Memorandum

ARUP

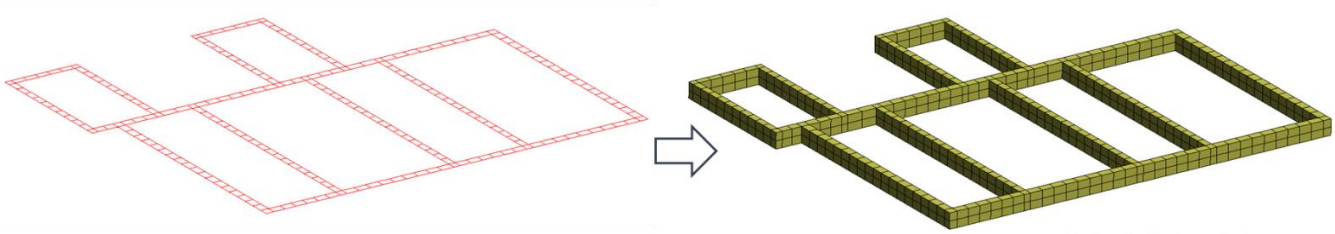
To	P500 Analysts	Date	22 November 2017
Copies		Reference number	
From	Brian Muriithi, Richard Sturt	File reference	
Subject	Creating Thick Shell models of strip footings and grade beams		

1 Outline

Up to now we have been modelling grade beams and strip footings with Solid elements (*ELEMENT_SOLID) representing the concrete, coated in shell elements representing the reinforcement. Starting from a shell element "template" of the top or bottom horizontal surface of the foundation, the solids were created by extruding from the shells. The Thick Shell model (*ELEMENT_TSHELL) looks almost the same, but differs in two respects:

- We have to ensure the correct local axes for the Thick Shell elements.
- Only one element across the width of the foundation (and therefore the shell element template also has one element across the width)

The reinforcement coating is the same as for the Solid element foundation model.



Shell template

Thick Shell foundation

Although Thick Shells can be created in PRIMER by extruding from the shell element template, PRIMER's tools for modifying the local axes of Thick Shells are not yet up to the job. There is a work-around (described in the Appendix to this note) but it is an awkward process. We now have a script to create the Thick Shells with the correct local axes. Overall, the PRIMER process is:

- Ensure the shell element template is complete and appropriately meshed, without cracks.
- **Run the script to create the Thick Shells.**
- Select Material properties for the Thick Shells.
- Coat the Thick Shells with reinforcement (shell elements), using PRIMER's Coat tool.

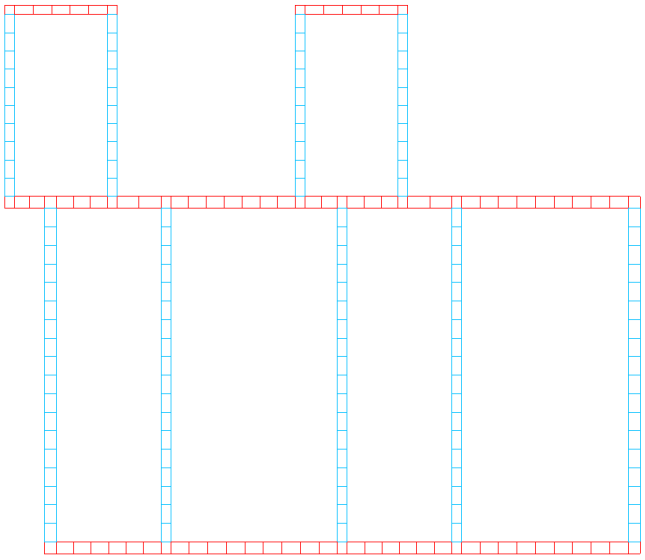
- Check and adjust the local axes of the reinforcement shells.

This memo deals with the second step only.

2 Create Thick Shells using the script

1. Separate the template shells so that the strips running in the x-direction can be selected from those running in the y-direction (red and blue in the Figure). The corner elements can be grouped with the X or Y strips, it does not matter.

   A method of doing this in PRIMER is to display only the template shells, select the 'Lock' button and then blank either the X or Y strips. You can then toggle between the X and Y strips using the 'R' button to reverse blanking.



