Use of MSC.Dytran in Developing Blast-Resistant Building Columns

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Case Study Description

Objective

- Establish the structural response of a steel column under blast loading

- Explore possible improvements to performance of steel sections through the addition of concrete

Case Study Description

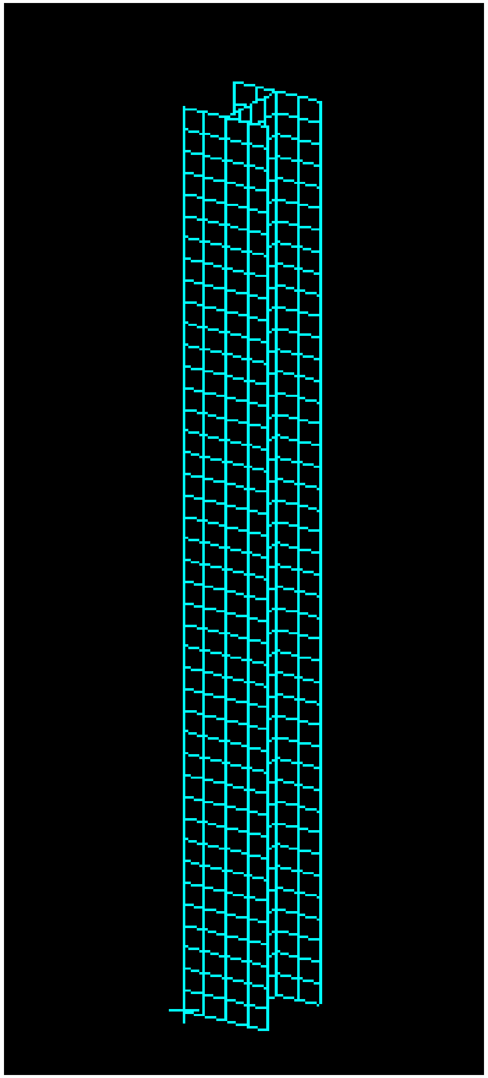
<u>*Parameters*</u>

- Pin-Ended Boundary Conditions
  - Allow for “worst case scenario” in terms of bending capacity
- Blast Location
  - Blast placed 10 ft away at mid-height
- Varying Axial Load
  - Heavy Load: 60% of axial capacity
  - Light Load: 30% of axial capacity

Case Study Description

Selected Column Size

- W14x145 column selected
  - Column was designed to carry gravity loads that would be expected on ground level in typical 10 story office building
  - Column designed to carry ~1500 kips pure axial load at design capacity ratio of 0.92
- First floor story height of 14 ft



Building the Models

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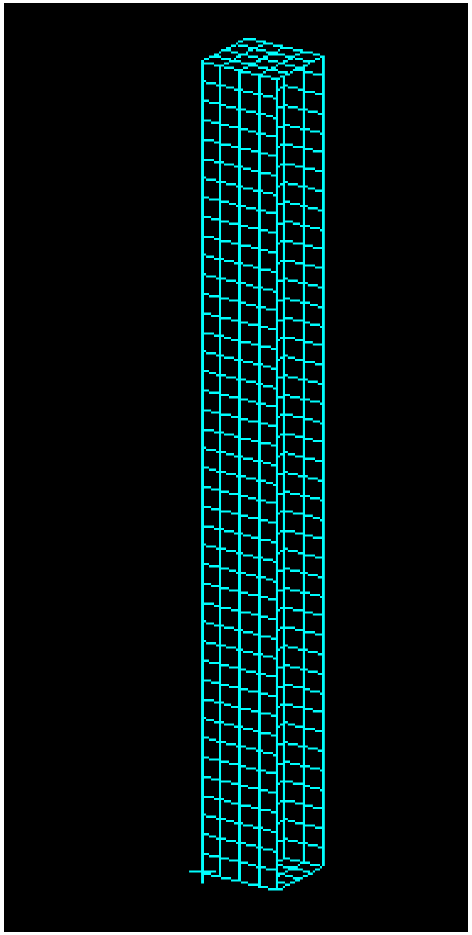
MSC.Dytran used for blast analysis

