

TO: All Design Section Staff  
FROM: Bijan Khaleghi  
DATE: April 13, 2017  
SUBJECT: Handling and Shipping of Prestressed Concrete Girders

This design memorandum specifies required design criteria for temporary condition service limit state checks associated with handling and shipping of prestressed girders. See the attached Bridge Design Manual Revisions.

Handling and shipping checks are a required part of the design to provide a reasonable assurance of constructability for prestressed girders. All handling and shipping support parameters assumed in design, which include truck roll stiffness and wheel spacing, shall be identified in the plans. Designers are encouraged to assume the smallest feasible hauling vehicle for each girder in their designs. By providing a range of shipping support parameters to designers, the contractor is given flexibility in selecting the hauling equipment and schedule. However, the contractor shall be contractually responsible for the actual handling and shipping of prestressed girders.

Additional contract requirements are included in the amendments to the *Standard Specifications* dated April 3, 2017.

**Background:**

Historically, checks for stability and safety of prestressed girders during handling and shipping have been performed as part of design in PGSuper. But the criteria and results have not been fully specified in the BDM or contract documents. This memo supplements specification changes to addresses that inconsistency.

Additionally, the development of larger hauling vehicles has created the need to distinguish which hauling vehicles have been assumed in the design of prestressed girders. By specifying this information in the plans, contractors can more accurately bid the work, and they are alerted when a proposed shipping plan may require modification to the prestressed girder design.

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## **Bridge Design Manual Revisions:**

### **Section 5.6.2 C2 shall be revised to read as follows:**

*The stress limits as described in Table 5.2.1-1 shall not be exceeded for prestressed concrete girders at all stages of construction and in service. The stages of construction for which stress limits shall be checked shall include, but not be limited to the following:*

- a. Prestressing release at casting yard using Service I Limit State*
- b. Lifting at casting yard using Service I Limit State. Dead load impact need not be considered during lifting. This check shall be done in accordance with Section 5.6.3.C.2.*
- c. Shipping for a girder with impact using Service I Limit State. A dead load impact of 20 percent shall be included acting both up and down. The angle of inclination shall be the equilibrium tilt angle computed for lateral stability (see Section 5.6.3.D.6) with a roadway superelevation of 2 percent. This check shall be done in accordance with Section 5.6.3.D.6. This condition represents the girder traveling along a straight road at a typical 2% superelevation with dynamic load effects.*
- d. Shipping for a girder without impact using Service I Limit State. Dead load impact, wind and centrifugal forces need not be included. The angle of inclination shall be the equilibrium tilt angle computed for lateral stability (see Section 5.6.3.D.6) with a roadway superelevation of 6 percent. This check shall be done in accordance with Section 5.6.3.D.6. This condition represents the girder going slowly through a corner with a 6% superelevation.*
- e. Deck and diaphragm placement using Service I Limit State*
- f. Final condition without live load using Service I Limit State*
- g. Final condition with live load using Service I Limit State for compressive stresses and Service III Limit State for tensile stresses*
- h. Final condition with live load using Fatigue I Limit State*

### **Section 5.6.3 C2 shall be revised to read as follows:**

*The designer shall specify the lifting embedment locations (centroid 3' minimum from ends - see Standard Specifications Section 6-02.3(25)L), maximum midspan vertical deflection and the corresponding concrete strength at release that satisfies the allowable stress criteria from Section 5.2.1.C and provides an adequate factor of safety for lateral stability. The calculations shall conform to methods as described in Standard Specifications Section 6-02.3(25) and reference 26. Factors of safety of 1.0 against cracking and 1.5 against failure shall be used.*

*As a result of the assumed lifting embedment transverse placement tolerance and the girder sweep tolerance, biaxial stresses due to lateral bending occur at the girder tilt equilibrium*

condition. Allowable stresses shall be evaluated for the girder tilt equilibrium condition for a hanging girder as described in Standard Specifications Section 6-02.3(25) and reference 26.

Lateral stability can be a concern when handling long, slender girders. Lateral bending failures are sudden, catastrophic, costly, pose a serious threat to workers and surroundings, and therefore shall be considered by designers. When the girder forms are stripped from the girder, the prestressing level is higher and the concrete strength is lower than at any other point in the life of the member. Lifting embedment/support misalignment, horizontal girder sweep and other girder imperfections can cause the girder to roll when handling, causing a component of the girder weight to be resisted by the weak axis.

Lateral stability may be improved using the following methods:

- a. Move the lifting embedments away from the ends. This may increase the required concrete release strength, because decreasing the distance between lifting devices increases the concrete stresses at the harp point. Stresses at the support may also govern, depending on the exit location of the harped strands.
- b. Select a girder section that is relatively wide and stiff about its vertical (weak) axis.
- c. Add temporary prestressing in the top flange.
- d. Brace the girder.
- e. Raise the roll axis of the girder with a rigid yoke.

