Project title: **Innovative lightweight cold-formed steel-concrete composite floor system**
Acronym: **LWT-FLOOR** Project ID: **UIP-2020-02-2964**
4th LWT-FLOOR Project Workshop

Advancements in Lightweight Cold-Formed Composite Steel-Concrete Floor Systems: Recent Findings from the LWT-FLOOR Project

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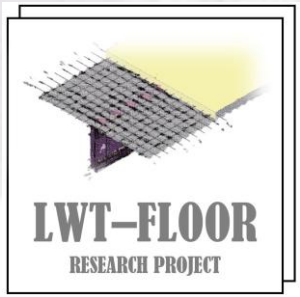


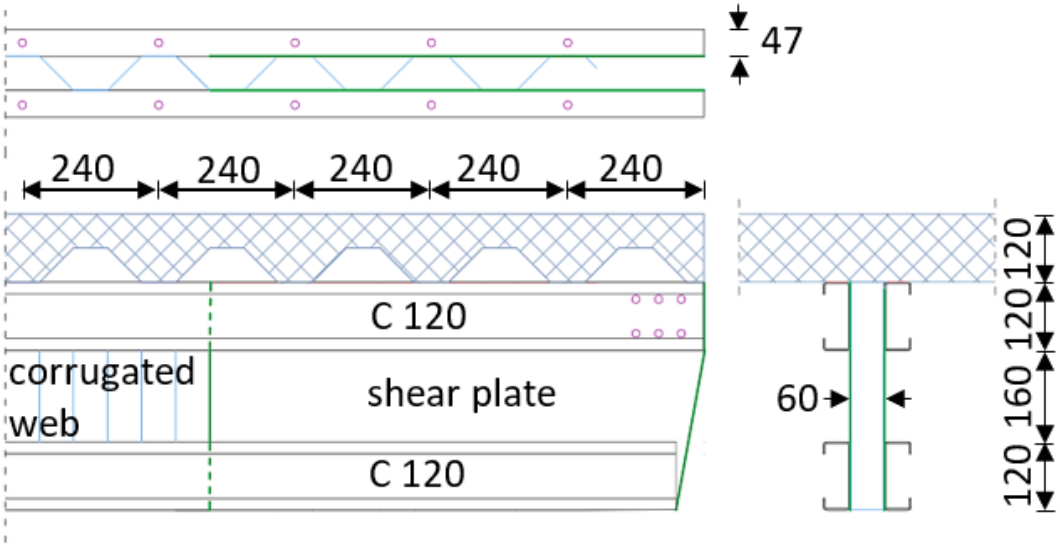
University of Zagreb/Faculty of Civil Engineering
http://www.grad.unizg.hr/lwtfloor

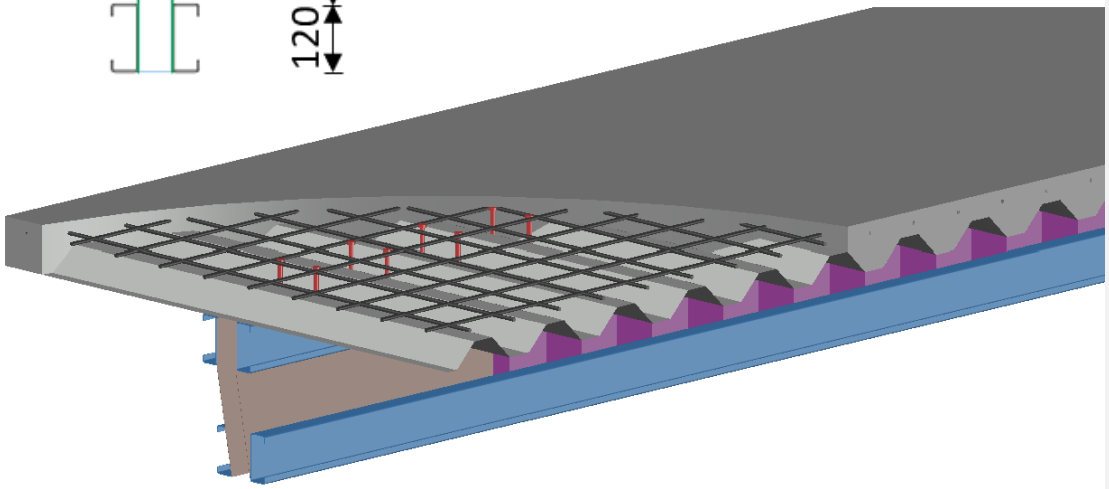
Introduction to LWT-FLOOR project

- **Background**
- Steel-concrete composite action has been widely used in civil engineering due to multiple benefits that occur through the combination of favourable mechanical properties of steel and concrete.
- CWB represents a relatively new structural element that has emerged in the past two decades and was developed for various applications. Due to the thin webs, CWB allows significant weight reduction compared to hot-rolled or welded profiles.

Introduction to LWT-FLOOR project

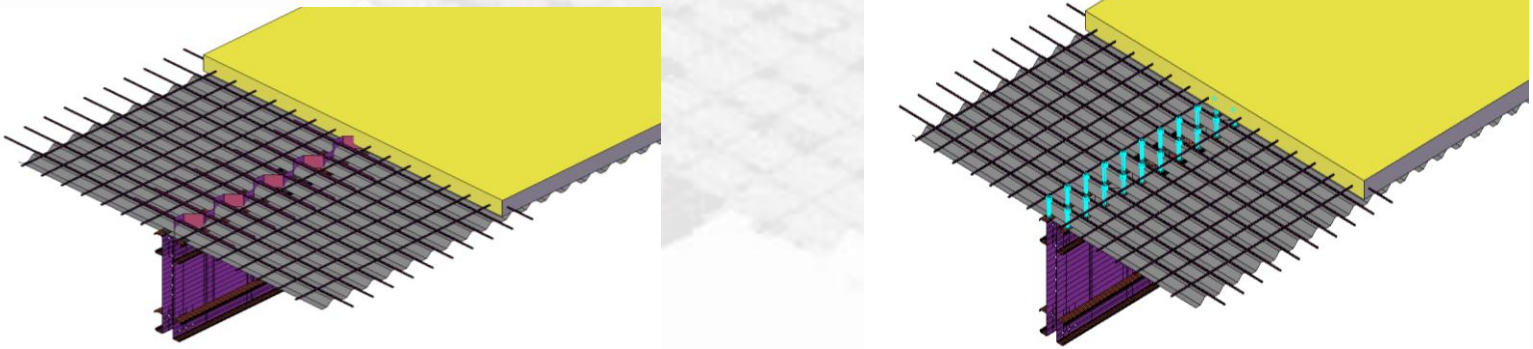
- **Schematic view and visualisation of the LWT-FLOOR system**





Introduction to LWT-FLOOR project

- **Project objectives**
- O2 …to investigate and validate, experimentally, numerically and probabilistically components of proposed floor system
- experimental research is divided into five phases
- system materials and spot welds between different cold-formed sheet thicknesses are performed
- two alternative solutions of shear connection

