Reinforced Concrete Structure Tutorial

RC8 - Reinforced Concrete Tee Beam Using BrD LRFD Engine
RC6 – Reinforced Concrete Tee Beam Using Opis LRFD Engine

Elevation

Typical Section

8" Total, 7 ½" Eff.

8-#9

3.064"

26"

3'-0"

40"

72"

8" Including ½" integral wearing surface

Jersey Barrier

4 spaces @ 6'-0" = 24'-0"

6" 40'-0"

#4 stirrups @ 12"

3'-0"
Framing Plan

Diaphragm weight = 1.2 kips/.each

**Material Properties**

Slab Concrete: Class A (US) $f'c = 4.0$ ksi, modular ratio $n = 8$
Slab Reinforcing Steel: AASHTO M31, Grade 60 with $F_y = 60$ ksi
BrD Training

RC6 - Reinforced Concrete Tee Beam Using BrD LRFD Engine

Topics Covered

- Reinforced concrete schedule based tee input as girder system.
- Export of schedule based reinforced concrete beams to the BrD LRFD analysis engine
- BrD LRFD specification checking

Open the Bridge Workspace for BID 11, “RCTrainingBridge1”.
The Bridge Workspace is shown below.
Double click on SUPERSTRUCTURE DEFINITIONS to create a new structure definition. The dialog shown below will appear.

![New Superstructure Definition dialog](image)
Select Girder System and the Structure Definition window will open. Enter the appropriate data as shown below:
Click Load Case Description to define the dead load cases. Use the “Add Default…” button to create the following load cases.

<table>
<thead>
<tr>
<th>Load Case Name</th>
<th>Description</th>
<th>Stage</th>
<th>Type</th>
<th>Time* (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC1</td>
<td>DC acting on non-composite section</td>
<td>Non-composite (Stage 1)</td>
<td>D, DC</td>
<td></td>
</tr>
<tr>
<td>DC2</td>
<td>DC acting on long-term composite section</td>
<td>Composite (long term) (Stage 2)</td>
<td>D, DC</td>
<td></td>
</tr>
<tr>
<td>DW</td>
<td>DW acting on long-term composite section</td>
<td>Composite (long term) (Stage 2)</td>
<td>D, DW</td>
<td></td>
</tr>
<tr>
<td>SIP Forms</td>
<td>Weight due to stay-in-place forms</td>
<td>Non-composite (Stage 1)</td>
<td>D, DC</td>
<td></td>
</tr>
</tbody>
</table>

*Prestressed numbers only
Double-click on Framing Plan Detail to describe the framing plan. Enter the appropriate data as shown below.
Switch to the Diaphragms tab to enter diaphragm spacing. Enter the following diaphragms for Girder Bay 1 as shown below:

Click the Copy Bay To button to copy the diaphragms entered for Bay to the other bays.

Click Apply to copy the diaphragms to girder bay 2.

Select Ok to close Structure Framing Plan Details window.
Next define the structure typical section by double-clicking on Structure Typical Section in the Bridge Workspace tree. Input the data describing the typical section as shown below. This screen initially shows steel girders as the default girder type until the member alternatives are defined.

Basic deck geometry:
The Deck (cont’d) tab is used to enter information about the deck concrete and thickness. The material to be used for the deck concrete is selected from the list of bridge materials described above.
Parapets:
The two parapets are described using the Parapet tab. Click New to add a row to the table. The name of the parapet defaults to the only barrier described for the bridge. Change the “Load Case” to “DC2”. Reinforced concrete structures only have 1 stage but we will select DC2 here since we want the dead load of the parapets to be uniformly distributed to all girders and BrD only allows that type of load distribution in stage 2. We will discuss this more when we review the Superstructure Loads window.

