T. J. Wipf, F. W. Klaiber, L. W. Brehm, T. F. Konda

Investigation of the Modified Beam-in-Slab Bridge System

Design Manual
Volume 2 of 3

November 2004

Sponsored by the
Highway Division of the Iowa
Department of Transportation and the
Iowa Highway Research Board

Iowa DOT Project TR-467

Final

REPORT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Department of Civil, Construction and Environmental Engineering

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ABSTRACT

This project (Phase 3 of the Investigation of Two Bridge Alternatives for Low Volume Roads) is a continuation of research which addresses some of the numerous bridge problems on Iowa's secondary road system. In the previous phases, Iowa DOT projects HR-382 (Phase 1) and TR-410 (Phase 2), alternative designs for replacing bridges on low volume roads (LVRs) were investigated. Phase 1 investigated two replacement concepts, the first being the development of Steel Beam Pre-cast Units and the second the modification of the original Benton County Beam-in-Slab Bridge (BISB) design. Phase 2 continued with the development of an alternative shear connector (ASC) for obtaining composite action in the BISB system and an arch formwork between the girders to reduce the self weight of the system.

Results from the first two phases of investigation supported the continued refinement of the Modified Beam-in-Slab Bridge (MBISB) design. This final phase of the investigation was undertaken to develop a competitive alternative bridge replacement for longer spans (i.e. greater than 50 ft). Building on the previous investigations, laboratory tests were undertaken to evaluate the combined behavior of the ASC and the transverse arch.

Three laboratory specimens were designed, constructed and tested to determine the strength, stiffness and constructability of the proposed MBISB design. The results from the laboratory tests indicated that the proposed MBISB system met all applicable design requirements for use on LVRs. Two demonstration bridges were designed and constructed; the construction process was monitored and documented to aid in the implementation of future MBISB designs. The demonstration bridges were field tested to quantify their behavior and to confirm design assumptions. Results from the field tests were used to assist in the development of design criteria for the MBISB system.

The final report for this investigation consists of three volumes; this volume (Volume 2) is a design manual and construction guide. Volume 1 focuses on the design, evaluation and interpretation of the results obtained from the laboratory and field tests which verified the applicability of the MBISB system. Volume 3 is a Design Guide that contains background information on the evaluation and results that lead to the development of the MBISB design criteria.

The Design Manual, (Volume 2) can be divided into two distinct parts; the first is a design example which provides a designer with the necessary information to design a specific MBISB. Using the design criteria developed, selected MBISB designs were produced. The designs are organized by length, width and material strength and are presented in a tabular format. Using the information presented in the tabular summary and the design example, the designer can specify the remaining components necessary for the design and construction of the desired MBISB.

The second portion of the Design Manual includes a PowerPoint slide show that describes the construction of the second demonstration bridge. The slide show focuses on the development of the desired cross slope, girder fabrication and placement, formwork construction, reinforcement configuration and placing the concrete deck.

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1. INTRODUCTION

In Iowa, county engineers are faced with the challenge of upgrading or replacing deficient off system structures, a majority of which are found on low volume roads (LVR) with an Average Daily Traffic (ADT) count significantly less than 400 vehicles. As reported by the National Bridge Inventory, approximately 31% of the 19,659 bridge structures found on Iowa's county owned (off system) roads are either structurally deficient or functionally obsolete (*1*). Due to limited resources and the costs associated with maintaining and upgrading an aging bridge population, county engineers have expressed interest in low cost alternative replacements for the purpose of extending available replacement funds (*2*).

Through funding provided by the Highway Division of the Iowa Department of Transportation (Iowa DOT) and the Iowa Highway Research Board, the Bridge Engineering Center (BEC) of Iowa State University (ISU) has developed the Modified Beam-in-Slab Bridge (MBISB) System as an alternative design. Based on the original Beam-in-Slab Bridge (BISB) design, the MBISB system was developed to address the need for an alternative applicable for spans up to 80 ft while still being constructed by in-house forces (*3*).

The MBISB system is similar to both the BISB system and a typical composite slab/steel girder bridge with two major differences. As opposed to the BISB system, composite action is developed between the longitudinal girders and the concrete deck. However, composite action is obtained through the use of an alternative shear connector (ASC) rather than by traditional shear studs which require specialized equipment to install. The ASC, which was developed at ISU, consists of 1 1/4 in. diameter holes fabricated in the girder web on 3 in. centers down the length of the girder and positioned below the top flange of the steel W section. Reinforcement is installed transverse to the path of traffic through every fifth hole to confine the concrete shear dowels that form in the ASC holes when the deck is placed. Detailed information on the development of the ASC can be found in the final reports for Iowa DOT Projects HR-382 and TR-410 (*3*, *4*).

The second modification is the removal of structurally inefficient concrete from the tension side of the cross section. This was accomplished by using a transverse arch between the longitudinal girders. The transverse arch has the added benefit of changing the mode of structural resistance in the deck from transverse flexure to an arching action which allows for a considerable reduction in the required deck reinforcement. A typical cross section of a MBISB bridge is presented in Figure 1.1.

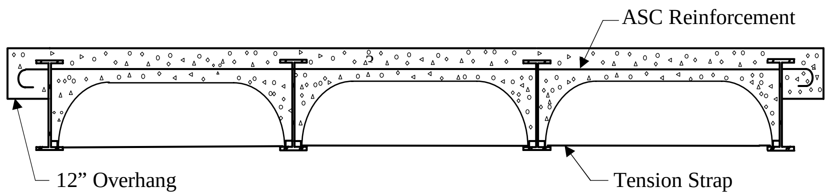


Figure 1.1. Typical MBISB cross section.

1.1 Development and Verification of MBISB System

The MBISB system was developed by ISU BEC researchers and verified through a series of laboratory tests, demonstration bridges and analytical modeling. Three laboratory specimens were designed, constructed and tested to investigate the feasibility of the transverse arch and the behavior of the combined modifications in a model bridge. Results from the laboratory testing phase provided evidence that the MBISB system exceeded required levels of resistance leading to the design and construction of two demonstration bridges.

The demonstration bridges were designed and constructed to establish the construction processes as well as to verify the design assumptions and structural behavior through field testing. The design of the first demonstration bridge (MBISB 1, L = 50 ft, W = 31 ft) closely resembled a BISB with the exception of the two previously described modifications. This demonstration bridge was constructed at a cost of approximately $50 psf. The second demonstration bridge (MBISB 2, L = 70 ft, W = 32 ft) was designed to comply with American Association of State Highway Transportation Officials (AASHTO) Load Resistance Factored Design (LRFD) Bridge

Specification and was constructed at a cost of approximately $52 psf (*5*). Both bridges were constructed by in-house forces with standard construction equipment that Tama County, Iowa had. A more detailed explanation of the laboratory and field testing of the MBISB system and the results of these evaluations are presented in Volume 1 of the final report for Iowa DOT project TR-467 (*6*).

1.2 Design Methodology

The laboratory and field testing results provided evidence that the MBISB system meets the required performance specifications and is a cost competitive alternative that can be employed on the LVR system. A design methodology for the MBISB system was then developed based on the resulting test data and the AASHTO LRFD Bridge Specification for a concrete slab/steel girder bridge. A more complete discussion of the assumptions made and criteria applied during the development of the design methodology is presented in the Design Manual, "Investigation of the Modified Beam-in-Slab Bridge System, Volume 3 of 3" of the final report for Iowa DOT project TR-467 (*7*). The third volume is meant to be a direct supplement of the Design Manual (Volume 2).

1.3 Design Variables

The design methodology developed was used to create a series of MBISB designs that are listed in Appendix A and are based on the following variables:

- Bridge length
- Bridge width
- Girder spacing
- Steel yield strength
- Concrete compressive strength
- Depth of cover

Following the information presented in this manual, the tabular design output provides the information required to specify the member size, spacing, material quantities, etc. needed to construct the desired MBISB. In addition to the tabular design output, a series of construction drawings (Appendix B) and a PowerPoint slide show describing the techniques applied during the construction process of MBISB 2 is included to aid in the design and construction process.

1.4 Design Limitations

Limitations on the bridge length, size of members considered, girder spacing and material strengths were imposed upon the MBISB design methodology. The limitations result from geometric constrains, strength and serviceability considerations and economic feasibility; these limitations are described in detail in the following sections.

1.4.1 MBISB Length

The length of the MBISB system ranges from 40 ft to 80 ft with the design length taken from the centerlines of the supports. The span length is limited for reasons of feasibility; at lengths of less than 40 ft and in excess of 80 ft other bridge systems become more feasible. The tabular design output is limited to 5 ft increments, thus nine individual lengths are presented in Appendix A. For a desired length in this range that is between the lengths provided, one simply uses the next length (i.e. if one desires a 62 ft long MBISB, use the design information for the 65 ft MBISB).

1.4.2 MBISB Width

The MBISB bridge design widths are limited to 26 ft and 32 ft and are in reference to the overall bridge width. However, the MBISB design is compatible with the abutment design widths, 24 ft and 30 ft, presented in Iowa DOT final report TR-486 “Development of Abutment Design Standards for Local Bridge Designs” (*8*). The 24 ft and 30 ft abutment design width indicated in the TR-486 report is in reference to the distance between the centerlines of the exterior girders which is the case in the MBISB design. The additional 2 ft of deck width for the MBISB design results from the 1 ft overhang on each exterior girder.

1.4.3 MBISB Girder Size and Spacing

The girder spacing for the MBISB designs is limited by the specified bridge width, the necessity of the number of girders used being an integer and the diameter of the arched formwork system. The girder spacing is between 3 ft and 6 ft; the spacing used is based on the number of girders and the selected bridge width. The arched formwork has not been evaluated for girder spacing in excess of 6 ft, thus use of a wider girder spacing is not recommended.

The W sections considered in the MBISB design criteria are restricted by section depth, section properties and self weight. The allowable girder depth is restricted to range from 12 in. to 30 in. (nominal depth). Shallower girders are too inefficient for spanning the distances at the girder spacing considered in the MBISB system while girders with a depth greater than 30 in. are excluded due to limitations with the custom rolled arched formwork. To satisfy AASHTO LRFD Bridge Specifications, all parts of the W sections must be at least 1/4 in. thick and meet flange and web buckling criteria. Sections must also have a flange width equal to or greater than 8 in. because the arched formwork resting upon the bottom flange requires a ledge of at least 1 in.

While girders with depths up to 30 in. (nominal) are considered in the MBISB design criteria, girders with depths greater than the value presented in the second column of Table 1.1 are limited to a girder spacing greater than the spacing listed in the first column of Table 1.1. The reason for the lower bound on the girder spacing for the deeper sections is due to the formwork; a circular radius will not geometrically “fit” in a girder spacing that is smaller than the values listed while maintaining the prescribed minimum slab depth. For girder spacing in excess of 4 ft, all girder depths considered for the MBISB system are applicable.

The maximum weight/ft for a section is limited to 161 lb/ft; as heavier sections are inefficient in the MBISB design.

Table 1.1. Maximum girder depth/size for a given girder spacing.

Girder Spacing (ft)	Maximum Girder Size
3	W21
3.75	W24
4	W27

1.4.4 Material Strengths

The concrete compressive strengths for the MBISB deck is conservatively specified as 4 ksi. The remaining concrete material properties are calculated based upon the concrete compressive strength using the relationships presented in the AASHTO LRFD Bridge Specifications (*5*). Yield strengths of the longitudinal girders are specified as either 36 ksi or 50 ksi which are readily available structural steels. The yield strength for the deformed reinforcing bars used in the concrete deck is specified as 60 ksi.

2. DESIGN OUTPUT PARAMETERS

In this chapter, the procedure for interpreting the MBISB design output is illustrated following the procedure presented in Chapters 4 and 5 of the Design Guide (Volume 3). The design example illustrated here utilizes the tabulated design output for a 65 ft long, 32 ft wide bridge which is presented in Table 2.1 as well as Table A32.2.65.3 and Table A32.2.65.0 in Appendix A. The example is prepared assuming the user has reviewed the other two volumes (Volume1 and Volume 2) of this final report.

2.1 Organization of the Design Output

The MBISB designs cataloged in Appendix A are organized in the following manner. The designs are grouped by the two stated bridge widths of 26 ft and 32 ft and material strengths. For each of the two bridge widths, a design was completed for the nine investigated lengths ranging from 40 ft to 80 ft in 5 ft increments. For each given length and selected bridge width (26 ft and 32 ft) designs considering two combinations of steel strength and a concrete compressive strength of 4 ksi are presented. Two cases of cover over the girders, 3 in. and 0 in., are considered for each combination in conjunction with the predetermined girder spacing for a selected bridge width. The design output was created with the assumption that the designer would evaluate numerous combinations for a given span, taking into account construction time, material cost, and the formwork system to obtain the most efficient design.

More specifically, the presented design example has the following defining criteria:

- Length of the bridge = 65 ft
- Width of the bridge = 32 ft
- Girder spacing = 6 ft
- Steel yield strength = 50 ksi
- Concrete compressive strength = 4 ksi
- Depth of cover = 3 in.

Table 2.1. Design output example for a 65 ft long, 32 ft wide MBISB.

a. Material and section properties: f_y = 50 ksi, f'_c = 4 ksi, Cover = 3 in.

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X116	23.5	91	45.94	4.25	3.75	2	21	0.642	Y	29.6
	W30X124	23.5	91	49.1	4	3.5	2	21	0.615	Y	29.8
	W27X129	20.5	86	51.08	4.25	3.75	2	21	0.752	Y	26.9
	W24X131	17.5	79	51.88	4.5	4	1	0	0.964	Y	23.6
	W30X132	23.5	92	52.27	3.75	3.25	2	21	0.594	Y	29.9
7 @ 5 ft	W30X108	23.5	97	49.9	4	3.5	2	21	0.61	Y	29.4
	W27X114	20.5	90	52.67	4.25	3.75	2	21	0.737	Y	26.6
	W30X116	23.5	98	53.59	3.75	3.25	2	21	0.582	Y	29.6
	W24X117	17.5	83	54.05	4.5	4	1	0	0.935	Y	23.4
	W30X124	23.5	98	57.29	3.5	3	2	21	0.557	Y	29.8
8 @ 4.29 ft	W27X102	20.5	95	53.86	4.25	3.75	2	21	0.718	Y	26.4
	W27X114	20.5	95	60.19	4	3.5	2	21	0.676	Y	26.6
	W24X117	17.5	87	61.78	4.25	3.75	1	0	0.855	Y	23.4
	W21X122	15	80	64.42	4.5	4	1	0	1.09	N	20.7
	W27X129	20.5	96	68.11	3.5	3	2	21	0.623	Y	26.9
9 @ 3.75 ft	W24X103	17.5	91	61.18	4.5	4	2	21	0.85	Y	23.6
	W24X104	17.5	90	61.78	4.25	3.75	1	0	0.851	Y	23.2
	W21X111	15	82	65.93	4.5	4	1	0	1.073	N	20.5
	W24X117	17.5	91	69.5	4	3.5	1	0	0.791	Y	23.4
	W21X122	15	83	72.47	4.25	3.75	1	0	1.007	N	20.7
11 @ 3 ft	W21X93	15	89	67.52	5	4.5	2	19	1.06	N	20.6
	W21X101	15	88	73.33	4.5	4	1	0	0.991	N	20.4
	W18X106	12	80	76.96	5	4.5	1	0	1.33	N	17.7
	W21X111	15	88	80.59	4.25	3.75	1	0	0.938	Y	20.5
	W18X119	12	80	86.39	4.75	4.25	1	0	1.213	N	18

L/800 = 0.975 in.

b. Material and section properties: f_y = 50 ksi, f'_c = 4 ksi, Cover = 0 in.

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X116	23.5	73	45.94	3.5	3	2	21	0.822	Y	26.3
	W30X124	23.5	73	49.1	3.25	2.75	2	21	0.783	Y	26.5
	W27X129	20.5	68	51.08	3.5	3	2	21	0.964	Y	23.7
	W30X132	23.5	74	52.27	3.25	2.75	2	21	0.753	Y	26.6
	W27X146	20.5	67	57.82	3	2.5	1	0	0.884	Y	23.5
7 @ 5 ft	W30X108	23.5	79	49.9	3.5	3	2	21	0.78	Y	26.1
	W27X114	20.5	72	52.67	3.75	3.25	2	21	0.948	Y	23.4
	W30X116	23.5	79	53.59	3.25	2.75	2	21	0.739	Y	26.3
	W30X124	23.5	80	57.29	3.25	2.75	2	21	0.704	Y	26.5
	W27X129	20.5	73	59.6	3.25	2.75	2	21	0.865	Y	23.7
8 @ 4.29 ft	W27X102	20.5	77	53.86	3.75	3.25	2	21	0.925	Y	23.2
	W27X114	20.5	77	60.19	3.5	3	2	21	0.864	Y	23.4
	W24X117	17.5	68	61.78	3.5	3	1	0	1.102	N	20.3
	W21X122	15	62	64.42	4	3.5	1	0	1.422	N	17.7
	W27X129	20.5	78	68.11	3	2.5	2	21	0.787	Y	23.7
9 @ 3.75 ft	W24X103	17.5	73	61.18	3.75	3.25	2	21	1.102	N	20.5
	W24X104	17.5	72	61.78	3.75	3.25	1	0	1.099	N	20.1
	W21X111	15	64	65.93	4	3.5	1	0	1.401	N	17.6
	W24X117	17.5	72	69.5	3.5	3	1	0	1.011	N	20.3
	W21X122	15	65	72.47	3.75	3.25	1	0	1.303	N	17.7
11 @ 3 ft	W21X101	15	70	73.33	3.75	3.25	1	0	1.285	N	17.5
	W21X111	15	70	80.59	3.5	3	1	0	1.206	N	17.6
	W18X119	12	62	86.39	4	3.5	1	0	1.583	N	15.2
	W21X122	15	71	88.57	3.25	2.75	1	0	1.121	N	17.7
	W18X130	12	62	94.38	3.75	3.25	1	0	1.446	N	15.5

L/800 = 0.975 in.

2.2 Evaluating Design Output

Once the design parameters are selected and the specific design output is chosen from Table 2.1, the individual components, material quantities etc. are determined using information presented in the following sections.

2.2.1 Girder Selection and Fabrication

The first components specified for the MBISB design are the longitudinal girders since all of the remaining quantities are functions of the selected girder and girder spacing. The first five sections (if applicable) that satisfy the design criteria are listed for a given girder spacing in order of increasing weight with the lightest section listed first. For the design example, W27x129 girders set at a spacing of 6 ft are selected.

The girders selected for the design require the following fabrication: cambering (See Section 2.2.3) and the coring/torching of holes, including the holes for the ASC, the diaphragm connectors and the backwall reinforcement. The MBISB design criteria were developed with the girders being cambered to counteract the deflection due to the self weight; such cambering will most likely be preformed by a steel fabrication shop. If recycled girders without camber are utilized, the designer may chose to simply allow the girders to deflect, resulting in a concave deck. However, if the deflection due to the self weight exceeds acceptable limits, temporary shoring of the girders can significantly reduce the dead load deflection and stress. The design and placement of such temporary shoring is the responsibility of the designer; in particular, the compression flanges of the longitudinal girders must be adequately braced in both the positive and negative moment regions.

The ASC holes (1 1/4 in. diameter on 3 in. centers for the length of the girder) can be torched or cored with little difference in performance and may be installed by the steel fabricator or county forces. Coring the holes for the diaphragm connections and the backwall reinforcement may be performed by the steel fabricator as well if the quality control of the substructure ensures proper alignment. The layout for the ASC and backwall reinforcement holes for a typical W27 section is illustrated in Figure 2.1.

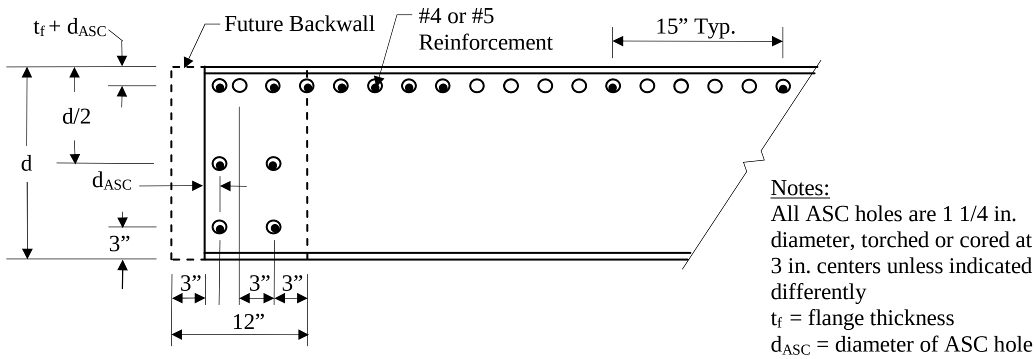


Figure 2.1. ASC and backwall hole layout for the selected W27x129 section.

2.2.2 Sectional Properties, Material Quantities

With the selection of the longitudinal girders, the following criteria are listed in the design output, all of which are directly related to the selected girders. The material quantities are listed to provide a ready comparison of costs for the various designs being considered.

2.2.2.1 Radius of formwork

The MBISB design program was created with the assumption that custom rolled arch sections will be used for the interior formwork. The radius of the arch formwork section which is equal to 20.5 in. for a W27x129 section is calculated based on the depth of both the girder and the deck. A more detailed discussion of the design, construction and specification of the formwork system is presented in Section 3.2.

2.2.2.2 Volume of concrete

The concrete volume specified for the deck (85 yards for the 65 ft design example) is calculated based on the approximated cross section used for all section property calculations. The final volume of concrete is determined by rounding up to the nearest yard and adding an additional yard to account for losses attributed to construction. The concrete volume listed does not include the concrete needed to complete the backwalls or perform quality control testing.

2.2.2.3 Weight of structural steel

The weight of the required structural steel is calculated based on the length of the span (centerline to centerline of abutment) plus one additional foot (i.e. 6 in. past the centerline of the supports). The 65 ft long example design, supported by six W27x129 girders, requires 25.54 tons of Grade 50 structural steel.

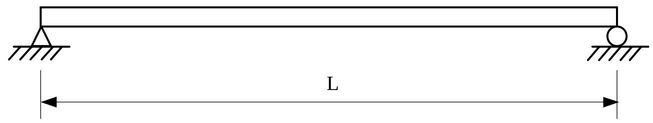
2.2.3 Girder Camber

Cambering the girders is necessary to counter act deflections due to self weight, future overlay and barrier rail loads. Due to a larger tributary area, the deflection of the interior girders controls the camber. The expected interior girder deflection due to the self weight is calculated and then rounded up to the nearest 1/4 in. The camber of the exterior girders is then specified to this interior girder value. An additional 1/2 in. of camber is added to all interior girders to ensure a final convex transverse bridge profile. The interior and exterior camber for the design example is specified as 4.25 in. and 3.75 in. respectively.

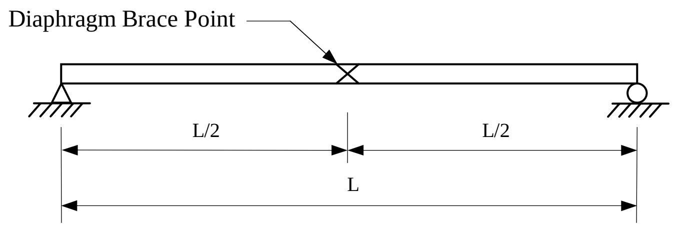
As discussed in Section 2.2.1, if recycled girders are used, the designer can either allow the girders to deflect or provide shoring during the construction phase.

2.2.4 Number of Diaphragms and Spacing

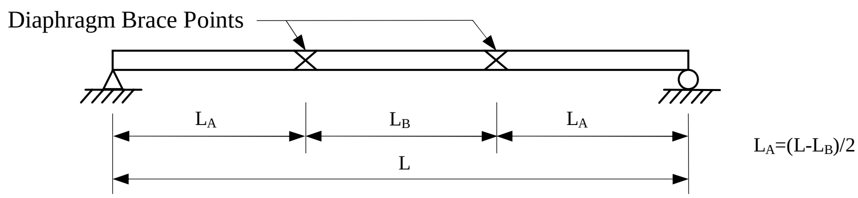
The number of diaphragms needed to adequately brace the compression flanges of the girders during the placement of the deck concrete is a function of the girder properties, the unbraced length and the construction loading. The design methodology developed considers four possible bracing configurations with either zero, one, two or three diaphragms; the required number for a specific design is listed in the Number of Diaphragms column. The positioning of the diaphragms for the four bracing conditions and the corresponding unbraced lengths are presented in Figure 2.2.



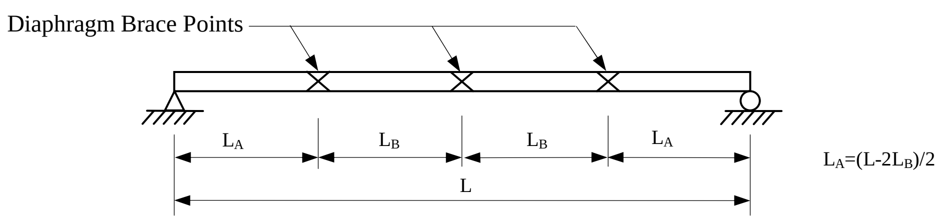
a. Zero diaphragm case



b. One diaphragm case



c. Two diaphragm case



d. Three diaphragm case

Figure 2.2. Possible diaphragm layouts for the MBISB design.

For the design output, only the L_B length is listed and the other braced lengths are calculated based on the information presented in Figure 2.2. Two diaphragms are required for the design example, corresponding to the bracing configuration shown in Figure 2.2c with the L_B length listed as 21 ft; the L_A length, calculated using the relationship in Figure 2.2c is equal to 22 ft.

2.2.5 Diaphragm and Diaphragm Connector Design

Channel diaphragm and angle connection sections listed in Table 2.2 are specified based on the depth of the longitudinal girders. The diaphragm connectors are presented in Figure 2.3 and typical interior bolted connection is detailed in Figure 2.4. The bolt lengths are calculated by Equation 1; the length and number of diaphragms and connectors needed for a given design are calculated using Equation 2 and Equation 3, respectively. The design example is assumed to have no skew so the diaphragm connectors can be bolted back to back to save bolts and holes; the diaphragms are sloped to account for the elevation difference between the longitudinal girders due to the cross slope and camber.

The design example will require 10 – 68 in. long C15x33.9 A36 diaphragm sections and 20 – 15 in. long 5x3x7/16 A36 angle connector sections attached using 36 - 2.5 in. x 7/8 in. and 12 – 3 in. x 7/8 in. A325 bolts assuming the connectors will be bolted back to back. A bridge cross section showing the installed diaphragms for the design example is presented in Figure 2.5. The designer has the option of specifying a structurally equivalent diaphragm system rather than the one presented.

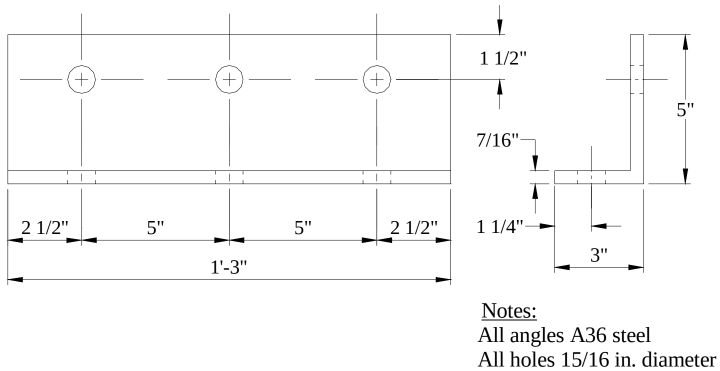
2.2.6 Optional Serviceability Deflection Control

AASHTO LRFD Bridge Specification suggests the maximum live load deflection be limited to a value equal to L/800, 0.975 in. for the design example. The estimated deflection presented in the Service Level Deflection column for the design example is 0.752 in., which is less than the required, meeting the serviceability criterion; this is reflected by the “Y” response in

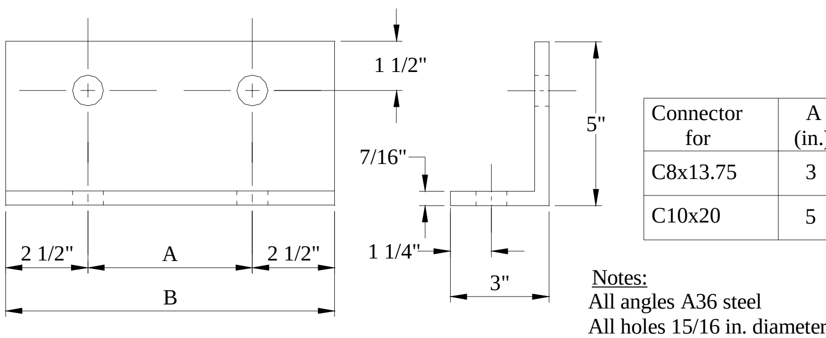
Table 2.2. Specified diaphragm sections and connectors based on longitudinal girder depth.

Longitudinal Girders	Diaphragm Sections	Diaphragm Connector Length (in.) (5x3x7/16” angle)
W24 and Up	C15x33.9	15
W18 and W21	C10x20	10
W12 and W14	C8x13.75	8

Note: Diaphragms and connectors are fabricated using A36 steel.



a. Diaphragm connector for C15x33.9 section



Connector for	A (in.)	B (in.)
C8x13.75	3	8
C10x20	5	10

b. Diaphragm connector for C10x20 and C8x13.75 sections

Figure 2.3. Diaphragm connection detail.

$$\text{7/8 in. diameter A325 Structural Bolt Lengths (in.)} = \qquad \text{Eqn 1}$$

$$\begin{aligned}\text{Two connectors back to back} &= (2)(\text{Angle leg thickness}) + \text{Web Thickness} \\ &\quad + (2)(\text{Washer Thickness}) + \text{Nut Thickness} = \\ &= (2)(7/16\text{ in.}) + (5/8\text{ in.}) + (2)(5/32\text{ in.}) + 1\ 1/8\text{ in.} = 3\text{ in} \\ &\qquad (\text{Round up to nearest 1/4 in.})\end{aligned}$$

$$\begin{aligned}\text{Single connector} &= \text{Angle leg thickness} + \text{Web Thickness} \\ &\quad + (2)(\text{Washer Thickness}) + \text{Nut Thickness} = \\ &= (7/16\text{ in.}) + (5/8\text{ in.}) + (2)(5/32\text{ in.}) + 1\,1/8\text{ in.} = 2.5\text{ in.} \\ &\qquad (\text{Round up to nearest 1/4 in.})\end{aligned}$$

$$\text{Length of Diaphragms (in.)} = S - t_w - 3 \qquad \text{Eqn 2}$$

Where:

S = Girder Spacing (in.)

t_w = Web Thickness (in.)

$$\text{Length of Diaphragms (in.)} = 72\text{ in.} - 5/8\text{ in.} - 3\text{ in.} = 68\text{ in.}$$

(Round to nearest inch)

$$\text{Number of Diaphragms} = (\text{Number of Diaphragm Lines})(\text{Number of Girders} - 1) \qquad \text{Eqn 3}$$
$$= (2)(6-1) = 10$$

$$\text{Number of Diaphragm Connectors} = (\text{Number of Diaphragms})(2)$$
$$= (10)(2) = 20$$

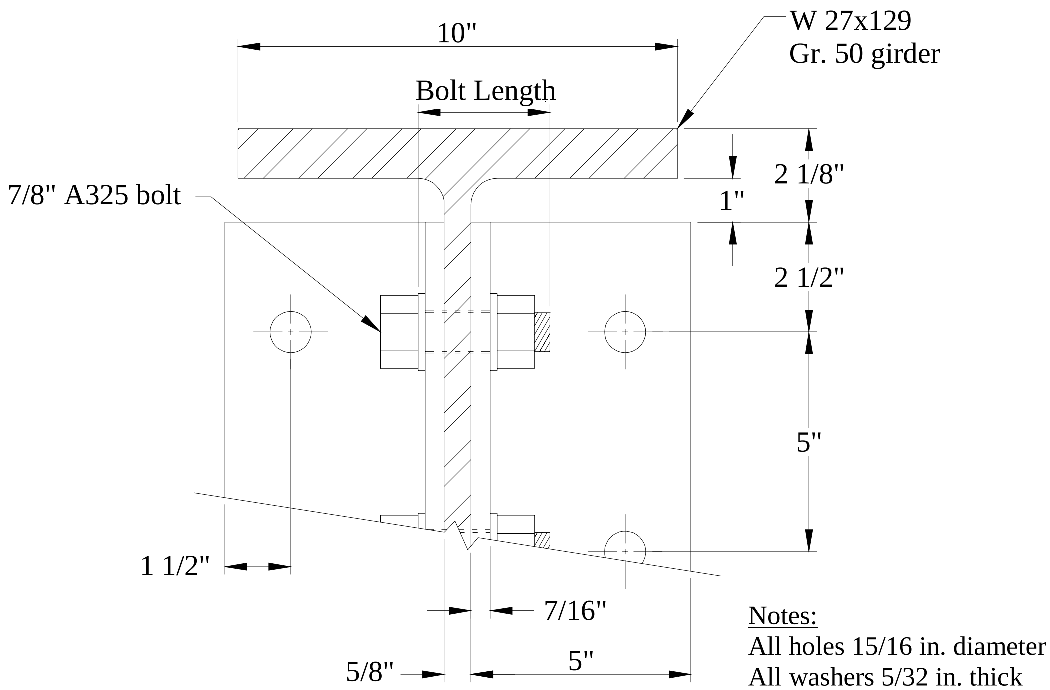


Figure 2.4. Bolted diaphragm connection detail for the design example.

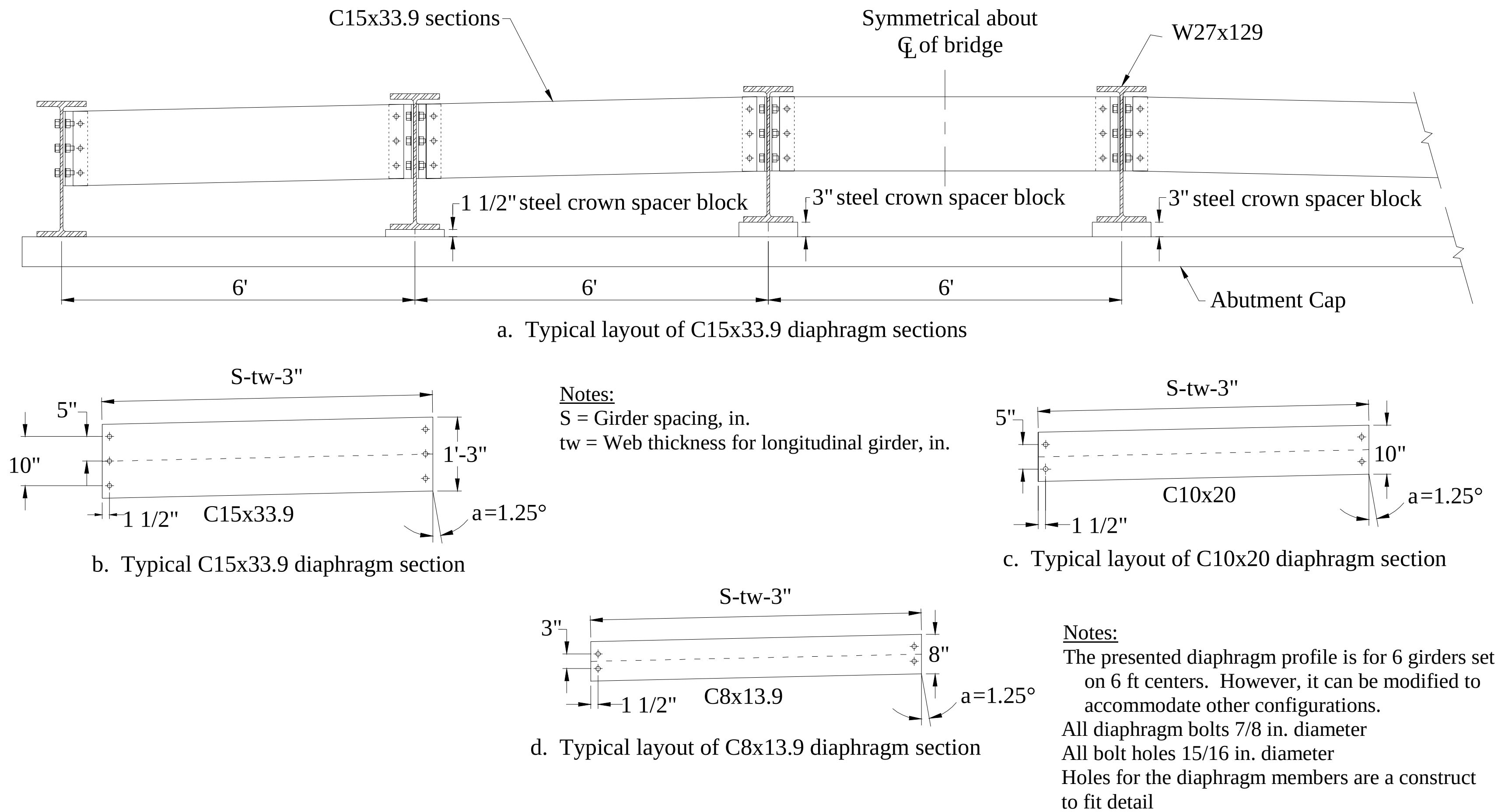


Figure 2.5. Diaphragm profile for the design example.

the Optional Deflection Control column. If a response of “N” is listed, the designer can compare the estimated deflection to the limiting value and make an engineering judgment whether to reject or accept the design.

2.2.7 Water Sliding Force/Floating

An estimated lateral force (design example = 26.94 kips per abutment) due to 6 in. of water flowing over the bridge at 10 mph is transferred to each abutment. While none of the MBISB designs will float, there is the uplift caused by the buoyant force which will reduce frictional resistance to sliding. Therefore, the designer is encouraged to take measures to prevent the superstructure from sliding off the substructure if there is the possibility that such a high water event could occur.

This completes the information presented in the tabular design output; however, additional design calculations, such as specifying the cross slope blocks, formwork systems, reinforcement quantities, etc. must be completed to finish a MBISB design. These additional calculations are presented in Chapter 3, Design Parameters.

3. DESIGN PARAMETERS

The information presented in the tabular design output addresses the global requirements for specific designs but does not include the necessary details to construct a MBISB. This chapter addresses the additional materials and quantities that are needed to complete a selected design such as the required reinforcement. Demonstrative calculations are based on the design example started in Chapter 2. The components not included in the design output are presented in the following sections.

3.1 Cross Slope Spacer Blocks

AASHTO design specifications for LVRs require a minimum 2% cross slope, referred to as crown, to ensure proper bridge deck drainage (*9*). Crown was obtained in the demonstration bridges by welding a series of steel plates to the abutment caps at the girder support points to obtain the elevation difference necessary for the required cross slope. The plates used must be large enough to transfer the reaction forces to the abutment without exceeding maximum bearing stresses. The plates used for MBISB 2 were 12 in. wide with the lengths varied to provide adequate space for the fillet welds that joined the plates. The top section of the stack must be 2 in. longer then the flange width of the longitudinal girder to allow for adjustment and the flange tip weld connection that is installed on one end of the bridge. The other end of the bridge is left in a free condition allowing for movement. An example of an installed cross slope spacer block is shown in Figure 3.1.

The number and thickness of the respective crown spacer blocks is a function of the bridge width, the number of girders, and specified crown. Following AASHTO design standards, the cross slope is set to 2%; the distance between the exterior girders is limited to 24 ft and 30 ft as previously discussed (*9*). Table 3.1 and Equations 4 and 5 are presented to calculate the thickness of the crown spacer block under a given girder. The spacer blocks are calculated with reference to the center line of the bridge and are rounded up to the nearest 1/4 in. with the exterior girders resting on the abutment cap. The cross section of the bridge design is considered to be

Figure 3.1. Stack of steel plates for introducing crown in the bridge deck.

Table 3.1. Height of crown spacer blocks for the design example.

Girder Number	1	2	3	4	5	6	7	8	9	10	11
Distance from Bridge Centerline (ft)	15	9	3	3	9	15					
Height of Spacer Block (in.)	0	1.5	3	3	1.5	0					

Note: The girder spacing is equal to 6 ft for the design example resulting in only 6 girders. If a smaller girder spacing were selected, more girders would be required and there would be data in the additional columns in Table 3.1. The table is meant as a template for multiple design combinations.

$$\text{Distance from Centerline (ft)} = \left(\frac{\text{Bridge Width} - 2}{2}\right) - (\text{n} \times \text{Girder Spacing}) \qquad \text{Eqn 4}$$

Where:

n = number of girder spacings from exterior

$$\text{Distance from Centerline} = \left(\frac{32-2}{2}\right) - (1\times 6) = 9\text{ ft}$$

Eqn 5

$$\text{Height of Crown Spacer (in.)} = \left[\left(\frac{\text{Bridge Width} - 2}{2}\right) - \text{Distance from Centerline}\right] \times 0.24$$

$$= \left[\left(\frac{32-2}{2}\right) - 9\right] \times 0.24 = 1.44 \text{ in.; Round up to} = 1.5 \text{ in.}$$

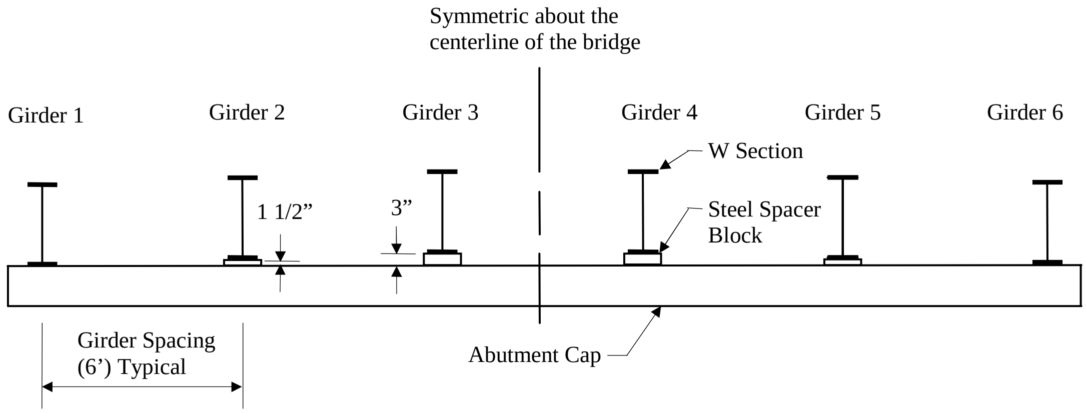


Figure 3.2. Profile of cross slope spacer blocks.

symmetric about the center line of the bridge and can be viewed in Figure 3.2.

3.2 Formwork Design

The MBISB system utilizes unique formwork that can be grouped into interior and exterior systems the majority of which are modular, allowing for a considerable amount of the formwork to be constructed and assembled offsite.

