# DEVELOPMENT OF A NEW COLD-FORMED TRUSS SYSTEM

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# BACKGROUND

R&D project with industrial background

Aim

- Development of a truss system and design method
- Verification/validation of the design method

Main characteristics of the system

- Span: 12…24 meter
- Using only cold-formed C-sections
- Flexible system allowing free design
- Out-of-box solutions

# STRUCTURAL ARRANGEMENT

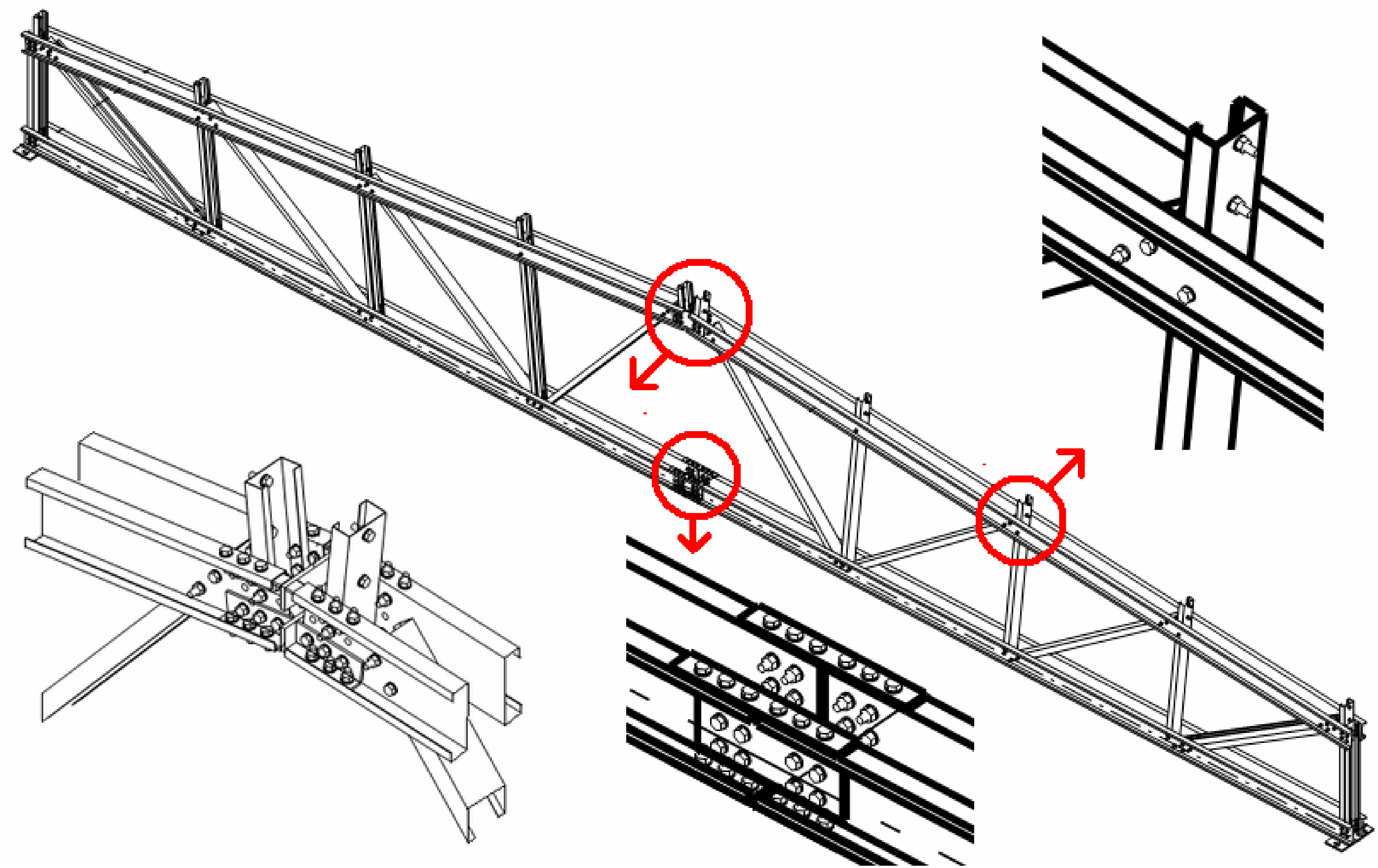
## Structural elements

- Chord: two C-sections in back-to-back arrangement
- Bracing: single C-sections, doubled at the supports

