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RAPID REPAIR DESIGN OF TEMPORARY SUPPORT SYSTEMS FOR BRIDGES DAMAGED BY EARTHQUAKES IN THE STATE OF WASHINGTON

APPENDIX A – DESIGN MANUAL

WA-RD 542.2

Final Report
October 2001

Washington State Department of Transportation

Washington State Transportation Commission
Planning and Capital Program Management
in cooperation with:
U.S. DOT - Federal Highway Administration

Final Report
for
Research Project Contract No. T1804-9
Emergency Bridge Repair

RAPID REPAIR DESIGN OF TEMPORARY SUPPORT SYSTEMS FOR BRIDGES DAMAGED BY EARTHQUAKES IN THE STATE OF WASHINGTON

Appendix A – Design Manual

By

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Technical Monitor
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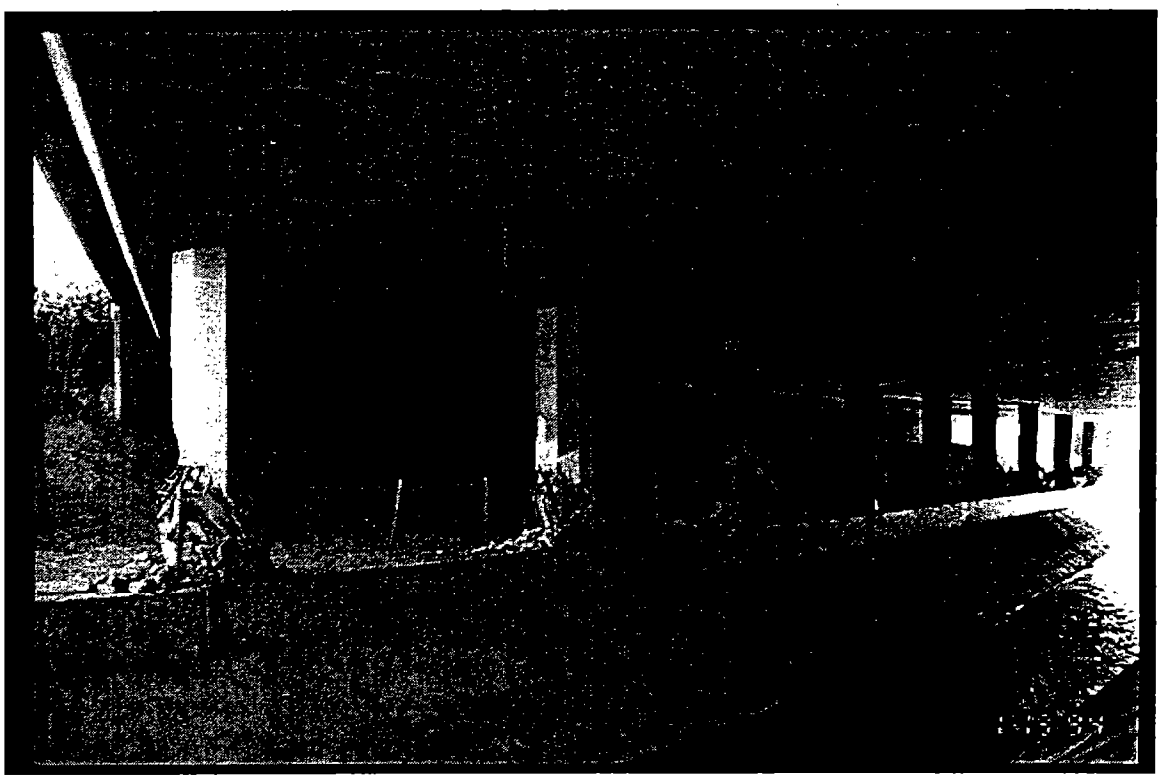
Bridge Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation

October 2001

Manual for the Rapid Repair Design of Temporary Support Systems for Bridges Damaged by Earthquakes in the State of Washington



Prepared for the
Washington State Department of Transportation

By the
Department of Civil and Environmental Engineering of
Washington State University

October 29, 2001

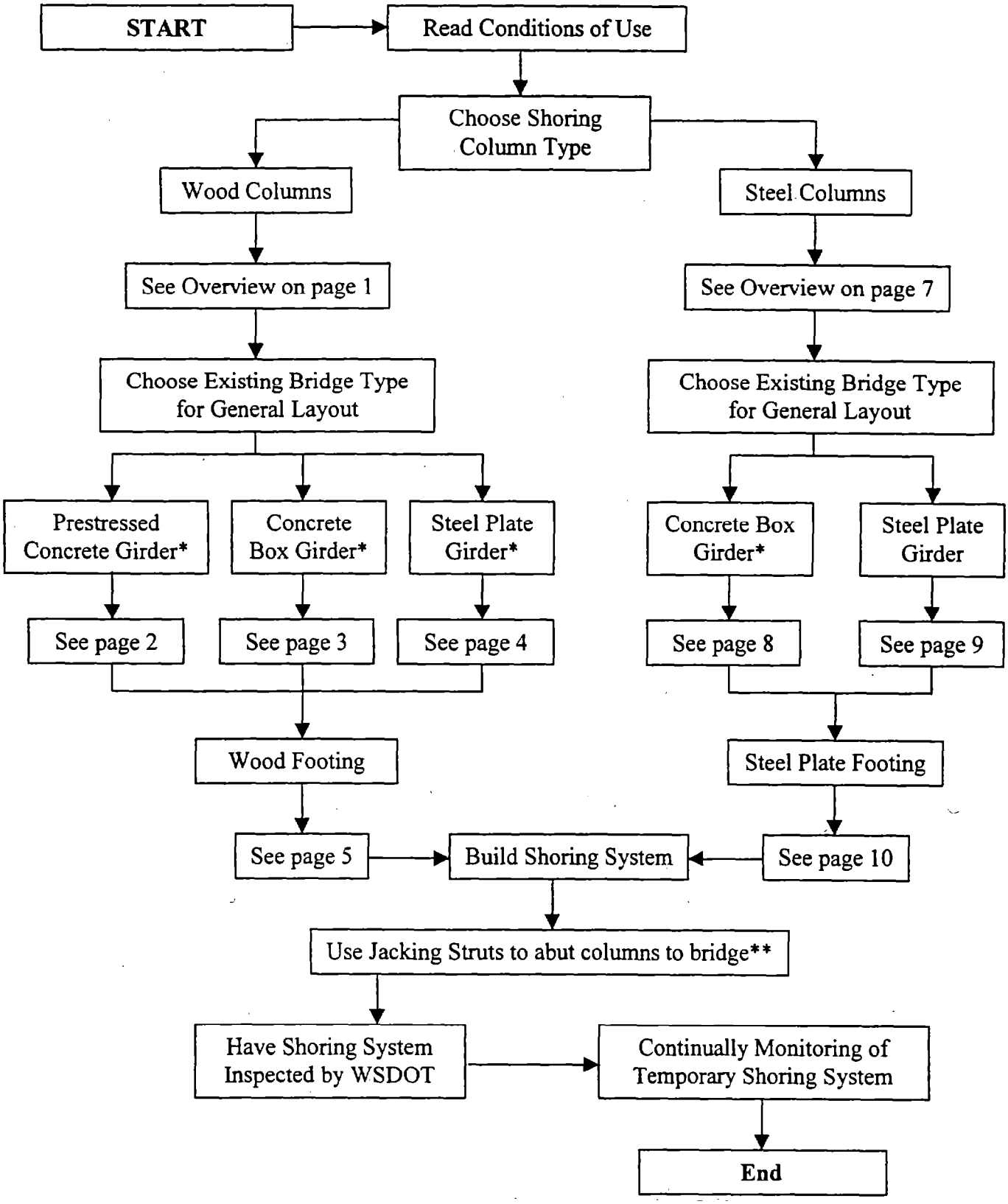
Purpose and Scope

This project provides a design manual that includes guidelines and procedures for constructing rapid temporary shoring systems for damaged bridges. This manual will be further integrated into the WSDOT Bridge Design Manual. The designs provided here will be used by the WSDOT bridge officials who will oversee all construction of the temporary shoring systems. This manual could also be implemented into the FEMA handouts for bridge inspection and could be provided to assist other local governments.

WSDOT responsibilities after an earthquake that damages the state transportation system are to insure the safety of the traveling public, protect transportation facilities from further damage, restore traffic on the highway system as quickly and safely as possible, and to maintain a timely and current assessment of the extent of damage and operation status of the transportation system.