**Section 5.6.3 D6 shall be revised to read as follows:**

The designer shall specify concrete strengths, shipping support locations, minimum shipping support rotational spring constants, shipping support center-to-center wheel spacing, maximum midspan vertical deflections and temporary top strand configurations in the Plans that satisfy the allowable stress criteria from Section 5.2.1.C and provide adequate factors of safety for lateral stability during shipping. The calculations shall conform to methods described in Standard Specifications Section 6-02.3(25) and reference 26. Factors of safety of 1.0 against cracking and 1.5 against failure and rollover shall be used. See the discussion above on lateral stability during handling of prestressed concrete girders for suggestions on improving stability.

The rotational stiffness and center-to-center wheel spacing used in design shall be taken from Table 5.6.3-1. Design the girder for transportation with the least stiff support system as possible while achieving recommended factors of safety.

Shipping Support Rotational Spring Constant, $K_{\theta}$ (kip-in/radian)	Shipping Support Center-to- Center Wheel Spacing, $W_{cc}$ (in)
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<i>40,000</i>	<i>72</i>
<i>50,000</i>	<i>72</i>
<i>60,000</i>	<i>72 or 96</i>
<i>70,000</i>	<i>96</i>
<i>80,000</i>	<i>96</i>

*Shipping Support Parameters*  
*Table 5.6.3-1*

### Implementation Support in PGSuper:

PGSuper Version 3.0, which is part of the BridgeLink suite of tools, supports these requirements. The lifting and hauling stability analysis conforms to the procedures described in BDM reference 26.

The Temporary Conditions tab of the Girder Details window includes a new Haul Truck parameter as shown in Figure 1. The parameter references one of the haul trucks defined in the new Haul Trucks library. Use this parameter to specify a haul truck configuration for hauling stress and stability analysis.

