Paper Title: **PRACTICES FOR PIER AND INTERMEDIATE DIAPHRAGMS OF PRECAST CONCRETE GIRDER BRIDGES**

Authors: Chung C. Fu, Ph.D., P.E., Director/Associate Professor, the Bridge Engineering Software & Technology (BEST) Center

Tarek Kudsi, Ph.D., Research Associate, the BEST Center

Department of Civil & Environmental Engineering

University of Maryland

College Park, MD 20742

Tel: 301-405-2011

Fax: 301-314-9129

E-mail: ccfu@eng.umd.edu

Jeff Robert, Maryland State Highway Administration

Call for Paper:

A2C03 Concrete Bridges, Session 2

Title of Session:

Diaphragms in Concrete Bridges

Length:

Text	2287 words
Tables (2)	500 words
Figures (7)	1750 words
---------	--
Total	4537 words

PRACTICES FOR PIER AND INTERMEDIATE DIAPHRAGMS OF PRECAST CONCRETE GIRDER BRIDGES

By Chung C. Fu, Tarek Kudsi, University of Maryland, and Jeff Robert, Maryland State Highway Administration

ABSTRACT:

The objective of this study is to provide optimal standard pier and intermediate diaphragm details for the State of Maryland to make simple span pre-cast concrete girders continuous for live load and lateral stability. The study is based partially on a survey prepared and sent to the Departments of Transportation of all 50 states requesting their standard detail drawings of diaphragms over piers. Thirty-three states replied, sending their various approaches to continuity over piers. Based on the survey, a standard detail for a concrete diaphragm over pier is designed, accounting for the negative and positive moments. The choice of such a diaphragm type is based on factors such as economy, constructibility, and the use of the post-tensioned tendons and steel reinforcement to resist positive moment induced by creep, shrinkage, and elastic shortening. Also, along with the survey, some of the states replied with the type and placement of intermediate diaphragms.

A spreadsheet was developed for all the types of AASHTO and Bulb-Tee girders with different span lengths that were cited in the states' replies.

PRACTICES FOR PIER AND INTERMEDIATE DIAPHRAGMS OF PRECAST CONCRETE GIRDER BRIDGES

By Chung C. Fu, Tarek Kudsi, University of Maryland, and Jeff Robert, Maryland State Highway Administration

INTRODUCTION

The objective of this study for the State of Maryland is to provide an optimal standard pier diaphragm detail for making simple span precast concrete girders continuous for live load and lateral stability. Recommendations for intermediate diaphragms are also provided.

The use of prestressed precast girders in bridge construction started in the United States in the early 1950's. Although the girders are designed as simple span for dead load, reinforcement in the deck girders provided negative moment capacity. Recently, the demand in the State of Maryland for making simple span precast girders continuous over pier has increased; thus, a standard detail for diaphragms over piers, showing the necessary reinforcements for different span lengths, is needed.

The study was carried out by sending letters to the Departments of Transportation in all 50 states requesting their standard detail drawings of diaphragms over piers. Thirty-three states replied, sending their various approaches to continuity over piers. Although some states do not make simple spans continuous, many states make the deck longitudinal reinforcement resist the negative moment, and some stipulate that the diaphragm over pier resist the negative moment due to live load. In addition to designing for negative moment over pier, many states design for positive moment at the supports resulting from creep, shrinkage and elastic shortening.

A spreadsheet is then prepared for all the types of AASHTO and Bulb-Tee girders with different span lengths cited by the states' replies. The spreadsheet calculates the required reinforcement for negative and positive moments for various types of girders and span lengths that are listed. Positive moment in the diaphragm is usually a result of creep, shrinkage, and elastic shortening; thus, extended tendons or reinforcements, from the adjacent girders, are used in resisting the positive moment (*2*). The issue of using positive moment reinforcement at the interior pier has been discussed in many previous reports. NCHRPR 322 (*3*), "Design of Precast Bridge Girders Made Continuous," concluded that positive moment connections are costly and provide no structural benefits. On the other hand, an interim report prepared for the National Cooperative Highway Research Program (NCHRP) Project 12-53 (*4*), "Connection between Simple Span Precast Concrete Girders Made Continuous," discusses the importance of accounting for positive moment resulting from creep and shrinkage. The author of the 1999 NCHRP Project 12-53 interim report does not give a closed form solution to standardize the calculation of the positive moment; he states that current PCA practice does not perform a time dependent analysis, and, instead, details the positive moment connection using $1.2M_{cr}$.

In the presented spreadsheet, the user has the choice to use the default $1.2M_{cr}$ as positive moment at the connection, or to input the calculated time dependent positive moment due to shrinkage, creep, and elastic shortening.

SURVEY & COMMENTARY

Diaphragm over pier

Table 1 shows a brief description for every state's practice for continuity over pier. The states that replied are categorized as follows:

A. States using diaphragm over pier to resist live load and superimposed dead load, and using extended dowels or strands into the diaphragm to resist positive moments. Sample detail of type A is shown in Figure 1:
   1. Alaska
   2. Colorado
   3. Delaware
   4. Idaho
   5. Illinois
   6. Kansas
   7. Missouri
   8. New Jersey
   9. New York
   10. North Carolina
   11. Ohio
   12. Oregon
   13. Pennsylvania
   14. Tennessee
   15. Utah
   16. Vermont
   17. Virginia
   18. Washington
   19. Wyoming

B. States using diaphragm over pier without positive moment reinforcement shown. Sample detail of type B is shown in Figure 2:
   1. California
   2. Iowa
   3. Kentucky
   4. Louisiana
   5. Massachusetts
   6. Michigan
   7. North Dakota
   8. Wisconsin

C. States using deck slab to assess for continuity:
   1. Florida
   2. Georgia
   3. Minnesota
   4. Texas

   These four states, based on their past experience, are not using continuity in the design for the precast prestressed concrete girder bridges. Florida and Texas, two major concrete states with a long history of using precast prestressed concrete girders, have been telephone interviewed by the researcher. After experiencing difficulty in attaining continuity, spalling concrete at the pier diaphragm, rotating at the end abutment, Florida and Texas abandoned the practice of continuity and are mainly designing simple span girder bridge. A majority of the Texas precast concrete girders are modified AASHTO Type IV girder with span lengths up to 45 m (150 feet), if High Performance Concrete (HPC) is used. Stability is not a concern for the Type IV girder used by the State of Texas after erection so no interior diaphragm is used.

