On the Partitioned Analysis of Cellular Beams for Controlling Floor Depth

By

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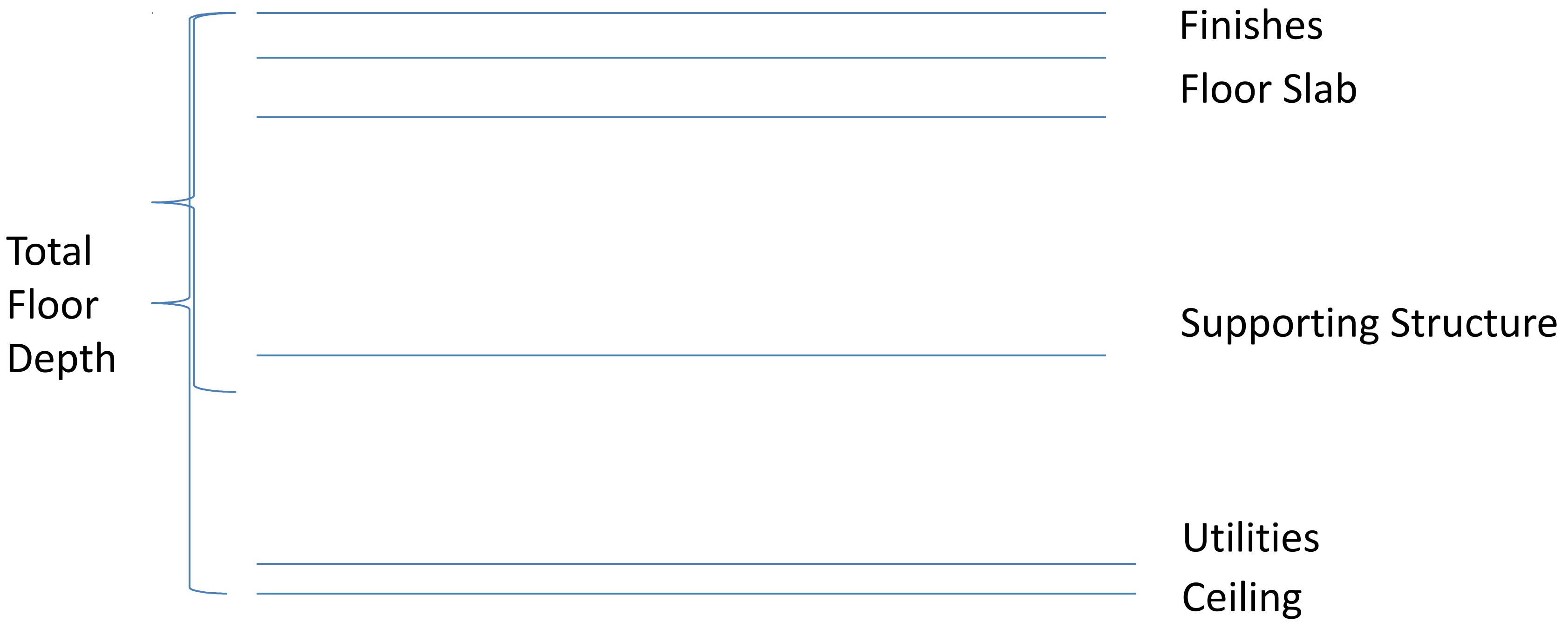
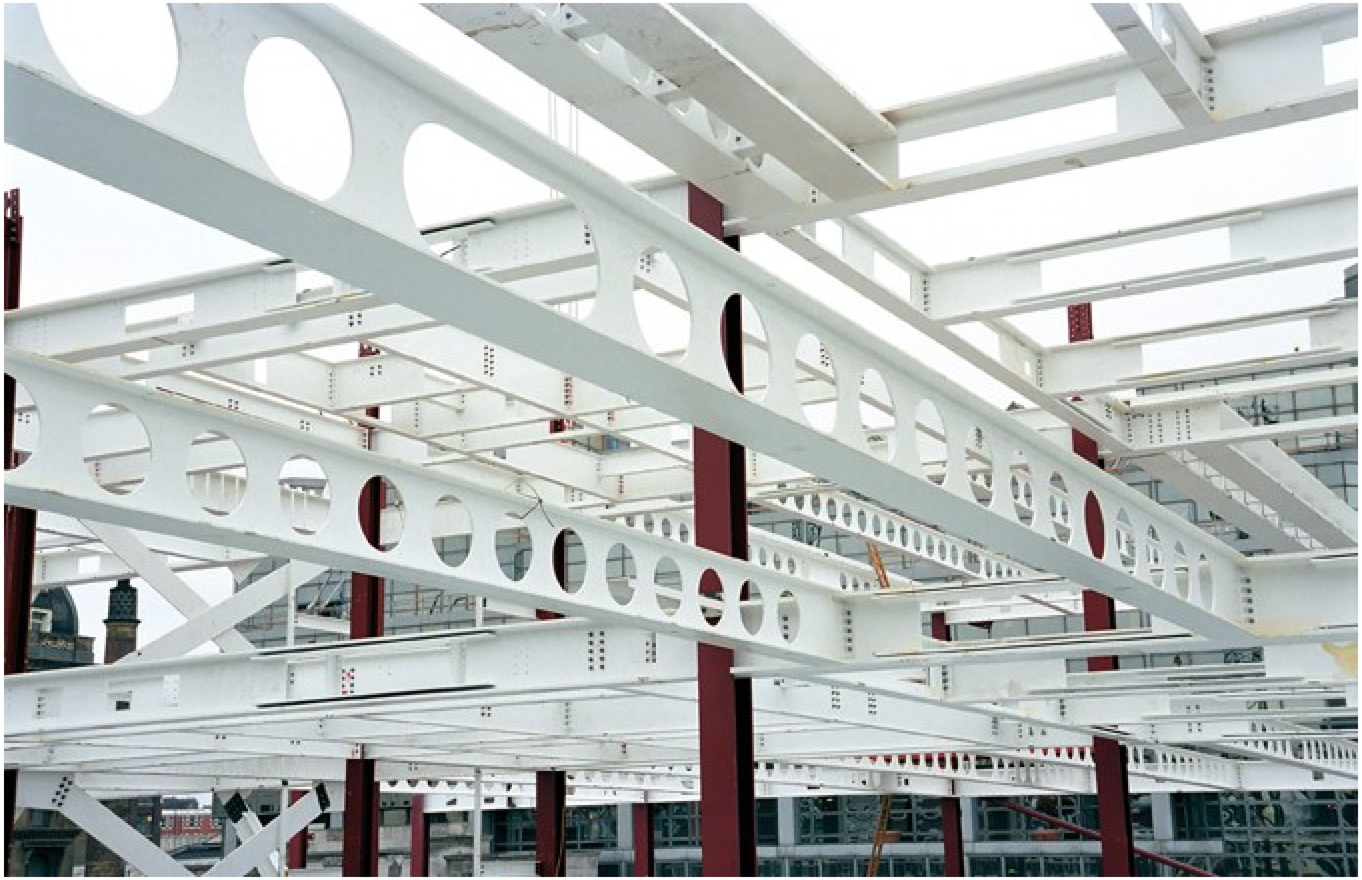
Effects of Floor Depth on Building Heights