The scope of this project deals primarily with the technical aspects of building a rapid pre-engineered shoring system for damaged bridges. Broad criteria were set forth by the WSDOT Bridge and Structures Office to accommodate 75% of all bridges within the state of Washington. The shoring system is to retain heights between 15 to 40-feet.

Flow Chart of Temporary Shoring Construction Plans



*Transverse Cap Details are included **Retighten connections after columns are firmly secured

Conditions of Use

This temporary shoring system is intended to be only a temporary solution. In no case shall the temporary shoring system act as a permanent solution or be in use for more than one year from the time of erection. Any changes to the manual must be documented and approved by a licensed Washington State Civil Engineer. The temporary shoring system is not intended to withstand after-shocks that follow the initial seismic event. This manual may be used only under the following conditions:

- Any chosen option in the flow chart must be followed through completely for each damaged column (or row of columns) such that there is no mixing and matching of flow chart options.

- Columns may not be subjected to any lateral earth pressures.

- Each damaged column must support its self-weight and the superstructure must maintain its integrity.

- All shoring foundations must be placed upon level ground.

- No vehicular traffic is allowed to traverse the damaged bridge without the prior consent from WSDOT. Temporary shoring must be in place and approved by the engineer of record before traffic may traverse the damaged bridge.

- Vehicular travel must be regulated in such a manner as to limit the effects from super-elevation, bridge curvature, acceleration and deceleration of vehicles. The suggested construction speed across the damaged bridge is to be 15 mph.

- Upon each after-shock, the damaged bridge and the temporary shoring system shall be thoroughly checked over to assess the integrity of the structure and the shoring system. Access to the road should be closed during this time until officials deem the bridge safe to open again to the public. WSDOT shall be notified of any signs of failure and the bridge shall be closed immediately.

- The depicted bridges in the manual represent 75% of all bridges within the State of Washington. The shoring system is only applicable if the damaged bridge's geometry is the same or smaller than the bridge geometry shown in the manual.

- Jacking struts with hydraulic jacks will be used to pre-load the shoring system, such that bridge is shored properly. Steel or wood wedges shall be used to abut the temporary shoring system to the bridge. Shoring columns closest to the damaged columns or support will be preloaded more to distribute load equally with the outer most shoring columns.

- No welding is to take place on the existing damaged steel plate girder bridge.

Explanation of the Outline of Temporary Shoring Construction Plans

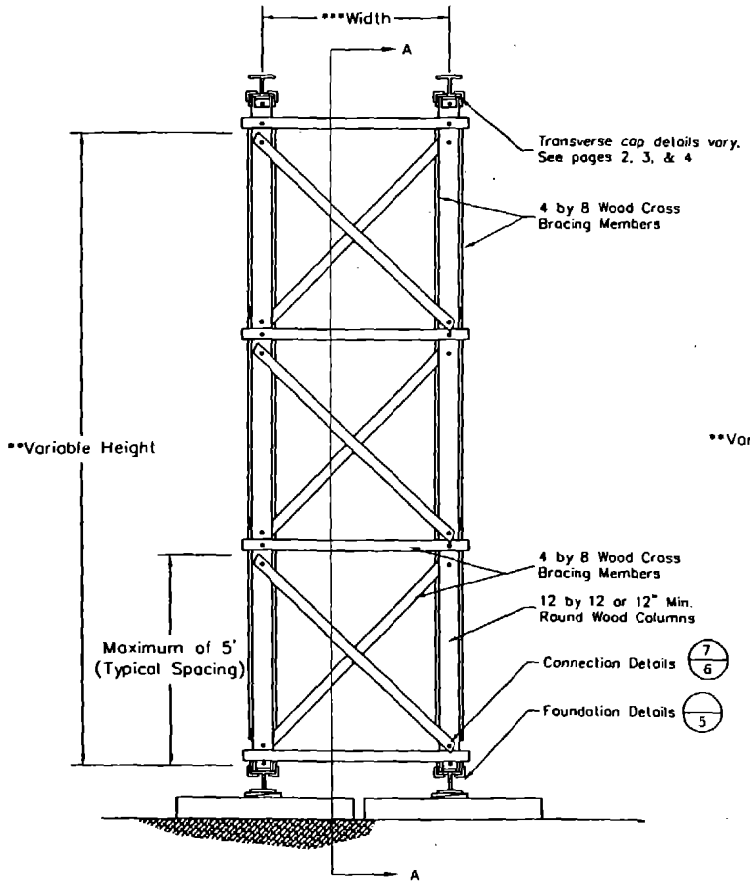
The flow chart is an aide for the rapid construction of temporary shoring systems for the Washington State Department of Transportation (WSDOT). This manual is designed to cover 75% of all bridges within the State of Washington in the event of a catastrophic earthquake. The following is an explanation of the flowchart.

The first step is to read the Conditions of Use, which provide limits and necessary information for which the shoring systems are valid. The second step is to determine the materials, either steel or wood, that the shoring columns will be comprised of. The initial overview drawings include design stresses, assumptions, criteria, and a general shoring layout. Identifying the type of bridge is the third step, either prestressed concrete girder bridge, concrete box girder bridge, or steel plate girder bridge. Please note, that the wood column shoring tower must be used for the prestressed girder bridges. Each bridge type has a drawing with construction details for the layout of the transverse cap, columns, cross bracing, connections, etc. The overview drawing is to be the main reference for assembling the temporary shoring tower for the particular bridge type. Finally, the footings for the shoring tower are the last general construction detail mentioned in the flowchart. Specific details are incorporated throughout the manual on the final drawing sheet.

Use of these shoring systems is contingent upon a safe working environment and a prior investigation of the damaged bridge. A suitable site for the footings and the shoring columns must also be determined, preferably within 10-feet of the damaged columns and 5-feet for simply supported bridge spans. The footings shall be placed upon level ground. Jacking struts with hydraulic jacks shall be used to pre-load the shoring system, such that bridge is shored properly. Steel or wood wedges shall be used to abut the temporary shoring system to the bridge. All bolted connections, after the jacking struts are removed, shall be re-tightened to complete the construction of the shoring systems.

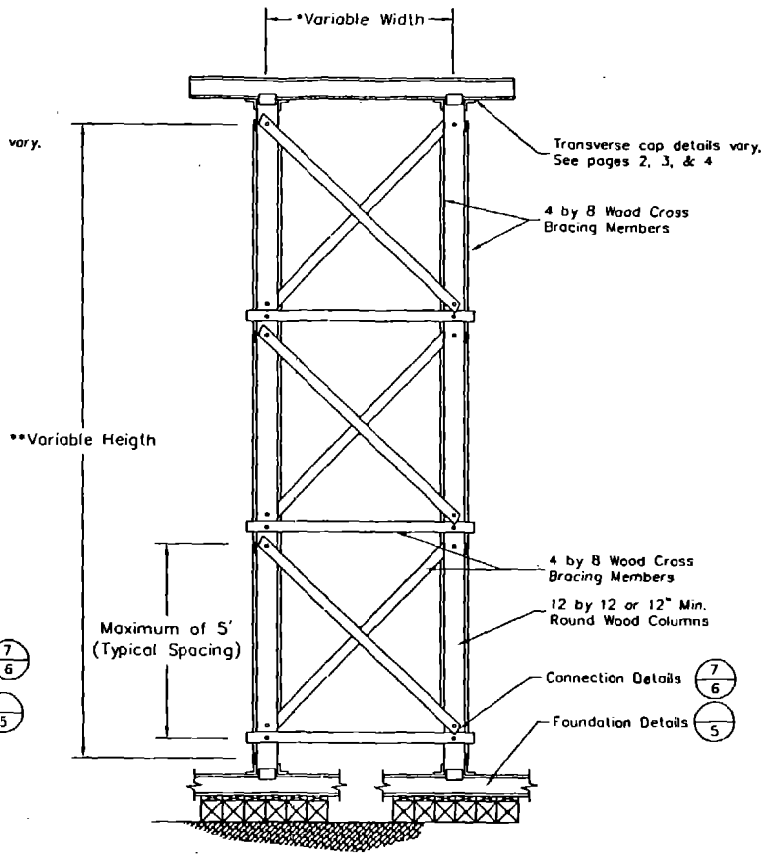
The shoring system shall be checked and approved by a WSDOT official before traffic is allowed to travel across the bridge. The temporary shoring shall be monitored closely along with the bridge after the completion of the shoring system. WSDOT shall be notified of any signs of failure and the bridge shall be closed immediately.

Following these outlined steps will ensure consistency and safety for the construction crew and the public. The Department of Transportation Bridge and Structure's Office shall address any questions about the construction of the temporary shoring systems.