D. States having no standards for continuity or not designing for continuity over pier for live load
   1. Connecticut
   2. Maine

   These two states are mainly steel states and use concrete girder occasionally. There is no standard established.

A map of states presenting the status in color is shown in Figure 3. States in categories A and B assess for continuity over pier by using a diaphragm, but states in category B do not show clearly the assessment for the positive moment resulting from time dependent losses in the precast girders. Two reports are also reviewed, addressing the subject of assessing for positive moment over pier resulting from creep, shrinkage, and elastic shortening.

In reference to Appendix G of the NCHRP report 322 (*3*), "Design of Precast Prestressed Bridge Girders Made Continuous," November 1989, "Results of an analytical study (G-1) of time-dependent restraint moment and service load moments at supports in prestressed concrete girders made continuous indicate that there is little structural advantage gained by providing positive moment reinforcement at supports."

The report also states that the creep and shrinkage will produce "A positive restraint moment at the supports that will generally induce a crack in the bottom of the diaphragm concrete. With application of live load, the positive moment crack must close prior to inducing negative moment at the continuity connection. There is a loss of negative continuity moment associated with the closing of cracks in the bottom of the diaphragm. The presence of positive moment reinforcement in the diaphragm helps to maintain a relatively small crack, thereby increasing apparent live load. However, the positive restraint moment resulting from the presence of the reinforcement in the bottom of the diaphragm increases the positive moment within the span. This increase in positive moment when bottom reinforcement is used at supports is virtually equal to the loss of negative moment continuity if positive reinforcement is not used. The net result on the effective continuity moment is the same, irrespective of whether or not positive moment reinforcement is provided at supports. Therefore, providing positive moment reinforcement has no significant benefit for reducing service load moments."

NCHRPR 322 proposes that the commentary should be added to section 9.7.2.2 of the Standard Specifications (AASHTO).

AASHTO Standard Specifications for Highway Bridges (*1*), Sixteenth Edition (with Interims up to 2000) contains the statement for positive moment at connection at piers (9.7.2.2.1), "Provision shall be made in the design for the positive moments that may develop in the negative moment region due to the combined effects of creep and shrinkage in the girders and deck slab, and due to the effect of live load plus impact load in remote spans. Shrinkage and elastic shortening of the pier shall be considered when significant."

In September 1999, the University of Cincinnati submitted an interim report to the NCHRP, "Connection Between Simple Span Precast Concrete Girders Made Continuous. " The unpublished report was obtained from NCHRP and it has not yet been released for publication (*4*) when this paper is produced. The report concluded that many engineers and state agencies think that positive moment connections are needed to control cracking in the diaphragm and to provide continuity. The report also revealed that PCA was first to identify cracking of the connection caused by time dependent positive moments. In addition, many studies discussed in the report state that the cause of cracking appears to be positive moment developed from time dependent deformations of the prestressed girders.

Based on the above-presented reports, it was worthwhile to assess for positive moment at the connection for crack control. In the submitted spreadsheet, the user is left with the choice of assessing for positive moment reinforcement at the connection. If the user does not wish to input any moment due to time dependent losses in the girders, the spreadsheet will use a default entry equal to $1.2M_{cr}$ to assess for crack control in the diaphragm.

Intermediate diaphragm

AASHTO Standard (*1*) recommends one intermediate diaphragm at the point of maximum positive moments for spans exceeding 40 ft. Such diaphragms are used to resist lateral forces and to maintain section geometry, allowing the bridge to behave as one entity. Also, their presence can help in the construction phase of the bridge. However, AASHTO LRFD Specifications (5) allows diaphragms be omitted where tests or structural analysis show them to be unnecessary. Three types of intermediate diaphragms can be presented and they are:

1. Steel
2. In-situ concrete
3. Precast concrete

Additional information associated with intermediate diaphragm sent by states for the survey is also studied and tabulated in Table 2. Most states are following AASHTO's recommendation using either steel or concrete diaphragm. The state of Texas, with their long history of build concrete bridges, is not using permanent intermediate diaphragm with their typical Type IV girders. Temporary diaphragms are used during construction to stabilize the system. Based on their study, there is not clear evidence that the intermediate diaphragms assist in the stabilization and load distribution.

DESIGN CONSIDERATIONS

In general, the pier will experience negative moment induced by making simple spans continuous for live load, positive moment induced by the creep shrinkage and elastic shortening of the pre-stressed concrete girders, and shear and torsion.

1. For resisting negative moment, reinforcement additional to the standard slab reinforcement is presented. Different types of reinforcement are presented, based on the adjacent span lengths.
2. For resisting positive moment, it is proposed that extended reinforcement or tendons be provided from adjacent girders. The positive moment is a result of creep, shrinkage and elastic shortening of adjacent prestressed girders.
3. For resisting shear and torsion, closed stirrups are provided in the transverse and longitudinal directions of the bridge. In providing closed stirrups, the moment capacity of the block diaphragm will increase, and will be valuable in load distribution.
4. For ease of construction, recent development in the steel industry recommends concrete block diaphragms over the piers with similar configurations as the one presented for precast concrete girders.
5. In general the piers are normal to the girders. In the case of skewed precast or steel concrete girders, the recommended block diaphragm with closed stirrups can be an efficient counter for the torsion induced from the bridge skewness.
6. The advantage of an in-situ concrete diaphragm over a precast one is that the construction can be monolithic with the adjacent bridge girders.

The design example for the pier diaphragms is presented in this study in a spreadsheet form. Figure 4 shows the spreadsheet calculation and Figure 5 shows the design steps. Figures 6 and 7 show the elevation and the cross section of the proposed standards for the Maryland pier diagram.

CONCLUSION

The presented study is valuable in surveying other states' approaches for continuity over pier for making simple spans continuous for live loads. Although the purpose of the study is to standardize diaphragms over pier for precast girders for the state of Maryland, the proposed detail can also be used by other engineers, as it accounts for economy, constructibility, and assessing for the negative moment and positive moment induced by shrinkage, creep and elastic shortening of adjacent spans. This is the reason for choosing a concrete diaphragm to address the continuity issue, as the extended reinforcement or tendons can be used to counter the positive moment. Also the stirrups are used to counter the torsion over the pier.

REFERENCE

1. AASHTO, "Standard Specifications for Highway Bridges, Sixteenth Edition (with Interims up to 2001).

2. Fu, C. C., "Study Report; Survey and Design of Simple Span Precast Concrete Girders Made Continuous," the BEST Center, University of Maryland, 2000.

3. NCHRP report 322, "Design of Precast Prestressed Bridge Girders Made Continuous," November 1989.

4. University of Cincinnati interim report to the NCHRP, "Connection Between Simple Span Precast Concrete Girders Made Continuous," September 1999.

5. AASHTO, "LRFD Bridge Design Specifications, (with Interims up to 2001).

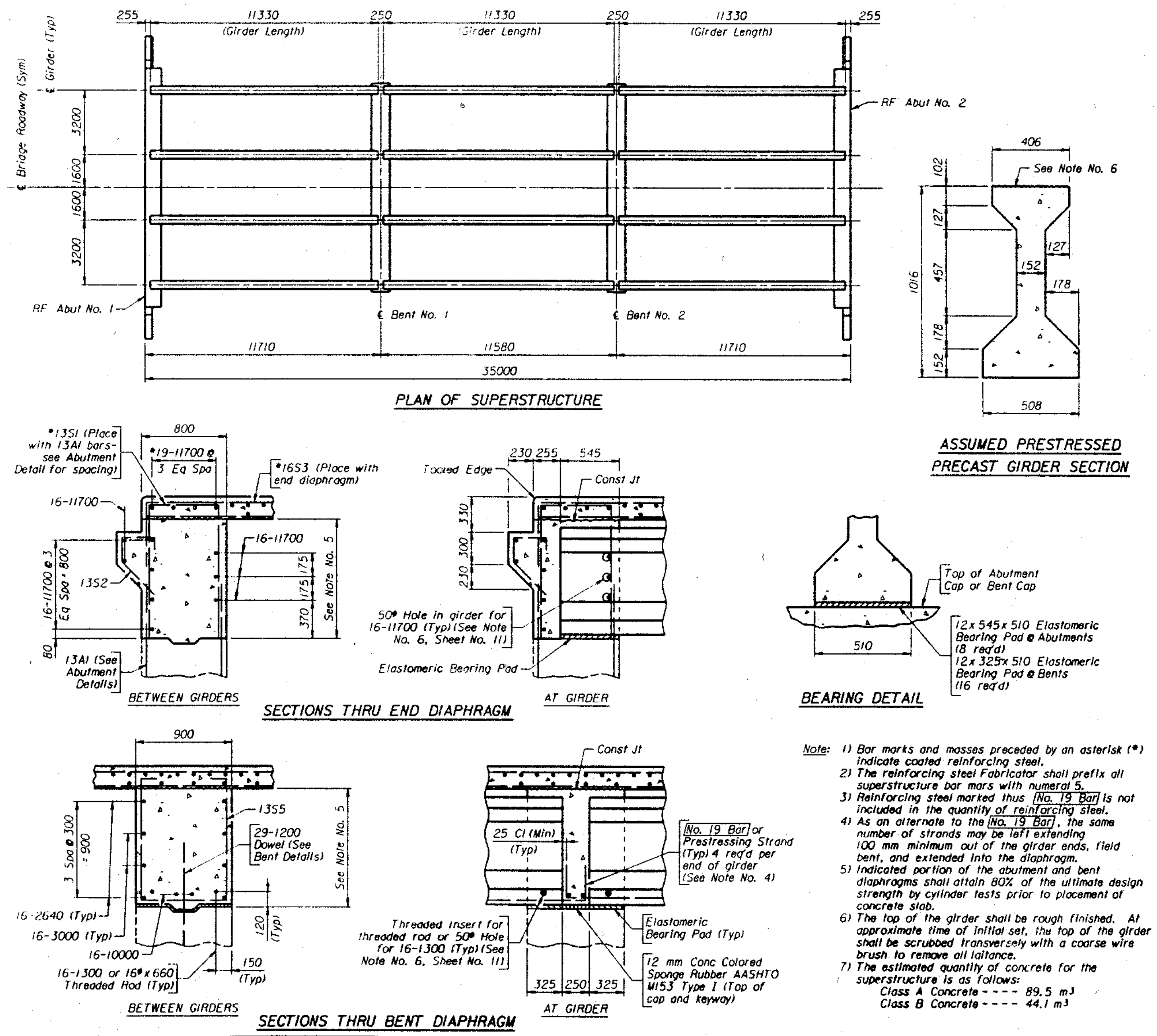

FIGURE 1 - SAMPLE DETAIL OF PIER DIAPHRAGM OVER PIER WITH POSITIVE MOMENT REINFORCEMENT (TYPE A) AND ITS INTERMEDIATE DIAGRAM (WYOMING)