- Sometimes Floor Depths can take up to 25% of the Total Story Height
- Reducing that depth by 40%, the total story height may be reduced by around 10%
- For a 10 story building, that will mean almost the height of a story …
- This may allow you an additional story

Floor Depths



Cellular Beams



http://www.bouwenmetstaal.nl

Cellular Beams

http://www.steelconstruction.info

Analysis of Cellular Beams

- The analysis of Cellular Beams is slightly complicated because of the presence of holes in the beam web
- There occurs local buckling in the web post, which is not accounted for while using linear finite elements
- The use of area elements for modeling the beam flanges and webs makes the problem size quite large

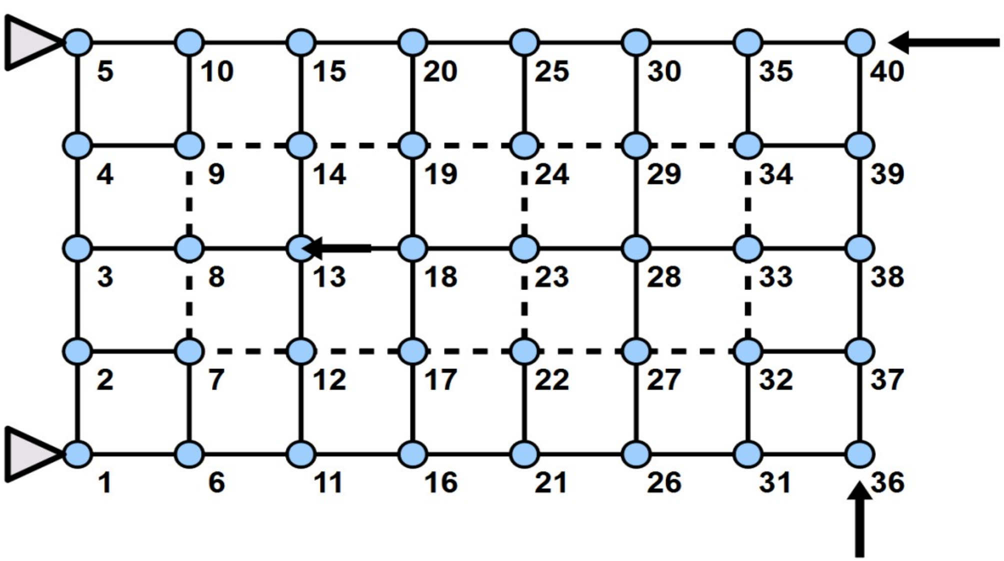
The Solution – Partitioned Parallel Analysis

