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EXPERIMENTAL INVESTIGATIONS ON BUILT-UP COLD-FORMED STEEL CORRUGATED WEB BEAMS ASSEMBLED WITH WELDING

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CEMSIG
Centrul de cercetari pentru mecanica materialelor si siguranta structurilor

ACADEMIA ROMANA

CCTFA

2017

Objectives

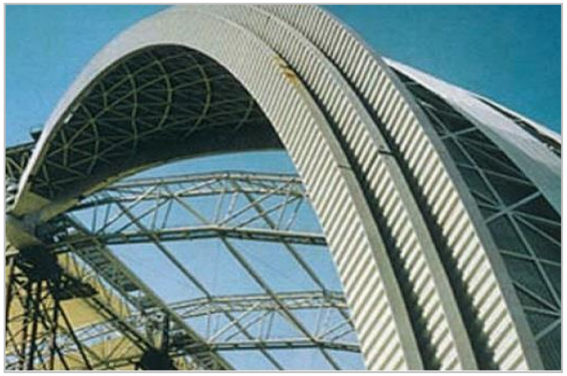
To present new research developments on cold-formed steel beams of corrugated web (CWB)

ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

Exemplification by Zeman & Co (http://www.zeman-stahl.com/)








ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

Exemplification by Zeman & Co (http://www.zeman-stahl.com/)

Corrugated H Beam Robotic Welding Machine (www.rollformingmachines.com.au)

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ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

The main benefits:

- the corrugated webs increase the beam's stability against buckling;
- the use of thinner webs results in lower material cost (an estimated cost savings of 10-30% in comparison with conventional fabricated sections and more than 30% compared with standard hot-rolled beams);
- the buckling resistance of used sinusoidal corrugated sheeting used for webs is comparable with plane webs of 12 mm thickness or more.

DESIGN $\Rightarrow$ adapted to EN 1993-1-5 Annex D

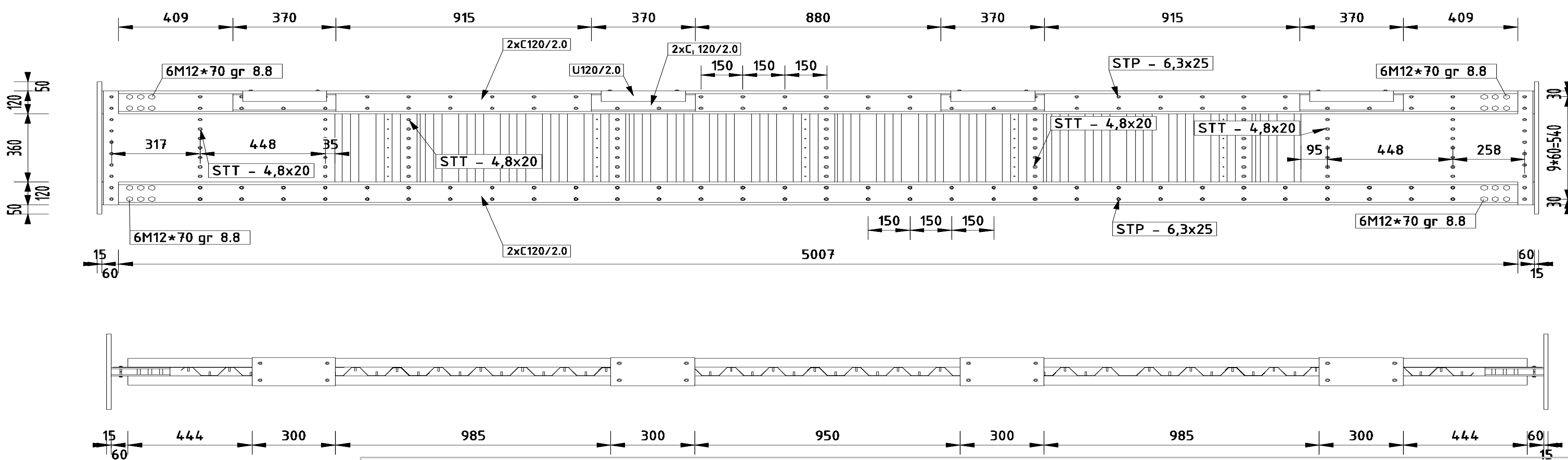
IDEA

CEMSIG Research Centre of PU Timisoara

- is 100% composed of cold-formed steel elements, avoiding the combination of two types of products;
- high protection to corrosion due to the fact that all components are galvanized;
- to develop a structural system able to enable easy and/or automated prefabrication, reduced erection time, mass production and possibility of high-precision quality control.

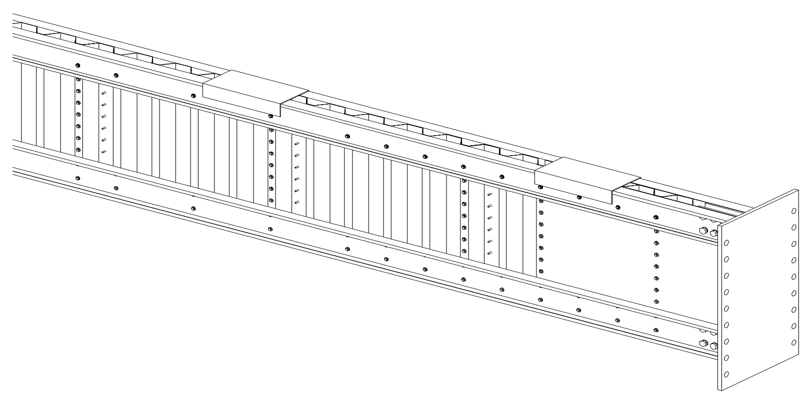
EXPERIMENTAL PROGRAM

CEMSIG Research Centre of PU Timisoara



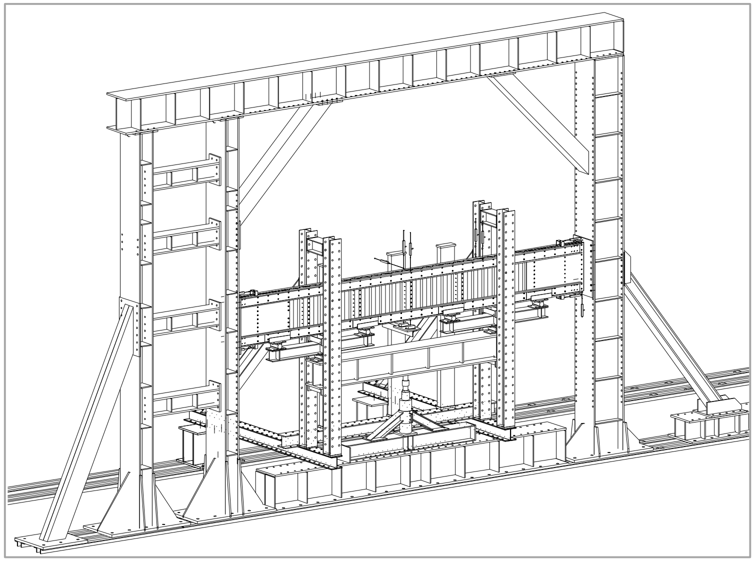
- flanges: – 2xC120/2.0
- corrugated web: -A45/0.7
- supplementary shear panels of 1mm thickness
- self-drilling screws for flange-to-web connections – 6.3x25
- self-drilling screws as seam fasteners – 4.8 x20
- M12 class 8.8 bolts for end connections of back-to-back lipped channels to the supports

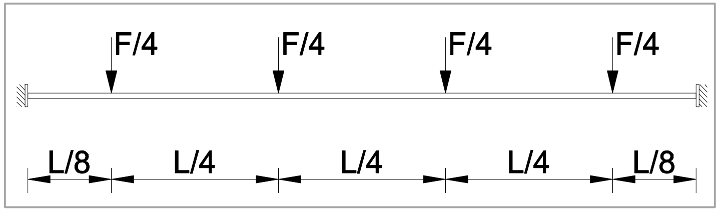
Actual solution : SCREWED !