- Gas to Solid Interaction possible
- Explicit code
  - No stiffness matrix to invert allowing fast results for short duration event
  - Models can undergo large deformations and rotations
- Non-linear material behavior
  - Allows plastic behavior and deformations
  - Allows material failure

Building the Model



<u>Column Geometry</u>

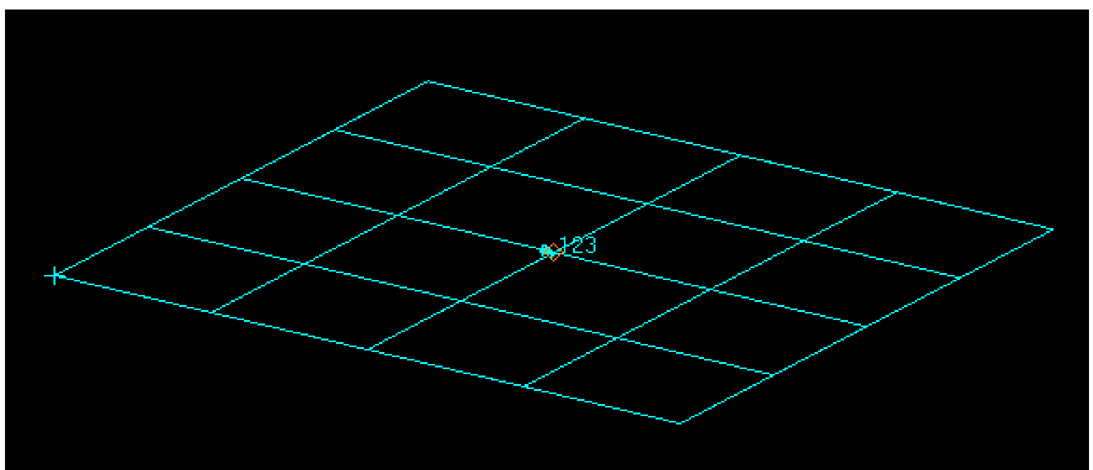
- Shell Elements used in column construction
  - 4 - Noded Quadrilateral Elements used with assigned thickness corresponding to column dimensions
  - QUAD4 generally perform well when structure thickness is small compared to structure length

- 6 inch steel boundary plates placed on column ends to allow for even distribution of axial load

Building the Model

Pinned Boundary Conditions

- Center node of boundary plate is pinned
  - Bottom plate restrained from translation in x,y,z direction
  - Top plate restrained from translation in x and y, but not z direction due to desired displacement from axial load



Building the Model

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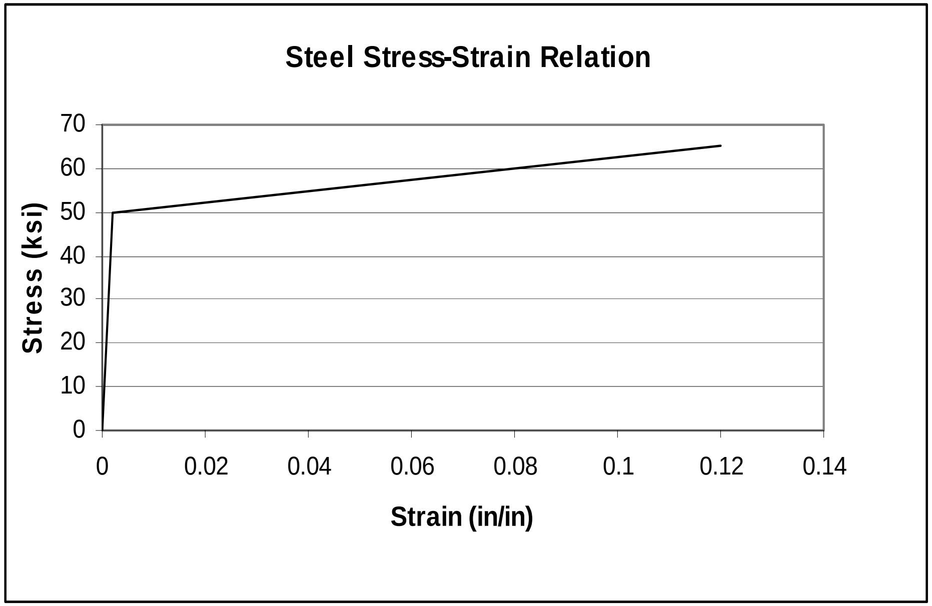
Steel Material Model