3.2.1 Interior Formwork System

As previously stated, the MBISB differs from more traditional slab/girder bridge designs by including a transverse arch spanning between the longitudinal girders. Two different systems were employed in the forming of the transverse arch for the demonstration bridges; the first system was a stay-in-place system while the second was a removable/reusable system referred to as the custom rolled arch formwork system.

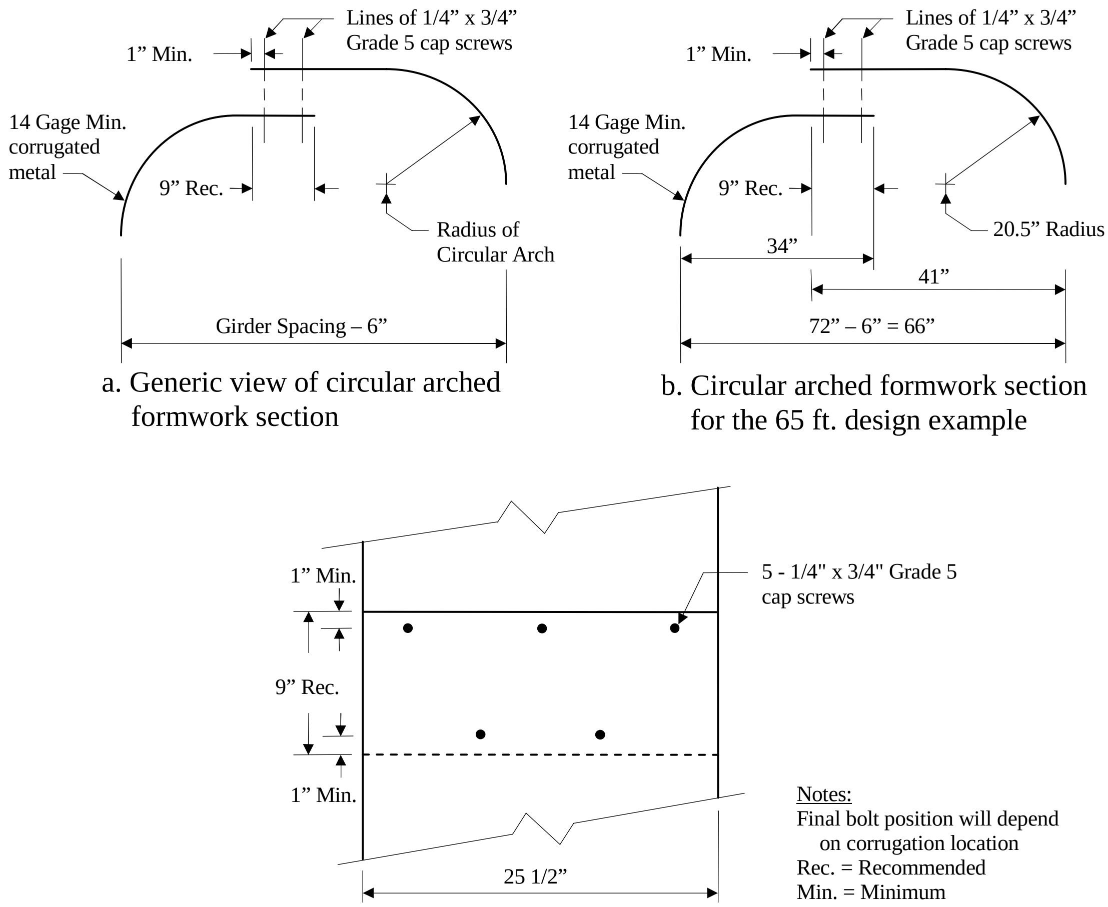
3.2.1.1 Stay-in-place formwork

Stay-in-place formwork, consisting of a section cut from a corrugated metal pipe (CMP), was used for the first demonstration bridge (MBISB 1); a more in depth description of the stay-in-place formwork is presented in Volumes 1 and 3. The use of stay-in-place formwork is not an Iowa DOT standard practice and is limited in application. Based on the developed MBISB design criteria, W21 sections spaced at 3 ft and W27 sections spaced at 4 ft readily accept a stay-in-place formwork system constructed from 1/2 sections of 14 gage 30 in. and 42 in. diameter, 2 2/3 in. x 1/2 in. CMP, respectively. Due to the girder spacing used in the design example (6 ft), the stay-in-place formwork system was not applicable.

3.2.1.2 Removable custom rolled formwork

A removable/reusable formwork system which maximized the amount of concrete removed by the transverse arch was desired. The custom rolled formwork, constructed from the same galvanized steel (2 2/3 in. x 1/2 in. corrugation) normally used to construct CMP was developed to efficiently form an arch between the girders. An individual arch formwork section consisting of two 24 in. wide components (nominal width) rolled to the radius specified in the design output establishes the depth of the concrete deck. There must be strict quality control during the rolling process to ensure proper fit. The manufactures that rolled the arched sections for this project are listed in Appendix C. The dimensions of the individual components for the design example are presented in Figures 3.3a and 3.3b; the patterns of 5 – 3/4 in. x 1/4 in. Grade 5 cap screws used to connect the sections are shown in Figure 3.3c.

The number of individual arched sections required for the demonstration bridge can be calculated using the relationships in Equation 6. Assembly of the individual sections was aided through the use of a jig; the assemble process is illustrated in Figure 3.4.



a. Generic view of circular arched formwork section

b. Circular arched formwork section for the 65 ft. design example

c. Layout of cap screws for the individual formwork sections

Figure 3.3. Individual arched formwork section dimensions.

$$\text{Number of arched sections required per bay} = \left(\frac{\text{Length - 1 ft}}{2}\right) \qquad \text{Eqn 6}$$

Where :

Length = Centerline to centerline of abutments

$$= \left(\frac{\text{65 ft - 1 ft}}{2}\right) = \text{32 Sections}$$

$$\text{Total number of sections} = \text{number of arched sections per bay} \times \text{number of bays}$$

$$= \text{32 Sections/bay} \times \text{5 bays} = \text{160 individual sections}$$

a. Jig for assembling individual components

b. Jig with first component in position

c. Individual components clamped in preparation of drilling the bolt holes

d. Completed individual arched section

Figure 3.4. Assembly process of the individual arched sections.

To expedite the in-field construction process, the individual sections can be bolted together in groups of 4 or 5, forming batteries that are then installed on the bridge. The individual sections are joined together with 4 – 1 in. x 1/4 in. Grade 5 bolts per joint following the sequence presented in Figure 3.5. The individual sections that make up a battery are positioned in an ‘over/under’ configuration as shown in Figure 3.6 to prevent the entrapment of the individual sections. Due to the many different configurations that the batteries can take, the specific battery layout is left to the designer.

a. Individual arch section fitted in the jig

b. Fitting individual sections in position

c. Bolting the individual sections together

d. Moving completed battery to storage

Figure 3.5. Assembly of the formwork batteries.

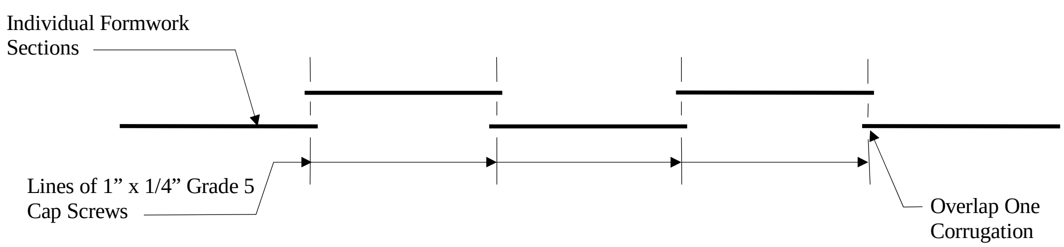
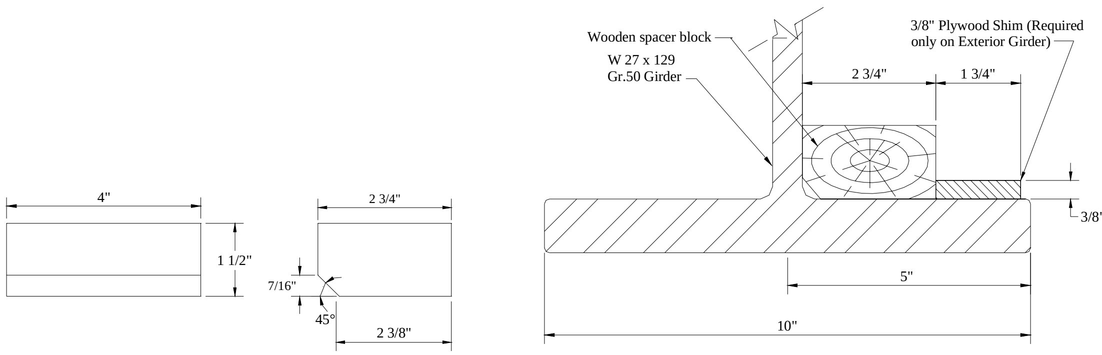


Figure 3.6. Typical ‘over/under’ battery layout configuration.

When installed between the longitudinal girders, the batteries and individual sections were held in place with wooden spacer blocks spaced at 2 ft. intervals along the length of the



a. Wooden spacer block

b. Installed wooden spacer block on a typical exterior girder

Figure 3.7. Wooden spacer block for securing the custom rolled formwork.

girder. The design details of the wooden spacer blocks are presented in Figure 3.7 and the number of blocks needed in the example design is calculated using Equation 7.

$$\text{Number of spacer blocks} = ((\text{Length}) + 3) \times \text{number of bays} \qquad \text{Eqn 7}$$

$$\text{Where:}$$

$$\text{Length} = \text{Centerline to centerline of abutments}$$

$$= ((65\ \text{ft}) + 3) \times 5 = 355$$

$$(\text{Round up to nearest integer}) = 355$$

3.2.2 Exterior Formwork System

The developed design criteria relies on composite action for all longitudinal girders, therefore, the exterior girders must also have the ASC which requires the full development of the transverse reinforcement. A deck extension (i.e. overhang) consisting of a 12 in. x 12 in. block of concrete cast on the exterior side of each exterior girder provides the necessary length. The overhangs for MBISB 2 were formed using the system described in the following sections.

3.2.2.1 Exterior formwork panels

The 8 ft modular exterior formwork panels are constructed with 2x4 studs and 3/4 in. plywood. The exterior panels also establish the final deck elevation, in the case of the design example 3 in. above the top flange of the W27x129 girders, which requires the height of the formwork panel to be 30 5/8 in. Since the exterior formwork panels are designed to be reusable with different height girders, the final 5/8 in. is obtained by placing a shim under the panels. Plans for a typical exterior panel are shown in Figure 3.8; the number of 8 ft exterior panels required for the design can be calculated using Equation 8.

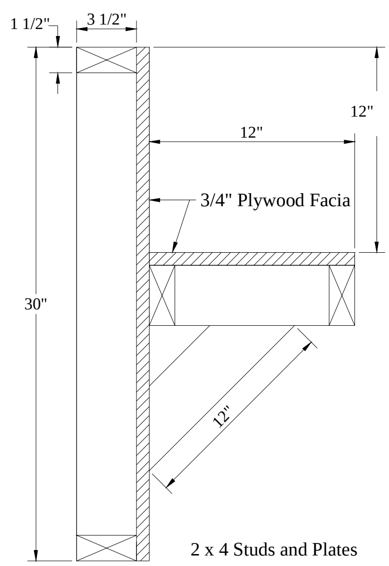


Figure 3.8. Typical exterior formwork panel.

3.2.2.2 Exterior formwork supports

The exterior formwork panels are supported by the exterior formwork supports which are constructed from 3x3x1/4 A36 angles that are clamped to the bottom flange of the exterior girders at a maximum spacing of 36 in. An "exploded" view of an exterior formwork support and the individual components which make up the exterior supports are presented in

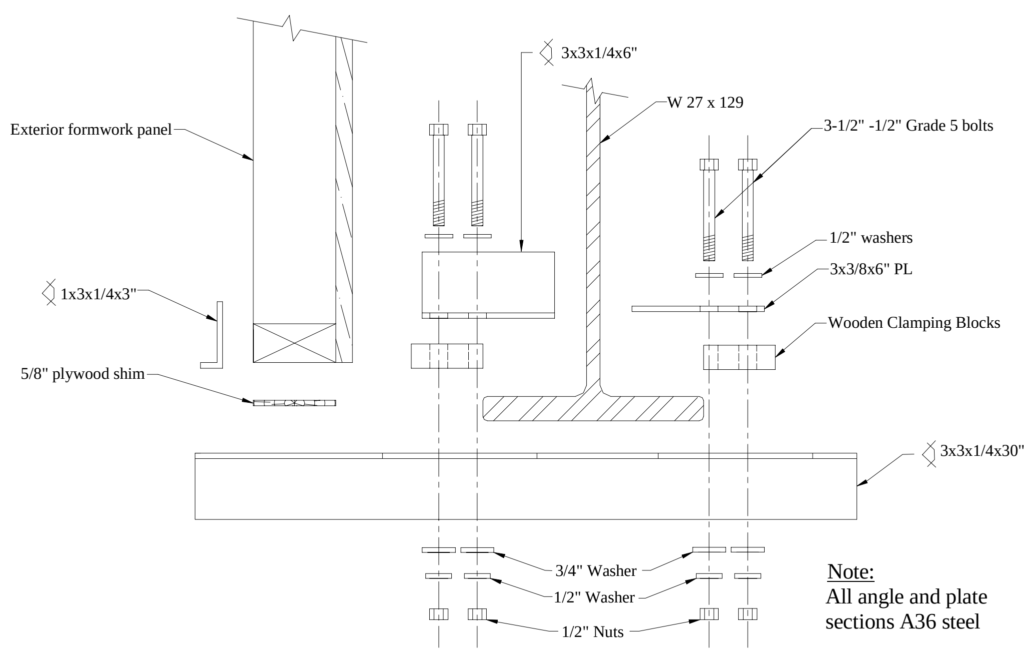
$$\text{Number of 8 ft formwork panels} = \left(\frac{\text{Length - 1ft}}{\text{8 ft}}\right) \times 2 \qquad \text{Eqn 8}$$

Where:
Length = Centerline to centerline of abutments

$$= \left(\frac{\text{65 ft - 1ft}}{\text{8 ft}}\right) \times 2 = 16 \text{ panels}$$

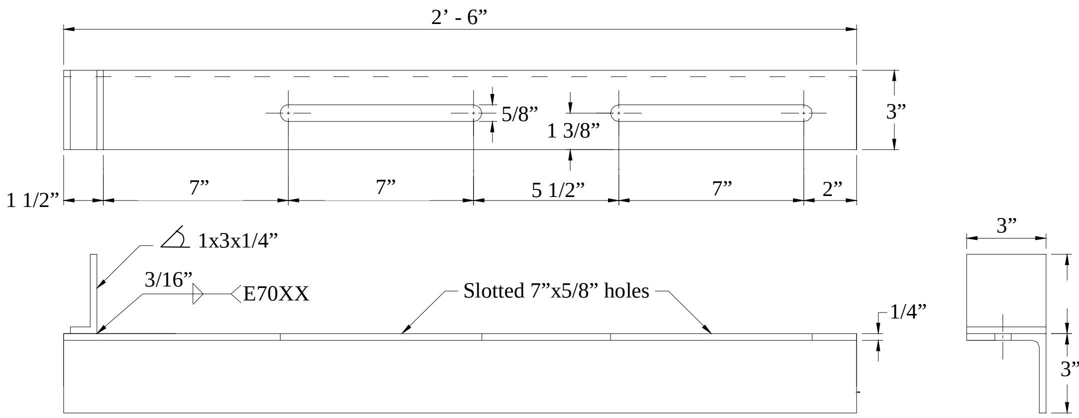
(Round up to nearest even integer)

Figure 3.9. The number of exterior formwork supports required for the design example is calculated using Equation 9. Figure 3.10 illustrates a fully installed exterior formwork panel, including the wire ties that hold the exterior panels in place, as used in MBISB 2.

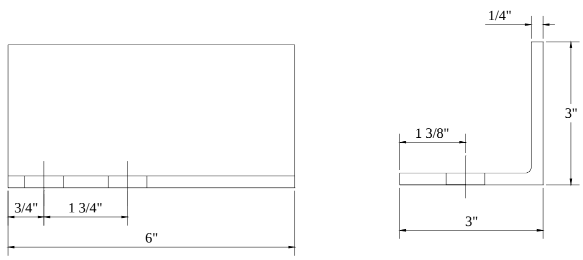


a. Exploded view of the exterior formwork support

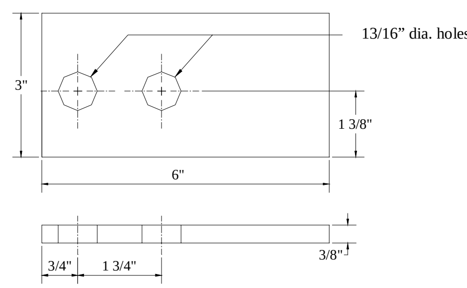
Figure 3.9. Exterior formwork support and its corresponding components.



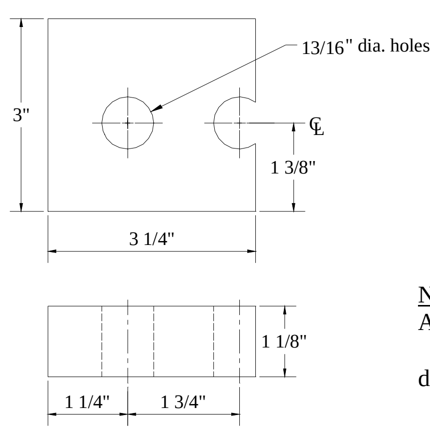
b. Angle section for the exterior formwork support



c. Angle clamp component



d. Plate clamp component



Note:
All angle and plate sections A36 steel
dia. = diameter, in.

e. Wooden clamping block

Figure 3.9. Continued.

$$\text{Number of exterior formwork supports} = \left[\left(\left(\frac{(\text{Length - 1 ft})}{3\text{ ft}}\right)+1\right)\right]\times 2 \qquad \text{Eqn 9}$$

Where:

Length = Centerline to centerline of abutments

$$= \left[\left(\left(\frac{(65\text{ ft - 1 ft})}{3\text{ ft}}\right)+1\right)\right]\times 2 = 44.67$$

(Round up to nearest even integer) = 48 supports

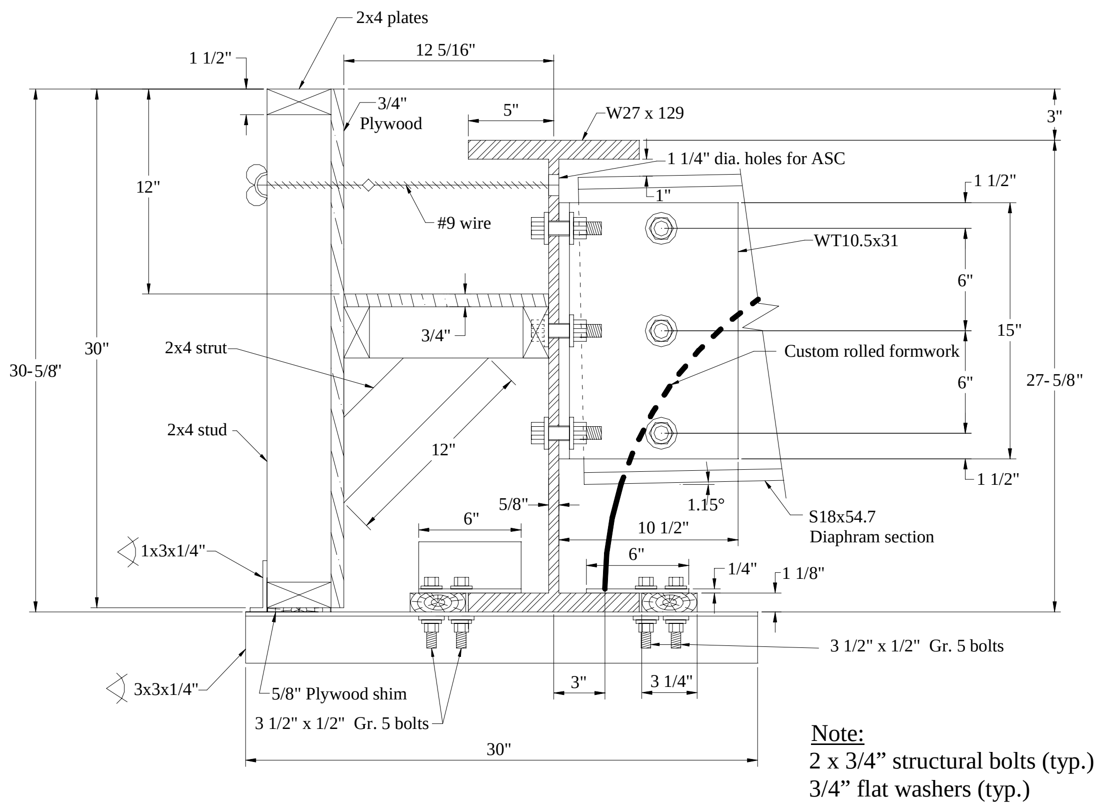


Figure 3.10. Installed exterior support and formwork used in MBISB 2.

3.3 Backwall Formwork

Concrete backwalls at each end of the MBISB are designed to retain the approach soil and “tie” the end of the bridge together. The backwall design presented here is a suggestion based on prior implementation; the designer may chose to design a structurally equivalent backwall if desired. The design has been revised; the backwall used in MBISB 2 was too conservative. In the revised backwall, the amount of reinforcement is reduced and the backwall is positioned to provide adequate cover at the ends of the girders. The 12 in. thick backwall is cast between the longitudinal girders and rests atop the abutment cap. Required reinforcement for the backwall is presented in Section 3.4.1.1. Typical wooden formwork panels and standard 12 in. snap ties are used to form the backwall. The formwork panels on the soil side of the backwall are constructed to match the final deck elevation.

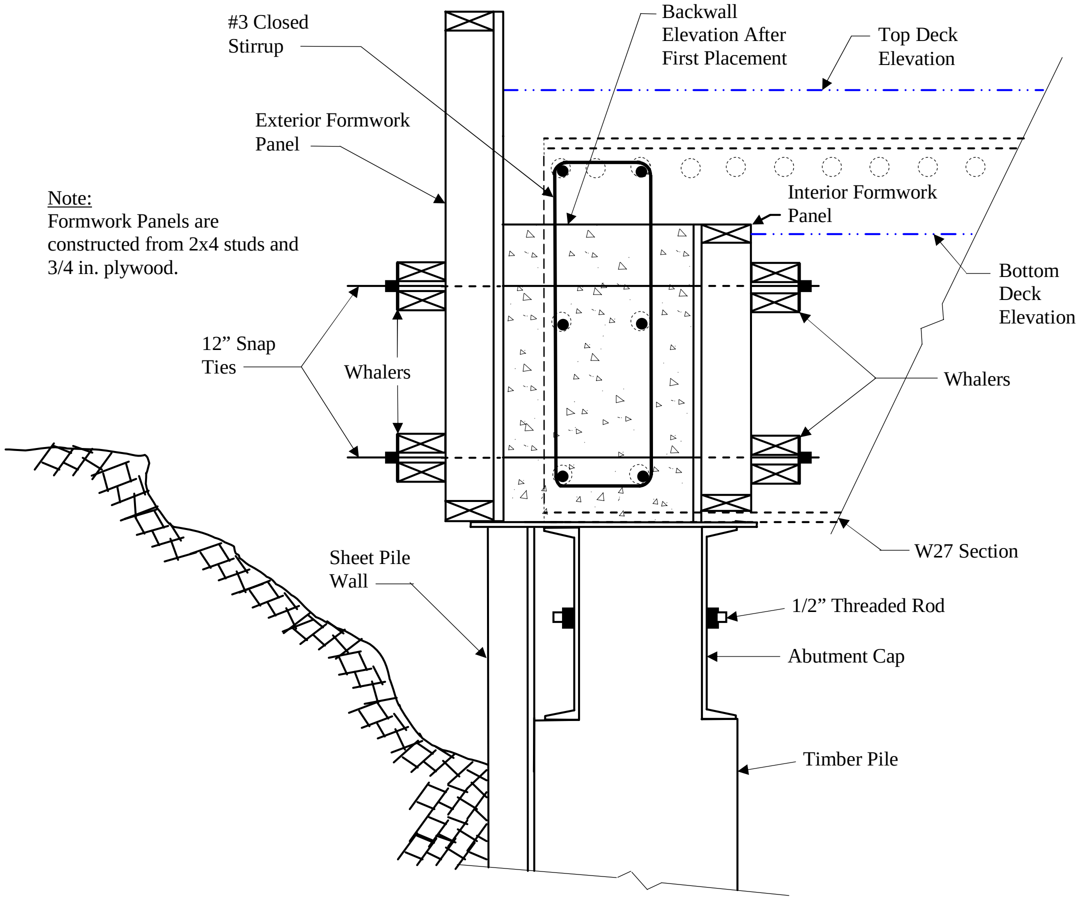
During construction of the deck, the interior side of the backwall serves as a vertical surface to retain the interior arched formwork. Thus, the backwall is placed in two stages; the first placement raises the backwall elevation to approximately 1 in. above the bottom of the future deck. The remaining portion (second placement) of the backwall is completed when the deck concrete is placed. After adequate curing, the interior backwall formwork is removed and the interior arched formwork is matched to the backwall. Calculating the volume of concrete for the backwalls is left to the designer. The installed backwall formwork for future MBISBs and the abutted custom rolled formwork, as used in MBISB 2, are shown in Figure 3.11.

3.4 Reinforcement

The tabular design output does not provide information on the reinforcement required for the desired MBISB due to the large number of design combinations. Once a specific design is selected, the reinforcement required, including temperature and shrinkage reinforcement (T &S), can be calculated using the following criteria.

3.4.1 Transverse Reinforcement

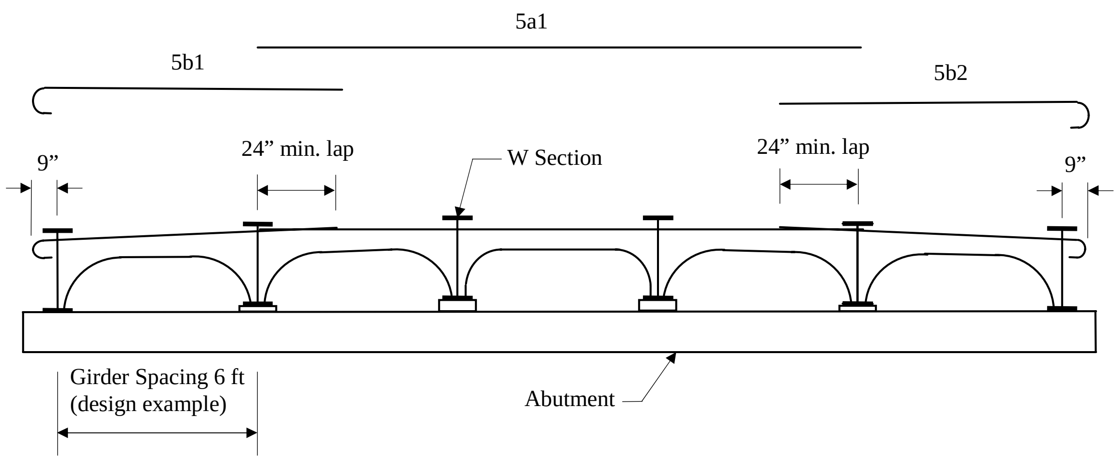
The transverse reinforcement needed for a MBISB design consists of the reinforcement for the backwalls and deck. Due to the arched deck, the only reinforcement required in the deck is the transverse ASC reinforcement; therefore, all the transverse reinforcement in the deck slab is #5 Grade 60 reinforcing bars. The layout and dimensions of the reinforcement are presented in Figure 3.12; the reinforcement lengths presented are prior to the bending of the 180 degree hook.



a. Cross section of formwork for the presented backwall design

b. Custom rolled arched formwork abutted to the backwall as used in MBISB 2

Figure 3.11. Backwall construction.



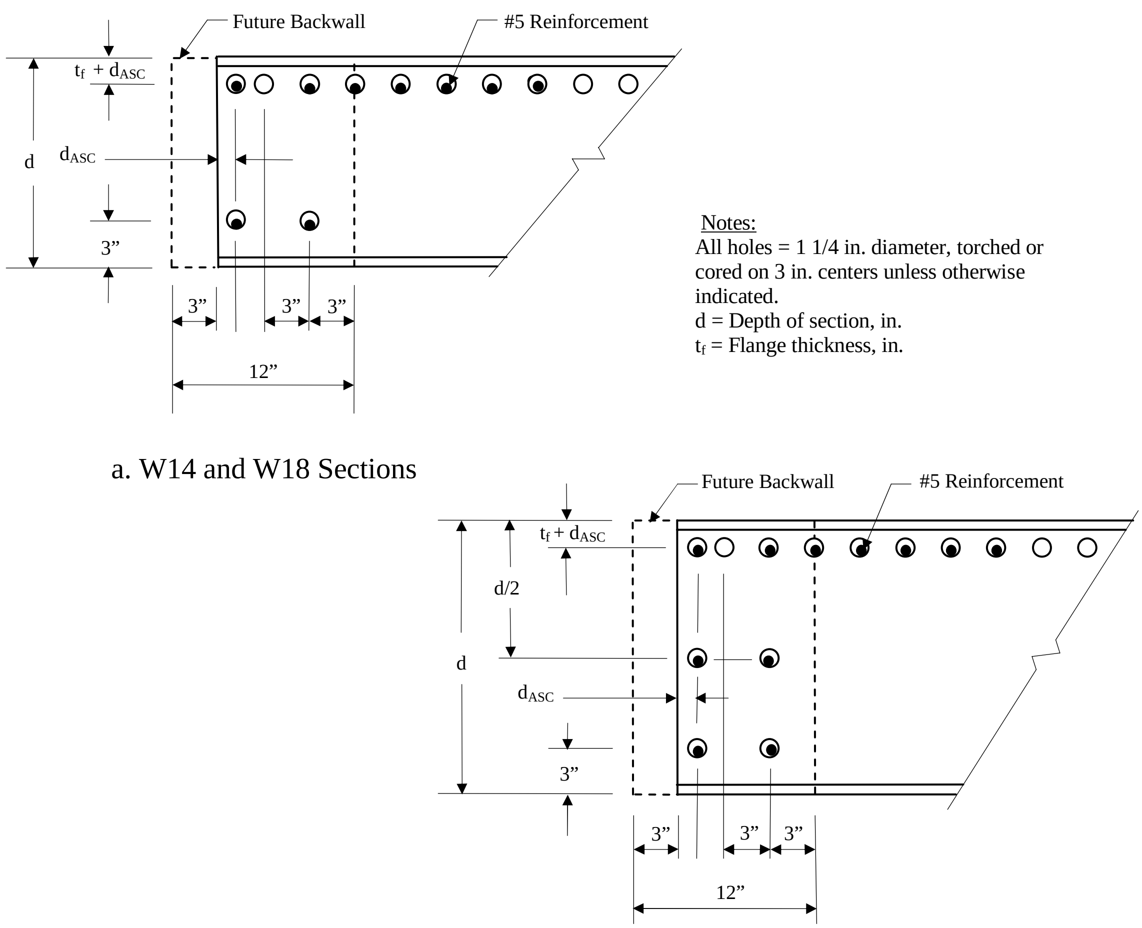
Required reinforcement

Width of Bridge (ft)	Bar/Length (in.)		
	5a1	5b1	5b2
26	-	120	240
32	240	86	154

Figure 3.12. Transverse ASC and backwall reinforcement.

3.4.1.1 Backwall reinforcement

The amount of reinforcement required for the presented backwall design is a function of the depth of the selected longitudinal girders. The placement of the lines of reinforcement required to complete a single backwall based on the selected section is illustrated in Figure 3.13 and listed in Table 3.2. Therefore, 6 lines of reinforcement are needed for each backwall for the design example. Closed loop stirrups, consisting of #3 Grade 60 reinforcing bars, are spaced on 12 in. centers within the bays to provide confinement and shear reinforcement and to satisfy maximum spacing criteria. A total of four additional stirrups (two per exterior overhang) are provided for the portions of the backwall outside of the exterior girders to confine the hooked ends of the transverse reinforcement. The dimensions of the stirrups needed for the design example are presented in Figure 3.14; based on the bridge width and girder spacing, a total of 58 stirrups are required (see Table 3.3).



a. W14 and W18 Sections

b. W21, W24, W27 and W30 Sections

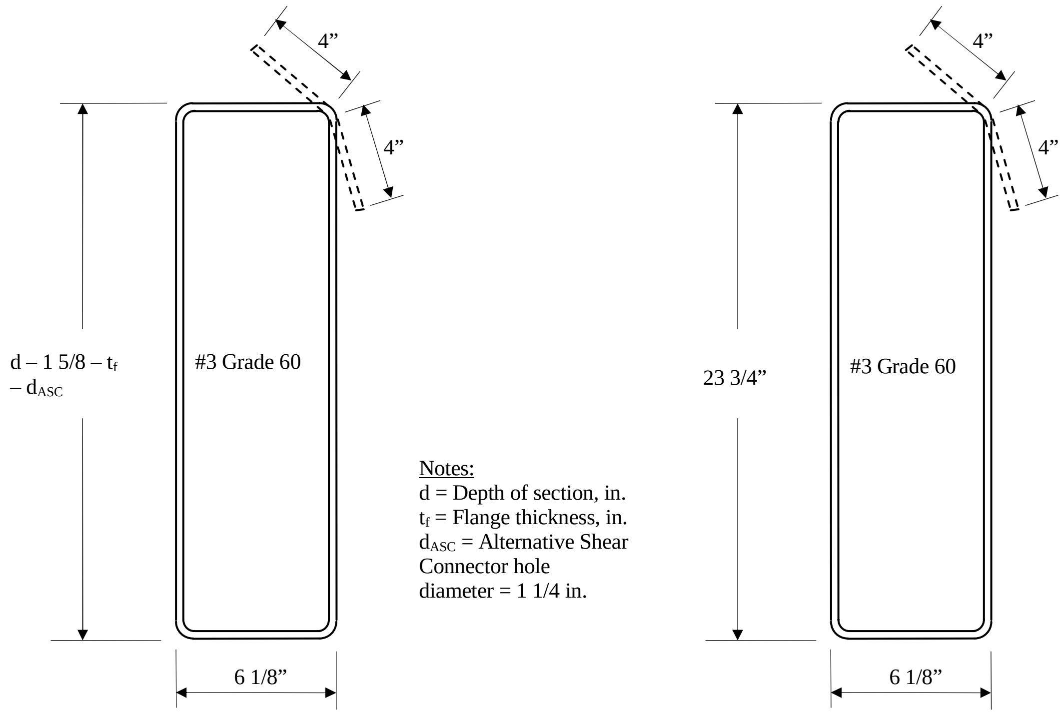
Figure 3.13. Layout of backwall reinforcement.

Table 3.2. Lines of backwall reinforcement required per backwall.

Selected Girder	W14	W18	W21	W24	W27	W30
Lines of Reinforcement	4	4	6	6	6	6

3.4.1.2 End stiffening reinforcement

The arched deck requires the ends of the bridge deck to be stiffened, confining the arches in the longitudinal direction; this is accomplished by placing 5 lines of reinforcement inside each



a. Generic closed loop stirrup for the backwall

b. Closed loop stirrup for the design example

Figure 3.14. Typical closed loop stirrup.

Table 3.3. Number of closed loop stirrups required per backwall.

Girder Spacing (ft)	Closed Loop Stirrups	
	32 ft Wide Bridge	26 ft Wide Bridge
6	29	24
5	28	-
4.8	-	24
4.29	25	-
4	-	22
3.75	28	-
3	28	20

backwall (See Figure 2.1 and 3.13). The five lines of reinforcement are run through the ASC holes, similar to the backwall reinforcement and the remaining deck reinforcement. When calculating quantities of reinforcement, the fifth line of reinforcement on each end is considered the first line of ASC reinforcement spaced on 15 in. centers. Therefore, a total of 8 lines of reinforcement are considered for the end stiffening when calculating the total transverse reinforcement.

3.4.1.3 Total transverse reinforcement

Through the implementation of the arched deck, the require reinforcement is reduced to only that which is required in the ASC, resulting in lines of #5 Grade 60 reinforcement spaced on 15 in. centers. The total amount of reinforcement for a MBISB design is calculated by summing the reinforcement required for the backwall, the end stiffening, and the deck reinforcement by using Equation 10. Seventy lines of transverse reinforcement, meeting the requirements presented in Figure 3.12, are needed in the 65 ft design example. The length in Equation 10 is the out to out length of the bridge, 66 ft, assuming the bridge extends 6 in. past the centerline of supports.

$$\mathrm{TR} = ((\text{Lines of backwall reinforcement}) \text{ x } 2) + \mathrm{ES} + (\text{Length} - (3\ 1/2)) \text{ x } \mathrm{BS} \qquad \text{Eqn 10}$$

Where:
TR = Total number of lines of transverse reinforcement
ES = Lines of End Stiffening reinforcement = 8
Length = Out to out bridge length, ft
BS = Bar spacing coefficient = $12''/15'' = 0.8$

$$= ((6) * 2) + 8 + (66\text{ ft} - 3.5\text{ ft}) * 0.8 = 70 \text{ lines}$$

(Round up to nearest integer)

3.4.2 Longitudinal Temperature and Shrinkage Reinforcement

While the reinforcement required for the MBISB system is reduced to the transverse steel completing the ASC, additional longitudinal reinforcement is needed to control cracking due to temperature and shrinkage effects. The number of lines of #4 reinforcing bars specified for this purpose is a function of the number of bays and the bridge width. The reinforcement is distributed within a bay in the following manner: A line of T & S reinforcement is placed 18 in.

from each girder web, the resulting distance between the reinforcing bars is divided into equal spaces for placement of the remaining T & S reinforcement. The maximum spacing between the remaining longitudinal reinforcement is 12 in.

Three additional "lines" of T & S reinforcement are placed in each overhang to provide both crack control and continuity, adding six lines of reinforcement. A typical layout of the longitudinal reinforcement for the design example is shown in Figure 3.15. The total number of lines of reinforcement required, including the overhang reinforcement, (26 lines of #4 Grade 60 reinforcement for the design example) are listed in Table 3.4. The longitudinal layout and the

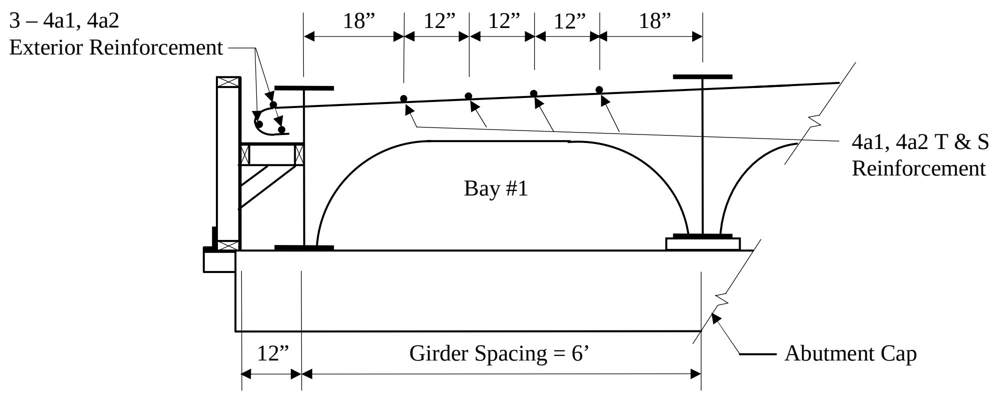


Figure 3.15. Typical layout of the longitudinal T & S reinforcement.

Table 3.4. Longitudinal T &S reinforcement quantities.

Girder Spacing (ft)	Lines of Reinforcement	
	32 ft Wide Bridge	26 ft Wide Bridge
6	26	22
5	24	-
4.8	-	21
4.29	27	-
4	-	18
3.75	22	-
3	16	14

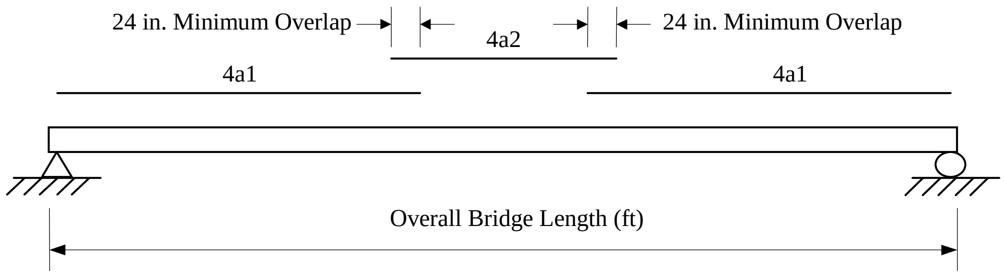


Figure 3.16. Typical longitudinal layout of the T & S reinforcement.

Table 3.5. Number and lengths of the longitudinal T & S reinforcement.

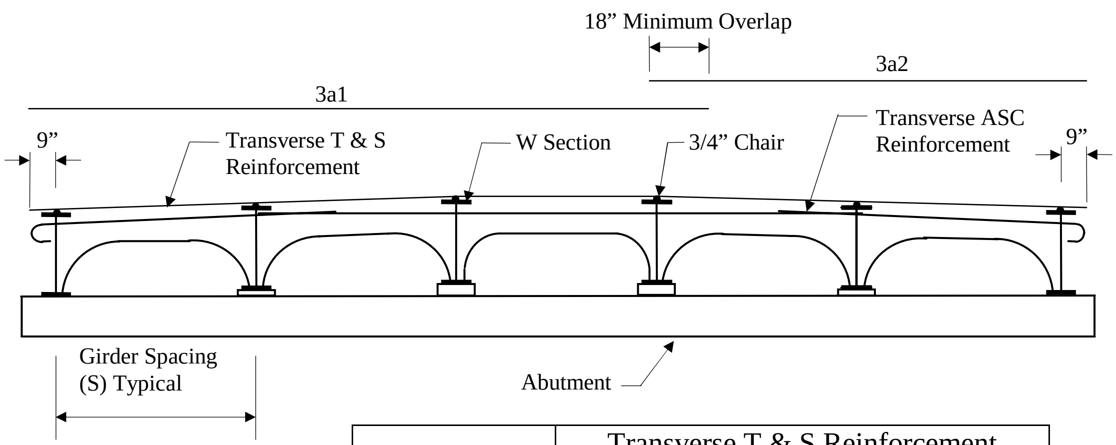
Bar Marks	Bridge Length (ft)								
	40	45	50	55	60	65	70	75	80
	Number and length of T & S reinforcement								
4a1	2-20’	2-20’	2-20’	2-20’	3-20’	3-20’	3-20’	4-20’	4-20’
4a2	1-4’	1-9’	1-14’	1-19’	1-6’	1-11’	1-16’	1-3’	1-8’

Note: Bridge length = centerline to centerline of abutments

needed lengths of the T & S reinforcement needed for the given bridge span are presented in Figure 3.16 and Table 3.5. For the design example, a total of 78 - 20 ft #4 bars (4a1) and 26 - 11 ft #4 bars (4a2) are required to complete the 26 individual “lines” of T & S reinforcement.