2. Run script '***thick_shell_foundation_v2.js***', located here:

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   The script will take you through several steps requiring user input in order to specify the foundation depth, extrusion direction, and elements in the depth of the foundation. It will then generate the thick shells in a new Part ID complete with the appropriate section ID, and keeping the same material properties as the template shells

3. Assigning the correct MAT_EC2 concrete grade from the Materials Library to the part containing the Thick Shells.

4. Coat the thick shells to create the reinforcement.

The script will allocate the Thick Shells to Parts following the pattern in the shell template, e.g. if the red/blue template elements in the image above are different Parts, then the Thick Shells will also be in two Parts following the same pattern. The script deletes the template shell elements together with their Part and Section after creating the Thick Shells.

3 Appendix: Manual method – step-by-step procedure

It should not be necessary to use this work-around when creating the foundation model. However, there may be other occasions when some of the steps are useful, for instance if you wish to modify an existing foundation model consisting of solid elements. The work-around is designed around the fact that Primer is better at aligning the axes of Solid elements than Thick Shell elements.

In outline:

1. Separately extrude shell elements constituting the X and Y direction foundation segments into separate new solid element parts.
2. Use PRIMER's Element=>Solid=>Align tool to modify the local element axes of the newly created solid elements.
3. Write out the solid elements only (not the nodes, Part, etc) to a keyword file, text-edit to change *ELEMENT_SOLID to *ELEMENT_TSHELL.
4. In PRIMER, delete the solid elements (retaining their nodes) and import the text file back into the working model.
5. Insert the required material properties from MAT_LIBRARY and section properties from Paolo's memo on grade beams
6. Create reinforcement coating

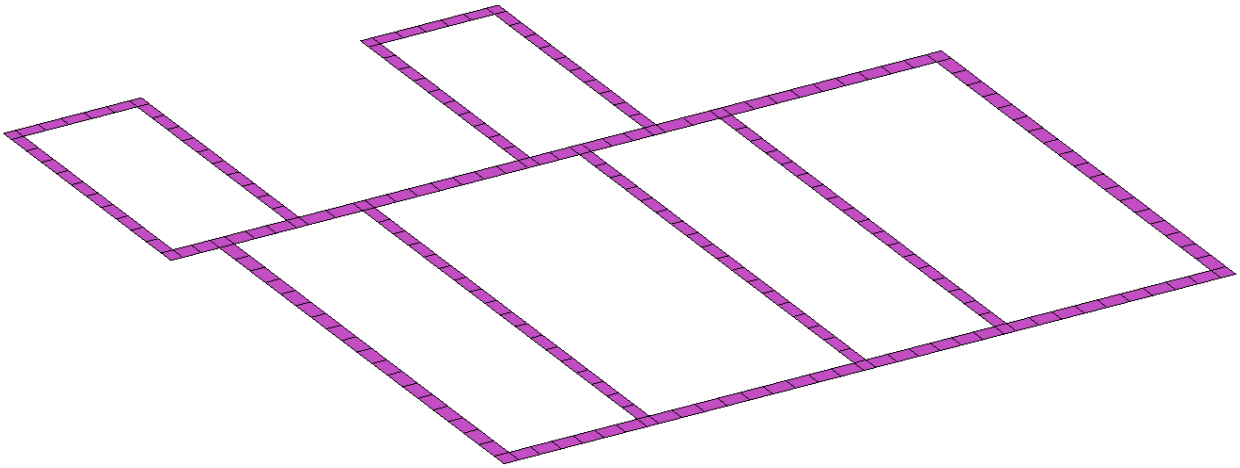


Figure 1: Initial concrete foundation beam modelled with thin shells

1. Extrude the shell elements in strips along the x-direction to create solids (in brown, Figure 3), assigning them to a new part. The result should be as shown in Figure 3. Repeat this step for the elements in strips along the y-direction (in blue, Figure 3).