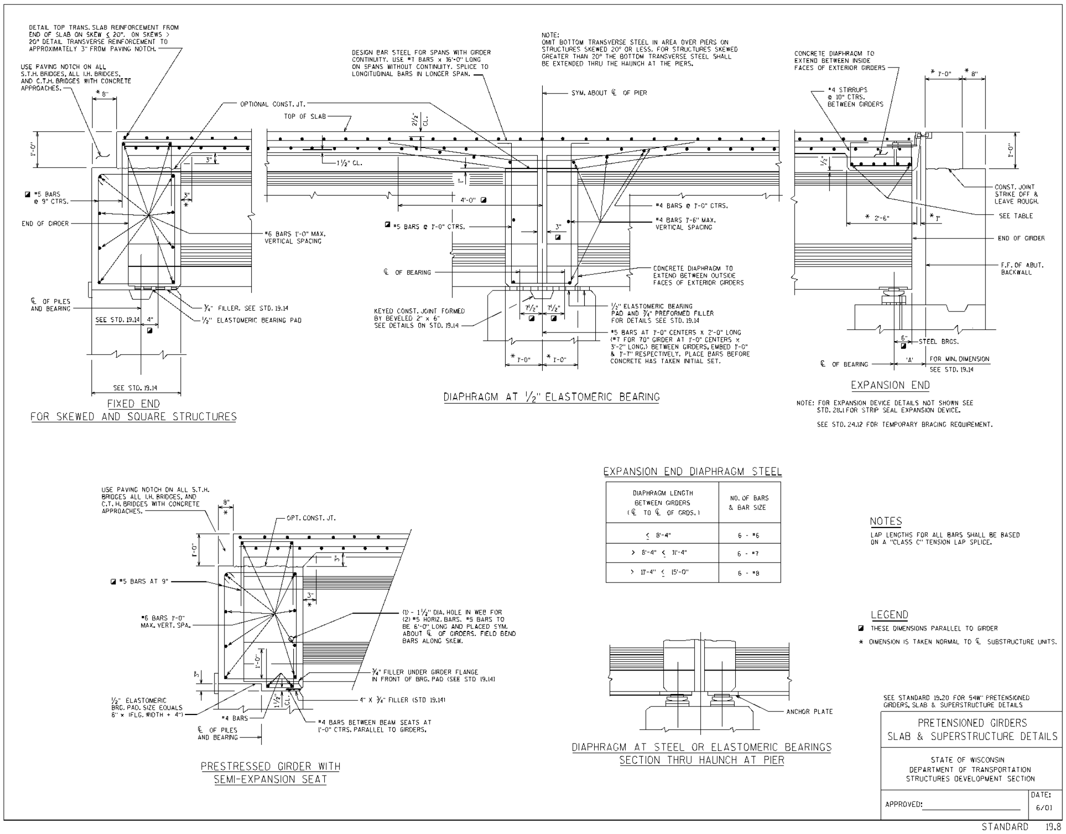

FIGURE 2 - SAMPLE DETAIL OF PIER DIAPHRAGM OVER PIER WITHOUT POSITIVE MOMENT REINFORCEMENT (TYPE B) AND ITS INTERMEDIATE DIAGRAM (WICONSIN)