## Structural joints

- Eccentric bolted connections

# STRUCTURAL ARRANGEMENT



# PROBLEM STATEMENT

CHORDS

\+

BRACING

} JOINT

✓

Stability issues
- EC-based design

Similar problems solved

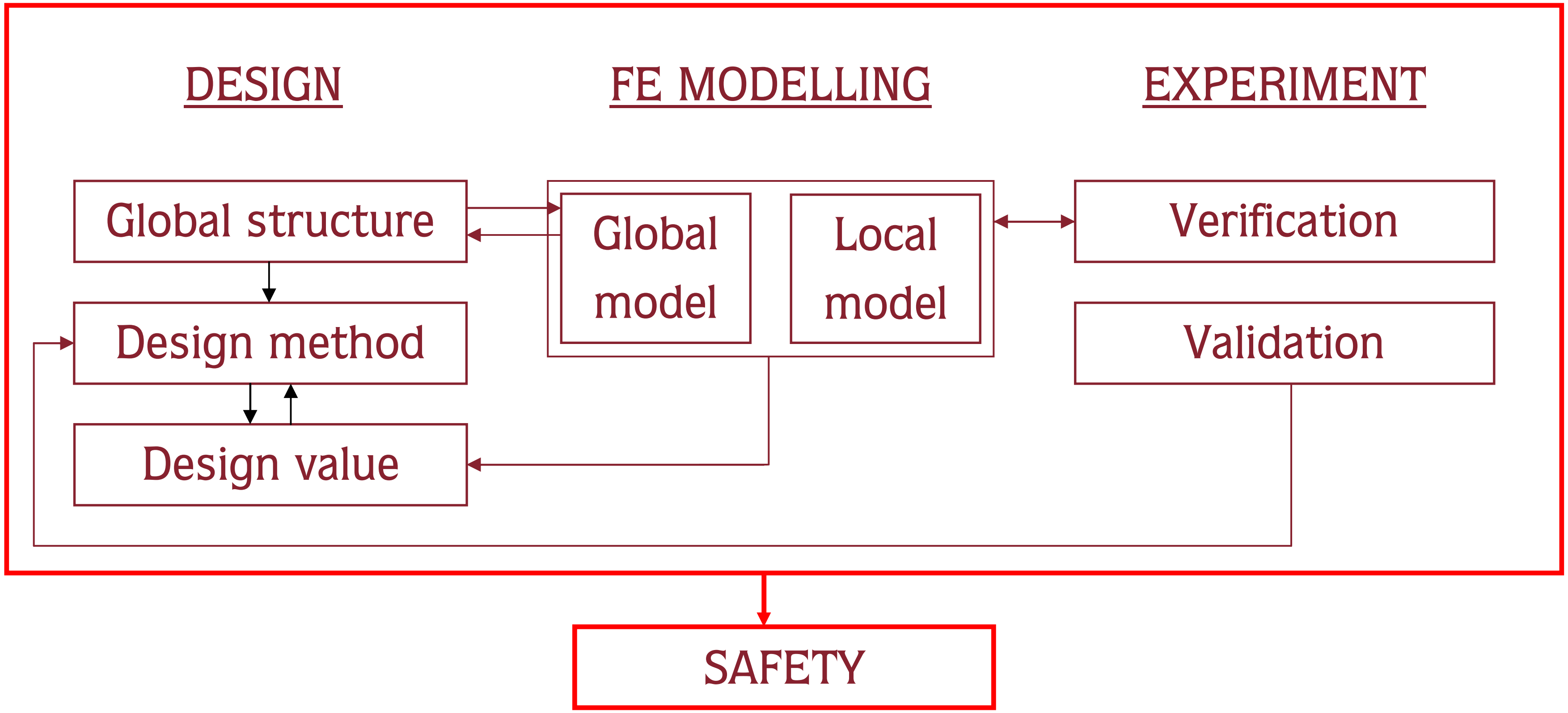
?

Eccentricity
- in-plane, out-of-plane

Load-bearing capacity, local stability behaviour

Rigidity, interaction with members

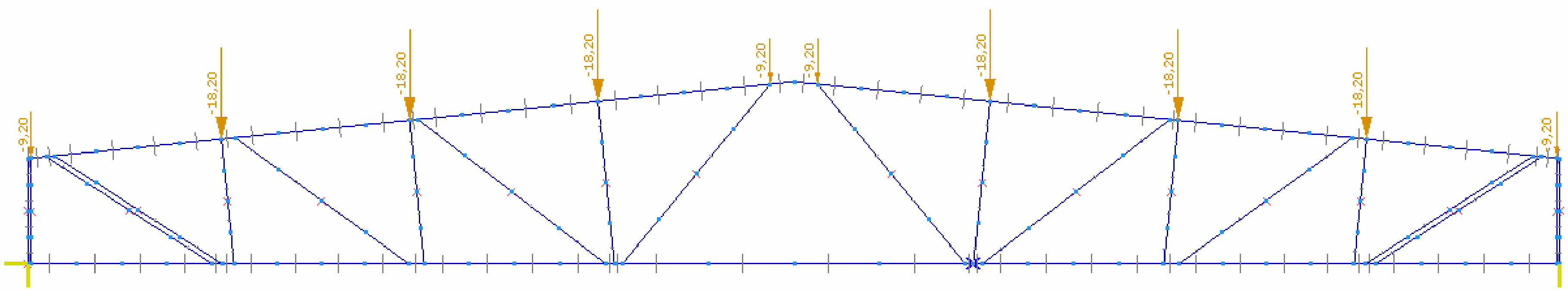
# SOLUTION STRATEGY



# FE MODELLING – BEAM MODEL

## Global model – for design

- 2-D beam model taking into account only in-plane eccentricities
- Used to determine the internal forces needed for design



# DESIGN METHOD – MEMBERS

## BRACE MEMBERS

- Dominant mode: Compression and bending or interaction of flexural buckling and bending about the weak axis