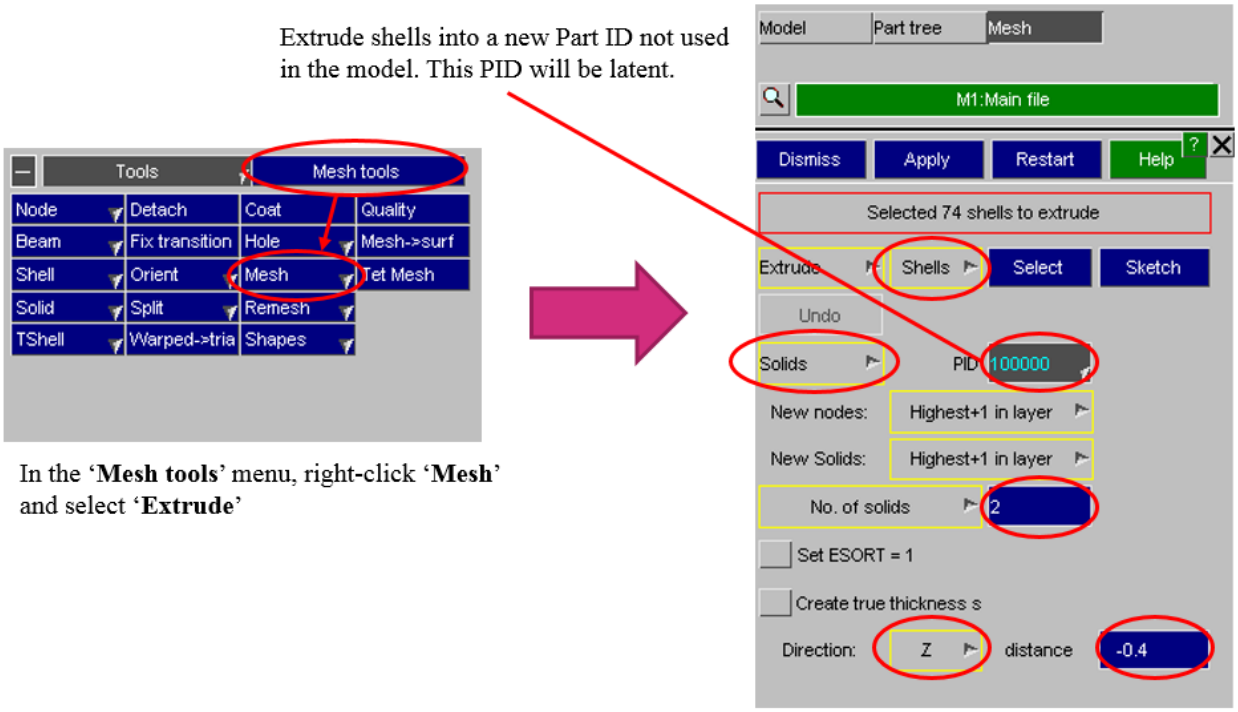


Figure 2: Steps to extrude the shell elements to create solid elements.

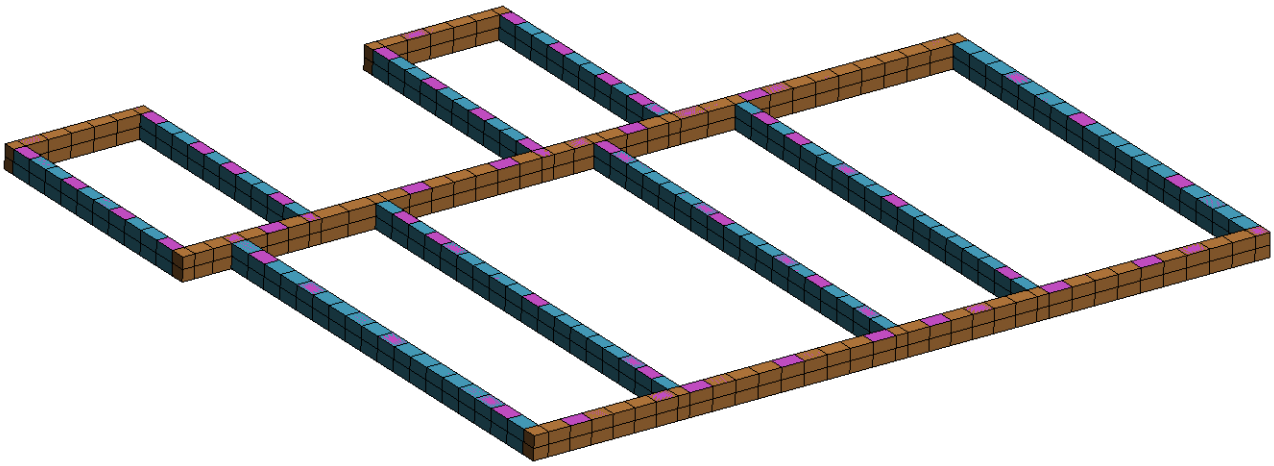


Figure 3: Created solid elements with new Part IDs (indicated by different colours). Pink elements represent the thin shell elements which are still present in the model.