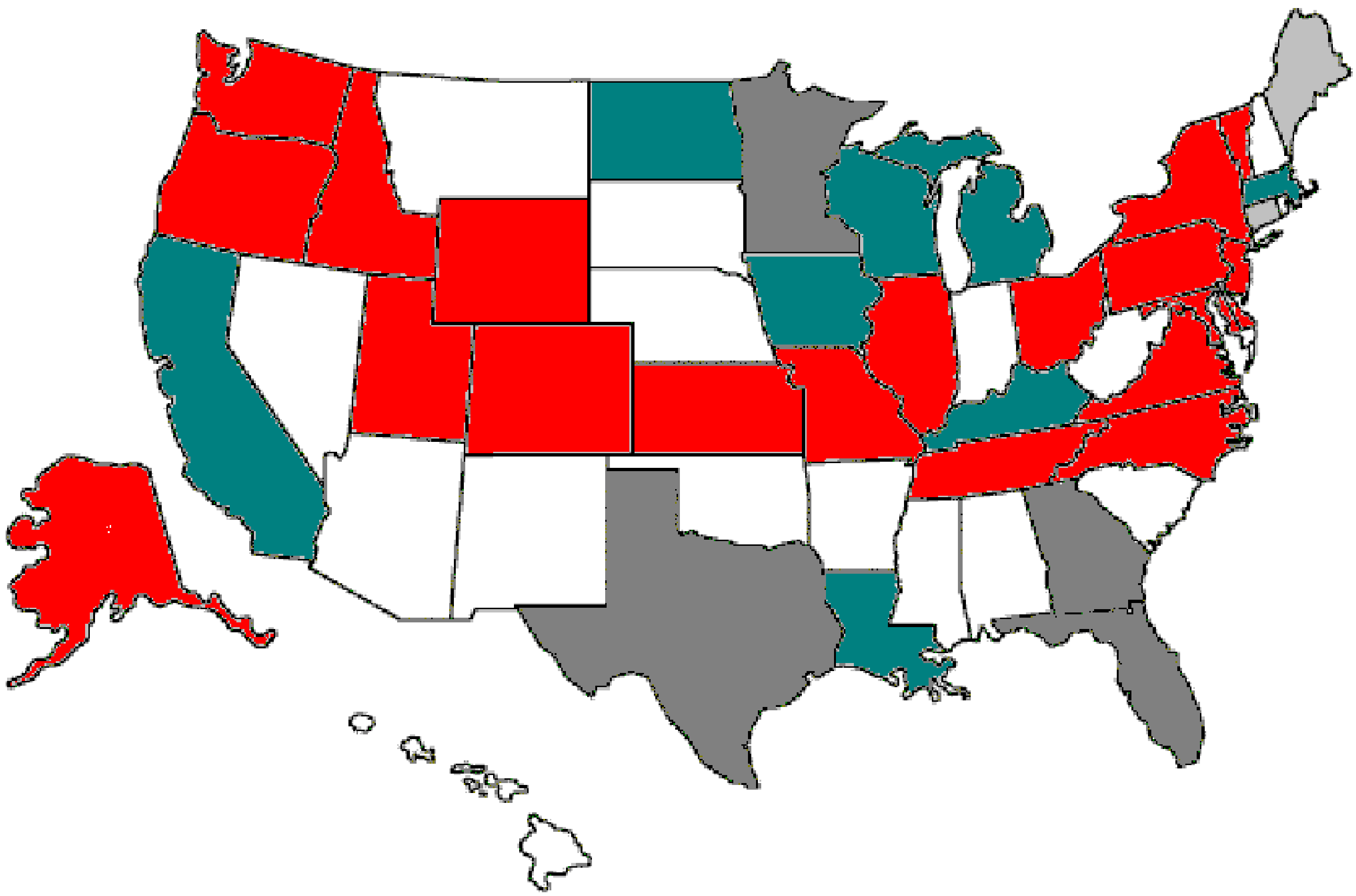

FIGURE 3 - MAP OF STATES SHOWING THE CONTINUITY PRACTICES
(GROUP A – RED, GROUP B – GREEN, GROUP C – DARK GRAY, GROUP D – LIGHT GRAY)

AASHTO Girders	Type I	Type II	Type III	Type IV	Type V	Type VI
Max Span Length, ft	45	50	80	100	120	140
Depth, in *	36.5	44.5	53.5	62.5	71.5	80.5
Girder width, in	16	18	22	26	28	28

*Depth = height of Beam + slab Thickness +Haunch - 2.5

Load Input

M_{DL}^-, k-ft*	0	0	0	0	0	0
M_{SDL}^-, k-ft*	57	70	181	283	408	556
M_{LL+I}^-, k-ft*	261.87	328.5	681.5	934.34	1204.5	1485.4

* No sign needed

Negative Moment Analysis (Bar A)

M_U^-, k-ft	642.62	804.174	1714.84	2396.35	3145.37	3947.6
R_n, psi	401.96	300.81	363.10	314.60	292.98	290.08
A_{est}^-, in^2	4.05437	4.12284	7.3546	8.75837	10.0291	11.1769
$A_{s(chosen)}^-$, in^{2*}	7.75	7.75	7.75	11.23	11.23	11.23
ϕMn, k-ft	1187.76	1476.23	1803.87	3048.38	3511.06	3965.88
ρ	0.006942	0.005147	0.006249	0.005390	0.005010	0.004959
$0.75\rho_b$	0.030813	0.030813	0.030813	0.030813	0.030813	0.030813
$1.2M_{cr}$, k-ft	229.078	381.203	670.918	1079.23	1518.04	1921.26

* $A_{s(chosen)}^-$ = Additional $A_{s(chosen)}^-$ + Standard Slab Reinf A_s

Negative Moment Checks

$\phi M_n > M_u$	OK	OK	OK	OK	OK	OK
$\rho < 0.75\rho_b$	OK	OK	OK	OK	OK	OK
$\phi M_n > 1.2M_{cr}$	OK	OK	OK	OK	OK	OK

Positive Moment Analysis (Bar B)

*Mu^+, k-ft	0.00	0.00	0.00	0.00	0.00	0.00
Rn, psi	143.29	142.59	142.06	141.68	141.40	141.18
ρ	0.00	0.00	0.00	0.00	0.00	0.002382
A_{est}^+ in^2	1.4119	1.92701	2.82087	3.88407	4.7755	5.36816
$A_{s(chosen)}^+$, in^2	3.08	3.08	3.08	4.2	5.53	5.53

* if no value is input, spreadsheet uses a default value of 1.2Mcr

Adequacy of Chosen Area Of Steel

$A_{est}^- >= A_{s(chosen)}^-$	OK	OK	OK	OK	OK	OK
$A_{est}^+ >= A_{chosen}^+$	OK	OK	OK	OK	OK	OK

Minimum Pier Diaphragm Reinfocement between Beam (Bars C & D)

$A_{s\,(Min)}$, Stirrups, Bar C	0.50	0.50	0.50	0.50	0.50	0.50
Bar C, chosen in^2/ft	0.62	0.62	0.62	0.62	0.62	0.62
Adequacy of Bar C	OK	OK	OK	OK	OK	OK
$A_{s(Min,\,T\&S)}$, Bar D	0.66	0.66	0.66	0.66	0.66	0.66
Bar D, chosen in^2/ft	0.62	0.62	0.62	0.88	0.88	0.88
Adequacy of Bar D	NO	NO	NO	OK	OK	OK

Diaphragm Width	30	in
fy	60000	psi
f'c	7000	psi
Slab Thickness	9	in
Haunch	2	in
ϕ	0.9	
β_1	0.7	
m	10.08	
f_r	627.5	psi

Table 1: Bar A*

AASHTO Girders	Additional $A_{s(chosen)}^-$			Standard Slab Reinf. As		
Type I	12	#	5	13	#	5
Type II	12	#	5	13	#	5
Type III	12	#	5	13	#	5
Type IV	12	#	7	13	#	5
Type V	12	#	7	13	#	5
Type VI	12	#	7	13	#	5

* Over the effective width

Table 2 : **Bar B

AASHTO Girders	$A_{s(chosen)}^+$		
Type I	7	#	6
Type II	7	#	6
Type III	7	#	6
Type IV	7	#	7
Type V	7	#	8
Type VI	7	#	8

Table 3 : **Bar C

AASHTO Girders	$A_{s(Stirrups)}$				
Type I	#	5	@	12	in c/c closed strirrup
Type II	#	5	@	12	in c/c closed strirrup
Type III	#	5	@	12	in c/c closed strirrup
Type IV	#	5	@	12	in c/c closed strirrup
Type V	#	5	@	12	in c/c closed strirrup
Type VI	#	5	@	12	in c/c closed strirrup

Table 4 : Bar D**

AASHTO Girders	$A_{s(Temperature\&Shrinkage)}$				
Type I	#	5	@	12	in c/c /back & Front
Type II	#	5	@	12	in c/c /back & Front
Type III	#	5	@	12	in c/c /back & Front
Type IV	#	6	@	12	in c/c /back & Front
Type V	#	6	@	12	in c/c /back & Front
Type VI	#	6	@	12	in c/c /back & Front

**Note: Tables for Bars B,C,and D are standards, user can change the recommended reinforcement by inputting in the related cells the desired reinforcement.
The Spreadsheet wwill check the adequacy of the user's choice.

