Project title: **Innovative lightweight cold-formed steel-concrete composite floor system**
Acronym: **LWT-FLOOR** Project ID: **UIP-2020-02-2964**
5th LWT-FLOOR Project Workshop, Zagreb, 18th-19th December 2025

Najnovija dostignuća u sastavljenim čeličnim elementima od hladno oblikovanih profila s valovitim hrptom

Recent Developments in Built-Up Cold-Formed Steel Components with Corrugated Webs

Prof. Viorel Ungureanu

Universitatea Politehnica Timișoara

University of Zagreb/Faculty of Civil Engineering
http://www.grad.unizg.hr/lwtfloor

OBJECTIVES

To present recent research developments on cold-formed steel beams with corrugated web (CWB) using

spot welding;
MIG brazing;
laser welding

from components to structures;

Self drilling screws ➔ Spot welding / MIG brazing

➔ Laser welding

ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

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






ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

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

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 ⇒ EN 1993-1-5 Annex D

The IDEA

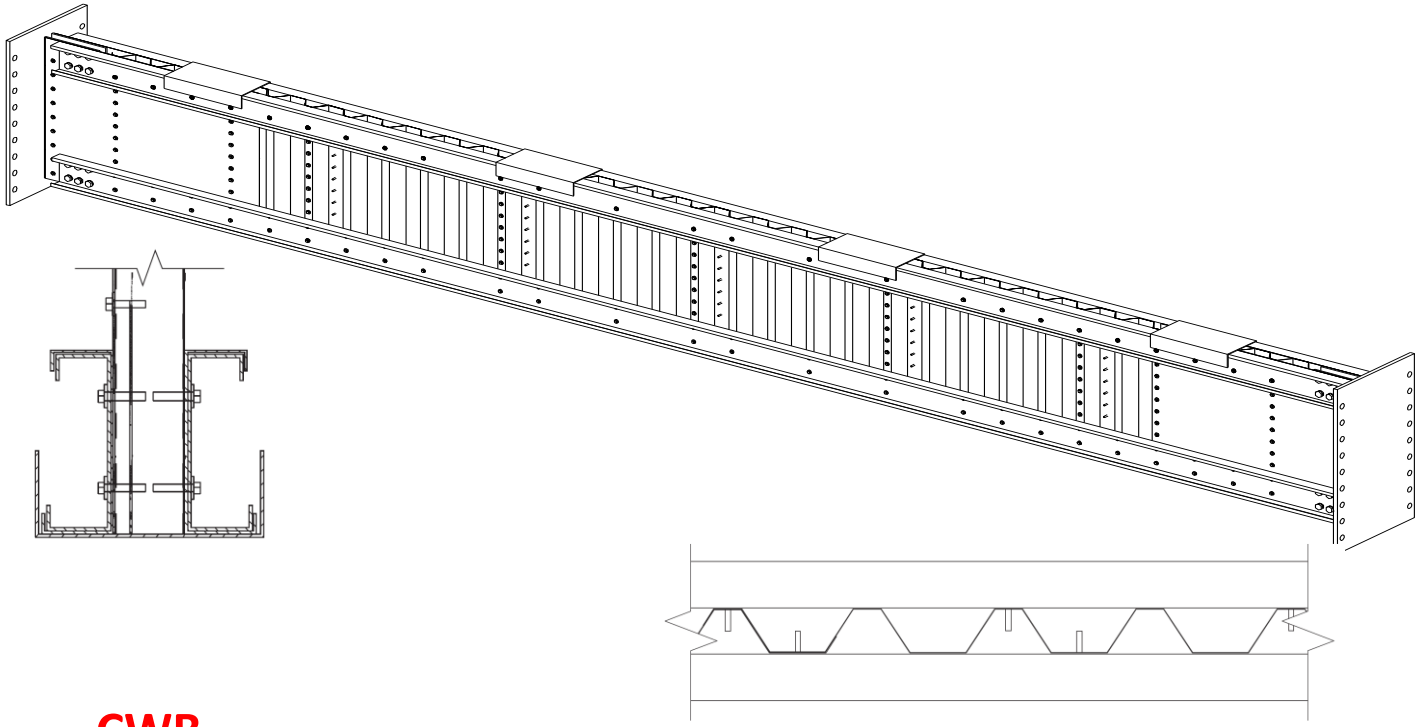
CEMSIG Research Centre of PU Timisoara

- 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.

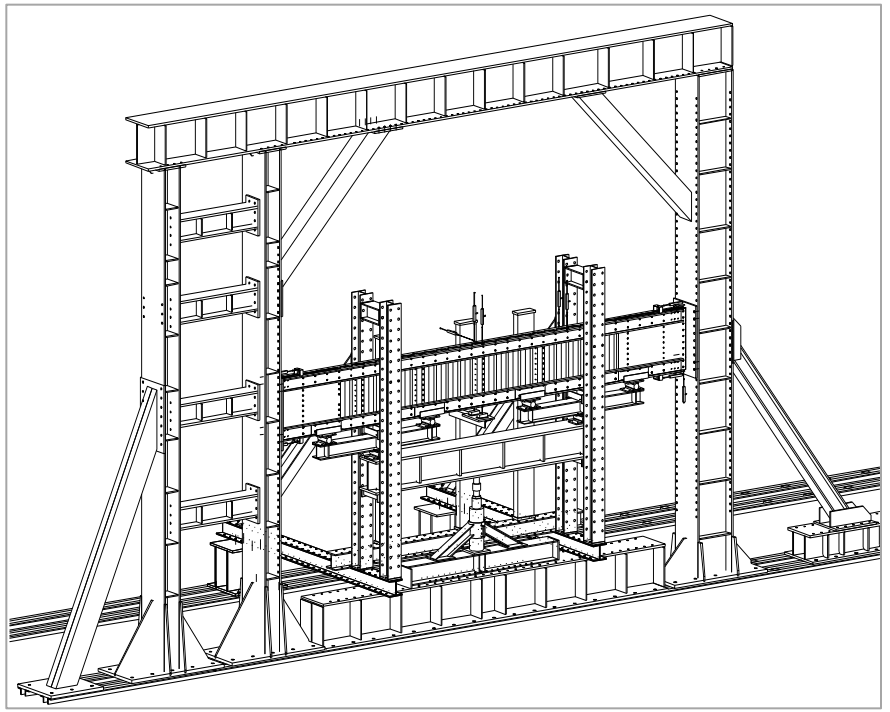
Initial solution : Self-drilling Screws!

Dubina D., Ungureanu V., Gîlia L. (2015): Experimental investigations of cold-formed steel beams of corrugated web and built-up section for flanges. *Thin-Walled Structures*, 90(2015), pp. 159-170.

EXPERIMENTAL PROGRAM ⇒ 5 SPECIMENS

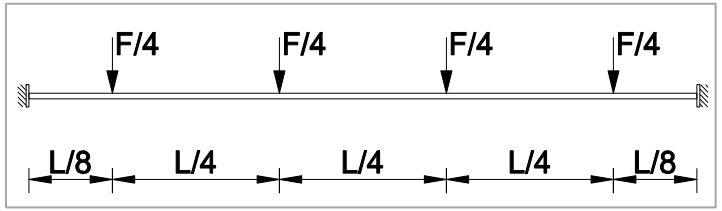


Initial solution : Self-drilling Screws!



CWB

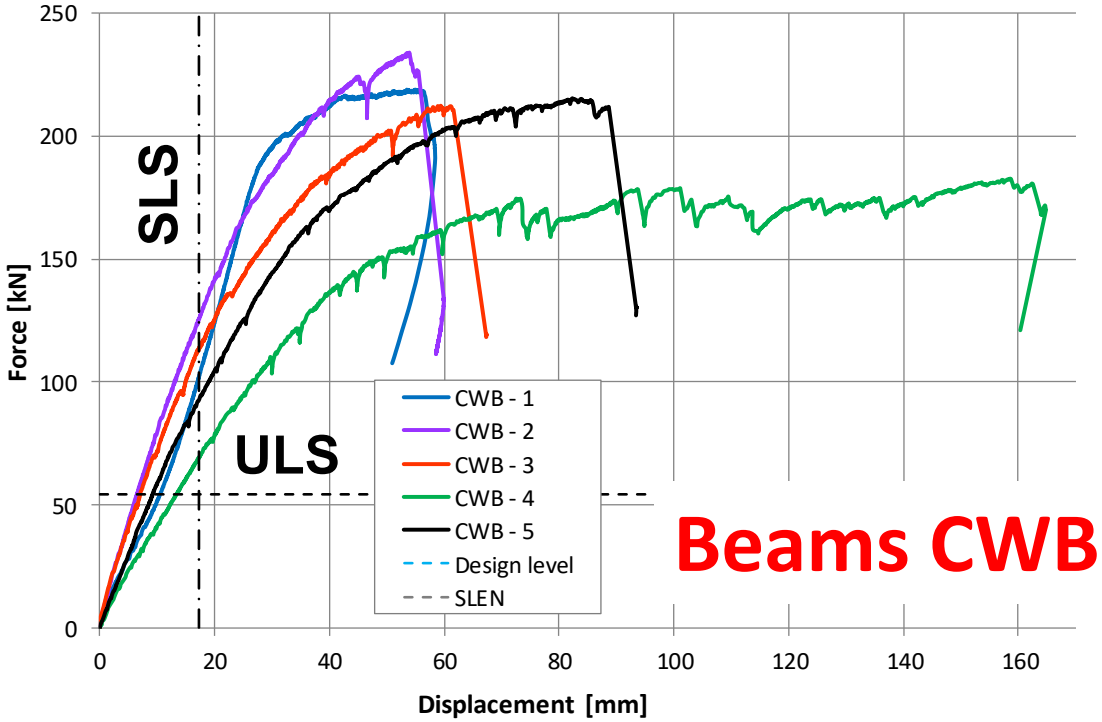
- Flanges: - 2xC120/2.0;
- Corrugated web: - A45/0.7;
- Supplementary shear panels: 1 mm;
- Self-drilling screws for flange-to-web connections: 6.3x25;
- Self-drilling screws as seam fasteners to connect web: 4.8 x20;
- Bolts – end plate connections of the beam: M12 gr. 8.8.



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

D. Dubina, V. Ungureanu și L. Gilia, „Experimental investigations of cold-formed steel beams of corrugated web and built-up section for flanges”, *Thin-Walled Structures,* nr. vol. 90, 2015.

EXPERIMENTAL PROGRAM

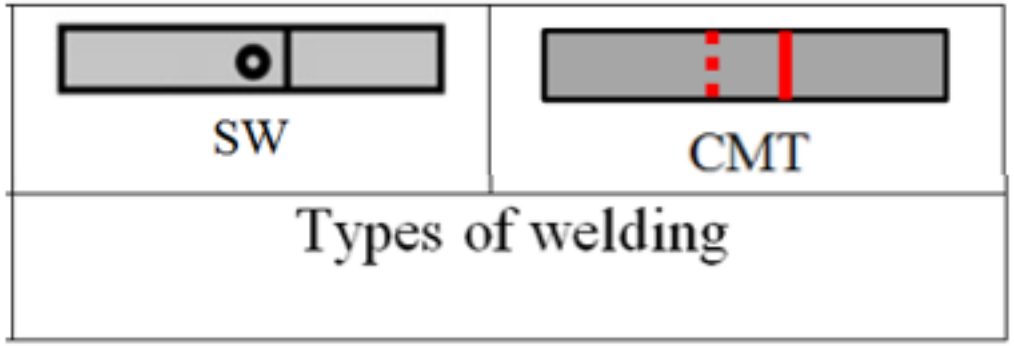


Beams CWB 1…5

Improvements need:

reduce manual labor and improve efficiency to support mass production

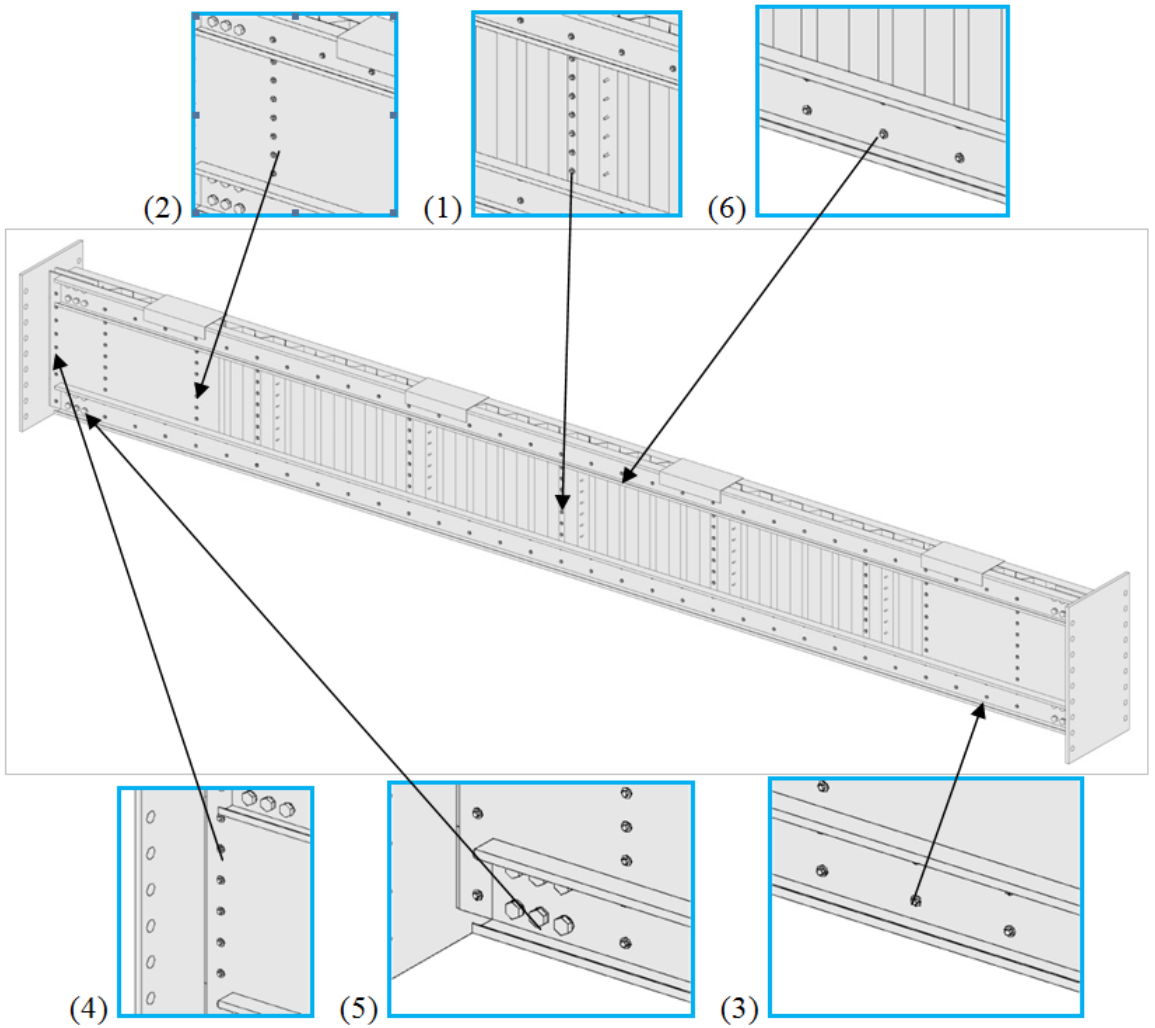
Tests of welded connections and optimisation of fastening technology



