Numerical analysis of a composite steel-concrete column subjected to fire, using ABAQUS

Ioan Both
“Politehnica” University of Timisoara

Introduction

Methods for evaluation of structural response of elements subjected to fire

- Tabulated data
- Simple calculation models
- Advanced calculation models

Common used cross-sections

Any model (material, CS, load, etc.)

Verification and Validation

- By comparison to existing experimental tests
- German annex EN1991-1-2
  - Comparison examples
  There are 11 examples analyzing:
  - heat transfer for different material properties
  - elongation of elements
  - forces and stresses
  - fire resistance time

For each example there are given results and their error tolerances

Example 11

Parabolic longitudinal path – midspan imperfection L/1000

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>l (m)</th>
<th>h (m)</th>
<th>b (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Load</td>
<td>N</td>
<td>E,fi,d,t</td>
<td>KN</td>
</tr>
<tr>
<td>Concrete</td>
<td>C25/30</td>
<td>3% moisture</td>
<td>(by mass)</td>
</tr>
<tr>
<td>Reinforcing steel</td>
<td>S500</td>
<td>fyk (20°C)</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Structural steel</td>
<td>S235</td>
<td>fak (20°C)</td>
<td>N/mm²</td>
</tr>
</tbody>
</table>

Stress–strain curve

Concrete:
- DIN EN 1994-1-2

Reinforcing steel:
- DIN EN 1994-1-2

Temperature load:
- DIN EN 1991-1-2

Heat transfer coefficient:
- DIN EN 1991-1-2

Analysis

Previous verification using SAFIR

- 2D beam elements
  - For displacement at 60 minutes the criterion is not fulfilled

The result is not consistent with the other values:
- at 30min the displacement is bigger than the reference value while for 60 minutes the displacement is smaller than the reference value
- For smaller displacement it is expected longer resistance time; but for this case the fire resistance is smaller

Model - ABAQUS

Material properties

Steel
- Conductivity
- Specific heat
- Thermal elongation

Concrete
- Conductivity
- Specific heat
- Thermal elongation
Model
Part definition
Separated parts for each material
-contact problem

Model
Concrete model
Piecewise stress-strain
Large tensile stress for concrete
Smeared concrete
-elongation & BC problems

Model
Boundary conditions
Fully fixed -surface
Fully fixed -node

Analysis
Thermal analysis - 2D - verification
Grid Convergence Index (GCI) for temperatures at 90min

Analysis
Structural analysis
Sequentially coupled analysis

Results
Fully coupled analysis
Results

The results do not fulfill 2 criterion: fire resistance time and displacement for 60min.

<table>
<thead>
<tr>
<th>ABAQUS</th>
<th>Reference value</th>
<th>Calculated value</th>
<th>Deviation [%]</th>
<th>Limit [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>92</td>
<td>87</td>
<td>5.43</td>
<td>±5</td>
</tr>
<tr>
<td>Displ.</td>
<td>4.40</td>
<td>4.56</td>
<td>3.52</td>
<td>±5</td>
</tr>
</tbody>
</table>

It can be observed that, as is case of SAFIR analysis, fire resistance time is smaller than the reference value. On the other hand, displacement for 60 minutes is higher than the reference value (still, the Abaqus results are consistent since for a smaller resistance time there is a corresponding larger deflection for the column, with respect to the reference value).

Conclusions

- Extra information needed for the calculation model
- Mechanical interaction between elements - unknown
- Concrete model - difficult to define
- Analysis time – long
- What happens after debonding? – thermal condition

References


THANK YOU!

Ioan Both
ioan.both@ct.upt.ro
"Politehnica" University of Timisoara