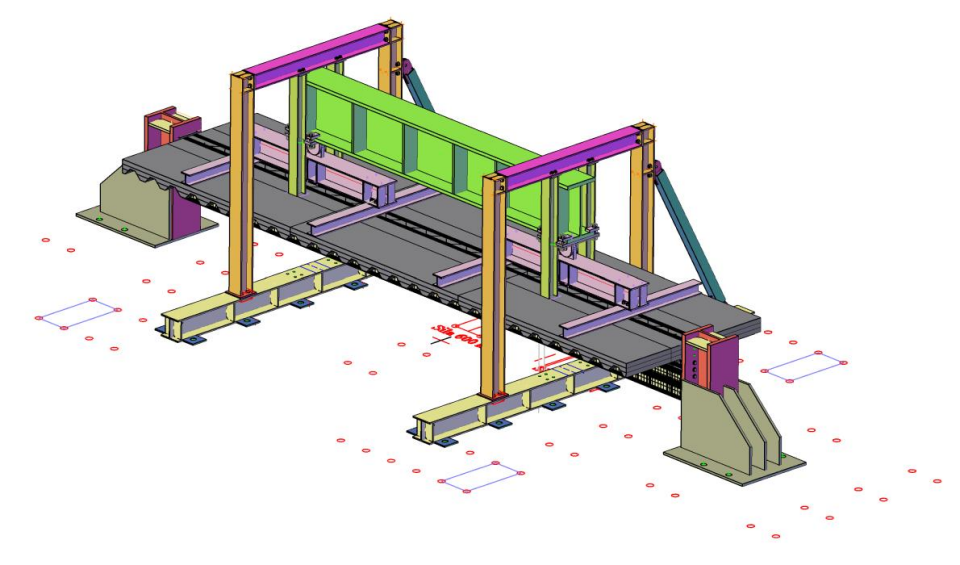


a) Composite dowel rib connectors b) Demountable headed shear studs connectors

Proposed solutions for shear connection

Introduction to LWT-FLOOR project

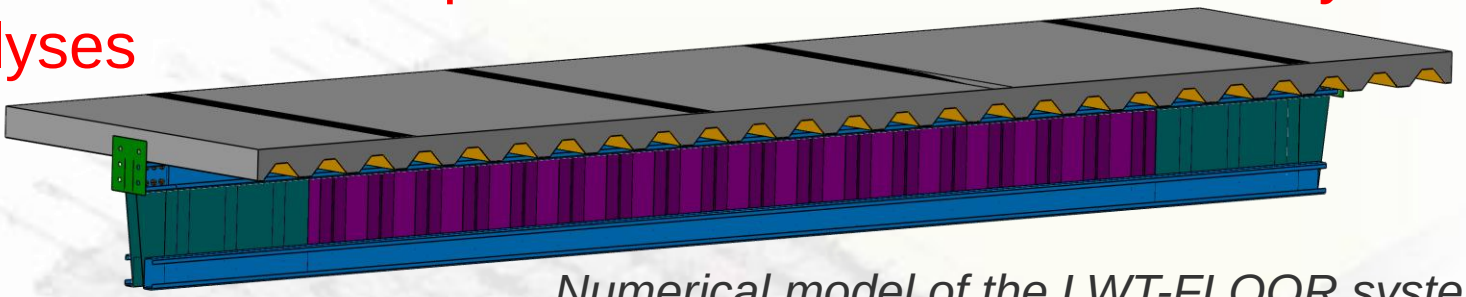
- **Project objectives**
- O3 …to investigate and validate, experimentally, numerically and probabilistically proposed system
- Based on obtained results for optimal shear connection and steel girder solution the experimental tests of the composite LWT-FLOOR system is performed.



LWT-FLOOR system (test set-up)

Introduction to LWT-FLOOR project

- **Project objectives**
- O4 …to validate proposed floor system through numerical parametric studies, probabilistic methods and life cycle analyses



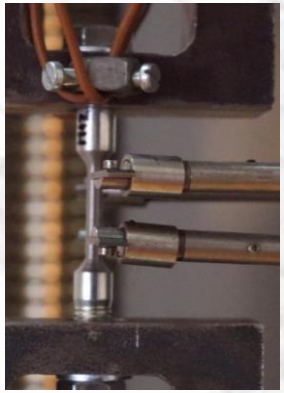
Numerical model of the LWT-FLOOR system

- O5 …to establish an analytical proposal for design recommendations for this new type of floor system
- Based on probabilistic analyses and life cycle analyses analytical proposal will be established for **analysed types of shear connections, steel girders with and without web openings, and composite LWT-FLOOR system with and without web openings.**

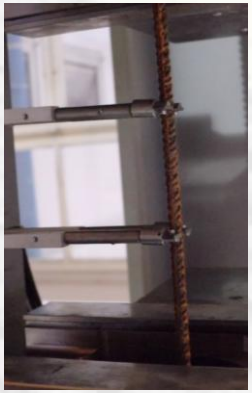
Experimental tests

- **Testing of system components**

Steel sheets



Bolts



Reinforcement

Concrete

Spot welds

Shear connection

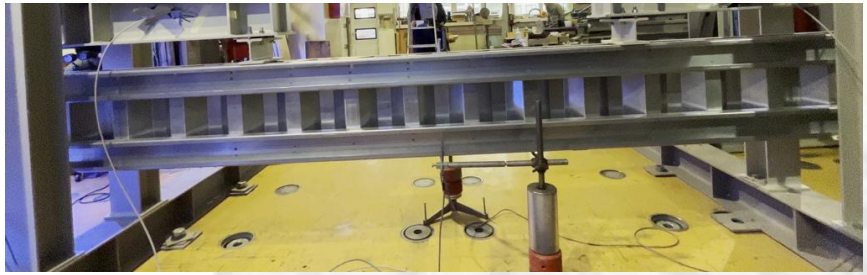
Experimental tests

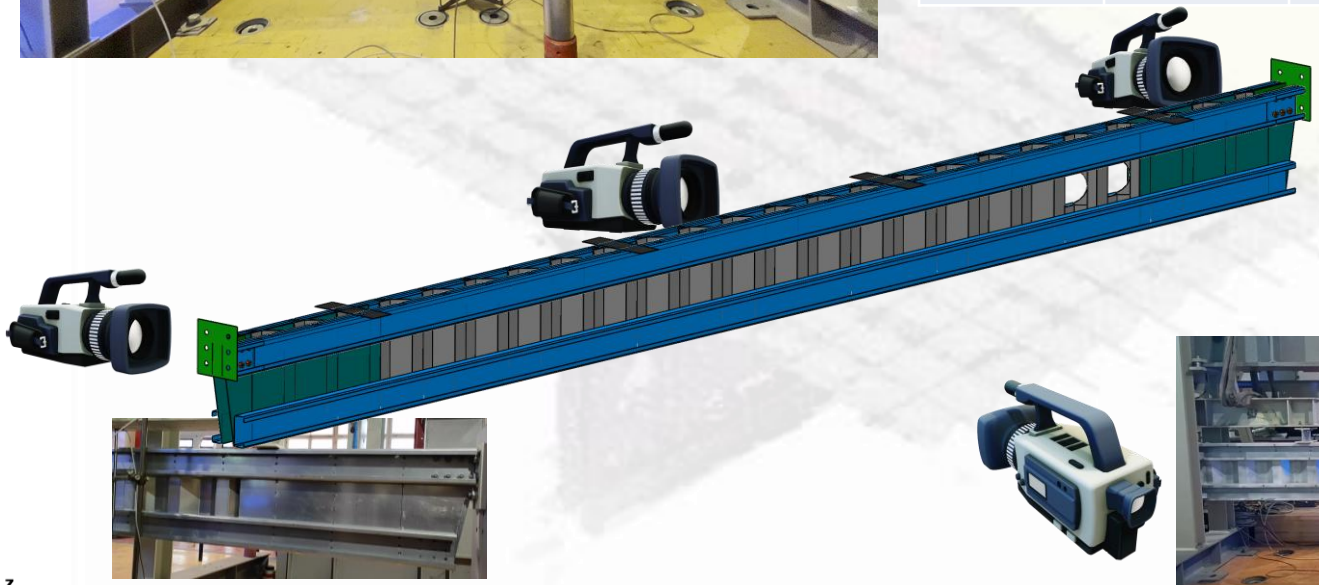
- **Testing of system components**
- **Steel sheets**: 0,8 mm, 1,0 mm, 1,25 mm, 1,5 mm, 2,0 mm, 2,5 mm and 3,0 mm, steel grades DX51 and GD 350 for 3,0 mm only, **135 specimens**
- **Bolts:** M12 and M16, grade 8.8, **11 specimens**
- **Reinforcement:** bars 8 mm and mesh 10 mm, B500, **10 specimens**
- **Concrete:** LC 20/22 and NC 20/25, **43 specimens**
- **Spot welds:** diferent combinations of steel sheet thicknesses, **558 specimens**
- **Shear connections**: different types (with concrete dowels (LC and NC) and demountable types with and without additional corrugated web (NC only)), **30 specimens**

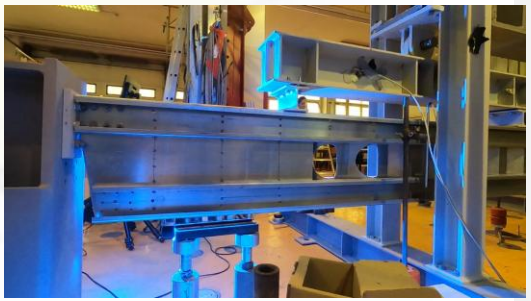
Experimental tests

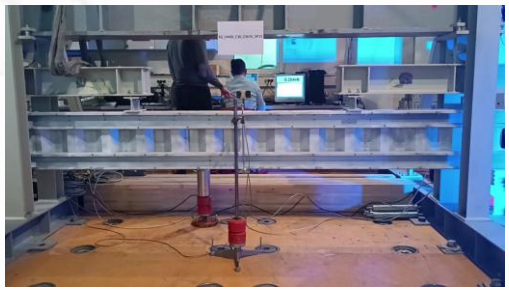
- **Testing of LWT-FLOOR system**

STEEL GIRDER				
	height [mm]	channel thickness [mm]	CW thickness [mm]	Shear plate thickness [mm]
SG1	400	3.0	1.5	1.5
SG2	500	2.0	1.0	1.0
SG3	400	2.5	1.0	1.0





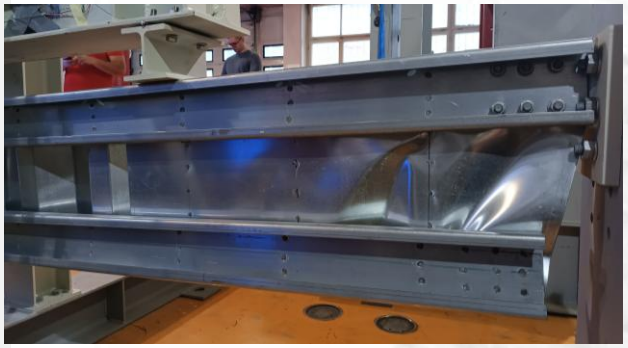




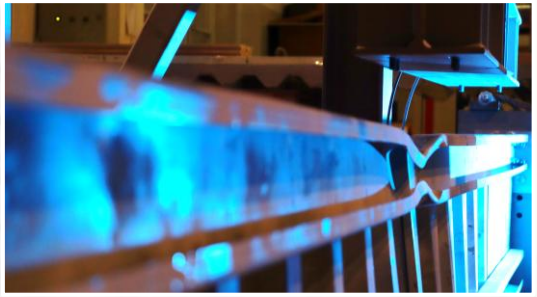
Experimental tests

- **Testing of LWT-FLOOR system**

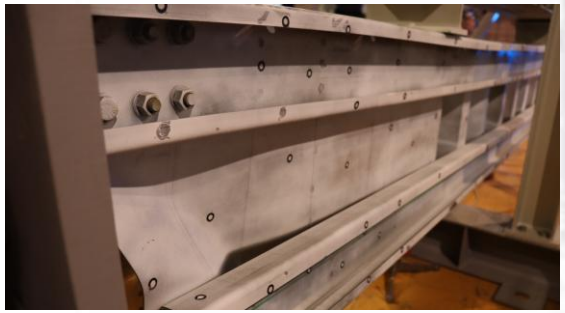
SG1

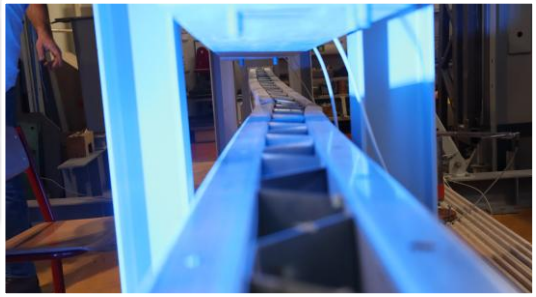


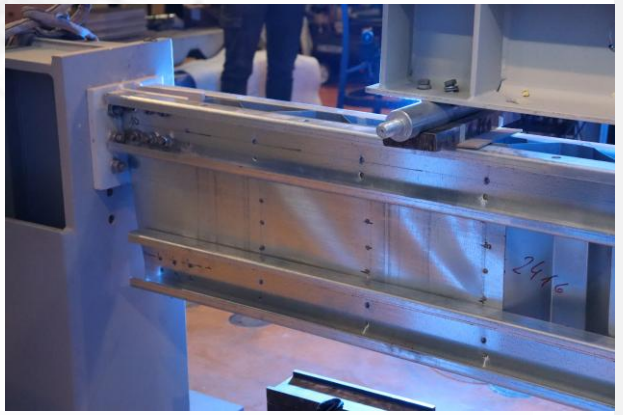
SG2



SG3



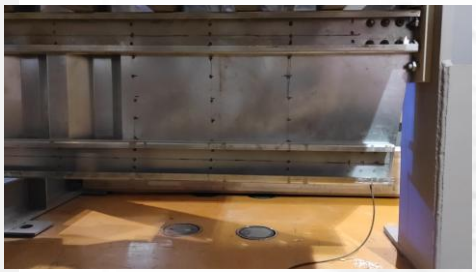


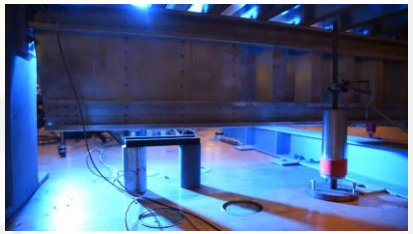


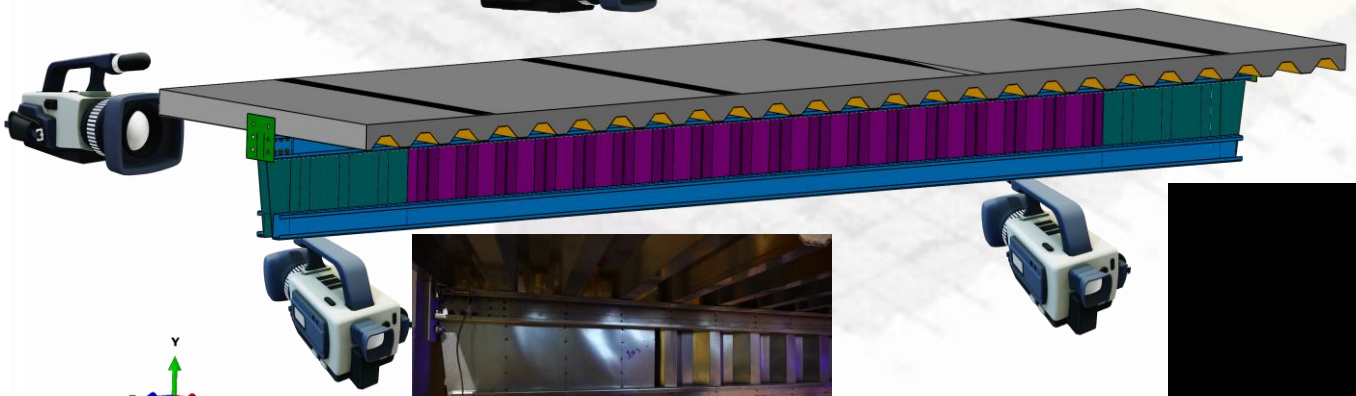
Experimental tests

- **Testing of LWT-FLOOR system**

COMPOSITE GIRDER				
	height [mm]	channel thickness [mm]	CW thickness [mm]	Shear plate thickness [mm]
CG1	400	2.5	1.0	1.0
CG2	500	2.0	1.0	1.0
CG3	400 WEB OPENINGS	3.0	1.5	1.5



