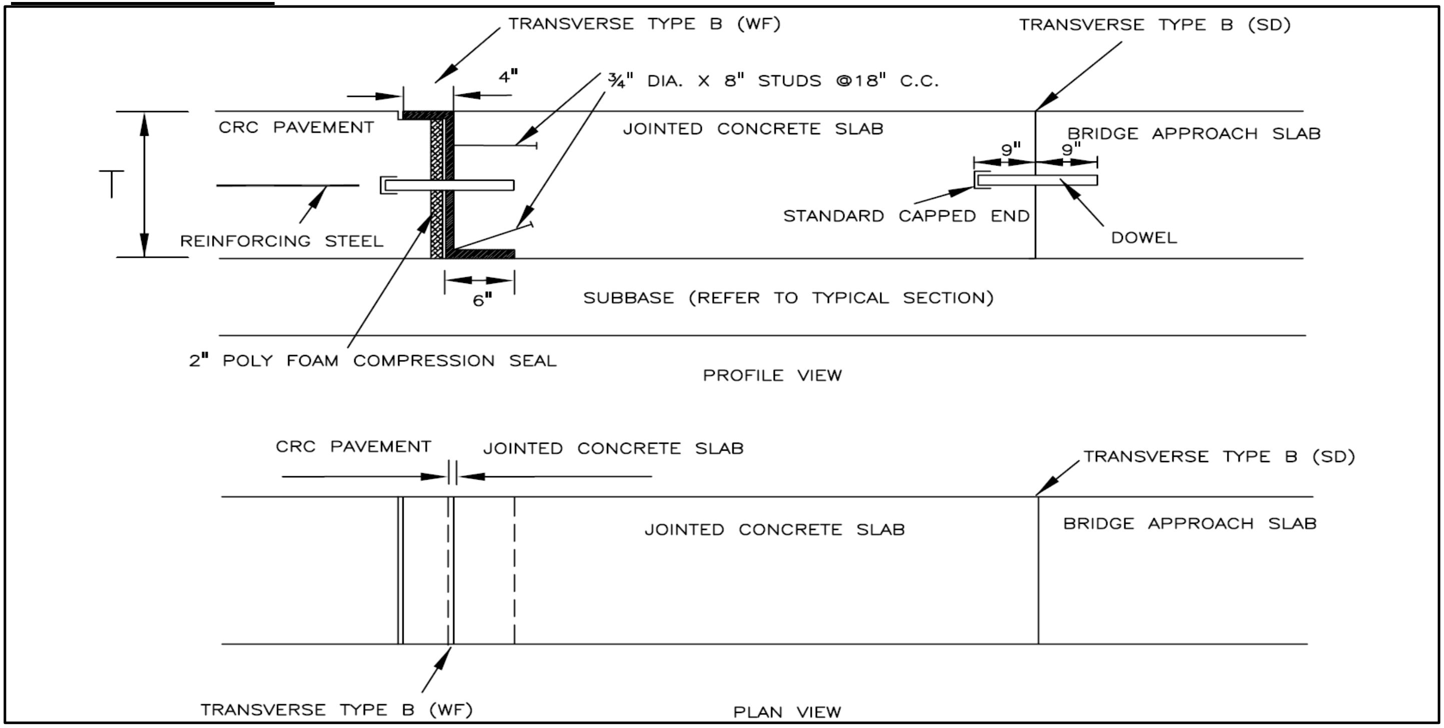
Radius of Relative Stiffness, ℓ (ft)	JCP slab length (ft)	Minimum Design LTE (%)	Aggregate LTE only (%)	JCP Dowel size - spacing	Dowels length (in.)	Aggregate + Dowel LTE (%)
3.6	15	22.0	1.8	#8 - 11 in. ▼	18	63.0

Construction Issues

1. Dowel alignment is critical for doweled options.

Transition Type: CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 2)

Plan View & X-Section



Design Options/ Factors

1. Design analysis entails determination of dowel bar size and spacing.
   # of dowel bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that are required to achieve the design J factor
   Design J factor = Aggregate J factor + dowel bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	Wide flange width, Wwf (in.)	Design JCP slab length (ft)	Expected joint opening of JCP (in.)
HOU	High - 80	0.86	4	15	0.04