EXPERIMENTAL PROGRAM ⇒ 5 SPECIMENS

CWB - 1	Standard solution: flange-to-web connection in every corrugations and uniformly distributed seam fasteners
CWB - 2	Standard solution + supplementary lipped channel sections C under the load application points
CWB - 3	Optimized solution by adapting the flange-to-web connections according to the distribution of shear stresses (connections at each second corrugations where the shear force decreases)
CWB - 4	Optimized solution by eliminating shear panels and doubling of corrugated webs in the zones with high shear forces
CWB - 5	Optimized solution by adapting both the flange-to-web connections and seam fasteners to the distribution of shear stresses





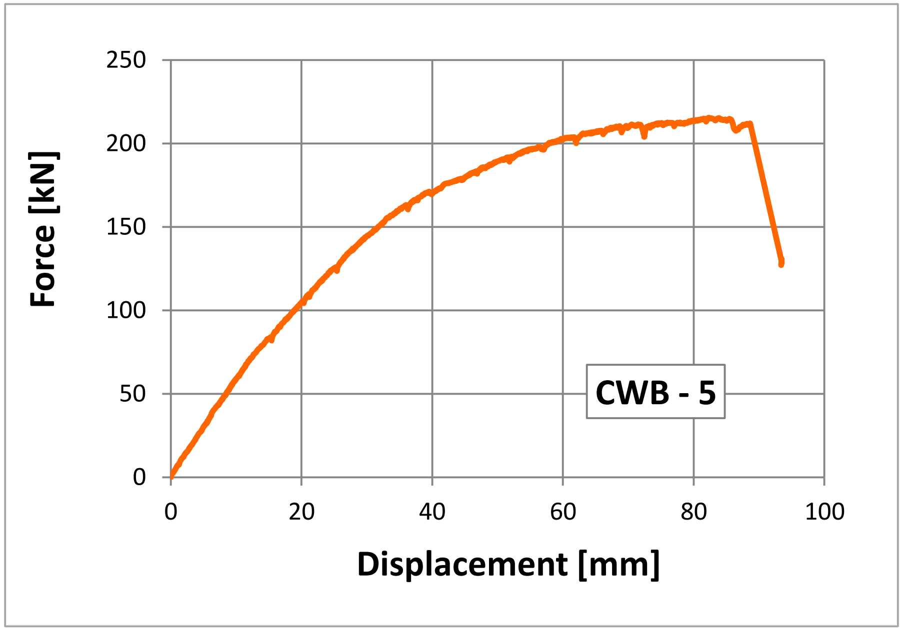
Monotonic load - v_{test}=2mm/min

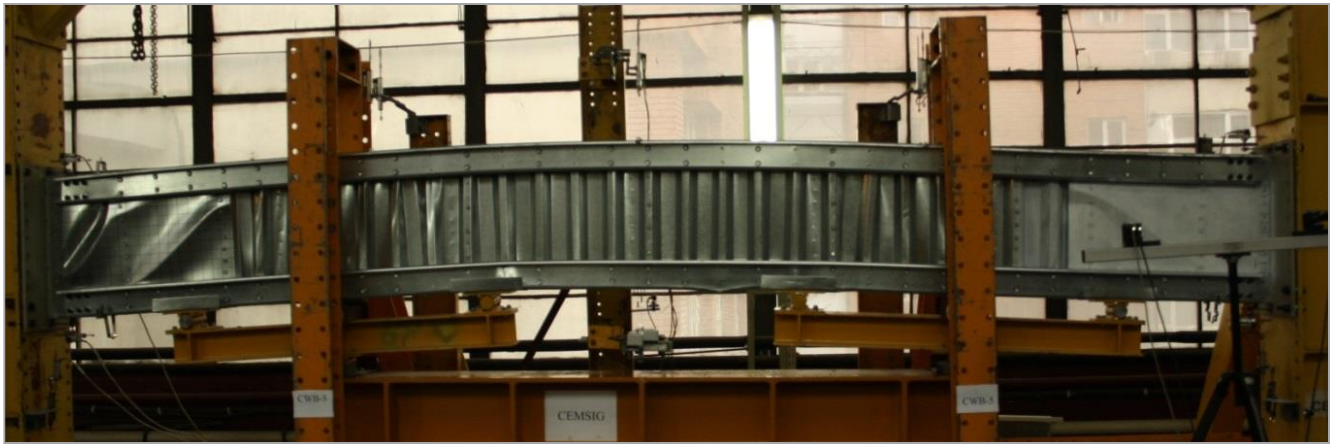
6 points bending test

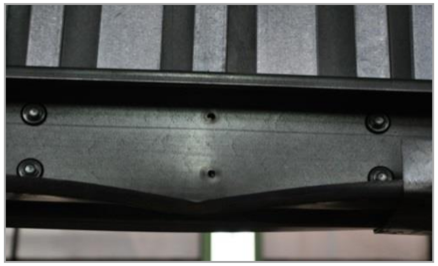
EXPERIMENTAL PROGRAM

Beam CWB-5

- First deformation – distortion of corrugated web near support – 21mm
- $K_{0\text{-}Exp}$ =5516.23 N/mm
- F_{max}= 214.575 kN
- Collapse at 88mm displacement



