Stability behaviour of non-conventional cold-formed steel structures

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„Non-conventional”

Cold-formed sections fabrication; new generation of products

↓

Novel structural functions in buildings

↓

New structural arrangements

↕

Design rules ?

↓

Experimental research and development

↓

DESIGN

Non-conventional arrangements

Section types combined sections

Eccentricities eccentric section arrangements in joints
eccentric load introduction on section elements

Connections connectors, contacts

Lateral supports discrete position; partial rigidity

Interaction

section ⟷ section

connection ⟷ structural element

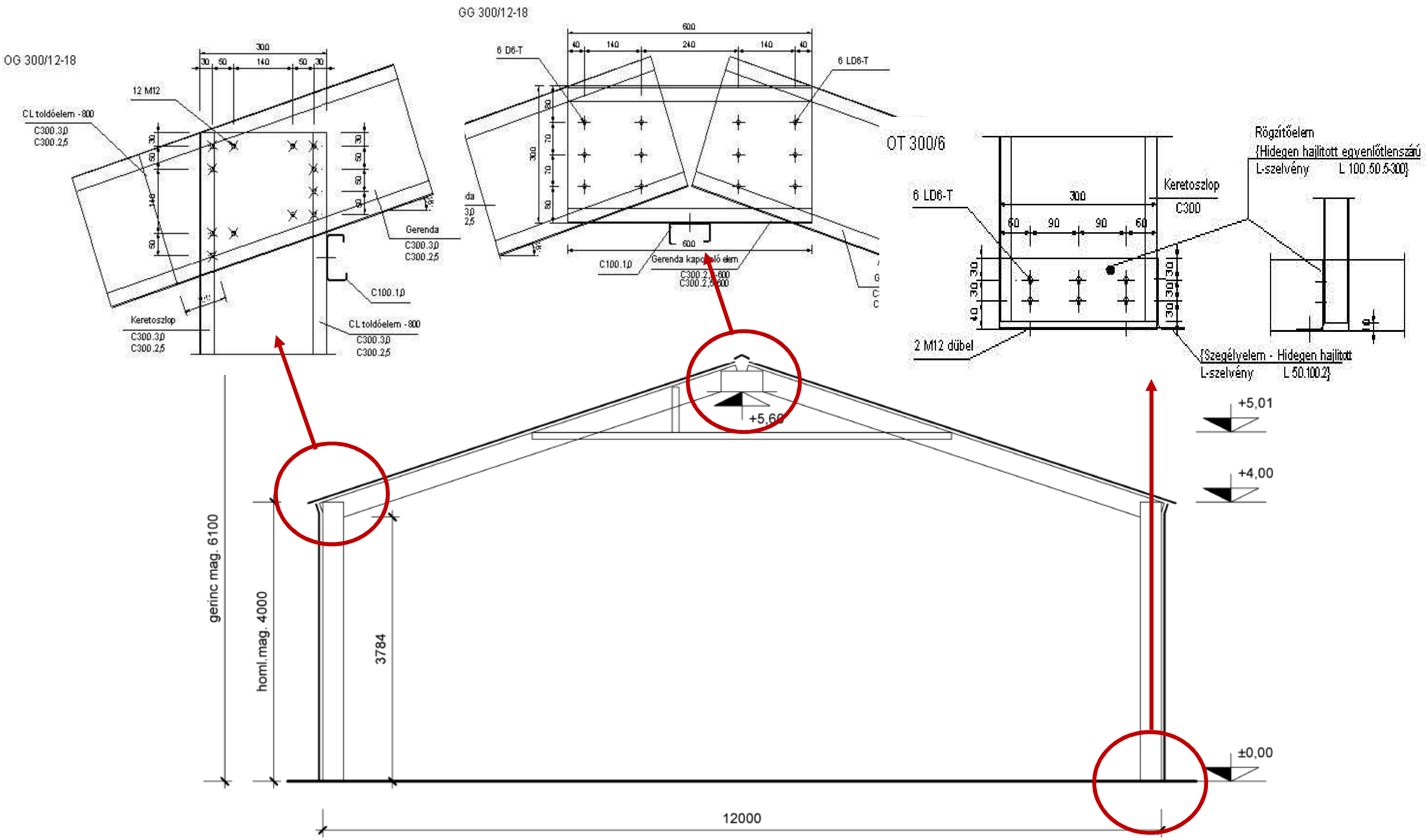
⟷

structural element joint

↓

Stability behaviour ?

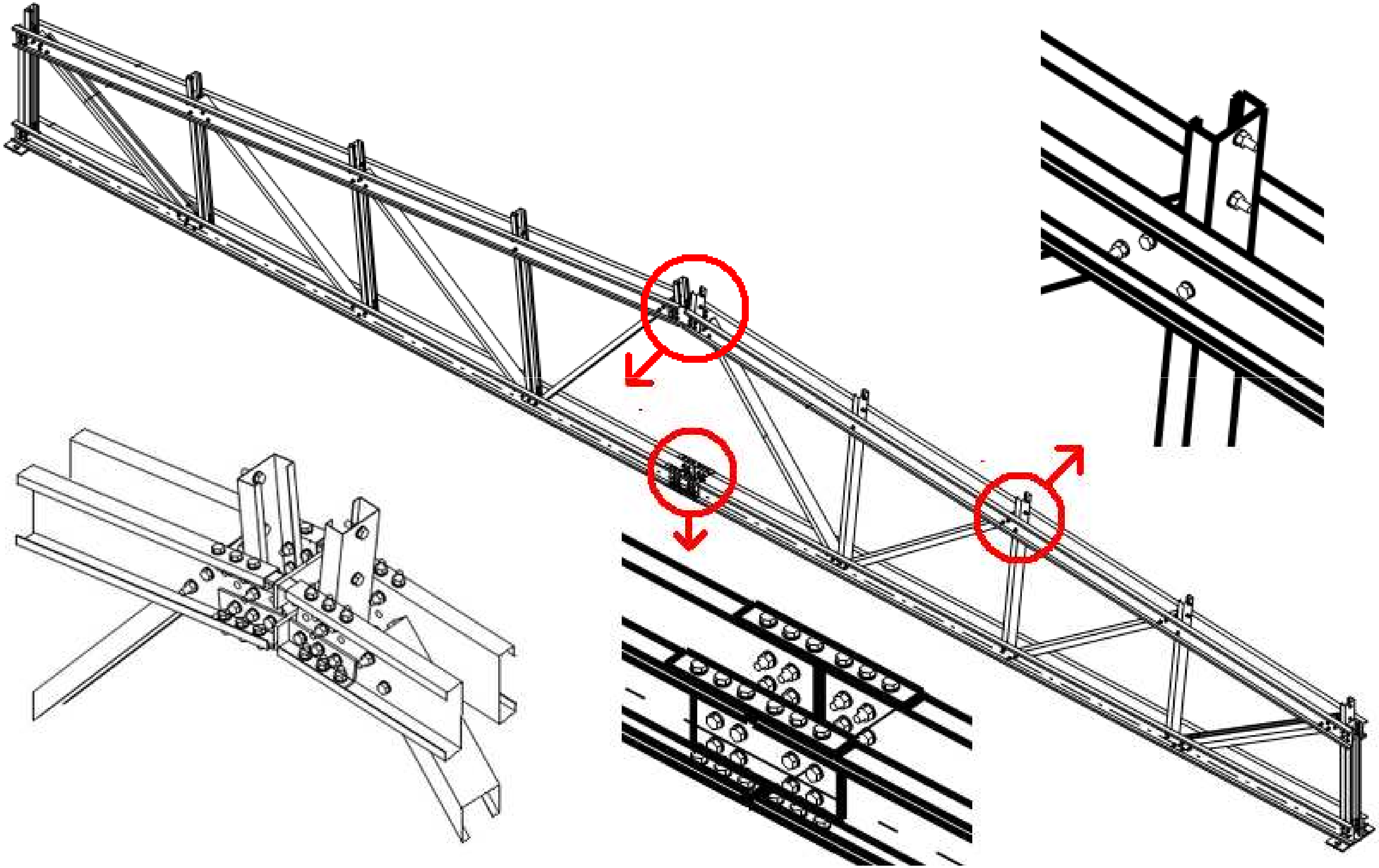
Frame


OG 300/12-18
GG 300/12-18
OT 300/6
Keretoszlop
Gerenda
C100.1,0
CL toldóelem -800
6 LD6-T
Rögzítőelem
2 M12 dübel
+5,01
+4,00
±0,00
+5,60
gerinc mag. 6100
homl.mag. 4000
3784
12000

