EXPERIMENTS OF END PLATE JOINTS IN AMBIENT AND FIRE CONDITIONS UNDER BIAXIAL BENDING

RESEARCH TEAM: Hilkka Ronni, Henri Perttola, Markku Heinisuo, Keijo Fränti

PRESENTATION: Keijo Fränti

Tampere University of Technology
Research Centre of Metal Structures,
Frami, Kampusranta 9 C, FI-60320 Seinäjoki, Finland
FOUR TEST DESCRIBED …

▪ Two pairs of tests (four tests) on splice joints for (RHS) tubes are described. All the joints were under biaxial bending.

▪ In a pair, two similar joints were tested: one in room temperature and another one at elevated temperature (in furniture under ISO 834 standard fire).

▪ These four tests belong to the larger test series (of 29 tests) through which the applicability of the component method for three dimensional (3D) analysis is studied.

▪ The preliminary results of the ongoing research on the 3D component method are presented in the case of the described tests.
JOINT TESTS: SPECIMEN

TUBE: CFRHS 250x150x10 - S355

END PLATE JOINT (FLANGED SPLICE)
Steel S355

Similar joints in room temperature and in fire tests, dimensions and properties of end plates:

<table>
<thead>
<tr>
<th>Test pairs</th>
<th>$t_{pn}$ (nominal) [mm]</th>
<th>$t_p$ (measured) [mm]</th>
<th>$R_{eh}$ [MN/m²]</th>
<th>$R_m$ [MN/m²]</th>
<th>A5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE1 and TE1*</td>
<td>10</td>
<td>11.0</td>
<td>429</td>
<td>582</td>
<td>24</td>
</tr>
<tr>
<td>TE3 and TE3*</td>
<td>20</td>
<td>20.3</td>
<td>380</td>
<td>564</td>
<td>26</td>
</tr>
</tbody>
</table>

* = SPECIMEN IN FIRE TEST

METNET, Aarhus 2011
TESTING ARRANGEMENTS ($T=20\, ^\circ\text{C}$), BIAXIAL BENDING:

TRANSVERSE MOVEMENT IS ALLOWED AT MID SPAN!
TEST RESULTS ($T = 20 \, ^\circ C$), BIAXIAL BENDING:

- PROCEDURE: LOAD IS INCREASED (IN RATE 0.1kN/s) UP TO FAILURE
- MAIN INTEREST IS IN THE ROTATIONAL BEHAVIOUR OF THE JOINT

\[ M_R = \frac{PL}{4} \]

\[ \theta = \frac{2(v - v_{b,el})}{L} \]

DIMENSIONS OF THE SPECIMEN (=TUBES AND THEIR SPLICE) ARE SELECTED IN SUCH A WAY THAT THE DEFORMATIONS WERE CONCENTRATED ON THE JOINT!
FAILURE MODES, $T = 20\, ^\circ\mathrm{C}$

**TE1: THIN ENDPLATE** ($t = 11.0\, \text{mm}$):

VISBLE NECKING IN THE LOWEST BOLT!

**TE3: THICK ENDPLATE** ($t = 20.3\, \text{mm}$):

LOWEST BOLT

EC3: MODE I (COMPLETE YIELDING OF THE FLANGE) **OK!!**

EC3: MODE II (BOLT FAILURE WITH YIELDING OF THE FLANGE) **OK!!**
TESTING ARRANGEMENT, FIRE TESTS:

NOTE: Tests in room temperature and in fire were both three point (biaxial) bending tests!
**TEST TE1:** STANDARD FIRE IN FURNACE ➔ TEMPERATURES OF FLANGES AND BOLTS

**TE1**: SUSTAINED LOAD LEVEL $M = 0.16*M_u$, $T = 20°C$ ➔ FAILURE WHEN $T = T_{cr} = 800°C$

13 min:  
20 min:  
26 min:  

TEST IS OVER (few minutes after failure)
FIRE TEST TE3*

SUSTAINED LOAD LEVEL: $M = 0.16^*M_u, T=20^\circ C$

$T_{kr} = 655^\circ C$
FAILURE MODES IN FIRE TESTS

TE1: THIN ENDPLATE \( (t = 11 \text{ mm}) \)

\[ M = 0.23^* M_u, \ T=20^\circ \text{C} \]
\[ T_{cr, \text{average}} = 800 \ ^\circ \text{C} \]

FAILURE MODE: EXCESSIVE DEFORMATIONS
= FLANGE YIELDING + BOLT EXTENSION

TE3: THICK ENDPLATE \( (t = 20.3 \text{ mm}) \)

\[ M = 0.16^* M_u, \ T=20^\circ \text{C} \]
\[ T_{cr, \text{average}} = 655 \ ^\circ \text{C} \]

FAILURE MODE: FAILURE OF THREADS IN THE LOWEST BOLT OF THE JOINT

(completely different failure mode than in test TE3 arranged in room temperature)
COMPONENT METHOD, FIRE TESTS (SIMPLIFIED RESULTS)

Moment resistance versus temperature, TE1*

ON SAFE SIDE AT LOW TEMPERATURES
(reductions according to carbon steel)

NOTE1: Different failure modes for the joint in ambient and fire conditions.

NOTE2: In fire, the behaviour of the bolt is in the decisive role!

ON SAFE SIDE AT HIGH TEMPERATURES
(redaction according to bolts)!

ON SAFE SIDE BOTH AT ROOM TEMPERATURES AND IN FIRE

NOTE: Excessive deformation of the end plate in the decisive role in both cases!
SUMMARY

1) No tests on the bolted end plate steel joints in biaxial bending were found in literature … the tests described were ”pilot tests” in their character!

   NOTE1: Some weak axis bending tests has been arranged in ambient conditions

   NOTE2: In general, there is lack of joint tests in fire (quite new research area!)

2) Observations based on four tests were described:
   ▪ The failure modes of two similar joints may be different in room temperaturture and in fire!

3) Remarks concerning the ongoing research on 3D component method:
   ▪ The preliminary results on the applicability of the 3D component method are quite encouraging for the joints under biaxial bending in ambient conditions.
   ▪ ”Joints in fire” is more challenging case than ”joints in room temperature”!

MORE 3D JOINT TESTS ARE NEEDED IN FUTURE!
THAT’S IT, THANK YOU!

SPECIMEN UPSIDE DOWN ON LABORATORY FLOOR AFTER ROOM TEMPERATURE TEST TE3, $P_{\text{max}} \sim 400 \text{ kN}$ ($M_{\text{max}} \sim 100\text{kN}$)

FEM SIMULATION BY ABAQUS: