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2.1 Organizational Charts

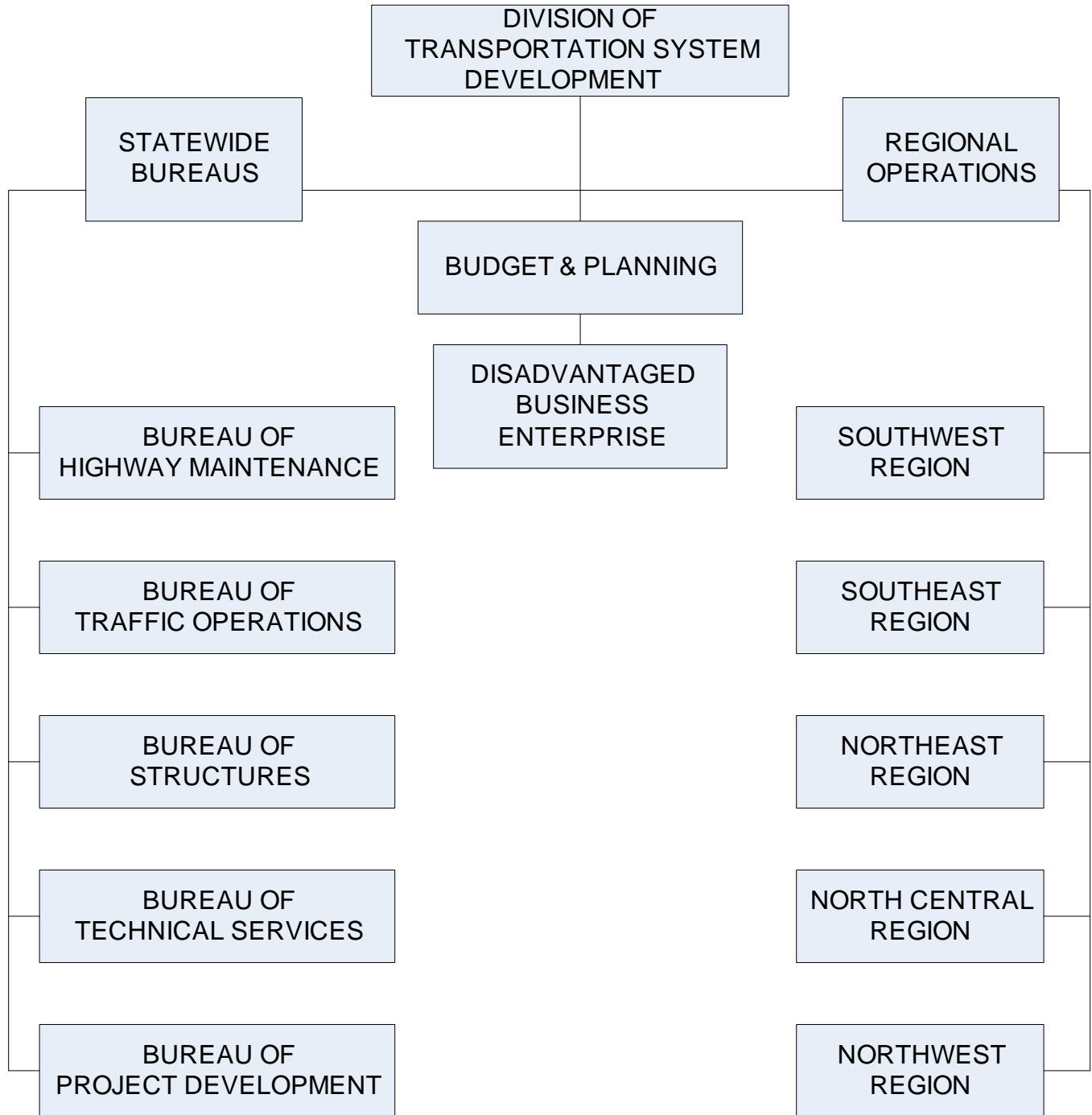


Figure 2.1-1
Division of Transportation System Development

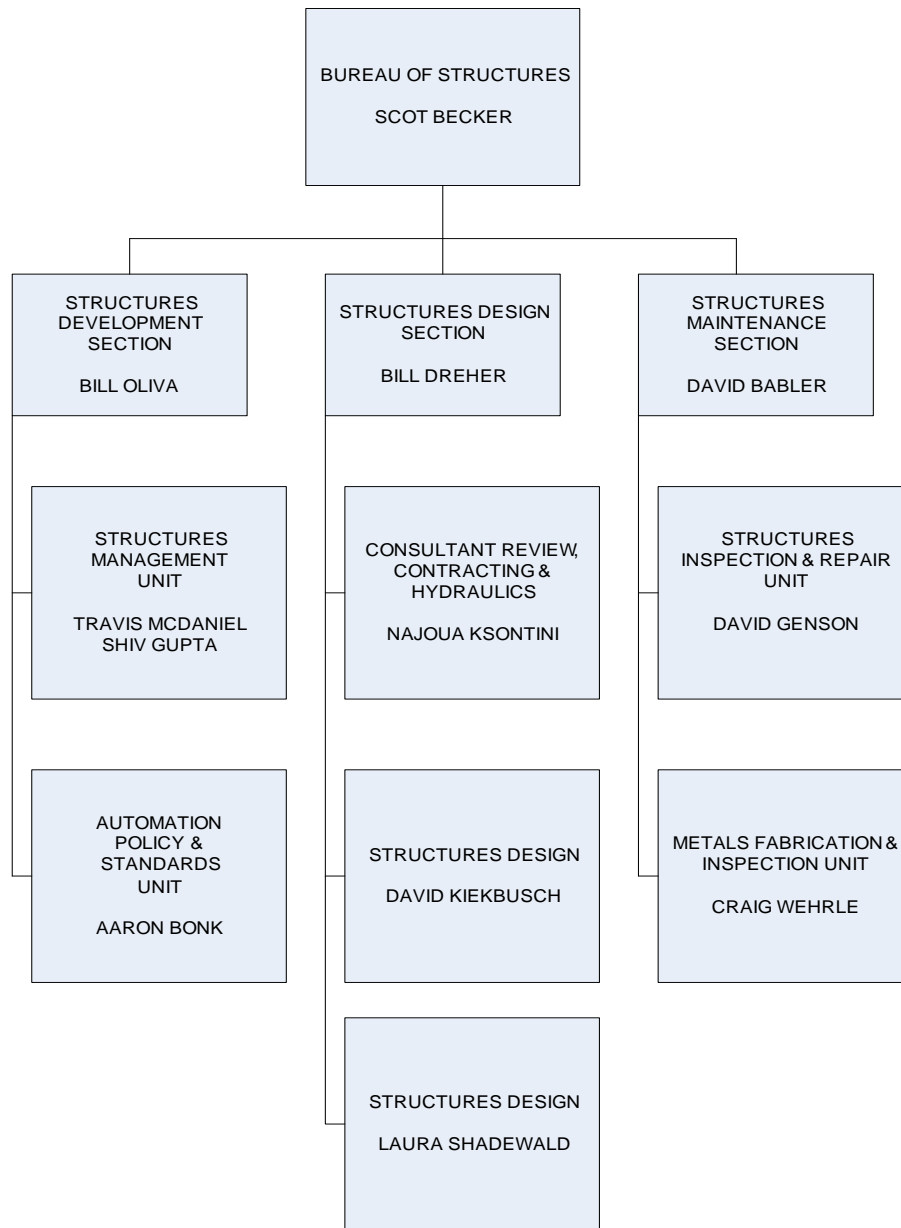


Figure 2.1-2
Bureau of Structures



NO.	COUNTY	REGION	NO.	COUNTY	REGION
1	ADAMS	NORTH CENTRAL	37	MARATHON	NORTH CENTRAL
2	ASHLAND	NORTHWEST	38	MARQUETTE	NORTH CENTRAL
3	BARRON	NORTHWEST	39	MILWAUKEE	SOUTHEAST
4	BAYFIELD	NORTHWEST	40	MONROE	SOUTHWEST
5	BROWN	NORTHWEST	41	OCONTO	NORTH CENTRAL
6	BUFFALO	NORTHWEST	42	ONEIDA	NORTH CENTRAL
7	BURNETT	NORTHWEST	43	OUTAGAMIE	NORTH CENTRAL
8	CALUMET	NORTHWEST	44	OZAUKEE	SOUTHEAST
9	CHIPPEWA	NORTHWEST	45	PEPIN	NORTHWEST
10	CLARK	NORTHWEST	46	PIERCE	NORTHWEST
11	COLUMBIA	SOUTHWEST	47	POLK	NORTHWEST
12	CRAWFORD	SOUTHWEST	48	PORTAGE	NORTH CENTRAL
13	DANE	SOUTHWEST	49	PRICE	NORTH CENTRAL
14	DODGE	SOUTHWEST	50	RACINE	SOUTHEAST
15	DOOR	NORTHWEST	51	RICHLAND	SOUTHWEST
16	DOUGLAS	NORTHWEST	52	ROCK	SOUTHWEST
17	DUNN	NORTHWEST	53	RUSK	NORTHWEST
18	EAU CLAIRE	NORTHWEST	54	SAUK	NORTHWEST
19	FLORENCE	NORTH CENTRAL	55	ST CROIX	NORTHWEST
20	FOND DU LAC	NORTH CENTRAL	56	SAUK	NORTHWEST
21	FOREST	NORTH CENTRAL	57	SAWYER	NORTHWEST
22	GRANT	SOUTHWEST	58	SHAWANO	NORTH CENTRAL
23	GREEN	SOUTHWEST	59	SHEBOYGAN	NORTH CENTRAL
24	GREEN LAKE	NORTH CENTRAL	60	TAYLOR	NORTHWEST
25	IOWA	SOUTHWEST	61	TREMPERLEAU	NORTHWEST
26	IRON	NORTH CENTRAL	62	VERNON	SOUTHWEST
27	JACKSON	NORTHWEST	63	VILAS	NORTH CENTRAL
28	JEFFERSON	SOUTHWEST	64	WALWORTH	SOUTHEAST
29	JUNEAU	SOUTHWEST	65	WASHBURN	NORTHWEST
30	KENOSHA	SOUTHWEST	66	WASHINGTON	SOUTHWEST
31	KEWAUNEE	NORTHEAST	67	WAUKESHA	SOUTHWEST
32	LA CROSSE	SOUTHWEST	68	WAUPACA	NORTH CENTRAL
33	LAFAYETTE	SOUTHWEST	69	WAUSHARA	NORTH CENTRAL
34	LANGLADE	NORTH CENTRAL	70	WINNEBAGO	NORTHWEST
35	LINCOLN	NORTH CENTRAL	71	WOOD	NORTH CENTRAL
36	MANITOWOC	NORTHEAST	73	MENOMINEE	NORTH CENTRAL

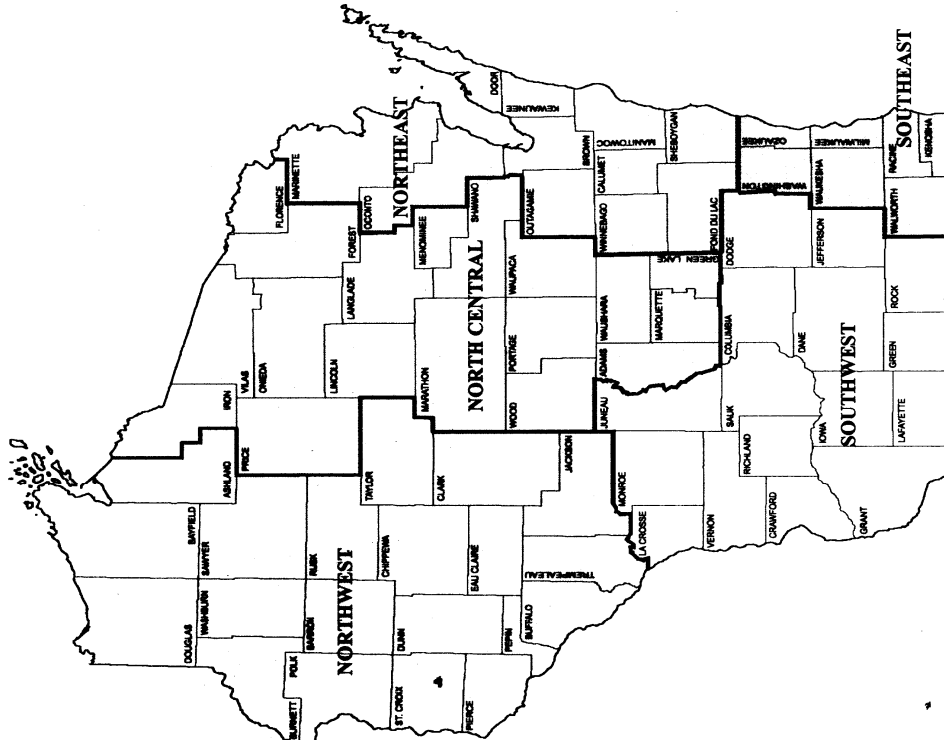


Figure 2.1-3
Region Map



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4.1 Introduction

Transportation structures, such as bridges and retaining walls, have a strong influence on the appearance of transportation projects, as well as the overall appearance of the general vicinity of the project. In locations where there is an opportunity to appreciate such structures, it is often desirable to add aesthetic enhancements to fit the project site.

Desirable bridge aesthetics do not necessarily need to cost much, if any, additional money. Aesthetic enhancements can be made in a number of ways. Primary features such as structure type and shape have the most influence on appearance, with color and texture playing secondary roles. Formliners, especially when used in conjunction with a multi-colored stain, are much more expensive than one or two single color stains on smooth concrete, and have on a number of occasions not fit the context of the project. It is the responsibility of the design team to identify aesthetic treatments that are consistent with the environment and goals of the project, are maintainable over the life of the structures, and are cost effective.



4.2 General Aesthetic Guidelines

Primary features – in relative order of importance:

- Superstructure type and shape, with parapets/railings/fencing being fairly prominent, as well. *NOTE: WisDOT is currently investigating the crash implications of pedestals, pilasters, railings/fencing and texture on the inside face of parapets due to vehicular snagging during vehicle impact to parapets.* See Chapter 30 – Railings for further guidance and the January 2013 Interim Policy on Use of Aesthetic Barriers on Bridges.
- Abutment type and shape, with the wings being most prominent.
- Pier type and shape, with the end elevation being the most notable, especially for a bridge over a highway.
- Grade and/or skews.

Secondary features – in relative order of importance:

- Color
- Pattern and texture
- Ornamentation

Consider the following key points, in relative order of importance, when designing structures:

1. Simplicity
2. Good proportions with an emphasis on thinner members, or members that appear thinner
3. Clear demonstration of how the structure works with recognizable flow of forces
4. Fitting its context/surroundings
5. Good proportions in 3 dimensions
6. Choice of materials
7. Coloring – neutral colors, preferably no more than two. (Chapter 9 – Materials lists federal color numbers used most commonly for girders)
8. Pattern and texture
9. Lighting

Consider the bridge shape, relative to the form and function at the location. Use a structural shape that blends with its surroundings. The aesthetic impact is the effect made on the



viewer by every aspect of a bridge in its totality and in its individual parts. The designer makes an aesthetic decision as well as a structural decision when sizing a girder or locating a pier.

The structure lines should flow smoothly with as few interruptions as possible. Do not clutter up the structure with distractive elements. If light standards are required, place them in line with the piers and abutments, so the vertical lines blend. Light spacing, however, needs to be coordinated with the Regional electrical engineer. Steel girder bearing stiffeners should be the only vertical stiffeners on the outside face of the exterior girders, although longitudinal stiffeners on the outside face can have an appealing look.



4.3 Primary Features

Superstructure Type and Shape

At highway speeds, highway structures are viewed from 300-500 feet away. The general shape of the bridge, with an emphasis on thinness, produces the most appealing structure. Given that there are realistic physical limitations on thinness (without resorting to anchored end spans or other costly measures), the designer has other options available to achieve the appearance of thinness such as:

- Larger overhangs to create better shadow lines.
- Horizontal recess on the backside of the parapet, which could be stained or left as plain concrete.
- Eliminate or minimize pedestals along the parapet. Such pedestals tend to break up the horizontal flow and make the superstructure appear top heavy. Pedestals, if desired, are better left on the wings to delineate the beginning or end of the bridge or to frame the bridge when viewed from below. If used on the superstructure, keep the pedestal size smaller and space apart far enough to avoid a top heavy appearance. NOTE: WisDOT is currently investigating the crash implications of pedestals and railings/fencing due to vehicular snagging.
- Minimize vertical or patterned elements on the backside of the parapet as such elements tend to break up the horizontal flow. Rock form liner has become an overused aesthetic enhancement for the backside of parapets, as its use oftentimes does not fit the surroundings. NOTE: WisDOT is currently investigating the crash implications of pedestals, pilasters, railings/fencing and texture on the inside face of parapets due to vehicular snagging during vehicle impact to parapets. See Chapter 30 – Railings for further guidance and the January 2013 Interim Policy on Use of Aesthetic Barriers on Bridges.

Abutment Type and Shape

Wing walls are the most visible portion of the abutment. Unless pedestrians or stopped traffic is beneath a bridge, formliners or other aesthetic enhancements are not viewable and should be left off of the abutment front face, as these treatments provide no additional aesthetic value.

Pier Type and Shape

Pier shapes should be kept relatively simple and uncluttered. For highway grade separations, the end elevation of the pier is the view most often seen by the traveling public. For slower speed roads or where pedestrians travel beneath a bridge, the front pier elevation is also seen. For taller piers, such as those used for multi-level interchanges or water crossings, the entire 3D-view of the pier is readily seen and the pier shape is very important. For such piers, a clean, smooth flowing slender shape that clearly demonstrates the flow of forces from the superstructure to the ground is essential.



Grade and/or Skew

While grade and skew cannot be controlled by the bridge design engineer, these geometric features do affect bridge appearance. For example, a steep grade or pronounced vertical curve makes the use of a block type rustication an awkward choice. Horizontal blocks are typically associated with buildings and block buildings tend to have level roof lines. Cut stone form liners used on steep grades or pronounced vertical curves require excessive cutting of forms, which drives up price. Consideration of abutment height warrants more consideration when bridges are on steep grades, with a more exposed abutment face on the high end of the bridge producing a more balanced look.

Large skews tend to make piers longer as well as making the front elevation of the pier more visible to properties adjacent to the bridge. With larger skews, having more than one multi-columned pier can create a ‘forest’ of pier columns if the columns are too numerous. Try to maximize column spacing or use multiple hammerhead piers to help alleviate this effect. Abutment wings tend to be longer on the acute corners of bridges. Whatever aesthetic treatment is used needs to be appropriate for both the longer and shorter wings.

The design engineer should keep in mind that a bridge is never entirely seen at a 90-degree angle as depicted in a side elevation view. As the person viewing the bridge moves closer to the bridge the pier directly in front of them will be seen nearly as an end elevation of the pier, while adjacent piers will start to be viewed more as a pier side elevation. The ‘forest’ of columns starts to take effect, again, especially for wider bridges.



4.4 Secondary Features

Color

Color can have a strong visual effect, either positive or negative. Using earth toned colors versus vivid colors is preferred. More neutral colors tend to blend in more with the surroundings. Also, over time earth tones will weather less and not appear as dingy or faded. A bright yellow, for example, will begin to appear dull and dirty soon after application. Avoid red as this color is not UV tolerant and will fade. Concrete stain behaves more like paint and is susceptible to fading and peeling, requiring re-application to avoid an unsightly structure. Stained concrete in need of maintenance looks worse than concrete that was originally left unstained.

Using a maximum of two colors will lend itself to the desired outcome of a clean appearance. On larger structures it may be desirable to use two colors for everything other than the girders, which may be a third color. Remember that plain concrete is a color, too. It should be utilized as much as possible (especially on smaller surfaces) to reduce initial cost and, especially, future maintenance costs.

Utilizing a ribbed, or broken ribbed pattern on a large expanse of plain concrete can give the appearance of color as the patterned section will appear darker than the adjacent plain concrete. This is a good way to add 'color' without the future maintenance costs associated with actual stain reapplication.

As much as possible, Federal color numbers should be used for color selection. A few colors are given in Chapter 9 – Materials, but others may be used. STSP's should be used as is for staining and multi-colored staining. Specific colors, areas to be applied, etc. should be referenced on the plan sheets.

Pattern and Texture

Large expanses of flat concrete, even if colored, are usually not desirable.

Most bridges are seen from below by people traveling at higher rates of speed. Detail smaller than 4-inches is difficult to discern. The general shape, and perhaps color, will have a greater visual effect than the pattern and/or texture. Sometimes texture is used to represent a building material that wasn't used for the construction of the structure, as would be the case of rock form liner. While a rock appearance might be appropriate for a smaller bridge over a stream in a small town, it seldom fits the context of a grade separation over a highway or busy urban interchange. Modern bridges should, for the most part, look like they are built out of modern materials appropriate to the current time. Texture consisting of random or ordered geometric forms is generally more preferred over simulating other materials.

On MSE retaining walls it is desirable to keep logos or depictions within a given panel. Matching lines across panels, especially horizontal lines susceptible to differential panel settlement, is difficult. Rock texturing is unconvincing as real stone due to panel joints. A random geometric pattern is a good way to give relief to a wall.



Repetition in pattern rather than an assembly of various patterns or details is more cost effective. For effects that are meant to appear random (e.g. rock), care must be taken in order for the pattern repetition to not appear noticeable.

At all locations on a structure (abutment wings and piers, MSE walls, etc.), form details should be terminated 1'-0" below low water or ground elevations where they will not be visible. See the Standard for Formliner Details.

Designers are cautioned about introducing textures and relief on the inside faces of vehicle barriers. The degree of relief and texture can influence the vehicle response during a crash.

NOTE: WisDOT is currently investigating the crash implications of pedestals, pilasters, railings/fencing and texture on the inside face of parapets due to vehicular snagging during vehicle impact to parapets.

Ornamentation

More is seldom better.

“In bridge building... to overload a structure or any part thereof with ornaments... would be to suppress or disguise the main members and to exhibit an unbecoming wastefulness. The plain or elaborate character of an entire structure must not be contradicted by any of its parts.”

- J.B. Johnson, 1912



4.5 Aesthetics Process

A number of parties can be responsible for the appearance of a structure, as well as the project as a whole. The structural design engineer should be instrumental in leading the aesthetic design process, a process that may include the Region, the Bureau of Structures, the public and aesthetic advisors (architects, landscape architects, urban planners, artists, etc).

Public input comes in a variety of ways. Advisory groups, special interest groups and general public information meetings are all ways to receive public input and are part of the CSS (Community Sensitive Solutions) process.

The structural design engineer needs to be involved early in the aesthetic decision making process. BOS should have representation on projects with considerable aesthetic concerns.

NOTE: At this time (January, 2013) BOS is forming a group with representation from many different areas to discuss bridge and retaining wall aesthetics, as well as the aesthetic process.



4.6 Levels of Aesthetics

The Regional Office should establish one of the following levels of aesthetics and indicate it on the Structure Survey Report. This will help the structural designer decide what level of effort and possible types of aesthetics treatments to consider. If Level 2 or greater is indicated, the Regional Office personnel or consultant must suggest particular requirements such as railing type, pier shape, special form liners, color, etc. in the comments area of the Structure Survey Report. Most Regions/municipalities prefer to leave anti-graffiti coating off of structures and would rather re-stain, as this is easier than trying to clean the graffiti.

Aesthetic treatments should be agreed upon prior to completion of preliminary plans in order for the final design to proceed efficiently. These details would be developed through the aesthetic process.

1. Level One: A general structure designed with standard structure details. This would apply in rural areas and urban areas with industrial development.
2. Level Two: Consists of cosmetic improvements to conventional Department structure types, such as the use of color stains/paints, texturing surfaces, modifications to fascia walls and beams or more pleasing shapes for columns. This would apply where there needs to be less visual impact from roadway structures.
3. Level Three: Emphasize full integration of efficiency, economy and elegance in structure components and the structure as a whole. Consider structure systems that are pleasing such as shaped piers and smooth superstructure lines. These structures would need to be in harmony with the surrounding buildings and/or the existing landscape.
4. Level Four: Provide overall aesthetics at the site with the structure incorporating level three requirements. The structure would need to blend with the surrounding terrain and landscaping treatment would be required to complete the appearance.



4.7 Accent Lighting for Significant Bridges

The Wisconsin DOT will consider as part of an improvement project accent lighting for significant urban bridges with a clear span length of 450 feet and greater. The lighting would accent significant components above the driving surface such as an arch, truss, or a cable stayed superstructure. This lighting would enhance the noteworthy structure components of these significant bridges. The Traffic Guideline Manual (TGM) and the Highway Program Manual (HPM) have respective guidance of maintenance and cost share policy.

The following structures would fall into this definition of significant urban bridges:

"Name"	Region	County	Feature On	Feature Under	Year Built	Border
Tower Drive	NE	Brown	IH 43	Fox River	1979	
Praire du Chien	SW	Crawford	USH 18-STH 60	Mississippi River	1974	X
Blatnik	NW	Douglas	IH 535-USH 53	St Louis Bay	1961	X
Bong	NW	Douglas	USH 2	St Louis River	1983	X
Cass Arch	SW	La Crosse	USH 14 EB	Mississippi River	2004	X
Cass Truss	SW	La Crosse	USH 14 WB	Mississippi River	1940	X
Hoan Bridge	SE	Milwaukee	IH 794 WB-Lake Freeway	Milwaukee River	1974	
Dubuque (Iowa)	SW	Grant	USH 61-USH 151	Mississippi River	1982	X
Stillwater	NW	St Croix	TH 36	St Croix River	New	X

Table 4.4-1 Accent Lighting for Significant Bridges



4.8 Resources on Aesthetics

The Bridge Aesthetic Sourcebook from AASHTO (noted in the References) is a very good source of practical ideas for short and medium span bridges. The Transportation Research Board (TRB) has the following website: <http://www.bridgeaesthetics.org>.

NOTE: At this time (January, 2013) BOS is forming a group with representation from many different areas to discuss bridge and retaining wall aesthetics, as well as the aesthetic process. It is intended to enhance this section in the future.



4.9 References

1. AASHTO, *Bridge Aesthetics Sourcebook*, 2010.
2. Gottemoeller, Frederick, *Bridgescape: The Art of Designing Bridges*, John Wiley & Sons, Inc., 2004.



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5.1 Factors Governing Bridge Costs

Bridge costs are tabulated based on the bids received for all bridges let to contract. While these costs indicate some trends, they do not reflect all the factors that affect the final bridge cost. Each bridge has its own conditions which affect the cost at the time a contract is let. Some factors governing bridge costs are:

1. Location - rural or urban, or remote regions
2. Type of crossing
3. Type of superstructure
4. Skew of bridge
5. Bridge on horizontal curve
6. Type of foundation
7. Type and height of piers
8. Depth and velocity of water
9. Type of abutment
10. Ease of falsework erection
11. Need for special equipment
12. Need for maintaining traffic during construction
13. Limit on construction time
14. Complex forming costs and design details
15. Span arrangements, beam spacing, etc.

Figure 5.2-1 shows the economic span lengths of various type structures based on average conditions. Refer to Chapter 17 for discussion on selecting the type of superstructure.

Annual unit bridge costs are included in this chapter. The area of bridge is from back to back of abutments and out to out of the concrete superstructure. Costs are based only on the bridges let to contract during the period. In using these cost reports exercise care when a small number of bridges are reported as these costs may not be representative.

In these reports prestressed girder costs are grouped together because there is a small cost difference between girder sizes. Refer to unit costs. Concrete slab costs are also grouped together for this reason.