Frame – application

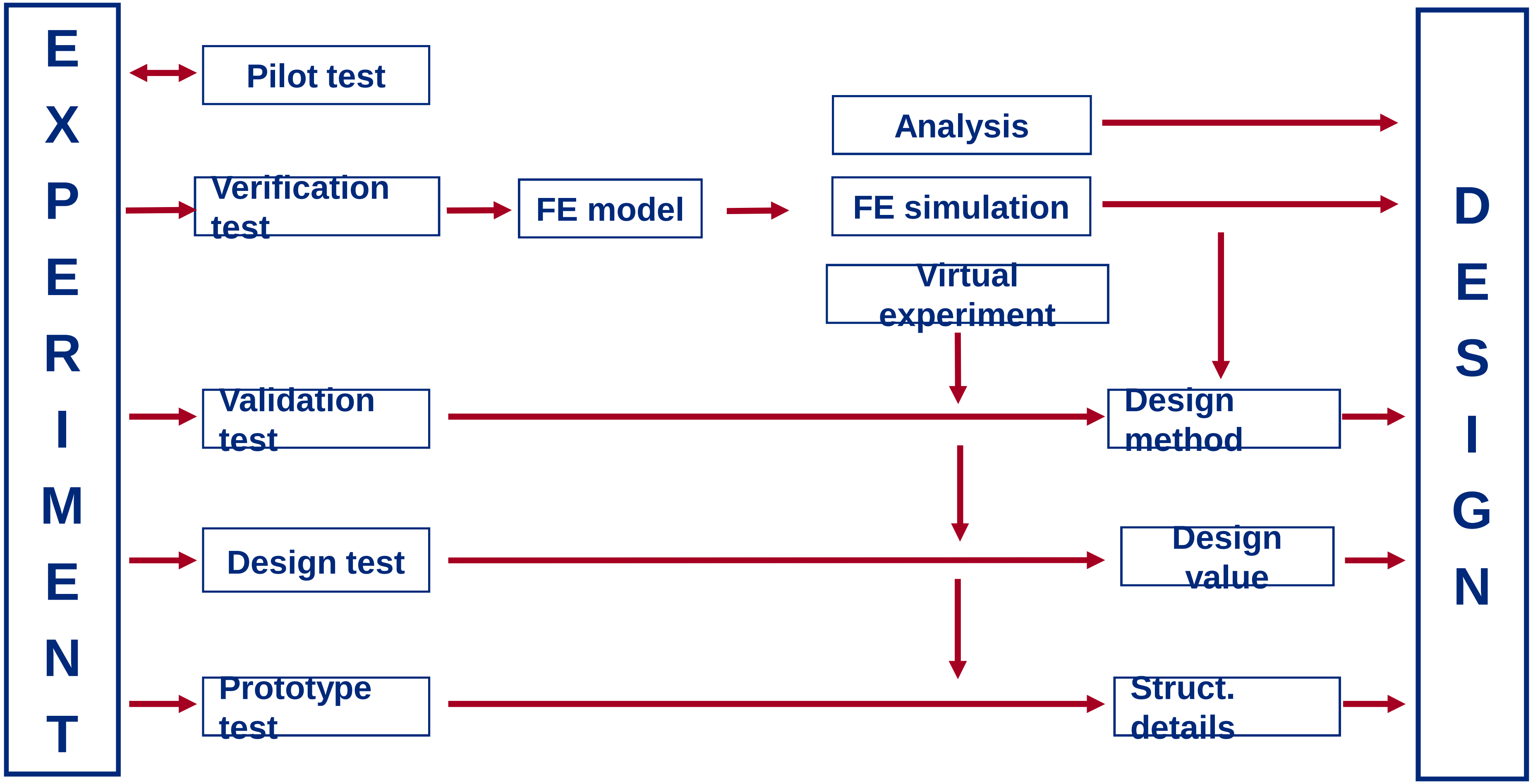



Truss



Truss – application

Research methodology



Research strategy

Structural element and connection

Structural joint

Global structure

Research strategy

Structural element and connection **C-section, screw connection**

Structural joint

Global structure **truss**

C-section structural elements

Fundamental research on element behaviour

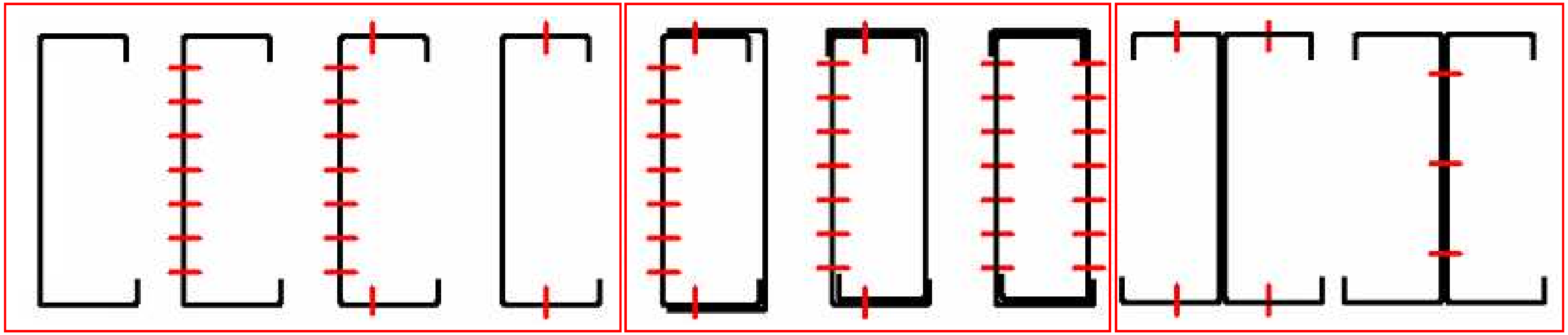
Subject of the research

- centric/eccentric compression
- combined built-up sections
- load introduction
- lateral restraints

Aims

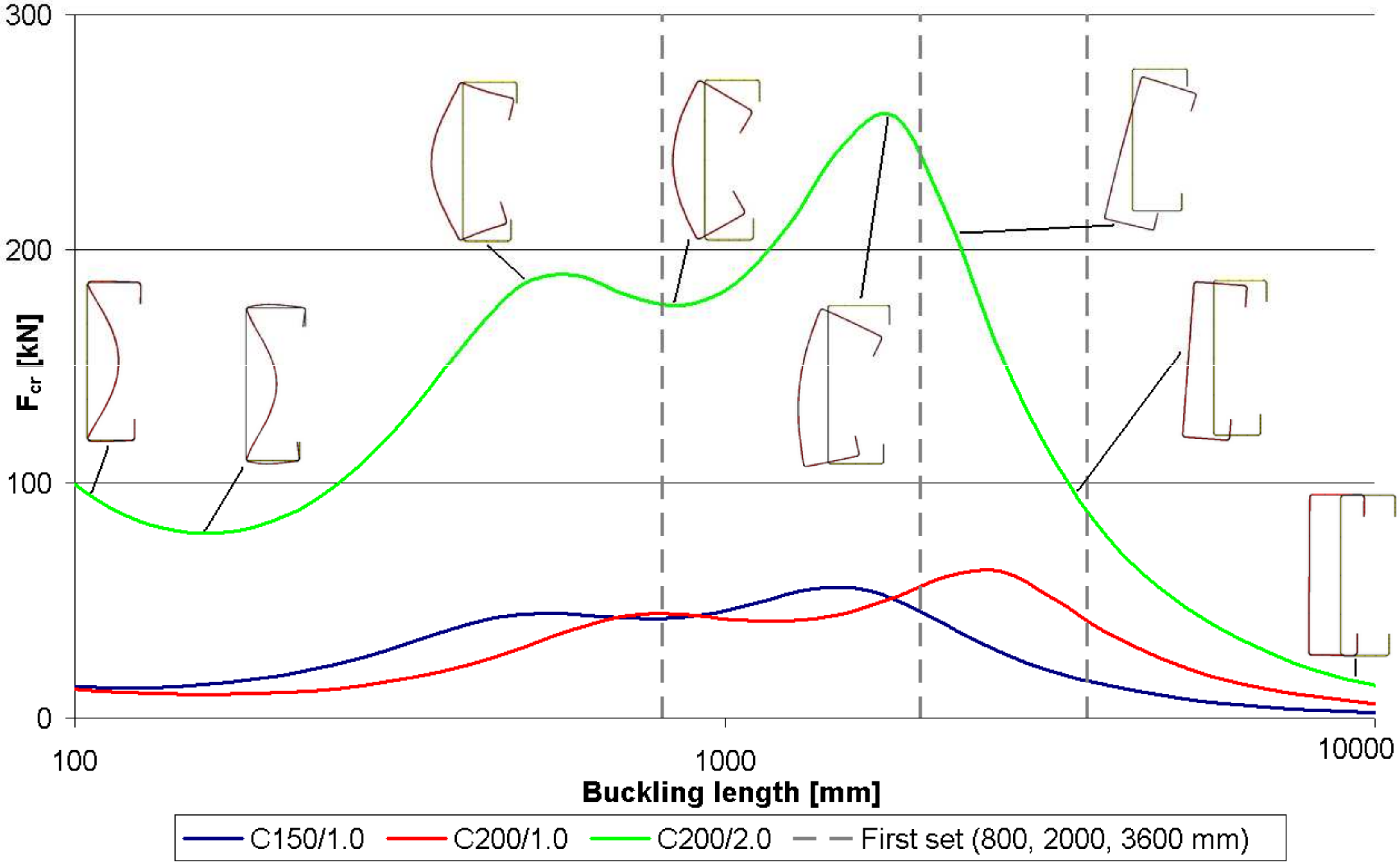
- stability behaviour
- failure mode identification
- FE model development, verification, application
- design method development, validation

Experimental program

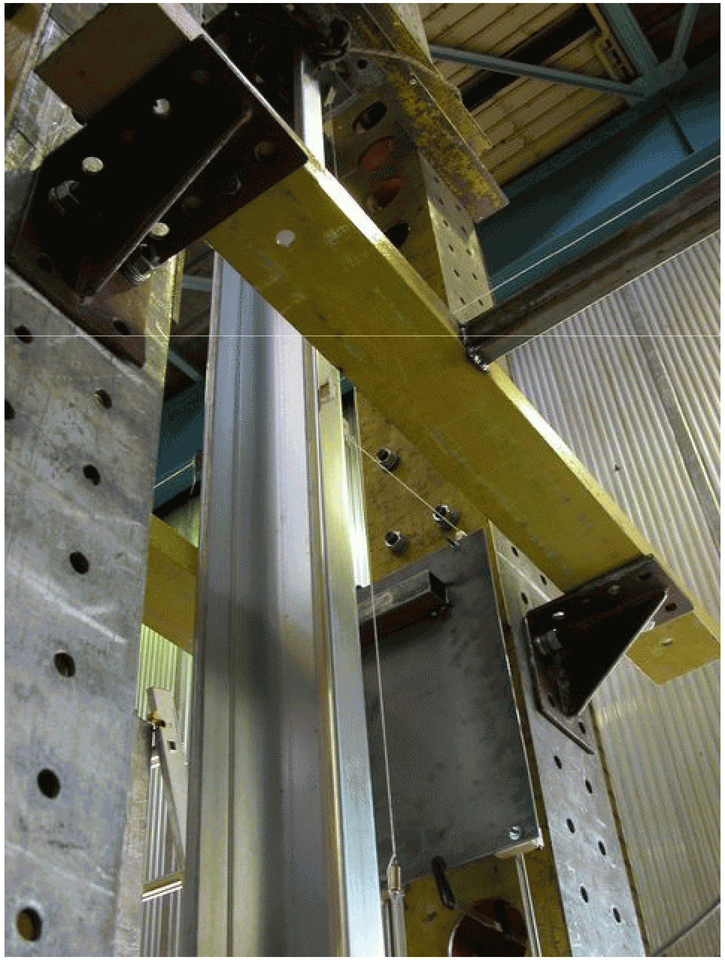


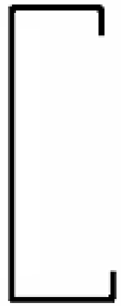
- **10 different section and end connection arrangements**
- **98 tests**
- **C150/1.0 – C200/2.5**
  - web b/t: 80-200
- **Specimen lengths**
  - 800, 1500, 2000, 2500, 3600 mm

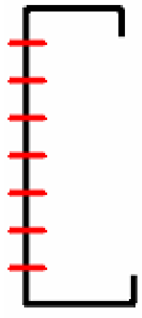
Test preliminary design

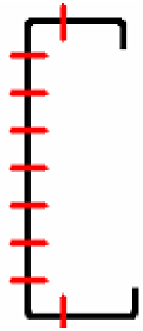


Single C-section elements









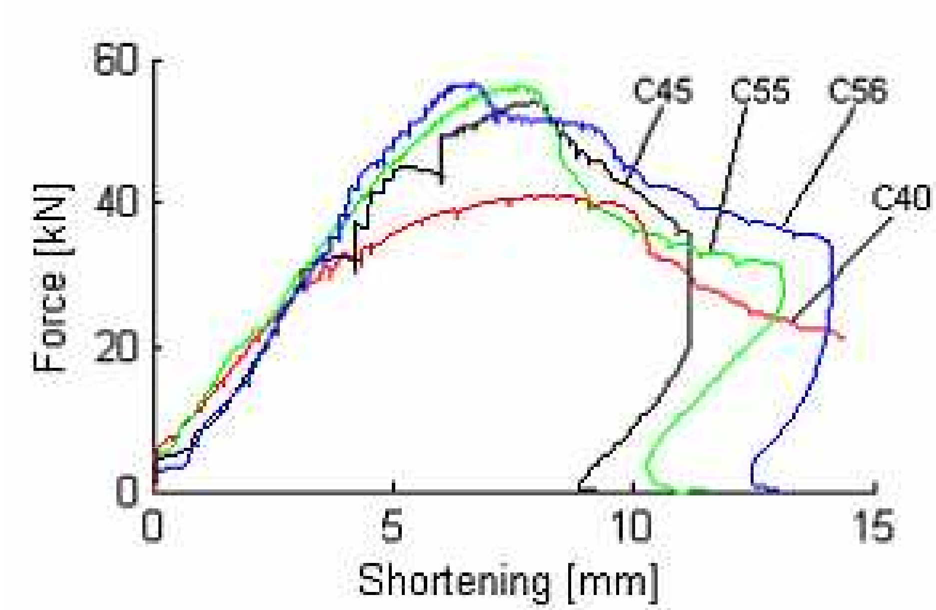
Element end failure

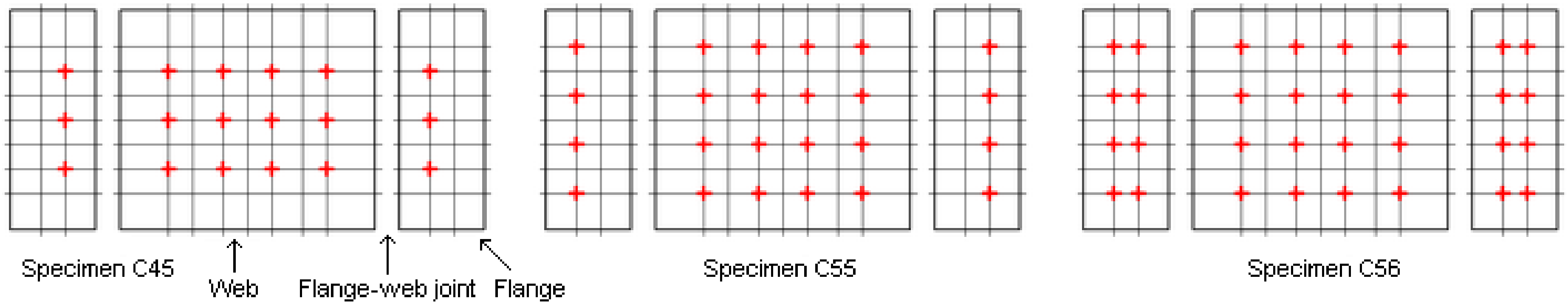
Short screw layout on web

Stub column – web connection

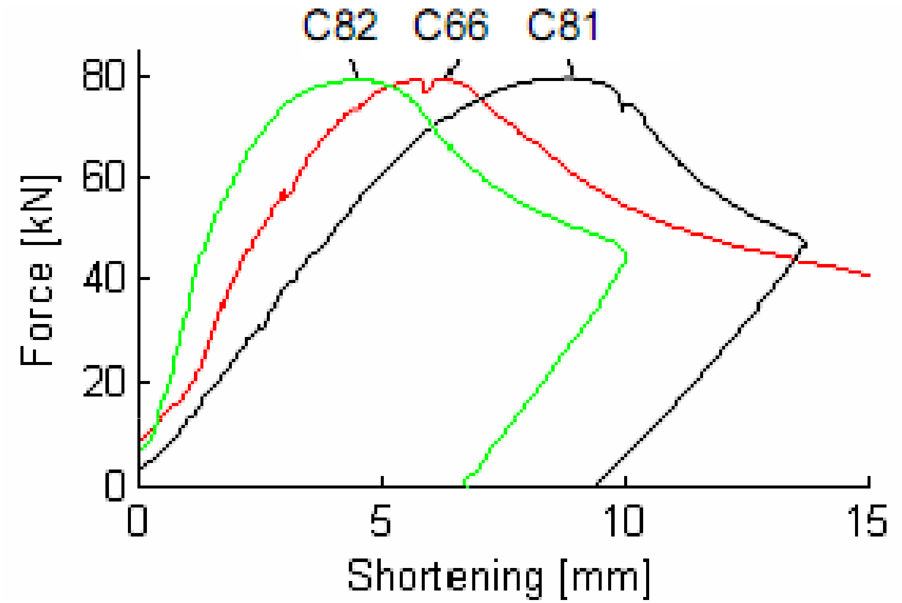
Load introduction at the whole section end

