Slab Bridge Designer 2.1
Help: Example Analysis

Using data from the Portland Cement Association
Engineering Bulletin 232, AASHTO LRFD Design
of Cast-In-Place Concrete Bridges

This example demonstrates how Slab
Bridge Designer 2.1 analyzes the design of a
flat slab reinforced concrete bridge.

From October 2007, all bridges receiving federal funding must be designed by
AASHTO LRFD Specifications. The Load Resistance Factor Design (LRFD) limit
states are based on the dynamic and static load states.

Slab Bridge Designer 2.1 from CRSI provides LRFD analysis of cast-in-place rein-
forced concrete slab bridge designs. This help file describes input and analysis features
of Slab Bridge Designer 2.1, using a constant depth slab bridge design included in a
Portland Cement Association publication of LRFD design of cast-in-place bridges, EB
232.

Each of the following sections displays the software user screens that require user input.
Read about the fields and data to learn how to correctly complete them.
1.0 Slab Bridge Designer Configuration

When you use Slab Bridge Designer 2.1 for the first time after installing the software, or if you delete the configuration settings file, you must configure some of the settings and destination files before proceeding to Screen Number 1. You may change the settings at any time by selecting "Configurations" from the File menu.

The purpose of the configuration settings is to identify paths to applications such as the Microsoft Windows compatible web browser that displays the reports, and default user and project information. You may change some of this information in Screen Number 1.

FIGURE 1.
Slab Bridge Designer 2.1 Configuration Settings Screen
2.0 Administrative Data

Slab Bridge Designer 2.1 requires administrative data before you get started. Complete Screen Number 1 with information about the bridge and the analysis type: for this example, Slab Bridge Designer 2.1 will analyze a flat slab bridge (or constant depth) based on LRFD requirements.

2.1 Administrative Data Screen Fields

The data fields in the Administrative Data Screen provide a project description. You may change the data at any time.

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Entry or Selection Ranges</th>
<th>Entry for this Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Title</td>
<td>Text entry field</td>
<td>EB 232</td>
</tr>
<tr>
<td>Job Description</td>
<td>Information about the bridge design, up to 250 characters</td>
<td>This problem is from Chapter 2 of the EB 232 document</td>
</tr>
<tr>
<td>Units System</td>
<td>US (customary, used by a majority of states) or SI (metric)</td>
<td>US</td>
</tr>
<tr>
<td>Designed By</td>
<td>CRSI Slab Bridge Designer</td>
<td>Matthew Peavy</td>
</tr>
<tr>
<td>Analysis Type</td>
<td>Standard (LFD) or LRFD</td>
<td>LRFD</td>
</tr>
<tr>
<td>Checked By</td>
<td>Design Reviewer or Approver</td>
<td>Jay Puckett</td>
</tr>
<tr>
<td>Slab Type</td>
<td>Constant Depth, Haunched Slab or Drop Panel</td>
<td>Constant Depth</td>
</tr>
</tbody>
</table>

Press the Next button to advance to Screen Number 2.
3.0 Bridge Geometry

The slab bridge in this example has a span length of 40.0 ft., center to center of bearings. The edge-to-edge width of the bridge is 28.0 ft. with Jersey barriers as the parapets. The barriers are 1.5 ft. wide, leaving 25.0 ft. of clear roadway.

\[ L = \text{span length (center to center of bearings)} = 40.0 \text{ ft.} \]
\[ L_1 = \text{modified span length (the lesser of the actual span or 60.0 ft.)} = 40.0 \text{ ft.} \]
\[ W = \text{edge-to-edge width of bridge} = 28.0 \text{ ft.} \]
\[ W_1 = \text{modified edge-to-edge width of bridge (the lesser of the actual width or 60.0 ft. for multi-lane loading, or 30.0 ft. for single-lane loading)} = 28.0 \text{ ft.} \]

3.1 Bridge Geometry Screen Fields

The data fields define the geometry of this bridge design. You may return to this screen and modify data at any time.

