

Concrete Pavement Design and Materials Selection

Hua Chen, P.E.
(512) 506-5846

Rigid Pavement and Concrete
Materials Branch, TxDOT

2011 Short Course

Overview

I. Current Design Guides

II. Concrete Pavement Details

I. Current Design Guides

- David B. Casteel, P.E. Memorandum
November 2, 2009

“Changes to the Texas Department of Transportation’s (TxDOT) Rigid Pavement Design Procedure”

Design Parameters

- 28-day Concrete Modulus of Rupture, psi
620 psi - no changes

However, each district should consider a higher value if their flexural strengths have historical been higher than 620 psi.

Design Parameters

TxDOT requires one of the following base layer combinations for concrete slab support:

- 4 in. of asphaltic concrete pavement (ACP) or asphalt stabilized base (ASB) or
- a minimum 1 in. asphalt concrete bond breaker over 6 in. of a cement stabilized base.

Design Parameters

- Effective Modulus of Subgrade Reaction, K
300 pci Changed to 300 - 800 pci
- A k-value of 300 psi/in. should be used in the rigid pavement design procedure with one of the stabilized base layer combinations.
- The designer may use a higher k-value up to 800 psi/in, with the requirement of field verification tests during the construction.

Design Parameters

Reliability %

95% changed to

90% when ESALs ≤ 5 million

95% when ESALS > 5 million

Design Parameters

- Load Transfer Coefficient, J
With Tied PCC Shoulders,
or Tied Curb and Gutter

$J = 2.9$ changed to

$J = 2.6$ for CRCP

$J = 2.9$ for JCP

Design Parameters

- 28-day Concrete Elastic Modulus, psi
- Serviceability Indices
- Drainage Coefficient
- Overall Standard Deviation

No changes

Maximum Slab Thickness

- Is reduced from 15" to 13".
- District should submit designs thicker than 13", including the justification for doing so, to the District Engineer for approval.

Minimum Slab Thickness

- Is reduced from 8" to 6".
- Utilizing thickened base/subbase layers will help ensure the structural adequacy for the pavement system.

Thickness Rounding

■ Changed from

“Round the thickness up to the next higher whole inch.” to

“Round the design thickness to the nearest full or half-in.”

Computed Thickness (in)	Old Rounding (in)	New Rounding (in)
11.40	12	11.5
9.24	10	9.0
14.50	15	13
6.28	8	6.5

- Reduction in thickness will increase the risk of potential distresses at earlier age and should be mitigated by proper maintenance.

II. Concrete Pavement Details

- Two types of concrete pavements commonly used in Texas are continuously reinforced concrete pavement (CRCP) and jointed concrete pavement (JCP).

Selection of Rigid Pavement Type

- CRCP provides excellent long-term performance requiring very low maintenance. The Department policy is to utilize CRCP for new or reconstructed rigid pavements in Texas. There are situations where jointed pavement may be desirable. If jointed pavement is to be utilized, its use must meet one of the following criteria:

- for roadways controlled and maintained by another government entity
- for parking areas or roadways with crosswalks, adjacent parking, or sidewalks
- for railroad crossings, approaches to structures or to widen existing jointed pavement

- for intersections and approaches in flexible pavement roadways that are associated with vehicle braking and acceleration which could cause shoving and rutting of an asphalt pavement
- for other situations approved by the Administration, after submittal of request and justification to the Materials & Pavements Section of the Construction Division (CST-M&P).

CRCP Standards

- CRCP contains both longitudinal and transverse steel. CRCP does not contain transverse joints except at construction joints.