3.4.3 Transverse Temperature and Shrinkage Reinforcement

For designs that include the 3 in. cover, such as the design example, transverse T & S steel (#3 Grade 60 deformed reinforcing bar) is required to control cracking and confine the concrete above the girders. The transverse T & S reinforcement rests on 3/4 in. chairs set on top the longitudinal girders and is spaced at 15 in. centers, in between the spacing of the transverse ASC reinforcement. Figure 3.17 illustrates the positioning of the transverse reinforcement and the lengths of the individual bars based on the bridge width. The number of lines of transverse reinforcement for a given bridge span (centerline to centerline of the abutments) is listed in



Bar Mark	Transverse T & S Reinforcement Lengths (in.) Bridge Width	
	26 ft	32 ft
3a1	240	240
3a2	84	156

Figure 3.17. Layout of transverse T & S reinforcement.

Table 3.6. Lines of transverse T & S reinforcement based on bridge length.

Bridge Length (ft)								
40	45	50	55	60	65	70	75	80
Lines of #3 Grade 60 T & S reinforcement								
32	36	40	44	48	52	56	60	64

Note: Bridge length = centerline to centerline of abutments

Table 3.6. For the design example, 52 lines of #3 Grade 60 reinforcement consisting of a 20 ft section (3a1) and a 13 ft section (3a2) per line are required.

3.5 Tension Rods and Clips

Threaded tension rods are installed to stabilize the bottom flanges of the longitudinal girders and maintain constant girder spacing during construction. Clips that attach to the bottom flange are used to connect the tension rods to the bottom flanges to avoid welding on a fracture critical member. The tension rods can also be used to remove sweep that may be present in the girders. A schematic of the tension clip for the W27x129 girders used in the design example is shown in Figure 3.18.

A minimum of two lines of tension rods must be installed prior to the placement of the concrete for designs with zero or one line of diaphragms. For designs with a greater number of diaphragms (two or three), a line of tension rods is placed at the midspan of each longitudinal section defined by the diaphragms and the abutments. The length of an individual tension rod is a function of the girder spacing; a schematic of a typical installed tension rod is shown in Figure 3.19. After adequate curing of the deck concrete, the tension rods and clips can be removed and stored for future use.

Three lines of 3/4 in. diameter A36 threaded tension rods are needed for the design example with five 94 in. rods per line; thus a total of 15 rods are required. Two tension clips are required per rod; therefore 30 clips are needed.

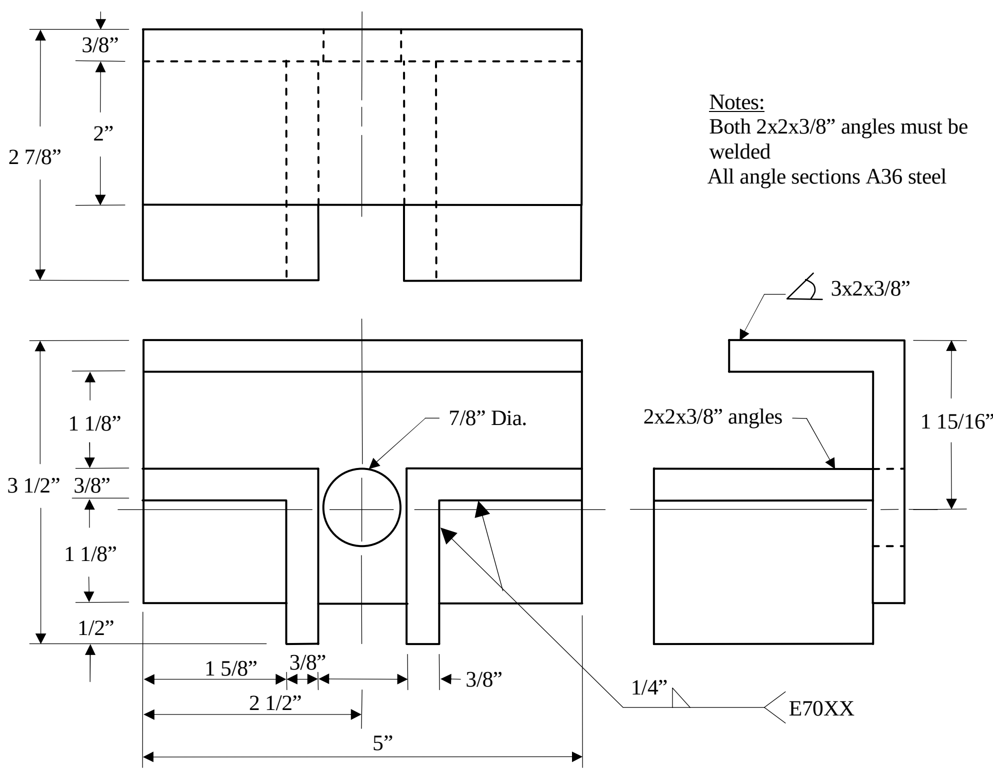


Figure 3.18. Tension clip for restraining the bottom flanges of the W27x129 girders.

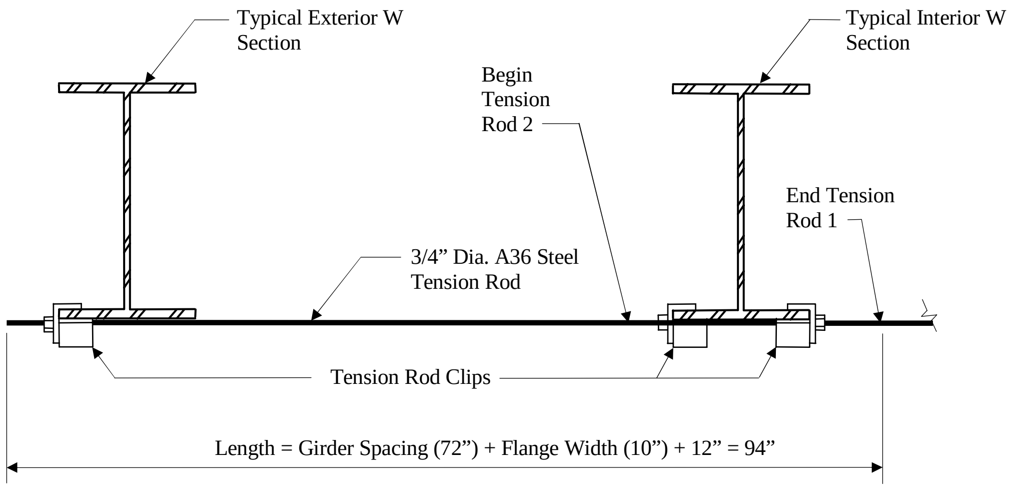


Figure 3.19. Typical layout of the tension rods and clips.

3.6 Guardrails

The guardrail for the MBISB system is left to the designer to specify; however, the design methodology assumes the selected system will have a weight of less than 100 plf. If the chosen system has a larger self weight, additional analysis should be performed by the designer. Examples of previously used guardrail systems are presented in the PowerPoint slide show contained in Chapter 4 of this document as well as in Volumes 1 and 3.

3.7 Summary of Design Example

Chapters 2 and 3 have provided information on the members, materials, and quantities required for the construction of the desired MBISB. In this design example, the following design criteria were used:

- Bridge length = 65 ft
- Bridge width = 32 ft
- Girder spacing = 6 ft
- Steel yield strength = 50 ksi
- Concrete compressive strength = 4 ksi
- Depth of cover = 3 in.

Based on the MBISB design output presented in Appendix A, six W27x129 girders spaced on 6 ft centers were required. With a specific design selected, the following quantities were obtained from the design output presented in Chapter 2 and the relationships presented in Chapter 3:

Number of girders: 6

Girder size: W27x129

Radius of formwork: 20.5 in.

Volume of concrete for the deck: 85 yd^3

Combined weight of the steel girders: 25.54 tons (51.08 kips)

Interior girder camber: 4.25 in.

Exterior girder camber: 3.75 in.

Number of lines of diaphragms required: 2

Diaphragm position, L_A: 22 ft

Diaphragm position, L_B: 21 ft

Total number of diaphragm sections: 10

Diaphragm sections: 68 in. long C15x33.9 A36 Steel

Total number of diaphragm connectors: 20

Diaphragm connector sections: L5x3x7/16, 15 in. long, A36 Steel

Diaphragm bolts: 36 – 2.5in. x 7/8 in. A325, 12 – 3in. x 7/8 in. A325

Passes optional serviceability deflection limits: Yes

Water sliding force: 26.94 kips

Cross slope spacer blocks: 4 - 1 1/2 in. thick, 4 – 3 in. thick

Type of interior formwork used: Removable custom rolled arched sections

Number of individual arched sections: 160

Number and size of formwork batteries: Designer’s responsibility

Number of wooden spacer blocks: 355

Number of 8 ft exterior formwork panels: 16

Number of exterior formwork supports: 46

Backwall formwork: Designer's responsibility

Volume of backwall concrete: Designer's responsibility

Lines of #5 Grade 60 reinforcement: 70

Lengths of structural reinforcement: 5a1 = 240 in.,   5b1 = 86 in.,   5b2 = 154 in.

Number of #3 Grade 60 Stirrups: 58

Lines of longitudinal #4 Grade 60 T & S reinforcement: 26

Lengths of longitudinal T & S reinforcement: 4a1 = 3 - 240 in.,   4a2 = 1 - 132 in.

Lines of transverse #3 Grade 60 T & S reinforcement: 52

Lengths of transverse T & S reinforcement: 3a1 = 240 in., 3a2 = 156 in.

Length of 3/4 in. chairs for transverse T & S reinforcement: Designer's responsibility

Number of 3/4 in. diameter A36 tension rods: 15

Length of individual rods: 94 in.

Number of clips: 30

Guardrail: Designer's responsibility

This summary of the material quantities required in the 65 ft long by 32 ft wide MBISB design example presented here have been developed in greater detail in this and the previous chapter. As with all design aids, it is the designer's responsibility to ensure the accuracy of the chosen design and construction methods employed. To assist the designer in developing a construction plan, the construction of the second MBISB is documented in the form of a PowerPoint slide show which is included on the enclosed CD. An explanation of each slide is included in Chapter 4. Additional generic drawings for the MBISB design are included in Appendix B and are similar to some of the figures presented throughout this report.

4. MBISB 2 CONSTRUCTION PROCESS

Construction of the MBISB 2 was completed in November of 2002 by Tama County, Iowa forces. The methods and processes employed in the construction of the demonstration bridge are presented in the following PowerPoint slide show as a reference for designers and construction crews for developing their own construction plan. The information presented is specific to the demonstration bridge; backwall details shown, although very similar, are not the same as those in the design methodology developed. Upon review, the reinforcement in the MBISB 2 backwall system was determined to be conservative and thus has been reduced in the final design. The construction methods presented are obviously not the only method of constructing the MBISB and the procedures used are the prerogative of the designer.

Construction of the Modified Beam-in-Slab Bridge

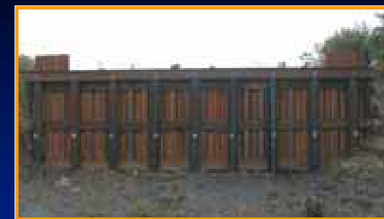
(TR-467)

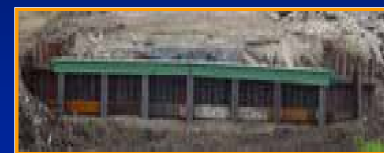
Bridge Engineering Center,
Iowa State University

Research Sponsored by:
Highway Division of the Iowa Department of Transportation and the
Iowa Highway Research Board

Subtructure

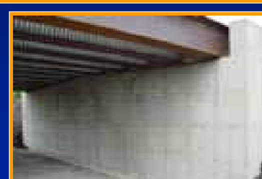
- Begin with completed sub structure
  - Wooden piles
  - Steel H-piles
  - Sheet pile back wall





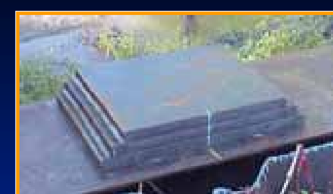
Abutment Caps

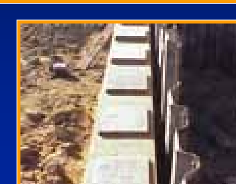
- Steel abutment caps
  - Constructed from two channels and steel plate
  - Fitted over piles
- Derivatives include concrete abutments



Development of Crown

- AASHTO design specifications require a 2% cross slope for drainage
  - Stacked steel plates
  - Sloping abutment cap





Slide 1: Introduction

The following slide show presents the construction of the second MBISB demonstration bridge (MBISB 2) which was part of Iowa DOT research project TR-467. The opinions, findings, and conclusions expressed in this PowerPoint slide show are those of the authors and not necessarily those of the Iowa Department of Transportation.

Slide 2: Substructure

The MBISB design methodology addresses only the superstructure; the design of the substructure is left the bridge owner. The construction of the MBISB superstructure can begin once the substructure is completed. Two types of superstructures have been implemented in the construction of the MBISB system and its various derivatives. Both substructures employ a steel sheet pile backwall supported by either wooden piles or steel H piles; either pile/abutment configuration is applicable. The designer is left with the task of specifying and designing the abutment to be compatible with the MBISB superstructure. Additional information on the design of LVR bridge abutments can be found in Iowa DOT final report TR-486, “Development of Abutment Design Standards for Local Bridge Designs” (*8*).

Slide 3: Abutment Caps

A horizontal abutment cap on the vertical piles supports the longitudinal girders. The abutment cap used in the MBISB demonstration bridges consists of two C12 channels orientated for strong axis bending with a 15 in. x 1/4 in. steel plate welded on the top of the channels. The cap is held in place by a 1/2 in. diameter bolt through each of the wooden piles or by welding the cap to the steel piles. Derivates of the MBISB system have employed a reinforced concrete backwall/abutment cap with the steel girders resting on steel bearing plates supported by the reinforced concrete cap.

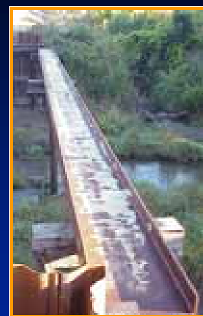
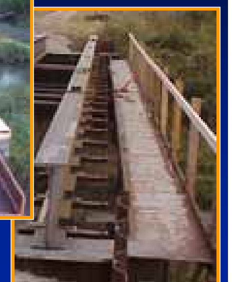
Slide 4: Development of Crown

Following AASHTO design specifications a 2% cross slope, referred to as the crown, is required to ensure proper bridge deck drainage. To create the specified cross slope, the differential elevation between the exterior girder and the centerline of a 32 ft wide bridge is approximately 3 3/4 in. and is approximately 3 in. for a 26 ft wide bridge. Two methods are commonly employed to introduce the specified crown in LVR bridges. In the first method (implemented in the construction of demonstration MBISBs), stacks of steel plates of the desired thickness are welded to the abutment cap at the girder support points, thus introducing the elevation difference necessary for the required cross slope. The use of steel plates to set the final elevation of the girder seats is the preferred method since the girders remain perpendicular to the horizontal abutment cap and thus are not subjected to biaxial bending.

The second method involved introducing the cross slope directly by sloping the abutment cap. This method, though effective, introduces biaxial bending since the webs of the girders are not vertical.

Installation of Construction Catwalk

- Self supported catwalk system
  - W27x94 in weak axis direction
  - Three temporary piles support each catwalk
  - Fall barrier installed

Slide 5

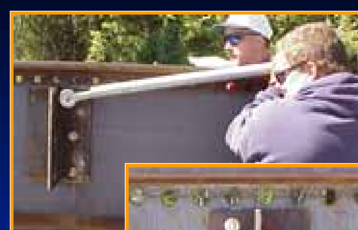
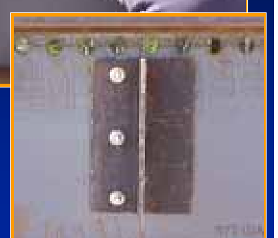
Fabrication of Girders

- Diaphragm connections
  - Prior to girder placement, holes for diaphragm connections are measured and cored


Slide 6

Installation of Diaphragm Connections

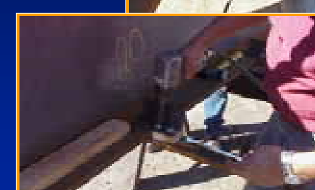
- Diaphragm connections are fitted and bolted in place
- Bolts are tensioned to a fully tight condition

Slide 7

Installation of Exterior Formwork Supports

- Previously prepared cantilever arms
- Measured, installed and tightened to a snug tight condition

Slide 8

Slide 5: Installation of Construction 'Catwalk'

A 'catwalk' system is needed for access to the exterior girders for the placement of the exterior formwork panels and operating the concrete placement equipment. The cantilevered exterior formwork support arms were not designed to support a 'catwalk' and supported the exterior formwork only. Obviously, other systems could be used for access to the exterior side of the bridge and the system implemented is left to the designer. A description of the 'catwalk' system used for the second demonstration bridge follows.

The main components of the 'catwalk' system were two recycled W27x94 beams, one on each side of the bridge. Each beam was supported by three temporary piles and was set with the beam web horizontal, thus forming a walkway. A safety rail was attached to the flange of the girders. The 'catwalk' system was installed before any of the girders were set and could be installed when the abutments are constructed. This system worked extremely well and provided an independently supported work platform on both sides of the bridge; it was removed with the completion of the bridge and obviously can be reused.

Slide 6: Fabrication of Girders

The camber necessary to counter the dead load deflection was built into the girders by the steel fabricator. For simplifying construction, the diaphragm connections were attached to the girders prior to placing them on the abutments. The purpose of the diaphragms is to provide compression flange bracing during the construction. To ensure alignment of the diaphragms and girders, one of the abutments should be designated as a baseline from which all measurements are taken.

The pre-cored diaphragm connections were bolted back to back in the demonstration bridge to reduce the number of bolts and holes required. If a bridge is skewed or if the abutments are not parallel, the diaphragm connections will need to be staggered to ensure proper alignment.

Bolt holes in the webs of the longitudinal girders for attaching the diaphragms should be cored with a drill.

Slide 7: Installation of Diaphragm Connections

Once the diaphragm connection holes are cored, the diaphragm connections consisting of either angles or, as was the case for MBISB 2 a structurally equivalent section, can be bolted in place with the bolts being tensioned to a fully tightened condition by the ‘turn-of-the-nut’ method. The WT10.5x31 diaphragm connections used in the MBISB demonstration bridge were cut from available recycled W21x62 girders and had excess structural capacity. The bolts used to fasten the diaphragm connections to the longitudinal girders shall be structural grade A325 bolts.

Slide 8: Installation of Exterior Formwork Supports

Prior to the exterior girders being set in place, the cantilevered exterior formwork supports can be installed on them in the staging area. The cantilever arms are designed to support only the exterior formwork and are adjustable for use with different size girders. They are spaced no more than 36 in. apart to support the 8 ft exterior formwork panels. The distance from the web of the exterior girder to the angle catch welded to the end of the cantilever arm can be readily set with a jig as shown in Slide 8. The support arms are set perpendicular to the longitudinal girder and clamped in place to the bottom flange by tightening the four 1/2 in. diameter (Grade 5 minimum) bolts to a snug tight condition. Over tightening will crush the wooden spacer blocks and potentially result in some misalignment.

Installed Exterior Formwork Supports

- Installed support arms
- Plywood spacers installed on interior side of the exterior girders

Slide 9

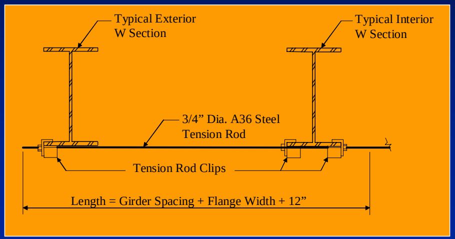
Placement of the Girders

- Swinging the girders into place
- Align longitudinally

Slide 10

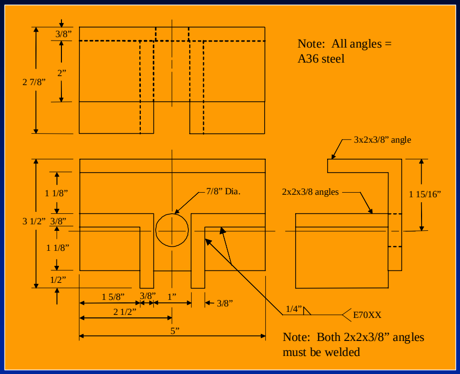
Transverse Girder Alignment

- Girders must be transversely aligned to maintain proper transverse spacing
- Girders aligned with transverse tension rods



Slide 11

Tension Clip Schematic



Slide 12

Slide 9: Installed Exterior Formwork Supports

The exterior formwork supports are clamped to the bottom flange with a 3 in. x 3/8 in. steel plate which rests on the interior top surface of the bottom flange; this results in an uneven surface for the custom rolled formwork. Thus, a 3/8 in. x 3 in. plywood spacer strip, held in place with adhesive, is placed between each support arm to create a uniform surface for supporting the formwork. A photograph of the installed exterior formwork supports is shown in Slide 9.

Slide 10: Placement of the Girders

Once the preliminary work on the girders has been completed, (installation of the diaphragm connections and the cantilevered exterior formwork supports), the girders can be set in place. The advised girder placement sequence is to set the most interior girders first and the exterior girders last. This sequence was not followed during the construction of MBISB 2 which caused considerable difficulty in aligning the girders transversely. The girders must also be aligned longitudinally so the diaphragm connections maintain alignment.

Slide 11: Transverse Girder Alignment

With the girders set in place, the position and camber of the girders should be measured and confirmed since later it will be difficult to correct improper placement or camber. One end of the girders is then welded either directly to the abutment cap or the crown spacer blocks (i.e., the pinned end). The other end of the girders is left in a free condition (i.e., the roller end), allowing for movement in the longitudinal direction to accommodate for changes in length due to environmental effects. Angle guides welded beside the girder flanges at the roller end may be added to resist lateral forces due to the wind and/or water loadings.

The girders may have a horizontal sweep, resulting in a spacing variation between the girders over their length. This variation, if excessive, must be remedied because the interior arched formwork panels rest on the bottom flanges and require a minimum ledge width of 1 in. An exterior bay was selected as the spacing reference line for the demonstration bridge. The spacing between the girders was adjusted through the use of transverse tension rods installed at the midspan between each of the diaphragm locations. A sketch of a typical installed tension rod is depicted in Slide 11. Additional details of the tension rods and the clips that hold the rods in place are presented in Slides 12 and 13.

The original function of the 3/4 in. diameter A36 steel tension rods, 8 ft in length with 9 in. of thread cut on each end, was to restrain the bottom flanges of the girders during the concrete placement. In addition to the original purpose, as was previously noted, the rods proved to be an excellent mechanism with which to transversely align the girders.

Using an impact wrench and a custom deep well socket, the girders were pulled into alignment by successively tightening and loosening the tension rods. The final exterior girder was pulled into place using a ‘come-a-long’ attached to the temporary catwalk. A string line was run along the bottom flange of the girders and was used as a guide to indicate when the ‘sweep’ had been removed. For a check, the girder spacing was measured at random locations with a tape measure. When two adjacent girders were pulled into position, the diaphragms were installed to maintain the desired girder spacing.

<u>Slide 12: Tension Clip Schematic</u>

The tension rods were connected to the bottom flanges of the girders using customized tension clips to avoid welding on a fracture critical member. Individual tension clips consist of one 3x2x3/8 angle (A36 steel), 5 in. long, braced by two 2x2x3/8 angles (A36 steel), 2 in. long. A 7/8 in. diameter hole was cored in the larger angle to accommodate the tension rod. Drawings of the tension clips are presented in Slide 12.

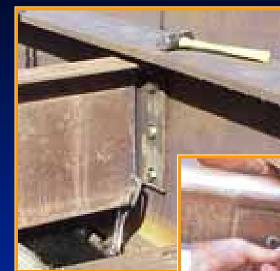
Installed Tension Clips and Rods

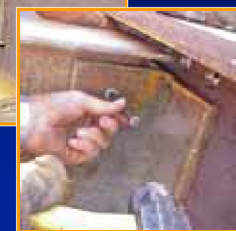
- Tension clips provide for a non-welded connection

Slide 13

Markup of Diaphragms

- Diaphragms were positioned and "fitted up"
- Bolt holes were aligned and transferred from the diaphragm connection





Slide 14

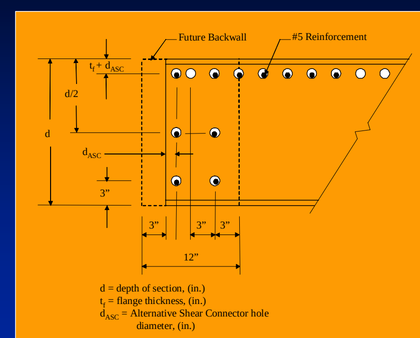
Diaphragm Fabrication and Installation

- Holes for diaphragm were cored in the staging area
- Diaphragms were installed and the bolts tightened

Slide 15

Backwall Design

- 12" Thick concrete backwall
- Required reinforcement a function of depth
- Reinforcement runs through girder webs



Slide 16

Slide 13: Installed Tension Clips and Rods

As previously stated, the clips allowed for the connection of the tension rod without welding on a fracture critical member. The individual components of the tension clip were cut in the shop and fitted to a fabrication jig which resulted in a tight fitting clip that, when combined with the tension rod, provided the desired confinement for the bottom flange. Measured strain values in the tension rods obtained from the field testing indicated the rods can be removed after the concrete cures. Thus, the tension clips and rods can be used again in the construction of a similar structure. The fabrication and installation of a tension clip and rod are shown in Slide 13.

Slide 14: Markup of Diaphragms

Once the girders that defined a bay were adjusted to the correct spacing, the diaphragms were installed. The diaphragms for the MBISB demonstration bridge were constructed from recycled S18x54.7 steel sections; this section size was chosen due to availability and its more than structurally adequate capacity rather than using the specified C15x33.9 sections. The diaphragms were cut to length in the field and the top and bottom flanges were both coped at 45-degree angles to facilitate bolt and formwork placement.

Due to the introduced transverse crown, an elevation difference of 3 in. existed between Girders 1-2 and 5-6. This elevation difference was twice as large as the elevation difference between Girders 2-3 and 4-5 due to the difference in camber resulting from the differing dead loads carried by the interior and exterior girders. To accommodate the differences in elevation, the diaphragms were sloped between the girders, maintaining a 1 in. clearance between the bottom of the top flange of the longitudinal girder and the top flange of the diaphragm.

The installation of the diaphragms proceeded in a ‘construct-to-fit’ fashion. A diaphragm section was first swung into position and clamped in place while still attached to the crane. A transfer punch was used to mark the diaphragm section for hole alignment based on the pre-cored holes in the stem of the T-section diaphragm connection as shown in Slide 14.

Slide 15: Diaphragm Placement

After the holes were marked with the transfer punch, the diaphragm section was returned to the staging area and the holes were cored with a magnetic drill. With the 7/8 in. holes cored, the diaphragms were fitted into position, and bolted into place with three 3/4 in. diameter structural bolts per connection. The diaphragm bolts for Bays 2, 3 and 4 were tightened to a slip critical condition by the ‘turn-of-the-nut’ method to prevent relative rotation of the ends of the diaphragms during the concrete placement. The bolts of Bays 1 and 5 (i.e. the exterior bays) were left in a snug tight condition to allow for the rotation of the diaphragm, due to the differential displacement that occurred between the interior and exterior girders. After discussing the methods employed for installing the diaphragms for MBISB 2 with Iowa DOT bridge engineers, the bolting criteria used was changed in the design criteria developed. Following the standard Iowa DOT practice, all diaphragms are to be bolted to a slip critical condition to maintain the elevation differences between the girders.

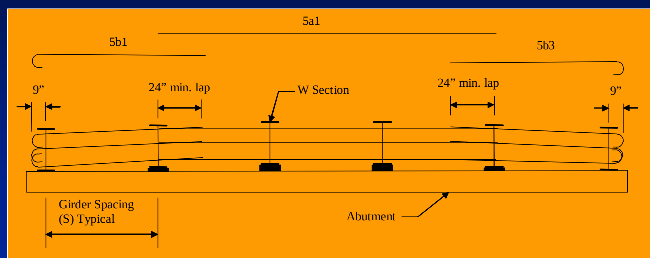
A temporary floor of bridge planks, resting on the bottom flanges of the girders, was used as a working platform allowing access to both the tension rods and the diaphragms. The design and implementation of the temporary scaffolding is the responsibility of the design engineer.

Slide 16: Backwall Design

After all the tension rods and diaphragms were in place, backwalls were needed to “close off” the ends of the bridge to resist the approach soil. A concrete backwall was designed to resist lateral earth pressure and vertical loads, code spacing requirements and shear reinforcement. The 12 in. thick concrete backwalls for MBISB 2 were reinforced with 10 lines of #5 reinforcing bars per bridge end. Holes were torched through the webs of the girders at each end to allow the reinforcement to pass through. The pattern for the holes and reinforcement is shown in Slide #15.

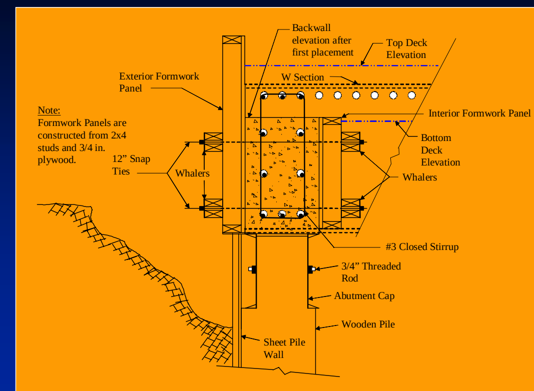
Backwall Reinforcement

- #5 Structural reinforcement, hooked bar ends
- #3 Stirrups spaced at 12 in.



Slide 17

Backwall Formwork



Slide 18

Back Wall Placement

- Interior back wall formwork is removed
- Exterior back wall formwork remains for deck placement
- Interior custom rolled arched formwork rests against back wall

Slide 19

Interior Deck Formwork

- Placement of custom rolled corrugated arched sections
- Pre-fabricated batteries
- Setting batteries

Slide 20

Slide 17: Backwall Reinforcement

Slide 17 indicates the positioning of the main structural reinforcement in the backwall. The number and lengths of the #5 reinforcement needed will vary depending on the bridge width and the girder depth. A listing of the reinforcement required for a variety of MBISB designs is presented in the design aids. The reinforcement layout presented in Slide 16 is for a 32 ft wide MBISB similar to MBISB 2.

The backwall was placed in two stages for MBISB 2; during the first stage, only the portion of the backwall between the girders was placed leaving the protruding hooks exposed; the remainder of the backwall was completed with the placement of the deck. A rebar was welded across the top of the girders for lateral restraint during the initial backwall concrete placement. Number 3 closed loop stirrups were placed at 12 in. intervals between the girders to provide confinement in the backwall.

Slide 18: Backwall Formwork

The backwall formwork was constructed of 3/4 in. plywood and 2 x 4 studs; 32 in. tall panels from a previous project were readily applicable to the construction of the backwall and were used for the exterior backwall formwork. Since both backwalls were cast at the same time, ten interior formwork panels (two for each bay) were constructed and attached to the exterior panels using 12 in. snap ties and whalers. The backwall formwork used for MBISB 2 is illustrated in Slide 18.

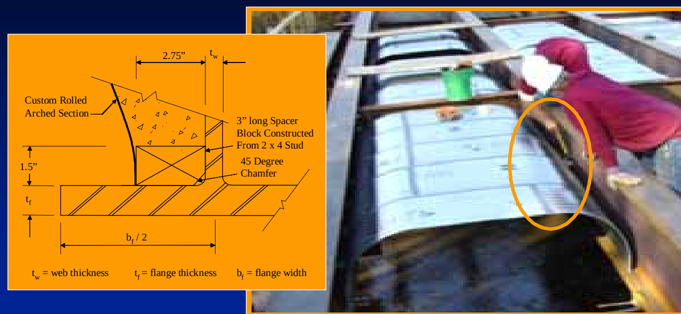
Slide 19: Backwall Placement

During the construction phase, the interior side of the backwall also serves as an end surface for the custom rolled arched formwork. As previously discussed, the backwall was placed in two stages; the first placement raised the backwall elevation to approximately 1 in. above the bottom of the future deck (see Slide 18 for reference). The interior backwall formwork was removed after the concrete had adequately cured and the custom rolled arched formwork was matched to the backwall. The remaining portion (second placement) of the backwall was completed when the deck concrete was placed. An example of the abutted custom rolled formwork is presented in Slide 19.

Slide 20: Interior Deck Formwork

Once the backwall had cured and the interior backwall formwork removed, the interior custom rolled arched formwork was placed. As previously described, the arched formwork is assembled offsite, first into individual sections and then into batteries. The batteries were transported on a flatbed to the construction site. The batteries were placed, leaving a 24 in. gap between each of the batteries, directly into the bridge from the transport vehicle and adjusted into position. The gap was left so that workers could adjust the battery's position.

Installing Interior Formwork



Slide 21

In Place Interior Formwork

- Individual formwork section connects the batteries
- Seams sealed with duct tape

Slide 22

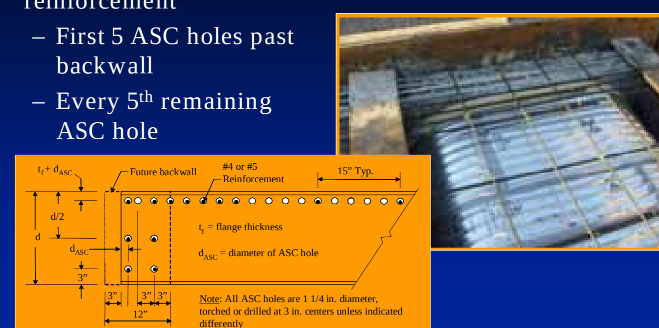
Completed Interior Deck Formwork

- Shim gaps at diaphragms and backwalls

Slide 23

Transverse Reinforcement

- Transverse #5 reinforcement
  - First 5 ASC holes past backwall
  - Every 5th remaining ASC hole



Slide 24

Slide 21: Installing Interior Formwork

The batteries were held in place with wooden spacer blocks on 2 ft centers. Epoxy was used to hold the blocks in place on each side of the battery. A cross section illustrating an installed spacer block as well as the procedure used to install them is presented in Slide 21.

Slide 22: In Place Interior Formwork

The 24 in. gap between the batteries is closed by placing an individual arched section over the gap. Using the individual section to cover the gap maintained the staggered layout of the arched sections and thus prevented the “entrapment” of a section once the concrete was placed. The seams between the individual sections were sealed with duct tape to prevent concrete from flowing into the seams.

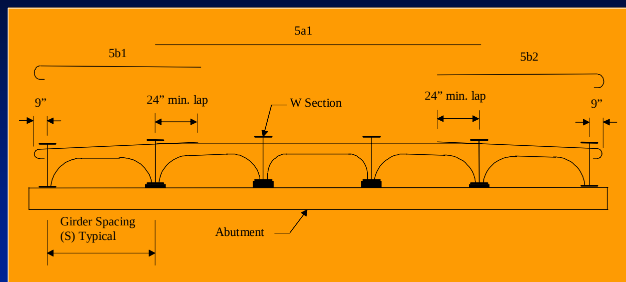
Slide 23: Completed Interior Deck Formwork

After all the batteries and individual sections were in place, shimming was necessary to close the interior deck formwork around the diaphragms and some backwalls. The gaps at the walls and diaphragms, all less than 4 in., were covered with strips of 1/4 in. plywood that were bent to fit and held in place with self tapping screws. On the underside at the diaphragm lines, 3/4 in. plywood pieces were installed to close the remaining gaps. Both the bent plywood matching the backwall and the closing of the underside diaphragm gaps are shown in Slide 23.

Slide 24: Transverse Structural Reinforcement

With the interior deck formwork completed, the transverse ASC reinforcement was installed. At each end of the bridge, five lines of reinforcement were placed inside of the backwall to provide lateral confinement of the arch. Over the remaining length of the bridge, the reinforcement is spaced on 15 in. centers, (i.e. through every fifth ASC hole). A typical layout of the transverse ASC reinforcement over the length of the bridge is presented in Slide 24 along with the reinforcement installed in MBISB 2.

Transverse Reinforcement Schedule



Slide 25

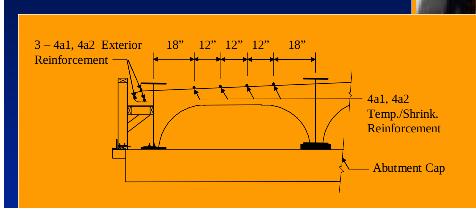
Longitudinal Temperature Reinforcement

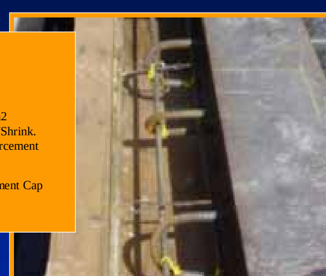
- #4 Reinforcement
  - 18 in. Spacing from girders
  - 12 in. Spacing over remaining distance

Slide 26

Longitudinal Temperature Reinforcement in Overhang Section

- 3 Lines of #4 longitudinal reinforcement

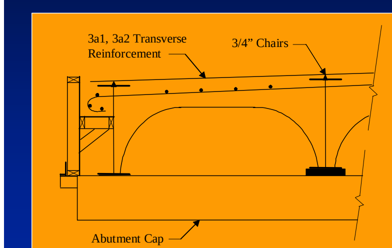


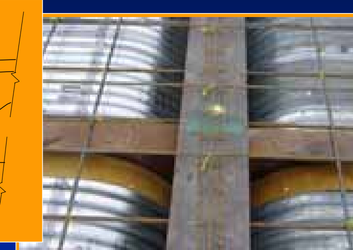


Slide 27

Transverse Temperature Reinforcement

- #3 Reinforcement
  - 3/4 in. chairs
  - Centered between ASC reinforcement





Slide 28

Slide 25: Transverse Reinforcement Schedule

The transverse deck reinforcement has the same dimensions as the reinforcement used in the backwall. The total amount of transverse reinforcement necessary for a given bridge as well as the required lengths for 26 ft and 32 ft wide bridges may be determined using the design aids provided.

Slide 26: Longitudinal Temperature Reinforcement

Temperature and shrinkage reinforcement is needed to prevent cracking; in MBISB 2, four lines of #4 reinforcement were placed in each bay. The spacing of the longitudinal reinforcement is determined by placing the first bars 18 in. from the web of the girders with the remaining spacing limited to a maximum of 12 in. The amount of longitudinal temperature reinforcement needed will vary depending on the girder spacing and is so noted in the design aids.

Slide 27: Longitudinal Temperature Reinforcement, Overhang Section

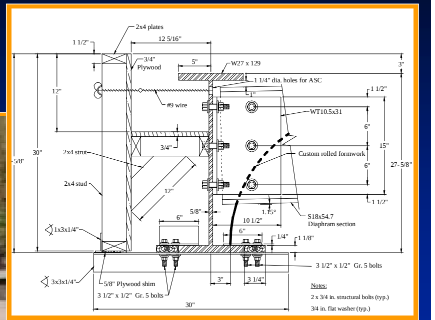
In addition to the longitudinal reinforcement in the interior bays, three lines of #4 reinforcement were placed in each reinforced concrete overhang. While the amount of longitudinal temperature and shrinkage reinforcement will vary based on the girder spacing, three lines of reinforcement must be included in each overhang to satisfy minimum reinforcement requirements. The positioning of the reinforcement can be viewed in Slide 27 along with the layout of the exterior longitudinal temperature and shrinkage steel used in MBISB 2.

Slide 28: Transverse Temperature Reinforcement

The MBISB design has the option of embedding the top flange of the longitudinal girders 3 in. to increase the flexural rigidity of the section and protect the girders from the elements. This is a design change from the original BISB system where the concrete is struck off even with the top flange of the girders. When the 3 in. of cover is used, additional transverse reinforcement, #3 deformed bars spaced on 15 in. centers between the ASC reinforcement, is needed to control temperature and shrinkage (T & S) cracking. The transverse T & S reinforcement rests on 3/4 in. chairs placed on the top flange of the girders; the amount of T & S reinforcement required in a given bridge may be determined using the design aids provided.

Exterior Formwork

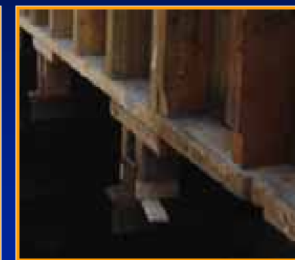
- 8 ft panels supported by previously installed exterior formwork supports



Slide 29

Establishing Exterior Formwork Elevation

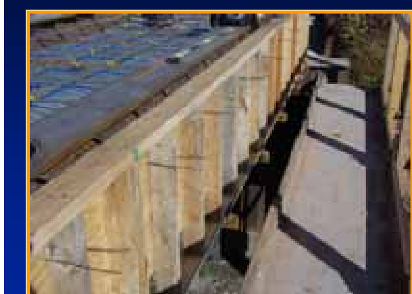
- Exterior formwork sets deck elevation
  - Pre-fabricated extensions
  - Tapered shims

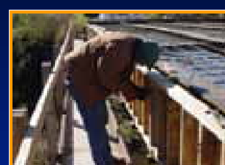


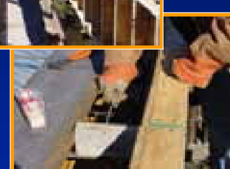
Slide 30

Attaching Exterior Formwork

- 3 Lines of wire per 8 ft panel



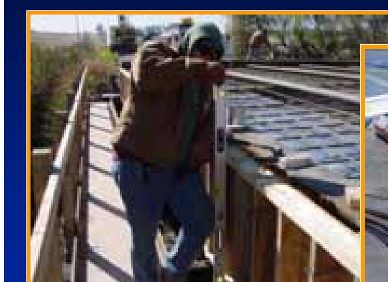




Slide 31

Aligning Exterior Formwork

- Panels are leveled
- 3 in. cover is maintained



Slide 32

Slide 29: Exterior Formwork

The exterior formwork panels were installed after the transverse ASC reinforcement and the longitudinal temperature reinforcement was in place. The exterior formwork panels, as previously discussed, can be constructed off site and reused on other bridges. The formwork panels are supported on the previously installed exterior formwork supports. A sectional view of the installed exterior formwork used in MBISB 2 can be viewed in Slide 29.

Slide 30: Establishing Exterior Formwork Elevation

The exterior formwork, in addition to forming the bridge overhang, establishes the final deck elevation. Since this elevation is a function of the girder depth and the cover over the girder, the height of the exterior formwork panel may vary. Rather than constructing numerous depths of exterior formwork panels, standard height panels (24 in. and 30 in.) were constructed and extensions plus shims were added to establish the desired exterior panel elevation. The 30 in. sections were adjusted to the desired elevation through the addition of tapered shims which were treated with epoxy to prevent them from vibrating out during the concrete placement.