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Entry or Selection Ranges</th>
<th>Entry for this Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width, ft.</td>
<td>4.0 - 999.99</td>
<td>28.0 ft.</td>
</tr>
<tr>
<td>Number of spans</td>
<td>1-5</td>
<td>1</td>
</tr>
<tr>
<td>Number of analysis points per span</td>
<td>4-100</td>
<td>11</td>
</tr>
<tr>
<td>Span, ft.</td>
<td>15.0 - 1000.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Thickness, in.</td>
<td>7.0 - 99.99</td>
<td>24.0</td>
</tr>
</tbody>
</table>
Note that the number of analysis points affects the time it will take to complete the analysis: more points produces a more thorough analysis.

4.0 Materials

Screen Number 3, Materials, inputs more information about the properties of the materials used in the bridge and about the design of the bridge. This information ensures the correct analysis takes place.

For the bridge in this example, the design method is the Equivalent Strip Width Method, specified in PCA Section 4.6.2.3. The final design specifies a 1.5 in. thick concrete cover over the top mat of reinforcing bars and 1.5 in. thick cover below the bottom mat of reinforcing bars. Other material properties include:

\[ f'_{c} = \text{specified concrete strength} = 4.0 \text{ ksi} \]
\[ w_{c} = \text{concrete unit weight including reinforcement} = 0.150 \text{ kcf} \]
\[ E_{c} = \text{modulus of elasticity of concrete} = 33,000 \left( w_{c} \right)^{1/2} f'_{c} = 3,834 \text{ ksi} \]
\[ f_{y} = \text{reinforcing bars, specified yield strength} = 60.0 \text{ ksi} \]
\[ \gamma_{e} = \text{Exposure Condition} = \text{Class 2} (\gamma_{e} = 0.75). \text{Class 2 is a more conservative design factor that predicts fewer or smaller cracks, because of an increased concern about appearance and/or corrosion} \]
4.1 Materials Screen Fields

The data you provide in the Materials screen describes the properties of the materials used in the bridge. Note that for slab bridges, there are no individual beams, so the LRFD specification instead requires an equivalent width, $E$, that will carry the full design live load. You may also specify a custom interior and exterior strip width.

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Entry or Selection Ranges</th>
<th>Entry for this Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 Day Compressive Strength, $f'_{c}$</td>
<td>2,000 - 12,000 psi</td>
<td>4000 psi</td>
</tr>
<tr>
<td>Unit Weight (Self Weight)</td>
<td>75 - 200 pcf</td>
<td>150 pcf</td>
</tr>
<tr>
<td>Unit Weight (For $E_c$)</td>
<td>75 - 200 pcf</td>
<td>150 pcf</td>
</tr>
<tr>
<td>Concrete Cover: Top Clear</td>
<td>0.75 - 9.99 in</td>
<td>1.5 in</td>
</tr>
<tr>
<td>Concrete Cover: Bottom Clear</td>
<td>0.75 - 9.99 in</td>
<td>1.5 in</td>
</tr>
<tr>
<td>Reinforcement Yield Strength, $F_y$</td>
<td>30.0 - 100.0 ksi</td>
<td>60.0 ksi</td>
</tr>
<tr>
<td>Exposure Condition</td>
<td>Class 1 (1.00) or Class 2 (0.75)</td>
<td>Class 2 (0.75)</td>
</tr>
<tr>
<td>Equivalent Strip Width</td>
<td>LRFD Specification, Unit Width, or Custom Width</td>
<td>LRFD Specification</td>
</tr>
</tbody>
</table>

5.0 Loads

Screen Number 4, Loads, requires inputs of both live and dead loads. The live load default is LRFD-US, calculated using equation HL-93. HL-93 is a combination of:

- Design truck loading or design tandem truck loading with dynamic allowance and
- Design lane load of 0.640 klf without dynamic allowance.

The design truck, HS-20, is specified in the AASHTO LRFD Bridge Design Specifications. See the PCA publication EB232, Section 1.9 or the AASHTO Specification for more information.