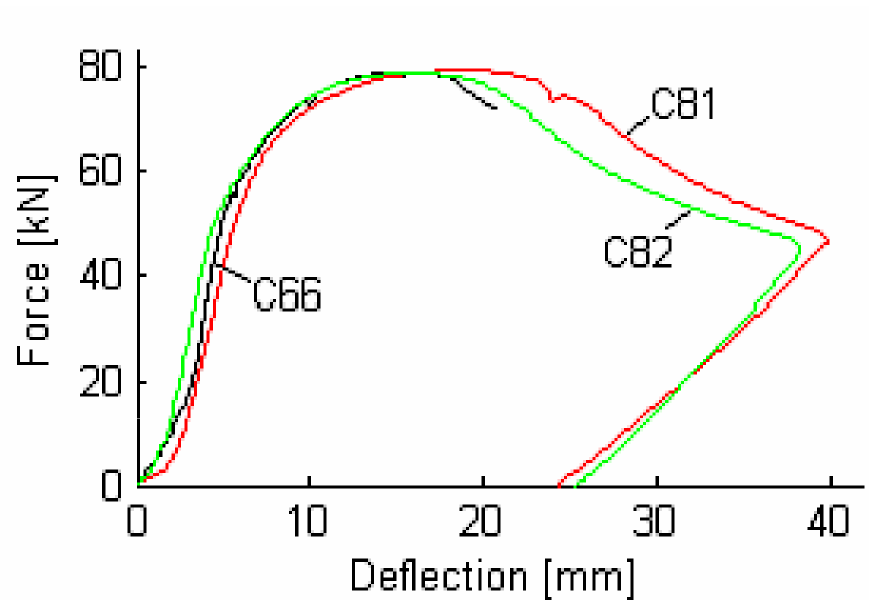
Screw arrangement – web/flange

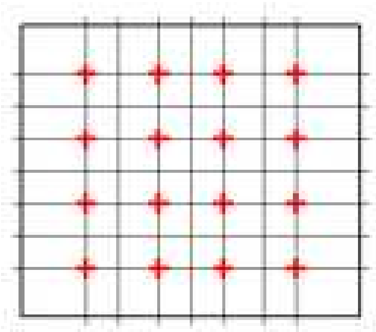




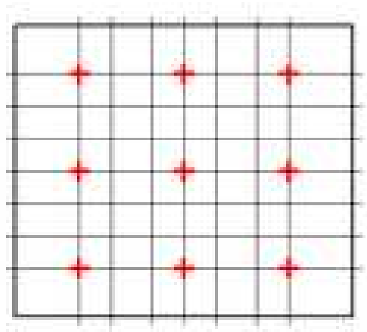
Screw arrangement – web



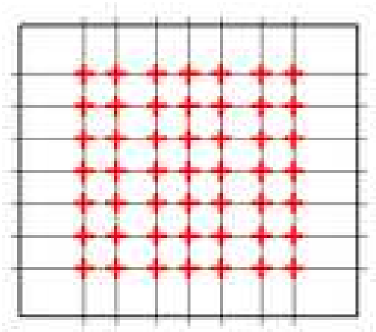




C66

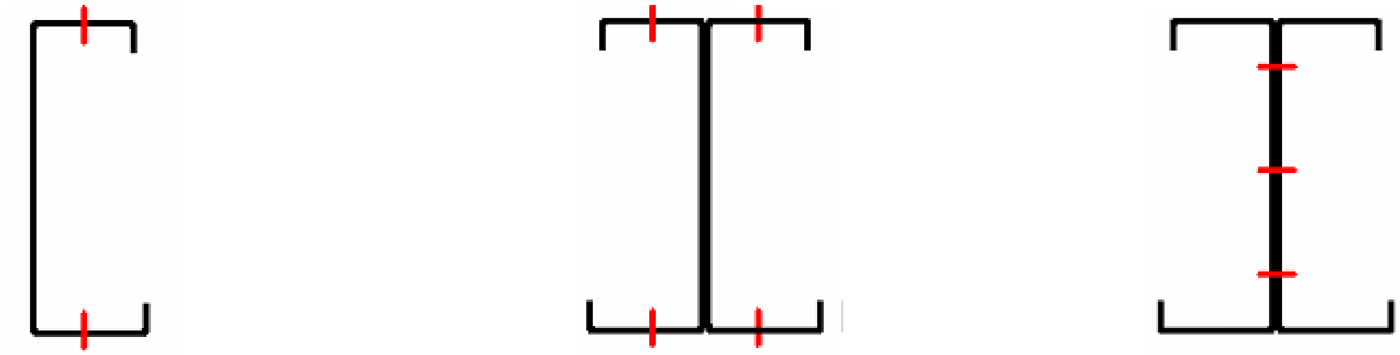


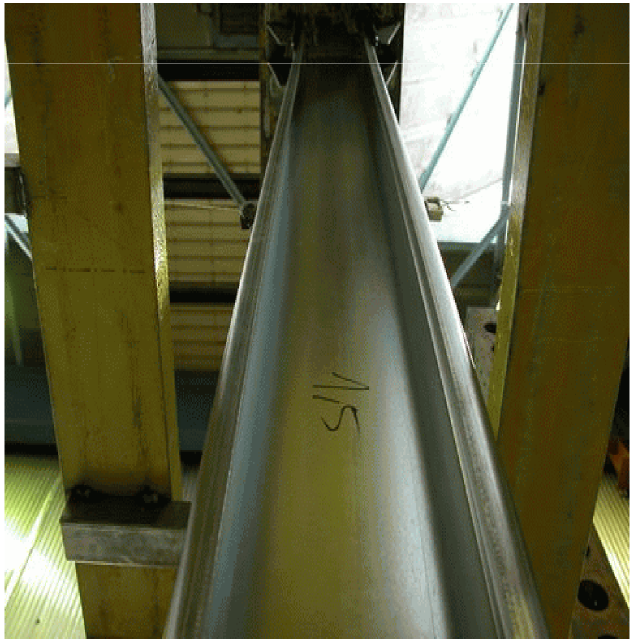
C81

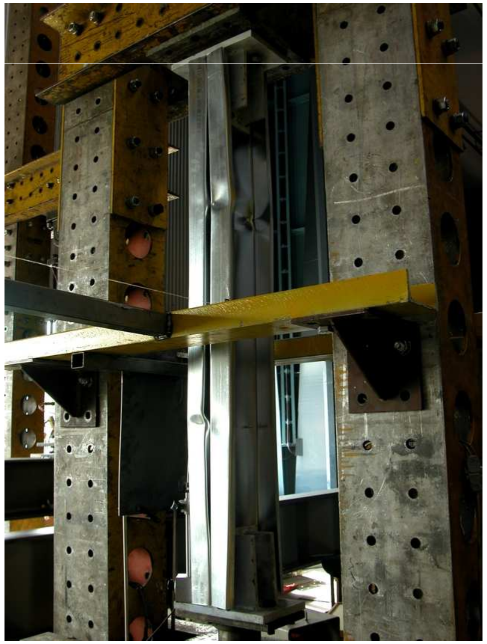


C82

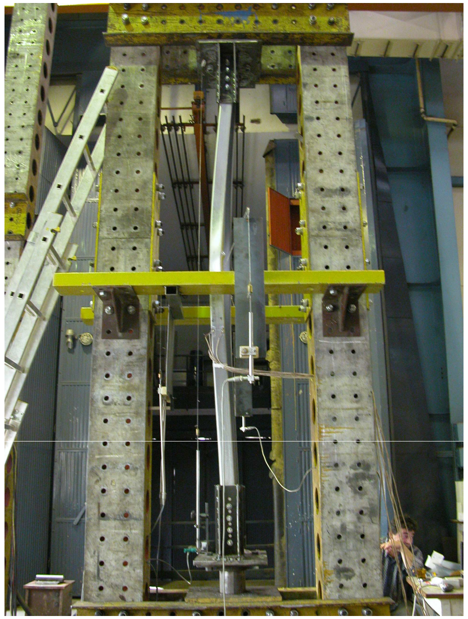
„I-section" elements

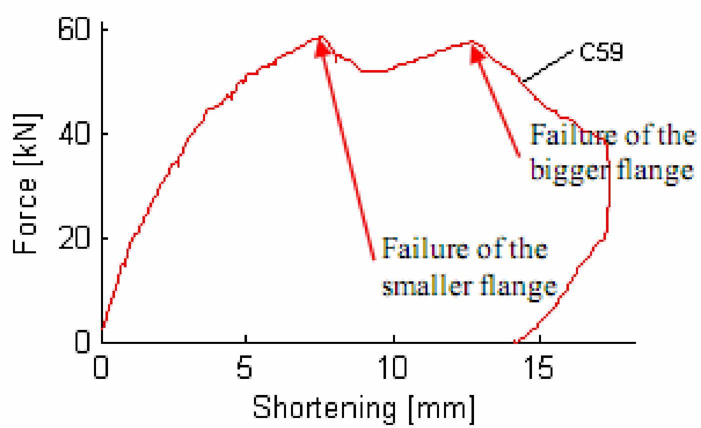


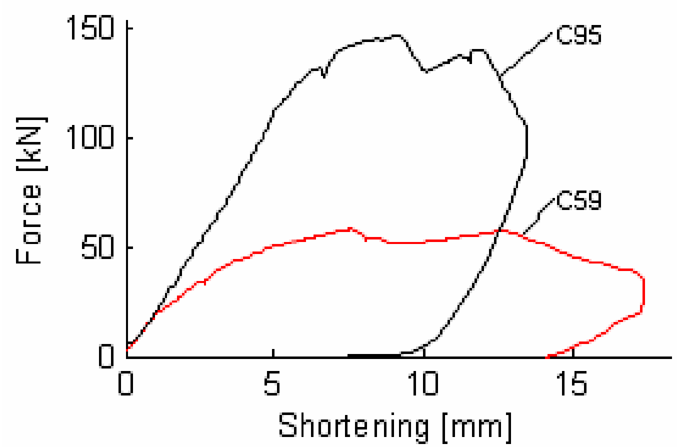




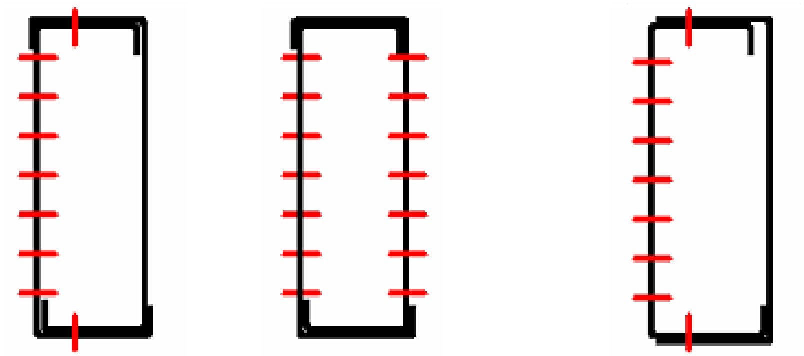
Single ↔ double section

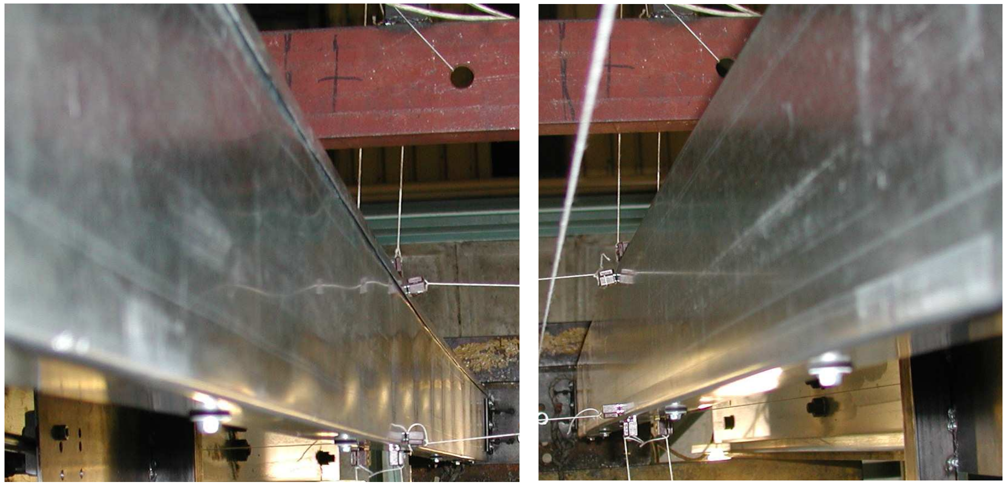




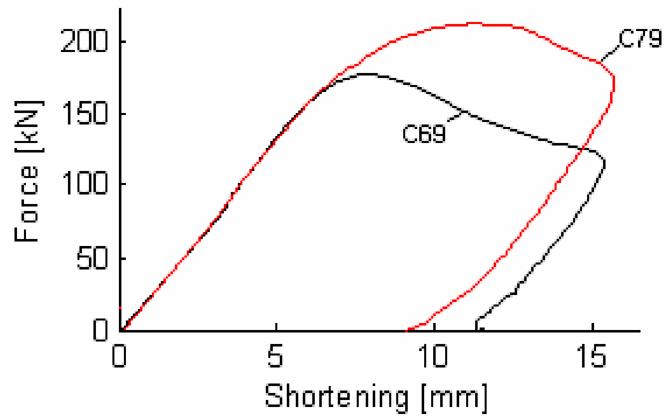


„Hollow” section elements



