

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
DATE: August 5, 2011
SUBJECT: Damaged Girders in Existing Bridges

This memorandum addresses the repair or replacement of prestressed girders damaged by over-height loads. This memorandum is in addition to the requirements of BDM Section 5.6.6 for Repair of Damaged Girders in Existing Bridges. For repair or replacement of damaged prestressed girders the following guidelines shall be considered:

- In case of replacement of a damaged girder, the intermediate diaphragms adjacent to the damaged girder shall be replaced with full depth diaphragms as shown in Figure 1.
- In case of replacement of a damaged girder, the replacement girder shall be the same type as the original damaged girder. If the original girder type is no longer available, a replacement girder closely match the original girder dimensions shall be used.
- In case of repair of a damaged girder with broken or damaged prestressing strands, the original damaged diameter strands shall be replaced with similar diameter strands. Currently, 0.6" diameter strand couplers are not commercially available. If 0.6" diameter strands must be replaced, 0.5" diameter strands may be used instead. Restoration of the prestress force as outlined in BDM 5.6.6 B-2b shall be considered.
- Existing bridges with pigmented sealer shall have replacement girders sealed. Those existing bridges without pigmented sealer need not be sealed.

Background:

Strand couplers for 0.6" diameter strands are not commercially available. Strand couplers may be used to transition from 0.6" to 0.5" diameter strand to accommodate the use of 0.5" diameter strand splice to re-tension damaged or broken strands.

Prestressed girder bridges with full depth intermediate diaphragms provide better resistance to over-height load impacts than partial depth diaphragms. Damaged girder replacement often requires replacement of the intermediate diaphragms. This provides the designer an opportunity to specify full depth intermediate diaphragms for replacement.

Replacement for damaged girders should preferably be of the same type as the original girders. Damaged girder replacement often involves outside parties for cost recovery. Replacement in-kind is preferable for cost negotiations.

If you have any questions regarding these issues, please contact Bijan Khaleghi at 360-705-7181.

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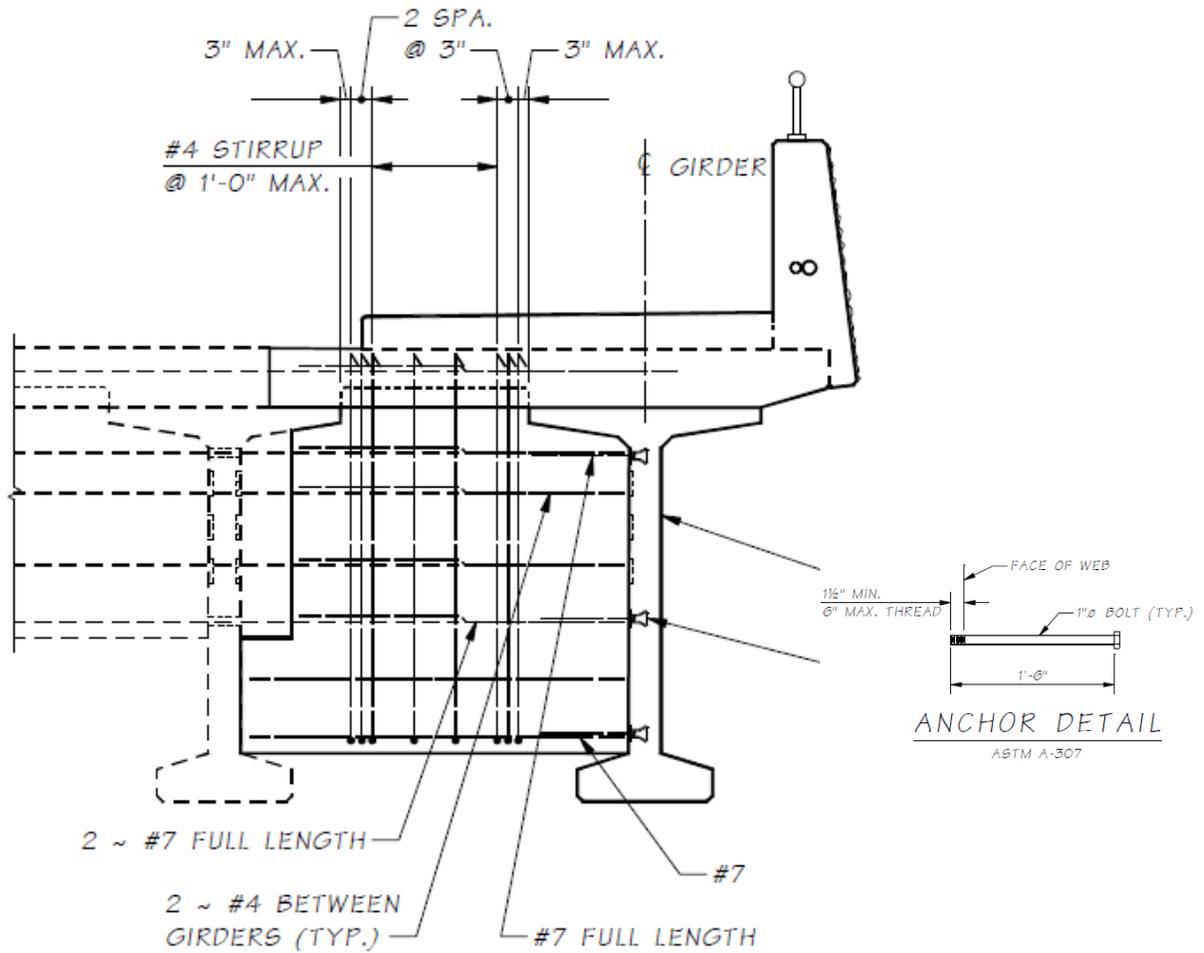