Change “Measure To” to “Back” (we are locating the parapet on the deck by referencing the back of the parapet to the left edge of the deck). Enter 0.0 for the “Distance at Start” and “Distance at End”. Change the “Front Face Orientation” to “Right”. The completed tab is shown below.
Lane Positions:

Select the Lane Position tab. Enter the values shown below or click the “Compute…” button to automatically compute the lane positions. A dialog showing the results of the computation opens. Click Apply to apply the computed values. The Lane Position tab is populated as shown below.
The schematic of the Structure Typical Section is shown below.
The DL Distribution tab of the Superstructure Loads window is shown below. BrD only provides the “Uniformly to all girders” distribution option for stage 2 dead loads. Even though reinforced concrete only has 1 stage, we previously assigned our parapets to stage 2 on the Structure Typical Section window to take advantage of the uniformly to all girders option. The export to the BrD LRFD analysis engine will uniformly distribute the parapets to all girders and assign that load to the stage 1 model.
Define shear reinforcement to be used by the girders. Expand the shear Reinforcement Definitions tree item and double click on Vertical. Define the stirrup as shown below. Click Ok.
Create the following Bar Mark Definition to be used for the longitudinal reinforcement in the beam.

![Bar Mark Definition](image)

- **Name**: #9 Bar
- **Material**: Grade 60
- **Bar size**: 9
- **Bar type**: Straight
- **Dimension**: 40.5000 ft

(Bar Mark Definition Diagram)
Describing member G2:

The member window shows the data that was generated when the structure definition was created. No changes are required at this time. After Member Alternatives are defined it will appear in the list of member alternatives.
Support constraints were generated when the structure definition was created and are shown below.

Defining a Member Alternative:
Double click MEMBER ALTERNATIVES in the tree to create a new alternative. The New Member Alternative dialog shown below will open. Select Reinforced Concrete for the Material Type and Reinforced Concrete Tee for the Girder Type.
Enter the following data in the Member Alternative window:

For a schedule based reinforced concrete member, it is important to enter a value for the End Bearing Locations in this window. This data describes the distance from the physical end of the beam to the centerline of the end bearings. It is important for us to enter this value here so that when we assign bar mark definitions to the reinforcement profile we can start our bars to the left of the first support line and to the right of the last support line.

If our bars start to the left of the first support line and to the right of the last support line, BrD will consider the bars to be partially developed at the centerline of the bearing. Then the analysis engine will be able to compute the “d” distance from the extreme compression fiber to the centroid of the tension reinforcement. This “d” value is required to compute the shear capacity of the section. If the rebar starts at the centerline of the bearing, it will be considered as zero percent developed at this point so a “d” distance cannot be computed and the shear capacity of the beam will be zero.
The BrD LRFD analysis engine will compute live load distribution factors for you. You do not have to enter any values if you want the BrD engine to compute them for you. We will review the computed values later in this example.
Enter the following section properties.

The LRFD effective flange width is computed as follows:

AASHTO LRFD Article 4.6.2.6.1:

For interior beams, effective flange width taken as least of:

- average spacing of adjacent beams = 6'(12")/ = 72"
The web is described as follows:

![Girder Profile](image)

The types of reinforcement are:

1. Reinforced Concrete Tee
2. Reinforced Concrete Tee using BrD LRFD Engine
The reinforcement is entered as follows:

Enter the following shear reinforcement ranges:
To perform a design review, select the View Analysis Settings button on the toolbar to open the window shown below. Use the “HL-93 Design Review” template to select the vehicles to be used and click Ok.

Next click the Analyze button on the toolbar to perform the design review.
You should always review the analysis log that is created when you do an analysis with the BrD LRFD engine. Informational messages are displayed in blue, warning messages are displayed in green and error messages are displayed in red font.

The following steps are performed when doing a design review using the BrD LRFD analysis engine:

1. Finite element models are generated for the dead load and live load analyses. A Stage 1 FE model is generated for the dead loads on the reinforced concrete beam. A Stage 3 FE model is generated for the live load analysis. Reinforced concrete beams only have 1 stage so the Stage 1 and Stage 3 models contain the same cross section properties.

The model generated by the export to the BrD LRFD analysis engine will contain node points at locations where the cross section properties change, span tenth points, support locations, and user defined points of interest.
2. The Stage 1 FE model is analyzed for the dead load. The Stage 3 FE model is loaded with unit loads at each node to generate influence lines for the beam. The influence loads are then loaded with the selected vehicles to find the maximum live load effects.