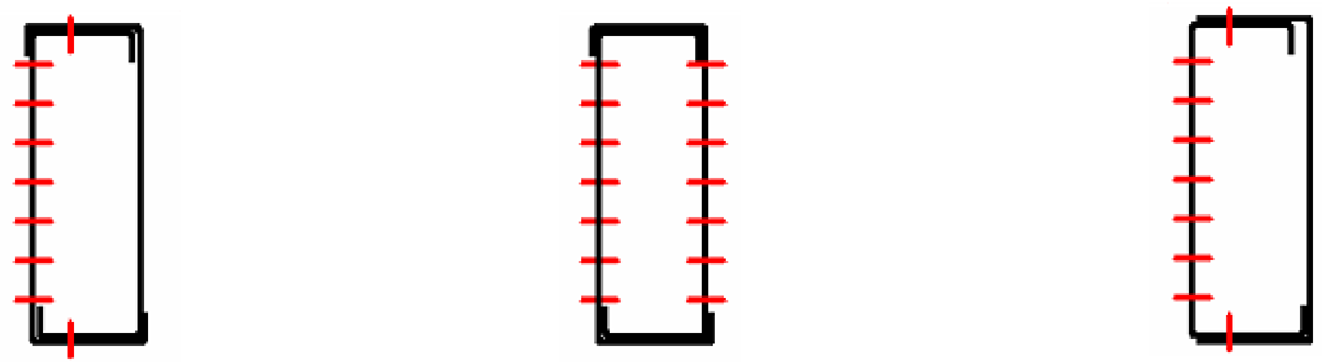


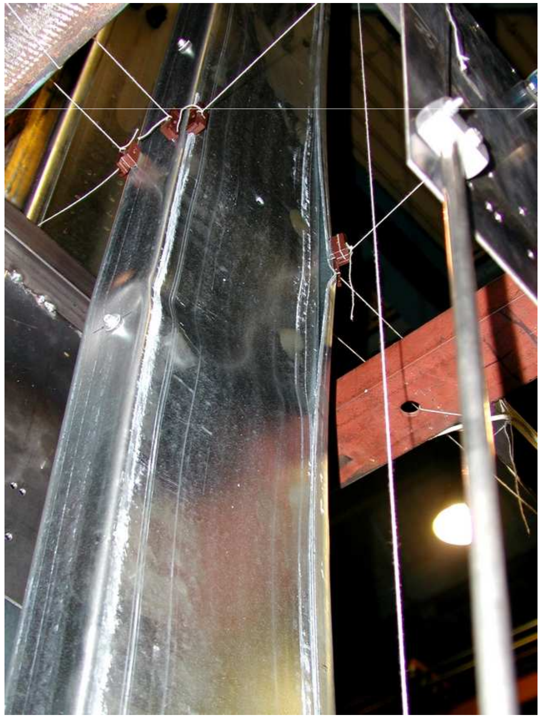
Tension and compression side



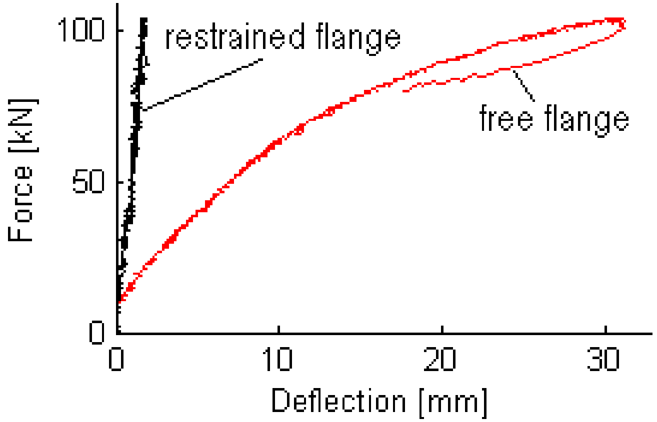
C or U loaded

Behaviour modes

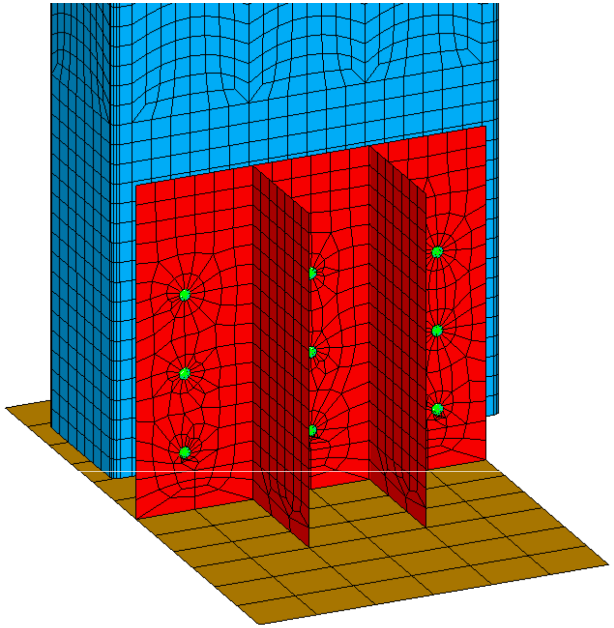


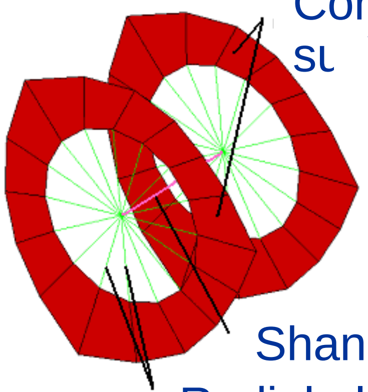


Laterally supported elements



Single C-section element FE model





Software: ANSYS

Element: SHELL181 (4-node, 24 DOF's)

Material model: linear elastic – hardening plastic

Contact surfaces: CONTA173/TARGE170

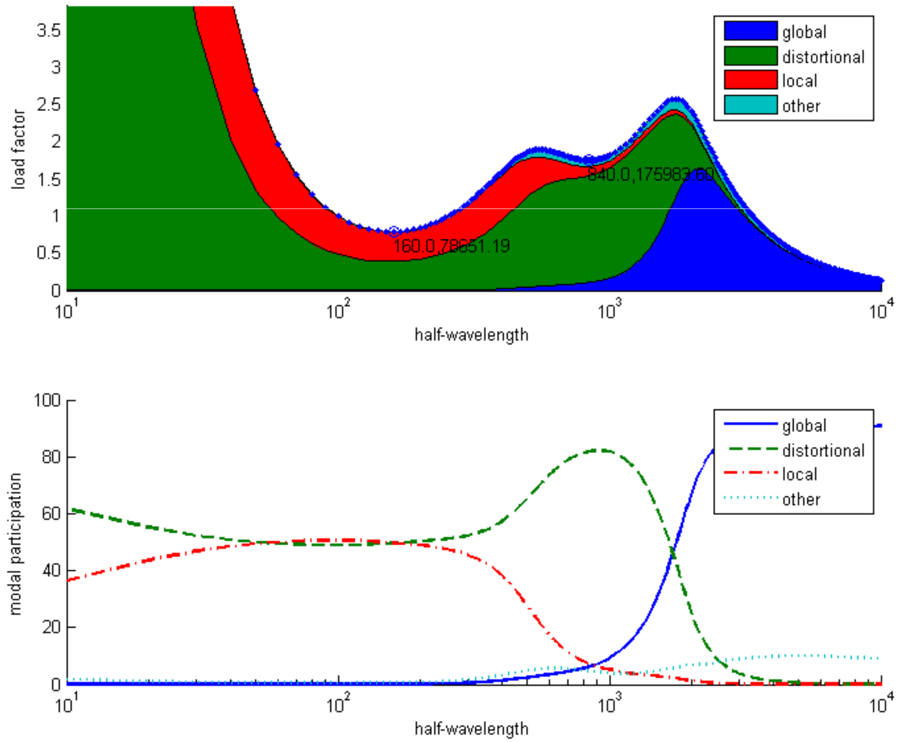
Self-drilling screw model:

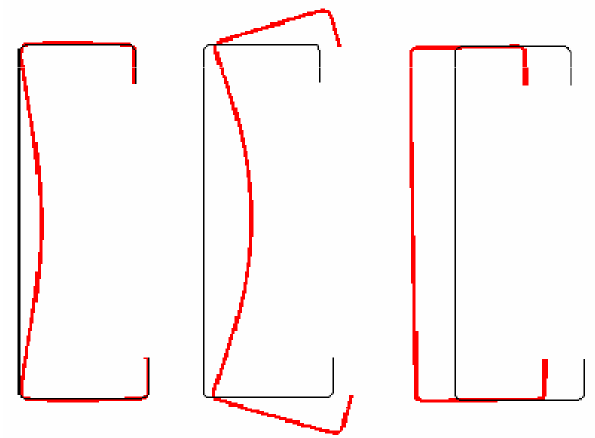
- „beamstar"; BEAM4
- calibrated stiffness parameters

Model size: ~ 100000 DOF's (L=2500 mm)