- An independent PhD study has recently been completed at Imperial College London using Mesh-Free methods
- The analysis presented here is partitioned parallel analysis
- A domain decomposition method for hierarchic partitioned parallel analysis of nonlinear structural systems developed by the first author is used

Overview of the Partitioning Method

- The partitioning method introduced the concept of ‘dual partition super-elements’
- Parts of a finite element model are removed and replaced by partition super elements
- Removed parts are modeled separately with their partitioned boundary wrapped around by dual partition super element

Overview of the Partitioning Method



$$\delta R_{\{80\}} = K_{[80\times 80]}\,\delta d_{\{80\}}$$

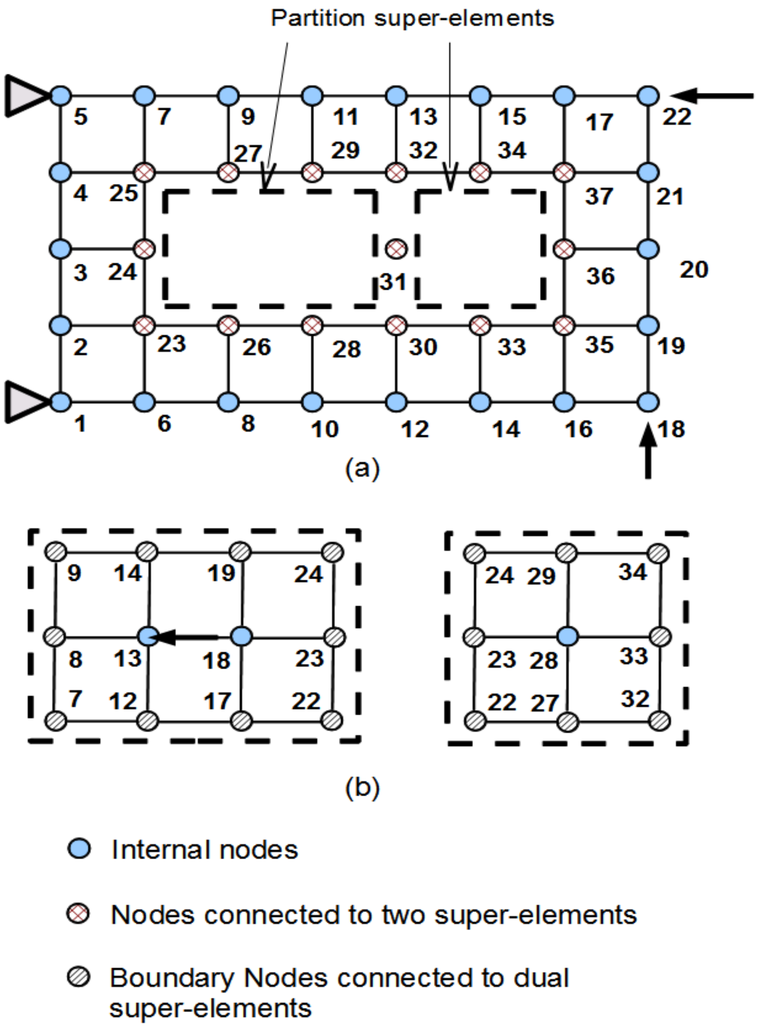
$$G_{\{80\}} = R_{\{80\}} - P_{\{80\}}$$