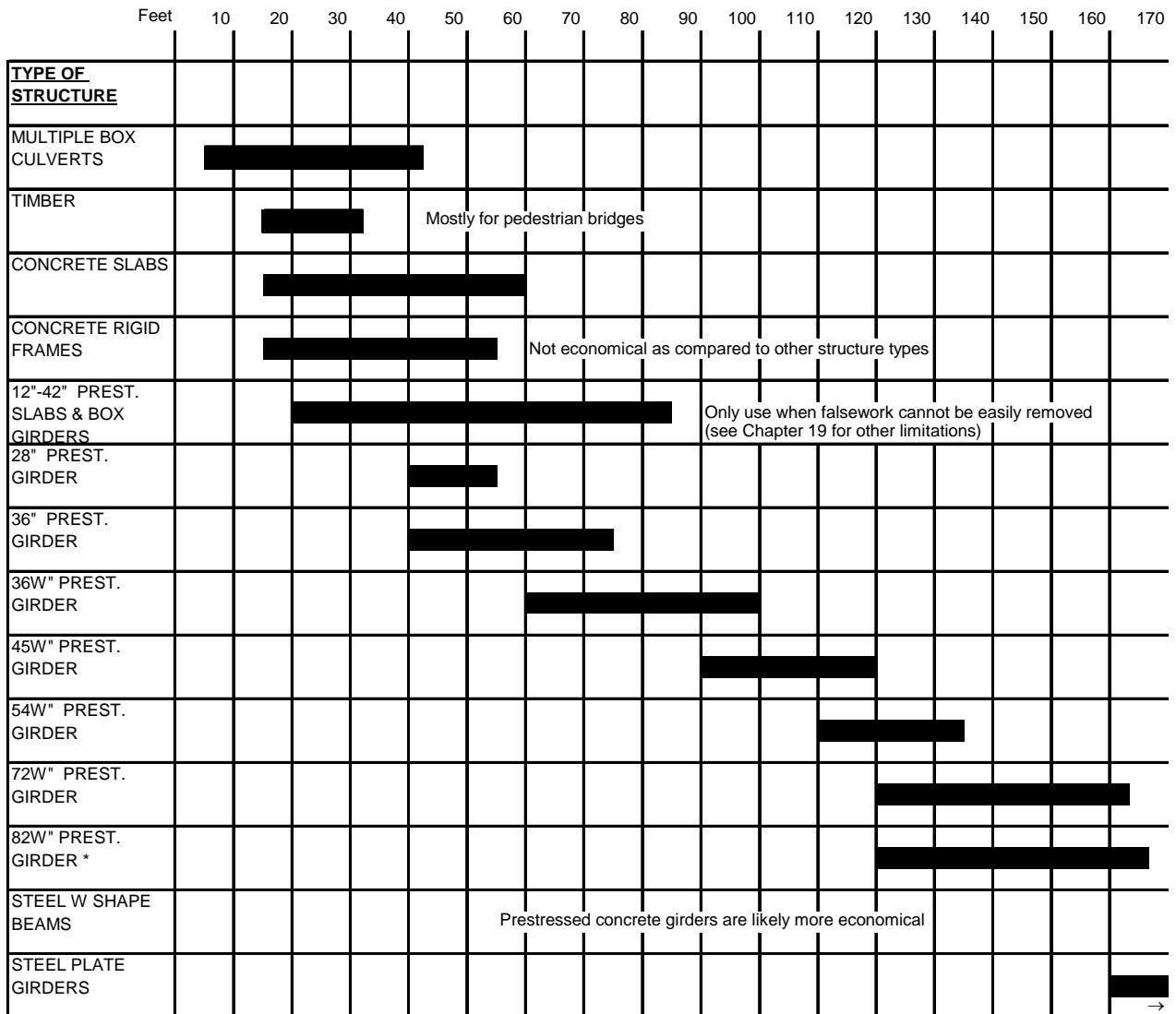
No costs are shown for rolled steel sections as these structures are not built very often. They have been replaced with prestressed girders which are usually more economical. The cost of plate girders is used to estimate rolled section costs.

For structures over a railroad, use the costs of grade separation structures. Costs vary considerably for railroad structures over a highway due to different railroad specifications.

Note: Current costs are given in English units.



5.2 Economic Span Lengths



*Currently there is a moratorium on the use of 82W" prestressed girders in Wisconsin

Figure 5.2-1
Economic Span Lengths



5.3 Contract Unit Bid Prices

Item No.	Bid Item	Unit	Cost
206.6010.S	Temporary Shoring	LF	16.90
210.0100	Backfill Structure	CY	20.59
303.0115	Pit Run	CY	16.84
311.0115	Breaker Run	CY	17.20
502.0100	Concrete Masonry Bridges	CY	501.80
502.1100	Concrete Masonry Seal	CY	186.28
502.2000	Compression Joint Sealer Preformed Elastomeric (width)	LF	26.08
502.3100	Expansion Device (structure) (LS)	LF	163.12
502.3110.S	Expansion Device Modular (structure) (LS)	LF	1,664.00
502.3200	Protective Surface Treatment	SY	2.35
502.6500	Protective Coating Clear	GAL	65.00
503.0128	Prestressed Girder Type I 28-Inch	LF	145.00
503.0136	Prestressed Girder Type I 36-Inch	LF	175.45
503.0137	Prestressed Girders Type I 36W-Inch	LF	160.40
503.0145	Prestressed Girder Type I 45-Inch	LF	182.66
503.0146	Prestressed Girders Type I 45W-Inch	LF	161.24
503.0154	Prestressed Girder Type I 54-Inch	LF	282.73
503.0155	Prestressed Girder Type I 54W-Inch	LF	178.94
503.0170	Prestressed Girder Type I 70-Inch	LF	--
503.0172	Prestressed Girders Type I 72W-Inch	LF	211.80
503.0182	Prestressed Girder Type I 82W-Inch	LF	--
504.0100	Concrete Masonry Culverts	CY	461.75
504.0500	Concrete Masonry Retaining Walls	CY	521.15
505.0405	Bar Steel Reinforcement HS Bridges	LB	0.87
506.2605	Bar Steel Reinforcement HS Culverts	LB	0.90
506.2610	Bar Steel Reinforcement HS Retaining Walls	LB	0.76
506.3005	Bar Steel Reinforcement HS Coated Bridges	LB	0.91
506.3010	Bar Steel Reinforcement HS Coated Culverts	LB	1.31
506.3015	Bar Steel Reinforcement HS Coated Retaining Walls	LB	0.99
506.0105	Structural Carbon Steel	LB	2.30
506.0605	Structural Steel HS	LB	1.43
506.2605	Bearing Pads Elastomeric Non-Laminated	EACH	71.95
506.2610	Bearing Pads Elastomeric Laminated	EACH	971.54
506.3005	Welded Shear Stud Connectors 7/8 x 4-Inch	EACH	4.50
506.3010	Welded Shear Stud Connectors 7/8 x 5-Inch	EACH	3.30
506.3015	Welded Shear Stud Connectors 7/8 x 6-Inch	EACH	3.18
506.3020	Welded Shear Stud Connectors 7/8 x 7-Inch	EACH	4.55
506.3025	Welded Shear Stud Connectors 7/8 x 8-Inch	EACH	3.33
506.4000	Steel Diaphragms (structure)	EACH	501.00
506.5000	Bearing Assemblies Fixed (structure)	EACH	838.90
506.6000	Bearing Assemblies Expansion (structure)	EACH	1,369.65
507.0200	Treated Lumber and Timber	MBM	7,416.00
508.1600	Piling Treated Timber Delivered	LF	56.00
510.2005	Preboring Cast-in-Place Concrete Piling	LF	99.30
510.3021	Piling CIP Concrete Delivered and Driven 10 ¾ x 0.219-Inch	LF	28.50



510.3030	Piling CIP Concrete Delivered and Driven 10 ¾ x 0.25-Inch	LF	29.07
510.3040	Piling CIP Concrete Delivered and Driven 10 ¾ x 0.365-Inch	LF	37.57
510.3050	Piling CIP Concrete Delivered and Driven 10 ¾ x 0.5-Inch	LF	--
510.3023	Piling CIP Concrete Delivered and Driven 12 ¾ x 0.219-Inch	LF	--
510.3033	Piling CIP Concrete Delivered and Driven 12 ¾ x 0.25-Inch	LF	35.49
510.3043	Piling CIP Concrete Delivered and Driven 12 ¾ x 0.375-Inch	LF	39.80
510.3053	Piling CIP Concrete Delivered and Driven 12 ¾ x 0.5-Inch	LF	65.00
510.3024	Piling CIP Concrete Delivered and Driven 14 x 0.219-Inch	LF	--
510.3034	Piling CIP Concrete Delivered and Driven 14 x 0.25-Inch	LF	--
510.3044	Piling CIP Concrete Delivered and Driven 14 x 0.375-Inch	LF	41.83
510.3054	Piling CIP Concrete Delivered and Driven 14 x 0.5-Inch	LF	--
510.3026	Piling CIP Concrete Delivered and Driven 16 x 0.219-Inch	LF	--
510.3036	Piling CIP Concrete Delivered and Driven 16 x 0.25-Inch	LF	--
510.3046	Piling CIP Concrete Delivered and Driven 16 x 0.375-Inch	LF	--
510.3056	Piling CIP Concrete Delivered and Driven 16 x 0.5-Inch	LF	--
511.2105	Piling Steel Delivered and Driven HP 10-Inch x 42 LB	LF	33.95
511.2110	Piling Steel Delivered and Driven HP 12-Inch x 53 LB	LF	36.98
511.2115	Piling Steel Delivered and Driven HP 12-Inch x 74 LB	LF	--
511.2120	Piling Steel Delivered and Driven HP 14-Inch x 73 LB	LF	46.00
511.3000	Pile Points	EACH	125.25
511.6000	Piling Steel Preboring	LF	101.20
512.1000	Piling Steel Sheet Temporary	SF	15.00
513.4050	Railing Tubular Type F (structure) (LS)	LF	125.20
513.4052 or 3	Railing Tubular Type F- (4 or 5) Modified (structure) (LS)	LF	138.42
513.4055	Railing Tubular Type H (structure) (LS)	LF	92.97
513.4060	Railing Tubular Type M (structure) (LS)	LF	169.63
513.4065	Railing Tubular Type PF (structure) (LS)	LF	--
513.4090	Railing Tubular Screening Structure B-	LF	97.17
513.7050	Railing Type W Structure B-	LF	75.29
00000	Concrete Railing, "Texas Rail"	LF	160.00
00000	Concrete Parapet, Type 'LF' & 'A' (estimate)	LF	80.00
513.7005	Railing Steel Type C1 (structure) (LS)	LF	71.39
513.7010	Railing Steel Type C2 (structure) (LS)	LF	149.28
513.7015	Railing Steel Type C3 (structure) (LS)	LF	108.25
513.7020	Railing Steel Type C4 (structure) (LS)	LF	89.16
513.7025	Railing Steel Type C5 (structure) (LS)	LF	--
513.7030	Railing Steel Type C6 (structure) (LS)	LF	107.76
514.0445	Floor Drains Type GC	EACH	2,064.45
514.2625	Downspouts 6-Inch	LF	100.00



516.0500	Rubberized Membrane Waterproofing	SY	27.19
517.1010.S	Concrete Staining	SF	1.12
517.1015.S	Concrete Staining Multi-Color	SF	2.80
517.1050.S	Architectural Surface Treatment	SF	5.05
604.0400	Slope Paving Concrete	SY	47.57
604.0500	Slope Paving Crushed Aggregate	SY	16.90
604.0600	Slope Paving Select Crushed Material	SY	22.62
606.0100	Riprap Light	CY	70.00
606.0200	Riprap Medium	CY	70.13
606.0300	Riprap Heavy	CY	44.82
606.0500	Grouted Riprap Light	CY	57.20
606.0600	Grouted Riprap Medium	CY	--
606.0700	Grouted Riprap Heavy	CY	78.17
612.0106	Pipe Underdrain 6-Inch	LF	5.11
612.0206	Pipe Underdrain Unperforated 6-Inch	LF	14.05
612.0406	Pipe Underdrain Wrapped 6-Inch	LF	6.19
616.0205	Fence Chain Link 5-FT	LF	21.69
616.0206	Fence Chain Link 6-FT	LF	--
616.0208	Fence Chain Link 8-FT	LF	--
645.0105	Geotextile Fabric Type C	SY	2.92
645.0111	Geotextile Fabric Type DF Schedule A	SY	2.42
645.0120	Geotextile Fabric Type HR	SY	2.94
652.0125	Conduit Rigid Metallic 2-Inch	LF	16.31
652.0135	Conduit Rigid Metallic 3-Inch	LF	23.69
652.0225	Conduit Rigid Nonmetallic Schedule 40 2-Inch	LF	5.50
652.0235	Conduit Rigid Nonmetallic Schedule 40 3-Inch	LF	4.88
SPV.0035	HPC Masonry Superstructure	CY	576.36
SPV.0085	Stainless Steel Reinforcement	LB	4.04
SPV.0165	Anti-Graffiti Coating	SF	1.42
SPV.0180	Pigmented Protective Surface Treatment	SY	6.08
SPV.0180	Protective Polymer Coating	SY	43.50

Table 5.3-1
Contract Unit Bid Prices for New Structures



Item No.	Bid Item	Unit	Cost
455.0__	Asphaltic Material _____	TON	50.00
460.1__	HMA Pavement Type _____	TON	48.62
502.5002	Masonry Anchors Type L No. 4 Bars	EACH	11.99
502.5005	Masonry Anchors Type L No. 5 Bars	EACH	16.87
502.5010	Masonry Anchors Type L No. 6 Bars	EACH	16.16
502.5015	Masonry Anchors Type L No. 7 Bars	EACH	16.53
502.5020	Masonry Anchors Type L No. 8 Bars	EACH	23.96
502.5025	Masonry Anchors Type L No. 9 Bars	EACH	26.00
502.6102	Masonry Anchors Type S ½-Inch	EACH	22.63
502.6105	Masonry Anchors Type S 5/8-Inch	EACH	15.49
502.6110	Masonry Anchors Type S ¾-Inch	EACH	15.10
502.6115	Masonry Anchors Type S 7/8-Inch	EACH	--
502.6120	Masonry Anchors Type S 1-Inch	EACH	--
505.0904	Bar Couplers No. 4	EACH	11.73
505.0905	Bar Couplers No. 5	EACH	19.24
505.0906	Bar Couplers No. 6	EACH	11.70
505.0907	Bar Couplers No. 7	EACH	21.76
505.0908	Bar Couplers No. 8	EACH	39.26
505.0909	Bar Couplers No. 9	EACH	59.09
509.0301	Preparation Decks Type 1	SY	97.58
509.0302	Preparation Decks Type 2	SY	79.47
509.0500	Cleaning Decks	SY	8.25
509.1000	Joint Repair	SY	756.47
509.1200	Curb Repair	LF	38.96
509.1500	Concrete Surface Repair	SF	71.00
509.2000	Full-Depth Deck Repair	SY	456.60
509.2500	Concrete Masonry Overlay Decks	CY	514.50
SPV.0165	Epoxy Overlay	SF	24.27

Table 5.3-2
Contract Unit Bid Prices for Rehab Structures



5.4 Bid Letting Cost Data

This section includes past information on bid letting costs per structure type. Values are presented by structure type and include: number of structures, total area, total cost, superstructure cost per square foot and total cost per square foot.

5.4.1 2008 Year End Structure Costs

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	27	354,319	37,636,697	56.00	106.00
Reinf. Conc. Slabs (All But A5)	28	29,381	3,892,609	45.00	98.50
Reinf. Conc. Slabs (A5 Abuts)	20	19,900	2,529,658	53.50	127.00
Prestressed Box Girders	1	762	106,847	109.00	140.00

Table 5.4-1
Stream Crossing Structures

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	68	617,067	52,412,539	64.50	85.00
Steel Plate Girders	0	--	--	--	--
Reinf. Conc. Slabs (All But A5)	2	23,777	2,769,953	58.50	116.50
Reinf. Conc. Slabs (A5 Abuts)	0	--	--	--	--

Table 5.4-2
Grade Separation Structures



Box Culverts	No. of Culverts	Cost per Lin. Ft.
Single Cell	7	1,059.00
Twin Cell	15	1,914.00
Triple Cell	0	--
Aluminum	0	--

Table 5.4-3
Box Culverts

Pedestrian Bridges	Cost per Sq. Ft.
None this Year	--

Table 5.4-4
Pedestrian Bridges

Railroad Bridges	Cost per Sq. Ft.
None this Year	--

Table 5.4-5
Railroad Bridges

Bascule Bridge	Cost per Sq. Ft.
None this Year	--

Table 5.4-6
Bascule Bridges

Retaining Walls	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Cost per Square Foot
MSE Walls	4	14,292	520,912	36.50
Modular Walls	0	--	--	--
Concrete Walls	14	23,572	2,572,658	108.00
Panel Walls	5	11,939	782,972	65.50

Table 5.4-7
Retaining Walls



5.4.2 2009 Year End Structure Costs

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	27	225,572	23,546,996	54.77	104.39
Reinf. Conc. Slabs (All but A5)	39	108,422	11,214,819	46.46	103.44
Reinf. Conc. Slabs (A5 Abuts)	32	58,049	6,312,845	51.00	108.75
Prestressed Box Girders	0				

Table 5.4-8
Stream Crossing Structures

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	124	776,329	67,163,261	50.71	86.51
Steel Plate Girders	2	21,725	4,038,011	114.36	185.87
Reinf. Conc. Slabs (All but A5)	0				
Reinf. Conc. Slabs (A5 Abuts)	0				
Steel I-Beam	4	34,227	3,454,905	58.22	100.94
Arch Structures	2	4,750	1,637,760	0	344.79
Pedestrian Structures	1	2,286	1,712,743	0	749.23

Table 5.4-9
Grade Separation Structures

Box Culverts	No. of Culverts	Cost per Lin. Ft.
Single Cell	16	1,470.36
Twin Cell	11	2,331.10
Triple Cell	1	6,922.41
Pipe	2	1,072.73

Table 5.4-10
Box Culverts



Pedestrian Bridges	Cost per Sq. Ft.
None this Year	--

Table 5.4-11
Pedestrian Bridges

Timber Bridges	Cost per Sq. Ft.
B-9-285 (County Built)	47.20

Table 5.4-12
County Timber Bridges

Bascule Bridge	Cost per Sq. Ft.
None this Year	--

Table 5.4-13
Bascule Bridges

	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Cost per Square Foot
Retaining Walls				
MSE Walls	26	103,486	5,460,180	52.76
Modular Walls	0			
Concrete Walls	6	25,025	1,109,328	44.33
Panel Walls	2	5,873	863,092	146.96
Pile Walls	5	168,403	2,930,175	17.40

Table 5.4-14
Retaining Walls



5.4.3 2010 Year End Structure Costs

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	20	255,157	23,302,014	58.02	91.32
Reinf. Conc. Slabs (All but A5)	24	60,992	6,851,861	61.34	112.34
Reinf. Conc. Slabs (A5 Abuts)	25	54,354	6,988,519	70.10	128.57
Prestressed Box Girders	1	3,351	463,639	78.97	138.36

Table 5.4-15
Stream Crossing Structures

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	31	315,515	25,858,760	58.18	81.96
Steel Plate Girders	4	71,510	21,217,890	99.42	296.71
Reinf. Conc. Slabs (All but A5)	20	168,719	13,881,152	36.77	82.27
Reinf. Conc. Slabs (A5 Abuts)	0				
Trapezoid Box	3	82,733	10,546,181	89.12	127.50

Table 5.4-16
Grade Separation Structures



Box Culverts	No. of Culverts	Cost per Lin. Ft.
Single Cell	22	1,718.00
Twin Cell	8	1,906.00
Triple Cell	1	928.00
Pipe	1	1,095.00

Table 5.4-17
Box Culverts

Pre-Fab Pedestrian Bridge	Cost per Sq. Ft.
B-23-61	133.90

Table 5.4-18
Pre-Fab Pedestrian Bridge

Pedestrian Bridges	Cost per Sq. Ft.
4	179.56

Table 5.4-19
Pedestrian Bridges

Bascule Bridge	Cost per Sq. Ft.
None this Year	--

Table 5.4-20
Bascule Bridges



Retaining Walls	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Cost per Square Foot
MSE Walls	74	448,972	26,243,005	58.45
Modular Walls	0			
Concrete Walls	6	38,680	2,223,277	57.48
Panel Walls	17	113,113	11,827,963	104.57
Tangent Pile Walls	4	36,974	2,347,442	63.49
Wired Faced MSE Wall	2	22,130	907,330	41.00
Secant Wall	1	8,500	913,292	107.45
Soldier Pile Wall	3	251,344	4,448,344	17.72

Table 5.4-21
Retaining Walls

5.4.4 2011 Year End Structure Costs

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	36	218,311	18,719,353	50.45	85.75
Reinf. Conc. Slabs (All but A5)	22	63,846	7,135,430	52.90	111.76
Reinf. Conc. Slabs (A5 Abuts)	14	21,005	2,470,129	53.00	117.60
Prestressed Box Girders	0				

Table 5.4-22
Stream Crossing Structures



Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	44	337,346	31,596,585	65.90	93.66
Steel Plate Girders	0				
Reinf. Conc. Slabs (All but A5)	6	33,787	3,462,995	52.90	102.49
Reinf. Conc. Slabs (A5 Abuts)	0				
Trapezoid Box	0				

Table 5.4-23
Grade Separation Structures

Box Culverts	No. of Culverts	Cost per Lin. Ft.
Single Cell	5	2,140.00
Twin Cell	6	1,998.00
Triple Cell	5	3,518.00
Precast	1	7,385.00

Table 5.4-24
Box Culverts

Pre-Fab Pedestrian Bridge	Cost per Sq. Ft.
None this Year	

Table 5.4-25
Pre-Fab Pedestrian Bridge

Pedestrian Bridges	Cost per Sq. Ft.
None this Year	

Table 5.4-26
Pedestrian Bridges



Railroad Bridge	Cost per Sq. Ft.
B-20-210	3,654.30

Table 5.4-27
Bascule Bridges

Retaining Walls	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Cost per Square Foot
MSE Block Walls	6	7,893	494,274	62.62
MSE Panel Walls	19	87,000	6,679,782	76.78
Modular Walls	0			
Concrete Walls	3	3,516	237,230	67.47
Panel Walls	2	14,832	3,458,722	233.19
Tangent Pile Walls	3	10,139	1,581,071	155.94
Wired Faced MSE Wall	18	149,735	11,412,474	76.22
Secant Wall	0			
Soldier Pile Wall	2	7,849	779,563	99.32

Table 5.4-28
Retaining Walls



5.4.5 2012 Year End Structure Costs

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	18	115,512	11,610,435	53.88	100.50
Reinf. Conc. Slabs (All but A5)	22	80,797	8,269,942	53.04	102.35
Reinf. Conc. Slabs (A5 Abuts)	3	6,438	739,983	53.24	114.95
Prestressed Box Girders	0				

Table 5.4-29
Stream Crossing Structures

Structure Type	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Super. Only Cost Per Square Foot	Cost per Square Foot
Prestressed Concrete Girders	58	697,381	65,044,526	65.91	93.27
Steel Plate Girders	0				
Reinf. Conc. Slabs (All but A5)	1	5,812	491,683	43.73	84.60
Reinf. Conc. Slabs (A5 Abuts)	0				
Trapezoid Box	0				

Table 5.4-30
Grade Separation Structures



Box Culverts	No. of Culverts	Cost per Lin. Ft.
Single Cell	5	1,516.50
Twin Cell	6	3,292.00
Triple Cell	5	2,624.60
Precast	1	0

Table 5.4-31
Box Culverts

Pre-Fab Pedestrian Bridge	Cost per Sq. Ft.
B-40-761/762	325.22

Table 5.4-32
Pre-Fab Pedestrian Bridge

Pedestrian Bridges	Cost per Sq. Ft.
B-53-265	91.93

Table 5.4-33
Pedestrian Bridges

Buried Slab Bridge	Cost per Sq. Ft.
C-13-155	170.77

Table 5.4-34
Buried Slab Bridges



Retaining Walls	No. of Bridges	Total Area (Sq. Ft.)	Total Costs	Cost per Square Foot
MSE Block Walls	17	30,536	1,604,280	52.54
MSE Panel Walls	25	111,365	7,215,980	64.80
Modular Walls	1	500	49,275	98.50
Concrete Walls	2	5,061	416,963	82.39
Panel Walls	2	6,476	1,094,638	169.03
Tangent Pile Walls	0			
Wired Faced MSE Wall	21	109,278	16,130,424	147.61
Secant Wall	1	12,545	2,073,665	165.30
Soldier Pile Wall	2	4,450	298,547	66.49
MSE Gravity Walls	1	975	61,470	63.05
Steel Sheet Piling	5	8,272	352,938	42.67

Table 5.4-35
Retaining Walls



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6.1 Approvals, Distribution and Work Flow

Production of Structural Plans

Regional Office	Prepare Structure Survey Report.
Geotechnical Section (Bur. of Tech. Services)	Make site investigation and prepare Site Investigation Report. See 6.2.1 for exceptions.
Structures Development Sect. (Bur. of Structures)	Record Structure Survey Report.
Structures Design Section (Bur. of Structures)	Determine type of structure. Perform hydraulic analysis if required. Check roadway geometrics and vertical clearance. Review Site Investigation Report and determine foundation requirements. Check criteria for scour critical Bridges and record scour critical code on the preliminary plans. Draft preliminary plan layout of structure. Send copies of preliminary plans to Regional Office. If a railroad is involved, send copies of preliminary plans to the Rails & Harbors Section (Bureau of Transit, Local Roads, Rails & Harbors) who will forward details and information to the railroad company. If Federal aid funding is involved, send copies of preliminary plans to the Federal Highway Administration for major, moveable, and unusual bridges. If a navigable waterway is crossed, a Permit



drawing to construct the bridge is sent to the Coast Guard. If FHWA determines that a Coast Guard permit is needed, send a Permit drawing to the Coast Guard. If Federal aid is involved, preliminary plans are sent to the Federal Highway Administration for approval.

Review Regional Office comments and other agency comments, modify preliminary plans as necessary.

Review and record project for final structural plan preparation.

Assign project to a Structures Design Unit.

Structures Design Units
(Bur. of Structures)

Prior to starting project, Designer contacts Regional Office to verify preliminary structure geometry, alignment, width and the presence of utilities.

Prepare and complete design and final plans for the specified structure.

Give completed job to Manager of Structures Design Section.

Manager, Structures Design
Section (Bur. of Structures)

Review final structural plans.

Review and revise or write special provisions as needed.

Send copies of final structural plans and special provisions to Regional Offices.

If a railroad is involved, send copies of final plans to the Rails & Harbors Section.

Sign lead structural plan sheet.

Deliver final structural plans and special



provisions to the Bureau of Project Development.

Bur. of Project Development

Prepare final approved structural plans for pre- contract administration.

A map of navigable waterways in Wisconsin as defined by the Coast Guard is kept in the Consultant Design and Hydraulics Unit (Bureau of Structures).



6.2 Preliminary Plans

6.2.1 Structure Survey Report

The Structure Survey Report is prepared by Regional Office personnel to request a structure improvement project. The following forms in word format are used and are available at: <http://www.dot.wisconsin.gov/forms/index.htm>

Under the “Plans and Projects” heading:

DT1694	Separation Structure Survey Report
DT1696	Rehabilitation Structure Survey Report
DT1698	Stream Crossing Structure Survey Report (use for Culverts also)

The front of the form lists the supplemental information to be included with the report. Duplicate reports and supplemental information are required for Federal aid primary and Interstate projects.

When preparing the Structure Survey Report, designers will make their best estimate of structure type and location of substructure units. The completed Structure Survey Report with the locations of the substructure units and all required attachments and supporting information will then be submitted to the Geotechnical Section, attention Chief Geotechnical Engineer, through the Regional Soils Engineer, and to the Consultant Design & Hydraulics Unit, attention Consultant Design & Hydraulics Supervisor. This submittal will take place a minimum of 15 months in advance of the final plans due date shown on the Structure Survey Report. The Geotechnical Section has responsibility for conducting the necessary soil borings. The Consultant Design and Hydraulics Unit and the Geotechnical Section will coordinate activities to deliver the completed preliminary plans on schedule.

In most instances, the geotechnical work will proceed after the receipt of the Structure Survey Report, but in advance of the development of the preliminary bridge plans. However, special circumstances may require that the preliminary bridge plans precede the geotechnical work. The Geotechnical Section may request preliminary bridge plans under the following conditions.

1. A review of available subsurface information indicates the probability of very shallow and highly variable bedrock.
2. The span on the Structure Survey Report falls in the 30 to 40 range and the decision between a bridge or a box culvert is not evident.
3. The Structure Survey Report indicates a multiple span structure in excess of 100 feet over a body of water.



The Project Manager may also request information on structure type and substructure locations if such information is necessary to expedite the environmental process.

Under this process, the scheduling of geotechnical work is coordinated with the Consultant Design & Hydraulics Unit toward completion of the bridge plans by the final plan due date. If other geotechnical work is required for the project, the designer should coordinate with the Regional Soils Engineer and the Geotechnical Section to promote efficiency of field drilling operations.

If the preliminary bridge plans are required more than one year in advance of the final plan due date on the Structure Survey Report due to the unique needs of the project, the project manager should discuss this situation with the Consultant Design & Hydraulics Supervisor prior to submitting the Structure Survey Report. A note discussing the agreed upon schedule should then be attached to all copies of the Structure Survey Report so all parties are aware of the schedule. The Geotechnical Section is responsible for scheduling the borings.

Coordination early in the design process with DNR regarding removal techniques for the existing structure, and new structure placement and type is very important. The status of any agreements with the DNR, that affect the structure should be noted under additional information on the Structure Survey Report.

6.2.2 Preliminary Layout

6.2.2.1 General

The preparation of a preliminary layout for structures is primarily for the purpose of presenting an exhibit to the agencies involved for approval, before proceeding with final design and preparation of detail plans. When all the required approvals are obtained, the preliminary layout is used as a guide for final design and plan preparation.

For box culverts a preliminary drawing is usually not prepared. Information required to be submitted as a part of the survey report for a box culvert is usually sufficient to serve as a preliminary layout.

The drawings for preliminary layouts are on sheets having an overall width of 11 inches and an overall length of 17 inches.



6.2.2.2 Basic Considerations

The following criteria are used for the preparation of preliminary plans.