3. Load combinations are generated for the loadings and specification checks are performed at each of the nodes in finite element model as well as the locations where schedule based reinforcement is developed.

The report containing the calculations of the rebar development locations is shown below.
A summary and a detailed report of the computed live load distribution factors are available.
A summary report of the specification check results is also available. This summary report lists the design ratios for each spec article at each spec check location point. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.

### Specification Check Summary

<table>
<thead>
<tr>
<th>Article</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexure (5.7.3.2, 5.7.3.3.2)</td>
<td>Pass</td>
</tr>
<tr>
<td>Crack Control (5.7.3.4)</td>
<td>Pass</td>
</tr>
<tr>
<td>Shear (5.8.3.3, 5.8.2.5, 5.8.2.7, 5.8.3.5)</td>
<td>Fail</td>
</tr>
<tr>
<td>Fatigue (5.5.3.2)</td>
<td>Pass</td>
</tr>
<tr>
<td>Deflection (2.5.2.6.2)</td>
<td>Pass</td>
</tr>
</tbody>
</table>

### Girder Positive Flexure Analysis

<table>
<thead>
<tr>
<th>Location (ft)</th>
<th>LS</th>
<th>Load Comb</th>
<th>Mr (kip-ft)</th>
<th>Mu (kip-ft)</th>
<th>Mr/Mu</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>STR-1</td>
<td>1</td>
<td>120.91</td>
<td>0.00</td>
<td>99.00</td>
<td>Pass</td>
</tr>
<tr>
<td>2.457</td>
<td>STR-1</td>
<td>1</td>
<td>1276.49</td>
<td>298.37</td>
<td>4.28</td>
<td>Pass</td>
</tr>
</tbody>
</table>
The specification checks can be viewed by selecting the “View Spec Check” button.

The BrD RC LRFD engine performs spec checks at span tenth points, cross section property change points, and support locations. In addition, the program will perform spec checks a distance dv from the support and at locations where schedule based reinforcement starts/stops and is fully developed. The program will perform spec checks at user defined points of interest as well but note that you do not have to create an BrD point of interest to have spec checks performed at the preceding locations.

Open the spec check detail window for the flexural resistance at midspan. The following is noted for this window, other spec articles are similar:

1. For each spec check location, both the left and right sides of the point are evaluated. The Deflection article is an exception to this since deflection must be the same between the left and right sides of a point.
2. The design ratio is printed out for the article. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.
3. The Strength-I, Service-I and Fatigue limit states are the only limit states investigated. For each limit state, the max and min force effect is checked. Thus each limit state shows two rows of data.
4. The LL load combination is shown in this column. If the location is not at a node in the FE model (e.g., the node is at a point where the rebar is fully developed), this column will list two load combinations separated by a comma. The first load combination is the combination considered at the left end and the second load combination is the combination considered at the right end of the FE element that contains this location. The resulting load displayed is a linear interpolation between the two displayed load cases.
Tabular dead load and live load analysis results are available in the Analysis Results window.
Note these values include dynamic load allowance, distribution factors and any live load scale factor entered on the Analysis Settings window.

You may find different live load values between the BrD LRFD analysis engine and the BRASS™ LRFD engine due to a difference in how the live load distribution factors are applied. The BRASS™ engine applies the LL distribution factor based on the region where the analysis point is located. The BrD engine applies the LL.

The Method of Solution manual can be accessed from the Help menu in BrD.
Introduction

Program: AASHTO LRFD/LRFR Superstructure Analysis Engine
Version: 6.0
Specifications: The following specifications may be used with this analysis engine:
- AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2015 Interims
- AASHTO LRFD Bridge Design Specifications, 8th Edition, with 2019 Interims
- AASHTO LRFD Bridge Design Specifications, 10th Edition, with 2019 Interims

This document describes the procedures that the AASHTO LRFD/LRFR Superstructure analysis engine follows to perform an LRFD analysis and specification check of reinforced concrete and prestressed concrete members. Load and Resistance Factor Design (LRFD) can also be performed by the program for these members. Only LRFR is supported for prestressed concrete members. For