$$G_{\{80\}} \cong O_{\{80\}}$$

$$\delta d_{\{80\}} = K^{-1}_{[80\times 80]}\left(-G_{\{80\}}\right)$$

$$d_{n\{80\}} = d_{\{80\}} + \delta d_{\{80\}}$$

Overview of the Partitioning Method



$$K_{[74,74]} = K_{\Omega_0[74,74]}$$

$$K_{[45:64,45:64]} = K_{[45:64,45:64]} + K^{c}_{\Omega_1[20,20]}$$

$$K_{[59:74,59:74]} = K_{[59:74,59:74]} + K^{c}_{\Omega_2[16,16]}$$

$$\delta R_{\{74\}} = K_{[74,74]} \delta d_{\{74\}}$$

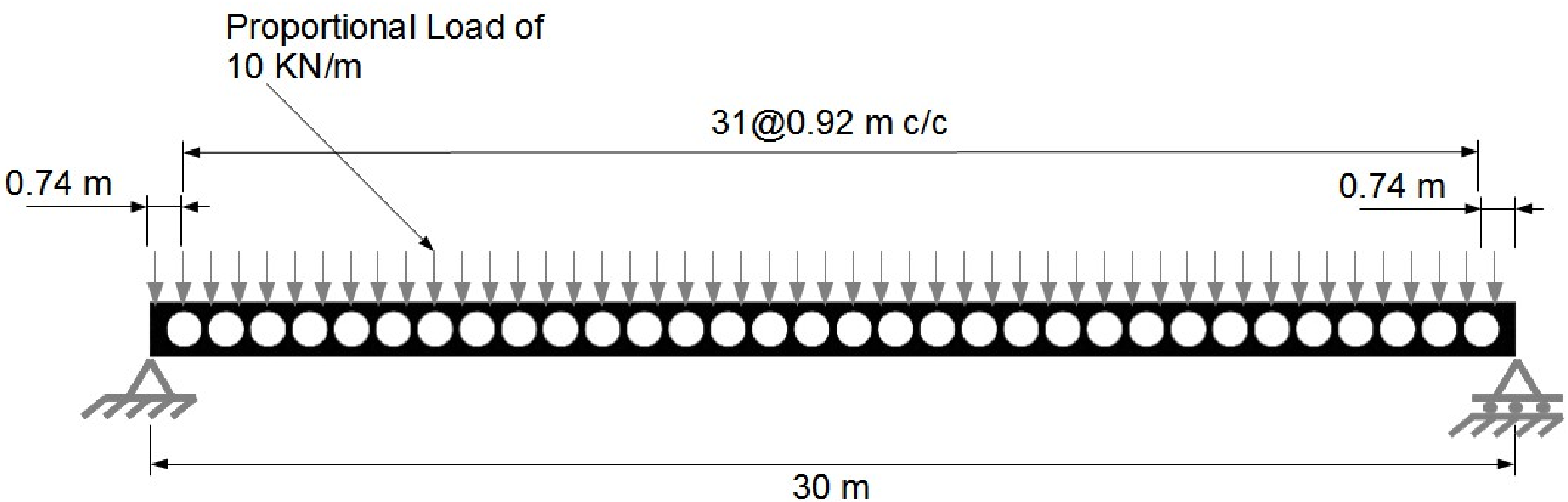
$$G_{\{74\}} = R_{\{74\}} - P_{\{74\}}$$

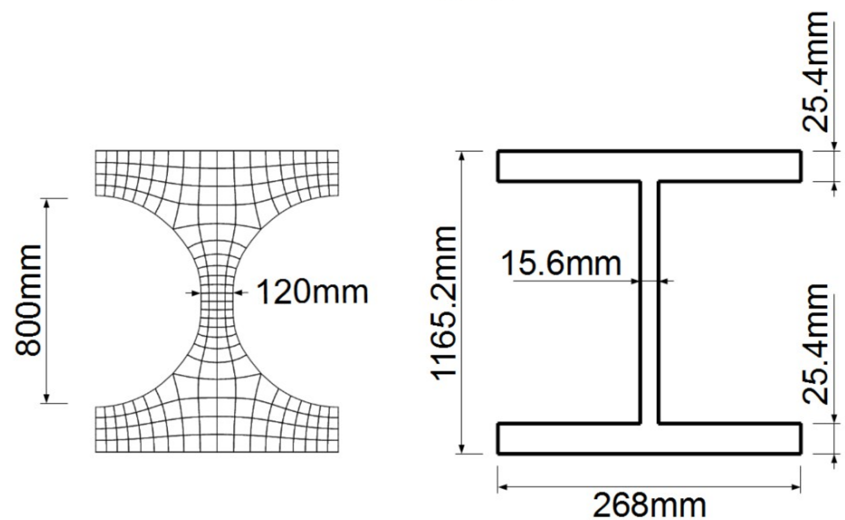
$$\delta d_{\{74\}} = K^{-1}_{[74\times 74]} \left(-G_{\{74\}} \right)$$