Figure 1. Full Depth Intermediate Diaphragms Replacement

BDM Revisions:

5.6.6 Repair of Damaged Girders in Existing Bridges

- A. General** - This section is intended to cover repair of damaged girders on existing bridges. For repair of newly constructed girders, see Section 5.6.5. Overheight loads are a fairly common source of damage to prestressed girder bridges. The damage may range from spalling and minor cracking of the lower flange of the girder to loss of a major portion of a girder section. Occasionally, one or more strands may be broken. The damage is most often inflicted on the exterior or first interior girder.
- B. Repair Procedure** - The determination of the degree of damage to a prestressed girder is largely a matter of judgment. Where the flange area has been reduced or strands lost, calculations can aid in making this judgment decision. The following are general categories of damage and suggested repair procedures^{15,16}.
1. **Minor Damage** - If the damage is slight and concerns only spalling of small areas of the outside surface of the concrete, repair may be accomplished by replacing damaged concrete areas with concrete grout. The area where new concrete is to be applied shall first be thoroughly cleaned of loose material, dried, and then coated with epoxy.
 2. **Moderate Damage** - If damage is moderate, consisting of loss of a substantial portion of the flange and possibly loss of one or more strands, a repair procedure must be developed using the following guidelines. It is probable that some prestress will have been lost in the damaged area due to reduction in section and consequent strand shortening or through loss of strands. The following repair procedure is recommended to assure that as much of the original girder strength as possible is retained:
 - a. **Determine Condition** - Sketch the remaining cross section of the girder and compute its reduced section properties. Determine the stress in the damaged girder due to the remaining prestress and loads in the damaged state. If severe overstresses are found, action must be taken to restrict loads on the structure until the repair has been completed. If the strand loss is so great that AASHTO prestress requirements cannot be met with the remaining strands, consideration should be given to replacing the girder.
 - b. **Restore Prestress If Needed** - If it is determined that prestress must be restored, determine the stress in the bottom fiber of the girder as originally designed due to $DL + LL + I + Prestress$. (This will normally be about zero psi). Determine the additional load (P) that, when applied to the damaged girder in its existing condition, will result in this same stress. Take into account the reduced girder section, the effective composite section, and any reduced prestress due to strand loss. Should the damage occur outside of the middle one-third of the span length, the shear stress with the load (P) applied should also be computed. Where strands are broken, consideration should be given to coupling and jacking them to restore their prestress.
 - c. **Prepare a Repair Plan** - Draw a sketch to show how the above load is to be applied and specify that the damaged area is to be thoroughly prepared, coated with epoxy, and repaired with grout equal in strength to the original concrete. Specify that this load is to remain in place until the grout has obtained sufficient strength. The effect of this load is to restore lost prestress to the strands which have been exposed.

- d. **d. Test Load** - Consideration should be given to testing the repaired girder with a load equivalent to $1.0DL + 1.5(LL+IM)$. The LL Live Load for test load is HL-93.
3. **Severe Damage** - Where the damage to the girder is considered to be irreparable due to loss of many strands, extreme cracking, etc., the girder may need to be replaced. This has been done several times, but involves some care in determining a proper repair sequence. In general, the procedure consists of cutting through the existing deck slab and diaphragms and removing the damaged girder. Adequate exposed reinforcement steel must remain to allow splicing of the new bars. The new girder and new reinforcement is placed and previously cut concrete surfaces are cleaned and coated with epoxy. New deck slab and diaphragm portions are then poured.