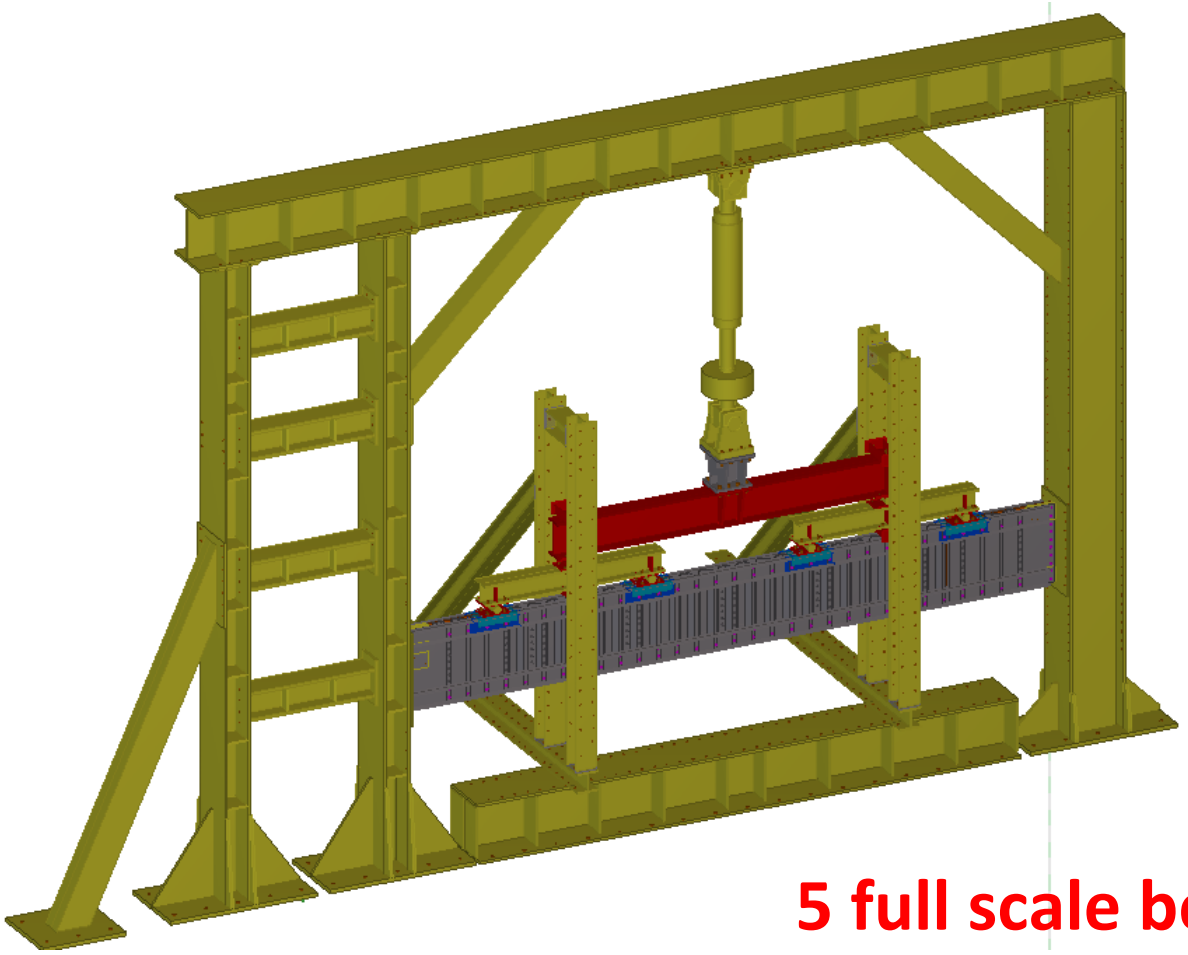
Tensile-shear tests on lap joint specimens t = 0.8; 1.0, 1.2; 1.5; 2.0 and 2.5 mm);

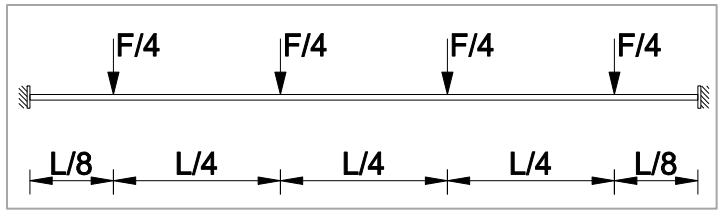
670 specimens for welded connections (SW and CMT)

95 specimens for tensile tests



Tests on full scale CWB beams





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

5 full scale beam specimens

2 using SW and 3 using MIG brazing

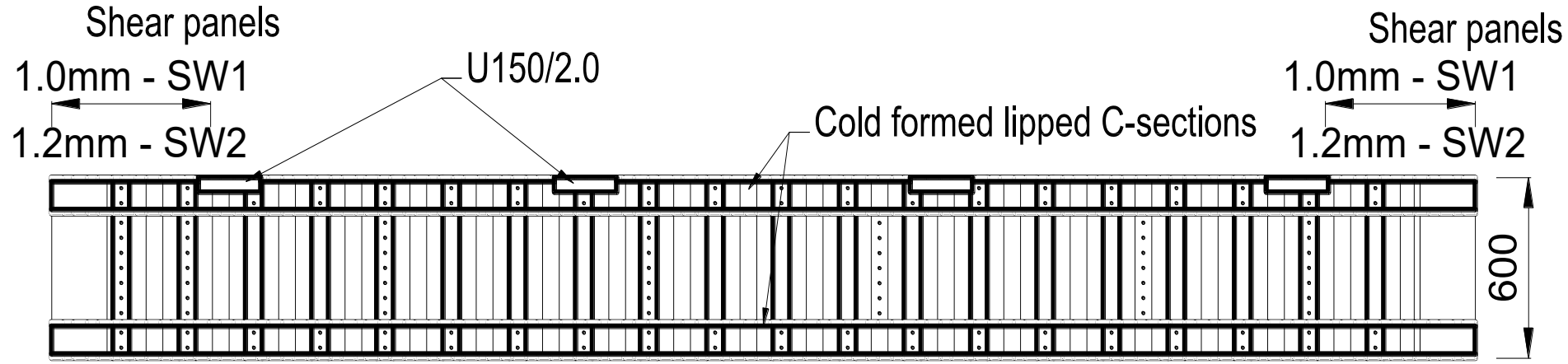
+

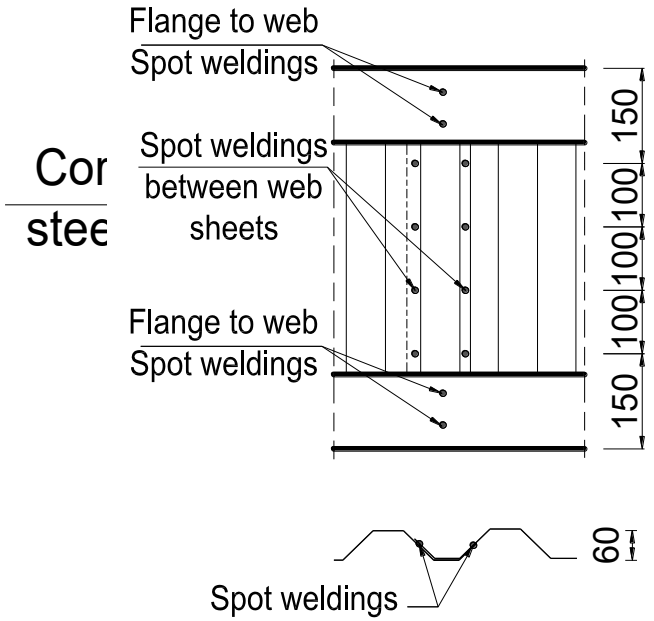
2 full scale beam specimens with web openings

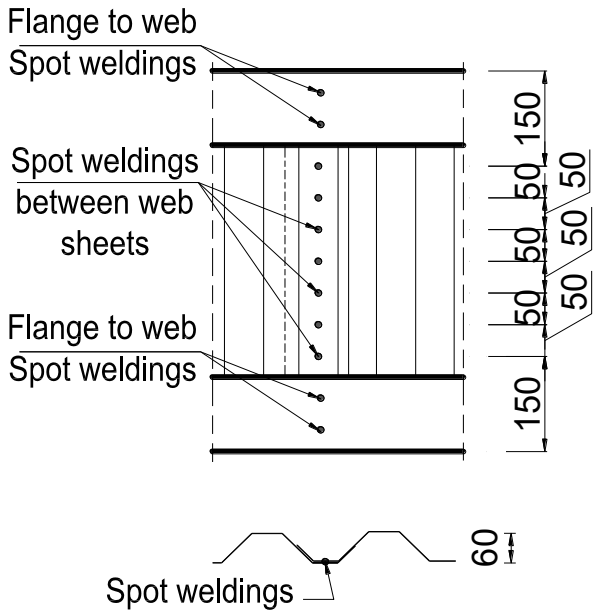
TESTS ON FULL SCALE CWB BEAMS

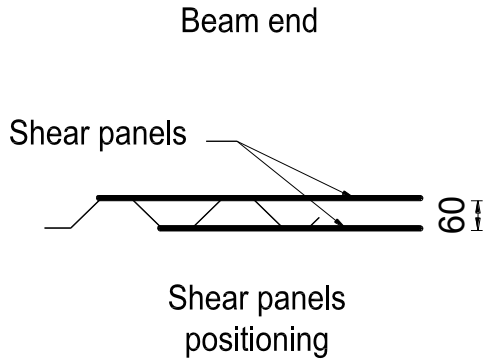
Spot welding

2 full scale beam specimens / span: 5157 mm and height: 600 mm









TESTS ON FULL SCALE CWB BEAMS

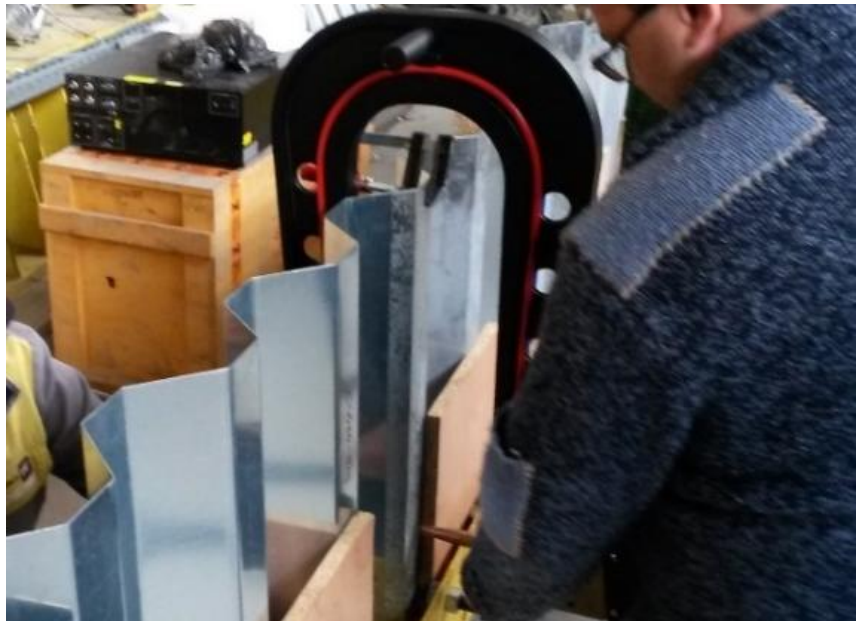
Spot welding

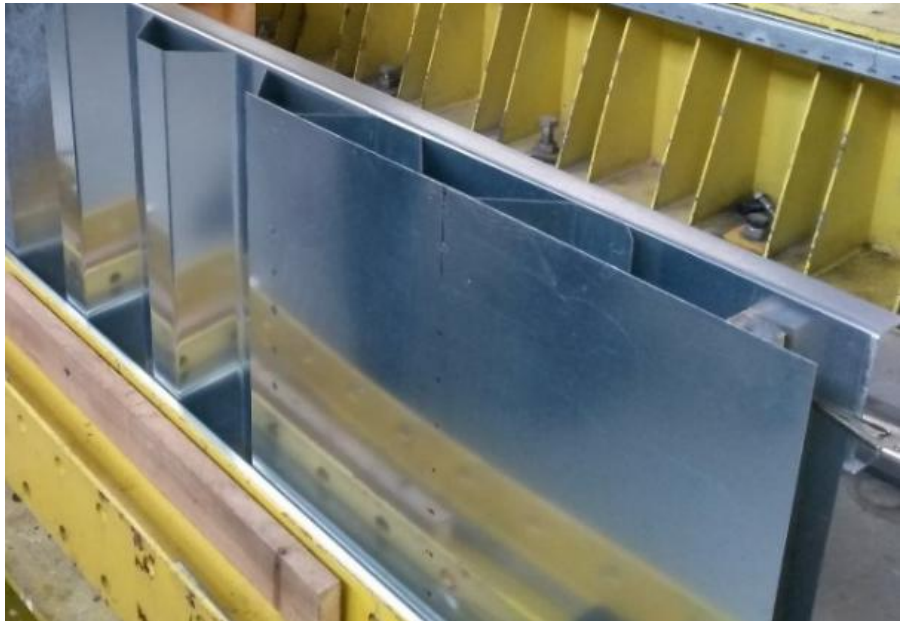
2 full scale beam specimens

The components of the built-up beams:

- two back-to-back lipped channel sections for flanges - 2 × C120/2.0;
- corrugated steel sheets (panels of 1.05 m length with 60 mm height of the corrugation);
- additional shear panels - flat plates of 1.0 or 1.2 mm;
- reinforcing profiles U150/2.0 under the load application points;
- bolts M12 grade 8.8 for endplate connection.

Name	Thickness			Length of shear panels*
	Outer corrugated sheets	Inner corrugated sheets	Shear panels	
CWB SW-1	1.2 mm	0.8 mm	1.0 mm	470 mm; 570 mm
CWB SW-2	1.2 mm	0.8 mm	1.2 mm	510 mm; 630 mm
* the length of the shear panels is different due to variable position of the web corrugation				



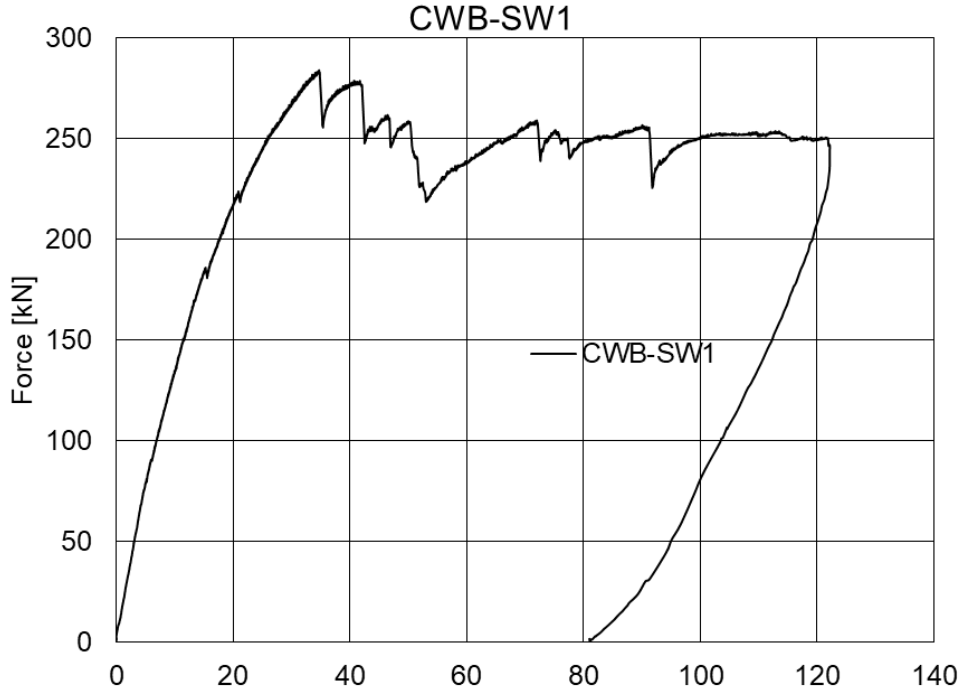


process of manufacturing

TESTS ON FULL SCALE CWB BEAMS

CWB SW-1

- First deformation – buckling of the shear panels , followed by distortion of corrugated web
- $K_{0\text{-}Exp}$ =11352.6 N/mm
- F_{max}= 283.8 kN
- Collapse at 123 mm

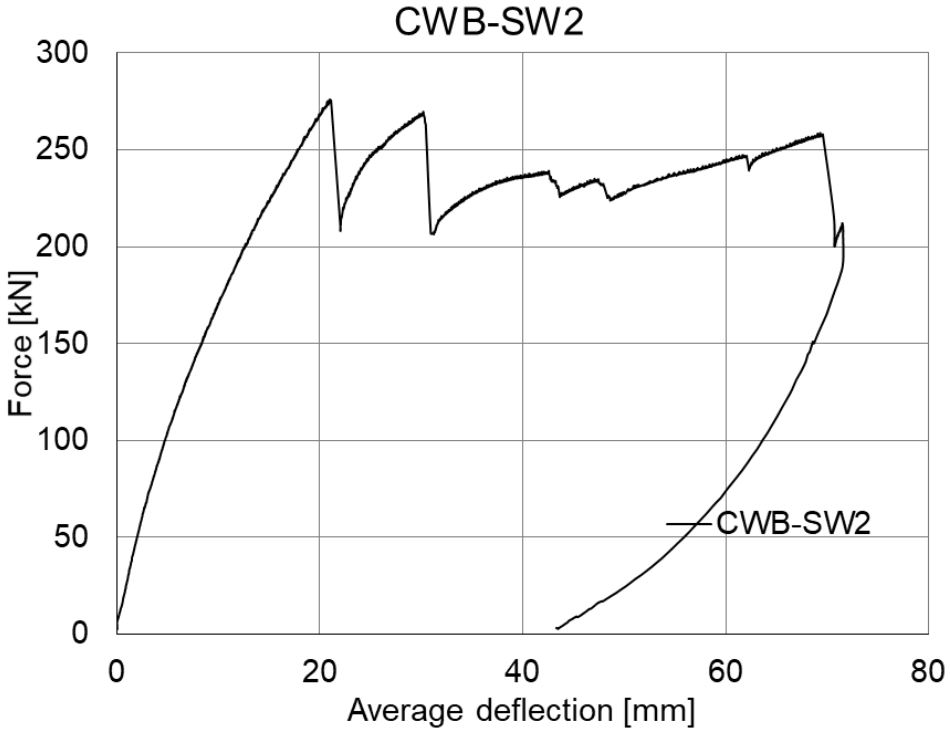


Ungureanu, V.; Both, I.; Burca, M.; Radu, B.; Neagu, C.; Dubina, D. (2021) Experimental and numerical investigations on built-up cold-formed steel beams using resistance spot welding. Thin–Walled Structures 161, 107456.