2. Activate the triads so you can see the local x-axis of the solids in PRIMER. Navigate to the '***ELEMENT - SOLID***' keyword.

3. In the resulting menu, select 'Align'. Under 'Object Type', select 'Part'. Select the part containing the elements to adjust triads, and then select 'Apply Selection'

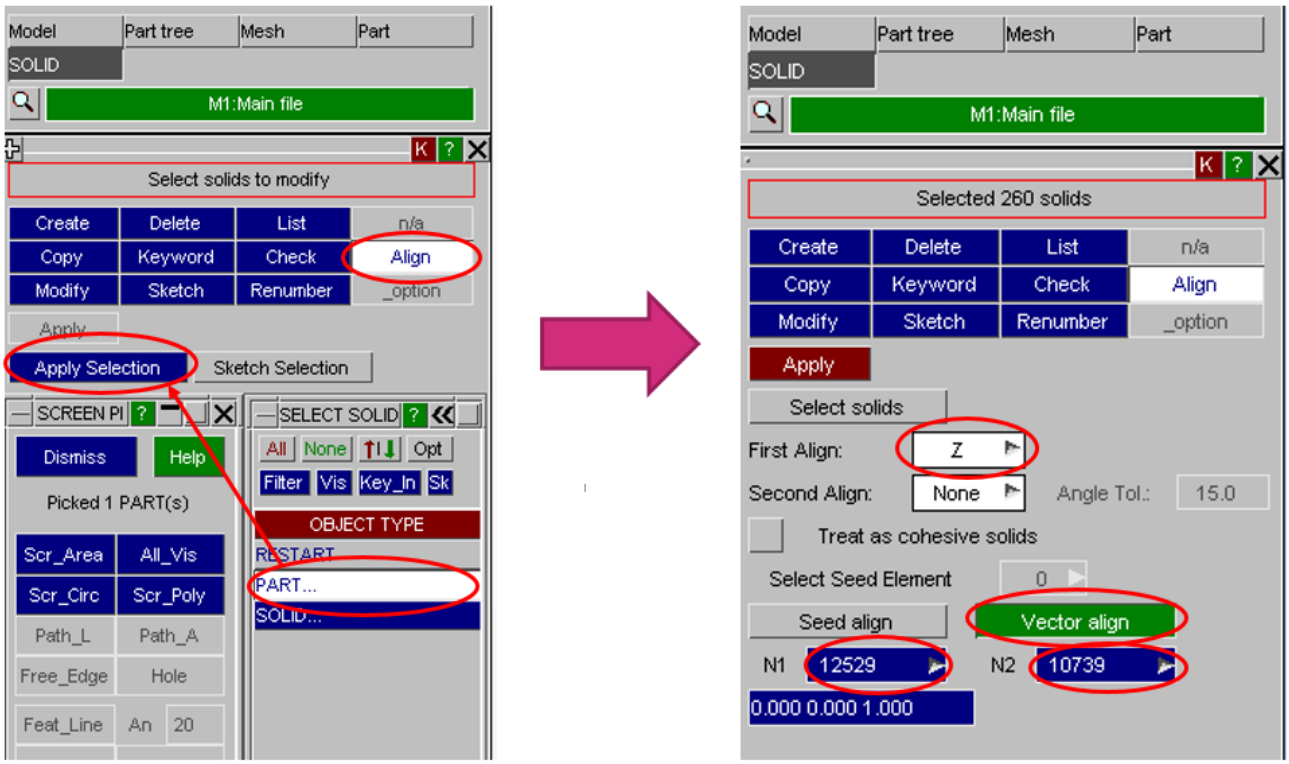


Figure 4: Aligning the local element axes of the solid elements to the desired orientation.

4. Choose the appropriate axis to align (X, Y, or Z) and select ‘Vector align’. Select 2 nodes to align the axis, or alternatively type in a vector coordinate to align the thick shells appropriately, as they should appear in the thick shells.