Setup of Shoring Tower along Bridge Length

Drawing Not to Scale



Section A–A of Shoring Tower along Bridge Width

Drawing Not to Scale

Wood Shoring Column Assumptions and Notes:

Shoring columns shall be 12" by 12" or larger Timbers or by 12" minimum diameter round piles. Round columns must conform to ASTM Standard D3200

All cross bracing and lateral bracing members are to be 4" by 8" or larger Dimensional Lumber

All Wood members are to be Hem-Fir or Douglas Fir-Larch and No 2 or better

Sill Beams and Transverse Caps shall be either HP12X53 or HP14X89, steel shall be A36.

Allowable Design Stresses
Wood: Fc= 1000 psi
E = 1,300,000 psi
Fv = 110 psi
Ft = 600 psi
Fc(perpendicular) = 400 psi
Fb = 1100 psi
Steel: Fy = 36 ksi
E = 29,000 ksi
Concrete: F'c = 4000 psi
Soil: Allowable Bearing = 3000 psf

Design Loads
Dead Load: Concrete = 160 pcf
Steel = 490 pcf
Live Load: AASHTO HS20-44

Each wood column is designed for an axial load of 17 kips and cross bracing designed for 2% of the axial load applied horizontally.

Shoring Dimensions
* Shoring column spacing along width of bridge – Concrete Box Girder = 5'9" – Steel Plate Girder Bridge and Prestressed Girder Bridge, columns will be placed directly under existing girders
** Height of shoring column – Column height shall be 15' to 40'
*** Shoring column spacing along length of bridge – Concrete Box Girder = 8' – Steel Plate Girder Bridge = 8' – Prestressed Girder Bridge = 8'

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Overview of Wood Column and Cross Bracing Setup		Page 1
	Designed By:	LAH	7/01			Scale: Not to scale	Date: August 15, 2001	of 11
	Drawn By:	LAH	7/01					
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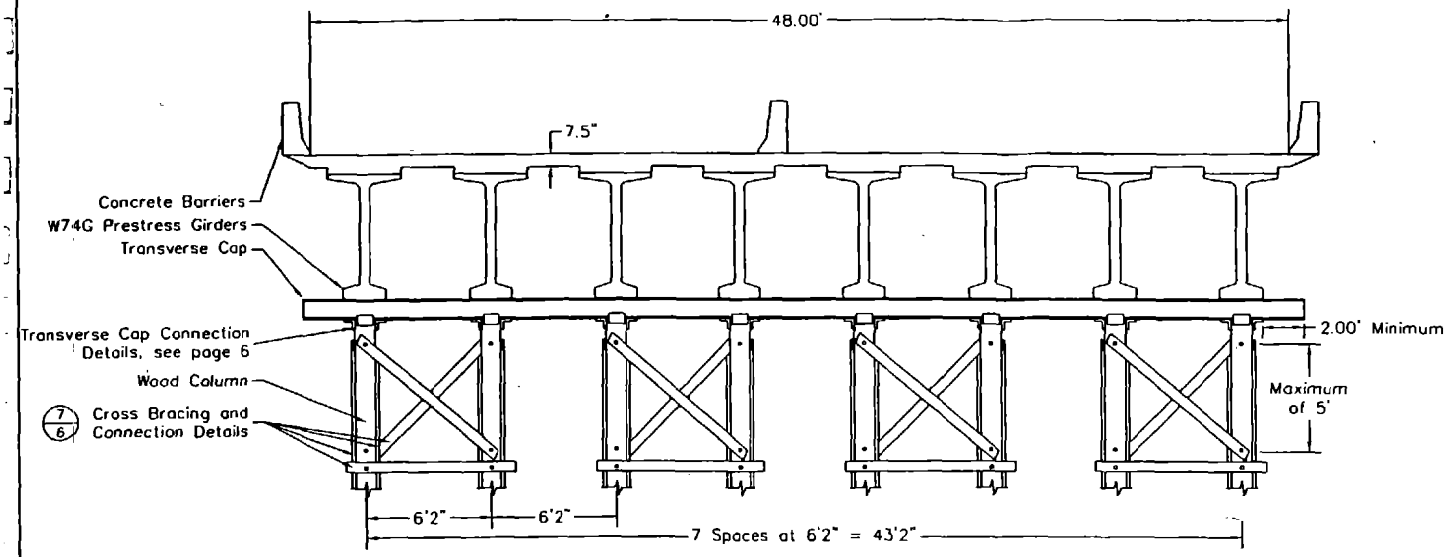
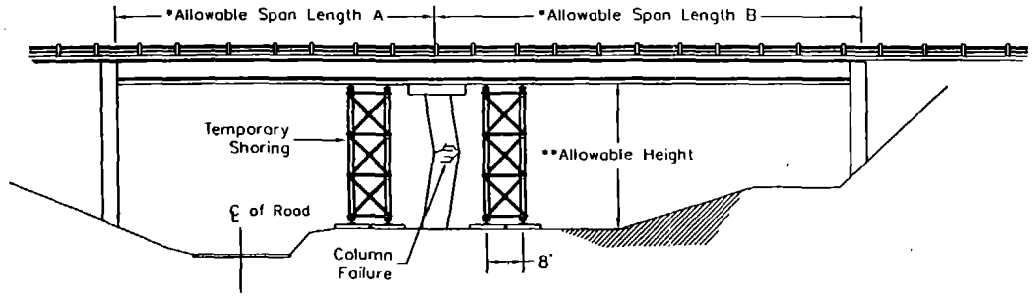


Concrete Prestressed Bridge Column and Transverse Cap Layout for Wood Column Shoring System



Typical Column Overpass Failure
Drawing not to scale

Notes:

Lateral Bracing will span every 5 feet along shoring columns

Shoring columns shall be 12" by 12" or larger Timbers or by 12" minimum diameter round piles Round columns must conform to ASTM Standard D3200

All wood members shall be Hem-Fir or Douglas Fir-Larch and No. 2 or better

All Steel Shoring Members (Transverse Cap, Sill Beam, or Corbels) shall be either HP12X53 or HP14X89, steel shall be A36.

The shoring system shall be placed within 10 feet of the failed column, except for simply supported spans which must be within 5 feet.

All shoring columns shall be placed vertically and plumb. All Footings shall be placed upon level ground.

Number of 12" by 12" or 12" Min. Diameter wood shoring columns needed per side of damaged column Concrete Prestressed Girder Bridge = 16 (2 columns per concrete Prestressed girder)

Concrete Prestressed Girder Bridge has 3 Lanes

Disclaimer: This Shoring System is only applicable if the existing damaged bridge has the same geometry or smaller.

* Max Allowable Span Length A = 140'
Max Allowable Span Length B = 140'
** Allowable Shoring Heigth is 15' to 40'