Slide 31: Attaching Exterior Formwork

The exterior formwork was attached to the exterior girders with three lines of #9 wire per 8 ft panel. The wires, which pass through the ASC holes, were cold twisted tight to hold the exterior formwork panel to the web of the girder as shown in Slide 31. Final adjustments to the alignment of the exterior panels were made as shown in Slide 32.

Slide 32: Aligning Exterior Formwork

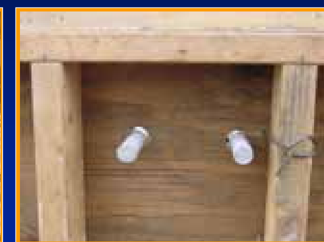
Prior to the final tightening of the wires, the exterior formwork panels are adjusted to ensure the desired final position. The panels are leveled with adjustments being made to the exterior formwork supports. The final deck elevation is also checked to ensure a 3 in. cover is maintained over the top flange of the girders. As previously stated, the final deck elevation is set by driving the shims between the exterior formwork support and the bottom of the exterior formwork panel.

Joining Backwall and Exterior Formwork

Slide 33

Threaded Guardrail Anchor Rods

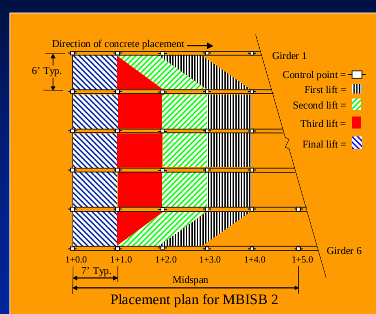
- Anchor rods cast integral with deck
  - Set on 6 ft centers
  - Anchor rods run through ASC holes



Slide 34

Concrete Placement Plan

- Concrete placement control points marked on girders



Placement plan for MBISB 2

Slide 35

Setting Power Screed Profile

Slide 36

Slide 33: Joining Backwall and Exterior Formwork

At the ends of the bridge, formwork was constructed to complete the exterior portion of the backwall and to connect the pre-fabricated exterior formwork panels. The protruding backwall hook bars can be seen in Slide 33 along with the completed exterior portion of the backwall.

Slide 34: Threaded Guardrail Anchor Rods

The guardrail system used for MBISB 2 required the placement of anchor rods in the concrete deck. Pairs of rods were spaced on 6 ft centers to match the prefabricated guardrail sections and were run through the ASC holes and the exterior formwork panels. After the installation of the guardrail anchor rods, MBISB 2 was ready for the concrete placement.

Slide 35: Concrete Placement Plan

A concrete placement plan was developed to counteract the differential camber between the interior and exterior girders by dividing the MBISB into ten sections and calculating the girder deflections due to the construction loading at each tenth point. A schematic of the resulting concrete placement sequence is presented in Slide 35. The placement control points (tenth points) were marked on the bridge in spray paint to keep the placement on track. By placing a larger loading on the interior girders, a larger deflection was created and the differential camber between the interior and exterior girders was reduced.

Placement plans help reduce complications during the concrete placement. Concrete should be placed transversely across the bridge, filling each bay in the process. Similar to the plan used for MBISB 2, concrete should be placed sequentially down the length of the bridge in 6 ft to 8ft lengths.

Slide 36: Setting Power Screed Profile

The final elevation of the deck surface in MBISB 2 was set by a power screed that rested on the exterior formwork. The power screed was set to match the transverse crown of the bridge maintaining 3 in. of cover over the top of each girder. In future construction, if a power screed is used, it must be adjustable to conform to the shape of the transverse crown. The power screed profile was established by setting the screed into position at the end of the bridge and adjusting it by measuring from the top flange of the girders.

Formwork Surface Preparation

Slide 37

Concrete Placement: First Lift

- First lift: windrow on interior formwork

Slide 38

Concrete Placement: Second Lift

- Second lift: concrete 1/2 the depth of the arched section

Slide 39

Concrete Placement: Third Lift

- Third lift: concrete to the ASC depth

Slide 40

Slide 37: Formwork Surface Preparation

Before the concrete placement, both the interior and exterior formwork was oiled to ensure the formwork would release from the concrete. Care was taken during the oiling process to prevent excess oil from getting on the webs of the longitudinal girders and the reinforcing steel. A piece of cardboard was placed between the web of the girder and the interior formwork to assist in the containment of the form oil as shown in Slide 37.

Slide 38: Concrete Placement, First Lift

The deck concrete was placed in four distinct lifts; the concrete lifts should be sequentially staggered down the length of the bridge as detailed in the concrete placement plan. The first lift involved placing a windrow of concrete down the middle of the arched interior formwork to cause the formwork to "arch out" against the wooden spacer blocks. This first lift "preloads" the formwork to counteract the lateral loading of the plastic concrete.

Slide 39: Concrete Placement, Second Lift

In the second lift, concrete was placed on each side of the arched interior formwork (to a depth of approximately one half the girder depth as shown) to counteract the lateral pressure of the plastic concrete. After placement, the second lift of concrete was vibrated to ensure adequate consolidation.

Slide 40: Concrete Placement, Third Lift

The third lift of concrete raised the depth to the level of the ASC holes. As with the second lift, the concrete must be placed on each side of the arched interior formwork to balance the lateral concrete forces and be appropriately consolidated. The concrete was raised to the level of the ASC holes to prepare for the final lift when the concrete flows through the holes forming the shear dowels necessary to complete the ASC.

Concrete Placement: Fourth Lift

- Fourth lift: final deck elevation

Slide 41

Texturing Deck Surface

Slide 42

Curing of Concrete

- Sealed with curing compound
- Canvas tarplin added to aid curing

Slide 43

Stripping Exterior Formwork

Slide 44

Slide 41: Concrete Placement, Fourth Lift

The fourth and final lift raises the plastic concrete to the final deck elevation. During this phase of the placement, special attention must be paid to ensure adequate vibration of the concrete near the girders so the concrete flows through the ASC holes. The deck surface was struck off and finished with a power screed.

Slide 42: Texturing Deck Surface

The deck surface of MBISB 2 was textured using a broom to provide a roughened surface. Scarifying the deck surface with a stiff tined rake was ruled out since the depth could not be readily controlled.

Slide 43: Curing of Concrete

After the deck had initial cure, curing compound was applied and the deck covered with canvas tarps to aid in the curing process. The tarps were left in place for seven days before being removed.

Slide 44: Stripping Exterior Formwork

The formwork was stripped in two stages; the exterior formwork was stripped seven days after the concrete placement while the interior arched formwork was removed four months after the concrete placement during the construction off season. The exterior formwork support arms were removed first, leaving the exterior formwork panels supported by only the wire and the guardrail bolts. The wires were cut, one panel at a time, and the panels were removed from the bridge.


Stripping Interior Formwork
Slide 45


Guardrail Anchor Rods
Slide 46


Installed Guardrail
Slide 47


Completed MBISB
Slide 48

Slide 45: Stripping Interior Formwork

As previously stated, the bridge was in service for approximately four months before the interior formwork was removed during the construction off season. The formwork was removed by unbolting the individual arch sections and “popping” them loose with a small pry bar. All of the bolts that held the individual sections and the batteries together were removed without any difficulty and all the arched sections were recovered. The duct tape used to seal the seams of the individual sections proved to be important in that it prevented the “entrapment” of the individual sections at the joints. The removed arched sections were marked to aid in future assembly and then stacked together for storage.

Slide 46: Installed Guardrail Anchor Rods

After the exterior formwork was removed, the installed guardrail anchor rods were exposed and the remainder of the guardrail system was installed. Steel bearing plates are held in place by nuts on the threaded anchor rods; the upright posts, consisting of galvanized ST 6x3x1/4 structural tubes, were then bolted to the steel bearing plates.

Slide 47: Installed Guardrail

A rolled Thrie beam rail was bolted to the upright posts to complete the guardrail system. A close up view of the guardrail connection and an overall view of the completed guardrail is presented in Slide 47.

Slide 48: Completed MBISB

The completed MBISB 2 demonstration bridge is shown in Slide 48. The overall cost of the bridge was approximately \$52 per ft^2 of surface area making the MBISB system competitive with conventional bridge designs. The actual cost of such a structure will be influenced by site and market conditions.

Testing MBISB 2

Slide 49

Acknowledgements

– Sponsor: Iowa Department of Transportation, Highway Division and the Iowa Highway Research Board
– Tama County Engineer, Lyle Brehm, and the Tama County Bridge Crew
– ISU Research Laboratory Manager
– Numerous ISU undergraduate students

Slide 50

Slide 49: Testing MBISB 2

The second demonstration bridge was field tested to compare the actual behavior of the structure when subjected to a typical truck loading to design parameters. Instrumentation was installed at critical locations to measure the bridge's response. Results from the field tests indicated the structure met all design parameters. A more detailed description of the field test and the results obtained can be found in Volume 1 of the Iowa DOT report (TR-467) (*6*).

Slide 50: Acknowledgements

The study presented in this paper was conducted by the Bridge Engineering Center at Iowa State University through funding provided by the Iowa Department of Transportation, Highway Division and the Iowa Highway Research Board. The authors wish to thank the Tama County Engineer, Lyle Brehm, the Tama County Bridge Crew and Doug Wood, ISU Research Laboratory Manager for their help with the construction, instrumentation, and field testing of the demonstration bridges. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation.

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The purpose of this Design Manual, Volume 2 of the final report for Iowa DOT project TR-467, is to provide an engineer with the information required to design and construct a specific MBISB system. This includes an example problem which details the steps and calculations required to complete a MBISB. The example utilizes the design output from the Design Manual (Appendix A) for a series of selected geometric configurations and material strengths. The Design Manual also includes a PowerPoint slide show describing the construction process used in the construction of the second demonstration bridge, MBISB 2. The slide show is meant to be a guide for the engineer and the construction crew by addressing the nuances of implementing the ASC and the transverse arch.

5.1.1 Evaluation of Design Output

Using the design methodology developed and presented in the Design Guide, numerous MBISB designs were generated based on the following six variables:

- Bridge length = 65 ft
- Bridge width = 32 ft
- Girder spacing = 6 ft
- Steel yield strength = 50 ksi
- Concrete compressive strength = 4 ksi
- Depth of cover = 3 in.

The generated tabular output presents design information for MBISBs ranging in length from 40 ft to 80 ft increasing in length by 5 ft increments. Design combinations for two bridge widths, 26 ft and 32 ft, and two steel yield strengths, 36 ksi and 50 ksi, are also presented while the concrete compressive strength of 4 ksi is held constant in all designs. Two cases of concrete cover are considered, zero cover where the concrete is struck off even with the top flanges and

3 in. of cover where the top flange of the girders is embedded in the deck concrete. The remaining geometric constraint, the girder spacing, is a function of the selected bridge width and the requirement that the number of girders used be an integer.

For a selected length and width, the engineer can choose from the various possible girder sizes, listed in ascending order by weight, that satisfy the design criteria for a specific girder spacing. This selection will influence the remaining properties of the design since the bridge length, width, girder depth and spacing dictates the remaining output parameters. Using the tabular output, the engineer is given the material quantities for the selected design (the volume of the deck concrete and the weight of the steel girders). With these quantities, the engineer can readily estimate the material costs. Girder fabrication can include the installation of the ASC holes and the desired camber to offset self weight deflections.

Since the MBISB design has rolled W sections for the longitudinal girders, diaphragms are required to brace the compression flanges of the girders during the placement of the concrete deck. The number of diaphragms required and their location are provided in the tabular design output. The size of diaphragm sections required and the connection details, based on the depth of girders used, are given; however, the engineer may use other structurally equivalent diaphragm sections and connection details.

The estimated live load deflection due to a service level loading (HS-20 truck) is presented for the engineer and compared to the L/800 optional deflection limit. If the section fails the deflection criteria, the engineer can compare the values and make an engineering judgment to accept or reject the design (*5*).

Since most LVR bridges cross intermittent streams that occasionally flood, the MBISB design may be inundated and subjected to a lateral sliding force due to water striking the exterior girder. An estimated sliding force for each abutment is presented based on the bridge being overtopped by 6 in. of water flowing at 10 mph. The abutment connection should be able to resist such a lateral force and thus prevent the bridge from being pushed off the abutment.

5.1.2 Design Specific Parameters

The tabular output provides the engineer with multiple combinations for a given set of geometric parameters and material strengths but does not present all the details required for a particular design. Additional calculations are presented in Chapter 3 of the Design Manual (Volume 2) to provide information on the formwork, reinforcement, etc. required.

5.1.2.1 Cross Slope

Cross slope must be introduced to the MBISB design to provide for adequate deck drainage. Cross slope can be introduced by placing steel spacer blocks of varying thickness beneath the longitudinal girders. The number and thickness of the required blocks is a function of the number and spacing of the girders.

5.1.2.2 Formwork

Due to the implemented modifications, the ASC and the transverse arch, the MBISB system requires a different formwork system than conventional designs. The formwork can be divided into interior and exterior systems. The interior formwork consists of the custom rolled arched formwork constructed from the same material as CMP; the sections are rolled to the radius indicated in the tabular output to provide adequate cover and deck thickness. The sections are best assembled offsite, transported to the bridge and placed between the girders. After adequate curing of the concrete, the interior formwork can be removed and prepared for future use on another MBISB.

The developed MBISB design methodology relies on composite action between the girders and the concrete; therefore, the transverse reinforcement in the ASC requires adequate embedment to develop full tension. An overhang on the exterior side of the exterior girders is provided so that of the ASC reinforcement can develop. The exterior formwork is supported by support arms designed for use with the MBISB system.

Plans for the interior and exterior formwork as well as the exterior formwork supports are included in the design manual. Relationships are also provided for determining the number of formwork components required in the selected design.

5.1.2.3 Reinforcement

Due to the transverse arch, the reinforcement required in the deck of a MBISB is significantly less than that required in a conventional steel girder/concrete slab bridge. Laboratory testing indicated that the only reinforcement needed in the deck is the transverse reinforcement (#5 Grade 60 reinforcing bars) completing the ASC; similar reinforcement is required in the backwalls. Longitudinal temperature and shrinkage reinforcement (#4 Grade 60 reinforcing bars) is also specified to control transverse cracking. For MBISB designs with 3 in. of cover over the steel girders, an additional layer of transverse reinforcement (#3 Grade 60 reinforcing bars) is required to control temperature and shrinkage effects. Relationships are provided to calculate the amount of reinforcement required in a particular MBISB.

5.1.2.4 Tension Rods

Tension rods are attached to the bottom flange of the longitudinal girders with custom clips to prevent the girders from bending out of plane during the placement of the concrete deck. The tension rods also served as a means to align the girders prior to the installation of the diaphragms. Based on the measured strains in the tension rods resulting from the service level field testing, the tension rods can be removed and reused on future MBISBs.

5.1.3 Construction Slide Show

A PowerPoint slide show, complete with explanations, describing the sequence and construction methods used in the construction of MBISB 2 is provided. The procedures presented are those that were used in the construction of MBISB 2. They, however, may be applied in the construction of future MBISBs.

5.2 Conclusions

The Design Manual uses the developed MBISB design methodology to assist engineers in the design of future MBISBs. The MBISB system, defined by the use of the ASC and the transverse arch, is a viable alternative design for use on LVRs for spans ranging from 40 ft to 80 ft. The design meets the original objectives of being lower in cost than conventional systems and is constructible by in-house forces. By applying the information presented in the Design Manual, (Volume 2) an engineer can determine the components required to complete the desired MBISB.

6. ACKNOWLEDGEMENTS

The study presented in this report was conducted by the Iowa State University Bridge Engineering Center under auspices of the Engineering Research Institute of Iowa State University. The research was sponsored by the Project Development Division of the Iowa Department of Transportation and Iowa Research Board under Research Project TR-467.

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Special thanks are extended to the Doug Wood, Manager of the ISU Structural Engineering Laboratory and the following Civil Engineering graduate and undergraduate students for their assistance in various aspects of the project: Riley Smith, Eric Cannon, Ben Woline, Curtis Holub, Jonathon Greenlee, Milan Jolley, Holly Boomsma, Alfred Wessling, Toni Tabbert, Ben Drier, Kristine Palmer, Emily Allison, Toshia Akers and Michelle Heikens.

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APPENDIX A

Tabular Design Output

This appendix contains the design output for the design methodology developed for the MBISB system based on the following design variables.

- Bridge length
- Bridge width
- Girder spacing
- Steel yield strength
- Concrete compressive strength
- Depth of cover

The tabular design outputs are divided into four groups based on the two design widths (26 ft and 32 ft) and the two steel yield strengths, (36 ksi and 50 ksi). Within each design groups, nine bridge lengths (if applicable, MBISBs constructed with 36 ksi steel are limited to spans of 70 ft) are considered ranging from 40 ft to 80 ft in increments of 5 ft. For each length, two cases of concrete cover above the top flanges (3 in. and 0 in.) are presented. The concrete compressive strength is 4 ksi in all the designs.

Each table is labeled with the follow format:

Table A26.1.65.3

Table A 26 . 1 . 65 . 3

A= Appendix A

26 or 32 = Width of the bridge, ft

1 or 2 = Steel yield strength in ksi, (1 = 36 ksi, 2 = 50 ksi)

65 = bridge length, ft (ranges from 40 ft to 80 ft by 5 ft increments)

3 or 0 = Cover over the top flanges of the girder, in.

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Group 1

Bridge Width = 26 ft

Steel Yield Strength = 36 ksi

Table A26.1.40.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W24X84	17.5	40	17.22	1.5	1	1	0	0.276	Y	14.3
	W21X93	15	38	19.07	1.5	1	1	0	0.349	Y	12.7
	W27X94	20.5	43	19.27	1.25	0.75	1	0	0.201	Y	16.1
	W24X94	17.5	40	19.27	1.5	1	1	0	0.259	Y	14.4
	W30X99	23.5	46	20.3	1.25	0.75	1	0	0.156	Y	18
6 @ 4.8 ft	W24X76	17.5	42	18.7	1.5	1	1	0	0.261	Y	14.1
	W21X83	15	39	20.42	1.5	1	1	0	0.332	Y	12.6
	W24X84	17.5	42	20.66	1.5	1	1	0	0.246	Y	14.3
	W21X93	15	40	22.88	1.5	1	1	0	0.311	Y	12.7
	W27X94	20.5	46	23.12	1.25	0.75	1	0	0.179	Y	16.1
7 @ 4 ft	W21X68	15	41	19.52	1.75	1.25	1	0	0.334	Y	12.4
	W21X73	15	41	20.95	1.5	1	1	0	0.322	Y	12.4
	W24X76	17.5	45	21.81	1.5	1	1	0	0.236	Y	14.1
	W21X83	15	41	23.82	1.5	1	1	0	0.301	Y	12.6
	W24X84	17.5	45	24.11	1.25	0.75	1	0	0.223	Y	14.3
9 @ 3 ft	W21X62	15	45	22.88	1.5	1	1	0	0.298	Y	12.3
	W21X68	15	45	25.09	1.5	1	1	0	0.285	Y	12.4
	W21X73	15	45	26.94	1.5	1	1	0	0.274	Y	12.4
	W21X83	15	45	30.63	1.25	0.75	1	0	0.256	Y	12.6
	W18X86	12	40	31.73	1.5	1	0	0	0.342	Y	10.7

Table A26.1.40.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W24X84	17.5	31	17.22	1.25	0.75	1	0	0.371	Y	12.4
	W27X94	20.5	34	19.27	1.25	0.75	1	0	0.264	Y	14.1
	W24X94	17.5	31	19.27	1.25	0.75	1	0	0.345	Y	12.5
	W30X99	23.5	37	20.3	1.25	0.75	1	0	0.202	Y	16
	W21X101	15	29	20.7	1.25	0.75	0	0	0.443	Y	10.7
6 @ 4.8 ft	W24X76	17.5	33	18.7	1.25	0.75	1	0	0.351	Y	12.3
	W24X84	17.5	34	20.66	1.25	0.75	1	0	0.328	Y	12.4
	W21X93	15	31	22.88	1.25	0.75	1	0	0.42	Y	10.9
	W27X94	20.5	37	23.12	1.25	0.75	1	0	0.234	Y	14.1
	W24X94	17.5	34	23.12	1.25	0.75	1	0	0.305	Y	12.5
7 @ 4 ft	W21X73	15	32	20.95	1.5	1	1	0	0.44	Y	10.6
	W24X76	17.5	36	21.81	1.25	0.75	1	0	0.316	Y	12.3
	W21X83	15	32	23.82	1.25	0.75	1	0	0.407	Y	10.7
	W24X84	17.5	36	24.11	1.25	0.75	1	0	0.295	Y	12.4
	W18X86	12	29	24.68	1.5	1	0	0	0.555	Y	9
9 @ 3 ft	W21X62	15	36	22.88	1.5	1	1	0	0.408	Y	10.5
	W21X68	15	36	25.09	1.25	0.75	1	0	0.386	Y	10.6
	W21X73	15	36	26.94	1.25	0.75	1	0	0.369	Y	10.6
	W21X83	15	36	30.63	1.25	0.75	1	0	0.341	Y	10.7
	W18X86	12	31	31.73	1.25	0.75	0	0	0.462	Y	9

Note: Optional Deflection Control Limit for 40 ft = 0.6 in.

Table A26.1.45.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	48	21.62	1.75	1.25	1	0	0.311	Y	18.1
	W30X99	23.5	51	22.77	1.5	1	1	0	0.24	Y	20.3
	W27X102	20.5	48	23.46	1.75	1.25	1	0	0.295	Y	18.3
	W24X103	17.5	45	23.69	1.75	1.25	1	0	0.379	Y	16.3
	W24X104	17.5	45	23.92	1.75	1.25	1	0	0.38	Y	16.1
6 @ 4.8 ft	W21X93	15	44	25.67	2	1.5	1	0	0.479	Y	14.3
	W27X94	20.5	52	25.94	1.5	1	1	0	0.277	Y	18.1
	W24X94	17.5	48	25.94	1.75	1.25	1	0	0.356	Y	16.2
	W30X99	23.5	56	27.32	1.5	1	1	0	0.215	Y	20.3
	W21X101	15	44	27.88	1.75	1.25	1	0	0.45	Y	14.1
7 @ 4 ft	W24X76	17.5	50	24.47	1.75	1.25	1	0	0.365	Y	15.9
	W21X83	15	46	26.73	2	1.5	1	0	0.464	Y	14.1
	W24X84	17.5	50	27.05	1.75	1.25	1	0	0.344	Y	16.1
	W21X93	15	46	29.95	1.75	1.25	1	0	0.434	Y	14.3
	W27X94	20.5	55	30.27	1.5	1	1	0	0.251	Y	18.1
9 @ 3 ft	W21X73	15	50	30.22	2	1.5	1	0	0.423	Y	14
	W21X83	15	51	34.36	1.75	1.25	1	0	0.395	Y	14.1
	W18X86	12	45	35.6	1.75	1.25	1	0	0.528	Y	12.1
	W21X93	15	51	38.5	1.75	1.25	1	0	0.369	Y	14.3
	W18X97	12	45	40.16	1.75	1.25	1	0	0.487	Y	12.2

Table A26.1.45.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	38	21.62	1.5	1	1	0	0.408	Y	15.9
	W30X99	23.5	41	22.77	1.5	1	1	0	0.312	Y	18
	W27X102	20.5	38	23.46	1.5	1	1	0	0.385	Y	16.1
	W24X104	17.5	35	23.92	1.5	1	0	0	0.501	Y	13.9
	W30X108	23.5	41	24.84	1.25	0.75	1	0	0.296	Y	18
6 @ 4.8 ft	W27X94	20.5	42	25.94	1.5	1	1	0	0.361	Y	15.9
	W24X94	17.5	38	25.94	1.5	1	1	0	0.47	Y	14.1
	W30X99	23.5	46	27.32	1.25	0.75	1	0	0.276	Y	18
	W21X101	15	34	27.88	1.5	1	0	0	0.6	Y	12.1
	W27X102	20.5	42	28.15	1.5	1	1	0	0.341	Y	16.1
7 @ 4 ft	W24X84	17.5	40	27.05	1.5	1	1	0	0.455	Y	13.9
	W21X93	15	36	29.95	1.5	1	1	0	0.582	Y	12.2
	W27X94	20.5	45	30.27	1.5	1	1	0	0.325	Y	15.9
	W24X94	17.5	41	30.27	1.5	1	1	0	0.423	Y	14.1
	W21X101	15	36	32.52	1.5	1	0	0	0.537	Y	12.1
9 @ 3 ft	W21X83	15	41	34.36	1.5	1	1	0	0.526	Y	12.1
	W18X86	12	35	35.6	1.75	1.25	1	0	0.712	N	10.1
	W21X93	15	41	38.5	1.5	1	1	0	0.486	Y	12.2
	W18X97	12	35	40.16	1.5	1	0	0	0.649	Y	10.2
	W21X101	15	40	41.81	1.25	0.75	0	0	0.447	Y	12.1

Note: Optional Deflection Control Limit for 45 ft = 0.68 in.

Table A26.1.50.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X108	23.5	57	27.54	2	1.5	1	0	0.334	Y	22.6
	W27X114	20.5	54	29.07	2	1.5	1	0	0.404	Y	20.5
	W30X116	23.5	57	29.58	1.75	1.25	1	0	0.318	Y	22.8
	W24X117	17.5	50	29.84	2.25	1.75	1	0	0.513	Y	18
	W30X124	23.5	58	31.62	1.75	1.25	1	0	0.305	Y	23
6 @ 4.8 ft	W27X94	20.5	57	28.76	2	1.5	1	0	0.402	Y	20.1
	W30X99	23.5	62	30.29	2	1.5	1	0	0.312	Y	22.5
	W27X102	20.5	57	31.21	2	1.5	1	0	0.382	Y	20.3
	W24X103	17.5	53	31.52	2.25	1.75	1	0	0.489	Y	18.2
	W24X104	17.5	52	31.82	2	1.5	1	0	0.49	Y	17.8
7 @ 4 ft	W27X94	20.5	61	33.56	2	1.5	1	0	0.365	Y	20.1
	W24X94	17.5	56	33.56	2.25	1.75	1	0	0.468	Y	18
	W21X101	15	51	36.06	2.25	1.75	1	0	0.59	Y	15.7
	W27X102	20.5	61	36.41	1.75	1.25	1	0	0.346	Y	20.3
	W24X103	17.5	56	36.77	2	1.5	1	0	0.443	Y	18.2
9 @ 3 ft	W21X93	15	56	42.69	2.25	1.75	1	0	0.535	Y	15.9
	W18X97	12	50	44.52	2.25	1.75	1	0	0.707	Y	13.6
	W21X101	15	56	46.36	2	1.5	1	0	0.5	Y	15.7
	W18X106	12	50	48.65	2.25	1.75	1	0	0.671	Y	13.6
	W21X111	15	56	50.95	1.75	1.25	1	0	0.473	Y	15.8

Table A26.1.50.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X108	23.5	46	27.54	1.75	1.25	1	0	0.43	Y	20.1
	W27X114	20.5	42	29.07	1.75	1.25	1	0	0.523	Y	18
	W30X116	23.5	46	29.58	1.75	1.25	1	0	0.407	Y	20.2
	W30X124	23.5	46	31.62	1.5	1	1	0	0.388	Y	20.4
	W27X129	20.5	43	32.9	1.75	1.25	1	0	0.478	Y	18.2
6 @ 4.8 ft	W30X99	23.5	51	30.29	1.75	1.25	1	0	0.401	Y	20
	W27X102	20.5	46	31.21	1.75	1.25	1	0	0.494	Y	17.8
	W30X108	23.5	51	33.05	1.75	1.25	1	0	0.38	Y	20.1
	W27X114	20.5	46	34.88	1.75	1.25	1	0	0.462	Y	18
	W30X116	23.5	51	35.5	1.5	1	1	0	0.36	Y	20.2
7 @ 4 ft	W27X94	20.5	50	33.56	1.75	1.25	1	0	0.471	Y	17.7
	W27X102	20.5	50	36.41	1.75	1.25	1	0	0.445	Y	17.8
	W24X103	17.5	45	36.77	1.75	1.25	1	0	0.576	Y	15.8
	W24X104	17.5	44	37.13	1.75	1.25	1	0	0.575	Y	15.5
	W21X111	15	40	39.63	1.75	1.25	1	0	0.733	Y	13.5
9 @ 3 ft	W21X93	15	45	42.69	2	1.5	1	0	0.706	Y	13.6
	W21X101	15	45	46.36	1.75	1.25	1	0	0.649	Y	13.4
	W18X106	12	39	48.65	2	1.5	1	0	0.887	N	11.5
	W21X111	15	45	50.95	1.75	1.25	1	0	0.609	Y	13.5
	W18X119	12	39	54.62	1.75	1.25	1	0	0.8	N	11.7

Note: Optional Deflection Control Limit for 50 ft = 0.75 in.

Table A26.1.55.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X124	23.5	63	34.72	2.25	1.75	1	0	0.423	Y	25.2
	W27X129	20.5	59	36.12	2.5	2	1	0	0.517	Y	22.8
	W30X132	23.5	63	36.96	2.25	1.75	1	0	0.409	Y	25.3
	W27X146	20.5	59	40.88	2.25	1.75	1	0	0.48	Y	22.6
	W24X146	17.5	55	40.88	2.5	2	1	0	0.616	Y	20.2
6 @ 4.8 ft	W30X108	23.5	68	36.29	2.5	2	1	0	0.413	Y	24.9
	W27X114	20.5	63	38.3	2.5	2	1	0	0.499	Y	22.5
	W30X116	23.5	68	38.98	2.25	1.75	1	0	0.394	Y	25.1
	W30X124	23.5	69	41.66	2.25	1.75	1	0	0.377	Y	25.2
	W27X129	20.5	63	43.34	2.25	1.75	1	0	0.46	Y	22.8
7 @ 4 ft	W27X102	20.5	67	39.98	2.5	2	1	0	0.481	Y	22.3
	W27X114	20.5	68	44.69	2.25	1.75	1	0	0.452	Y	22.5
	W24X117	17.5	61	45.86	2.25	1.75	1	0	0.572	Y	19.8
	W21X122	15	56	47.82	2.5	2	1	0	0.728	Y	17.5
	W27X129	20.5	68	50.57	2	1.5	1	0	0.417	Y	22.8
9 @ 3 ft	W21X101	15	61	50.9	2.5	2	1	0	0.694	Y	17.3
	W21X111	15	61	55.94	2.5	2	1	0	0.657	Y	17.4
	W18X119	12	55	59.98	2.75	2.25	1	0	0.85	N	15.3
	W21X122	15	61	61.49	2.25	1.75	1	0	0.616	Y	17.5
	W18X130	12	56	65.52	2.5	2	1	0	0.785	Y	15.5

Table A26.1.55.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X124	23.5	51	34.72	2	1.5	1	0	0.538	Y	22.4
	W30X132	23.5	51	36.96	2	1.5	1	0	0.518	Y	22.5
	W27X146	20.5	46	40.88	2	1.5	1	0	0.608	Y	19.9
	W24X146	17.5	43	40.88	2	1.5	1	0	0.791	Y	17.5
	W27X161	20.5	47	45.08	1.75	1.25	1	0	0.567	Y	20.1
6 @ 4.8 ft	W30X108	23.5	56	36.29	2	1.5	1	0	0.528	Y	22.1
	W27X114	20.5	51	38.3	2.25	1.75	1	0	0.641	Y	19.8
	W30X116	23.5	56	38.98	2	1.5	1	0	0.5	Y	22.2
	W30X124	23.5	56	41.66	2	1.5	1	0	0.476	Y	22.4
	W27X129	20.5	51	43.34	2	1.5	1	0	0.585	Y	20.1
7 @ 4 ft	W27X114	20.5	55	44.69	2	1.5	1	0	0.576	Y	19.8
	W24X117	17.5	49	45.86	2	1.5	1	0	0.734	Y	17.2
	W27X129	20.5	56	50.57	1.75	1.25	1	0	0.524	Y	20.1
	W24X131	17.5	49	51.35	2	1.5	1	0	0.676	Y	17.4
	W21X132	15	44	51.74	2.25	1.75	1	0	0.894	N	15.1
9 @ 3 ft	W21X111	15	49	55.94	2.25	1.75	1	0	0.845	N	14.9
	W18X119	12	43	59.98	2.25	1.75	1	0	1.109	N	12.8
	W21X122	15	49	61.49	2	1.5	1	0	0.785	Y	15
	W18X130	12	44	65.52	2.25	1.75	1	0	1.013	N	13.1
	W21X132	15	49	66.53	2	1.5	1	0	0.741	Y	15.1

Note: Optional Deflection Control Limit for 55 ft = 0.83 in.

Table A26.1.60.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X146	20.5	64	44.53	2.75	2.25	1	0	0.643	Y	24.7
	W27X161	20.5	64	49.1	2.5	2	1	0	0.603	Y	24.9
6 @ 4.8 ft	W30X124	23.5	75	45.38	2.75	2.25	1	0	0.505	Y	27.5
	W27X129	20.5	69	47.21	2.75	2.25	2	20	0.617	Y	24.9
	W30X132	23.5	75	48.31	2.5	2	1	0	0.488	Y	27.6
	W27X146	20.5	68	53.44	2.5	2	1	0	0.571	Y	24.7
	W24X146	17.5	63	53.44	2.75	2.25	1	0	0.732	Y	22
7 @ 4 ft	W27X114	20.5	74	48.68	3	2.5	2	20	0.606	Y	24.6
	W27X129	20.5	74	55.08	2.75	2.25	1	0	0.558	Y	24.9
	W24X131	17.5	67	55.94	2.75	2.25	1	0	0.713	Y	21.8
	W27X146	20.5	73	62.34	2.25	1.75	1	0	0.516	Y	24.7
	W24X146	17.5	67	62.34	2.5	2	1	0	0.66	Y	22
9 @ 3 ft	W21X122	15	67	66.98	3	2.5	1	0	0.825	Y	19.1
	W18X130	12	61	71.37	3.25	2.75	1	0	1.051	N	16.9
	W21X132	15	67	72.47	2.75	2.25	1	0	0.784	Y	19.2

Table A26.1.60.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X161	20.5	51	49.1	2.25	1.75	1	0	0.759	Y	21.9
6 @ 4.8 ft	W30X124	23.5	61	45.38	2.5	2	1	0	0.638	Y	24.5
	W30X132	23.5	61	48.31	2.25	1.75	1	0	0.612	Y	24.6
	W27X146	20.5	55	53.44	2.25	1.75	1	0	0.716	Y	21.7
	W24X146	17.5	50	53.44	2.5	2	1	0	0.93	N	19.1
	W27X161	20.5	55	58.93	2	1.5	1	0	0.667	Y	21.9
7 @ 4 ft	W27X129	20.5	61	55.08	2.25	1.75	1	0	0.702	Y	21.9
	W24X131	17.5	53	55.94	2.5	2	1	0	0.906	N	18.9
	W27X146	20.5	60	62.34	2	1.5	1	0	0.64	Y	21.7
	W24X146	17.5	54	62.34	2.25	1.75	1	0	0.831	Y	19.1
	W27X161	20.5	60	68.75	2	1.5	1	0	0.596	Y	21.9
9 @ 3 ft	W21X122	15	53	66.98	2.75	2.25	1	0	1.052	N	16.4
	W21X132	15	53	72.47	2.5	2	1	0	0.993	N	16.5

Note: Optional Deflection Control Limit for 60 ft = 0.90 in.

Table A26.1.65.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 4.8 ft	W27X146	20.5	74	57.82	3.25	2.75	1	0	0.743	Y	26.7
	W27X161	20.5	74	63.76	3	2.5	1	0	0.698	Y	26.9
7 @ 4 ft	W27X146	20.5	79	67.45	3	2.5	1	0	0.672	Y	26.7
	W24X146	17.5	72	67.45	3.5	3	1	0	0.86	Y	23.8
	W27X161	20.5	79	74.38	2.75	2.25	1	0	0.63	Y	26.9
9 @ 3 ft	W21X132	15	72	78.41	3.75	3.25	1	0	1.022	N	20.8

Table A26.1.65.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 4.8 ft	W27X161	20.5	60	63.76	2.75	2.25	1	0	0.868	Y	23.7
7 @ 4 ft	W27X146	20.5	65	67.45	2.75	2.25	1	0	0.834	Y	23.5
	W24X146	17.5	58	67.45	3	2.5	1	0	1.082	N	20.7
	W27X161	20.5	65	74.38	2.5	2	1	0	0.776	Y	23.7

Note: Optional Deflection Control Limit for 65 ft = 0.98 in.

Table A26.1.70.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 4 ft	W27X161	20.5	85	80.02	3.5	3	1	0	0.802	Y	29

Table A26.1.70.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 4 ft	W27X161	20.5	70	80.02	3.25	2.75	1	0	0.988	Y	25.5

Note: Optional Deflection Control Limit for 70 ft = 1.05 in.

Group 2

Bridge Width = 32 ft

Steel Yield Strength = 36 ksi

Table A32.1.40.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W24X84	17.5	49	20.66	1.5	1	1	0	0.23	Y	14.3
	W21X93	15	46	22.88	1.5	1	1	0	0.291	Y	12.7
	W27X94	20.5	52	23.12	1.25	0.75	1	0	0.168	Y	16.1
	W24X94	17.5	49	23.12	1.5	1	1	0	0.216	Y	14.4
	W30X99	23.5	56	24.35	1.25	0.75	1	0	0.13	Y	18
7 @ 5 ft	W24X76	17.5	51	21.81	1.5	1	1	0	0.221	Y	14.1
	W21X83	15	48	23.82	1.5	1	1	0	0.281	Y	12.6
	W24X84	17.5	51	24.11	1.5	1	1	0	0.208	Y	14.3
	W21X93	15	48	26.69	1.5	1	1	0	0.263	Y	12.7
	W27X94	20.5	56	26.98	1.25	0.75	1	0	0.152	Y	16.1
8 @ 4.29 ft	W21X73	15	49	23.94	1.5	1	1	0	0.276	Y	12.4
	W24X76	17.5	54	24.93	1.5	1	1	0	0.202	Y	14.1
	W21X83	15	50	27.22	1.5	1	1	0	0.258	Y	12.6
	W24X84	17.5	54	27.55	1.25	0.75	1	0	0.191	Y	14.3
	W18X86	12	45	28.21	1.5	1	1	0	0.346	Y	10.7
9 @ 3.75 ft	W21X68	15	51	25.09	1.5	1	1	0	0.265	Y	12.4
	W21X73	15	51	26.94	1.5	1	1	0	0.255	Y	12.4
	W24X76	17.5	56	28.04	1.25	0.75	1	0	0.188	Y	14.1
	W21X83	15	52	30.63	1.5	1	1	0	0.239	Y	12.6
	W24X84	17.5	56	31	1.25	0.75	1	0	0.177	Y	14.3
11 @ 3 ft	W21X62	15	55	27.96	1.5	1	1	0	0.244	Y	12.3
	W21X68	15	55	30.67	1.5	1	1	0	0.233	Y	12.4
	W21X73	15	55	32.92	1.5	1	1	0	0.224	Y	12.4
	W21X83	15	55	37.43	1.25	0.75	1	0	0.209	Y	12.6
	W18X86	12	49	38.79	1.5	1	0	0	0.28	Y	10.7

Table A32.1.40.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W24X84	17.5	38	20.66	1.25	0.75	1	0	0.309	Y	12.4
	W27X94	20.5	41	23.12	1.25	0.75	1	0	0.22	Y	14.1
	W24X94	17.5	38	23.12	1.25	0.75	1	0	0.288	Y	12.5
	W30X99	23.5	45	24.35	1.25	0.75	1	0	0.168	Y	16
	W21X101	15	35	24.85	1.25	0.75	0	0	0.369	Y	10.7
7 @ 5 ft	W24X76	17.5	40	21.81	1.25	0.75	1	0	0.297	Y	12.3
	W24X84	17.5	40	24.11	1.25	0.75	1	0	0.278	Y	12.4
	W21X93	15	37	26.69	1.25	0.75	1	0	0.357	Y	10.9
	W27X94	20.5	44	26.98	1.25	0.75	1	0	0.198	Y	14.1
	W24X94	17.5	41	26.98	1.25	0.75	1	0	0.259	Y	12.5
8 @ 4.29 ft	W24X76	17.5	43	24.93	1.25	0.75	1	0	0.271	Y	12.3
	W21X83	15	39	27.22	1.25	0.75	1	0	0.35	Y	10.7
	W24X84	17.5	43	27.55	1.25	0.75	1	0	0.254	Y	12.4
	W21X93	15	39	30.5	1.25	0.75	1	0	0.324	Y	10.9
	W27X94	20.5	48	30.83	1	0.5	1	0	0.181	Y	14.1
9 @ 3.75 ft	W21X68	15	40	25.09	1.5	1	1	0	0.364	Y	10.6
	W21X73	15	40	26.94	1.25	0.75	1	0	0.348	Y	10.6
	W24X76	17.5	45	28.04	1.25	0.75	1	0	0.25	Y	12.3
	W21X83	15	40	30.63	1.25	0.75	1	0	0.322	Y	10.7
	W24X84	17.5	45	31	1.25	0.75	1	0	0.234	Y	12.4
11 @ 3 ft	W21X62	15	44	27.96	1.5	1	1	0	0.334	Y	10.5
	W21X68	15	44	30.67	1.25	0.75	1	0	0.316	Y	10.6
	W21X73	15	44	32.92	1.25	0.75	1	0	0.302	Y	10.6
	W21X83	15	44	37.43	1.25	0.75	1	0	0.279	Y	10.7
	W18X86	12	38	38.79	1.25	0.75	0	0	0.378	Y	9

Note: Optional Deflection Control Limit for 40 ft = 0.6 in.