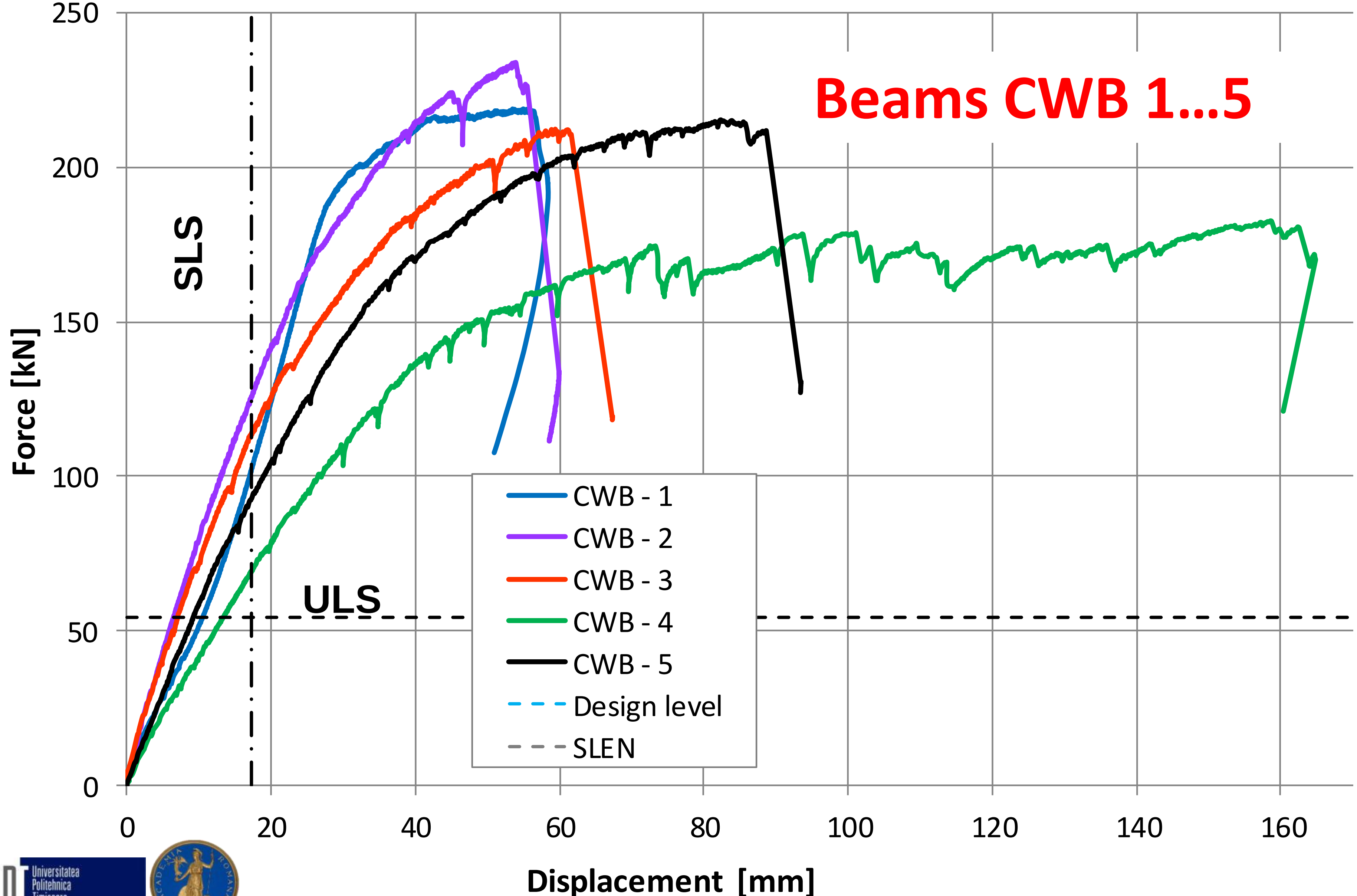




EXPERIMENTAL PROGRAM

Beam CWB-5

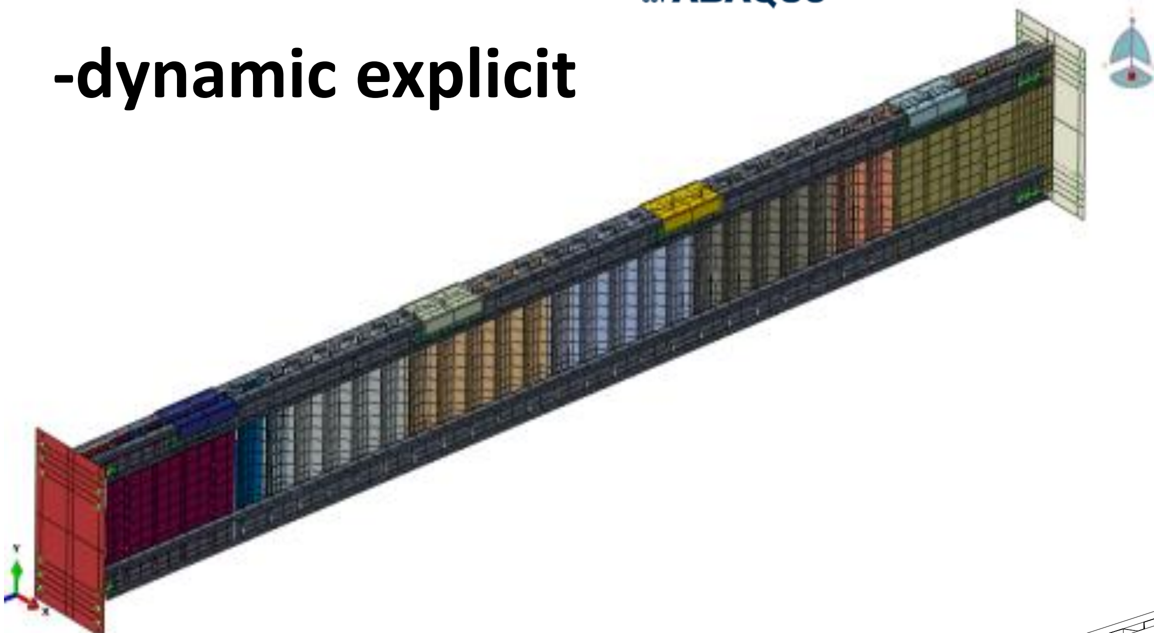
EXPERIMENTAL PROGRAM

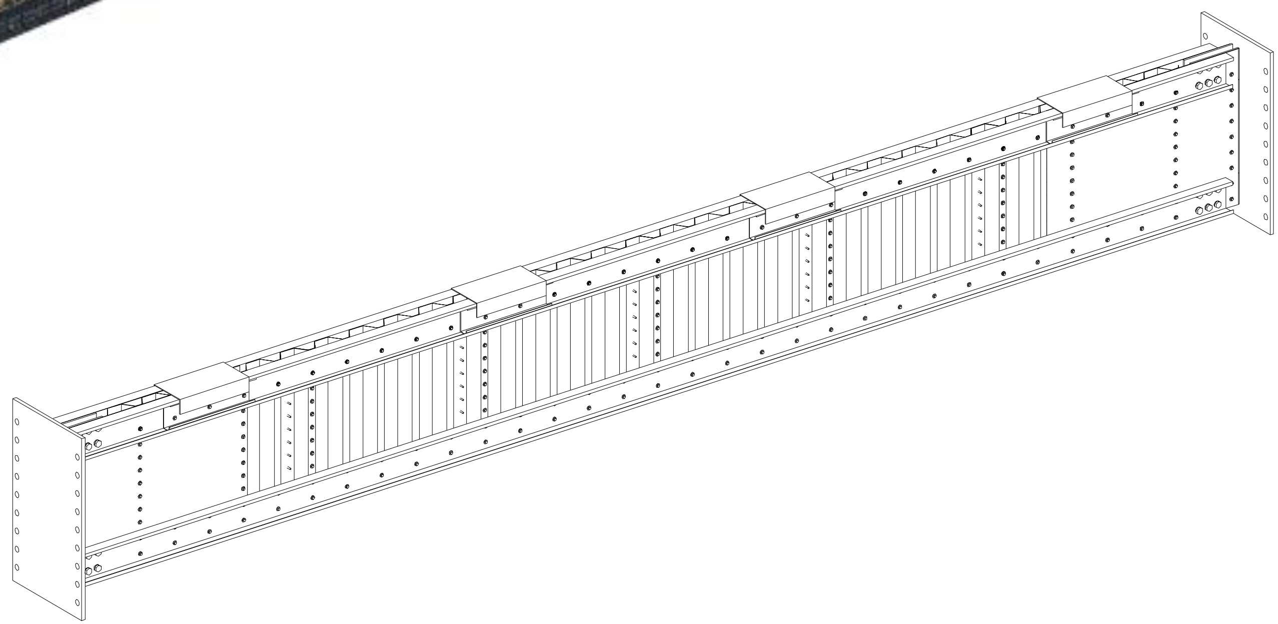


Numerical model calibration and validation

ABAQUS/CAE 6.7.1

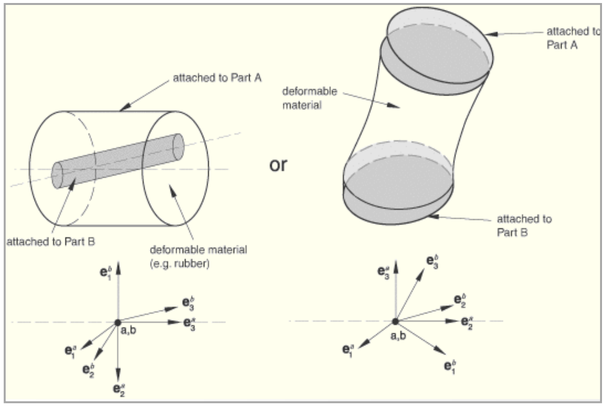
-dynamic explicit

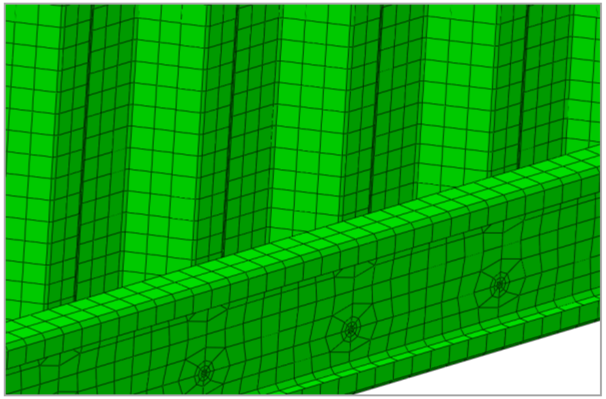


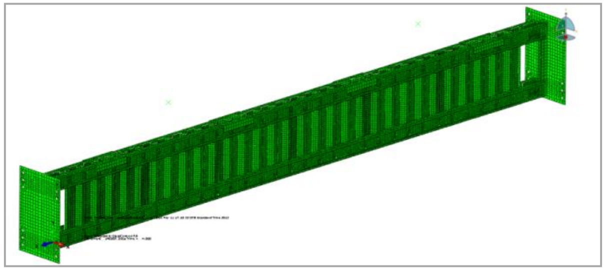


Numerical model calibration and validation

- SHELL Element – S4R type
  - 4 nodes, reduced integration
- CONECTOR Element – CONN3D2 type
  - for self-drilling screws and bolts
  - 2 nodes, 6 DOF per node
  - Non-linear deformation according to imposed load
- BEAM Element – RB3D2
  - rigid body, for load transfer
- BEAM Element – MPC-BEAM type
  - Multi-point constrain beam for DOF coupling

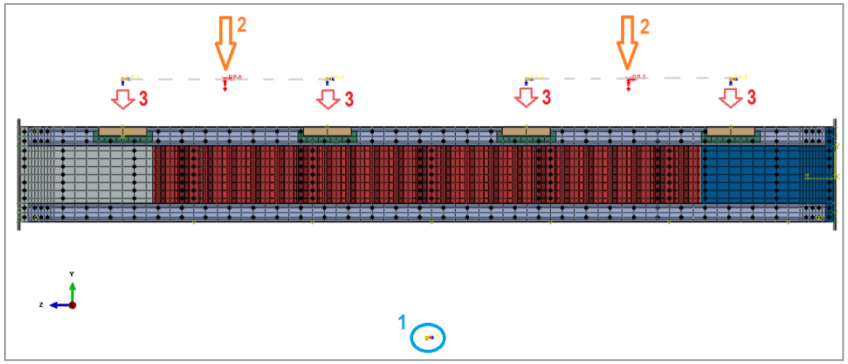


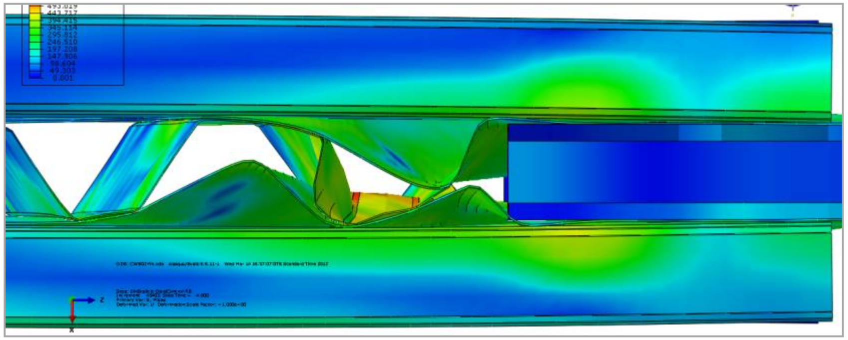




Numerical model

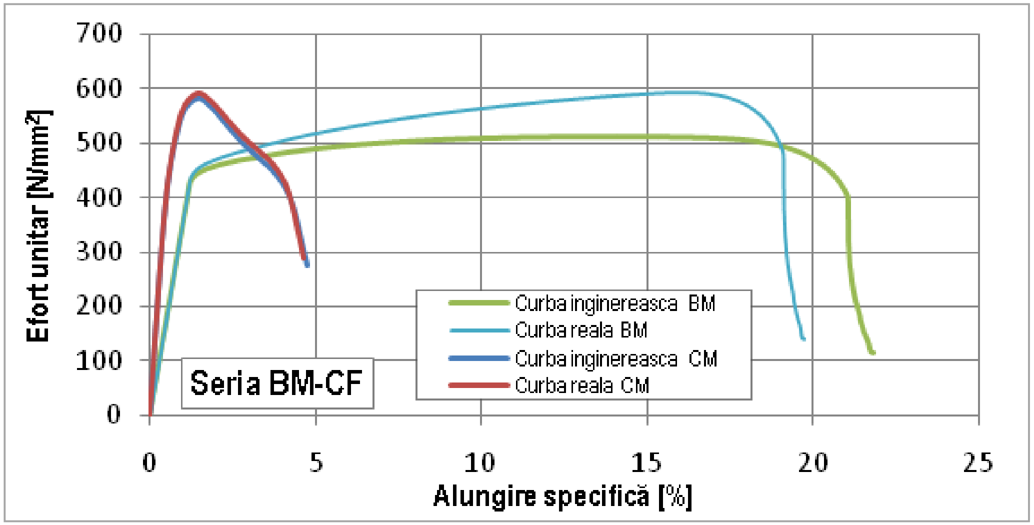
- General contact
  - Normal direction – HARD CONTACT
  - Transversal direction with a friction coefficient of μ=0.1