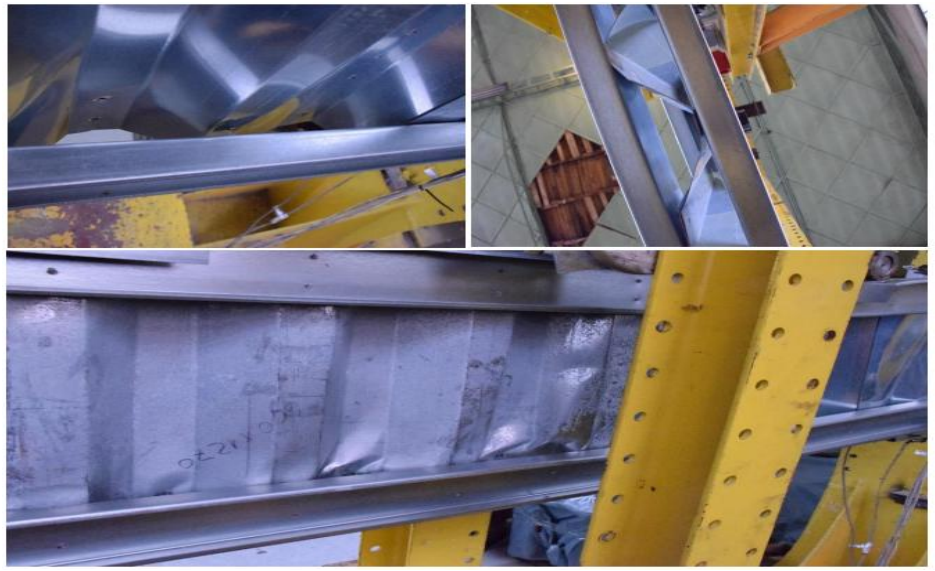
TESTS ON FULL SCALE CWB BEAMS

CWB SW-2

- First deformation – buckling of the shear panels , followed by distortion of corrugated web
- $K_{0\text{-}Exp}$ =15846.5 N/mm
- F_{max}= 276.0 kN
- Collapse at 69.5 mm



Development of the buckling of the end shear panels

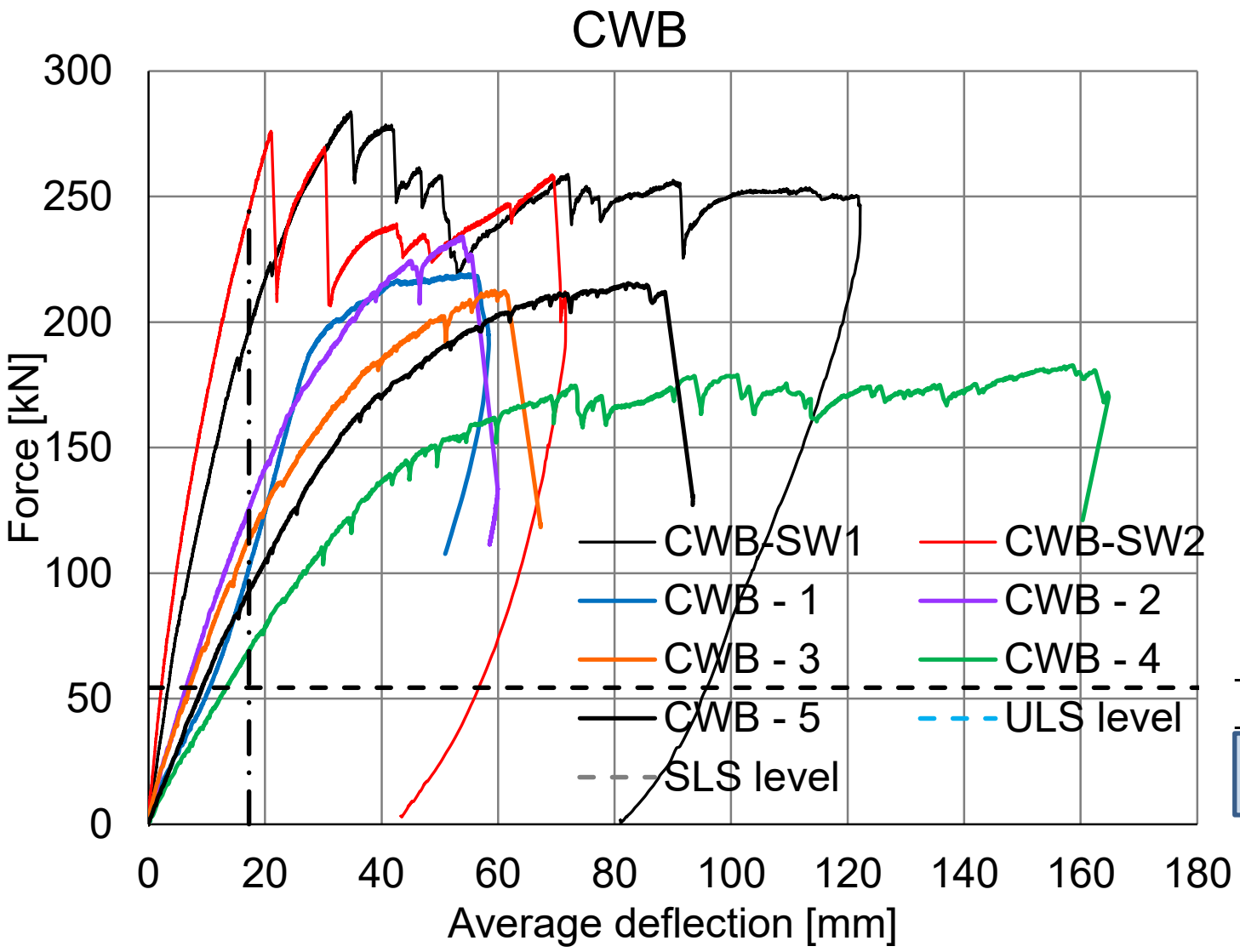


Distortion of the web corrugation

TESTS ON FULL SCALE CWB BEAMS

Spot welding failure between the web and the flange

Ungureanu, V.; Both, I.; Burca, M.; Radu, B.; Neagu, C.; Dubina, D. (2021) Experimental and numerical investigations on built-up cold-formed steel beams using resistance spot welding. Thin–Walled Structures 161, 107456.

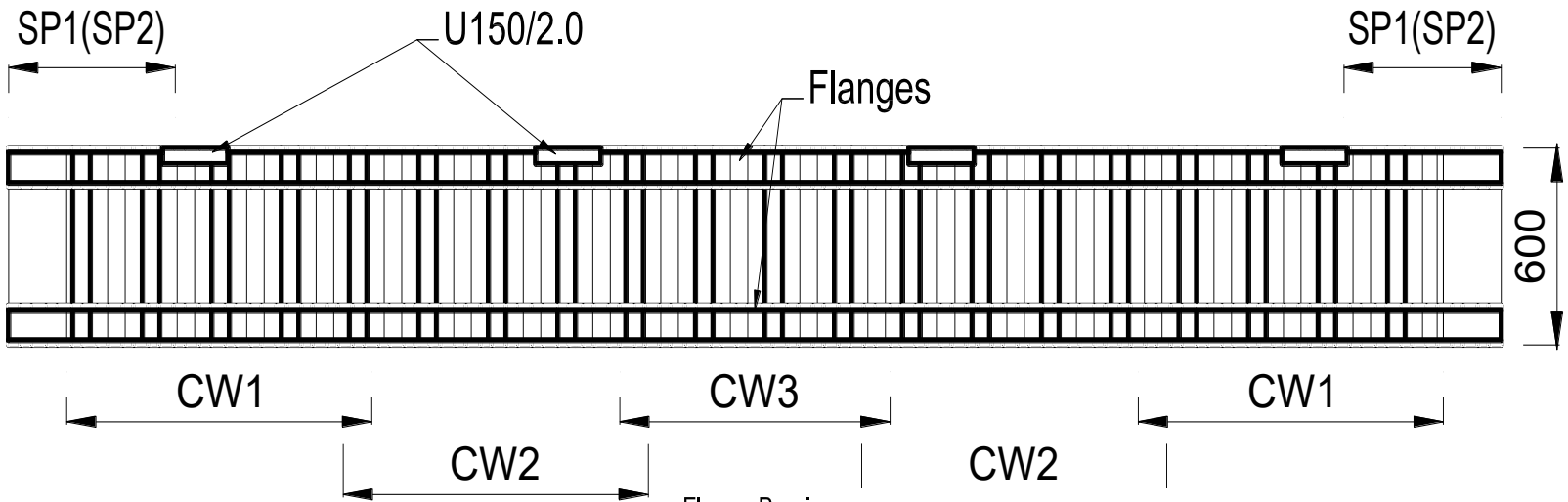


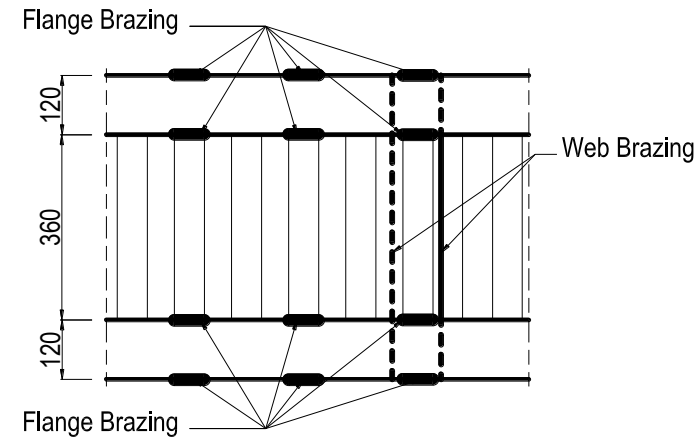
Beam type	$K_{0\text{-}Exp}$ (N/mm)	F_{max} (kN)
CWB SW-1	11352.6	283.8
CWB SW-2	15846.5	276.0
CWB-1	6862.2	219.0
CWB-2	7831.5	230.6
CWB-3	7184.9	211.9
CWB-4	3985.0	161.8
CWB-5	5516.2	215.5

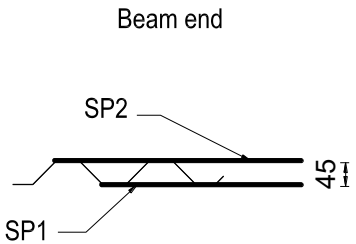
TESTS ON FULL SCALE CWB BEAMS

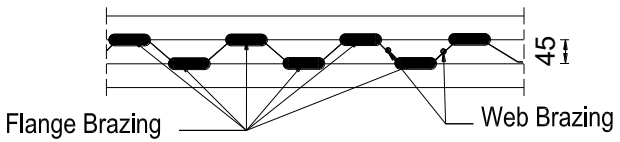
MIG brazing

3 full scale beam specimens / span: 5157 mm and height: 600 mm









TESTS ON FULL SCALE CWB BEAMS

MIG brazing

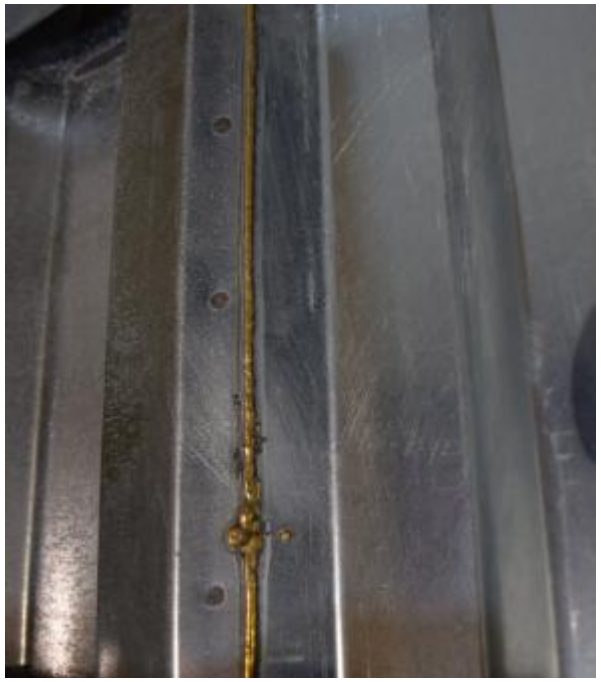
3 full scale beam specimens

The components of the built-up beams:

- two back-to-back lipped channel sections for flanges - 2 × C120/2.0;
- corrugated steel sheets (panels of 1.05 m length with 45 mm height of the corrugation);
- additional shear panels - flat plates of 1.0 or 1.2 mm;
- reinforcing profiles U150/2.0 under the load application points;
- bolts M12 grade 8.8 for endplate connection.

Name	Thickness				Length of shear panels*
	CW1	CW2	CW3	SP1(SP2)	
CWB CMT-1	1.2 mm	0.8 mm	0.8 mm	1.2 mm	470 mm; 570 mm
CWB CMT-2	0.8 mm	0.8 mm	0.8 mm	1.0 mm	470 mm; 570 mm
CWB CMT-3	1.0 mm	0.8 mm	0.8 mm	1.0 mm	470 mm; 570 mm
* the length of the shear panels is different due to variable position of the web corrugation					

Ungureanu V., Both I., Țunea D., Groșan M., Neagu C., Georgescu M., Dubina D. (2018). Experimental investigations on built-up cold-formed steel beams using MIG brazing. *Proceedings of the Eighth International Conference on THIN-WALLED STRUCTURES - ICTWS 2018*, Lisbon, Portugal, July 24-27

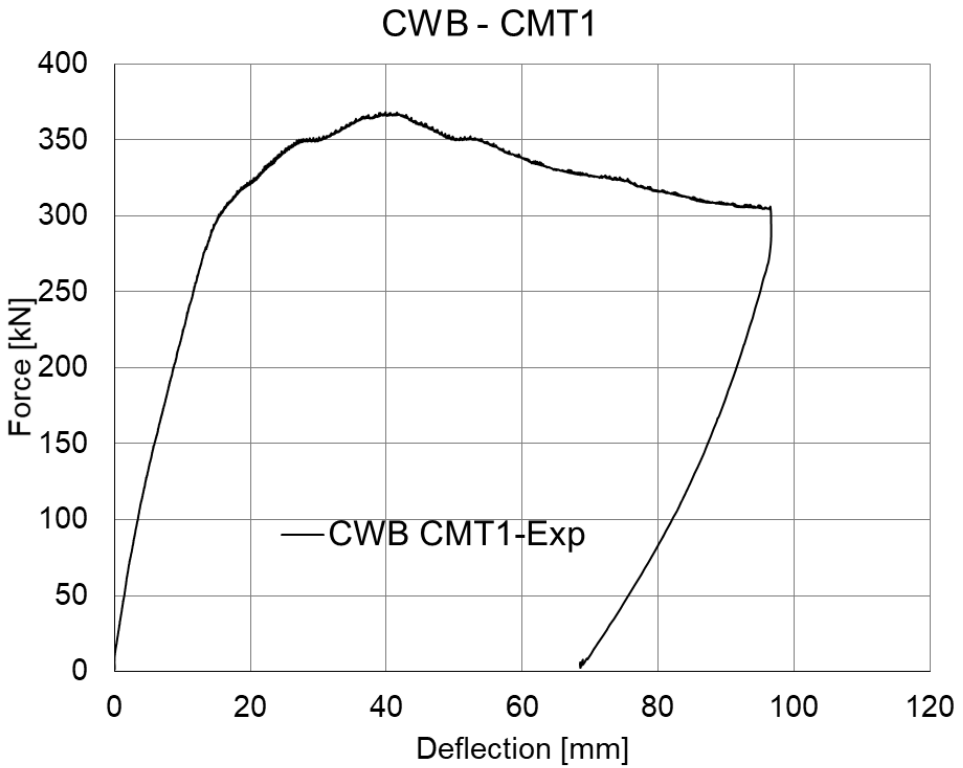


process of manufacturing

TESTS ON FULL SCALE CWB BEAMS

CWB CMT-1

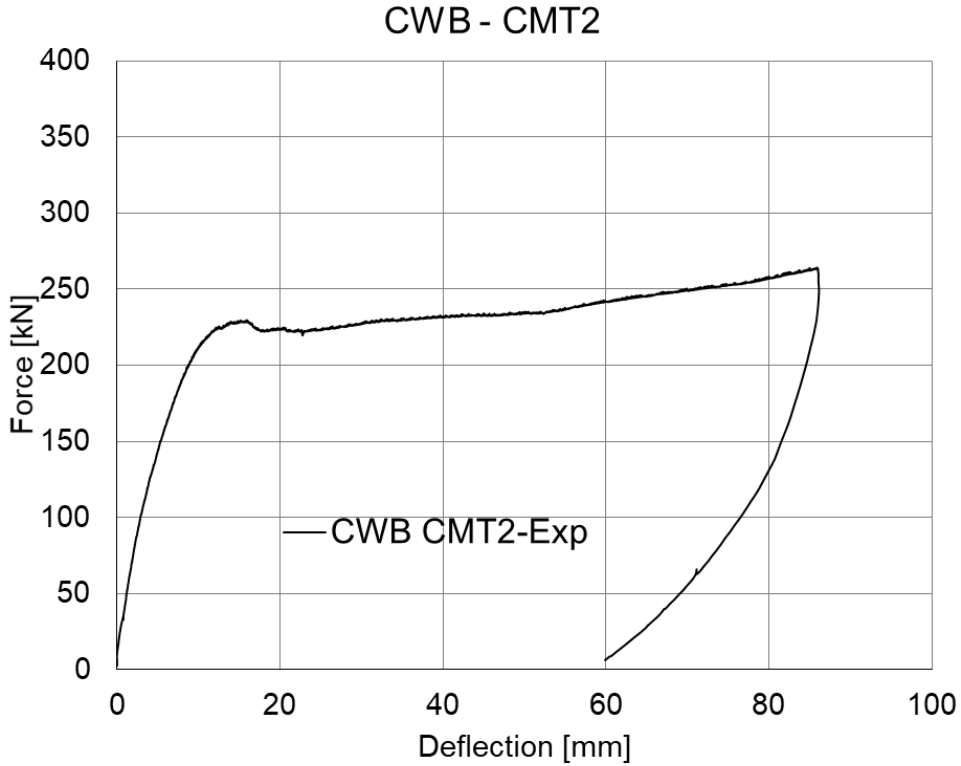
- First deformation – buckling of the shear panels , followed by shear buckling of web corrugation
- $K_{0\text{-}Exp}$ =25787 N/mm
- F_{max}= 368.28 kN
- Collapse at 96.6 mm



TESTS ON FULL SCALE CWB BEAMS

CWB CMT-2

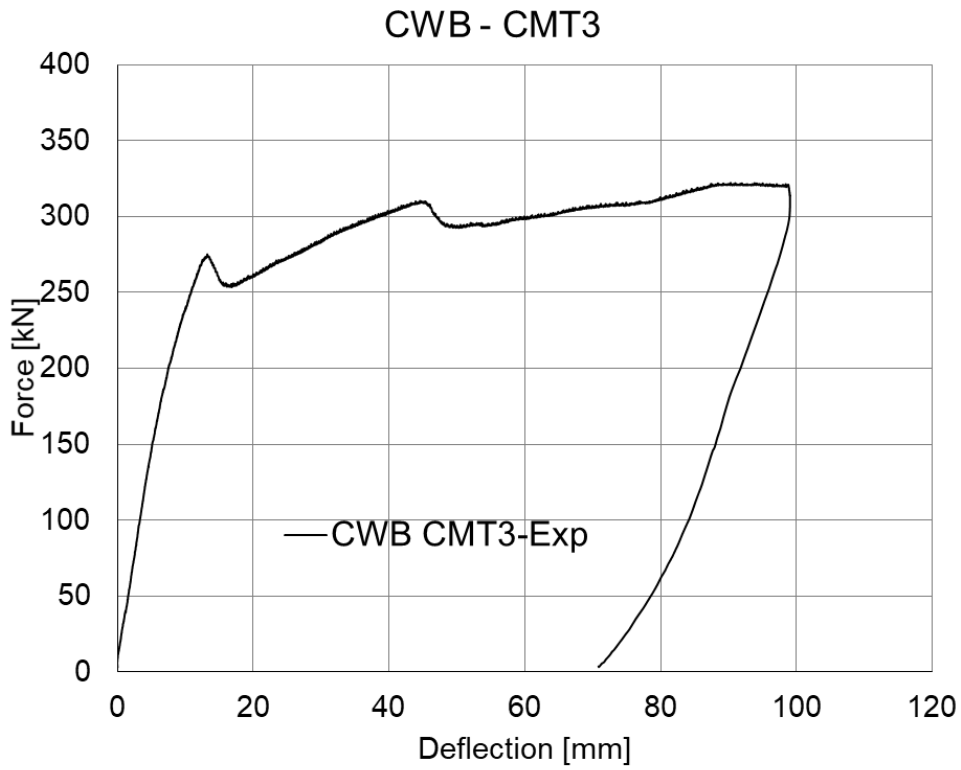
- First deformation – buckling of the shear panels , followed by shear buckling of web corrugation
- $K_{0\text{-}Exp}$ =22559 N/mm
- F_{max}= 227.9 kN

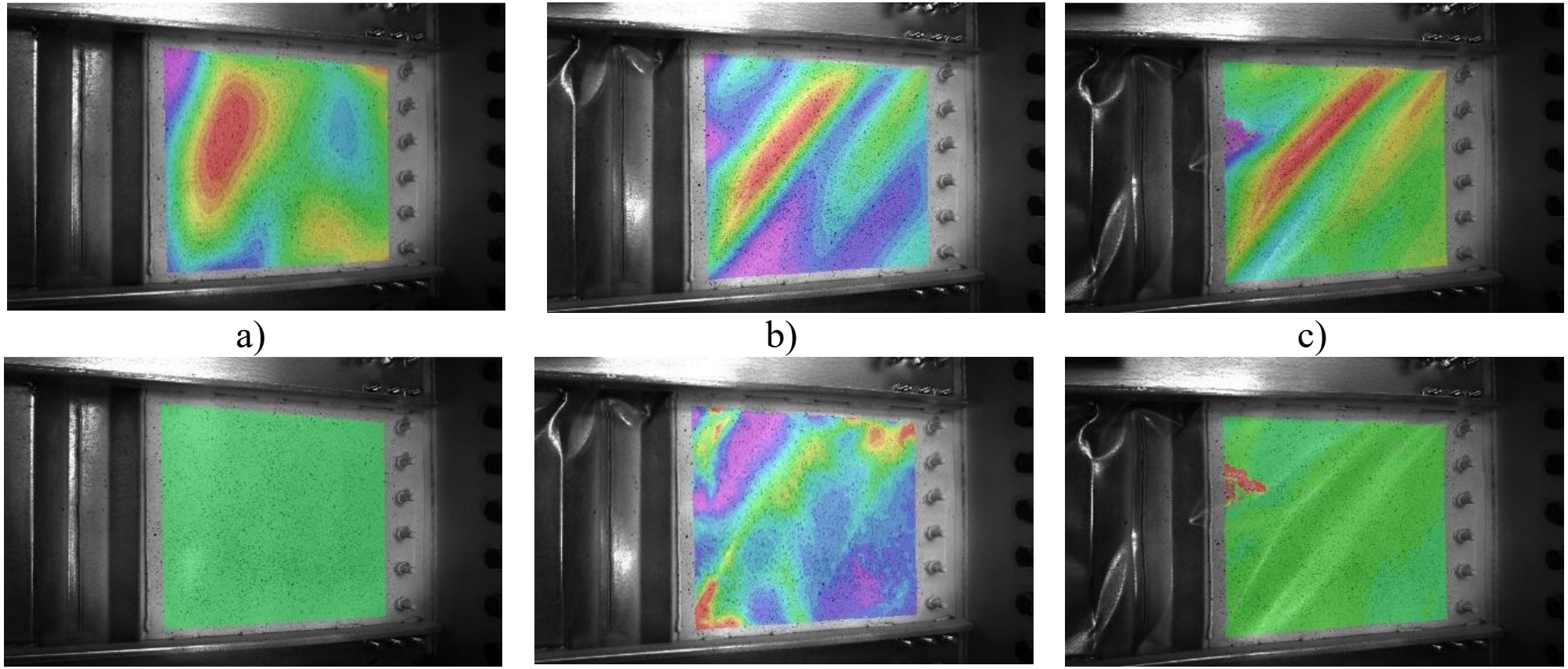


TESTS ON FULL SCALE CWB BEAMS

CWB CMT-3

- First deformation – buckling of the shear panels , followed by shear buckling of web corrugation
- $K_{0\text{-}Exp}$ =24792 N/mm
- F_{max}= 273.5 kN

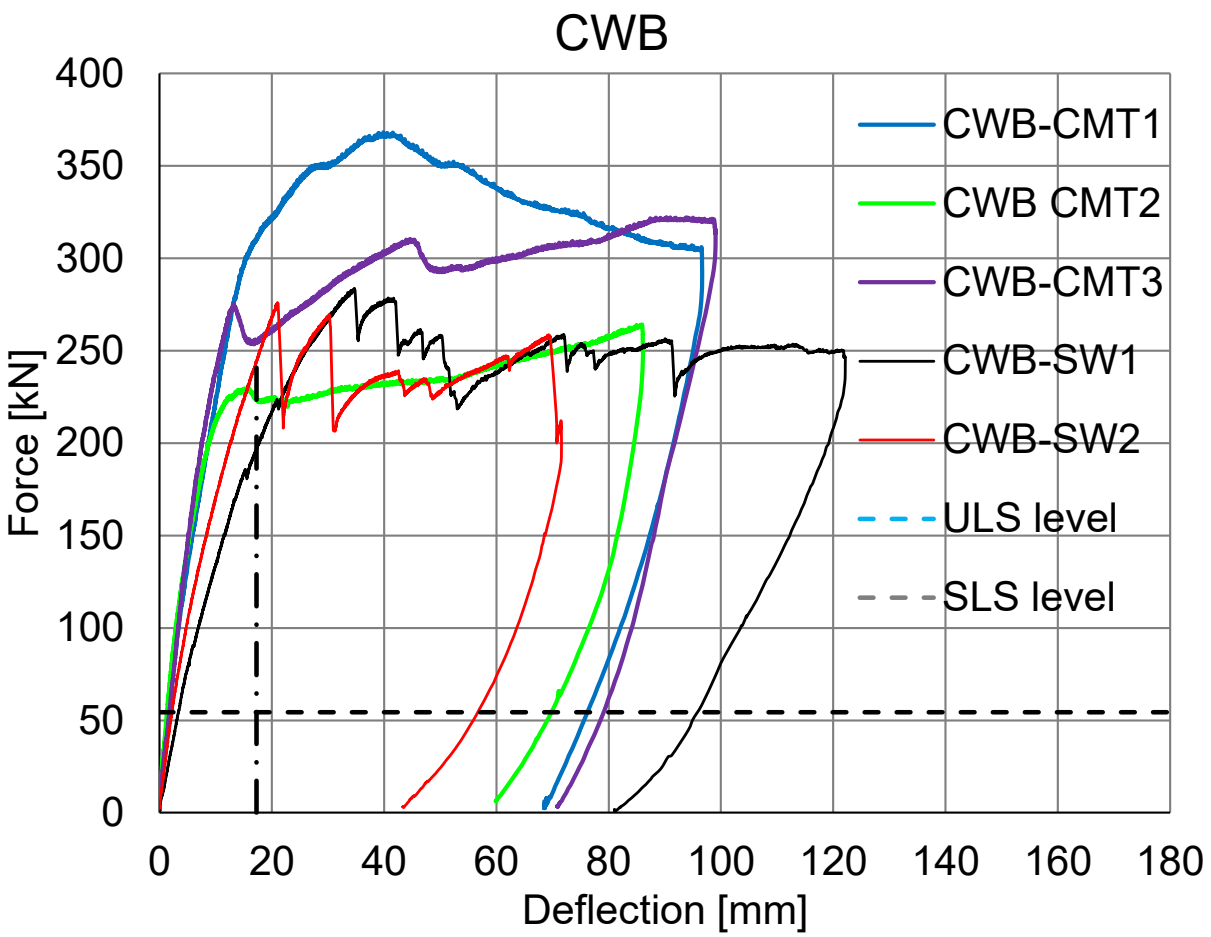




Evolution of the out of plane deformations (a, b, c) and the corresponding principal strains (d, e, f) of a given shear panel

digital image correlation system (DIC)

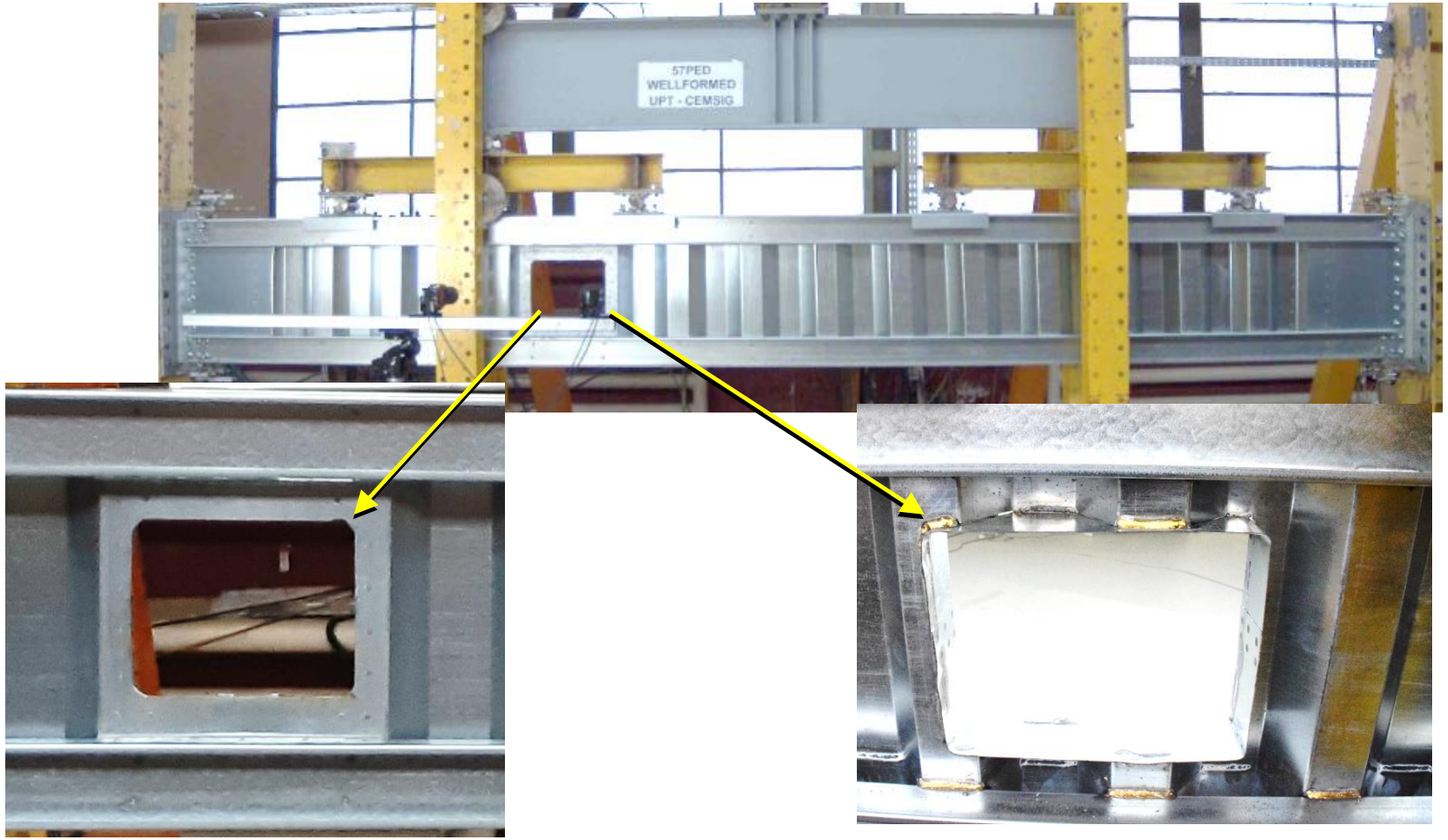
isi-sys GmbH. Two GT6600 Prosilica series



Beam type	$K_{0\text{-}Exp}$ (N/mm)	$F_{max\text{-}Exp}$ (kN)
CWB-CMT1	25787	368.2
CWB-CMT2	22559	227.9
CWB-CMT3	24792	273.5
CWB-SW1	11353	283.8
CWB-SW2	15847	276.0

TESTS ON FULL SCALE CWB BEAMS WITH WEB OPENINGS

To assess the effect of web openings on the global response of built-up CWB and to study the solution of web strengthening (Service ducts requirements for multi-storey buildings).