$$\delta d^{c}_{\Omega_1\{20\}} = \delta d_{\{45:64\}}$$

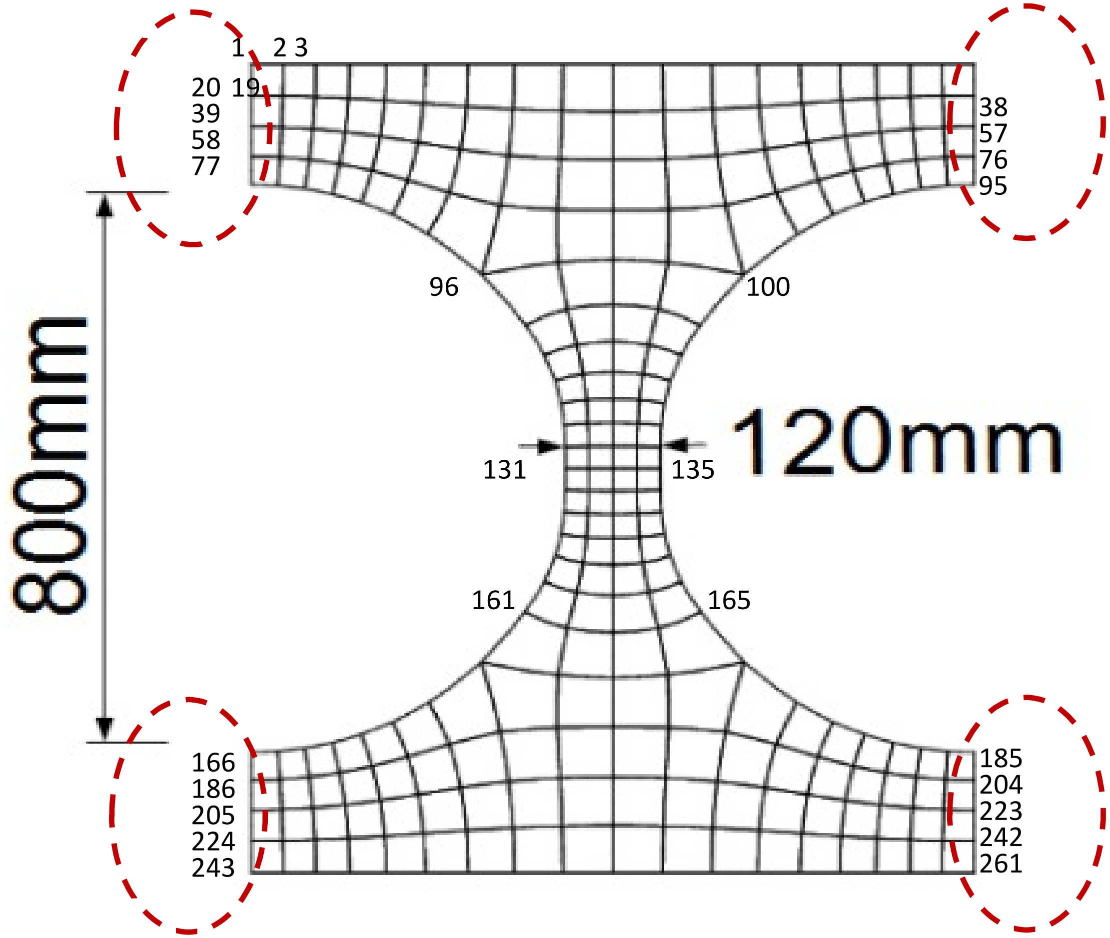
$$\delta d^{c}_{\Omega_2\{16\}} = \delta d_{\{59:74\}}$$