Output Design Factors

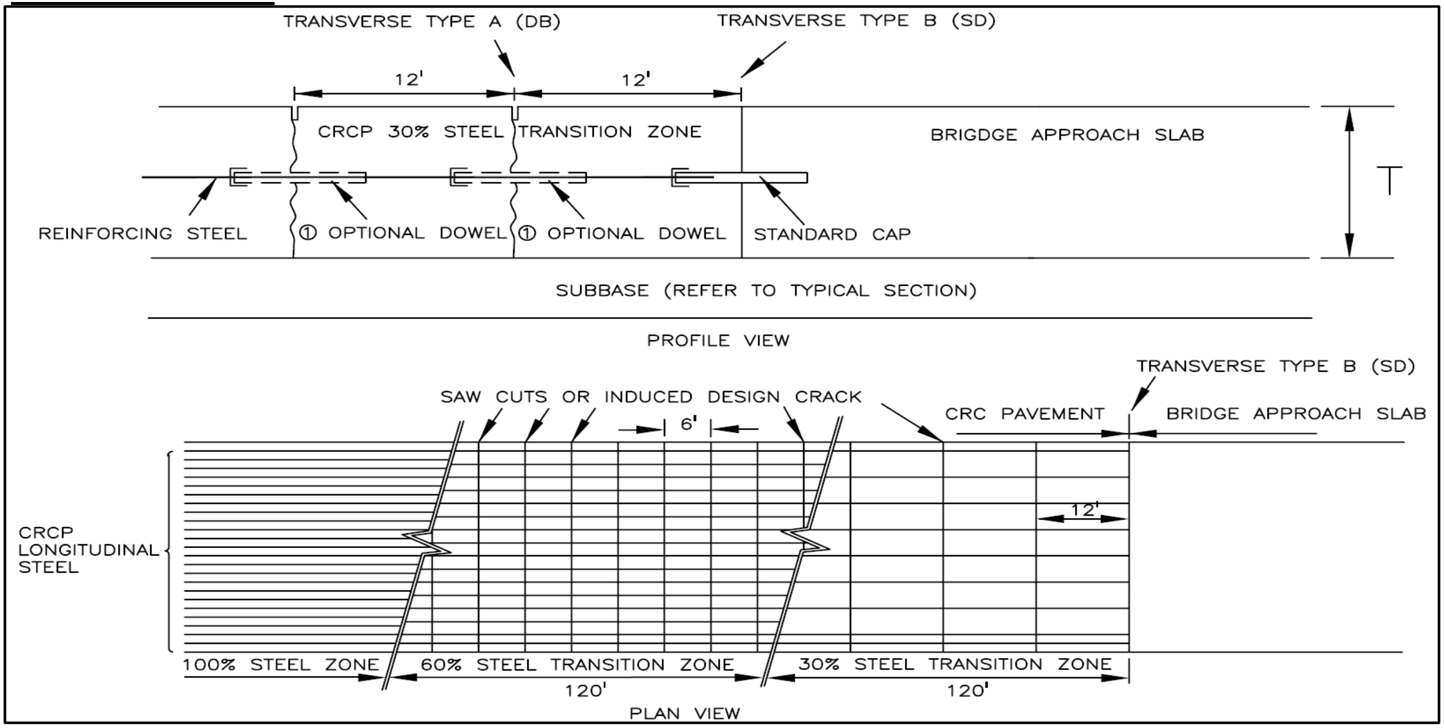
Minimum Design LTE (%)	CRCP to JCP Dowel size -spacing	CRCP to JCP Dowels length (in.)	CRCP to JCP LTE (%)	JCP slab length (ft)	JCP Dowel size - spacing	JCP Dowels length (in.)	JCP Aggregate + Dowel LTE (%)
22.0	#8 - 12 in.	18	60.8	15	Needless	18	31.7

Construction Issues

1. Dowel alignment is critical for doweled options.
2. This design is experimental until sufficient experience using it has been gained.
3. Sleeper slab is not required with this design.

Transition Type: **CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 3)**

Plan View & X-Section



Design Options/ Factors

1. Reinforcing steel is gradually reduced through the transition to distribute the movement of the terminal joint over the joints/cracks in the transition zone.
2. Transition zone saw cuts are a minimum 1 inch deep and are used to induce the crack pattern at dowel bar locations.
3. The additional load transfer dowels are placed in the wheel paths; min 3 bars per wheel path.
4. Joints with 30 percent or 60 percent steel; provide additional load transfer dowels as needed to provide load transfer.
5. Design crack spacing with 60 percent steel is a function of the percent steel, but saw cut interval should not be less than three times the ℓ-value.

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	21	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Terminal joint movement (in.)	60% transition zone saw cut spacing (ft)	30% transition zone saw cut spacing (ft)	Expected joint opening of CRCP to bridge (in.)
HOU ▼	High - 80 ▼	0.86	6	12	0.04

Output Design Factors

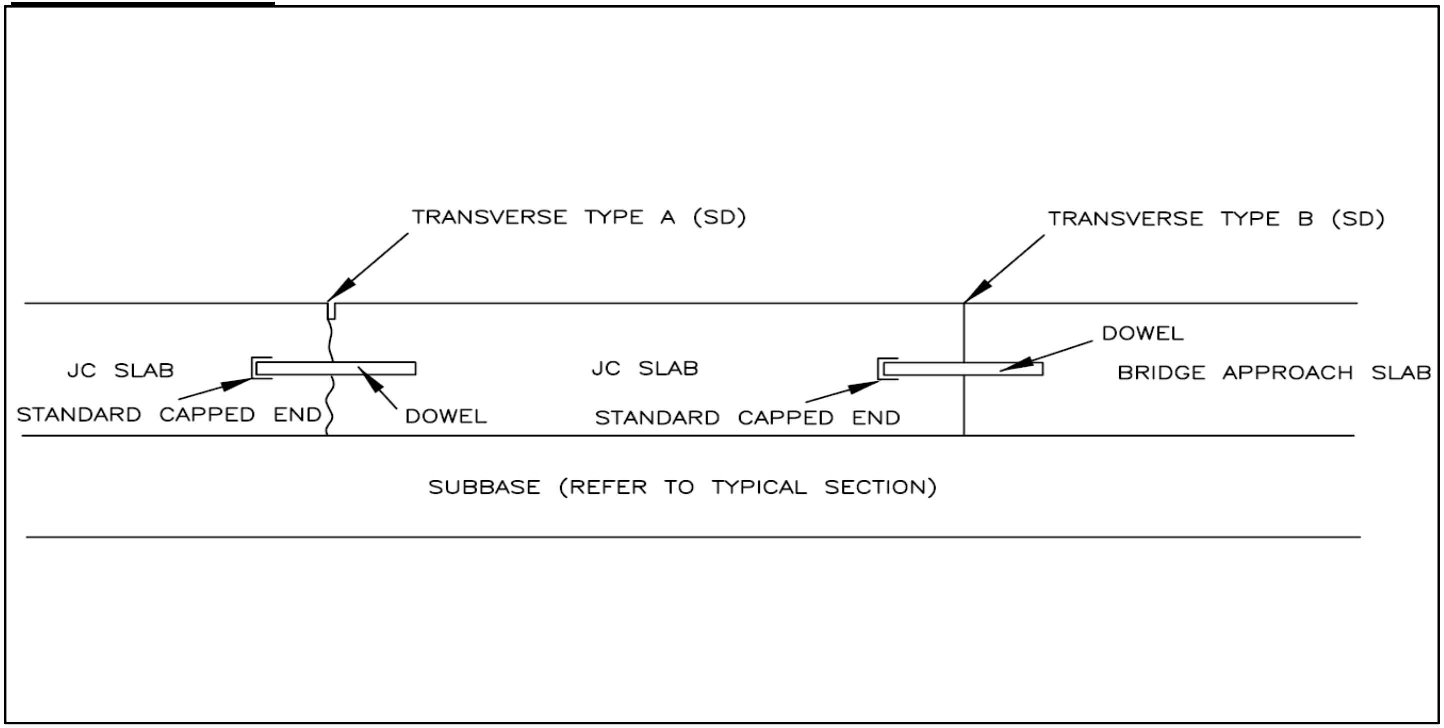
Minimum Design LTE (%)	30% transition zone LTE without dowel (%)	30% transition zone dowel size -spacing	30% transition zone dowel length (in.)	30% transition zone LTE with dowel (%)	CRCP to bridge Dowel size -spacing	CRCP to bridge Dowels length (in.)
22.0	51.7	Needless ▼	18	51.7	Needless ▼	18

Construction Issues

1. Saw cuts need to be made soon after as possible initial setting of the concrete.
2. This design is experimental until sufficient experience using it has been gained.
3. Dowel alignment is critical through the 30 percent steel transition zone.

Transition Type: **JC PAVEMENT TO BRIDGE APPROACH SLAB**

Plan View & X-Section



Design Options/ Factors

1. The stiffness of treated subbase and the maximum allowable differential deflection between the concrete and bridge approach slab pavements.
2. Design analysis considers the maximum differential deflection between the concrete and bridge approach slab pavements based on the strength of the cement treated base.

Input Design Factors

JCP slab thickness (in.)	Bridge approach slab thickness (in.)	Aggregate type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
10 ▼	10 ▼	Limestone ▼	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening of JCP to JCP (in.)	Design JCP slab length (ft)	JCP to JCP dowels length (in.)	Expected joint opening of JCP to bridge (in.)	JCP to bridge slab dowels length (in.)
HOU ▼	High - 80 ▼	0.86	15	18	0.04	18

Output Design Factors

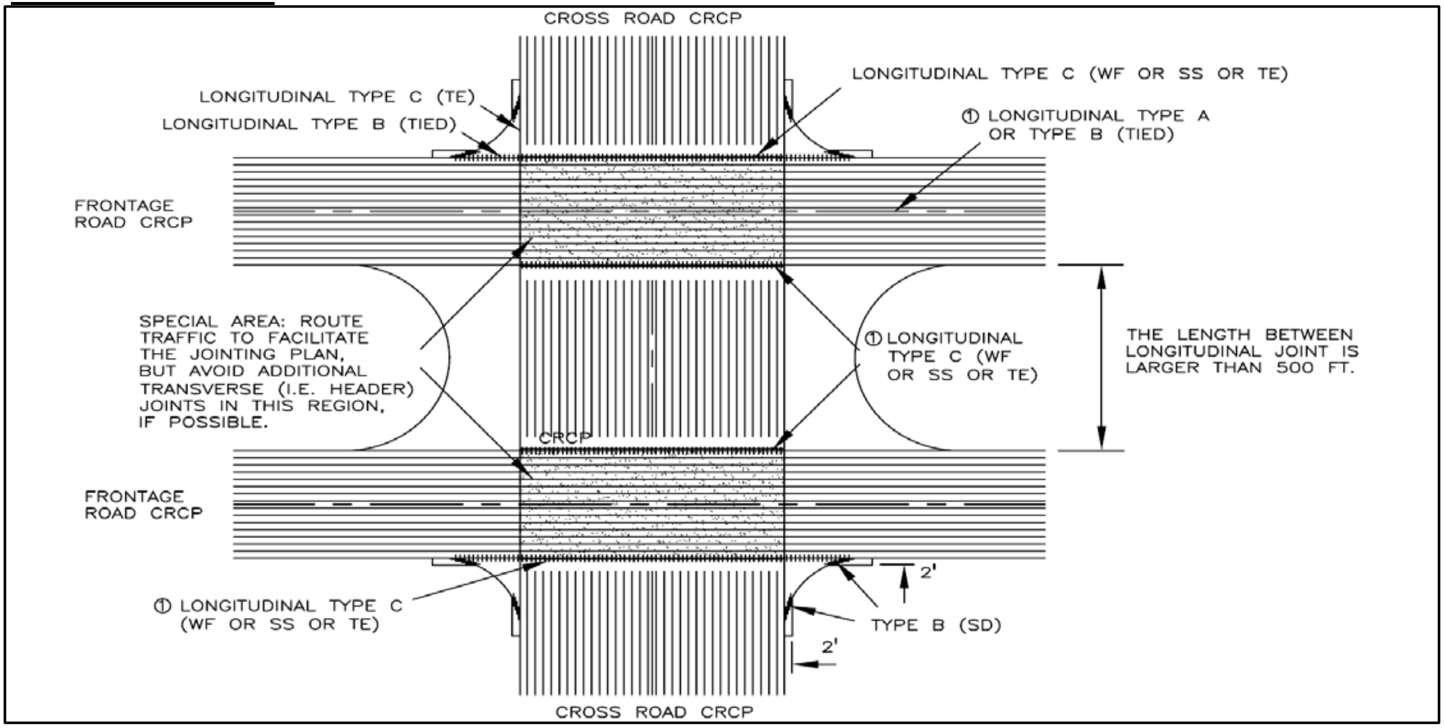
JCP to JCP minimum design LTE (%)	JCP slab length (ft)	JCP to JCP Dowel size -spacing	JCP to JCP LTE (%)	JCP to bridge slab minimum design LTE (%)	JCP to bridge Dowel size -spacing	JCP to bridge LTE (%)
22.0	15	#8 - 12 in. ▼	60.8	22.0	Needless ▼	31.7