Table A32.1.45.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X94	20.5	59	25.94	1.75	1.25	1	0	0.259	Y	18.1
	W30X99	23.5	63	27.32	1.5	1	1	0	0.2	Y	20.3
	W27X102	20.5	59	28.15	1.75	1.25	1	0	0.246	Y	18.3
	W24X103	17.5	55	28.43	1.75	1.25	1	0	0.315	Y	16.3
	W24X104	17.5	55	28.7	1.75	1.25	1	0	0.316	Y	16.1
7 @ 5 ft	W27X94	20.5	62	30.27	1.75	1.25	1	0	0.234	Y	18.1
	W24X94	17.5	58	30.27	1.75	1.25	1	0	0.301	Y	16.2
	W30X99	23.5	68	31.88	1.5	1	1	0	0.182	Y	20.3
	W21X101	15	53	32.52	1.75	1.25	1	0	0.381	Y	14.1
	W27X102	20.5	63	32.84	1.5	1	1	0	0.223	Y	18.3
8 @ 4.29 ft	W24X84	17.5	60	30.91	1.75	1.25	1	0	0.295	Y	16.1
	W21X93	15	56	34.22	2	1.5	1	0	0.372	Y	14.3
	W27X94	20.5	66	34.59	1.5	1	1	0	0.215	Y	18.1
	W24X94	17.5	61	34.59	1.75	1.25	1	0	0.276	Y	16.2
	W21X101	15	55	37.17	1.75	1.25	1	0	0.349	Y	14.1
9 @ 3.75 ft	W24X76	17.5	63	31.46	1.75	1.25	1	0	0.29	Y	15.9
	W21X83	15	58	34.36	2	1.5	1	0	0.368	Y	14.1
	W24X84	17.5	63	34.78	1.75	1.25	1	0	0.273	Y	16.1
	W21X93	15	58	38.5	1.75	1.25	1	0	0.344	Y	14.3
	W24X94	17.5	64	38.92	1.5	1	1	0	0.256	Y	16.2
11 @ 3 ft	W21X73	15	62	36.94	2	1.5	1	0	0.346	Y	14
	W21X83	15	62	42	1.75	1.25	1	0	0.323	Y	14.1
	W18X86	12	55	43.52	1.75	1.25	1	0	0.432	Y	12.1
	W21X93	15	62	47.06	1.75	1.25	1	0	0.302	Y	14.3
	W18X97	12	56	49.08	1.75	1.25	1	0	0.399	Y	12.2

Table A32.1.45.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X94	20.5	46	25.94	1.5	1	1	0	0.34	Y	15.9
	W30X99	23.5	51	27.32	1.5	1	1	0	0.26	Y	18
	W27X102	20.5	46	28.15	1.5	1	1	0	0.321	Y	16.1
	W24X104	17.5	42	28.7	1.5	1	0	0	0.418	Y	13.9
	W30X108	23.5	51	29.81	1.25	0.75	1	0	0.247	Y	18
7 @ 5 ft	W27X94	20.5	50	30.27	1.5	1	1	0	0.306	Y	15.9
	W24X94	17.5	45	30.27	1.5	1	1	0	0.399	Y	14.1
	W30X99	23.5	55	31.88	1.25	0.75	1	0	0.234	Y	18
	W27X102	20.5	50	32.84	1.5	1	1	0	0.289	Y	16.1
	W24X103	17.5	46	33.17	1.5	1	1	0	0.375	Y	14.2
8 @ 4.29 ft	W24X84	17.5	48	30.91	1.5	1	1	0	0.391	Y	13.9
	W21X93	15	43	34.22	1.75	1.25	1	0	0.5	Y	12.2
	W27X94	20.5	53	34.59	1.5	1	1	0	0.279	Y	15.9
	W24X94	17.5	48	34.59	1.5	1	1	0	0.363	Y	14.1
	W21X101	15	43	37.17	1.5	1	0	0	0.462	Y	12.1
9 @ 3.75 ft	W24X76	17.5	51	31.46	1.5	1	1	0	0.386	Y	13.8
	W24X84	17.5	51	34.78	1.5	1	1	0	0.36	Y	13.9
	W21X93	15	46	38.5	1.5	1	1	0	0.46	Y	12.2
	W24X94	17.5	51	38.92	1.5	1	1	0	0.334	Y	14.1
	W18X97	12	40	40.16	1.75	1.25	1	0	0.617	Y	10.2
11 @ 3 ft	W21X83	15	50	42	1.5	1	1	0	0.43	Y	12.1
	W18X86	12	43	43.52	1.75	1.25	1	0	0.583	Y	10.1
	W21X93	15	50	47.06	1.5	1	1	0	0.398	Y	12.2
	W18X97	12	43	49.08	1.5	1	0	0	0.531	Y	10.2
	W21X101	15	49	51.11	1.25	0.75	0	0	0.366	Y	12.1

Note: Optional Deflection Control Limit for 45 ft = 0.68 in.

Table A32.1.50.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X108	23.5	70	33.05	2	1.5	1	0	0.278	Y	22.6
	W27X114	20.5	66	34.88	2	1.5	1	0	0.337	Y	20.5
	W30X116	23.5	70	35.5	1.75	1.25	1	0	0.265	Y	22.8
	W24X117	17.5	61	35.8	2.25	1.75	1	0	0.428	Y	18
	W30X124	23.5	71	37.94	1.75	1.25	1	0	0.254	Y	23
7 @ 5 ft	W30X99	23.5	75	35.34	2	1.5	1	0	0.264	Y	22.5
	W27X102	20.5	69	36.41	2	1.5	1	0	0.323	Y	20.3
	W24X104	17.5	64	37.13	2.25	1.75	1	0	0.415	Y	17.8
	W30X108	23.5	75	38.56	1.75	1.25	1	0	0.252	Y	22.6
	W27X114	20.5	70	40.7	2	1.5	1	0	0.305	Y	20.5
8 @ 4.29 ft	W27X94	20.5	73	38.35	2	1.5	1	0	0.312	Y	20.1
	W24X94	17.5	67	38.35	2.25	1.75	1	0	0.401	Y	18
	W27X102	20.5	73	41.62	2	1.5	1	0	0.297	Y	20.3
	W24X103	17.5	68	42.02	2	1.5	1	0	0.379	Y	18.2
	W24X104	17.5	67	42.43	2	1.5	1	0	0.38	Y	17.8
9 @ 3.75 ft	W24X94	17.5	70	43.15	2	1.5	1	0	0.371	Y	18
	W21X101	15	64	46.36	2.25	1.75	1	0	0.468	Y	15.7
	W24X103	17.5	71	47.28	2	1.5	1	0	0.351	Y	18.2
	W24X104	17.5	70	47.74	2	1.5	1	0	0.351	Y	17.8
	W21X111	15	64	50.95	2	1.5	1	0	0.443	Y	15.8
11 @ 3 ft	W21X93	15	69	52.17	2.25	1.75	1	0	0.438	Y	15.9
	W18X97	12	62	54.42	2.25	1.75	1	0	0.578	Y	13.6
	W21X101	15	68	56.66	2	1.5	1	0	0.409	Y	15.7
	W18X106	12	62	59.47	2.25	1.75	1	0	0.549	Y	13.6
	W21X111	15	68	62.27	1.75	1.25	1	0	0.387	Y	15.8

Table A32.1.50.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X108	23.5	56	33.05	1.75	1.25	1	0	0.358	Y	20.1
	W27X114	20.5	52	34.88	1.75	1.25	1	0	0.436	Y	18
	W30X116	23.5	56	35.5	1.75	1.25	1	0	0.339	Y	20.2
	W30X124	23.5	57	37.94	1.5	1	1	0	0.323	Y	20.4
	W27X129	20.5	52	39.47	1.75	1.25	1	0	0.398	Y	18.2
7 @ 5 ft	W30X99	23.5	61	35.34	1.75	1.25	1	0	0.34	Y	20
	W27X102	20.5	56	36.41	1.75	1.25	1	0	0.419	Y	17.8
	W30X108	23.5	61	38.56	1.75	1.25	1	0	0.322	Y	20.1
	W27X114	20.5	56	40.7	1.75	1.25	1	0	0.392	Y	18
	W30X116	23.5	61	41.41	1.5	1	1	0	0.305	Y	20.2
8 @ 4.29 ft	W27X94	20.5	59	38.35	1.75	1.25	1	0	0.405	Y	17.7
	W27X102	20.5	60	41.62	1.75	1.25	1	0	0.382	Y	17.8
	W24X103	17.5	54	42.02	1.75	1.25	1	0	0.495	Y	15.8
	W24X104	17.5	53	42.43	1.75	1.25	1	0	0.494	Y	15.5
	W21X111	15	48	45.29	1.75	1.25	1	0	0.631	Y	13.5
9 @ 3.75 ft	W24X94	17.5	57	43.15	1.75	1.25	1	0	0.485	Y	15.6
	W21X101	15	50	46.36	2	1.5	1	0	0.616	Y	13.4
	W24X103	17.5	57	47.28	1.75	1.25	1	0	0.455	Y	15.8
	W24X104	17.5	56	47.74	1.75	1.25	1	0	0.454	Y	15.5
	W21X111	15	50	50.95	1.75	1.25	1	0	0.579	Y	13.5
11 @ 3 ft	W21X93	15	55	52.17	2	1.5	1	0	0.578	Y	13.6
	W21X101	15	55	56.66	1.75	1.25	1	0	0.531	Y	13.4
	W18X106	12	48	59.47	2	1.5	1	0	0.726	Y	11.5
	W21X111	15	54	62.27	1.75	1.25	1	0	0.498	Y	13.5
	W18X119	12	48	66.76	1.75	1.25	1	0	0.654	Y	11.7

Note: Optional Deflection Control Limit for 50 ft = 0.75 in.

Table A32.1.55.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X124	23.5	78	41.66	2.25	1.75	1	0	0.353	Y	25.2
	W27X129	20.5	73	43.34	2.5	2	1	0	0.431	Y	22.8
	W30X132	23.5	78	44.35	2.25	1.75	1	0	0.341	Y	25.3
	W27X146	20.5	72	49.06	2.25	1.75	1	0	0.4	Y	22.6
	W24X146	17.5	67	49.06	2.5	2	1	0	0.513	Y	20.2
7 @ 5 ft	W30X108	23.5	82	42.34	2.5	2	1	0	0.35	Y	24.9
	W27X114	20.5	76	44.69	2.5	2	1	0	0.423	Y	22.5
	W30X116	23.5	83	45.47	2.25	1.75	1	0	0.333	Y	25.1
	W30X124	23.5	83	48.61	2.25	1.75	1	0	0.319	Y	25.2
	W27X129	20.5	77	50.57	2.25	1.75	1	0	0.39	Y	22.8
8 @ 4.29 ft	W27X102	20.5	81	45.7	2.5	2	1	0	0.412	Y	22.3
	W27X114	20.5	81	51.07	2.25	1.75	1	0	0.387	Y	22.5
	W24X117	17.5	73	52.42	2.5	2	1	0	0.49	Y	19.8
	W21X122	15	68	54.66	2.75	2.25	1	0	0.625	Y	17.5
	W27X129	20.5	81	57.79	2	1.5	1	0	0.357	Y	22.8
9 @ 3.75 ft	W24X103	17.5	78	51.91	2.5	2	1	0	0.487	Y	20
	W24X104	17.5	77	52.42	2.5	2	1	0	0.488	Y	19.6
	W24X117	17.5	77	58.97	2.25	1.75	1	0	0.453	Y	19.8
	W21X122	15	70	61.49	2.5	2	1	0	0.577	Y	17.5
	W18X130	12	65	65.52	2.75	2.25	1	0	0.736	Y	15.5
11 @ 3 ft	W21X101	15	75	62.22	2.5	2	1	0	0.568	Y	17.3
	W21X111	15	75	68.38	2.5	2	1	0	0.537	Y	17.4
	W18X119	12	68	73.3	2.75	2.25	1	0	0.695	Y	15.3
	W21X122	15	75	75.15	2.25	1.75	1	0	0.504	Y	17.5
	W18X130	12	68	80.08	2.5	2	1	0	0.642	Y	15.5

Table A32.1.55.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X124	23.5	62	41.66	2	1.5	1	0	0.449	Y	22.4
	W30X132	23.5	62	44.35	2	1.5	1	0	0.431	Y	22.5
	W27X146	20.5	57	49.06	2	1.5	1	0	0.506	Y	19.9
	W24X146	17.5	52	49.06	2	1.5	1	0	0.659	Y	17.5
	W27X161	20.5	57	54.1	1.75	1.25	1	0	0.472	Y	20.1
7 @ 5 ft	W30X116	23.5	67	45.47	2	1.5	1	0	0.424	Y	22.2
	W30X124	23.5	68	48.61	2	1.5	1	0	0.404	Y	22.4
	W27X129	20.5	62	50.57	2	1.5	1	0	0.496	Y	20.1
	W24X131	17.5	55	51.35	2	1.5	1	0	0.641	Y	17.4
	W30X132	23.5	68	51.74	1.75	1.25	1	0	0.388	Y	22.5
8 @ 4.29 ft	W27X114	20.5	66	51.07	2	1.5	1	0	0.495	Y	19.8
	W24X117	17.5	58	52.42	2.25	1.75	1	0	0.631	Y	17.2
	W27X129	20.5	66	57.79	2	1.5	1	0	0.451	Y	20.1
	W24X131	17.5	58	58.69	2	1.5	1	0	0.582	Y	17.4
	W21X132	15	53	59.14	2.25	1.75	1	0	0.771	Y	15.1
9 @ 3.75 ft	W24X117	17.5	62	58.97	2	1.5	1	0	0.58	Y	17.2
	W21X122	15	55	61.49	2.25	1.75	1	0	0.747	Y	15
	W24X131	17.5	62	66.02	2	1.5	1	0	0.534	Y	17.4
	W21X132	15	55	66.53	2	1.5	1	0	0.706	Y	15.1
	W24X146	17.5	62	73.58	1.75	1.25	1	0	0.489	Y	17.5
11 @ 3 ft	W21X111	15	60	68.38	2.25	1.75	1	0	0.691	Y	14.9
	W18X119	12	53	73.3	2.25	1.75	1	0	0.907	N	12.8
	W21X122	15	60	75.15	2	1.5	1	0	0.642	Y	15
	W18X130	12	53	80.08	2.25	1.75	1	0	0.829	N	13.1
	W21X132	15	60	81.31	2	1.5	1	0	0.606	Y	15.1

Note: Optional Deflection Control Limit for 55 ft = 0.83 in.

Table A32.1.60.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X146	20.5	78	53.44	2.75	2.25	1	0	0.536	Y	24.7
	W27X161	20.5	79	58.93	2.5	2	1	0	0.503	Y	24.9
7 @ 5 ft	W30X124	23.5	91	52.95	2.75	2.25	2	20	0.428	Y	27.5
	W30X132	23.5	91	56.36	2.75	2.25	1	0	0.413	Y	27.6
	W27X146	20.5	83	62.34	2.5	2	1	0	0.483	Y	24.7
	W24X146	17.5	77	62.34	3	2.5	1	0	0.62	Y	22
	W27X161	20.5	83	68.75	2.5	2	1	0	0.454	Y	24.9
8 @ 4.29 ft	W27X129	20.5	89	62.95	2.75	2.25	1	0	0.478	Y	24.9
	W24X131	17.5	80	63.93	3	2.5	1	0	0.611	Y	21.8
	W27X146	20.5	88	71.25	2.5	2	1	0	0.442	Y	24.7
	W24X146	17.5	80	71.25	2.75	2.25	1	0	0.567	Y	22
	W27X161	20.5	88	78.57	2.25	1.75	1	0	0.415	Y	24.9
9 @ 3.75 ft	W24X131	17.5	84	71.92	2.75	2.25	1	0	0.565	Y	21.8
	W21X132	15	77	72.47	3	2.5	1	0	0.736	Y	19.2
	W24X146	17.5	84	80.15	2.5	2	1	0	0.523	Y	22
11 @ 3 ft	W21X122	15	82	81.86	3	2.5	1	0	0.675	Y	19.1
	W18X130	12	74	87.23	3.25	2.75	1	0	0.86	Y	16.9
	W21X132	15	82	88.57	2.75	2.25	1	0	0.642	Y	19.2

Table A32.1.60.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X161	20.5	62	58.93	2.25	1.75	1	0	0.633	Y	21.9
7 @ 5 ft	W30X132	23.5	74	56.36	2.25	1.75	1	0	0.519	Y	24.6
	W27X146	20.5	66	62.34	2.25	1.75	1	0	0.608	Y	21.7
	W24X146	17.5	60	62.34	2.5	2	1	0	0.789	Y	19.1
	W27X161	20.5	67	68.75	2.25	1.75	1	0	0.566	Y	21.9
8 @ 4.29 ft	W27X129	20.5	72	62.95	2.5	2	1	0	0.604	Y	21.9
	W27X146	20.5	71	71.25	2.25	1.75	1	0	0.551	Y	21.7
	W24X146	17.5	64	71.25	2.25	1.75	1	0	0.716	Y	19.1
	W27X161	20.5	71	78.57	2	1.5	1	0	0.513	Y	21.9
9 @ 3.75 ft	W24X131	17.5	67	71.92	2.5	2	1	0	0.715	Y	18.9
	W24X146	17.5	67	80.15	2.25	1.75	1	0	0.656	Y	19.1
11 @ 3 ft	W21X122	15	65	81.86	2.5	2	1	0	0.86	Y	16.4
	W21X132	15	65	88.57	2.5	2	1	0	0.812	Y	16.5

Note: Optional Deflection Control Limit for 60 ft = 0.90 in.

Table A32.1.65.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 5 ft	W27X161	20.5	90	74.38	3	2.5	1	0	0.591	Y	26.9
8 @ 4.29 ft	W27X146	20.5	95	77.09	3	2.5	1	0	0.576	Y	26.7
	W27X161	20.5	95	85.01	3	2.5	1	0	0.54	Y	26.9
9 @ 3.75 ft	W24X146	17.5	91	86.72	3.25	2.75	1	0	0.682	Y	23.8
11 @ 3 ft	W21X132	15	89	95.83	3.75	3.25	1	0	0.836	Y	20.8

Table A32.1.65.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 5 ft	W27X161	20.5	72	74.38	2.75	2.25	1	0	0.737	Y	23.7
8 @ 4.29 ft	W27X146	20.5	77	77.09	2.75	2.25	1	0	0.718	Y	23.5
	W27X161	20.5	77	85.01	2.5	2	1	0	0.669	Y	23.7
9 @ 3.75 ft	W24X146	17.5	73	86.72	2.75	2.25	1	0	0.854	Y	20.7

Note: Optional Deflection Control Limit for 65 ft = 0.98 in.

Table A32.1.70.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
8 @ 4.29 ft	W27X161	20.5	102	91.45	3.75	3.25	1	0	0.688	Y	29

Table A32.1.70.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
8 @ 4.29 ft	W27X161	20.5	83	91.45	3.25	2.75	1	0	0.851	Y	25.5

Note: Optional Deflection Control Limit for 70 ft = 1.05 in.

Group 3

Bridge Width = 26 ft

Steel Yield Strength = 50 ksi

Table A26.2.40.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W21X62	15	37	12.71	2	1.5	1	0	0.433	Y	12.3
	W21X68	15	37	13.94	2	1.5	1	0	0.414	Y	12.4
	W21X73	15	37	14.96	1.75	1.25	1	0	0.399	Y	12.4
	W24X76	17.5	40	15.58	1.5	1	1	0	0.292	Y	14.1
	W21X83	15	38	17.02	1.75	1.25	1	0	0.373	Y	12.6
6 @ 4.8 ft	W21X62	15	39	15.25	1.75	1.25	1	0	0.385	Y	12.3
	W21X68	15	39	16.73	1.75	1.25	1	0	0.368	Y	12.4
	W21X73	15	39	17.96	1.75	1.25	1	0	0.355	Y	12.4
	W24X76	17.5	42	18.7	1.5	1	1	0	0.261	Y	14.1
	W21X83	15	39	20.42	1.5	1	1	0	0.332	Y	12.6
7 @ 4 ft	W21X62	15	41	17.79	1.75	1.25	1	0	0.35	Y	12.3
	W21X68	15	41	19.52	1.75	1.25	1	0	0.334	Y	12.4
	W21X73	15	41	20.95	1.5	1	1	0	0.322	Y	12.4
	W14X74	8	34	21.24	2.25	1.75	1	0	0.765	N	8.3
	W24X76	17.5	45	21.81	1.5	1	1	0	0.236	Y	14.1
9 @ 3 ft	W14X61	7.5	35	22.51	2.25	1.75	1	0	0.743	N	8.2
	W21X62	15	45	22.88	1.5	1	1	0	0.298	Y	12.3
	W21X68	15	45	25.09	1.5	1	1	0	0.285	Y	12.4
	W14X68	7.5	35	25.09	2	1.5	1	0	0.695	N	8.2
	W12X72	6	33	26.57	2.25	1.75	0	0	0.877	N	7.3

Table A26.2.40.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W21X68	15	28	13.94	1.75	1.25	1	0	0.579	Y	10.6
	W21X73	15	29	14.96	1.5	1	1	0	0.555	Y	10.6
	W24X76	17.5	31	15.58	1.5	1	1	0	0.396	Y	12.3
	W21X83	15	29	17.02	1.5	1	1	0	0.514	Y	10.7
	W24X84	17.5	31	17.22	1.25	0.75	1	0	0.371	Y	12.4
6 @ 4.8 ft	W21X62	15	30	15.25	1.5	1	1	0	0.539	Y	10.5
	W21X68	15	30	16.73	1.5	1	1	0	0.511	Y	10.6
	W21X73	15	30	17.96	1.5	1	1	0	0.49	Y	10.6
	W24X76	17.5	33	18.7	1.25	0.75	1	0	0.351	Y	12.3
	W21X83	15	31	20.42	1.5	1	1	0	0.453	Y	10.7
7 @ 4 ft	W21X62	15	32	17.79	1.5	1	1	0	0.485	Y	10.5
	W21X68	15	32	19.52	1.5	1	1	0	0.46	Y	10.6
	W21X73	15	32	20.95	1.5	1	1	0	0.44	Y	10.6
	W24X76	17.5	36	21.81	1.25	0.75	1	0	0.316	Y	12.3
	W14X82	7.5	25	23.53	1.75	1.25	1	0	1.065	N	6.7
9 @ 3 ft	W21X62	15	36	22.88	1.5	1	1	0	0.408	Y	10.5
	W21X68	15	36	25.09	1.25	0.75	1	0	0.386	Y	10.6
	W14X68	7.5	26	25.09	1.75	1.25	1	0	1.02	N	6.6
	W21X73	15	36	26.94	1.25	0.75	1	0	0.369	Y	10.6
	W14X74	8	26	27.31	1.75	1.25	0	0	0.946	N	6.7

Note: Optional Deflection Control Limit for 40 ft = 0.6 in.

Table A26.2.45.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W24X76	17.5	45	17.48	2.25	1.75	1	0	0.451	Y	15.9
	W21X83	15	42	19.09	2.5	2	1	0	0.575	Y	14.1
	W24X84	17.5	45	19.32	2	1.5	1	0	0.426	Y	16.1
	W21X93	15	42	21.39	2.25	1.75	1	0	0.539	Y	14.3
	W27X94	20.5	48	21.62	1.75	1.25	1	0	0.311	Y	18.1
6 @ 4.8 ft	W21X68	15	44	18.77	2.5	2	1	0	0.568	Y	13.9
	W21X73	15	44	20.15	2.25	1.75	1	0	0.548	Y	14
	W24X76	17.5	47	20.98	2	1.5	1	0	0.402	Y	15.9
	W21X83	15	44	22.91	2.25	1.75	1	0	0.512	Y	14.1
	W24X84	17.5	48	23.18	1.75	1.25	1	0	0.379	Y	16.1
7 @ 4 ft	W21X62	15	46	19.96	2.5	2	1	0	0.539	Y	13.9
	W21X68	15	46	21.9	2.25	1.75	1	0	0.515	Y	13.9
	W21X73	15	46	23.51	2	1.5	1	0	0.497	Y	14
	W24X76	17.5	50	24.47	1.75	1.25	1	0	0.365	Y	15.9
	W21X83	15	46	26.73	2	1.5	1	0	0.464	Y	14.1
9 @ 3 ft	W21X62	15	50	25.67	2	1.5	1	0	0.46	Y	13.9
	W21X68	15	50	28.15	2	1.5	1	0	0.439	Y	13.9
	W21X73	15	50	30.22	2	1.5	1	0	0.423	Y	14
	W14X74	8	39	30.64	2.75	2.25	1	0	1.006	N	9.4
	W14X82	7.5	39	33.95	2.5	2	1	0	0.947	N	9.4

Table A26.2.45.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W24X76	17.5	35	17.48	2	1.5	1	0	0.611	Y	13.8
	W24X84	17.5	35	19.32	1.75	1.25	1	0	0.573	Y	13.9
	W21X93	15	32	21.39	2	1.5	1	0	0.736	N	12.2
	W27X94	20.5	38	21.62	1.5	1	1	0	0.408	Y	15.9
	W24X94	17.5	35	21.62	1.75	1.25	1	0	0.533	Y	14.1
6 @ 4.8 ft	W21X68	15	34	18.77	2	1.5	1	0	0.789	N	11.9
	W21X73	15	34	20.15	2	1.5	1	0	0.756	N	11.9
	W24X76	17.5	37	20.98	1.75	1.25	1	0	0.541	Y	13.8
	W21X83	15	34	22.91	1.75	1.25	1	0	0.699	N	12.1
	W24X84	17.5	38	23.18	1.75	1.25	1	0	0.506	Y	13.9
7 @ 4 ft	W21X62	15	36	19.96	2	1.5	1	0	0.749	N	11.8
	W21X68	15	36	21.9	2	1.5	1	0	0.709	N	11.9
	W21X73	15	36	23.51	1.75	1.25	1	0	0.679	N	11.9
	W24X76	17.5	40	24.47	1.75	1.25	1	0	0.487	Y	13.8
	W21X83	15	36	26.73	1.75	1.25	1	0	0.628	Y	12.1
9 @ 3 ft	W21X62	15	40	25.67	1.75	1.25	1	0	0.63	Y	11.8
	W21X68	15	40	28.15	1.75	1.25	1	0	0.596	Y	11.9
	W21X73	15	40	30.22	1.75	1.25	1	0	0.57	Y	11.9
	W14X82	7.5	29	33.95	2.25	1.75	1	0	1.357	N	7.6
	W21X83	15	41	34.36	1.5	1	1	0	0.526	Y	12.1

Note: Optional Deflection Control Limit for 45 ft = 0.68 in.

Table A26.2.50.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	53	23.97	2.25	1.75	1	0	0.451	Y	20.1
	W24X94	17.5	50	23.97	2.5	2	1	0	0.58	Y	18
	W30X99	23.5	57	25.24	2	1.5	1	0	0.349	Y	22.5
	W21X101	15	46	25.76	2.75	2.25	1	0	0.736	Y	15.7
	W27X102	20.5	53	26.01	2.25	1.75	1	0	0.429	Y	20.3
6 @ 4.8 ft	W24X76	17.5	52	23.26	2.75	2.25	2	16	0.583	Y	17.7
	W21X83	15	49	25.4	3	2.5	2	16	0.743	Y	15.7
	W24X84	17.5	53	25.7	2.5	2	1	0	0.551	Y	17.8
	W21X93	15	49	28.46	2.75	2.25	2	16	0.695	Y	15.9
	W27X94	20.5	57	28.76	2	1.5	1	0	0.402	Y	20.1
7 @ 4 ft	W21X73	15	51	26.06	3	2.5	2	16	0.721	Y	15.5
	W24X76	17.5	56	27.13	2.5	2	1	0	0.529	Y	17.7
	W21X83	15	51	29.63	2.75	2.25	2	16	0.673	Y	15.7
	W24X84	17.5	56	29.99	2.25	1.75	1	0	0.499	Y	17.8
	W18X86	12	47	30.7	3	2.5	1	0	0.903	N	13.4
9 @ 3 ft	W21X62	15	56	28.46	3	2.5	2	16	0.668	Y	15.4
	W21X68	15	56	31.21	2.75	2.25	2	16	0.638	Y	15.5
	W21X73	15	56	33.51	2.5	2	1	0	0.614	Y	15.5
	W21X83	15	56	38.1	2.25	1.75	1	0	0.573	Y	15.7
	W18X86	12	50	39.47	2.5	2	1	0	0.766	N	13.4

Table A26.2.50.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	42	23.97	2	1.5	1	0	0.592	Y	17.7
	W24X94	17.5	39	23.97	2.25	1.75	1	0	0.773	N	15.6
	W30X99	23.5	46	25.24	1.75	1.25	1	0	0.452	Y	20
	W21X101	15	35	25.76	2.25	1.75	1	0	0.991	N	13.4
	W27X102	20.5	42	26.01	2	1.5	1	0	0.559	Y	17.8
6 @ 4.8 ft	W24X76	17.5	41	23.26	2.25	1.75	1	0	0.785	N	15.3
	W24X84	17.5	42	25.7	2.25	1.75	1	0	0.734	Y	15.5
	W21X93	15	38	28.46	2.25	1.75	1	0	0.941	N	13.6
	W27X94	20.5	46	28.76	1.75	1.25	1	0	0.524	Y	17.7
	W24X94	17.5	42	28.76	2	1.5	1	0	0.683	Y	15.6
7 @ 4 ft	W24X76	17.5	45	27.13	2.25	1.75	1	0	0.707	Y	15.3
	W21X83	15	40	29.63	2.25	1.75	1	0	0.911	N	13.4
	W24X84	17.5	45	29.99	2	1.5	1	0	0.661	Y	15.5
	W18X86	12	36	30.7	2.5	2	1	0	1.243	N	11.2
	W21X93	15	40	33.2	2.25	1.75	1	0	0.844	N	13.6
9 @ 3 ft	W21X62	15	45	28.46	2.5	2	1	0	0.914	N	13.1
	W21X68	15	45	31.21	2.25	1.75	1	0	0.864	N	13.2
	W21X73	15	45	33.51	2.25	1.75	1	0	0.827	N	13.3
	W21X83	15	45	38.1	2	1.5	1	0	0.763	N	13.4
	W18X86	12	39	39.47	2.25	1.75	1	0	1.033	N	11.2

Note: Optional Deflection Control Limit for 50 ft = 0.75 in.

Table A26.2.55.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	58	26.32	3	2.5	2	18	0.625	Y	22.1
	W30X99	23.5	62	27.72	2.75	2.25	2	18	0.484	Y	24.8
	W27X102	20.5	58	28.56	3	2.5	2	18	0.595	Y	22.3
	W24X103	17.5	55	28.84	3.25	2.75	2	18	0.762	Y	20
	W24X104	17.5	54	29.12	3.25	2.75	1	0	0.764	Y	19.6
6 @ 4.8 ft	W27X94	20.5	63	31.58	2.75	2.25	2	18	0.557	Y	22.1
	W24X94	17.5	58	31.58	3	2.5	2	18	0.717	Y	19.8
	W30X99	23.5	68	33.26	2.5	2	1	0	0.432	Y	24.8
	W21X101	15	53	33.94	3.25	2.75	1	0	0.906	N	17.3
	W27X102	20.5	63	34.27	2.75	2.25	1	0	0.53	Y	22.3
7 @ 4 ft	W24X84	17.5	61	32.93	3	2.5	2	18	0.693	Y	19.6
	W21X93	15	56	36.46	3.25	2.75	2	18	0.874	N	17.4
	W27X94	20.5	67	36.85	2.5	2	1	0	0.506	Y	22.1
	W24X94	17.5	62	36.85	2.75	2.25	2	18	0.649	Y	19.8
	W18X97	12	52	38.02	3.5	3	1	0	1.158	N	14.9
9 @ 3 ft	W21X73	15	61	36.79	3.5	3	2	18	0.852	N	17.1
	W21X83	15	61	41.83	3.25	2.75	2	18	0.795	Y	17.3
	W18X86	12	55	43.34	3.5	3	1	0	1.062	N	14.8
	W21X93	15	62	46.87	3	2.5	2	18	0.743	Y	17.4
	W18X97	12	55	48.89	3	2.5	1	0	0.981	N	14.9

Table A26.2.55.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X94	20.5	46	26.32	2.75	2.25	1	0	0.821	Y	19.4
	W30X99	23.5	50	27.72	2.5	2	1	0	0.627	Y	22
	W27X102	20.5	46	28.56	2.5	2	1	0	0.776	Y	19.6
	W24X103	17.5	43	28.84	2.75	2.25	2	18	1.008	N	17.4
	W24X104	17.5	42	29.12	2.75	2.25	1	0	1.009	N	17
6 @ 4.8 ft	W27X94	20.5	50	31.58	2.5	2	1	0	0.726	Y	19.4
	W24X94	17.5	46	31.58	2.75	2.25	1	0	0.947	N	17.2
	W30X99	23.5	56	33.26	2.25	1.75	1	0	0.556	Y	22
	W21X101	15	41	33.94	2.75	2.25	1	0	1.208	N	14.8
	W27X102	20.5	51	34.27	2.25	1.75	1	0	0.686	Y	19.6
7 @ 4 ft	W24X84	17.5	49	32.93	2.75	2.25	2	18	0.917	N	17
	W21X93	15	44	36.46	2.75	2.25	2	18	1.171	N	14.9
	W27X94	20.5	55	36.85	2.25	1.75	1	0	0.654	Y	19.4
	W24X94	17.5	49	36.85	2.5	2	1	0	0.851	N	17.2
	W21X101	15	44	39.59	2.5	2	1	0	1.081	N	14.8
9 @ 3 ft	W21X83	15	49	41.83	2.75	2.25	2	18	1.058	N	14.8
	W18X86	12	43	43.34	3	2.5	1	0	1.433	N	12.4
	W21X93	15	49	46.87	2.5	2	1	0	0.979	N	14.9
	W18X97	12	43	48.89	2.75	2.25	1	0	1.306	N	12.5
	W21X101	15	49	50.9	2.25	1.75	1	0	0.9	N	14.8

Note: Optional Deflection Control Limit for 55 ft = 0.83 in.

Table A26.2.60.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X99	23.5	68	30.2	3.75	3.25	2	20	0.648	Y	27
	W30X108	23.5	68	32.94	3.5	3	2	20	0.62	Y	27.1
	W27X114	20.5	64	34.77	3.5	3	2	20	0.751	Y	24.6
	W30X116	23.5	68	35.38	3.25	2.75	2	20	0.592	Y	27.3
	W24X117	17.5	59	35.68	3.75	3.25	1	0	0.954	N	21.6
6 @ 4.8 ft	W27X94	20.5	68	34.4	3.75	3.25	2	20	0.747	Y	24.2
	W30X99	23.5	74	36.23	3.25	2.75	2	20	0.579	Y	27
	W27X102	20.5	68	37.33	3.5	3	2	20	0.71	Y	24.4
	W24X103	17.5	64	37.7	3.75	3.25	2	20	0.908	N	21.8
	W24X104	17.5	63	38.06	3.75	3.25	1	0	0.91	N	21.4
7 @ 4 ft	W27X94	20.5	73	40.14	3.5	3	2	20	0.677	Y	24.2
	W24X94	17.5	67	40.14	3.75	3.25	2	20	0.87	Y	21.6
	W21X101	15	61	43.13	4	3.5	1	0	1.097	N	18.8
	W27X102	20.5	73	43.55	3.25	2.75	2	20	0.644	Y	24.4
	W24X103	17.5	67	43.98	3.5	3	2	20	0.822	Y	21.8
9 @ 3 ft	W21X83	15	67	45.57	4.25	3.75	2	19	1.064	N	18.8
	W21X93	15	67	51.06	3.75	3.25	2	20	0.995	N	19
	W18X97	12	60	53.25	4.25	3.75	1	0	1.314	N	16.3
	W21X101	15	67	55.45	3.5	3	1	0	0.929	N	18.8
	W18X106	12	60	58.19	4	3.5	1	0	1.247	N	16.4

Table A26.2.60.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X108	23.5	55	32.94	3	2.5	2	20	0.798	Y	24.1
	W27X114	20.5	51	34.77	3	2.5	2	20	0.972	N	21.6
	W30X116	23.5	55	35.38	2.75	2.25	2	20	0.757	Y	24.3
	W30X124	23.5	55	37.82	2.75	2.25	1	0	0.721	Y	24.5
	W27X129	20.5	51	39.34	2.75	2.25	1	0	0.888	Y	21.9
6 @ 4.8 ft	W27X94	20.5	55	34.4	3.25	2.75	2	20	0.973	N	21.2
	W30X99	23.5	61	36.23	3	2.5	2	20	0.745	Y	24
	W27X102	20.5	55	37.33	3	2.5	2	20	0.919	N	21.4
	W24X103	17.5	50	37.7	3.25	2.75	2	20	1.191	N	18.9
	W24X104	17.5	49	38.06	3.25	2.75	1	0	1.19	N	18.6
7 @ 4 ft	W27X94	20.5	60	40.14	3	2.5	2	20	0.876	Y	21.2
	W24X94	17.5	54	40.14	3.25	2.75	2	20	1.14	N	18.8
	W21X101	15	48	43.13	3.25	2.75	1	0	1.449	N	16.1
	W27X102	20.5	60	43.55	2.75	2.25	1	0	0.826	Y	21.4
	W24X103	17.5	54	43.98	3	2.5	2	20	1.07	N	18.9
9 @ 3 ft	W21X93	15	54	51.06	3.25	2.75	2	20	1.312	N	16.3
	W18X97	12	47	53.25	3.5	3	1	0	1.75	N	13.7
	W21X101	15	53	55.45	3	2.5	1	0	1.205	N	16.1
	W18X106	12	47	58.19	3.25	2.75	1	0	1.648	N	13.8
	W21X111	15	53	60.94	2.75	2.25	1	0	1.131	N	16.2

Note: Optional Deflection Control Limit for 60 ft = 0.90 in.

Table A26.2.65.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X116	23.5	74	38.28	4.25	3.75	2	21	0.771	Y	29.6
	W30X124	23.5	74	40.92	4	3.5	2	21	0.738	Y	29.8
	W27X129	20.5	70	42.57	4.25	3.75	2	21	0.903	Y	26.9
	W24X131	17.5	64	43.23	4.5	4	1	0	1.157	N	23.6
	W30X132	23.5	74	43.56	3.75	3.25	2	21	0.713	Y	29.9
6 @ 4.8 ft	W30X99	23.5	80	39.2	4.5	4	2	21	0.754	Y	29.3
	W30X108	23.5	80	42.77	4	3.5	2	21	0.721	Y	29.4
	W27X114	20.5	74	45.14	4.25	3.75	2	21	0.871	Y	26.6
	W30X116	23.5	81	45.94	3.75	3.25	2	21	0.687	Y	29.6
	W24X117	17.5	68	46.33	4.5	4	1	0	1.103	N	23.4
7 @ 4 ft	W27X94	20.5	79	43.43	4.5	4	2	21	0.882	Y	26.2
	W27X102	20.5	79	47.12	4.25	3.75	2	21	0.839	Y	26.4
	W24X103	17.5	73	47.59	4.5	4	2	20	1.071	N	23.6
	W24X104	17.5	72	48.05	4.5	4	1	0	1.073	N	23.2
	W27X114	20.5	80	52.67	3.75	3.25	2	21	0.789	Y	26.6
9 @ 3 ft	W21X93	15	73	55.24	5	4.5	2	19	1.296	N	20.6
	W21X101	15	72	59.99	4.5	4	1	0	1.211	N	20.4
	W18X106	12	65	62.96	5	4.5	1	0	1.625	N	17.7
	W21X111	15	72	65.93	4.25	3.75	1	0	1.146	N	20.5
	W18X119	12	65	70.69	4.75	4.25	1	0	1.483	N	18

Table A26.2.65.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X116	23.5	60	38.28	3.5	3	2	21	0.986	N	26.3
	W30X124	23.5	60	40.92	3.5	3	2	21	0.94	Y	26.5
	W27X129	20.5	55	42.57	3.5	3	2	21	1.157	N	23.7
	W30X132	23.5	60	43.56	3.25	2.75	2	21	0.903	Y	26.6
	W27X146	20.5	54	48.18	3	2.5	1	0	1.061	N	23.5
6 @ 4.8 ft	W30X108	23.5	66	42.77	3.5	3	2	21	0.921	Y	26.1
	W27X114	20.5	60	45.14	3.5	3	2	21	1.118	N	23.4
	W30X116	23.5	66	45.94	3.25	2.75	2	21	0.872	Y	26.3
	W24X117	17.5	54	46.33	3.75	3.25	1	0	1.429	N	20.3
	W30X124	23.5	66	49.1	3	2.5	2	21	0.83	Y	26.5
7 @ 4 ft	W27X102	20.5	65	47.12	3.75	3.25	2	21	1.076	N	23.2
	W24X104	17.5	57	48.05	3.75	3.25	1	0	1.391	N	20.1
	W27X114	20.5	65	52.67	3.25	2.75	2	21	1.005	N	23.4
	W24X117	17.5	58	54.05	3.5	3	1	0	1.28	N	20.3
	W21X122	15	52	56.36	3.75	3.25	1	0	1.651	N	17.7
9 @ 3 ft	W21X101	15	58	59.99	3.75	3.25	1	0	1.57	N	17.5
	W21X111	15	57	65.93	3.5	3	1	0	1.474	N	17.6
	W18X119	12	51	70.69	4	3.5	1	0	1.935	N	15.2
	W21X122	15	58	72.47	3.5	3	1	0	1.37	N	17.7
	W18X130	12	51	77.22	3.75	3.25	1	0	1.767	N	15.5

Note: Optional Deflection Control Limit for 65 ft = 0.98 in.

Table A26.2.70.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X132	23.5	80	46.86	4.75	4.25	2	20	0.908	Y	32.3
	W27X146	20.5	74	51.83	4.75	4.25	1	0	1.066	N	28.8
	W27X161	20.5	74	57.16	4.25	3.75	1	0	1.001	Y	29
6 @ 4.8 ft	W30X116	23.5	87	49.42	4.75	4.25	2	20	0.875	Y	31.9
	W30X124	23.5	87	52.82	4.5	4	2	23	0.838	Y	32.1
	W27X129	20.5	80	54.95	4.75	4.25	2	23	1.023	Y	29
	W24X131	17.5	73	55.81	5.25	4.75	2	23	1.308	N	25.4
	W30X132	23.5	87	56.23	4.25	3.75	2	23	0.809	Y	32.3
7 @ 4 ft	W27X114	20.5	86	56.66	5	4.5	2	21	1.005	Y	28.7
	W24X117	17.5	77	58.15	5.25	4.75	2	23	1.27	N	25.2
	W27X129	20.5	86	64.11	4.5	4	2	23	0.926	Y	29
	W24X131	17.5	78	65.11	4.75	4.25	1	0	1.182	N	25.4
	W21X132	15	71	65.6	5.5	5	2	23	1.54	N	22.4
9 @ 3 ft	W21X111	15	77	70.93	5.25	4.75	2	23	1.459	N	22.1
	W21X122	15	78	77.96	5	4.5	1	0	1.368	N	22.3
	W21X132	15	77	84.35	4.75	4.25	1	0	1.301	N	22.4

Table A26.2.70.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W30X132	23.5	65	46.86	4	3.5	2	23	1.15	N	28.7
	W27X146	20.5	59	51.83	4	3.5	1	0	1.35	N	25.3
	W27X161	20.5	59	57.16	3.75	3.25	1	0	1.259	N	25.5
6 @ 4.8 ft	W30X116	23.5	71	49.42	4.25	3.75	2	23	1.11	N	28.3
	W30X124	23.5	71	52.82	4	3.5	2	23	1.057	N	28.5
	W27X129	20.5	65	54.95	4.25	3.75	2	23	1.299	N	25.5
	W24X131	17.5	58	55.81	4.5	4	1	0	1.679	N	22.1
	W30X132	23.5	71	56.23	3.75	3.25	2	23	1.016	Y	28.7
7 @ 4 ft	W27X114	20.5	70	56.66	4.25	3.75	2	23	1.279	N	25.2
	W27X129	20.5	70	64.11	3.75	3.25	2	23	1.165	N	25.5
	W24X131	17.5	62	65.11	4	3.5	1	0	1.502	N	22.1
	W21X132	15	56	65.6	4.75	4.25	1	0	1.987	N	19.2
	W27X146	20.5	70	72.56	3.5	3	1	0	1.062	N	25.3
9 @ 3 ft	W21X111	15	62	70.93	4.75	4.25	1	0	1.877	N	18.9
	W21X122	15	62	77.96	4.25	3.75	1	0	1.744	N	19.1
	W18X130	12	55	83.07	4.75	4.25	1	0	2.25	N	16.6
	W21X132	15	62	84.35	4	3.5	1	0	1.646	N	19.2

Note: Optional Deflection Control Limit for 70 ft = 1.05 in.