Note: Design of continuity was based on a concrete block having the width of the bottom flange and the height of the chosen beam and chosen slab thickness
Note: Loading is Based on HS-25

FIGURE 4 - CALCULATION OF THE REQUIREMENT OF THE PIER DIAPHRAGMS

Negative Moment Analysis

PCI-8.2.3: Design of Negative Moment Regions For Members Made Continous for Live Load

Use the width of the bottom flange as the width of the concrete compressive block, b. Determine the required steel in the deck to resist the total factored negative Moment, assuming the compression block is uniform

Step 1	$M_u = 1.3*(M_{DL}+M_{SDL}+1.67*M_{LL+I})$, (7.3.1-3, PCI Bridge Design Manual)
Step 2	$R_n = M_u/(\phi bd^2)$, (8.2.3.1-1, PCI Bridge Design Manual) ,b = width of Selected Girder
Step 3	$\rho = (1/m)*(1-sqrt(1-2mR_n/f_y))$, (8.2.3.1-2, PCI Bridge Design Manual)
Step 4	$m = f_y/(0.85f'_c)$, (8.2.3.1-3, PCI Bridge Design Manual)
Step 5	$A_s = \rho bd$,b = width of Selected Girder
Step 6	$\phi Mn = \phi A_s f_y(d-a/2)$, (STD Eq. 8-16)
Step 7	$a = A_s f_y/0.85f'_c b$, (STD Eq. 8-17) ,b = width of Selected Girder

Reinforcment Limits (Standard Specifications)

Step 8	$\rho_b = (0.85\beta_1 f'_c/f_y)*(87{,}000/(87{,}000+f_y))$, (STD Art. 8.16.3.1)
Step 9	$\rho_{max} = 0.75\rho_b$, (STD Art. 8.16.3.1.1)

Minimum Reinforcement, (STD Art.8.17.1)

the total amount of nonprestressed reinforcement should be adequate to develop an ultimate moment at the crtical section at least 1.2 times the cracking moment. The cracking moment may be calculated as for a prestressed concrete section except fpe = 0

Step 10	$\phi M_n >= 1.2M_{cr}$

Positive Moment Analysis

Step 11	M_u^+ = User should input its value as per STD Art 9.7.2.2.1; If no value is input, spreadsheet will use a default value of $1.2M_{cr}$

Minimum Reinforcement For Stirrups Calculations

Step 12	$A_{s\,(Min)}$, Stirrups, Bar C = $0.0316*sqrt(f'_c)*b_w*s/f_y$, s = spacing = 12 in, (AASHTO LRFD-5.8.2.5-1) where f_y and f'_c in step 12 are in KSI bw = width of Diaphragm over Pier, in inches

Temperature & Shrinkage Reinforcement Calculations

Step 13	$A_{s\,(Min,\,T\&S)}$, Bar D = $0.0018*b_w*h$, (ACI 7.12.2.1) b_w = width of diaphragm