The Cellular Beam

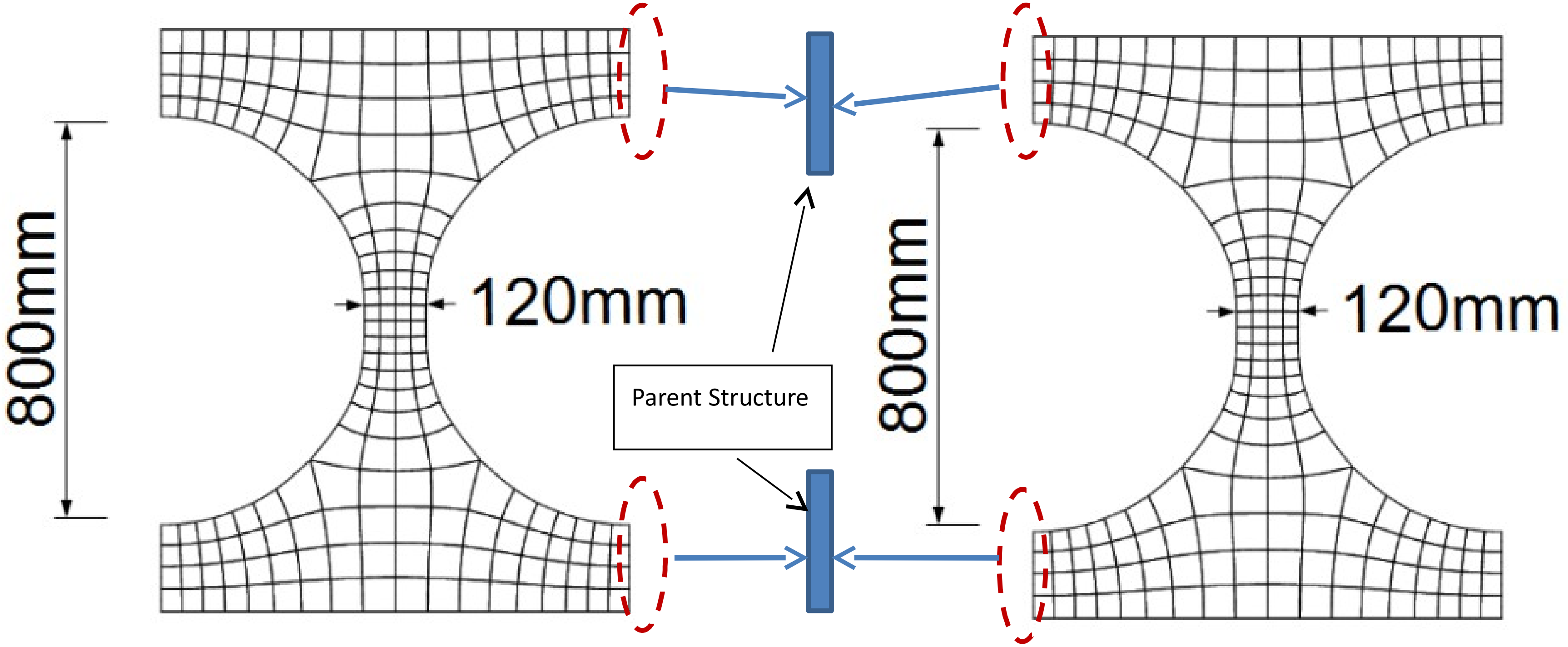




Modular Modelling



Modular Modeling



Computational Efficiency

- No. of Multiplication Operations (MOps) to bring a matrix to its Upper-Echelon form:

$$\Psi = \frac{(n-1)n(n+2)}{3}$$

- For full structure:
  - No. of nodes about 6000
  - Assuming 1 DOF per node
  - MOps = 0.13 Trillion

Computational Efficiency

- No. of nodes in each partition is 261
- MOps = 6 Million
- No. of nodes in parent structure is 320
- MOps = 11 Million
- Since all the partitions are being analysed in parallel, the total MOps in terms of wall-clock time remains around 17 Million for the entire structure

Computational Efficiency

- In addition to the structure size, computational efficiency in a parallel setting also depends on;
- Communication overhead, which in turn depends upon:
- The type of network, and
- The physical location of processing cores

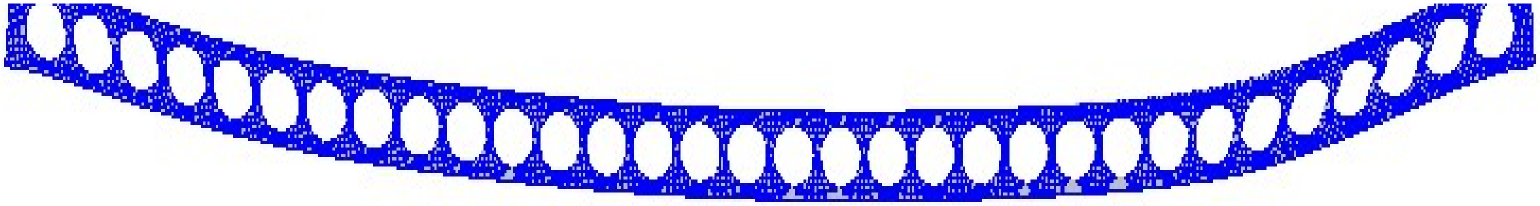
Computational Efficiency

- The actual computational efficiency can only be verified through running examples
- The example under consideration and other examples run using the domain decomposition method have indicated the computational efficiency in proportion to the no. of cores being utilized