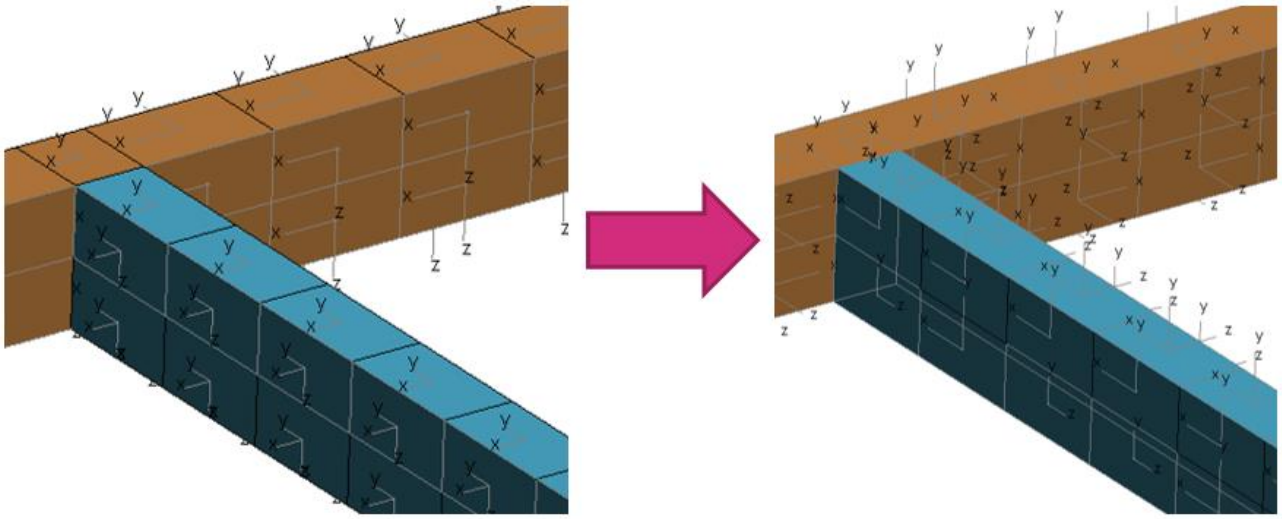
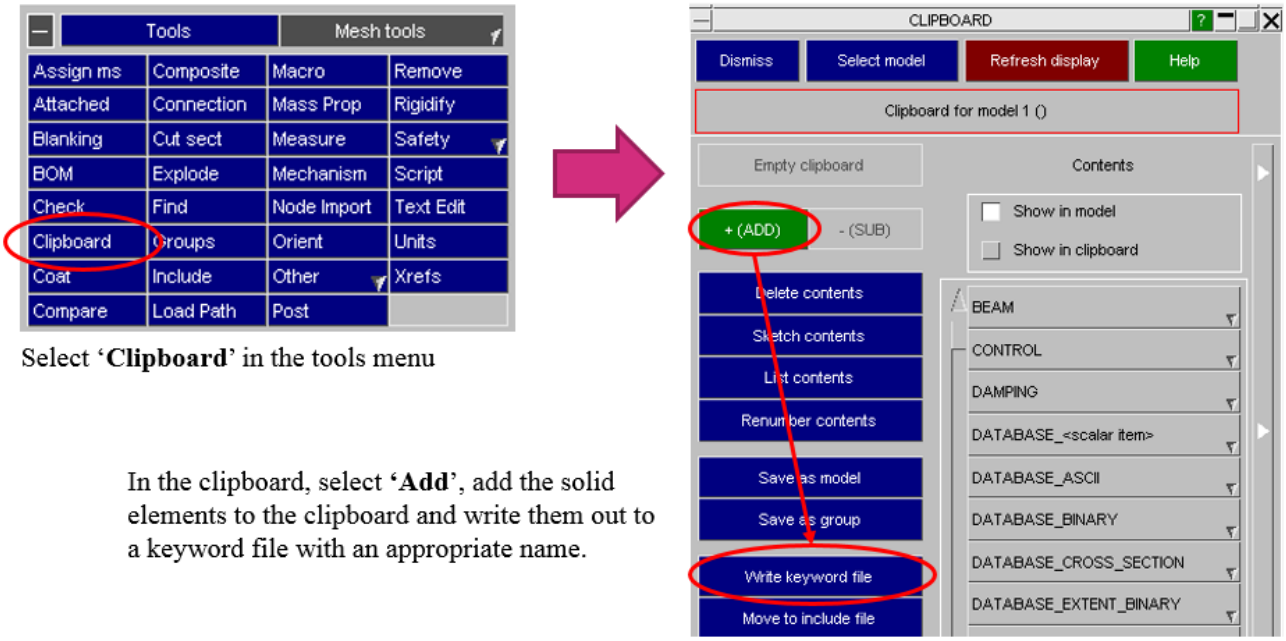