- Grade 50 Steel
  - Yield Point: 50 ksi
  - Young's Modulus: 29,000 ksi
  - Hardening Modulus; 127 ksi
  - Failure Strain: 0.12 in/in

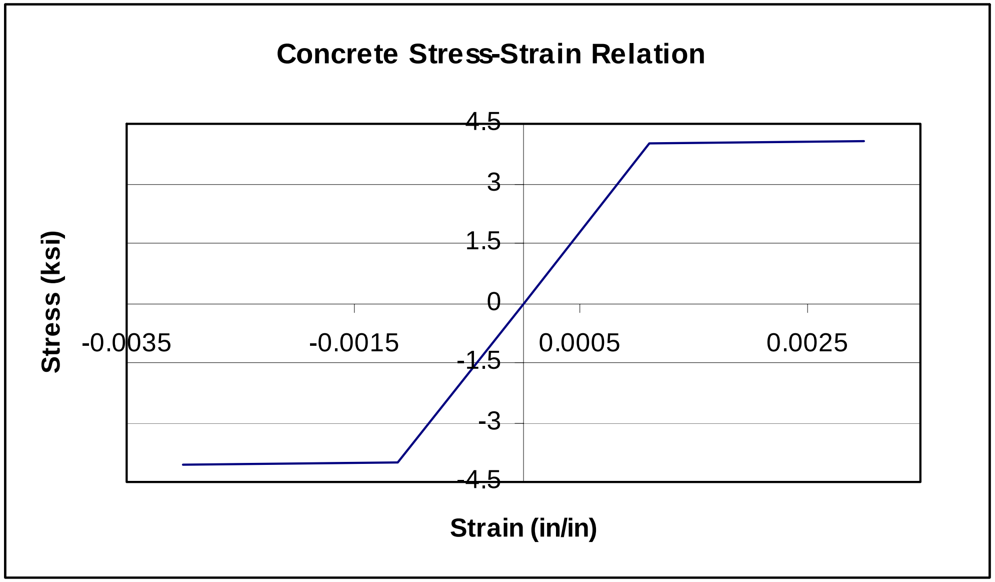


- MSC.Dytran DMAT24
  - Elastoplastic materials
  - Piecewise linear strain relation

