Building Better Boundary Conditions eLearning

Peter Barrett
December 2012
Assembly Modeling Webinar

- Do you effectively manage your boundary conditions?
  - Do you take full advantage of symmetry and/or simplified connections?

- This webinar will demonstrate:
  - How to evaluate boundary conditions
  - Efficiently utilize remote supports
  - Apply symmetry, anti-symmetry, and cyclic BC’s
  - Apply nodal-based BC’s
  - Expose the features of advanced connections
Results from a Simple Beam Model

- An example beam/column model under a uniform load is used to illustrate boundary condition assumptions vs. results accuracy.
Results from a Simple Beam Model

- **Model Just the Beam**
  - Brick meshed beam
  - Higher order brick elements
  - Coarse mesh vs. fine mesh
  - Varied support conditions

- **Beam element model**
  - Beam (188) modeled fixed and pinned supports
  - Coarse mesh vs. Fine mesh
### 12"x12"x144" Beam example

<table>
<thead>
<tr>
<th>Element Type</th>
<th>Mesh</th>
<th>Support</th>
<th>Peak Axial Stress (psi)</th>
<th>Mid-span displ. (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>Coarse</td>
<td>Fully Fixed</td>
<td>8,602</td>
<td>-0.0287</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Fully Fixed</td>
<td>10,509</td>
<td>-0.0288</td>
</tr>
<tr>
<td>Brick</td>
<td>Coarse</td>
<td>FrictionLess / Edge</td>
<td>9,618</td>
<td>-0.0293</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>FrictionLess / Edge</td>
<td>13,946</td>
<td>-0.0296</td>
</tr>
<tr>
<td>Beam</td>
<td>Coarse</td>
<td>Fully fixed</td>
<td>7,184</td>
<td>-0.0290</td>
</tr>
<tr>
<td>Beam</td>
<td>Fine</td>
<td>Fully fixed</td>
<td>7,197</td>
<td>-0.0291</td>
</tr>
<tr>
<td>Beam</td>
<td>Fine</td>
<td>Fixed / symm</td>
<td>7,197</td>
<td>-0.0291</td>
</tr>
<tr>
<td>Beam</td>
<td>Fine</td>
<td>Pin/symm</td>
<td>10,800</td>
<td>-0.1369</td>
</tr>
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</table>

**Brick Stresses are at a singularity and provided for reference comparison only**
Add a Simplified Model of the Column

- Compare beam only model with the addition of a remote support point to model a simplified representation of the column using MPC Rigid, Flexible CE’s, a series of spoke beams or MPC based “couples”
Remote Point Support Options

Figure 9.5: Rigid Surface Constraint

Constrained surface remains rigid

Contact elements

Imposed displacement at pilot node

Figure 9.6: Force-Distributed Constraint

Deformed constraint surface

Contact elements

Figure 9.7: Coupling Constraint

Coupling constraint surface — contact nodes have the same displacement as the pilot node in the direction(s) specified by KEYOPT(4)

Contact elements

Imposed displacement at pilot node
“Beta” Beam Support

- Beam Method
  - Creates a series of “spokes” from remote point to surface nodes
  - Cross sectional area is approximately equal to nodal surface area
Remote Point vs. Beam only Model

12"x12"x144" Beam example

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<td>Brick</td>
<td>Fine</td>
<td>Fully Fixed</td>
<td>3,600</td>
<td>-0.0288</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>FrictionLess / Edge support</td>
<td>3,587</td>
<td>-0.0296</td>
</tr>
<tr>
<td>Beam</td>
<td>Fine</td>
<td>Fixed / symm</td>
<td>3,600</td>
<td>-0.0291</td>
</tr>
<tr>
<td>Beam</td>
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<td>Pin/symm</td>
<td>10,800</td>
<td>-0.1369</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Remote Point / Rigid</td>
<td>4,818</td>
<td>-0.0357</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Remote Point / Deformable</td>
<td>5,115</td>
<td>-0.0395</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Remote Point / Beam</td>
<td>5,065</td>
<td>-0.0451</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Remote Point / Couple</td>
<td>4,818</td>
<td>-0.0357</td>
</tr>
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- Remote Point Support is a better approximation vs. Fixed / Pinned Beam models
Model the Column Explicitly