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Wood Tower Layout for Prestressed Girder Bridges		Page 2
	Designed By:	LAH	7/01			Scale: Not to Scale	Date: August 15, 2001	of 11
	Drawn By:	LAH	7/01					
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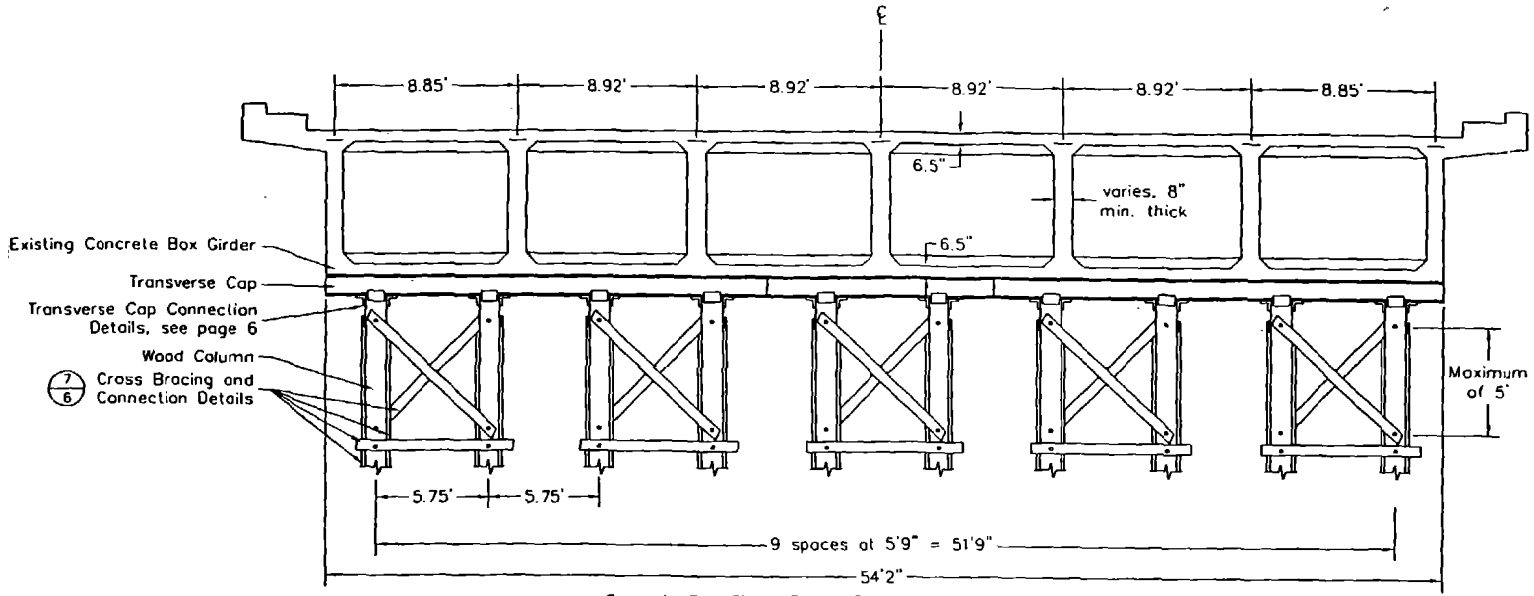
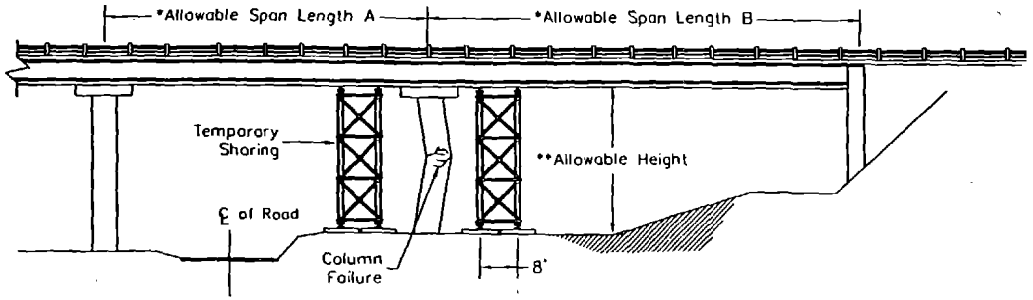


Concrete Box Girder Bridge Column and Transverse Layout for Wood Column Shoring System



Typical Column Overpass Failure
Drawing not to scale

Disclaimer: This Shoring System is only applicable if the existing damaged bridge has the same geometry or smaller.

* Max Allowable Span Length A = 140'
Max Allowable Span Length B = 110'
** Allowable Shoring Heigth is 15' to 40'

Notes:

Lateral Bracing will span every 5 feet along shoring columns

Shoring columns shall be 12" by 12" or larger Timbers or by 12" minimum diameter round piles. Round columns must conform to ASTM Standard D3200

All wood members shall be Hem-Fir or Douglas Fir-Larch and No 2 or better.

All Steel Shoring Members (Transverse Cap, Sill Beam, or Corbels) shall be either HP12X53 or HP14X89, steel shall be A36.

The depicted Concrete Box Girder Bridge has 4 Lanes

The shoring system shall be placed within 10 feet of the failed column, except for simply supported spans which must be within 5 feet.

All shoring columns shall be placed vertically and plumb. All Footings shall be placed upon level ground.

Total Number of 12" by 12" or 12" Min. Diameter wood shoring columns needed per side of damaged column Concrete Box Girder Bridge= 20

For smaller sized Box Girders, maintain shown spacing between shoring columns.

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Wood Tower Layout for Concrete Box Girder Bridges		Page 3
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	Drawn By:	LAH	7/01					
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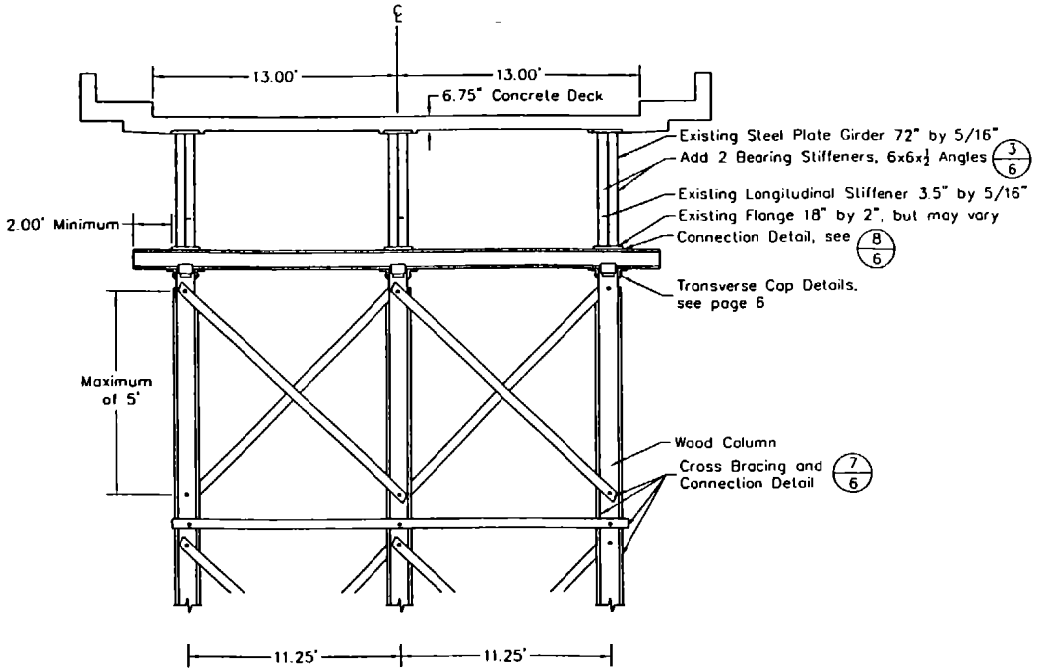


Steel Plate Girder Bridge Column and Transverse Cap Layout for Wood Column Shoring System

Notes:

Lateral Bracing will span every 5 feet along shoring columns

Shoring columns shall be 12" by 12" or larger Timbers or by 12" minimum diameter round piles.
Round columns must conform to ASTM Standard D3200

All wood members shall be Hem-Fir or Douglas Fir-Larch and No. 2 or better.

All steel shoring members (Transverse Cap, Sill Beam, or Corbels) shall be either HP12X53 or HP14X89, steel shall be A36.

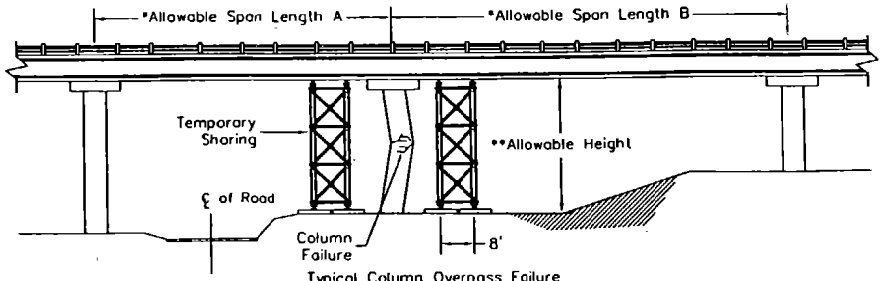
The shoring system shall be placed within 10 feet of the failed column, except for simply supported spans which must be within 5 feet.

All shoring columns shall be placed vertically and plumb. All footings shall be placed upon level ground.

Number of 12" by 12" or 12" Min. Diameter wood shoring columns needed per side of damaged column for Steel Plate Girder Bridge = 6 (2 wood columns per steel plate girder)

Two full length, steel 6x6x1/2 angle stiffeners shall be placed at each column on the steel plate girder bridge and bolted. Now welding is premitted to the superstructure.

The depicted bridge has a 2 lane capacity



Typical Column Overpass Failure
Drawing not to scale

*Max Allowable Span Length A = 133.5'
Max Allowable Span Length B = 107.5'
** Allowable Shoring Height is 15' to 40'

Disclaimer: This Shoring System is only applicable if the existing damaged bridge has the same geometry or smaller.