Construction Issues

1. Stabilized subgrade may be either cement or lime treated.

Transition Type: **INTERSECTION (OPTION 1 - DISTANCE BETWEEN JOINTS > 500 FT)**

Plan View & X-Section



Design Options/ Factors

1. Cross road pavement should be isolated from the continuously paved frontage road to avoid lateral restraint caused by differential directional movement.
2. Use of a wide flange, sleeper slab, or thickened edge.
3. Design of the reinforcing bar size and spacing.
   # of reinforcing bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + load transfer bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening of CRCP (in.)	Sleeper slab thickness, Tss (in.)	Sleeper slab Length, Lss (in.)	Wide flange width, Wwf (in.)	Expected joint opening of JCP to CRCP (in.)
HOU	High - 80	0.86	10	60	4	0.04

Output Design Factors

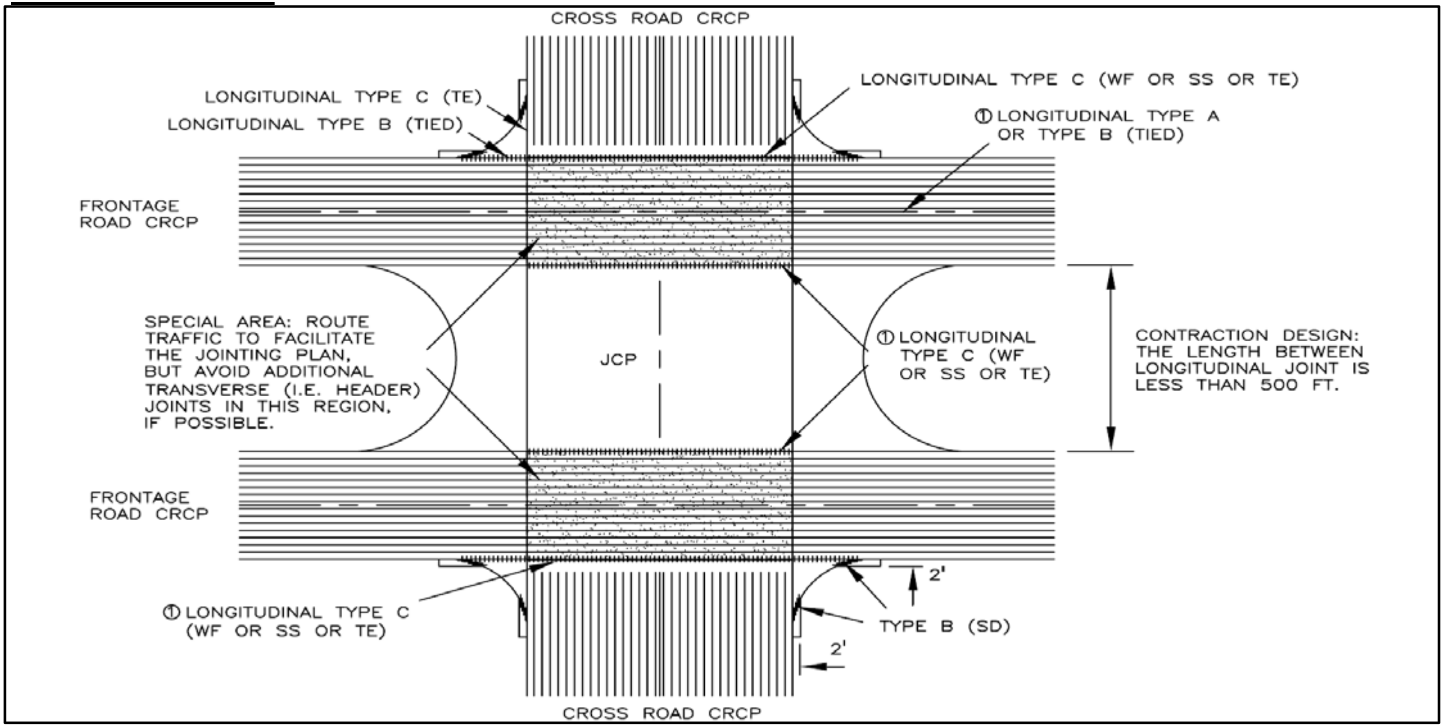
Minimum Design LTE (%)	CRCP LTE without Add bar (%)	CRCP add. bar size -spacing	CRCP additional bar length (in.)	CRCP Current+Add bar LTE (%)	JCP Dowel size - spacing	Dowel length (in.)
22.0	60.5	Needless	36	60.5	Needless	18

Construction Issues

1. Use of wide flange, sleeper slab, or thickened edge between frontage road and cross road.
2. Route traffic to facilitate the jointing plan, but avoid transverse (i.e., header) joints in this region, if possible.
3. Thickened edge joint can be employed when construction of sleeper slab is not available on turning radius.

Transition Type: **INTERSECTION (OPTION 2 - DISTANCE BETWEEN JOINTS < 500 FT)**

Plan View & X-Section



Design Options/ Factors

1. Cross road pavement should be isolated from the continuously paved frontage road to avoid lateral restraint caused by differential directional movement.
2. Use of a wide flange, sleeper slab, or thickened edge.
3. Design of the reinforcing bar size and spacing.
   # of reinforcing bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + load transfer bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10	Limestone	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening of CRCP (in.)	Sleeper slab thickness, Tss (in.)	Sleeper slab Length, Lss (in.)	Wide flange width, Wwf (in.)	Design JCP slab length (ft)	Expected joint opening of JCP (in.)
HOU	High - 80	0.86	10	60	4	15	0.04

Output Design Factors

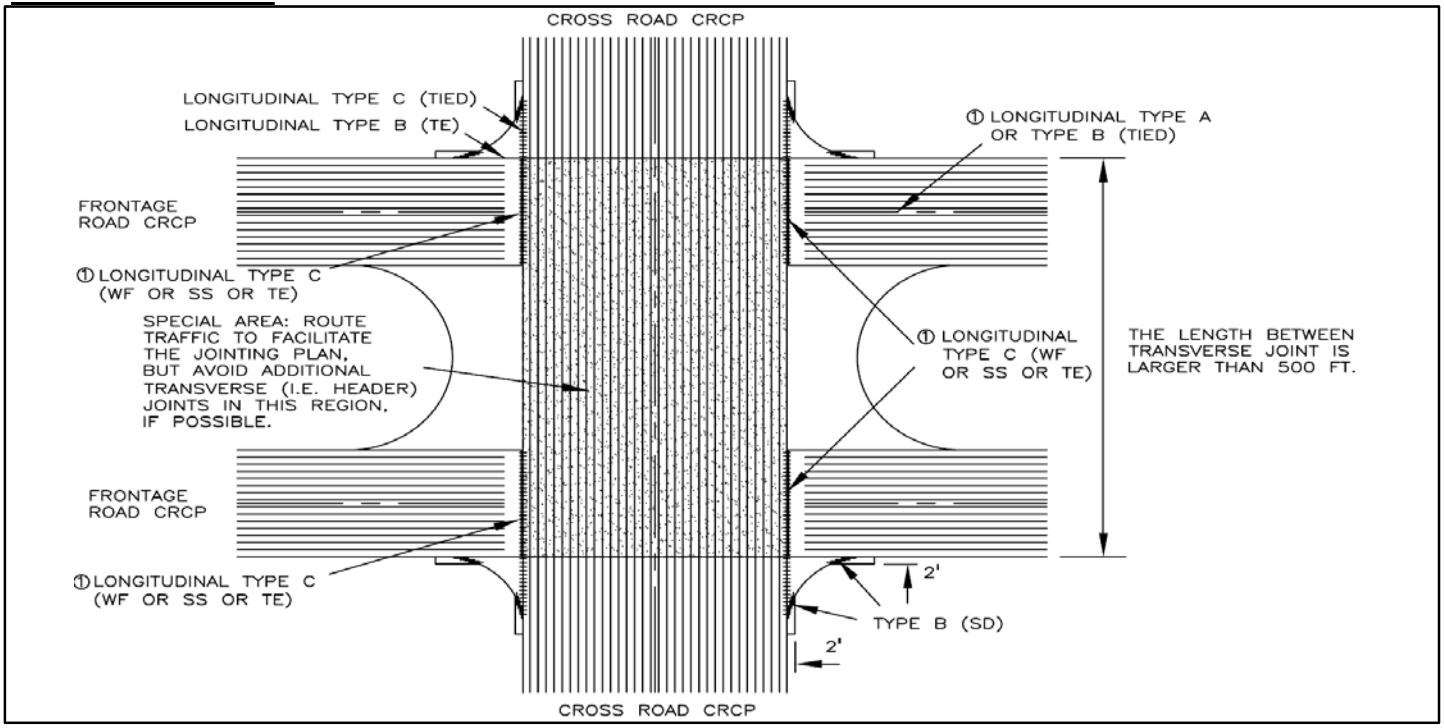
Minimum Design LTE (%)	CRCP LTE without Add bar (%)	CRCP add. bar size -spacing	CRCP additional bar length (in.)	CRCP Current+Add bar LTE (%)	JCP slab length (ft)	JCP Dowel size - spacing	Dowel length (in.)
22.0	60.5	Needless	36	60.5	15	Needless	18

Construction Issues

1. Use of wide flange, sleeper slab, or thickened edge between frontage road and cross road.
2. Route traffic to facilitate the jointing plan, but avoid transverse (i.e., header) joints in this region, if possible.
3. Thickened edge joint can be employed when construction of sleeper slab is not available on turning radius.

Transition Type: **INTERSECTION (OPTION 3)**

Plan View & X-Section



Design Options/ Factors

1. Frontage road pavement should be isolated from the continuously paved main road to avoid lateral restraint caused by differential directional movement.
2. Use of a wide flange, sleeper slab, or thickened edge.
3. Design of the reinforcing bar size and spacing.
   # of reinforcing bars = Slab width / Required bar spacing
   Required bar spacing (maximum) = that required to achieve the design J factor
   Design J factor = Aggregate J factor + load transfer bar J factor

Input Design Factors

CRCP slab thickness (in.)	Aggregate type	CRCP Steel bar size		Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
		diameter (in.)	spacing (in.)				
10 ▼	Limestone ▼	6/8	7	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening of CRCP (in.)	Sleeper slab thickness, Tss (in.)	Sleeper slab Length, Lss (in.)	Wide flange width, Wwf (in.)	Expected joint opening of JCP to CRCP (in.)
HOU ▼	High - 80 ▼	0.86	10	60	4	0.04

Output Design Factors

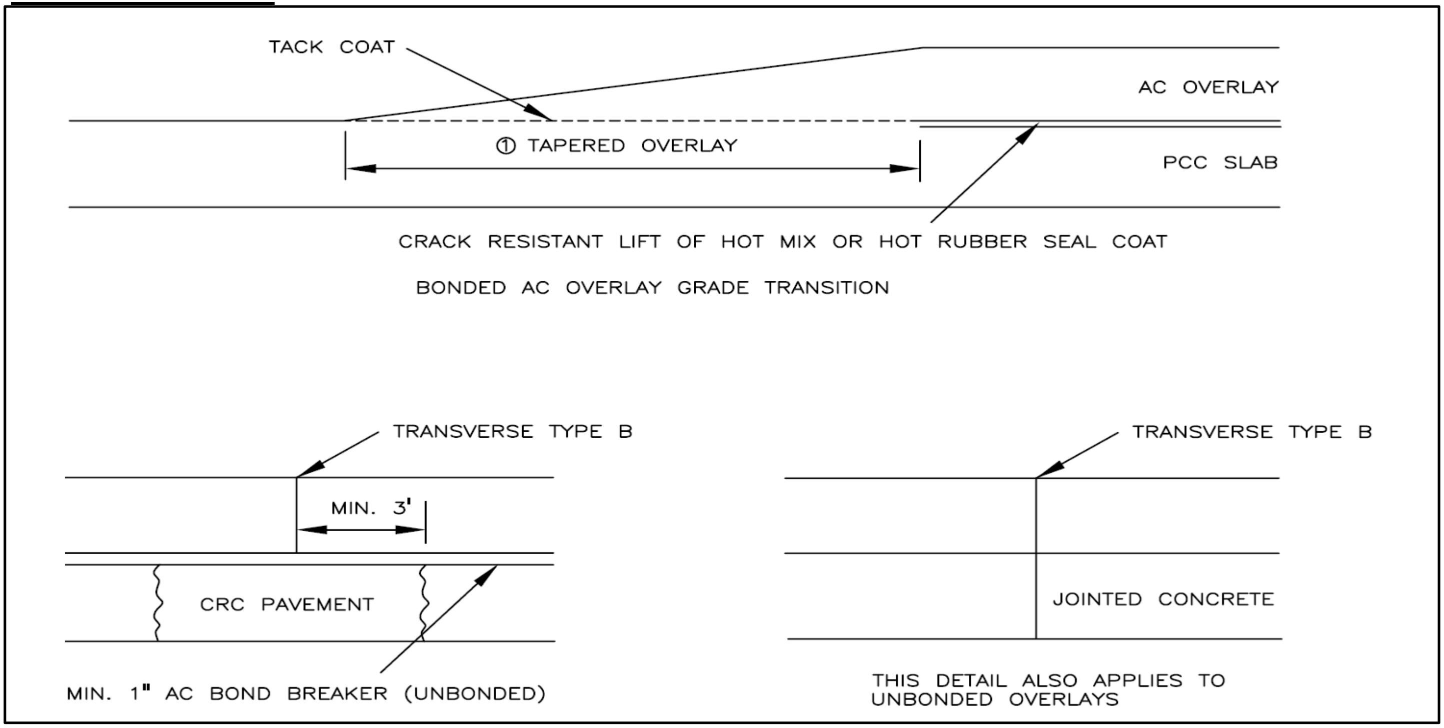
Minimum Design LTE (%)	CRCP LTE without Add bar (%)	CRCP add. bar size -spacing	CRCP additional bar length (in.)	CRCP Current+Add bar LTE (%)	JCP Dowel size - spacing	Dowel length (in.)
22.0	60.5	Needless ▼	36	60.5	Needless ▼	18

Construction Issues

1. Use of wide flange, sleeper slab, or thickened edge between frontage road and cross road.
2. Route traffic to facilitate the jointing plan, but avoid additional transverse (i.e., header) joints in this region, if possible.
3. Thickened edge joint can be employed when construction of sleeper slab is not available on turning radius.