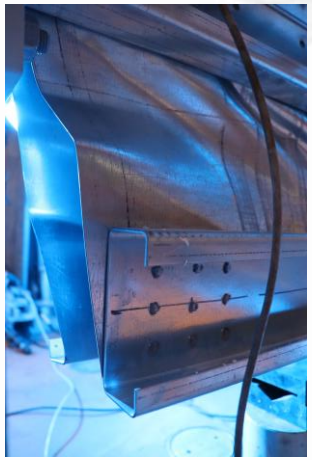




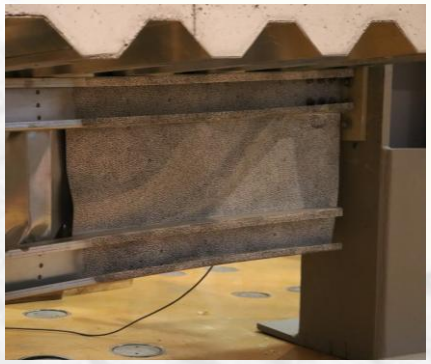
Experimental tests

- **Testing of LWT-FLOOR system**

CG1



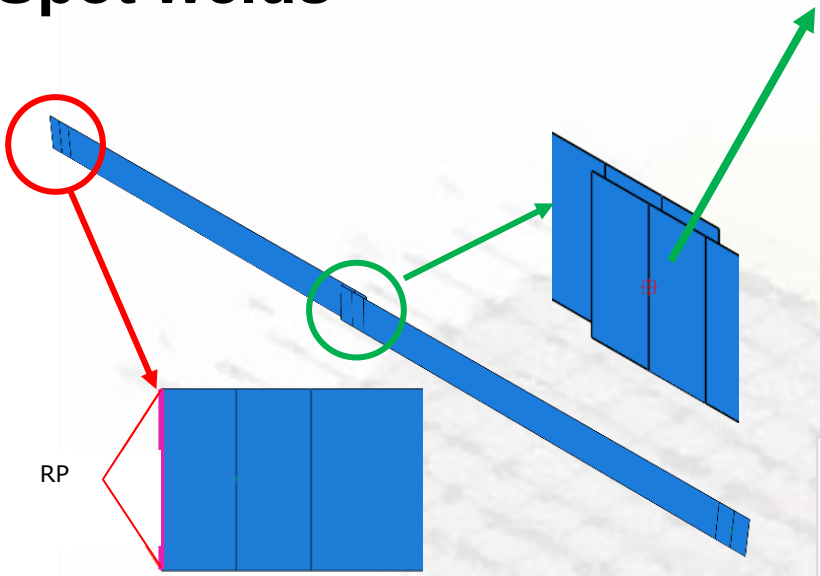
CG2

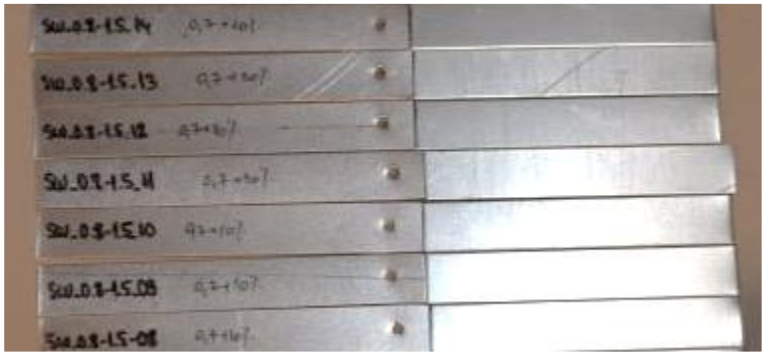


CG3

Finite element analyses and results

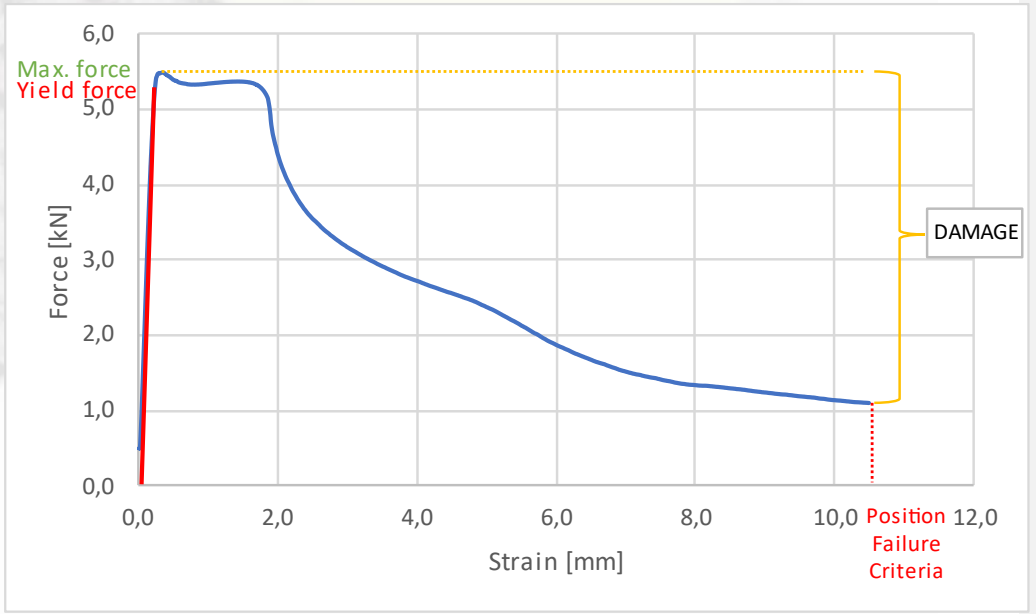
Spot welds





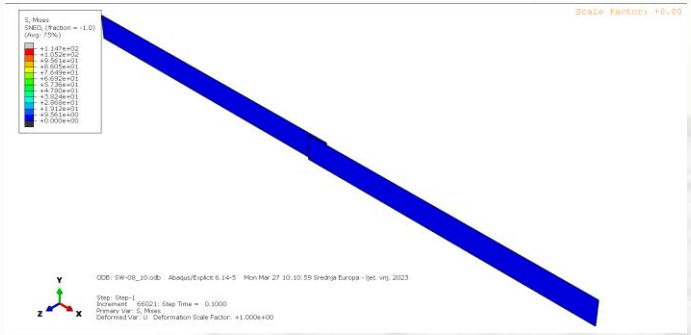
POINT BASED CONNECTOR

- Bushing-type section
  - Elasticity