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Wood Tower Layout for Steel Plate Girder Bridges	Page 4
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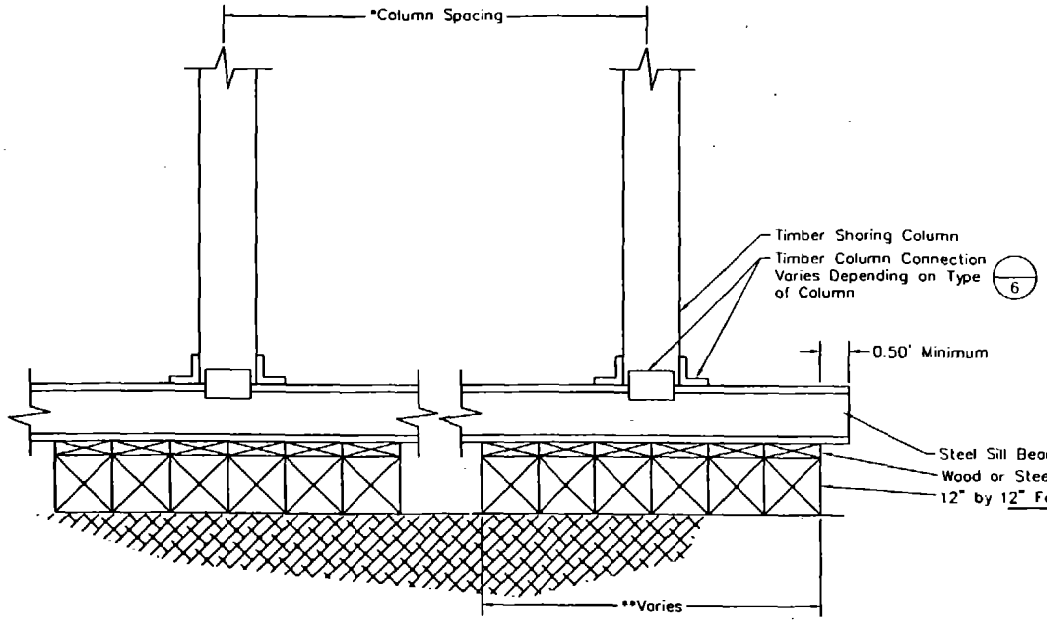
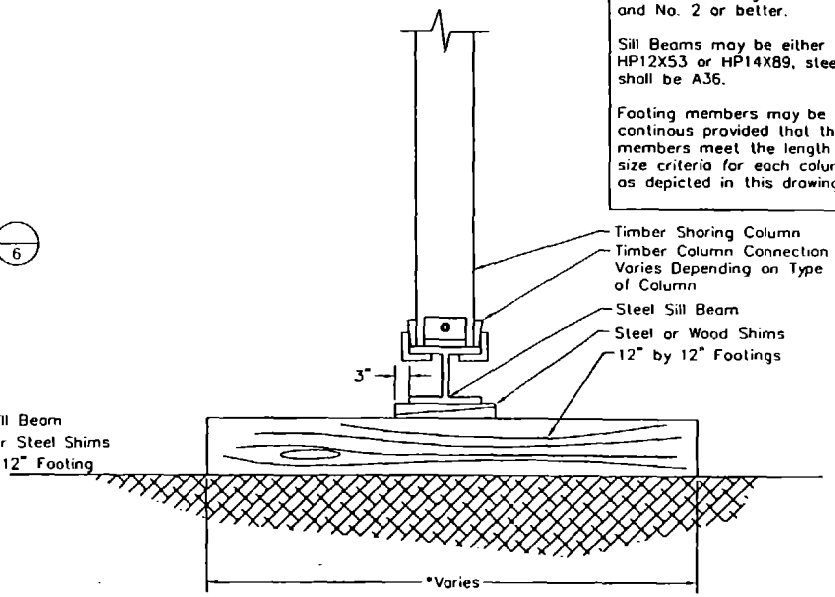


Layout of Timber Shoring Foundation along Bridge Width

Sill Beam = HP12X53 or HP14X89
Footings= 12" by 12"
* Spacing of Columns
  Prestressed Girder Bridge = 6'2"
  Steel Plate Girder Bridge = 11'3"
  Concrete Box Girder Bridge = 5'9"
** Number of 12" by 12" Footings
  Prestressed Girder Bridge = 6
  Steel Plate Girder Bridge = 6
  Concrete Box Girder = 6



Layout of Typical Shoring Foundation along Bridge Length

Sill Beam = HP12X53 or HP14X89
* Length of 12" by 12" Footings
  Prestressed Girder Bridge = 8'
  Steel Plate Girder Bridge = 8'
  Concrete Box Girder = 8'

Notes:

Footings will be made up of 12" by 12" Timbers

Wood members shall be Hem-Fir or Douglas Fir-Larch and No. 2 or better.

Sill Beams may be either HP12X53 or HP14X89, steel shall be A36.

Footing members may be continous provided that the members meet the length and size criteria for each column as depicted in this drawing.

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Timber Foundation Layout for Wood Tower		Page 5
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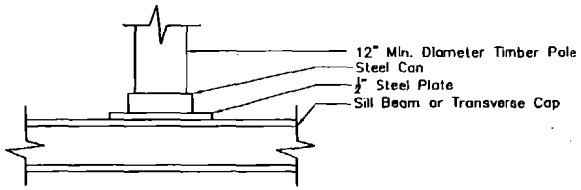
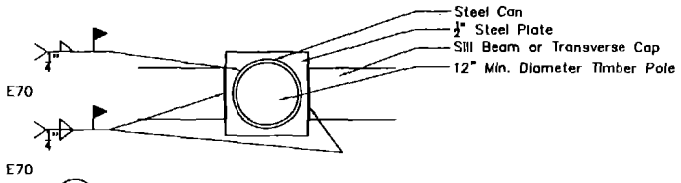
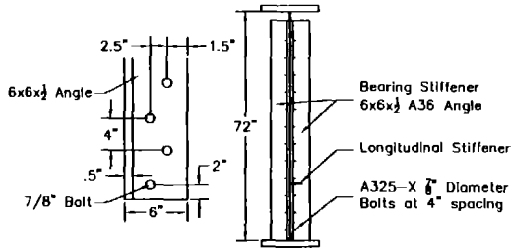


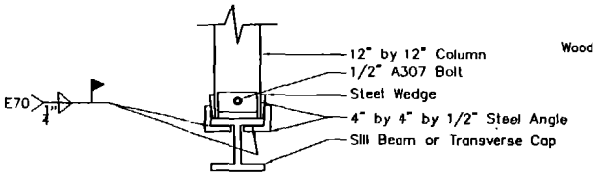
1/6 Side View of Timber Shoring Pole Connection
This diagram is applicable for both the Transverse cap and sill beam



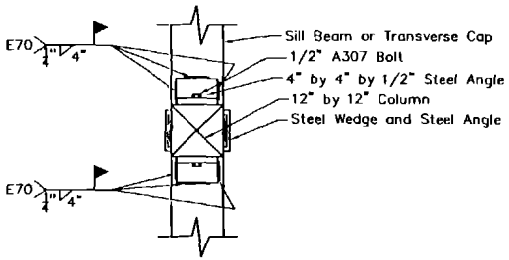
2/6 Top View of Timber Shoring Pole Steel Can Connection
This diagram is applicable for both the Transverse cap and sill beam



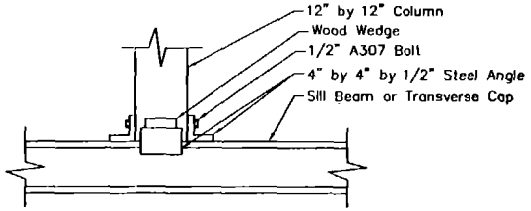
3/6 Double Plate Bearing Stiffeners for the Steel Plate Girder at Shoring Column
- Bearing Stiffeners shall be A36 steel and coped to clear welds.
- If existing longitudinal stiffeners are encountered, the angle section can be terminated to clear the longitudinal stiffener and then resumed again.
- Steel angles are to bear on the bottom flange of steel girder. Provide 1" gap between angles and top flange of the steel girder.
- For connection detail to shoring system, see Diagram B



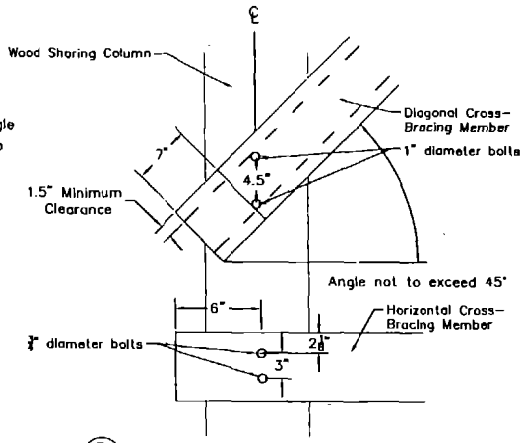
4/6 Side View of Timber Shoring Column Connection
This diagram is applicable for both the Transverse cap and sill beam



