AASHTOWare BrDr 6.8

3D FEM Analysis Tutorial
Steel Diaphragm and Lateral Bracing Specification Checking Example
3DFEM1 - Diaphragm Spec Checking

BrD and BrR Training

3DFEM1 - Steel Diaphragm and Lateral Bracing Specification Checking Example

Topics Covered

- Steel Diaphragm Connection Data Entry
- Bracing Deterioration
- Bracing Specification Checking

This example describes data entry and specification checking for a steel diaphragm. Bottom flange lateral bracing members have the same features as diaphragms.

Import the “3DFEM1 - Diaphragm Spec Checking.xml” file into BrDR. Click OK to close the Bridge window.

![Diaphragm Training Window](image)

- Name: Steel Diaphragm Example
- Year Built
- Description:
- Location:
- Facility Carried (7):
- Feature Intersected (6):
- Default Units: US Customary
- Bridge ID: Diaphragm Training
- NBI Structure ID (8): Diaphragm Training
- Template
- Bridge Completely Defined
- Superstructures
- Culverts
- Length: __ ft
- Route Number: 1
- Mi Post:
- AASHTOWare Association...
“Connectors” have been moved up in the Bridge Workspace tree and are now located below the Bridge instead of under a particular superstructure definition. This was done to allow bolts to be assigned to Diaphragm Definitions.

Open the highlighted bolt definition to review the bolt to be used in the diaphragms.
The following sketch illustrates the intermediate diaphragm that will be described for this example.

Double-click the “Diaphragm Definitions” folder and create the following diaphragm definition:
The following sketch from the Help illustrates the “Section Location” selection.

![Diagram](image1)

The Diaphragm: Connections tab is a new tab in BrDR 6.8. Enter the following data to describe the bolts in the diaphragm.

![Table](image2)

**Description of the Work Point Offset:**

![Diagram](image3)

Dashed lines show the member lengths as computed based on the girder spacing and Y offsets entered by the user. The user can enter the Work Point Offset shown to reduce the length of member AE used in the slenderness ratio ($Kl/r$) calculations.
3DFEM1 - Diaphragm Spec Checking

The following sketch describes the bolt entry fields. For this example, 1 longitudinal bolt line that contains 2 bolts per line is described.

![Sketch of bolt entry fields]

The following new fields were added to the Superstructure Definition: Analysis tab to control the bracing specification checking. “3D Bracing Member End Connection Analysis” allows the user to specify what forces should be used when connection specification checking is implemented in the future. The LRFR factor data selected here will be used for all bracing members unless the bracing member has different factor data entered on the Bracing Deterioration window.
The finite element analysis can now consider wind load applied to the FE model. Open the Load Case Description window and add the following load case for the wind load:

Open the Framing Plan Details: Diaphragms tab and assign the diaphragm definitions to the interior diaphragm locations for all 3 girder bays:
The Framing Plan Schematic displays the location labels for the bracing members:

The new Bracing Deterioration window allows the user to describe deterioration on the bracing members. Double-click the "Bracing Deterioration" label in the BWS tree and create a new deterioration description for the diaphragm assigned to location 1-2 in Bay 1:
Enter the following values for section loss on Member AB. This section loss will be used in rating, not in design review. The superstructure definition LRFR condition factor can also be overridden for this particular member on this tab.

The Bracing Specification Check Selection window allows the user to select which diaphragms and lateral bracing should be specification-checked:
Open the Superstructure Loads: Wind tab to enter the following information. Note that wind is only considered in an LRFD design review, not in a rating. The wind load path data only applies to line girder analysis where the wind load is approximated on the exterior girder.

Since wind is a horizontal load that is now being considered, at least 2 bearings should be constrained in the Z direction for at least 1 girder. The following is the Supports: 3D General tab for G1:
Open the Analysis Settings window and select the following settings for a 3D LRFD design review.
Select the name of the superstructure definition in the Bridge Workspace tree and click Analyze.

In this example, only the selected diaphragms will be analyzed and specification checked. None of the girder members have member alternatives marked as Existing (E), so they are not included in the analysis.
3DFEM1 - Diaphragm Spec Checking

After the analysis completes, open the Tabular Results window while the superstructure definition is selected to see the bracing member results:

The wind load results can also be viewed in this window:
Specification check details can be viewed for the bracing members:

The following specification article illustrates how the wind load is combined with the live load:

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**Spec Check Detail for 6.9.4.1.1 Nominal Compressive Resistance**