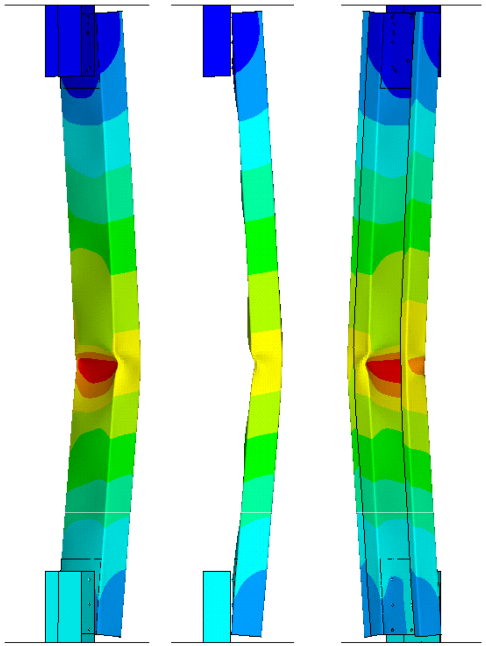
Geometrical imperfections

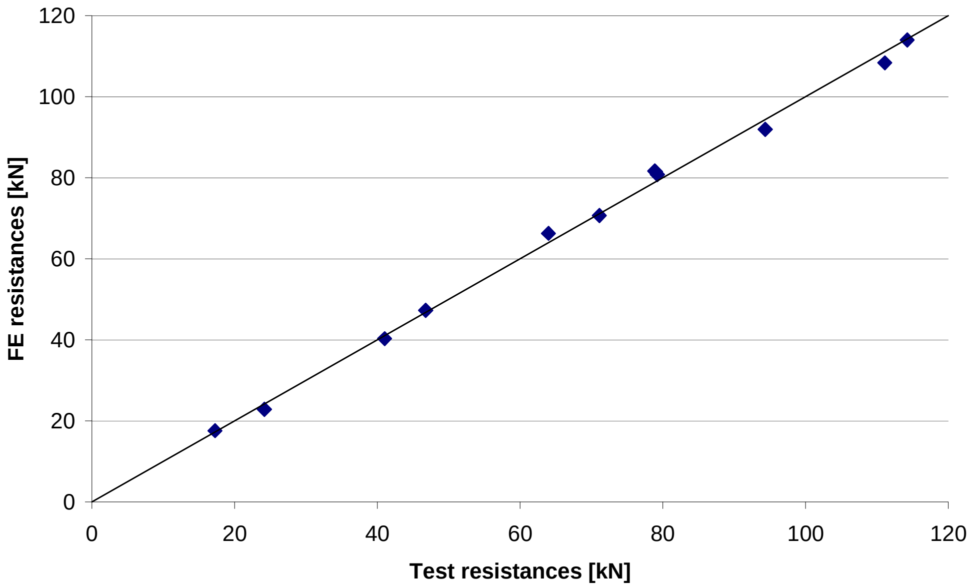
cFSM analysis model → pure modes → FE



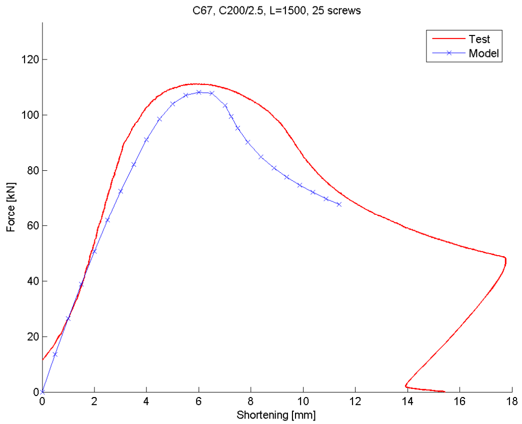


FE analysis

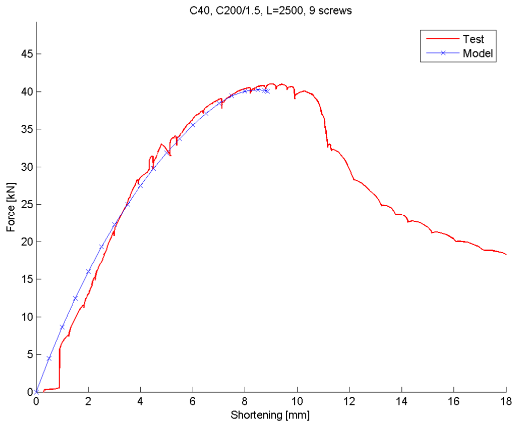




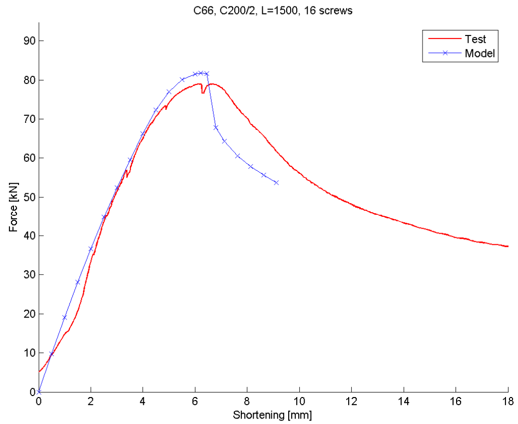
FE resistances [kN]
Test resistances [kN]
0
20
40
60
80
100
120



C67, C200/2.5, L=1500, 25 screws
Test
Model
Force [kN]
Shortening [mm]

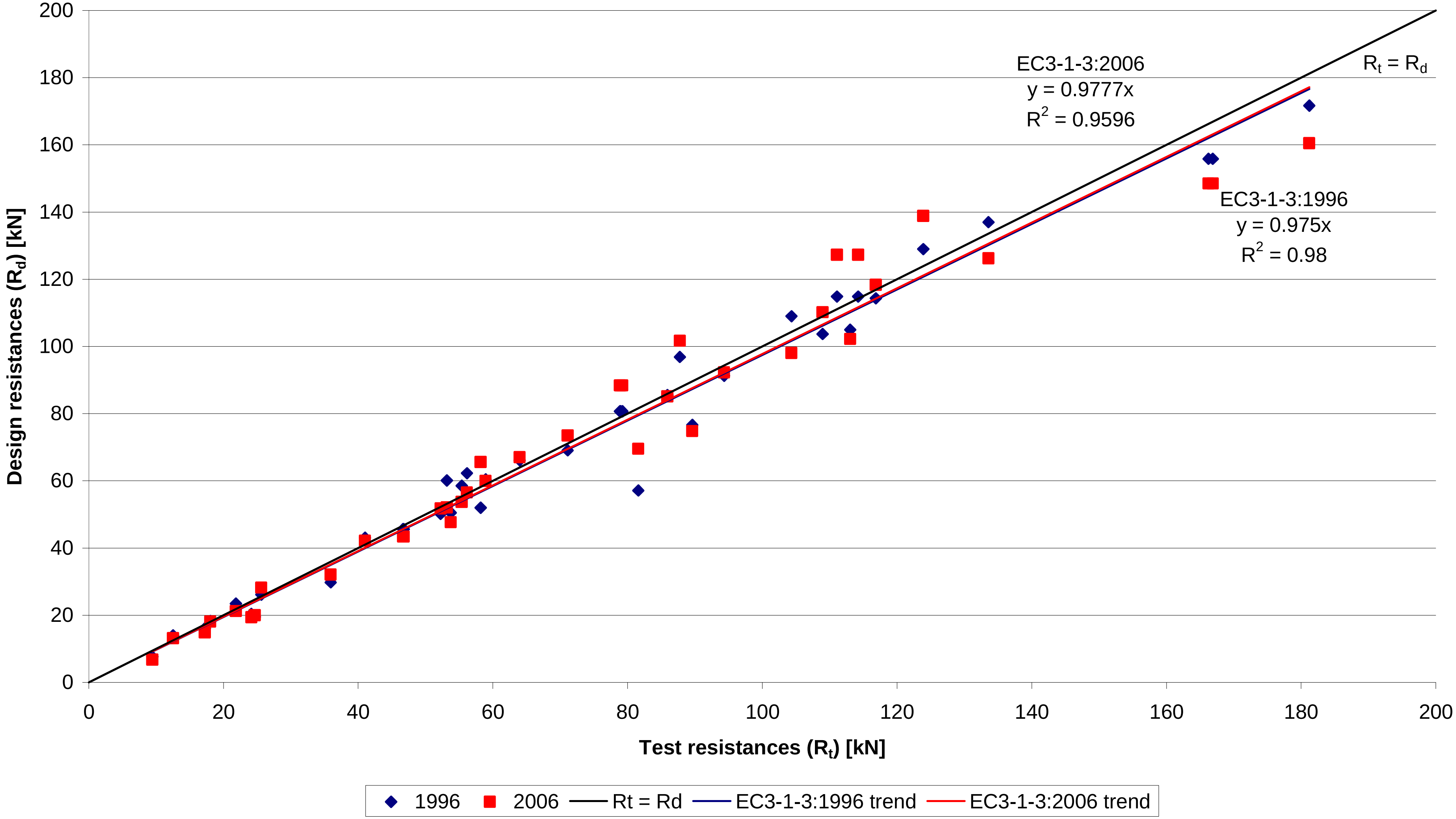


C40, C200/1.5, L=2500, 9 screws
Test
Model
Force [kN]
Shortening [mm]



C66, C200/2, L=1500, 16 screws
Test
Model
Force [kN]
Shortening [mm]

Single section element resistances



Buckling – bending design resistance

EC3-1-3:1996

$$\frac{N_{Ed}}{\chi_{\min}\cdot f_{yb}\cdot A_{eff}/\gamma_{M0}}+\frac{\kappa_z\cdot(\boxed{M_{z,Ed}}+\Delta M_{z,Ed})}{f_{yb}\cdot W_{eff,z,com}/\gamma_{M0}}\le 1$$

$$M_{z,Ed}=N_{Ed}\cdot e_{nom}$$

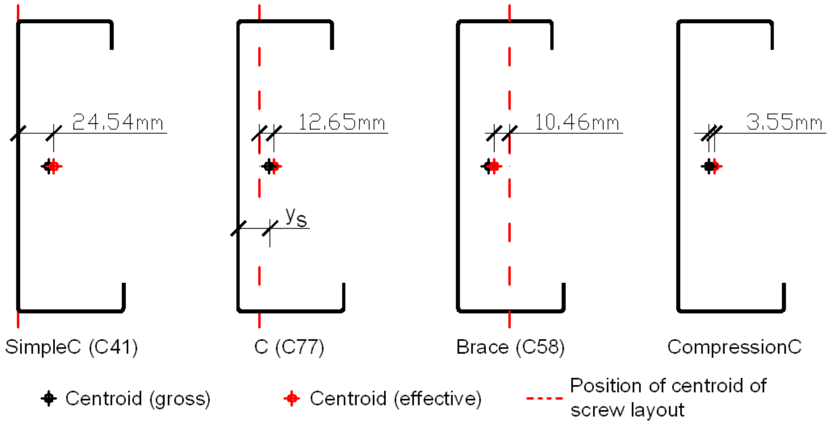
$$\Downarrow$$

$$e_{\mathrm{mod}}=1.4\cdot e_{nom}$$

$$e_{\mathrm{mod}}\ge 0.4\cdot y_S$$

EC3-1-3:2006

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{\boxed{0.8}}+\left(\frac{M_{Ed}+\Delta M_{Ed}}{M_{b,Rd}}\right)^{\boxed{0.8}}\le 1$$



$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{\boxed{0.65}}+\left(\frac{M_{Ed}+\Delta M_{Ed}}{M_{b,Rd}}\right)^{\boxed{0.65}}\le 1$$

Double section design resistance

$$\frac{N_{Ed}}{\chi_{\min} \cdot f_{yb} \cdot A_{eff} / \gamma_{M1}} + \frac{\kappa_z \cdot (M_{z,Ed} + \Delta M_{z,Ed})}{f_{yb} \cdot W_{eff,z,com} / \gamma_{M1}} \leq \alpha$$

Section type	α
I column	0.8·L+1.0, L – element length [m]
CC	1.8
CU	1.3 – C-section loaded 1.8 – U-section loaded
I brace	2.5

C-section truss

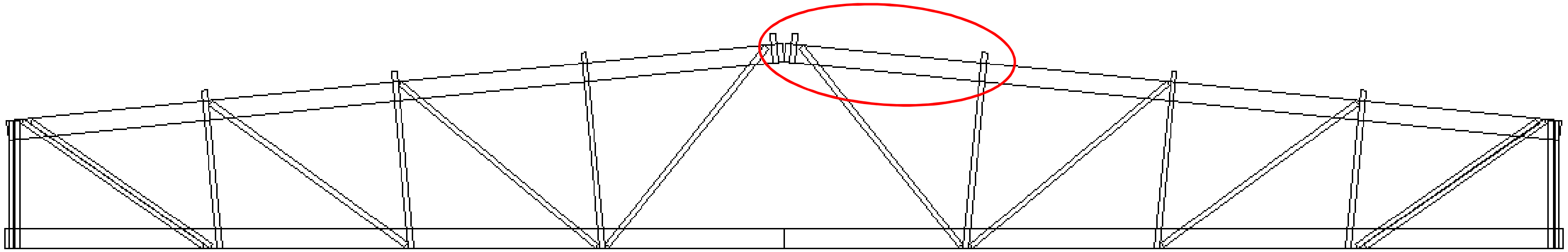
Subject of the research

- full-scale truss experimental study
- different structural elements
- different joints