Table A26.2.75.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X161	20.5	80	61.18	5.5	5	2	25	1.25	N	31.1
6 @ 4.8 ft	W30X124	23.5	93	56.54	5.75	5.25	3	18	1.047	Y	34.4
	W30X132	23.5	93	60.19	5.5	5	3	18	1.01	Y	34.6
	W27X146	20.5	85	66.58	5.25	4.75	2	25	1.182	N	30.8
	W24X146	17.5	79	66.58	6	5.5	2	25	1.516	N	27.5
	W27X161	20.5	85	73.42	5	4.5	1	0	1.109	Y	31.1
7 @ 4 ft	W27X129	20.5	92	68.63	5.5	5	2	21	1.156	N	31.1
	W24X131	17.5	83	69.69	6	5.5	2	25	1.476	N	27.2
	W27X146	20.5	91	77.67	4.75	4.25	1	0	1.068	Y	30.8
	W24X146	17.5	83	77.67	5.5	5	2	25	1.368	N	27.5
	W27X161	20.5	91	85.65	4.5	4	1	0	1.002	Y	31.1
9 @ 3 ft	W21X122	15	83	83.45	6.5	6	2	25	1.709	N	23.9

Table A26.2.75.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
5 @ 6 ft	W27X161	20.5	63	61.18	4.75	4.25	1	0	1.573	N	27.4
6 @ 4.8 ft	W30X132	23.5	76	60.19	4.75	4.25	2	23	1.269	N	30.7
	W27X146	20.5	69	66.58	4.5	4	1	0	1.483	N	27.1
	W24X146	17.5	62	66.58	5.25	4.75	2	25	1.926	N	23.9
	W27X161	20.5	69	73.42	4.25	3.75	1	0	1.381	N	27.4
7 @ 4 ft	W27X129	20.5	75	68.63	5	4.5	2	24	1.456	N	27.4
	W24X131	17.5	66	69.69	5.25	4.75	2	25	1.877	N	23.7
	W27X146	20.5	74	77.67	4.25	3.75	1	0	1.327	N	27.1
	W24X146	17.5	67	77.67	4.75	4.25	1	0	1.722	N	23.9
	W27X161	20.5	75	85.65	4	3.5	1	0	1.235	N	27.4
9 @ 3 ft	W21X122	15	66	83.45	5.5	5	2	25	2.179	N	20.5

Note: Optional Deflection Control Limit for 75 ft = 1.13 in.

Table A26.2.80.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 4.8 ft	W27X161	20.5	91	78.25	6.25	5.75	2	26	1.364	N	33.2
7 @ 4 ft	W27X146	20.5	97	82.78	6	5.5	2	26	1.313	N	32.9
	W24X146	17.5	89	82.78	7	6.5	2	26	1.682	N	29.3
	W27X161	20.5	97	91.29	5.75	5.25	2	26	1.231	N	33.2

Table A26.2.80.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 4.8 ft	W27X161	20.5	73	78.25	5.25	4.75	2	26	1.698	N	29.2
7 @ 4 ft	W27X146	20.5	79	82.78	5.25	4.75	2	26	1.631	N	28.9
	W24X146	17.5	71	82.78	6	5.5	2	26	2.116	N	25.5
	W27X161	20.5	79	91.29	5	4.5	1	0	1.518	N	29.2

Note: Optional Deflection Control Limit for 80 ft = 1.2 in.

Group 4

Bridge Width = 32 ft

Steel Yield Strength = 50 ksi

Table A32.2.40.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W21X62	15	45	15.25	2	1.5	1	0	0.36	Y	12.3
	W21X68	15	46	16.73	2	1.5	1	0	0.345	Y	12.4
	W21X73	15	46	17.96	1.75	1.25	1	0	0.332	Y	12.4
	W24X76	17.5	49	18.7	1.5	1	1	0	0.244	Y	14.1
	W21X83	15	46	20.42	1.75	1.25	1	0	0.311	Y	12.6
7 @ 5 ft	W21X62	15	47	17.79	2	1.5	1	0	0.326	Y	12.3
	W21X68	15	47	19.52	1.75	1.25	1	0	0.312	Y	12.4
	W21X73	15	48	20.95	1.75	1.25	1	0	0.301	Y	12.4
	W24X76	17.5	51	21.81	1.5	1	1	0	0.221	Y	14.1
	W21X83	15	48	23.82	1.5	1	1	0	0.281	Y	12.6
8 @ 4.29 ft	W21X62	15	49	20.34	1.75	1.25	1	0	0.299	Y	12.3
	W21X68	15	49	22.3	1.75	1.25	1	0	0.286	Y	12.4
	W21X73	15	49	23.94	1.5	1	1	0	0.276	Y	12.4
	W24X76	17.5	54	24.93	1.5	1	1	0	0.202	Y	14.1
	W14X82	7.5	41	26.9	2.25	1.75	1	0	0.617	N	8.4
9 @ 3.75 ft	W21X62	15	51	22.88	1.75	1.25	1	0	0.278	Y	12.3
	W21X68	15	51	25.09	1.5	1	1	0	0.265	Y	12.4
	W14X68	7.5	41	25.09	2.25	1.75	1	0	0.647	N	8.2
	W21X73	15	51	26.94	1.5	1	1	0	0.255	Y	12.4
	W14X74	8	42	27.31	2.25	1.75	1	0	0.607	N	8.3
11 @ 3 ft	W14X61	7.5	43	27.51	2.25	1.75	1	0	0.608	N	8.2
	W21X62	15	55	27.96	1.5	1	1	0	0.244	Y	12.3
	W21X68	15	55	30.67	1.5	1	1	0	0.233	Y	12.4
	W14X68	7.5	43	30.67	2	1.5	1	0	0.569	Y	8.2
	W12X72	6	40	32.47	2.25	1.75	0	0	0.717	N	7.3

Table A32.2.40.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W21X68	15	34	16.73	1.75	1.25	1	0	0.483	Y	10.6
	W21X73	15	35	17.96	1.5	1	1	0	0.463	Y	10.6
	W24X76	17.5	38	18.7	1.5	1	1	0	0.33	Y	12.3
	W21X83	15	35	20.42	1.5	1	1	0	0.428	Y	10.7
	W24X84	17.5	38	20.66	1.25	0.75	1	0	0.309	Y	12.4
7 @ 5 ft	W21X62	15	36	17.79	1.75	1.25	1	0	0.457	Y	10.5
	W21X68	15	36	19.52	1.5	1	1	0	0.433	Y	10.6
	W21X73	15	36	20.95	1.5	1	1	0	0.415	Y	10.6
	W24X76	17.5	40	21.81	1.25	0.75	1	0	0.297	Y	12.3
	W21X83	15	37	23.82	1.5	1	1	0	0.384	Y	10.7
8 @ 4.29 ft	W21X62	15	38	20.34	1.5	1	1	0	0.417	Y	10.5
	W21X68	15	38	22.3	1.5	1	1	0	0.395	Y	10.6
	W21X73	15	38	23.94	1.5	1	1	0	0.378	Y	10.6
	W24X76	17.5	43	24.93	1.25	0.75	1	0	0.271	Y	12.3
	W14X82	7.5	30	26.9	1.75	1.25	1	0	0.918	N	6.7
9 @ 3.75 ft	W21X62	15	40	22.88	1.5	1	1	0	0.384	Y	10.5
	W21X68	15	40	25.09	1.5	1	1	0	0.364	Y	10.6
	W21X73	15	40	26.94	1.25	0.75	1	0	0.348	Y	10.6
	W24X76	17.5	45	28.04	1.25	0.75	1	0	0.25	Y	12.3
	W14X82	7.5	31	30.26	1.75	1.25	1	0	0.84	N	6.7
11 @ 3 ft	W21X62	15	44	27.96	1.5	1	1	0	0.334	Y	10.5
	W21X68	15	44	30.67	1.25	0.75	1	0	0.316	Y	10.6
	W14X68	7.5	32	30.67	1.75	1.25	1	0	0.835	N	6.6
	W21X73	15	44	32.92	1.25	0.75	1	0	0.302	Y	10.6
	W14X74	8	32	33.37	1.75	1.25	0	0	0.774	N	6.7

Note: Optional Deflection Control Limit for 40 ft = 0.6 in.

Table A32.2.45.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W24X76	17.5	55	20.98	2.25	1.75	1	0	0.376	Y	15.9
	W21X83	15	51	22.91	2.25	1.75	1	0	0.479	Y	14.1
	W24X84	17.5	55	23.18	2	1.5	1	0	0.355	Y	16.1
	W21X93	15	52	25.67	2.25	1.75	1	0	0.449	Y	14.3
	W27X94	20.5	59	25.94	1.75	1.25	1	0	0.259	Y	18.1
7 @ 5 ft	W21X68	15	53	21.9	2.5	2	1	0	0.481	Y	13.9
	W21X73	15	53	23.51	2.25	1.75	1	0	0.464	Y	14
	W24X76	17.5	57	24.47	2	1.5	1	0	0.34	Y	15.9
	W21X83	15	54	26.73	2.25	1.75	1	0	0.433	Y	14.1
	W24X84	17.5	58	27.05	2	1.5	1	0	0.321	Y	16.1
8 @ 4.29 ft	W21X62	15	55	22.82	2.5	2	1	0	0.462	Y	13.9
	W21X68	15	55	25.02	2.25	1.75	1	0	0.441	Y	13.9
	W21X73	15	55	26.86	2.25	1.75	1	0	0.425	Y	14
	W24X76	17.5	60	27.97	2	1.5	1	0	0.312	Y	15.9
	W21X83	15	56	30.54	2	1.5	1	0	0.397	Y	14.1
9 @ 3.75 ft	W21X62	15	57	25.67	2.25	1.75	1	0	0.428	Y	13.9
	W21X68	15	57	28.15	2.25	1.75	1	0	0.409	Y	13.9
	W21X73	15	58	30.22	2	1.5	1	0	0.394	Y	14
	W24X76	17.5	63	31.46	1.75	1.25	1	0	0.29	Y	15.9
	W21X83	15	58	34.36	2	1.5	1	0	0.368	Y	14.1
11 @ 3 ft	W21X62	15	62	31.37	2	1.5	1	0	0.377	Y	13.9
	W21X68	15	62	34.41	2	1.5	1	0	0.359	Y	13.9
	W21X73	15	62	36.94	2	1.5	1	0	0.346	Y	14
	W14X74	8	48	37.44	2.75	2.25	1	0	0.823	N	9.4
	W14X82	7.5	48	41.49	2.5	2	1	0	0.775	N	9.4

Table A32.2.45.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W24X76	17.5	42	20.98	2	1.5	1	0	0.509	Y	13.8
	W21X83	15	39	22.91	2	1.5	1	0	0.661	Y	12.1
	W24X84	17.5	42	23.18	1.75	1.25	1	0	0.477	Y	13.9
	W21X93	15	39	25.67	2	1.5	1	0	0.613	Y	12.2
	W27X94	20.5	46	25.94	1.5	1	1	0	0.34	Y	15.9
7 @ 5 ft	W21X73	15	41	23.51	2	1.5	1	0	0.641	Y	11.9
	W24X76	17.5	45	24.47	1.75	1.25	1	0	0.458	Y	13.8
	W21X83	15	41	26.73	1.75	1.25	1	0	0.593	Y	12.1
	W24X84	17.5	45	27.05	1.75	1.25	1	0	0.429	Y	13.9
	W18X86	12	37	27.69	2	1.5	1	0	0.813	N	10.1
8 @ 4.29 ft	W21X62	15	43	22.82	2	1.5	1	0	0.643	Y	11.8
	W21X68	15	43	25.02	2	1.5	1	0	0.609	Y	11.9
	W21X73	15	43	26.86	2	1.5	1	0	0.584	Y	11.9
	W24X76	17.5	48	27.97	1.75	1.25	1	0	0.418	Y	13.8
	W21X83	15	43	30.54	1.75	1.25	1	0	0.54	Y	12.1
9 @ 3.75 ft	W21X62	15	45	25.67	2	1.5	1	0	0.593	Y	11.8
	W21X68	15	45	28.15	2	1.5	1	0	0.561	Y	11.9
	W21X73	15	45	30.22	1.75	1.25	1	0	0.537	Y	11.9
	W24X76	17.5	51	31.46	1.5	1	1	0	0.386	Y	13.8
	W21X83	15	45	34.36	1.75	1.25	1	0	0.496	Y	12.1
11 @ 3 ft	W21X62	15	49	31.37	1.75	1.25	1	0	0.515	Y	11.8
	W21X68	15	49	34.41	1.75	1.25	1	0	0.487	Y	11.9
	W21X73	15	49	36.94	1.75	1.25	1	0	0.466	Y	11.9
	W14X82	7.5	36	41.49	2.25	1.75	1	0	1.11	N	7.6
	W21X83	15	50	42	1.5	1	1	0	0.43	Y	12.1

Note: Optional Deflection Control Limit for 45 ft = 0.68 in.

Table A32.2.50.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W21X93	15	57	28.46	3	2.5	2	16	0.651	Y	15.9
	W27X94	20.5	65	28.76	2.25	1.75	1	0	0.376	Y	20.1
	W24X94	17.5	61	28.76	2.5	2	1	0	0.484	Y	18
	W30X99	23.5	70	30.29	2	1.5	1	0	0.291	Y	22.5
	W21X101	15	57	30.91	2.75	2.25	1	0	0.613	Y	15.7
7 @ 5 ft	W24X76	17.5	64	27.13	2.75	2.25	2	16	0.494	Y	17.7
	W21X83	15	59	29.63	3	2.5	2	16	0.629	Y	15.7
	W24X84	17.5	64	29.99	2.5	2	1	0	0.466	Y	17.8
	W21X93	15	60	33.2	2.75	2.25	2	16	0.589	Y	15.9
	W27X94	20.5	69	33.56	2.25	1.75	1	0	0.34	Y	20.1
8 @ 4.29 ft	W24X76	17.5	67	31.01	2.5	2	2	16	0.453	Y	17.7
	W21X83	15	62	33.86	2.75	2.25	2	16	0.577	Y	15.7
	W24X84	17.5	67	34.27	2.5	2	1	0	0.428	Y	17.8
	W18X86	12	56	35.09	3	2.5	1	0	0.774	N	13.4
	W21X93	15	62	37.94	2.5	2	1	0	0.54	Y	15.9
9 @ 3.75 ft	W21X68	15	64	31.21	3	2.5	2	16	0.594	Y	15.5
	W21X73	15	64	33.51	2.75	2.25	2	16	0.572	Y	15.5
	W24X76	17.5	70	34.88	2.5	2	1	0	0.42	Y	17.7
	W21X83	15	64	38.1	2.5	2	1	0	0.534	Y	15.7
	W24X84	17.5	70	38.56	2.25	1.75	1	0	0.396	Y	17.8
11 @ 3 ft	W21X62	15	68	34.78	3	2.5	2	16	0.547	Y	15.4
	W21X68	15	68	38.15	2.75	2.25	2	16	0.522	Y	15.5
	W21X73	15	69	40.95	2.5	2	1	0	0.502	Y	15.5
	W21X83	15	69	46.56	2.25	1.75	1	0	0.469	Y	15.7
	W18X86	12	61	48.25	2.5	2	1	0	0.627	Y	13.4

Table A32.2.50.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X94	20.5	51	28.76	2	1.5	1	0	0.493	Y	17.7
	W24X94	17.5	47	28.76	2.25	1.75	1	0	0.644	Y	15.6
	W30X99	23.5	56	30.29	1.75	1.25	1	0	0.377	Y	20
	W21X101	15	43	30.91	2.25	1.75	1	0	0.826	N	13.4
	W27X102	20.5	51	31.21	2	1.5	1	0	0.466	Y	17.8
7 @ 5 ft	W24X76	17.5	50	27.13	2.5	2	1	0	0.665	Y	15.3
	W24X84	17.5	50	29.99	2.25	1.75	1	0	0.623	Y	15.5
	W21X93	15	46	33.2	2.25	1.75	1	0	0.798	N	13.6
	W27X94	20.5	55	33.56	2	1.5	1	0	0.444	Y	17.7
	W24X94	17.5	50	33.56	2	1.5	1	0	0.579	Y	15.6
8 @ 4.29 ft	W24X76	17.5	53	31.01	2.25	1.75	1	0	0.607	Y	15.3
	W21X83	15	48	33.86	2.25	1.75	1	0	0.783	N	13.4
	W24X84	17.5	53	34.27	2	1.5	1	0	0.568	Y	15.5
	W21X93	15	48	37.94	2.25	1.75	1	0	0.726	Y	13.6
	W27X94	20.5	59	38.35	1.75	1.25	1	0	0.405	Y	17.7
9 @ 3.75 ft	W21X73	15	50	33.51	2.5	2	1	0	0.78	N	13.3
	W24X76	17.5	56	34.88	2.25	1.75	1	0	0.559	Y	15.3
	W21X83	15	50	38.1	2.25	1.75	1	0	0.72	Y	13.4
	W24X84	17.5	56	38.56	2	1.5	1	0	0.523	Y	15.5
	W18X86	12	44	39.47	2.5	2	1	0	0.981	N	11.2
11 @ 3 ft	W21X62	15	55	34.78	2.5	2	1	0	0.748	Y	13.1
	W21X68	15	55	38.15	2.25	1.75	1	0	0.707	Y	13.2
	W21X73	15	55	40.95	2.25	1.75	1	0	0.676	Y	13.3
	W21X83	15	55	46.56	2	1.5	1	0	0.624	Y	13.4
	W18X86	12	47	48.25	2.25	1.75	1	0	0.845	N	11.2

Note: Optional Deflection Control Limit for 50 ft = 0.75 in.

Table A32.2.55.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X94	20.5	71	31.58	3	2.5	2	18	0.521	Y	22.1
	W30X99	23.5	77	33.26	2.75	2.25	2	18	0.403	Y	24.8
	W27X102	20.5	72	34.27	3	2.5	2	18	0.496	Y	22.3
	W24X103	17.5	67	34.61	3.25	2.75	2	18	0.635	Y	20
	W24X104	17.5	66	34.94	3	2.5	1	0	0.637	Y	19.6
7 @ 5 ft	W27X94	20.5	76	36.85	2.75	2.25	2	18	0.472	Y	22.1
	W24X94	17.5	70	36.85	3.25	2.75	2	18	0.607	Y	19.8
	W30X99	23.5	82	38.81	2.5	2	1	0	0.366	Y	24.8
	W21X101	15	65	39.59	3.25	2.75	1	0	0.767	Y	17.3
	W27X102	20.5	76	39.98	2.75	2.25	1	0	0.449	Y	22.3
8 @ 4.29 ft	W24X84	17.5	74	37.63	3.25	2.75	2	18	0.593	Y	19.6
	W21X93	15	68	41.66	3.5	3	2	18	0.749	Y	17.4
	W27X94	20.5	80	42.11	2.75	2.25	1	0	0.433	Y	22.1
	W24X94	17.5	74	42.11	3	2.5	2	18	0.556	Y	19.8
	W21X101	15	67	45.25	3	2.5	1	0	0.702	Y	17.3
9 @ 3.75 ft	W24X76	17.5	77	38.3	3.25	2.75	2	18	0.583	Y	19.4
	W21X83	15	70	41.83	3.5	3	2	18	0.741	Y	17.3
	W24X84	17.5	77	42.34	3	2.5	2	18	0.55	Y	19.6
	W21X93	15	71	46.87	3.25	2.75	2	18	0.693	Y	17.4
	W24X94	17.5	77	47.38	2.75	2.25	2	18	0.515	Y	19.8
11 @ 3 ft	W21X73	15	75	44.97	3.5	3	2	18	0.697	Y	17.1
	W21X83	15	75	51.13	3.25	2.75	2	18	0.65	Y	17.3
	W18X86	12	67	52.98	3.5	3	1	0	0.869	N	14.8
	W21X93	15	76	57.29	3	2.5	2	18	0.608	Y	17.4
	W18X97	12	68	59.75	3	2.5	1	0	0.802	Y	14.9

Table A32.2.55.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X94	20.5	56	31.58	2.75	2.25	1	0	0.684	Y	19.4
	W30X99	23.5	61	33.26	2.5	2	1	0	0.523	Y	22
	W27X102	20.5	56	34.27	2.5	2	1	0	0.646	Y	19.6
	W24X103	17.5	52	34.61	2.75	2.25	2	18	0.84	N	17.4
	W24X104	17.5	51	34.94	2.75	2.25	1	0	0.841	N	17
7 @ 5 ft	W27X94	20.5	61	36.85	2.5	2	1	0	0.616	Y	19.4
	W24X94	17.5	55	36.85	2.75	2.25	2	18	0.803	Y	17.2
	W30X99	23.5	67	38.81	2.25	1.75	1	0	0.471	Y	22
	W21X101	15	50	39.59	2.75	2.25	1	0	1.025	N	14.8
	W27X102	20.5	61	39.98	2.25	1.75	1	0	0.581	Y	19.6
8 @ 4.29 ft	W24X84	17.5	58	37.63	2.75	2.25	2	18	0.788	Y	17
	W21X93	15	53	41.66	3	2.5	2	18	1.007	N	14.9
	W27X94	20.5	65	42.11	2.25	1.75	1	0	0.562	Y	19.4
	W24X94	17.5	59	42.11	2.5	2	1	0	0.731	Y	17.2
	W21X101	15	52	45.25	2.5	2	1	0	0.931	N	14.8
9 @ 3.75 ft	W24X76	17.5	61	38.3	2.75	2.25	2	18	0.776	Y	16.8
	W24X84	17.5	62	42.34	2.75	2.25	1	0	0.725	Y	17
	W21X93	15	55	46.87	2.75	2.25	2	18	0.926	N	14.9
	W24X94	17.5	62	47.38	2.5	2	1	0	0.673	Y	17.2
	W18X97	12	49	48.89	3	2.5	1	0	1.242	N	12.5
11 @ 3 ft	W21X83	15	60	51.13	2.75	2.25	2	18	0.866	N	14.8
	W18X86	12	52	52.98	3	2.5	1	0	1.173	N	12.4
	W21X93	15	60	57.29	2.5	2	1	0	0.801	Y	14.9
	W18X97	12	52	59.75	2.75	2.25	1	0	1.069	N	12.5
	W21X101	15	60	62.22	2.25	1.75	1	0	0.736	Y	14.8

Note: Optional Deflection Control Limit for 55 ft = 0.83 in.

Table A32.2.60.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X99	23.5	84	36.23	3.75	3.25	2	20	0.54	Y	27
	W30X108	23.5	84	39.53	3.5	3	2	20	0.517	Y	27.1
	W27X114	20.5	78	41.72	3.5	3	2	20	0.626	Y	24.6
	W30X116	23.5	84	42.46	3.25	2.75	2	20	0.493	Y	27.3
	W24X117	17.5	73	42.82	3.75	3.25	1	0	0.795	Y	21.6
7 @ 5 ft	W27X94	20.5	83	40.14	3.75	3.25	2	20	0.632	Y	24.2
	W30X99	23.5	90	42.27	3.5	3	2	20	0.49	Y	27
	W27X102	20.5	83	43.55	3.5	3	2	20	0.601	Y	24.4
	W24X103	17.5	77	43.98	4	3.5	2	20	0.769	Y	21.8
	W24X104	17.5	76	44.41	3.75	3.25	1	0	0.771	Y	21.4
8 @ 4.29 ft	W27X94	20.5	87	45.87	3.5	3	2	20	0.58	Y	24.2
	W24X94	17.5	80	45.87	4	3.5	2	20	0.745	Y	21.6
	W27X102	20.5	88	49.78	3.25	2.75	2	20	0.551	Y	24.4
	W24X103	17.5	81	50.26	3.5	3	2	20	0.705	Y	21.8
	W24X104	17.5	80	50.75	3.5	3	1	0	0.706	Y	21.4
9 @ 3.75 ft	W24X94	17.5	84	51.61	3.75	3.25	2	20	0.69	Y	21.6
	W21X101	15	76	55.45	3.75	3.25	1	0	0.87	Y	18.8
	W24X103	17.5	85	56.55	3.5	3	2	20	0.652	Y	21.8
	W24X104	17.5	83	57.1	3.25	2.75	1	0	0.653	Y	21.4
	W18X106	12	70	58.19	4.25	3.75	1	0	1.168	N	16.4
11 @ 3 ft	W21X83	15	82	55.69	4.25	3.75	2	19	0.871	Y	18.8
	W21X93	15	82	62.4	3.75	3.25	2	20	0.814	Y	19
	W18X97	12	74	65.09	4	3.5	1	0	1.075	N	16.3
	W21X101	15	82	67.77	3.5	3	1	0	0.76	Y	18.8
	W18X106	12	74	71.13	3.75	3.25	1	0	1.021	N	16.4

Table A32.2.60.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X108	23.5	67	39.53	3	2.5	2	20	0.665	Y	24.1
	W27X114	20.5	62	41.72	3	2.5	2	20	0.81	Y	21.6
	W30X116	23.5	67	42.46	2.75	2.25	2	20	0.631	Y	24.3
	W30X124	23.5	68	45.38	2.5	2	1	0	0.601	Y	24.5
	W27X129	20.5	62	47.21	2.75	2.25	1	0	0.74	Y	21.9
7 @ 5 ft	W30X99	23.5	73	42.27	3	2.5	2	20	0.631	Y	24
	W27X102	20.5	66	43.55	3	2.5	2	20	0.779	Y	21.4
	W30X108	23.5	73	46.12	2.75	2.25	2	20	0.599	Y	24.1
	W27X114	20.5	67	48.68	2.75	2.25	1	0	0.728	Y	21.6
	W30X116	23.5	73	49.53	2.5	2	1	0	0.568	Y	24.3
8 @ 4.29 ft	W27X94	20.5	71	45.87	3	2.5	2	20	0.752	Y	21.2
	W27X102	20.5	71	49.78	2.75	2.25	2	20	0.71	Y	21.4
	W24X103	17.5	64	50.26	3	2.5	2	20	0.92	N	18.9
	W24X104	17.5	63	50.75	3	2.5	1	0	0.918	N	18.6
	W21X111	15	57	54.17	3.25	2.75	1	0	1.173	N	16.2
9 @ 3.75 ft	W24X94	17.5	68	51.61	3.25	2.75	2	20	0.902	N	18.8
	W21X101	15	60	55.45	3.25	2.75	1	0	1.144	N	16.1
	W24X103	17.5	68	56.55	3	2.5	2	20	0.846	Y	18.9
	W24X104	17.5	67	57.1	2.75	2.25	1	0	0.844	Y	18.6
	W21X111	15	60	60.94	3	2.5	1	0	1.075	N	16.2
11 @ 3 ft	W21X93	15	66	62.4	3.25	2.75	2	20	1.073	N	16.3
	W18X97	12	57	65.09	3.5	3	1	0	1.432	N	13.7
	W21X101	15	65	67.77	3	2.5	1	0	0.986	N	16.1
	W18X106	12	57	71.13	3.25	2.75	1	0	1.348	N	13.8
	W21X111	15	65	74.48	2.75	2.25	1	0	0.926	N	16.2

Note: Optional Deflection Control Limit for 60 ft = 0.90 in.

Table A32.2.65.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X116	23.5	91	45.94	4.25	3.75	2	21	0.642	Y	29.6
	W30X124	23.5	91	49.1	4	3.5	2	21	0.615	Y	29.8
	W27X129	20.5	86	51.08	4.25	3.75	2	21	0.752	Y	26.9
	W24X131	17.5	79	51.88	4.5	4	1	0	0.964	Y	23.6
	W30X132	23.5	92	52.27	3.75	3.25	2	21	0.594	Y	29.9
7 @ 5 ft	W30X108	23.5	97	49.9	4	3.5	2	21	0.61	Y	29.4
	W27X114	20.5	90	52.67	4.25	3.75	2	21	0.737	Y	26.6
	W30X116	23.5	98	53.59	3.75	3.25	2	21	0.582	Y	29.6
	W24X117	17.5	83	54.05	4.5	4	1	0	0.935	Y	23.4
	W30X124	23.5	98	57.29	3.5	3	2	21	0.557	Y	29.8
8 @ 4.29 ft	W27X102	20.5	95	53.86	4.25	3.75	2	21	0.718	Y	26.4
	W27X114	20.5	95	60.19	4	3.5	2	21	0.676	Y	26.6
	W24X117	17.5	87	61.78	4.25	3.75	1	0	0.855	Y	23.4
	W21X122	15	80	64.42	4.5	4	1	0	1.09	N	20.7
	W27X129	20.5	96	68.11	3.5	3	2	21	0.623	Y	26.9
9 @ 3.75 ft	W24X103	17.5	91	61.18	4.5	4	2	21	0.85	Y	23.6
	W24X104	17.5	90	61.78	4.25	3.75	1	0	0.851	Y	23.2
	W21X111	15	82	65.93	4.5	4	1	0	1.073	N	20.5
	W24X117	17.5	91	69.5	4	3.5	1	0	0.791	Y	23.4
	W21X122	15	83	72.47	4.25	3.75	1	0	1.007	N	20.7
11 @ 3 ft	W21X93	15	89	67.52	5	4.5	2	19	1.06	N	20.6
	W21X101	15	88	73.33	4.5	4	1	0	0.991	N	20.4
	W18X106	12	80	76.96	5	4.5	1	0	1.33	N	17.7
	W21X111	15	88	80.59	4.25	3.75	1	0	0.938	Y	20.5
	W18X119	12	80	86.39	4.75	4.25	1	0	1.213	N	18

Table A32.2.65.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X116	23.5	73	45.94	3.5	3	2	21	0.822	Y	26.3
	W30X124	23.5	73	49.1	3.25	2.75	2	21	0.783	Y	26.5
	W27X129	20.5	68	51.08	3.5	3	2	21	0.964	Y	23.7
	W30X132	23.5	74	52.27	3.25	2.75	2	21	0.753	Y	26.6
	W27X146	20.5	67	57.82	3	2.5	1	0	0.884	Y	23.5
7 @ 5 ft	W30X108	23.5	79	49.9	3.5	3	2	21	0.78	Y	26.1
	W27X114	20.5	72	52.67	3.75	3.25	2	21	0.948	Y	23.4
	W30X116	23.5	79	53.59	3.25	2.75	2	21	0.739	Y	26.3
	W30X124	23.5	80	57.29	3.25	2.75	2	21	0.704	Y	26.5
	W27X129	20.5	73	59.6	3.25	2.75	2	21	0.865	Y	23.7
8 @ 4.29 ft	W27X102	20.5	77	53.86	3.75	3.25	2	21	0.925	Y	23.2
	W27X114	20.5	77	60.19	3.5	3	2	21	0.864	Y	23.4
	W24X117	17.5	68	61.78	3.5	3	1	0	1.102	N	20.3
	W21X122	15	62	64.42	4	3.5	1	0	1.422	N	17.7
	W27X129	20.5	78	68.11	3	2.5	2	21	0.787	Y	23.7
9 @ 3.75 ft	W24X103	17.5	73	61.18	3.75	3.25	2	21	1.102	N	20.5
	W24X104	17.5	72	61.78	3.75	3.25	1	0	1.099	N	20.1
	W21X111	15	64	65.93	4	3.5	1	0	1.401	N	17.6
	W24X117	17.5	72	69.5	3.5	3	1	0	1.011	N	20.3
	W21X122	15	65	72.47	3.75	3.25	1	0	1.303	N	17.7
11 @ 3 ft	W21X101	15	70	73.33	3.75	3.25	1	0	1.285	N	17.5
	W21X111	15	70	80.59	3.5	3	1	0	1.206	N	17.6
	W18X119	12	62	86.39	4	3.5	1	0	1.583	N	15.2
	W21X122	15	71	88.57	3.25	2.75	1	0	1.121	N	17.7
	W18X130	12	62	94.38	3.75	3.25	1	0	1.446	N	15.5

Note: Optional Deflection Control Limit for 65 ft = 0.98 in.

Table A32.2.70.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X132	23.5	99	56.23	4.75	4.25	2	20	0.757	Y	32.3
	W27X146	20.5	91	62.2	4.75	4.25	1	0	0.888	Y	28.8
	W27X161	20.5	91	68.59	4.25	3.75	1	0	0.834	Y	29
7 @ 5 ft	W30X116	23.5	105	57.65	5	4.5	2	20	0.741	Y	31.9
	W30X124	23.5	105	61.63	4.75	4.25	2	23	0.709	Y	32.1
	W27X129	20.5	98	64.11	5	4.5	2	21	0.866	Y	29
	W30X132	23.5	106	65.6	4.5	4	2	23	0.685	Y	32.3
	W27X146	20.5	97	72.56	4.25	3.75	1	0	0.802	Y	28.8
8 @ 4.29 ft	W27X114	20.5	103	64.75	5	4.5	2	21	0.861	Y	28.7
	W27X129	20.5	103	73.27	4.5	4	2	23	0.793	Y	29
	W24X131	17.5	93	74.41	5	4.5	1	0	1.014	Y	25.4
	W27X146	20.5	102	82.93	4	3.5	1	0	0.733	Y	28.8
	W24X146	17.5	94	82.93	4.5	4	1	0	0.94	Y	25.7
9 @ 3.75 ft	W24X117	17.5	97	74.76	5	4.5	2	23	1.007	Y	25.2
	W21X122	15	89	77.96	5.5	5	2	23	1.282	N	22.3
	W24X131	17.5	98	83.71	4.5	4	1	0	0.937	Y	25.4
	W21X132	15	89	84.35	5.25	4.75	1	0	1.22	N	22.4
	W24X146	17.5	98	93.29	4.25	3.75	1	0	0.868	Y	25.7
11 @ 3 ft	W21X111	15	95	86.69	5.25	4.75	2	23	1.194	N	22.1
	W21X122	15	95	95.28	5	4.5	1	0	1.119	N	22.3
	W21X132	15	95	103.09	4.75	4.25	1	0	1.064	N	22.4

Table A32.2.70.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W30X132	23.5	79	56.23	4	3.5	2	23	0.959	Y	28.7
	W27X146	20.5	72	62.2	4	3.5	1	0	1.125	N	25.3
	W27X161	20.5	72	68.59	3.75	3.25	1	0	1.049	Y	25.5
7 @ 5 ft	W30X116	23.5	85	57.65	4.25	3.75	2	23	0.942	Y	28.3
	W30X124	23.5	86	61.63	4	3.5	2	23	0.897	Y	28.5
	W27X129	20.5	78	64.11	4.25	3.75	2	23	1.102	N	25.5
	W30X132	23.5	86	65.6	3.75	3.25	2	23	0.862	Y	28.7
	W27X146	20.5	77	72.56	3.75	3.25	1	0	1.008	Y	25.3
8 @ 4.29 ft	W27X114	20.5	83	64.75	4.5	4	2	23	1.1	N	25.2
	W27X129	20.5	84	73.27	4	3.5	2	23	1.002	Y	25.5
	W24X131	17.5	74	74.41	4.25	3.75	1	0	1.293	N	22.1
	W27X146	20.5	83	82.93	3.5	3	1	0	0.915	Y	25.3
	W24X146	17.5	74	82.93	3.75	3.25	1	0	1.187	N	22.3
9 @ 3.75 ft	W24X117	17.5	78	74.76	4.25	3.75	1	0	1.288	N	21.9
	W24X131	17.5	78	83.71	4	3.5	1	0	1.186	N	22.1
	W21X132	15	70	84.35	4.5	4	1	0	1.568	N	19.2
	W24X146	17.5	78	93.29	3.75	3.25	1	0	1.088	N	22.3
11 @ 3 ft	W21X111	15	76	86.69	4.75	4.25	1	0	1.535	N	18.9
	W21X122	15	76	95.28	4.25	3.75	1	0	1.427	N	19.1
	W18X130	12	67	101.53	4.75	4.25	1	0	1.841	N	16.6
	W21X132	15	76	103.09	4	3.5	1	0	1.347	N	19.2

Note: Optional Deflection Control Limit for 70 ft = 1.05 in.

Table A32.2.75.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X161	20.5	98	73.42	5.5	5	2	25	1.042	Y	31.1
7 @ 5 ft	W30X132	23.5	113	70.22	5.5	5	3	18	0.855	Y	34.6
	W27X146	20.5	103	77.67	5.5	5	2	25	1.002	Y	30.8
	W27X161	20.5	104	85.65	5	4.5	1	0	0.94	Y	31.1
8 @ 4.29 ft	W27X129	20.5	110	78.43	5.75	5.25	3	18	0.991	Y	31.1
	W27X146	20.5	109	88.77	5	4.5	1	0	0.916	Y	30.8
	W24X146	17.5	100	88.77	5.75	5.25	2	25	1.174	N	27.5
	W27X161	20.5	110	97.89	4.75	4.25	1	0	0.859	Y	31.1
9 @ 3.75 ft	W24X131	17.5	104	89.6	5.75	5.25	2	25	1.17	N	27.2
	W24X146	17.5	105	99.86	5.25	4.75	2	25	1.084	Y	27.5
11 @ 3 ft	W21X122	15	102	101.99	6.25	5.75	2	25	1.398	N	23.9

Table A32.2.75.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
6 @ 6 ft	W27X161	20.5	77	73.42	4.75	4.25	1	0	1.311	N	27.4
7 @ 5 ft	W30X132	23.5	92	70.22	4.75	4.25	2	23	1.076	Y	30.7
	W27X146	20.5	83	77.67	4.75	4.25	1	0	1.259	N	27.1
	W27X161	20.5	83	85.65	4.25	3.75	1	0	1.173	N	27.4
8 @ 4.29 ft	W27X129	20.5	90	78.43	5	4.5	2	23	1.252	N	27.4
	W27X146	20.5	88	88.77	4.25	3.75	1	0	1.143	N	27.1
	W24X146	17.5	79	88.77	4.75	4.25	1	0	1.483	N	23.9
	W27X161	20.5	89	97.89	4	3.5	1	0	1.064	Y	27.4
9 @ 3.75 ft	W24X131	17.5	84	89.6	5	4.5	1	0	1.482	N	23.7
	W24X146	17.5	84	99.86	4.5	4	1	0	1.359	N	23.9
11 @ 3 ft	W21X122	15	81	101.99	5.5	5	2	25	1.783	N	20.5

Note: Optional Deflection Control Limit for 75 ft = 1.13 in.

Table A32.2.80.3

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 5 ft	W27X161	20.5	111	91.29	6.25	5.75	2	26	1.155	Y	33.2
8 @ 4.29 ft	W27X146	20.5	116	94.61	6.25	5.75	2	26	1.126	Y	32.9
	W27X161	20.5	117	104.33	5.75	5.25	2	26	1.056	Y	33.2
9 @ 3.75 ft	W24X146	17.5	112	106.43	6.75	6.25	2	26	1.333	N	29.3

Table A32.2.80.0

Number of girders @ spacing	Section	Radius of formwork (in.)	Volume of concrete (yd^3)	Weight of steel (kips)	Interior camber (in.)	Exterior camber (in.)	Number of diaphragms	Diaphragm spacing B (ft)	Service level deflection (in.)	Optional defl. control	Water sliding force (kips)
7 @ 5 ft	W27X161	20.5	88	91.29	5.5	5	2	26	1.442	N	29.2
8 @ 4.29 ft	W27X146	20.5	94	94.61	5.5	5	2	26	1.405	N	28.9
	W27X161	20.5	95	104.33	5	4.5	1	0	1.307	N	29.2
9 @ 3.75 ft	W24X146	17.5	89	106.43	5.75	5.25	2	26	1.67	N	25.5

Note: Optional Deflection Control Limit for 80 ft = 1.2 in.

APPENDIX B

Generic Standard MBISB Construction Drawings

APPENDIX B TABLE OF CONTENTS

DESCRIPTION OF GENERIC DRAWINGS

B.1 General Information

These generic standard design sheets were developed to provide the user with a means of producing a set of drawings for a Modified Beam-in-Slab Bridge (MBISB) which meets the requirements presented in the Design Manual. By using the information presented in the Design Manual to determine the size, number, etc. of components required for the desired MBISB, the engineer can generate a set of construction drawings.

Although an effort has been made to provide sufficiently complete information and to allow for adaptation to a specific bridge, requirements imposed by site conditions may necessitate modification of these drawings.

The completed set of MBISB drawings assembled from these templates shall be reviewed and sealed by a Registered Professional Engineer prior to the beginning of construction. It is important that the substructure which needs to be compatible with the MBISB superstructure be designed and approved. It is recommended to implement a substructure similar to those discussed in the Design Manual.

The concepts, designs, details, and notes shown in these standard plans for the MBISB have been developed by the Bridge Engineering Center (BEC) of Iowa State University using the guidelines specified in the AASHTO LRFD Bridge Specification and design practices developed through the design and construction of demonstration bridges (*5*). While the bridge system shown has been carefully designed, detailed and checked, any user should independently determine the appropriateness and potential adaptability of the MBISB design methodology and drawings for specific bridge sites.

B.2 Instructions for Using Construction Drawings

Prior to using these design drawings, the designer must obtain the basic survey and geometric data of the bridge site. Information concerning the foundation material and the elevation of the potential foundation bearing surface must also be obtained.

The feasibility of the MBISB design and the applicability of the standard construction drawings shall be determined using the flowchart provided in Figure B.1. Once the design has been completed and all necessary geometry, bearing elevations, finished ground elevations, etc. have been determined, the designer can produce the final construction drawings. Completed drawings should be included with the final set of construction documents. The following steps should be followed in the preparation process:

1. Complete an appropriate substructure design.
2. Complete the MBISB superstructure design.
3. Fill in all information pertinent to the bridge and construction site in the indicated locations (i.e., fill in all of the blank boxes) including :
    - Basic survey data
    - Design details provided in the MBISB Design Manual
4. Add drawing titles and add miscellaneous information including:
    - Customizing the standard drawings by adding necessary location and route information to the title block of each sheet
    - Add necessary information pertaining to utilities and specific construction concerns.