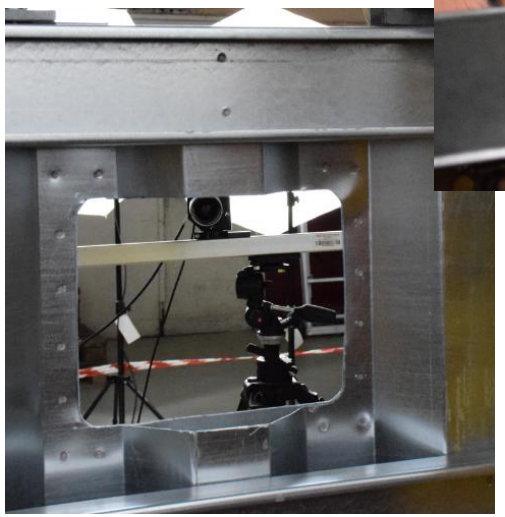


V. Ungureanu, I. Both, C. Neagu, M. Burca, D. Dubina, A.A. Cristian: Built-up cold-formed steel beams with web openings. Proceedings of the International Colloquia on Stability and Ductility of Steel Structures (SDSS 2019, Czech Republic, 11-13 September 2019), 1185–1192

TEST ON THE CWB BEAM WITH WEB OPENING

Spot welding

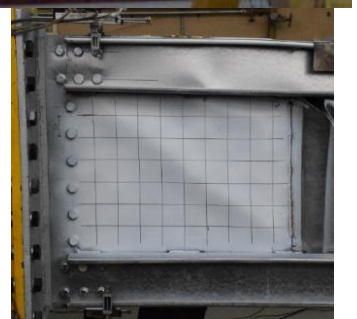
Non symmetric failure



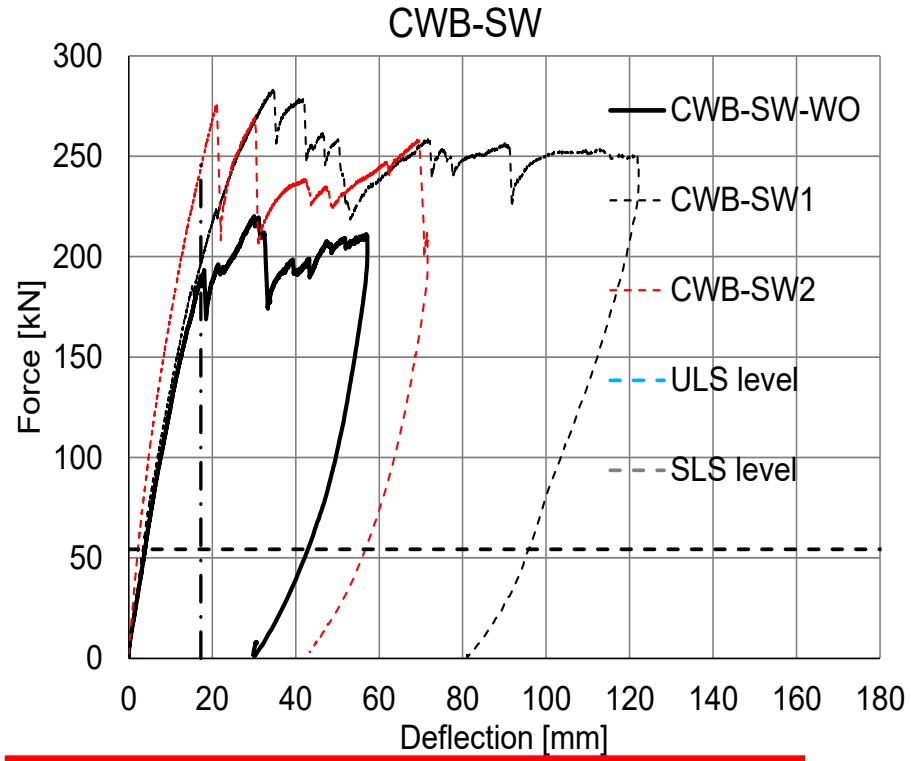
TEST ON THE CWB BEAM WITH WEB OPENING

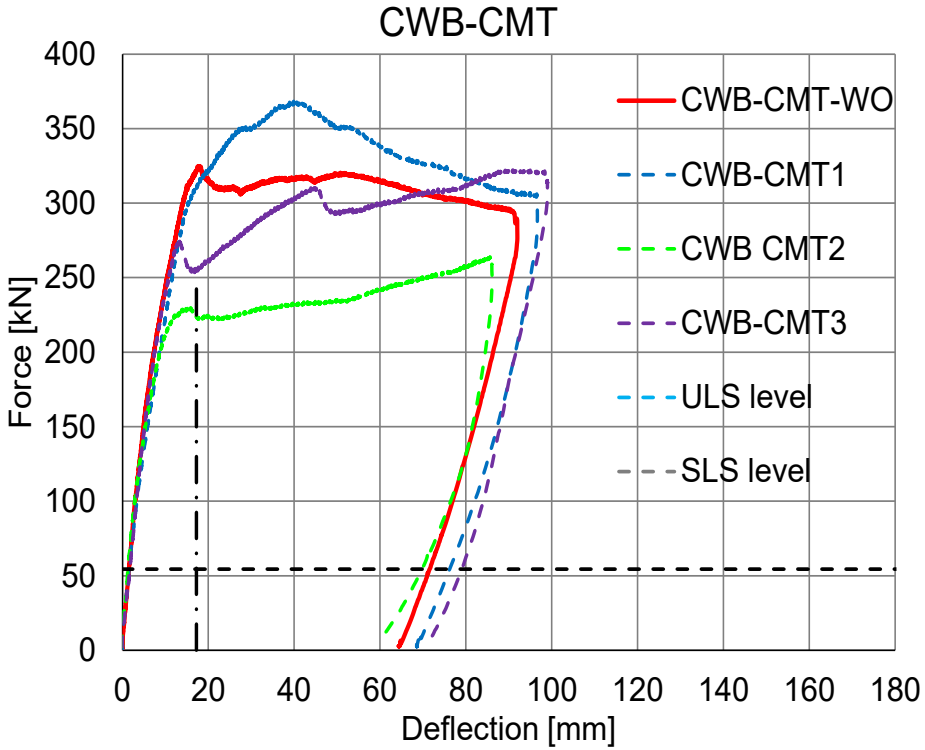
MIG brazing

Symmetry of the failure

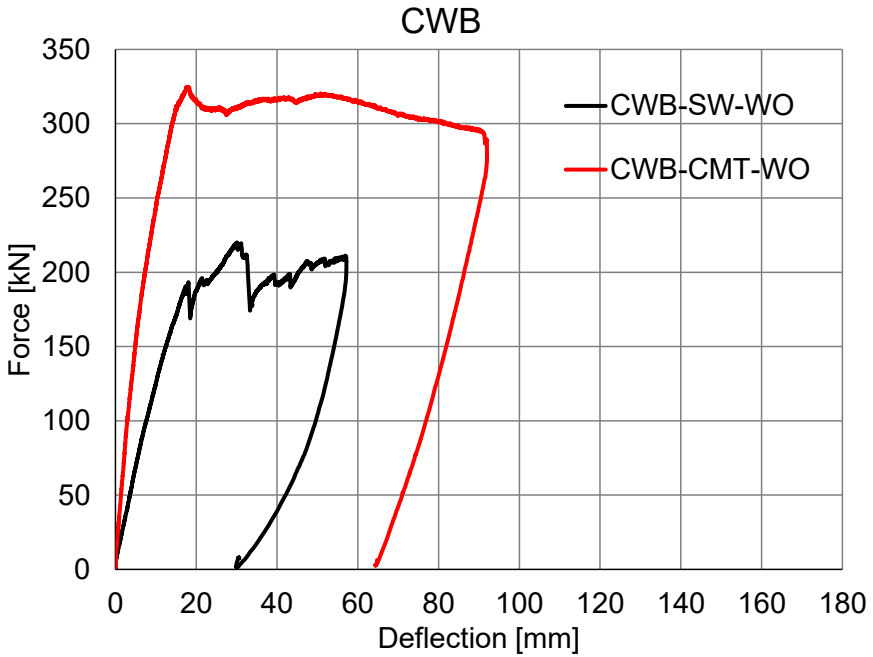


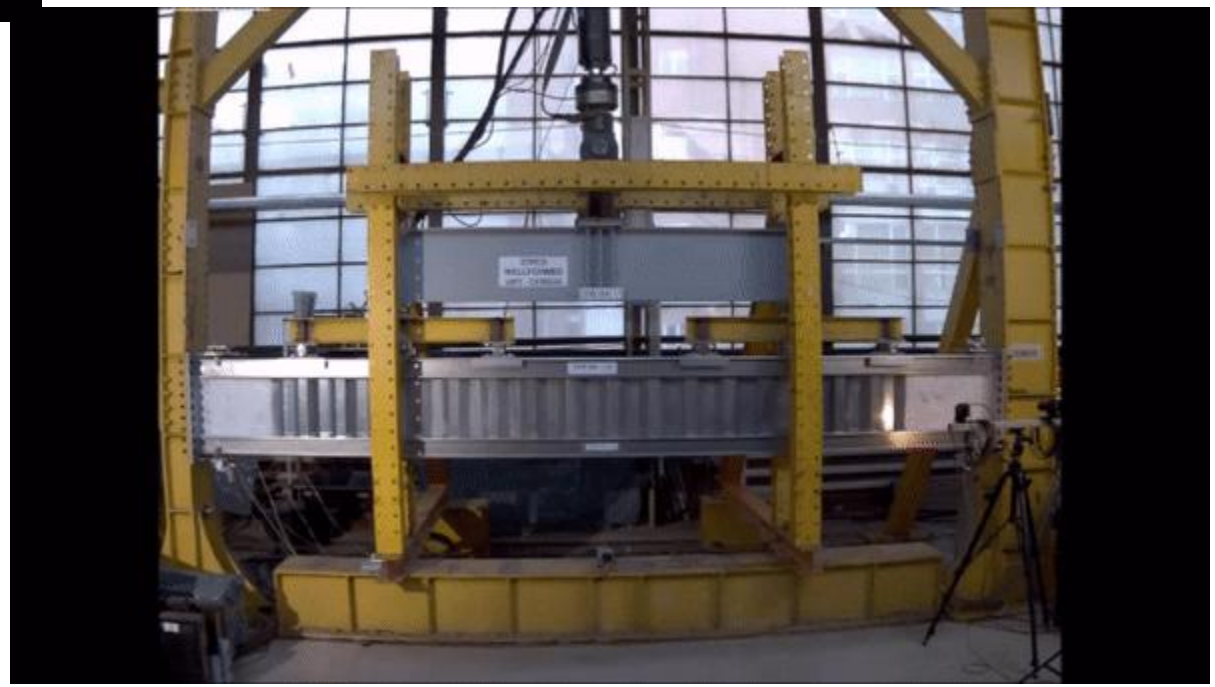
RESULTS





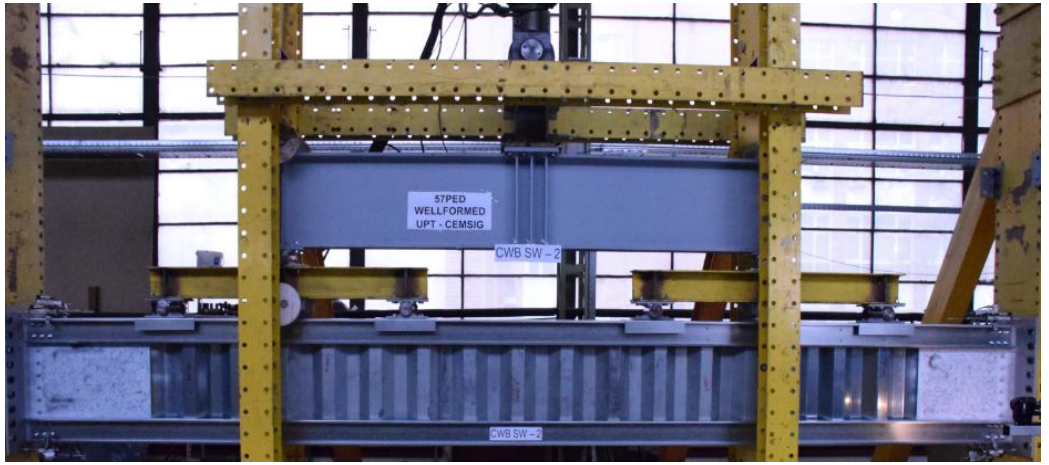
In case of SW technology, the small rigidity of the corrugations due to the discrete connection of the spot weld, only 61% of the bearing capacity of the MIG brazed specimen was reached.

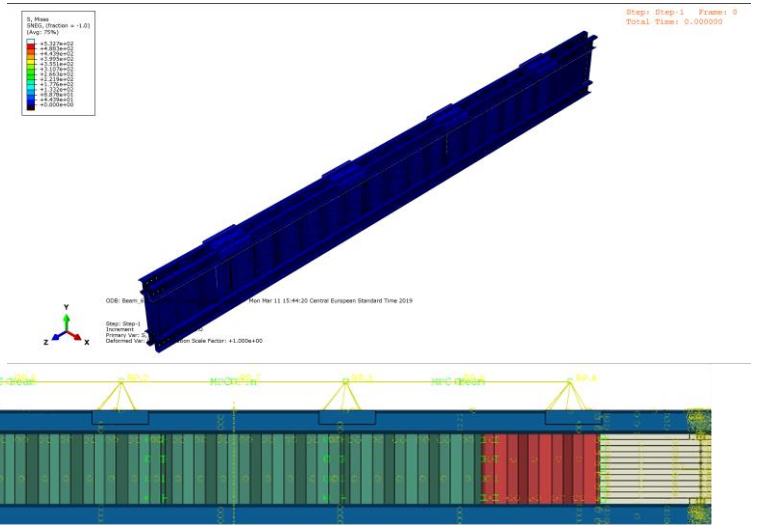




NUMERICAL INVESTIGATIONS

- Validate the numerical model
- Assess:
  - the effect of imperfections
  - the number, position and distance between SW
  - the effect of the thickness of the flanges
  - the effect of the thickness of the corrugated web
  - the effect of the thickness of the shear panels,





V. Ungureanu, I. Lukačević, I. Both, M. Burca, D. Dubina: Numerical investigation of built-up cold-formed steel beams with corrugated web. Proceedings of the International Colloquia on Stability and Ductility of Steel Structures (SDSS 2019, Czech Republic, 11-13 September 2019), 1193–1200.

FIRST PART CONCLUSIONS

SW

•both the capacity and the ductility are very good;

•compared to the solution using self-drilling screws, they show an increased capacity but, the deformation is consistent less;

Advantage: FAST / Disadvantage: corrugation height

CMT

•the capacity and ductility are very good;

•compared to the SW solution, the results show an increased rigidity (no distortion of the corrugation);

Advantage: higher capacity / Disadvantage: increased time for manufacturing.