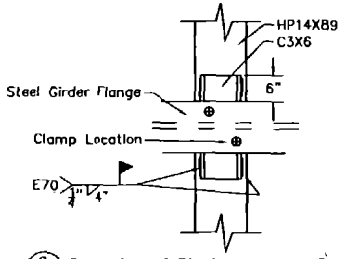
5/6 Top View of Timber Shoring Column Connection
This diagram is applicable for both the Transverse cap and sill beam



6/6 Side View of Timber Column Connection
This diagram is applicable for both the Transverse cap and sill beam



7/6 Typical Wood Shoring Connection with 2 Bolts
- Cross-bracing member to be 4" by 8" or larger
- Wood Column to be 12" by 12" or 12" Minimum Diameter Pole
- Horizontal cross-bracing members are allowed to use ¾ inch diameter bolts.
- All diagonal cross-bracing members shall use 1 inch diamter bolts and not exceed 45°
- Bolts are to be ASTM A307



8/6 Plan View of Steel Girder to HP14X89 Connection
- No welding is permitted to the Steel Plate Girder Bridge
- Two 2000 lb clamps are to be placed at each connection as indicated by the symbol of ⊕

Washington State University		Name	Date	Professional Engineer's Liscense	**Temporary Shoring Project**	**Miscellaneous Details for Wood Tower**	Page 6
	Designed By:	LAH	7/01			Scale: Not to Scale / Date: August 15, 2001	of 11
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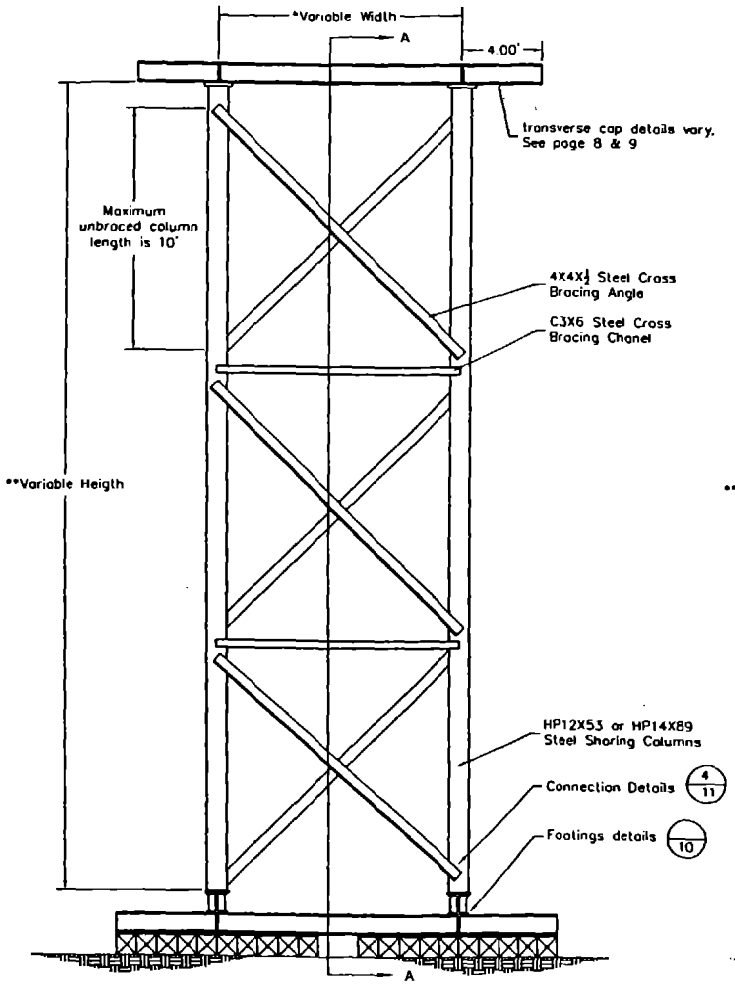
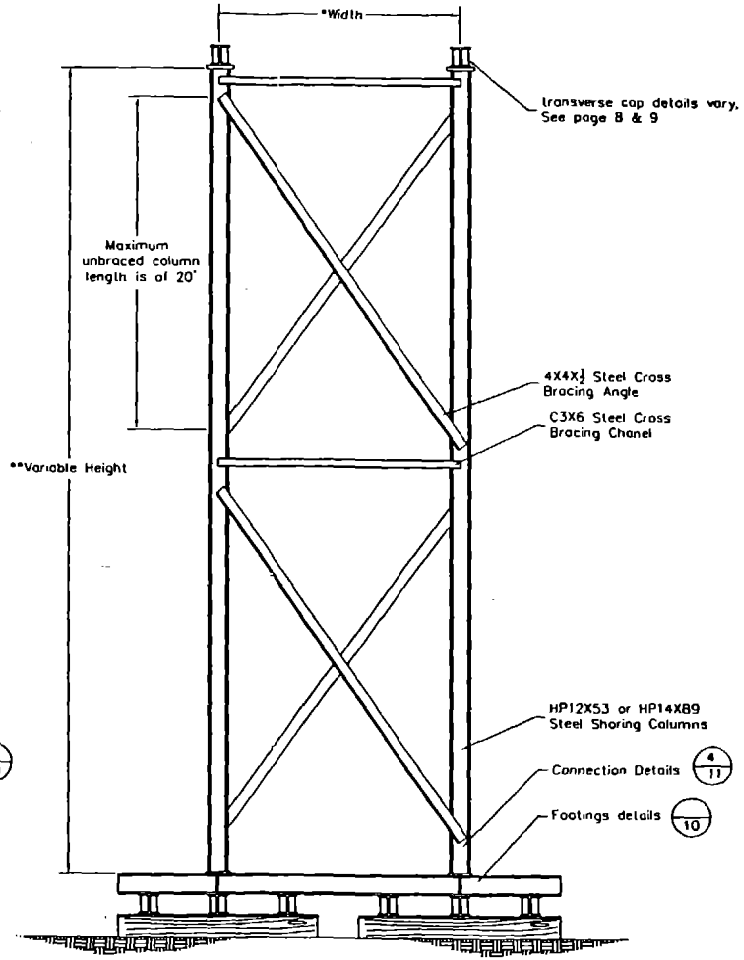


Shoring Tower along Bridge Width

- The depicted columns are placed for weak axis bending



Section A–A Setup of Shoring Tower along Bridge Length

- The depicted columns are placed for strong axis bending

Steel Shoring Column Assumptions and Notes:

Shoring Columns shall be steel HP12X53 or HP14X89.

All diagonal cross bracing are to be 4X4X½ angles or larger and lateral bracing members are to be C3X6 or larger.

Bracing will span every 10 feet about weak axis of column and 20 feet for strong axis of column as depicted

Sill Beams, Traverse Cap, and Corbels shall be HP14X89.

All connections are to be welded with 1/4" E70 electrodes.

All steel shall be A36.

Design Stresses
Steel: Fy = 36 ksi
E = 29,000 ksi
Concrete: F'c = 4000 psi
Soil: Allowable Bearing = 3000 psf

Design Loads
Dead Load: Concrete = 160 pcf
Steel = 490 pcf
Live Load: AASHTO HS20-44

Each Steel Column is designed for an axial load of 269 kips and cross bracing is designed for 5% of the axial load applied horizontally

Shoring Dimensions
* Shoring column spacing along width of bridge – Concrete Box Girder = directly under a concrete web or 10 feet – Steel Plate Girder Bridge: columns will be placed directly under existing girders
** Height of shoring column – Column height shall be 15' to 40'
*** Shoring column spacing along length of bridge – Concrete Box Girder = 10' – Steel Plate Girder Bridge = 10'