These standard MBISB plans consist of four different types of sheets. The first type (A series) consists of two general sheets that describe the location, overall dimensions and materials required to construct the selected design. Sheet (D1) provides general information and instructions relating to the usage of the construction sheets and is not to be included in the final set of construction documents. The seven construction sheets (C series) describe the components

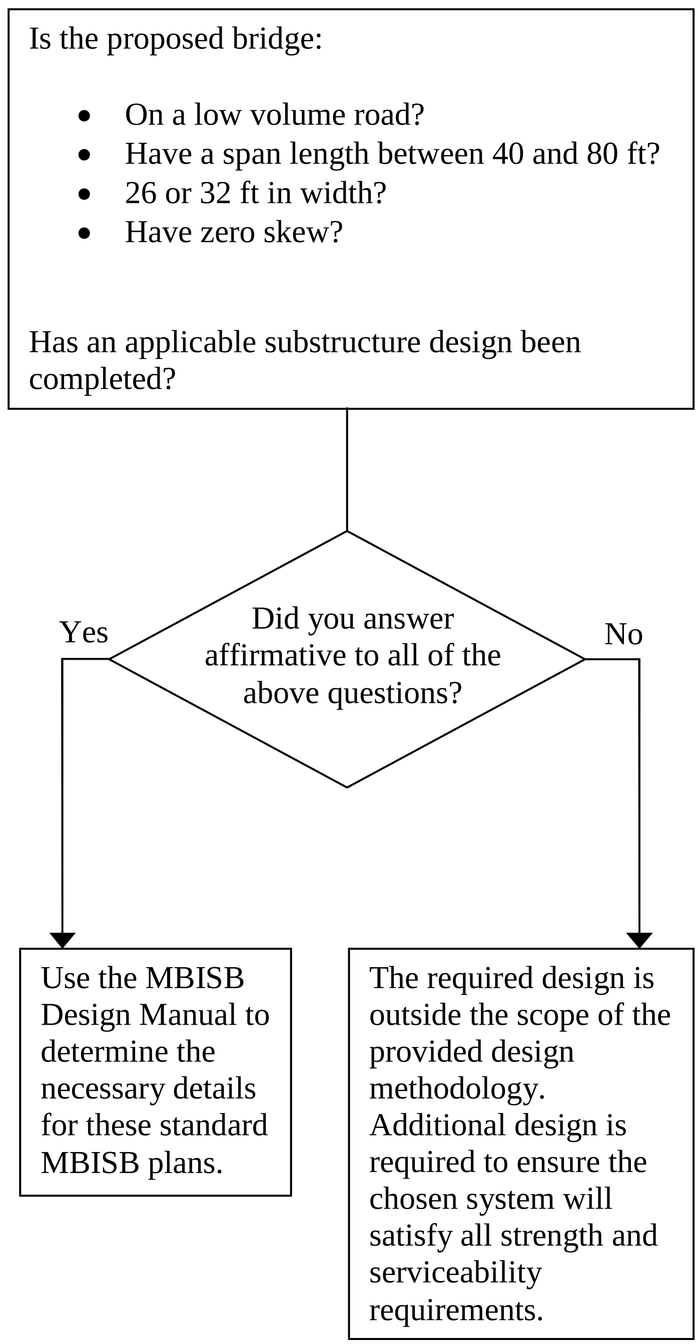


Figure B.1. MBISB feasibility flowchart.

necessary to complete the selected design. To accommodate the different designs, four worksheets (1-4) that contain drawings for the location of the diaphragms, diaphragm components and girder profiles are also included. The appropriate figures from the worksheets for a specific design are to be imported into the A and C sheets to describe the selected design. A complete set of construction drawings consists of the A and C series sheets, modified to reflect the specific design using the information from the four worksheets.

Generic Standard MBISB Construction Drawings

IOWA
DEPARTMENT OF TRANSPORTATION

Project Development Division

PLANS OF PROPOSED IMPROVEMENT ON THE

SECONDARY ROAD SYSTEM
COUNTY
BRIDGE

The Standard Specifications, Series of 2002, of the Iowa Department of Transportation Shall Apply to Construction Work on this Project

Plus Current Special Provisions and Supplemental Specifications

Scales: As Noted

N

SITE

MAP

AADT V.P.D.

Project No.

roadway width
piles
backwall
pile cap
superstructure

APPROVED

County Engineer
Date __/__/__

Approved: County
Board of Supervisors

INDEX OF SHEETS

No.	Description

MILEAGE SUMMARY

Div.	Location	Lin. Ft.	Miles

ROAD STANDARD PLANS

The following Standard Plans shall be considered applicable to construction work on this project.

Identification	Date	Identification	Date	Identification	Date

BRIDGE STANDARDS

The following Bridge Standards shall be be considered applicable

Standard	Date Issued	Latest Revision	Standard	Date Issued	Latest Revision

Designed by: ____________ Design checked by: ____________
Drawn by: ____________ Drawings checked by: ____________

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed professional Engineer under the laws of the State of Iowa

Iowa Registration # Date __/__/__
Registration Subject to Renewal __/__/__

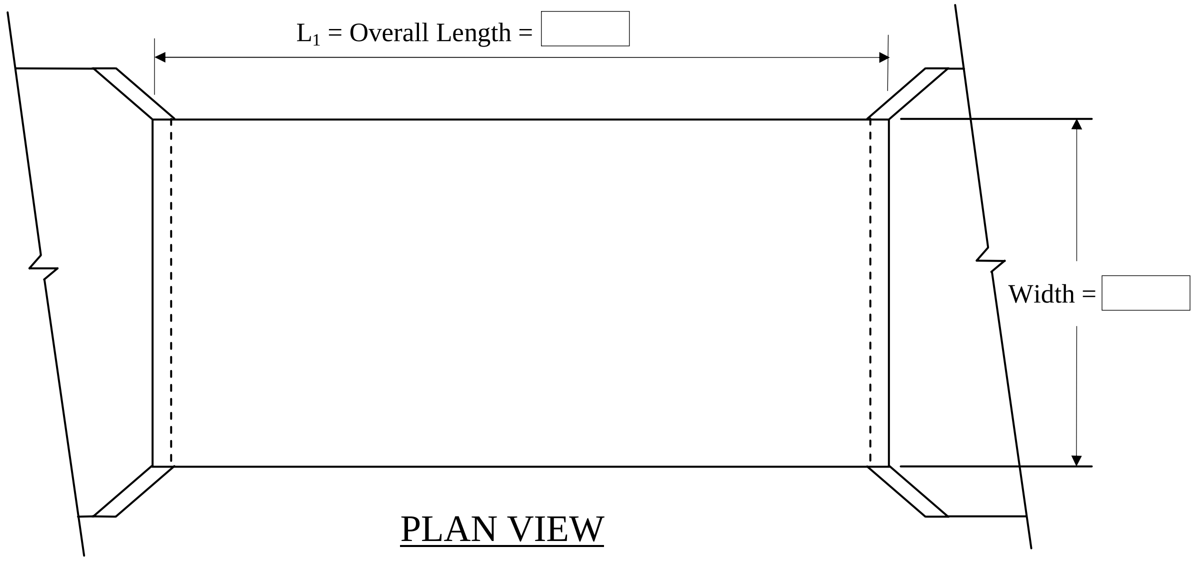
REVISIONS

149

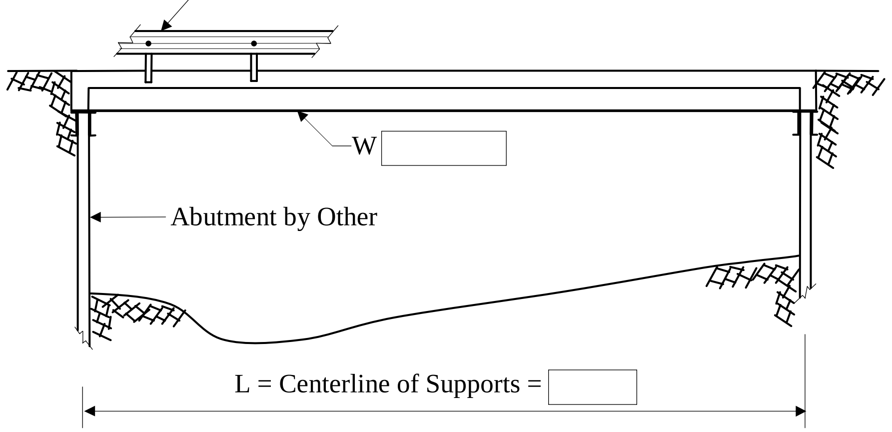
COVER SHEET

DATE:
DRAWN BY:
CHECKED BY:
SCALE:
PROJECT NO:
SHEET NO:

A 1



PLAN VIEW



ELEVATION VIEW

Insert from Worksheet 3 or 4 Depending on Bridge Width

NOTE: All Girder Profiles are Symmetric about the Center Line of the Bridge

GIRDER PROFILE

GENERAL NOTES

- Materials and workmanship shall be in accordance with all applicable Iowa Department of Transportation standards.
- Structural timber shall conform to ASTM ______ designation as noted.
- Structural steel shall conform to ASTM ______ designation as noted.
- Exposed steel and or timber shall be painted as noted and conform to ______ .
- Structural steel and hardware shall be galvanized and shall conform to ASTM ______ designation as noted.
- Concrete cover on reinforcement shall be as noted.
- Concrete shall be class ______.
- All reinforcement steel shall meet applicable requirements for ASTM ______ Grade ______.
- Reinforcement shall be epoxy coated as noted and shall conform to ASTM ______ .
- All dimensions are horizontal and shall be accurate at a temperature of ______ degrees.
- The ______ shall notify all involved utility companies a minimum of 7 days prior to starting work. Utilities shall not be disturbed or endangered during construction operations.

SUMMARY OF ESTIMATED QUANTITIES FOR MBISB SUPERSTRUCTURE

ITEM	QTY.	UNIT	TOTAL

GENERAL PLAN ______ Girders on ______ ft Centers

Modified Beam-in-Slab Bridge: ______ ft Long, ______ ft Wide

LOCATION: ______

REVISIONS

GENERAL BRIDGE PLAN AND ELEVATION

TABLE OF QUANTITIES

DATE:

DRAWN BY:

CHECKED BY:

SCALE:

PROJECT NO:

SHEET NO:

A 2

Sheet Description

Sheet	Sheet Type	Sheet Contents
A1	Applications	Cover sheet
A2	Applications	General bridge plan and elevation, Table of quantities
D1	Directions	General information and notes
C1	Construction	Diaphragm layout, components, ASC/backwall holes
C2	Construction	Transverse tension rods, Diaphragm profile
C3	Construction	Backwall reinforcement, Exterior formwork support
C4	Construction	Exterior formwork support components Installed exterior formwork
C5	Construction	Interior formwork, ASC/backwall reinforcement
C6	Construction	Backwall and longitudinal T & S reinforcement
C7	Construction	Transverse T & S reinforcement
1	Worksheet	Diaphragm layout and connectors
2	Worksheet	Diaphragm sections and backwall layout
3	Worksheet	Girder elevations for 26 ft wide MBISBs
4	Worksheet	Girder elevations for 32 ft wide MBISBs

General Information

These generic standard design sheets were developed to provide the user with a means of producing a set of drawings for a Modified Beam-in-Slab Bridge (MBISB) which meets the requirements presented in the Design Manual. By using the information presented in the Design Manual to determine the size, number, etc. of components required for the desired MBISB, the engineer can generate a set of construction drawings.

Although an effort has been made to provide sufficiently complete information and to allow for adaptation to a specific bridge, requirements imposed by site conditions may necessitate modification of these drawings.

The completed set of MBISB drawings assembled from these templates shall be reviewed and sealed by a Registered Professional Engineer prior to the beginning of construction. It is important that the substructure which needs to be compatible with the MBISB superstructure be designed and approved. It is recommended to implement a substructure similar to those discussed in the Design Manual.

The concepts, designs, details, and notes shown in these standard plans for the MBISB have been developed by the Bridge Engineering Center (BEC) of Iowa State University using the guidelines specified in the AASHTO LRFD Bridge Specification and design practices developed through the design and construction of demonstration bridges. While the bridge system shown has been carefully designed, detailed and checked, any user should independently determine the appropriateness and potential adaptability of the MBISB design methodology and drawings for specific bridge sites.

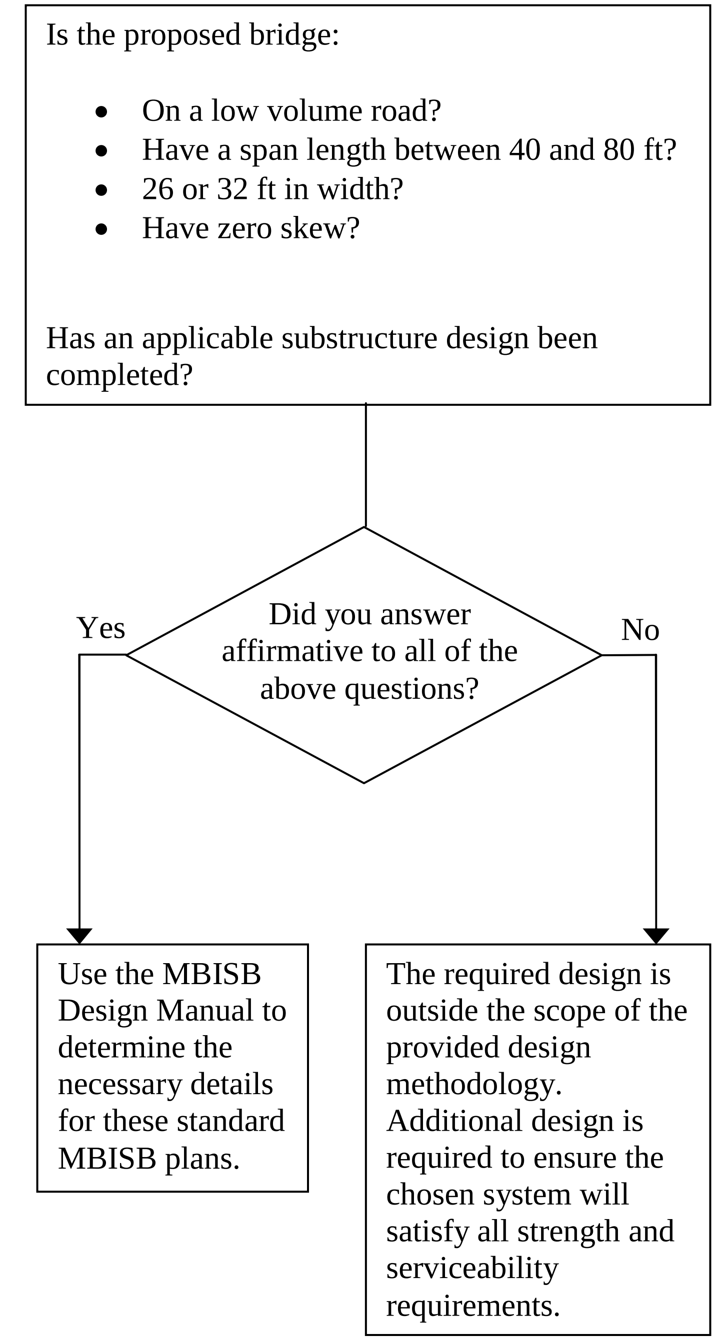
Instructions for Using Construction Drawings

These standard MBISB plans consist of four different types of sheets. The first type (A series) consists of two general sheets that describe the location, overall dimensions and materials required to construct the selected design. This sheet (D1) provides general information and instructions relating to the usage of the construction sheets and is not to be included in the final set of construction documents. The seven construction sheets (C series) describe the components necessary to complete the selected design. To accommodate the different designs, four worksheets (1-4) that contain drawings for the location of the diaphragms, diaphragm components and girder profiles are also included. The appropriate figures from the worksheets for a specific design are to be imported into the A and C sheets to describe the selected design. A complete set of construction drawings consists of the A and C series sheets, modified to reflect the specific design using the information from the four worksheets.

Prior to using these design drawings, the designer must obtain the basic survey and geometric data of the bridge site. Information concerning the foundation material and the elevation of the potential foundation bearing surface must also be obtained.

The design of the MBISB structure shall be completed following the methodology presented in the Design Manual and the presented flowchart. Once the design has been completed and all necessary geometry, bearing elevations, finished ground elevations, etc. have been determined, the designer can produce the final construction drawings. Completed drawings should be included with the final set of construction documents. The following steps should be followed in the preparation process:

1. Complete an appropriate substructure design.
2. Complete the MBISB superstructure design.
3. Fill in all information pertinent to the bridge and construction site in the indicated locations (i.e., fill in all of the blank boxes) including :
    - Basic survey data
    - Design details provided in the MBISB Design Manual
4. Add drawing titles and miscellaneous information including:
    - Customizing the standard drawings by adding necessary location and route information to the title block of each sheet
    - Add necessary information pertaining to utilities and specific construction concerns.



REVISIONS

GENERAL INFORMATION AND NOTES

DATE:

DRAWN BY:

CHECKED BY:

SCALE:

PROJECT NO:

SHEET NO:

INSTRUCTIONS

Modified Beam-in-Slab Bridge: ______ ft Long, ______ ft Wide

LOCATION: ______

D 1

Insert from Worksheet 1

DIAPHRAGM LAYOUT

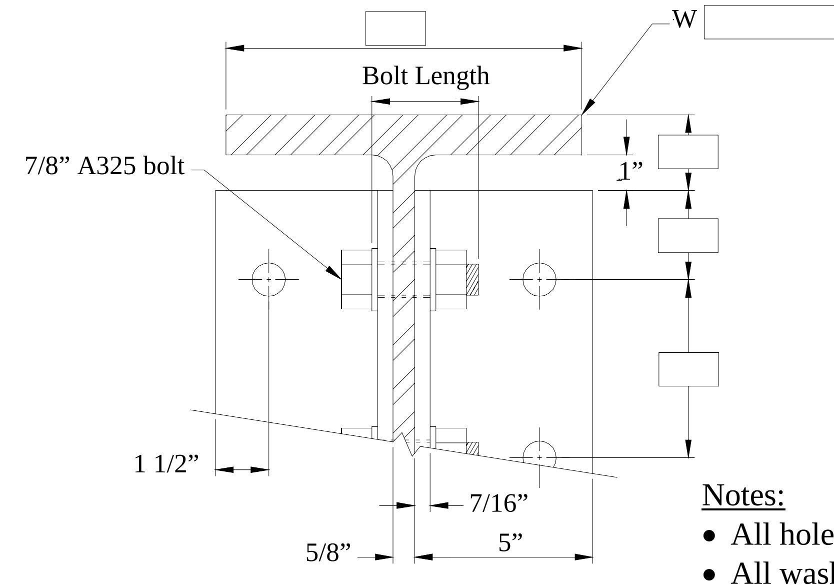
Insert from Worksheet 1

DIAPHRAGM CONNECTOR FOR C ______ SECTIONS

Insert from Worksheet 2

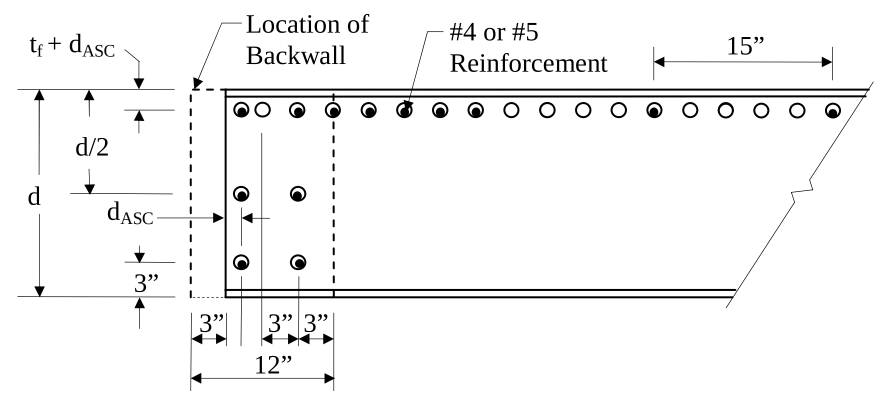
C ______ DIAPHRAGM SECTION

Notes:
- S = Girder spacing, in.
- t_w = Web thickness for longitudinal girder, in.
- All holes 15/16 in. diameter



Notes:
- All holes 15/16 in. diameter
- All washers 5/32 in. thick

TYPICAL BOLTED DIAPHRAGM CONNECTION DETAIL



Notes:
- All holes = 1 1/4 in. diameter, torched or cored on 3 in. centers unless otherwise indicated.
- d = Depth of section, in.
- t_f = Flange thickness, in.

TYPICAL LAYOUT OF ASC REINFORCEMENT

Insert from Worksheet 2

Notes:
- All holes = 1 1/4 in. diameter, torched or cored on 3 in. centers unless otherwise indicated.
- d = Depth of section, in.
- t_f = Flange thickness, in.

LAYOUT W ______ BACKWALL REINFORCEMENT

REVISIONS

MBISB

DIAPHRAGM LAYOUT, COMPONENTS ASC/BACKWALL HOLES

DATE:

DRAWN BY:

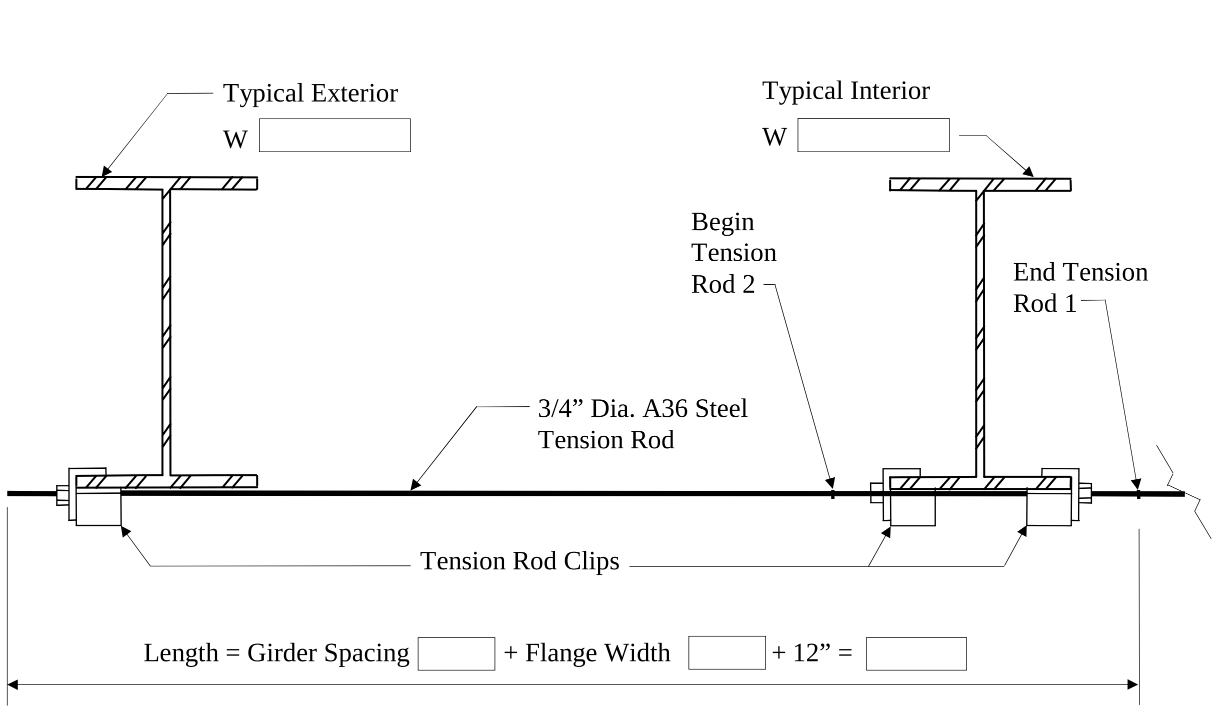
CHECKED BY:

SCALE:

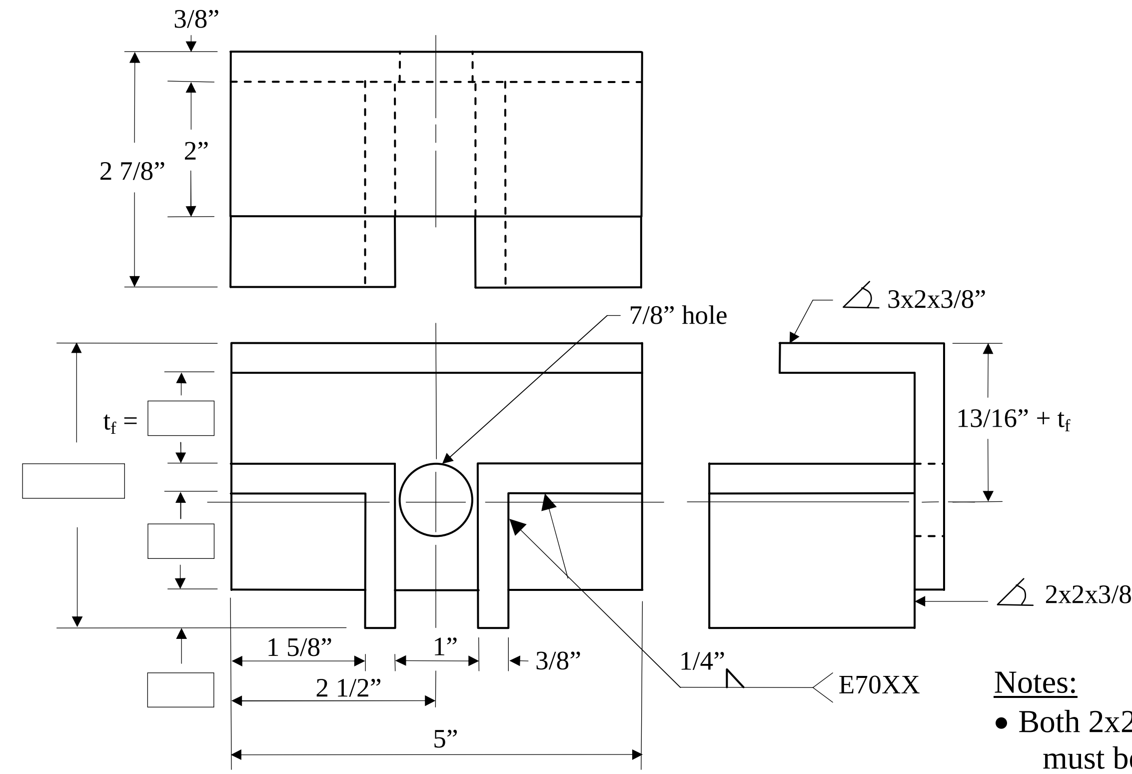
PROJECT NO:

SHEET NO:

C 1



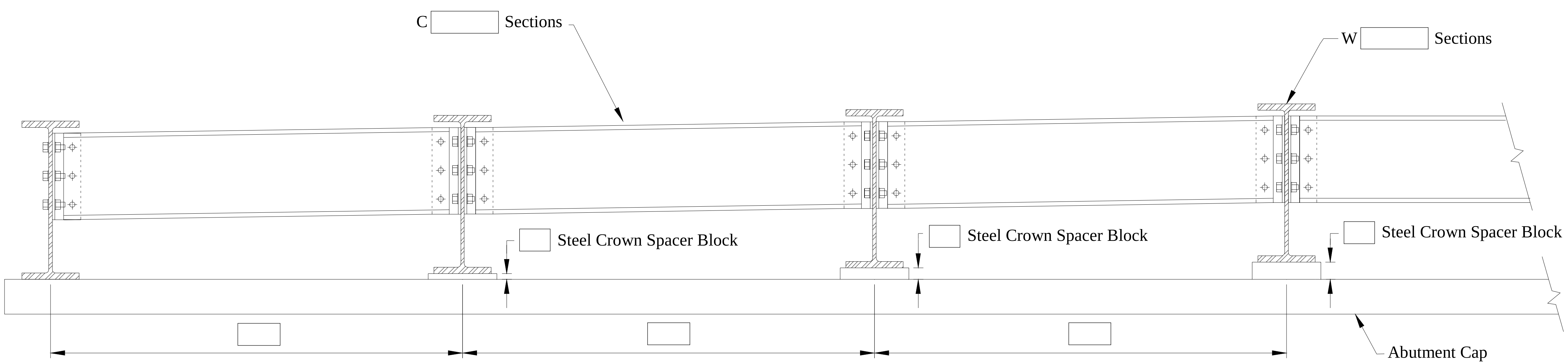
TYPICAL LAYOUT OF THE TENSION RODS AND CLIPS



Notes:

- Both 2x2x3/8" angles must be welded
- All angle sections A36 steel

TENSION CLIPS



Layout of C Diaphragm Sections

TYPICAL DIAPHRAGM PROFILE

Notes:

- The presented diaphragm profile is for the 8 girders on 4.29 ft centers. However, this profile can be modified to accommodate other configurations.
- All diaphragm bolts 7/8 in. diameter
- All holes 15/16 in. diameter
- Holes for the diaphragm members are a construct to fit detail.

REVISIONS

MBISB

TRANSVERSE TENSION RODS
DIPHRAGM PROFILE

DATE:

DRAWN BY:

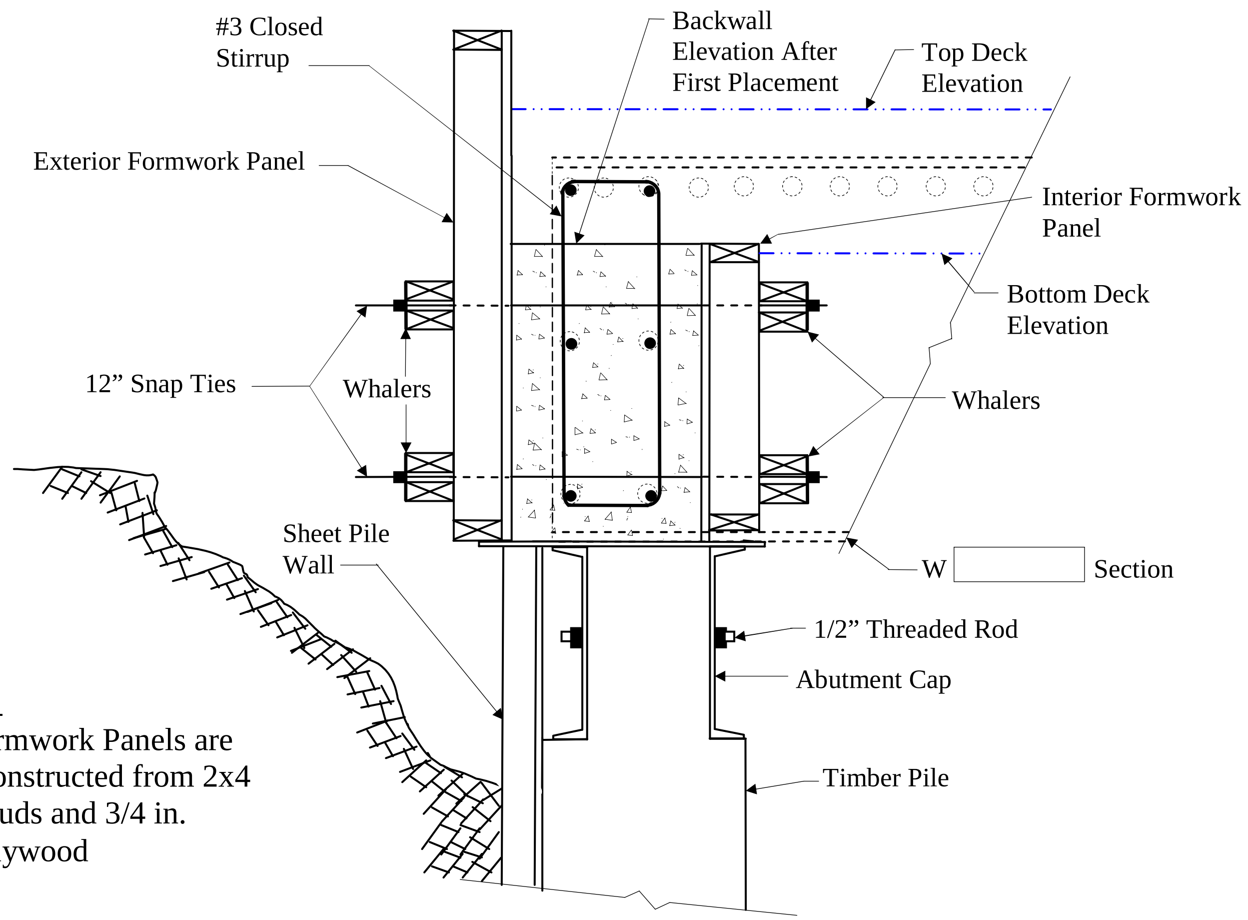
CHECKED BY:

SCALE:

PROJECT NO:

SHEET NO:

C 2



Note:

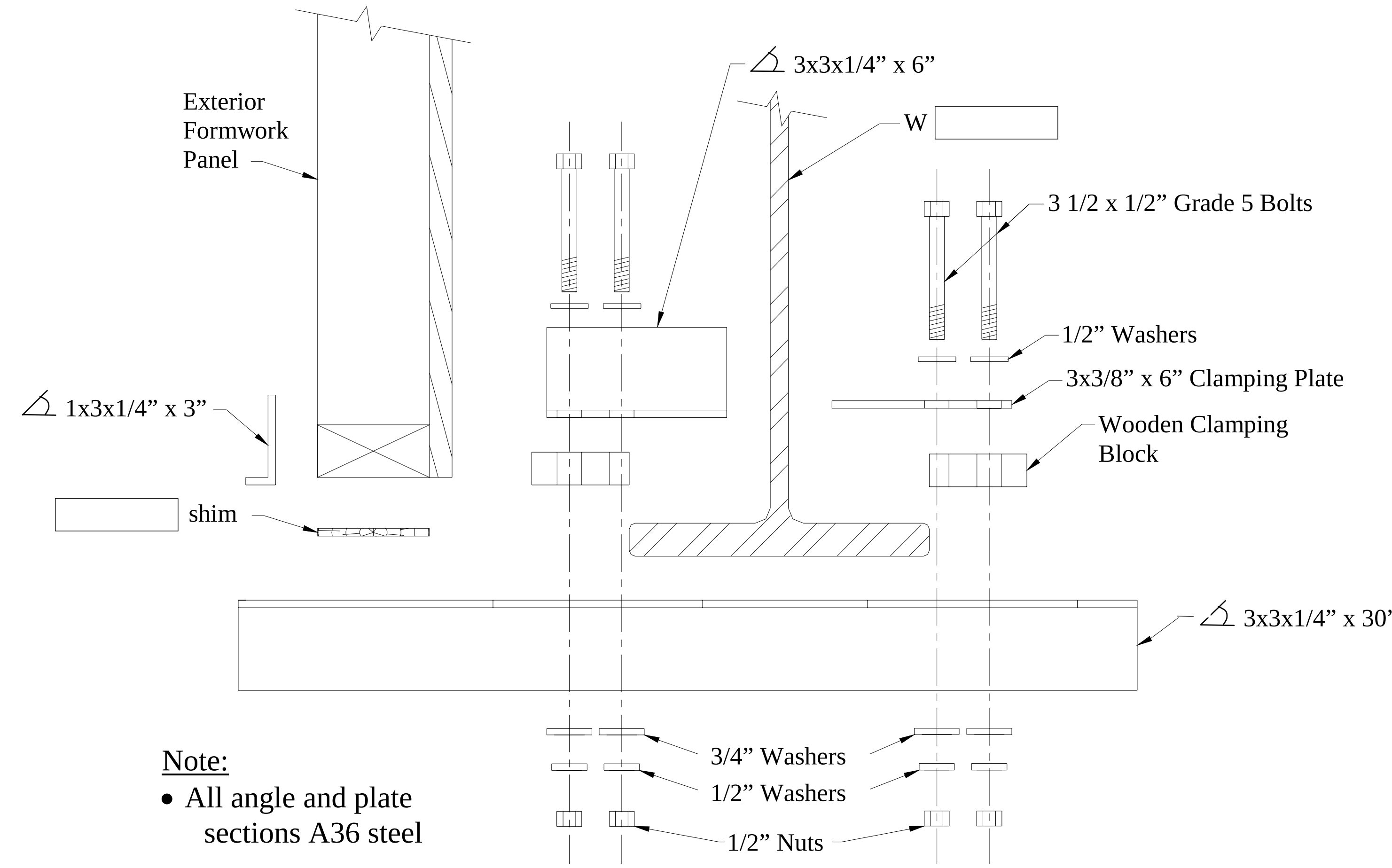
- Formwork Panels are constructed from 2x4 studs and 3/4 in. plywood

GENERIC CROSS SECTION OF BACKWALL

TABLE 1 Lines of Reinforcement Required Per Backwall

Selected Girder	W14	W18	W21	W24	W27	W30
Lines of Reinforcement	4	4	6	6	6	6

Note: Reinforcement layout shown in above figure of a generic cross section



Note:

- All angle and plate sections A36 steel

EXPLODED EXTERIOR FORMWORK SYSTEM

REVISIONS

MBISB

BACKWALL REINFORCEMENT
EXTERIOR FORMWORK SUPPORT

DATE:

DRAWN BY:

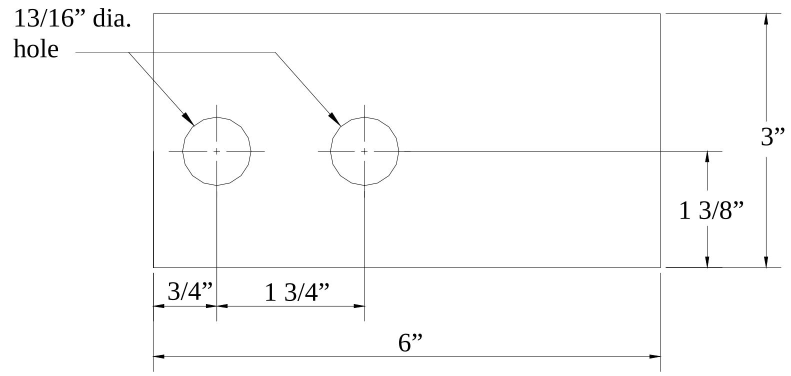
CHECKED BY:

SCALE:

PROJECT NO:

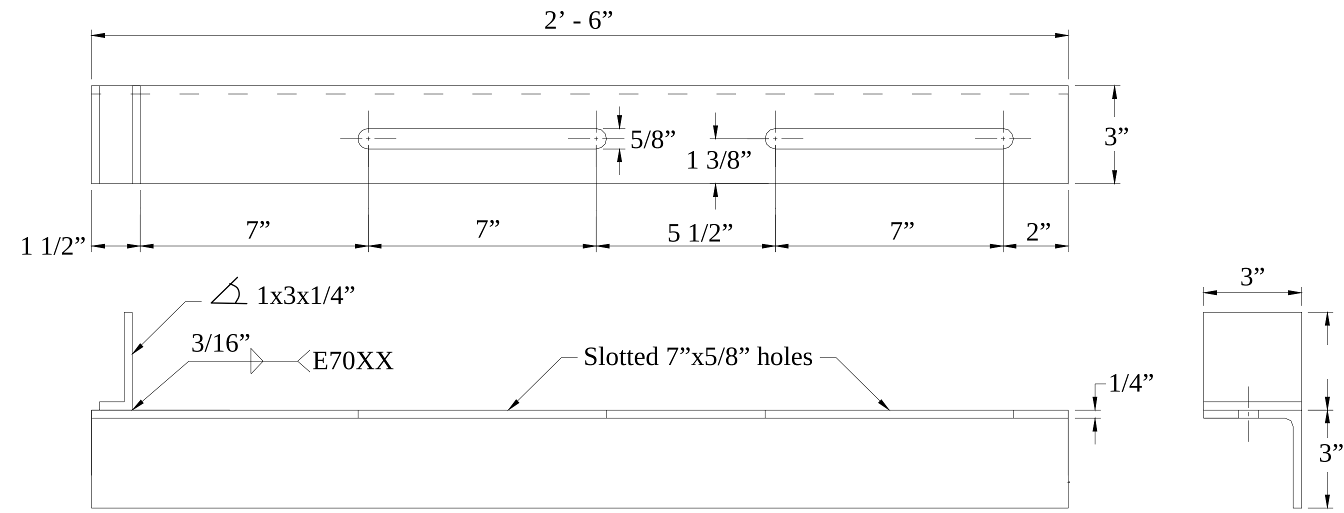
SHEET NO:

C 3



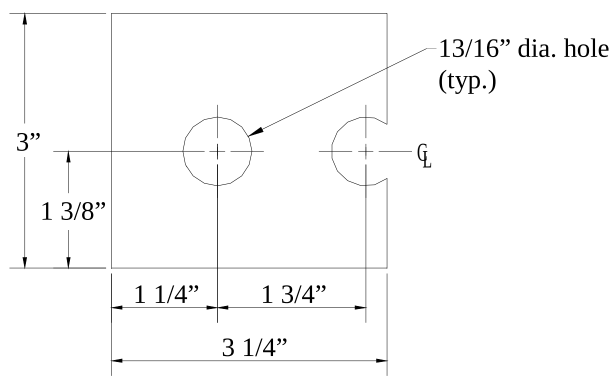
Note:
- Plate thickness = 3/8 in.