Aims

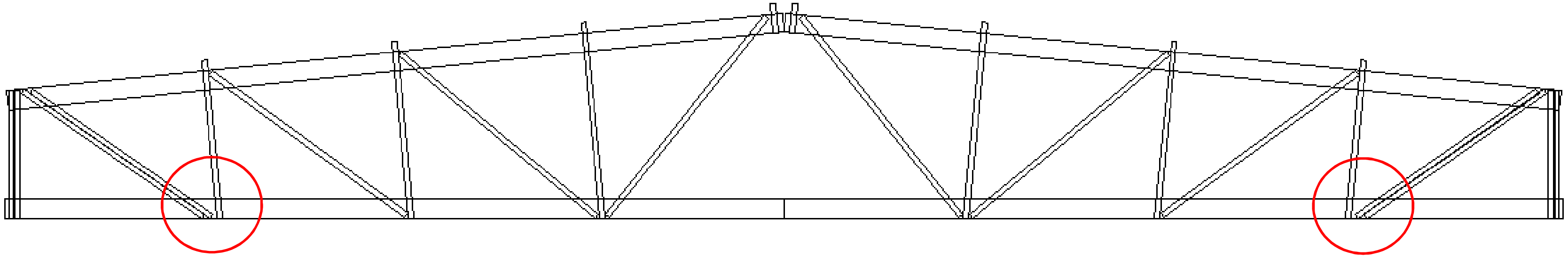
- interacting stability behaviour
- failure mode identification
- FE model development, verification
- design method validation

Test #1



failure in the upper chord, interaction bending and

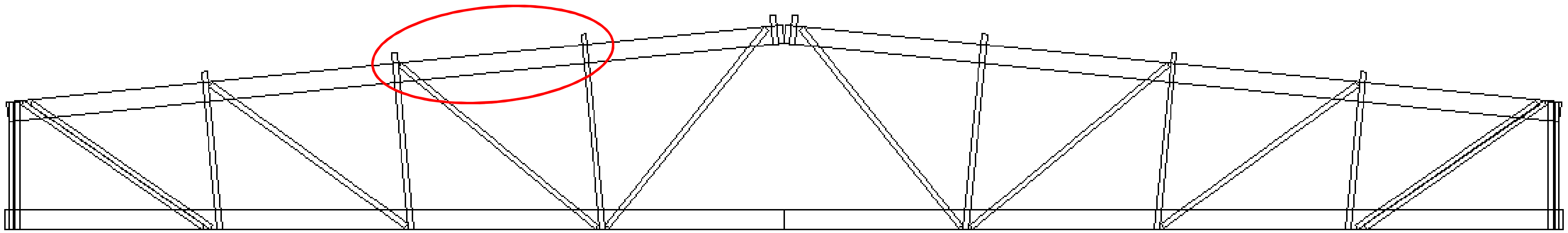
Test #5/1



failure in the lower chord

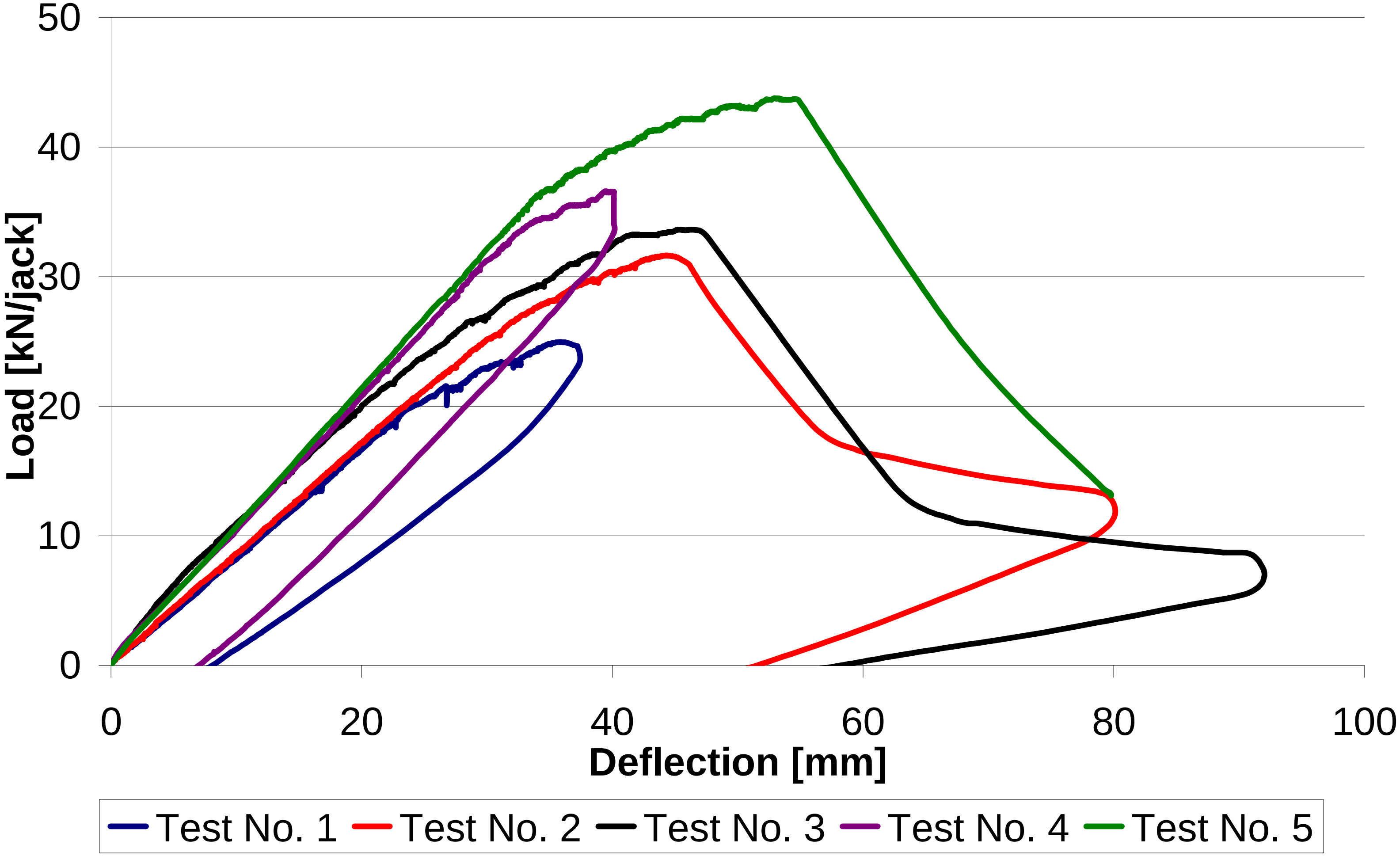
joint nearest to the support
interaction of shear and

Test #5/2

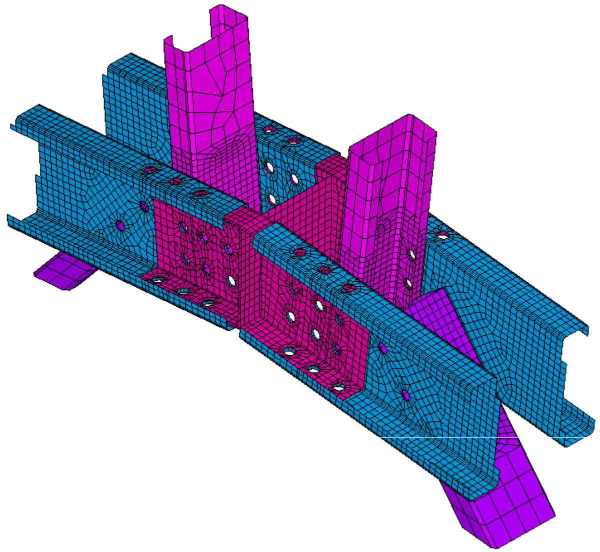


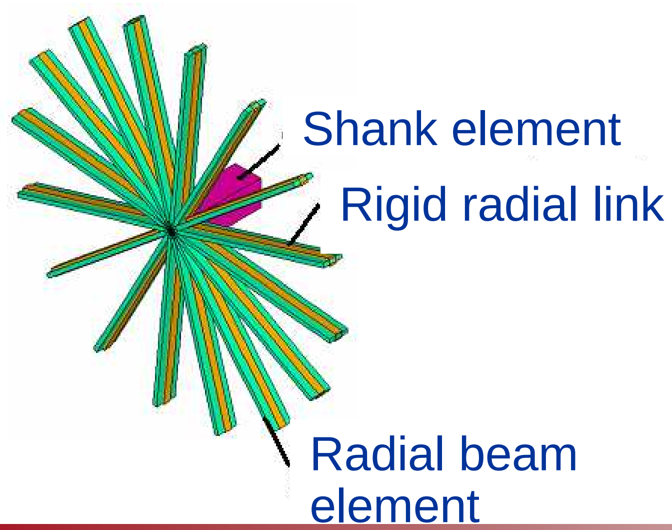
failure of the upper chord;
interaction of bending and
flexural buckling

Load-deflection relationship



Truss FE model





Software: ANSYS

Element: SHELL181 (4-node, 24 DOF’s)

Material model: linear elastic – hardening plastic

Contact surfaces: CONTA173/TARGE170

Bolt model:

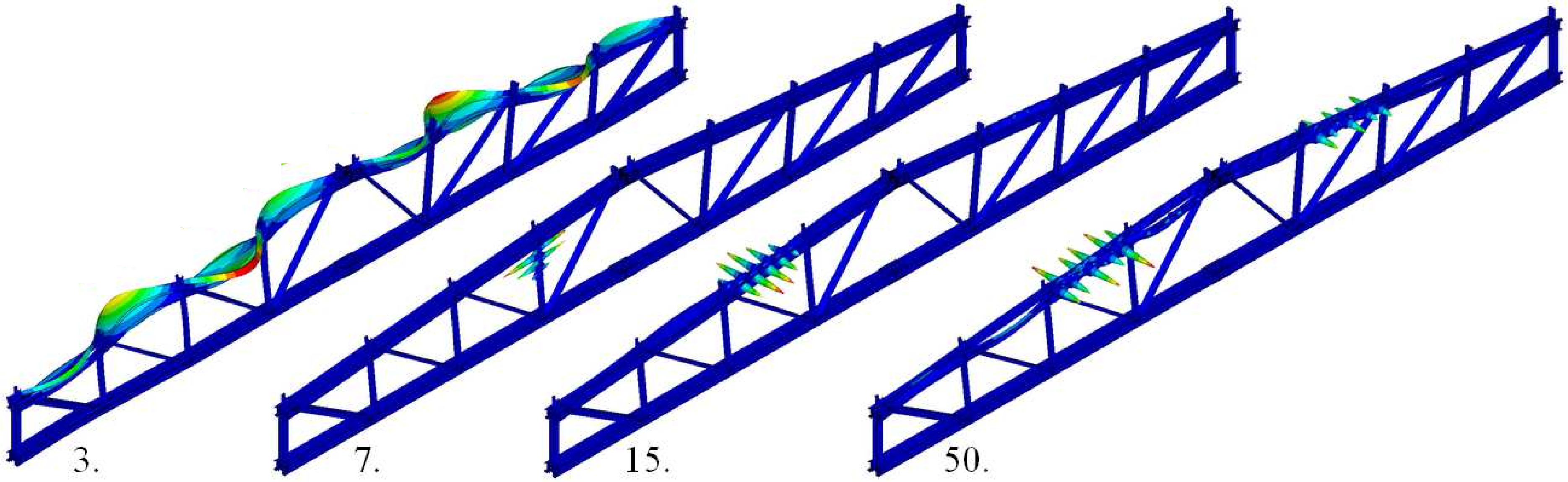
– modified „beamstar”; BEAM4

– calibrated stiffness parameter

Imperfections: selected eigenmodes

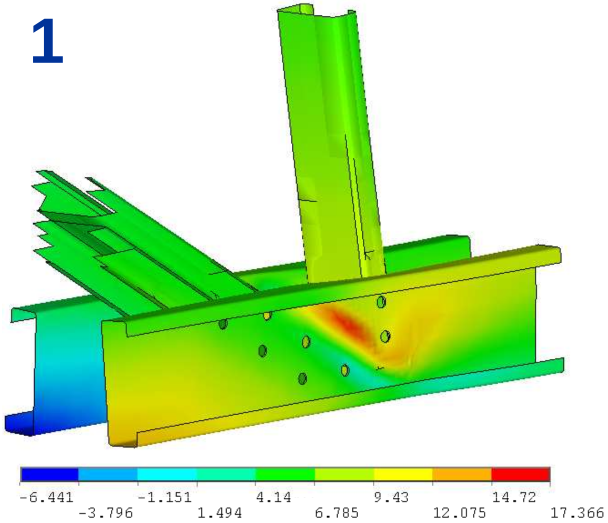
Model size: ~ 1.400.000 DOF’s

Eigenmodes – imperfections

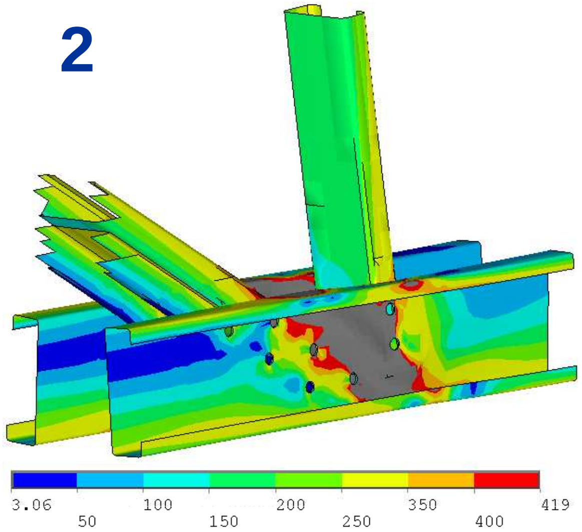


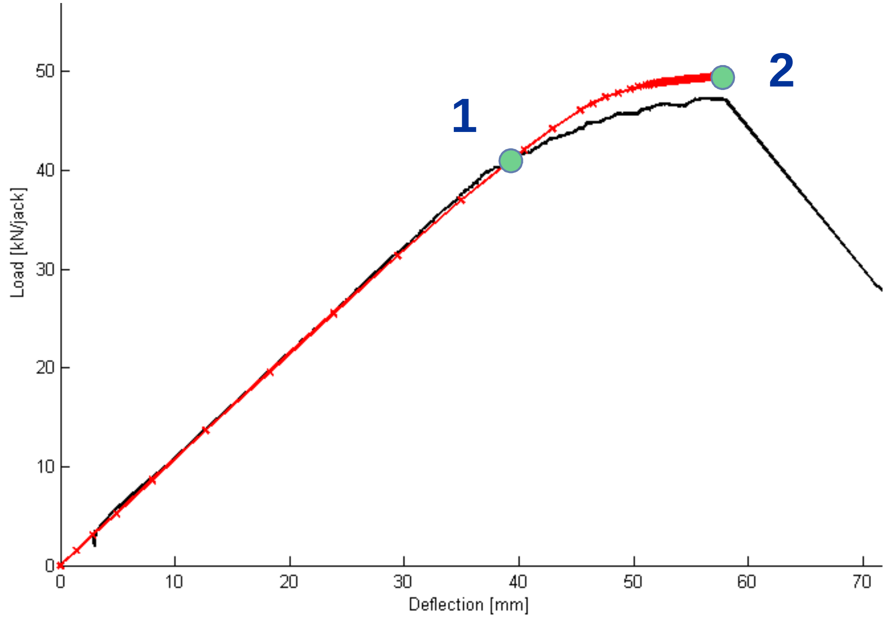
FE analysis – joint failure

1

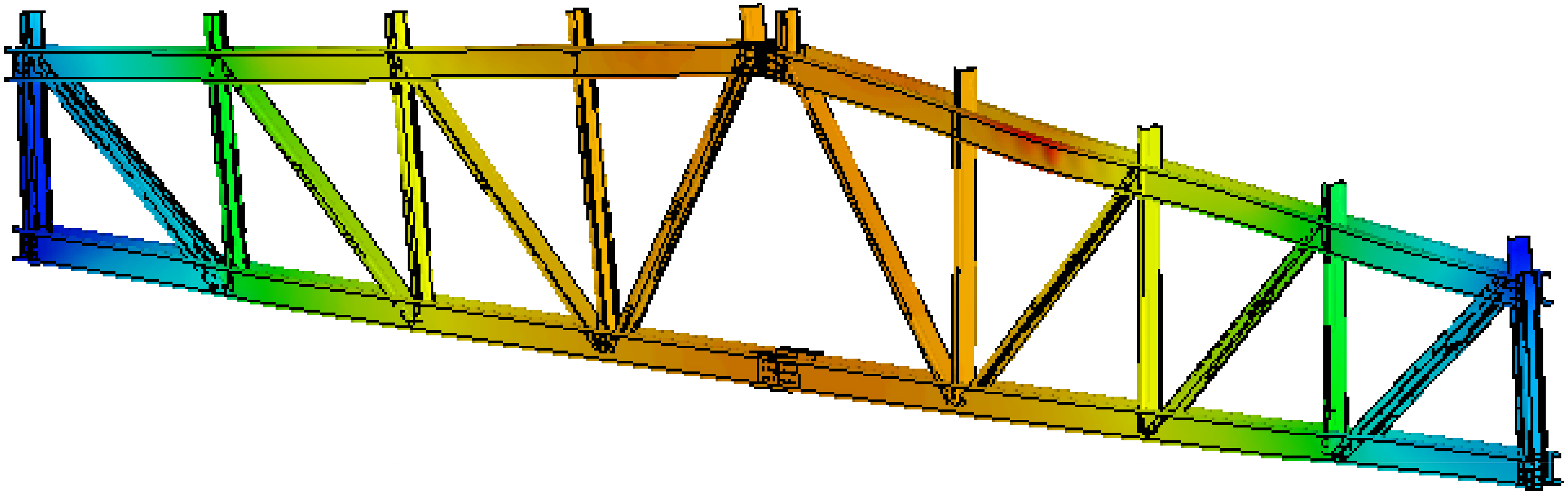


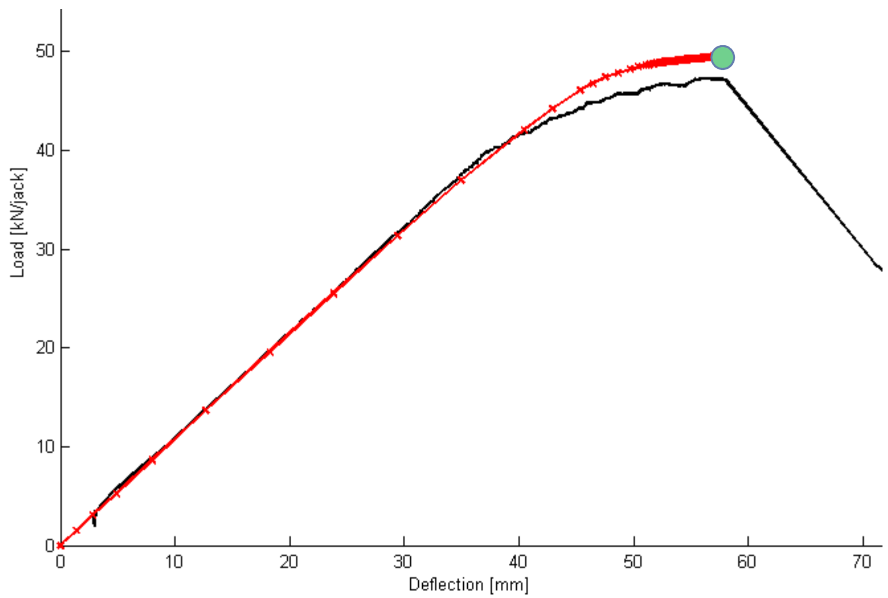
2





FE analysis – chord buckling





Design method

Compression chord: single section resistance --- reduced out-of-plane eccentricity

$$\frac{N_{Ed}}{\chi_{\min} \cdot f_{yb} \cdot A_{eff} / \gamma_{M1}} + \frac{\kappa_{LT} \cdot (M_{y,Ed} + \Delta M_{y,Ed})}{\chi_{LT} \cdot f_{yb} \cdot W_{eff,y,com} / \gamma_{M1}} + \frac{\kappa_z \cdot (0.5 \cdot M_{z,Ed} + \Delta M_{z,Ed})}{f_{yb} \cdot W_{eff,z,com} / \gamma_{M1}} \leq 1$$

Brace: single and I-section resistance

N-joint: shear resistance and interaction of joint and chord member

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

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

Concluding remarks

Research methodology: from experiments to design of non-conventional cold-formed steel structures.

Experiments on C-section elements: test results for a wide range of arrangement (section, load introduction); modified stability behaviour modes.

FE model for screwed members: screw model, cFSM pure mode imperfections, calibration, test domain extension.

Development of cold-formed structures: truss, frame, purlin, composite floor beam; experimental and numerical research.

Global advanced FE model: development, verification, applicability.

Design methods: experimental and numerical validation of modified and/or new application rules for the structural elements, joints and

Thank you for your attention!