# AASHTO T-3 TRIAL DESIGN BRIDGE DESCRIPTION

State: Montana

Trial Design Designation: MT-2

Bridge Name: MRL Overpass at Logan

Superstructure Type: Continuous rolled steel girder

Span Length(s): 95.125ft (29.0m) – 123.0 ft (37.5 m) – 95.125 ft (29.0 m)

Substructure Type: 6-ft (1.8m) diameter single drilled shaft/column piers

Foundation: 6-ft (1.8 m) diameter prismatic drilled shafts

Abutments: Semi-integral stub abutment on driven piles

Seismic Design Category (SDC): B

Seismic Design Strategy (Type 1, 2 or 3): Type 1

Design Spectral Acceleration at 1-second Period ($S_{D1}$): 0.29

Additional Description: Structure also designed for railroad impact loads

Montana Department of Transportation
PO Box 201001
Helena, MT 59620-1001

## *Memorandum*

From: Stephanie Brandenberger, P.E.
Bridge Seismic Engineer

Date: November 16, 2006

Subject: T3 Trial Bridge Designs

The Montana Department of Transportation has completed two trial designs for the T3 committee using the proposed Seismic Design Guidelines 2006.

These trial designs are intended to provide insight into the usability and clarity of the Guideline document, and evaluate the potential impacts the proposed philosophy will have on a state agency, both in terms of computational effort and construction economics.

<u>Trial Design Statement</u>

MDT completed design evaluations on a 3-span continuous rolled steel girder bridge supported on prismatic drilled shaft foundations at piers and driven piles at abutments. One evaluation was conducted on this structure in a Seismic Design Category (SDC) C and compared with the results for the same structure using the seismic design provisions in the current AASHTO LRFD Design Specifications for a Zone 3 (as submitted in plans). Another trial evaluation was conducted on the same structure in a SDC B to compare the differences between SDC B and C. Please note, the design shown on the plans submitted also includes provisions for railroad impact loads.

The evaluation focuses primarily on the substructure performance assuming a Type 1 system (ductile substructure with essentially elastic superstructure). It is assumed that the design philosophy for this particular configuration will have little to no effect on the superstructure, hence those calculations and plans have not been submitted.

<u>Results</u>

The philosophy of the proposed guidelines appears to result in only minor changes in the detailing and construction, thus the construction costs, of a typical bridge foundation type in Montana. There were no substantial changes required to the foundation design between the original LRFD Zone 3 design and the proposed Seismic Guideline SDC C bridge designs for this particular case. The results for a SDC B, although not detailed on the plans submitted, seemed reasonable and do not appear to be unacceptably restrictive or costly.

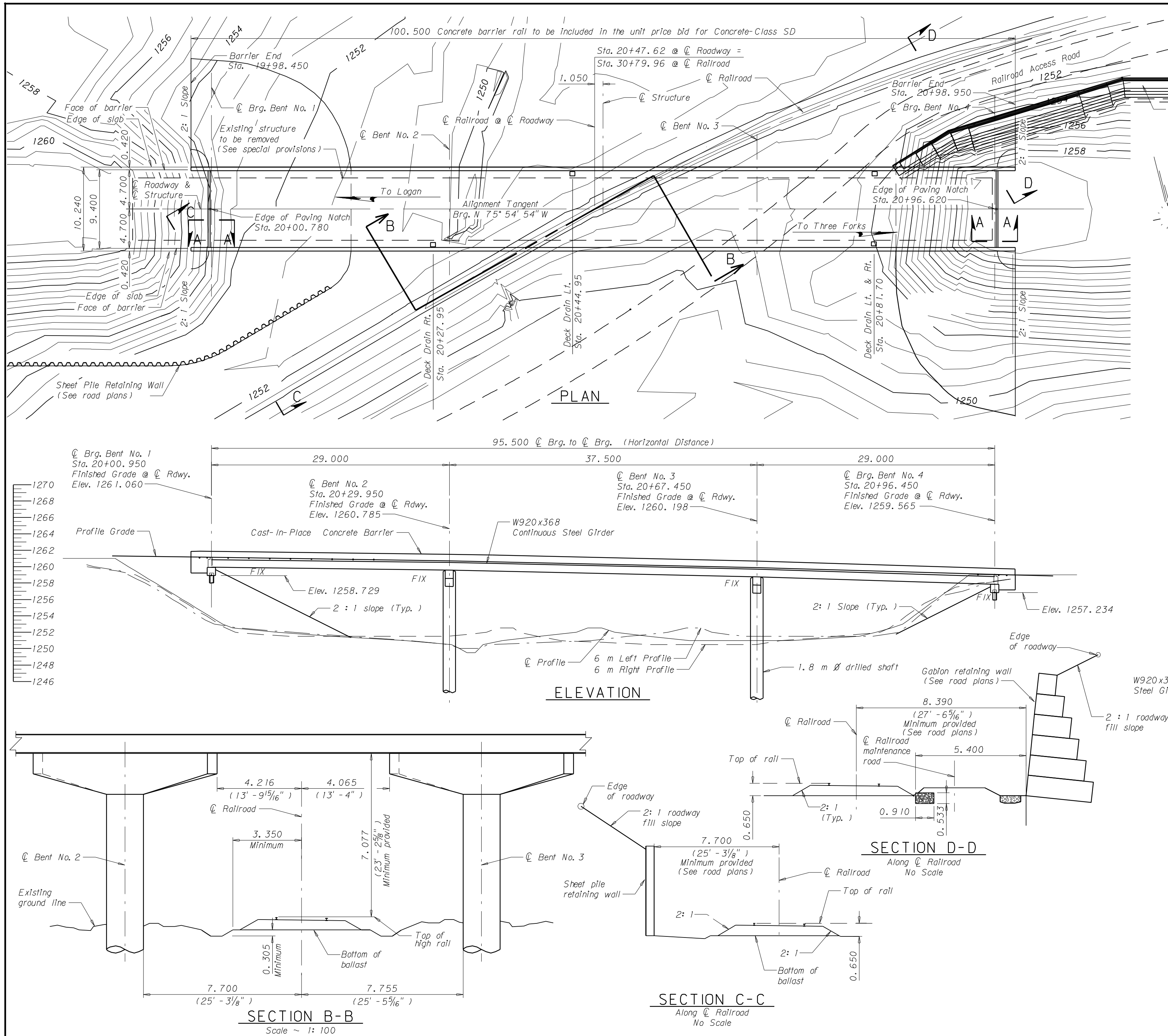
The design was approached using the Guideline's flowcharts to direct the engineer through the document. Trial design worksheet headings will indicate which flowchart was consulted. The flowcharts were easy to follow for the most part, and seemed to cover all important points.

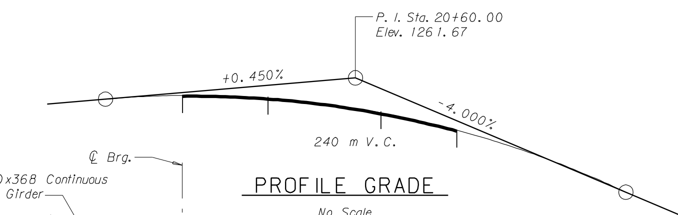
More computational effort was necessary for both SDC C and B trial designs than for corresponding LRFD designs. Although more effort was anticipated, it was unclear, at times, the nature or purpose of many of the guideline provisions. A few situations were encountered where an equation produced unreasonable or irrelevant results, or seemed to be contrary to the engineer's intuition. The commentary did not always provide much insight into the intent or origin of the provision, or offer any guidance to the designer on how to evaluate the results.

The provisions for a SDC B bridge were not always obvious. They were grouped with SDC C and D sometimes, other times they stood alone. This often led us to wonder whether we were missing something, or if we were making it more difficult than it needed to be.

With that in mind, we offer this general comment on the usability of the Guidelines. This is a monumental work representing the wisdom and experience of the author, public agencies, countless researchers, and the T3 committee members. While many of the concepts, terminologies, and methodologies contained in the guideline may seem like "second nature" to those whose education and experience has focused on the practice of seismic engineering, it will be new territory for many engineers who will encounter these same concepts, terms, and design methodologies for the first time using this document. Clarity of purpose and intent will be essential for acceptance and uniform application of this Guideline at a national level.

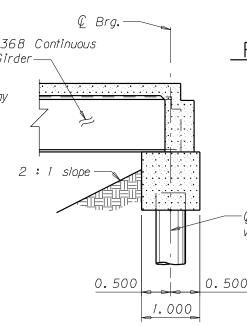
Thank you for the opportunity to review and comment on the proposed Guidelines. As T3 committee members, MDT supports this effort and will continue to offer assistance to the committee whenever possible.




PROFILE GRADE

No Scale




SECTION A-A

Scale ~ 1:50

## NOTES

FINISHED GRADE: Finished grade of bridge at centerline roadway is the same as the Profile Grade shown on Road Plans.

LIVE LOAD: Standard HL-93 loading.

SPECIFICATIONS: Montana Department of Transportation and the Montana Transportation Commission Standard Specifications for Road and Bridge Construction, 2006 edition, and any amendments thereto, and the Special Provisions govern unless otherwise noted. Design was prepared in accordance with AASHTO LRFD Bridge Design Specifications, 2004 edition, and any amendments thereto.

REINFORCING STEEL: Use new deformed type reinforcing steel meeting the requirements of AASHTO M 31M Grade 420. Include all costs associated with furnishing and placing new reinforcing steel in the unit price bid for either Reinforcing Steel or Reinforcing Steel - Epoxy Coated.

CAST IN PLACE CONCRETE: Unless otherwise approved or specified, use Class DD for all substructure concrete and Class SD for all superstructure concrete.

CONCRETE STRENGTH: Use f'c = 21 MPa for Class DD concrete. Use f'c = 31 MPa for Class SD concrete.

STRUCTURE EXCAVATION: Include structure excavation in the unit price bid for Class DD concrete.

TRAFFIC CONTROL PLAN AND SEQUENCE OF OPERATIONS: See Special Provisions.

UTILITIES: Call 1-800-424-5555 for utility locates at least two working days prior to starting any construction activity that could disturb the utility.

EXISTING STRUCTURE: Remove the existing structure (see Road Plans sheets and Special Provisions).

DIMENSIONS: All dimensions shown on the General Layout are in meters. All other drawings are dimensioned in millimeters except as noted. Stations and elevations are expressed in meters.

STRUCTURAL STEEL: All structural steel will be measured and paid for on the lump sum basis as set forth in the Standard Specifications. Use structural steel meeting the requirements of AASHTO M 270M Grade 345W: Estimated amount = 155 404 kg

MONTANA DEPARTMENT OF TRANSPORTATION

# M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT NO. IM 0002(697)

GALLATIN COUNTY

GENERAL LAYOUT

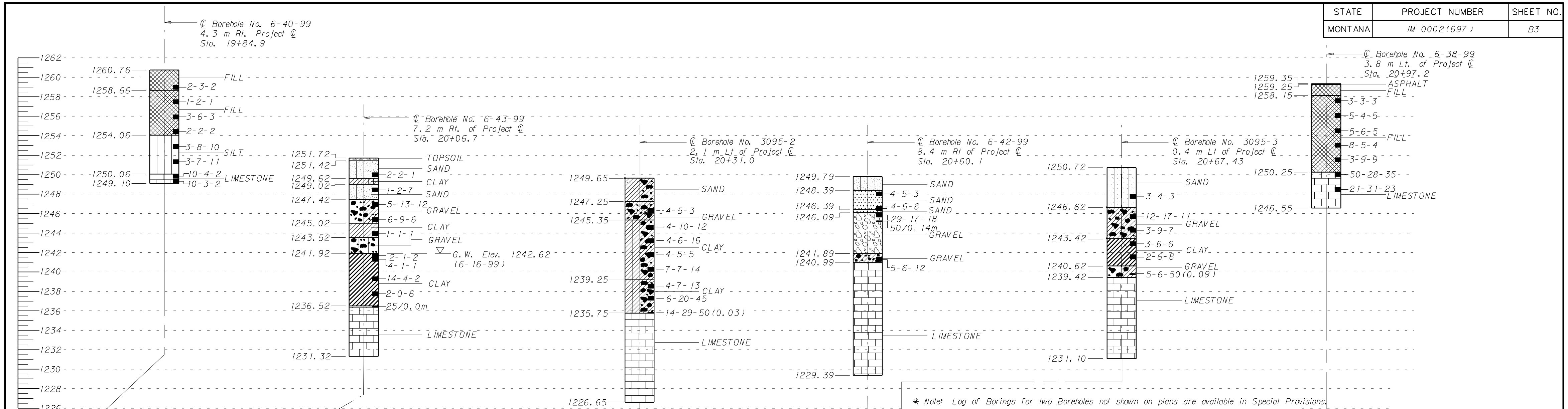
Scale ~ 1:250 Except as noted

| | | |
| --- | --- | --- |
| DESIGNED | 2-4-99 | N.E.C. |
| DRAWN | 2-24-99 | K.L.S. |
| CHECKED | 12-2-05 | M.L.R. |
| APPROVED | | |
| REVISED | | |
| REVISED | | |

FILENAME: 3095MRLGL.BRG    DRAWING NO. 19658

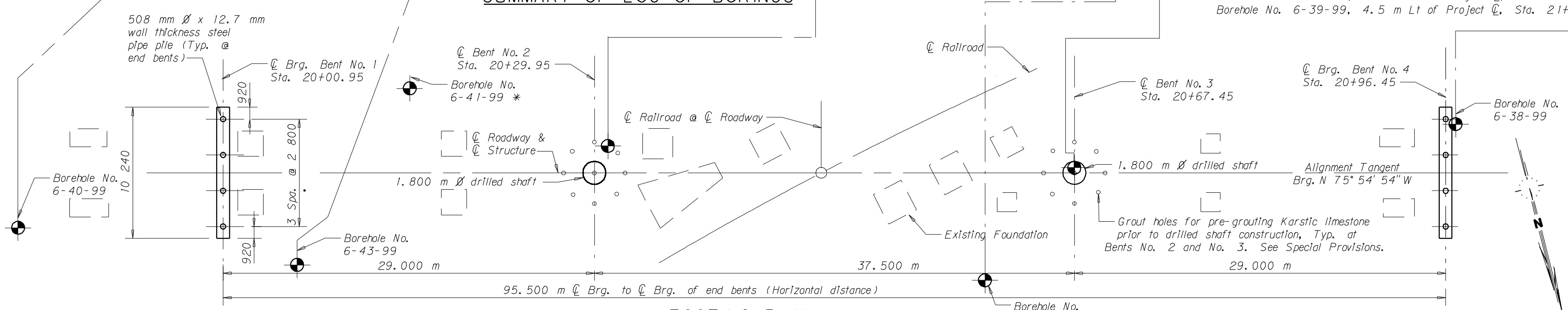
$FILEABBREV$ $DATE$ $TIME$ $username$

| STATE | PROJECT NUMBER | SHEET NO. |
|---|---|---|
| MONTANA | IM 0002(697) | B3 |




## SUMMARY OF LOG OF BORINGS

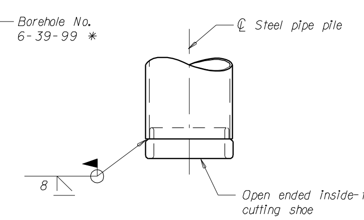
* Note: Log of Borings for two Boreholes not shown on plans are available in Special Provisions.
Borehole No. 6-41-99, 6.6 m Lt of Project ℄, Sta. 20+15.5
Borehole No. 6-39-99, 4.5 m Lt of Project ℄, Sta. 21+08.3




## FOOTING PLAN

Scale ~ 1: 200

NOTE: The footing dimensions @ Bent No. 1 are typical for Bent No. 4.




## CUTTING SHOE WELD PROCEDURE

Slip shoe inside pipe. Use 7018 SMAW rod.

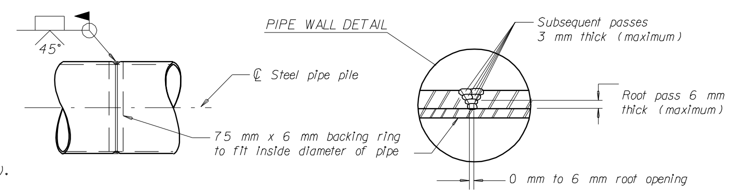
No Scale

## NOTES

SOILS AND FOUNDATION MATERIALS: The Footing Plan shows points where the State of Montana, Department of Transportation, drilled boreholes.

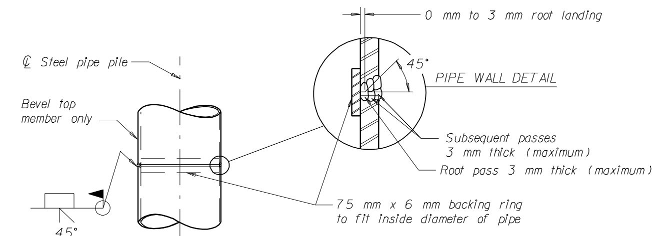
The series of numbers on the Log of Borings shows the number of blows from a 63.5 kg hammer with a 0.760 m drop required to drive a 51 mm split spoon sampler 0.150 m (Standard Penetration Test). The length of the split spoon sampler is 0.450 m. The sampler length is measured as three 0.150 m intervals. If the split spoon sampler did not penetrate 0.150 m after 50 blows, the Log of Borings shows the measured penetration within that particular interval.

See the Special Provisions for original boring logs and additional subsurface information.




## PILE EXTENSION BEFORE DRIVING

(Rotate pile so that all welding is done in the flat position)




NOTE: Refer to AWS D1.1 for prequalified joint designation B-U4a.