➔ laser welding (LW)

Full scale experimental tests

2 welding technologies: laser welding (LW)

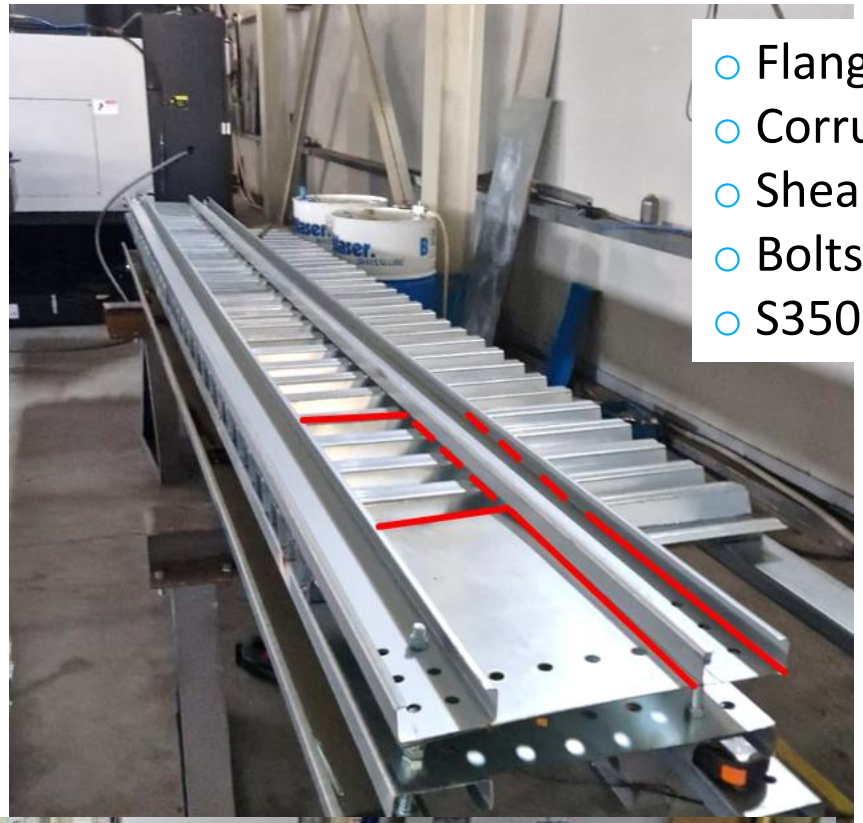
7 specimens

1 CWB beam CWB-LW (monotonic) = **1**

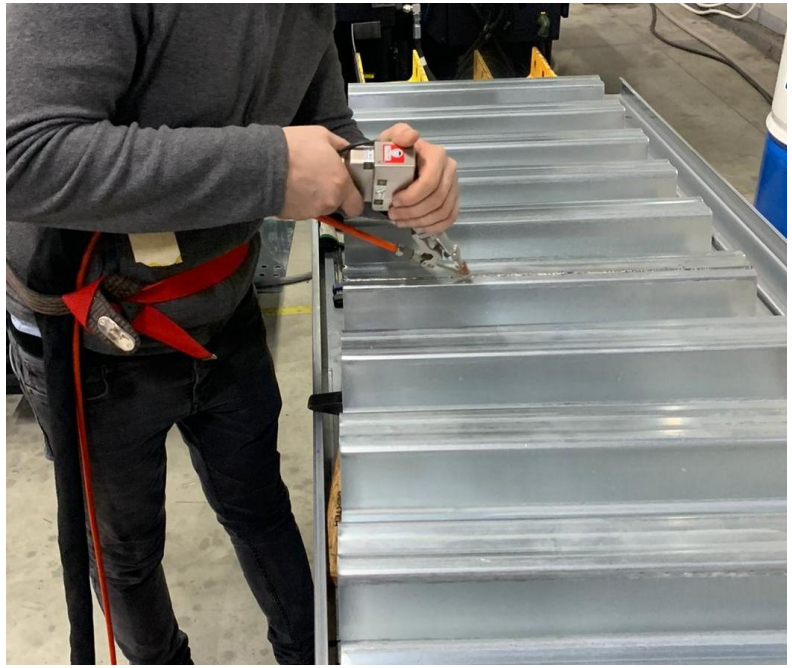
1+1 CW columns CWB-LW (monotonic + cyclic) = **4**

1+1 joints CWB-LW (monoton + cyclic) = **2**

2 full scale tests on portal frames (1 CWB-LW and 1 CWB-SW)

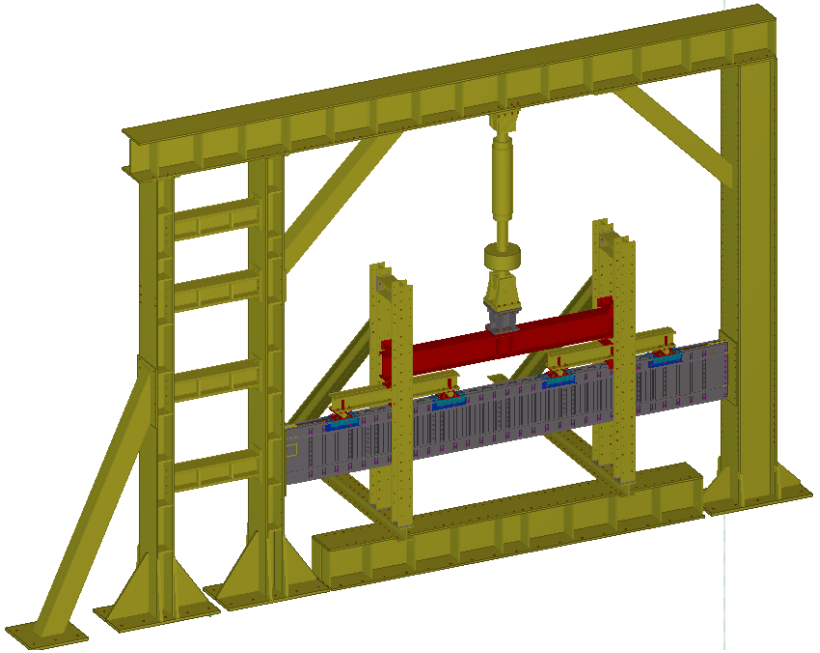


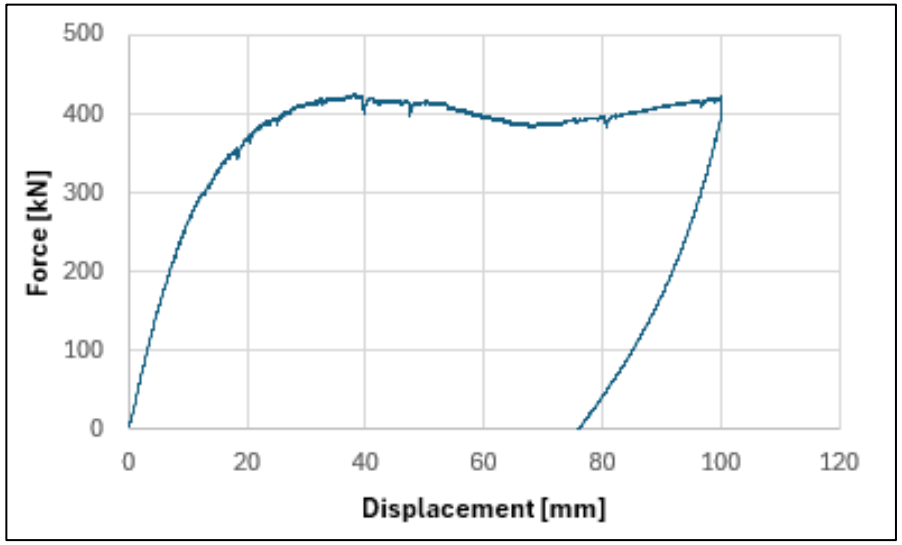
- Flanges: - 2xC120/2.0;
- Corrugated web: - COFRAPUS 60/1.2;
- Shear panels 1 mm (supplementary flat plates);
- Bolts M12/M16 - 8.8 (end connections);
- S350GD+Z

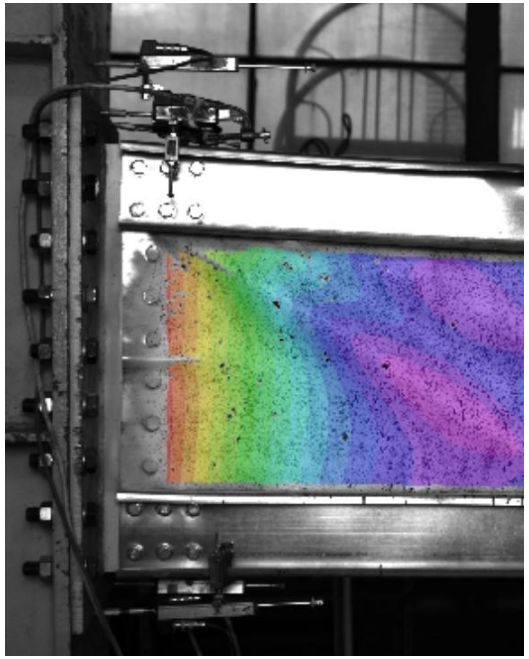


Laser welding assembly technology: high productivity, low temperature, high precision, reduced distortion of corrugations, suitable for galvanized steel.

Test on CW beam





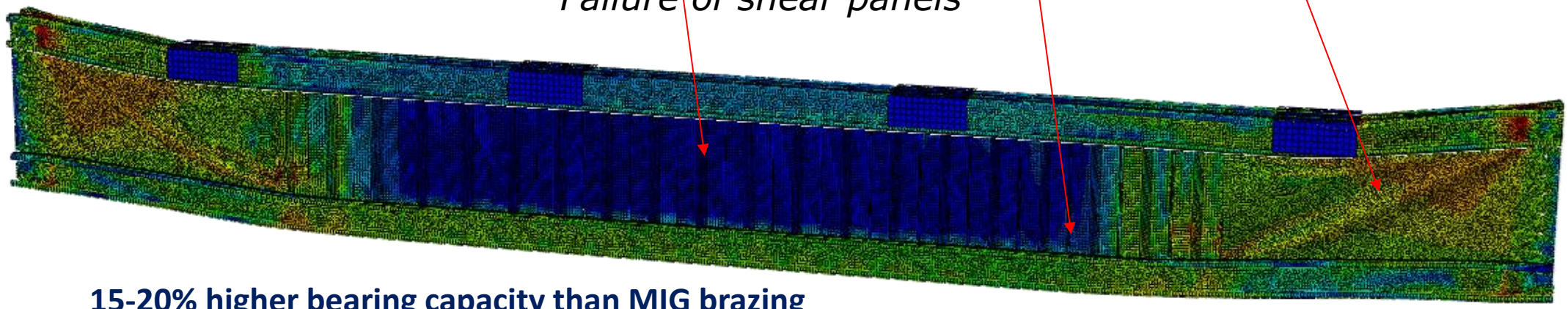


Failure of shear panels

15-20% higher bearing capacity than MIG brazing
(420 kN vs. 350 kN)

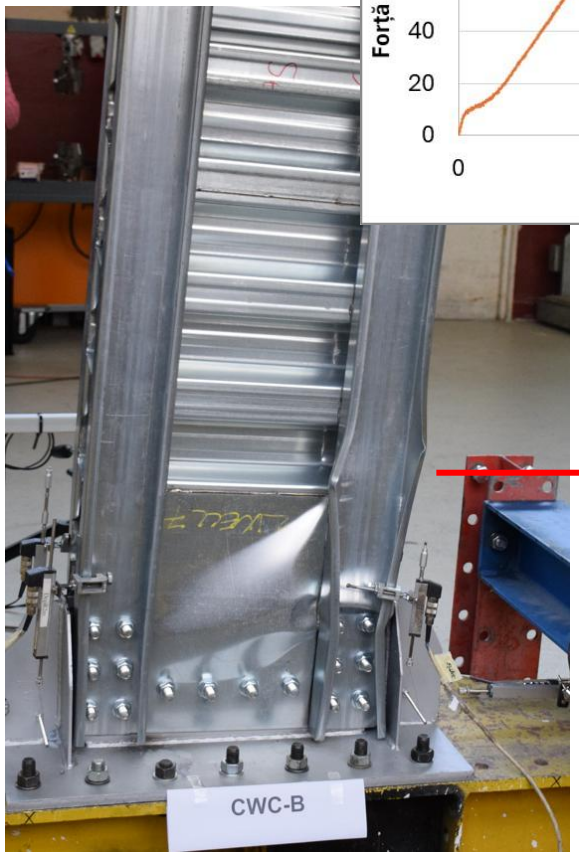
Test on CW beam

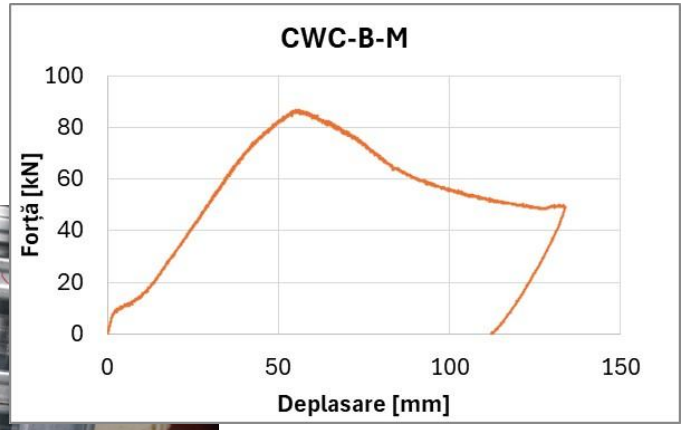
Failure of shear panels

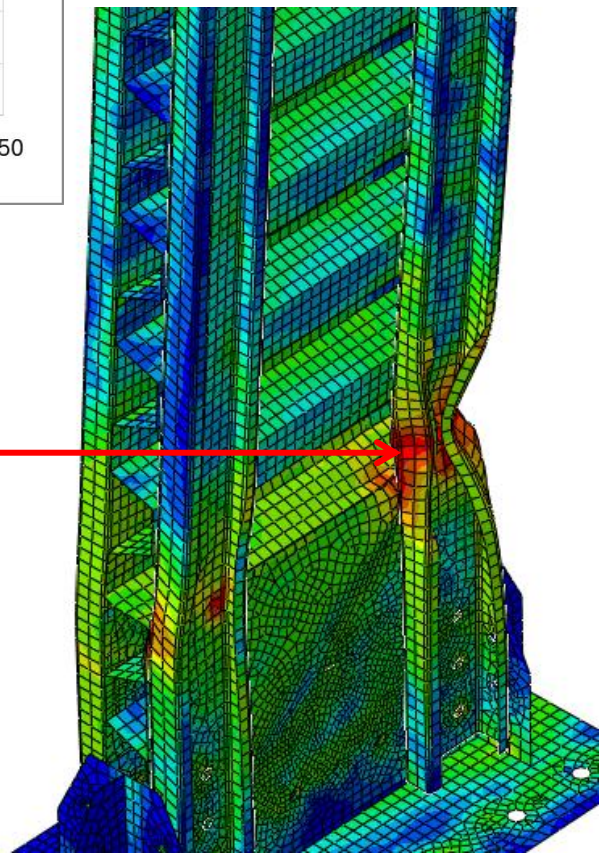


15-20% higher bearing capacity than MIG brazing (420 kN vs. 350 kN)

