FEA of structures with insulation damage in fire

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FEA of structures with insulation damage in fire

• Topics
  – Motivation
  – Physics
  – Procedures
  – Test Case
  – Future Work
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• Motivation – WTC Disaster
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• Motivation
  – WTC destruction
    • Need to treat fire as a structural load
    • Analyze complex structures under fire all the way to collapse
    • National Construction Safety Team recommended enhancing capabilities of available computational software to study the effect of fire on buildings and the design of fire protection systems
  – Interface limited to compatible elements
  – Intense fire of long duration requires modeling damage and collapse
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• Physics: Fire-Structure Interaction

Diagram:
- **Fire**
  - Combustion
  - Heated Gases
- **Heat Transfer**
  - Heated Gases
  - Heated Structure
- **Structural Deflections**
  - Thermal Body and Other Loads
- Deflection and Failure
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- Procedure

1. Fire Dynamics Simulator
   - Combustion
   - Heated Gases

2. Thermal Analysis
   - Heated Gases
   - Heated Structure

3. Structural Analysis
   - Thermal Body and Other Loads
   - Structural FEM
   - Geom_up
   - Temp2body_Id

4. Deflection and Failure
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• Temp2Body_Id
  – Same Global CSYS
  – Transfer Nodes
  – Temperature Mapping
  – Gradient Calculation and Body Load Definition
  – Use Area-Weighted Averages

• Geom_up
  – Maps Deflections and Strains from Structural onto Thermal Model Domain
  – For Deflections use the Kinematics Relationship
    \[ U = u + r \times d \]
  – Interpolates Strains from Selected Cross Section Cell Nodes of Structural onto Thermal Model Domain
Temp2Body_Id Transfer Nodes

- Temperature transfer nodes
Common cross sections

- Cells and strain transfer nodes
Test Case - Floor Slab Supported by an Open Web Structural FEM – Beam and Shell Elements
Test Case - Floor Slab Supported by an Open Web
Thermal FEM – Solid Elements
Test Case - Floor Slab Supported by an Open Web
Thermal FEM – Insulation Details
Thermal Finite Element Model – Thermal Flux
Test Case - Floor Slab Supported by an Open Web Thermal and Structural FEM

- Temperature Solution and Thermal Body Load
Test Case - Floor Slab Supported by an Open Web
Thermal and Structural FEM

Temperature Solution and Thermal Body Loads - Slab
Test Case - Floor Slab Supported by an Open Web Structural and Thermal FEM

- Deflected and Updated Shapes
Structural strains $\varepsilon_{xx}$ at 1800 s
Failed Insulation of Thermal Model
(Red)
Failed Insulation of Thermal Model
(Removed)
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• Future Work
  – Better failure criteria for insulation (experiments)
  – Predicting structural failure: computational criteria