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
<th>Load Combination</th>
<th>Value</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>STR-JV</td>
<td>Compression</td>
<td>3.38</td>
<td>6.30</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-JV</td>
<td>Compression</td>
<td>-3.38</td>
<td>10.69</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-JV</td>
<td>Compression</td>
<td>-3.38</td>
<td>6.30</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-V</td>
<td>Tension</td>
<td>--</td>
<td>--</td>
<td>NA</td>
</tr>
<tr>
<td>STR-V</td>
<td>Compression</td>
<td>-5.87</td>
<td>3.65</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-V</td>
<td>Tension</td>
<td>--</td>
<td>--</td>
<td>NA</td>
</tr>
<tr>
<td>STR-V</td>
<td>Compression</td>
<td>-5.87</td>
<td>3.63</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-V</td>
<td>Tension</td>
<td>--</td>
<td>--</td>
<td>NA</td>
</tr>
<tr>
<td>STR-V</td>
<td>Compression</td>
<td>-5.87</td>
<td>3.59</td>
<td>Pass</td>
</tr>
<tr>
<td>STR-V</td>
<td>Tension</td>
<td>--</td>
<td>--</td>
<td>NA</td>
</tr>
<tr>
<td>STR-V</td>
<td>Compression</td>
<td>-5.87</td>
<td>3.59</td>
<td>Pass</td>
</tr>
</tbody>
</table>

NA - This article is for compression only.

Load Combination Legend:

1. K-93 (US) I-T-L
2. K-93 (IT) T-L-L
3. K-93 (US) I-T-L + Wind from Left
4. K-93 (US) I-T-L + Wind from Right
5. K-93 (US) T-L-L + Wind from Left
6. K-93 (US) T-L-L + Wind from Right
7. LBF-D Fatigue Truck (BS) 1T

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Last Modified: 8/12/2016

AASHTOWare BrDR 6.8
The following new output files are available:

Wind load is calculated based on the projected area of the superstructure elevation. Wind load on the barrier, deck and ½ the girder depth (as measured between the top flange and bottom flange nodes in the FE model) is applied to the top flange node in the windward side exterior beam. Wind load on the bottom ½ the girder depth is applied to the bottom flange node in the windward side exterior beam.
For curved structures, wind is applied along the chord length. This is done by adjusting the user input wind pressure by the ratio of the chord length divided by the arc length. For curved girder systems with superelevation, wind load is also computed for the additional height of exposed barrier and additional exposed beam depth.
A summary of the bracing specification check results is also available:

### Specification Check Summary

<table>
<thead>
<tr>
<th>Article</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexure (6.10.8.1.1, 6.10.8.1.2, 6.8.2.3, 6.9.2.2)</td>
<td>NA</td>
</tr>
<tr>
<td>Axial Tension (6.8.2)</td>
<td>Pass</td>
</tr>
<tr>
<td>Axial Compression (6.9.4.1.1)</td>
<td>Pass</td>
</tr>
<tr>
<td>Block Shear Rupture (6.12.4)</td>
<td>Pass</td>
</tr>
</tbody>
</table>

### Tensile Resistance

<table>
<thead>
<tr>
<th>Bracing</th>
<th>Bracing Member</th>
<th>LS</th>
<th>LC</th>
<th>Pu (kip)</th>
<th>Pr (kip)</th>
<th>Design Ratio</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>AB STR-I</td>
<td>1</td>
<td>1</td>
<td>11.22</td>
<td>100.55</td>
<td>8.96</td>
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<td></td>
<td>AB STR-I</td>
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<td>6.77</td>
<td>100.55</td>
<td>8.68</td>
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<tr>
<td></td>
<td>AB STR-I</td>
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<td>3</td>
<td>11.58</td>
<td>100.55</td>
<td>9.76</td>
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<td></td>
<td>AB STR-I</td>
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<td>1</td>
<td>-6.85</td>
<td>100.55</td>
<td>9.90</td>
<td>NA</td>
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<tr>
<td></td>
<td>AB STR-I</td>
<td>1</td>
<td>2</td>
<td>-2.03</td>
<td>100.55</td>
<td>9.95</td>
<td>NA</td>
</tr>
<tr>
<td>3-4</td>
<td>AB STR-III</td>
<td>1</td>
<td>1</td>
<td>-2.82</td>
<td>100.55</td>
<td>9.90</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>AB STR-III</td>
<td>1</td>
<td>2</td>
<td>-2.03</td>
<td>100.55</td>
<td>9.90</td>
<td>NA</td>
</tr>
</tbody>
</table>
In a similar manner, an LRFR or LFR rating can be performed. Note that wind is not included in the rating analysis but section loss is.

The section loss that was entered for member AB in Diaphragm 1-2 is considered.
If the user wants to change a piece of data that does not directly impact the FE analysis or results, such as the bolt details in a diaphragm, the Analysis Settings window allows the user to process just a specification check without redoing a full analysis.

The following shows the details for Article 6.8.2 for Member EB in the diaphragm 1-2. Note the net area.

Open the Diaphragm Definition window for the Type 2 diaphragm and modify the bolt details for Member EB by adding an extra line of bolts:
Open the Analysis Settings window and select just a Specification Check. Click OK and run the analysis again.
BrDR will regenerate the FE Models and compare them to the previously generated FE models. Since the models are the same, the previous FE results are re-used and the specification checking considers the revised details: