Section Slicing of a 3D Shell Structure

For LUSAS version:	21.1
For software product(s):	Any Plus version.
With product option(s):	None

Description

This example uses the Slice Resultants Beams/Shells facility to investigate the behaviour of a bridge deck modelled using thick shell elements. The results are converted into forces and moments of an equivalent beam using this facility.

Units used are N, m, kg, s, C throughout.

Combination
Entity: Beam/Shell Slice Resultants
Component: My (Units: N.m)

-6.05889E6
-5.38568E6
-4.71247E6
-4.03926E6
-3.36605E6
-2.69284E6
-2.01963E6
-1.34642E6
-673.21E3

Maximum -389.893E3 at Deck Slice 1
Minimum -6.44878E6 at Deck Slice 8

Objectives

The output requirements of the analysis are:

❑ Forces and bending moments along length for whole structure
❑ Forces and bending moments associated with central girder effective width

Keywords

3D, Shell, Force, Bending Moments, Forces, Section, Slicing, Effective Width, Shells.
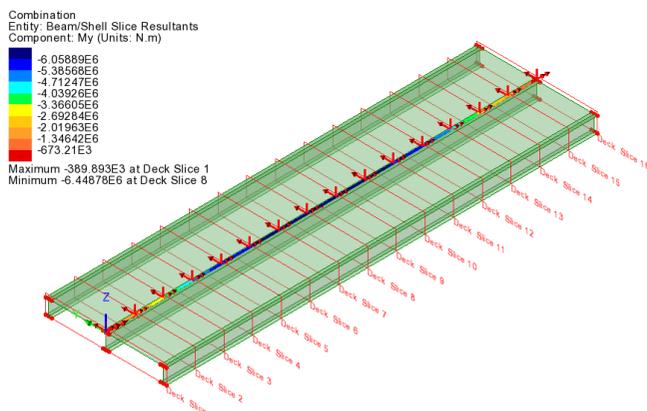
Associated Files

Associated files can be downloaded from the user area of the LUSAS website.

❑ **shell_slicing.lvb** This creates an initial model for further development.

Modelling

Running LUSAS Modeller

For details of how to run LUSAS Modeller see the heading ***Running LUSAS Modeller*** in the *Introduction to LUSAS Worked Examples* document.

Creating a New Model

File
New…

- Enter a file name of **shell_slicing.lvb**

- Use the default **User-defined** working folder.

- Ensure an Analysis type of **Structural** is set.

- Ensure an Analysis category of **3D** is set.

- Click the **OK** button.

Note. There is no need to enter any other new model details when the intention is to run a script to build an initial model, since the contents of the script will overwrite any other settings made.

File
Script   >
Run Script…

- To create the model required for this example, open the read-only file **shell_slicing.lvb** that was downloaded and placed in a folder of your choosing.
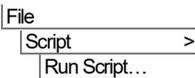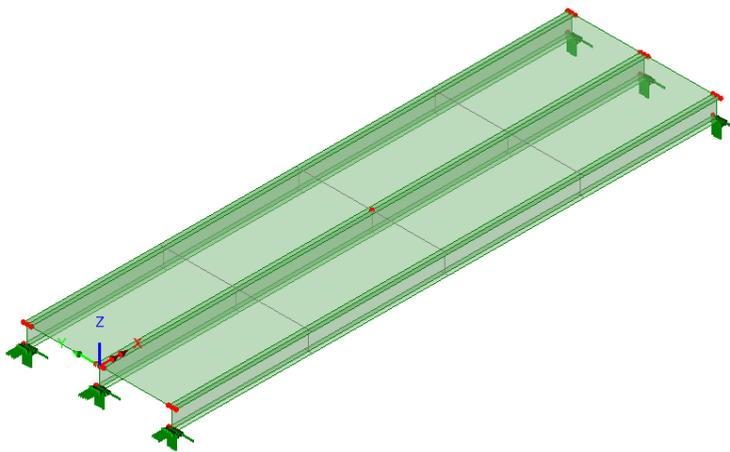
⊕ If necessary, click the isometric button to view the model in 3D

↑ If necessary, turn-on the display of the supports.

File
Save

- Save the model to your local projects folder.

In the 🕒 Treeview two loadcases can be seen. One corresponds to the self-weight of the structure (note that because gravity loading is assigned to the loadcase directly, no loading arrows will be seen on the model) and the other to an applied load of a United Kingdom HB vehicle. For the post-processing, a combination has also been defined which combines these two load cases.

- Turn off the **Geometry** and **Attributes** layers to see the Mesh as defined.

✏️ **Note.** For the purposes of this example the mesh discretisation of the model is set to be extremely coarse. When carrying out this type of slicing on realistic models it is recommended that a much finer mesh discretisation is used to accurately capture the response of the structure, particularly if 3- and 4-noded shell elements are being used for the modelling.

The deck is 4.21m wide and consists of a concrete slab and three steel girders as indicated in the following figures:

Idealisation of the Bridge Structure

For this example shell elements are used to idealise the bridge structure.
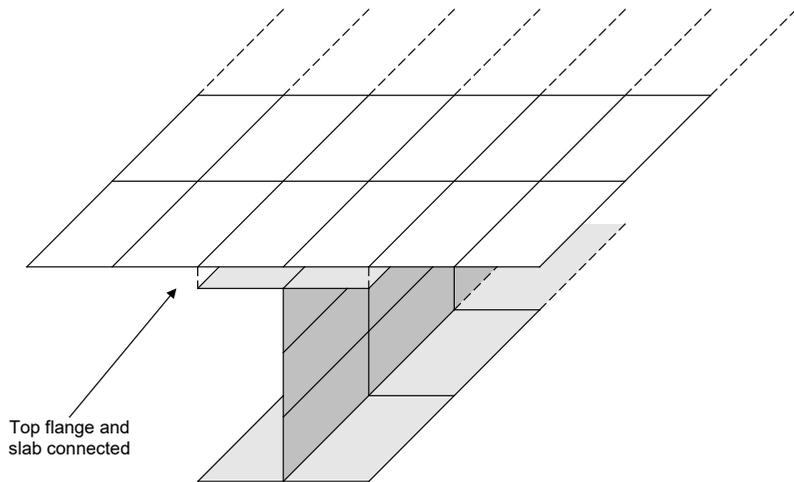
Shell element modelling of the whole structure

Shell elements are used for the girder components and also the concrete slab as illustrated. For the modelling, discrete features have been defined for the top flange and the slab since their materials are not identical. The slab has an eccentricity to define a bending plane that is not coincident with the top flange and these two components are combined using an equivalence attribute. This is just one of many ways that the idealisation for this type of bridge structure can be undertaken.

Based upon this idealisation method the whole model showing element discretisation is as shown:
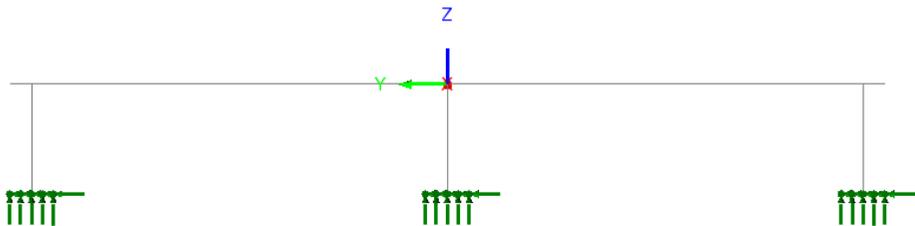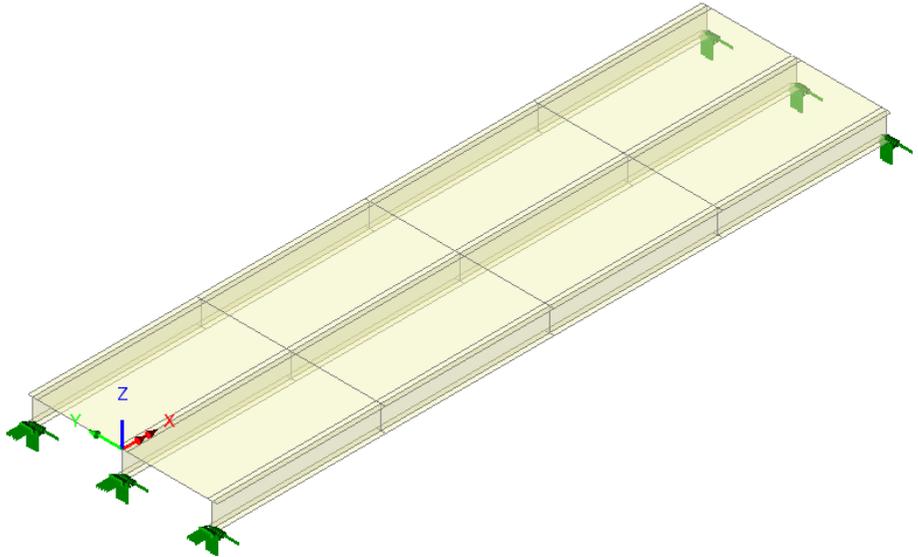
Alternative idealisations

The following figure shows the same structure but this time the shell elements representing the top and bottom flanges of the girder have been replaced by beam elements running along the top and bottom of the girder with the appropriate properties for the flange members.
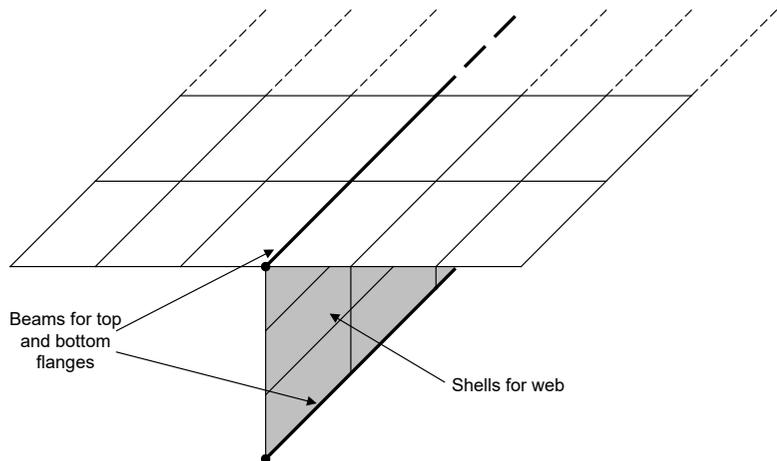
Beam element modelling of flanges

In the last figure the whole girder has been replaced by beam elements with appropriate geometric properties and an eccentricity to offset the bending plane of the beams.
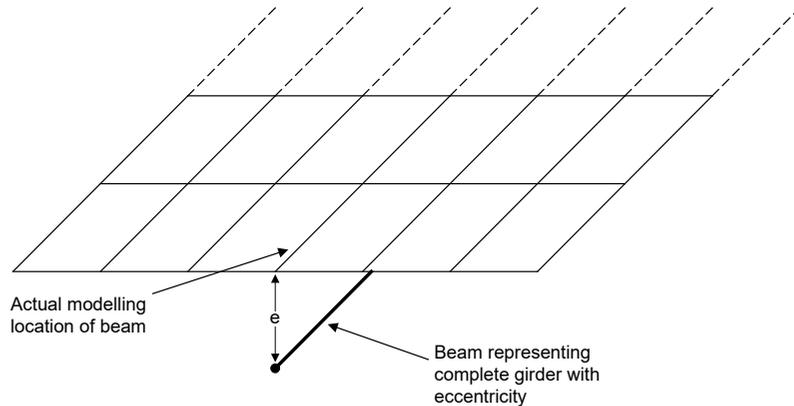
Beam element modelling of the whole girder

The choice of which analysis idealisation should be used depends upon what is required from the results of the analysis. For instance, if a curved girder analysis is being performed and the lateral forces in the top and bottom flanges are required then shell element modelling of the whole structure or beam element modelling of the flanges (as shown in the first two figures) are suitable but beam element modelling of the whole girder (as shown in the last figure) is not.

Running the Analysis

With the model loaded:

Open the **Solve Now** dialog, ensure **Analysis 1** is selected and press **OK**.

A LUSAS Datafile will be created from the model information. The LUSAS Solver uses this datafile to perform the analysis.

Viewing the Results

Analysis loadcase results are present in the Treeview, and the loadcase results for the self-weight loadcase will be set to be active by default.

Plotting deformed shapes

- In the Treeview, ensure the **Mesh, Geometry** and **Attributes** layers are present and turned off. Leave the Deformed Mesh layer turned on.

• Show the **Window Summary** for an overview of the results.

Scale: 1: 49.8435
Zoom: 100.0
Eye: (-0.57735, -0.57735, 0.57735)
Linear/dynamic analysis
Analysis: Analysis 1
Loadcase: 1:Self Weight
Results file: section_slicing~Analysis 1.mys
Maximum displacement 0.0120097 at node 16
Deformation exaggeration: 24.9016
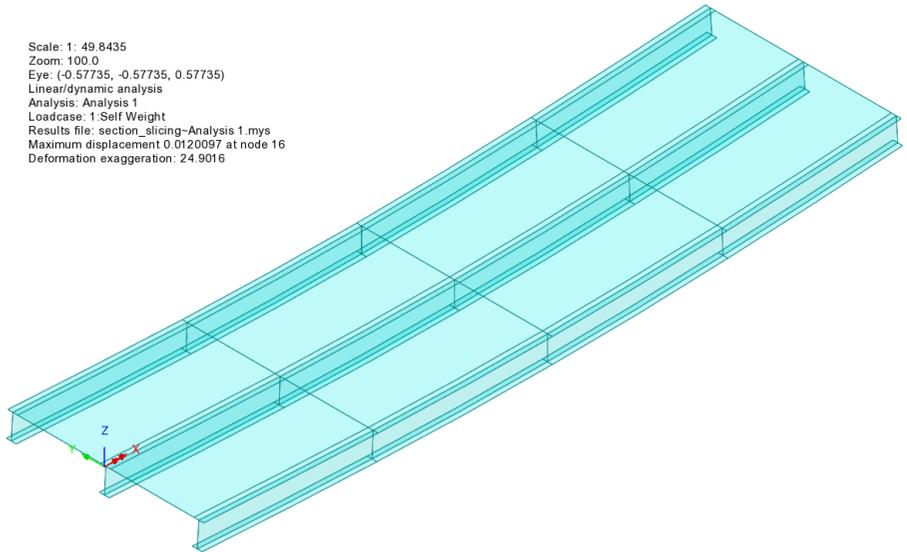
Computing forces and bending moments at locations along the deck

• Turn off the **Deformed Mesh** layer in the ⬛ Treeview.

• Turn on the **Geometry** layer

• Select the centre line of the model (Line 11). This line will be used to define the path along which the slicing will take place.

The slicing dialog will be displayed.

- Select the **Incremental distances from start of path** option.

- Enter **0;15@1** into the associated box which will cut slices at the start of the line (0m) and every 1m up to and including 15m.

- De-select **Include additional slices at the points along path**

- Ensure the **Distance from reference origin to start of path (chainage)** is set to **0**

- Ensure the **Neutral axis** option is set to calculate the forces and moments about the neutral axis of the sliced section.

- Ensure that the **Slice width** option is de-selected.

- Ensure the **Extent** is set to **Full model**.

- Enter the dataset name as **Deck**.

- Click the **OK** button to add the slice definition to the 🔧 treeview.

Utilities
  Slice Resultants
  Beams/Shells

🖉 **Note.** Four methods are available for the definition of the slice locations.

❏ **Incremental distances from start of path** allows the definition of progressive slice distances governed by the supplied increments. These increments can be positive or negative so long as the accumulated distance is within the path length.

❏ **Absolute distances from start of path** allows the definition of known distances along the slicing path for slices to be taken.

❏ **Parametric distances from start of path** allows distances to be entered as a proportion of the whole path length.

❏ **Constant spacing** will define slice locations at the constant spacing entered. The option to **Include slices at points** can be used with any option to add additional slice locations at any line ends within the selected path.

🖉 **Note.** The **Smooth corners on path** option is used to traverse sharp corners in the defined slicing path. If smoothing is selected, then the orientation of the slice plane is set to be at an angle of half the path angle change at the connection if this location coincides with a slice. If smoothing is not selected, two slices will be taken at a sharp corner with angles taken from both lines/arcs at the connection.

To continue:

- Double-click on the **Utilities** layer in the 🖿 Treeview.

- On the Utilities layer properties dialog select the **Beam/Shell Slicing** tab, and press the **Settings** button

- Ensure the **Show definition axes**, **Show slice planes** and **Show slice labels** check boxes are checked.

- Click **OK** to close the Visualisation Settings and **OK** again to close the layer properties

🖉 **Note.** **The location of the generated slice planes can only be visualised on the model after the results have been requested through any of the drawing layers.**

Viewing results

- In the Analyses 🔍 Treeview set the **Combination** active. Click **OK** to solve results. Click **OK** to confirm.

| View |
| Drawing Layers > |
| Contours |

The equivalent forces and moments calculated at each slice location can be contoured on the model as shown below.

- In the contours properties dialog select the entity **Beam/Shell Slice Resultants** and component **My**. Click **OK.**

Results contours and locations of the slices will be shown on the model as illustrated. The slice annotations include the physical location of the slice, its title and a local coordinate set indicating the axes of the slice.
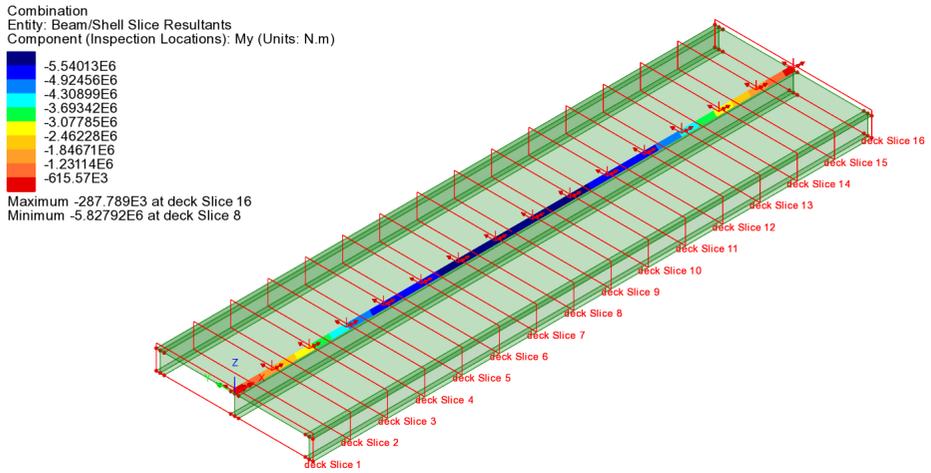
> **Note.** The size of the drawn slice plane depends upon the elements that are sliced. By default, slice planes and local slice axes are drawn in red, but these and other visualisation settings relating to slice axes, slice planes and slice labels can be specified from the Utilities layer properties dialog, which is accessed from the Utilities treeview.

> **Note.** The visibility of the slices is controlled by selecting the Visible or Invisible context menu item for the Deck utility.

> **Note.** If the option to calculate the forces and moments about the neutral axis has been selected this local coordinate set will be defined at the neutral axis location. If however the option to calculate the forces and moments about the slice path has been selected, the local coordinate set will be defined at the intersection between the slice path and the slice plane. The local coordinates of the slice planes is taken from the line axes defining the slice path.

Printing results

For the active load combination:

Utilities
Print Result Wizard

The beam shell slice resultants can be tabulated in the Print Result Wizard facility.

- In the Print Results Wizard dialog select the entity **Beam/Shell Slice Resultants**

- Check (tick) the **Threshold** value checkbox and specify a value of **1e-3** to ensure that any values, which are effectively zero, are tabulated as zero.

- Ensure **Tabular and Summary** is selected, **Display now** is selected, **Decimal places** is set to **1**, and check all other settings are as shown, and click **OK** to display the tabular results.

All beam/shell slice components are displayed in the Print Results Wizard Table. The axes defining the forces and moments are those displayed by the local coordinate system of each slice.

Computing Forces and Bending Moments for Girder Effective Width

- In the Utilities 🔧 treeview, double click the Beam/Shell Slicing utility named **Deck.**

The slicing dialog will be displayed.

- Select the **Absolute distances from start of path** option.

✏️ **Note.** List separators vary according to a PC's regional locale settings. For example, English (UK) and English (US) settings use a comma as a list separator. French, Swedish and other language settings use a semi-colon.

Please enter whatever is appropriate to your region. In this example an English (UK) comma separator is shown.

- Enter **0,2.5,5,7.5,10,12.5,15** (using an appropriate list separator for your PC's regional settings) into the

associated box. This will cut slices at the start of the line (0m) and every 2.5m up to and including 15m.

- Set the **Distance from reference origin to start of path (chainage)** to **100**. The start of the slicing path will therefore have a distance/chainage of 100m, and the end of the slicing path will have a distance/chainage of 115m.

- Select the **Slice width** option and enter **2.0** in the associated box. This will set the slice width to be 2.0m centred on the slicing path (i.e. 1.0m either side)

- Click the **OK** to save the changes.

The contours and slice definitions will be updated as shown:

Combination
Entity: Beam/Shell Slice Resultants
Component (Inspection Locations): My (Units: N.m)

-2.09722E6
-1.86419E6
-1.63117E6
-1.39815E6
-1.16512E6
-932.097E3
-699.073E3
-466.049E3
-233.024E3

Maximum -5.30505E3 at deck Slice 1
Minimum -2.10252E6 at deck Slice 4 (+X)
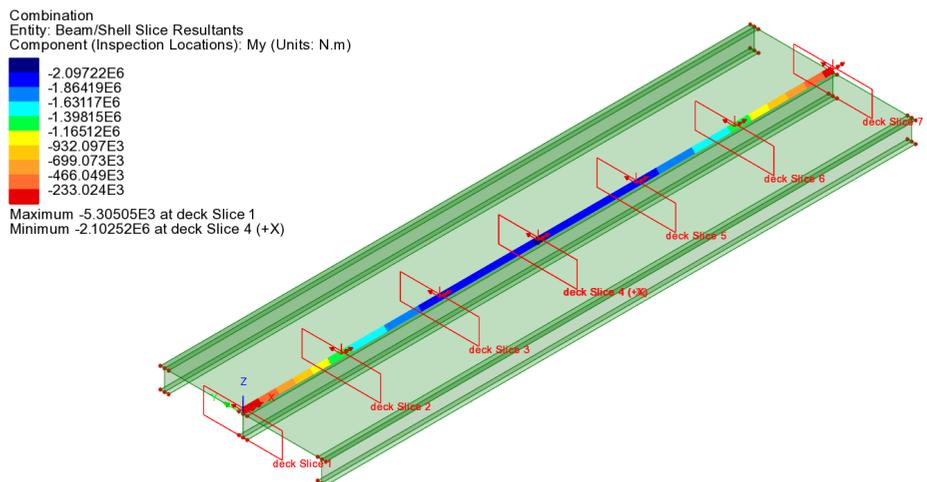
Note. The reference to (-X) for the minimum value is due to the fact that at that location two slice planes are present (because the slice plane occurs at a node) and this indicates that the value stated is from the plane to the left of the node.

File
Save

Save the model.

This completes the example.

Notes

- ❑ Curved structures can also be sliced using this facility.

- ❑ If skewing of a slice plane along a beam is required, create a line at an appropriate skew angle from a point at one end of the beam and of sufficient length to extend beyond the extent of the model. This line can then be selected

as a path line from which orthogonal slice sections will be generated according to the extent stated.