INTERACTION PHENOMENA OF COLD-FORMED TRUSS MEMBERS AND JOINTS

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Fifth International Conference on Coupled Instabilities in Metal Structures
Sydney, Australia, 23-25 June, 2008

BACKGROUND

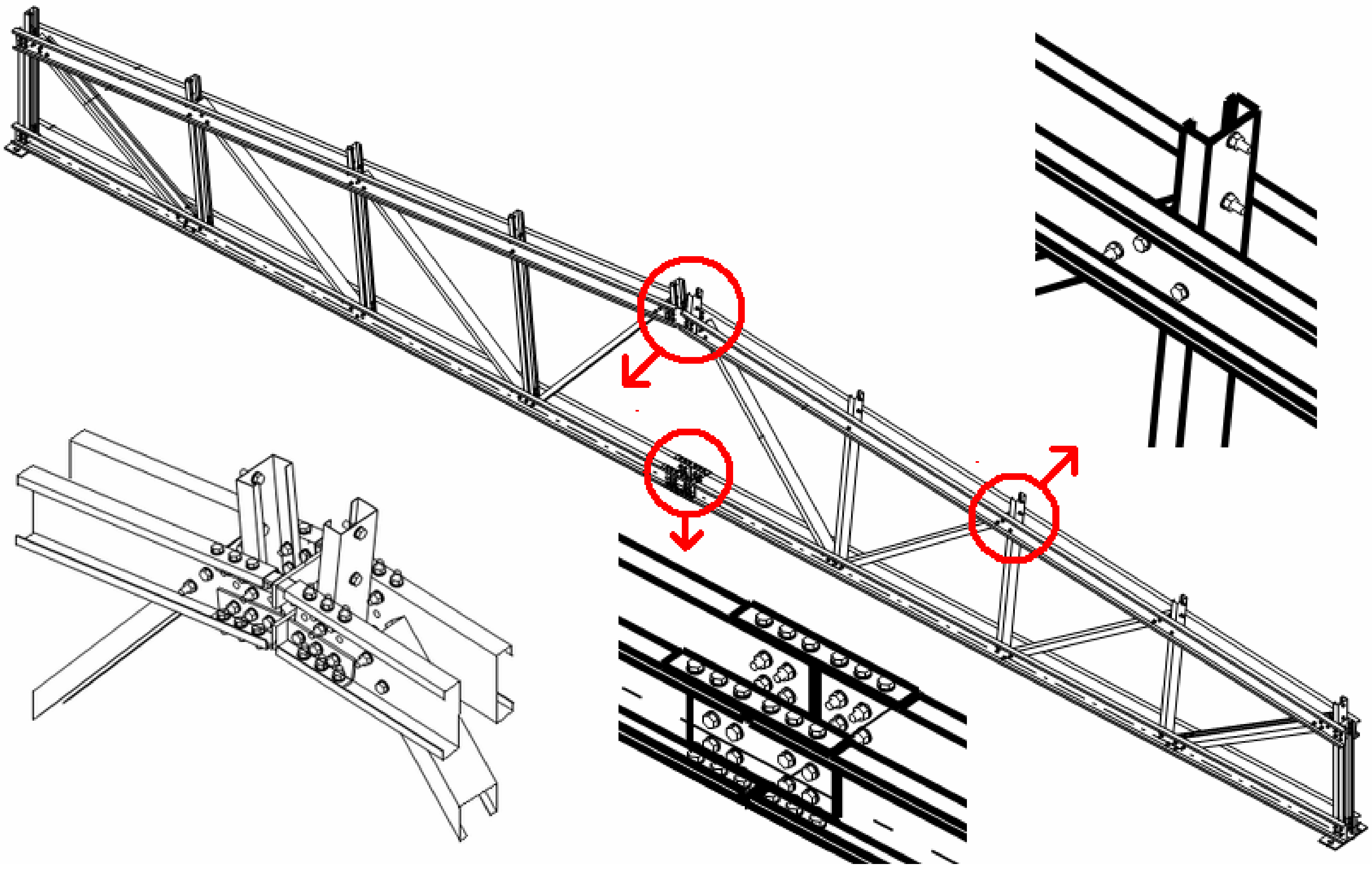
- R&D project with industrial background
- Aim:
  - Development of a truss system and design method
  - Verification of the design method
- Main characteristics of the system:
  - Using only cold-formed C-sections
  - Flexible system allowing free design
  - Out-of-box solutions

BACKGROUND

STRUCTURAL ARRANGEMENT

- Span: 12…24 meter
- Structural elements
  - Chord: two C-sections in back-to-back arrangement
  - Bracing: single C-sections, doubled at the supports
- Structural joints
  - Eccentric bolted connections

STRUCTURAL ARRANGEMENT

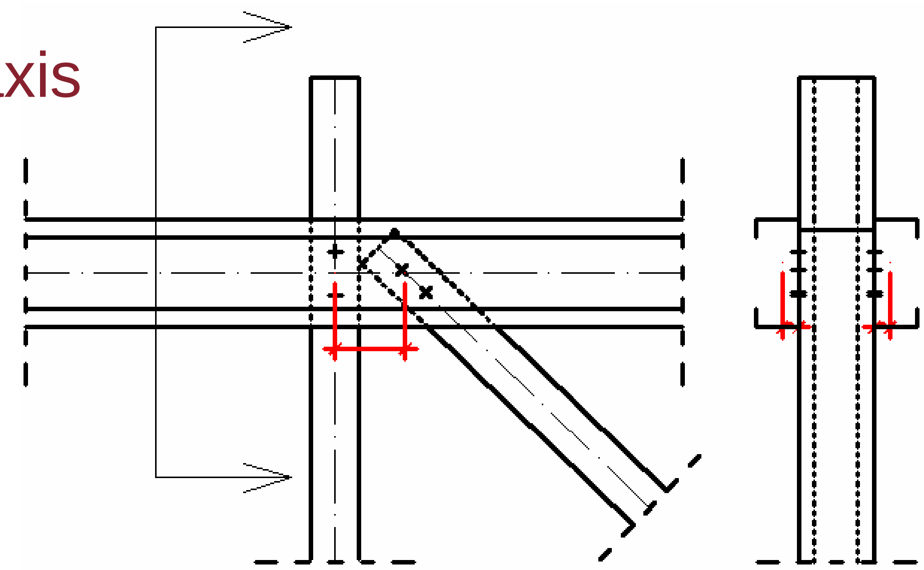


INTERNAL ACTIONS

BRACE MEMBERS

Axial force and bending

- In-plane bending: weak axis



CHORD MEMBERS

Axial force and bending about both axes

- In-plane bending: strong axis
- Out-of-plane bending: weak axis

PROBLEM STATEMENT

CHORDS
+
BRACING } JOINT

✓

Stability issues
– EC-based design

Similar problems solved

?

Eccentricity
– in-plane, out-of-plane

Load-bearing capacity, local stability behaviour

Rigidity, interaction with members

LABORATORY TESTING - SETUP

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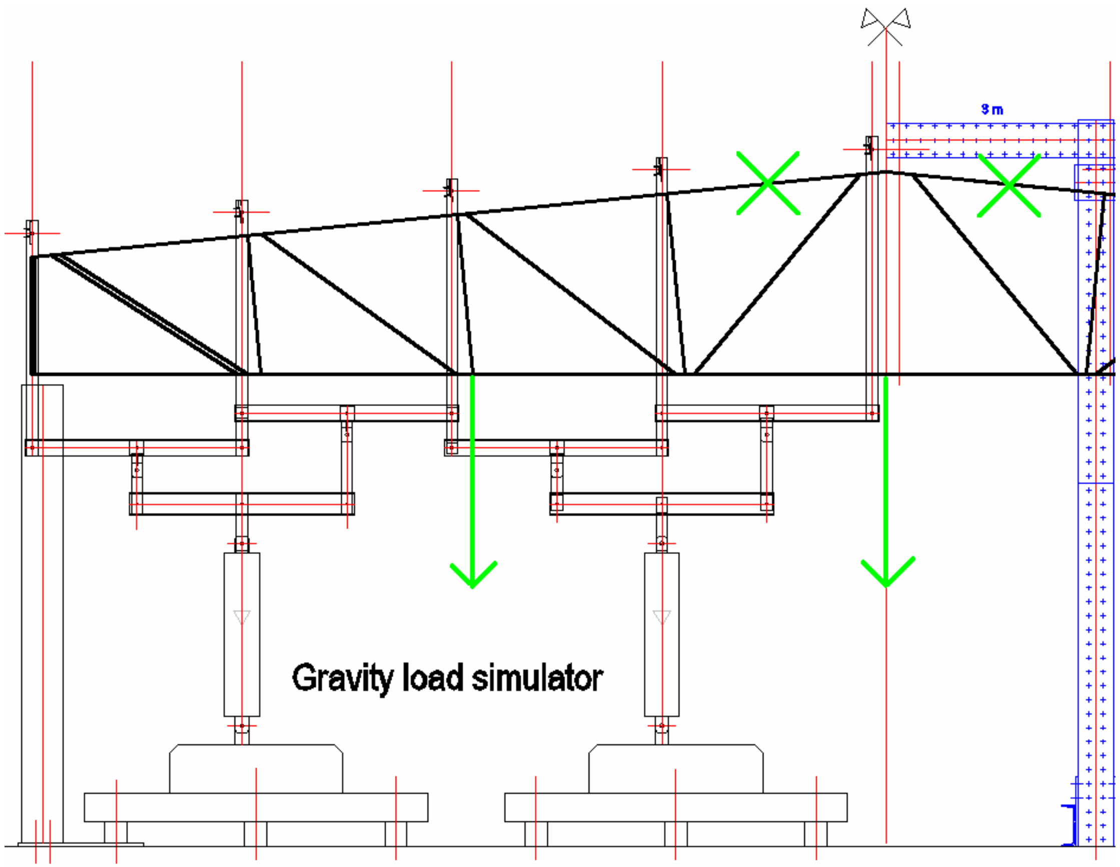
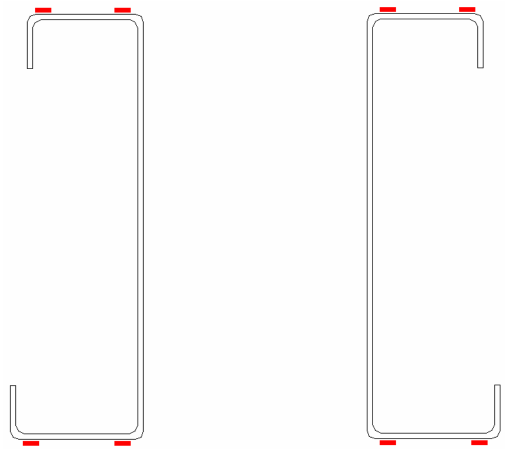


MEASUREMENT

- Load via oil pressure
- Strains – strain gage
- Displacements



LABORATORY TESTING – TEST 1

Test 1, final failure

failure in the upper chord; interaction of bending and flexural buckling (weak axis)

Load: 28.5 kN/jack

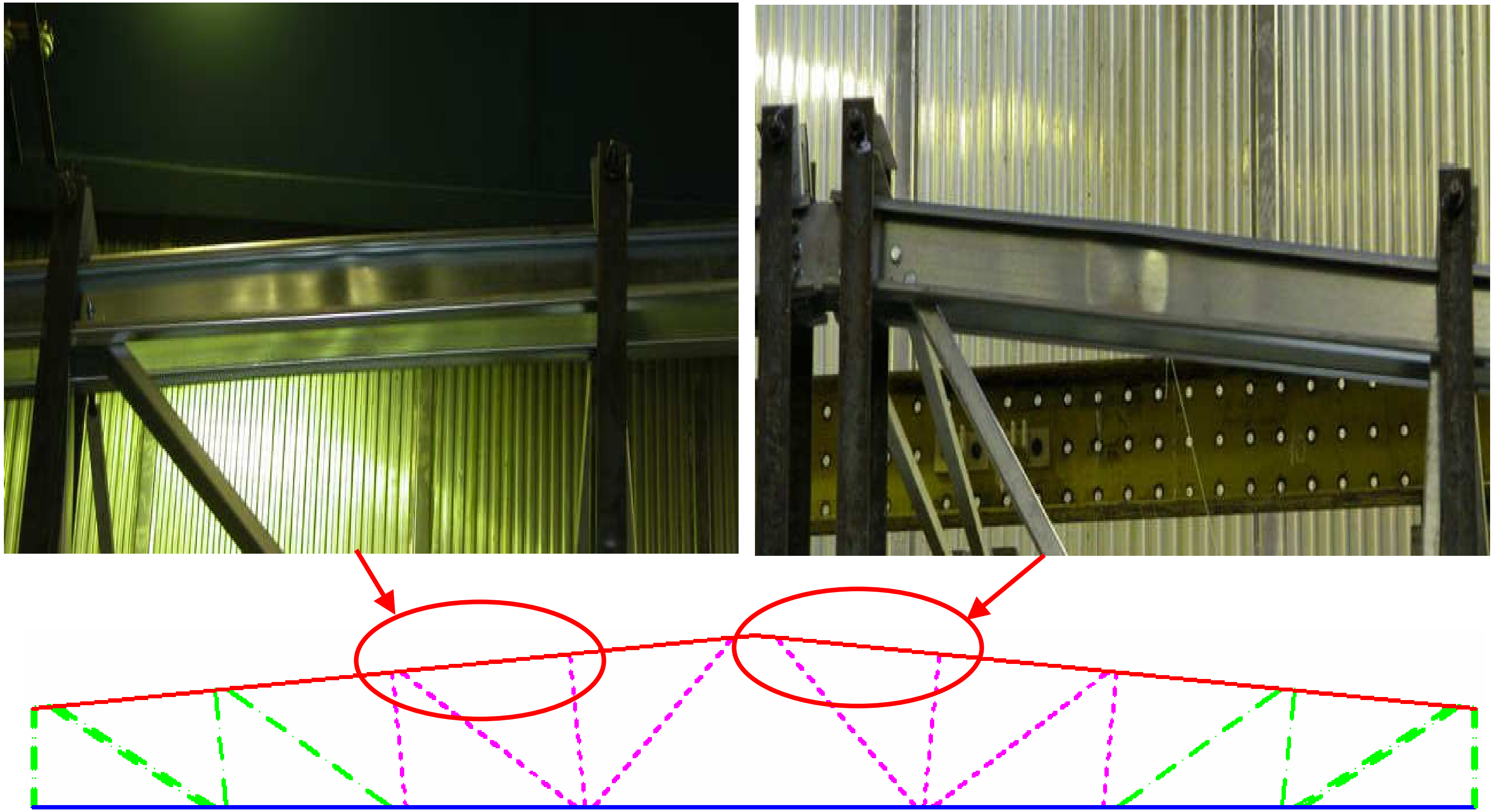
LABORATORY TESTING – TEST 5

Test 5, final failure

Failure of the compression chord; interaction of bending and flexural buckling

Load: 47.4 kN/jack

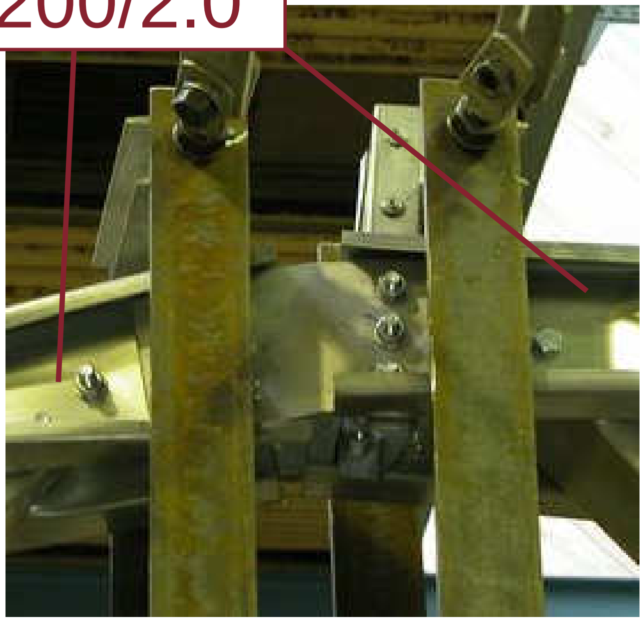
INTERACTIONS – UPPER CHORD



INTERACTIONS – UPPER CHORD

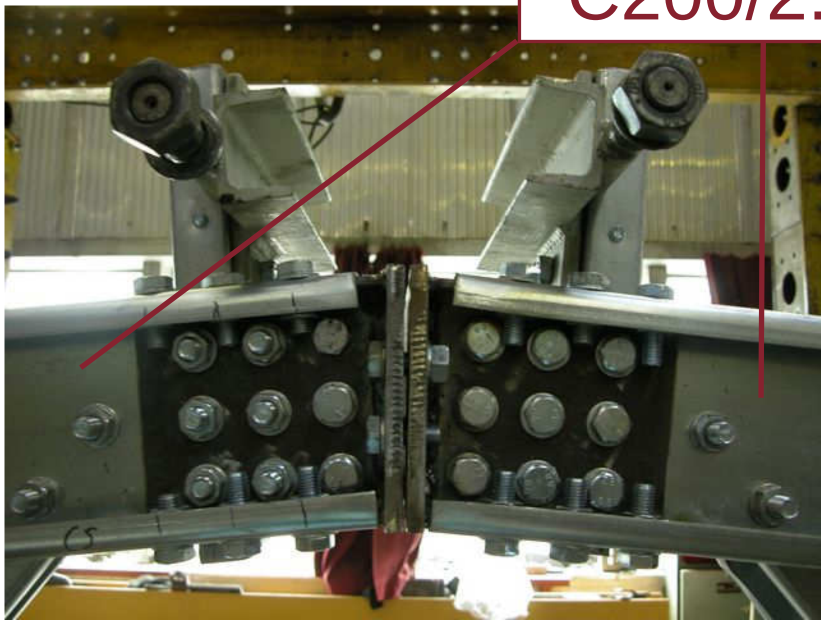
Interaction of bending and flexural buckling vs. joint type

C200/2.0



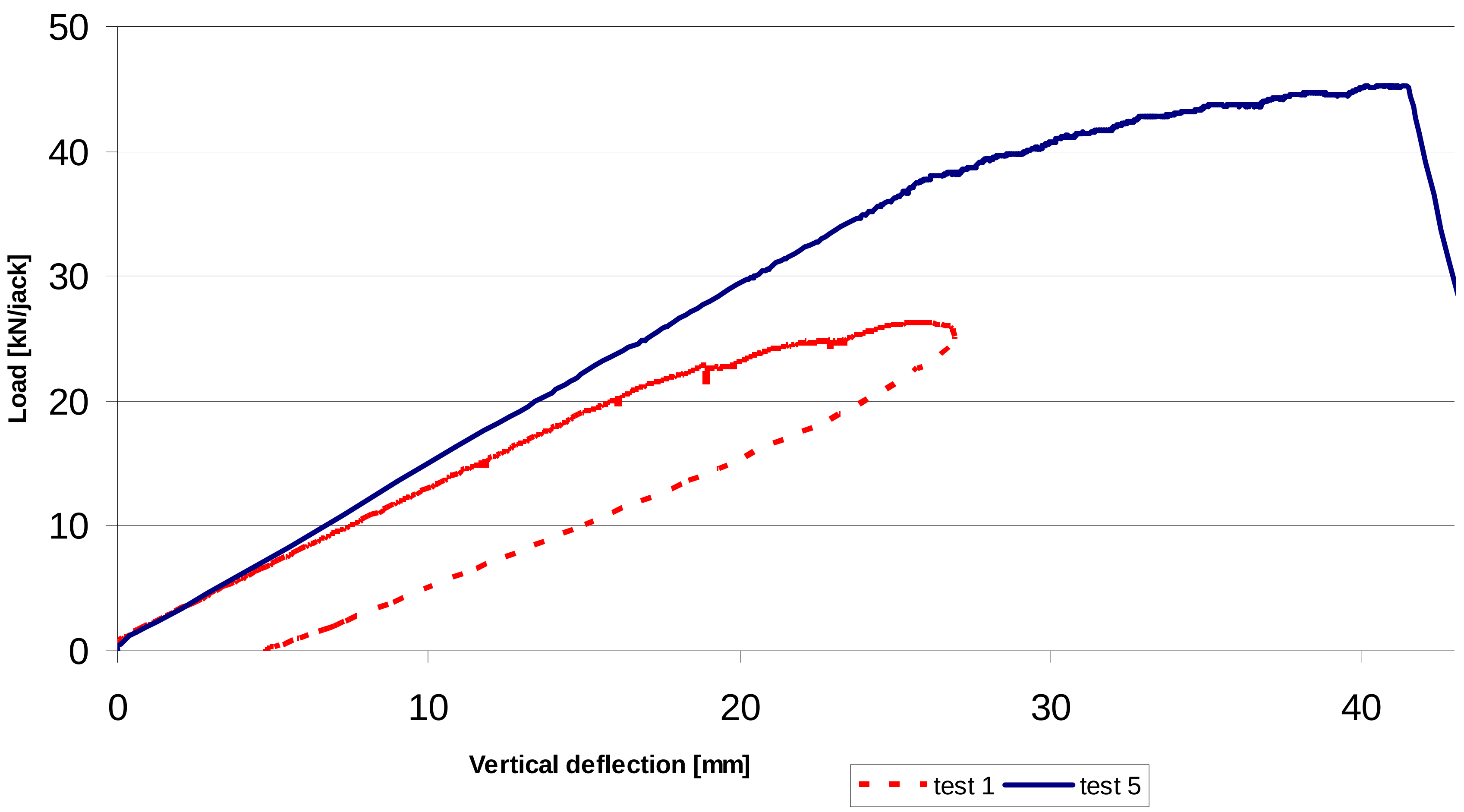
Test 1

C200/2.5

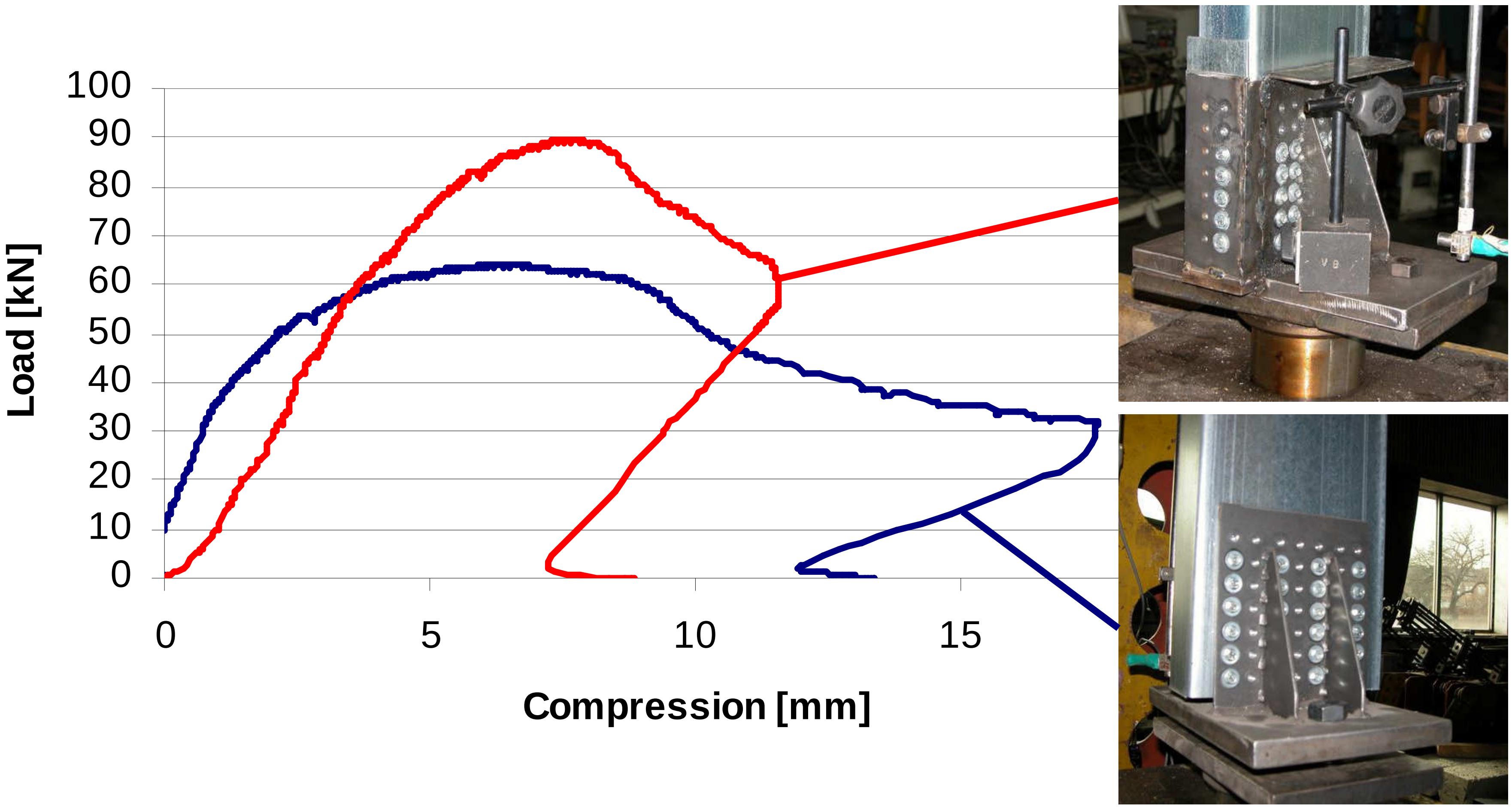


Test 5

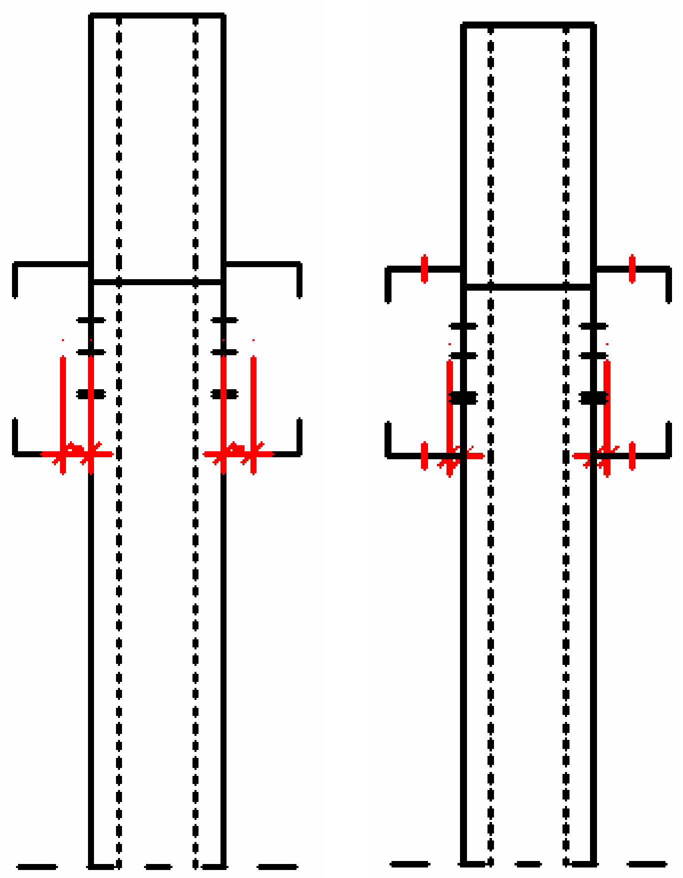
INTERACTIONS – UPPER CHORD



EFFECT OF LOAD INTRODUCTON



INTERACTIONS – UPPER CHORD



Nominal value of in-plane eccentricity: distance of centroid to the web

Based on strain measurement and measured load-bearing capacity, if both web and flanges are connected in the peak joint the nominal value may be reduced by 50%.

UPPER CHORD – DESIGN METHOD

$$\frac{N_{Ed}}{\chi_z \cdot A_{eff} \cdot f_{yb}/\gamma_{M1}} + \frac{\kappa_y \cdot M_{y,Ed}}{W_{eff,y} \cdot f_{yb}/\gamma_{M1}} + \frac{\kappa_z \cdot N_{Ed} \cdot e_{N,y}}{W_{eff,z} \cdot f_{yb}/\gamma_{M1}} \leq 1$$

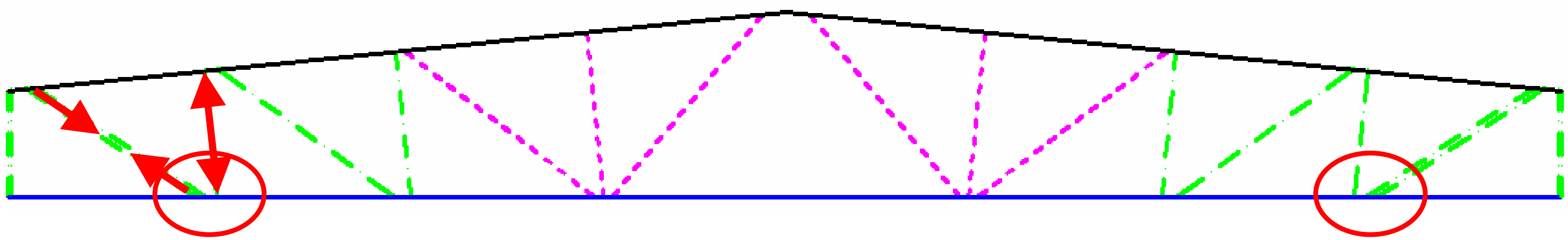
45.8% + 7.8% + 46.4% = 100%

$$\frac{N_{Ed}}{\chi_z \cdot A_{eff} \cdot f_{yb}/\gamma_{M1}} + \frac{\kappa_y \cdot M_{y,Ed}}{W_{eff,y} \cdot f_{yb}/\gamma_{M1}} + \frac{\kappa_z \cdot N_{Ed} \cdot 0.5 \cdot e_{N,y}}{W_{eff,z} \cdot f_{yb}/\gamma_{M1}} \leq 1$$

45.8% + 7.8% + 23.2% = 76.8%

INTERACTIONS – LOWER CHORD

Test 5: Interaction of axial tension and shear

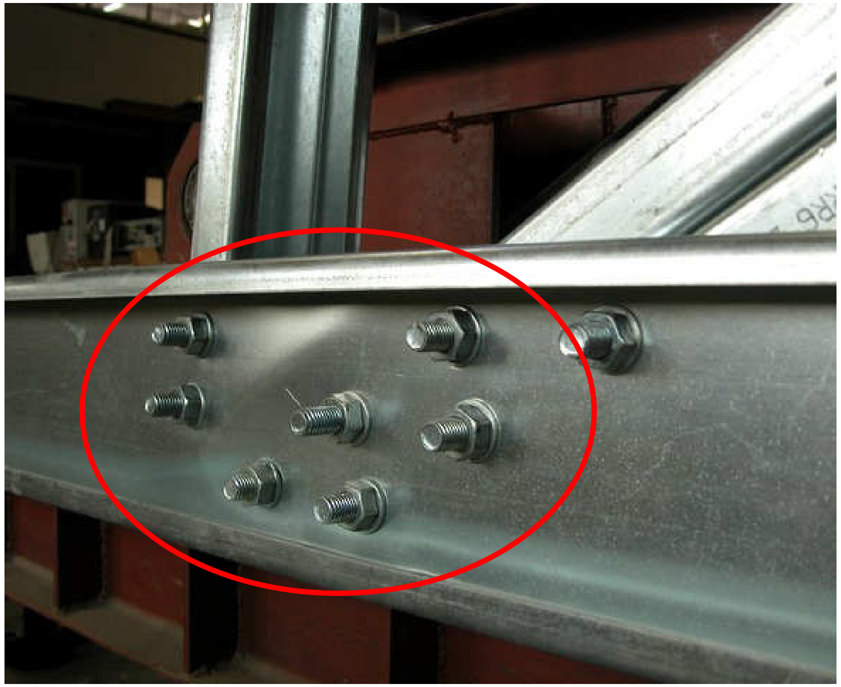


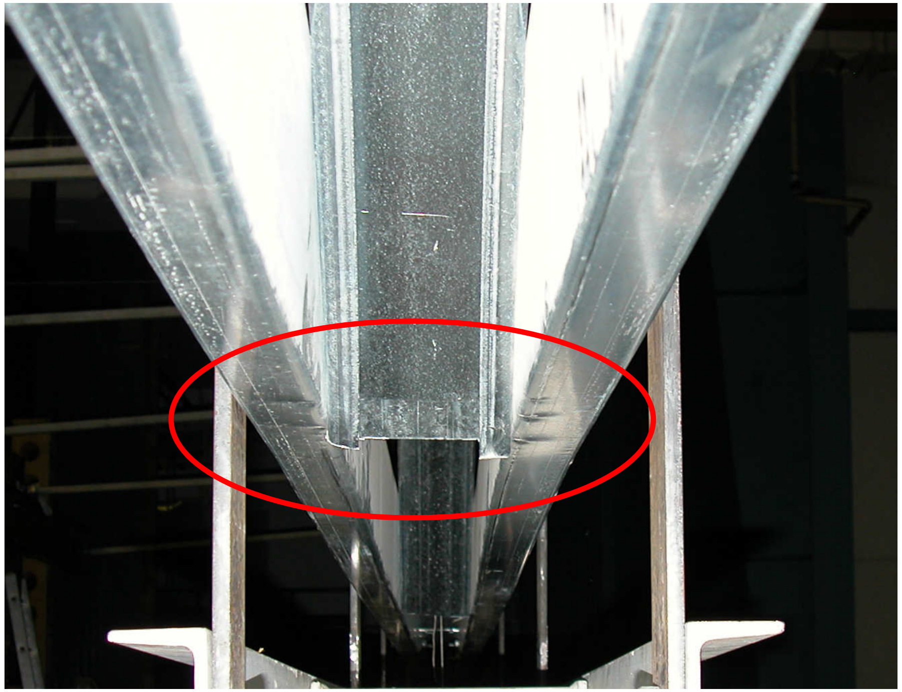
Most utilized brace members

Double C-section tension brace member

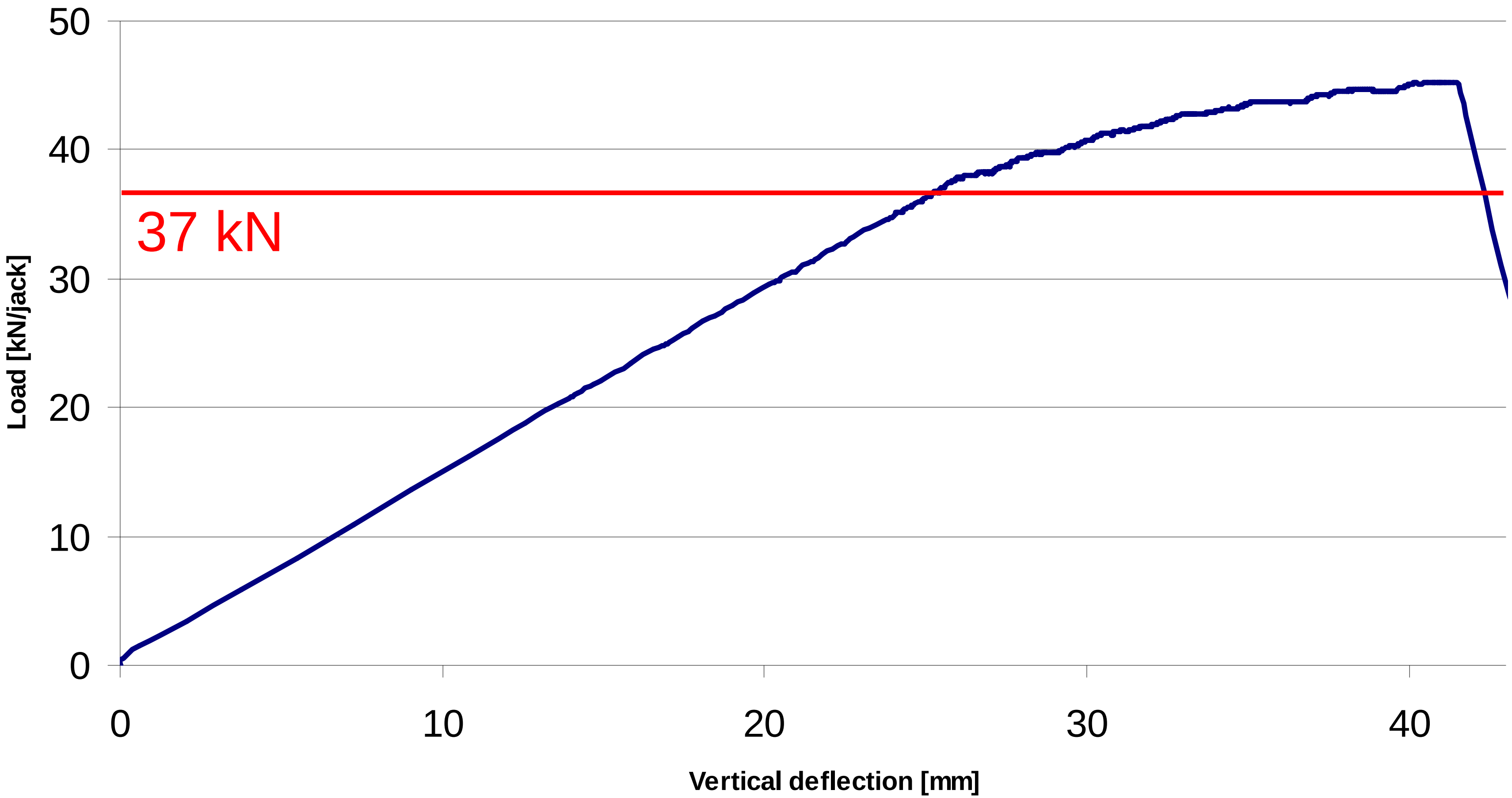
Not final failure

LABORATORY TESTING – TEST 5

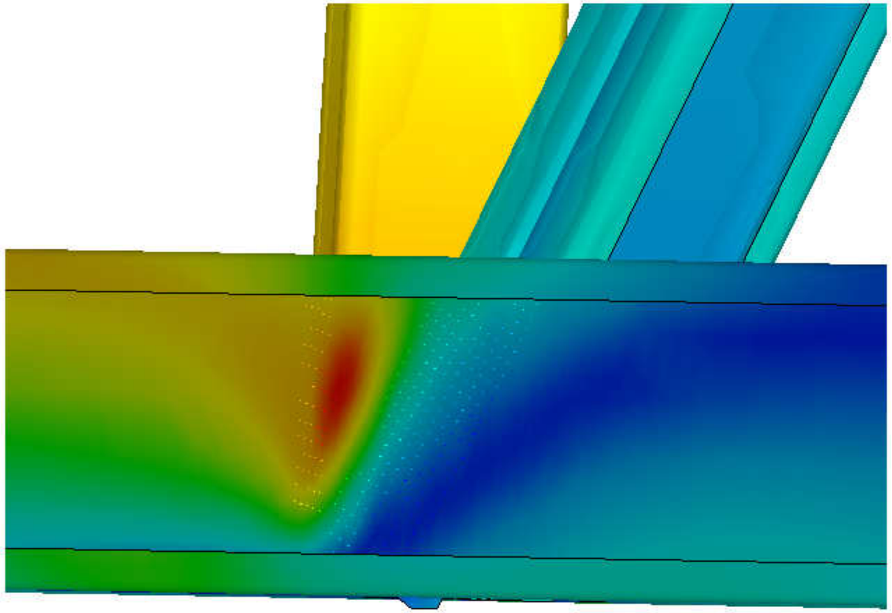




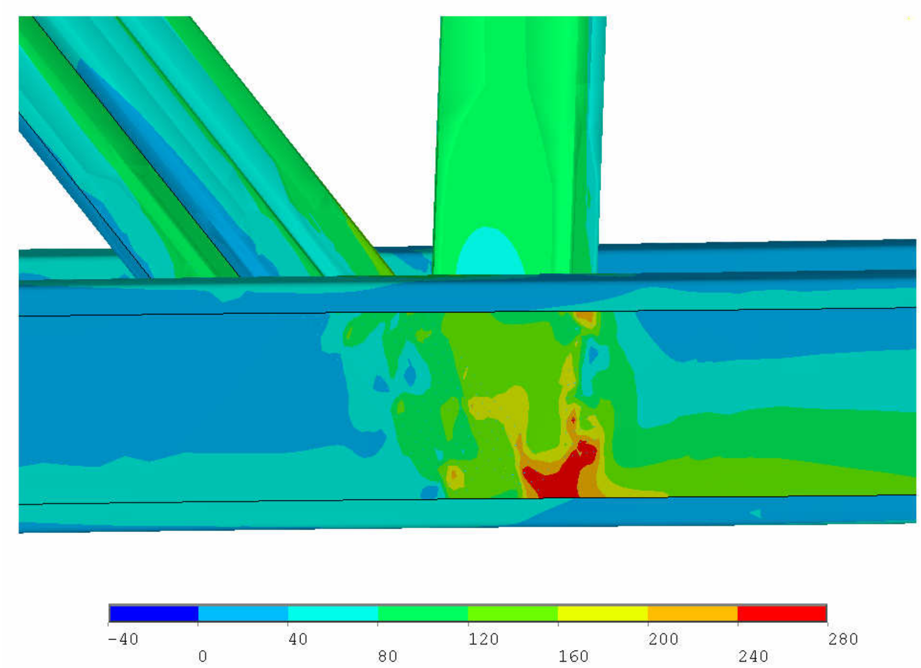
LABORATORY TESTING – TEST 5



FINITE ELEMENT MODELLING – TEST 5



Eigenshape from bifurcation analysis



Von Mises stress distribution from linear static analysis

DESIGN METHOD

Design resistance of a tension chord joint

$$N_{0,Rd} = \left[\left(A_0 - A_v\right) \cdot f_{y0} + A_v \cdot f_{y0} \cdot \sqrt{1 - \left(V_{Ed} / V_{b,Rd}\right)^2} \right] / \gamma_{M5}$$

$$V_{b,Rd} = \frac{\chi_w \cdot f_{y0} \cdot A_v}{\sqrt{3} \cdot \gamma_{M5}}$$

Design resistance of a compression chord joint

$$N_{0,Rd} = \left[\left(A_{0,eff} - A_{v,eff}\right) \cdot f_{y0} + A_{v,eff} \cdot f_{y0} \cdot \sqrt{1 - \left(V_{Ed} / V_{b,Rd}\right)^2} \right] / \gamma_{M5}$$

$$V_{b,Rd} = \frac{\chi_w \cdot f_{y0} \cdot A_{v,eff}}{\sqrt{3} \cdot \gamma_{M5}}$$

SUMMARY

- A new truss system is outlined
- Laboratory tests carried out
- Stability phenomena, failure modes introduced
  - Effect of detailing
- EC3-based design formulae developed based on observed failure modes

- It is shown, that the use of laboratory tests is inevitable for the non-conservative design of unconventional structural arrangements

Thank you for your attention!