Longitudinal Joint

11" CRCP

TieBars

Transverse Steel

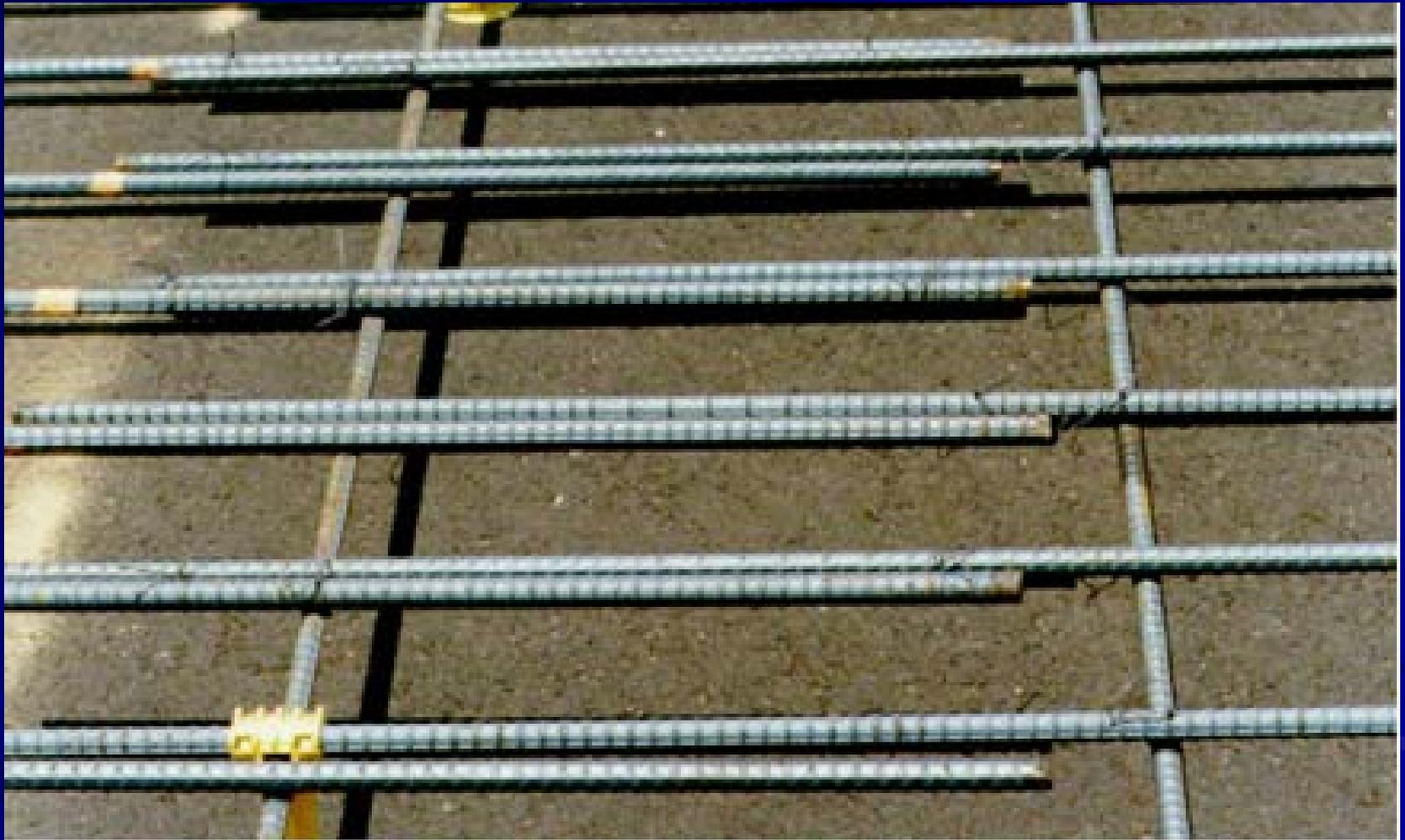
Longitudinal Steel

4" ACP Base

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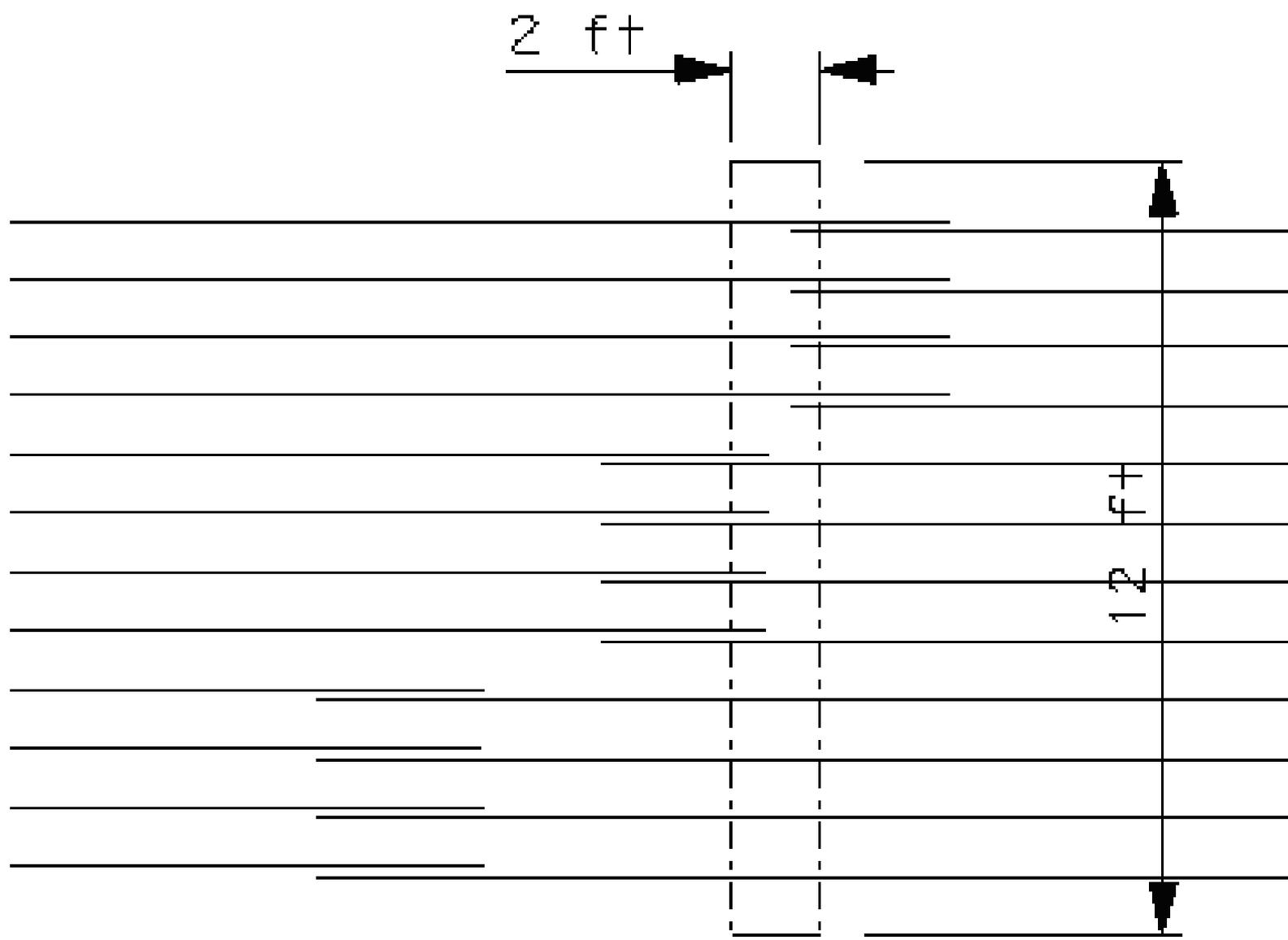