It is important that the camber of the new girder be matched with that in the old girders. Excessive camber in the new girder can result in inadequate deck slab thickness. Girder camber can be controlled by prestress, curing time, or dimensional changes.

Pouring the new deck slab and diaphragms simultaneously in order to avoid overloading the existing girders in the structure should be considered. Extra bracing of the girder at the time of deck slab pour shall be required.

Methods of construction shall be specified in the plans that will minimize inconvenience and dangers to the public while achieving a satisfactory structural result. High early strength grouts and concretes should be considered.

In case of replacement of a damaged girder, the intermediate diaphragms adjacent to the damaged girder shall be replaced with full depth diaphragms as shown in Figure 1.

In case of replacement of a damaged girder, the replacement girder shall preferably be the same type as the original damaged girder.

In case of repair of a damaged girder with broken or damaged prestressing strands, the original damaged diameter strands shall be replaced with similar diameter strands. Currently, 0.6" diameter strand couplers are not commercially available. If 0.6" diameter strands must be replaced, 0.5" diameter strands may be used instead. Restoration of the prestress force as outlined in BDM 5.6.6 B-2b shall be considered.

Existing bridges with pigmented sealer shall have replacement girders sealed. Those existing bridges without pigmented sealer need not be sealed.

4. **Repair vs. Replacement of Damaged Girder** - Several factors need to be considered when evaluating whether to repair or to replace a damaged girder. Among them are the level of concrete damage, number of broken strands, location and magnitude of web damage, permanent offset of the original girder alignment, and overall structural integrity. Other considerations include fresh damage to previously damaged girders, damage to adjacent girders, and cost of repair versus replacement. Ultimately, the evaluation hinges on whether the girder can be restored to its original capacity and whether the girder can be repaired sufficiently to carry its share of the original load.

The following guidelines describe damaged girder conditions which require replacement:

- **Strand Damage:** More than 25% of prestressing strands are damaged/severed. If over 25% of the strands have been severed, replacement is required. Splicing is

routinely done to repair severed strands. However, there are practical limits as to the number of couplers that can be installed in the damaged area.

- **Girder Displacements:** The bottom flange is displaced horizontally position more than ½" per 10' of girder length. If the alignment of the girder has been permanently altered by the impact, replacement is required. Examples of non-repairable girder displacement include cracks at the web/flange interface that remain open. Abrupt lateral offsets may indicate that stirrups have yielded. A girder that is permanently offset may not be restorable to its original geometric tolerance by practical and cost-effective means.
- **Concrete Damage at Harping Point:** Concrete damage at harping point resulting in permanent loss of prestress. Extreme cracking or major loss of concrete near the harping point may indicate a change in strand geometry and loss in prestress force. Such loss of prestress force in the existing damaged girder cannot be restored by practical and cost effective means, and requires girder replacement.
- **Concrete Damage at Girder Ends:** Severe concrete damage at girder ends resulting in permanent loss of prestress or loss of shear capacity. Extreme cracking or major loss of concrete near the end of a girder may indicate unbonding of strands and loss in prestress force or a loss of shear capacity. Such loss of prestress force or shear capacity in the existing damaged girder cannot be restored by practical and cost-effective means, and requires girder replacement.

There are other situations as listed below which do not automatically trigger replacement, but require further consideration and analysis.

- **Significant Concrete Loss:** for girder damage involving significant loss of concrete from the bottom flange, consideration should be given to verifying the level of stress remaining in the exposed prestressing strands. Residual strand stress values will be required for any subsequent repair procedures.
- **Adjacent Girders:** Capacity of adjacent undamaged girders. Consideration must be given as to whether dead load from the damaged girder has been shed to the adjacent girders and whether the adjacent girders can accommodate the additional load.
- **Previously Damaged Girders:** Damage to a previously damaged girder. An impact to a girder that has been previously repaired may not be able to be restored to sufficient capacity.
- **Cost:** Cost of repair versus replacement. Replacement may be warranted if the cost of repair reaches 70% of the replacement project cost.