## PILE EXTENSION AFTER DRIVING

(Pile Vertical)

## PERMISSIBLE WELDED SPLICE DETAILS FOR STEEL PIPE PILES

No Scale

NOTE: Use only E7018 or E7028 series electrodes. Maximum electrode size is 5 mm. Prepare the weld surfaces to a smooth, uniform finish. Remove all fins, tears, loose scale, slag, rust, grease, moisture and other material that would prevent proper welding.

| | | |
|---|---|---|
| DESIGNED | 6-14-99 | N.E.C. |
| DRAWN | 6-14-99 | P.H.J. |
| CHECKED | 12-2-05 | M.L.R. |
| REVISED | | |
| REVISED | | |

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M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT NO. IM 0002(697)

GALLATIN COUNTY

FOOTING PLAN

Scale ~ As noted

FILENAME: 3095MRLFP.BRG DRAWING NO. 19659

BRIDGE BUREAU

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| STATE | PROJECT NUMBER | SHEET NO. |
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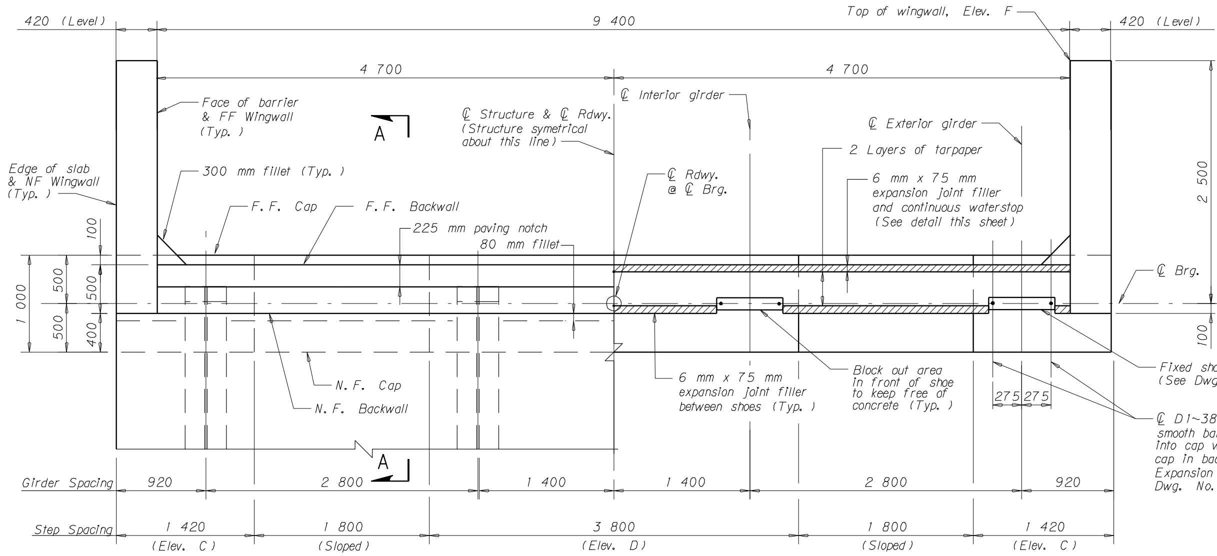
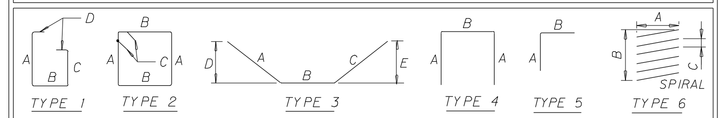
| MONTANA | IM 0002(697) | B4 |




PLAN

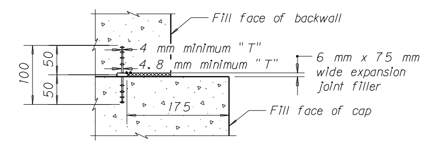
| TABLE OF ELEVATIONS | | |
|---|---|---|
| Elev. | Bent No. 1 | Bent No. 4 |
| A | 1261.060 | 1259.565 |
| B | 1260.966 | 1259.471 |
| C | 1259.729 | 1258.234 |
| D | 1259.785 | 1258.290 |
| E | 1258.729 | 1257.234 |
| F | 1260.982 | 1259.409 |

## BILL OF REINFORCING STEEL (For one bent only)




| STRAIGHT BARS | | | |
|---|---|---|---|
| Mark | Size | No. | Length |
| BW1E | 16 | 4 | 10 140 |
| BW3 | 16 | 8 | 2 680 |
| BW4 | 16 | 12 | 2 400 |
| | | | |
| D1* | 38 | 8 | 1 200 |
| C1 | 25 | 8 | 10 140 |
| C2 | 16 | 4 | 10 140 |
| C4 | 13 | 16 | 1 000 |
| C6 | 19 | 3 | 2 180 |
| WW1 | 19 | 12 | 1 900 |
| WW2 | 19 | 36 | 2 500 |

| BENT BARS (All dimensions are out to out) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mark | Size | No. | Type | Length | A | B | C | D | E |
| BW2 | 16 | 8 | 5 | 5 660 | 5 350 | 310 | | | |
| BW5 | 16 | 8 | 5 | 1 040 | 730 | 310 | | | |
| BW6E | 13 | 30 | 1 | 2 560 | 1 100 | 400 | 800 | 130 | |
| BW7E | 13 | 24 | 5 | 1 220 | 610 | 610 | | | |
| C3 | 16 | 27 | 2 | 3 800 | 870 | 900 | 130 | | |
| C5 | 13 | 16 | 4 | 1 500 | 300 | 900 | | | |
| C7 | 19 | 32 | 5 | 2 865 | 2 390 | 475 | | | |
| C8 | 16 | 4 | 6 | 13 290 | 380 | 2 000 | 305 | | |
| C9 | 16 | 4 | 6 | 8 010 | 380 | 290 | 75 | | |
| WW3 | 13 | 14 | 3 | 1 720 | 410 | 900 | 410 | 290 | 290 |
| WW4 | 13 | 6 | 2 | 3 080 | 1 120 | 290 | 130 | | |
| WW5 | 13 | 22 | 2 | 4 580 | 1 870 | 290 | 130 | | |
| WW6 | 13 | 24 | 4 | 770 | 260 | 250 | | | |




WATERSTOP DETAIL

No Scale

NOTE: Hold waterstop in accurate position while placing concrete.

*NOTE: Use D1~38 mm Ø smooth bars meeting the requirements of AASHTO M 270M Grade 250.

NOTE: The suffix E denotes epoxy coated reinforcing steel.

NOTE: Design pile tip elevation:

Bent No. 1 = 1242.5 Estimated pile length = 16.729 m
Bent No. 4 = 1248.5 Estimated pile length = 9.234 m

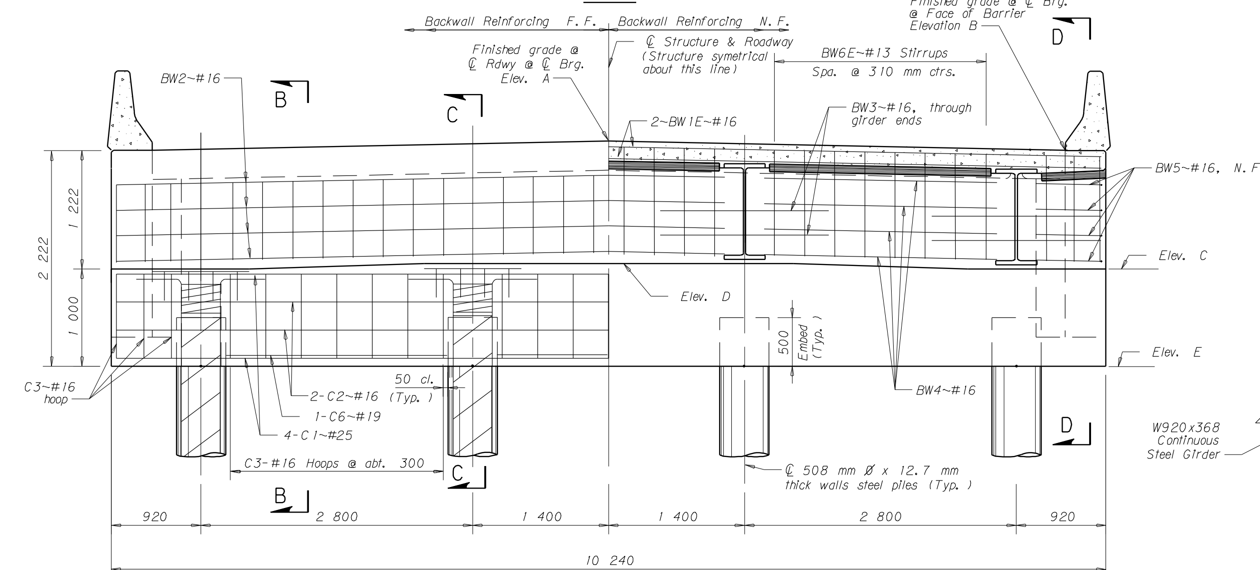
Ultimate pile capacity during driving: 2400 kN

Contact the MDT Geotechnical Section at (406)444-6281 if pile tip elevations deviate more than 300 mm from the elevation indicated.

NOTE: Include all costs associated with furnishing and placing the expansion joint filler, tarpaper, neoprene waterstop and metal expansion caps in the unit price bid for Concrete - Class DD.

NOTE: Securely nail expansion joint filler to pile cap concrete and hold in proper position while placing backwall concrete.

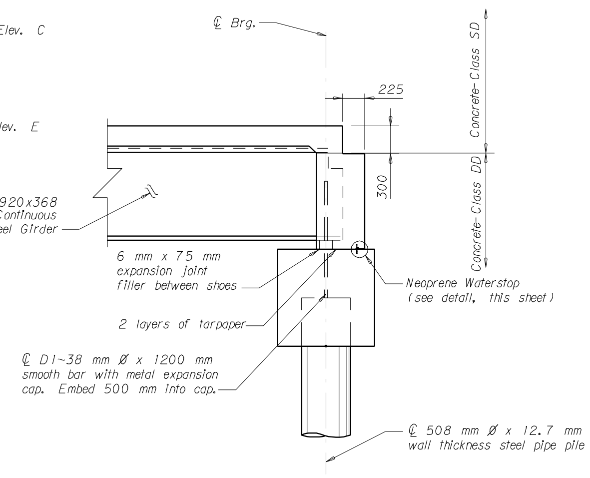
NOTE: N.F. denotes near face. F.F. denotes fill face.




ELEVATION

(Bent No. 1 - back on line)
(Bent No. 4 - ahead on line)

NOTE: For sections B-B, C-C and D-D see Dwg. No. 19661.




SECTION A-A

Scale ~ 1:30

NOTE: Lap #13 bars 430 mm minimum.
Lap #16 bars 550 mm minimum.
Lap #19 bars 680 mm minimum.

NOTE: Slab reinforcing steel is omitted for clarity.

NOTE: Finish beam seats level to the elevations shown on this drawing. Slope areas between beam seats as shown.

NOTE: Fill the steel pipe piles with Class DD concrete. Wait a minimum of one day before placing the pile cap concrete.

NOTE: For fixed shoe Detail, see Dwg. No. 19665.

NOTE: For Concrete Barrier Rail at wingwalls, See Dwg. No. 19668.

| | | |
|---|---|---|
| DESIGNED | 6-15-99 | N.E.C. |
| DRAWN | 6-21-99 | PH/JL |
| CHECKED | 1-5-06 | M.L.R. |
| | | |
| REVISED | | |
| REVISED | | |

MONTANA DEPARTMENT OF TRANSPORTATION

M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT IM 0002(697)

GALLATIN COUNTY

BENT NO. 1 & NO. 4

Scale ~ 1:30

FILENAME: 3095MRLB.BRG DRAWING NO. 19660

MDT BRIDGE BUREAU

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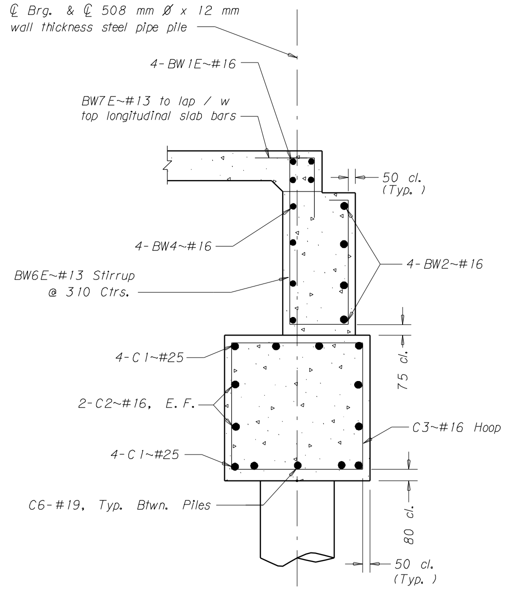
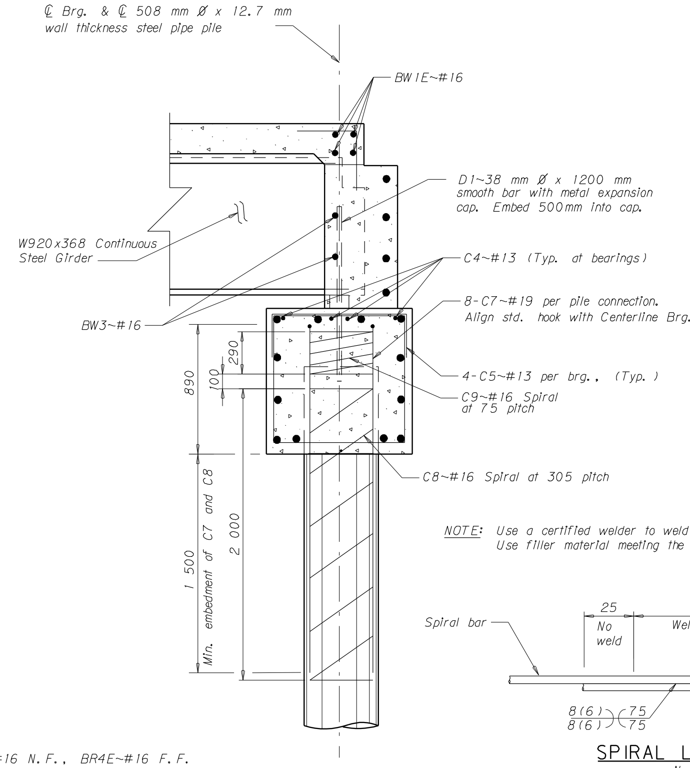
| MONTANA | IM 0002(697) | B5 |

MDT BRIDGE BUREAU



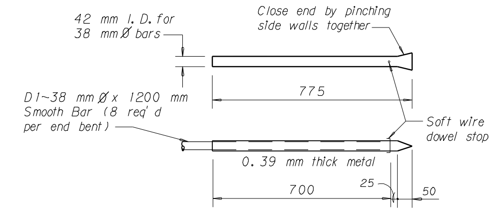

## SECTION B-B

Scale ~ 1: 20




## SECTION C-C

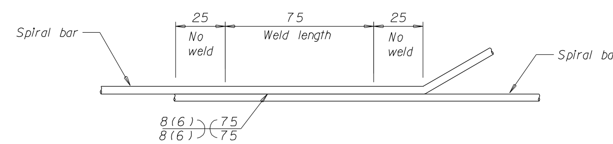
Scale ~ 1: 20




## METAL EXPANSION CAP DETAIL

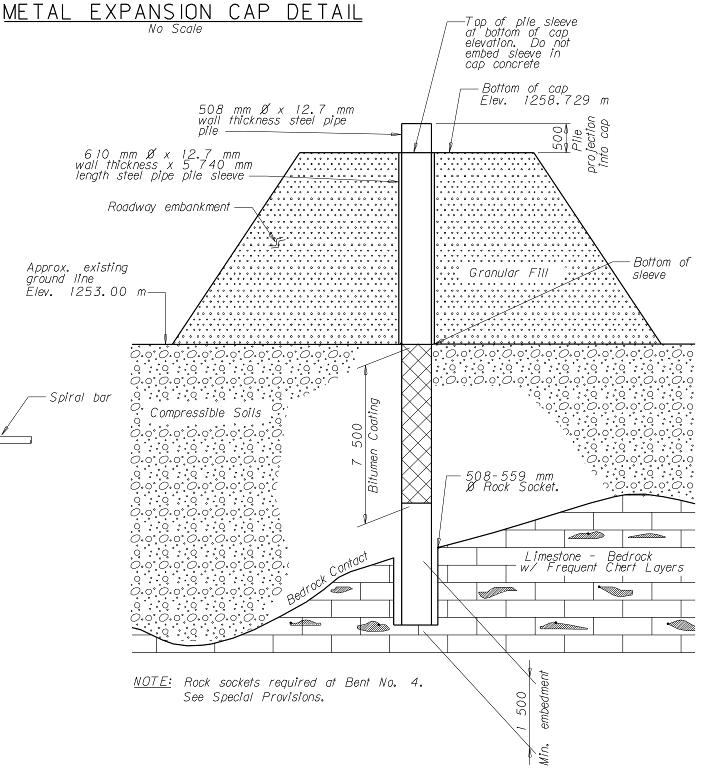
No Scale

NOTE: Use a certified welder to weld according to AWS D1.4. Use filler material meeting the requirements of AWS A5.5.




## SPIRAL LAP DETAIL

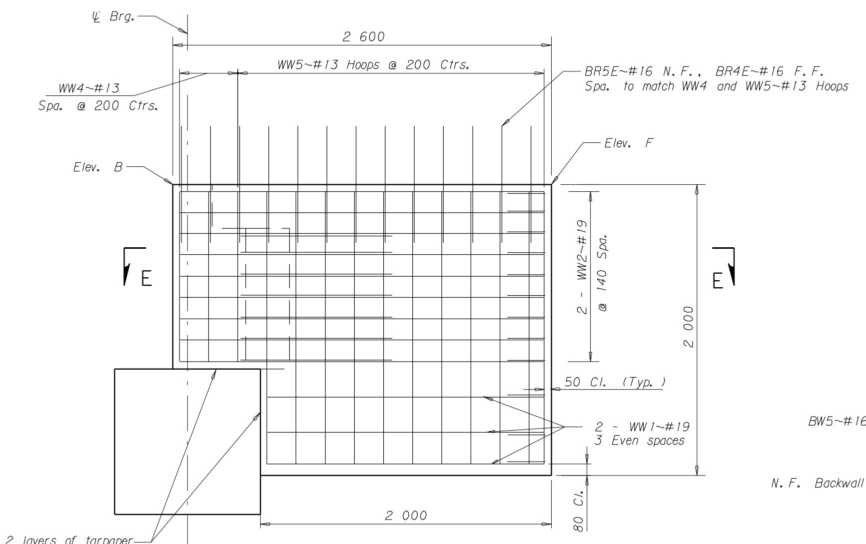
No Scale




NOTE: Rock sockets required at Bent No. 4. See Special Provisions.

## BENT NO. 1 PILE DETAIL

No Scale



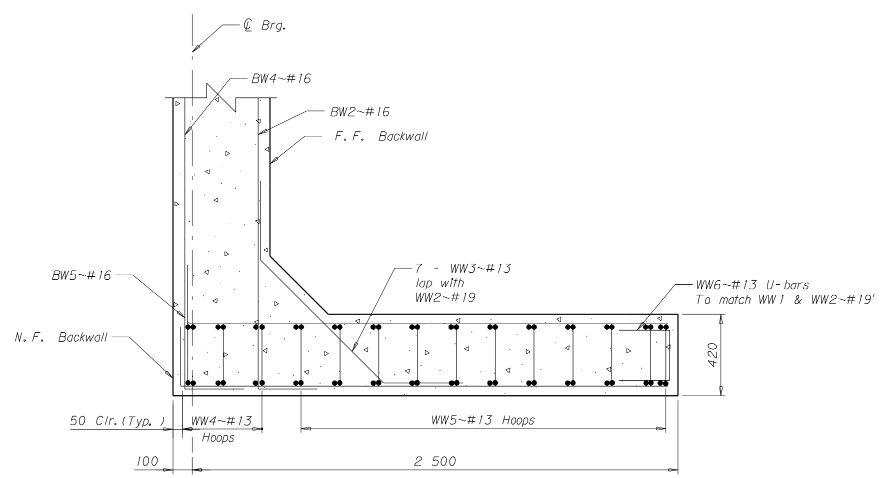

## SECTION D-D

Scale ~ 1: 20

NOTE: For table of elevations see Dwg. No. 19660.

NOTE: For Bill of Reinforcing Steel, See Dwg. No. 19660.

NOTE: For Concrete Barrier Rail at wingwall, See Dwg. No. 19668.




## SECTION E-E

Scale ~ 1: 15

MONTANA DEPARTMENT OF TRANSPORTATION

M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT NO. IM 0002(697)

GALLATIN COUNTY

MISCELLANEOUS BENT DETAILS

Scale ~ As noted

| | | |
|---|---|---|
| DESIGNED | 6-15-99 | N.E.C. |
| DRAWN | 6-22-99 | PH/JL |
| CHECKED | 1-5-06 | M.L.R. |
| REVISED | | |
| REVISED | | |
| REVISED | | |

FILENAME: 3095MRLC.brg DRAWING NO. 19661

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| STATE | PROJECT NUMBER | SHEET NO. |
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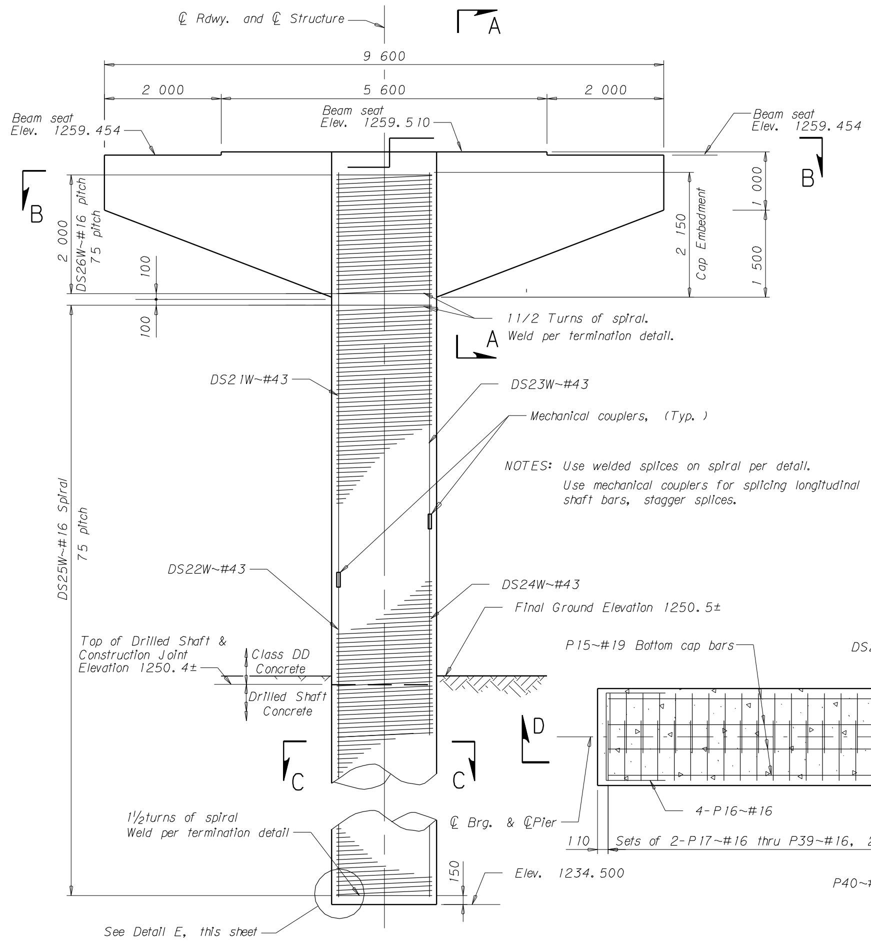
| MONTANA | IM 0002(697) | B6 |

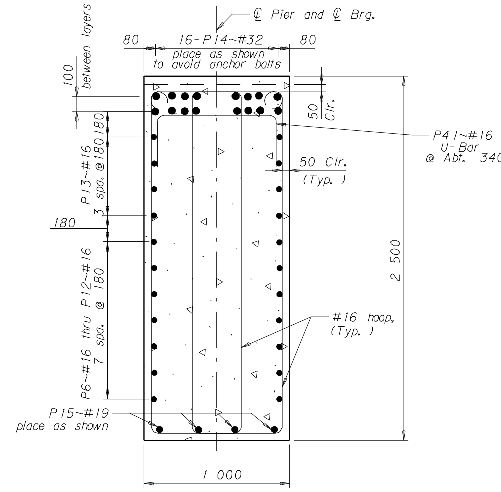
BRIDGE BUREAU




NOTES: Use welded splices on spiral per detail.
Use mechanical couplers for splicing longitudinal shaft bars, stagger splices.