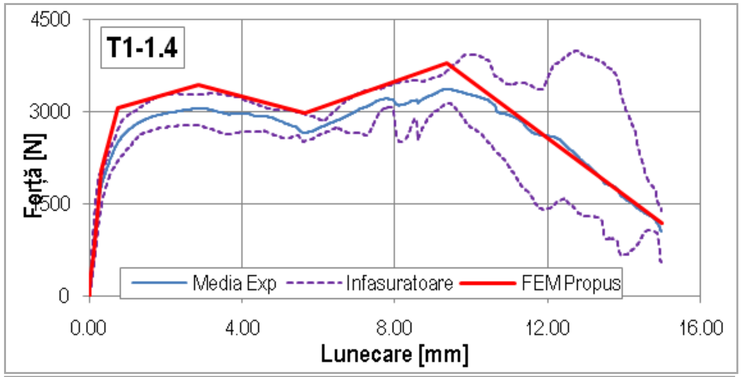
- Material behavior – curves obtained from tests on materials cut from specimens

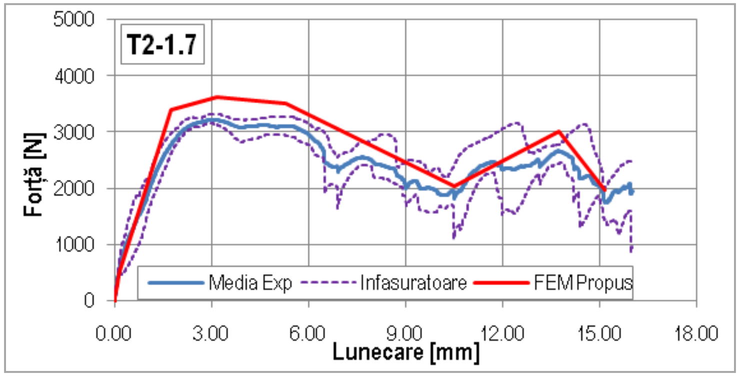
- Initial imperfections – according to first 3 eigenmodes from a LBA

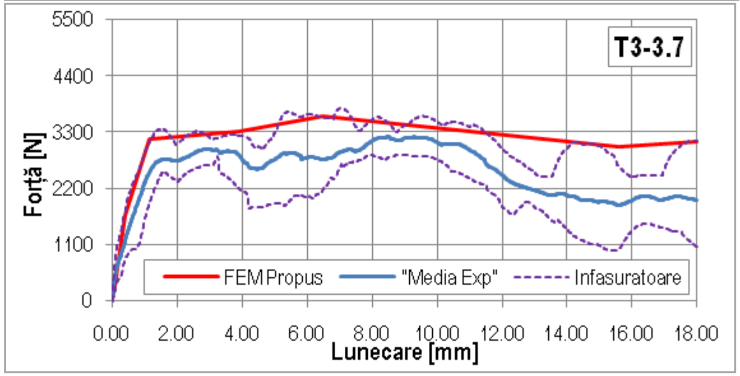


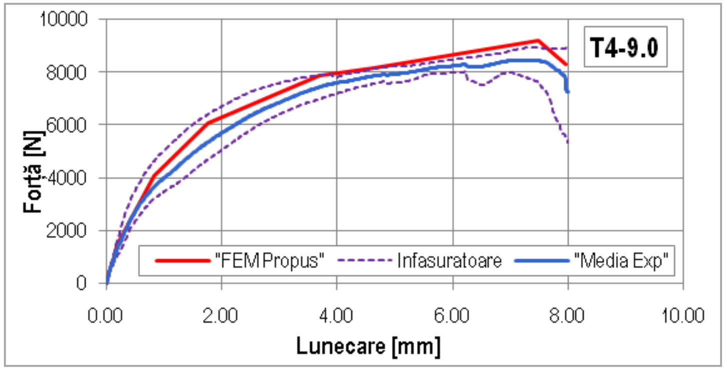
Numerical model

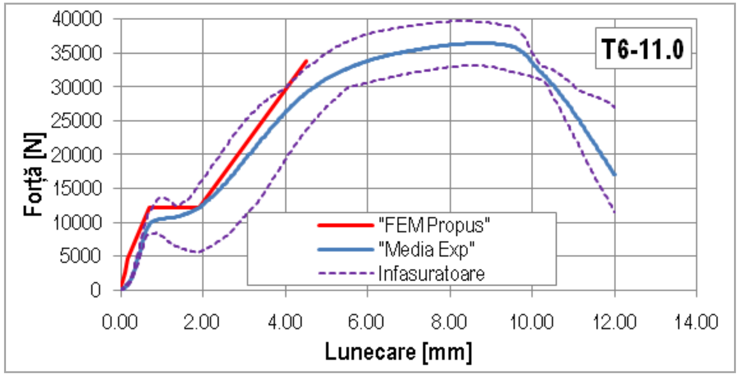
Self-drilling screws and bolts were introduced using CONN3D2 element type according to the mean values recorded from tests of each type of connection.

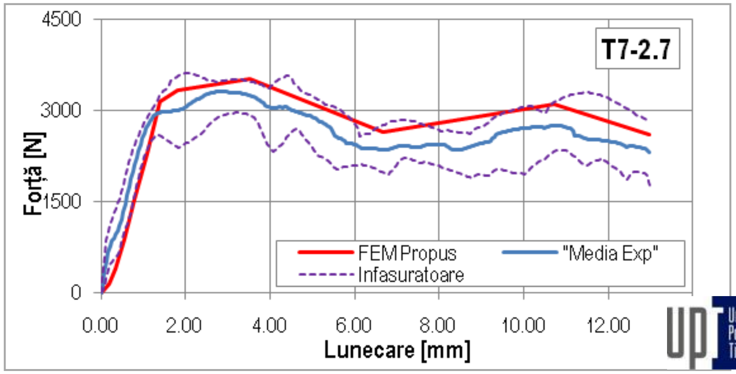












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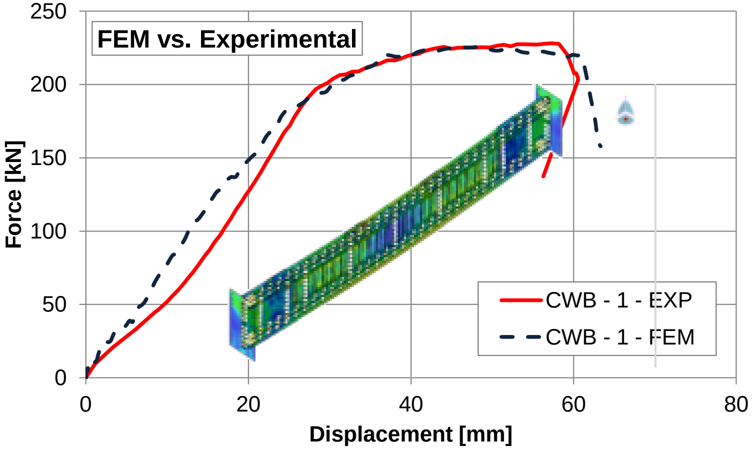
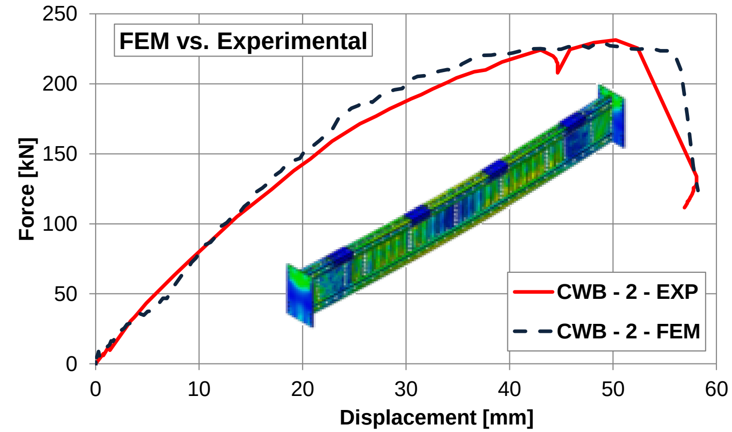
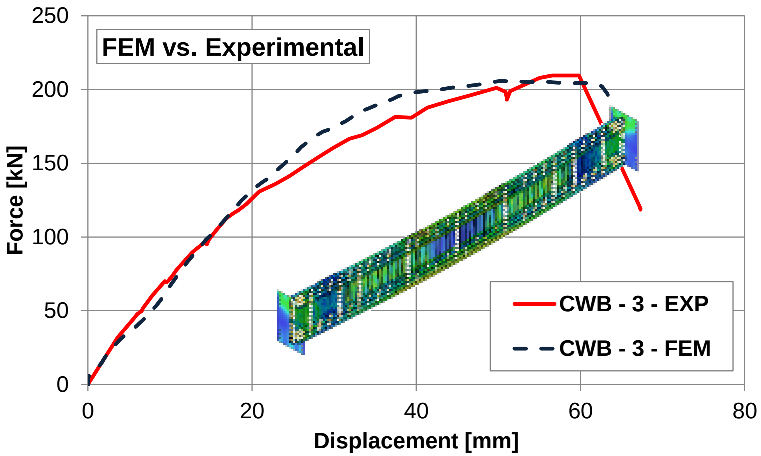
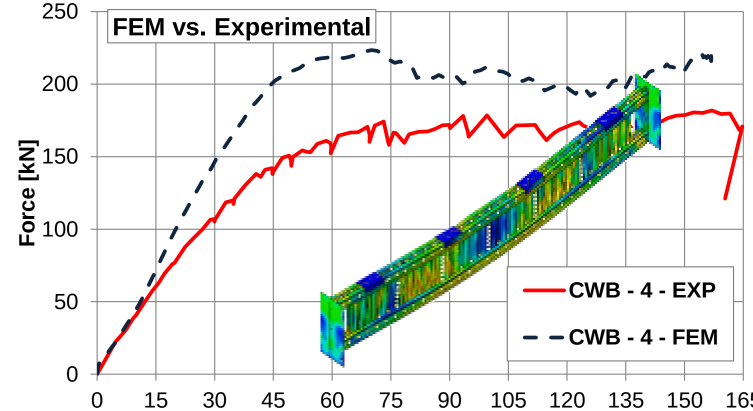
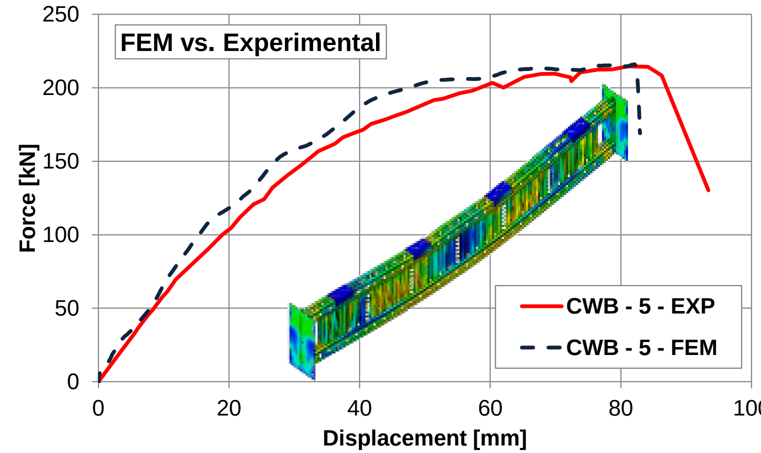
Numerical model











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INITIAL STIFFNESS AND ULTIMATE LOAD: FEM VS. EXPERIMENTAL RESULTS

Beam type	$K_{0\text{-}Exp}$ (N/mm)	$K_{0\text{-}FEM}$ (N/mm)	$F_{max\text{-}Exp}$ (kN)	$F_{max\text{-}FEM}$ (kN)
CWB-1	6862.2	7721.1	218.9	225.9
CWB-2	7831.5	7834.6	231.3	229.5
CWB-3	7184.9	6819.3	209.5	205.8
CWB-4	3985.0	4932.0	181.9	223.5
CWB-5	5516.2	6594.9	214.6	216.0

- it can be noted that the behaviour and maximum load accurately replicate the experimental tests
- in case of CWB-4 beam the numerical results are 23% higher than experimental one. The reason could be the higher degree of flexibility (no shear plates to stiffen the beam).

PN-III-P2-2.1-PED-2016-1684

Fast welding cold-formed steel beams of corrugated sheet web

WELLFORMED

The main objectives of the project:

•to validate a new technological solution, CWB where the connections made of intermittent SW and MIG/MAG W;

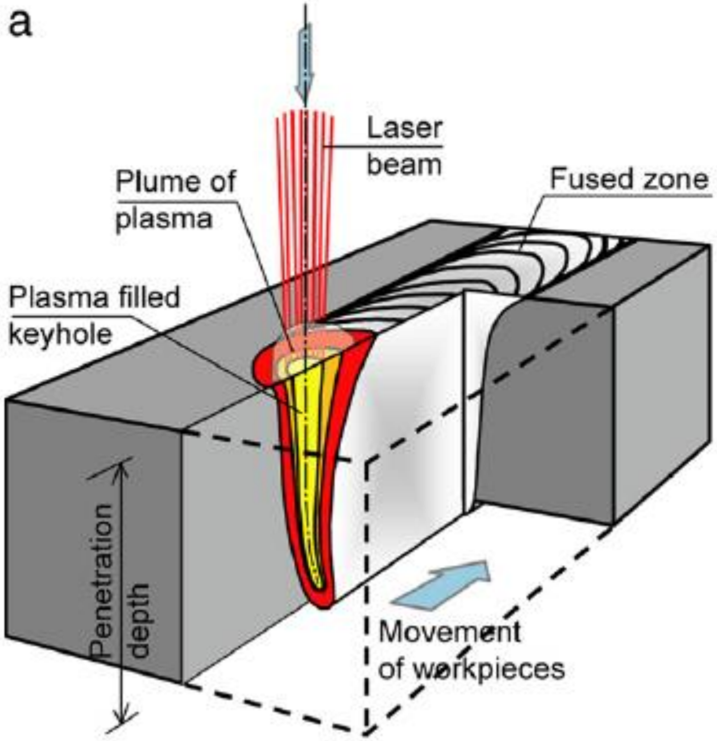
•to validate it by a parametric study via numerical models using ABAQUS FEM tool;

•to adapt/extend the rules of the EN 1993-1-5, Annex D to this new type of beams;

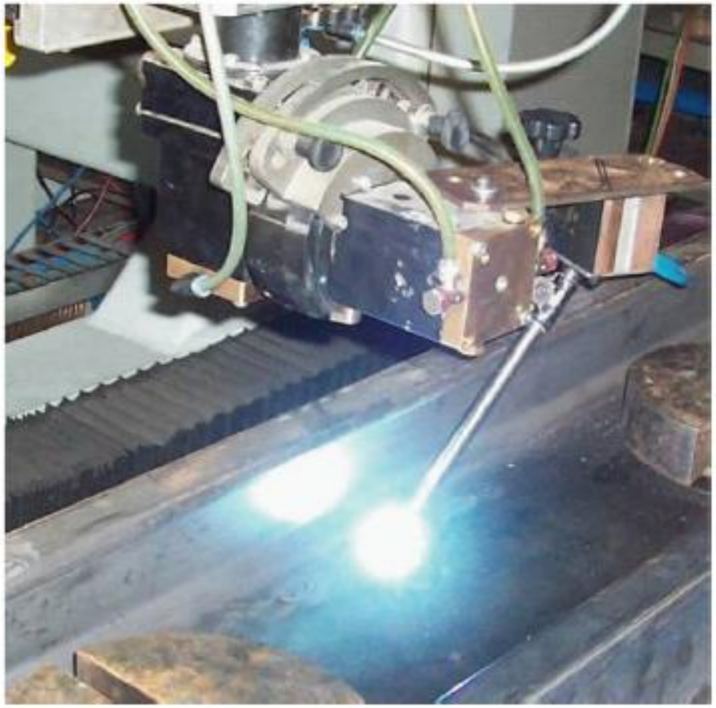
•to develop a structural system able to satisfy easy prefabrication, automation and mass production.

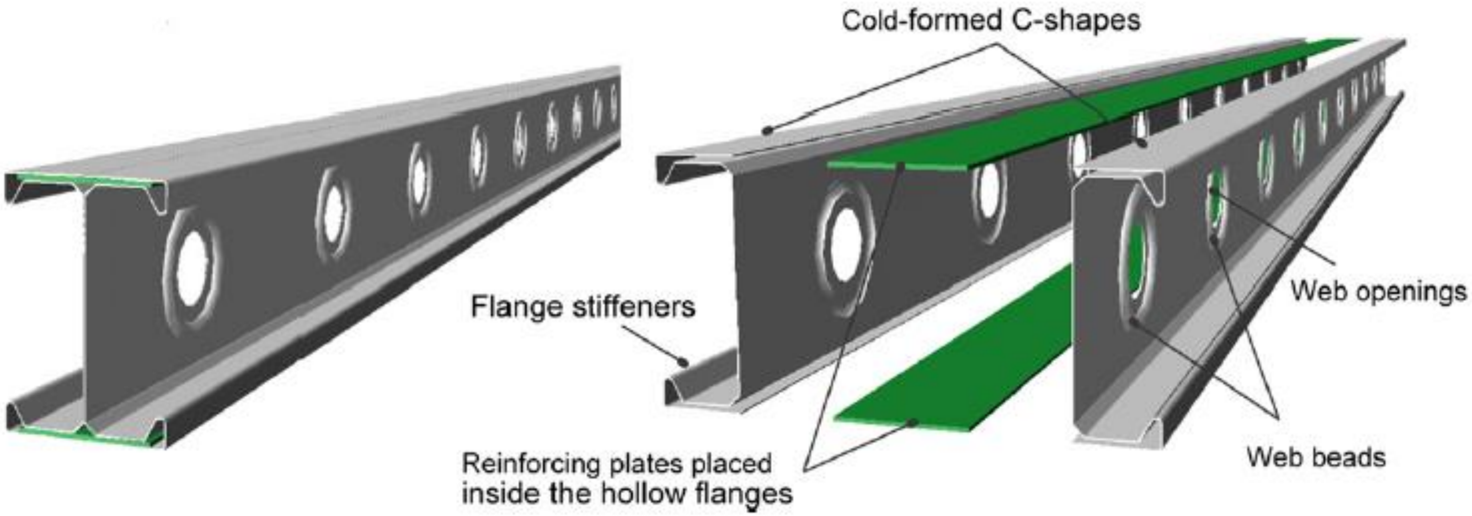
Laser welding

a

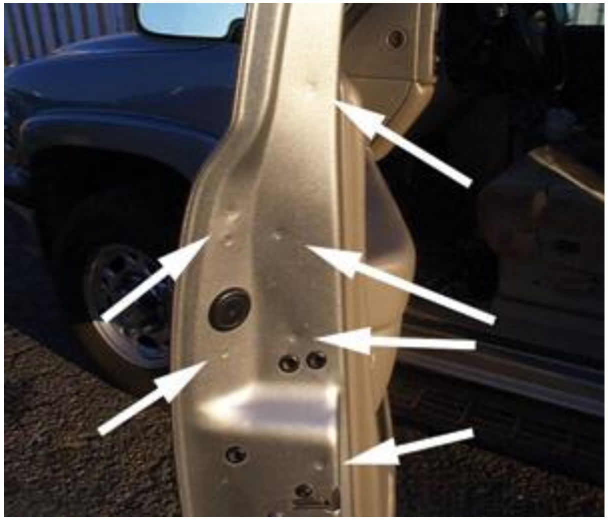


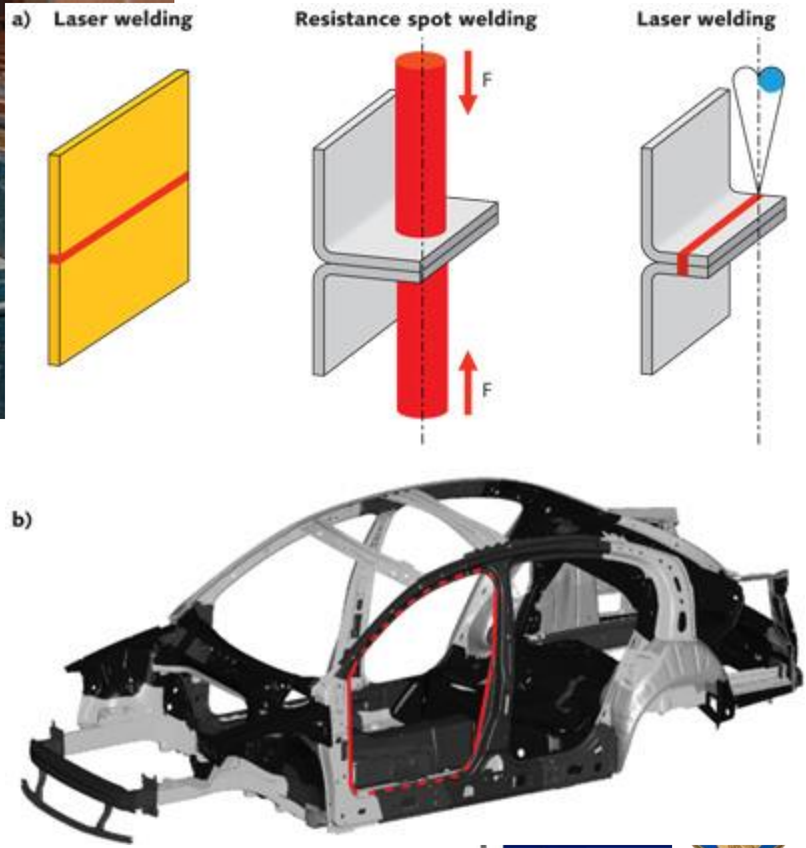
b





Spot welding





Spot welding

TELWIN

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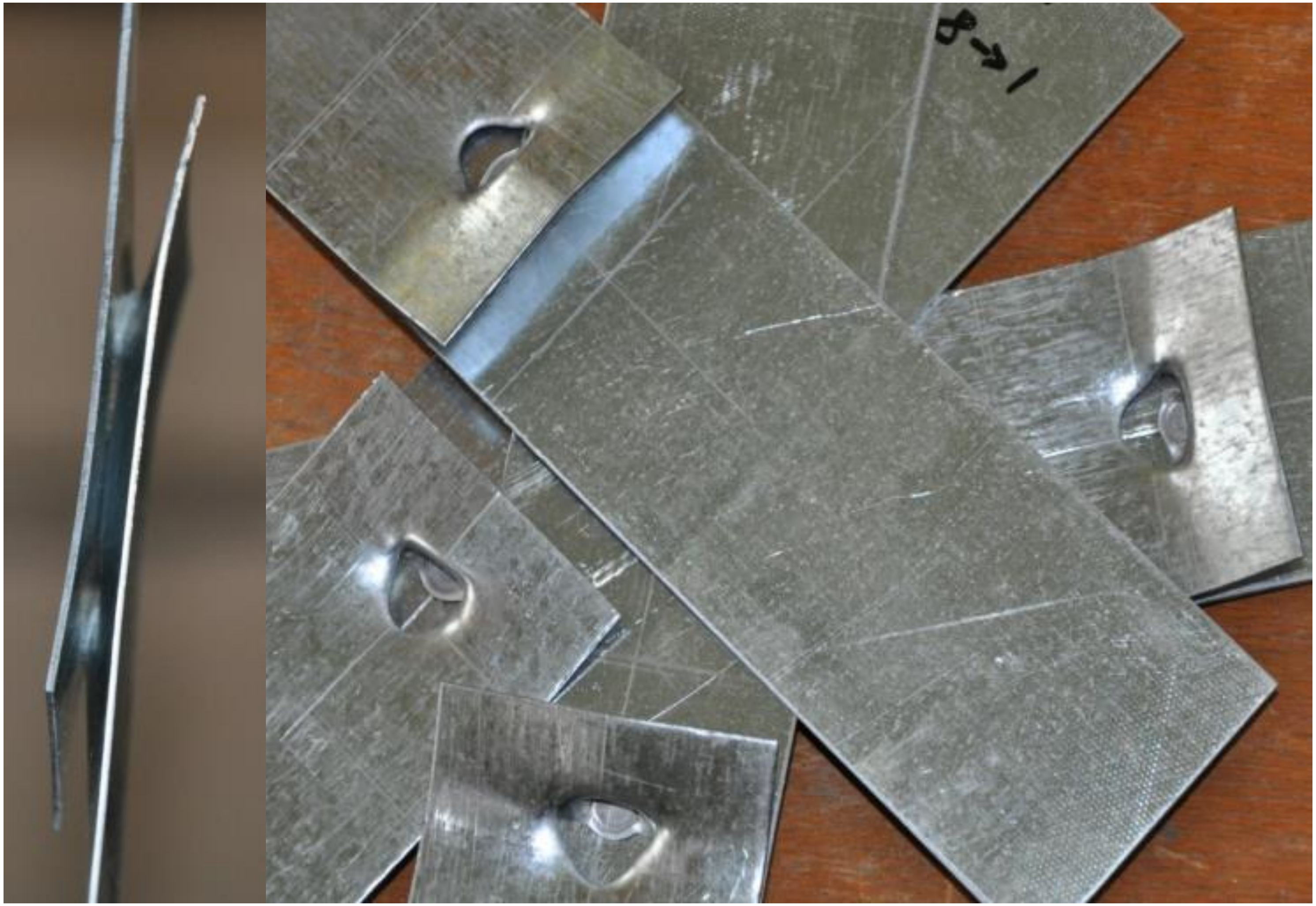
Spot welding – preliminary investigations



MIG/MAG welding equipment impulse welding

REHM® Welding Technology

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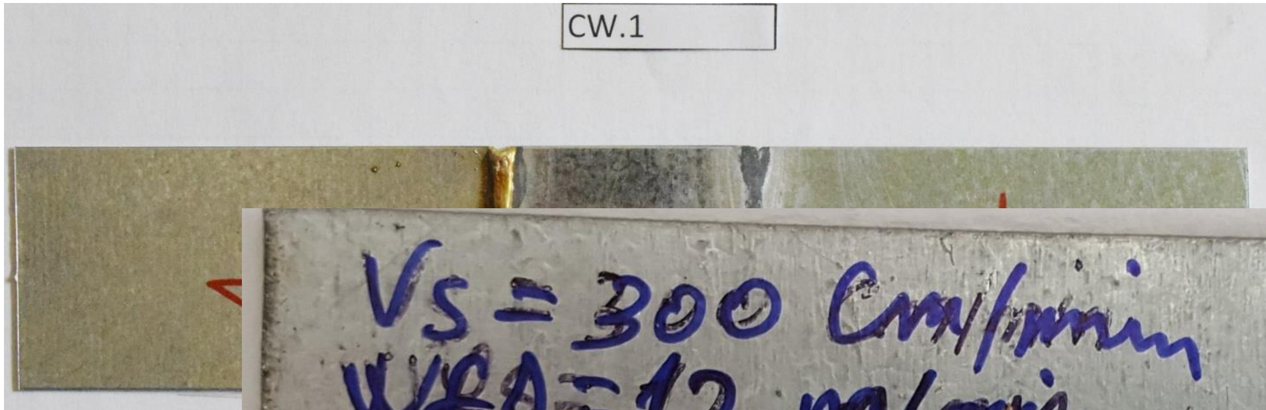
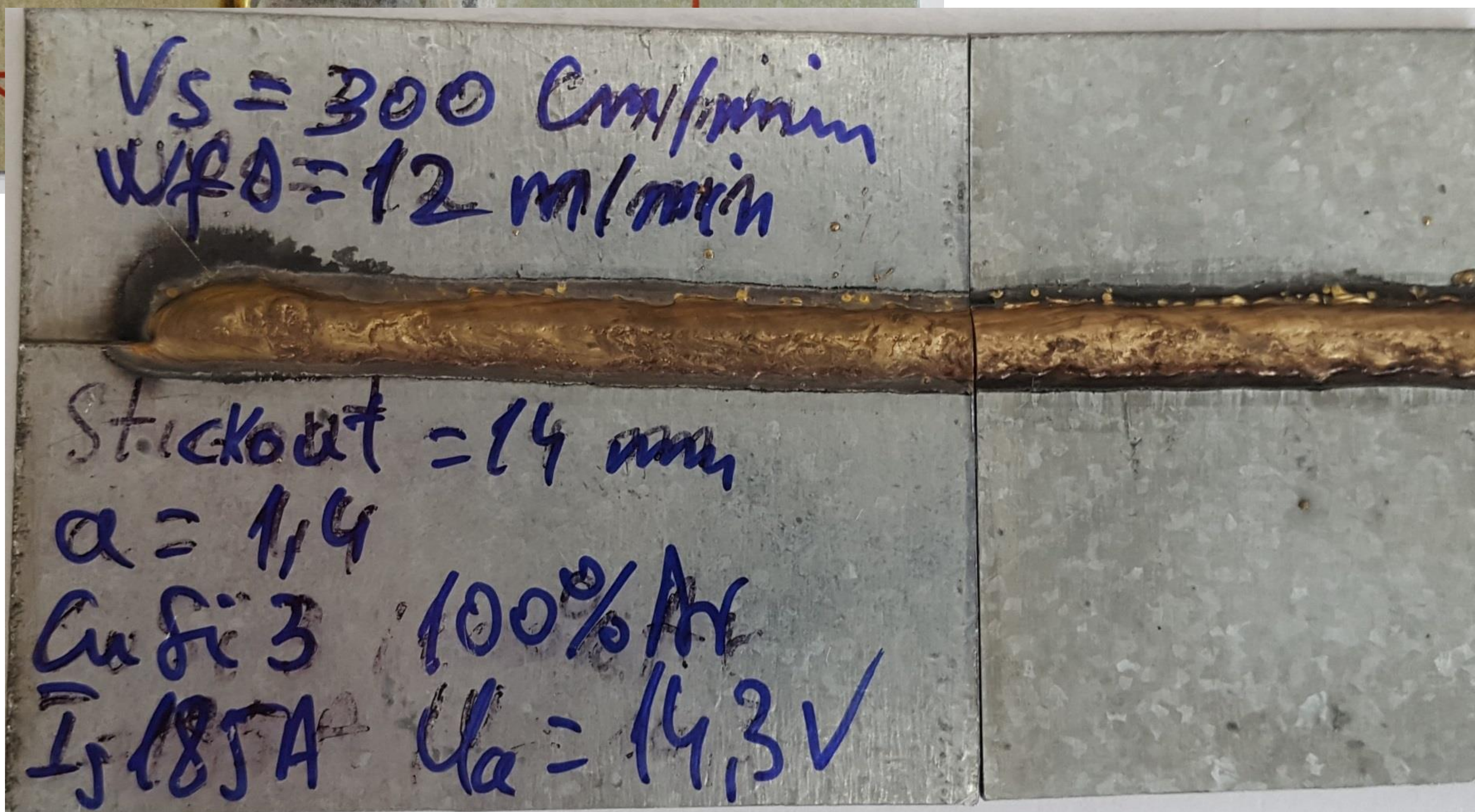
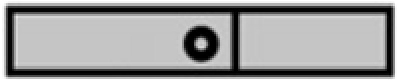
MIG/MAG welding equipment impulse welding - preliminary investigations

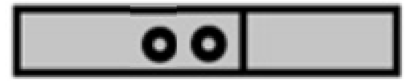


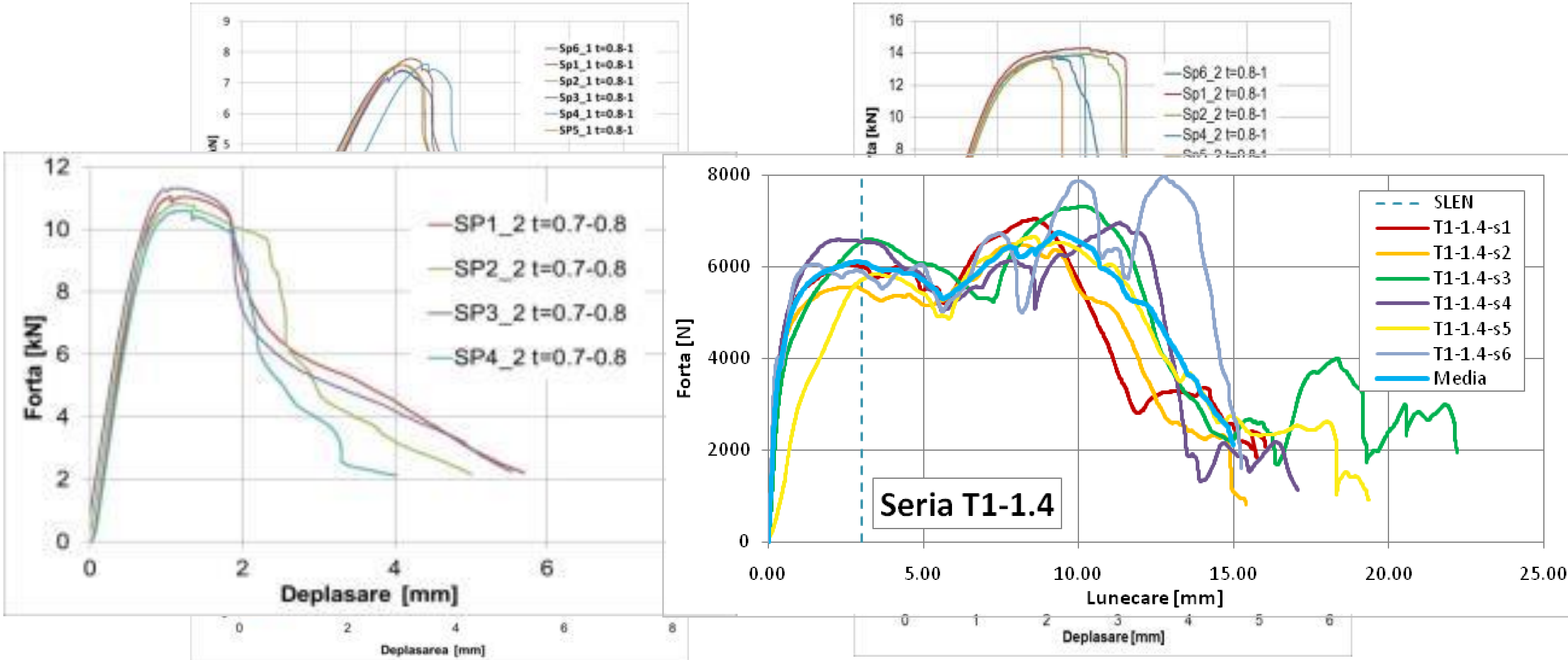


(a), (b), (c) one spot

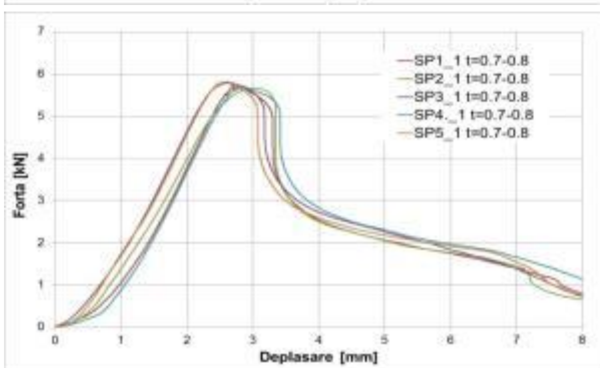


(d), (e), (f) two spots

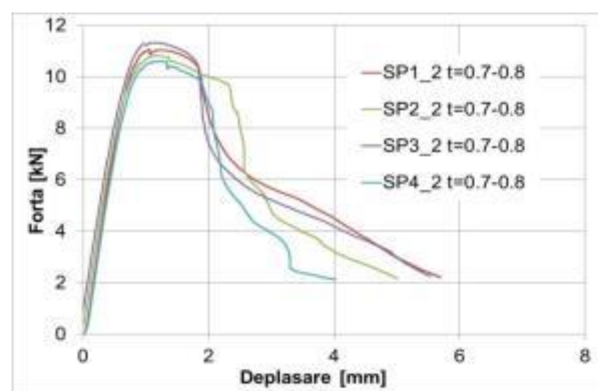




c)



f)



WPs:

WP 1: Design of testing program

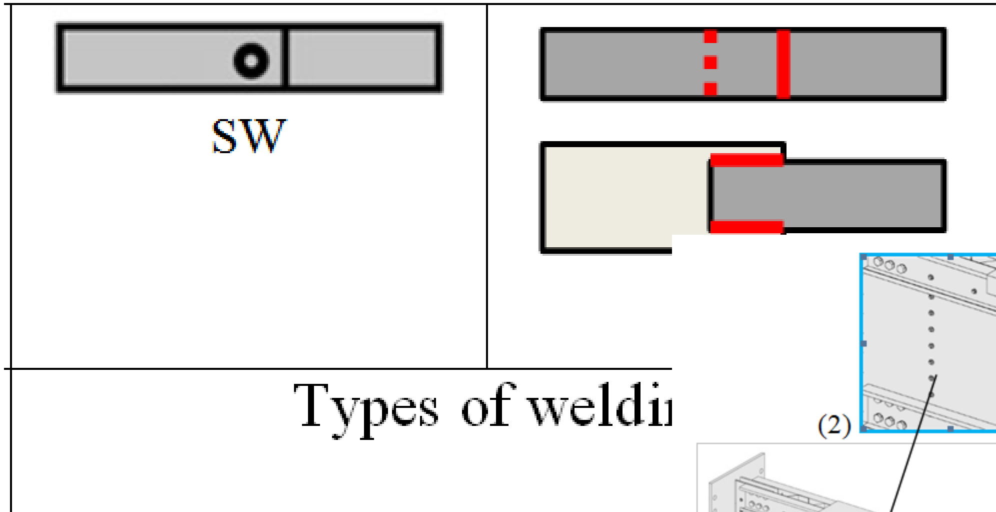
WP 2: Tests of welded connections and optimisation of fastening technology

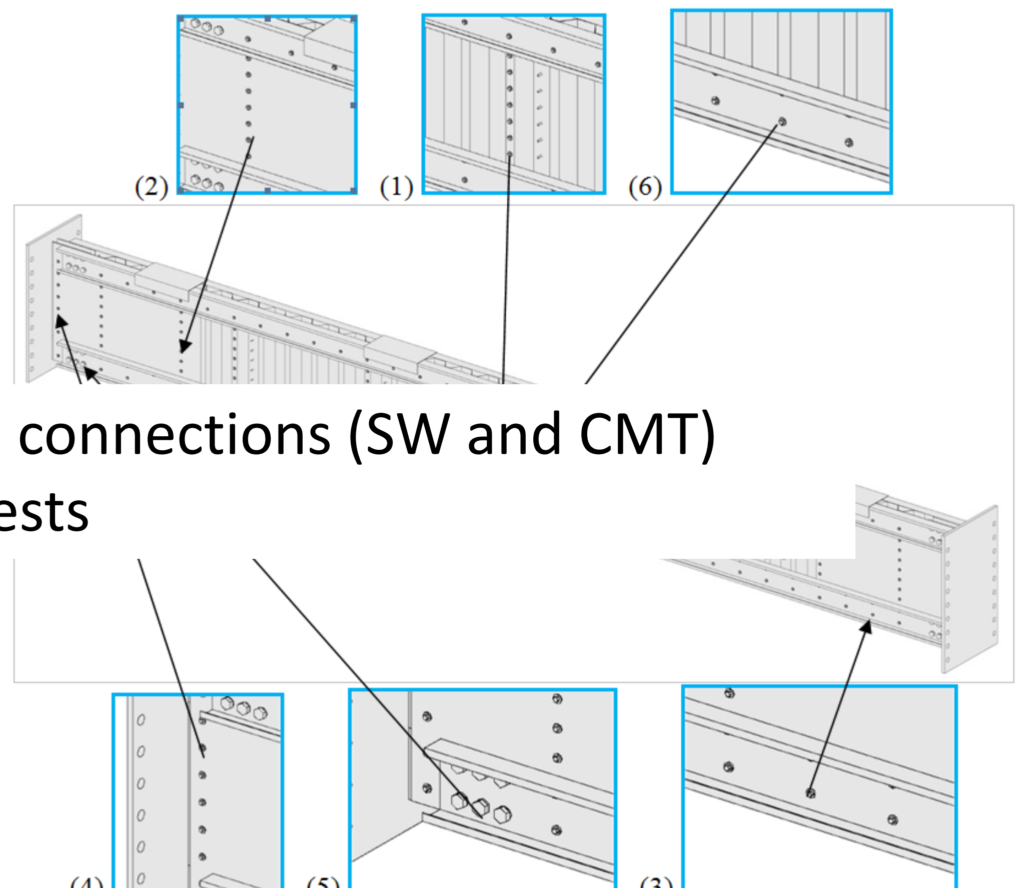
WP 3: Tests on full scale CWB beams

WP 4: Numerical testing of beams and parametric investigations

WP 5: Exploitation and dissemination of results

WP 2: Tests of welded connections and optimisation of fastening technology

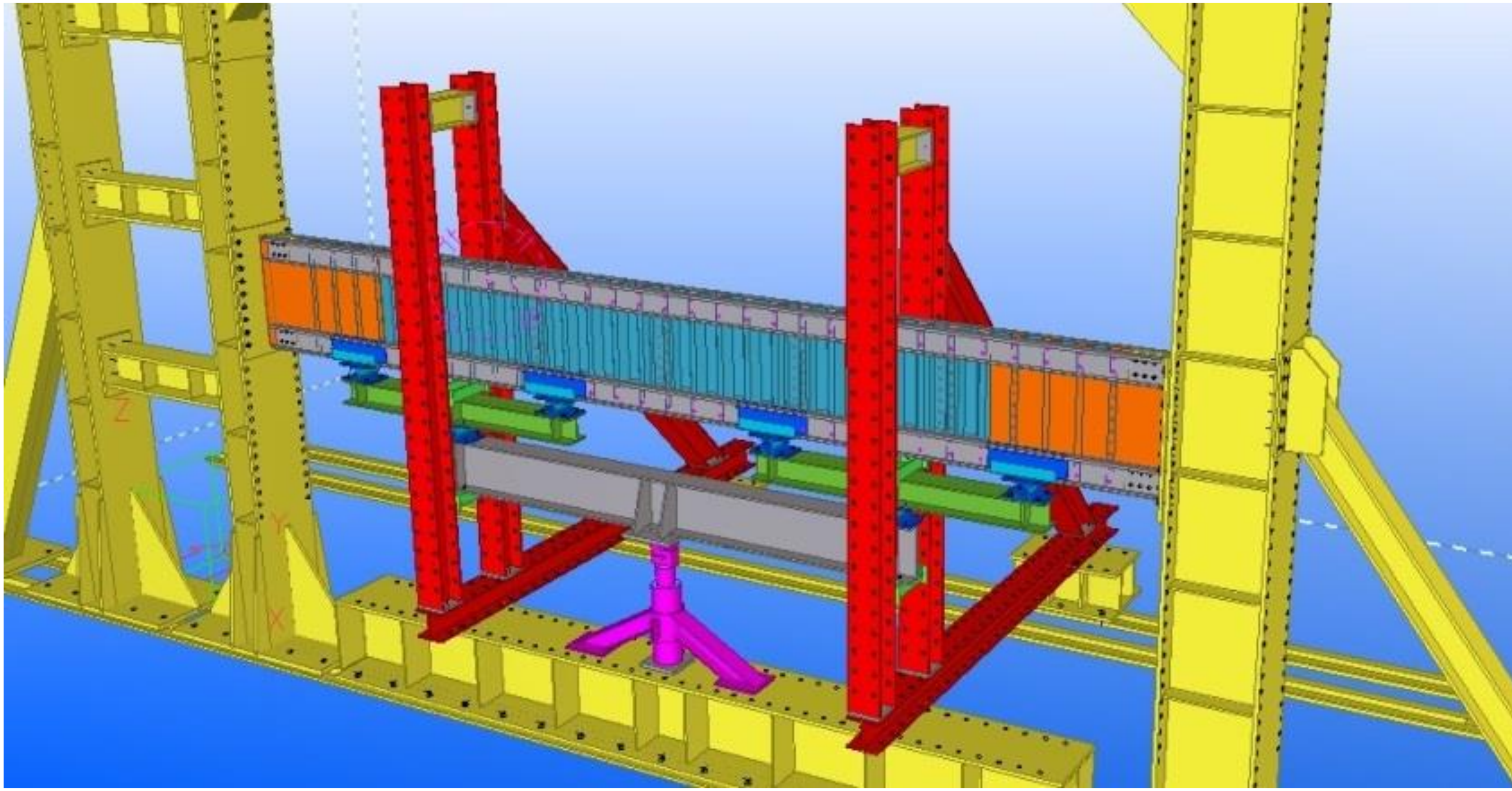




670 specimens for welded connections (SW and CMT)

95 specimens for tensile tests

WP 3: Tests on full scale CWB beams



4 full scale beam specimens two using SW and two using CMT

CONCLUSIONS

- several types of beams with corrugated webs and different arrangements for self-drilling screws and shear panels were experimentally tested;
- very good agreement between numerical models and experimental ones, both in failure modes and load-displacement curves;
- a new experimental program on connecting details (using SW and MIG/MAG W) and full-scale beams has started at the PU Timisoara, on the purpose to demonstrate and evaluate the performances of proposed solutions;
- the results are encouraging and prove the potential of this solution to standardized beams and industrialized fabrication.

Thank you for your attention!

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