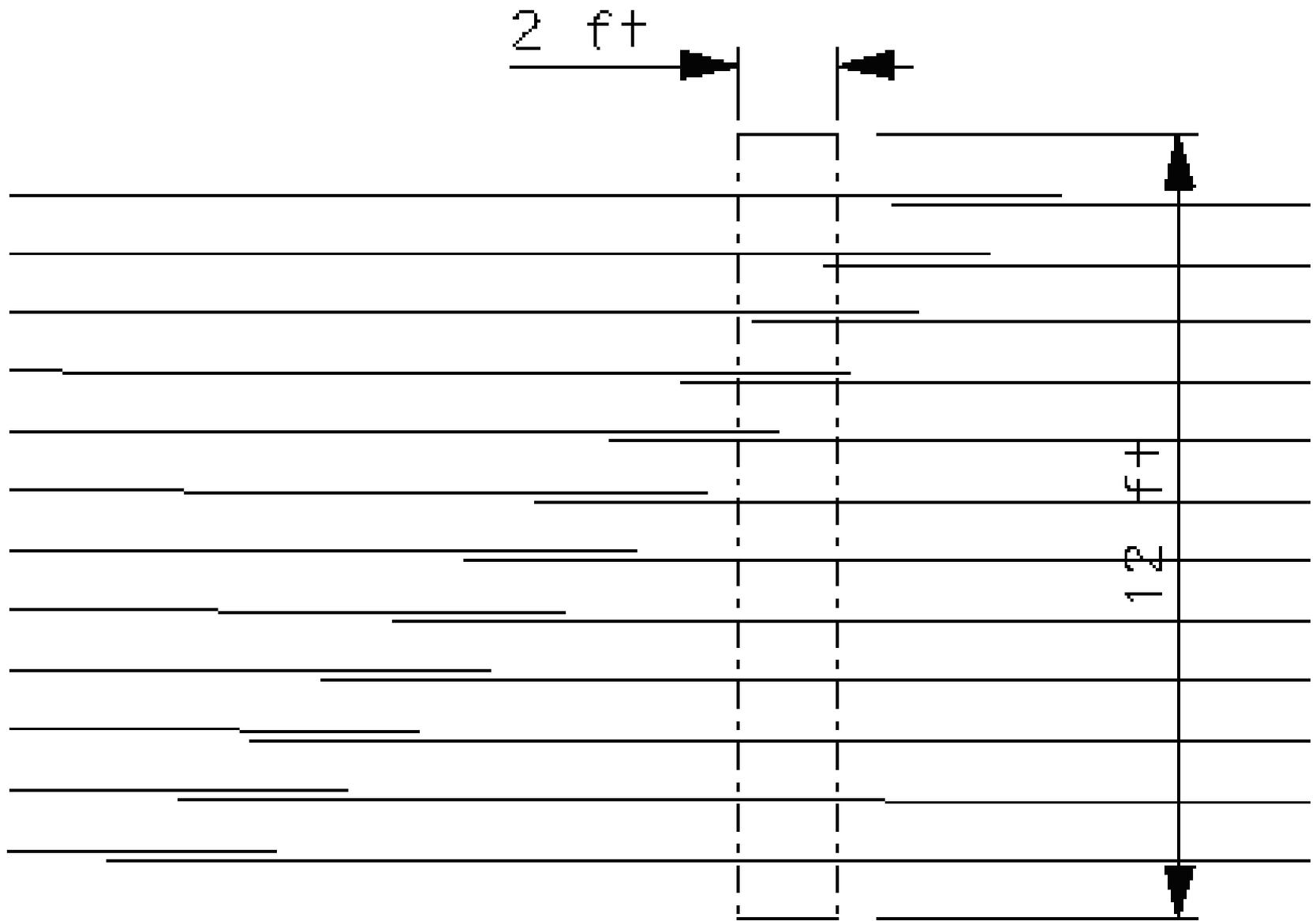
- In CRCP, maintaining steel continuity in the longitudinal direction is important in ensuring good performance of the pavement. The length of the reinforcing steel bars is 60 ft. The continuity of the longitudinal steel is achieved by overlapping individual steel bars. Extensive testing shows that as long as the overlapping is more than 33 times bar diameter, stresses in one steel is effectively transferred to the next steel via surrounding concrete. For example, No. 6 bars would need a 25-in. splice for effective stress transfer.