1. Selection of Structure Type. Refer to Chapter 17 - Superstructure-General, for a discussion of structure types.
2. Span Arrangements. For stream crossings the desired minimum vertical clearance from high water to low steel is given in Chapter 8 - Hydraulics. Span lengths for multiple span stream crossings are in most cases a matter of economics and the provision for an opening that adequately passes ice and debris. For structures over navigable streams, the vertical and horizontal clearance of the navigable span are determined by the U.S. Coast Guard after considering the interests of both highway and waterway transportation users.

For most of the ordinary grade separation structures the requirements for horizontal clearance determine the span arrangements. Refer to Chapter 17 - Superstructure-General for span length criteria.

3. Economics.

Economy is a primary consideration in determining the type of structure to be used. Refer to Chapter 5 – Economics and Costs, for cost data.

At some stream crossings where the grade line permits considerable head room, investigate the economy of a concrete box culvert versus a bridge type structure. When economy is not a factor, the box culvert is the preferred type from the standpoint of maintenance costs, highway safety, flexibility for roadway construction, and provision of a facility without roadway width restrictions.

4. Aesthetics. Recognition of aesthetics as an integral part of a structure is essential if bridges are to be designed in harmony with adjacent land use and development. Refer to Chapter 4 - Aesthetics.
5. Hydraulic Consideration. Stream crossing structures are influenced by stream flow, drift, scour, channel conditions, ice, navigation, and conservation requirements. This information is submitted as part of the Structure Survey Report. Refer to Chapter 8 - Hydraulics for Hydraulic considerations and Section 8.1.5 for Temporary Structure Criteria.
6. Geometrics of Design. The vertical and horizontal clearance roadway widths, design live loading, alignment, and other pertinent geometric requirements are given in Chapter 3.
7. Maintenance. All bridge types require structural maintenance during their service life. Maintenance of approaches, embankments, drainage, substructure, concrete deck, and minor facilities is the same for the various types of bridges. A minimum draining grade of 0.5% across the bridge is desirable to eliminate small ponds on the deck except for open railings where the cross slope is adequate.



Epoxy coated bar steel is required in all new decks and slabs.

Steel girders require periodic painting unless a type of weathering steel is used. Even this steel may require painting near the joints. It is more difficult to repaint steel girders that span busy highways.

Reinforced concrete box girders and voided slabs have a poor experience in Wisconsin. They should not be used on new structures.

Deck expansion joints have proved to be a source of maintenance problems. Bridges designed with a limited number of watertight expansion devices are recommended.

8. Construction. Occasionally a structure is proposed over an existing highway on which traffic must be maintained. If the roadway underneath carries high volumes of traffic, any obstruction such as falsework would be hazardous as well as placing undesirable vertical clearance restrictions on the traveled way. This is also true for structures over a railroad.

For structures over most high-volume roadways construction time, future maintenance requirements, and provision for future expansion of the roadway width, have considerable influence on the selection of the final product.

9. Foundations. Poor foundation conditions may influence the structure geometry. It may be more economical to use longer spans and fewer substructure units or a longer structure to avoid high approach fills.
10. Environmental Considerations. In addition to the criteria listed above all highway structures must blend with the existing site conditions in a manner that is not detrimental to environmental factors. Preservation of fish and wildlife, pollution of waters, and the effects on surrounding property are of primary concern in protecting the environment. The design of structures and the treatment of embankments must consider these factors.
11. Safety. Safety is a prime consideration for all aspects of the structure design and layout. Bridge railings are approved through actual vehicle crash testing.

6.2.2.3 Requirements of Drawing

6.2.2.3.1 Plan View

The plan view is preferably placed in the upper left-hand portion of the sheet at the largest scale practical (1"=10') and shows the following basic information:

1. Structure span lengths, (center-to-center of piers and to centerline of bearing at abutments, end distance from centerline of bearing to back face of abutment and overall length of structure).
2. Dimensions along the reference line except for structures on a curve in which case they are along a tangent to the curve.



3. Stations are required at centerline of piers, centerline of bearing at abutments, and end of deck or slab.
4. Stations at intersection with reference line of roadway underneath for grade separation structures.
5. Direction of stationing increase for highway or railroad beneath a structure.
6. Detail the extent of slope paving or riprap.
7. Direction of stream flow and name if a stream crossing.
8. Highway number and direction and number of traffic lanes.
9. Horizontal clearance dimensions, pavement, shoulder, sidewalk, and structure roadway widths.
10. Median width if dual highway.
11. Skew angles and angles of intersection with other highways, streets or railroads.
12. Horizontal curve data if within the limits of the structure showing station of P.C., P.T., and P.I. Complete curve data of all horizontal curves which may influence layout of structure.
13. Location of and vertical clearance at point of critical vertical clearance if highway or railroad separation. (For both roadway directions on divided highways).
14. If floor drains are proposed the type, approximate spacing, and whether downspouts are to be used.
15. Existing structure description, number, station at each end, buildings, underground utilities and pole lines giving owner's name and whether to remain in place, be relocated or abandoned.
16. Indicate which wingwalls have beam guard rail attached if any and wing lengths.
17. Structure numbers on plan. North Arrow.
18. Excavation protection for railroads.
19. Location of deck lighting or utilities if any.
20. Name Plate location. Locate the structure name plate on the roadway side of the first right wing traveling in the highway cardinal directions of North or East.
21. Bench Mark Cap Location
22. Locations of surface drains on approach pavement.



23. Tangent offsets between reference line and tangent line along C_L substructure unit. Also include tangent offsets for edge of deck and reference line at 10 foot intervals.

6.2.2.3.2 Elevation View

The elevation view is preferably placed below the plan view. If the structure is not skewed the substructure units are to be a straight projection from the plan view. If skewed, the elevation is a view normal to substructure units. The view shows the following basic information:

1. Profile of existing groundline or streambed.
2. Cross-section of highway or channel below showing back slopes at abutments.
3. Elevation of top of berm and rate of back slope used in figuring length of structure.
4. Type and extent of slope paving or riprap on back slopes.
5. Proposed elevations of bottom of footings and type of piling if required.
6. Depth of footings for piers of stream crossing and if a seal is required, show and indicate by a note.
7. Location and amount of minimum vertical clearance.
8. Streambed, observed and high water elevations for stream crossings.
9. Location of underground utilities, with size, kind of material and elevation indicated.
10. Location of fixed and expansion bearings.
11. Location and type of expansion devices.
12. Use a scale of 1" = 10' whenever possible.

6.2.2.3.3 Cross-Section View

The cross-section view need only be a half section if symmetrical about a reference line, otherwise it is a full section taken normal to reference line. Use a scale of (1" = 4') whenever possible. A view of a typical pier is shown as a part of the cross-section. The view shows the following general information:

1. Slab thickness, curb height and width, type of railing.
2. Horizontal dimensions tied into a reference line or centerline of roadway.
3. Steel beam or girder spacing with beam/girder depth.
4. For prestressed girders approximate position of exterior girders.
5. Direction and amount of crown or superelevation.



6. Point referred to on profile grade.
7. Type of pier with size and number of columns proposed.
8. For solid, hammerhead or other type pier approximate size to scale.
9. If length of concrete pier cap between outer pier columns exceeds approximately 60 feet, provide an opening in the cross girder for temperature changes and concrete shrinkage, or design the pier cap for temperature and shrinkage to eliminate the opening.
10. Dimension minimum depth of bottom of footings below ditch or finished ground line or if railroad crossing below top of rail.
11. Location for public and private utilities to be carried in the superstructure. Label owner's name of utilities.
12. Location of lighting on the deck or under the deck if any.

6.2.2.3.4 Other Requirements

1. Profile grade line across structure showing tangent grades and length of vertical curve. Station and elevation of P.C., P.I., P.T., and centerline of all substructure units.

Profile grade line of highway beneath structure if highway separation or of top rail if railroad separation. Stations along top of rail are to be tied into actual stationing as established by railroad company.

2. Channel change section if applicable. Approximate stream bed elevation at low point.
3. Any other view or detail which may influence the bridge type, length or clearance.
4. List design data including:

Ultimate Stresses for Materials:

- Concrete Superstructure
- Concrete Substructure
- Bar Steel Reinforcement
- Structural Steel
- Prestressed Concrete
- Prestressing Steel



Foundations

- Soil Bearing Pressure
- Pile Type and Capacity (see 6.3.2.1)

Ratings

Live Load:

Design Loading: HL-93

Inventory Rating Factor: RF = X.XX

Operating Rating Factor: RF = X.XX

Wisconsin Standard Permit Vehicle (Wis-SPV)

(See Chapter 45 – Bridge Rating (45.8.2) for additional information)

Hydraulic Data

Base Flood

- 100 Year Discharge
- Stream Velocity
- 100 Year Highwater Elevation
- Q_2 & Q_2 Elevation (Based on new structure opening)
- Waterway Area
- Drainage Area
- Scour Critical

Overtopping Flood OR (Overtopping N/A, for Floods > the 100 Year Flood)

- Overtopping Frequency
- Overtopping Elevation
- Overtopping Discharge

5. Show traffic data. Give traffic count, data and highway for each highway on grade separation or interchange structure.



6.2.2.4 Utilities

In urban areas, public and private utilities generally have their facilities such as sewers, water cables, pipes, ducts, etc., underground, or at river crossings, in the streambed.

If these facilities cannot be relocated, they may interfere with the most economical span arrangement. The preferred location of light poles is at the abutments or piers.

Overhead power lines may cause construction problems or maintenance inspection problems. Verify if they exist and notify Utilities & Access Management Unit (Bureau of Tech. Services) to have them removed.

It is the general policy to not place utilities on the structure. The Utilities & Access Management Unit approves all utility applications and determines whether utilities are placed on the structures or can be accommodated some other way. Refer all requests to them. Also see Chapter 18 of the FDM and Chapter 4 of "*WisDOT Guide to Utility Coordination*".

6.2.3 Distribution of Exhibits

6.2.3.1 Federal Highway Administration (FHWA).

FHWA memorandums "Implementing Guidance-Project Oversight under Section 1305 of the Transportation Equity Act for the 21st Century (TEA-21) of 1998" dated August 20, 1998, and "Project Oversight Unusual Bridges and Structures" dated November 13, 1998, indicate that **FHWA Headquarters Bridge Division or the Division Office must review and approve preliminary plans for unusual bridges and structures on the following projects:**

1. Projects on the Interstate System
2. Projects on the National Highway System (NHS) but not on the Interstate System, unless it is determined by FHWA and WisDOT that the responsibilities can be assumed by WisDOT
3. Projects on non-NHS Federal-aid highways, and eligible projects on public roads which are not Federal-aid highways if WisDOT determines that it is not appropriate for WisDOT to assume the responsibilities

Technical assistance is also available upon request for projects/structures that are not otherwise subject to FHWA oversight.

Unusual bridges have the following characteristics:

- Difficult or unique foundation problems
- New or complex designs with unique operational or design features
- Exceptionally long spans
- Design procedures that depart from currently recognized acceptable practices



Examples of unusual bridges:

- Cable-stayed
- Suspension
- Arch
- Segmental concrete
- Movable
- Truss
- Bridges types that deviate from AASHTO bridge design standards or AASHTO guide specifications for highway bridges
- Major bridges using load and resistance factor design specifications
- Bridges using a three-dimensional computer analysis
- Bridges with spans exceeding 350 feet

Examples of unusual structures:

- Tunnels
- Geotechnical structures featuring new or complex wall systems or ground improvement systems
- Hydraulic structures that involve complex stream stability countermeasures, or designs or design techniques that are atypical or unique

Timing of submittals is an important consideration for FHWA approval and assistance, therefore, **FHWA should be involved as early as possible.**

The following preliminary documents should be submitted electronically (PDF format) to FHWA:

1. Preliminary plans (Type, Size and Location)
2. Bridge/structures related environmental concerns and suggested mitigation measures
3. Studies of bridge types and span arrangements
4. Approach bridge span layout plans and profile sheets
5. Controlling vertical and horizontal clearance requirements



6. Roadway geometry
7. Design specifications used
8. Special design criteria
9. Cost estimates
10. Hydraulic and scour design studies/reports showing scour predictions and related mitigation measures
11. Geotechnical studies/reports
12. Information on substructure and foundation types

Note: Much of this information may be covered by the submittal of a Structure Type Selection Report.

6.2.3.2 Coast Guard

Current permit application guides published by the 2nd or 9th Coast Guard District should be followed. For Federal Aid projects, applicants must furnish two copies of the Final Environmental Impact Statement accepted by the lead agency. The Regional Office will also forward Water Quality Certification obtained from the Department of Natural Resources.

6.2.3.3 Regions

One print of all preliminary drawings is sent to the Regional Office involved, for their review. For structures financed partially or wholly by a county, city, village or township, their approval should be obtained by the Regional Office and approval notice forwarded to the Bureau of Structures.

6.2.3.4 Utilities

For all structures which involve a railroad, four prints of the preliminary drawing are submitted to the Utilities & Access Management Unit for submission to the railroad company for approval.

If private or public utilities wish to make application to attach their facilities (water, and sewer mains, ducts, cables, etc.) to the structure, they must apply to the Utilities & Access Management Unit for approval.

6.2.3.5 Other Agencies

One set of preliminary plans (preliminary layout, plan & profile, and contour map) for stream crossing bridges are forwarded to the Department of Natural Resources for comment, in accordance with the cooperative agreement between the Department of Transportation and the Department of Natural Resources. (See Chapter 8 - Hydraulics).



6.3 Final Plans

This section describes the general requirements for the preparation of construction plans for bridges, culverts, retaining walls and other related highway structures. It provides a standard procedure, form, and arrangement of the plans for uniformity.

6.3.1 General Requirements

6.3.1.1 Drawing Size

Sheets are 11 inches wide from top to bottom and 17 inches long. A border line is provided on the sheet 1 inch from the left edge, and $\frac{1}{4}$ inch from other edges. Title blocks are provided on the first sheet for a signature and other required information. The following sheets contain the same information without provision for a signature.

6.3.1.2 Scale

All drawings insofar as possible are drawn to scale. Such details as reinforcing steel, steel plate thicknesses, etc. are not scaled. The scale is adequate to show all necessary details.

6.3.1.3 Line Thickness

Object lines are the widest line on the drawing. Lines showing all or part of an existing structure or facility are shown by dashed lines of somewhat lighter weight.

Lines showing bar steel are lighter than object lines and are drawn continuous without any break. Dimension and extension lines are lighter than bar steel lines but heavy enough to make a good reproduction.

6.3.1.4 Lettering and Dimensions

All lettering is upper case. Lettering and dimensions are read from the bottom or right hand side and should be placed above the dimension lines. Notes and dimension text are 0.12 inches high; view titles are 0.20 inches high (based on full size sheet, 22" x 34"). Dimensions are given in feet and inches. Elevations are given in decimal form to the nearest 0.01 of a foot. Always show two decimal places. Although plan dimensions are very accurate, the contractor should use reasonable tolerances during construction of the project by building to the accuracy required. Detail structural steel to the thickness of the material involved.

6.3.1.5 Notes

Show any notes to make the required details clear on the plans. Do not include material that is part of the specifications.



6.3.1.6 Standard Insert Drawings

Standard detail sheets are available for railings and parapets, prestressed girders, bearings, expansion joints, and drains. Fill in the dimensions and titles required and insert in the final plans.

Standard insert sheets can be found at:

http://trust.dot.state.wi.us/extntgtwy/dtid_bos/extranet/structures/index.htm

6.3.1.7 Abbreviations

Abbreviations are to be used throughout the plans whenever possible. Abbreviations approved to be used are as follows:

Abutment	ABUT.	East	E.
Adjacent	ADJ.	Elevation	EL.
Alternate	ALT.	Estimated	EST.
And	&	Excavation	EXC.
Approximate	APPROX.	Expansion	EXP.
At	@	Fixed	F.
Back Face	B.F.	Flange Plate	FI. PI.
Base Line	B/L	Front Face	F.F.
Bench Mark	B.M.	Galvanized	GALV.
Bearing	BRG.	Gauge	GA.
Bituminous	BIT.	Girder	GIR.
Cast-in-Place	C.I.P.	Highway	HWY.
Centers	CTRS.	Horizontal	HORIZ.
Center Line	C/L	Inclusive	INCL.
Center to Center	C to C	Inlet	INL.
Column	COL.	Invert	INV.
Concrete	CONC.	Left	LT.
Construction	CONST.	Left Hand Forward	L.H.F.
Continuous	CONT.	Length of Curve	L.
Corrugated Metal Culvert Pipe	C.M.C.P.	Live Load	L.L.
Cross Section	X-SEC.	Longitudinal	LONGIT.
Dead Load	D.L.	Maximum	MAX.
Degree of Curve	D.	Minimum	MIN.
Degree	°	Miscellaneous	MISC.
Diaphragm	DIAPH.	North	N.
Diameter	DIA.	Number	NO.



Discharge	DISCH.	Near Side, Far Side	N.S.F.S.
Per Cent	%	Sidewalk	SDWK.
Plate	PL	South	S.
Point of Curvature	P.C.	Space	SPA.
Point of Intersection	P.I.	Specification	SPEC
Point of Tangency	P.T.	Standard	STD.
Point on Curvature	P.O.C.	Station	STA.
Point on Tangent	P.O.T.	Structural	STR.
Property Line	P.L.	Substructure	SUBST.
Quantity	QUAN.	Superstructure	SUPER.
Radius	R.	Surface	SURF.
Railroad	R.R.	Superelevation	S.E.
Railway	RY.	Symmetrical	SYM
Reference	REF.	Tangent Line	TAN. LN.
Reinforcement	REINF.	Transit Line	T/L
Reinforced Concrete Culvert Pipe	R.C.C.P.	Transverse	TRAN.
Required	REQ'D.	Variable	VAR.
Right	RT.	Vertical	VERT.
Right Hand Forward	R.H.F.	Vertical Curve	V.C.
Right of Way	R/W	Volume	VOL.
Roadway	RDWY.	West	W.
Round	∅	Zinc Gauge	ZN. GA.
Section	SEC.		

Table 6.3-1
Abbreviations

6.3.1.8 Nomenclature and Definitions

Universally accepted nomenclature and approved definitions are to be used wherever possible.

6.3.2 Plan Sheets

The following information describes the order of plan sheets and the material required on each sheet.

Plan sheets are placed in order of construction generally as follows:



1. General Plan
2. Subsurface Exploration
3. Abutments
4. Piers
5. Superstructure and Superstructure Details
6. Railing and Parapet Details

Show all views looking up station.

6.3.2.1 General Plan (Sheet 1)

See the BOS web page, CADD Resource Files, for the latest sheet borders to be used. Sheet borders are given for new bridges, rehabilitation projects and concrete box culverts. A superstructure replacement utilizing the existing substructure, bridge widenings, as well as damaged girder replacements should use the sheet border for a new structure. See Chapter 40 - Bridge Rehabilitation for criteria as to when superstructure replacements are allowed.

1. Plan View

Same requirements as specified for preliminary drawing, except do not show contours of groundline and as noted below.

- a. Sufficient dimensions to layout structure in the field.
- b. Describe the structure with a simple note such as: Four span continuous steel girder structure.
- c. Station at end of deck on each end of bridge.

On Structure Replacements

Show existing structure in dashed-lines on Plan View.

2. Elevation View

Same requirements as specified for preliminary plan except:

- a. Show elevation at bottom of all substructure units.
- b. Give estimated pile lengths where used.

3. Cross-Section View

Same requirements as specified for preliminary plan except:



- a. For railroad bridges show a railroad cross-section.
- b. View of pier if the bridge has a pier (s), if not, view of abutment.

4. Grade Line

Same requirements as specified for preliminary plan.

5. Design and Traffic Data

Same requirements as specified for preliminary plans, plus see 6.3.2.1 for guidance regarding sheet border selection. .

6. Hydraulic Information, if Applicable

7. Foundations

Give soil/rock bearing capacity or pile capacity.

Example for General Plan sheet: Abutments to be supported on HP 10 x 42 steel piling driven to a required driving resistance of 180 tons * per pile as determined by the Modified Gates Dynamic Formula. Estimated 50'-0" long.

*The factored axial resistance of piles in compression used for design is the required driving resistance multiplied by a resistance factor of 0.5 using modified Gates to determine driven pile capacity.

Abutments with spread footings to be supported on sound rock with a required factored bearing resistance of "XXX" PSF ***. A geotechnical engineer will determine the factored bearing resistance by visual inspection prior to construction of the abutment footing.

*** The factored bearing resistance is the value used for design.

Repeat the note above on each substructure sheet, except the asterisk (*) and subsequent explanation of factored design resistance need not appear on individual substructure sheets.

See Table 11.3-5 for typical maximum driving resistance values.

8. Estimated Quantities

- a. Enter bid items and quantities as they appear, and in the order in which they appear in the "Schedule of Bid Items" of the Standard Specifications. Put items not provided for at the bottom of the list. Enter quantities for each part of the structure, (superstructure, each abutment, each pier) under a separate column with a grand total.

Quantities are to be bid under items for the Structure Type and not by the "B" or "C" numbers. For example, concrete for a multi-cell box culvert exceeding a



total length of 20 feet is to be bid under item Concrete Masonry Culverts. As another example, a bridge having a length less than 20 feet would be given a "C" number; however, the concrete bid item is Concrete Masonry Bridges.

- b. For incidental items to be furnished for which there is no bid item, and compensation is not covered by the *Standard Specifications* or *Special Provisions*, note on the plans the most closely related bid item that is to include the cost in the price bid per unit of item. As an example, the cost of concrete inserts is to be included in the price bid per cubic yard of concrete masonry.

9. General Notes

A standard list of notes is given in [6.3.2.1.1](#) and [6.3.2.1.2](#). Use the notes in this table that apply to the structure drawn on the plans.

10. List of Drawings

Each sheet is numbered sequentially beginning with 1 for the first sheet. Give the sheet number and title of sheet.

11. Bench Marks

Give the location, description and elevation of the nearest bench mark.

12. Title Block

Fill in all data for the Title Block except the signature. The title of this sheet is "General Plan". Use the line below the structure number to describe the type of crossing. (Example: STH 15 SB OVER FOX RIVER). See [6.3.2.1](#) for guidance regarding sheet border selection.

13. Professional Seal

All final bridge plans prepared by Consultants or Governmental Agencies shall be professionally sealed, signed, and dated on the general plan sheet.

This is not required for WisDOT prepared plans, as they are covered elsewhere.

6.3.2.1.1 Plan notes for New Bridge Construction

1. Drawings shall not be scaled. Bar Steel Reinforcement shall be embedded 2" clear unless otherwise shown or noted.
2. All field connections shall be made with 3/4" diameter friction type high-tensile strength bolts unless shown or noted otherwise.
3. Slab falsework shall be supported on piles or the substructure unless an alternate method is approved by the Engineer.



4. The first or first two digits of the bar mark signifies the bar size.
5. The slope of the fill in front of the abutments shall be covered with heavy riprap and geotextile fabric Type 'HR' to the extent shown on sheet 1 and in the abutment details.
6. The slope of the fill in front of the abutments shall be covered with slope paving material to the extent shown on sheet 1 and in the abutment details.
7. The stream bed in front of the abutment shall be covered with riprap as shown on this sheet and in the abutment details.
8. The existing stream bed shall be used as the upper limits of excavation at the piers.
9. The existing ground line shall be used as the upper limits of excavation at the piers.
10. Within the length of the box all spaces excavated and not occupied by the new structure shall be backfilled with Structure Backfill to the elevation and section existing prior to excavation within the length of the culvert.
11. At the backface of abutment all volume which cannot be placed before abutment construction and is not occupied by the new structure shall be backfilled with structure backfill.
12. Concrete inserts to be furnished by the utility company and placed by the contractor. Cost of placing inserts shall be included in the bid price for concrete masonry.
13. Prestressed Girder Bridges - The haunch concrete quantity is based on the average haunch shown on the Prestressed Girder Details sheet.

6.3.2.1.2 Plan Notes for Bridge Rehabilitation

WisDOT policy item:

The note "Dimensions shown are based on the original structure plans" is acceptable. However, any note stating that the contractor shall field verifying dimensions is not allowed.

It is the responsibility of the design engineer to use original structure plans, as-built structure plans, shop drawings, field surveys and structure inspection reports as appropriate when producing rehabilitation structure plans. If uncertainty persists after reviewing available documentation, a field visit may be necessary by the design engineer.

1. Dimensions shown are based on the original structure plans.
2. All concrete removal not covered with a concrete overlay shall be defined by a 1 inch deep saw cut.
3. Utilize existing bar steel reinforcement where shown and extend 24 bar diameters into new work, unless specified otherwise.



4. Concrete expansion bolts and inserts to be furnished and placed by the contractor under the bid price for concrete masonry.
5. At "Curb Repair" expose existing reinforcement a minimum of 1 1/2" clear.
6. Existing floor drains to remain in place. Remove top of deck in drain area as directed by the Field Engineer to allow placing and sloping of 1 1/2" concrete overlay.
7. Expansion joint assembly, including anchor studs and hardware shall be paid for in the lump sum price bid as "Expansion Device B-_____" or "Expansion Device Modular B- _____".
8. Clean and fill existing longitudinal and transverse cracks with penetrating epoxy as directed by the Field Engineer.
9. Variations to the new grade line over 1/4" must be submitted by the Field Engineer to the Structures Design Section for review.
10. The contractor shall supply a new name plate in accordance with Section 502.3.11 of the *Standard Specifications* and the standard detail drawings. Name plate to show original construction year.

6.3.2.2 Subsurface Exploration

This sheet is initiated by the Geotechnical Engineer. The following information is required on the sheet. Bridge details are not drawn by the Geotechnical Engineer.

1. Plan View

Show a plan layout of structure with survey lines, reference lines, pier and abutment locations and location of borings and probings plotted to scale.

On box culvert structure plans, show three profile lines of the existing ground elevations (along the centerline and outer walls of the box). Scale the information for these lines from the site contour map that is a part of the structure survey report.

2. Elevation

Show a centerline profile of existing ground elevation.

Show only substructure units at proper elevation w/no elevations shown. Also show the pile lengths.

Show the kind of material, its located depth, and the blow count of the split spoon sampler for each boring. Give the blow count at about 5 foot intervals or where there is a significant change in material.



6.3.2.3 Abutments

Use as many sheets as necessary to show details clearly. Show all bar steel required using standard notations; solid lines lengthwise and solid dots in cross section. Give dimensions for a skewed abutment to a reference line which passes through the intersection for the longitudinal structural reference line and centerline of bearing of the abutment. Give the dimension, from centerline of bearing to backface of abutment along the longitudinal reference line and the offset distance if on a skew. Show the skew angle.

If there is piling, show a complete footing layout giving piling dimensions tied to the reference line. Number all the piles. Give the type of piling, length and required driving resistance. Show a welded field splice for cast in place concrete or steel H piles.

Bridge seats for steel bearings and laminated elastomeric bearings are level within the limits of the bearing plate. Slope the bearing area utilizing non-laminated elastomeric bearings if the slope of the bottom of girder exceeds 1%. Slope the bridge seat between bearings 1" from front face of backwall to front face of abutment. Give all beam seat elevations.

1. Plan View

- a. Place a keyed construction joint near the center of the abutment if the length of the body wall exceeds 50 feet. Make the keyway as large as feasible and extend the horizontal bar steel through the joint.
- b. Dimension wings in a direction parallel and perpendicular to the wing centerline.
- c. Dimension angle between wing and body if that angle is different from the skew angle of the abutment.

2. Elevation

- a. Give beam seat, wing (front face and wing tip), and footing elevations to the nearest .01 of a foot.
- b. Give vertical dimension of wing.

3. Wing Elevation

4. Body Section

Place an optional keyed construction joint in the parapet at the bridge seat elevation if there is a parapet.

5. Wing Sections

6. Bar Steel Listing and Detail

Use the following views where necessary:



7. Pile Plan & Splice Detail
8. View Showing Limits of Excavation and Backfill
9. Special Details for Utilities
10. Drainage Details

6.3.2.4 Piers

Use as many sheets as necessary to show all details clearly. One sheet may show several piers if only the height, elevations and other minor details are different.

Give dimensions for a skewed pier to a reference line which passes through the intersection of the longitudinal structural reference line and the pier centerline. Show the skew angle. Dimension the centerline spacing of superstructure girders.

1. Plan View

Show dimensions, footings, cap steps, beam spacings and skew angle.

2. Elevation

Show dimensions and elevations. Show lengths of all columns for clarity. Give the elevation of the bottom of footings and beam seats. Refer to abutments for detailing bridge seats. Dimension all bar steel and stirrups.

3. Footing Plan

Show dimensions for pile spacing, pile numbers and reinforcing steel in footing.

4. Bar Steel Listing and Details

5. Pile Splice Detail (If different from abutment only).

6. Cross Section thru Column and Pier Cap

Detail anchor bolts between reinforcing bars to provide clearance. Long steel bridges may require more clearance. This allows an erection tolerance for the structural steel so that the bar steel is not pierced by the anchor bolts if the bearing is shifted.

6.3.2.5 Superstructure

Use as many sheets as are necessary to show all details clearly. Standard insert sheets are available to show many standard details. The title, project number, and a few basic dimensions are added to these standard sheets.