Analysis and Results

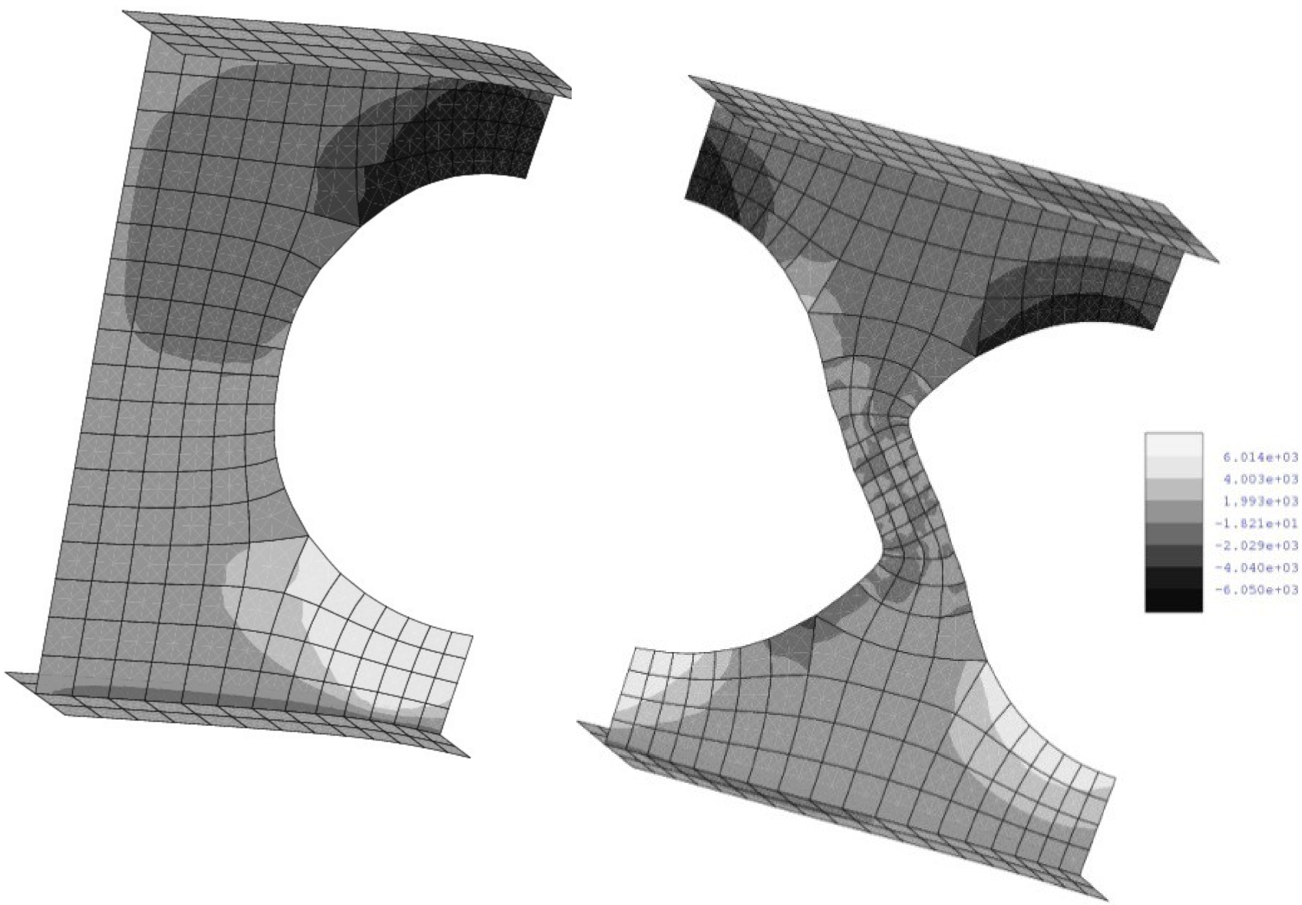
- The proportional load is defined internally at partition level
- Random imperfections are introduced in two end units in the form of very small out-of-plane loads to induce web buckling
- The post-buckling response is associated with snap-back behavior
- So the arc-length displacement control is used beyond the limit point