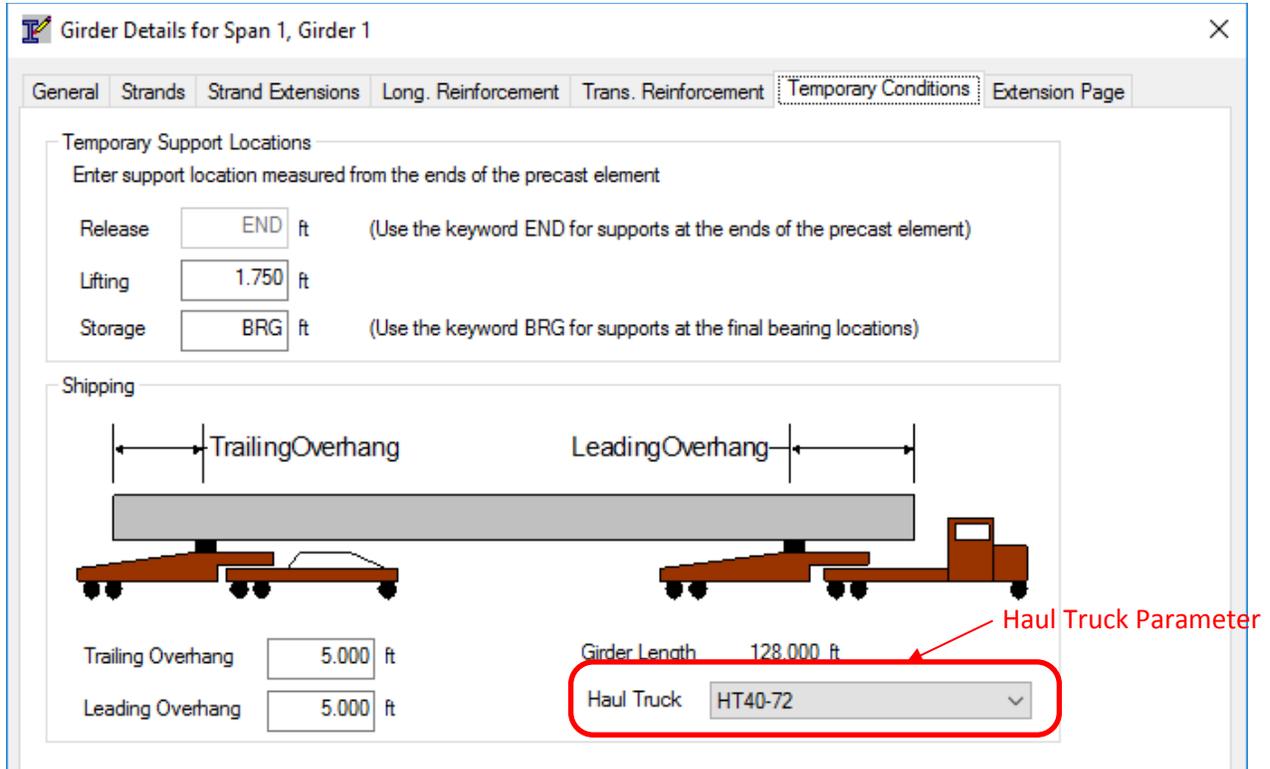


Figure 1 New Haul Truck Parameter

For the WSDOT configuration of PGSuper, the new Haul Trucks library models the haul trucks defined in BDM Table 5.6.3-1. The PGSuper Girder Designer will automatically select the smallest haul hauling vehicle, based on rotational stiffness and wheel spacing, from the library that satisfies the design requirements.

Previous versions of PGSuper used an algorithm to estimate the rotational stiffness of the haul truck based on the girder weight. PGSuper creates haul trucks named “Old Haul Truck - n”, where n is an integer, when opening previously created files to represent the old haul trucks. The Haul Truck parameter of the girder definitions are set to these haul trucks. Eliminate the old haul truck from design consideration by removing them from the Project Library.

The WSDOT Girder Schedule Report lists the lifting and hauling parameters for the Girder Schedule.

The BEToolbox includes a new girder stability tool called PGStable. This tool performs lifting and hauling stability analysis for an individual girder. You can define the girder directly or export it from PGSuper.

Refer to program documentation for additional details.

Download the BridgeLink suite of tools, which includes PGSuper and BEToolbox, from <http://www.wsdot.wa.gov/eesc/bridge/software>.

# PGSuper™ Technical Note (TN002)

Updated Girder Stability Design and Analysis

## Background

The Precast/Prestressed Concrete Institute (PCI) has published recommended practices for lateral stability of precast, prestressed concrete bridge girders. PCI Pacific Northwest (PCI/PNW) and local heavy haulers have requested WSDOT update design practices to account for modern hauling equipment and provide better communication of design assumptions. The WSDOT Standard Specifications, Bridge Design Manual, Girder Standards and the PGSuper software incorporate changes to the engineering practice related to girder stability analysis.

This document provides guidance for using PGSuper Versions 2.9 and 3.0 with respect to the new design approach and new information required for the girder schedule.

## New Design Approach for Girder Stability during Hauling

The new approach to designing girders for stability during hauling is very simple. Design girders for the least stiff hauling configuration, chosen from a list of hauling configurations representative of the regional fleet of hauling equipment, for which stress and stability requirements are satisfied. The hauling vehicle parameters, with the exception of the support rotational spring constant and the center-to-center wheel spacing, are unchanged from the previous design method. Table 1 shows the support rotational spring constant and center-to-center wheel spacing.

Put simply, the new design approach is to start with configuration 1 from Table 1 and design the girder. Repeat the design process with each subsequent configuration until the design is successful.

	Shipping Support Rotational Spring Constant $K_{\theta}$ (kip-in/rad)	Center to Center Wheel Spacing $W_{cc}$ (in)
<b>1</b>	40,000	72
<b>2</b>	50,000	72
<b>3</b>	60,000	72
<b>4</b>	60,000	96
<b>5</b>	70,000	96
<b>6</b>	80,000	96

Table 1- Haul Configuration Parameters

## New Girder Schedule Information

Figure 1 shows the new parameters on the girder schedule. These parameters, along with the information in the Standard Specifications, provide builders, fabricators, and haulers the complete set of assumptions used when determining the lifting and bunking locations.

SHIPPING AND HANDLING DETAILS					
MAXIMUM MIDSPAN VERTICAL DEFLECTION AT SHIPPING	L	L1	L2	$K_{\theta}$ MINIMUM SHIPPING SUPPORT ROTATIONAL SPRING CONSTANT	$W_{CC}$ MINIMUM SHIPPING SUPPORT CNTR.-TO-CNTR. WHEEL SPACING
-	-	-	-	-	-
-	-	-	-	-	-

Figure 1 - New Girder Schedule Information

The Shipping and Handling Details girder schedule parameters are:

- Maximum Midspan Vertical Deflection At Shipping = The deflection due to self-weight and prestressing at mid-span of the girder in the shipping configuration.
- L = Location of lifting support locations
- L1, L2 = Location of bunk points
- $K_{\theta}$ , Minimum Shipping Support Rotational Spring Constant = rotational spring constant determined from analysis
- $W_{CC}$ , Minimum Shipping Support Cntr-to-Cntr wheel spacing = center-to-center, transverse, wheel spacing of the hauling vehicle, determined from analysis.