6.3.2.5.1 All Structures

1. Show the cross-section of roadway, plan view and related details, elevation of typical girder or girders, details of girders, and other details not shown on standard insert sheets. All drawings are to be fully dimensioned and show such sections and views as needed to detail the superstructure completely.
2. For girder bridges:
Show the total dead load deflections, including composite dead load (without future wearing surface) acting on the composite section, at tenth points of each span. Distribute the composite dead load evenly to all girders and provide one deflection value for a typical interior girder. Chapter 17 – Superstructure-General illustrates three load cases for exterior girder design with raised sidewalks, cases that provide a conservative envelope to ensure adequate girder capacity. However, the above composite dead load distribution should be used for deflection purposes. For prestressed concrete girders, the dead load deflection reported does not include the weight of the girder. See Chapter 24 – Steel Girder Structures for camber and blocking, top of steel elevation and deflection reporting criteria.

A separate deflection value for interior and exterior girders *may* be provided if the difference, accounting for load transfer between girders, warrants multiple values. A weighted distribution of composite dead load could be used for deflection purposes *only*. For example, an extremely large composite load over the exterior girder could be distributed as 40-30-30 percent to the exterior and first two interior girders respectively. Use good engineering judgment to determine whether to provide separate deflection values for individual girder lines. In general, this is not necessary.

For slab bridges:

Provide camber values at the tenth points of all spans. The camber is based on 3 times the deflection of the slab, only. For multi-span bridges, the deflection calculations are based on a continuous span structure since the falsework supports the bridge until the concrete slab has cured.

Deflection and camber values are to be reported to the nearest 0.1 inch, for all girder and slab superstructures.

3. For girder structures, provide finished grade top of deck elevations for each girder line at the tenth points of all spans. Show the top of deck elevations at the outside edge of deck at tenth points. If staged construction, include tenth point elevations along the construction joint. For slab structures, provide the finished grade elevations at the reference line and/or crown and edge of slab at tenth points.
4. Decks of uniform thickness are used on all girders. Variations in thickness are achieved by haunching the deck over each girder. Haunches are formed off the top of the top flange. See the standards for details. In general the minimum haunch depth along the edge of girder is to be 1 1/4" although 2" is recommended to allow for construction tolerances. Haunch depth is the distance from the bottom of the concrete deck to the top of the top flange.



5. Provide a paving notch at each end of all structures for rigid approach pavements. See standard for details.
6. If the structure contains conduit for a deck lighting system, place the conduit in the concrete parapet. Place expansion devices on conduit which passes through structure expansion joints.
7. Show the bar steel reinforcement in the slab, curb, and sidewalk with the transverse spacing and all bars labeled. Show the direction and amount of roadway crown.
8. On bridges with a median curb and left turn lane, water may be trapped at the curb due to the grade slope and crown slope. If this is the case, make the cross slope flat to minimize the problem. Existing pavers cannot adjust to a variable crown line.
9. On structures with modular joints consider cover plates for the back of parapets when aesthetics are a consideration.
10. Provide a table of tangent offsets for the reference line and edges of deck at 10 foot intervals for curved bridges.

6.3.2.5.2 Steel Structures

1. Show the diaphragm connections on steel girders. Show the spacing of rail posts on the plan view.
2. Show a steel framing plan for all steel girders. Show the spacing of diaphragms.
3. On the elevation view of steel girders show dimension, material required, field and shop splice locations, stiffener spacing, shear connector spacing, and any other information necessary to construct the girder. In additional views show the field splice details and any other detail that is necessary.
4. Show the size and location of all weld types with the proper symbols except for butt welds. Requirements for butt welds are covered by A.W.S. Specifications.
5. See Chapter 24 – Steel Girder Structures for camber and blocking, top of steel elevation and deflection reporting criteria.
6. Existing flange and web sizes should be shown to facilitate the sizing of bolts on Rehabilitation Plans.

6.3.2.5.3 Railing and Parapet Details

Standard drawings are maintained by the Structures Development Section showing railing and parapet details. Add the details and dimensions to these drawings that are unique to the structure being detailed. Compute the length along the slope of grade line rather than the horizontal dimension.



6.3.3 Miscellaneous Information

6.3.3.1 Bill of Bars

Show a complete bill of bar steel reinforcement for each unit of the structure. Place this bill on the sheet to which the bars pertain. If the abutments or piers are similar, only one bar list is needed for each type of unit.

Give each bar or group of bars a different mark if they vary in size, length, or location in a unit. Each bar list is to show the mark, number of bars, length, location and detail for each bar. Give bar lengths to the nearest 1" and segment lengths of bent bars to the nearest 1/2". Show all bar bends and hooks in detail.

Identify all bars with a letter indicating the unit in which the bar is placed - A for abutment, P for pier, S for superstructure. Where units are multiple, each unit should have a different letter. Next use a one or two digit number to sequentially number the bars in a unit. P1008 indicates bar number 08 is a size number 10 bar located in a Pier.

Use a Bar Series Table where a number of bars the same size and spacing vary in length is a uniform progression. Use only one mark for all these bars and put the average length in the table.

Refer to the Standard drawings in Chapter 9 – Materials for more information on reinforcing bars such as minimum bend diameter, splice lengths, bar supports, etc.

When a bridge is constructed in stages, show the bar quantities for each stage. This helps the contractor with storage and retrieval during construction.

6.3.3.2 Box Culverts

Detail plans for box culverts are to be fully dimensioned and have sectional drawings needed to detail the structure completely. The following items are to be shown when necessary:

1. Plan View
2. Longitudinal section
3. Section thru box
4. Wing elevations
5. Section thru wings
6. Section thru cutoff wall
7. Vertical construction joint
8. Bar steel clearance details
9. Header details



10. North point, Bench mark, Quantities
11. Bill of bars, Bar details
12. General notes, List of drawings, Rip rap layout
13. Inlet nose detail on multiple cell boxes
14. Corner details

Bid items commonly used are excavation, concrete masonry, bar steel, rubberized membrane waterproofing, backfill and rip rap. Filler is a non bid item. In lieu of showing a contour map, show profile grade lines as described for Subsurface Exploration sheet.

See the standard details for box culverts for the requirements on vertical construction joints, apron and cutoff walls, longitudinal construction joints, and optional construction joints.

Show name plate location on plan view and on wing detail.

6.3.3.3 Miscellaneous Structures

Detail plans for other structures such as retaining walls, sign bridges, pedestrian bridges, and erosion control structures are to be detailed with the same requirements as previously mentioned.

6.3.3.4 Standard Drawings

Standard drawings are maintained and furnished by the Structures Development Section. These drawings show the common types of details required on the contract plans.

6.3.3.5 Insert Sheets

These sheets are maintained by the Structures Development Section and are used in the contract plans to show standard details.

6.3.3.6 Change Orders and Maintenance Work

These plans are drawn on full size sheets.

6.3.3.7 Bench Marks

Bench mark caps are shown on all bridges and larger culverts. Locate the caps on a horizontal surface flush with the concrete. Show the location in close proximity to the Name Plate.

6.3.4 Checking Plans

Upon completion of the design and drafting of plans for a structure, the final plans are usually checked by one person. Dividing plans checking between two or more Checkers for any one



structure leads to errors many times. The plans are checked for compliance with the approved preliminary drawing, design, sufficiency and accuracy of details, dimensions, elevations, and quantities. Generally the information shown on the preliminary plan is to be used on the final plans. Revisions may be made to footing sizes and elevations, pile lengths, dimensions, girder spacing, column shapes, and other details not determined at the preliminary stage. Any major changes from the preliminary plan are to be approved by the Chief Structural Design Engineer.

Give special attention to unique details and unusual construction problems. Take nothing for granted on the plans.

The Checkers check the final plans against the Engineer's design and sketches to be sure all information is shown correctly. The Engineer prepares all sketches and notations not covered by standard drawings. A good Checker checks what is shown and noted on the plan and also checks to see if any essential details, dimensions, or notation have been omitted. Check the final plan Bid Items for conformity with those scheduled in the WisDOT Standard Specifications for Highway and Structure Construction.

The Checker makes an independent Bill of Bars list to be sure the detailer has not omitted any bars when checking the quantity of bar steel.

Avoid making minor revisions in details or dimensions that have very little effect on cost, appearance, or adequacy of the completed structure. Check grade and bridge seat elevations and all dimensions to the required tolerances. The Checkers make all corrections, revisions, and notations on a print of the plan and return it to the Plan Preparer. The Plan Preparer back checks all marks made by the checker before changing. Any disagreements are resolved with the supervisor.

Common complaints received from field people are dimension errors, small details crowded on a drawing, lettering is too small, and reinforcing bar length or quantity errors.

After the plans are completed, the items in the survey folder are separated into the following groups by the Structures Design Unit Supervisor or plans checker:

6.3.4.1 Items to be Destroyed When Construction is Completed (Group A)

1. Miscellaneous correspondence and Transmittal letters
2. Preliminary drawings and computations
3. Prints of soil borings and plan profile sheets
4. Quantity computations and bill of bars
5. Shop steel quantity computations*
6. Design checker's computations
7. Designer Computations and computer runs of non-complex structures on non state maintained structures.



8. Layout sheets
9. Elevation runs and bridge geometrics
10. *Falsework plans*
11. Miscellaneous Test Report
12. Photographs of Bridge Rehabs

* These items are added to the packet during construction.

6.3.4.2 Items to be Destroyed when Plans are Completed (Group B)

1. All "void" material
2. All copies except one of preliminary drawings
3. Extra copies of plan and profile sheets
4. Preliminary computer design runs

Items in Group A should be placed together and labeled. Items in Group B should be discarded.

The following items are part of the Data Management System for Structures. The location is shown for all items that need to be completed in order to properly manage the Structure data either by Structures Design personnel for in-house projects or consultants for their designs. Data for filing that is generated outside the Bureau of Structures should be sent to the Structures Development Section.

1. Structure Inventory Form (Available on DOTNET) - New Bridge File – Data for this form is completed by the preliminary designer and plans checker. It is submitted to the Structures Development Section for entry into the File.
2. Load Rating Input File - Permits File - The designers submit an electronic copy of the input data for load rating the structure to the Structures Development Section. It is located for internal use at //H32751/rating.
3. Designer Computations and Inventory Superstructure Design Run (Substructure computer runs as determined by the Engineer) - **HSI – The designers record design, inventory, operating ratings and maximum vehicle weights on the plans and place into the scanned folder.
4. Pile Driving Reports - An electronic copy of Forms DT1924 (Pile Driving Data) and DT1315 (Piling Record) are to be submitted to the Bureau of Structures by e-mail to "DOTDTSDDStructuresPiling@dot.wi.gov". These two documents will be placed in HSI for each structure and can be found in the "Shop" folder.



5. Shop Drawings for Steel Bridges, Sign Bridges, Prestressed Girders, High Mast Poles, Retaining Walls, Floor Drains, Railings and all Steel Joints - HSI - Metals Fabrication & Inspection Unit or other source sends to the Structures Development Section to scan all data into HSI.
6. Mill Tests, Heat Numbers and Shop Inspection Reports for all Steel Main Members - HSI - Metals Fabrication & Inspection Unit sends electronic files data into HSI.
7. Hydraulic and Scour Computations, Contour Maps and Site Report - HSI - Data is placed into scanned folder by Consultant Design & Hydraulics Unit.
8. Subsurface Exploration Report - HSI - Report is placed into scanned folder by Consultant Design & Hydraulics Unit or electronic copies are loaded from Geotechnical files.
9. Structure Survey Report - HSI - Report is placed into scanned folder by Consultant Design & Hydraulics Unit.
10. As Built Plans - HSI - At bid letting, the printers place a digital image of plans in a computer folder and send to the Structures Development Section where the plan sheets are labeled and placed in HSI. As Built plans will replace bid letting plans when available and will be scanned by the Structures Development Section.
11. Inspection Reports - New Bridge File - The Structures Maintenance Section loads a copy of the following Inspection Reports into the New Bridge File.

Initial	Underwater (UW)-Probe/Visual
Routine Visual	Movable
Fracture Critical	Damage
In-Depth	Interim
Underwater (UW)-Dive	Posted
Underwater (UW)-Surv	

Table 6.3-2
Various Inspection Reports

** HSI – Highway Structures Information System – The electronic file where bridge data is stored for future use.

6.3.5 Processing Plans

1. Before P.S. & E. Process

File plans in plan drawers by county for consultant work, or



Maintain plans as PDF on E-plan server.

2. At P.S. & E. Processing

Prepare plans for bid letting process.

3. After Structure Construction

Any data in Design Folder is scanned and placed with bridge plans.

Original plan sheets and Design Folders are discarded.



6.4 Computation of Quantities

When the final drafting and checking is completed, the Engineering Specialist and checker are to prepare individual quantity calculations for the bid items listed on the plans. The following instructions apply to the computation on quantities.

Be neat and orderly with the work. Divide the work into units that are repetitive such as footings, columns, and girders. Label all items with a clear description. Use sketches for clarity. These computations may be examined by others in future years so make them understandable.

One of the most common errors made in quantity computation is computing only half of an item which is symmetrical about a centerline and forgetting to double the result.

Staged Construction - On projects where there is staged construction that will involve two construction seasons the following quantities should be split to match the staging to aid the contractor/fabricator: Concrete Masonry, Bar Steel Reinforcement, Structural Steel and Bar Couplers. The other items are not significant enough to justify separating.

Following is a list of commonly used bridge quantities. Be sure to use the appropriate item and avoid using incidental items as this is too confusing for the contractor and project manager. Items such as Incentive Strength Concrete Structures, Construction Staking Structure Layout, etc. should not be included on the structure plans.

A column with the title “Bid Item Number” should be the first column for the “Total Estimated Quantities” table shown in the plans. The numbers in this column will be the numbers associated with the bid items as found in the Standard Specification, STSP, and/or Special Provisions.

6.4.1 Excavation for Structures Bridges (Structure)

This is a lump sum bid item. The limits of excavation are shown in the chapter in the manual which pertains to the structural item, abutments, piers, retaining walls, box culverts, etc.

The limits of excavation made into solid rock are the neat line of the footing.

6.4.2 Backfill Granular or Backfill Structure

Backfill Granular and Backfill Structure are bid in units of cubic yard. The pay limits and quantity computations of backfill at abutments are shown in Chapter 12 – Abutments.

6.4.3 Concrete Masonry Bridges

Show unit quantities to the nearest cubic yard, as well as the total quantity. In computing quantities no deduction is made for metal reinforcement, floor drains, conduits and chamfers less than 2”. Flanges of steel and prestressed girders projecting into the slab are deducted.



Deduct the volume of pile heads into footings and through seals for all piling except steel H sections. Deduct the actual volume displaced for precast concrete and cast-in-place concrete piling.

Consider the concrete parapet railing on abutment wing walls as part of the concrete volume of the abutment.

6.4.4 Prestressed Girder Type I (28-Inch; 36-Inch; 36W-Inch; 45W-Inch; 54W-Inch; 72W-Inch, 82W-Inch)

Record the total length of prestressed girders to the nearest 1 foot.

6.4.5 Bar Steel Reinforcement HS Bridges or Bar Steel Reinforcement HS Coated Bridges

Record this quantity to the nearest 10 lbs. Designate if bar steel is coated. Include the bar steel in C.I.P. concrete piling in bar steel quantities.

6.4.6 Structural Steel Carbon or Structural Steel HS

See 24.2.4.

6.4.7 Bearing Pads Elastomeric Non-Laminated or Bearing Pads Elastomeric Laminated or Bearing Assemblies Fixed (Structure) or Bearing Assemblies Expansion (Structure)

Record as separate item with quantity required. Bid as Each.

6.4.8 Piling Test Treated Timber (Structure)

Record this quantity as a lump sum item. Estimate the pile lengths by examining the subsurface exploration sheet and the Site Investigation Report. Give the length and location of test piles in a footnote. Do not use this quantity for steel piling or concrete cast-in-place piling.

6.4.9 Piling CIP Concrete Delivered and Driven ___-Inch, Piling Steel Delivered and Driven ___ -Inch

Record this quantity in feet for Steel and C.I.P. types of piling delivered and driven. Timber piling are Bid as separate items, delivered and driven. Pile lengths are computed to the nearest 5.0 foot for each pile within a given substructure unit, unless a more exact length is known due to well defined shallow rock (approx. 20 ft.), etc.. Typically, all piles within a given substructure unit are shown as the same length.

The length of foundation piling driven includes the length through any seal and embedment into the footing. The quantity delivered is the same as quantity driven. For trestle piling the amount of piling driven is the penetration below ground surface.



Oil field pipe is allowed as an alternate on all plans unless a note is added in the General Notes stating it is not allowed on that specific project.

6.4.10 Preboring CIP Concrete Piling or Steel Piling

Record the type, quantity in feet. Calculate to the nearest lineal foot per pile location.

6.4.11 Railing Steel Type (Structure) or Railing Tubular Type (Structure)

Record the type, quantity is a Lump Sum.

6.4.12 Slope Paving Concrete or Slope Paving Crushed Aggregate or Slope Paving Select Crushed Material

Record this quantity to the nearest square yard. Deduct the area occupied by columns or other elements of substructure units.

6.4.13 Riprap Medium, Riprap Heavy or Grouted Riprap, Riprap Light

Record this quantity to the nearest 5 cubic yards.

6.4.14 Pile Points

When recommended in soils report. Bid as each.

6.4.15 Floordrains Type GC or Floordrains Type H

Record the type and number of drains. Bid as Each.

6.4.16 Cofferdams (Structure)

Lump Sum

6.4.17 Rubberized Membrane Waterproofing

Record the quantity to the nearest square yard.

6.4.18 Expansion Device (Structure)

Record this quantity in lump sum.

6.4.19 Electrical Work

Refer to Standard Construction Specifications for bid items.



6.4.20 Conduit Rigid Metallic ___-Inch or Conduit Rigid Nonmetallic Schedule 40 -Inch

Record this quantity in feet.

6.4.21 Preparation Decks Type 1 or Preparation Decks Type 2

Estimate Type 2 Deck Preparation as 40% of Type 1 Deck Preparation. Record this quantity to the nearest square yard. Use 2" for depth of each Preparation, compute concrete quantity and add to Concrete Masonry Overlay Decks.

6.4.22 Cleaning Decks

Record this quantity to the nearest square yard.

6.4.23 Joint Repair

Record this quantity to the nearest square yard.

6.4.24 Concrete Surface Repair

Record this quantity to the nearest square foot.

6.4.25 Full-Depth Deck Repair

Record this quantity to the nearest square yard. Concrete quantity used, should be added to Concrete Masonry Overlay Decks.

6.4.26 Concrete Masonry Overlay Decks

Record this quantity to the nearest cubic yard. Estimate the quantity by using a thickness measured from the existing ground concrete surface to the plan gradeline. Calculate the minimum overlay thickness and add ½" for variations in the deck surface. Provide this average thickness on the plan, as well. Usually 1" of deck surface is removed by grinding.

6.4.27 Removing Old Structure STA. XX + XX.XX

Covers the entire or partial removal of an existing structure. Bid as Lump Sum.

6.4.28 Anchor Assemblies for Steel Plate Beam Guard

Attachment assembly for Beam Guard at the termination of concrete parapets. Bid as each.

6.4.29 Steel Diaphragms (Structure)

In span diaphragms used on bridges with prestressed girders. Bid as each.



6.4.30 Welded Stud Shear Connectors X -Inch

Total number of shear connectors with the given diameter. Bid as each.

6.4.31 Concrete Masonry Seal

Seal concrete bid to the nearest cubic yard. Whenever a concrete seal is shown on the plans, then "Cofferdams (Structure)" is also to be a bid item.

6.4.32 Geotextile Fabric Type

List type of fabric. Type HR is used in conjunction with Heavy Riprap. Bid in square yards.

6.4.33 Masonry Anchors Type L No. Bars

Used when anchoring reinforcing bars into concrete. Bid as each.

6.4.34 Piling Steel Sheet Permanent Delivered or Piling Steel Sheet Permanent Driven

Record this quantity to the nearest square foot for the area of wall below cutoff.

6.4.35 Piling Steel Sheet Temporary

This quantity is used when the designer determines that retention of earth is necessary during excavation and soil forces require the design of steel sheet piling.

Record this quantity to the nearest square foot for the area below the retained grade and one foot above the retained grade.

Following is a list of commonly used STSP's and Bureau of Structures Special Provisions.

6.4.36 Temporary Shoring

This quantity is used when earth retention may be required and the method chosen is the contractor's option.

Bid as square foot of exposed surface as shown on the plans.

6.4.37 Concrete Masonry Deck Patching

(Deck preparation areas) x 2" deck thickness.

6.4.38 Sawing Pavement Deck Preparation Areas

Use 10 lineal feet per S.Y. of Preparation Decks.



6.4.39 Removing Bearings

Used to remove existing bearings for replacement with new expansion or fixed bearing assemblies. Bid as each.



6.5 Production of Bridge Plans by Consultants, Regional Offices and Other Agencies

The need for structures is determined during the Preliminary Site Survey and recorded in the Concept Definition or Work Study Report. On Federal (FHWA) or State Aid Projects completed Structure Survey Reports and plans are submitted to the Structures Design Section with a copy forwarded to the Regional Office for approval prior to construction. Structure and project numbers are assigned by the Regional Offices. In preparation of the structural plans, the appropriate specifications and details recommended by the Structures Design Section are to be used. If the consultant elects to modify or use details other than recommended, approval is required prior to their incorporation into the final plans.

On all Federal or State Aid Projects involving Maintenance work, the Concept Definition or Work Study Report, the preliminary and final bridge reconstruction plans shall be submitted to the Structures Design Section for review.

Consultants desiring eligibility to perform engineering and related services on WisDOT administered structure projects must have on file with the Bureau of Structures, an electronic copy of their current Quality Assurance/Quality Control (QA/QC) plan and procedures. The QA/QC plan and procedures shall include as a minimum:

- Procedures to detect and correct bridge design errors before the design plans are made final.
- A means for verifying that the appropriate design calculations have been performed, that the calculations are accurate, and that the capacity of the load-carrying members is adequate with regard to the expected service loads of the structure.
- A means for verifying the completeness, constructability and accuracy of the structure plans.
- Verification that independent checks, reviews and ratings were performed.

A QA/QC verification summary sheet is required as part of every final structure plan submittal, demonstrating that the QA/QC plan and procedures were followed for that structure. The QA/QC verification summary sheet shall include the signoff or initialing by each individual that performed the tasks (design, checking, plan review, technical review, etc.) documented in the QA/QC plan and procedures. The summary sheet must be submitted with the final structure plans as part of the ESubmit process.

6.5.1 Approvals, Distribution, and Work Flow

Consultant	Meet with Regional Office and/or local units of government to determine need.
	Prepare Structure Survey Report including recommendation of structure type.
Geotechnical Consultant	Make site investigation and prepare Site Investigation Report.
Consultant	Prepare Preliminary Plan documents including scour computations for spread footings and/or shallow pile foundations. Record scour critical



	code on preliminary plans. Refer to Chapter 8, Appendix 8-D.
	If a navigable waterway is crossed, complete necessary Coast Guard coordination.
	Submit preliminary plans and documents via ESubmit for review and processing.
Structures Design Section	Record Bridge and project numbers.
	Review hydraulics for Stream Crossings.
	Review Preliminary Plan.
	If a railroad is involved, send a copy of preliminary plans to the Rails & Harbors Section.
	For special structure types (lift or moveable bridges; cost greater than \$10,000,000), send preliminary plans to Federal Highway Administration for approval.
	Return preliminary plans and comments from Structures Design Section and other appropriate agencies to Consultant with a copy to the Regional Office.
	Forward Preliminary Plan and Hydraulic Data to DNR.
Consultant	Modify preliminary plan as required.
	Prepare and complete final design and plans for the specified structure.
	Write special provisions.
	At least two months in advance of the PS&E date, submit the following via ESubmit: final plans, special provisions, computations, quantities, QA/QC Verification Sheet, Inventory Data Sheet, Bridge Load Rating Summary Form, LRFD Input File (Excel ratings spreadsheet).
Structures Design Section	Determine which final plans will be reviewed and perform review as applicable.
	If a railroad is involved, send a copy of final plans to Rails & Harbors Section.
	For special structure types (lift or moveable bridges; cost greater than \$10,000,000), send final plans to Federal Highway Administration.
	For final plans that are reviewed, return comments to Consultant and send copy to Regional Office.
Consultant	Modify final plans and specifications as required.
	Submit modified final plans via ESubmit as required.



Structures Design Section	Review modified final plans as applicable.
	Sign final plans.
Bureau of Project Development	Prepare final approved bridge plans for pre-Development contract administration.

Table 6.5-1
Approvals, Distribution and Work Flow

6.5.2 Consultant Preliminary Plan Requirements

The Consultant prepares the Structure Survey Report for the improvement. Three types of Structure Survey Reports are available at the Regional Offices and listed in 6.2.1 of this Chapter. Preliminary layout requirements are given in 6.2.2. The Preliminary Plan exhibits are as follows:

1. Structure Survey Report.
2. Preliminary Drawings.
3. Log Borings shown on the Subsurface Exploration Drawing which must be submitted now and can be included with the Final Plans.
4. Evaluation Report of Borings.
5. Contour Map.
6. Typical Section for Roadway Approaches.
7. Plan and Profile of Approach Roadways.
8. Hydraulic Report (see Chapter 8 - Hydraulics) is required for Stream Crossing Structures.
9. County Map showing Location of New and/or Existing Structures.
10. Any other information or Drawings which may influence Location, Layout or Design of Structure.

The above information is also required for Box Culverts except that a separate preliminary drawing is usually not prepared unless the Box Culvert has large wings or other unique features.

The type of structure is usually determined by the local unit of government and the Regional Office. However, Bureau of Structures personnel review the structure type and may recommend that other types be considered. In this regard it is extremely important that



preliminary designs be coordinated to avoid delays and unnecessary expense in plan preparation.

If the final approach roadways are unpaved, detail protective armor angles at the roadway ends of bridge decks/slabs as shown on the Standard for Strip Seal Cover Plate Details.

6.5.3 Final Plan Requirements

The guidelines and requirements for Final Plan preparation are given in 6.3. The following exhibits are included as part of the Final Plans:

1. Final Drawings.

For all highway structures provide the maximum vehicle weight that can be safely carried based on the procedure and vehicle configuration provided in Chapter - Bridge Rating.

2. Design and Quantity Computations

3. Special Provisions covering unique items not in the Standard Specifications such as Electrical Equipment, New Proprietary Products, etc.

4. QA/QC Verification Sheet

5. Inventory Data Sheet, Bridge Load Rating Summary Form, LRFD Input File (Excel ratings spreadsheet).

On Federal or State Aid projects the contracts are let and awarded by the Wisconsin Department of Transportation. Shop drawing review and fabrication inspection are generally done by the Metals Fabrication and Inspection Unit. However, in some cases the consultant may check the shop drawings and an outside agency may inspect the fabrication. The Consultant contract specifies the scope of the work to be performed by the Consultant. Construction supervision and final acceptance of the project are provided by the State.

6.5.4 Design Aids & Specifications

The following items are available for assistance in the preparation of structure plans on the department internet sites:

http://on.dot.wi.gov/dtid_bos/extranet/structures/LRFD/index.htm

- Bridge Manual
- Highway Structures Information System (HSI)
- Insert sheets
- Standard details
- Posted bridge map
- Standard bridge CADD files
- Structure survey reports and check lists



Structure costs
Structure Special Provisions

<http://www.dot.wisconsin.gov/business/engrserv/index.htm>

Facilities Development Manual
Standard Specifications for Highway and Structures Construction
Construction and Materials Manual

Additional information is available on the AASHTO and AREMA websites listed below:

<http://bridges.transportation.org>

<http://www.arema.org>



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7.1 Introduction

Disclaimer:

This chapter is in the early stages of development. The information is limited and will develop over time. The intent of this chapter is to provide guidance to designers, but is far from all-inclusive.

The purpose of the Accelerated Bridge Construction (ABC) Chapter is to provide guidance for the planning and implementation of projects that may benefit from the application of rapid bridge construction technologies and methods. This chapter was prepared to provide planners and engineers with a basic understanding of different ABC methods available, help guide project specific selection of ABC methods, and to encourage the use of the ABC methods described in this chapter.

7.1.1 WisDOT ABC Initiative

The Department's mission is to provide leadership in the development and operation of a safe and efficient transportation system. One of our values relates to Improvement - Finding innovative and visionary ways to provide better products and services and measure our success. The application of Accelerated Bridge Construction (ABC) is consistent with our Mission and Values in promoting efficient development and operation of the transportation system through innovative bridge construction techniques that better serve the public. This service may manifest as safer projects with shorter and less disruptive impacts to the traveling public, and potential cost savings.