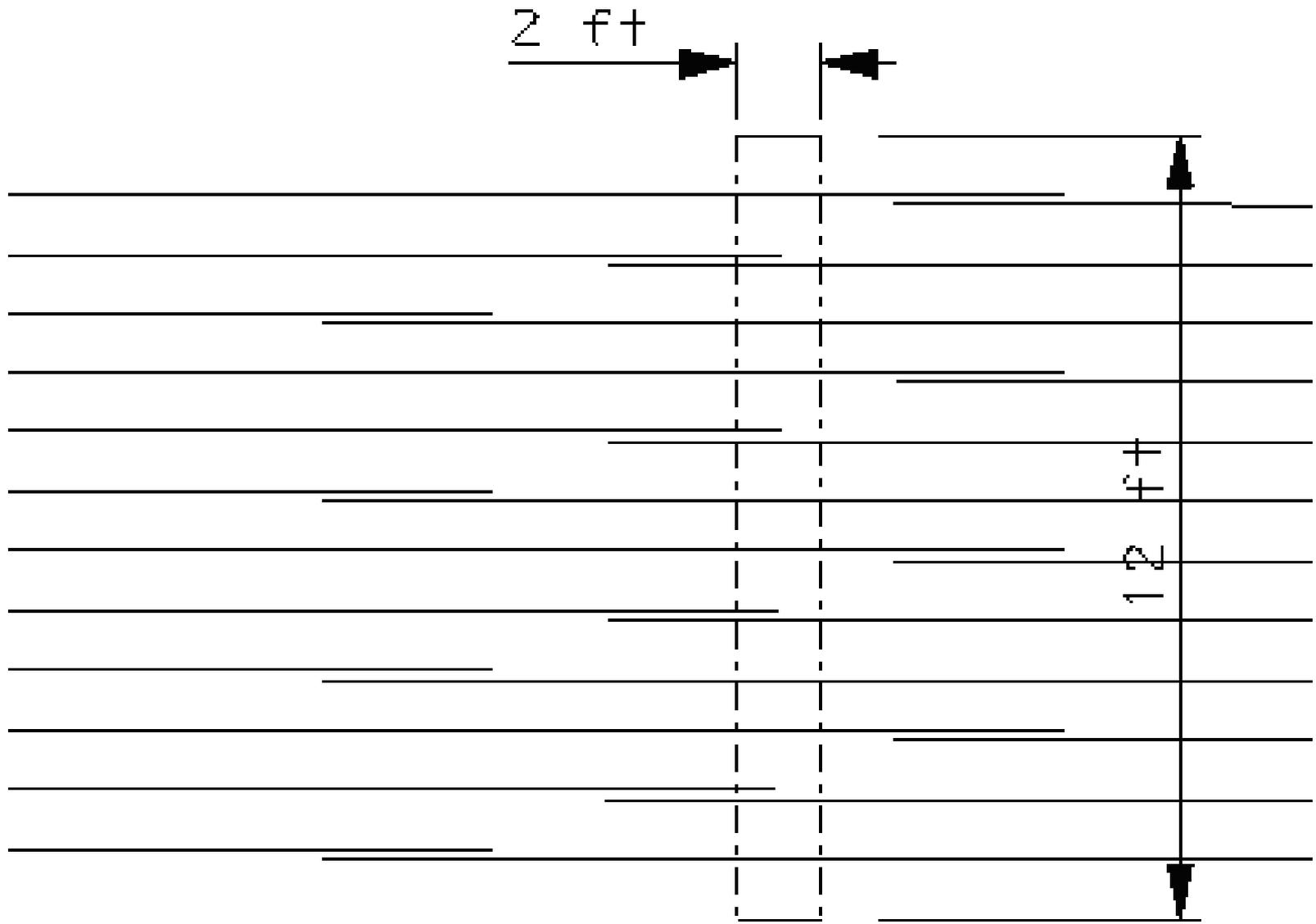


Splice Locations

- If all the splices occur at the same longitudinal location, transverse cracks that occur at the location could cause steel bonding failure, resulting in wide cracks and performance problems. To make sure that all the splices do not occur at the same transverse location, Item 360 requires staggering splices to avoid having more than $1/3$ of the splices within a 2-ft. longitudinal length of each lane of the pavement.









Check Steel height



At Transverse Construction Joint





- When two adjoining lanes are placed with separate concrete placements, the joint between the two placements is called a longitudinal construction joint. Across longitudinal construction joints are short pieces of reinforcing steel called tie bars. The tie bars keep the two adjoining slabs from pulling away from each other and keep the surface across the joints flat.

- Multiple piece tie bars are threaded in the middle to allow the two halves of the tie bar to be separated and then reconnected only prior to the casting of the second pavement.







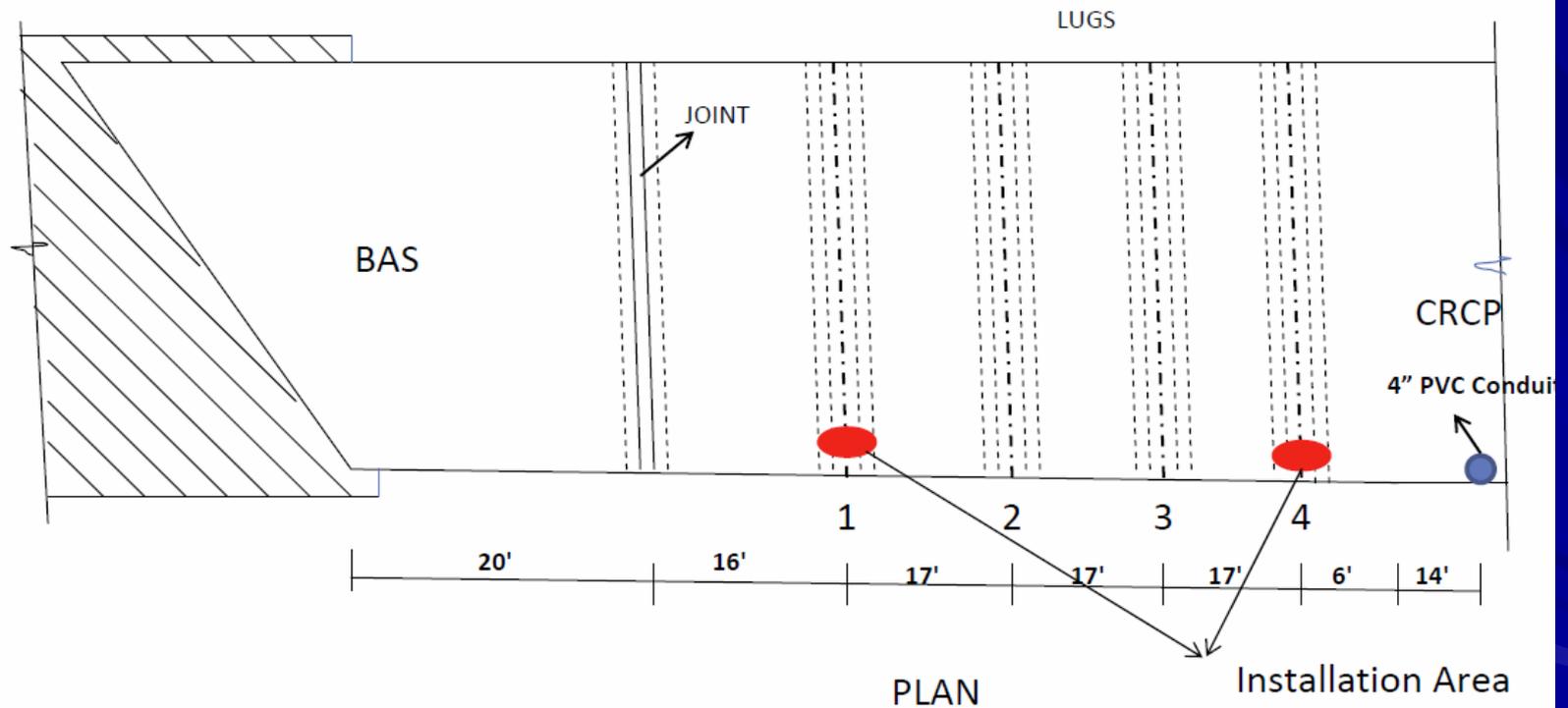
Preventing curing compounds from dropping on tie bars