## CHORD MEMBERS

- Dominant mode: Interaction of flexural buckling and biaxial bending

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

45.8% + 7.8% + 46.4% = 100%

# DESIGN METHOD – JOINTS

## BOLTED CONNECTION

- Shear failure
- Dominant mode: bearing failure

## NO JOINT FAILURE MODES CONSIDERED

# LABORATORY TESTING - SETUP

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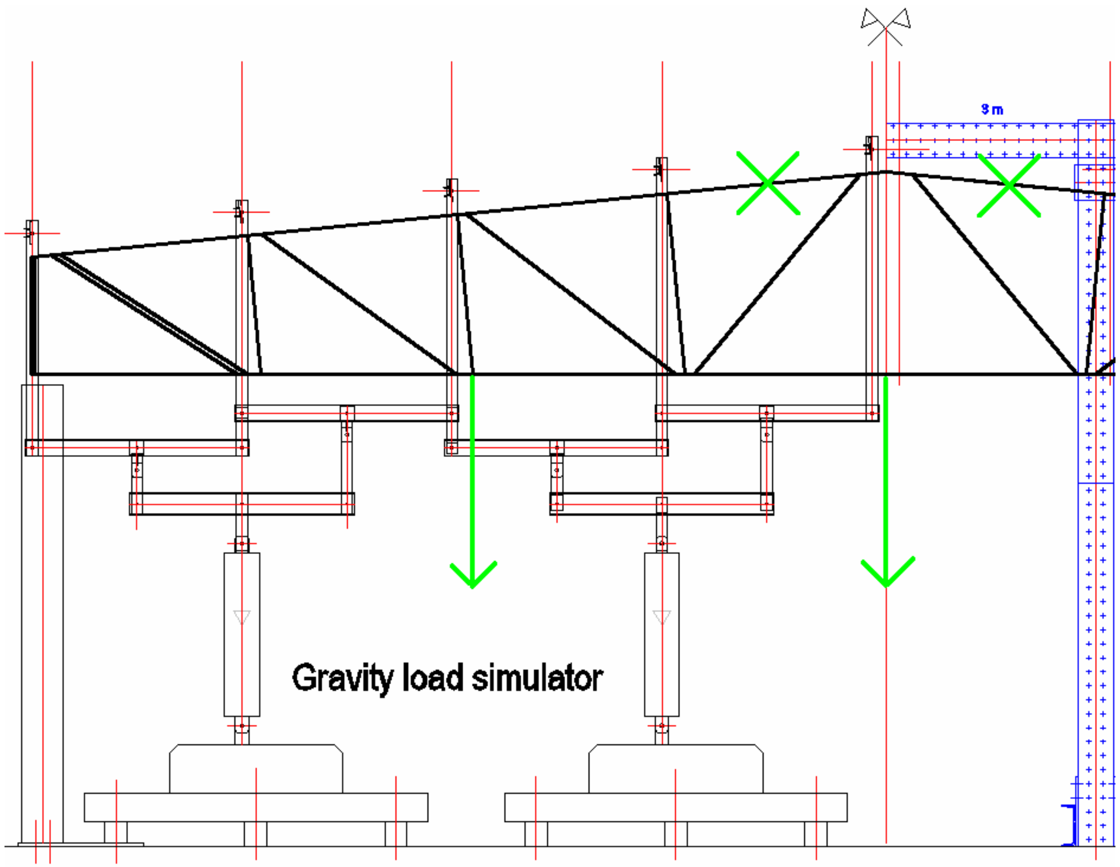
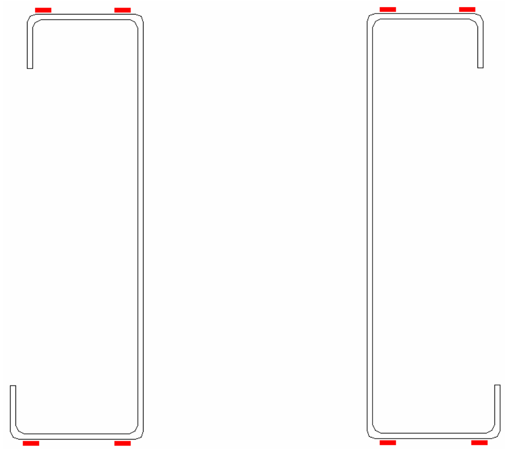