Transition Type: **OVERLAY - UNBONDED, BONDED, AC OVERLAYS**

Plan View & X-Section



Design Options/ Factors

1. Use stress-absorbing membrane interlayer to minimize reflection cracking in AC overlays on PCC pavements.

Design Factors

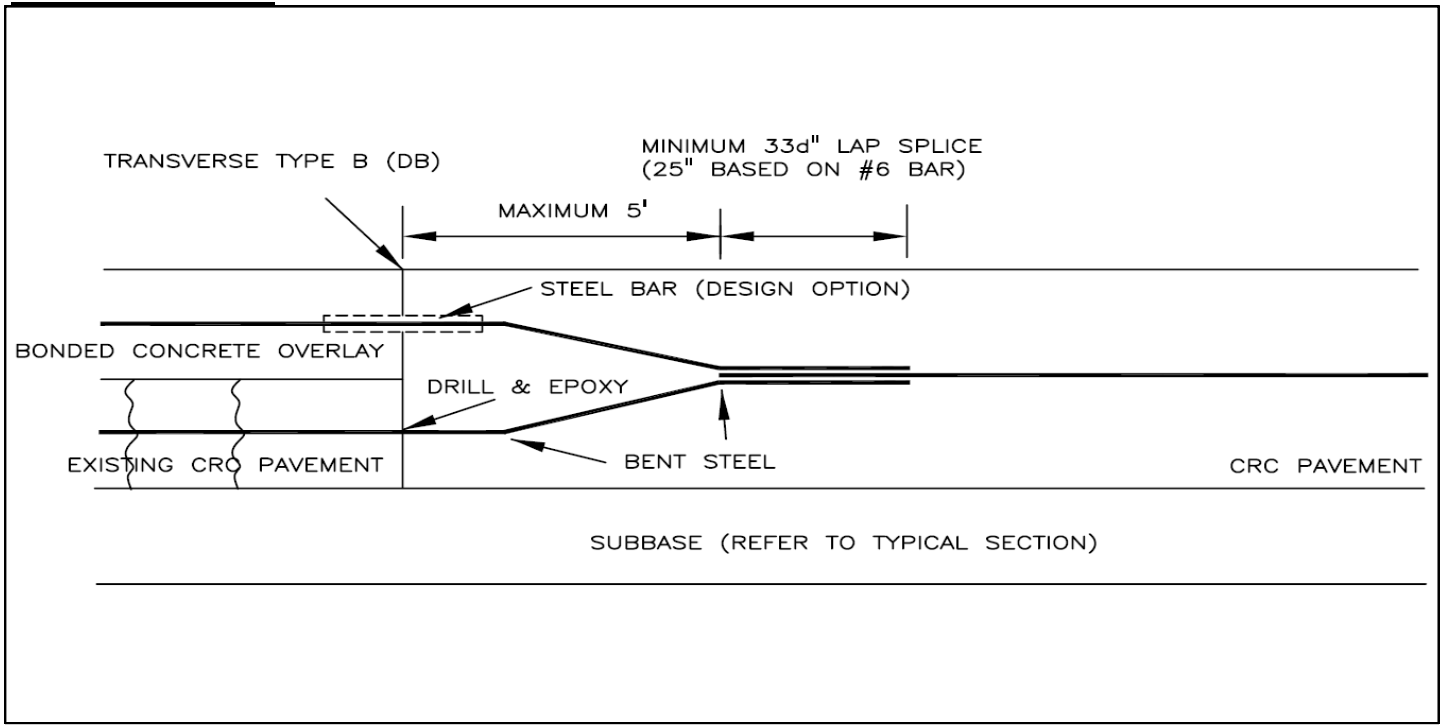
PCC slab thickness (in.)	AC overlay thickness (in.)	Tapered overlay length (ft)
10	2	20

Construction Issues

1. Use tack coat between PCC slab and AC overlay.
2. Construction joint of bonded or unbonded overlay needs to be matched with transverse joint of existing pavement.

Transition Type: CRC BONDED OVERLAY TO CRC PAVEMENT

Plan View & X-Section



Design Options/ Factors

1. Use reinforcing bar when subgrade cannot satisfy deflection criteria.
2. Double layer of steel pavement design would be applied when CRCP pavement thickness is over 13 inches.
3. If the combined thickness of overlay and old CRC pavement is different with new pavement, refer to CRC pavement to CRC pavement thickness transition.

Input Design Factors

Existing slab thickness (in.)	Existing slab condition	Overlay slab thickness (in.)	Bonded type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
7	Bad	5	Unbonded	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Aggregate type	Expected joint opening (in.)
HOU	High - 80	Limestone	1.30

Output Design Factors

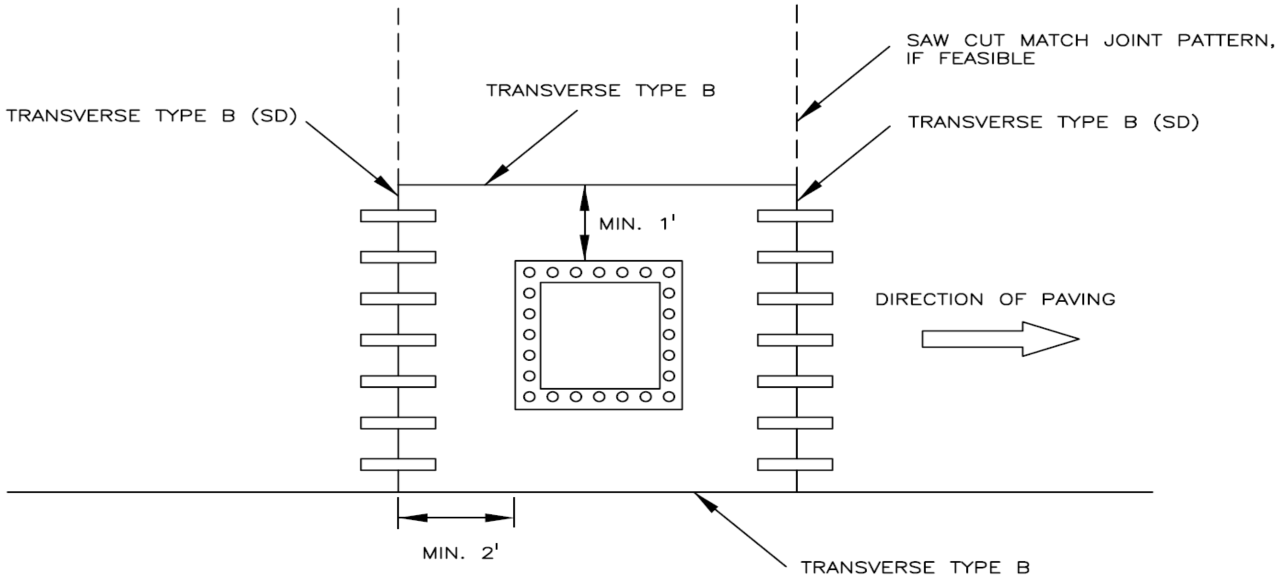
Minimum Design LTE (%)	Current LTE (%)	Steel bar # - spacing	Overlay to New pavement LTE (%)	Minimum lap splice length (in.)
75.0	63.1	N/A	66.8	25