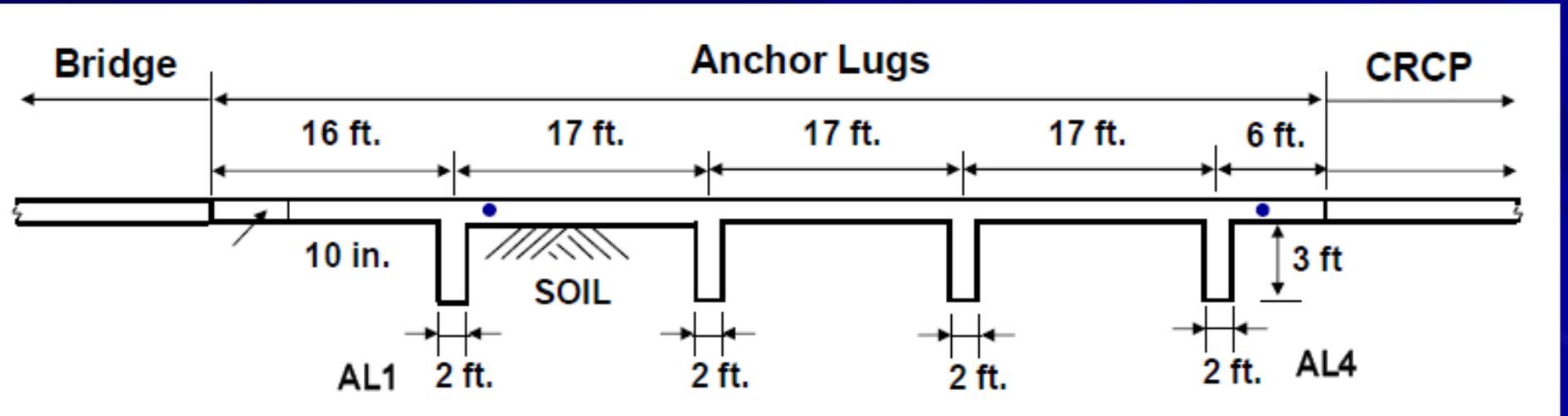


Terminal Anchors

- Anchor lugs
- Expansion joints
- Wide Flange joints

Anchor Lug Instrumentation Plan





Excavation fo



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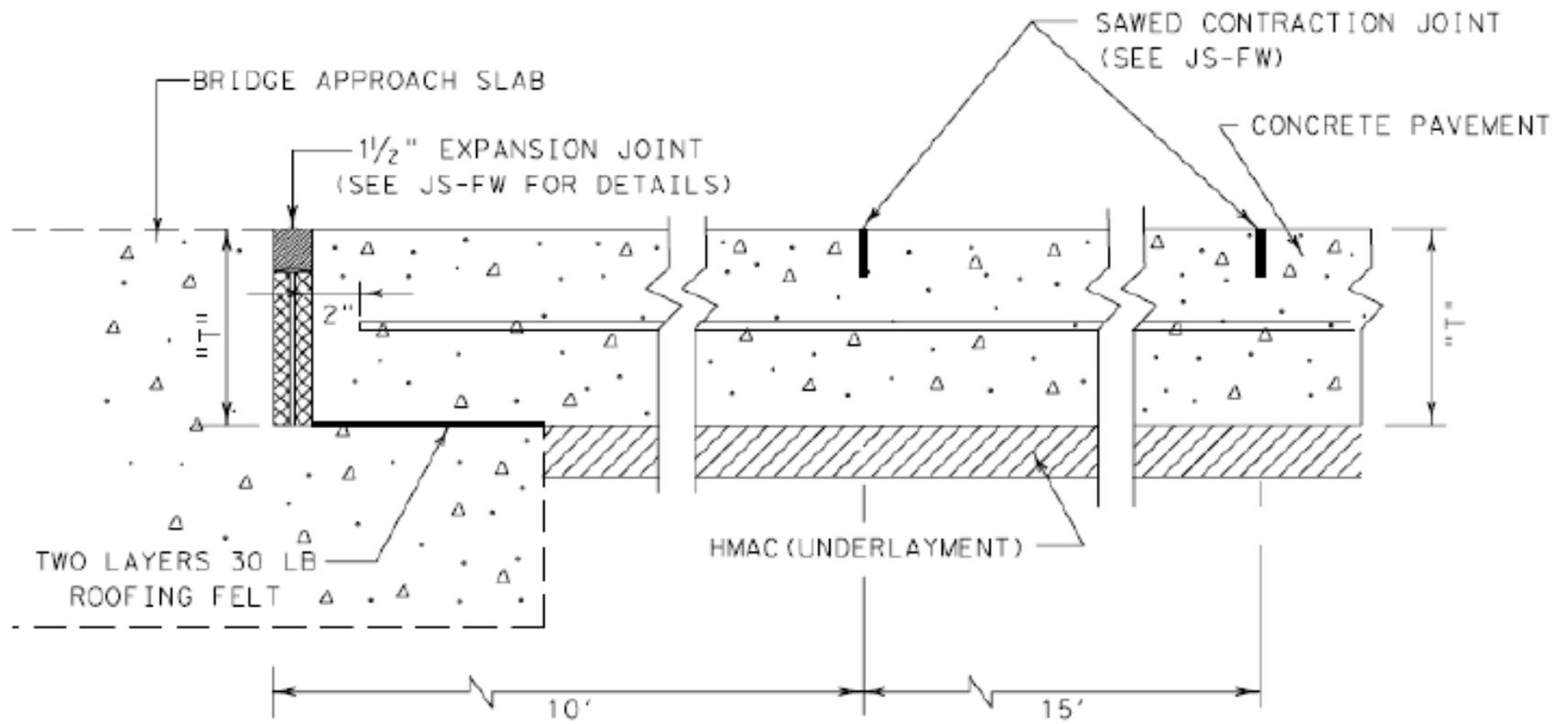
Anchor Lug Cage Being Tied



The Anchor Lug Cage Put into Ditch



Expansion Joint (FTW)



CONCRETE PAVEMENT TERMINUS



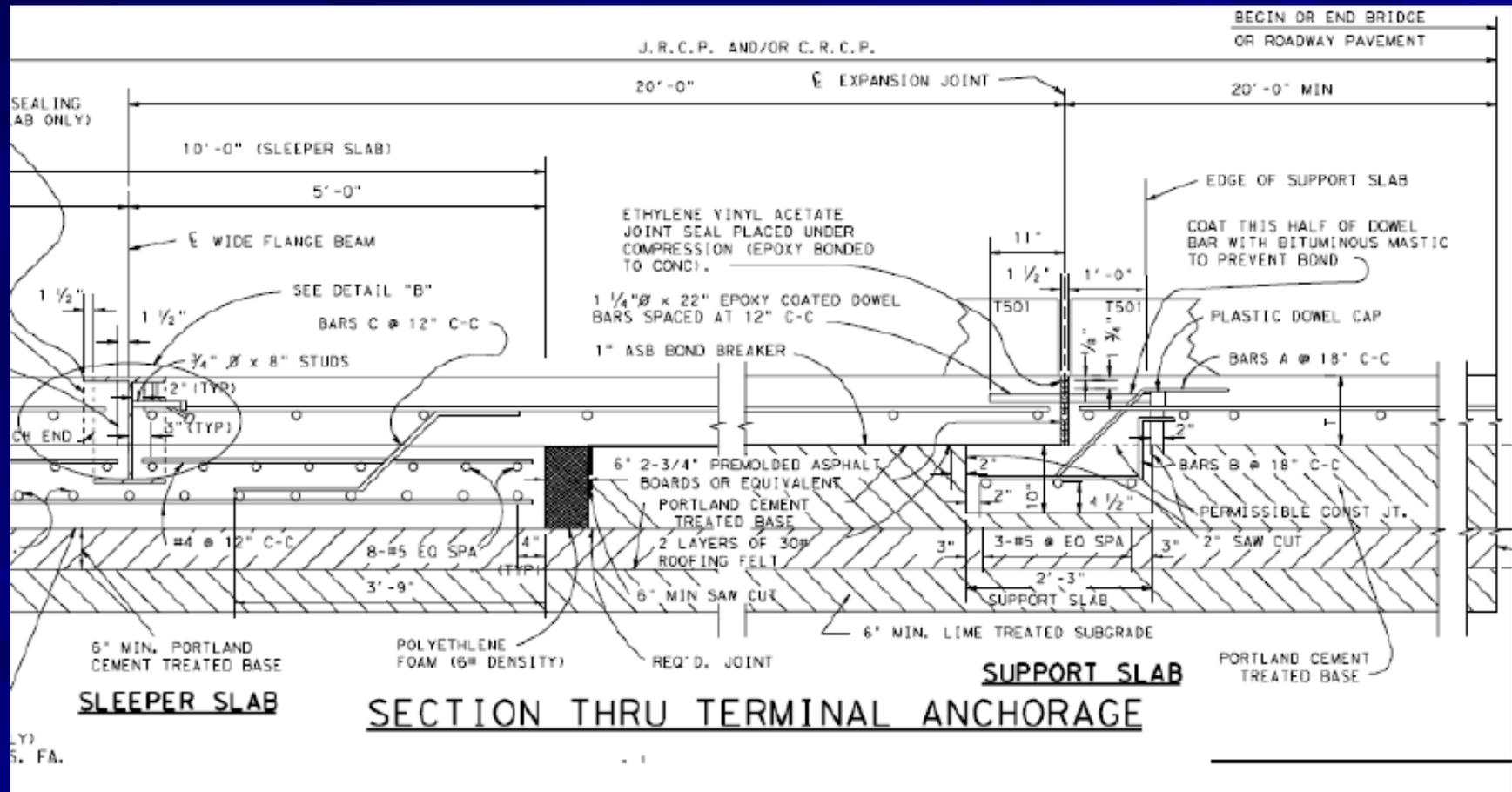
Approach Slab

CRCP

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Wide Flange Joints





Research project 0-6326 Rational Use of Terminal Anchorages in Portland Cement Concrete Pavement