Tests on CW columns - monotonic



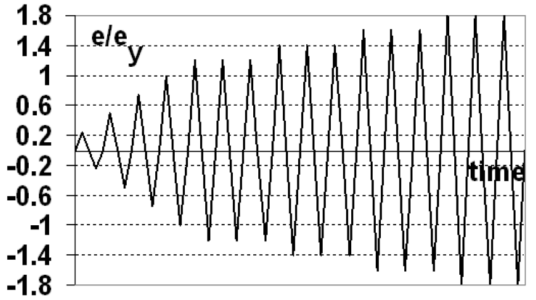


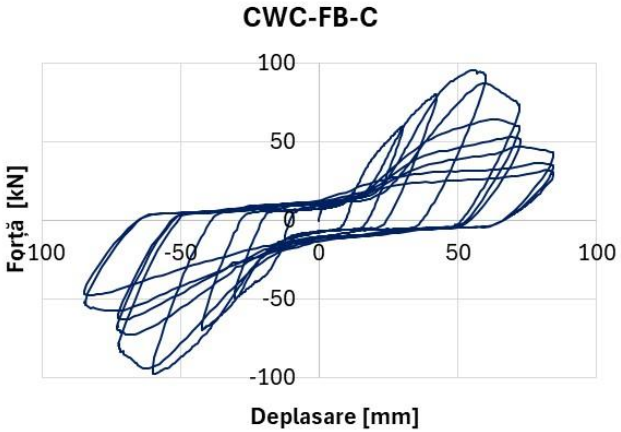


Tests on CW columns - cyclic

Cyclic bending test on laser welded column

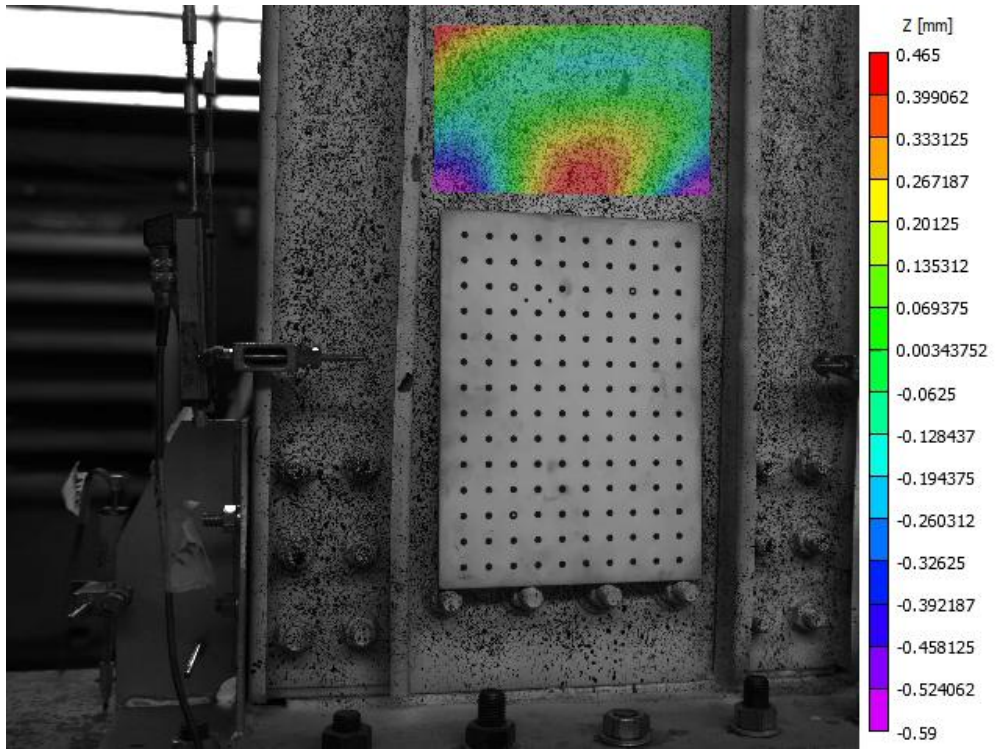
Failure of compressed flange

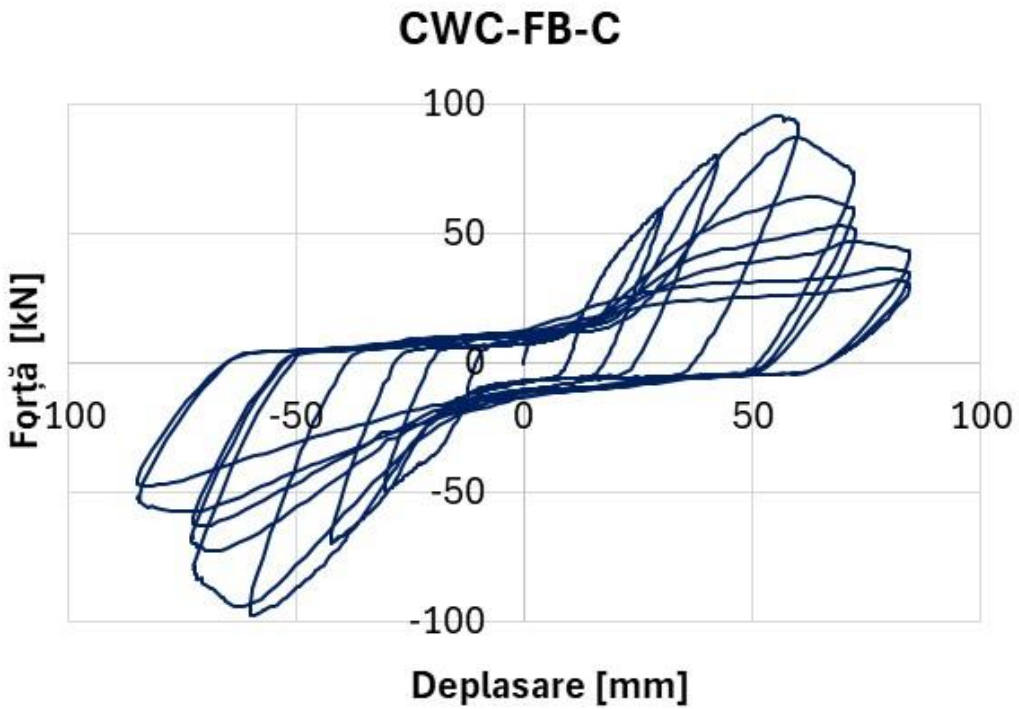




Hysteretic curve of the cyclic loading

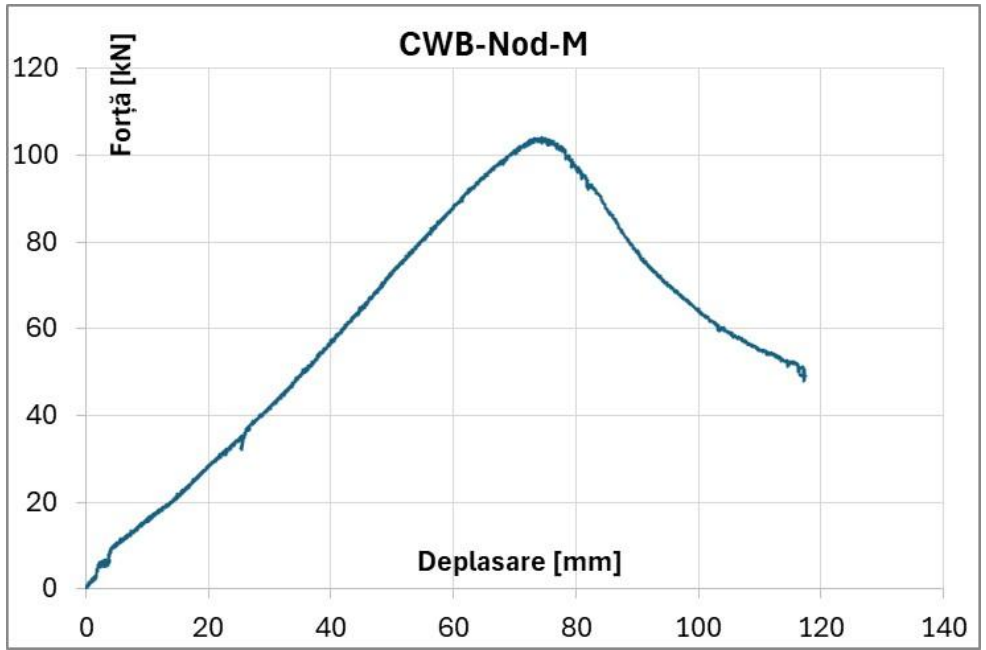
After-test image of the column with bolted flanges (CWC-FB) subjected to monotonic displacement

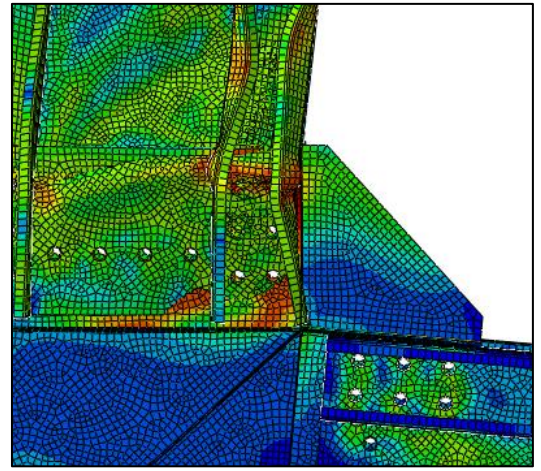


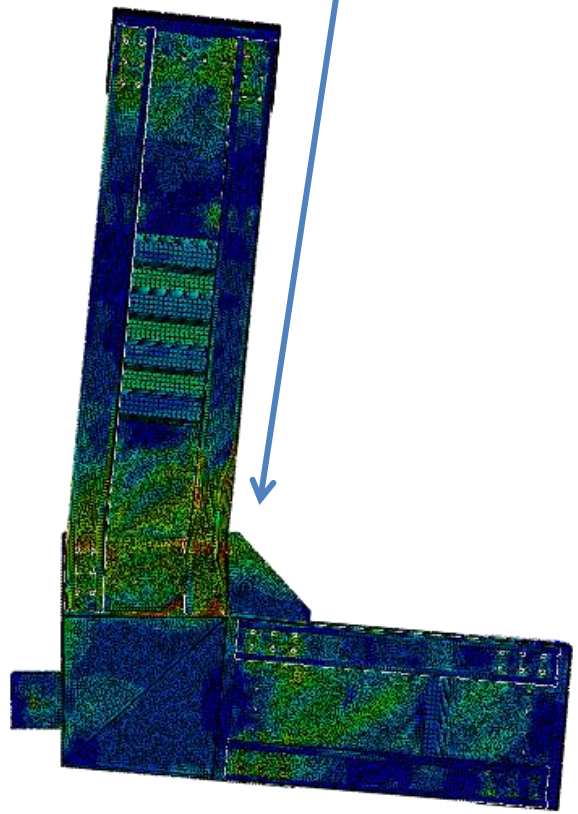


Hysteretic curve for the built-up column (CWC-FB-C) assembled with laser welding with supplementary bolts (flange-bolted)

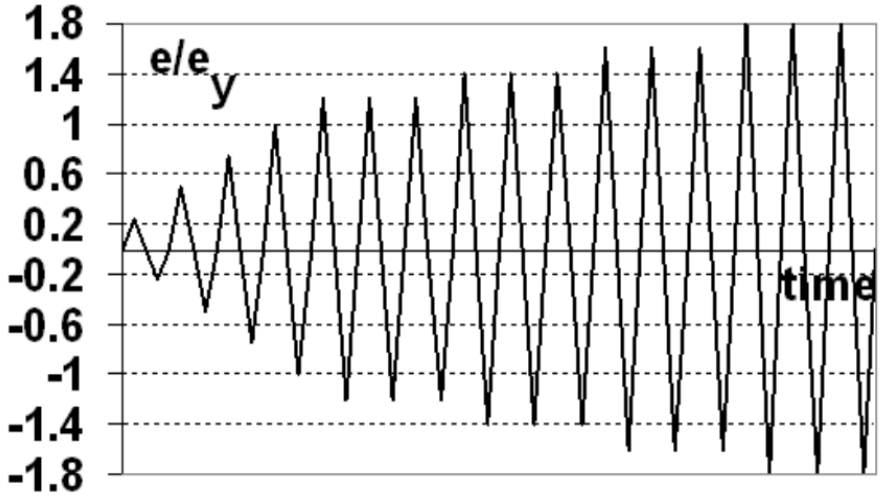
Tests on CW columns - monotonic

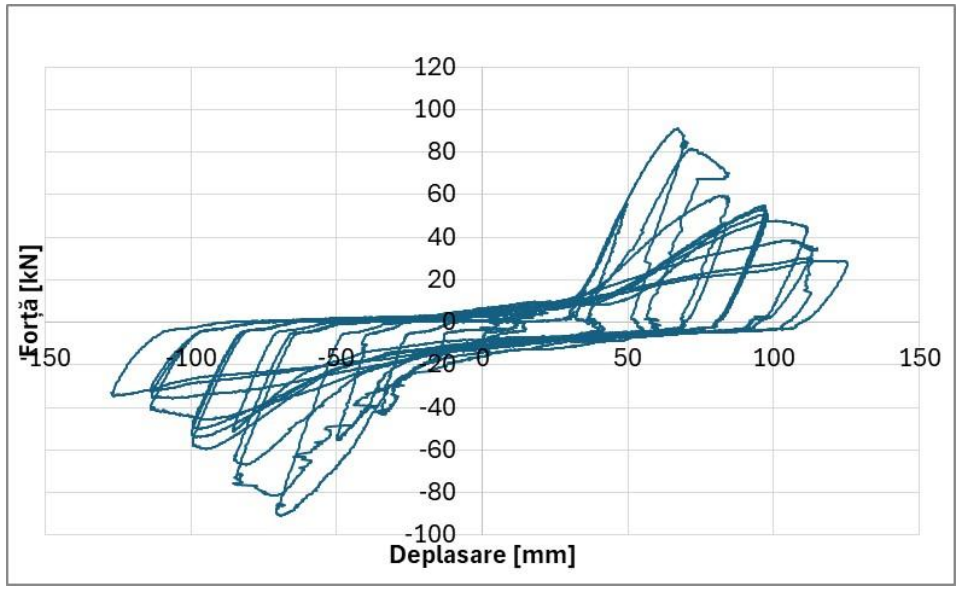


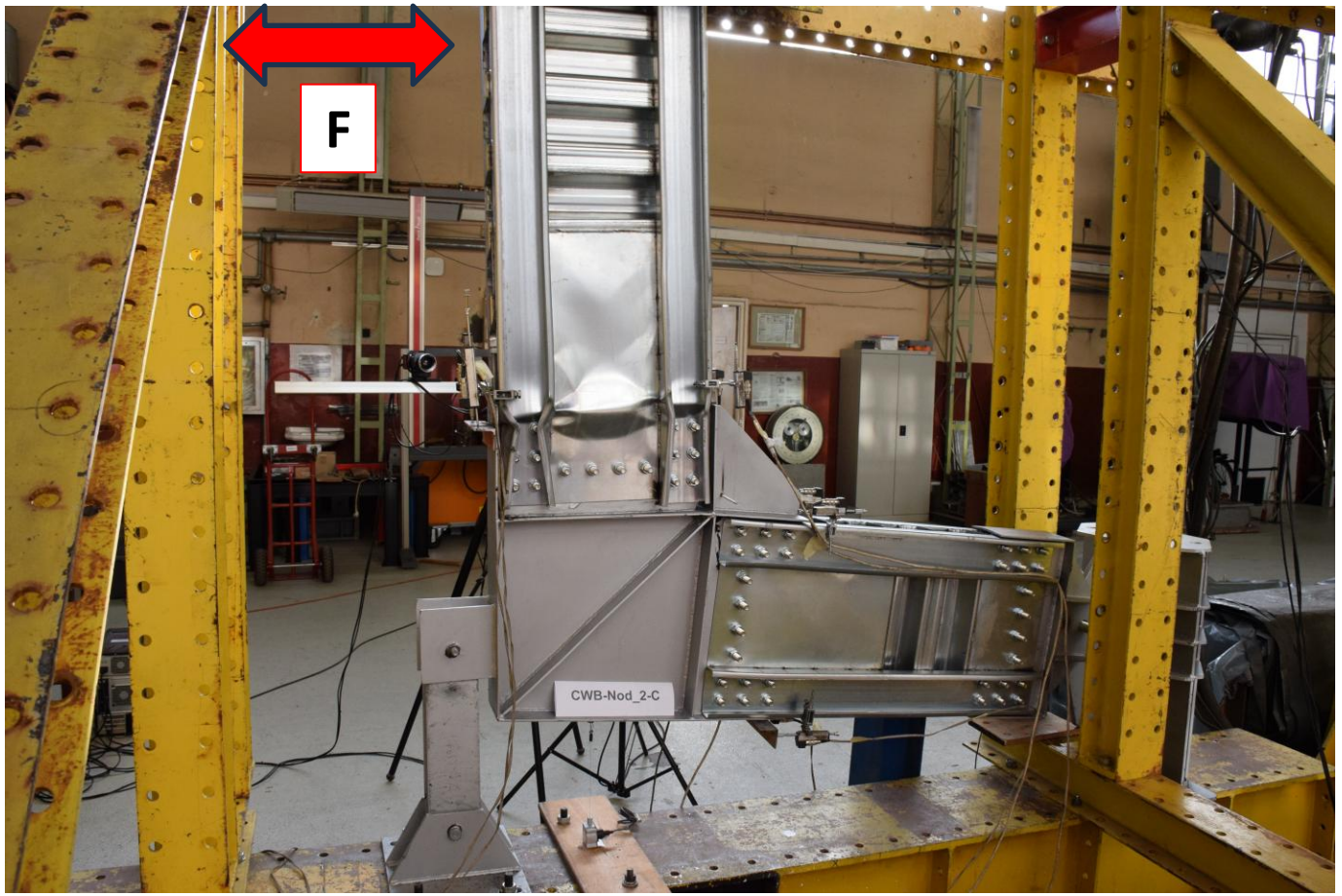




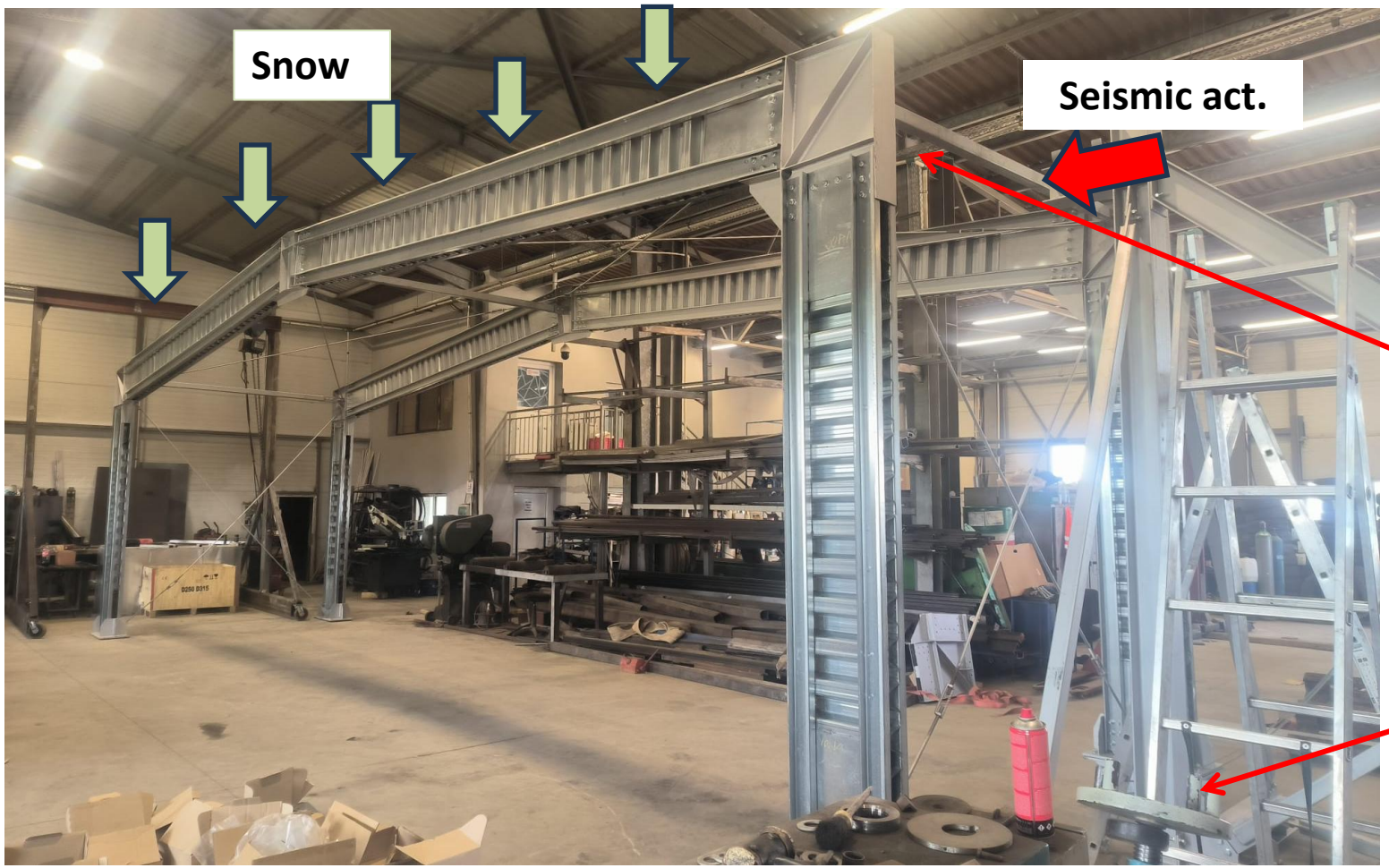
Tests on CW columns - cyclic

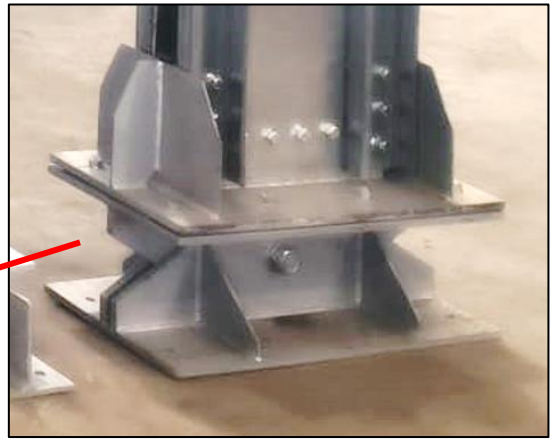






Full scale tests on portal frames (SW și LW)





Timișoara: s_k = 1.5 kN/m² / a_g = 0.2g, q = 1

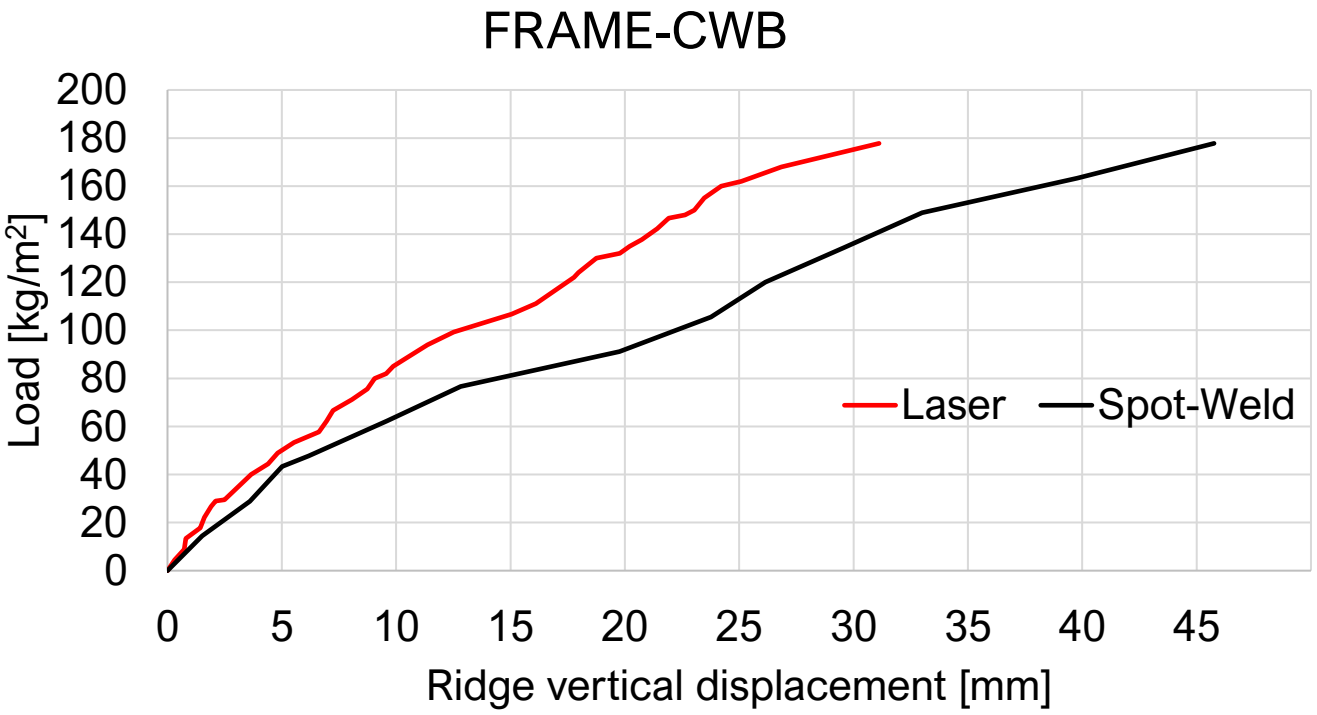
SLU - FC: 88.3 kN

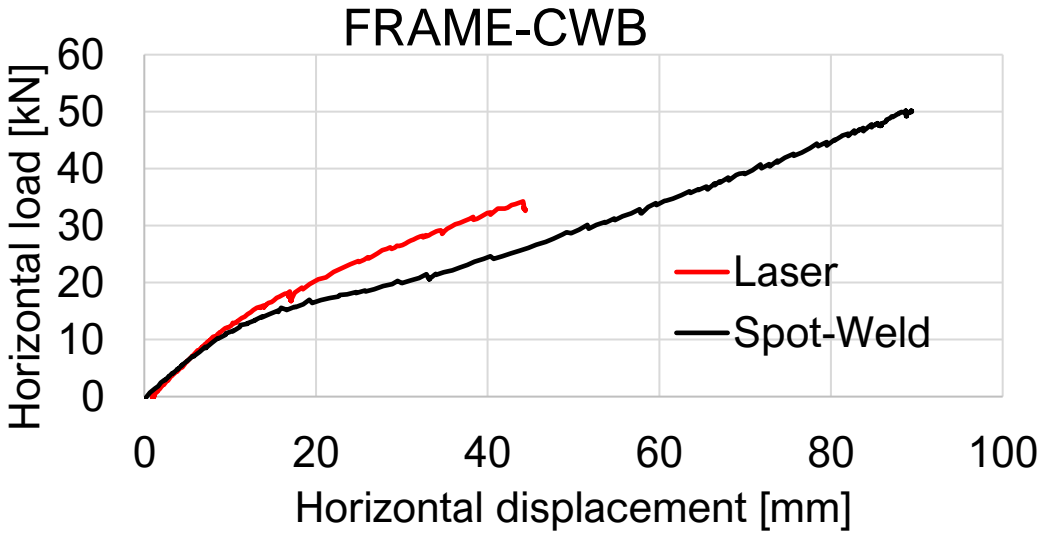
SLU - AC: 19.6 kN (+0.4 S incl.)

Full scale tests on portal frames (LW)

Full scale tests on portal frames (SW)

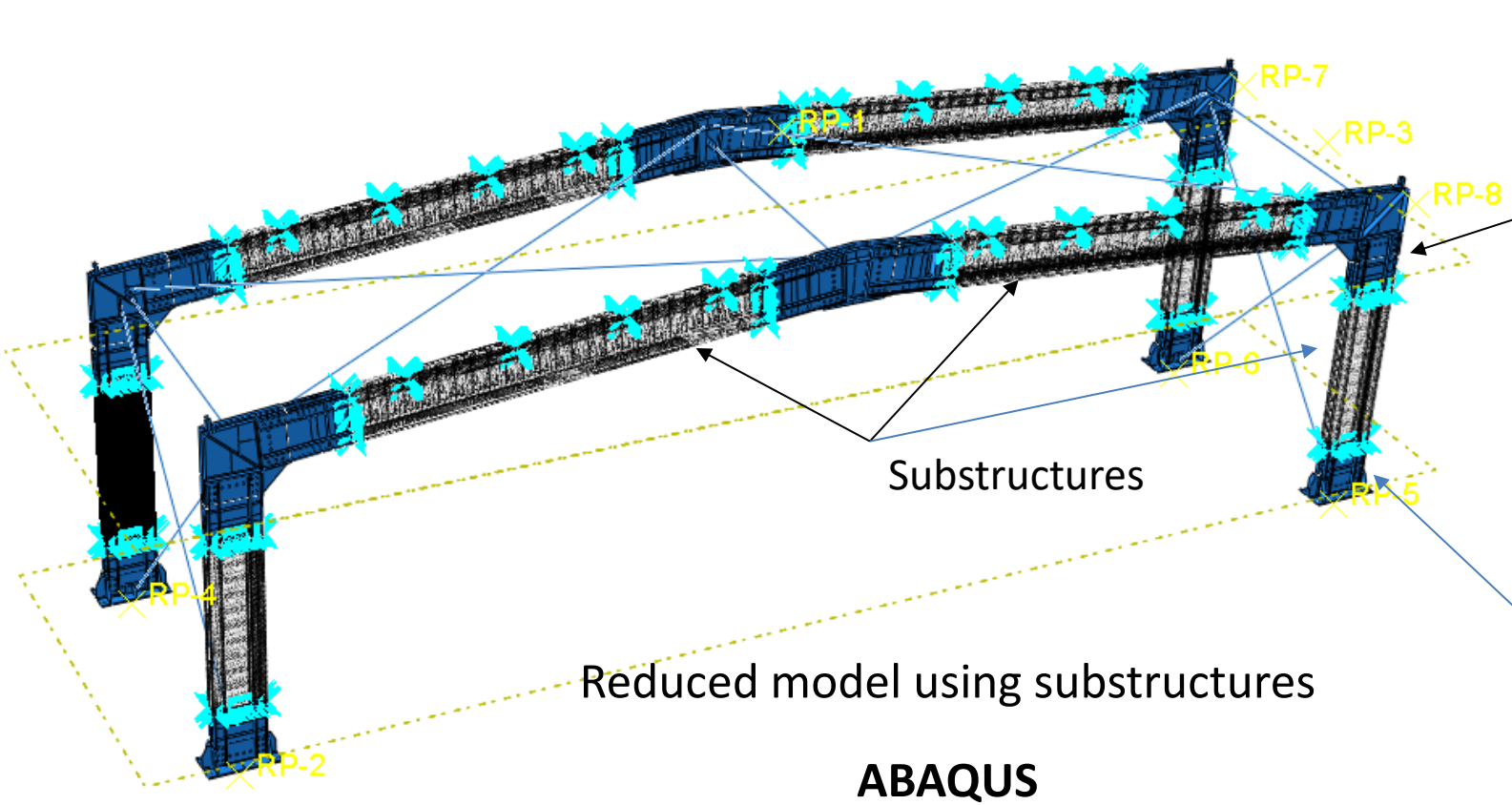
Full scale tests on portal frames (SW și LW)

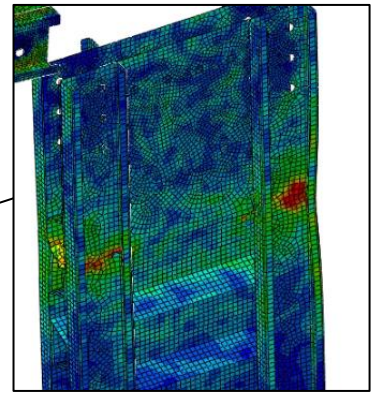


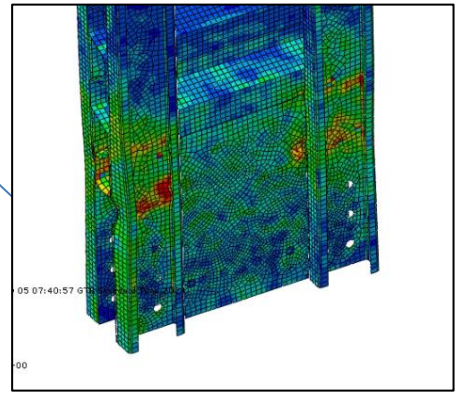


2.5 x code lateral seismic load – elastic behavior

Numerical model (in progress)







Substructures

Reduced model using substructures

ABAQUS

CONCLUSIONS

- **Laser welding** was adopted to improve structural performance and reduce manufacturing costs, validated through experiments and simulations.
- Tests showed laser-welded beams outperform spot-welded and MIG-brazed beams in bearing capacity.
- Columns and joints under cyclic loading displayed **stable behavior**, with degradation only after reaching maximum design force.
- Cost-effective technology – using laser welding and cold rolling for profiles → cheaper technology.

THE TEAM

Structural investigations – experimental / numeric

Acad. Dan Dubină – UPT/AR

Assoc.Prof. Ioan Both – UPT

Sen. Lect. Calin Neagu – UPT

Prof. Ivan Lukačević - UZG

PhD student Antonio Andrei Cristian – UTCB/UPT/Anotech

PhD student Alin Popescu, PhD student Silviu Saraolu – UPT

PhD student Stefan Benzar – UPT/EBENS BLUE BAU

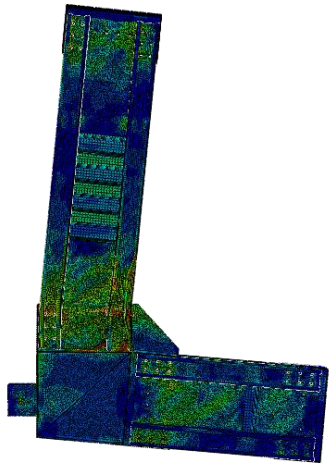
ing. Ovidiu Abrudan, tech. Miloico Ung – UPT

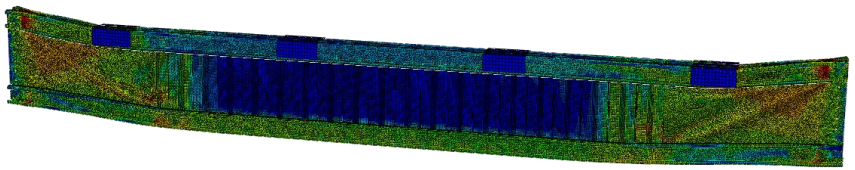
Welding and welding technologies

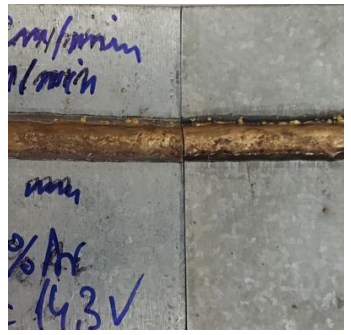
Sen. Lect. Mircea Burcă, Sen. Lect. Daniel Ţunea – UPT

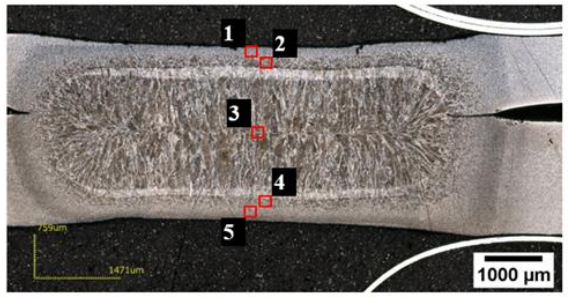
Micro-structural and hardness investigations

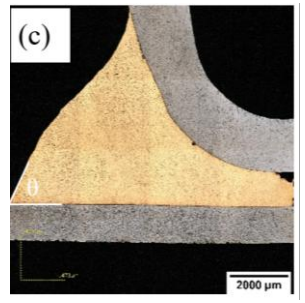
Assoc.Prof. Bogdan Radu, dr.ing. Iosif Hulka - UPT











Universitatea Politehnica Timișoara

Thank you!

Hvala vam na pažnji!

LWT–FLOOR RESEARCH PROJECT

HrZZ Croatian Science Foundation