Building the Model

<u>*Concrete Material Model*</u>

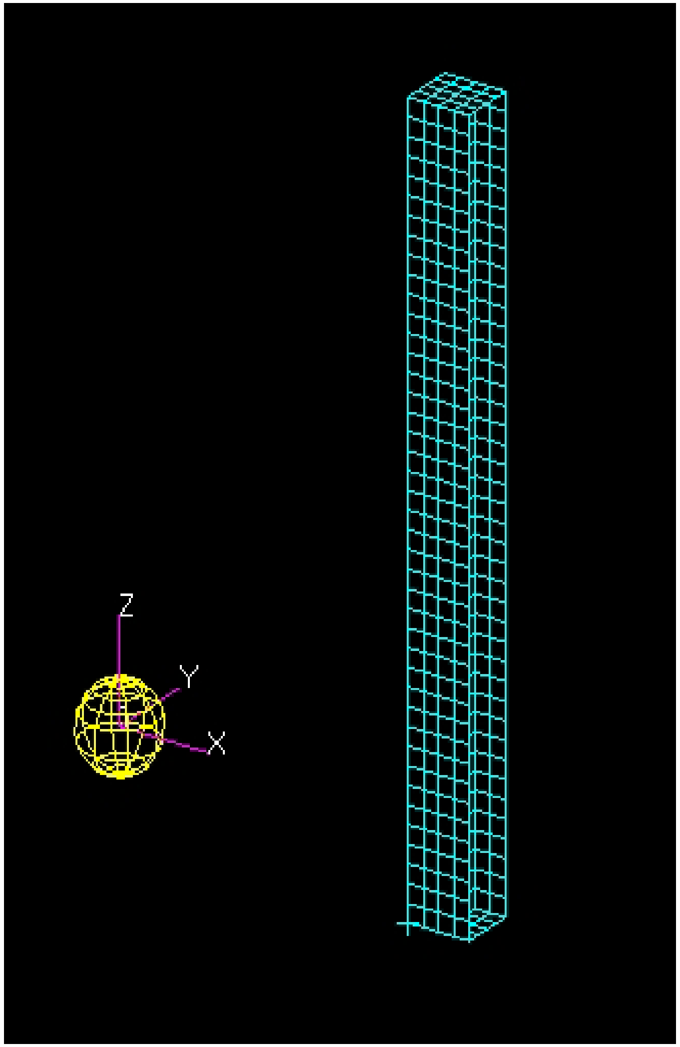
- 4 ksi Concrete
  - Strain relation approximated with bilinear model
  - Yield Point: 4 ksi
  - Longitudinal steel used to provide identical properties in tension and compression



Building the Model

Blast and Surrounding Air

- Blast created as region of compressed air contained in a spherical Euler region at a distance of 10 ft
  - Blast given specific energy of equivalent TNT mass
- Region of "air-at-rest" created to surround the column
  - Air assigned using Eulerian elements and defined with corresponding density and specific energy



Results

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<u>Steel Column Behavior (No axial load)</u>

- Column bends globally in first mode
- Stresses in column center enter inelastic range
- Front flange begins to fold backwards due to high blast pressure
- Plastic hinge forms in column center
- Column begins to fold at center until back flange fractures

Results: Steel Column

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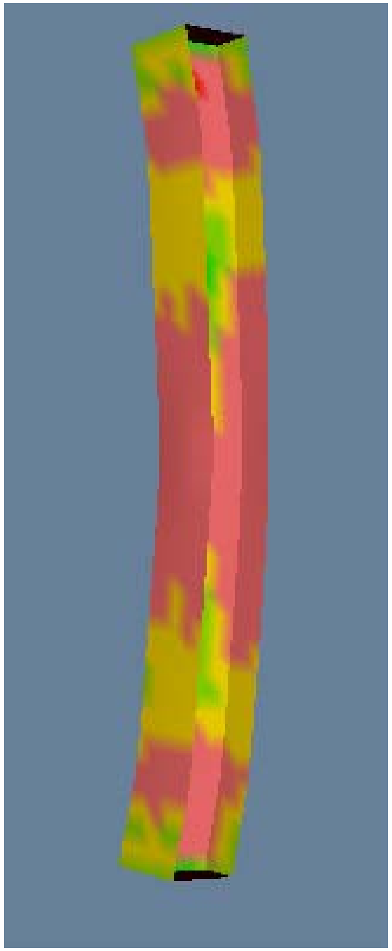