ELEVATION

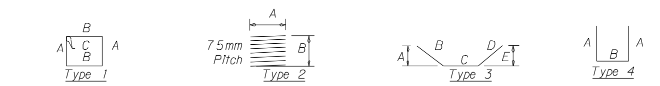
Scale ~ 1:50




SECTION A-A

Scale ~ 1:20

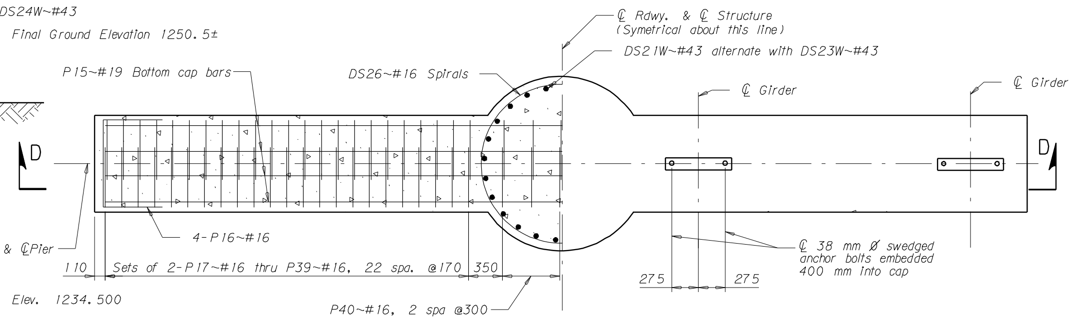
# BILL OF REINFORCING STEEL




| STRAIGHT BARS | | | |
|---|---|---|---|
| Mark | Size | No. | Length |
| DS21W | 43 | 12 | 7 000 |
| DS22W | 43 | 12 | 17 520 |
| DS23W | 43 | 12 | 6 230 |
| DS24W | 43 | 12 | 18 290 |
| P6 | 16 | 2 | 3 020 |
| P7 | 16 | 2 | 3 950 |
| P8 | 16 | 2 | 4 890 |
| P9 | 16 | 2 | 5 830 |
| P10 | 16 | 2 | 6 760 |
| P11 | 16 | 2 | 7 700 |
| P12 | 16 | 2 | 8 640 |
| P13 | 16 | 8 | 9 380 |
| P14 | 32 | 16 | 9 380 |

| BENT BARS (All dimensions are out to out) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mark | Size | No. | Type | Length | A | B | C | D | E |
| DS25W | 16 | 1 | 2 | 1545660 | 1 640 | 22 160 | | | |
| DS26W | 16 | 1 | 2 | 152850 | 1 640 | 2 000 | | | |
| P15 | 19 | 4 | 3 | 9 920 | 1 440 | 4 000 | 1 920 | 4 000 | 1 440 |
| P16 | 16 | 8 | 4 | 2 090 | 610 | 870 | | | |
| P17 | 16 | 4 | 1 | 3 280 | 890 | 620 | 130 | | |
| P18 | 16 | 4 | 1 | 3 420 | 960 | 620 | 130 | | |
| P19 | 16 | 4 | 1 | 3 540 | 1 020 | 620 | 130 | | |
| P20 | 16 | 4 | 1 | 3 680 | 1 090 | 620 | 130 | | |
| P21 | 16 | 4 | 1 | 3 800 | 1 150 | 620 | 130 | | |
| P22 | 16 | 4 | 1 | 3 940 | 1 220 | 620 | 130 | | |
| P23 | 16 | 4 | 1 | 4 060 | 1 280 | 620 | 130 | | |
| P24 | 16 | 4 | 1 | 4 200 | 1 350 | 620 | 130 | | |
| P25 | 16 | 4 | 1 | 4 320 | 1 410 | 620 | 130 | | |
| P26 | 16 | 4 | 1 | 4 460 | 1 480 | 620 | 130 | | |
| P27 | 16 | 4 | 1 | 4 580 | 1 540 | 620 | 130 | | |
| P28 | 16 | 4 | 1 | 4 720 | 1 610 | 620 | 130 | | |
| P29 | 16 | 4 | 1 | 4 860 | 1 680 | 620 | 130 | | |
| P30 | 16 | 4 | 1 | 4 980 | 1 740 | 620 | 130 | | |
| P31 | 16 | 4 | 1 | 5 120 | 1 810 | 620 | 130 | | |
| P32 | 16 | 4 | 1 | 5 240 | 1 870 | 620 | 130 | | |
| P33 | 16 | 4 | 1 | 5 380 | 1 940 | 620 | 130 | | |
| P34 | 16 | 4 | 1 | 5 500 | 2 000 | 620 | 130 | | |
| P35 | 16 | 4 | 1 | 5 640 | 2 070 | 620 | 130 | | |
| P36 | 16 | 4 | 1 | 5 760 | 2 130 | 620 | 130 | | |
| P37 | 16 | 4 | 1 | 5 900 | 2 200 | 620 | 130 | | |
| P38 | 16 | 4 | 1 | 6 020 | 2 260 | 620 | 130 | | |
| P39 | 16 | 4 | 1 | 6 160 | 2 330 | 620 | 130 | | |
| P40 | 16 | 10 | 1 | 6 160 | 2 330 | 620 | 130 | | |
| P41 | 16 | 29 | 4 | 1 530 | 350 | 830 | | | |

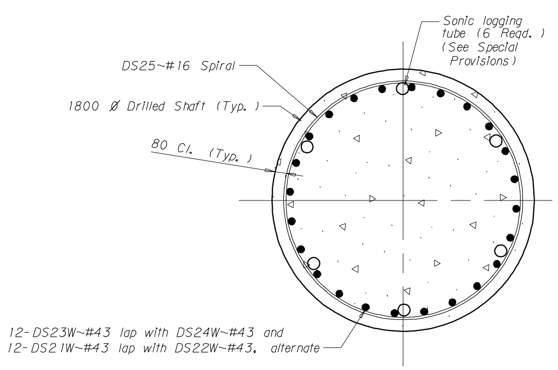
NOTE: The suffix W denotes ASTM A706 Reinforcing Steel.




SECTION B-B

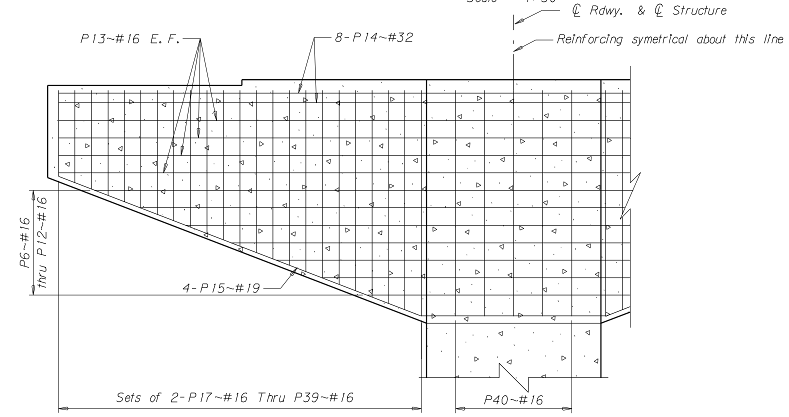
Scale ~ 1:30

NOTE: See spiral lap and termination detail on Dwg. No. 19663.




SECTION C-C

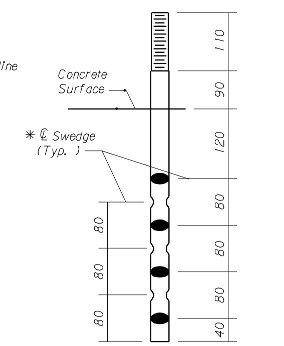
Scale ~ 1:20




Note: Shaft bars omitted for clarity.

SECTION D-D

Scale ~ 1:30

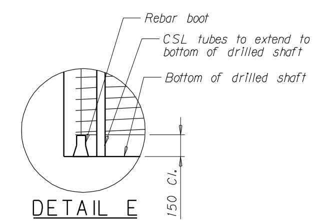



ANCHOR BOLT DETAIL

No Scale

* Make swedge deformations approximately 5 mm deep without removing metal.

Note: For fixed shoe detail, see Dwg. No. 19665.




DETAIL E

Scale ~ 1:20

MONTANA DEPARTMENT OF TRANSPORTATION

M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT NO. IM 0002(697)

GALLATIN COUNTY

PIER NO. 2

Scale ~ as noted

| | | |
|---|---|---|
| DESIGNED | 1-30-02 | K.T.B. |
| DRAWN | 2-25-02 | J.D.L. |
| CHECKED | 1-6-06 | M.L.R. |
| REVISED | | |
| REVISED | | |
| REVISED | | |

FILENAME: 3095BRPRD001.dgn DRAWING NO. 19662

$FILEABBREV$ $DATE$ $TIME$ $username$

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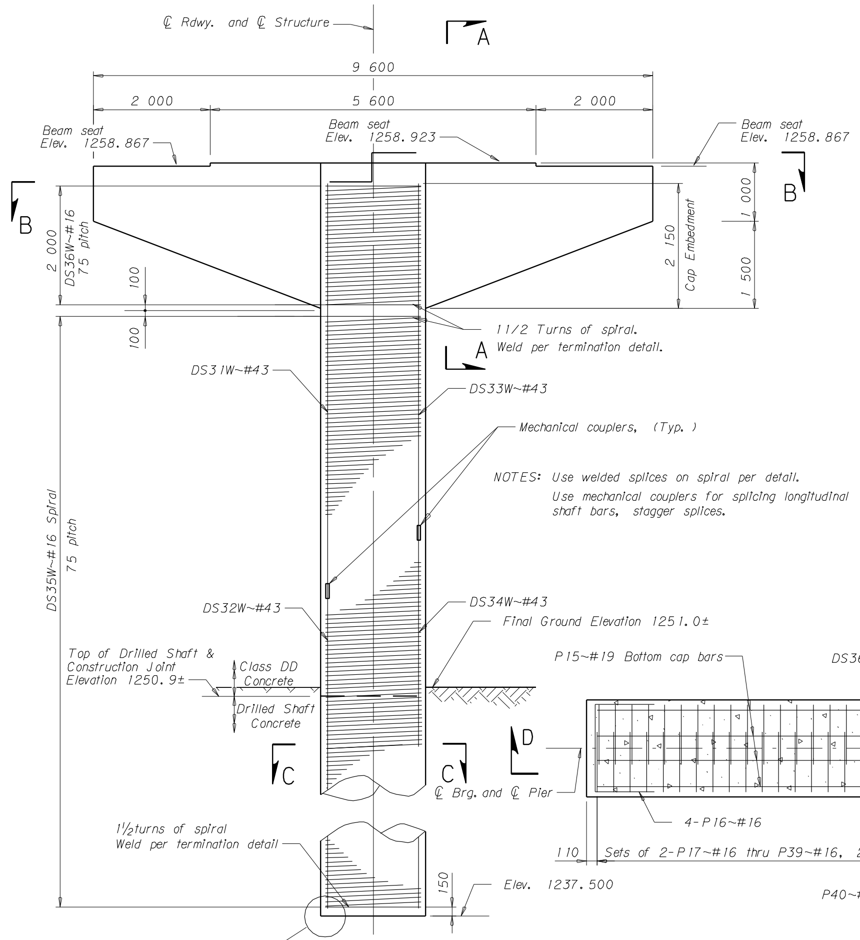
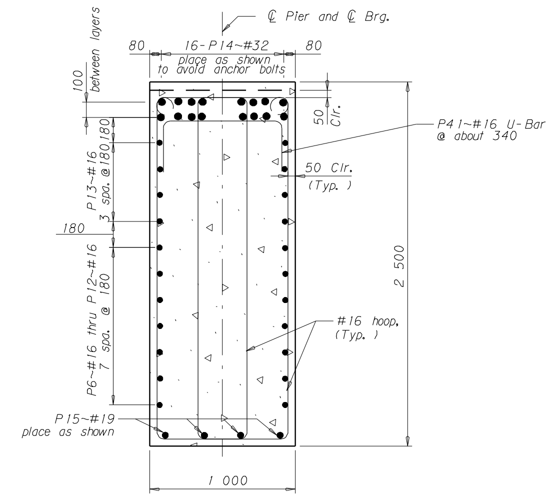
| STATE | PROJECT NUMBER | SHEET NO. |
|---|---|---|
| MONTANA | IM 0002(697) | B7 |



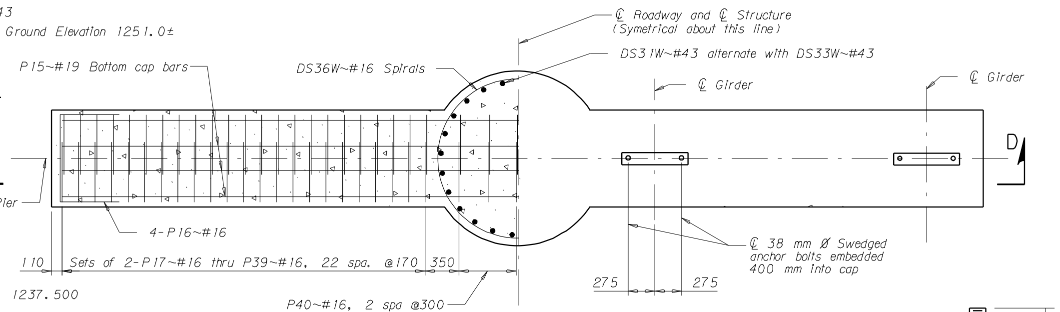

ELEVATION

Scale ~ 1:50



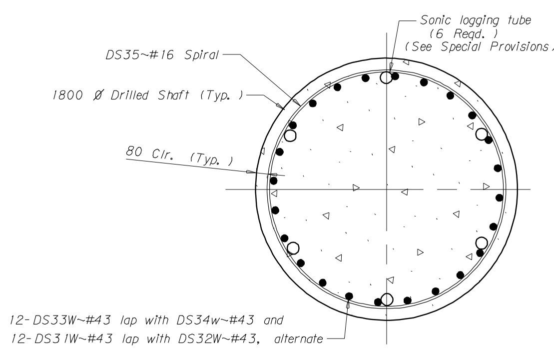

SECTION A-A

Scale ~ 1:20



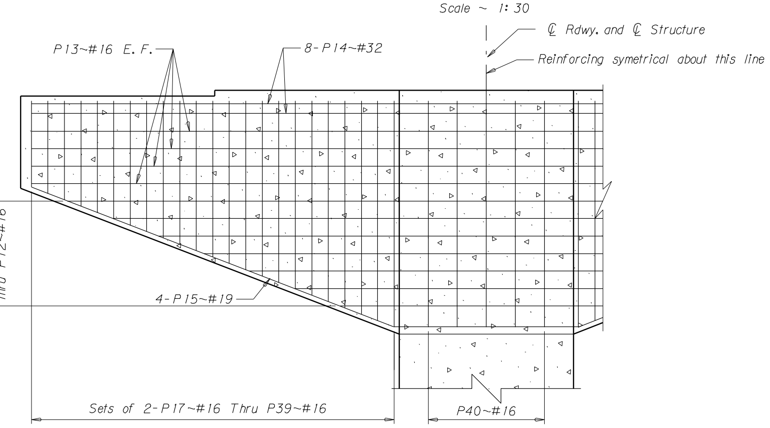

SECTION B-B

Scale ~ 1:30




SECTION C-C

Scale ~ 1:20

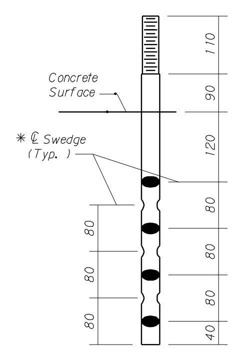



Note: Shaft bars not shown for clarity.

SECTION D-D

Scale ~ 1:30

Note: For fixed shoe detail, see Dwg. No. 19665.

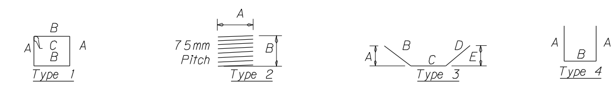



ANCHOR BOLT DETAIL

No Scale

*Make swedge deformations approximately 5 mm deep without removing metal.

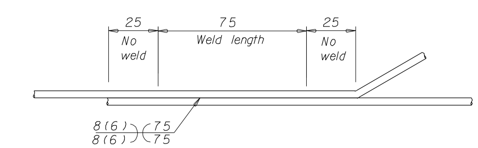
# BILL OF REINFORCING STEEL




| STRAIGHT BARS | | | |
|---|---|---|---|
| Mark | Size | No. | Length |
| DS31W | 43 | 12 | 7 000 |
| DS32W | 43 | 12 | 13 890 |
| DS33W | 43 | 12 | 6 000 |
| DS34W | 43 | 12 | 14 890 |
| P6 | 16 | 2 | 3 020 |
| P7 | 16 | 2 | 3 950 |
| P8 | 16 | 2 | 4 890 |
| P9 | 16 | 2 | 5 830 |
| P10 | 16 | 2 | 6 760 |
| P11 | 16 | 2 | 7 700 |
| P12 | 16 | 2 | 8 640 |
| P13 | 16 | 8 | 9 380 |
| P14 | 32 | 16 | 9 380 |

| BENT BARS (All dimensions are out to out) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mark | Size | No. | Type | Length | A | B | C | D | E |
| DS35W | 16 | 1 | 2 | 1298010 | 1 640 | 18 670 | | | |
| DS36W | 16 | 1 | 2 | 152850 | 1 640 | 2 000 | | | |
| P15 | 19 | 4 | 3 | 9 920 | 1 440 | 4 000 | 1 920 | 4 000 | 1 440 |
| P16 | 16 | 8 | 4 | 2 090 | 610 | 870 | | | |
| P17 | 16 | 4 | 1 | 3 280 | 890 | 620 | 130 | | |
| P18 | 16 | 4 | 1 | 3 420 | 960 | 620 | 130 | | |
| P19 | 16 | 4 | 1 | 3 540 | 1 020 | 620 | 130 | | |
| P20 | 16 | 4 | 1 | 3 680 | 1 090 | 620 | 130 | | |
| P21 | 16 | 4 | 1 | 3 800 | 1 150 | 620 | 130 | | |
| P22 | 16 | 4 | 1 | 3 940 | 1 220 | 620 | 130 | | |
| P23 | 16 | 4 | 1 | 4 060 | 1 280 | 620 | 130 | | |
| P24 | 16 | 4 | 1 | 4 200 | 1 350 | 620 | 130 | | |
| P25 | 16 | 4 | 1 | 4 320 | 1 410 | 620 | 130 | | |
| P26 | 16 | 4 | 1 | 4 460 | 1 480 | 620 | 130 | | |
| P27 | 16 | 4 | 1 | 4 580 | 1 540 | 620 | 130 | | |
| P28 | 16 | 4 | 1 | 4 720 | 1 610 | 620 | 130 | | |
| P29 | 16 | 4 | 1 | 4 860 | 1 680 | 620 | 130 | | |
| P30 | 16 | 4 | 1 | 4 980 | 1 740 | 620 | 130 | | |
| P31 | 16 | 4 | 1 | 5 120 | 1 810 | 620 | 130 | | |
| P32 | 16 | 4 | 1 | 5 240 | 1 870 | 620 | 130 | | |
| P33 | 16 | 4 | 1 | 5 380 | 1 940 | 620 | 130 | | |
| P34 | 16 | 4 | 1 | 5 500 | 2 000 | 620 | 130 | | |
| P35 | 16 | 4 | 1 | 5 640 | 2 070 | 620 | 130 | | |
| P36 | 16 | 4 | 1 | 5 760 | 2 130 | 620 | 130 | | |
| P37 | 16 | 4 | 1 | 5 900 | 2 200 | 620 | 130 | | |
| P38 | 16 | 4 | 1 | 6 020 | 2 260 | 620 | 130 | | |
| P39 | 16 | 4 | 1 | 6 160 | 2 330 | 620 | 130 | | |
| P40 | 16 | 10 | 1 | 6 160 | 2 330 | 620 | 130 | | |
| P41 | 16 | 29 | 4 | 1 530 | 350 | 830 | | | |

NOTE: The suffix W denotes ASTM A706 Reinforcing Steel.