## MEASUREMENT

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



# LABORATORY TESTING – FAILURE MODES

## Test 1

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

Load: 28,5 kN/jack

# LABORATORY TESTING – FAILURE MODES

Test 2

failure of the peak joint

Load: 35,5 kN/jack

New peak joint arrangement

# LABORATORY TESTING – FAILURE MODES

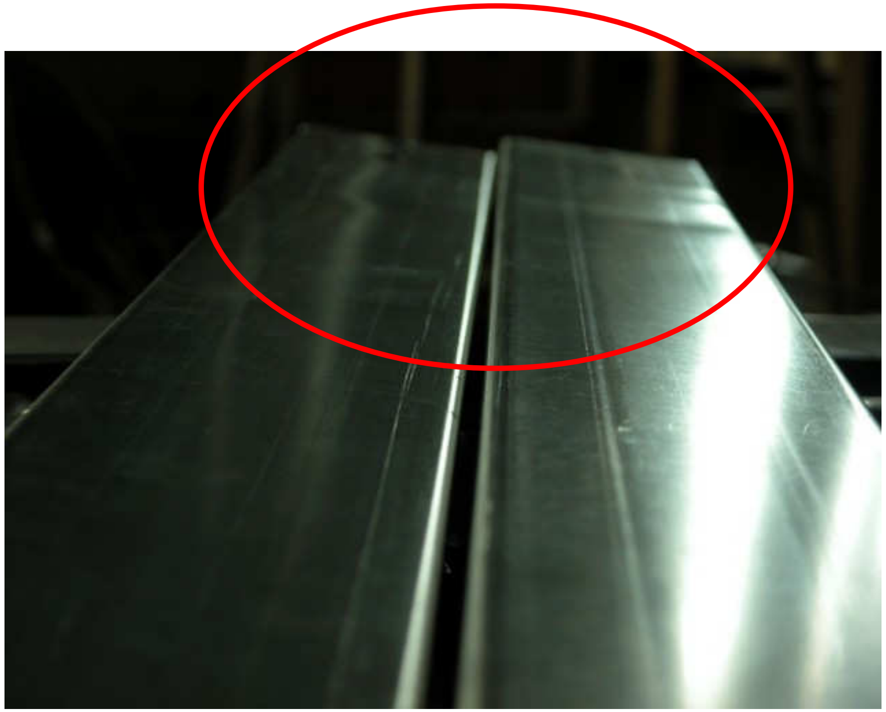
## Test 3

failure of the upper chord (built-up section)

Load: 36,4 kN/jack

# LABORATORY TESTING – FAILURE MODES

## Test 4



failure of a compression brace member; interaction of compression and bending

Load: 37,4 kN/jack

# LABORATORY TESTING – FAILURE MODES

## Test 5 – first failure

failure in the lower chord joint nearest to the support; interaction of shear and tension

Load: 37 kN/jack

# LABORATORY TESTING – FAILURE MODES

## Test 5 – final failure

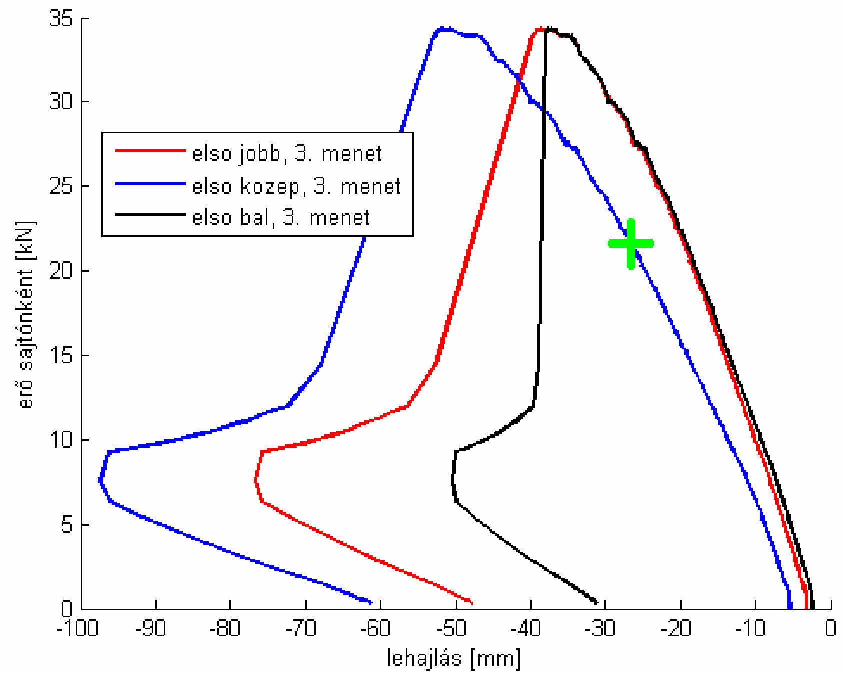
failure of the upper chord; interaction of bending and flexural buckling

Load: 47,4 kN/jack

ULS load: 31.65 kN/jack

# LABORATORY TESTING – FE-MODEL

## SLS level




| ULS level | Axial force [kN] | |
|---|---|---|
| | FE | test |
| Upper chord | 144,76 | 135,56 |
| Lower chord | 137,96 | 129,78 |
| Brace | 46,97 | 50,20 |

⇨ The model is applicable for design

# LABORATORY TESTING – DESIGN METHOD

## Compression chord member failure mode identified

– EC3 design rule modified based on strain measurement

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

## Brace member failure modes identified

– EC3 design rule modified – calibrated – to ensure safety level

## Joint failure mode identified

– EC3-based design formulae developed based on the existing design method of N-type RHS-RHS joints

# AN EXAMPLE

# FURTHER STEPS

Global FE surface model under development

Recently finished test series of cold-formed C sections with different end supports to study the truss members individually