PLATE CLAMP COMPONENT



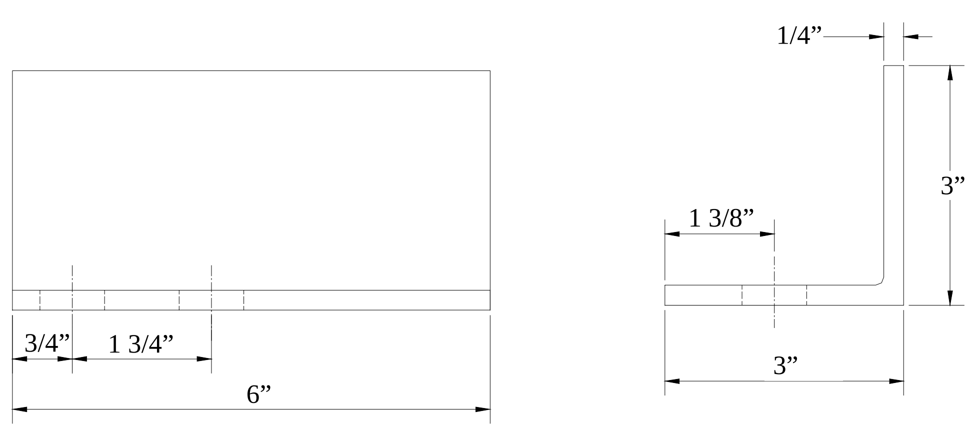
Note:
- All angle and plate sections A36 steel

ANGLE SECTION FOR THE EXTERIOR FORMWORK SUPPORT



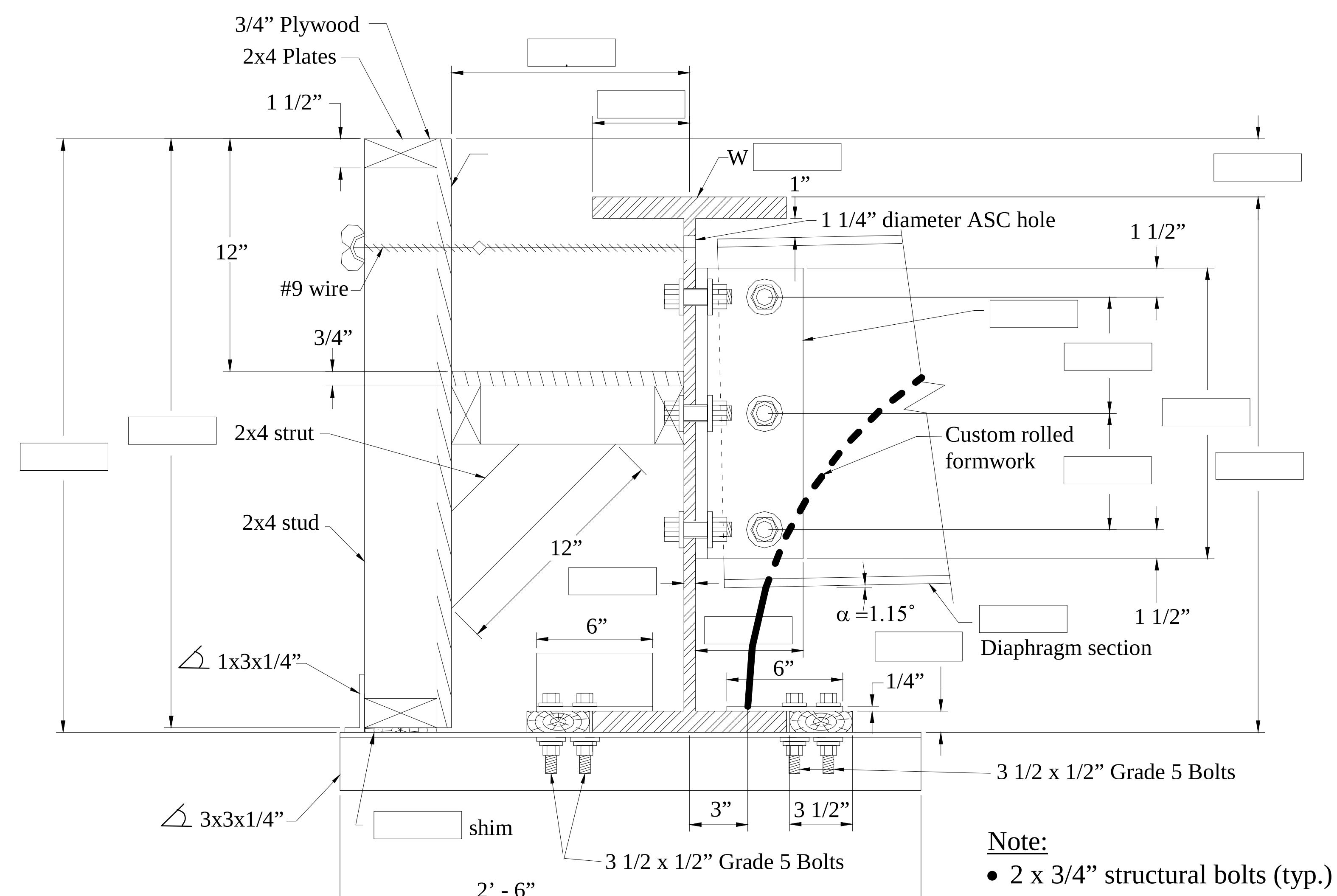
Note:
- Block thickness = Longitudinal girder flange thickness (t_w) =

WOODEN CLAMPING BLOCK



Note:
- All holes 13/16 in. diameter

ANGLE CLAMP COMPONENT



Note:
- 2 x 3/4” structural bolts (typ.)
- 3/4” flat washers (typ.)

INSTALLED EXTERIOR FORMWORK

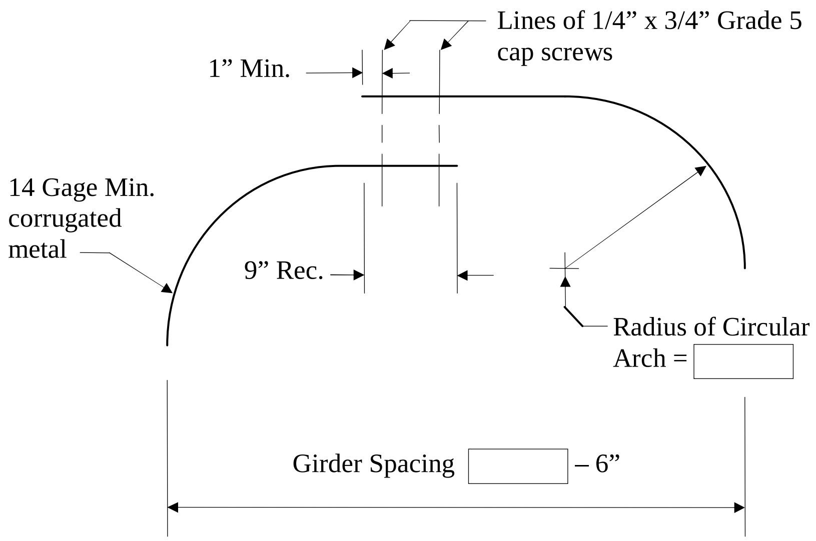
REVISIONS

MBISB

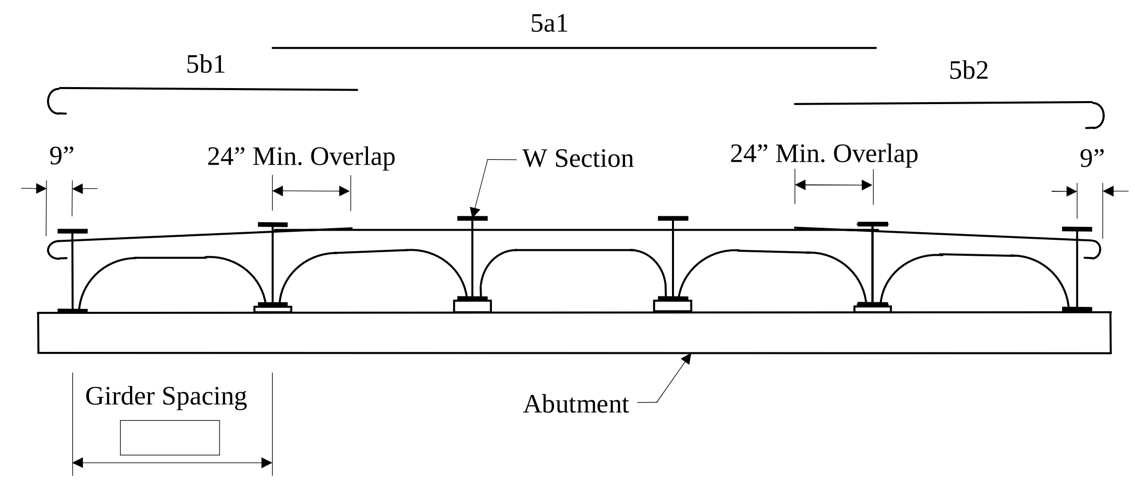
EXTERIOR FORMWORK SUPPORT
COMPONENTS
INSTALLED EXTERIOR FORMWORK

DATE:
DRAWN BY:
CHECKED BY:
SCALE:
PROJECT NO:
SHEET NO:

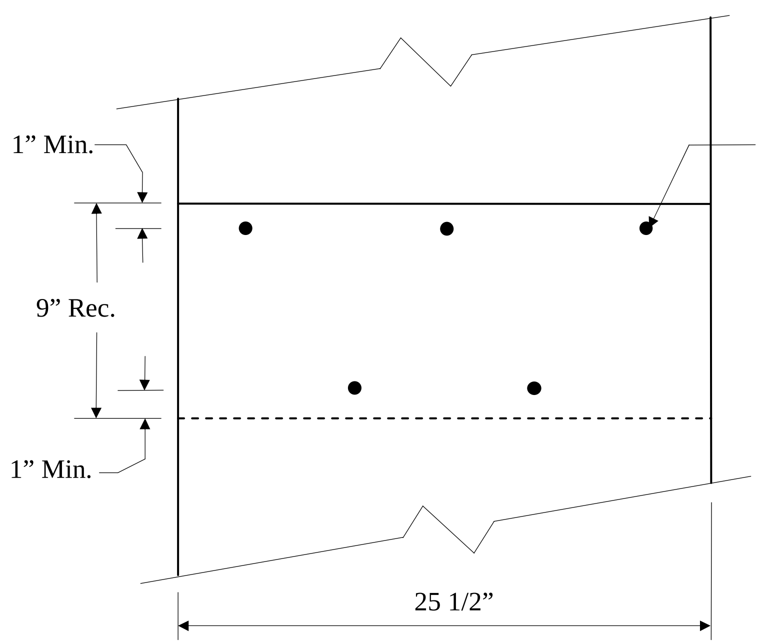
C 4



Profile of Typical Custom Rolled Arched Formwork



TRANSVERSE ASC AND BACKWALL REINFORCEMENT



Notes:
- Final bolt position will depend on corrugation location
- Rec. = Recommended
- Min. = Minimum

Cap Screw Placement for the Individual Formwork Sections

INTERIOR FORMWORK SYSTEM

Table 2 Dimensions of the Transverse ASC and Backwall Reinforcement

Width of Bridge (ft)	Bar/Length (in.)		
	5a1	5b1	5b2
26	-	120	240
32	240	86	154

REVISIONS

MBISB

INTERIOR FORMWORK
ASC/BACKWALL REINFORCEMENT

DATE:

DRAWN BY:

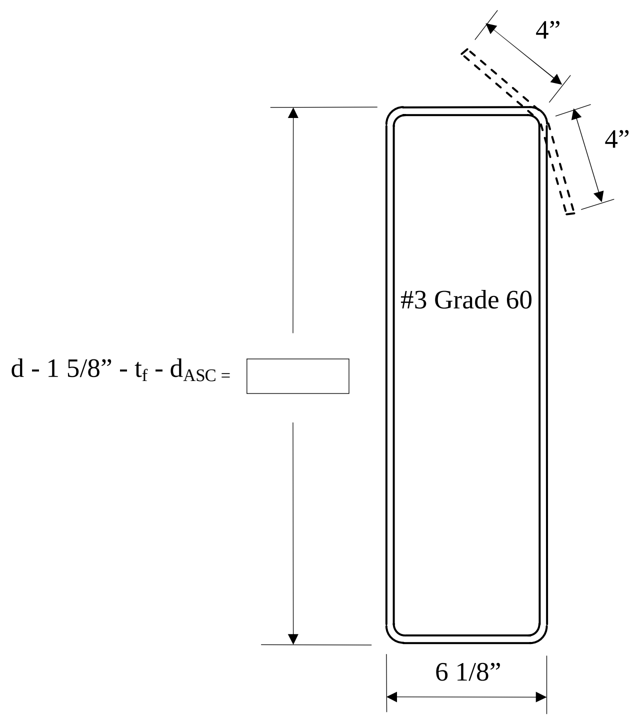
CHECKED BY:

SCALE:

PROJECT NO:

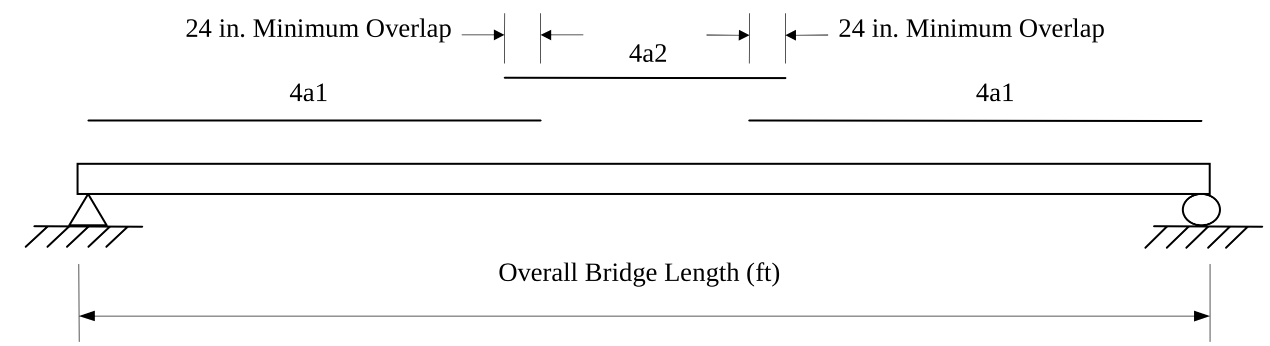
SHEET NO:

C 5



Notes:
- d = Depth of section, in.
- t_f = Flange thickness, in.
- d_{ASC} = Alternative Shear Connector hole diameter = 1 1/4 in.

TYPICAL CLOSED BACKWALL STIRRUP



LAYOUT OF LONGITUDINAL TEMPERATURE AND SHRINKAGE (T &S) REINFORCEMENT

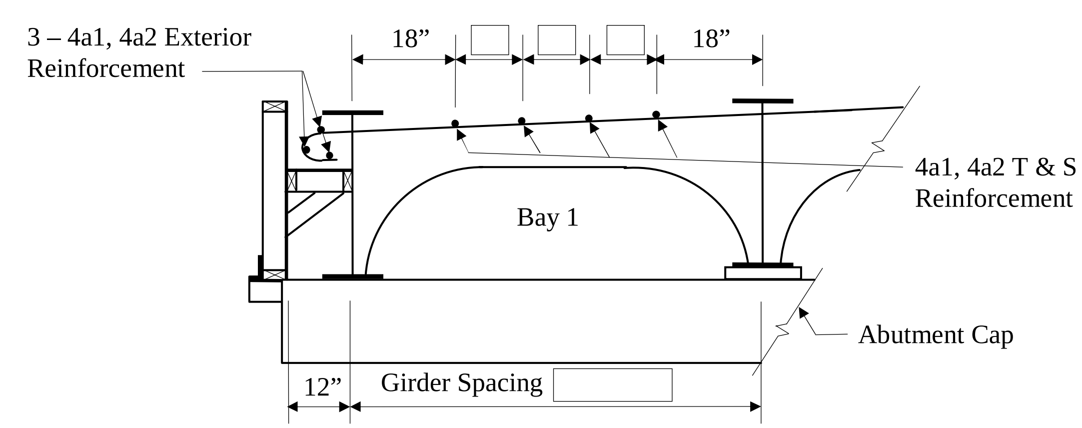
Table 4 Number and Length of Longitudinal T & S Reinforcing Bar Per Line

Bar Marks	Bridge Length (ft)								
	40	45	50	55	60	65	70	75	80
	Number and length of T & S reinforcement								
4a1	2-20’	2-20’	2-20’	2-20’	3-20’	3-20’	3-20’	4-20’	4-20’
4a2	1-4’	1-9’	1-14’	1-19’	1-6’	1-11’	1-16’	1-3’	1-8’

NOTE: Bridge length = centerline to centerline of supports

Table 3 Number of Stirrups Required Per Backwall

Girder Spacing	Closed Loop Stirrups	
(ft)	32 ft Wide Bridge	26 ft Wide Bridge
6	29	24
5	28	-
4.8	-	24
4.29	25	-
4	-	22
3.75	28	-
3	28	20



LOCATION OF THE LONGITUDINAL T & S REINFORCEMENT

REVISIONS

MBISB

BACKWALL AND LONGITUDINAL T & S REINFORCEMENT

DATE:

DRAWN BY:

CHECKED BY:

SCALE:

PROJECT NO:

SHEET NO:

C 6

Table 5 Lines of Longitudinal Temperature and Shrinkage (T & S) Reinforcement

Girder Spacing	Closed Loop Stirrups	
(ft)	32 ft Wide Bridge	26 ft Wide Bridge
6	29	24
5	28	-
4.8	-	24
4.29	25	-
4	-	22
3.75	28	-
3	28	20

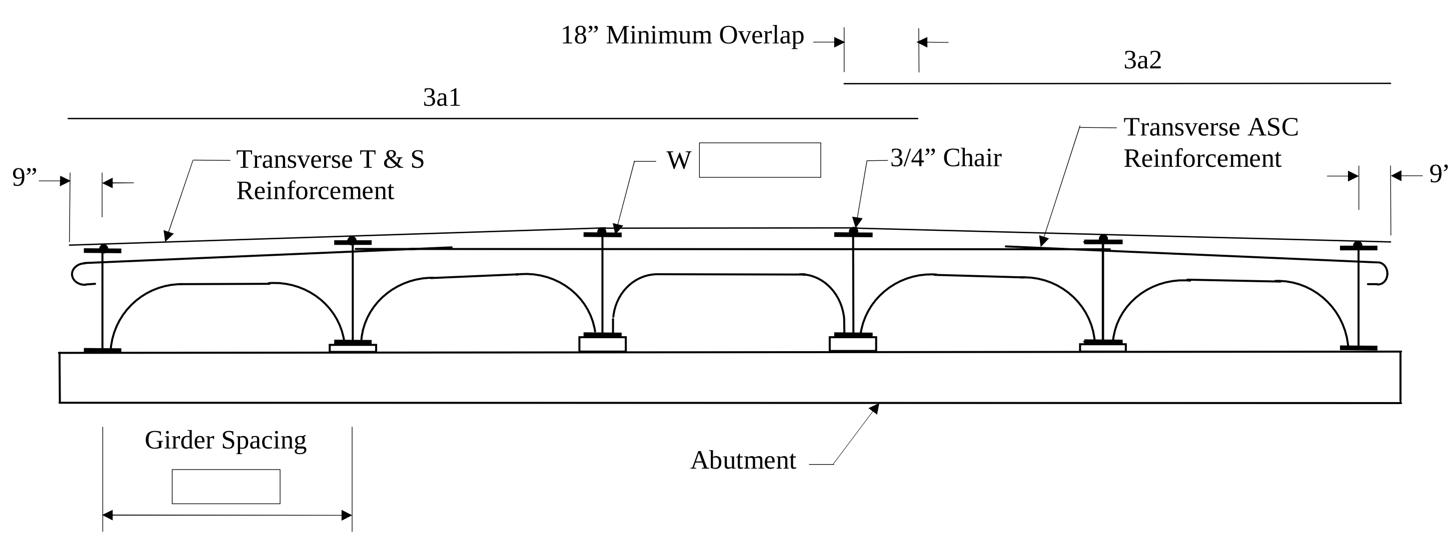
Table 6 Lengths of Transverse T & S Reinforcement

Bar Mark	Transverse T & S Reinforcement Lengths (in.)	
	Bridge Width	
	26 ft	32 ft
3a1	240	240
3a2	84	156

Table 7 Lines of Transverse T &S Reinforcement

Bridge Length (ft)								
40	45	50	55	60	65	70	75	80
Lines of #3 Grade 60 T & S reinforcement								
32	36	40	44	48	52	56	60	64

NOTE: Bridge length = Centerline to centerline of supports



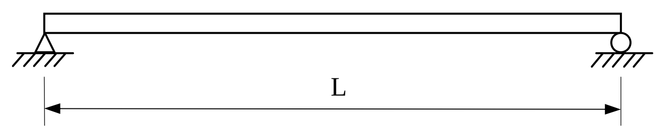
TRANSVERSE REINFORCEMENT

REVISIONS

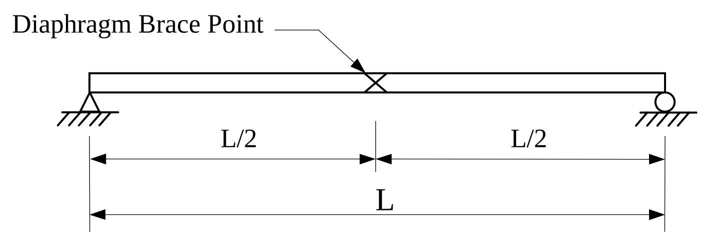
MBISB
TRANSVERSE T & S REINFORCEMENT

DATE:
DRAWN BY:
CHECKED BY:
SCALE:
PROJECT NO:
SHEET NO:

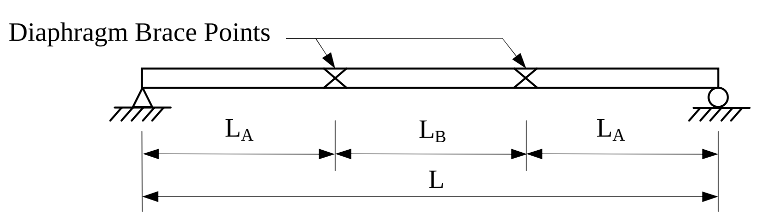
C 7



No Diaphragm Case

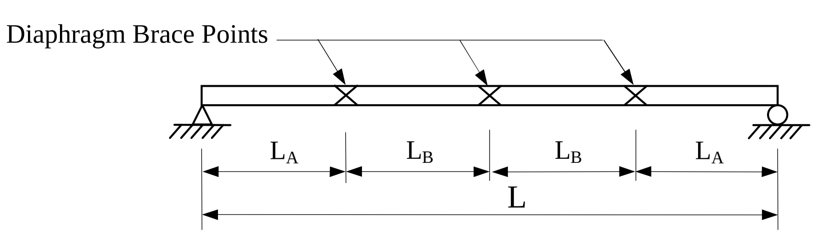


One Diaphragm Case



$L_A=(L-L_B)/2$

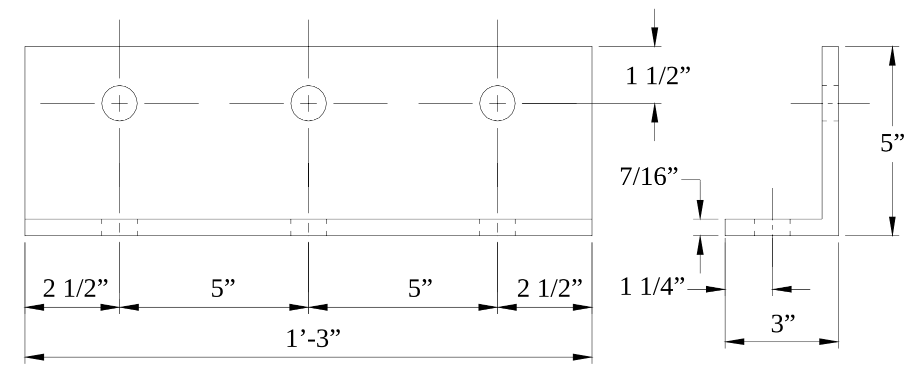
Two Diaphragms Case



$L_A=(L-2L_B)/2$

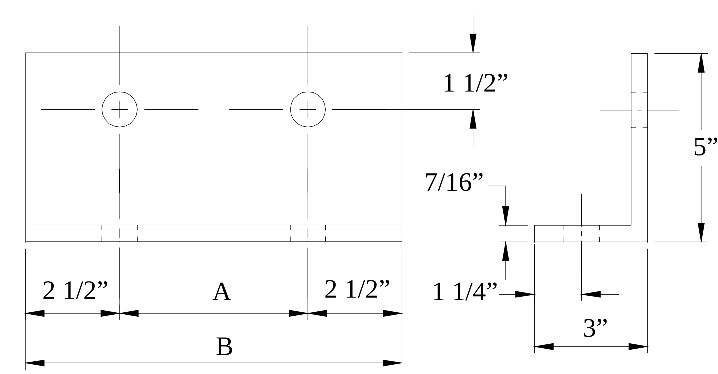
Three Diaphragms Case

DIAPHRAGM LAYOUT



Notes:
- All angles A36 steel
- All holes 15/16 in. diameter

DIAPHRAGM CONNECTOR FOR C15x39 SECTIONS



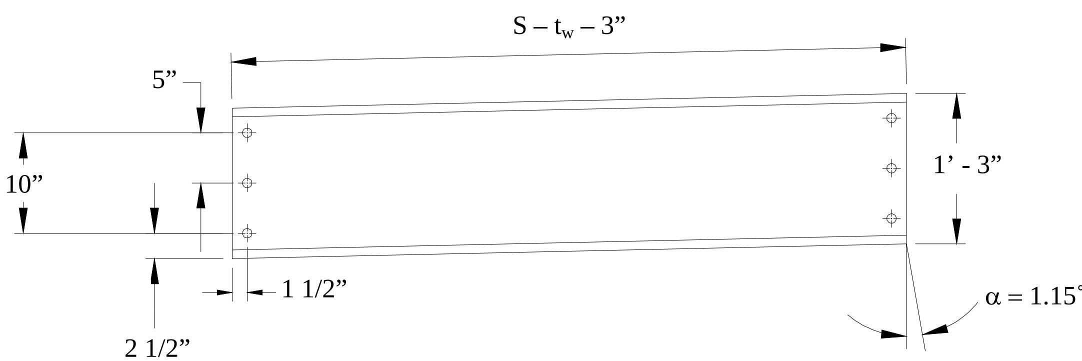
Connector for	A (in.)	B (in.)
C8x13.75	3	8
C10x20	5	10

Notes:
- All angles A36 steel
- All holes 15/16 in. diameter

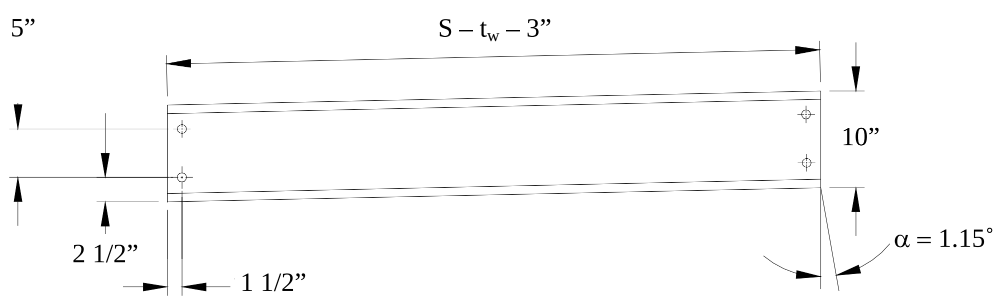
DIAPHRAGM CONNECTOR FOR C10x20 AND C8x13.75 SECTIONS

DIAPHRAGM LAYOUT AND CONNECTORS

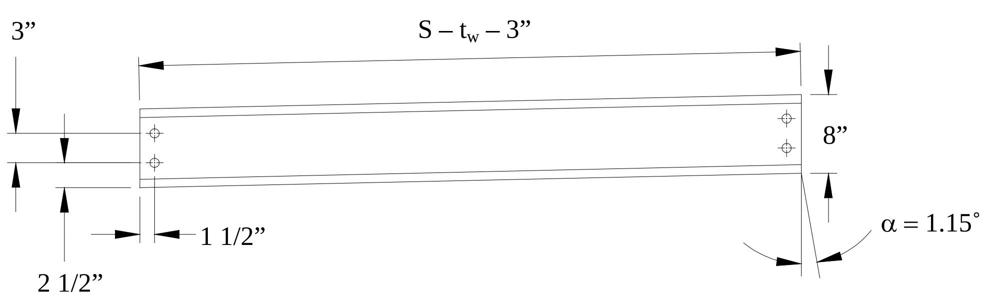
Worksheet 1



C8x13.9 Diaphragm Section



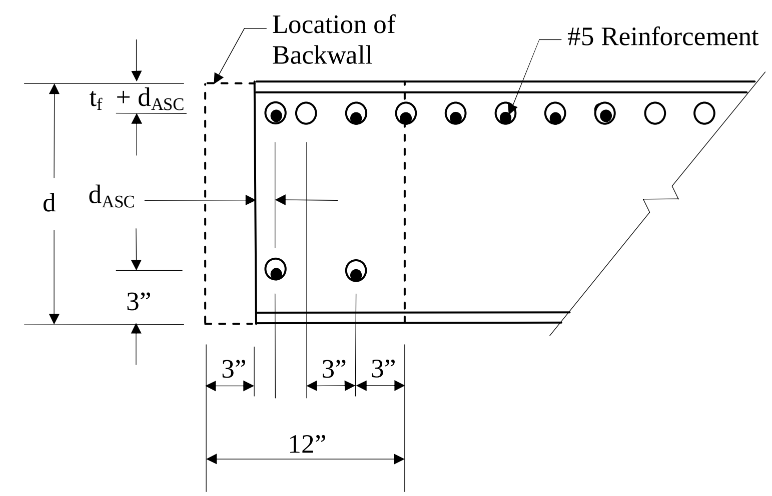
C10x20Diaphragm Section



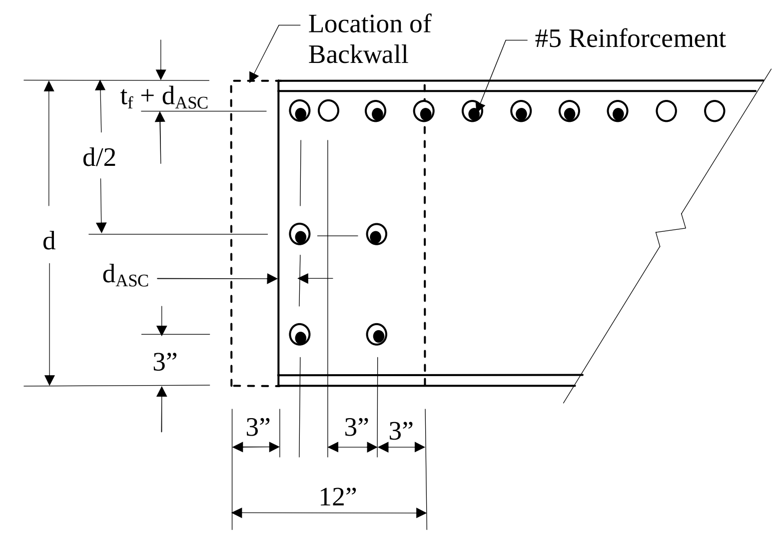
C8x13.9 Diaphragm Section

Notes:
- S = Girder spacing, in.
- t_w = Web thickness for longitudinal girder, in.
- All holes 15/16 in. diameter

DIAPHRAGM SECTIONS BASED ON GIRDER DEPTH



W14 and W18 Sections



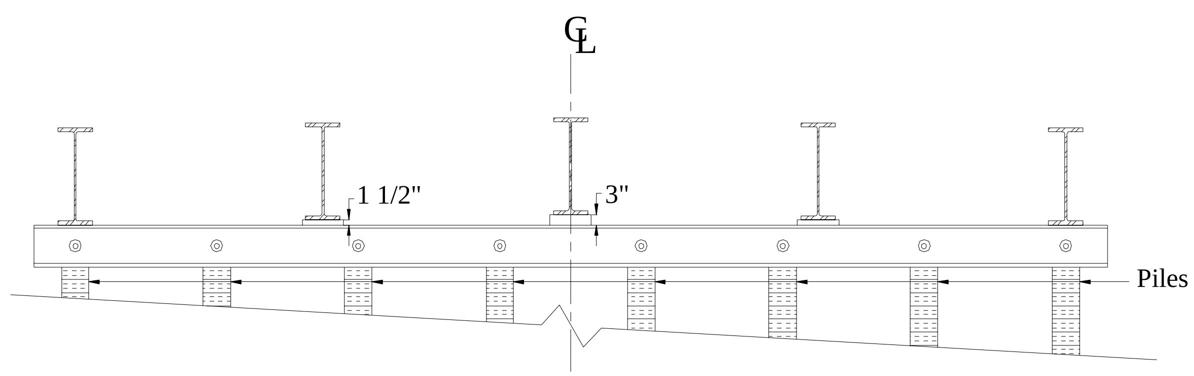
W21, W24, W27 and W30 Sections

Notes:
- All holes = 1 1/4 in. diameter, torched or cored on 3 in. centers unless otherwise indicated.
- d = Depth of section, in.
- t_f = Flange thickness, in.

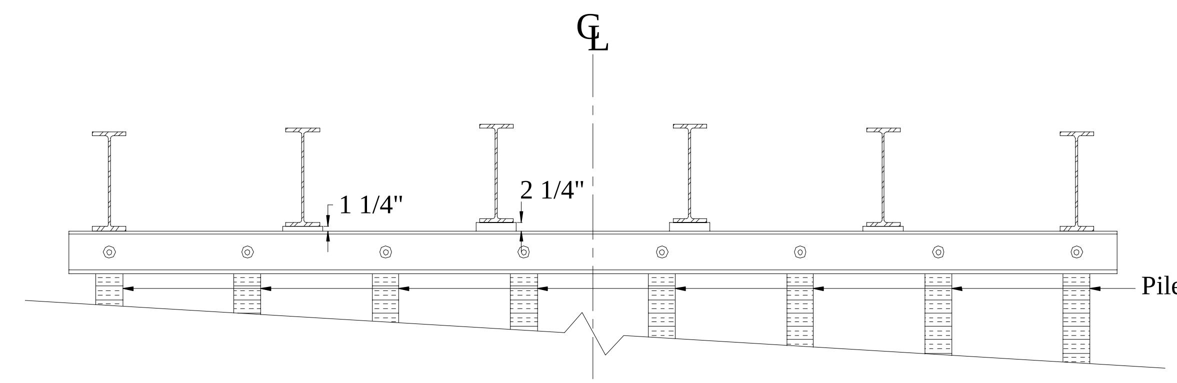
LAYOUT OF BACKWALL REINFORCEMENT

DIAPHRAGM SECTIONS AND BACKWALL LAYOUT

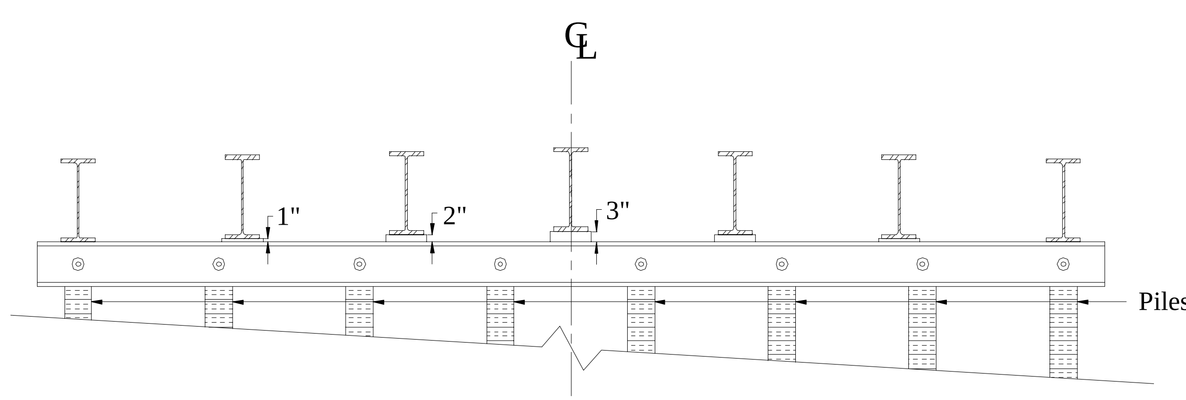
Worksheet 2



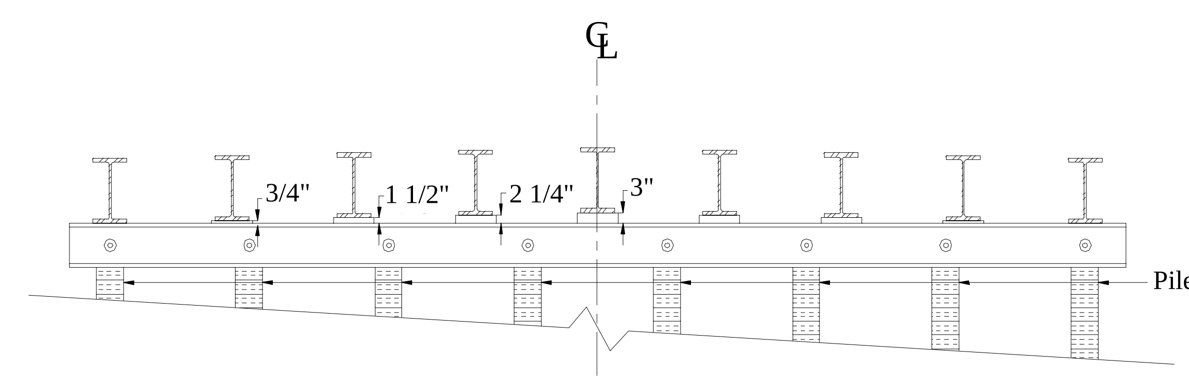
5 Girders on 6 ft Centers



6 Girders on 4.8 ft Centers



7 Girders on 4 ft Centers



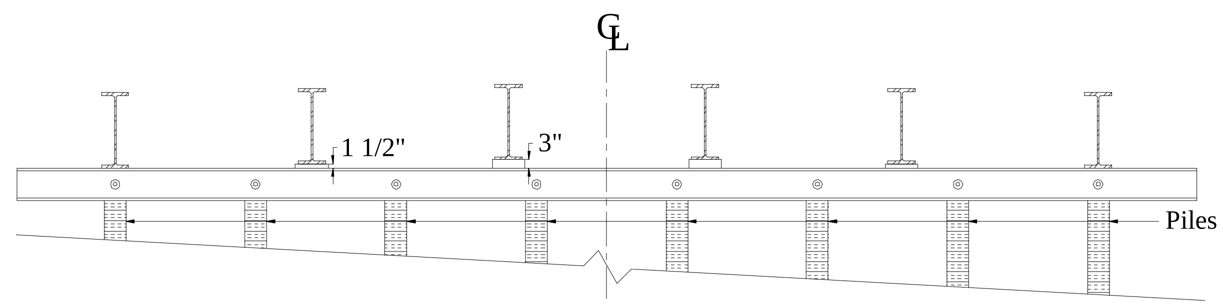
9 Girders on 3 ft Centers

Note:

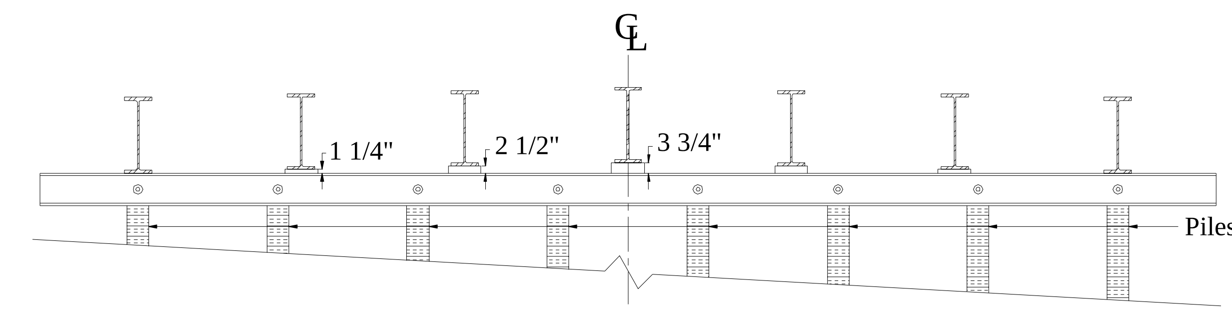
- All girder profiles are symmetric about the center line of the bridge.

GIRDER ELEVATIONS FOR 26 FT WIDE MBISBs

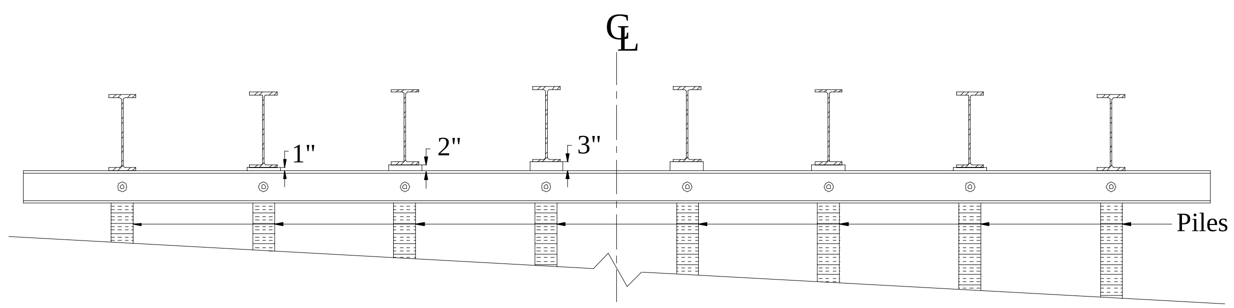
Worksheet 3



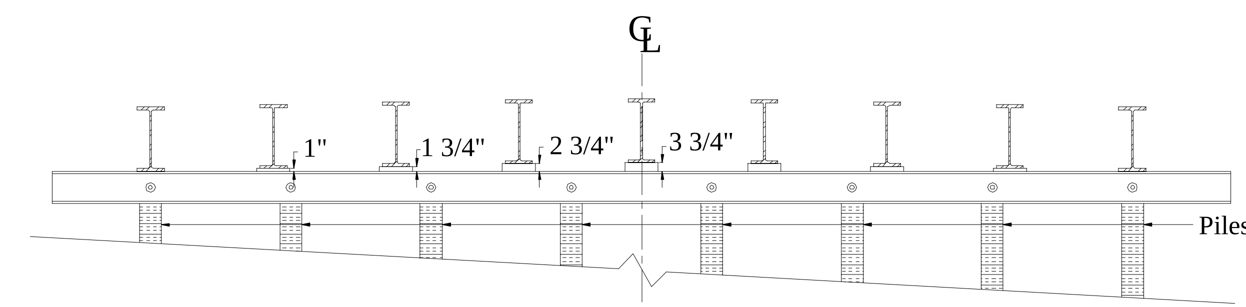
6 Girders on 6 ft Centers



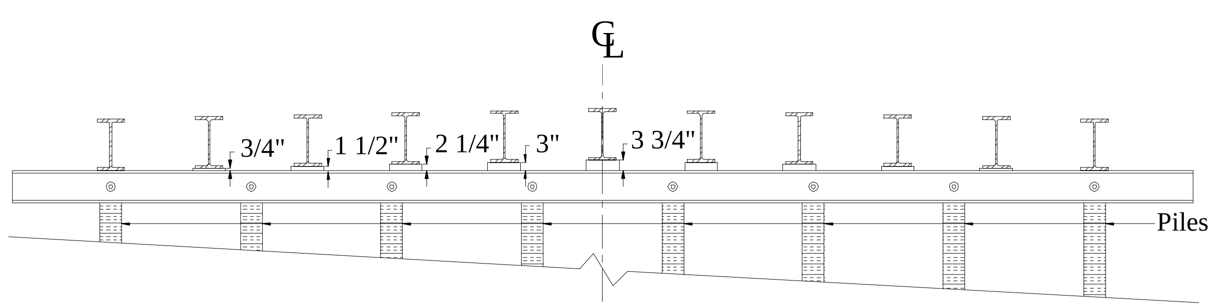
7 Girders on 5 ft Centers



8 Girders on 4.29 ft Centers



9 Girders on 3.75 ft Centers



11 Girders on 3 ft Centers

Note:
- All girder profiles are symmetric about the center line of the bridge.

GIRDER ELEVATIONS FOR 32 FT WIDE MBISBs

Worksheet 4

APPENDIX C

Custom Rolled Arched Formwork Manufactures

The following manufactures supplied the custom rolled arched sections for the laboratory specimen (Contech) and MBISB #2 (Midwest Culvert, LTD.)

Contech Construction Products Inc.
5335 Merle Hay Road, Suite 4
Johnston, Iowa 50131
Phone: (515) – 331 – 2517
Fax: (515) – 331 – 2518

Midwestern Culvert, LTD.
1114 S.E. Lorenz Drive
Ankeny, Iowa 50021
Phone: (515) – 964 – 0497
Fax: (515) – 964 – 0545