PERSPECTIVE

WSDOT Policies and Criteria for Girders Damaged in Service

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Every year in Washington state, several bridges experience overheight vehicle collisions. These collisions may result in damage to or failure of bridge girders or even collapse of the bridge system. The damage to precast, prestressed concrete girders may range from spalling and minor cracking of the bottom flange and web of a girder to loss of a major portion of a girder section. This article presents categories and criteria used by the Washington State Department of Transportation (WSDOT) for the assessment of structural damage to precast, prestressed concrete bridge girders caused by overheight collisions, and discusses guidelines to determine the repair or replacement of those girders that appear in Section 5.6.6 of the WSDOT *Bridge Design Manual*.[1]

Girder damage due to overheight collisions is relatively common in Washington state. **Figure 1** shows an example of the damage to the Interstate 5 (I-5) Chamber Way overpass bridge caused when a semitruck hauling a pair of excavators hit a portion of the bridge spanning southbound I-5 in Chehalis on July 22, 2016. The existing Chamber Way overpass was built in 1958 with a vertical clearance of only 14 ft 8 in. Though this clearance is adequate for the 14-ft-maximum vehicle height allowed without a permit, it does not meet the modern design standard of 16 ft 6 in. that is required for new construction highway crossings in Washington. Before the 2016 incident, this bridge had been damaged and repaired with strand splice anchors, as shown in **Fig. 2**. As a result of the significant structural damage incurred in 2016, WSDOT demolished the damaged span in its entirety (**Fig. 3**) and installed a temporary bridge until the replacement span could be constructed.

Repair of Damaged Prestressed Concrete Girders in Existing Bridges

Girder damage is divided into three categories: minor, moderate, and severe. The determination of the degree of damage to a prestressed concrete girder is largely a matter of judgment. Where the flange area has been reduced or strands lost, calculations can aid in making this judgment.

To determine the damage category and prepare the repair plan for bridges, the

Figure 1: In July 2016, a collision by an overheight vehicle damaged the prestressed concrete girder bridge over southbound Interstate 5 at Chamber Way in Chehalis, Wash. All Photos: Washington State Department of Transportation.

Figure 2: Before the 2016 collision, the same bridge had been damaged at the same location. The severed prestressing strands were repaired using strand splices (shown in inset photo and visible in the first girder in Fig. 1).

Figure 3: Because significant structural damage was incurred during the 2016 collision, the Washington State Department of Transportation demolished the damaged span in its entirety and installed a temporary bridge until the replacement span could be constructed.

location of damage and the size and extent of spalls and loose concrete are quantified and documented, and a sketch of the largest loss of cross section is prepared. Out-of-plane deformation is measured and reported as relative lateral deformation over a 10 ft length of girder. A crack map showing the orientation and width of all cracks, including those in the flanges, web, deck slab, diaphragms, and barrier walls, is included. Bridge bearings and expansion joints are inspected for any signs of damage, dislocation, or altered orientation.

The following sections present general damage categories, suggested repair procedures, and guidelines for the damaged girder conditions that require girder replacement.[1]

Minor Damage

Minor damage involves cracking and spalling, typically in the bottom flange, that may partially or fully expose at least one prestressing strand. However, no severed strands should be present. Strands with damaged, deformed, or kinked wire(s) should be considered severed, and this category would not apply.

To repair minor damage, the damaged area is to be thoroughly prepared, coated with an epoxy bonding agent and repaired to the original cross section with grout equal in strength to the original concrete. All cracks wider than 0.006 in. should be injected with epoxy.

Moderate Damage

This category of damage involves localized loss of between 25% and 50% of the cross section, no damage to the interface shear reinforcement, no cracking observed near the supports due to girder deformation, and girder sweep (at the top flange) that is less than ⅛ in. per 10 ft. Under the moderate damage category, the moment strength would generally be unchanged despite the damage, but service level stresses would change.

Patching, with the same procedures outlined for the minor damage cases, may be required. Inject all cracks that are wider than 0.006 in. with epoxy. If the interface shear reinforcement is damaged, it should be repaired or restored. If it is determined that patching of the top flange is required, and there is no existing transverse steel in the top flange, anchorage bars installed with epoxy adhesive may be provided, as required by structural calculations, before patching. As a general guide, ½-in.-diameter adhesive anchors at 6 in. spacing should be considered.

If damage is moderate, it is probable that some prestress will have been lost in the damaged area due to reduction in concrete cross section and consequent strand shortening, or through loss of strands. If the damage does not exceed the criteria for girder replacement, a repair procedure should be developed according to the following guidelines.

1. **Determine condition:** 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 the stress limitations in Article 5.9.2 of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[2] cannot be met with the remaining strands, replacement of the girder should be considered.
2. **Restore prestress if needed:** Prestress in damaged and severed strands can sometimes be restored with mechanical strand couplers. Damaged girders with broken 0.6-in.-diameter strands may need to be repaired with 0.5-in.-diameter strands and additional post-tensioning. Current commercially available couplers are capable of restoring full prestressing force in strands of up to 0.5-in. diameter. Verify that the restoration of full prestressing force will not cause overstress in the damaged girder section.
3. **Prepare a repair plan:** Draw a sketch to show the area of concrete removal required for replacement, and for the installation of any required mechanical strand couplers. The damaged area is to be thoroughly prepared, coated with an epoxy bonding agent, and repaired with grout equal in strength to the original concrete.

Severe Damage

Severe damage involves localized loss of greater than 50% of the cross section, extensive damage to the interface shear reinforcement, or out-of-tolerance sweep of the top flange of the girder.

Although repair may be possible in some cases classified to this damage category, any such repairs should be considered only after careful review of structural strength, serviceability, and stability considerations. Otherwise, replacement of the girder(s) should be considered. If there is excessive girder sweep, replacement may be the only practical option.

Girder Repair versus Replacement

Several factors need to be considered when evaluating whether to repair or replace a damaged girder. Among them are the extent of concrete damage, the number of broken strands, the location and magnitude of web damage, permanent offset of the original girder alignment, and overall structural integrity.

The following guidelines describe girder conditions that require replacement.

- **Strand damage:** If more than 25% of prestressing strands are damaged or severed, replacement is required. Although splicing is routinely done to repair severed strands, there are practical limits as to the number of couplers that can be installed in the damaged area.
- **Girder displacements:** If the bottom flange is displaced from its original horizontal position by more than ½ in. per 10 ft of girder length, the alignment of the girder has been permanently altered by the impact and replacement is required. Examples of nonrepairable 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 the harping point:** If concrete damage at the harping point results in permanent loss of prestress, girder replacement is required. Severe damage at the harping point would include any damage such that the hardware and strands have moved significantly. Extreme cracking or major loss of concrete near the harping point may indicate a change in strand geometry and loss of prestress. Such loss of prestress in the existing damaged girder cannot be restored by practical and cost-effective means, so girder replacement is required.
- **Concrete damage at girder ends:** If there is severe concrete damage at girder ends resulting in permanent loss of prestress or loss of shear capacity, girder replacement is required. Extreme cracking or major loss of concrete near the end of a girder may indicate loss of strand bond with the concrete and loss of prestress, or a loss of shear capacity.
- **Significant concrete loss from the web:** If significant concrete damage in the web results in loss of shear capacity, girder replacement is required. The web damage shall be considered significant when more than 25% of the web section is damaged or when shear reinforcement has yielded.

There are other issues that do not automatically trigger replacement but require further consideration and analysis. These issues include significant concrete loss from the bottom flange, the capacity of adjacent undamaged girders, repairs to previously damaged girders, and the cost of repair versus replacement. The WSDOT *Bridge Design Manual*[1] provides additional guidance on evaluating girder or superstructure replacement.

Girder Replacement Considerations

The WSDOT *Bridge Design Manual*[1] requires that damaged girders be replaced in accordance with current WSDOT design criteria and with current girder series. The replacement girder should be of the same type or the same depth as the original damaged girder. Furthermore, replacing a damaged girder involves some care in determining a proper replacement sequence. In general, the procedure consists of cutting through the existing deck slab and diaphragms and removing the damaged girder. Adequate exposed reinforcing steel must remain in the deck slab and diaphragms to allow splicing to new reinforcement.

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

When a damaged girder is replaced, the intermediate diaphragms adjacent to the damaged girder shall be replaced with full-depth diaphragms and the replacement girder should be of the same type or the same depth as the original damaged girder. Casting the new bridge deck and diaphragms simultaneously to avoid overloading the existing girders in the structure should be considered. Extra bracing of the replacement girder at the time of bridge deck placement will be required.

Conclusion

It is not uncommon for prestressed concrete girders to be damaged by collisions caused by overheight vehicles. WSDOT has developed criteria to evaluate the severity of the damage and whether the girders should be repaired or replaced. The guidelines presented in this article are intended to help engineers exercise the judgment required to make decisions regarding the repair of damaged prestressed concrete girders.

References

1. Washington State Department of Transportation (WSDOT). 2020. *Bridge Design Manual*. M23-50.20. Olympia: WSDOT. https://www.wsdot.wa.gov/publications/manuals/fulltext/M23-50/BDM.pdf
2. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.

EDITOR'S NOTE

Bridge damage due to overheight vehicle strikes is a common occurrence throughout the United States. There is a pending National Cooperative Highway Research Project (NCHRP) to develop a Guide for Preventing and Mitigating the Risk of Bridge and Tunnel Strikes by Motor Vehicles *to help state departments of transportation, public safety agencies, and the motor carrier industry prevent these events. More information can be found at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4950.*

Other resources are available for the evaluation and repair of prestressed concrete girders with impact damage. One such resource is the Guide to Recommended Practice for the Repair of Impact-Damaged Prestressed Concrete Bridge Girders, *developed by Harries et al. for NCHRP Project 20-07, Task 307. It was published in 2012 and can be found at http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(307)_AppendixA-GUIDE.pdf. The final report on the project is available at http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(307)_FR.pdf.*