Figure 5: Element axes before and after step 3 (alignment of element local axes to desired orientation).

5. In the Tools menu, select '**Clipboard**'. Add the solid elements to the clipboard and write them out to an appropriately named keyword file.



Select '**Clipboard**' in the tools menu

In the clipboard, select '**Add**', add the solid elements to the clipboard and write them out to a keyword file with an appropriate name.

Figure 6: Tools menu used to write out keyword file.

6. Delete the created solid elements from the working model*, **BUT leave their associated nodes in the model**. This will also delete the latent Part ID's containing the soil model as these Part ID's are not cross-referenced to anything once the solid elements are deleted.

   **Working model = model containing the building.*

7. In a text editor, modify the solid element keyword title from *ELEMENT_SOLID to *ELEMENT_TSHELL.

8. Read the modified file containing the thick shells into working model in PRIMER, ensuring you read it into the current model (Model number 1 generally) instead of a new model.

9. Complete the thick shell foundation Part keyword by assigning the correct MAT_EC2 concrete grade from the Materials Library and adding a section card with the properties outlined in Paolo's memo (see image below).

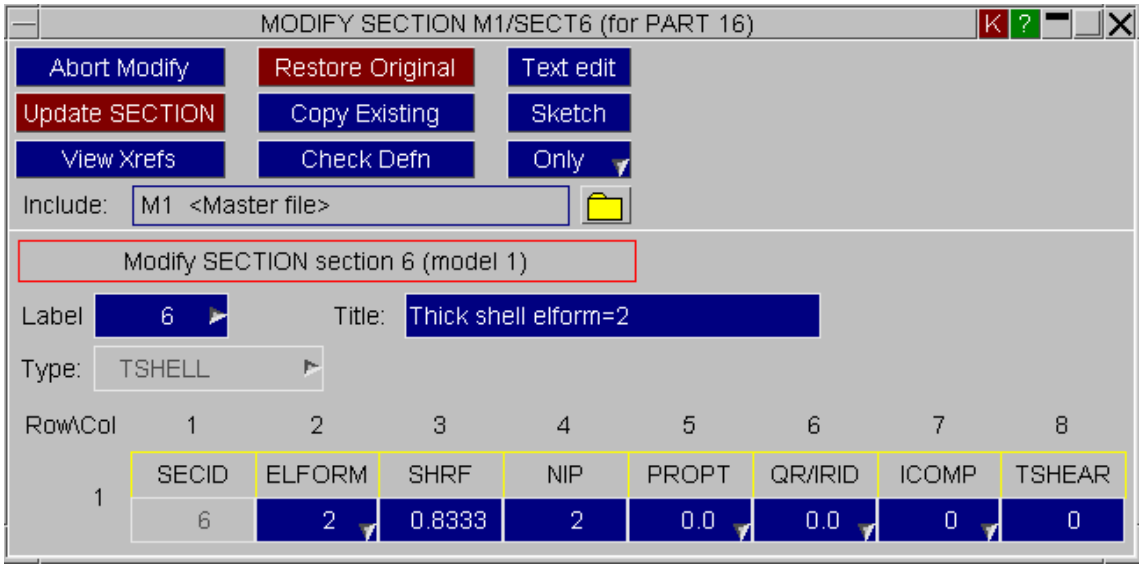


Figure 7: Section properties to use for the thick shell concrete grade beams.

10. Delete the template shell elements which were initially used to model the concrete foundation beam.

11. Coat the thick shells by the same method used when modelling solid concrete foundation beams using MAT_WINFRITH.