Washington State University		Name	Date	Professional Engineer's Liscense	Temporary Shoring Project	Overview of Steel Column and Cross Bracing Setup	Page 7
	Designed By:	LAH	7/01			Scale: Not to Scale	Date: August 15, 2001	of 11
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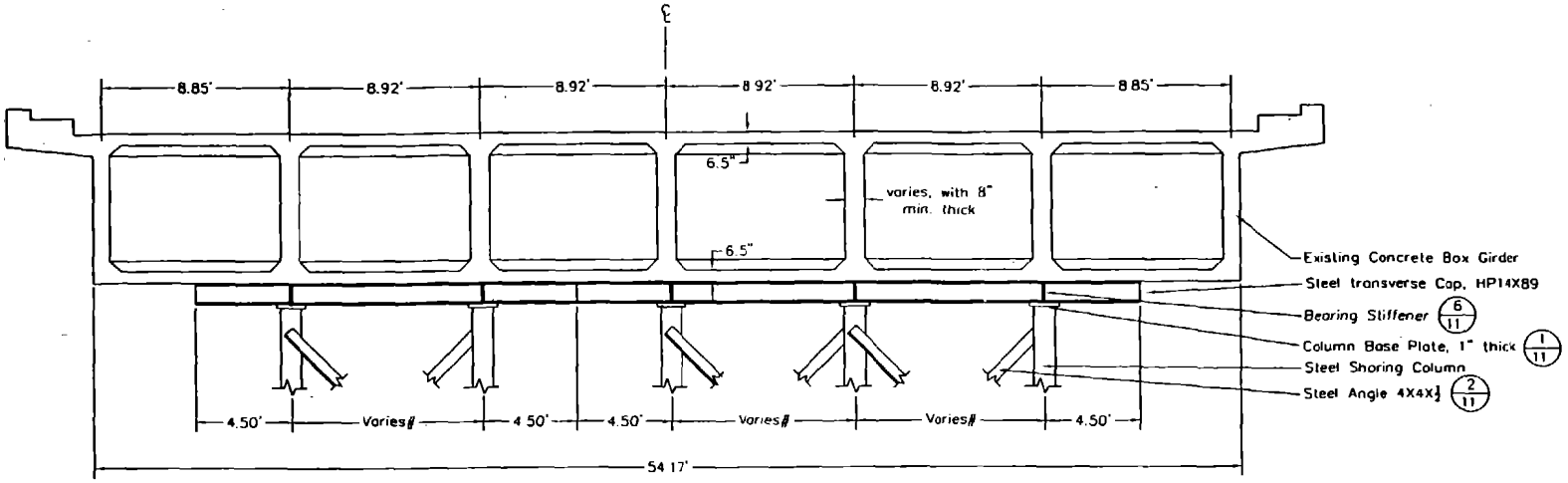
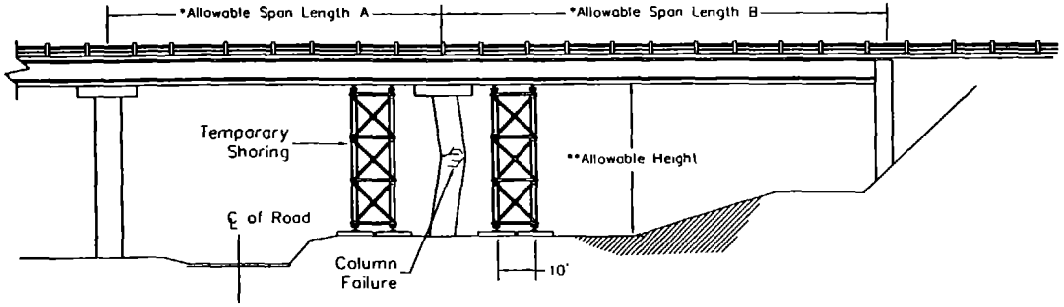


Concrete Box Girder Bridge Layout for all Steel Shoring System

– If the As-Built Dimensions are known, place the shoring columns directly beneath the webs, otherwise space columns at distance of 10 feet and center sets of shoring towers about the bottom of the box girder.



Typical Column Overpass Failure
Drawing not to scale

*Allowable Span Length A = 140'
Allowable Span Length B = 110'
** Allowable Shoring Heigth is 15' to 40'

Notes:

All steel is to be Fy = 36 ksi or greater

The transverse beam is to be A36 HP14X89

All Column Base Plates are to be welded to sill and transverse beams.

Concrete Box Girder Bridge Details has 4 Lanes

The shoring system shall be placed within 10 feet of the failed column, except for simply supported spans which must be within 5 feet.

All shoring columns shall be placed vertically and plumb. Footings shall be placed upon level ground.

Number of steel shoring columns needed per side of damaged column for the Concrete Box Girder Bridge is 10

For smaller sized box girders, maintain the same number of columns and layout

Disclaimer: This Shoring System is only applicable if the existing damaged bridge has the same geometry or smaller.

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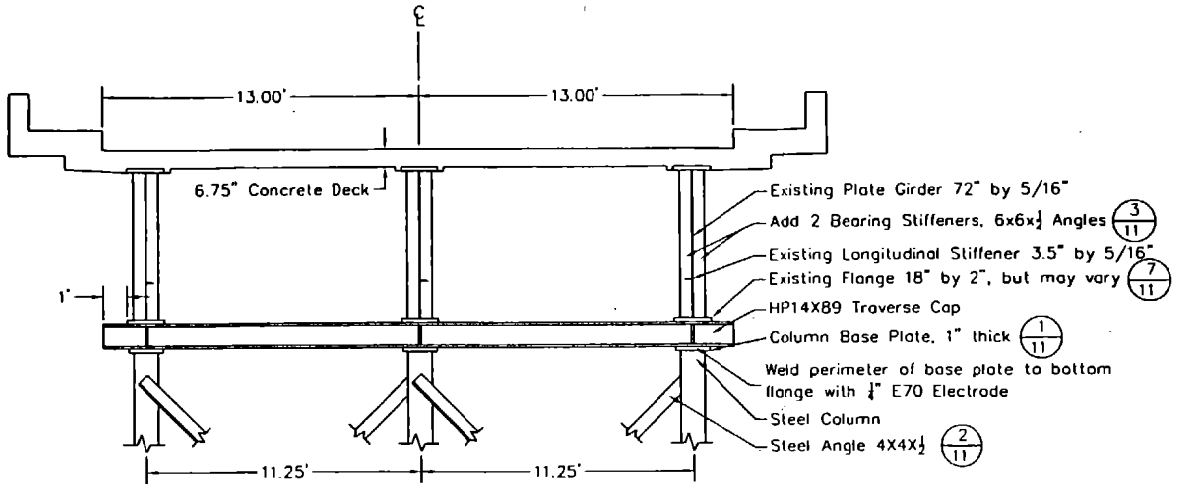
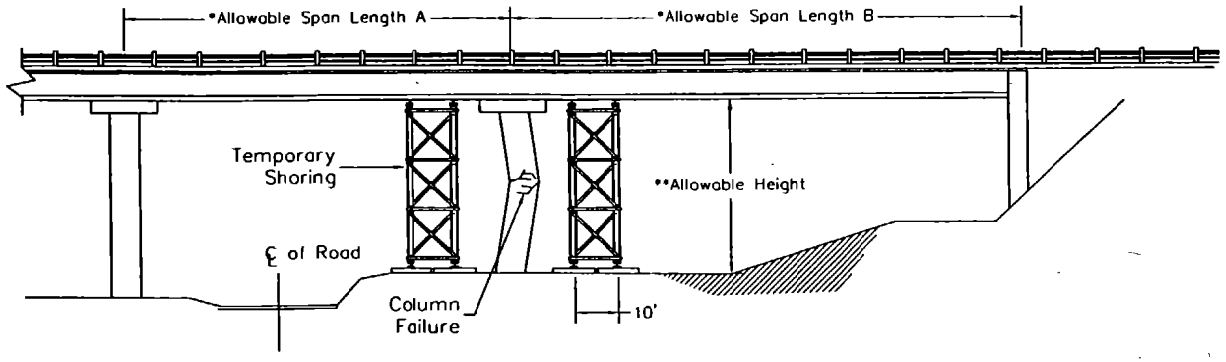
	Checked By:							

File Name: Steel Assembly.dwg



Steel Plate Girder Bridge Layout for all Steel Shoring System
Drawing Not to Scale



Typical Column Overpass Failure
Drawing not to scale

*Allowable Span Length A = 133.5'
Allowable Span Length B = 107.5'
** Allowable Shoring Height is 15' to 40'

Notes:

All steel is to be Fy = 36 ksi or greater

Column Base Plates will be secured to prevent lateral or vertical movement of the columns

Bearing Stiffeners are to be placed concentrically with each column shoring support as shown

Steel Plate Girder Bridge has 2 Lanes

The shoring system shall be placed within 10 feet of the failed column, except for simply supported spans which must be within 5 feet.

All shoring columns shall be placed vertically and plumb. Footings shall be placed upon level ground.

Number of steel shoring columns needed per side of damaged column for the Steel Plate Girder Bridge is 6 (2 columns per girder)

Disclaimer: This Shoring System is only applicable if the existing damaged bridge has the same geometry or smaller.