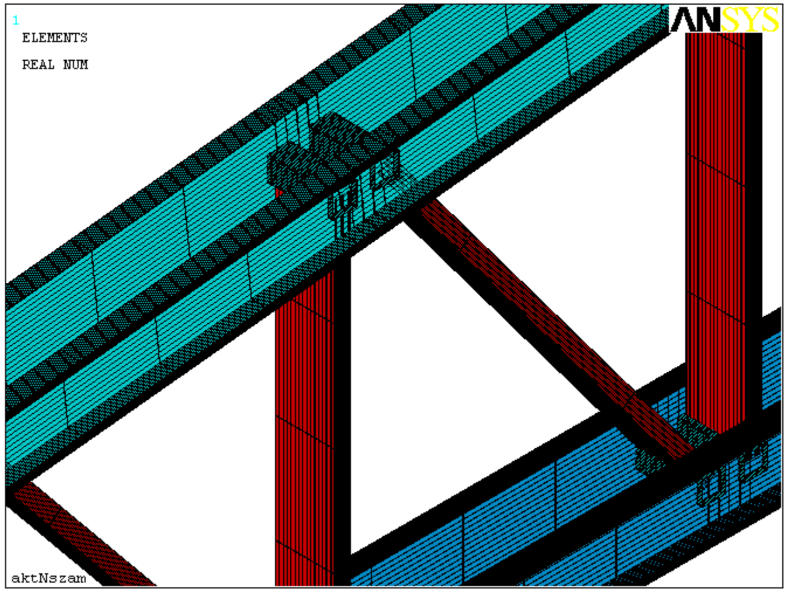
DimTruss – a program to design these trusses – under development

# Thank you for your attention!

# Thank you for your attention!

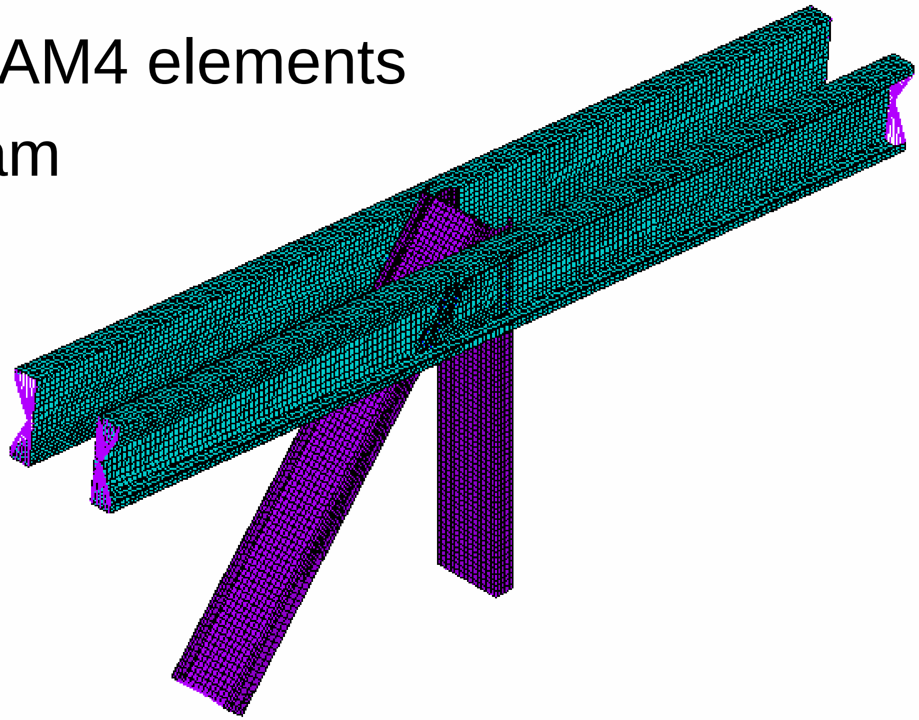
# FE MODELLING – BEAM MODEL No. 2

- Global model – for development
  - Developed in ANSYS
  - 3-D beam model taking into account in-plane and out-of-plane eccentricities
  - 6 DOF’s BEAM188 elements
  - Used to examine the joint area using submodel-ling technique