SPIRAL LAP AND TERMINATION DETAIL

No Scale

NOTE: Use a certified welder to weld according to AWS D1.4.
Use filler material meeting the requirements of AWS A5.5.

MONTANA DEPARTMENT OF TRANSPORTATION

M.R.L. OVERPASS AT LOGAN

AT STA. 20+48.70

FEDERAL AID PROJECT NO. IM 0002(697)

GALLATIN COUNTY

PIER NO. 3

Scale ~ as noted

| | | |
|---|---|---|
| DESIGNED | 1-30-02 | K.T.B. |
| DRAWN | 2-25-02 | J.D.L. |
| CHECKED | 1-9-06 | M.L.R. |
| REVISED | | |
| REVISED | | |
| REVISED | | |

FILENAME: 3095BRPRD002.dgn DRAWING NO. 19663

BRIDGE BUREAU

$username$

$FILEABBREV$
$DATE$
$TIME$

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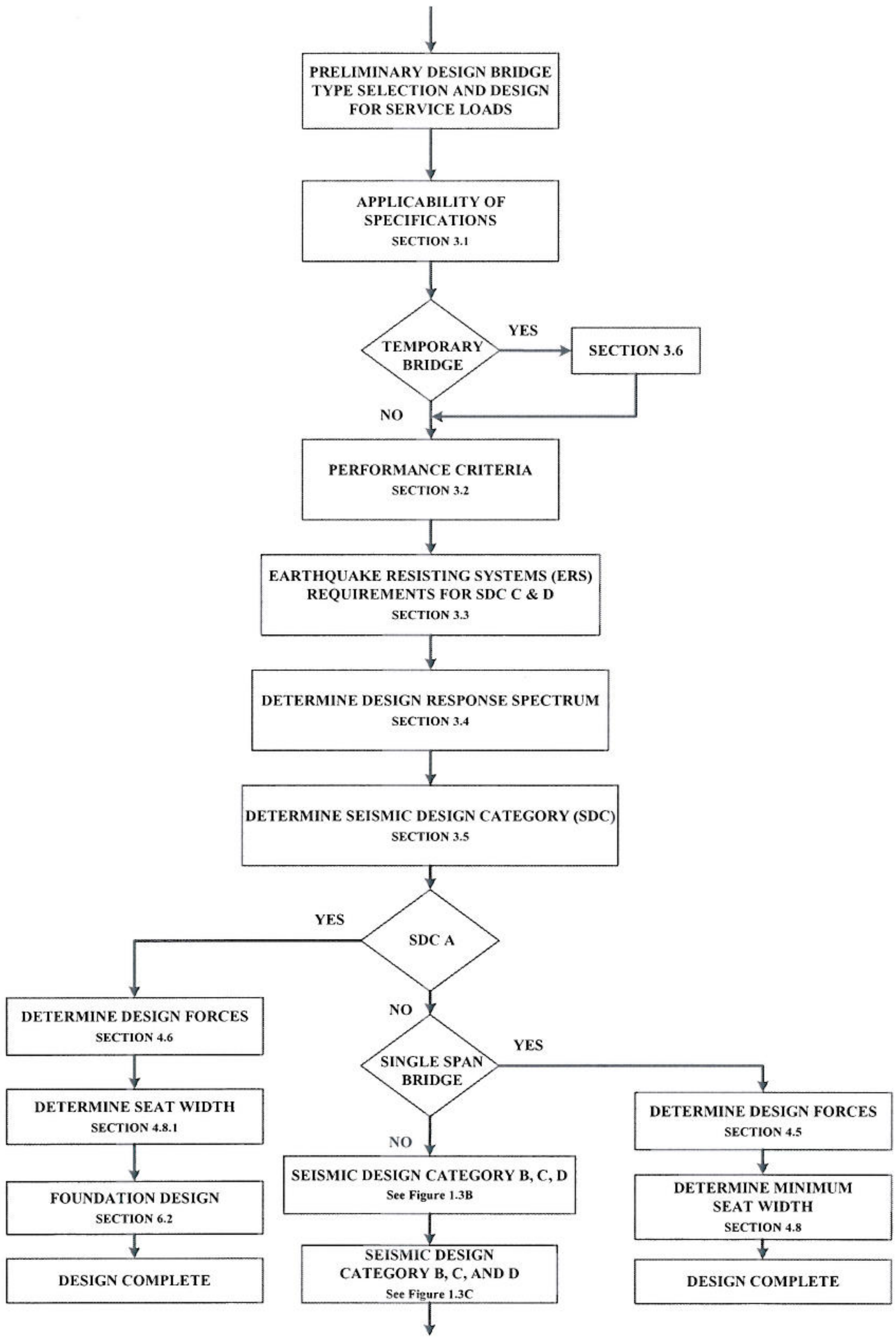



**FIGURE 1.3A: Design Procedure Flow Chart A**

# Trial Design of a 3-Span Continuous Steel Girder Bridge on Large Diameter Drilled Shaft Piers in Seismic Design Category B using the Proposed LRFD Seismic Design Guidelines 2006

***Prepared by Montana Department of Transporation,for the AASHTO T-3 Subcommittee***

## *Design Procedure Flowchart A*

### Applicability of Specifications (3.1)

This structure consists of a 3-span continuous rolled steel girder with a composite concrete deck. Span lengths are 95 ft - 123 ft - 95 ft for a total bridge length of 313 ft. Spans do not exceed 500 ft and construction is conventional, therefore this specification applies.

### Performance Criteria (3.2)

Design for the life safety performance objective considering a design event with a 5% probability of exceedance in 50 years.

### Seismic Ground Shaking Hazard (3.4)

Subsurface Boring Logs indicate bearing stratum to be comprised of limestone with standardized blow counts greater than 50 blows/ft (N > 50) with overlying layers of sand, gravel, clay, and non-cohesive fills, generally with blow counts in the range of 15 > N > 50. Shear wave velocity measurements were not taken at this particular site. The limestone material best matches Site Class C description, and the remaining layers would be most appropriately labeled Site Class D. Use Site Class D for determining Response Spectra for the site.

There are no active faults within 6 miles of the project vicinity. Liquefaction potential is low for this site and will not be considered in this design. Site specific procedures for determining response spectra will not be necessary.

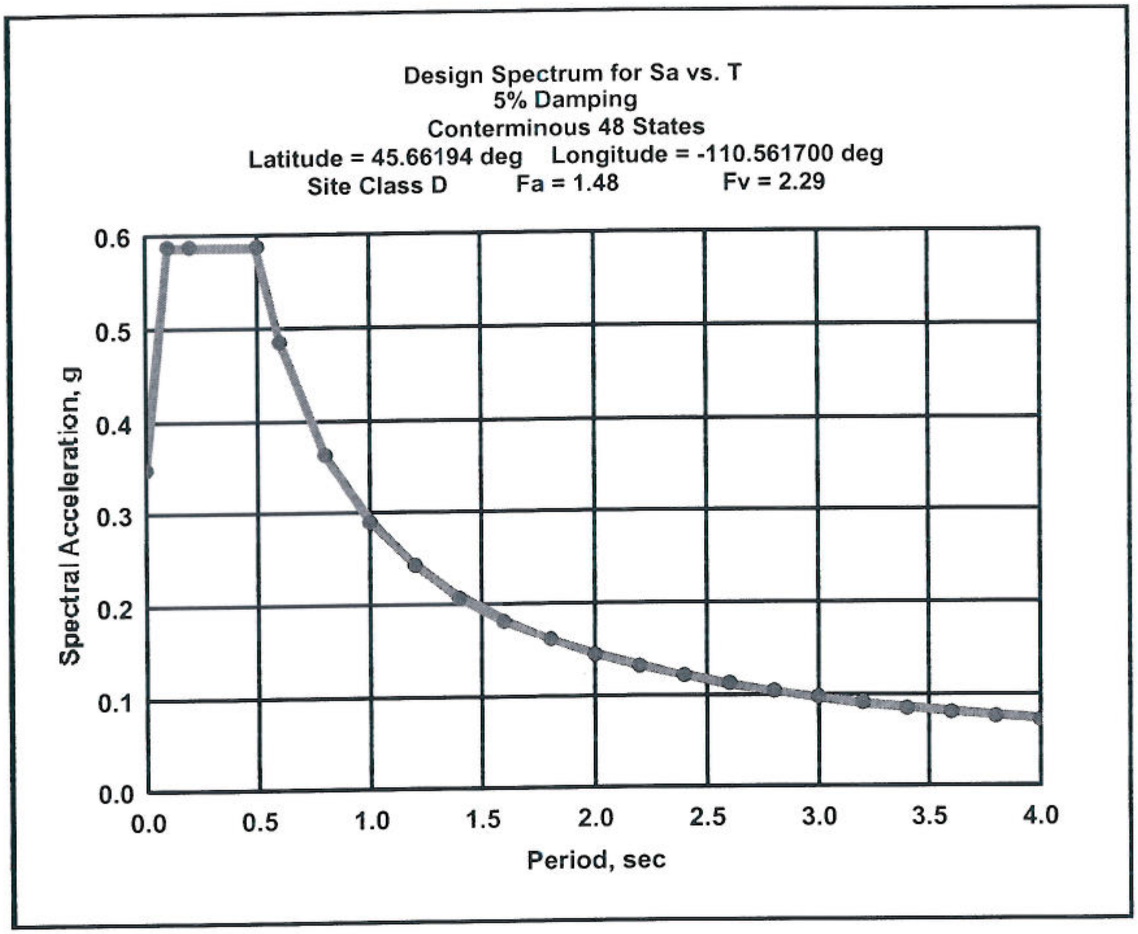
Design Response Spectrum constructed using 2-point method (Ss and S1) obtained from the *Seismic Design Parameters* published by USGS.

### Selection of Seismic Design Category (SDC) (3.5)

Latitude = 45.66194 decimal degrees
Longitude = -110.5617 decimal degrees
Site Class D

$S_{D1} := .290$ Design spectral response acceleration parameter at one second.

SDC = B for $0.15g < S_{D1} < 0.30g$




| Graph Data | |
|---|---|
| Period, sec | Sa, g |
| 0.00 | 0.3474 |
| 0.10 | 0.5868 |
| 0.20 | 0.5868 |
| 0.50 | 0.5868 |
| 0.60 | 0.4842 |
| 0.80 | 0.3631 |
| 1.00 | 0.2905 |
| 1.20 | 0.2421 |
| 1.40 | 0.2075 |
| 1.60 | 0.1816 |
| 1.80 | 0.1614 |
| 2.00 | 0.1453 |
| 2.20 | 0.1320 |
| 2.40 | 0.1210 |
| 2.60 | 0.1117 |
| 2.80 | 0.1038 |
| 3.00 | 0.0968 |
| 3.20 | 0.0908 |
| 3.40 | 0.0854 |
| 3.60 | 0.0807 |
| 3.80 | 0.0764 |
| 4.00 | 0.0726 |

Conterminous 48 States
2006 AASHTO Bridge Design Guidelines
AASHTO Spectrum for 5% PE in 50 years
Latitude = 45.661940
Longitude = -110.561700
B/C Boundary
Data are based on a 0.05 deg grid spacing.

| Period (sec) | Sa (g) | |
|---|---|---|
| 0.2 | 0.397 | Ss, B/C Boundary |
| 1.0 | 0.127 | S1, B/C Boundary |

Conterminous 48 States
2006 AASHTO Bridge Design Guidelines
Spectral Response Accelerations SMs and SM1
Latitude = 45.661940
Longitude = -110.561700
SMs = FaSs and SM1 = FvS1
Site Class D - Fa = 1.48, Fv = 2.29
Data are based on a 0.05 deg grid spacing.

| Period (sec) | Sa (g) | |
|---|---|---|
| 0.2 | 0.587 | SMs, Site Class D |
| 1.0 | 0.291 | SM1, Site Class D |

Conterminous 48 States
2006 AASHTO Bridge Design Guidelines
Map Response Spectra for Site Class B
Latitude = 45.661940
Longitude = -110.561700
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.00, Fv = 1.00
Data are based on a 0.05 deg grid spacing.

| Period (sec) | Sa (g) | Sd in. |
|---|---|---|
| 0.000 | 0.159 | 0.000 |
| 0.064 | 0.397 | 0.016 |
| 0.200 | 0.397 | 0.155 |
| 0.320 | 0.397 | 0.397 |
| 0.400 | 0.317 | 0.496 |
| 0.600 | 0.211 | 0.744 |
| 0.800 | 0.159 | 0.992 |
| 1.000 | 0.127 | 1.239 |
| 1.200 | 0.106 | 1.487 |
| 1.400 | 0.091 | 1.735 |
| 1.600 | 0.079 | 1.983 |
| 1.800 | 0.070 | 2.231 |
| 2.000 | 0.063 | 2.479 |
| 2.200 | 0.058 | 2.727 |
| 2.400 | 0.053 | 2.975 |
| 2.600 | 0.049 | 3.222 |
| 2.800 | 0.045 | 3.470 |
| 3.000 | 0.042 | 3.718 |
| 3.200 | 0.040 | 3.966 |
| 3.400 | 0.037 | 4.214 |
| 3.600 | 0.035 | 4.462 |
| 3.800 | 0.033 | 4.710 |

| | | |
|---|---|---|
| 4.000 | 0.032 | 4.958 |

Conterminous 48 States
2006 AASHTO Bridge Design Guidelines
Design Response Spectra for Site Class D
Latitude = 45.661940
Longitude = -110.561700
SDs = FaSs and SD1 = FvS1
Site Class D - Fa = 1.48, Fv = 2.29
Data are based on a 0.05 deg grid spacing.

| Period (sec) | Sa (g) | Sd in. |
|---|---|---|
| 0.000 | 0.347 | 0.000 |
| 0.099 | 0.587 | 0.056 |
| 0.200 | 0.587 | 0.229 |
| 0.495 | 0.587 | 1.405 |
| 0.600 | 0.484 | 1.703 |
| 0.800 | 0.363 | 2.271 |
| 1.000 | 0.291 | 2.838 |
| 1.200 | 0.242 | 3.406 |
| 1.400 | 0.208 | 3.974 |
| 1.600 | 0.182 | 4.541 |
| 1.800 | 0.161 | 5.109 |
| 2.000 | 0.145 | 5.677 |
| 2.200 | 0.132 | 6.244 |
| 2.400 | 0.121 | 6.812 |
| 2.600 | 0.112 | 7.379 |
| 2.800 | 0.104 | 7.947 |
| 3.000 | 0.097 | 8.515 |
| 3.200 | 0.091 | 9.082 |
| 3.400 | 0.085 | 9.650 |
| 3.600 | 0.081 | 10.218 |
| 3.800 | 0.076 | 10.785 |
| 4.000 | 0.073 | 11.353 |