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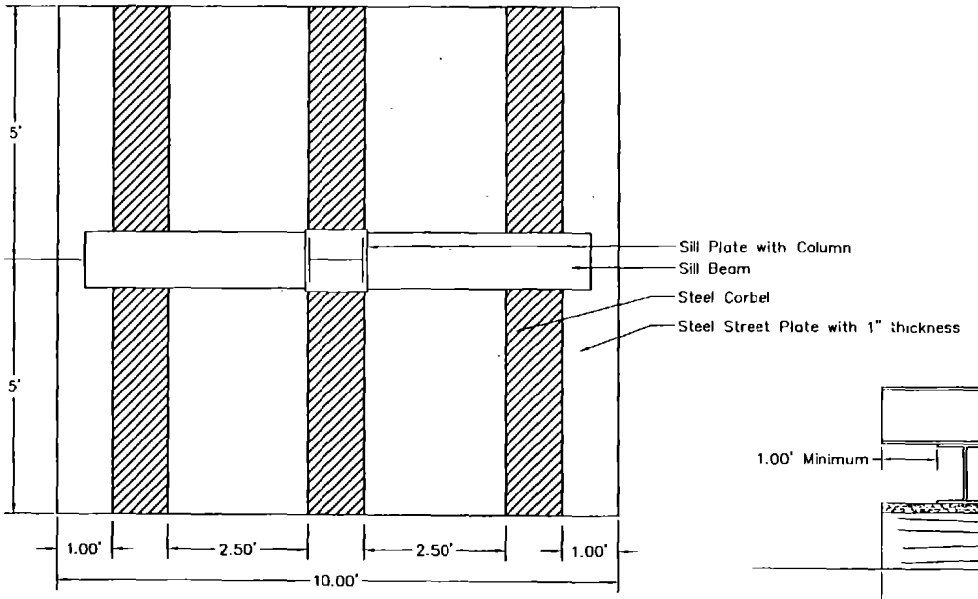
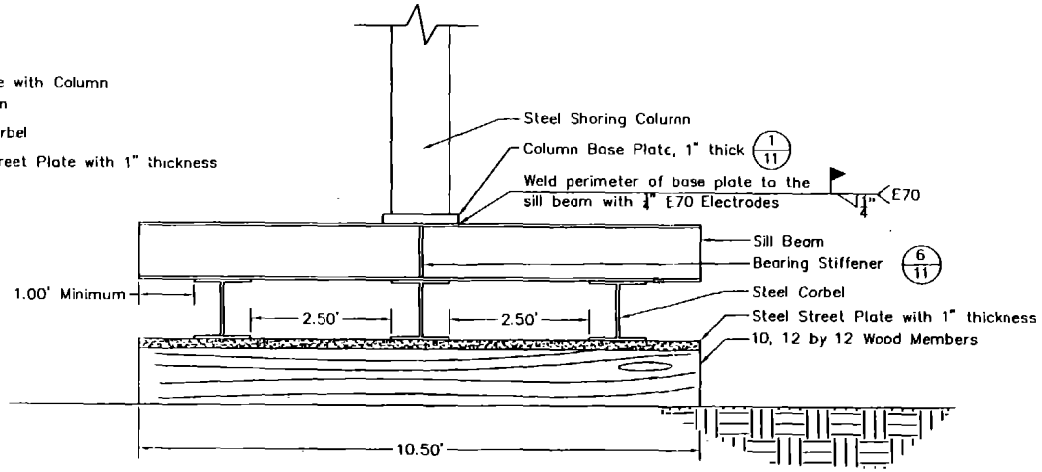


(1/10) Plan View of Steel Tower Foundation Layout

Sill Beam = HP14X89
Corbel = HP14X89 or HP12X53
Steel Plate = 5' by 10' by 1"



(2/10) Cross Section of Steel Shoring Tower Foundation Layout

Place 10 full length 12 by 12 underneath the steel plate. All wood members are to be Hem-Fir or Douglas Fir-Larch and No. 2 or better.

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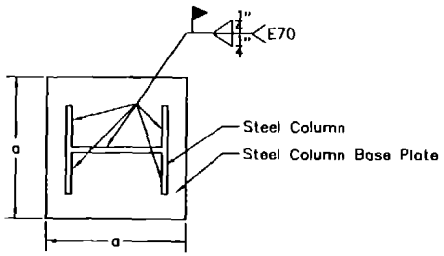
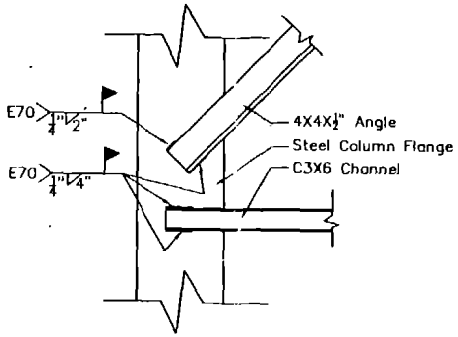
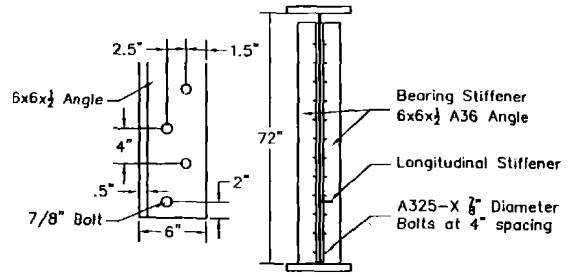


1/11 Column Base Plate Details

Dimensions for "a"
HP12X53: a=14"
HP14X89: a=16"
Base Plate Thickness = 1"
Weld perimeter of H-Pile and column plate

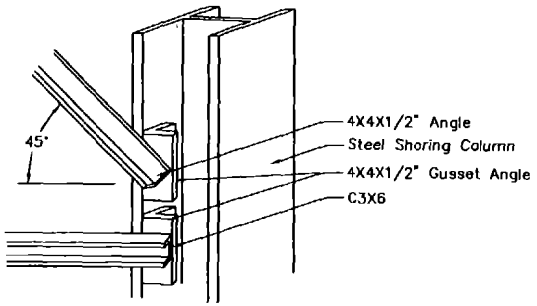


2/11 Cross Bracing Column Connections for Weak Axis Bending



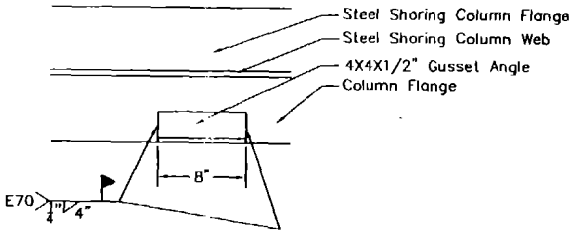
3/11 Double Plate Bearing Stiffeners for the Steel Plate Girder at Shoring Column

- Bearing Stiffeners shall be A36 steel and coped.
- If existing longitudinal stiffeners are encountered, the angle section can be terminated to clear the longitudinal stiffener and then resumed again.
- The steel angles are to bear on the bottom flange of the steel girder. Cope angles to clear welds. Provide 1" gap between angles and top flange of the steel girder.
- For Steel Plate Girder to Shoring System Connection see Diagram 7

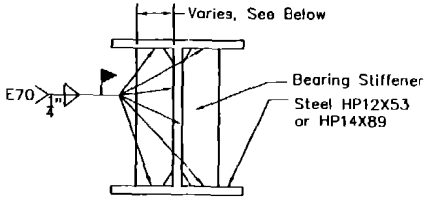


4/11 Cross Bracing Column Connections for Strong Axis Bending

- All Welds are ¼" E70 Fillet Welds
- Steel Shoring Columns are HP12X53 or HP14X89
- Max angle of Steel Angle is 45°
- Weld full lengths of gusset angle legs to column flanges as depicted in diagram 5 of this page.
- *All cross bracing members are to be welded in* the same manner as depicted in diagram 2 of this page.



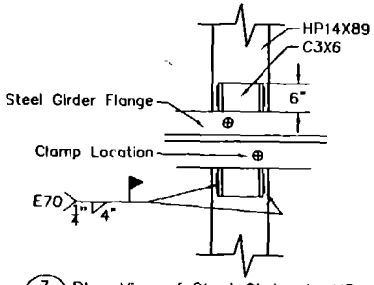
5/11 Gusset Angle Connection Details



6/11 Bearing Stiffeners for HP12X53 or HP14X89

Stiffener Size:
HP12X53 use 4" by ½"
HP14X89 use 6" by ½"

Stiffeners may also be coped with ½" fillets and are required at each point load



7/11 Plan View of Steel Girder to HP14X89 Connection

- No welding is permitted to the Steel Plate Girder Bridge
- Two 2000 lb clamps are to be placed at each connection as indicated by the symbol of ⊕

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