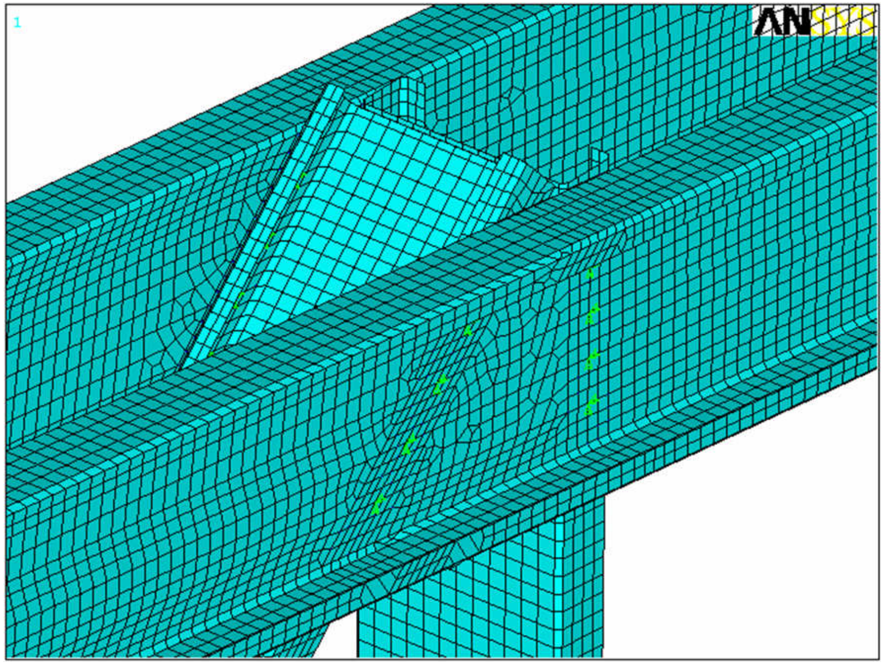
# FE MODELLING – JOINT SURFACE MODEL

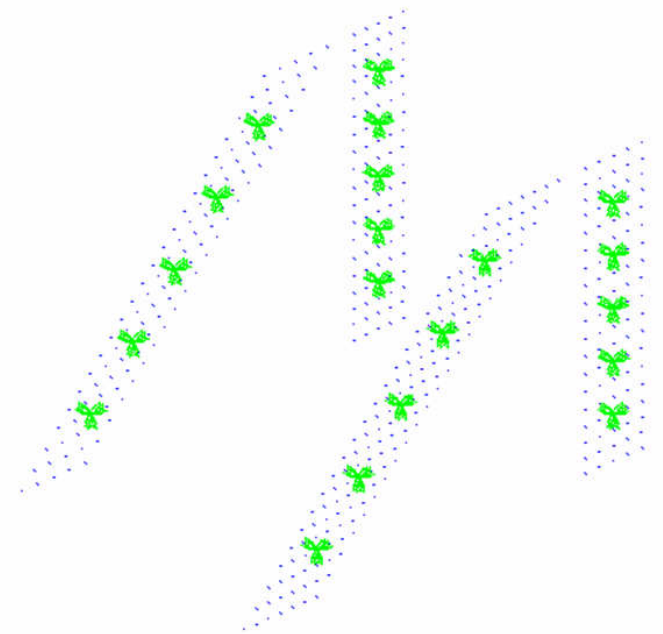
- Local model – for development
  - Developed in ANSYS
  - SHELL181, LINK10, BEAM4 elements
  - Kinematic load from beam model Nr. 2
  - ~100k DOF's
  - GMNIA