C. **Miscellaneous References** – The following girder replacement contracts and similar jobs should be used for guidance:

Contract	Project Name	Bridge Number	Total Bridge Length (ft)	Year work planned	Work Description
C-7425	I-5 Bridge 005/518 Girder Replacement	5/518	322	2008	Replace damaged PCG
C-7637	SR 520/ W Lake Sammamish Pkwy To SR 202 HOV And SR	11/1	287	2009	Replace damaged PCG in one span
C-7095	SR 14, Lieser Road Bridge Repair	14/12	208	2006	Replace damaged PCG
C-7451	I-90 Bridge No. 90/121- Replace Portion Of Damaged	90/121	250	2007	Replace damaged PCG

C-7567	Us395 Col Dr Br & Court St Br - Bridge Repair	395/103	114	2008	Replace damaged PCG
C-7774	SR 509, Puyallup River Bridge Special Repairs	509/11	3584	2010	Replace fire damage PCG span
C-9593	Columbia Center IC Br. 12/432(Simple Span)				Repair
C-9593	16th Avenue IC Br. 12/344 (Continuous Span)				Repair
C-9446	Mae Valley U Xing (Simple Span)				
KD-2488	13th Street O Xing 5/220 (Northwest Region)				
KD-2488	SR 506 U Xing 506/108 (Northwest Region)				
C-5328	Bridge 5/411 NCD (Continuous Span)				
KD-2976	Chamber of Commerce Way Bridge 5/227				
KD-20080	Golden Givens Road Bridge 512/10				
KD-2154	Anderson Hill Road Bridge 3/130W				

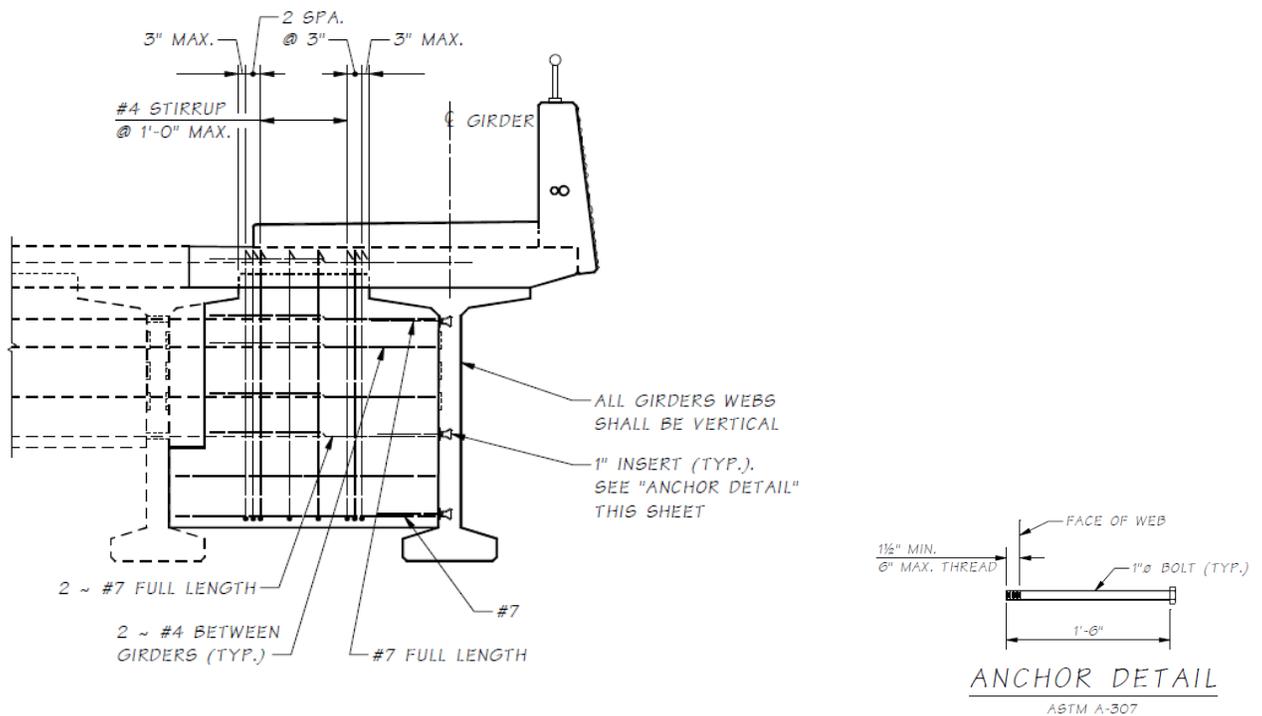


Figure 5.6.6-1. Full Depth Intermediate Diaphragms Replacement