- Model the Column explicitly with combined solid & beam mesh using MPC
- Bonded Vertex to Face Contact to extend the column model
- Column to beam interface is modeled both bonded and frictionless
### Beam-Column vs. Simplified Methods

#### 12"x12"x144" Beam example

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</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Remote Point / Beam</td>
<td>5,065</td>
<td>-0.0451</td>
</tr>
<tr>
<td>Brick</td>
<td>Coarse</td>
<td>Bonded Support Modeled</td>
<td>6,450</td>
<td>-0.0780</td>
</tr>
<tr>
<td>Brick</td>
<td>Fine</td>
<td>Frictionless Support Modeled</td>
<td>10,108</td>
<td>-0.1274</td>
</tr>
</tbody>
</table>

- For the Beam/Column Rigid connection, the remote Point/Beam option is a reasonable approximation.
- For the Frictionless Column/Beam Connection, a pinned beam element is a reasonable approach.
Reflective Symmetry

- The most common type of symmetry is reflective or mirror symmetry, i.e., the model has a plane of symmetry.
  - The geometry and materials are symmetric about the plane
  - The loading can be symmetric or anti-symmetric.

Symmetric Loading

Antisymmetric Loading
Symmetry & Antisymmetric BC’s

- A linear structure with unsymmetric loading can be modeled using symmetry + anti-symmetry via superposition
Symmetry & Antisymmetric BC’s

- Modeling a structure with Unsymmetric loading using Symmetry and Antisymmetry
Symmetry & Antisymmetric BC’s

- Design Assessment can be used to perform the load case combination
Periodic Symmetry

- Periodic symmetry means that the entire structure can be reproduced by copying a single repeatable piece:
  - in a Cartesian direction (translational symmetry)
  - or about an axis (rotational or cyclic symmetry).

- To enforce periodic symmetry the nodes on the opposite faces must be forced to behave exactly the same. This is usually done by coupling the DOFs.
Periodic Symmetry – New in Mech. at 14.5

- Example Analysis
  - Circuit Board subject to lateral acceleration loading
Periodic Symmetry

- Example Analysis
  - Linear Periodic Symmetry Model

- Symmetry Expansion

C: Copy of Static Structural
Directional Deformation 2
Type: Directional Deformation (Z Axis)
Unit: in
Global Coordinate System
Time: 11/30/2012 11:24 AM

0.0037452 Max
0.0030748
0.0024045
0.0017341
0.0010643
0.00039413
-0.00027692
-0.00094726
-0.0016176
-0.002288 Min
Periodic Symmetry

- Example Analysis
  - Circuit Board subject to lateral acceleration loading

Type: Equivalent (von-Mises) Stress
Unit: psi
Time: 1
11/30/2012 10:52 AM

*85.571 Max*
- 76.12
- 66.669
- 57.218
- 47.767
- 38.316
- 28.865
- 19.414
- 9.9627

*0.51174 Min*
Cyclic Symmetry

- Example Cyclic Symmetric Modal Analysis
Cyclic Symmetry

- Example Cyclic Symmetric Modal Analysis
Cyclic Symmetry

- Example Cyclic Symmetric Modal Analysis
  - Modal Analysis setup defines the Harmonic Index solution(s)
Nodal Based Constraints

- Can one apply Boundary Conditions that do not conform to the Geometry in Mechanical?
  - Yes!
  - Nodal Based Constraints are based on Mechanical APDL “Select Logic”
Nodal Based Constraints

- “NSEL” Isolation of Nodes simulate the sequential combination of NSEL,S… and NSEL,R… commands

- These options automatically update for changes in mesh, parametric geometry changes and in design of experiments and optimization studies
Nodal Based Constraints

- Normal Stress – indicates region of Nodal Pressure loading
Section Post – New in Mech. at 14.5

- Section Postprocessing for “Net Force/Moment Data” at any location
  - Create Local Coord. Sys.
  - Create Construction Geometry
  - Surface
  - Define Force Reaction
  - Define Moment Reaction
    - Select Orientation
    - Select Summation
Advanced Connections

- Example – Joints

- MPC 184 Documentation
Joint Connection

- Translational Joint: ANSYS creates Point to Surface Contact with the target Pilot node(s) connected to the MPC184 element
- Example illustrates free axial motion of the beam end with all other degrees of freedom fixed