# FE MODELLING – JOINT MODEL

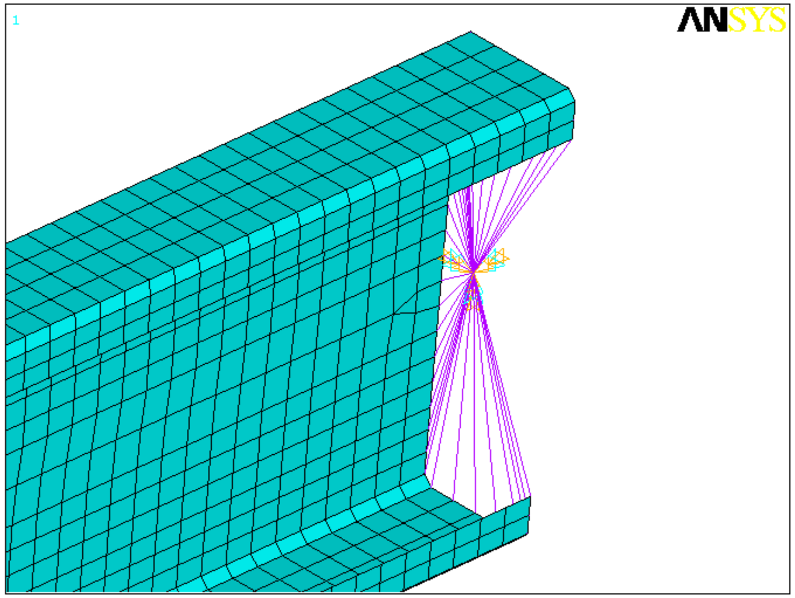
- CONTACT AREA, BOLTS

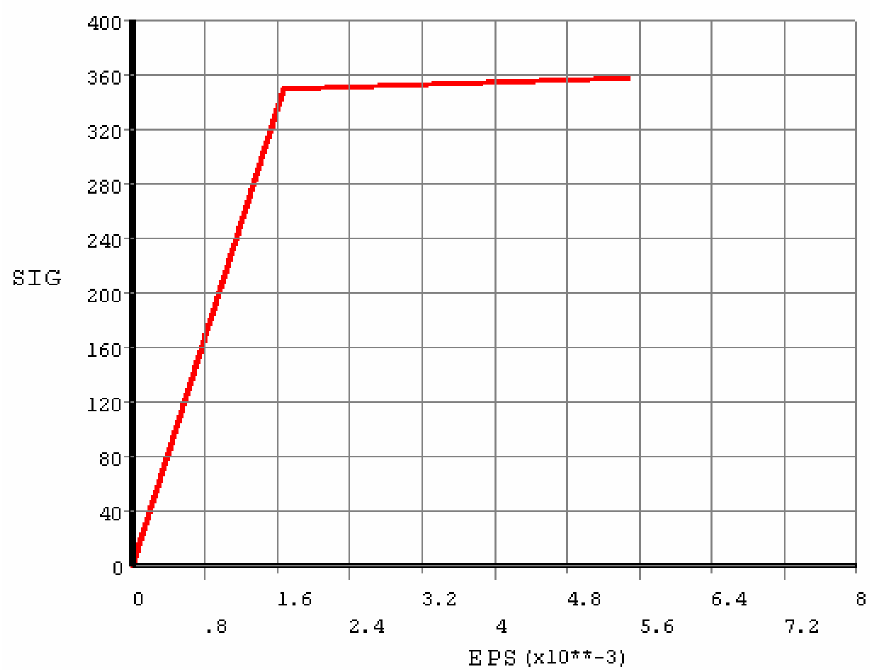




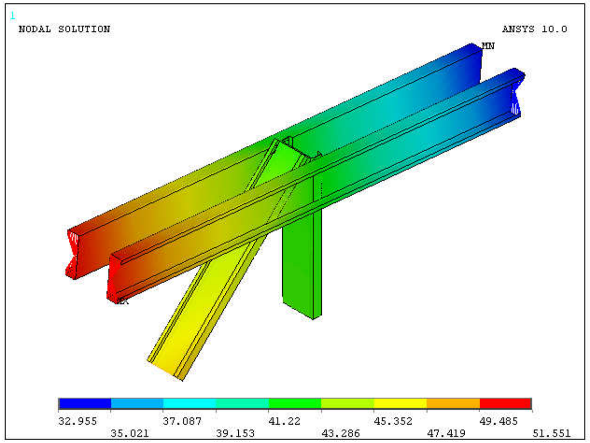
# FE MODELLING – JOINT MODEL

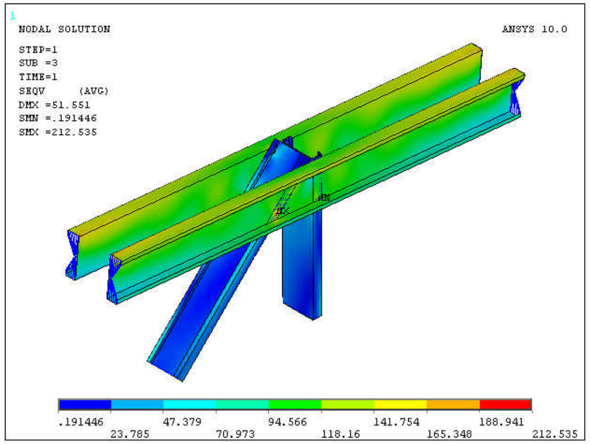
- LOADS, MATERIAL PROPERTIES

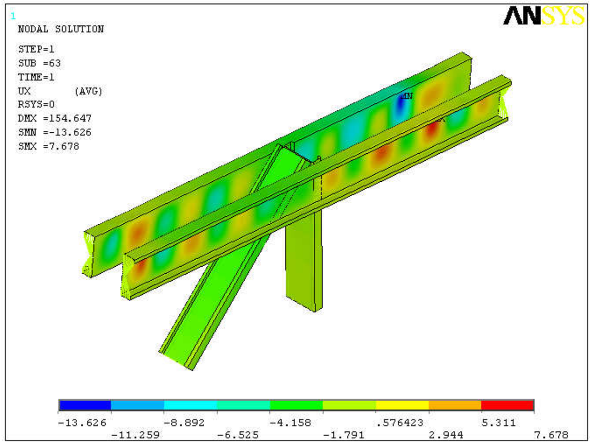


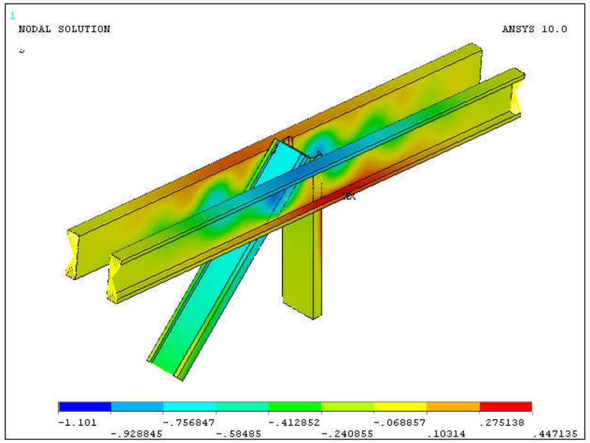



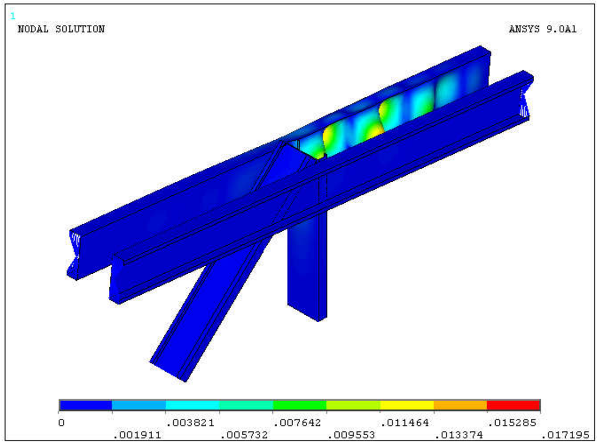