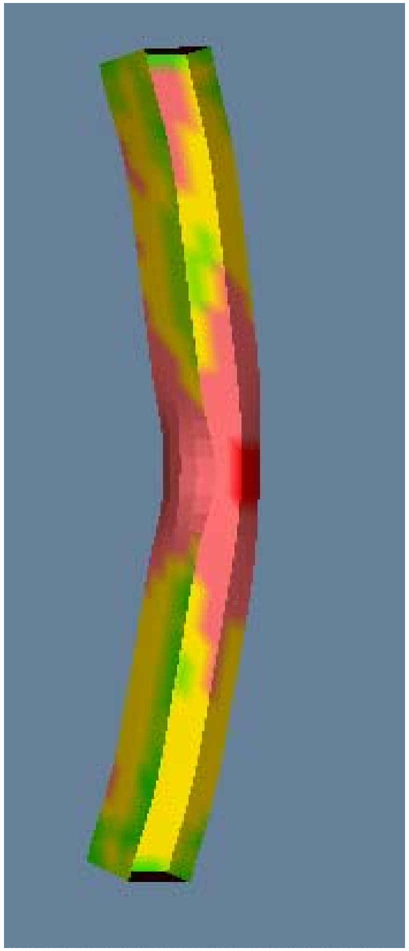

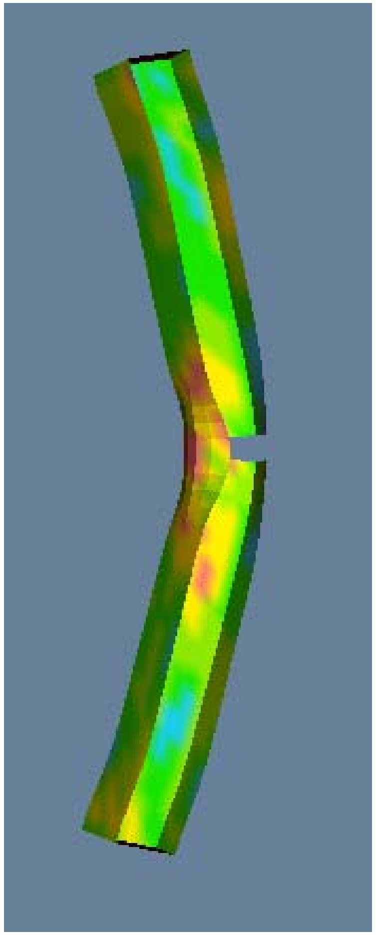

Results

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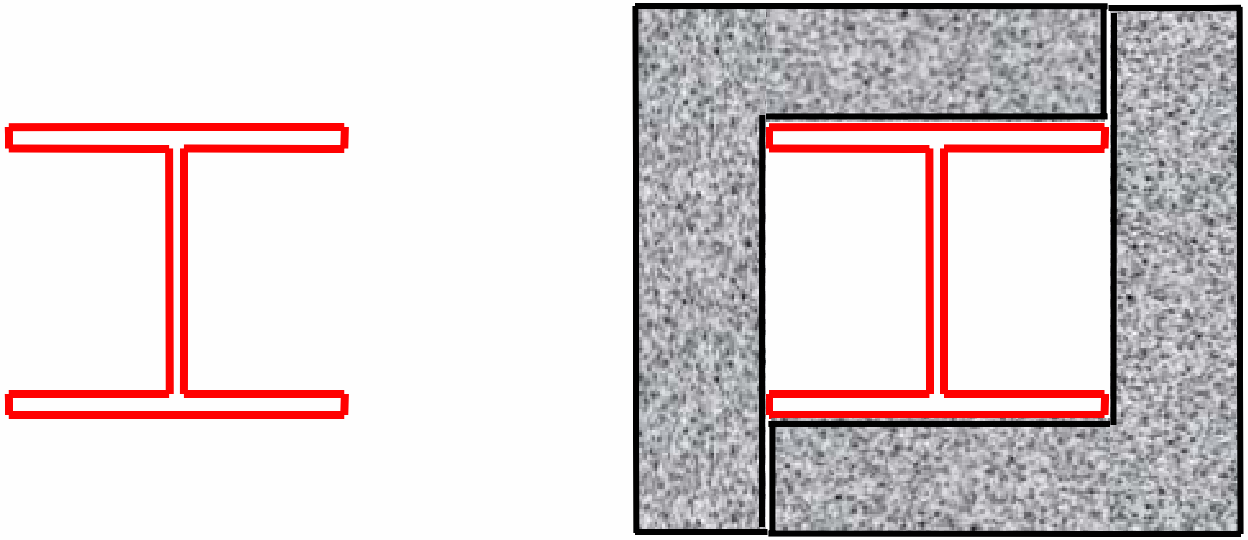
Composite Column

❖Steel Column is surrounded with 6-inch concrete shells



Results

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Concrete Column Behavior (No axial load)