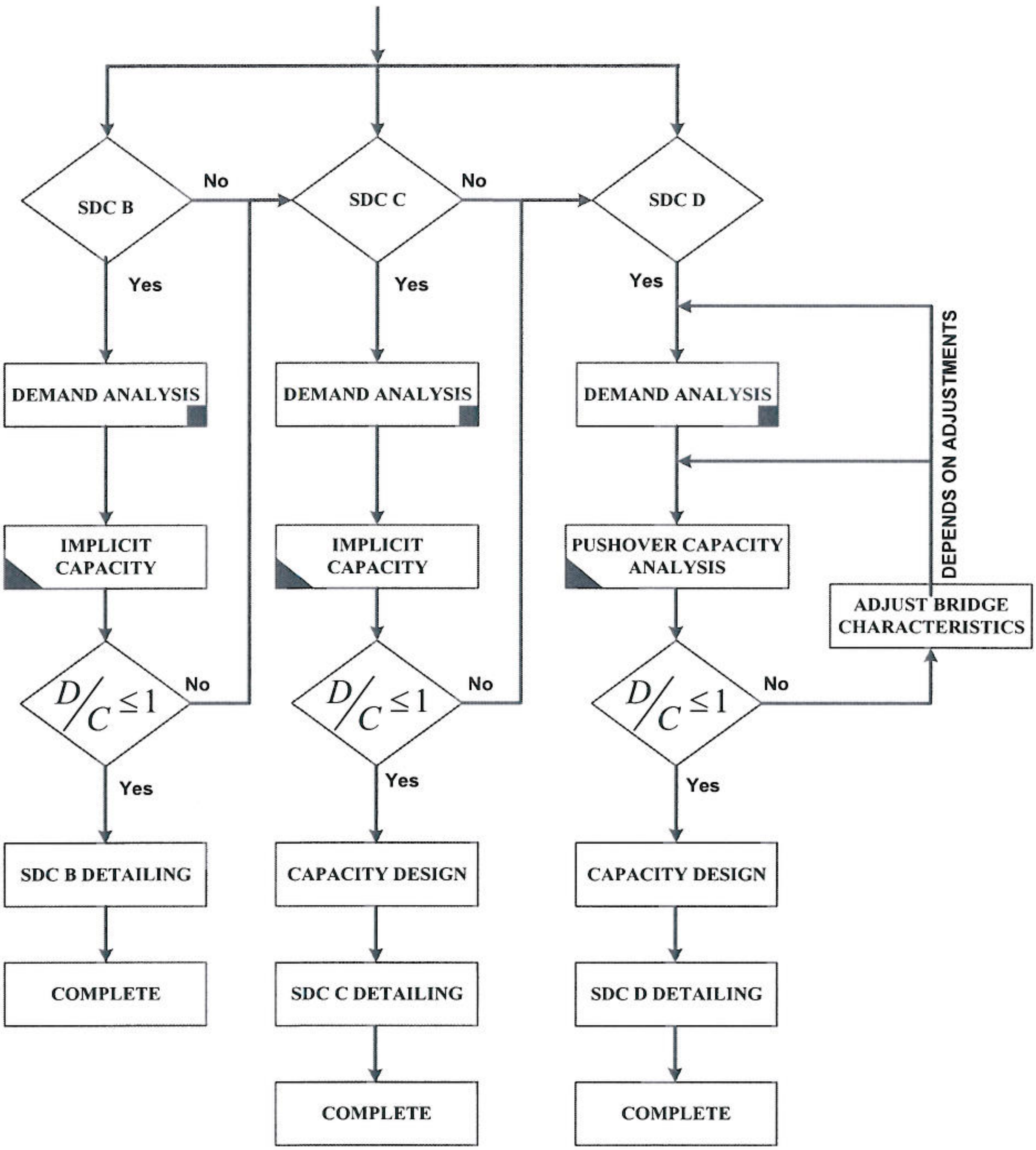



**FIGURE 1.3B: Design Procedure Flow Chart B**

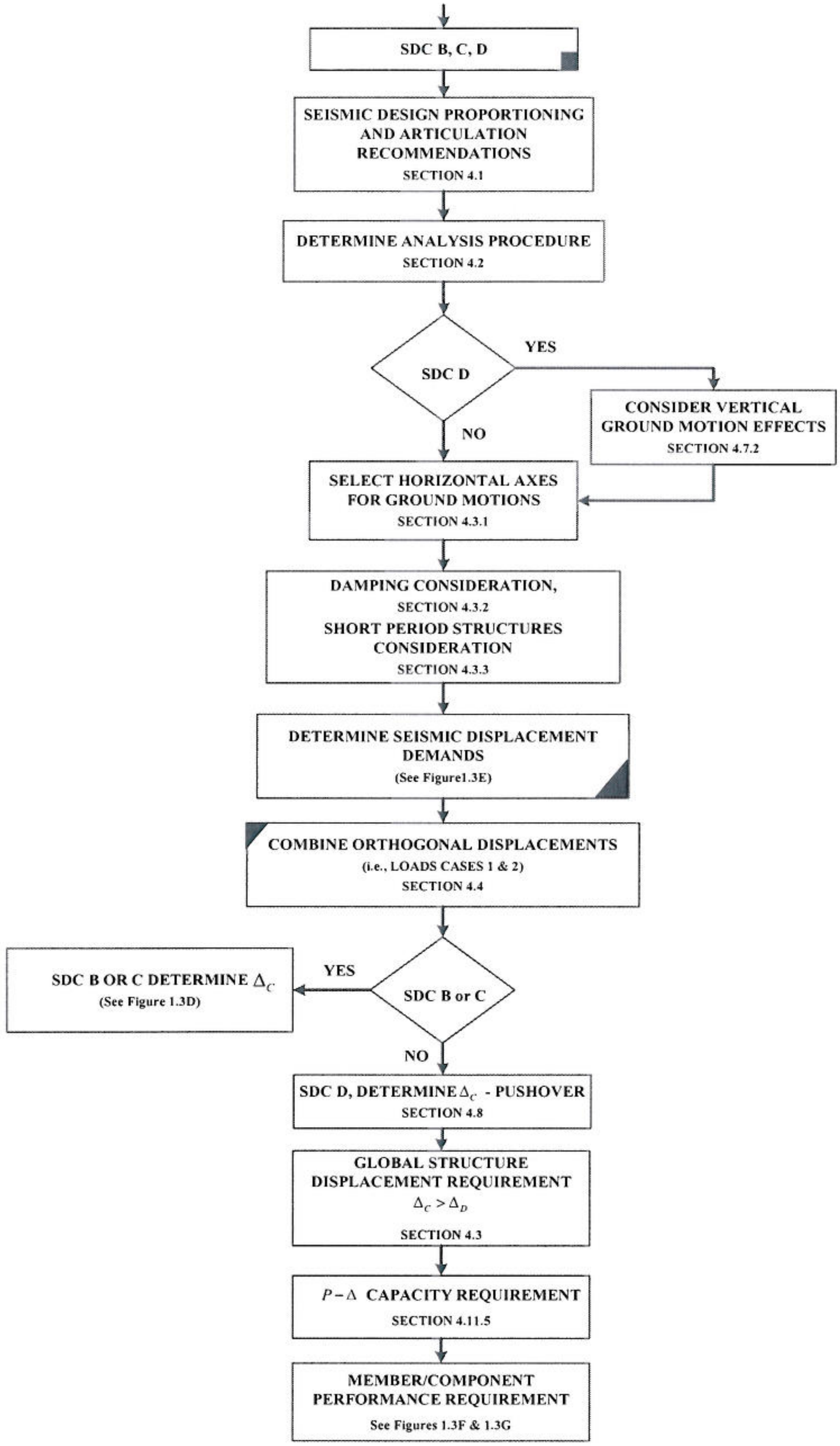



**FIGURE 1.3C: Design Procedure Flow Chart C**

## *Design Procedure Flowchart C*

### Seismic Design Proportioning and Articulation Recommendations (4.1.2)

By inspection this requirement is satisfied.

### Select Analysis Procedure (4.2)

The structure is a regular 3 span bridge in SDC B. Use analysis procedure 2 (Multimodal Spectral) suggested in Table 4.1.

### Seismic Lateral Displacement Demands (4.3)

Determine Global seismic displacement demands independently along two perpendicular axes coincident with the centerline of the roadway and superstructure, and centerline of the piers.

Length = 313 ft,
Regular plan geometry,
Abutments designed to sustain soil mobilization,
Continuous superstructure without hinges and expansion joints

$\xi := 0.05$

$$R_D := \left(\frac{0.05}{\xi}\right)^{.4}$$

Reduction Factor:

$R_D = 1$

### Displacement Magnification for Short Period Structures (4.3.3)

$$T := 2\cdot\pi\cdot\sqrt{\frac{m}{k}}$$

Basic equation for the fundamental period of vibration.

- Material properties of the structure.

$\gamma_{concrete} := .150\text{kcf}$ — Unit weight of concrete.

$\gamma_{steel} := .49\text{kcf}$ — Unit weight of steel.

$f'_{c1} := 3\cdot\text{ksi}$ — Compressive strength of concrete in substructure.

$$E_{c1} := 33000\text{ksi}\cdot\left(\frac{\gamma_{concrete}}{\text{kcf}}\right)^{1.5}\cdot\sqrt{\frac{f'_{c1}}{\text{ksi}}}$$

Modulus of Elasticity of Concrete (LRFD 5.4.2.4)

$E_{c1} = 3320.56\ \text{ksi}$

$f'_{c2} := 4.5\text{ksi}$ — Compressive strength of concrete in deck.

$$E_{c2} := 33000\text{ksi}\cdot\left(\frac{\gamma_{concrete}}{\text{kcf}}\right)^{1.5}\cdot\sqrt{\frac{f'_{c2}}{\text{ksi}}}$$

Modulus of Elasticity of Concrete

$E_{c2} = 4066.84\ \text{ksi}$

- Determine effective seismic mass.

$W_{deck} := (33.583ft)\cdot(8in)\cdot(313.25ft)\,\gamma_{concrete}$ $\qquad W_{deck} = 1051.99\,kip$

$W_{barrier} := 2\cdot 2.38ft^2\cdot(313.25ft)\,\gamma_{concrete}$ $\qquad W_{barrier} = 223.66\,kip$

$W_{beams} := 4\cdot(313.25ft)\cdot\left(247\frac{lb}{ft}\right)$ $\qquad W_{beams} = 309.49\,kip$

$W_{diaphragms} := 42.7\frac{lb}{ft}(8.92ft)\cdot(3)\cdot(15) + 105.3in^3\cdot(\gamma_{steel})\cdot(6)\cdot(15)$ $\qquad W_{diaphragms} = 19.83\,kip$

$W_{pier\_cap} := \left[[3.25\cdot ft\cdot(3.25\cdot ft)\cdot 31.5\cdot ft] + 4.92\cdot ft\cdot(3.25\cdot ft)\cdot\left(\frac{31.5\cdot ft}{2}\right)\right]\cdot\gamma_{concrete}$ $\qquad pier\_cap = 87.68\,kip$

$W_{wear\_surface} := 10\frac{lb}{ft^2}\cdot(313.25ft)\cdot 30.833ft$ $\qquad W_{wear\_surface} = 96.58\,kip$

$W_s := W_{deck} + W_{barrier} + W_{wear\_surface} + W_{beams} + W_{diaphragms} + 2W_{pier\_cap}$

$W_s = 1876.92\,kip$

$m := \frac{W_s}{g}$ *Effective Seismic Mass*

Assuming that the stiffness of the superstructure is significantly larger than the stiffness of the substructure elements, substructure elements will control period calculation.

- Determine total stiffness of bridge - Longitudinal

Stiffness at the abutment (soil only, neglect pile contribution at this time):

$k_1 := \frac{20\frac{kip}{in}}{ft}\cdot\frac{(4.0ft\cdot 30.83ft)}{5.5ft}$ $\qquad k_1 = 5381.24\frac{kip}{ft}$

Stiffness of the piers:

$\phi_{pier} := 6ft$

$I_{g\_pier} := \frac{\pi\cdot\phi_{pier}^4}{64}$ $\qquad I_e := I_{g\_pier}$

$I_e := 0.32\cdot I_{g\_pier}$ Effective Flexural Stiffness per Figure 5.4

$H_e := 43ft$ For stiffness calculations, assume effective length is from top of cap to point of fixity below ground line.

$$k_2 := \frac{3 \cdot E_{c1} \cdot I_e}{H_e^{\,3}}$$

$$k_2 = 1147.8\,\frac{kip}{ft}$$

$$k_{T\_long} := k_1 + 2 \cdot k_2$$

*Longitudinal Stiffness of the structure*

$$k_{T\_long} = 7676.83\,\frac{kip}{ft}$$

$$T_{long} := 2 \cdot \pi \cdot \sqrt{\frac{m}{k_{T\_long}}}$$

*Longitudinal Period of the structure*

$$T_{long} = 0.55\,s$$

- Determine total stiffness of bridge - Transverse

  Stiffness of the wingwalls (soil only, neglect pile contribution):

$$k_3 := \frac{20\,\frac{kip}{in}}{ft} \cdot \frac{(6.583ft \cdot 6.583ft)}{5.5ft}$$

$$k_3 = 1891.02\,\frac{kip}{ft}$$

Stiffness of the piers:

Piers are symmetrical in shape about longitudinal and transverse axes.

$$k_2 = 1147.8\,\frac{kip}{ft}$$

Total stiffness of the structure - transverse:

$$k_{T\_transv} := 2k_3 + 2 \cdot k_2$$

*Transverse Stiffness of the structure*

$$k_{T\_transv} = 6077.63\,\frac{kip}{ft}$$

$$T_{transv} := 2 \cdot \pi \cdot \sqrt{\frac{m}{k_{T\_transv}}}$$

*Transverse Period of the structure*

$$T_{transv} = 0.62\,s$$

- Determine T' for Mean Earthquake Moment Magnitude (Mw):

Site Class = D

$S_s := 0.587$

$0.4 \cdot S_s = 0.23$

$T' := 0.49s$ Characteristic Ground Motion Period (Table 4.3).

SDC = B

$R := 2$ from Art 4.3.3 and 4.4.

$$T := \begin{pmatrix} T_{long} \\ T_{transv} \end{pmatrix} \qquad \frac{T'}{T} = \begin{pmatrix} 0.89 \\ 0.8 \end{pmatrix}$$

*Design displacement demand factor:*

$$R_{d\_long} := \text{if}\left[\frac{T'}{T_{long}} \geq 1, \left(1 - \frac{1}{R}\right) \cdot \frac{T'}{T_{long}} + \frac{1}{R}, 1\right] \qquad R_{d\_long} = 1$$

$$R_{d\_transv} := \text{if}\left[\frac{T'}{T_{transv}} \geq 1, \left(1 - \frac{1}{R}\right) \cdot \frac{T'}{T_{transv}} + \frac{1}{R}, 1\right] \qquad R_{d\_transv} = 1$$

## Combination of Orthogonal Seismic Displacement Demands (4.4)

$$LC1 := 1.0 \cdot (\Delta_{long}) \cdot R_{d\_long} + 0.30 \cdot (\Delta_{transv}) \cdot R_{d\_transv} \qquad 1.0 \cdot R_{d\_long} = 1 \qquad 0.3 \cdot R_{d\_transv} = 0.3$$

$$LD2 := 0.30 \cdot (\Delta_{long}) \cdot R_{d\_long} + 1.0 \cdot (\Delta_{transv}) \cdot R_{d\_transv} \qquad 0.3 \cdot R_{d\_long} = 0.3 \qquad 1.0 \cdot R_{d\_transv} = 1$$

## *Go to Flow Chart E to determine displacement demand $\Delta_D$*

## Displacement Capacity for SDC B (4.8.1)

$\Delta_D := .14ft$ Ductile member (drilled shaft pier) displacement demand along the local principal axes resulting from seismic motion applied to the total structural system. Result from SEISAB analysis, transverse direction controls.

$B_o := \phi_{pier}$ Column diameter = 6.0 ft

$H_o := 35ft$ Clear height of column from point of fixity below ground to bottom of cap.

$\Lambda := 1.0$ fixity factor for pinned top and fixed bottom

$$x := \Lambda \cdot \frac{B_o}{H_o} \qquad x = 0.17$$

$$\Delta_C := \max\left[\frac{H_o}{100}\cdot(-1.27\cdot\ln(x) - 0.32), \frac{H_o}{100}\right]$$

$\Delta_C = 0.67\ \text{ft}$

$\frac{H_o}{100} = 0.35\ \text{ft}$

$\frac{H_o}{100}\cdot(-2.32\cdot\ln(x) - 1.22) = 1.01\ \text{ft}$

$\Delta_C > \Delta_D = 1$

$\frac{H_o}{100} > \Delta_D = 1$

Displacement capacity exceeds demand - OK.

## *Design Procedure Flowchart D*

### Satisfy Support Width Requirements for SDC B (4.12)

$\Delta_{eq} := 2.94\text{in}$ Seismic demand displacement.

$S_k := 0\text{deg}$ Skew angle of support.

$\Delta_{ot} := \frac{1\text{in}}{100\text{ft}}\cdot 313.25\text{ft}$ $\Delta_{ot} = 3.13\ \text{in}$ Movement due to thermal expansion, etc.

$$N_{req} := \max\left[\left(4\cdot\text{in} + \Delta_{ot} + 1.65\cdot\Delta_{eq}\right)\cdot\frac{1 + S_k^{\,2}}{4000}, 12\text{in}\right]$$

$N_{req} = 12\ \text{in}$ Minimum required seat width

$N_{abut} := 19.625\text{in}$

$N_{abut} > N_{req} = 1$

Seat width provided is adequate.

## *Design Procedure Flowchart E*

Mathematical modeling for the bridge in a SDC B will be similar to those for SDC C except elastic section properties will be used in the model for the drilled shaft.

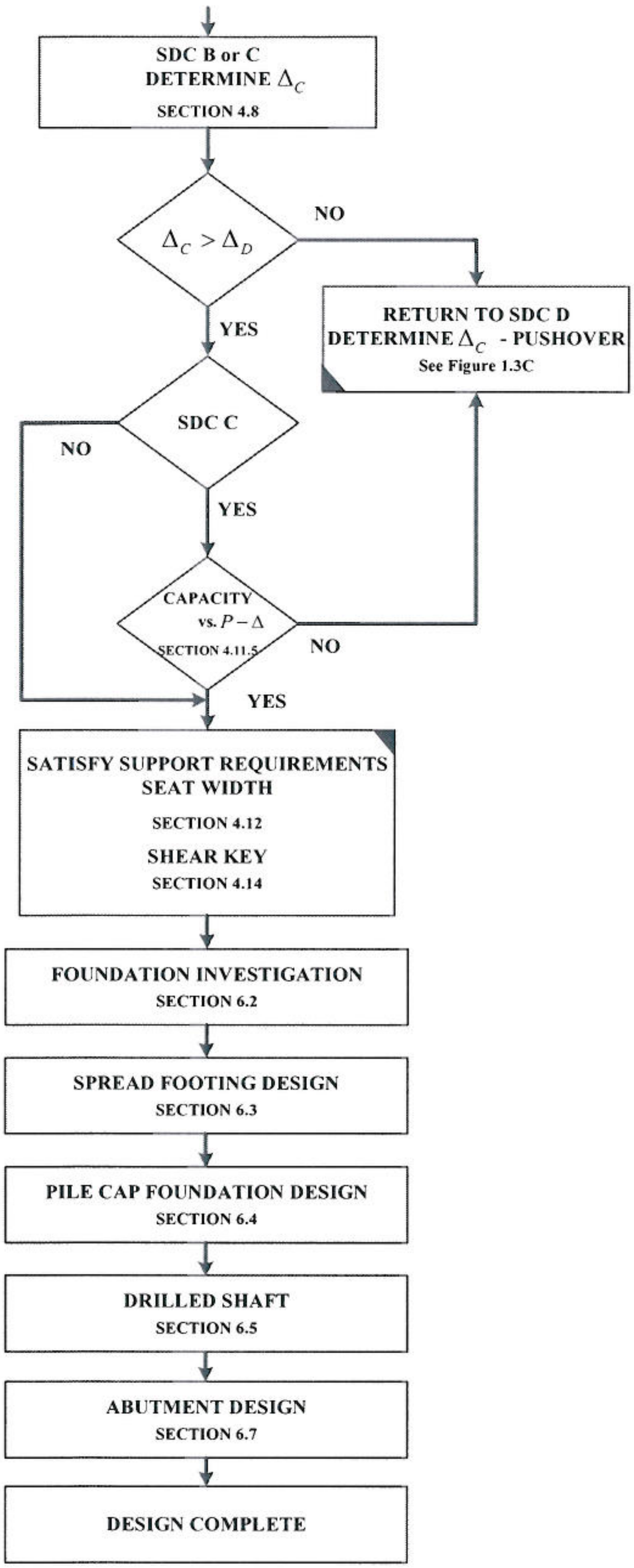



**FIGURE 1.3D: Design Procedure Flow Chart D**

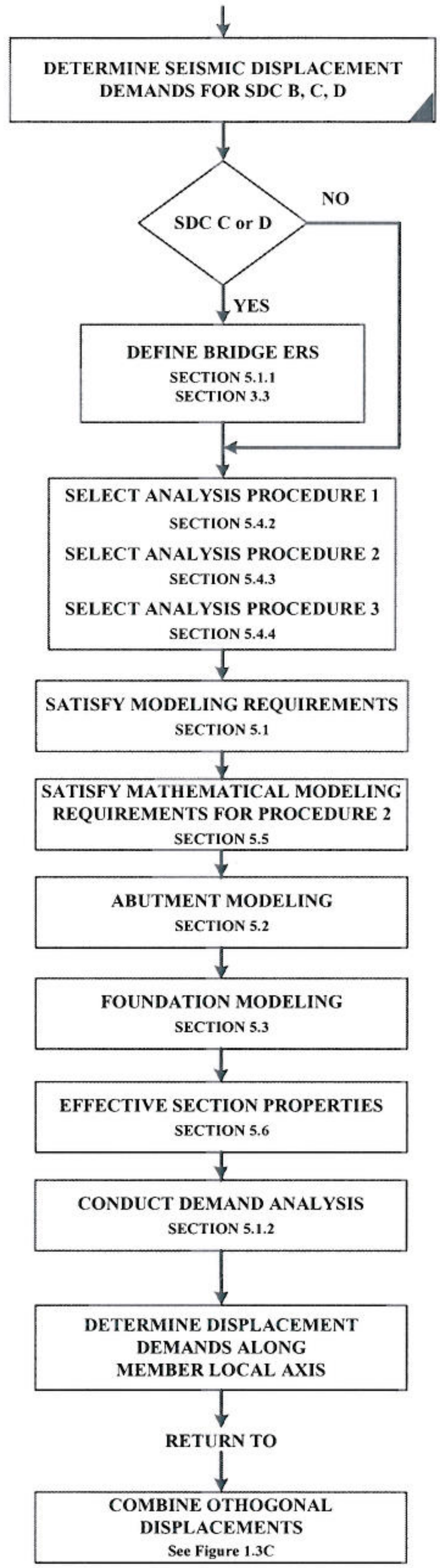



**FIGURE 1.3E: Design Procedure Flow Chart E**

# Trial Design of a 3-Span Continuous Steel Girder Bridge on Large Diameter Drilled Shaft Piers using the Proposed LRFD Seismic Design Guidelines 2006

***Prepared by Montana Department of Transporation for the AASHTO T-3 Subcommittee***

## *Design Procedure Flowchart E*

### Analytical Model and Procedures (5.1.2 & 5.4)

Use SEISAB V 5.0.5 to perform a Linear Elastic Multi-Modal Spectral Analysis.
Develop mathematical model of the structure using information below.

### Abutments - passive pressure (5.2)

Determine passive pressure at abutments using Mononobe-Okabe Analysis (LRFD Art. A11.1.1.1)

$E_{PE}(\gamma, H, k_v, K_{PE}) := \frac{1}{2}\cdot\gamma\cdot H^2\cdot(1 - k_v)\cdot K_{PE}$ Passive force if abutment is being pushed into the backfill.

$\beta := 0\cdot deg$ Backfill slope with respect to horizontal.

$i := 0\cdot deg$ Wall slope with respect to vertical.

$\phi_f := 35\cdot deg$ Angle of internal friction of backfill

$\gamma_{soil} := .130\cdot kcf$ Unit weight of soil

$\delta_s := 30\cdot deg$ Angle of friction between backfill and wall. (Table 5-1, ATC 32-1, P. 75)

$k_h := \frac{.366}{2}$ Horizontal acceleration coefficient, assumed 1/2 of PGA.