# JOINT MODEL - RESULTS

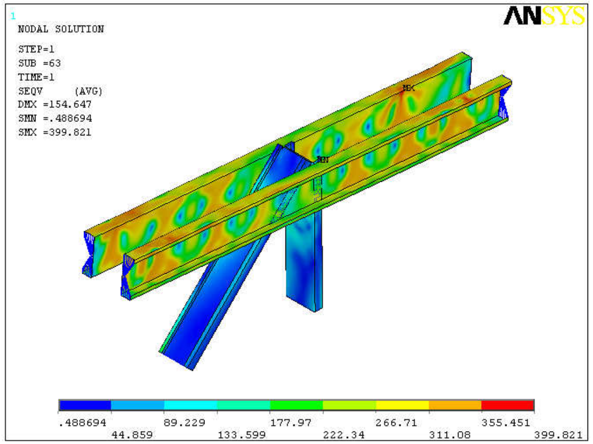


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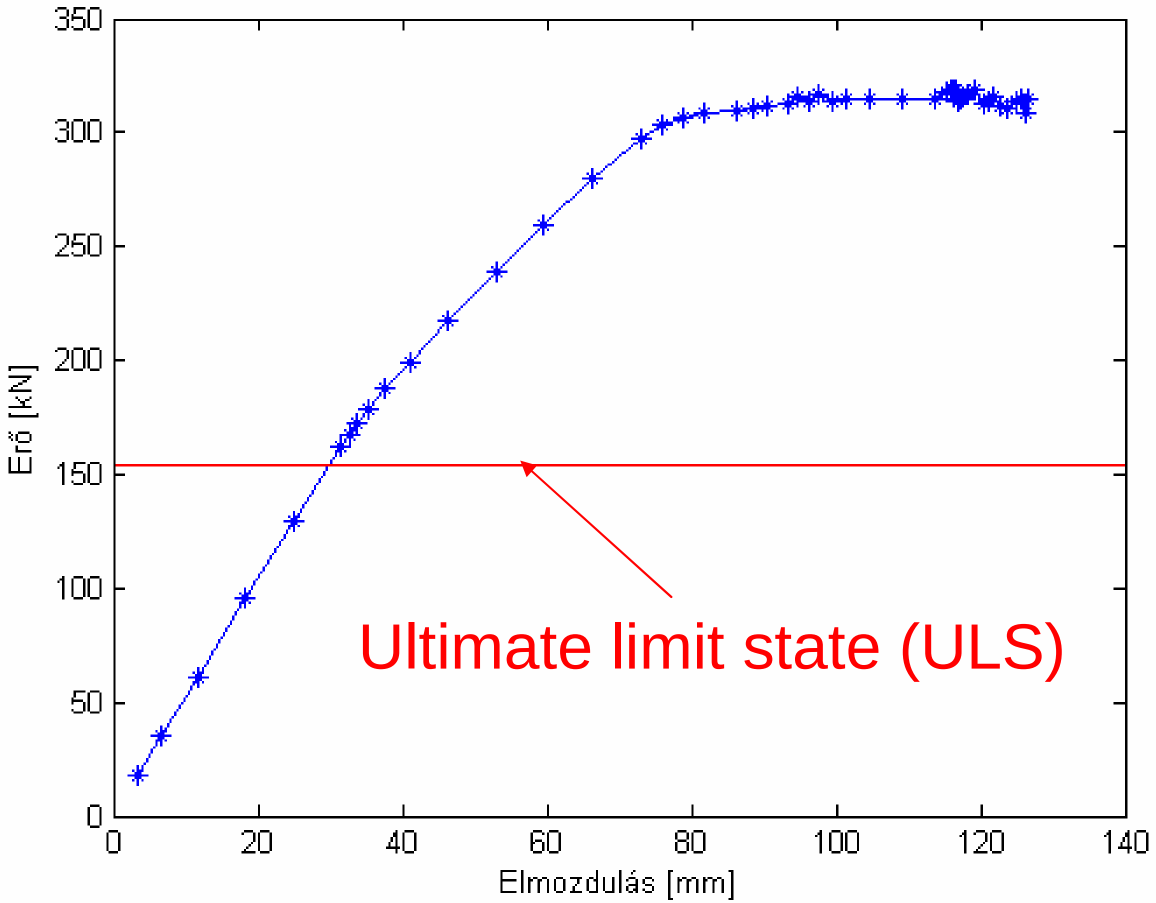

# DESIGN METHOD – TENSION ELEMENTS

## BRACE MEMBERS

- Tension and bending about the weak axis
- Plastic design resistance reduced

$$N_{pl,Rd} = 0,6 \cdot \frac{A_g \cdot f_{yb}}{\gamma_{M0}}$$

## CHORD MEMBERS

- Tension and biaxial bending