  - Plasticity
  - Damage
  - Failure

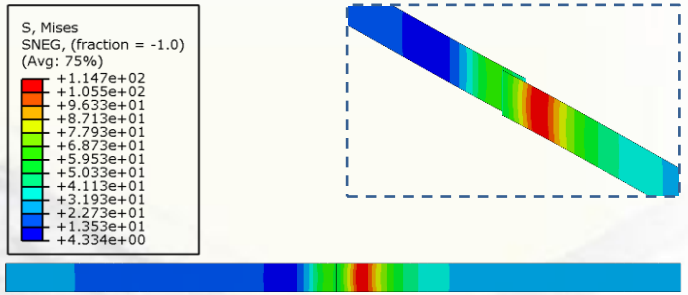


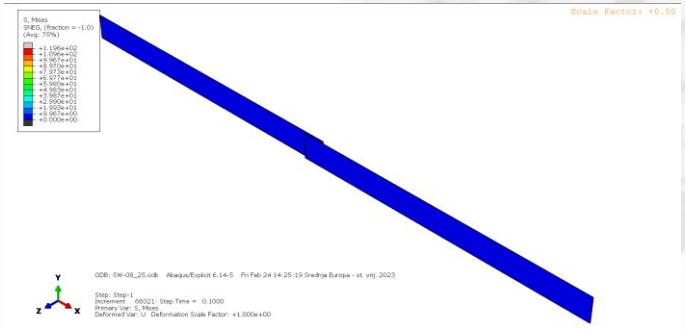
Finite element analyses and results

Spot welds

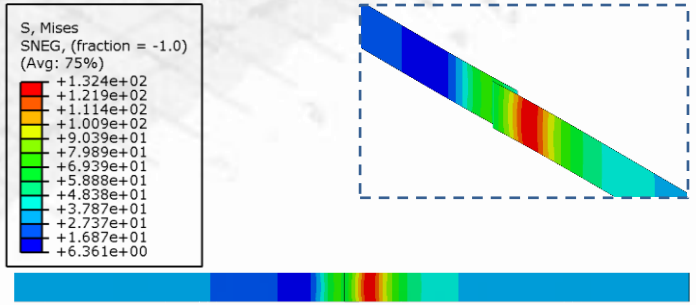


0.8-1.0





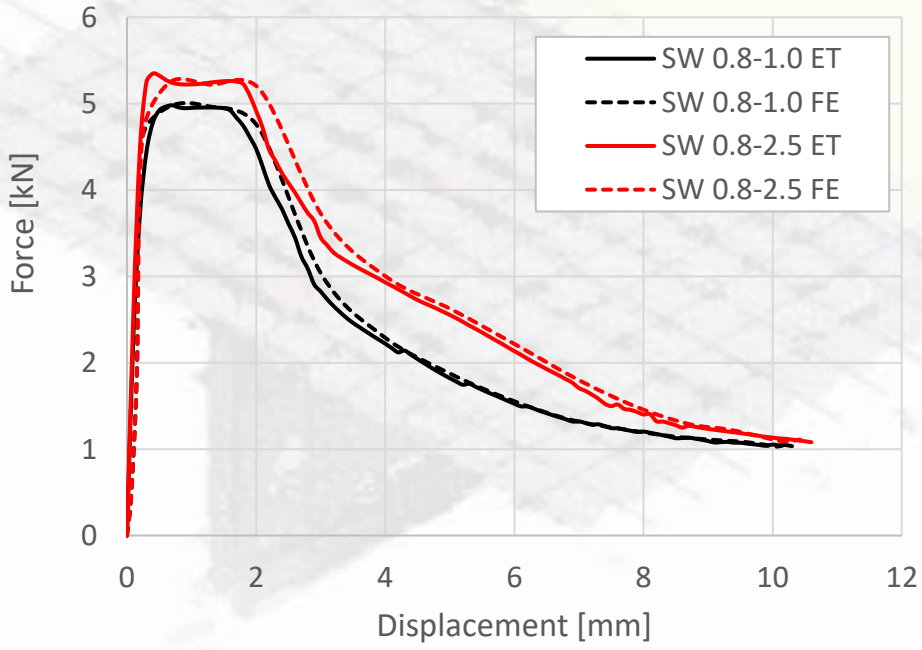
0.8-2.5



Finite element analyses and results

Spot welds

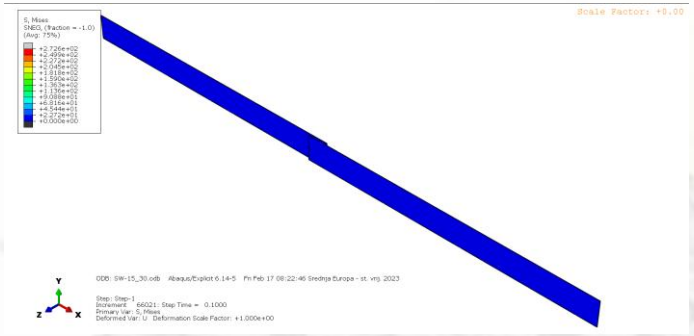
Name	Experimental [kN]	Numerical [kN]
SW 0.8-1.0	4.98	4.97
SW 0.8-2.5	5.35	5.24