The dead load is divided into two categories, DC and DW. DC is the dead load of structural components and nonstructural attachments. In the PCA example, the weight of the barriers is considered in the design of the edge beam. In Slab Bridge Designer 2.1, the Sidewalk and Parapet loads are also only applied to the edge beam (external lane). DW is the dead load of the wearing surface and utilities, which in this example is a 2.0 in. thick concrete topping (no utilities).

$$DW = \text{wearing surface load} = (2/12)(0.150) = 0.025 \text{ klf}$$

The DC dead load is incorporated when you select the "Include Self Weight" radio button. The calculation is also illustrated below:

$$DC = \text{self-weight of the slab} = (288)(0.150)/144 = 0.300 \text{ klf}$$
5.1 Loads Screen Fields

Using Slab Bridge Designer, you may separate the dead loads into the individual loads that are part of the total. For example, if the bridge includes a sidewalk, utilities, or parapets, you should input them separately.

<table>
<thead>
<tr>
<th>Data Field</th>
<th>Entry or Selection Ranges</th>
<th>Entry for this Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Loads</td>
<td>LRFD-US</td>
<td>LRFD-US</td>
</tr>
<tr>
<td>Dead Loads: Wearing Surface Load (DW)</td>
<td>0.0 - 100.0</td>
<td>25 psf</td>
</tr>
<tr>
<td>Sidewalk Load (DC)</td>
<td>0.0 - 100.0</td>
<td>0.0 psf</td>
</tr>
<tr>
<td>Utilities Load (DW)</td>
<td>0.0 - 100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Parapet Load (DC)</td>
<td>0.0 - 100.0</td>
<td>75.0 psf</td>
</tr>
<tr>
<td>Other Load (DC)</td>
<td>0.0 - 100.0</td>
<td>0.0 psf</td>
</tr>
<tr>
<td>Self-Weight Dead Load</td>
<td>Include or Exclude</td>
<td>Include</td>
</tr>
</tbody>
</table>

This completes the data inputs required for Slab Bridge Designer 2.1 to analyze this bridge design. Click on the Run Analysis button, save the analysis, and observe the calculated results.
6.0 Influence Lines

Screen Number 5 displays the shear and moment influence lines at each designated node. Shear is on the top; moment is on the bottom. Figures 6 displays two examples of Screen Number 5: the shear and moment influence lines at nodes 2 and 7.

FIGURE 6. Slab Bridge Designer 2.1 Screen Number 5, Influence Lines (Nodes 2 and 7)

Screen Number 5 displays other values:

- Invert Plots: the shear and moment influence lines can be displayed with the Y axis inverse of the original display.
- View Values: two web browser windows open, displaying post-analysis reports for shear and moment influence lines for all the analysis nodes. The number of nodes was selected in Screen Number 2.
Influence Lines

- View Structural Model: a new web browser window displays a summary of the model, including node and section distances, and moments of inertia for each section.
Screen Number 6 displays the maximum and minimum critical shear values associated with this bridge design analysis. Maximum shear values are on top; minimum are on the bottom. Figure 9 displays the critical shear values for the Strength 1 limit state, Interior Lane, in Kip-ft, and Limit State Fatigue.

Slab bridges designed for moment in accordance with AASHTO LRFD Article 4.6.2.3 may be considered satisfactory for shear. Although Slab Bridge Designer analyzes critical shear values, this is not required.
There are several values you may select to display in Screen Number 6:

- **Limit State**: Strength 1, Strength 2, Service 1, or Fatigue.
- **Lane**: Interior or Exterior.
- **X-Axis**: Feet, MM or Meters.
- **Y-Axis**: Kips or kN
- **View Values**: Unfactored Shear, Factored Shear or Critical Shear. When selected, a new web browser window opens, displaying the report "Factored Moment Values" that includes the shear values generated in the analysis.
8.0 Critical Moment Values

Screen Number 7 displays the maximum and minimum critical moment values associated with this bridge design analysis. Maximum moment values are on top; minimum are on the bottom.

Choose the limit state and lane (exterior or interior) for the results you would like to view. Click "View Values" to view the critical values for the criteria specified. You may view ALL the values at use by choosing the View Critical Moment Values from the Analysis menu.
There are several values you may select to display in Screen Number 7:

- Limit State: Strength 1, Strength 2, Service 1, or Fatigue.
- Lane: Interior or Exterior.
- X-Axis: Feet, MM or Meters.
- Y-Axis: K-Ft, K-In or kN-M.
- View Values: Unfactored Moment, Factored Moment or Critical Moment. When selected, a new web browser window opens, displaying the report "Factored Moment Values," that includes the equation and values. For example:

\[ M_{u1} = \eta_l \eta_d \eta_1 \left[ 1.0DC + 1.0DW + (m)(g)(1.0)\left[ 1.33Truck + 1.0Lane \right] \right] \]

At midspan, the maximum moment equals 130 Kip-ft.

9.0 Interior Lane Reinforcement Design

Screen Number 8 provides a preliminary reinforcing bar schedule for the interior bridge lane. The design includes maximum and minimum demand moment values associated with this bridge design for the Strength 1 limit state along with the moment capacities provided. Select a row or rows in which to alter the reinforcement schedule. Click the Reselect Schedule button to select a new reinforcement schedule. Click the View Structural Model button to view a summary of the structural model, including node and section distances.
NOTE: if reinforcement has been altered, the cells are marked in light blue to indicate the change.

**FIGURE 12.**

Double-click on any section, or highlight several sections and click the Reselect Bottom Section button if you would like to reselect the rebar schedule for the selected cells. Within the Rebar Reselection dialog, those schedules that meet the maximum moment demand are shaded white. Those that do not meet demand are shaded gray. The current rebar schedule (originally selected to meet the maximum demand moment) is highlighted in yellow.
10.0  **Exterior Lane Reinforcement Design**

Screen Number 9 provides a reinforcing bar schedule for the exterior bridge lane. The maximum and minimum demand moment values associated with this bridge for the Strength 1 limit state are shown along with the moment capacities provided.

Select a row or rows in which to alter the reinforcement schedule. Click the Reselect Schedule button to select a new reinforcement schedule.

Click the View Structural Model button to view a summary of the structural model, including node and section distances.

NOTE: if reinforcement has been altered, the cells are marked in light blue to indicate the change.
Double-click on any section, or highlight several sections and click the Releselect Bottom Section button if you would like to reselect the rebar schedule for the selected cells. Within the Rebar Reselection dialog, those schedules that meet the maximum moment demand are shaded white. Those that do not meet demand are shaded gray. The current rebar schedule (originally selected to meet the maximum demand moment) is highlighted in yellow.

You may select a grayed value, although these values do not meet the Strength 1 specification. The screen displays sections that were selected and the start/end distances of the section.

NOTE: If more than one section is highlighted, the most critical section's properties are used. Choosing OK applies the new schedule to all sections initially selected.

### 11.0 Design Checks

Screen Number 10 displays the limit state design checks for each section.

Double click a cell to view the limit state calculations for this section. Or use the View Section Calcs button. You may go back and alter the design by clicking the Back button.

Cells that are colored light blue correspond to sections that have an updated rebar schedule. Cells that are red indicate sections that do not pass a limit state calculation.

Finalize the design and view the design report by clicking the Finalize Design button.
Finalize the design and view the design report by clicking the Finalize Design button.
12.0 Design Report

Screen Number 11, the Final Screen, displays the complete set of reports and logs you may view and/or save.

12.1 Bridge and Analysis Parameters

- Number of spans: 1
- Number of analysis points per span: 11
- Bridge width: 28 ft
- Bottom clear cover: 1.5 in
- Top clear cover: 1.5 in
- \( f' c \): 4000 lb / in²
- Unit weight of concrete (for self-weight): 150 lb / ft³
- Unit weight of concrete (for \( E_c \)): 150 lb / ft³

12.2 Interior and Exterior Strip Longitudinal Rebar Schedule Selections

This table shows the longitudinal reinforcement schedule for each section of the interior and exterior strips.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Provided Area of Steel/Width</th>
<th>Governing Bottom Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>24 in.</td>
<td>#10 @ 7 in.</td>
</tr>
</tbody>
</table>

NOTE: All of the sections contain the same schedule, so this table has been condensed.

12.3 Distribution Reinforcement (Interior and Exterior Strip)

Distribution reinforcement is placed along the bottom face, transverse to the bridge.

<table>
<thead>
<tr>
<th>Span No.</th>
<th>Min. Area of Steel/Width</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24 in.</td>
<td>#4 @ 6 in.</td>
</tr>
</tbody>
</table>

See the Critical Transverse Reinforcement to see if Distribution or Temperature and Shrinkage steel governs.