WisDOT is following the Federal Highway Administration's (FHWA) Every Day Counts initiative "aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment." Two of the five major methods that the FHWA has emphasized as accelerating technologies are Prefabricated Bridge Elements and Systems (PBES) and Geosynthetic Reinforced Soil – Integrated Bridge Systems (GRS-IBS). These accelerating technologies are incorporated in the following sections in this chapter, namely: Prefabricated Bridge Elements, Geosynthetic Reinforced Soil – Integrated Bridge Systems (GRS-IBS), Self-Propelled Modular Transporters (SPMTs) and Lateral Sliding (both SPMTs and Lateral Sliding are classified as Prefabricated Bridge Systems). WisDOT has had success using GRS-IBS and Prefabricated Bridge Elements, and is always looking for new technologies to improve construction and reduce impacts to traffic. For more information on the Every Day Counts Initiative, refer to www.fhwa.dot.gov/everydaycounts.

7.1.2 ABC Overview

In essence, ABC uses different methods of project delivery and construction to reduce the project schedule, on-site construction time, and public impact. With the ever increasing demand on transportation infrastructure, and the number of bridges that are approaching the end of their service lives, the need for ABC becomes more apparent.

Three main benefits of using ABC methods include minimized impact to traffic, increased safety during construction, and minimized impacts in environmentally sensitive areas. Where conventional bridge construction takes months or years, a bridge utilizing ABC may be



placed in a matter of weeks, days, or even a few hours depending on the methods used. ABC methods are generally safer than conventional construction methods because much of the construction can be done offsite, away from traffic. Quality can also be improved because the construction is often completed in a more controlled environment compared to on-site conditions. On the other hand, as with the implementation of all new technologies, the use of ABC comes with challenges that need to be overcome on a project-specific basis.

Oftentimes accelerating the schedule increases the cost of the project. This increased project delivery cost can be offset by reductions in road user costs. In some states, it has been shown that a high percentage of the public approves the use of ABC knowing that the cost can be significantly higher.

WisDOT policy item:
Prior to the implementation of ABC methods on a project, contact the Bureau of Structures Development Section Chief for discussion, resources, and approval.

7.1.3 Accelerated Bridge Construction Terminology

Acronym/Term	Definition
ABC (Accelerated Bridge Construction)	Bridge construction methods that use innovative planning, design, materials, and construction techniques in a safe and cost-effective manner to reduce the onsite construction time that occurs when building new bridges or replacing and rehabilitating existing bridges.
AC (Alternative Contracting)	Nontraditional project delivery systems, bidding practices, and specifications that may be used to reduce life-cycle costs, improve quality, and accelerate the delivery of construction projects.
BSA (Bridge Staging Area)	Location where a bridge is constructed near the final location for the bridge, where the traveling public is not affected. The bridge can be moved from the staging area to the final location with SPMTs or by sliding.
CM/GC (Construction Manager/General Contractor)	Hybrid of the DBB and D/B processes that allows the owner to remain active in the design process, while the risk is still taken by the general contractor. This method is not an option for WisDOT administered projects.
D/B (Design/Build)	Accelerated project delivery method where one entity (the “designer-builder”) assumes responsibility for both the design and construction of a project. This method is not an option for WisDOT administered projects.
DBB (Design-Bid-Build)	Traditional project delivery method where the owner contracts out the design and construction of a project to two different entities.



EDC (Every Day Counts)	Initiative put forth by FHWA designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment.
GRS-IBS (Geosynthetic Reinforced Soil – Integrated Bridge System)	An ABC technology that uses alternating layers of compacted granular fill material and fabric sheets of geotextile reinforcement to provide support for the bridge in place of a traditional abutment.
LBDB (Low Bid Design Build)	A type of D/B where the design and construction service is bundled into a single contract awarded to the lowest competent and responsible bidder.
PBES (Prefabricated Bridge Elements and Systems)	Structural components of a bridge or bridge system that are constructed offsite, or near-site of a bridge that reduce the onsite construction time and impact to the traveling public relative to conventional construction methods.
Pick Points	Locations where the SPMTs will lift and carry the bridge.
Program Initiative	The use of ABC methods to facilitate research, investigate technology, develop familiarity, or address other stakeholder needs.
Road User Costs	Costs pertaining to a project alternative borne by motorists and the community at-large as a result of work zone activity. (FDM 11-50-32)
SPMTs (Self Propelled Modular Transporters)	Remote-controlled, multi-axle platform vehicles capable of transporting several thousand tons of weight.
Stroke	Distance an SPMT can raise or lower its platform.
TMP (Transportation Management Plan)	A set of coordinated transportation management strategies that describes how they will be used to manage work zone impacts of a road project. (FDM 11-50-5)
TP (Travel Path)	Course that the SPMTs travel to carry the completed structure from the staging area to the final location.

Table 7.1-1
ABC Terminology



7.1.4 ABC Methods

7.1.4.1 Prefabricated Bridge Elements

Prefabricated bridge elements are a commonly used ABC method and can be incorporated into most bridge projects as a form of accelerated construction. Concrete bridge elements are prefabricated, transported to the construction site, placed in the final location, and tied into the structure. An entire bridge can be composed of prefabricated elements, or single bridge elements can be prefabricated as the need arises. Prefabricated bridge elements can also be used in combination with other accelerated bridge construction methods. Commonly used prefabricated bridge elements are prestressed concrete girders (including I-girders, adjacent inverted T-beams, and boxes), full depth and partial depth deck panels, abutments, pier caps, pier columns, and footings, as well as precast three-sided and four-sided box culverts.

For all prefabricated bridge elements, shop drawings shall be submitted by email to the Bureau of Structures Development Section Chief.



Figure 7.1-1
Prefabricated Pier Cap



Figure 7.1-2
Prefabricated Abutment

Prefabricated bridge elements are used to mitigate the on-site time required for concrete forming, rebar tying and concrete curing, saving weeks to months of construction time. Deck beam elements eliminate conventional onsite deck forming activities. To reduce onsite deck forming operations, deck beam elements are typically placed in an abutting manner. Prefabricated elements are often of higher quality than conventional field-constructed elements, because the concrete is cast and cured in a controlled environment. The elements are often connected using high strength grout, and post-tensioning or pretensioning. Because some previous prefabricated bridge element connections have had problems, close attention should be given to these connections.

7.1.4.2 Geosynthetic Reinforced Soil – Integrated Bridge Systems (GRS-IBS)

Geosynthetic Reinforced Soil-Integrated Bridge Systems (GRS-IBS) are composed of two main components: Geosynthetic Reinforced Soil (GRS) and Integrated Bridge Systems (IBS). GRS is an engineered fill of closely spaced alternating layers of compacted fill and geosynthetic reinforcement that eliminates the need for traditional concrete abutments. IBS is a quickly-built, potentially cost-effective method of bridge support that blends the roadway into the superstructure using GRS technology. This integration system creates a transition area that allows for uniform settlement between the bridge substructure and the roadway approach, alleviating the “bump at the bridge” problem caused from uneven settlement. The result of this system is a smoother bridge approach.

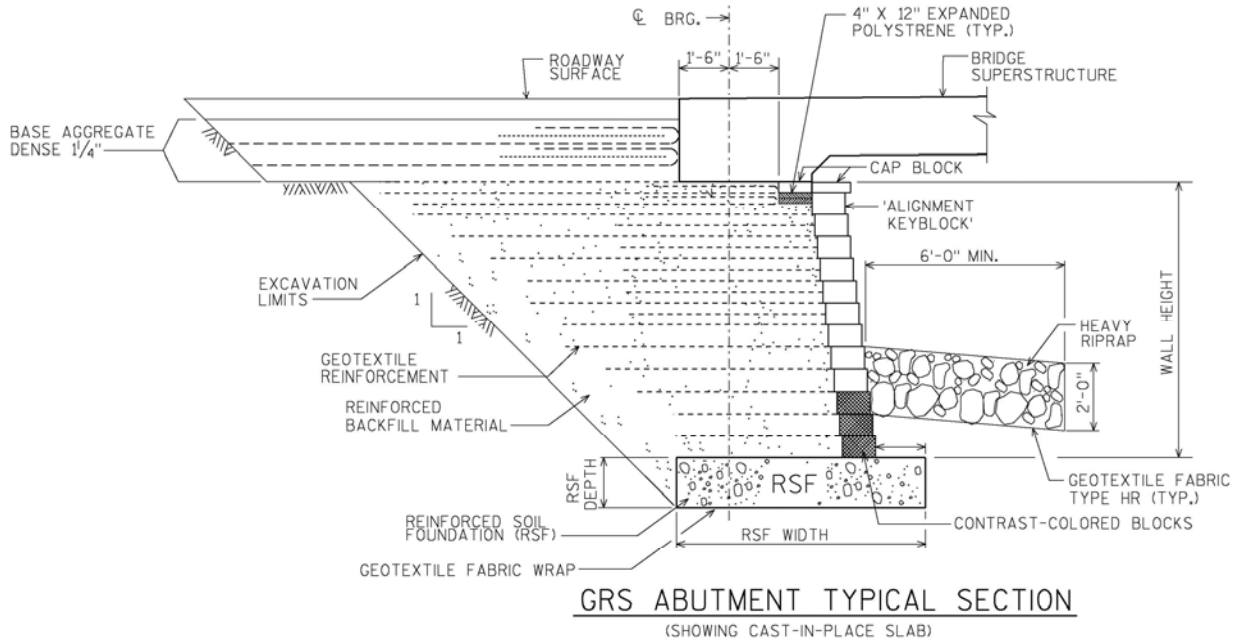


Figure 7.1-3
GRS-IBS Typical Cross Section



Figure 7.1-4
GRS-IBS Structure



Figure 7.1-5
GRS Abutment Layer During Construction

FHWA initially developed this accelerated construction technology, and the first bridge constructed in Wisconsin using the GRS-IBS technology was built in the spring of 2012. This structure (including structure numbers B-9-380, R-9-13, and R-9-14) is located on State



Highway 40 in Chippewa County. This structure utilized a single-span cast-in-place concrete slab, which is the first of its kind in the nation. This structure will be closely monitored for two years to assess its performance.

This technology has several advantages over traditional bridge construction methods. A summary of the benefits of using GRS-IBS technology include the following:

1. **Reduced Construction Time:** Due to the simplicity of the design, low number of components, and only requiring common construction equipment to construct, the abutments can be rapidly built.
2. **Potential Reduced Construction Costs:** Compared to typical bridge construction in Wisconsin, GRS-IBS abutments can achieve significant cost savings. Nationwide, the potential cost savings is reported to be between 25 to 60% over traditional methods. The savings comes largely from the reduced number of construction steps, readily available and economical materials, and the need of only basic tools and equipment for construction.
3. **Lower Weather Dependency:** GRS-IBS abutments utilize only precast modular concrete facing blocks, open-graded backfill, and geotextile reinforcement in the basic design. The abutments can be constructed in poor weather conditions, unlike cast-in-place concrete, reducing construction delays.
4. **Flexible Design:** The abutment designs are simplistic and can be easily field-modified where needed to accommodate a variety of field conditions.
5. **Potential Reduced Maintenance Cost:** Since there are fewer parts to GRS-IBS abutments, overall maintenance is reduced. In addition, when repairs are needed, the materials are typically readily available and the work can be completed by maintenance staff or a variety of contractors.
6. **Simpler Construction:** The basic nature of the design demands less specialized construction equipment and the materials are usually readily available. Contractor capability and capacity demands are also reduced, allowing smaller and more diverse contractors to bid and complete the work.
7. **Less Dependent on Quality Control:** GRS-IBS systems are simple and basic in both their design and construction. Lack of technically challenging components and construction methods results in higher overall quality, reducing the probability of quality control related problems.
8. **Minimized Differential Settlement:** The GRS-IBS system is designed to integrate the structure with the approach pavement. Even though settlements can accumulate, differential settlement between the superstructure and the transition pavement is small. This can substantially reduce the common “bump at the bridge” that can be felt when traveling over traditional bridge transitions.

For more information, see [7.3](#), WisDOT Standard Details 7.01 and 7.02, and the Department’s specification.



7.1.4.2.1 Design Standards

GRS Abutments shall be designed in conformance with the current *AASHTO Load and Resistance Factor Design Specifications* (AASHTO LRFD) and in accordance with the WisDOT Bridge Manual.

7.1.4.2.2 Application

In some cases GRS-IBS abutments may not be suitable for a particular bridge location and there are specific limitations that can cause concern. As with any preliminary bridge planning, the site should be thoroughly investigated for adequacy. The designer shall investigate the potential viability of using of GRS-IBS for any proposed bridge. The designer should be aware of the common criteria for use and the limitations of GRS-IBS systems. Some of the common criteria for usage of GRS-IBS are the following:

1. Scour potential at the abutment locations has been evaluated and is within acceptable limits
2. Water velocities are less than 5 ft/s
3. Adequate freeboard is provided (See Bridge Manual Chapter 8.3.1.5)
4. Soil conditions permit shallow foundations.
5. Low-volume roadways
6. Single span structure with a span length less than 90 feet
7. Abutment wall height less than 22 feet (measured at the maximum wall height, from the top of the RSF to the top of the wall)
8. Wingwalls are parallel to roadway
9. Maximum skew angle of 15°
10. Short and long term settlements are tolerable
11. Differential settlement along the length of the abutment is tolerable to avoid twisting of the superstructure
12. Suitable construction materials available



7.1.4.2.3 Design Considerations

7.1.4.2.3.1 Hydraulics

Similar to any bridge spanning a waterway, the hydraulic conditions must be evaluated. The integrity of this system is very susceptible to scouring and undercutting of the Reinforced Soil Foundation (RSF) which could lead to further erosion and movement of the backfill in the GRS mass, causing settlement and possible structural failure.

WisDOT policy item:

The use of GRS-IBS is subject to prior-approval by the Bureau of Structures for hydraulic design. Evaluation of scour vulnerability will include assessment of long-term aggradation and degradation, potential for lateral migration of the stream, and calculation of contraction scour and abutment scour. The conservative nature of abutment scour calculations is acknowledged. Placement of adequately designed permanent scour countermeasures will be required to resist calculated scour.

In some cases of bridge replacement, the new GRS-IBS abutments can be constructed behind old abutments which can be left partially in place to promote scour protection for the RSF and GRS mass. Rip-rap, gabion mattresses and other traditional permanent countermeasures can also be used.

To help bridge inspectors with scour detection, the lower rows of facing block below proposed grade should have an accent color (typically red, either integral or stained color treatment) that will become visible if scour is occurring. The accented colors provide a visual cue to inspectors that movement of soils has occurred. The top of the contrast-colored blocks shall be placed 2-3 block courses below the top of riprap elevation.

7.1.4.2.3.2 Reinforced Soil Foundation (RSF) and Reinforced Soil Mass

In the GRS-IBS system, bridge seat loads (including dead loads, live loads, etc.) and the weight of the GRS mass and facing blocks comprise the vertical loads that are carried by the RSF and ultimately transmitted to the soil. The vertical bridge seat loads are transferred to the RSF via the GRS mass. The facing blocks only carry their self-weight. Horizontal earth pressure forces are resisted by the GRS mass and little horizontal forces are carried by the facing blocks.

As with any bridge design, proper subsurface exploration should be conducted to ascertain the soil types and layer thicknesses in the vicinity of the proposed site. Laboratory testing may also be necessary to help determine the soil properties and provide the magnitude and time rate of total and differential settlements that may occur.

The external stability of the RSF and reinforced soil mass should be checked for failure against sliding, bearing capacity, and global stability. Due to the behavior of the reinforcement within the soil mass, overturning is an unlikely failure mode, but needs to be checked. The internal stability of the GRS mass should also be checked for bearing capacity, deformations, and the required reinforcement strength. FHWA (1) has provided general guidelines for GRS-IBS ultimate bearing capacities and the predicted deformations when



using the prescribed material properties (geotextile, backfill, etc.) and geometry (layer spacings, wall height, etc.). In addition, anticipated settlements should be included when designing for vertical clearance. Under the conditions recommended by FHWA (1), creep in the geotextile reinforcement is typically negligible since the sustained stresses are redistributed and relatively low and reduction factors for creep are not required. Creep testing and evaluation should be conducted when the loading conditions and backfill and reinforcement conditions prescribed by FHWA (1) are exceeded.

The wall facing is composed of precast modular concrete blocks, which have a height of 8-inches. These types of blocks are readily available and need to conform to the same physical and chemical requirements as WisDOT MSE Wall Modular Blocks.

Special consideration should be given to the degree of batter of the various facing block systems. The amount of batter integrated into the wall systems can vary between manufacturers. Batter that is greater than expected will result in a decreased width between abutments when the span distance is held constant. The designer should be familiar with typical batter ranges for suppliers, and plan for variations in batter.

The wall facing blocks only support their self-weight and are held in place by the friction generated from their self-weight, the mechanical block interlocks, and the geotextile reinforcing fabric placed between each block layer. The upper layers of block will be less stable than the lower layers and they should be bonded in accordance with the specifications. This prevents movement of the blocks from expansion and contraction, freeze-thaw forces, settlement forces and vandalism.

The backfill should be an open graded material with an assumed internal angle of friction of 38 degrees. Generally this will limit the material to a crushed aggregate product. The RSF and integrated approach should generally use a wrapped dense graded aggregate.

The RSF and GRS mass should utilize a biaxial woven geotextile reinforcement fabric from the same manufacturer and of the same type and strength. Using biaxial geotextiles reduces the possibility of construction placement errors.

7.1.4.2.3.3 Superstructure

Typically, the bridge superstructure is placed directly on the reinforced soil abutment. Prestressed girders are often placed on top of the GRS substructure, followed by a traditional cast-in-place deck or precast deck panels. Other methods include the use of a cast-in-place concrete slab capable of spanning between the abutments or precast box girders. Both of these superstructure alternatives should be placed directly on the GRS abutment. The bearing area should contain additional geotextile reinforcement layers, which ensures that the superstructure bears on the GRS mass and not the facing blocks. The clear space between the facing block and the superstructure should be a minimum of 3-inches or 2 percent of the wall height, whichever is greater.

If steel or concrete I-girders are used, a precast or cast-in-place beam seat should be used to help distribute the girder reactions to the GRS abutment. Since there is open space between I-girders, the beam seat can be used to support a backwall between the girders to retain the soil behind the girder ends.



7.1.4.2.3.4 Approach Integration

The approach construction that ties the roadway to the superstructure is essential for minimizing approach settlement and minimizing the bump at each end of the bridge. With a GRS abutment, this is accomplished by compacting and reinforcing the approach fill in wrapped geotextile layers and blending the integration zone with the approach pavement structure.

The integrated approach is constructed in a similar manner as the GRS mass, using layers of geotextile reinforcement and aggregate backfill. However, the integrated approach uses thinner layers until approximately 2 inches from the bottom of the pavement structure. The lift thicknesses should not exceed 6-inches and should be adjusted to accommodate the beam depths.

7.1.4.2.3.5 Design Details

Many of the typical detailing requirements for traditional bridges are still required on GRS-IBS bridges such as railings, parapets, guardrail end treatments, and drainage. Steel posts should be used for guardrail systems within the GRS and integrated approach areas, which can more easily penetrate the layers of geotextile than timber posts.

Penetrations and disturbances through the geotextile layers should be kept to a minimum and only used when absolutely necessary. Planning the locations of utilities and future utilities should be considered to avoid disturbing these layers. If utilities must be installed through a GRS-IBS abutment, all affected layers of geotextile should be overlapped/spliced according to the manufacturer's recommendations.

The backfill used for GRS-IBS is usually comprised of free draining, open graded material. The designer should give consideration to providing additional drainage if warranted. Surface drainage should be directed away from the wall face and the reinforced soil mass.

7.1.4.3 Lateral Sliding

Bridge placement using lateral sliding is another type of ABC where the entire superstructure is constructed in a temporary location and is moved into place over a night or weekend. This method is typically used for bridge replacement of a primary roadway where the new superstructure is constructed on temporary supports adjacent and parallel to the bridge being replaced. Once the superstructure is fully constructed, the existing bridge structure is demolished, and the new bridge is moved transversely into place. In some instances, a more complicated method known as a bridge launch has been used, which involves longitudinally moving a bridge into place.



Figure 7.1-6
Lateral Sliding

Several different methods have been used to slide a bridge into place. One common method is to push the bridge using a hydraulic ram while the bridge slides on a smooth surface and Teflon coated elastomeric bearing pads. Other methods have also been used, such as using rollers instead of sliding pads, and winches in place of a hydraulic ram. The bridge can also be built on a temporary support frame equipped with rails and pushed or pulled into place along those rails. Many DOTs have successfully replaced bridges overnight using lateral sliding.

This ABC method is used to replace bridges that are part of a main transportation artery traversing a minor road, waterway, or other geographic feature. The limiting factor with using lateral slide is having sufficient right-of-way, and space adjacent to the existing bridge to construct the new superstructure.

7.1.4.4 Self Propelled Modular Transporter (SPMT)

SPMTs are remote-controlled, multi-axle platform vehicles capable of transporting several thousand tons of weight. They have traditionally been used to move heavy equipment that is too large for standard trucks to carry. Over the past decade, the use of these SPMTs has been applied to rapid bridge replacement. The use of SPMTs for bridge placement has been used in Europe for more than 30 years. The United States has recently implemented this technique following the FHWA’s recommendation in 2004 to learn how other countries used prefabricated bridge components to minimize traffic disruption, improve work zone safety, reduce environmental impact, improve constructability, enhance quality, and lower life-cycle costs.



Figure 7.1-7
Self Propelled Modular Transporters Moving a Bridge

When replacing a bridge using SPMTs the new superstructure is built on temporary abutments off-site in a designated bridge staging area (BSA) near the bridge site. Once the new superstructure is constructed, the removal of the existing structure can also be expedited with SPMTs or can be demolished in conventional time frames, depending on the project-specific needs. Once the existing structure is removed, the new superstructure is moved from the staging area to the final location using two or more lines of SPMTs. SPMTs have the ability to move laterally, rotate 360° with carousel steering, and have a vertical lifting stroke of approximately 18-24 inches. The SPMTs lift the superstructure off of the temporary abutments and transport it to the permanent abutments. The placement of the bridge superstructure using SPMTs often requires only one evening of full road closure, and many bridges in the United States have been placed successfully in a matter of hours.



SPMTs are typically used to replace bridges that span major roads or highways, and the traffic closure restrictions govern the need for a quick replacement. Locating an off-site staging area to build the superstructure is a critical component to use SPMTs. There needs to be a clearly defined travel path between the staging area and the final bridge location that can support the SPMT movements (vertical clearances, horizontal clearances, turning radii, soil conditions, utility conflicts, etc.). SPMTs can also be used to place a bridge over a waterway. In this case, the bridge superstructure is constructed offsite, and then SPMTs transport the superstructure onto a barge which travels the waterway to the bridge site where it can be set in place.

To date, mostly single span bridges with spans ranging from approximately 100 to 200 feet have been moved. There have been a few two-span bridge moves with SPMTs in the United States. Many of the superstructure types that have been moved successfully are prestressed I-girders or steel plate girders. Moving forward, as SPMTs are used more frequently, the limits of SPMT move capabilities will expand.

7.1.5 Project Delivery Methods/Bidding Process

In addition to the accelerating technologies discussed in this chapter, the Every Day Counts initiative includes accelerated project delivery methods as a way to shorten the project duration. Traditionally, the Design-Bid-Build (DBB) method has been used for project delivery. This involves the design and construction to be completed by two different entities. Project schedules using the DBB method are elongated because the design and construction cannot be completed concurrently. The entire design process must be completed before the bidding process begins. Finally, after the bidding process is completed, the construction can begin.

Other state DOT's have used project delivery methods that can allow for more accelerated overall project delivery. These include Design/Build (D/B) and Construction Manager/General Contractor (CM/GC). The D/B process requires the designer-builder to assume responsibility for both the design and construction of the project. This method increases the risk for the design-builder, and reduces the risk for the owner. Project delivery time can be reduced, since the D/B process allows for the design and construction phases to overlap, unlike the DBB process. There is a specific type of D/B called Low Bid Design Build (LBDB) which has the same structure as the traditional D/B process, except that the lowest bidder wins the project (rather than having a quality component as with the traditional D/B process). Refer to the *Facilities Development Manual (FDM)* for further discussion on LBDB.

The CM/GC process is a hybrid of the DBB and D/B processes. In CM/GC, both the designer and the contractor have contracts with the owner, and the owner is part of the design team. In this process, a construction manager is selected, and is able to provide input regarding schedule, pricing, and phasing during the design phase. Around the 60% or 90% design completion, the owner and construction manager negotiate a "guaranteed maximum price" for the construction of the project based on the defined scope and schedule. CM/GC allows the owner to remain active in the design process, while the risk is still taken by the general contractor.



Generally, in Wisconsin, projects administered by the Department have been Design Bid Build with minimal use of the Low Bid Design Build method. Refer to the FDM Chapter 11-50-32 for additional discussion on Alternative Contracting (AC) methods.

WisDOT policy item:

Each state has different preferences and constraints to which project delivery method they use, and due to current legislation, CM/GC and traditional D/B are not viable options for the state of Wisconsin. To implement ABC using the DBB process, the contract should either specify to use the ABC method required by the owner, and/or provide opportunity for the contractor to propose ABC alternatives that meet contract requirements.



7.2 ABC Decision-making guidance

This section is intended to provide guidance on when to use ABC versus conventional construction. When ABC methods are appropriate, this section will also help determine which ABC method(s) are most practical for a particular project.

Figure 7.2-1 is a Decision Matrix that can be used to determine how applicable an ABC method is for a particular project. Each item in Figure 7.2-1 is described further in Table 7.2-1. Once a total score is obtained from the Decision Matrix, the score is used to enter the Decision Flowchart (Figure 7.2-2). After entering the Flowchart, the user could be directed to the question “Do the benefits of ABC outweigh any additional costs?” This question needs to be evaluated on a project-specific basis, using available project information and engineering judgment. This item is intended to force the user to step back, think about the project as a whole, and decide if an ABC method really makes sense with all the project-specific information considered. The remainder of the flow chart questions will help guide the user toward the ABC method(s) that are most appropriate for the project.

There is an acknowledged level of subjectivity in both the Decision Matrix and in the Flowchart. These tools are intended to provide general guidance, not to provide a specific answer for all projects. The tools present different types of considerations that should be taken into account to help guide the user in the right direction and are not intended to provide a “black and white” answer.

The flowchart item “Program Initiative” can encompass a variety of initiatives, including (but not limited to) research needs, public input, local initiatives, stakeholder requests, or structure showcases. These items should be considered on a project-specific basis.

The flowchart guides users towards specific ABC technologies. However, the user should also recognize the ability and opportunity to combine various ABC technologies. For example, the combination of PBES with GRS-IBS could be utilized.

For additional guidance or questions, contact the Bureau of Structures Development Section Chief.



% Weight	Category	Decision-Making Item	Possible Points	Points Allocated	Scoring Guidance
17%	Disruptions (on/under Bridge)	Railroad on Bridge?	8	<input type="text"/>	0 No railroad track on bridge 4 Minor railroad track on bridge 8 Major railroad track on bridge
		Railroad under Bridge?	3	<input type="text"/>	0 No railroad track under bridge 1 Minor railroad track under bridge 3 Major railroad track(s) under Bridge
		Over Navigation Channel that needs to remain open?	6	<input type="text"/>	0 No navigation channel that needs to remain open 3 Minor navigation channel that needs to remain open 6 Major navigation channel that needs to remain open
8%	Urgency	Emergency Replacement?	8	<input type="text"/>	0 Not emergency replacement 4 Emergency replacement on minor roadway 8 Emergency replacement on major roadway
23%	User Costs and Delays	ADT and/or ADTT (Combined Construction Year ADT on and under bridge)	6	<input type="text"/>	0 No traffic impacts 1 ADT under 10,000 2 ADT 10,000 to 25,000 3 ADT 25,000 to 50,000 4 ADT 50,000 to 75,000 5 ADT 75,000 to 100,000 6 ADT 100,000+
		Required Lane Closures/Detours? (Length of Delay to Traveling Public)	6	<input type="text"/>	0 Delay 0-5 minutes 1 Delay 5-15 minutes 2 Delay 15-25 minutes 3 Delay 25-35 minutes 4 Delay 35-45 minutes 5 Delay 45-55 minutes 6 Delay 55+ minutes
		Are only Short Term Closures Allowable?	5	<input type="text"/>	0 Alternatives available for staged construction 3 Alternatives available for staged construction, but undesirable 5 No alternatives available for staged construction
		Impact to Economy (Local business access, impact to manufacturing etc.)	6	<input type="text"/>	0 Minor or no impact to economy 3 Moderate impact to economy 6 Major impact to economy
14%	Construction Time	Impacts Critical Path of the Total Project?	6	<input type="text"/>	0 Minor or no impact to critical path of the total project 3 Moderate impact to critical path of the total project 6 Major impact to critical path of the total project
		Restricted Construction Time (Environmental schedules, Economic Impact – e.g. local business access, Holiday schedules, special events, etc.)	8	<input type="text"/>	0 No construction time restrictions 3 Minor construction time restrictions 6 Moderate construction time restrictions 8 Major construction time restrictions
5%	Environment	Does ABC mitigate a critical environmental impact or sensitive environmental issue?	5	<input type="text"/>	0 ABC does not mitigate an environmental issue 2 ABC mitigates a minor environmental issue 3 ABC mitigates several minor environmental issues 4 ABC mitigates a major environmental issue 5 ABC mitigates several major environmental issues
3%	Cost	Compare Comprehensive Construction Costs (Compare conventional vs. prefabrication)	3	<input type="text"/>	0 ABC costs are 25%+ higher than conventional costs 1 ABC costs are 1% to 25% higher than conventional costs 2 ABC costs are equal to conventional costs 3 ABC costs are lower than conventional costs
18%	Risk Management	Does ABC allow management of a particular risk?	6	<input type="text"/>	0-6 Use judgment to determine if risks can be managed through ABC that aren't covered in other topics
		Safety (Worker Concerns)	6	<input type="text"/>	0 Short duration impact with TMP Type 1 3 Normal duration impact with TMP Type 2 6 Extended duration impact with TMP Type 3-4
		Safety (Traveling Public Concerns)	6	<input type="text"/>	0 Short duration impact with TMP Type 1 3 Normal duration impact with TMP Type 2 6 Extended duration impact with TMP Type 3-4
12%	Other	Economy of Scale (repetition of components in a bridge or bridges in a project) (Total spans = sum of all spans on all bridges on the project)	5	<input type="text"/>	0 1 total span 1 2 total spans 2 3 total spans 3 4 total spans 4 5 total spans 5 6+ total spans
		Weather Limitations for conventional construction?	2	<input type="text"/>	0 No weather limitations for conventional construction 1 Moderate limitations for conventional construction 2 Severe limitations for conventional construction
		Use of Typical Standard Details (Complexity)	5	<input type="text"/>	0 No typical standard details will be used 3 Some typical standard details will be used 5 All typical standard details will be used
			Sum of Points:	0	(100 Possible Points)

Figure 7.2-1
ABC Decision-Making Matrix



7.2.1 Description of terms in ABC Decision-Making Matrix

The following text describes each item in the ABC Decision-Making Matrix (Figure 7.2-1). The points associated with the scoring guidance in the matrix and in the text below are simply guidance. Use engineering judgment and interpolate between the point ranges as necessary.

Decision-Making Item	Scoring Guidance Description
Railroad on Bridge?	This is a measure of how railroad traffic on the bridge will be affected by the project. If a major railroad line runs over the bridge that requires minimum closures and a shoo fly (a temporary railroad bridge bypass) cannot be used, provide a high score here. If a railroad line that is rarely used runs over the bridge, consider providing a mid-range or low score here. If there is no railroad on the bridge, assign a value of zero here.
Railroad under Bridge?	This is a measure of how railroad traffic under the bridge will be affected by the project. If a major railroad line runs under the bridge that would disrupt construction progress significantly, provide a high score here. If a railroad track runs under the structure, but it is used rarely enough that it will not disrupt construction progress significantly, provide a low score here. Consider if the railroad traffic is able to be suspended long enough to move a new bridge into place. If there is not a large enough window to move a new bridge into place, SPMT could be eliminated as an alternative for this project. For this case, PBES may be a more applicable alternative. If there is no railroad under the bridge, assign a value of zero here.
Over Navigation Channel that needs to remain open?	This is a measure of how a navigation channel under a bridge will be affected by the project. If a navigation channel is highly traveled and needs to remain open for shipments, provide a high score here. If a navigation channel is rarely traveled and there are not requirements for it to remain open at certain time periods, provide a low score here. If there is no navigation channel under the bridge, assign a value of zero here.
Emergency Replacement?	This is a measure of the urgency of the bridge replacement. A more urgent replacement supports the use of accelerated bridge construction methods, since demolition and construction can be progressing concurrently. Depending on the particular project, accelerated bridge construction methods can also allow multiple components of the bridge to be constructed concurrently. If the bridge replacement is extremely urgent and the bridge can be replaced quicker by using accelerated construction methods, provide a high score here.



<p>ADT and/or ADTT (Construction Year)</p>	<p>This is a measure of the total amount of traffic crossing the bridge site. A higher ADT value at a site will help support the use of accelerated bridge construction methods. Use a construction year ADT value equal to the sum of the traffic on the structure and under the structure. For cases where there is a very high ADT on the bridge and very low or no ADT under the bridge, consider using a “slide” method (on rollers or Polytetrafluorethylene (PTFE)/Elastomeric pads) or SPMT’s, which can be very cost effective ABC techniques for this situation. For structures with a higher-than-average percentage of truck traffic, consider providing a higher score than indicated solely by the ADT values in the table.</p>
<p>Required Lane Closures/Detours?</p>	<p>This is a measure of the delay time imposed on the traveling public. If conventional construction methods will provide significant delays to the traveling public, provide a high score here. If conventional construction methods will provide minimal delays to the traveling public, provide a low score here. Use the delay times provided in the table as guidance for scoring.</p>
<p>Are only Short Term Closures Allowable?</p>	<p>This is a measure of what other alternatives are available besides accelerated bridge construction. If staged construction is not an alternative at a particular site, the only alternative may be to completely shut down the bridge for an SPMT move, and therefore a high score should be provided here. If there is a good alternative available for staged construction that works at the site, a low score should be provided here.</p>
<p>Impact to Economy</p>	<p>This is a measure of the impact to the local businesses around the project location. Consider how the construction staging, road closures, etc. will impact local businesses (public access, employee access, etc.) A high impact to the economy equates to a high score here. A low impact to the economy equates to a low score here.</p>
<p>Impacts Critical Path of Total Project?</p>	<p>This is a measure of how the construction schedule of the structure impacts the construction schedule of the entire project. If the construction of the structure impacts the critical path of the entire project, and utilizing ABC methods provides shorter overall project duration, provide a high score here. If other project factors are more critical for the overall project schedule and utilizing ABC methods will not affect the overall project duration, provide a low score here.</p>
<p>Restricted Construction Time</p>	<p>This is a measure of how the construction schedule is impacted by environmental and community concerns or requirements. Items to consider are local business access windows, holiday schedules and traffic, special event traffic, etc. If there are significant restrictions on construction schedule, provide a high score here. If there are little to no restrictions on the construction schedule, provide a low score here.</p>



<p>Does ABC mitigate a critical environmental impact or sensitive environmental issue?</p>	<p>This is a measure of how using accelerated bridge construction methods can help mitigate impacts to the environment surrounding the project. Since accelerated methods allow a shorter on-site construction time, the impacts to the environment can be reduced. If the reduced on-site construction time provided by accelerated bridge construction methods mitigates a significant or critical environmental concern or issue, provide a high score here. If there are no environmental concerns that can be mitigated with accelerated construction methods, provide a low score here.</p>
<p>Compare Comprehensive Construction Costs</p>	<p>This is a measure of the complete comprehensive cost difference between conventional construction methods versus using an accelerated bridge construction method. Some costs will increase with the use of accelerated construction methods, such as the cost of the SPMT equipment and the learning curve that will be incorporated into using new technologies. However, some costs will decrease with the use of accelerated construction methods, such as the reduced cost for traffic control, equipment rentals, inspector wages, etc. Many of the reduced costs are a direct result of completing the project in less time. Use the cost comparisons in the table as guidance for scoring here.</p>
<p>Does ABC allow management of a particular risk?</p>	<p>This is an opportunity to add any project-specific items or unique issues that have risk associated with them that are not incorporated into another section in this text. Consider how ABC may or may not manage those particular risks.</p>
<p>Safety (Worker Concerns)</p>	<p>This is a measure of the relative safety of the construction workers between conventional construction methods and accelerated construction methods. The reduced on-site construction time from using accelerated bridge construction methods reduces the exposure time of workers in a construction zone, thus increasing safety. If a significant increase in safety can be seen by utilizing accelerated construction methods, provide a high score here. If utilizing accelerated construction methods does not provide additional safety, provide a low score here. Refer to the <i>Facilities Development Manual (FDM)</i> for definitions of TMP Types.</p>
<p>Safety (Traveling Public Concerns)</p>	<p>This is a measure of the relative safety of the traveling public between conventional construction methods and accelerated construction methods. The reduced on-site construction time from using accelerated bridge construction methods reduces the exposure time of the traveling public in a construction zone, thus increasing safety. If a significant increase in safety can be seen by utilizing accelerated construction methods, provide a high score here. If utilizing accelerated construction methods does not provide additional safety, provide a low score here. Refer to the <i>Facilities Development Manual (FDM)</i> for definitions of TMP Types.</p>



Economy of Scale	This is a measure of how much repetition is used for elements on the project, which can help keep costs down. Repetition can be used on both substructure and superstructure elements. To measure the economy of scale, sum the total number of spans that will be constructed on the project. For example, if there are 2 bridges on the project that each have 2 spans, the total number of spans on the project is equal to 4. Use the notes in the table for scoring guidance here.
Weather Limitations for Conventional Construction?	This is a measure of the restrictions that the local weather causes for on-site construction progress. Accelerated bridge construction methods may allow a large portion of the construction to be done in a controlled facility, which helps reduce delays caused by inclement weather (rain, snow, etc.). Depending on the location and the season, faster construction progress could be obtained by minimizing the on-site construction time.
Use of Typical Standard Details (Complexity)	This is a measure of the efficiency that can be gained by using standard details that have already been developed and approved. If standard details are used, some errors in the field can be prevented. If new details are going to be created for a project, the contractors will be less familiar with the details and problems may arise during construction that were not considered in the design phase. Use the notes in the table for scoring guidance here.

Table 7.2-1
ABC Decision-Making Matrix Terms

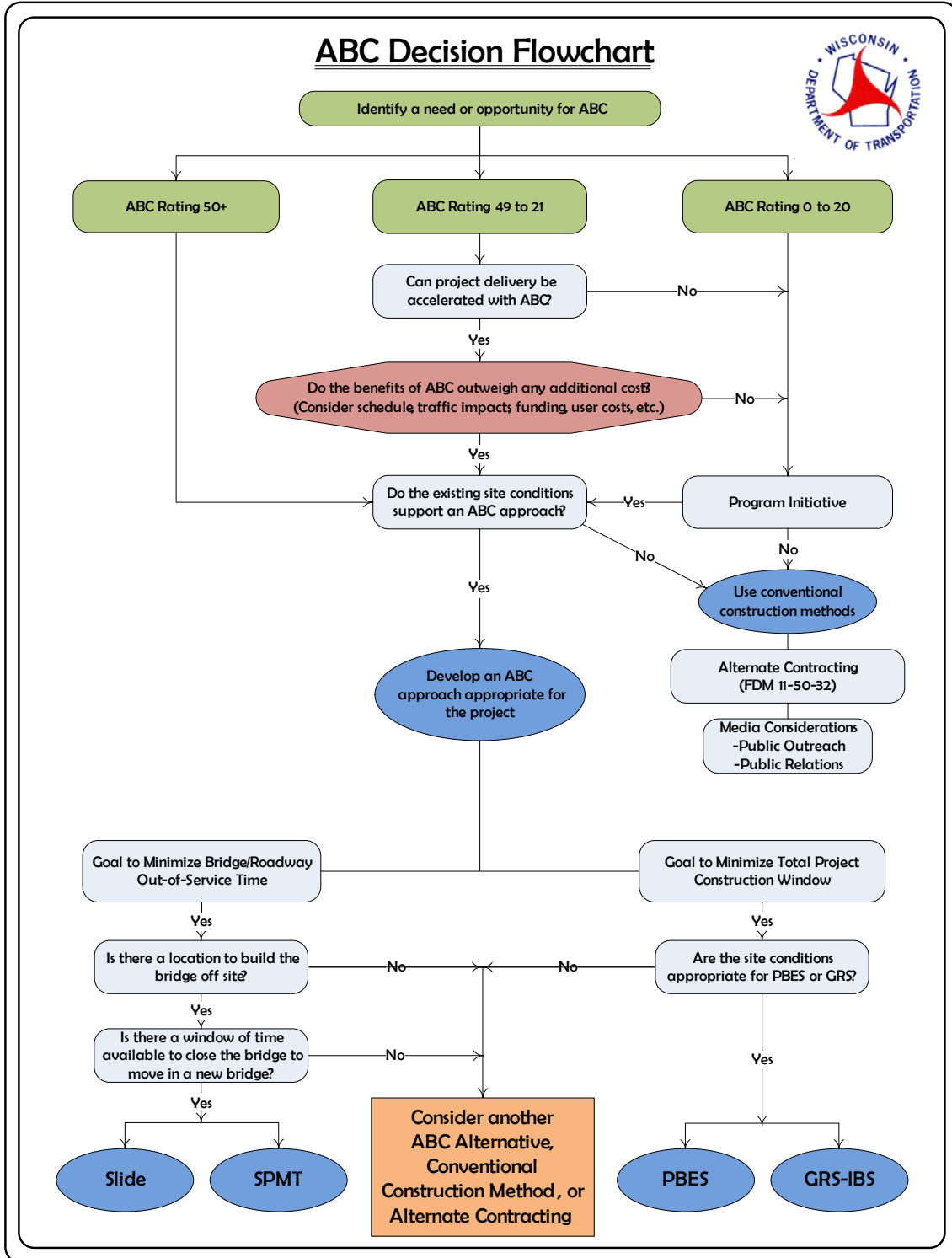


Figure 7.2-2
ABC Decision-Making Flowchart



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11.1 General

11.1.1 Overall Design Process

The overall foundation support design process requires an iterative collaboration to provide cost-effective constructible substructures. Input is required from multiple disciplines including, but not limited to, structural and geotechnical design. For a typical bridge design, the following four steps are required (see 6.2):

1. Structure Survey Report (SSR) – This design step results in a very preliminary evaluation of the structure type and approximate location of substructure units, including a preliminary layout plan.
2. Site Investigation Report – Based on the Structure Survey Report, a site investigation is required, including test borings to determine foundation requirements. A hydraulic analysis is also performed at this time, if required, to assess scour potential and maximum scour depth. The Site Investigation Report and Subsurface Exploration Drawing are used to identify known constraints that would affect the foundations in regard to type, location or size and includes foundation recommendations to support detailed structural design. Certain structure sites/types may require the preliminary structure plans (Step 3) prior to initiating the geotechnical site investigation. One example of this is a multi-span structure over water. See 6.2 for more information.
3. Preliminary Structure Plans – This design step involves preparation of a general plan, elevation, span arrangement, typical section and cost estimate for the new bridge structure. The Site Investigation Report is used to identify possible poor foundation conditions and may require modification of the structure geometry and span arrangement. This step may require additional geotechnical input, especially if substructure locations must be changed.
4. Final Contract Plans for Structures – This design step culminates in final plans, details, special provisions and cost estimates for construction. The Subsurface Exploration sheets are part of the Final Contract Plans. Unless design changes are required at this step, additional geotechnical input is not typically required to prepare foundation details for the Final Contract Plans.

11.1.2 Foundation Type Selection

The following items need to be assessed to select site-specific foundation types:

- Magnitude and direction of loading.
- Depth to suitable bearing material.
- Potential for liquefaction, undermining or scour.
- Frost potential.



- Performance requirements, including deformation (settlement), global stability and resistance to bearing, uplift, lateral, sliding and overturning forces.
- Ease and cost of construction.
- Environmental impact of construction.
- Site constraints, including restricted right-of-way, overhead and lateral clearance, construction access, utilities and vibration-sensitive structures.

Based on the items listed above, an assessment is made to determine if shallow or deep foundations are suitable to satisfy site-specific needs. A shallow foundation, as defined in this manual, is one in which the depth to the bottom of the footing is generally less than or equal to twice the smallest dimension of the footing. Shallow foundations generally consist of spread footings but may also include rafts that support multiple columns.

Shallow foundations are typically initially considered to determine if this type of foundation is technically and economically viable. Often foundation settlement and lateral loading constraints govern over bearing capacity. Other significant considerations for selection of shallow foundations include requirements for cofferdams, bottom seals, dewatering, temporary excavation support, overexcavation of unsuitable material, slope stability, available time to dissipate consolidation settlement prior to final construction, scour susceptibility, environmental impacts and water quality impacts. Shallow foundations may not be economically viable when footing excavations exceed 10 to 15 feet below the final ground surface elevation.

When shallow foundations are not satisfactory, deep foundations are considered. Deep foundations can transfer foundation loads through shallow deposits to underlying deposits of more competent deeper bearing material. Deep foundations are generally considered to mitigate concerns about scour, lateral spreading, excessive settlement and satisfy other site constraints.

Common types of deep foundations for bridges include driven piling, drilled shafts, micropiles and augercast piles. Driven piling is the most frequently-used type of deep foundation in Wisconsin. Drilled shafts may be advantageous where a very dense stratum must be penetrated to obtain required bearing, uplift or lateral resistance are concerns, or where obstructions may result in premature driving refusal or where piers need to be founded in areas of shallow bedrock and deep water. A drilled shaft may be more cost effective than driven piling when a monoshaft can be used to eliminate the need for a pile footing, pile casing or cofferdams.

Micropiles may be the best foundation alternatives where headroom is restricted or foundation retrofits are required at existing substructures.

Augercast piles are a potentially cost-effective foundation alternative, especially where lateral loads are minimal. However, restrictions on construction quality control including pile integrity and capacity need to be considered when augercast piles are being investigated.



11.1.3 Cofferdams

At stream crossings, tremie-sealed cofferdams are frequently used when footing concrete is required to be placed below the surrounding water level. The tremie-seal typically consists of a plain-cement concrete slab that is placed neat and underwater within a closed-sided cofferdam to aid in the removal of water from within the footing excavation for concrete placement in-the-dry. The tremie-seal serves as a counterweight to offset buoyancy, and it protects the footing subgrade against deterioration due to potential piping and bottom heave. Concrete for tremie-seals is permitted to be placed with a tremie pipe underwater (in-the-wet). Footing concrete is typically required to be placed in-the-dry. In the event that footing concrete must be placed in-the-wet, a special provision for underwater inspection of the footing subgrade is required.

When bedrock is exposed in the bottom of any excavation and prior to placement of tremie concrete, the bedrock surface must be cleaned and inspected to assure removal of loose debris. This will assure good contact between the bedrock and eliminate the potential consolidation of loose material as the footing is loaded.

Cofferdams need to be designed to determine the required sheetpile embedment to provide lateral support, control piping and prevent bottom heave. The construction sequence must be considered to provide adequate temporary support, especially when each row of ring struts is installed. Overexcavation may be required to remove unacceptable materials at the base of the footing. Piles may be required within cofferdams to achieve adequate nominal bearing resistance. WisDOT has experienced a limited number of problems achieving adequate penetration of displacement piles within cofferdams when sheetpiling is excessively deep in granular material. Cofferdams are designed by the Contractor.

Refer to 13.11.5 for further guidance to determine the required thickness of cofferdam seals and to determine when combined seals and footings are acceptable.

11.1.4 Vibration Concerns

Vibration damage is a concern during construction, especially during pile driving operations. The selection process for the type of pile and hammer must consider the presence of surrounding structures that may be damaged due to high vibration levels. Pile driving operations can cause ground displacement, soil densification and other factors that can damage nearby buildings, structures and/or utilities. Whenever pile-driving operations pose the potential for damage to adjacent facilities (usually when they are located within approximately 100 feet), a vibration-monitoring program should be implemented. This program consists of requiring and reviewing a pile-driving plan submittal, conducting pre-driving and post-driving condition surveys and conducting the actual vibration monitoring with an approved seismograph. A special provision for implementing a vibration monitoring program is available and should be used on projects whenever pile-driving operations pose a potential threat to nearby facilities. Contact the geotechnical engineer for further discussion and assistance if vibrations appear to be a concern.



drilled shaft may be cased or uncased, depending on the subsurface conditions and depth of bearing.

Drilled shafts have been used on only a small number of structures in Wisconsin. For unusual site conditions, the use of drilled shafts may be advantageous. Design methodologies for drilled shafts can be found in FHWA Publication IF-99-025, *Drilled Shafts: Construction Procedures and Design Methods*.

Strength limit states for drilled shafts are evaluated in the same way as for driven piles. Drivability is not required to be evaluated. The structural resistance of drilled shafts is evaluated in accordance with **LRFD [5.7 and 5.8]**. This includes evaluation of axial resistance, combined axial and flexure, shear and buckling. It is noted that the critical load case for combined axial and flexure may be a load case that results in the minimum axial load or tension.

11.3.2.2 Resistance Factors

Resistance factors for drilled shafts are presented in [Table 11.3-8](#) and are selected based on the method used to determine the nominal (ultimate) resistance capacity of the drilled shaft. The design intent is to adjust the resistance factor based on the reliability of the method used to determine the nominal shaft resistance. As with driven piles, the selection of a geotechnical resistance factor should be based on the intended method of resistance verification in the field. Because of the cost and difficulty associated with testing drilled shafts, much more reliance is placed on static analysis methods.



Condition/Resistance Determination Method				Resistance Factor
Static Analysis – Used in Design Phase	Nominal Resistance of Single-Drilled Shaft in Axial Compression, ϕ_{stat}	Shaft Resistance in Clay	Alpha Method	0.45
		Point Resistance in Clay	Total Stress	0.40
		Shaft Resistance in Sand	Beta Method	0.55
		Point Resistance in Sand	O'Neill and Reese	0.50
		Shaft Resistance in IGMs	O'Neill and Reese	0.60
		Point Resistance in IGMs	O'Neill and Reese	0.55
		Shaft Resistance in Rock	Horvath and Kenney O'Neill and Reese	0.55
			Carter and Kulhawy	0.50
	Point Resistance in Rock	Canadian Geotech. Soc. Pressuremeter Method O'Neill and Reese	0.50	
	Block Failure, ϕ_{bl}	Clay		0.55
	Uplift Resistance of Single-Drilled Shaft, ϕ_{up}	Clay	Alpha Method	0.35
		Sand	Beta Method	0.45
		Rock	Horvath and Kenney Carter and Kulhawy	0.40
	Group Uplift Resistance, ϕ_{ug}	Sand and Clay		0.45
	Horizontal Geotechnical Resistance of Single Shaft or Pile Group	All Soil Types and Rock		1.0

Table 11.3-8

Geotechnical Resistance Factors for Drilled Shafts LRFD [Table 10.5.5.2.4-1]

For drilled shafts, the base geotechnical resistance factors in Table 11.3-8 assume groups containing two to four shafts, which are slightly redundant. For groups containing at least five elements, the base geotechnical resistance factors in Table 11.3-8 should be increased by 20%.



WisDOT policy item:

When a bent contains at least 5 columns (where each column is supported on a single drilled shaft) the resistance factors in [Table 11.3-8](#) should be increased up to 20 percent for the Strength Limit State.

For piers supported on a single drilled shaft, the resistance factors in [Table 11.3-8](#) should be decreased by 20 percent for the Strength Limit State. Use of single drilled shaft piers requires approval from the Bureau of Structures.

Resistance factors for structural design of drilled shafts are obtained from **LRFD [5.5.4.2.1]**.

11.3.2.3 Bearing Resistance

Most drilled shafts provide geotechnical resistance in both end bearing and side friction. Because the rate at which side friction mobilizes is usually much higher than the rate at which end bearing mobilizes, past design practice has been to ignore either end bearing for shafts with significant sockets into the bearing stratum or to ignore skin friction for shafts that do not penetrate significantly into the bearing stratum. This makes evaluation of the geotechnical resistance slightly more complex, because in most cases it is not suitable to simply add the nominal (ultimate) end bearing resistance and the nominal side friction resistance in order to obtain the nominal axial geotechnical resistance.

When computing the nominal geotechnical resistance, consideration must be given to the anticipated construction technique and the level of construction control. If it is anticipated to be difficult to adequately clean out the bottom of the shafts due to the construction technique or subsurface conditions, the end bearing resistance may not be mobilized until very large deflections have occurred. Similarly, if construction techniques or subsurface conditions result in shaft walls that are very smooth or smeared with drill cuttings, side friction may be far less than anticipated.

Because these resistances mobilize at different rates, it may be more appropriate to add the ultimate end bearing to that portion of the side resistance remaining at the end of bearing failure. Or it may be more appropriate to add the ultimate side resistance to that portion of the end bearing mobilized at side resistance failure. Note that consideration of deflection, which is a service limit state, may control over the axial geotechnical resistance since displacements required to mobilize the ultimate end bearing can be excessive. More detailed discussion of design parameters is provided in Appendices C and D of FHWA Publication IF-99-025, *Drilled Shafts: Construction Procedures and Design Methods*.

11.3.2.3.1 Shaft Resistance

The shaft resistance is estimated by summing the friction developed in each stratum. When drilled shafts are socketed in rock, the shaft resistance that is developed in soil is generally ignored to satisfy strain compatibility. The following analysis methods are typically used to compute the static shaft resistance in soil and rock:

- Alpha method for cohesive soil, as specified in **LRFD [10.8.3.5.1]**



- Beta method (β -method) for cohesionless soil, as specified in **LRFD [10.8.3.5.2]**
- Horvath and Kenny method for rock, as specified in **LRFD [10.8.3.5.4]**

11.3.2.3.2 Point Resistance

The following analysis methods are typically used to compute the static shaft resistance in soil:

- Alpha method for cohesive soil, as specified in **LRFD [10.8.3.5.1]**
- Beta method (β -method) for cohesionless soil, as specified in **LRFD [10.8.3.5.2]**

The ultimate unit point resistance of a drilled shaft in intact or tightly jointed rock is computed as 2.5 times the unconfined compressive strength of the rock. For rock containing open or filled joints, the geomechanics RMR system is used to characterize the rock, and the ultimate point resistance in rock can be computed as specified in **LRFD [10.8.3.5.4c]**.

11.3.2.3.3 Group Capacity

For drilled shaft groups bearing in cohesive soils or ending in a strong layer overlying a weaker layer, the axial resistance is determined using the same approach as used for driven piles. For drilled shaft groups in cohesionless soil, a group efficiency factor is applied to the ultimate resistance of a single drilled shaft. The group efficiency factor is a function of the center-to-center shaft spacing and is linearly interpolated between a value of 0.65 at a center-to-center spacing of 2.5 shaft diameters and a value of 1.0 at a center-to-center spacing of 6.0 shaft diameters. This reduction is more than for driven piles at similar spacing, because construction of drilled shafts tends to loosen the soil between the shafts rather than densify it as with driven piles.

11.3.2.4 Lateral Load Resistance

Because drilled shafts are made of reinforced concrete, the lateral analysis should consider the nonlinear variation of bending stiffness with respect to applied bending moment. At small applied moments, the reinforced concrete section performs elastically based on the size of the section and the modulus of elasticity of the concrete. At larger moments, the concrete cracks in tension and the stiffness drops significantly.

11.3.2.5 Other Considerations

Detailing of the reinforcing steel in a drilled shaft must consider the constructability of the shaft. The reinforcing cages must be stiff enough to resist bending during handling and concrete placement. In addition, the spaces between reinforcement bars must be kept large enough to permit easy flow of the concrete from the center of shaft to the outside of shaft. These two requirements will generally force the use of larger, more widely spaced longitudinal and transverse reinforcement bars than would be used in the design of an above-grade column. In addition, when using hooked bars to tie the shaft to the foundation,



consideration must also be given to concrete placement requirements and temporary casing removal requirements.

11.3.3 Micropiles

11.3.3.1 General

In areas of restricted access, close proximity to settlement sensitive existing structures or difficult geology, micropiles may be considered when determining the recommended foundation type. Although typically more expensive than driven pile, constructability considerations may warrant selection of micropiles as the preferred foundation type. A micropile is constructed by drilling a borehole with drill casing, placing reinforcement and grouting the hole. Micropiles are installed by methods that cause minimal disturbance to adjacent structures, soil and the environment. They can be installed in areas with restricted access and vertical clearance. Drill casing permits installation in poor ground conditions. Micropiles are installed with the same type of equipment that is used for ground anchor and grouting projects. Micropiles can be either vertical or battered.

Micropiles are used for structural support of new structures, underpinning existing structures, scour protection and seismic retrofit at existing structures. Micropiles are also used to create a reinforced soil mass for ground stabilization.

With a micropile's smaller cross-sectional area, the pile design is more frequently governed by structural and stiffness considerations. Due to the small pile diameter, point resistance is usually disregarded for design. Steel casing for micropiles is commonly delivered in 5 to 20 foot long flush-joint threaded sections. The casing is typically 5.5 to 12 inches in diameter, with yield strength of 80 ksi. Grout is mixed neat with a water/cement ratio on the order of 0.45 and an unconfined compressive strength of 4 to 6 ksi. Grade 60, 90 and 150 single reinforcement bars are generally used with centralizers.

Grout/ground bond capacity varies directly with the method of placement and pressure used to place the grout. Common methods include grout placement under gravity head, grout placement under low pressure as temporary drill steel is removed and grout placement under high pressure using a packer and regrout tube. Some regrout tubes are equipped to allow regrouting multiple times to increase pile capacity.

11.3.3.2 Design Guidance

Micropiles shall be designed using an Allowable Stress Design approach until an LRFD approach has been developed and approved by the AASHTO Bridge Subcommittee. The design of micropiles shall be done in accordance with FHWA Publication SA-97-070, *Micropile Design and Construction Guidelines Implementation Manual*. When site-specific load tests are performed, the factor of safety can be reduced from 2.5 to 2.0 to determine the allowable axial compressive load capacity of the micropile. The reduction in factor of safety is consistent with the 2005 update to the FHWA guidelines for micropile design.



11.3.4 Augered Cast-In-Place Piles

11.3.4.1 General

Augered cast-in-place (ACIP) piles are installed by drilling a hole with a hollow stem auger. When the auger reaches a design depth (elevation) or given torque, sand-cement grout or concrete is pumped through the hollow-stem auger while the auger is withdrawn from the ground. Reinforcement steel can be placed while the grout is still fluid. A single reinforcement bar can also be installed inside the hollow stem auger before the auger is extracted. ACIP piles are installed by methods that cause minimal disturbance to adjacent structures, soil and the environment. They can also be installed in areas with restricted access and vertical clearance. Temporary casing is not required. In many situations, these foundation systems can be constructed more quickly and less expensively than other deep foundation alternatives.

ACIP piles are generally available in 12- to 36-inch diameters and typically extend to depths of 60 to 70 feet. In some cases, ACIP piles have been installed to depths of more than 100 feet. The torque capacity of the drilling equipment may limit the available penetration depth of ACIP piles, especially in stiff to hard cohesive soil. Typical Wisconsin bridge contractors do not own the necessary equipment to install this type of pile.

ACIP piles may be more economical; however, there is a greater inherent risk in their installation from the quality control standpoint. There is currently no method available to determine pile capacity during construction of ACIP piles. WisDOT does not generally use this pile type unless there are very unusual design/site requirements.

11.3.4.2 Design Guidance

In the future, the FHWA will distribute a Geotechnical Engineering Circular that will provide design and construction guidance for ACIP piles. WisDOT plans to reassess the use of ACIP piles at that time.



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In [Figure 13.7-3](#), the strut area is influenced by the stirrup spacing, s , as well as the diameter of the longitudinal tension steel, d_{ba} . In [Figure 13.7-4](#), the strut area is influenced by the bearing dimensions, L_b , in both directions, as well as the location of the center of gravity of the longitudinal tension steel, $0.5h_a$. In [Figure 13.7-5](#), the strut area is influenced by the bearing dimensions, L_b , in both directions, as well as the height of the compression strut, h_s . The value of h_s shall be taken as equal to “ a ” as shown in [Figure 13.7-2](#). The strut area in each of the three previous figures depends upon the angle of the strut with respect to the horizontal, θ_s .

If the initial strut width is inadequate to develop the required resistance, the engineer should increase the bearing block size.

13.7.6 Check the Tension Tie Anchorage

Tension ties shall be anchored to the nodal zones by either specified embedment length or hooks so that the tension force may be transferred to the nodal zone. As specified in **LRFD [5.6.3.4]**, the tie reinforcement shall be fully developed at the inner face of the nodal zone. In [Figure 13.7-4](#), this location is given by the edge of the bearing where θ_s is shown.

13.7.7 Provide Crack Control Reinforcement

Pier caps designed using the strut-and-tie method shall contain an orthogonal grid of reinforcing bars near each face in accordance with **LRFD [5.6.3.6]**. This reinforcement will control crack widths and ensure a minimum ductility. The ratio of reinforcement area to gross concrete area shall not be less than 0.003 in both directions. Maximum bar spacing shall not exceed 12”. The crack control steel, when located within the tension tie, may be considered as part of the tension tie reinforcement.



13.8 General Pier Cap Information

The minimum cap dimension to be used is 3' deep by 2'-6" wide, with the exception that a 2'-6" deep section may be used for caps under slab structures. If a larger cap is needed, use 6" increments to increase the size. The multi-column cap width shall be a minimum of 1 1/2" wider than the column on each side to facilitate construction forming. The pier cap length shall extend a minimum of 2' transversely beyond the centerline of bearing and centerline of girder intersection.

On continuous slab structures, the moment and shear forces are proportional between the transverse slab section and the cap by the ratio of their moments of inertia. The effective slab width assumed for the transverse beam is the minimum of 1/2 the center-to-center column spacing or 8.0'.

$$M_{cap} = M_{total} \frac{I_{cap}}{I_{cap} + I_{slab}}$$

Where:

- M_{cap} = Cap moment (kip-ft)
- M_{total} = Total moment (kip-ft)
- I_{cap} = Moment of inertia of pier cap (in⁴)
- I_{slab} = Moment of inertia of slab (in⁴)

The concrete slab is to extend beyond the edge of pier cap as shown on Standards for Continuous Haunched Slab and for Continuous Flat Slab. If the cap is rounded, measure from a line tangent to the pier cap end and parallel to the edge of the deck.

Reinforcement bars are placed straight in the pier cap. Determine bar cutoff points on wide caps. If the pier cap is cantilevered over exterior columns, the top negative bar steel may be bent down at the ends to ensure development of this primary reinforcement.

Do not place shear stirrups closer than 4" on centers. Generally only double stirrups are used, but triple stirrups may be used to increase the spacing. If these methods do not work, increase the cap size. Stirrups are generally not placed over the columns. The first stirrup is placed one-half of the stirrup spacing from the edge of the column into the span.

The cap-to-column connection is made by extending the column reinforcement straight into the cap the necessary development length. Stirrup details and bar details at the end of the cap are shown on Standard for Multi-Columned Pier.



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14.4.7.2 Wall Settlement

Retaining walls shall be designed for the effects of total and differential foundation settlement at the Service I limit state, in accordance with **LRFD [11.5.2]** and 11.2. Maximum tolerable retaining wall total and differential foundation settlements are controlled largely by the potential for cosmetic and/or structural damage to facing elements, copings, barrier, guardrail, signs, pavements, utilities, structure foundations, and other highway appurtenances supported on or near the retaining wall.

14.4.7.2.1 Settlement Guidelines

The following table provides guidance for maximum tolerable vertical and total differential Settlement for various retaining wall types where Δh is the total settlement in inches and

Wall Type	Total Settlement Δh in inches	Total Differential Settlement $\Delta h1:L$ (in/in)
CIP semi-gravity cantilever walls	1-2	1:500
MSE walls with large pre-cast panel facing (panel front face area $>30ft^2$)	1-2	1:500
MSE walls with small pre-cast panel facing (panel front face area $<30ft^2$)	1-2	1:300
MSE walls with full-height cast-in-panel facing	1-2	1:500
MSE walls with dry cast concrete block facing	2-4	1:200
MSE walls with geo-textile /welded-wire facing	4-8	1:50-1:60
Concrete block gravity retaining walls (wet or dry cast)	1-2	1:300
Concrete Crib walls	1-2	1:500
Bin walls	2-4	1:200
Gabion walls	4-6	1:50
Non-gravity cantilever and anchored walls	1-2.5	----

Table 14.4-3
Maximum Tolerable Settlement Guidelines for Retaining Walls



$\Delta h1:L$ is the ratio of the difference in total vertical settlement between two points along the wall base to the horizontal distance between the two points(L). It should be noted that the tolerance provided in [Table 14.4-3](#) are for guidance purposes only. More stringent tolerances may be required to meet project-specific requirements.

14.4.7.3 Overall Stability

Overall stability of the walls shall be checked at the Service I limit state using appropriate load combinations and resistance factors in accordance with **LRFD [11.6.2.3]**. The stability is evaluated using limit state equilibrium methods. The Modified Bishop, Janbu or Spencer method may be used for the analysis. The analyses shall investigate all potential internal, compound and overall shear failure surfaces that penetrate the wall, wall face, bench, back-cut, backfill, and/or foundation zone. The overall stability check is performed by the Geotechnical Engineering Unit for WISDOT designed walls.

14.4.7.4 Internal Stability

Internal stability checks including anchor pullout or soil reinforcement failure and/or structural failure checks are also required as applicable for different wall systems. As an example, see [Figure 14.4-11](#) for internal stability failure of MSE walls. Internal stability checks must be performed at Strength Limits in accordance with **LRFD [11.5.3]**.

14.4.7.5 Wall Embedment

The minimum wall footing embedment shall be 1.5 ft below the lowest adjacent grade in front of the wall.

The embedment depth of most wall footings should be established below the depths the foundation soil/rock could be weakened due to the effect of freeze thaw, shrink-swell, scour, scour, erosion, erosion, construction excavation. The potential scour elevation shall be established in accordance with 11.2.2.1.1 of the Bridge Manual.

The final footing embedment depth shall be based on the required geotechnical bearing resistance, wall settlement limitations, and all internal, external, and overall (global) wall stability requirements in *AASHTO LRFD* and the *Bridge Manual*.

14.4.7.6 Wall Subsurface Drainage

Retaining wall drainage is necessary to prevent hydrostatic pressure and frost pressure. Inadequate wall sub-drainage can cause premature deterioration, reduced stability and collapse or failure of a retaining wall.

A properly designed wall sub-drainage system is required to control potentially damaging hydrostatic pressures and seepage forces behind and around a wall. A redundancy in the sub-drainage system is required where subsurface drainage is critical for maintaining retaining wall stability. This is accomplished using a pervious granular fill behind the wall.



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ends where the dead load moment approaches zero and is not able to counter the tensile stress at the top of the beam induced by the prestress force. When the calculated tensile stress exceeds the stress limits, the strand pattern must be modified by draping or partially debonding the strand configuration.

- Verify that the Service I compressive stress due to beam self-weight and prestress applied to the basic beam at transfer does not exceed $0.60 f'_{ci}$, as presented in **LRFD [5.9.4.1.1]**. This will generally control at the bottom of the beam near the beam ends or at the hold-down point if using draped strands.
- Verify that the Service III tensile stress due to all dead and live loads applied to the appropriate sections after losses does not exceed the limits presented in **LRFD [Table 5.9.4.2.2-1]**. No tensile stress shall be permitted for unbonded strands. The tensile stress of bonded strands shall not exceed $0.19\sqrt{f'_c}$ as all strands shall be considered to be in moderate corrosive conditions. This will generally control at the bottom of the beam near midspan and at the top of the continuous end of the beam.
- Verify that the Service I compressive stress due to all dead and live loads applied to the appropriate sections after losses does not exceed the limits presented in **LRFD [Table 5.9.4.2.1-1]**. Two checks need to be made for girder bridges. The compressive stress due to the sum of effective prestress and permanent loads shall not exceed $0.45 f'_c$ (ksi). The compressive stress due to the sum of effective prestress, permanent loads and transient loads shall not exceed $0.60\phi_w f'_c$ (ksi). The term ϕ_w , a reduction factor applied to thin-walled box girders, shall be 1.0 for WisDOT standard girders.
- Verify that Fatigue I compressive stress due to fatigue live load and one-half the sum of effective prestress and permanent loads does not exceed $0.40 f'_c$ (ksi) **LRFD [5.5.3.1]**.
- Verify that the Service I compressive stress at the top of the deck due to all dead and live loads applied to the appropriate sections after losses does not exceed $0.40 f'_c$.

WisDOT policy item:

The top of the prestressed girders at interior supports shall be designed as reinforced concrete members at the strength limit state in accordance with **LRFD [5.14.1.4.6]**. In this case, the stress limits for the service limit state shall not apply to this region of the precast girder.

19.3.3.12 Raised, Draped or Partially Debonded Strands

When straight strands are bonded for the full length of a prestressed girder, the tensile and compressive stresses near the ends of the girder will likely exceed the allowable service limit state stresses. This occurs because the strand pattern is designed for stresses at or near midspan, where the dead load moment is highest and best able to balance the effects of the prestress. Near the ends of the girder this dead load moment approaches zero and is less able to balance the prestress force. This results in tensile stresses in the top of the girder and compressive stresses in the bottom of the girder. The allowable initial tensile and



compressive stresses are presented in the first two bullet points of [19.3.3.11](#). These stresses are a function of f'_{ci} , the compressive strength of concrete at the time of prestress force transfer. Transfer and development lengths should be considered when checking stresses near the ends of the girder.

The designer should start with a straight (raised), fully bonded strand pattern. If this overstresses the girder near the ends, the following methods shall be utilized to bring the girder within the allowable stresses. These methods are listed in order of preference and discussed in the following sections:

1. Use raised strand pattern (If excessive top flange reinforcement or if four or more additional strands versus a draped strand pattern are required, consider the draped strand alternative)
2. Use draped strand pattern
3. Use partially debonded strand pattern (to be used sparingly)

Only show one strand pattern per span (i.e. Do not show both raised and draped span alternatives for a given span).

A different girder spacing may need to be selected. It is often more economical to add an extra girder line than to maximize the number of strands and use debonding.

19.3.3.12.1 Raised Strand Patterns

Some of the standard strand patterns listed in the Standard Details show a raised strand pattern. Generally strands are placed so that the center of gravity of the strand pattern is as close as possible to the bottom of the girder. With a raised strand pattern, the center of gravity of the strand pattern is raised slightly and is a constant distance from the bottom of the girder for its entire length. Present practice is to show a standard raised arrangement as a preferred alternate to draping for short spans. For longer spans, debonding at the ends of the strands is an alternate (see [19.3.3.12.3](#)). Use 0.6" strands for all raised patterns.

19.3.3.12.2 Draped Strand Patterns

Draping some of the strands is another available method to decrease stresses from prestress at the ends of the I-beam where the stress due to applied loads are minimum.

The typical strand profile for this technique is shown in [Figure 19.3-1](#).



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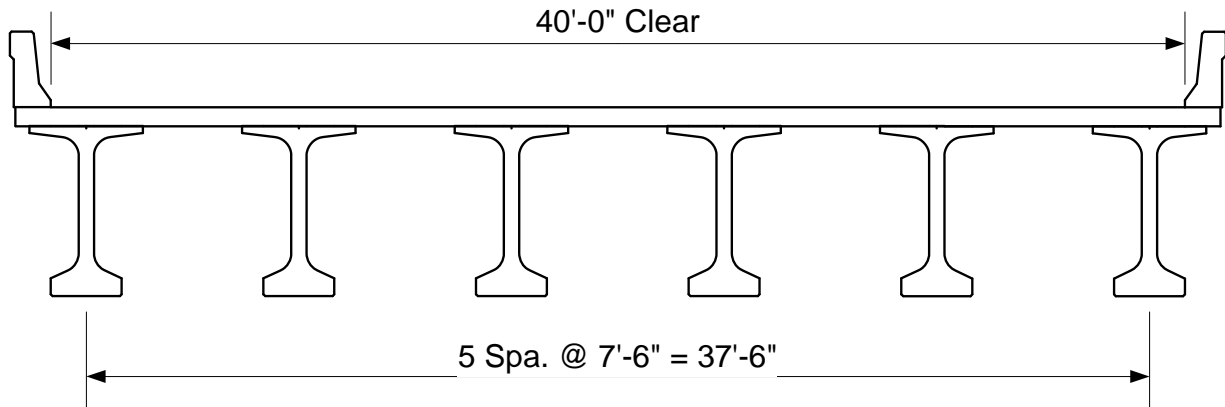
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E19-1 Single Span Bridge, 72W" Prestressed Girders - LRFD

This example shows design calculations for a single span prestressed girder bridge. The AASHTO LRFD Bridge Design Specifications are followed as stated in the text of this chapter. (Example is current through LRFD Sixth Edition - 2012)

E19-1.1 Design Criteria



L := 146	center to center of bearing, ft
L _g := 147	total length of the girder (the girder extends 6 inches past the center of bearing at each abutment).
w _b := 42.5	out to out width of deck, ft
w := 40	clear width of deck, 2 lane road, 3 design lanes, ft
f' _c := 8	girder concrete strength, ksi
f' _{ci} := 6.8	girder initial concrete strength, ksi New limit for release strength.
f' _{cd} := 4	deck concrete strength, ksi
f _{pu} := 270	low relaxation strand, ksi
d _b := 0.6	strand diameter, inches
A _s := 0.217	area of strand, in ²
w _p := 0.387	weight of Wisconsin Type LF parapet, klf
t _s := 8	slab thickness, in
t _{se} := 7.5	effective slab thickness, in
skew := 20	skew angle, degrees
E _s := 28500	ksi, Modulus of Elasticity of the Prestressing Strands
w _c := 0.150	kcf



Check at the girder and deck at midspan:

$e_s = -30.52$ inches

Initial condition at transfer: $f_{ti\text{all}} = -0.200$ ksi $f_{ci\text{all}} = 4.080$ ksi

Top of girder stress (Service 3):

$f_{ti} := \frac{T_o}{A_g} + \frac{T_o \cdot e_s}{S_t} + \frac{M_g \cdot 12}{S_t}$ $f_{ti} = 0.582$ ksi

Is f_{ti} greater than $f_{ti\text{all}}$? check = "OK"

Bottom of girder stress (Service 1):

$f_{bi} := \frac{T_o}{A_g} + \frac{T_o \cdot e_s}{S_b} + \frac{M_g \cdot 12}{S_b}$ $f_{bi} = 3.353$ ksi w

Is f_{bi} less than $f_{ci\text{all}}$? check = "OK"

Final condition:

Allowable Stresses, LRFD [5.9.4.2]:

| There are two compressive stress limits:

$f_{\text{call}1} := 0.45 \cdot f'_c$ PS + DL $f_{\text{call}1} = 3.600$ ksi

|

$f_{\text{call}2} := 0.60 \cdot f'_c$ LL + PS + DL $f_{\text{call}2} = 4.800$ ksi

Allowable Stresses (Fatigue), LRFD [5.5.3]:

Fatigue compressive stress limit:

$f_{\text{call_fat}} := 0.40 \cdot f'_c$ LLfat + 1/2(PS + DL) $f_{\text{call_fat}} = 3.200$ ksi

tension: $f_{\text{tall}} := -0.19 \cdot \sqrt{f'_c}$ $f_{\text{tall}} = -0.537$ ksi



Top of girder stress (Service 1):

$$f_{t1} := \frac{T}{A_g} + \frac{T \cdot e_s}{S_t} + \frac{M_{DLnc} \cdot 12}{S_t} + \frac{(M_{DLc} + M_{DWc}) \cdot 12}{S_{cgt}} \quad \boxed{f_{t1} = 2.465} \text{ ksi}$$

$$f_{t2} := \frac{T}{A_g} + \frac{T \cdot e_s}{S_t} + \frac{M_{DLnc} \cdot 12}{S_t} + \frac{(M_{DLc} + M_{DWc} + M_{LL}) \cdot 12}{S_{cgt}} \quad \boxed{f_{t2} = 3.177} \text{ ksi}$$

Is f_t less than f_{call} ? $\boxed{\text{check1} = \text{"OK"}}$

$\boxed{\text{check2} = \text{"OK"}}$

Top of girder stress (Fatigue 1):

$$f_{tfat} := \frac{1}{2} \left(\frac{T}{A_g} + \frac{T \cdot e_s}{S_t} + \frac{M_{DLnc} \cdot 12}{S_t} \right) + \frac{\left[\frac{1}{2} (M_{DLc} + M_{DWc}) + M_{LLfat} \right] \cdot 12}{S_{cgt}} \quad \boxed{f_{tfat} = 1.434} \text{ ksi}$$

Is f_{fat} less than f_{call_fat} ? $\boxed{\text{check} = \text{"OK"}}$

Bottom of girder stress (Service 3):

$$f_b := \frac{T}{A_g} + \frac{T \cdot e_s}{S_b} + \frac{M_{nc} \cdot 12}{S_b} + \frac{(M_{s3} - M_{nc}) \cdot 12}{S_{cgb}} \quad \boxed{f_b = -0.302} \text{ ksi}$$

Is f_{tb} greater than f_{tall} ? $\boxed{\text{check} = \text{"OK"}}$

Top of deck stress (Service 1):

$$f_{dall} := 0.40 \cdot f'_{cd} \quad \boxed{f_{dall} = 1.600} \text{ ksi}$$



$$f_{dt} := \frac{(M_{s1} - M_{nc}) \cdot 12}{S_{cugd}}$$

$f_{dt} = 0.800$ ksi

Is f_{dt} less than f_{dall} ?

check = "OK"

Bottom of deck stress (Service 1):

$$f_{db} := \frac{(M_{s1} - M_{nc}) \cdot 12}{S_{cgdb}}$$

$f_{db} = 0.617$ ksi

Is f_{db} less than f_{dall} ?

check = "OK"

Check at hold-down location:

At transfer:

$f_{tiall} = -0.200$ ksi

$f_{ciall} = 4.080$ ksi

Top of girder stress (Service 3):

$$f_{t3i} := \frac{T_o}{A_g} + \frac{T_o \cdot e_s}{S_t} + \frac{M_{ghd} \cdot 12}{S_t}$$

$f_{t3i} = 0.388$ ksi

Is f_{t3i} greater than f_{tiall} ?

check = "OK"

Bottom of girder stress (Service 1):

$$f_{b3i} := \frac{T_o}{A_g} + \frac{T_o \cdot e_s}{S_b} + \frac{M_{ghd} \cdot 12}{S_b}$$

$f_{b3i} = 3.535$ ksi

Is f_{b3i} less than f_{ciall} ?

check = "OK"

Final condition, after 50 years, full load:

$f_{tall} = -0.537$ ksi

$f_{call2} = 4.800$ ksi

Top of girder stress (Service 1):

$$f_{t3} := \frac{T}{A_g} + \frac{T \cdot e_s}{S_t} + \frac{M_{nchd} \cdot 12}{S_t} + \frac{M_{1chd} \cdot 12}{S_{cgt}}$$

$f_{t3} = 2.710$ ksi

Is f_{t3} less than f_{call2} ?

check = "OK"



Top of girder stress (Fatigue 1):

$$f_{tfat} := \frac{1}{2} \cdot \left(\frac{T}{A_g} + \frac{T \cdot e_s}{S_t} + \frac{M_{nchd} \cdot 12}{S_t} \right) + \frac{M_{fatchd} \cdot 12}{S_{cgt}}$$

$f_{tfat} = 1.317$ ksi

Is f_{tfat} less than f_{call_fat} ?

check = "OK"

Bottom of girder stress (Service 3):

$$f_{b3} := \frac{T}{A_g} + \frac{T \cdot e_s}{S_b} + \frac{M_{nchd} \cdot 12}{S_b} + \frac{M_{3chd} \cdot 12}{S_{cgb}}$$

$f_{b3} = 0.212$ ksi

Is f_{b3} greater than f_{tall} ?

check = "OK"

Top of deck stress (Service 1):

$$f_{dt3} := \frac{(M_{1chd}) \cdot 12}{S_{cgmt}}$$

$f_{dall} = 1.600$ ksi

$f_{dt3} = 0.715$ ksi

Is f_{dt} less than f_{dall} ?

check = "OK"

Bottom of deck stress (Service 1):

$$f_{db3} := \frac{(M_{1chd}) \cdot 12}{S_{cgdb}}$$

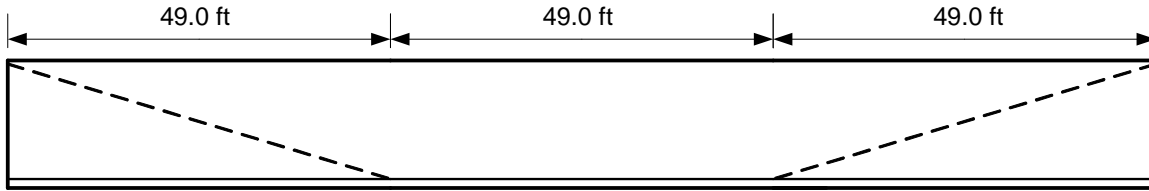
$f_{db3} = 0.551$ ksi

Is f_{db} less than f_{dall} ?

check = "OK"



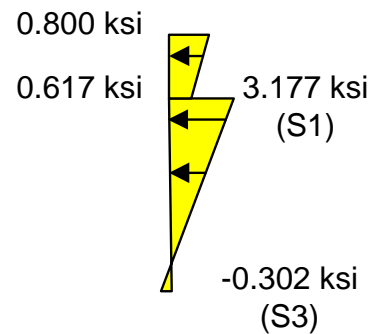
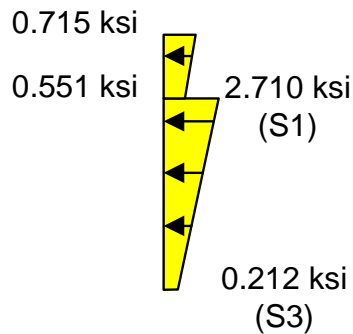
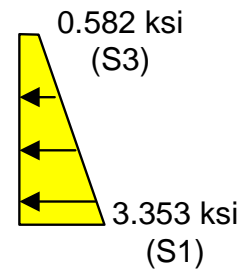
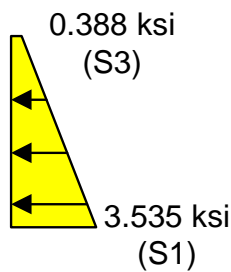
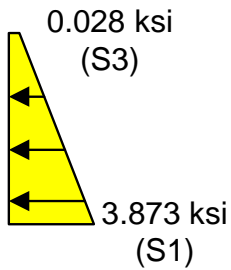
Summary of Design Stresses:



End

Hold Down

Mid Span



Initial Allowable:

compression := $f_{ci\text{all}}$ = 4.080 ksi

Final Allowable:

compression₁ := $f_{\text{call}1}$ = 3.60 ksi

compression₂ := $f_{\text{call}2}$ = 4.80 ksi

compression_fatigue := $f_{\text{call_fat}}$ = 3.20 ksi

tension = f_{tall} = -0.537 ksi

All stresses are acceptable!

E19-1.11 Calculate Jacking Stress

The fabricator is responsible for calculation of the jacking force. See **LRFD [5.9.3]** for equations for low relaxation strands.



E19-1.12 Flexural Strength Capacity at Midspan

Check f_{pe} in accordance with LRFD [5.7.3.1.1]:

$$f_{pe} = 160 \text{ ksi} \qquad 0.5 \cdot f_{pu} = 135 \text{ ksi}$$

Is $0.5 \cdot f_{pu}$ less than f_{pe} ?

check = "OK"

Then at failure, we can assume that the tendon stress is:

$$f_{ps} = f_{pu} \left(1 - k \cdot \frac{c}{d_p} \right)$$

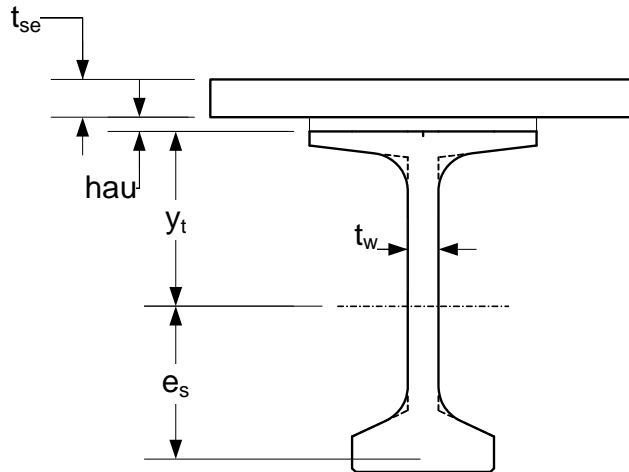
where:

$$k = 2 \left(1.04 - \frac{f_{py}}{f_{pu}} \right)$$

From LRFD Table [C5.7.3.1.1-1], for low relaxation strands, $k := 0.28$.

"c" is defined as the distance between the neutral axis and the compression face (inches).