Start Date - 10/01/2008 End Date - 08/31/2011

Project Director : Tomas Saenz, ELP

Project Advisors: Brian Merrill, BRG, Hua Chen, CST

Rashidah Dyer, DAL, Stacey Young, LBB

Research Supervisor: Moon Won, TECHMRT

Summary of Test Sections

Test Section	Terminal Type	Coarse Aggregate Type	Length of Pavement (miles)	Subbase Type	Date of Installation	Drying Shrinkage (mils)	Daily Mvt Rate (mil/°F)	Seasonal Mvt Rate (mil/°F)
ELP	EJ	LS	0.80	3 in. ACP Dolomitic	4/21/09	N/A	0.56	9.59
WFS	EJ	LS	0.50	3 in. ACP Ty B	3/18/09	N/A	0.56	9.69
ATL1	WF	SRG	> 1.00	4 in. ACP (open graded)	10/1/09	250	0.51	4.53
ATL2	AL	SRG	0.45	4 in. ACP	5/22/07	N/A	0.61	3.56
LBB1	AL	SRG	0.45	4 in. ACP	3/18/09	20	0.33	0.24
LBB2	AL	LS	0.45	1 in. ACP + 6 in. CSB Ty D	9/2/10	40	0.07	0.51
WAC	WF	LS	> 1.00	4 in. ACP	4/19/10	N/A	0.142	2.63

Crackmeter Installed at US82 Wichita Falls



CRCP End Movement

Free vs Restrained

- Free movement = $\alpha_c \cdot \Delta T \cdot L / 2$

ex) $(5 \times 10^{-6}) \times 100 \times (0.5 \times 5280 \times 12) / 2 = 7.9$ in.

- 0.75 in. for ΔT of 100 °F
- Severely restrained by subbase friction!!

- Subbase friction restrains slab movements effectively.
- Using rough texture subbase might be the most effective tool to control slab movements.
- Anchor lug system is not effective in the long run.
- Simple expansion joint system or wide-flange system is effective in accommodating slab movements.

Recommendations

- Simple expansion joint (EJ) system or wide-flange (WF) system with 1.5-in joint width is recommended for a terminal system.
- Between EJ and WF systems, EJ should cost less than WF system with comparable performance.
- Continuously reinforced concrete pavement: let's not have gaps.
- Seamless design

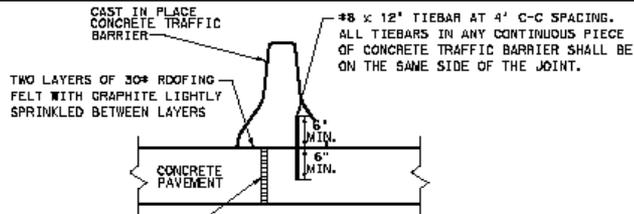
Issues to be Addressed

- Expansion of CRCP
- Sliding of pavement
- Best strategy to address CRCP expansion

CPCD-94

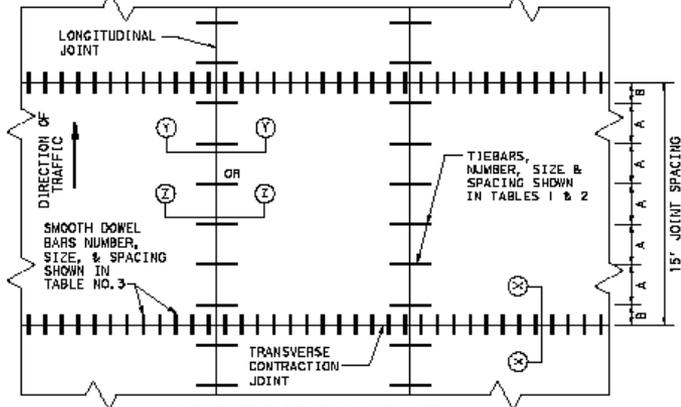
- Concrete Pavement Details, Contraction Design has details for Jointed Concrete Pavement (JCP)
- JCP has transverse joints spaced at regular intervals. The transverse joints are used to control temperature and moisture induced contraction and expansion in the concrete.
- Smooth dowels are used at the transverse joints for load transfer.

- JCP has transverse joints spaced at regular intervals. The transverse joints are used to control temperature induced contraction and expansion in the concrete. Smooth dowel bars are used at the transverse joints for load transfer. The transverse joints are spaced at 15 ft.
- Longitudinal joints are used to control random longitudinal cracking. Longitudinal joints are tied together with tie bars.

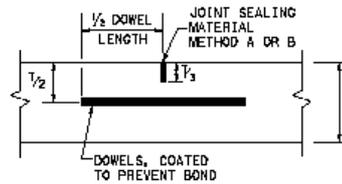


FREE LONGITUDINAL JOINT WITH NO TIEBARS. LOCATION OF THE JOINT WILL BE AS DIRECTED BY THE ENGINEER FORMED WITH PREFORMED FIBER BOARD OR ASPHALT BOARD IN ACCORDANCE WITH ITEM 'JOINT SEALANT AND FILLERS'.