Construction Issues

1. Reinforcing bar alignment is critical through the transition zone.

Transition Type: **DROP INLET / DRAINAGE BOX**

Plan View & X-Section



Design Options/ Factors

1. Drop inlet should be blocked out wide enough to allow for the isolation joint.
2. Only dowel the transverse construction joints.

Input Design Factors

Slab thickness (in.)	Aggregate type	Subbase thickness (in.)	Subbase modulus (psi)	Subgrade strength (pci)	Subgrade UCCS (psi)
10 ▼	Limestone ▼	6	1,000,000	100	20

Regional classification	Traffic level (Million ESAL)	Expected joint opening (in.)
HOU ▼	High - 80 ▼	0.86

Output Design Factors

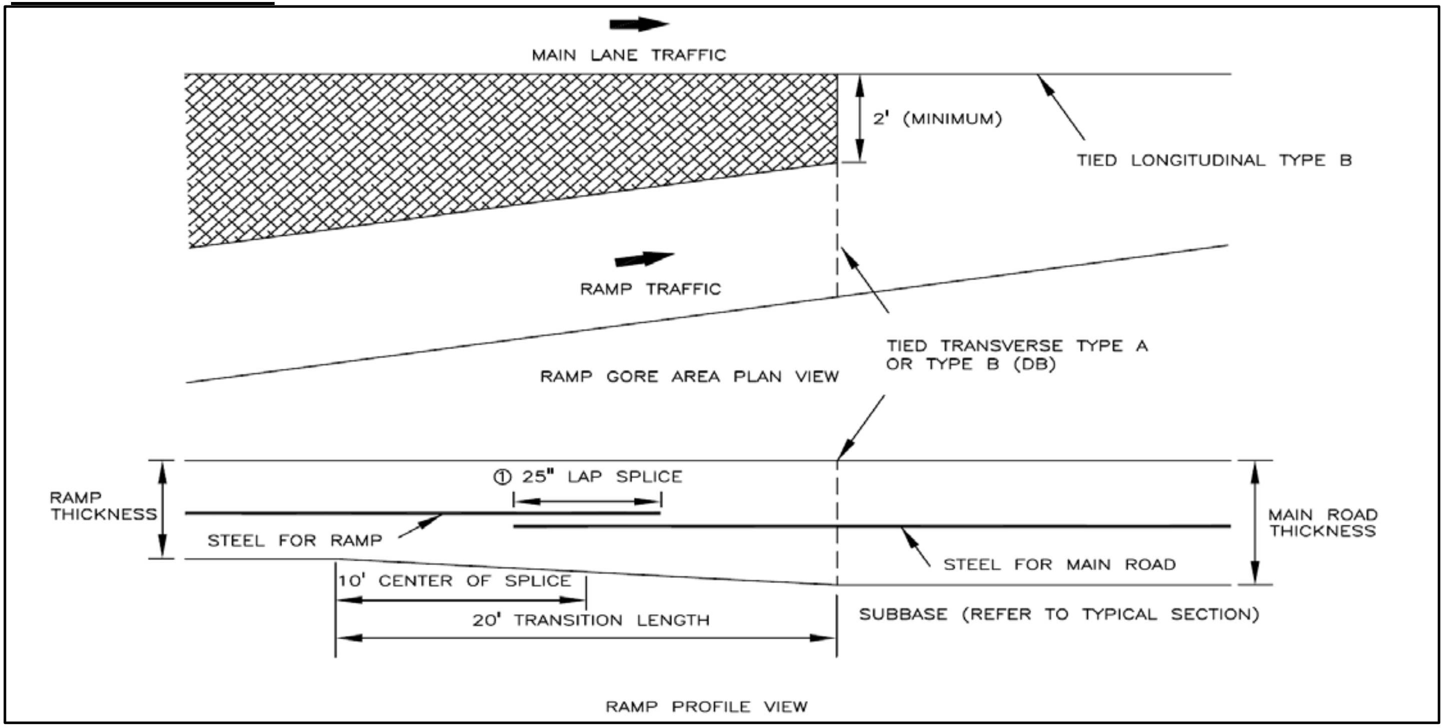
Minimum design LTE (%)	Dowel size -spacing	Dowels length (in.)	Aggregate and Dowel LTE (%)
22.0	#8 - 11 in. ▼	18	61.3

Construction Issues

1. Dowels need to be properly aligned.

Transition Type: **GORE AREA / RAMP**

Plan View & X-Section



Design Options/ Factors

1. Length and width of gore area.

Design Factors

Ramp slab thickness (in.)	Ramp steel bar size (in.)	Ramp steel bar spacing (in.)	Main road slab thickness (in.)	Main road Steel bar size (in.)	Main road steel bar spacing (in.)	Lap splice length (in.)
10 ▼	#6 - 0.75 in.	7	12 ▼	#6 - 0.75 in.	6	25

Construction Issues

1. Minimum 2 ft wide and squared off where main line and ramp meet; match a contraction joint with the squared off face.