12.4 Temperature and Shrinkage Reinforcement

Temperature and shrinkage reinforcement is placed along the top face of the bridge.

One half of the reinforcement is placed at the top, which is the amount represented below for both the interior and exterior strip.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Min. Area of Steel/Width</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td></td>
<td>#4 @ 9 in.</td>
</tr>
</tbody>
</table>
12.5 Critical Transverse Reinforcement

The critical tranverse reinforcement is chosen as the greater area of steel between the Temperature and Shrinkage and Distribution steel schedules.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Provided Area of Steel/Width</th>
<th>Schedule</th>
<th>Governing Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td></td>
<td>#4 @ 9 in.</td>
<td>Distribution</td>
</tr>
</tbody>
</table>

FIGURE 16. Slab Bridge Designer 2.1 Screen Number 11, Final Screen

You may save the design and analysis reports with a default name prefix using this project name, or select a different prefix for the reports by completing the Report Name Prefix field. Click on the Save Reports button to open a dialog box that browses for the report destination folder. Intermediate reports are saved where the user instructs after clicking the Save Reports button, such as the 'Results' and 'Logs' directories within the application directory.

From the Final Screen you may view analysis of every stage of your design input and output. For example, if you choose to view the Design Log, a new web browser window opens, and you will see analysis messages regarding the design of the bridge such as:

Interior Strip, Span #1: Distribution steel schedule design. Percentage of main steel = 15.8114%. Area of main reinforcement steel / width = 2.17714 in² / ft. Minimum distribution steel area per width: 0.344237 in² / ft. Selected schedule = #4 @ 6.
FIGURE 17. Slab Bridge Designer 2.1 Design Report - Design Log

CRSI Slab Designer Report - Design Report

Report Type: Design Report
Engineer: Matthew Peavy
Date: 02/12/2006
Project Title: EB 232

Report Description: The final design report for this bridge.

General Bridge Properties:

- Number of spans: 1
- Number of analysis points per span: 11
- Bridge width: 20 ft
- Bottom clear cover: 1.5 m
- Top clear cover: 1.5 m
- F = 4000 lb/ft²
- Unit weight of concrete (for self-weight): 150 lb/ft³
- Unit weight of concrete (for F): 150 lb/ft³

### Section Specifications

<table>
<thead>
<tr>
<th>Section Number</th>
<th>Section Depth</th>
<th>Bottom Rebar Schedule</th>
<th>Top Rebar Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24 in</td>
<td>#10 @ 7 in</td>
<td>#6 @ 10 in</td>
</tr>
<tr>
<td>2</td>
<td>24 in</td>
<td>#10 @ 7 in</td>
<td>#6 @ 10 in</td>
</tr>
<tr>
<td>3</td>
<td>24 in</td>
<td>#10 @ 7 in</td>
<td>#6 @ 10 in</td>
</tr>
<tr>
<td>4</td>
<td>24 in</td>
<td>#10 @ 7 in</td>
<td>#6 @ 10 in</td>
</tr>
<tr>
<td>5</td>
<td>24 in</td>
<td>#10 @ 7 in</td>
<td>#6 @ 10 in</td>
</tr>
</tbody>
</table>

Analysis messages:

- Interior Span #1: Distribution steel schedule design. Percentage of main steel = 15.0114%. Area of main reinforcement steel = 2.1774 in²/ft. Minimum distribution steel area per width = 0.344237 in²/ft. Selected schedule = #4 @ 6.
- Interior Span #2: Distribution steel schedule design. Percentage of main steel = 15.0114%. Area of main reinforcement steel = 2.1774 in²/ft. Minimum distribution steel area per width = 0.344237 in²/ft. Selected schedule = #4 @ 6.
- Interior Span, Section #1: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.328 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #2: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #3: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #4: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #5: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #6: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #7: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.
- Interior Span, Section #8: Shrinkage and temperature schedule design. Maximum area of steel/width (divided evenly between top and bottom face): 0.520 in²/ft². Selected schedule (for other face) = #4 @ 9.