FIGURE 5 - CALCULATION STEPS OF THE REQUIREMENT OF THE PIER DIAPHRAGMS

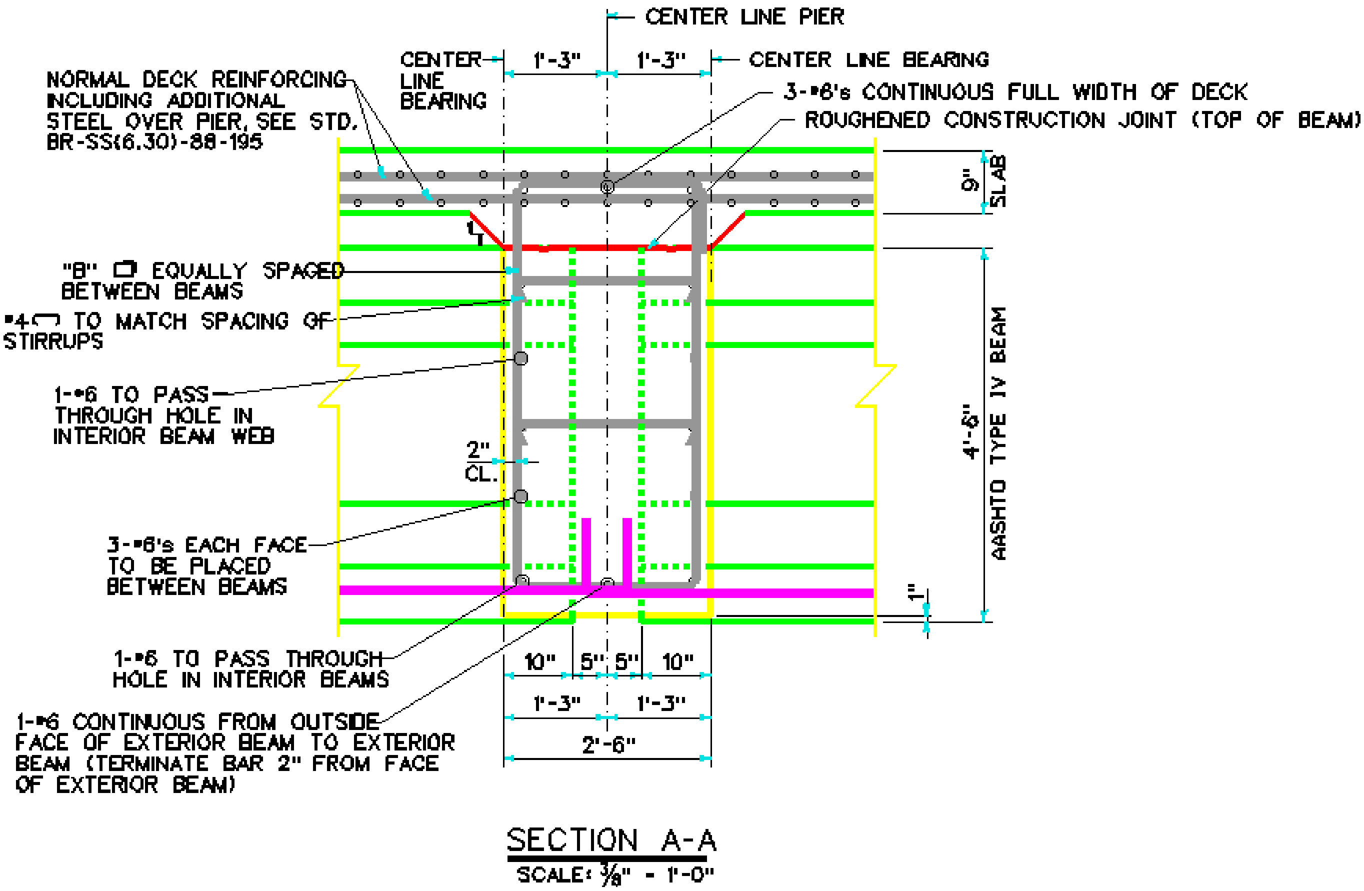

FIGURE 6 - DIAPHRAGM OVER PIER DETAIL

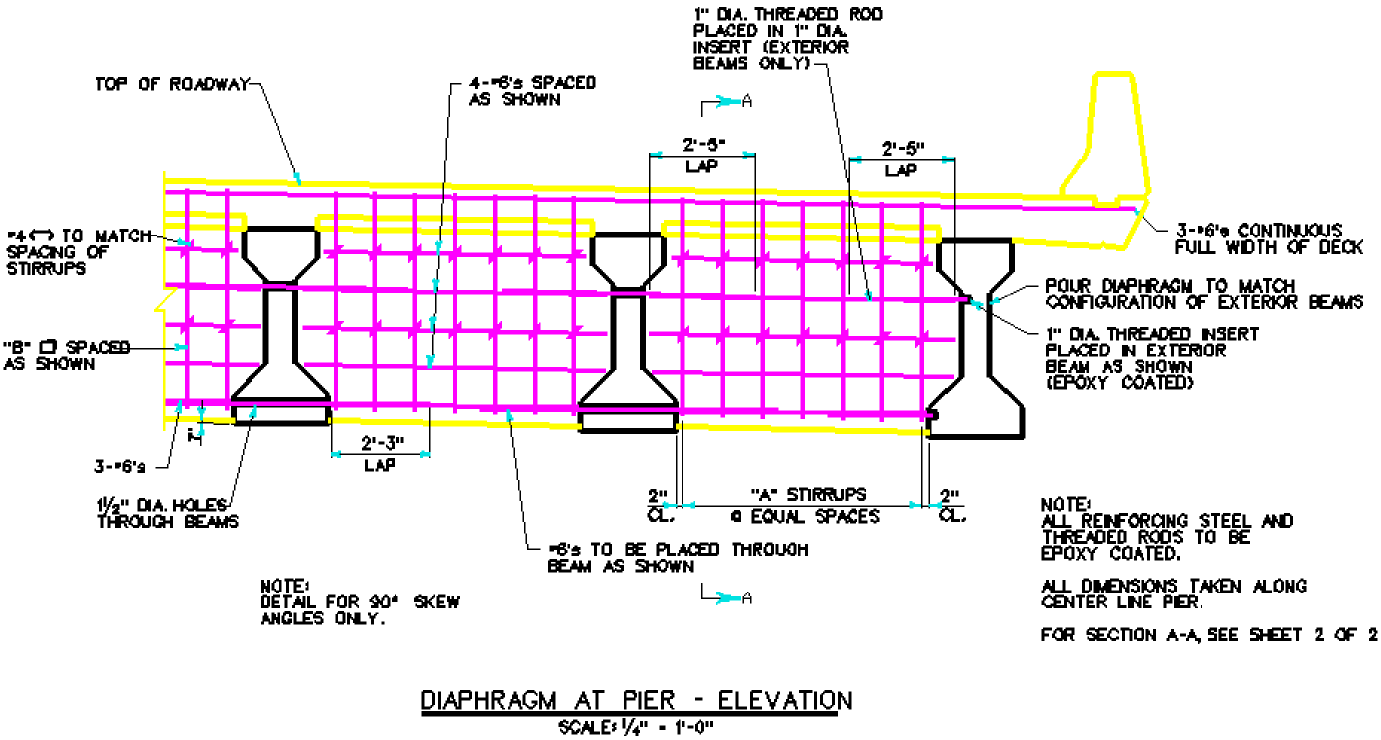

FIGURE 7 - TRANSVERSE CROSS-SECTION OF DIAPHRAGM

TABLE 1 - SURVEY SUMMARY AND COMMENTARY OF THE PIER DIAPHRAGM

States	agm Dimensions			Additional Descrition		
	A1	A2	A3	Filler	Bearing Type	Additional Descriptions
Alaska	600 mm	300 mm	-	-	-	**Continuous** Extends strands from girder into the diaphragm.
California	1'-8"	0'-3"	-		Elastomeric pad	**Continuous,** No +M reinforcement shown.
Colorado	3'-0"	-	-	-	-	**Continuous**. Use as per dwgs, or extend min 4 strands from girder into the diaphragm.
Connecticut	-	-	-	-	-	No Standards - Very few **PB** bridges.
Delaware	634 mm	280 mm	-	13 mm performed cork	-	**Continuous**
Florida	-	-	-	-	-	**Not Continuous**
Georgia	612 mm	-	12 mm, preformed joint filler	-	-	**Not Continuous**. Deck Slab is Continuous over the intermediate Bents.
Idaho	-	205 mm	-	-	Premolded joint filler	**Continuous**. Concrete Diaphragm Between **PB.**
Illinois	600 mm	150 mm	-	-	Elastomeric pad	**Continuous**
Iowa	650 mm	150 mm	-	Preformed Joint Filler	Neoprene pad	**Continuous,** No +M reinforcement shown.
Kansas	760 mm	300 mm	-	-	Elastomeric pad	**Continuous**
Kentucky	750 mm	-	-	-	-	**Continuous,** No +M reinforcement shown.
Louisiana	250 mm	-	-	-	Neoprene pad	**Continuous. PB** provide for LL and DL **-M**. The **+M** section of **PB** is designed for **SS** only.
Maine	3'-8"	-	-	-	-	No Standards for **PB** diaphragms**,** shown are for bridges built with the **NEBT** Girders.
Massachusetts	650 mm	300 mm	-	-	Elastomeric pad	Diaphragm keyed into pier, surrounded by closed 25 mm cell foam **NEBT. Continuous**
Michigan	300 mm	100 mm	-	-	-	**Continuous,** No +M reinforcement shown.
Minnesota	2'-4"	0'-4"	0'-2"	Polystrene	Polystrene	**Not Continuous**. Slab designed to assess for continuity.
Missouri	2'-3"	0'-7"		1/2" joint filler	Elastomeric pad	**Continuous**
New Jersey	-	300 mm	-	Filler under diaphragm	Elastomeric pad	Diaphragm keyed into pier 300 mm by a dowel bar extended the strands into diaphragm for **+M, Continuous**
New York	-	250 mm	-	-	-	**Continuous**
North Carolina	2'-6"	0'-10"	-	-	Elastomeric pad	**Continuous**
North Dakota	2'-6"	1'-0"	-	-	Joint filler	**Continuous,** No +M reinforcement shown.
Ohio	2'-0"	0'-9"	-	-	Laminated elastomeric pad	**Continuous**
Oregon	635 mm	520 mm	-	-	-	**Continuous**. Extended Prestressed strands. min 300 mm to a max 375 mm into the diaphragm
