Mechanical Properties of Grade 8.8 Bolts at Elevated Temperatures

MSc project
Yiannis Theodorou
Component approach to joint design

<table>
<thead>
<tr>
<th>Zone</th>
<th>REF</th>
<th>Checklist item</th>
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</thead>
<tbody>
<tr>
<td>Tension</td>
<td>A</td>
<td>Bolt Tension</td>
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<tr>
<td></td>
<td>B</td>
<td>End Plate Bending</td>
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<tr>
<td></td>
<td>C</td>
<td>Column Flange Bending</td>
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<tr>
<td></td>
<td>D</td>
<td>Beam Web Tension</td>
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<tr>
<td></td>
<td>E</td>
<td>Column Web Tension</td>
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<tr>
<td></td>
<td>F</td>
<td>Flange to End Plate Weld</td>
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<td></td>
<td>G</td>
<td>Web to End Plate Weld</td>
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<tr>
<td>Horizontal Zone</td>
<td>H</td>
<td>Column Web Panel Shear</td>
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<td>Compression</td>
<td>J</td>
<td>Beam Flange Compression</td>
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<tr>
<td></td>
<td>K</td>
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<tr>
<td></td>
<td>L</td>
<td>Column Web Crushing</td>
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<tr>
<td></td>
<td>M</td>
<td>Column Web Buckling</td>
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<td>Vertical Shear</td>
<td>N</td>
<td>Web to End Plate Weld</td>
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<tr>
<td></td>
<td>P</td>
<td>Bolt Shear</td>
</tr>
<tr>
<td></td>
<td>Q</td>
<td>Bolt Bearing(Plate or Flange)</td>
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</table>
Strength reduction factors measured by Kirby
Comparison of tensile strength of FR and ordinary bolts at elevated temperatures

![Graph showing the comparison of tensile strength at elevated temperatures.](chart.png)
Temperature Dependency of Young’s Modulus of FR Bolts

![Graph showing the reduction of Young's Modulus with increasing temperature. The x-axis represents temperature in °C, ranging from 0 to 900. The y-axis represents the reduction of Young's Modulus, ranging from 0 to 1.2. The graph shows a downward trend as temperature increases.]
Aim of study

- To measure the mechanical properties (strength, stiffness, expansion) of grade 8.8 bolts across a range of temperatures

Project Involved
- Designing and building furnace
- Devising instrumentation
Schematic diagram of apparatus

- load cell
- specimen
- furnace
- Hydraulic jack
- thermocouples
- camera
- PC for video recording
- PC for data recording
- Data acquisition system
- 12 V
Experimental apparatus
Cross-Section of Furnace

- isolated material
- halogen lamp
- specimen
- targets

Cross-Section of Furnace

- halogen lamp
- specimen

Dimensions:
- 47
- 60
- 63
- 130
- 100
- 60
- 30
View into furnace
Underside of lid showing halogen lamp
Location of cameras

- furnace
- specimen
- load cell
- hydraulic jack
- digital cameras
Thermocouples

thermocouple locations

specimen
cross section A-A

halogen lamp

thermocouple locations
Temperature control specimen
Measuring strain

at ambient temperatures 20°C

at high temperatures

tensile load
Specimens

Group A

Group B
Pilot test

- Little difference between side and bottom
- As much as 30°C along length
Thermocouple arrangement

- C hottest
- Average value used to present results
Range of temperatures recorded

<table>
<thead>
<tr>
<th>Test</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<tbody>
<tr>
<td>550 °C</td>
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<td>555</td>
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<td>555</td>
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<tr>
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<td>711</td>
<td>715</td>
<td>710</td>
<td>686</td>
<td>701</td>
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<tr>
<td>800 °C</td>
<td>787</td>
<td>807</td>
<td>812</td>
<td>807</td>
<td>786</td>
<td>800</td>
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</tbody>
</table>
Variation of stress-strain relationship at 650 °C
Summary

Group B
Comparison – tests, Kirby, BS5950
Comparison: temp + 15°C
Variation of Young’s Modulus with temperature

[Graph showing the variation of Young’s Modulus with temperature. The x-axis represents temperature in °C, ranging from 0 to 900. The y-axis represents the reduction of Young’s Modulus, ranging from 0 to 1.2. The graph includes data points labeled “Fire Tests.”]
Comparison of variation of E with EC3

Reduction of Young's Modulus vs. Temperature °C

- Red circles: Fire Tests
- Magenta squares: EC3:Part 1.2
- Blue triangles: FR-Bolts

Carbon steel

Temperature °C:
- 0
- 100
- 200
- 300
- 400
- 500
- 600
- 700
- 800
- 900

Reduction of Young's Modulus:
- 0
- 0.2
- 0.4
- 0.6
- 0.8
- 1.0
- 1.2
Conclusions

- Halogen furnace worked well
- Cameras reasonably accurate for strain measured
- Temperature variation along bolt length not ideal
- Strength reduction
  - BS5950 conservative
  - Kirby recommendations verified
- Stiffness reduction
  - EC3 Part 1.2 formula for structural steel applicable to bolts