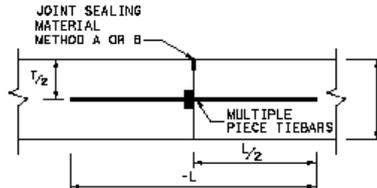
FREE LONGITUDINAL JOINT DETAIL



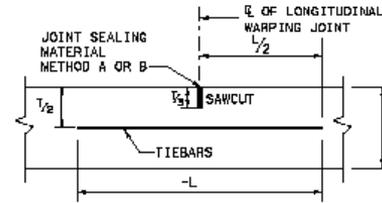
PAVEMENT DETAIL LAYOUT



TRANSVERSE CONTRACTION JOINT SECTION X-X



LONGITUDINAL CONSTRUCTION JOINT SECTION Y-Y



LONGITUDINAL WARPING JOINT SECTION Z-Z

GENERAL NOTE

1. CONCRETE SLABS WIDER THAN 100' WILL NOT COVERED BY THIS STANDARD.
2. FOR FURTHER INFORMATION REGARDING AND LOAD TRANSFER DEVICES REFER SPECIFICATIONS FOR "CONCRETE PAVEMENT STEEL."
3. DETAILS FOR PAVEMENT WIDTH, PAVEMENT CROSS SLOPE SHALL BE AS SHOWN ELSEWHERE ON THE PLANS.
4. THE DETAIL FOR THE JOINT SEALANT SHOWN IN CONCRETE PAVEMENT DETAIL STANDARD (J5-94).
5. PAVEMENT WIDTHS IN EXCESS OF 16' LONGITUDINAL JOINT (SECTION X-X) BE LOCATED WITHIN 6" OF THE LANE ELSEWHERE ON THE PLANS.
6. THE JOINT BETWEEN OUTSIDE LANE AND LONGITUDINAL WARPING JOINT (SECTION Y-Y) SHOWN IN THE PLANS.
7. THE SPACING BETWEEN TRANSVERSE JOINTS UNLESS OTHERWISE SHOWN IN THE PLANS.
8. WHERE A MONOLITHIC CURB IS SPECIFIED SHALL COINCIDE WITH PAVEMENT JOINT MEANS APPROVED BY THE ENGINEER.
9. TRANSVERSE CONSTRUCTION JOINTS MAY BE WOOD FORMS EQUAL IN DEPTH TO PAVEMENT, OR BY METHODS APPROVED BY THE ENGINEER.
10. THE ENGINEER WILL ADJUST THE REQUIRED SPACING FOR SLABS SHORTER OR LONGER THAN ADJUSTED TO MAINTAIN A MINIMUM CENTER TO CENTER SPACING OF 18" BETWEEN TIEBARS AND THE DOWEL BARS AT THE JOINT. THE "A" SPACING WILL REMAIN AS SHOWN ON THE PLANS.
11. MULTIPLE PIECE TIEBARS SHALL BE USED AT CONSTRUCTION JOINTS UNLESS OTHERWISE SHOWN IN THE PLANS.
12. THE SAW CUT FOR LONGITUDINAL WARPING JOINTS MAY BE ONE FOOT LONG WHEN CRUSHED LIMESTONE IS USED AS FILLER.

TABLE NO. 1 TIEBARS REQUIRED FOR LONGITUDINAL JOINTS FOR EACH 15' SLAB

ASPH 0-810 OR 0-812 GRADE NOT STRAIGHT OR MULTIPLE PIECE REINFORCING TIEBARS	CONCRETE SLAB THICKNESS	DISTANCE FROM THE LONGITUDINAL JOINT TO THE NEAREST LONGITUDINAL FREE EDGE				
		< OR = 15'	< OR = 24'	< OR = 34'	< OR = 50'	
42	8	5	5	8	8	
	9	5	5	7	10	
	10	5	5	7	11	
	11	5	5	8	12	
	12	5	6	9	12	
	13	5	7	9	13	
	14	6	7	10	NA	
	15	8	8	11	NA	
	60	8	5	5	8	8
		9	5	5	8	7
10		5	5	8	8	
11		5	5	8	8	
12		5	5	8	8	
13		5	5	7	10	
14		5	5	7	10	

THE DISTANCE TO THE FREE EDGE WILL BE DETERMINED BY THE ENGINEER AND THE DISTANCE WILL BE BASED ON THE NOMINAL WIDTHS OF THE LANES AND SHOULDERS PLUS ANY TIED RAMP OR CONNECTING ROADWAYS.

TABLE NO. 2 TIEBAR SPACINGS

SPACING REQUIREMENT FOR 15' SLAB FOR REQUIRED NUMBER OF BARS		
REQUIRED NO. OF BARS	REGULAR SPACING (INCHES)	F (FEET AT JOINT)
5	30	18
6	30	15
7	22	15
8	21	16.5
9	18	18
10	18	18
11	10	15
12	15	18.5
13	12	18

TABLE NO. 3 DOWELS REQUIREMENTS

T, IN.	DOWELS (SMOOTH BARS)	
	SIZE AND LENGTH	AVERAGE SPACING (INCHES)
8	1" x 18"	12
9	1 1/4" x 18"	12
10	1 1/4" x 18"	12
11	1 3/8" x 18"	12
12	1 1/2" x 18"	12
13	1 5/8" x 18"	12
14	1 3/4" x 18"	12
15	1 7/8" x 18"	12

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Jointed Concrete Pavement





Jointed Concrete Pavement



THANK YOU !