Pennsylvania	750 mm	250 mm (**+M**) 100 mm (**no +M**)	-	-	Styrofoam	**Continuous**
Tennessee	450 mm	150 mm	-	Foam under Diaphragm	Elastomeric pad	**Continuous**
Texas	-	-	-	-	-	**Not Continuous**
Utah	600 mm	-	-	Foam under Diaphragm	Elastomeric pad	No Standards for **PB**, shown was used on individual bridges.
Virginia	300 mm	-	-	-	Bearings pads	**Continuous**. Not official standard, but frequently used.
Washington	2'-0"	-	-	-	1/2" Premolded joint filler	**Continuous**. Min length of extended strands = 2'-6".
Wisconsin	1'-0"	-	-	-	-	**Continuous,** No +M reinforcement shown.
Wyoming	900 mm	250 mm	-	-	Elastomeric pad	**PB** assumed **SS** for DL and continuous for LL. R/C Diaphragm encasing ends of girder. **Continuous**
Vermont	-	-	-	-	Elastomeric pad	**Continuous,** Voided slab shown - No diaphragms.

<u>**Notes**</u>

A1 = Total Diaphragm Width
A2 = Clear Space between the Two girders
A3 = Space usually filled with cardboard or preformed filled when Deck is designed to account for continuity

+M = Positive Moment
-M = Negative Moment
SS = Simple Span

PB = Pre-stressed Beam
NEBT = New England Bulb Tee Beam
- = Not Available

TABLE 2 - SURVEY SUMMARY OF THE INTERMEDIATE DIAPHRAGM

States	Intermediate Diaphragm Practices
California	Concrete diaphragms placed 5 days before placing deck
Georgia	250mm wide concrete @midspan
Iowa	Steel channel or 10" wide concrete @midspan for I-beams Steel cross frame for Bulb-Tees: (i) @midspan for span < 120'; (ii) @1/4 points and midspan for span > 120'
Louisiana	200mm wide concrete with tie rod @midspan
Maryland	Concrete diaphragm w/spacing no more than 40'
Michigan	200mm wide concrete @midspan
Minnesota	Steel channel for 28"-54" deep beams Steel cross frame for 63"-81" deep beams
Missouri	Steel channel @midspan for I-beam span > 50'
New Jersey	Concrete or steel diaphragm (recently allowing diaphragm be omitted if proved by tests or structural analysis)
North Dakota	Concrete diaphragm
Ohio	Steel channel or 10" wide concrete for AASHTO Types 2,3,4 (i) @midspan for 40' < span < 80'; (ii) @1/4 points and midspan for span > 80'
Pennsylvania	Concrete diaphragm
Tennessee	1' wide concrete diaphragm @midspan for I-beam span > 80' For Bulb-Tees: (i) @midspan for 40' < span < 80'; (ii) @1/3 points for span > 80'
Texas	
Utah	Concrete diaphragm with spacing = 15m
Virginia	10" wide concrete diaphragm
Wisconsin	Steel channel for beam depth < 70" Steel cross frame for 70" deep beams spacing: (i) @midspan for span < 80'; (ii) @1/3 points for span > 80'