$k_v := 0$ Vertical acceleration coefficient, assumed zero for max horizontal effects on semi-integral stub abutment.

$\theta_a := atan\left(\frac{k_h}{1 - k_v}\right)$ Seismic intertial angle.

$\theta_a = 10.37\,deg$

Passive Pressure coefficient due to earthquake forces using Mononobe-Okabe Analysis.

$$K_{PE} := \frac{\cos(\phi_f - \theta_a + \beta)^2}{\cos(\theta_a)\cdot\cos(\beta)^2\cdot\cos(\delta_s - \beta + \theta_a)}\cdot\left(1 - \sqrt{\frac{\sin(\phi_f - \theta_a + i)\cdot\sin(\phi_f + \delta_s)}{\cos(\delta_s - \beta + \theta_a)\cdot\cos(i - \beta)}}\right)^{-2}$$

$K_{PE} = 12.59$

## Abutment - Longitudinal (5.2.2)

$w_{abw} := 30.833 \cdot ft$ Width of the abutment between fill face of wingwalls.

$h_{abw} := 4.0 \cdot ft$ Height of abutment wall is the portion integral with superstructure and diaphragm.

$t_{abw} := 1.635ft$ Thickness of abutment wall and diaphragm.

$E_{PE\_long} := E_{PE}(\gamma_{soil}, h_{abw}, k_v, K_{PE})$

Passive force on abutment wall per foot length of wall:

$E_{PE\_long} = 13.1 \frac{kip}{ft}$

$p_{avg} := \frac{E_{PE\_long}}{h_{abw}}$

Passive pressure on abutment wall:

$p_{avg} = 3.27 \frac{kip}{ft^2}$

$\zeta := .02$

Displacement factor, ratio of wall rotation or translation to wall height necessary to develop full passive soil resistance, (Table 5-2, ATC 32-1, P. 77)

$\Delta_p := \zeta \cdot h_{abw}$

Displacement of wall required to develop full passive pressure.

$\Delta_p = 0.96 \, in$

$KF1 := \frac{p_{avg} \cdot w_{abw} \cdot h_{abw}}{\Delta_p}$

Abutment longitudinal stiffness when backwall is mobilized to develop full passive pressure.

$KF1 = 5048 \frac{kip}{ft}$

$KM2 := \frac{p_{avg} \cdot w_{abw} \cdot h_{abw}}{\Delta_p} \cdot \frac{w_{abw}^2}{12}$

Rotational stiffness of abutment wall into the soil. Fig 5-7, ATC 32-1, P. 73.

$KM2 = 4.00 \times 10^5 \frac{kip \cdot ft}{rad}$

$KM3 := \frac{p_{avg} \cdot w_{abw} \cdot h_{abw}}{\Delta_p} \cdot \frac{h_{abw}^2}{12}$

$KM3 = 6730.19 \frac{kip \cdot ft}{rad}$

$KF1_{compression} := \frac{KF1}{2}$

For the SEISAB model, springs are tension/compression, therefore use 1/2 of the compression stiffness for one abutment at each end.

$KF1_{compression} = 2523.82 \frac{kip}{ft}$

## Abutments - Transverse : Wingwalls (5.2.2)

$h_{wing} := 6.583ft$ — Wingwall geometry, similar both abutments.

$l_{wing} := 6.583ft$

$t_{wing} := 1.375ft$

Assume soil resistance mobilized by wingwalls is 2/3 of one wingwall acting against abutment fill, and 1/3 of opposite wall acting against roadway embankment.

$$E_{PE\_T1} := E_{PE}\left(\gamma_{soil}, \frac{2}{3}h_{wing}, k_v, K_{PE}\right)$$

$$E_{PE\_T2} := E_{PE}\left(\gamma_{soil}, \frac{1}{3}h_{wing}, k_v, K_{PE}\right)$$

Passive force on wingwall per foot length of wall:

$$E_{PE\_T1} = 15.77\frac{kip}{ft}$$

$$E_{PE\_T2} = 3.94\frac{kip}{ft}$$

$$KF3_{wing} := \frac{E_{PE\_T1}\cdot l_{wing}}{\zeta\cdot\frac{2}{3}h_{wing}} + \frac{E_{PE\_T2}\cdot l_{wing}}{\zeta\cdot\frac{1}{3}h_{wing}}$$

Transverse stiffness of wingwalls at abutment.

$$KF3_{wing} = 1773.62\frac{kip}{ft}$$

$$\Delta_T := \zeta\cdot h_{wing}$$

Maximum transverse displacement of abutment in transverse direction if passive soil resistance used as part of ERS system. Shear keys allowed as part of ERS for bridges in SDC C. (Art. 5.2.4)

$$\Delta_T = 1.58\,in$$

$n_{piles} := 4$

$E_s := 29000ksi$

$I_{pile} := 1460in^4$

$$K_h := 125\frac{kip}{ft^2}$$

Modulus of subgrade reaction for cohesive soil with blow counts in the range of 8-15 blows/ft.

$$L_{pile} := 18.8ft + 0.44\cdot\left(\frac{E_s\cdot I_{pile}}{K_h}\right)^{0.25}$$

Length of pile for stiffness calculations, is depth to fixity from below sleeved portion of pile.

$$L_{pile} = 21.86\,ft$$

$$KF3_{piles} := n_{piles}\cdot\frac{12\cdot E_s\cdot I_{pile}}{L_{pile}^3}$$

$$KF3_{piles} = 1350.29\frac{kip}{ft}$$

$KF3 := KF3_{wing} + KF3_{piles}$ $KF3 = 3123.91\,\frac{kip}{ft}$

## Foundation Modelling Method (5.3.4)

$\phi_{shaft} := 6ft$ Drilled shaft foundation diameter.

$elev_{ground2} := 4102.69ft$ $elev_{ground3} := 4104.33ft$

$elev_{tip2} := 4050.20ft$ $elev_{tip3} := 4060.04ft$

Use estimated depth to fixity, verify assumptions with P-Y curves.

Use Figure 20.4D of MDT Bridge Design Manual Volume II- Depth To Point of Effective Fixity for Drilled Shafts in Clay. Subsurface Boring Logs for the site indicate layers of clayey materials with average N values of 10 blows/ft over a hard limestone layer. Shaft tip will extend into limestone layer.

$N_o := 3$ Depth to effective fixtiy is approximately 3 shaft diameters below ground line.

$N_o \cdot \phi_{shaft} = 18\,ft$

$DF_{Lpile} := 14.76ft$ Iterations with Lpile analysis indicate depth to moment fixity is approximately 14.76ft below ground line.

$elev_{bot2} := elev_{ground2} - DF_{Lpile}$ $elev_{bot2} = 4087.93\,ft$

$elev_{bot3} := elev_{ground3} - DF_{Lpile}$ $elev_{bot3} = 4089.57\,ft$

## Structure Modelling (5.5 & 5.6)

*Material Properties*

$f'_{c\_DD} := 3.000ksi$ Compressive strength of substructure concrete.

$f'_{c\_SD} := 4.500ksi$ Compressive strength of superstructure concrete.

$\gamma_c := 0.15kcf$ Unit weight of concrete.

$$E_c(f'_c, \gamma_c) := 33000 \cdot \left(\frac{\gamma_c}{kcf}\right)^{1.5} \cdot \sqrt{\frac{f'_c}{ksi}} \cdot ksi$$

Modulus of Elasticity of Concrete for normal weight concrete (ksi). Assume K1 = 1.0 for aggregate type. (LRFD Art 5.4.2.4)

$E_s := 29000ksi$ Steel Modulus of Elasticity

$\gamma_s := .49kcf$ Unit weight of steel.

*Steel Girders*

$n_b := 4$ Number of beams

$s := \begin{pmatrix} 4.59 \\ 13.78 \end{pmatrix} \cdot ft$ Beam spacing from CL of structure

$A_b := 72.5 \cdot in^2$ W 36 x 247 Beam Section Properties

$I_{33b} := 16700 in^4$ Beam Elastic Inertia about strong local axis

$I_{22b} := 1010 in^4$ Beam Elastic Inertia about weak local axis

$y_b := \frac{36.67in}{2}$ Beam neutral axis from top of beam

*Concrete Deck Slab*

$t_s := 8in - 1.375in$ Slab depth minus integral wearing surface.

$w_s := 33.5833 \cdot ft$ Slab width

$t_h := .886 \cdot in$ Haunch depth from top of flange to bottom of slab.

$E_{cs} := E_c(f'_{c\_SD}, \gamma_c)$ $E_{cs} = 4066.84\,ksi$

*Composite Superstructure*

$n := round\left(\frac{E_s}{E_{cs}}, 0\right)$

Modular Ratio.
Transform steel to concrete for SEISAB Model.

$n = 7.000$

$A_{st} := t_s \cdot w_s + n \cdot n_b \cdot A_b$

Transformed superstructure area

$A_{st} = 32.64\,ft^2$

$$y_{st} := \frac{t_s \cdot w_s \cdot \left(\frac{t_s}{2}\right) + n \cdot n_b \cdot A_b \cdot (t_s + t_h + y_b)}{(t_s \cdot w_s) + n \cdot n_b \cdot A_b}$$

Distance from top of slab to neutral axis of transformed section

$y_{st} = 1.087\,ft$

$$I_{33st} := \frac{w_s \cdot t_s^3}{12} + w_s \cdot t_s \cdot \left(y_{st} - \frac{t_s}{2}\right)^2 + n \cdot n_b \cdot I_{33b} + n \cdot n_b \cdot A_b \cdot (y_{st} - y_b - t_s - t_h)^2$$

Elastic Inertia of Superstructure about "x" axis.

$I_{33st} = 51.26\,ft^4$

$$I_{22st} := \frac{t_s \cdot w_s^3}{12} + n \cdot n_b \cdot I_{22b} + 2 \cdot n \cdot A_b \cdot \sum s^2$$

Elastic Inertia of Superstructure about "y" axis.

$I_{22st} = 3230.9\,ft^4$

$T(x,y) := \frac{1}{3} \cdot x^3 \cdot y \cdot \left(1 - 0.63 \cdot \frac{x}{y}\right)$

Define function for torsional constant of rectangular sections. Reference Wang & Salmon, Reinforced Concrete Design.

$I_{11st} := T(t_s, w_s)$

Torsional constant of concrete deck slab.

$I_{11st} = 1.86\,ft^4$

$\rho_{st} := \frac{(w_s \cdot t_s \cdot \gamma_c + A_b \cdot n_b \cdot \gamma_s)}{A_{st}}$

Transformed section unit weight.

$\rho_{st} = 115\,\frac{lb}{ft^3}$

$\rho_{st} \cdot A_{st} = 3.77\,\frac{kip}{ft}$

*Additional Superstructure Weight*

$L_{bridge} := 313.25ft$

$W_{contingencies} := 1.375in \cdot w_s \cdot \gamma_c + .010\,\frac{kip}{ft^2} \cdot w_s$ $\quad W_{contingencies} = 913.05\,\frac{lb}{ft}$

$W_{barrier} := 2 \cdot \left(.357 \cdot \frac{kip}{ft}\right)$ $\quad W_{barrier} = 714\,\frac{lb}{ft}$

$W_{dia} := \frac{42.7\,\frac{lb}{ft} \cdot 3 \cdot 8.917ft \cdot 15}{L_{bridge}}$ $\quad W_{dia} = 54.7\,\frac{lb}{ft}$

$W_{additional} := W_{contingencies} + W_{barrier} + W_{dia}$ $\quad W_{additional} = 1.68\,\frac{kip}{ft}$

*Drilled Shaft and Pier Column*

$\phi_{col} := \phi_{shaft}$

$elev_{top2} := 4124.08ft$ $\quad elev_{top3} := 4122.16ft$

$A_{col} := \frac{\pi}{4} \cdot \phi_{col}^2$ $\quad A_{col} = 28.27\,ft^2$

Elastic Inertia of round column / pier.

$I_{33col} := \frac{\pi}{64} \cdot \phi_{col}^4$ $\quad I_{33col} = 63.62\,ft^4$

$I_{22col} := I_{33col}$ $\quad I_{22col} = 63.62\,ft^4$

Elastic Torsional constant of round column / pier.

$I_{11col} := \frac{\pi}{32} \cdot \phi_{col}^4$ $\quad I_{11col} = 127.23\,ft^4$

$E_{col} := E_c(f'_{c\_DD}, \gamma_c)$

Modulus of Elasticity of substructure concrete.

$E_{col} = 3320.56\ ksi$

$\frac{54in^2}{A_{col}} = 0.01$

Longitudinal steel reinforcement ratio in shaft/column.

$\frac{890kip}{f'_{c\_DD} \cdot A_{col}} = 0.07$

Axial load ratio, Extreme Event I load combination.

$f_{Ieff} := 0.32$ Cracked flexural stiffness factor (Fig 5.4).

$f_{Jeff} := 0.2$ Cracked torsional stiffness factor (C5.5.1).

*Intermediate Pier Cap*

Describe as "special cap" in SEISAB to eliminate modes with cap vibrating independently of superstructure.

$w_{cap} := 3.25 \cdot ft$

Cap width.

$d_{cap} := 4.9 \cdot ft$

Average depth of cap for use in stiffness calcs.

$A_{cap} := w_{cap} \cdot d_{cap}$

$A_{cap} = 15.93\ ft^2$

$I_{33cap} := \frac{w_{cap} \cdot d_{cap}^3}{12}$

Elastic Inertia about strong axis of cross section.

$I_{33cap} = 31.86\ ft^4$

$W_{cap} := 95 \cdot kip$

Weight of cap input into SEISAB for "special cap" option.

*Abutment Wall and Pile Cap*

Use section properties of the abutment wall in the model. Add the weight of the pile cap and wingwalls to the model.

$A_{abw} := w_{abw} \cdot t_{abw}$

Abutment wall cross sectional area.

$A_{abw} = 50.41\ ft^2$

$I_{33abw} := \frac{t_{abw} \cdot w_{abw}^3}{12}$

Elastic inertia about strong axis of cross section.

$I_{33abw} = 3993.8\ ft^4$

$I_{22abw} := \frac{w_{abw} \cdot t_{abw}^3}{12}$

Elastic inertia about weak axis of cross section.

$I_{22abw} = 11.2\ ft^4$

$I_{11abw} := T(t_{abw}, w_{abw})$ Elastic torsional constant.

$I_{11abw} = 43.42\,ft^4$

$W_{pilecap} := 3.25ft \cdot 3.25ft \cdot 33.583ft \cdot \gamma_c$ Weight of the pile cap.

$W_{pilecap} = 53.21\,kip$

$W_{wingwall} := 1.375ft \cdot 6.583ft \cdot 6.583ft \cdot \gamma_c$ Weigh of one wingwall.

$W_{wingwall} = 8.94\,kip$

$W_{foundation} := W_{pilecap} + 2 \cdot W_{wingwall}$ $W_{foundation} = 71.08\,kip$

$elev_{top1} := 4137.03ft - y_{st}$ Elevation of top node for model at Bent No. 1

$elev_{top1} = 4135.94\,ft$

$elev_{bot1} := 4132.97ft$

$elev_{top4} := 4132.12ft - y_{st}$ Elevatation of top node for model at Bent No. 4

$elev_{top4} = 4131.03\,ft$

$elev_{bot4} := 4128.06ft$

```
                    W      W  III  N    N
                    W      W   I   NN   N
                    W  W   W   I   N N  N
                     W W W     I   N   NN
                      W W     III  N    N

 SSSSSSS   EEEEEEEEE  IIIIIIIII   SSSSSSS    AAAAAAA    BBBBBBBB
SSSSSSSSS  EEEEEEEEE  IIIIIIIII  SSSSSSSSS  AAAAAAAAA   BBBBBBBBB
SS     SS  EE            III     SS     SS  AA     AA   BB     BB
SSS        EE            III     SSS        AA     AA   BB    BBB
 SSSSSS    EEEEE         III      SSSSSS    AAAAAAAAA   BBBBBBBB
  SSSSSS   EEEEE         III       SSSSSS   AAAAAAAAA   BBBBBBBB
      SSS  EE            III           SSS  AA     AA   BB    BBB
SS     SS  EE            III     SS     SS  AA     AA   BB     BB
SSSSSSSSS  EEEEEEEEE  IIIIIIIII  SSSSSSSSS  AA     AA   BBBBBBBBB
 SSSSSSS   EEEEEEEEE  IIIIIIIII   SSSSSSS   AA     AA   BBBBBBBB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*                          WinSeisab                            *
*                                                               *
*                Seismic Analysis of Bridges                    *
*                                                               *
*       Version 5.0.5                   Release 07/2002         *
*                                                               *
*                                                               *
*                                                               *
*                  Imbsen Software Systems                      *
*                                                               *
*                      www.Imbsen.com                           *
*                                                               *
*                                                               *
*                                                               *
*          Windows (GUI) By:  CV-McBridge Software              *
*                                                               *
*                   www.CV-McBridge.com                         *
*                                                               *
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*                                                               *
*                                                               *
*                                                               *
*                  Written By:  Roy Imbsen                      *
*                               Jon Lea                         *
*                               Clark Verkler                   *
*                               James Gates                     *
*                                                               *
*****************************************************************

Date:  03-NOV-06                                 Time:  16:09:12
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Echo of this file:
C:\dgn\T3SDCC_3.ssb

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# WinSeisab Version 5.0.5

# Length_Unit ft
# Force_Unit  kip
# Time_Unit   sec

# Length_Prec      4
# Force_Prec       4
# Time_Prec        4
# Area_Prec        6
# Volume_Prec      4
# Inertia_Prec     4
# Moment_Prec      4
# LinWeight_Prec   4
# Stress_Prec      4
# Density_Prec     4
# Trans_K_Prec     4
# Rotat_K_Prec     4
# Couple_K_Prec    8
# Accel_Prec       2

# ShowExponentialK   No


C Elastic Section Properties

SEISAB "SDC C Bridge Model 2"
   RESPONSE SPECTRUM ANALYSIS
   SUPERSTRUCTURE JOINTS   3
   COLUMN JOINTS   2
   OUTPUT LEVEL   0
   BLOCKING FACTOR   0



ALIGNMENT
   STATION   0.0
   COORDINATES   N  0.0   E  0.0
   BEARING   N 90 00 00 E



SPANS
   LENGTHS          95.125  123.0  95.125
   USE SECTIONS     'Super'  'Super'  'Super'
   AREA             32.64  32.64  32.64
   I11              1.864  1.864  1.864
   I22              3230.9  3230.9  3230.9
   I33              51.26  51.26  51.26
   A22              0.0  0.0  0.0
   A33              0.0  0.0  0.0
   USE MATERIALS    'SD_conc'  'SD_conc'  'SD_conc'
   DENSITY          0.115  0.115  0.115
   WEIGHT           1.68  1.68  1.68
```

```
   E                 585648.0  585648.0  585648.0
   PRATIO            0.2  0.2  0.2


DESCRIBE
   SECTION   'Super'   "Transformed Section Properties of Superstructure"
      AREA  32.64
      I11   1.864
      I22   3230.9
      I33   51.26
      A22   0.0
      A33   0.0


   SECTION   'Column'   "Uncracked section 6-ft pier shaft/column"
      AREA  28.27
      I11   127.23
      I22   63.62
      I33   63.62
      A22   0.0
      A33   0.0


   SECTION   'AB Wall'   "Abutment wall gross section properties"
      AREA  50.41
      I11   43.42
      I22   11.2
      I33   3993.8
      A22   0.0
      A33   0.0


C Using transformed section density.

   MATERIAL   'SD_conc'   "Special Deck Concrete"
      DENSITY   0.115
      E         585648.0
      PRATIO    0.2


   MATERIAL   'DD_conc'   "Class DD substructure concrete"
      DENSITY   0.15
      E         478224.0
      PRATIO    0.2


   COLUMN   'Pier 2'
      USE SECTIONS      'Column'
      AREA              28.27
      I11               127.23
      I22               63.62
      I33               63.62
      A22               0.0
      A33               0.0
      USE MATERIALS     'DD_conc'
      DENSITY           0.15
```

```
      E                  478224.0
      PRATIO             0.2


   COLUMN    'Pier 3'
      USE SECTIONS       'Column'
      AREA               28.27
      I11                127.23
      I22                63.62
      I33                63.62
      A22                0.0
      A33                0.0
      USE MATERIALS      'DD_conc'
      DENSITY            0.15
      E                  478224.0
      PRATIO             0.2


   WALL    'Wall'
      USE SECTION  'AB Wall'
      AREA  50.41
      I11   43.42
      I22   11.2
      I33   3993.8
      A22   0.0
      A33   0.0
      USE MATERIAL  'DD_conc'
      DENSITY   0.15
      E         478224.0
      PRATIO    0.2


   SPECIAL CAP   'Pier Cap'
      I33        31.86
      A22        15.93
      E          478160.64
      PRATIO     0.2


ABUTMENT STATION 0.0
   BEARING  NORMAL  NORMAL

   ELEVATION TOP 4135.94 AT ABUTMENT 1
   ELEVATION TOP 4131.03 AT ABUTMENT 4

   ELEVATION WALL BOTTOM 4132.97  AT ABUTMENT 1
   ELEVATION WALL BOTTOM 4128.06  AT ABUTMENT 4

   CONNECTION FIX    AT ABUTMENT 1
   CONNECTION FIX    AT ABUTMENT 4

   WALL 'Wall'  AT ABUTMENT 1
   WALL 'Wall'  AT ABUTMENT 4

   WING WALL SPRING CONSTANTS AT ABUTMENT 1
C --  KF1F1   fixed
C --  KF2F2   fixed
      KF3F3   3124.0
```

```
C --  KM1M1   fixed
C --  KM2M2   fixed
C --  KM3M3   fixed
   WING WALL SPRING CONSTANTS AT ABUTMENT 4
C --  KF1F1   fixed
C --  KF2F2   fixed
      KF3F3   3124.0
C --  KM1M1   fixed
C --  KM2M2   fixed
C --  KM3M3   fixed

   WALL JOINTS 0  AT ABUTMENT 1
   WALL JOINTS 0  AT ABUTMENT 4


BENT
   BEARING  NORMAL  NORMAL

   ELEVATION TOP         4135.35  4133.42
   ELEVATION BEARINGS    4132.25  4130.32
   ELEVATION BOTTOM      4087.93  4089.57
   WEIGHT  95.0  95.0

   COLUMN  'Pier 2'  AT BENT 2
   COLUMN  'Pier 3'  AT BENT 3

   COLUMN TOP     FIX    AT BENT 2
   COLUMN BOTTOM  FIX    AT BENT 2
   COLUMN TOP     FIX    AT BENT 3
   COLUMN BOTTOM  FIX    AT BENT 3

   COLUMN TOP     END JOINT SIZE 8.17  AT BENT 2
   COLUMN TOP     END JOINT SIZE 8.17  AT BENT 3

   CONNECTION  PIN    AT BENT 2
   CONNECTION  PIN    AT BENT 3


C Half of Longitudinal compression stiffness is modelled at Abutment 1.

FOUNDATION
   AT ABUTMENT  1
      SPRING CONSTANTS
         KF1F1   2524.0
C --      KF2F2   fixed
         KF3F3   0.0
C --      KM1M1   fixed
         KM2M2   400000.0
         KM3M3   6730.0
      WEIGHT  71.0


C Half of Longitudinal Compression Stiffness is modelled at Abutment 4

   AT ABUTMENT  4
      SPRING CONSTANTS
         KF1F1   2524.0
C --      KF2F2   fixed
         KF3F3   0.0
```

```
C --      KM1M1   fixed
          KM2M2   400000.0
          KM3M3   6730.0
       WEIGHT  71.0



   AT BENT  2
      WEIGHT  0.0



   AT BENT  3
      WEIGHT  0.0


C Design response spectrum for Site Class D.

LOADS
   USE FIXED NOTATION FOR VIBRATION INFO
   USE FIXED NOTATION FOR DISPLACEMENTS
   USE FIXED NOTATION FOR FORCES

   RESPONSE SPECTRUM
      COMBINATION FACTOR   0.3
      MODE SHAPES   25
      DAMPING COEFFICIENT   0.05

      ARBITRARY CURVE
         PERIOD     0.0000  0.1000  0.2000  0.5000  0.6000  0.8000  1.0000 -
                    1.2000  1.4000  1.6000  1.8000  2.0000  2.2000  2.4000 -
                    2.6000  2.8000  3.0000  3.2000  3.4000  3.6000  3.8000 -
                    4.0000
         VALUE      0.3474  0.5868  0.5868  0.5868  0.4842  0.3631  0.2905 -
                    0.2421  0.2075  0.1816  0.1614  0.1453  0.1320  0.1210 -
                    0.1117  0.1038  0.0968  0.0908  0.0854  0.0807  0.0764 -
                    0.0726

      GRAVITY   32.2

FINISH
```

