Robustness of Joints between Steel Beams and Concrete Filled Tubular (CFT) Columns under Fire Conditions

CIDECT project 15S-13

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Objectives

- To provide detailed experimental data for calculation of temperatures in the joint region.
- To provide detailed experimental data of structural performance of the joints and structural assemblies in fire, including the cooling phase.
- To assess the ultimate state and fracture of different types of joints under extreme fire conditions.
Test Arrangement
Loading/Supports

Gap to allow free vertical movement of the column
# Summary of Tests

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Tube size</th>
<th>Thickness (mm)</th>
<th>Joint type</th>
<th>Applied load per jack (kN)</th>
<th>Design Load Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SHS 200</td>
<td>5mm</td>
<td>fin plate</td>
<td>30</td>
<td>0.5</td>
</tr>
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<td>2</td>
<td>SHS 200</td>
<td>5mm</td>
<td>bolted T</td>
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Joint Types

- Fin plate
- T-stub
- Reverse channel
- End plate
Temperature Developments – weld to tube (fin/reverse channel)

[Graph showing temperature development over time for different thermocouples and furnace temperature.]
Temperatures – fin plate/T-stub/beam web
Temperatures – End plate/T-stub
Summary of Temperature Data

- Joints can be divided into regions and each region has uniform temperature distribution.
- Joint regions:
  - Fin plate: fin/beam web/bolts, weld to tube
  - T-stub: leg/beam web/bolts, flange/tube
  - Reverse channel (RC): RC/end plate/bolts; weld to tube
  - End plate: end plate/bolts
Joint Temperature Calculation

- Calculation equation in EN 3 Part 1.2
- Equivalent section factor $A_m/V$ for each joint region: expressions derived and validated against experimental results

\[ \Delta T_a = \frac{A_m / V}{c_a \rho_a} \dot{h}_{net} \Delta t \]
Example of Validation
Structural Behaviour: Fin plate
Structural Behaviour – T-stub
Structural Behaviour – End plate
Structural Behaviour – Reverse Channel (load = 1.5 times)
Structural Behaviour – Reverse Channel

- Diagram showing deflection vs. maximum beam temperature.
- Photograph of a reverse channel structure.
- Graph showing axial reaction force vs. maximum beam temperature.
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Comparison of Structural Behaviour – Beam Deflections

- Catenary action can prolong beam fire resistance
- Reverse channel (tests 4,5,8) gave most stable behaviour in catenary action
Comparison of Structural Behaviour – Beam Axial Forces

- Axially restrained beam temperature at assembly failure >> limiting temperature of axially unrestrained beam (force = 0)

- Stable behaviour of reverse channel (tests 5 & 8) after peak tension in beam
Cooling Behaviour (tests 9 & 10)

- Beam temperature raised to limiting temperature of unrestrained beam
- No joint failure
- Behaviour sensitive to beam temperature when cooling starts
- Little recovery in deflection
Summary - 1

- Joint temperature can be calculated using EC 3 Part 1.2 equation. Equivalent section factor for joint components derived.
- Axially restrained beam able to resist higher temperatures than limiting temperature for axially unrestrained beam.
- Failure in joints/beams when beam in catenary action.
- Catenary action can be prolonged by fire protection/strengthening of joint components.
Summary - 2

- Little catenary action in fin plate joints.
- Bolts critical to end plate joints to CFT columns.
- T-Stub joints behave similar to fin plate joints.
- Reverse channel joints show most promise: high ductility & high resistance to beam catenary action.
Summary - 3

- Cooling behaviour of beam depends on beam temperature when cooling starts.
- It is possible to prevent joint failure by controlling the beam temperature when cooling starts.
- Extensive numerical study is now underway to simulate the fire tests and to develop robust joints, based on using reverse channels.
Acknowledgements

- Summer (Jun) Ding
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- CIDECT