- Column globally bends in first mode
- Plastic hinge forms at column center
- Surrounding concrete located along the column weak axis cracks and fails
- Back flange fails
- As hoped, front flange does not bend

Results: Concrete Column

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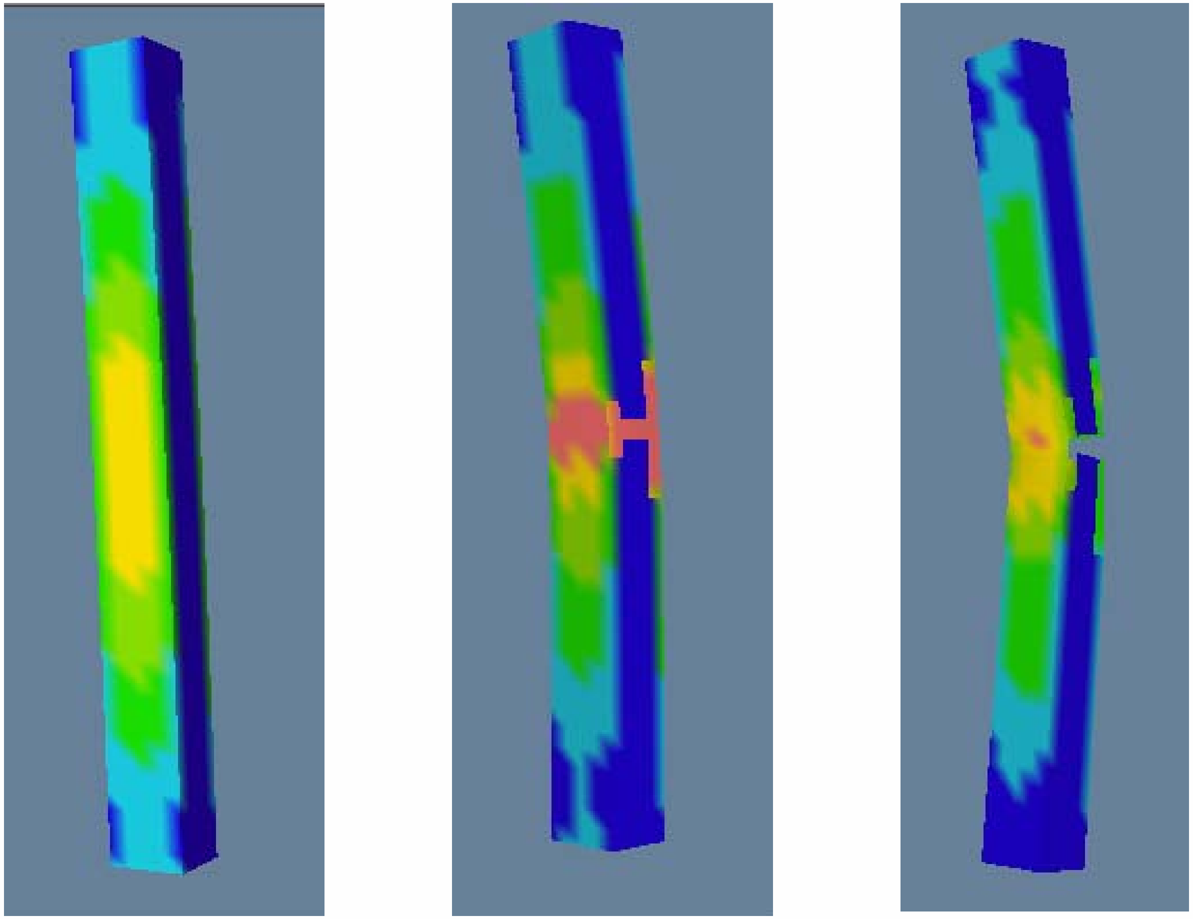

Conclusions

- Primary cause of failure in steel column is folding of the flange
- Concrete does prevent flange from folding
- Continued research currently underway to determine the effects of axial load on both steel and composite columns