Assumed dimensions:



Assume that the compression block is in the deck. Calculate the capacity as if it is a rectangular section (with the compression block in the flange). The neutral axis location, calculated in accordance with LRFD 5.7.3.1.1 for a rectangular section, is:

$$c = \frac{A_{ps} \cdot f_{pu}}{0.85 \cdot f'_{cd} \cdot \beta_1 \cdot b + k \cdot A_{ps} \cdot \frac{f_{pu}}{d_p}}$$



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E19-3 Box Section Beam

This example shows design calculations for a single span prestressed box multi-beam bridge having a 2" concrete overlay and is designed for a 20 pound per square foot future wearing surface. The *AASHTO LRFD Bridge Design Specifications* are followed as stated in the text of this chapter. **(Example is current through LRFD Sixth Edition - 2012)**

E19-3.1 Preliminary Structure Data

Design Data

A-1 Abutments at both ends

Skew: 0 degrees

Live Load: HL-93

Roadway Width: 28 ft. minimum clear

$L := 44$	Span Length, single span, ft
$L_g := 44.5$	Girder Length, the girder extends 3" past the CL bearing at each abutment, single span, ft
$N_L := 2$	Number of design lanes
$t_{overlay} := 2$	Minimum overlay thickness, inches
$f_{pu} := 270$	Ultimate tensile strength for low relaxation strands, ksi
$d_s := 0.5$	Strand diameter, inches
$A_s := 0.1531$	Area of prestressing strands, in ²
$E_s := 28500$	Modulus of elasticity of the prestressing strands, ksi
$f'_c := 5$	Concrete strength (prestressed box girder), ksi
$f'_{ci} := 4.25$	Concrete strength at release, ksi
$K_1 := 1.0$	Aggregate correction factor
$w_c := 0.150$	Unit weight of concrete for box girder, overlay, and grout, kcf
$f_y := 60$	Bar steel reinforcement, Grade 60, ksi.
$w_{rail} := 0.075$	Weight of Type "M" rail, klf
$W_{h_{rail}} := 0.42$	Width of horizontal members of Type "M" rail, feet
$\mu := 0.20$	Poisson's ratio for concrete, LRFD [5.4.2.5]

Based on past experience, the modulus of elasticity for the precast concrete are given in Chapter 19 as $E_{beam6} := 5500$ ksi for a concrete strength of 6 ksi. The values of E for different concrete strengths are calculated as follows:



E19-3.7 Load Factors

From LRFD [Table 3.4.11]:

	DC	DW	LL
Strength 1	$\gamma_{stDC} := 1.25$	$\gamma_{stDW} := 1.50$	$\gamma_{stLL} := 1.75$
Service 1	$\gamma_{s1DC} := 1.0$	$\gamma_{s1DW} := 1.0$	$\gamma_{s1LL} := 1.0$
Service 3	$\gamma_{s3DC} := 1.0$	$\gamma_{s3DW} := 1.0$	$\gamma_{s3LL} := 0.8$
Fatigue 1			$\gamma_{fLL} := 1.5$

E19-3.8 Factored Moments

WisDOT's policy is to set all of the load modifiers, η , equal to 1.0. The factored moments for each limit state are calculated by applying the appropriate load factor to the girder moments. For the exterior girder:

Strength 1

$$M_{str} := \eta \cdot (\gamma_{stDC} \cdot M_{DC} + \gamma_{stDW} \cdot M_{DW} + \gamma_{stLL} \cdot M_{LL})$$

$$= 1.0 \cdot (1.25 \cdot M_{DC} + 1.50 \cdot M_{DW} + 1.75 \cdot M_{LL}) \quad \boxed{M_{str} = 862} \quad \text{kip-ft}$$

Service 1 (for compression checks)

$$M_{s1} := \eta \cdot (\gamma_{s1DC} \cdot M_{DC} + \gamma_{s1DW} \cdot M_{DW} + \gamma_{s1LL} \cdot M_{LL})$$

$$= 1.0 \cdot (1.0 \cdot M_{DC} + 1.0 \cdot M_{DW} + 1.0 \cdot M_{LL}) \quad \boxed{M_{s1} = 554} \quad \text{kip-ft}$$

Service 3 (for tension checks)

$$M_{s3} := \eta \cdot (\gamma_{s3DC} \cdot M_{DC} + \gamma_{s3DW} \cdot M_{DW} + \gamma_{s3LL} \cdot M_{LL})$$

$$= 1.0 \cdot (1.0 \cdot M_{DC} + 1.0 \cdot M_{DW} + 0.8 \cdot M_{LL}) \quad \boxed{M_{s3} = 488} \quad \text{kip-ft}$$

Fatigue 1 (for compression checks)

$$M_{f1} := \eta \cdot \left[\frac{1}{2} \cdot (M_{DC} + M_{DW}) + \gamma_{fLL} \cdot M_{LLf} \right]$$

$$= 1.0 \cdot \left[\frac{1}{2} \cdot (M_{DC} + M_{DW}) + 1.5 \cdot M_{LLf} \right] \quad \boxed{M_{f1} = 330} \quad \text{kip-ft}$$



The transfer length may be taken as:

$$l_{tr} := 60 \cdot d_s \quad \boxed{l_{tr} = 30.00} \text{ in}$$

$$x := \frac{l_{tr}}{12} \quad \boxed{x = 2.50} \text{ feet}$$

The moment at the end of the transfer length due to the girder dead load:

$$M_{gt} := \frac{w_{g_ext}}{2} \cdot (L_g \cdot x - x^2) + \left(\frac{w_{diaph} \cdot x}{2} + w_{diaph_end} \cdot x \right)$$

$$\boxed{M_{gt} = 38} \text{ kip-ft}$$

The girder stresses at the end of the transfer length:

$$f_{tt} := \frac{T_o}{A} + \frac{T_o \cdot e_s}{S_t} + \frac{M_{gt} \cdot 12}{S_t}$$

$$\boxed{f_{tt} = -0.303} \text{ ksi}$$

$$\boxed{f_{tiall} = -0.195} \text{ ksi}$$

$$\boxed{\text{check} = \text{"NG"}}$$

If bonded reinforcement is provided in the top flange, the allowable stress is:

$$f_{tiall_bond} = -0.495 \text{ ksi}$$

$$\text{Is } f_{tt} \text{ less than } f_{tiall_bond} ? \quad \boxed{\text{check} = \text{"OK"}}$$

$$f_{bt} := \frac{T_o}{A} + \frac{T_o \cdot e_s}{S_b} + \frac{M_{gt} \cdot 12}{S_b}$$

$$\boxed{f_{bt} = 1.896} \text{ ksi}$$

$$\boxed{f_{ciall} = 2.55} \text{ ksi}$$

$$\text{Is } f_{bt} \text{ less than } f_{ciall} ? \quad \boxed{\text{check} = \text{"OK"}}$$

Check final stresses after all losses at the mid-span of the girder:

Top of girder stress (Compression - Service 1):

$$f_{t1} := \frac{T}{A} + \frac{T \cdot e_s}{S_t} + \frac{(M_{DC} + M_{DW}) \cdot 12}{S_t} \quad \text{PS + DL} \quad \boxed{f_{t1} = 0.459} \text{ ksi}$$

$$\boxed{\text{check} = \text{"OK"}}$$



|

$$f_{t2} := \frac{T}{A} + \frac{T \cdot e_s}{S_t} + \frac{M_{S1} \cdot 12}{S_t} \quad \text{LL + PS + DL} \quad \boxed{f_{t2} = 1.719} \quad \text{ksi}$$

check = "OK"

Bottom of girder stress (Compression - Service 1):

$$f_{b1} := \frac{T}{A} + \frac{T \cdot e_s}{S_b} + \frac{(M_{DC} + M_{DW}) \cdot 12}{S_b} \quad \text{PS + DL} \quad \boxed{f_{b1} = 0.958} \quad \text{ksi}$$

check = "OK"

Bottom of girder stress (Tension - Service 3):

$$f_b := \frac{T}{A} + \frac{T \cdot e_s}{S_b} + \frac{M_{S3} \cdot 12}{S_b} \quad \boxed{f_b = -0.051} \quad \text{ksi}$$

check = "OK"

Top of girder stress (Compression - Fatigue 1):

$$f_{tf1} := \frac{1}{2} \cdot \left[\frac{T}{A} + \frac{T \cdot e_s}{S_t} + \frac{(M_{DC} + M_{DW}) \cdot 12}{S_t} \right] + \frac{M_{LLf} \cdot 12}{S_t} \quad \text{1/2(PS + DL) + LLf}$$

f_{tf1} = 0.459 ksi

check = "OK"

allowable stress (tension) f_{tall} = -0.425 ksi

allowable stress (compression) f_{call1} = 2.250 ksi

|

f_{call2} = 3.000 ksi

f_{call_f} = 2.000 ksi



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27.1 General

Bridges supported in the conventional way by abutments and piers require bearings to transfer girder reactions without overstressing the supports, ensuring that the bridge functions as intended. Bridges usually require bearings that are more elaborate than those required for building columns, girders and trusses. Bridge bearings require greater consideration in minimizing forces caused by temperature change, friction and restraint against elastic deformations. A more detailed analysis in bridge bearing design considers the following:

- Bridges are usually supported by reinforced concrete substructure units, and the magnitude of the horizontal thrust determines the size of the substructure units. The coefficient of friction on bridge bearings should be as low as possible.
- Bridge bearings must be capable of withstanding and transferring dynamic forces and the resulting vibrations without causing eventual wear and destruction of the substructure units.
- Most bridges are exposed to the elements of nature. Bridge bearings are subjected to more frequent and greater total expansion and contraction movement due to changes in temperature than those required by buildings. Since bridge bearings are exposed to the weather, they are designed as maintenance-free as possible.

WisDOT policy item:

WisDOT uses an installation temperature of 60°F for designing bearings. The temperature range considered for prestressed concrete girder superstructures is 5°F to 85°F, resulting in a range of $60^\circ - 5^\circ = 55^\circ$ for bearing design. For prestressed girders an additional shrinkage factor of 0.0003 ft/ft should also be accounted for. The temperature range considered for steel girder superstructures is -30°F to 120°F, resulting in a range of $60^\circ - (-30^\circ) = 90^\circ$ for bearing design.

WisDOT policy item:

According to **LRFD [14.4.1]**, the influence of dynamic load allowance need not be included for bearings. However, dynamic load allowance shall be included when designing bearings for bridges in Wisconsin. Apply dynamic load allowance in **LRFD [3.6.2]** to HL-93 live loads as stated in **LRFD [3.6.1.2, 3.6.1.3]** and distribute these loads, along with dead loads, to the bearings.



ΔF_{TH} = Constant amplitude fatigue threshold for Category A as specified in LRFD [6.6] (ksi)

If holes exist in the reinforcement, the minimum thickness shall be increased by a factor equal to twice the gross width divided by the net width.

WisDOT exception to AASHTO:

Lateral rotation about the longitudinal axis of the bearing shall not be considered for straight girders.

WisDOT policy item:

Per LRFD [14.8.2], a tapered plate shall be used if the inclination of the underside of the girder to the horizontal exceeds 0.01 radians. Additionally, if the rotation multiplied by the plate length is 1/8 inch or more, taper the plate.

For several years, plain elastomeric bearing pads have performed well on prestressed concrete girder structures. Refer to the Standard for Bearing Pad Details for Prestressed Concrete Girders for details. Prestressed concrete girders using this detail are fixed into the concrete diaphragms at the supports, and the girders are set on 1/2" thick plain elastomeric bearing pads. Laminated (steel reinforced) bearing details and steel plate and elastomer thicknesses are given on the Standard for Elastomeric Bearings for Prestressed Concrete Girders.

27.2.2 Steel Bearings

For fixed bearings, a rocker plate attached to the girder is set on a masonry plate which transfers the girder reaction to the substructure unit. The masonry plate is attached to the substructure unit with anchor bolts. Pintles set into the masonry plate prevent the rocker from sliding off the masonry plate while allowing rotation to occur. This bearing is represented on the Standard for Fixed Bearing Details Type "A" - Steel Girders.

For expansion bearings, two additional plates are utilized, a stainless steel top plate and a Teflon plate allowing expansion and contraction to occur, but not in the transverse direction. This bearing is shown on the Standard for Stainless Steel - TFE Expansion Bearing Details Type "A-T".

Type "B" rocker bearings have been used for reactions greater than 400 kips and having a requirement for smaller longitudinal forces on the substructure unit. However, in the future, WisDOT plans to eliminate rocker bearings for new bridges and utilize pot bearings.

Pot and disc bearings are commonly used for moderate to large bridges. They are generally used for applications requiring a multi-directional rotational capacity and a medium to large range of load.

Hold down devices are additional details added to the Type "A-T" bearings for situations where live load can cause uplift at the abutment end of a girder. Ideally, proper span



configurations would eliminate the need for hold down devices as they have proven to be a maintenance problem.

Since strength is not the governing criteria, anchor bolts are designed with Grade 36 steel for all steel bearings.

27.2.2.1 Type "A" Fixed Bearings

Type "A" Fixed Bearings prevent translation both transversely and longitudinally while allowing rotation in the longitudinal direction. This bearing is represented on the Standard for Fixed Bearing Details Type "A" - Steel Girders. An advantage of this bearing type is that it is very low maintenance. See [27.2.2.2 Type "A-T" Expansion Bearings](#) for design information.

27.2.2.2 Type "A-T" Expansion Bearings

Type "A-T" Expansion bearings are designed to translate by sliding an unfilled polytetrafluoroethylene (PTFE or TFE) surface across a smooth, hard mating surface of stainless steel. Expansion bearings of Teflon are not used without provision for rotation. A rocker plate is provided to facilitate rotation due to live load deflection or change of camber. The Teflon sliding surface is bonded to a rigid back-up material capable of resisting horizontal shear and bending stresses to which the sliding surfaces may be subjected.

Design requirements for TFE bearing surfaces are given in **LRFD [14.7.2]**. Stainless steel-TFE expansion bearing details are given on the Standard for Stainless Steel – TFE Expansion Bearing Details Type "A-T."

Friction values are given in the **LRFD [14.7.2.5]**; they vary with loading and temperature. It is permissible to use 0.10 for a maximum friction value and 0.06 for a minimum value when determining unbalanced friction forces.

The design of type "A-T" bearings is relatively simple. The first consideration is the rocker plate length which is proportional to the contact stress based on a radius of 24" using Grade 50W steel. The rocker plate thickness is determined from a minimum of 1 1/2" to a maximum computed from the moment by assuming one-half the bearing reaction value ($N/2$) acting at a lever arm of one-fourth the width of the Teflon coated plate ($W/4$) over the length of the rocker plate. The Teflon coated plate is designed with a minimum width of 7" and the allowable stress as specified in **LRFD [14.7.2.4]** on the gross area; in many cases this controls the capacity of the expansion bearings as given in the Standard for Stainless Steel – TFE Expansion Bearing Details Type "A-T."

The design of the masonry plate is based on a maximum allowable bearing stress as specified in **LRFD [14.8.1]**. The masonry plate thickness is determined from the maximum bending moments about the x-or y-axis using a uniform pressure distribution.

In lieu of designing specific bearings, the designer may use Service I limit state loading, including dynamic load allowance, and Standards for Fixed Bearing Details Type "A" – Steel Girders, Stainless Steel – TFE Expansion Bearing Details Type "A-T" and Steel Bearings for Prestressed Concrete Girders to select the appropriate bearing.

27.2.2.3 High-Load Multi-Rotational Bearings

High-Load Multi-Rotational bearings, such as pot or disc bearings, are commonly used for moderate to large bridges. They are generally used for curved and/or highly skewed bridge applications requiring a multi-directional rotational capacity and a medium to large range of load.

Pot bearings consist of a circular non-reinforced neoprene or rubber pad, of relatively thin section, which is totally enclosed by a steel pot. The rubber is prevented from bulging by the pot containing it and acts similar to a fluid under high pressure. The result is a bearing providing suitable rotation and at the same time giving the effect of a point-contact rocker bearing since the center of pressure does not vary more than 4 percent. As specified in **LRFD [14.7.4.1]**, the minimum vertical load on a pot bearing should not be less than 20 percent of the vertical design load.

Pot bearings resist vertical load primarily through compressive stress in the elastomeric pad. The pad can deform and it has some shear stiffness, but it has very limited compressibility. Pot bearings generally have a large reserve of strength against vertical load. Pot bearings facilitate rotation through deformation of the elastomeric pad. During rotation, one side of the pad compresses and the other side expands. Pot bearings can sustain many cycles of small rotations with little or no damage. However, they can experience significant damage when subjected to relatively few cycles of large rotations.

Pot bearings can also resist horizontal loads. They can either be fixed, guided or non-guided. Fixed pot bearings (see [Figure 27.2-3](#)) can not translate in any direction, and they resist horizontal load primarily through contact between the rim of the piston and the wall of the pot. Guided pot bearings (see [Figure 27.2-4](#)) can translate in only one direction, and they resist horizontal load in the other direction through the use of guide bars. Non-guided pot bearings (see [Figure 27.2-5](#)) can translate in any direction, and they do not resist horizontal loads in any direction.

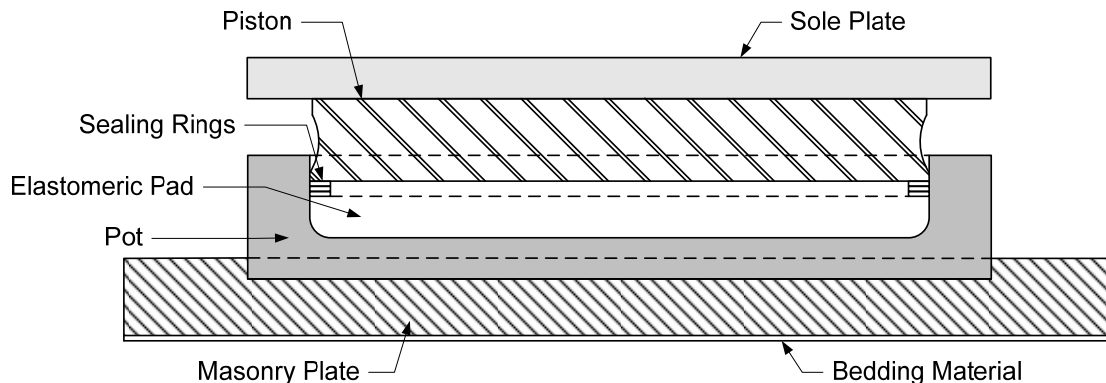


Figure 27.2-3
Fixed Pot Bearing

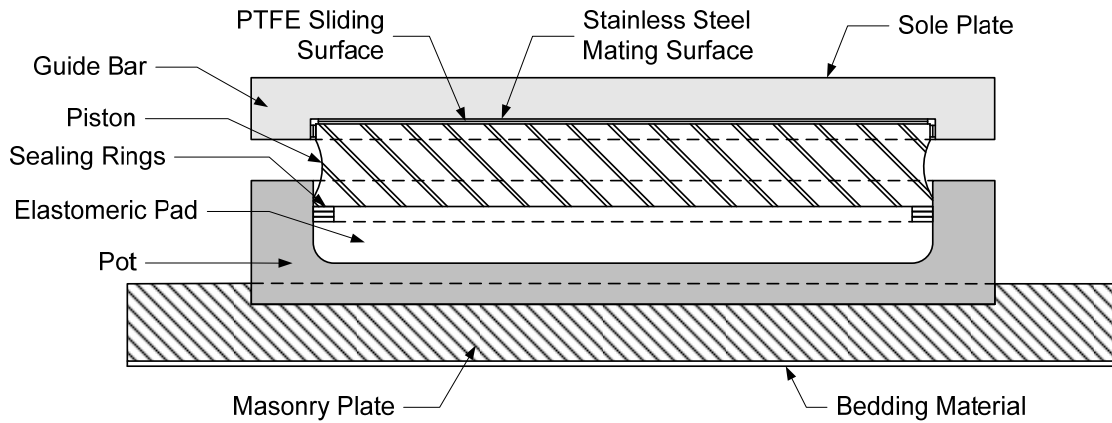


Figure 27.2-4
Guided Pot Bearing

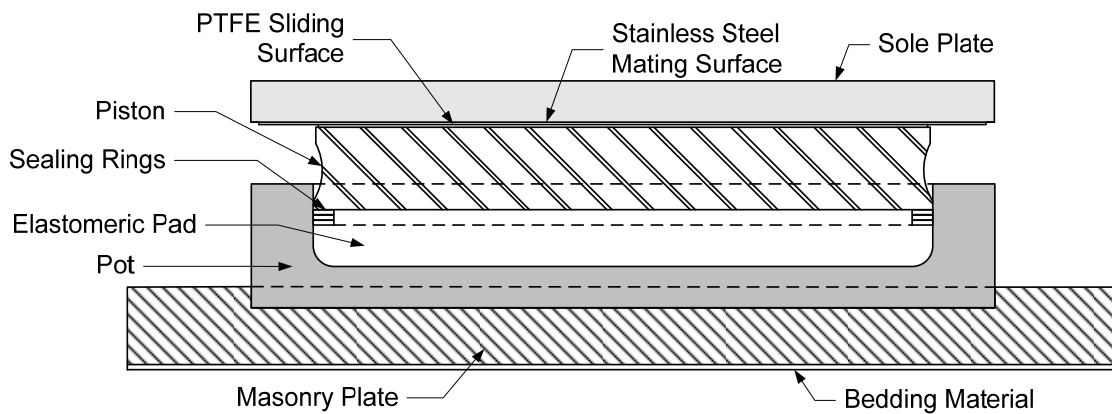


Figure 27.2-5
Non-Guided Pot Bearing

Disc bearings consist of a circular polyether urethane disc, confined by upper and lower steel plates and held in place by a positive location device. Limiting rings, either steel rings welded to the upper and lower steel plates or a circular recess in each of those plates, may also be used to partially confine the elastomer against lateral expansion. A shear-resisting mechanism shall be provided and it may be placed either inside or outside of the polyether urethane disc.

Disc bearings function by deformation of the polyether urethane disc, which should be stiff enough to resist vertical loads without excessive deformation and yet be flexible enough to accommodate the imposed rotations without liftoff or excessive stress on other components of the bearing assembly. The shear-resisting mechanism transmits horizontal forces between the upper and lower steel plates. As specified in **LRFD [14.7.8.4]**, the shear-resisting mechanism shall be capable of resisting a horizontal force in any direction equal to the larger

of the design shear force at the strength and extreme event limit states or 15 percent of the design vertical load at the service limit state.

Disc bearings can either be fixed, guided or non-guided. Fixed disc bearings (see [Figure 27.2-6](#)) can not translate in any direction. Guided disc bearings (see [Figure 27.2-7](#)) can translate in only one direction. Non-guided disc bearings (see [Figure 27.2-8](#)) can translate in any direction.

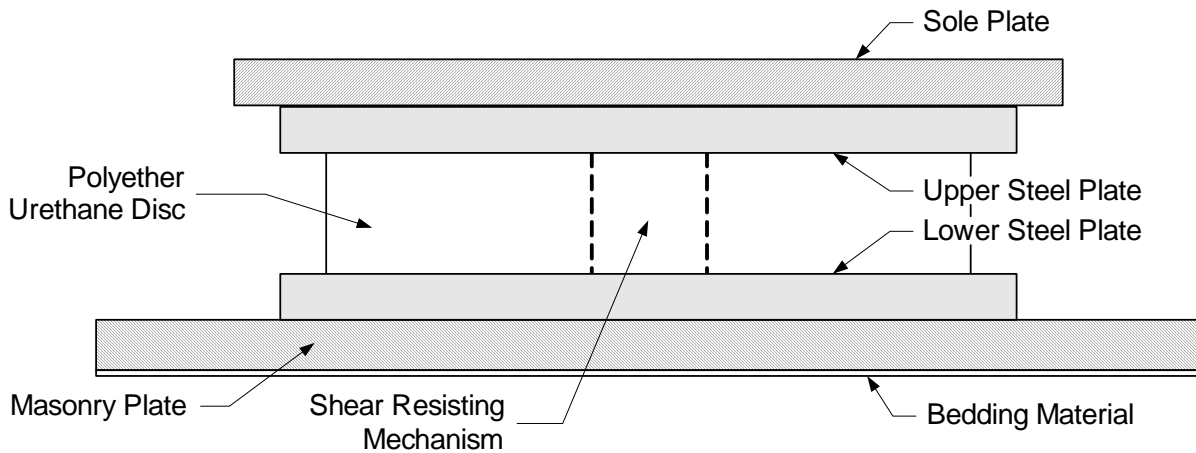


Figure 27.2-6
Fixed Disc Bearing

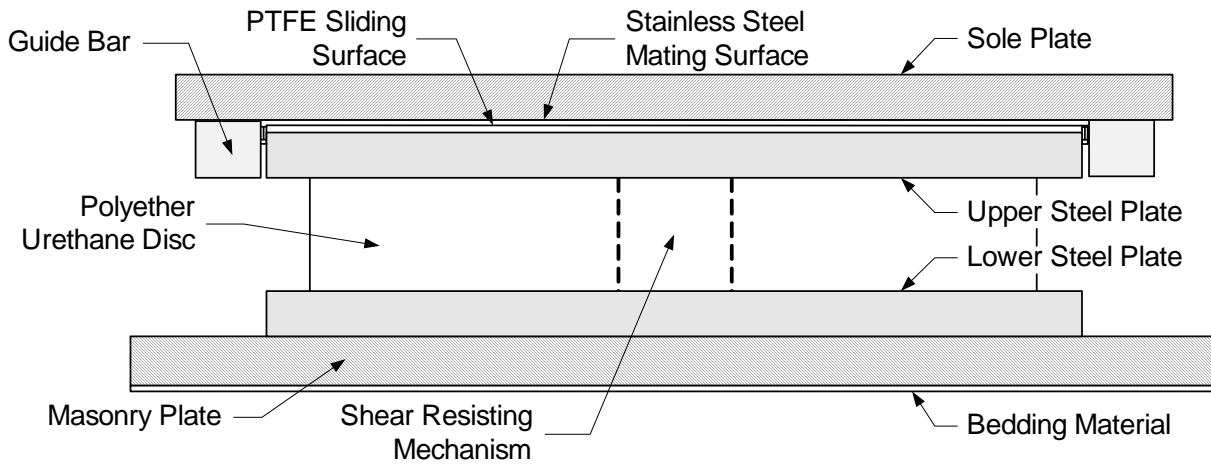


Figure 27.2-7
Guided Disc Bearing

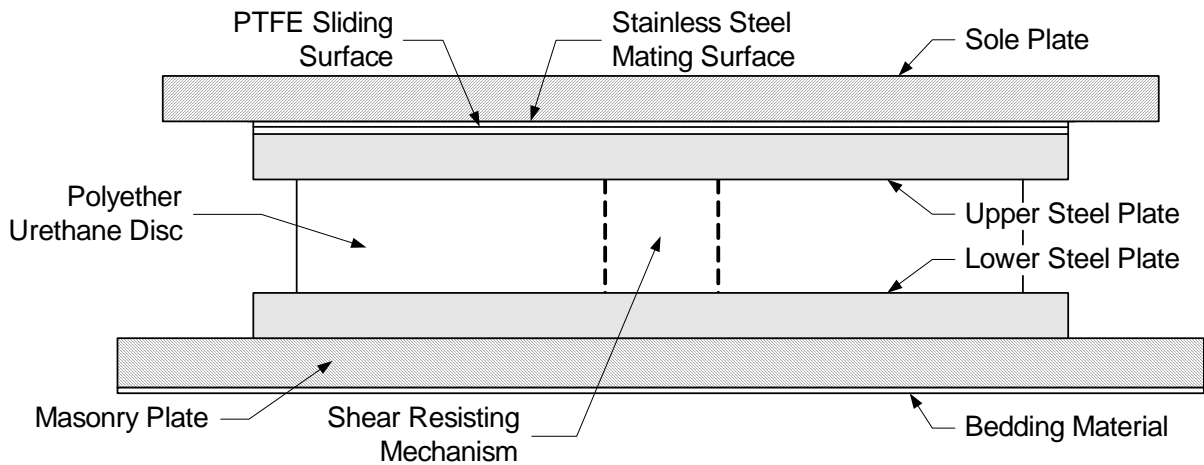


Figure 27.2-8
Non-Guided Disc Bearing

The design of a pot or disc bearing generally involves the following steps:

1. Obtain required design input **LRFD [14.4 & 14.6]**
2. Select a feasible bearing type: fixed, guided or non-guided
3. Select preliminary bearing properties
 - a. Pot bearings: **LRFD [14.7.4.2]**
 - b. Disc bearings: **LRFD [14.7.8.2]**
4. Design the bearing elements
 - a. Pot bearings:
 - i. Design the elastomeric disc **LRFD [14.7.4.3 and 14.7.4.4]**
 - ii. Design the sealing rings **LRFD [14.7.4.5]**
 - iii. Design the pot **LRFD [C14.7.4.3, 14.7.4.6 and 14.7.4.7]**
 - iv. Design the piston **LRFD [14.7.4.7]**
 - b. Disc bearings:
 - i. Design the elastomeric disc **LRFD [14.7.8.3]**
 - ii. Design the shear resisting mechanism **LRFD [14.7.8.4]**



5. Design the guides and restraints, if applicable **LRFD [14.7.9]**
6. Design the PTFE sliding surface, if applicable **LRFD [14.7.2]**
7. Design the sole plate, masonry plate (or bearing plate), anchorage and connections for pot bearings; design the sole plate, masonry plate (or bearing plate), upper and lower plates, anchorage and connections for disc bearings; as applicable **LRFD [6, 14.8 and 14.7.8.5]**
8. Check the concrete or steel support **LRFD [5.7.5 and 6]**

Although the steps for pot and/or disc bearing design are given above, the actual bearing design is typically done by the manufacturer. The design of the masonry plate is done either by the design engineer or by the bearing manufacturer (this should be coordinated and noted in the contract documents).

When using pot or disc bearings, the design plans need to specify the following:

- Degree of fixity (fixed, guided in one direction or non-guided)
- Maximum vertical load
- Minimum vertical load
- Maximum horizontal load (fixed and guided, only)
- Assumed bearing height

Note: The loads specified shall be Service I limit state loads, including dynamic load allowance.

Field adjustments to the given beam seat elevations will be required if the actual bearing height differs from the assumed bearing height stated on the plan. To facilitate such an adjustment without affecting the structural integrity of the substructure unit, a concrete pedestal (plinth) is detailed at each bearing location. Detailing a pedestal height of 10" based on the assumed bearing height will give sufficient room for adjustment should the actual bearing height differ from the assumed bearing height.



27.3 Hold Down Devices

Hold down devices are additional elements added to the Type "A-T" bearings for situations where live load can cause uplift at the abutment end of a girder. Ideally, proper span configurations would eliminate the need for hold down devices as they have proven to be a maintenance problem. Details for hold down devices are given in the Standard for Hold Down Devices.



27.4 Design Examples

E27-1 Steel Reinforced Elastomeric Bearing



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