Deflected Shape

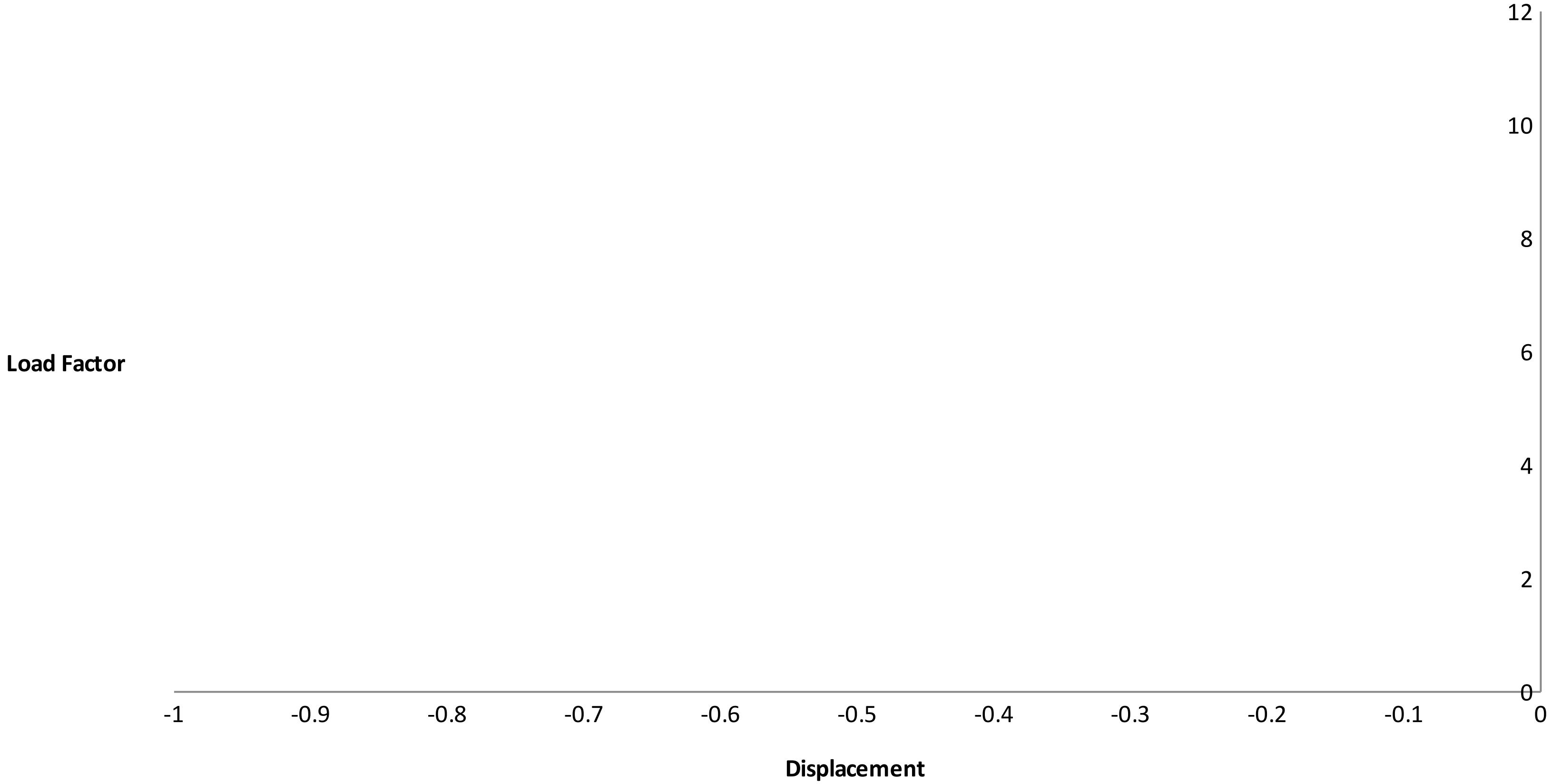


Displacement Scale = 5

Stress Contours



Load-Displacement



Conclusion

- The domain decomposition method was successfully applied to the analysis of cellular beam
- The entire analysis took just 30 minutes using 34 processing cores
- Monolithic analysis for the same example takes about 16 hours

Thank You