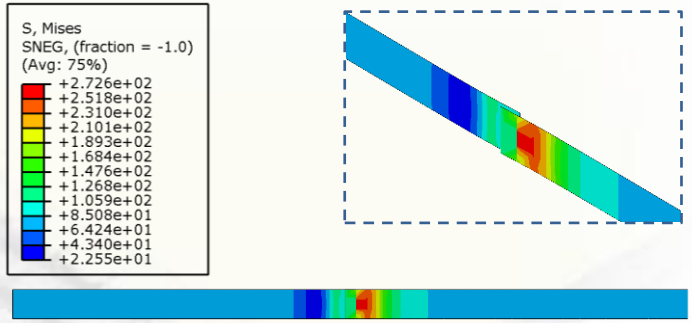
Calibration of spot welds

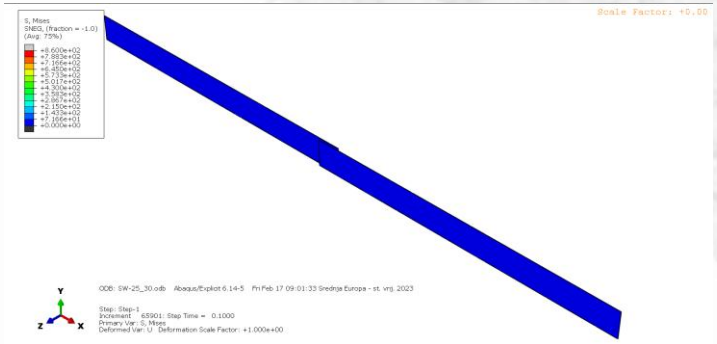
Finite element analyses and results

Spot welds

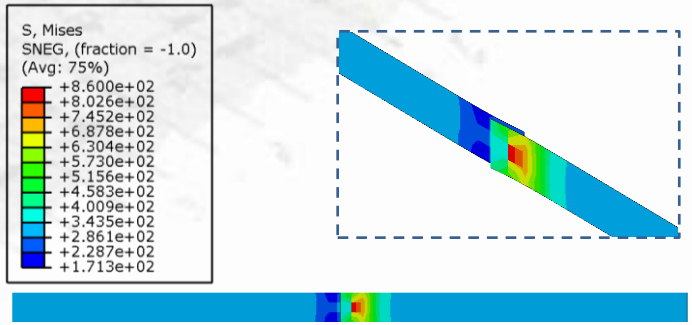


1.5-3.0





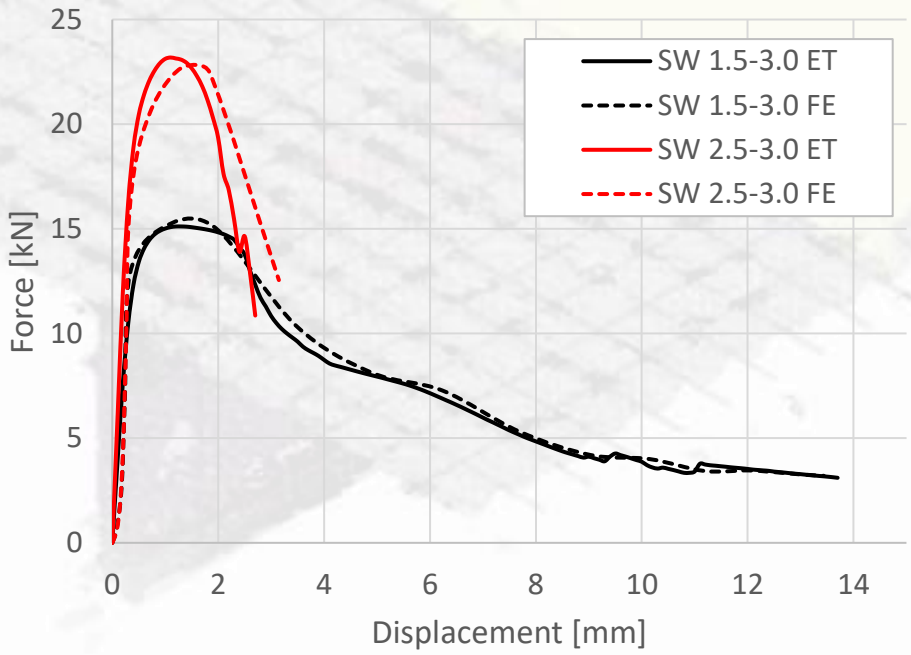
2.5-3.0



Finite element analyses and results

Spot welds

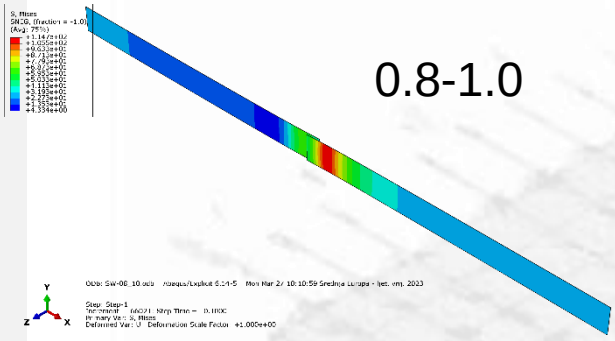
Name	Experimental [kN]	Numerical [kN]
SW 1.5-3.0	15.12	15.11
SW 2.5-3.0	23.19	22.79

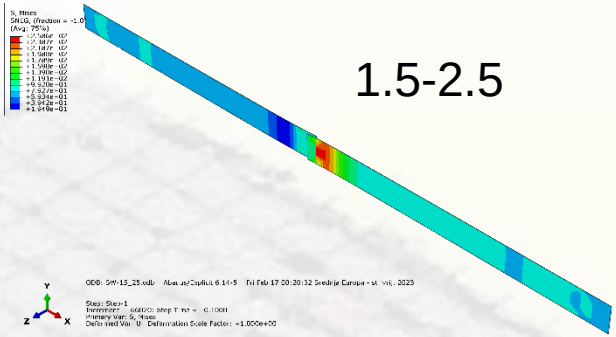


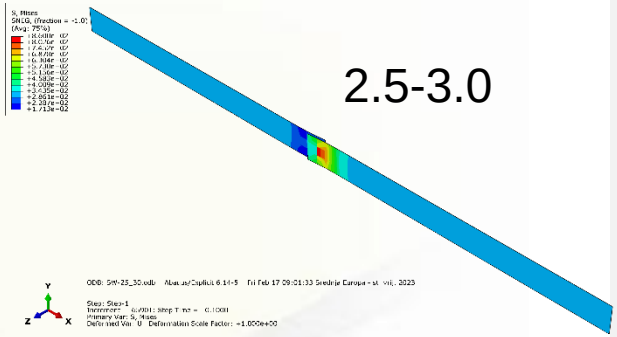
Calibration of spot welds

Finite element analyses and results

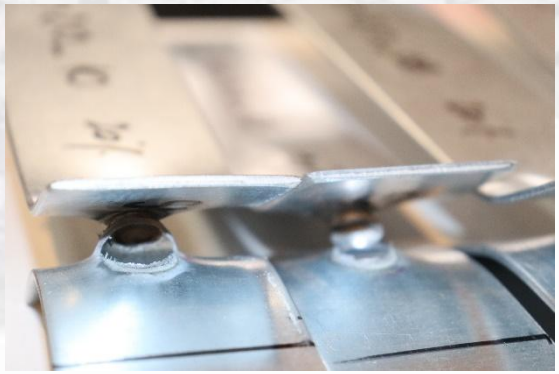
Spot welds







Full button pull-out

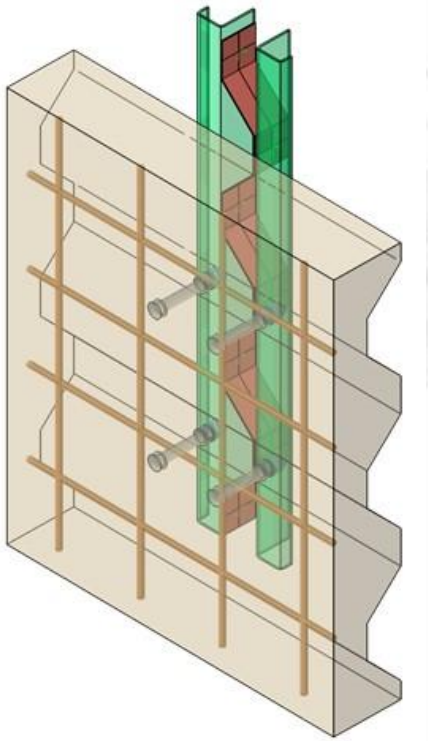


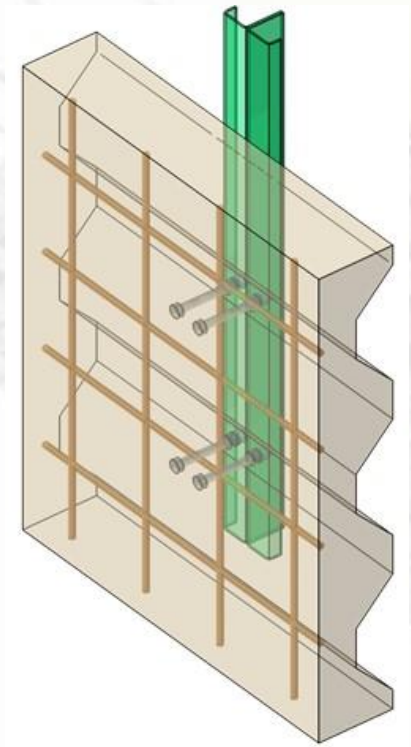
Mixed

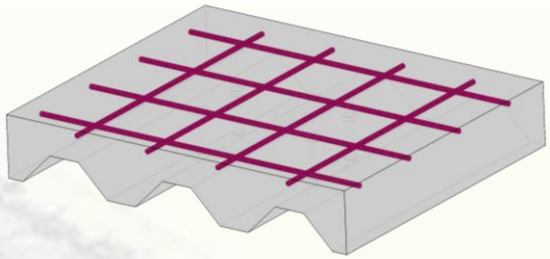
Interfacial fracture

Finite element analyses and results

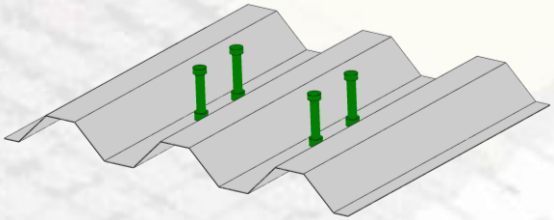
Shear connection



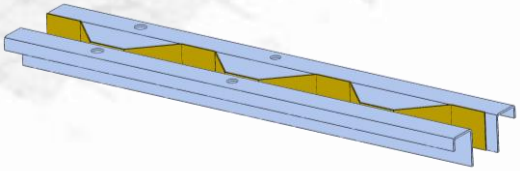




Concrete slab
+ reinforcement



Profiled sheeting
+ bolts



Built-up
CFS girder

Finite element analyses and results

Shear connection

- Boundary Conditions
- Symmetric boundary conditions (plane orthogonal to the X-axis)
- Bottom concrete plane (all directions)
- CFS beam top (horizontal directions)

Load

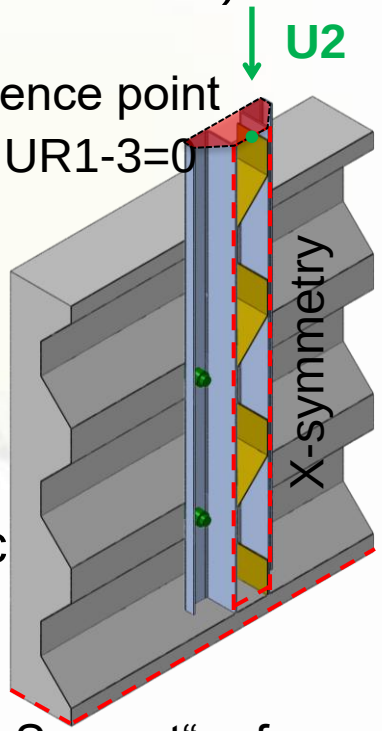
- Uniform vertical displacement at the CFS top

Interactions

- Normal behaviour (hard contact)
- Tangential behaviour (penalty friction - various coeffic
- Spot welds (bushing type connectors)

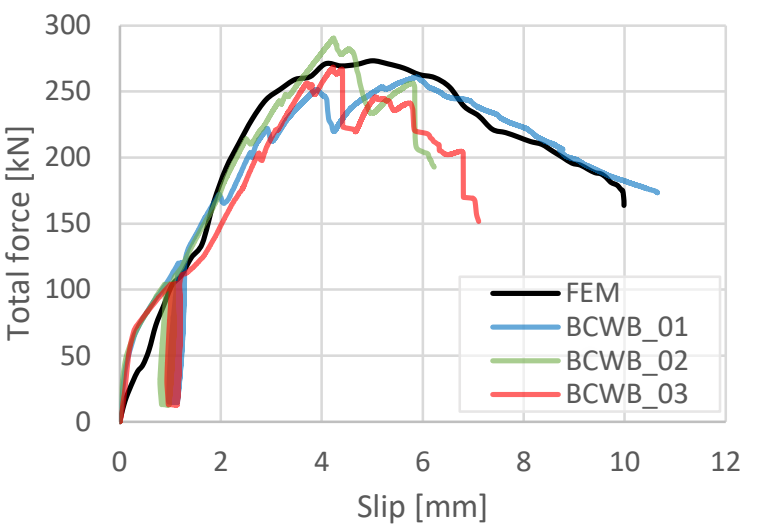
Constitutive models

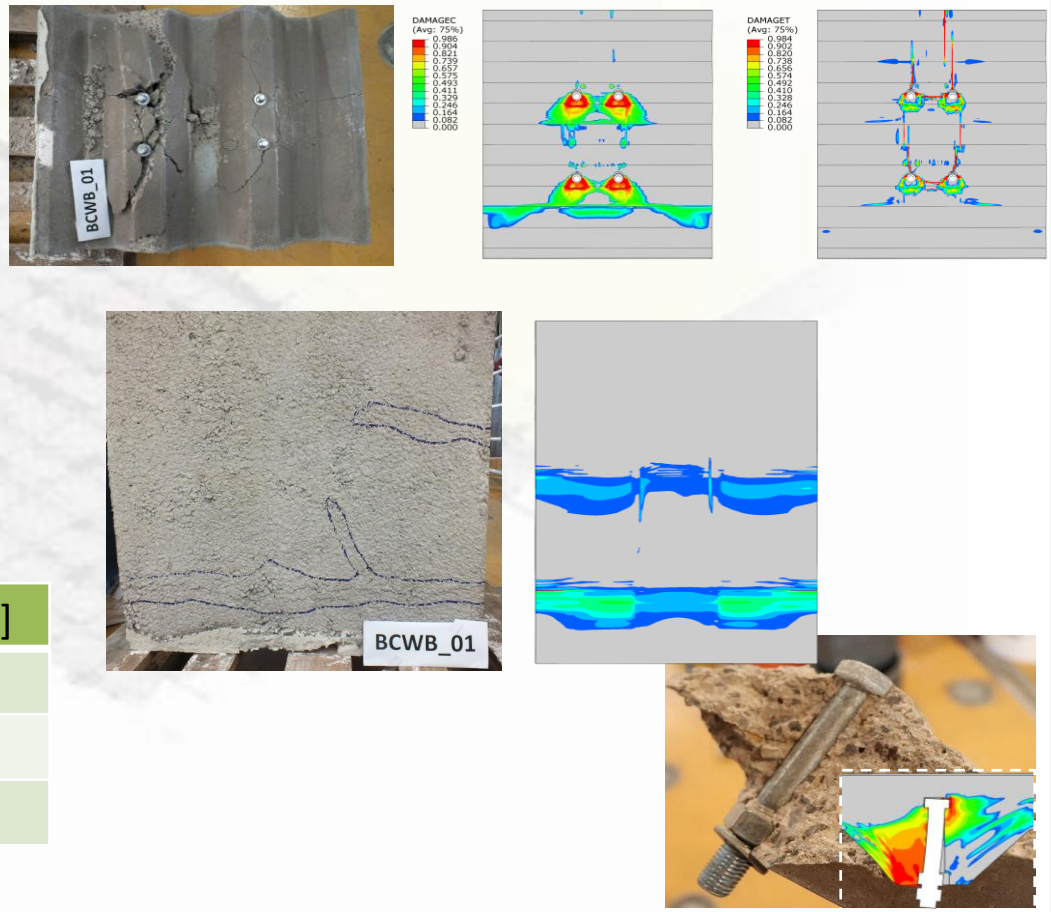
- Steel (true stress-strain curve from experiment)
- Concrete (CDP model with compression and tension failure)



Finite element analyses and results

Shear connection



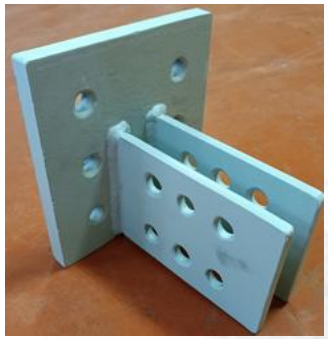


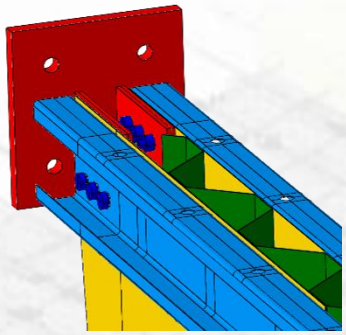
Calibration of shear connections

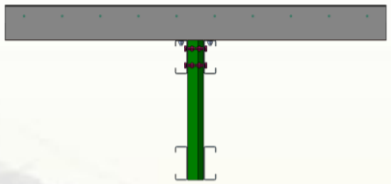
Specimen	Ultimate shear force [kN]	
	$P_{ult,EXP}$	$P_{ult,FEM}$
BCWB_01-03	273.3	273.3
BCWB_04-06	263.0	261.8

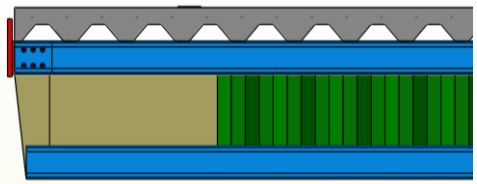
Finite element analyses and results

LWT-FLOOR system

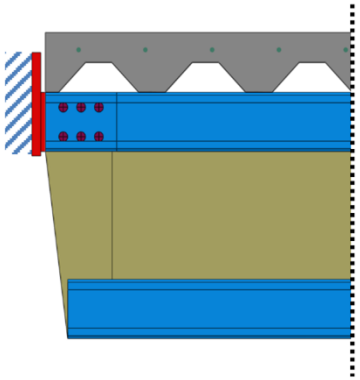


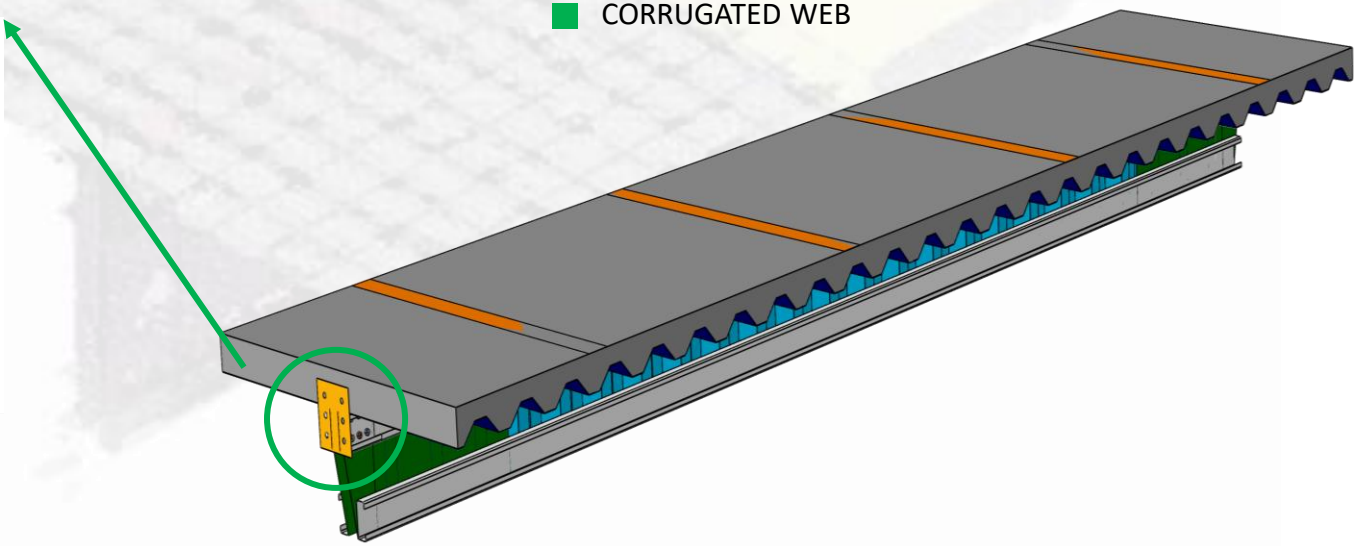






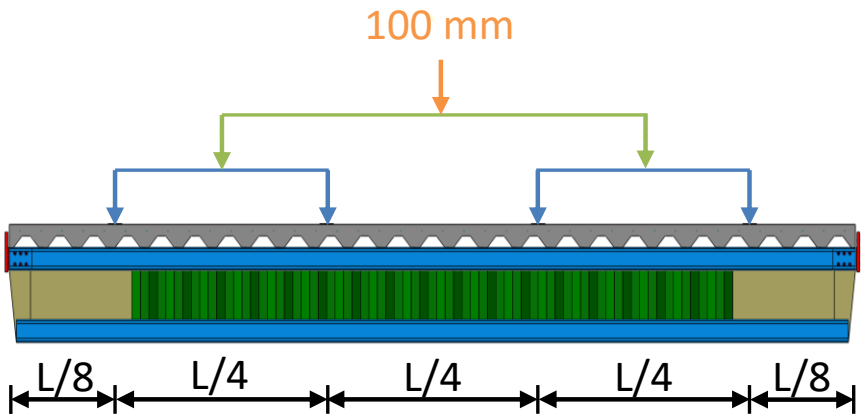
CONCRETE SLAB
CHANNEL PROFILES
SHEAR PLATE
CORRUGATED WEB

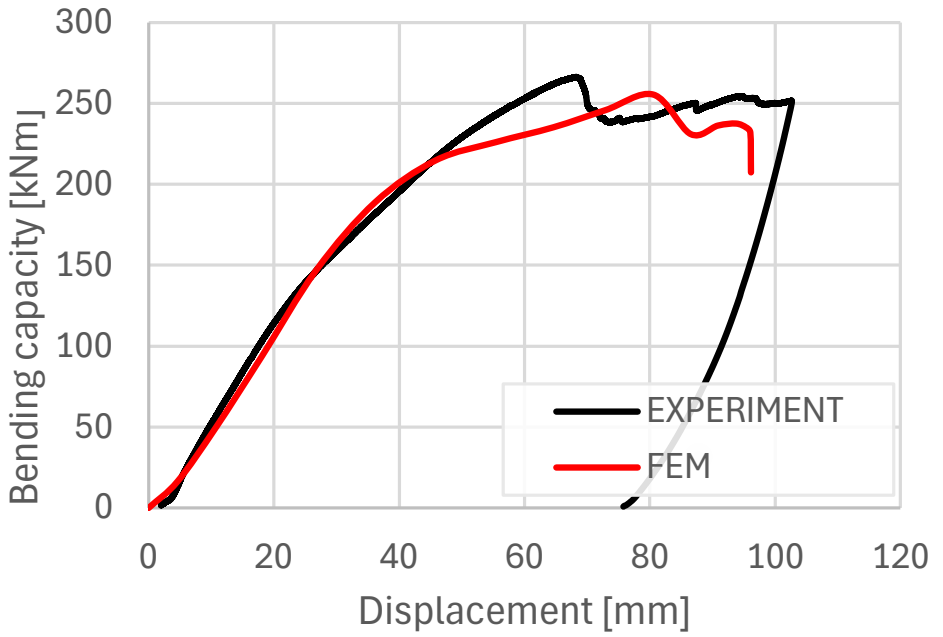




Finite element analyses and results

LWT-FLOOR system





Calibration of the composite LWT-FLOOR system

Conclusions and next steps

- **Calibrated numerical models of spot-welds, shear connection, and the overall system reliably describe experimentally obtained behaviour.**

- **All experimental findings will be utilized to refine numerical models for further parametric investigations.**

- **Numerical models of shear connection, along with future probabilistic analyses, will be employed to identify the most suitable shear connection solution.**

Conclusions and next steps

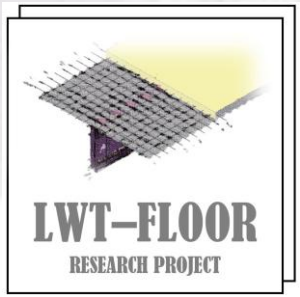
- **Future numerical research will focus on modelling built-up corrugated web beams as well as composite LWT-FLOOR system with and without web openings. Numerical parametric and probabilistic analyses will be used to determine optimal solution for larger spans, various web-opening configurations, various shear connections and various boundary conditions.**

- **Probabilistic and life cycle analyses of optimal solutions for shear connections, steel girders and composite LWT-FLOOR systems will be used to establish an analytical proposal for design recommendations.**

Project title: **Innovative lightweight cold-formed steel-concrete composite floor system**
Acronym: **LWT-FLOOR** Project ID: **UIP-2020-02-2964**
4th LWT-FLOOR Project Workshop

Advancements in Lightweight Cold-Formed Composite Steel-Concrete Floor Systems: Recent Findings from the LWT-FLOOR Project

Ivan Lukačević, Ivan Ćurković, Andrea Rajić, Vlaho Žuvelek



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