- - - - WinSEISAB - - - -     (Version 5.0.5)     03-NOV-06
Imbsen and Associates, Inc.

SDC C Bridge Model 2

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WinSEISAB DATA INPUT

```
**************************************************
*                                                *
*                                                *
*                                                *
*                                                *
*              RESPONSE SPECTRUM                 *
*                                                *
*                                                *
*                                                *
*                                                *
**************************************************
```

THE BRIDGE MODEL GENERATED IS BASED ON:

3 INTERMEDIATE JOINT(S) ON EACH SPAN

2 INTERMEDIATE JOINT(S) ON EACH COLUMN

- - - - WinSEISAB - - - - (Version 5.0.5) 03-NOV-06
Imbsen and Associates, Inc.

SDC C Bridge Model 2

ALIGNMENT DATA INPUT

INITIAL REFERENCE POINT AND ALIGNMENT

| STATION | STATION COORDINATE | | OFFSET DIR | OFFSET VALUE | BEARING |
|---|---|---|---|---|---|
| 0.00 | N | 0.00 | | 0.00 | N 90 0 0 E |
| | E | 0.00 | | | |

SPAN DATA INPUT

SEGMENT LENGTHS / SECTION AND MATERIAL PROPERTIES

| SEGMENT | LENGTH | AREA | I11 | I22 | I33 |
|---|---|---|---|---|---|
| SPAN 1 | 95.12 | | | | |
| 1 | 95.12 | 32.64 | 1.86 | 3230.90 | 51.26 |
| SPAN 2 | 123.00 | | | | |
| 1 | 123.00 | 32.64 | 1.86 | 3230.90 | 51.26 |
| SPAN 3 | 95.12 | | | | |
| 1 | 95.12 | 32.64 | 1.86 | 3230.90 | 51.26 |

| SEGMENT | A22 | A33 | ELASTIC MODULUS | P-RATIO | DENSITY | WT/LENGTH |
|---|---|---|---|---|---|---|
| SPAN 1 | | | | | | |
| 1 | 0.0 | 0.0 | 585648. | 0.20 | 0.115 | 1.680 |
| SPAN 2 | | | | | | |
| 1 | 0.0 | 0.0 | 585648. | 0.20 | 0.115 | 1.680 |
| SPAN 3 | | | | | | |
| 1 | 0.0 | 0.0 | 585648. | 0.20 | 0.115 | 1.680 |

DESCRIBE DATA INPUT

COLUMN INFORMATION

NO. 1 TITLE: Pier 2
INFORMATION:

| SEGMENT | LENGTH | AREA | I11 | I22 | I33 |
|---|---|---|---|---|---|
| 1 | 0.00 | 28.27 | 127.23 | 63.62 | 63.62 |

| SEGMENT | A22 | A33 | ELASTIC MODULUS | P-RATIO | DENSITY |
|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 478224. | 0.20 | 0.15 |

NO. 2 TITLE: Pier 3
INFORMATION:

| SEGMENT | LENGTH | AREA | I11 | I22 | I33 |
|---|---|---|---|---|---|
| 1 | 0.00 | 28.27 | 127.23 | 63.62 | 63.62 |

| SEGMENT | A22 | A33 | ELASTIC MODULUS | P-RATIO | DENSITY |
|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 478224. | 0.20 | 0.15 |

DESCRIBE DATA INPUT (CONTINUED)

SPECIAL BENT CAP INFORMATION

NO. 1 TITLE: Pier Cap
INFORMATION:
DENSITY:
ELASTIC MODULUS: 478161.
POISSONS RATIO: 0.20

| AREA | I11 | I22 | I33 | A22 | A33 |
|---|---|---|---|---|---|
| SPECIAL CAP MEMBER | | | 31.86 | 15.9 | |

ABUTMENT WALL INFORMATION

NO. 1 TITLE: Wall
INFORMATION:
DENSITY: 0.150
ELASTIC MODULUS: 478224.
POISSONS RATIO: 0.20

| AREA | I11 | I22 | I33 | A22 | A33 |
|---|---|---|---|---|---|
| 50.41 | 43.42 | 11.20 | 3993.80 | 0.0 | 0.0 |

## ABUTMENT DATA INPUT

### GEOMETRY AND GENERAL INFORMATION

| ABT | STATION | BEARING | SUPER CG ELEVATION | WALL BOT ELEVATION | ABUTMENT CONNECTION |
|---|---|---|---|---|---|
| 1 | 0.00 | NORMAL | 4135.94 | 4132.97 | FIX |
| 4 | | NORMAL | 4131.03 | 4128.06 | FIX |

### ABUTMENT WING WALL SPRING CONSTANTS

| ABUT | KF1F1 | KF1F2 | KF1F3 | KF1M1 | KF1M2 | KF1M3 |
|---|---|---|---|---|---|---|
| 1 | DOF FIXD | | | | | |
| | | KF2F2 | KF2F3 | KF2M1 | KF2M2 | KF2M3 |
| | | DOF FIXD | | | | |
| | | | KF3F3 | KF3M1 | KF3M2 | KF3M3 |
| | | | 3124. | | | |
| | | | | KM1M1 | KM1M2 | KM1M3 |
| | | | | DOF FIXD | | |
| | | | | | KM2M2 | KM2M3 |
| | | | | | DOF FIXD | |
| | | | | | | KM3M3 |
| | | | | | | DOF FIXD |

ABUTMENT DATA INPUT (CONTINUED)

ABUTMENT WING WALL SPRING CONSTANTS (CONTINUED)

| ABUT | KF1F1 | KF1F2 | KF1F3 | KF1M1 | KF1M2 | KF1M3 |
|---|---|---|---|---|---|---|
| 4 | DOF FIXD | | | | | |
| | | KF2F2 | KF2F3 | KF2M1 | KF2M2 | KF2M3 |
| | | DOF FIXD | | | | |
| | | | KF3F3 | KF3M1 | KF3M2 | KF3M3 |
| | | | 3124. | | | |
| | | | | KM1M1 | KM1M2 | KM1M3 |
| | | | | DOF FIXD | | |
| | | | | | KM2M2 | KM2M3 |
| | | | | | DOF FIXD | |
| | | | | | | KM3M3 |
| | | | | | | DOF FIXD |

## BENT DATA INPUT

### BENT GEOMETRY, WEIGHT AND CAP INFORMATION

| BENT | BEARING | WEIGHT | CAP TITLE | NOTE |
|---|---|---|---|---|
| 2 | NORMAL | 95.00 | | CAP NOT REQUIRED |
| 3 | NORMAL | 95.00 | | CAP NOT REQUIRED |

### BENT ELEVATION INFORMATION

| BENT | SUPER CG ELEVATION | DIAPHRAGM ELEVATION | BEAR. ELMT ELEVATION | BENT CAP ELEVATION | FOOTING ELEVATION |
|---|---|---|---|---|---|
| 2 | 4135.35 | | 4132.25 | | 4087.93 |
| 3 | 4133.42 | | 4130.32 | | 4089.57 |

### BENT CONNECTIVITY INFORMATION

| BENT | SUPERSTR CONTINUITY | BENT TO SUPERSTR CONNECTION TYPE |
|---|---|---|
| 2 | CONTINUOUS | PINNED |
| 3 | CONTINUOUS | PINNED |

## BENT DATA INPUT (CONTINUED)

### BENT COLUMN LAYOUT

| | | | | | ....GROUP OFFSET... | | |
|---|---|---|---|---|---|---|---|
| BENT | SPACING | COL | TITLE | DISTANCE | SPCNG | DIR | OFFSET |
| 2 | | 1 | Pier 2 | SINGLE | | | 0.00 |
| 3 | | 1 | Pier 3 | SINGLE | | | 0.00 |

### BENT COLUMN END INFORMATION

| | | ............TOP........... | | | ..........BOTTOM.......... | | |
|---|---|---|---|---|---|---|---|
| BNT | COL | LT LT ASSTMM | BRG ELMT | JNT SIZE | LT LT ASSTMM | BRG ELMT | JNT SIZE |
| 2 | 1 | | | 8.17 | | | 0.00 |
| 3 | 1 | | | 8.17 | | | 0.00 |

## FOUNDATION DATA

### ABUTMENT FOUNDATION INFORMATION

| ABUTMENT | WEIGHT | ROT. ANGLE | FOUNDATION TYPE | FTNG TITLE |
|---|---|---|---|---|
| 1 | 71.00 | 0.00 | SPRING CONSTANTS | |
| 4 | 71.00 | 0.00 | SPRING CONSTANTS | |

### ABUTMENT FOUNDATION SPRING CONSTANTS

| ABUT | KF1F1 | KF1F2 | KF1F3 | KF1M1 | KF1M2 | KF1M3 |
|---|---|---|---|---|---|---|
| 1 | 2524. | | 0. | | 0. | 0. |

| KF2F2 | KF2F3 | KF2M1 | KF2M2 | KF2M3 |
|---|---|---|---|---|
| DOF FIXD | | | | |

| KF3F3 | KF3M1 | KF3M2 | KF3M3 |
|---|---|---|---|
| 0. | | 0. | 0. |

| KM1M1 | KM1M2 | KM1M3 |
|---|---|---|
| DOF FIXD | | |

| KM2M2 | KM2M3 |
|---|---|
| 400000. | 0. |

| KM3M3 |
|---|
| 6730. |

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SDC C Bridge Model 2

FOUNDATION DATA (CONTINUED)

ABUTMENT FOUNDATION SPRING CONSTANTS (CONTINUED)

| ABUT | KF1F1 | KF1F2 | KF1F3 | KF1M1 | KF1M2 | KF1M3 |
|---|---|---|---|---|---|---|
| 4 | 2524. | | 0. | | 0. | 0. |

| KF2F2 | KF2F3 | KF2M1 | KF2M2 | KF2M3 |
|---|---|---|---|---|
| DOF FIXD | | | | |

| KF3F3 | KF3M1 | KF3M2 | KF3M3 |
|---|---|---|---|
| 0. | | 0. | 0. |

| KM1M1 | KM1M2 | KM1M3 |
|---|---|---|
| DOF FIXD | | |

| KM2M2 | KM2M3 |
|---|---|
| 400000. | 0. |

| KM3M3 |
|---|
| 6730. |

SDC C Bridge Model 2

LOADINGS DATA INPUT

THE NUMBER OF MODE SHAPES FOUND WILL BE 25

ACCELERATION SPECTRUM INFORMATION

USER SPECIFIED ACCELERATION SPECTRUM

DAMPING COEFFICIENT = 0.05
ACCELERATION DUE TO GRAVITY = 32.20

DIGITIZED ACCELERATION SPECTRUM

| POINT | PERIOD | VALUE |
|---|---|---|
| 1 | 0.000 | 0.3474 |
| 2 | 0.100 | 0.5868 |
| 3 | 0.200 | 0.5868 |
| 4 | 0.500 | 0.5868 |
| 5 | 0.600 | 0.4842 |
| 6 | 0.800 | 0.3631 |
| 7 | 1.000 | 0.2905 |
| 8 | 1.200 | 0.2421 |
| 9 | 1.400 | 0.2075 |
| 10 | 1.600 | 0.1816 |
| 11 | 1.800 | 0.1614 |
| 12 | 2.000 | 0.1453 |
| 13 | 2.200 | 0.1320 |
| 14 | 2.400 | 0.1210 |
| 15 | 2.600 | 0.1117 |
| 16 | 2.800 | 0.1038 |
| 17 | 3.000 | 0.0968 |
| 18 | 3.200 | 0.0908 |
| 19 | 3.400 | 0.0854 |
| 20 | 3.600 | 0.0807 |
| 21 | 3.800 | 0.0764 |
| 22 | 4.000 | 0.0726 |

---

LOADING DATA INPUT (CONTINUED)

---

```
         2.0+
            !                  USER INPUT ACCELERATION SPECTRUM
         1.9+
            !
         1.8+
            !
         1.7+
            !
         1.6+
   A        !
   C     1.5+
   C        !
   E     1.4+
   L        !
   E     1.3+
   R        !
   A     1.2+
   T        !
   I     1.1+
   O        !
   N     1.0+
            !
         0.9+
   I        !
         0.8+
            !
   X     0.7+
   G        !
         0.6+ XX   X
            !
         0.5+       X
            !
         0.4+
            !X        X
         0.3+          X
            !            X
         0.2+              X X
            !                  X X X
         0.1+                        X X X X X X X X
            !                                        X
         0.0+
             +---------+---------+---------+---------+---------+
             0         1         2         3         4         5
                           PERIOD  (SECONDS)
```

LOADINGS DATA INPUT (CONTINUED)

LOAD CASE AND LOAD CASE COMBINATION INFORMATION

| LOAD CASE/COMB | ........DIRECTION FACTORS....... X | Y | Z | DESCRIPTION |
|---|---|---|---|---|
| 1 | 1.000 | 0.000 | 0.000 | Longitudinal |
| 2 | 0.000 | 0.000 | 1.000 | Transverse |
| 3 | | | | 1.0*Long + 0.3*Trans |
| 4 | | | | 0.3*Long + 1.0*Trans |

RESPONSE SPECTRUM RESULTS

VIBRATION CHARACTERISTICS

| MODE | PERIOD | CS | PARTICIPATION FACTORS Long | PARTICIPATION FACTORS Vert | PARTICIPATION FACTORS Tran | % OF TOTAL MASS Long | % OF TOTAL MASS Vert | % OF TOTAL MASS Tran |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.656 | 0.45 | 0.000 | 0.000 | -8.043 | 0.000 | 0.000 | 89.705 |
| 2 | 0.599 | 0.49 | -8.239 | -0.181 | 0.000 | 94.125 | 0.049 | 89.705 |
| 3 | 0.556 | 0.53 | -0.395 | 0.707 | 0.000 | 94.341 | 0.788 | 89.705 |
| 4 | 0.396 | 0.59 | 0.000 | 0.000 | 0.165 | 94.341 | 0.788 | 89.743 |
| 5 | 0.351 | 0.59 | -0.522 | -0.022 | 0.000 | 94.719 | 0.788 | 89.743 |
| 6 | 0.291 | 0.59 | 0.123 | -6.037 | 0.000 | 94.740 | 54.623 | 89.743 |
| 7 | 0.234 | 0.59 | 0.000 | 0.000 | -1.813 | 94.740 | 54.623 | 94.299 |
| 8 | 0.151 | 0.59 | 0.078 | 0.013 | 0.000 | 94.749 | 54.623 | 94.299 |
| 9 | 0.115 | 0.59 | 0.000 | 0.000 | -0.010 | 94.749 | 54.623 | 94.299 |
| 10 | 0.103 | 0.59 | -0.009 | 0.462 | 0.000 | 94.749 | 54.939 | 94.299 |
| 11 | 0.095 | 0.58 | -0.063 | 0.015 | 0.000 | 94.754 | 54.939 | 94.299 |
| 12 | 0.078 | 0.53 | 0.021 | -1.571 | 0.000 | 94.755 | 58.585 | 94.299 |
| 13 | 0.068 | 0.51 | 0.029 | -0.076 | 0.000 | 94.756 | 58.594 | 94.299 |
| 14 | 0.058 | 0.49 | 0.000 | 0.000 | 0.760 | 94.756 | 58.594 | 95.101 |
| 15 | 0.053 | 0.47 | 0.000 | 0.000 | 1.035 | 94.756 | 58.594 | 96.586 |
| 16 | 0.051 | 0.47 | -0.249 | 0.443 | 0.000 | 94.842 | 58.884 | 96.586 |
| 17 | 0.051 | 0.47 | 0.116 | -1.517 | 0.000 | 94.861 | 62.282 | 96.586 |
| 18 | 0.048 | 0.46 | 1.197 | 0.317 | 0.000 | 96.849 | 62.431 | 96.586 |
| 19 | 0.046 | 0.46 | 0.000 | 0.000 | 1.189 | 96.849 | 62.431 | 98.546 |
| 20 | 0.041 | 0.44 | -1.173 | 0.078 | 0.000 | 98.758 | 62.439 | 98.546 |
| 21 | 0.035 | 0.43 | -0.177 | 0.120 | 0.000 | 98.802 | 62.461 | 98.546 |
| 22 | 0.033 | 0.43 | 0.000 | 0.000 | 0.050 | 98.802 | 62.461 | 98.549 |
| 23 | 0.031 | 0.42 | 0.020 | -2.681 | 0.000 | 98.802 | 73.078 | 98.549 |
| 24 | 0.030 | 0.42 | 0.041 | -1.124 | 0.000 | 98.805 | 74.944 | 98.549 |
| 25 | 0.028 | 0.42 | -0.050 | 3.167 | 0.000 | 98.808 | 89.755 | 98.549 |

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SDC C Bridge Model 2

RESPONSE SPECTRUM RESULTS

ABUTMENT CQC DISPLACEMENTS

| ITEM | LC | ....LEFT FACE.... LNGTUDNL | TRNSVRSE | ....RGHT FACE.... LNGTUDNL | TRNSVRSE | ...OPNNG/CLSNG... LNGTUDNL | TRNSVRSE |
|---|---|---|---|---|---|---|---|
| ABU 1 | 1 | 0.139 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 |
| | 2 | 0.000 | 0.094 | 0.000 | 0.094 | 0.000 | 0.000 |
| | 3 | 0.139 | 0.028 | 0.139 | 0.028 | 0.000 | 0.000 |
| | 4 | 0.042 | 0.094 | 0.042 | 0.094 | 0.000 | 0.000 |
| ABU 4 | 1 | 0.139 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 |
| | 2 | 0.000 | 0.085 | 0.000 | 0.085 | 0.000 | 0.000 |
| | 3 | 0.139 | 0.026 | 0.139 | 0.026 | 0.000 | 0.000 |
| | 4 | 0.042 | 0.085 | 0.042 | 0.085 | 0.000 | 0.000 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

SDC C Bridge Model 2

RESPONSE SPECTRUM RESULTS

BENT CQC DISPLACEMENTS

| ITEM | LC | ....LEFT FACE.... LNGTUDNL | ....LEFT FACE.... TRNSVRSE | ....RGHT FACE.... LNGTUDNL | ....RGHT FACE.... TRNSVRSE | ...OPNNG/CLSNG... LNGTUDNL | ...OPNNG/CLSNG... TRNSVRSE |
|---|---|---|---|---|---|---|---|
| BNT 2 | 1 | 0.145 | 0.000 | 0.145 | 0.000 | 0.000 | 0.000 |
| | 2 | 0.000 | 0.166 | 0.000 | 0.166 | 0.000 | 0.000 |
| | 3 | 0.145 | 0.050 | 0.145 | 0.050 | 0.000 | 0.000 |
| | 4 | 0.043 | 0.166 | 0.043 | 0.166 | 0.000 | 0.000 |
| BNT 3 | 1 | 0.144 | 0.000 | 0.144 | 0.000 | 0.000 | 0.000 |
| | 2 | 0.000 | 0.160 | 0.000 | 0.160 | 0.000 | 0.000 |
| | 3 | 0.144 | 0.048 | 0.144 | 0.048 | 0.000 | 0.000 |
| | 4 | 0.043 | 0.160 | 0.043 | 0.160 | 0.000 | 0.000 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

SDC C Bridge Model 2

RESPONSE SPECTRUM RESULTS

COLUMN CQC FORCES

| CL | LOC | LC | ....LNGITUDNL.... SHEAR | MOMENT | ....TRANSVRSE.... SHEAR | MOMENT | AXIAL | TORSION |
|---|---|---|---|---|---|---|---|---|
| BNT 2 | | | | | | | | |
| 1 | BOT | 1 | 161.5 | 6849. | 0.0 | 0. | 28.4 | 0.0 |
| | | 2 | 0.0 | 0. | 174.8 | 7716. | 0.0 | 0.0 |
| | | 3 | 161.5 | 6849. | 52.4 | 2315. | 28.4 | 0.0 |
| | | 4 | 48.4 | 2055. | 174.8 | 7716. | 8.5 | 0.0 |
| 1 | TOP | 1 | 148.2 | 1241. | 0.0 | 0. | 28.4 | 0.0 |
| | | 2 | 0.0 | 0. | 162.1 | 1616. | 0.0 | 0.0 |
| | | 3 | 148.2 | 1241. | 48.6 | 485. | 28.4 | 0.0 |
| | | 4 | 44.5 | 372. | 162.1 | 1616. | 8.5 | 0.0 |
| BNT 3 | | | | | | | | |
| 1 | BOT | 1 | 202.6 | 8028. | 0.0 | 0. | 40.7 | 0.0 |
| | | 2 | 0.0 | 0. | 210.7 | 8748. | 0.0 | 0.0 |
| | | 3 | 202.6 | 8028. | 63.2 | 2624. | 40.7 | 0.0 |
| | | 4 | 60.8 | 2408. | 210.7 | 8748. | 12.2 | 0.0 |
| 1 | TOP | 1 | 191.5 | 1593. | 0.0 | 0. | 40.7 | 0.0 |
| | | 2 | 0.0 | 0. | 200.3 | 2041. | 0.0 | 0.0 |
| | | 3 | 191.5 | 1593. | 60.1 | 612. | 40.7 | 0.0 |
| | | 4 | 57.4 | 478. | 200.3 | 2041. | 12.2 | 0.0 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

RESPONSE SPECTRUM RESULTS

ABUTMENT CQC FORCES

| | | | W/R TO BRIDGE C.L. | | W/R TO ITEM C.L. | |
|---|---|---|---|---|---|---|
| ITEM | LC | VERT SHEAR | LONGITUDNL | TRANSVERSE | NORMAL | PARALLEL |
| ABU 1 | 1 | 11.0 | 316.5 | 0.0 | 316.5 | 0.0 |
| | 2 | 0.0 | 0.0 | 273.0 | 0.0 | 273.0 |
| | 3 | 11.0 | 316.5 | 81.9 | 316.5 | 81.9 |
| | 4 | 3.3 | 95.0 | 273.0 | 95.0 | 273.0 |
| ABU 4 | 1 | 15.7 | 316.9 | 0.0 | 316.9 | 0.0 |
| | 2 | 0.0 | 0.0 | 248.0 | 0.0 | 248.0 |
| | 3 | 15.7 | 316.9 | 74.4 | 316.9 | 74.4 |
| | 4 | 4.7 | 95.1 | 248.0 | 95.1 | 248.0 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

SDC C Bridge Model 2

RESPONSE SPECTRUM RESULTS

ABUTMENT FOUNDATION SPRING CQC FORCES

| ABUT | LC | KF1F1 | KF2F2 | KF3F3 | KM1M1 | KM2M2 | KM3M3 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 350.2 | 0.0 | 0.0 | 0.0 | 0.0 | 9.3 |
| | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 393.8 | 0.0 |
| | 3 | 350.2 | 0.0 | 0.0 | 0.0 | 118.1 | 9.3 |
| | 4 | 105.1 | 0.0 | 0.0 | 0.0 | 393.8 | 2.8 |
| 4 | 1 | 350.6 | 0.0 | 0.0 | 0.0 | 0.0 | 8.6 |
| | 2 | 0.0 | 0.0 | 0.0 | 0.0 | 400.1 | 0.0 |
| | 3 | 350.6 | 0.0 | 0.0 | 0.0 | 120.0 | 8.6 |
| | 4 | 105.2 | 0.0 | 0.0 | 0.0 | 400.1 | 2.6 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

SDC C Bridge Model 2

RESPONSE SPECTRUM RESULTS

ABUTMENT WING WALL SPRING CQC FORCES

| ABUT | LC | KF1F1 | KF2F2 | KF3F3 | KM1M1 | KM2M2 | KM3M3 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 0.0 | 0.0 | 293.5 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.0 | 0.0 | 88.0 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.0 | 0.0 | 293.5 | 0.0 | 0.0 | 0.0 |
| 4 | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2 | 0.0 | 0.0 | 267.0 | 0.0 | 0.0 | 0.0 |
| | 3 | 0.0 | 0.0 | 80.1 | 0.0 | 0.0 | 0.0 |
| | 4 | 0.0 | 0.0 | 267.0 | 0.0 | 0.0 | 0.0 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

SDC C Bridge Model 2

## RESPONSE SPECTRUM RESULTS

### BENT CQC FORCES

| | | | W/R TO BRIDGE C.L. | | W/R TO ITEM C.L. | |
|---|---|---|---|---|---|---|
| ITEM | LC | VERT SHEAR | LONGITUDNL | TRANSVERSE | NORMAL | PARALLEL |
| BNT 2 | 1 | 28.3 | 88.8 | 0.0 | 88.8 | 0.0 |
| | 2 | 0.0 | 0.0 | 105.5 | 0.0 | 105.5 |
| | 3 | 28.3 | 88.8 | 31.6 | 88.8 | 31.6 |
| | 4 | 8.5 | 26.6 | 105.5 | 26.6 | 105.5 |
| BNT 3 | 1 | 40.7 | 133.6 | 0.0 | 133.6 | 0.0 |
| | 2 | 0.0 | 0.0 | 146.7 | 0.0 | 146.7 |
| | 3 | 40.7 | 133.6 | 44.0 | 133.6 | 44.0 |
| | 4 | 12.2 | 40.1 | 146.7 | 40.1 | 146.7 |

| *** LOAD CASE/COMB | DESCRIPTION |
|---|---|
| 1 | Longitudinal |
| 2 | Transverse |
| 3 | 1.0*Long + 0.3*Trans |
| 4 | 0.3*Long + 1.0*Trans |

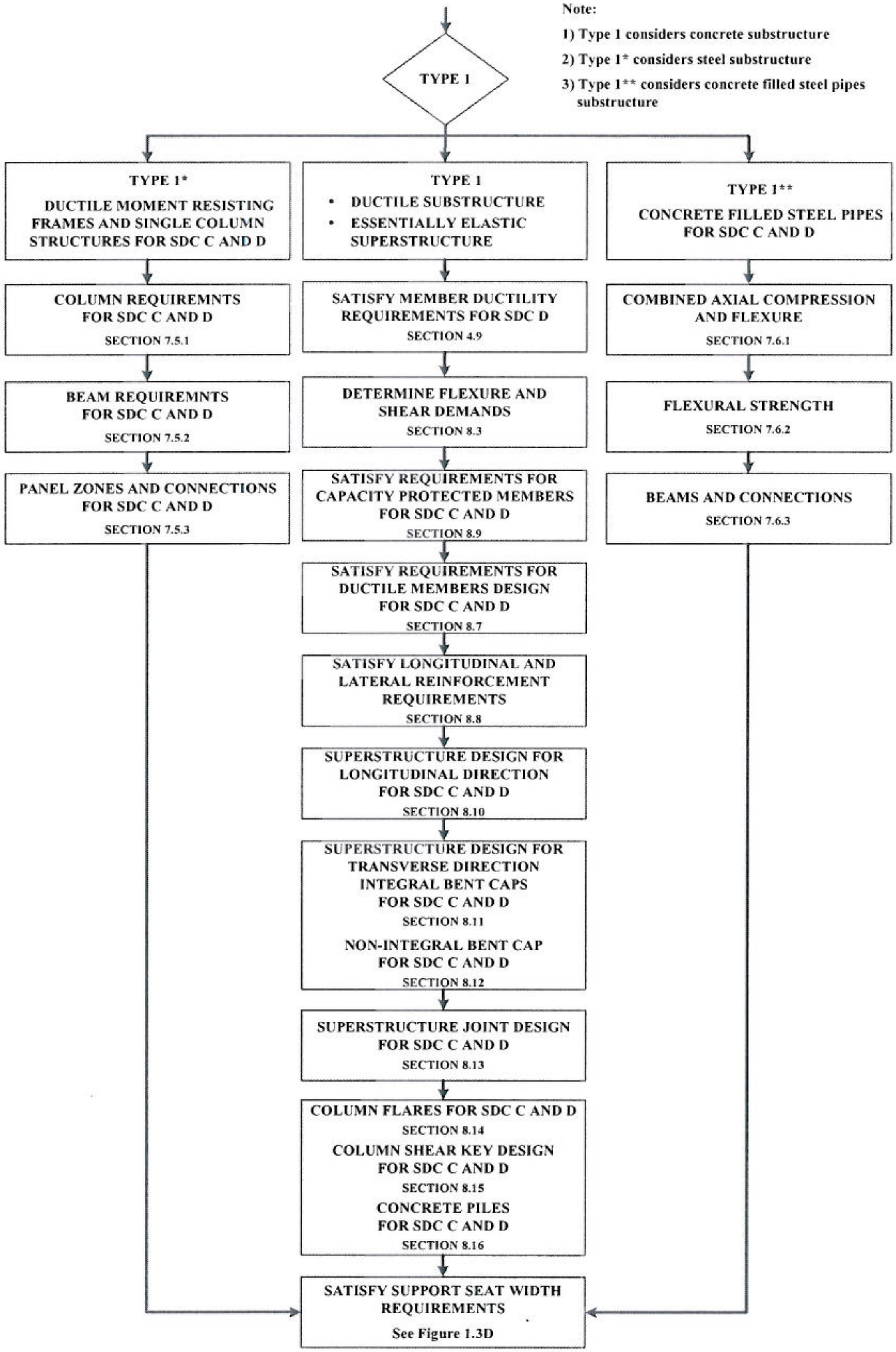


**FIGURE 1.3F: Design Procedure Flow Chart F**

# Trial Design of a 3-Span Continuous Steel Girder Bridge on Large Diameter Drilled Shaft Piers using the Proposed LRFD Seismic Design Guidelines 2006

***Prepared by Montana Department of Transporation,for the AASHTO T-3 Subcommittee***

## *Design Procedure Flowchart F*
## *(Type 1 - Ductile Substructure, Essentially Elastic Superstructure)*

### Determine Flexure and Shear Demands (8.3)

- Force Demands for SDC B (8.3.2)

Lesser of plastic hinging or unreduced elastic seismic forces.

Moment overstrength capacity of the reinforced concrete column (pier shaft) is Mpo = 1.2*Mp

$H_e = 43\,ft$ — Effective length of column from top to point of maximum moment (below ground).

$H' := H_e$ — Assuming single curvature.

$L_p := \phi_{pier} + 0.08 \cdot H'$ — Length of plastic hinge.

$L_p = 9.44\,ft$

$M_P = 12344\,kip \cdot ft$ — Idealized plastic moment capacity using expected material strengths.

$M_{Po} := 1.2 \cdot M_P$ — Column overstrength capacity.

$M_{Po} = 14812.8\,kip \cdot ft$

$V_{Po} := \dfrac{M_{Po}}{H_e}$ — Column shear force corresponding to column overstrength plastic moment.

$V_{Po} = 344.48\,kip$

$V_E := 219kip$ — Column shear force from linear elastic analysis.

$V_D := \min(V_{Po}, V_E)$ — Shear Demand force for SDC B

$V_D = 219\,kip$ Elastic shear force controls.

$M_D := 9073kip \cdot ft$ Flexure associated with elastic force.

Note: Flexural reinforcing to resist seismic induced forces could be reduced from what is shown on the drawings submitted for drilled shaft pier in a SDC C. This pier design is also influenced by train impact forces and in this case would govern the pier design.

## Requirements for Ductile Member Design (8.7)

- Minimum lateral strength (8.7.1)

$P_D := 886kip$

$F_{min} := 0.1 \cdot P_D$

Minimum lateral force.

$F_{min} = 88.6\,kip$

$M_{min} := F_{min} \cdot H'$

Minimum flexural design capacity of column.

$M_{min} = 3809.8\,kip \cdot ft$

$M_D \geq M_{min} = 1$

- Maximum Axial Load (8.7.2)

$f'_{ce} := 1.3 \cdot 3.000ksi$

Expected concrete strength.

$f'_{ce} = 3.9\,ksi$

$$A_g := \frac{\pi \cdot (\phi_{pier})^2}{4}$$

Gross cross sectional area of shaft/column.

$A_g = 4071.5\,in^2$

$P_{max} := 0.2 \cdot f'_{ce} \cdot A_g$

Maximum axial load.

$P_{max} = 3175.77\,kip$

$P_D \leq P_{max} = 1$

## Longitudinal and Lateral Reinforcement Requirements (8.8)

- Maximum and minimum longitudinal reinforcement (8.8.1 & 2)

$A_{long\_max} := .04 \cdot A_g$

Maximum longitudinal reinforcement.

$A_{long\_max} = 162.86\,in^2$

$A_{long\_min} := .007A_g$

Minimum longitudinal reinforcement for SDC B.

$A_{long\_min} = 28.5\,in^2$

$A_{long} := 24 \cdot (2.25 \cdot in^2)$

Longitudinal reinforcement provided is 24-#14.

$A_{long} = 54\,in^2$

$A_{long\_max} \geq A_{long} \geq A_{long\_min} = 1$

## Shear Demand and Capacity (8.6.1)

$V_d := \min(V_E, V_{Po})$

Shear Demand for SDC B.

$V_d = 219\,\text{kip}$

$P := 886\text{kip}$

Design axial load due to seismic and permanent loads.

$f'_c := 3.000\text{ksi}$

Nominal concrete strength for shear calculations.

$f_{yt} := 60\text{ksi}$

Actual yield strength of transverse spiral reinforcing.

$A_{sp} := 0.31\text{in}^2$

Area of #5 spiral reinforcing.

$s := 8\text{in}$

Spacing (pitch) of transverse reinforcement
Note: this is maximum spacing required to resist seismic forces. Tighter spacing may control for train collision load Case (Extreme I).

$$\rho_s := \frac{4 \cdot A_{sp}}{\phi_{pier} \cdot s}$$

Spiral reinforcement ratio.

$\rho_s = 0.0022$

$\rho_{s\_min} := .002$

Minimum reinforcement ratio (8.6.6)

$\rho_s \geq \rho_{s\_min} = 1$

$\alpha' := .015 \cdot \rho_s \cdot f_{yt}$ $\qquad \alpha' = 1.94\,\text{psi}$

$\alpha'' := .03 \cdot \rho_s \cdot f_{yt}$ $\qquad \alpha'' = 3.87\,\text{psi}$

$$\nu_c := \min\left[\alpha' \cdot \left(1 + \frac{\frac{P}{\text{kip}}}{2000 \frac{A_g}{\text{in}^2}}\right) \cdot \sqrt{\frac{f'_c \cdot 1000}{\text{ksi}}}, 3.5 \cdot \text{psi} \cdot \sqrt{\frac{f'_c \cdot 1000}{\text{ksi}}}\right]$$

Concrete shear stress capacity inside plastic hinge zone (eq 8.13)

$\nu_c = 106.13\,\text{psi}$

$$\nu'_c := \min\left[\alpha'' \cdot \left(1 + \frac{\frac{P}{\text{kip}}}{2000 \frac{A_g}{\text{in}^2}}\right) \cdot \sqrt{\frac{f'_c \cdot 1000}{\text{ksi}}}, 3.5 \cdot \text{psi} \cdot \sqrt{\frac{f'_c \cdot 1000}{\text{ksi}}}\right]$$

Concrete shear stress capacity outside plastic hinge zone

$\nu'_c = 191.7\,\text{psi}$

$A_e := 0.8 \cdot A_g$

Effective shear area of column.

$A_e = 22.62\,\text{ft}^2$

$V_c := \nu_c \cdot A_e$

Concrete shear capacity of column in plastic hinge zone.

$V_c = 345.7\,\text{kip}$

$n := 1$

Number of spiral core sections.

$A_v := n \cdot A_{sp}$

Total area of shear reinforcement

$A_v = 0.31\,in^2$

$V_s := \frac{\pi}{2} \cdot \left( \frac{A_v \cdot f_{yt} \cdot \phi_{pier}}{s} \right)$

Shear reinforcement strength capacity (eq 8.25)

$V_s = 262.95\,kip$

$V_{s\_max} := 8psi \cdot \sqrt{\frac{f'_{ce} \cdot 1000}{ksi}} \cdot A_e$

$V_{s\_max} = 1627.3\,kip$

$\phi := 0.85$

$V_n := V_c + V_s$

Nominal shear strength.

$V_n = 608.65\,kip$

$\phi \cdot V_n \geq V_d = 1$

$V_d = 219\,kip$