## PGSuper 2.9

PGSuper 2.9 uses the now obsolete method of determining the truck support rotational spring constant. Manual iteration through the hauling equipment configurations is required for design.

### Procedure for Design and Analysis

Use the following procedure for design and analysis:

- 1) Create custom project criteria
  - a. Open your PGSuper project or create a new project
  - b. Select **Library > Edit Libraries**
  - c. In the Library Editor window, select the Project criteria library
  - d. Right click on the project criteria with a red check next to it and select Duplicate. This will create a copy of the project criteria that is currently in use.
  - e. Right click on the copy and select Rename. Enter a meaningful name (we'll use MyCriteria for this example).
- 2) Select custom project criteria

- a. Select **Project > Project Criteria**. Select “MyCriteria” from the list. “MyCriteria” is now the project criteria. Modify the hauling parameters as needed.
- 3) Set haul truck parameters in “MyCriteria”
  - a. In the Library Editor window, double click on the “MyCriteria” object
  - b. Select the Hauling tab
  - c. In the Hauling Parameters section, select “Constant” for the Roll Stiffness of the Truck Trailer and enter the Roll Stiffness and Truck Width from the table above starting with configuration 1.
- 4) Design/Analysis
  - a. Perform a design or specification check analysis. A successful specification check analysis may require adjusting the bunking locations and temporary strands.
  - b. Return to Step 3 and use the next configuration if girder stability is inadequate.
  - c. Repeat until the hauling configuration is adequate.

## Girder Schedule Information

The new girder schedule parameters can be determined as follows:

- Maximum Midspan Vertical Deflection, Shipping: Estimate the effect of camber on the location of the center of gravity of the girder by increasing the location of the center of gravity with respect to the roll axis by 2%. Estimate the maximum midspan vertical deflection as  $0.02(Y_{bg} + H_{bg} - H_{rc})$  where  $Y_{bg}$  is the location of the girder centroid measured from the bottom of the girder,  $H_{bg}$  is the height of the bottom of girder above the roadway surface, and  $H_{rc}$  is the height of the roll axis above the roadway surface.  $H_{bg}$  and  $H_{rc}$  can be found in the Project Criteria on the Hauling tab.
- Minimum Shipping Support Rotational Spring Constant: Use the value  $K_{\theta}$  found in the Hauling Check Details chapter of the Hauling or Details Reports.
- Minimum Shipping Support Cntr-to-Cntr Wheel Spacing: Use two times the value  $z_{max}$  found in the Hauling Check Details chapter of the Hauling or Details Reports. Alternatively, use the value for Truck Width (C-C distance between dual tires) found in the Project Criteria on the Hauling tab.

## PGSuper 3.0

PGSuper 3.0, which is part of the BridgeLink suite of tools, uses the new method of determining the haul truck parameters. Update old PGSuper projects so that the old hauling parameters are not used.

## Updating Older Project Files

Update PGSuper™ projects created prior to adding the new stability and haul truck features. The following procedure details the necessary steps.

- 1) Identify if input modifications are required
  - a. Open your PGSuper project file

- b. Select **Library > Edit Libraries**
  - c. In the PGSLibrary Editor window, select the Haul Truck library
  - d. If there are haul truck entries in your project library (entries with a red check and without the lock icon) that have a name beginning with “Old Haul Truck –”, update the project.
- 2) Assign a pre-defined Haul Truck configuration to all girders
- a. Select **Edit > Girder**. Choose Span 1, Girder A
  - b. Select the Temporary Conditions tab
  - c. Change the haul truck to “HT40-72”
  - d. Press [OK]
  - e. Select **Edit > Copy Girder Properties**
  - f. Copy properties from Span 1, Girder A to All Girders, All Spans. Uncheck all properties to copy except for “Copy Temporary Conditions”.
  - g. Press [Copy Now] followed by [Close]. NOTE: This will copy all temporary support conditions, even those for lifting. If you need more fine control over changing the haul truck, edit each girder individually.
- 3) Delete “Old Haul Truck” from library
- a. Return to the Haul Trucks library in the PGSLibrary Editor window
  - b. The haul truck named “Old Haul Truck” should no longer have a red check. Right click on this truck and select Delete.
- 4) Design/Analysis
- a. Perform a design of specification check analysis. The designer will find the haul truck with the least stiffness that satisfies the project criteria.
  - b. If performing a specification check analysis, change the hauling bunk points, temporary strands, and haul truck as needed to satisfy the project criteria.

## Girder Schedule Information

The new parameters for the girder schedule are available in the WSDOT Girder Schedule report. Simply create a WSDOT Girder Schedule report, verify the information, and enter the information into the girder schedule.