A comparative life cycle assessment of structural composite steel-concrete floor systems – A Case Study

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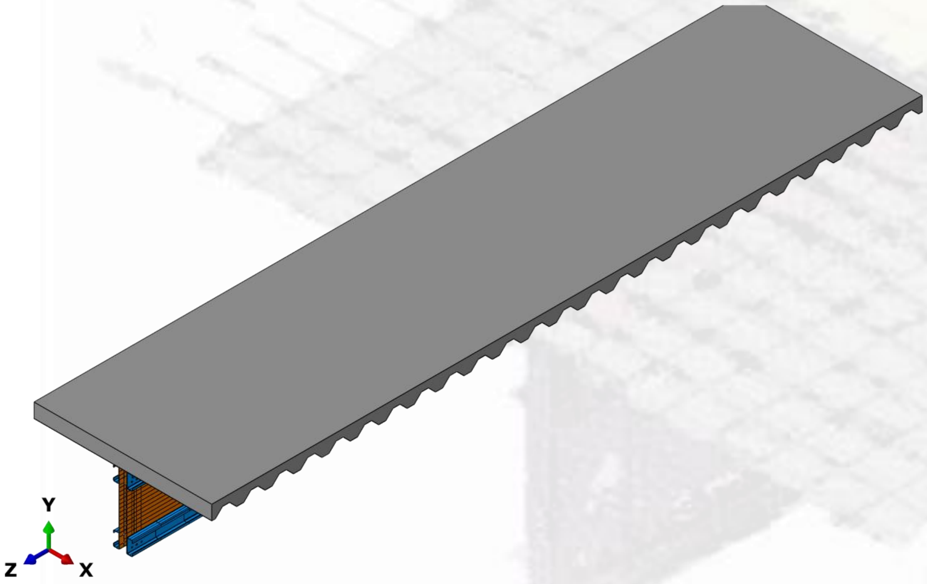
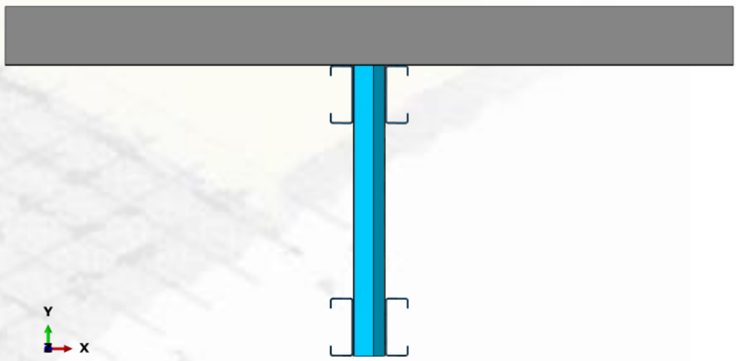
LWT–FLOOR
RESEARCH PROJECT

HRZZ Croatian Science Foundation

Objective

- A comparative Life Cycle Assessment (LCA) and costing between an innovative lightweight cold-formed steel-concrete composite floor system and the traditional composite structural floor system with hot-rolled steel beams.





The IDEA

CEMSIG Research Centre of PU Timisoara

- A comparative Life Cycle Assessment (LCA) and costing between an innovative lightweight cold-formed steel-concrete composite floor system and the traditional composite structural floor system with hot-rolled steel beams.

Introduction

LWT-FLOOR Project

http://www.grad.unizg.hr/lwtfloor

O1 …to establish research group

ER1: Research group equipped with knowledge and instrumentation for specimen's preparation, experimental, numerical and probabilistic testing, understanding components and overall behaviour of the proposed system through the entire life cycle.

O2 …to investigate and validate, experimentally, numerically and probabilistically components of proposed system

ER2: Technical report with test results on materials and optimal welded and shear connections solutions.

O3 …to investigate and validate, experimentally, numerically and probabilistically proposed system

ER3: Technical report with results for the proposed system

O4 …to validate proposed floor system through on numerical parametric studies, probabilistic methods and life cycle analyses

ER4: Report with validation of FE models for different floor system typologies and results of numerical, probabilistic and life cycle studies of specimens with larger spans.

O5 …to establish an analytical proposal for design recommendations for this new type of floor system

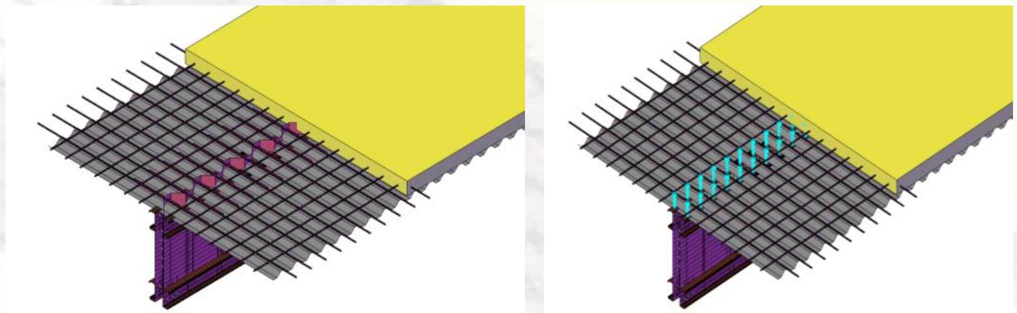
ER5: Technical recommendations for design and fabrication will be proposed

O6 …to prepare project proposals and applying to other sources of funding

ER6: Research group as a centre of expertise self-sustained through other national and international funding sources.

Introduction

- O2 …to investigate and validate, experimentally and numerically the components of proposed floor system



a) Composite dowel rib connectors

b) Demountable headed shear studs connectors

Proposed solutions for shear connection

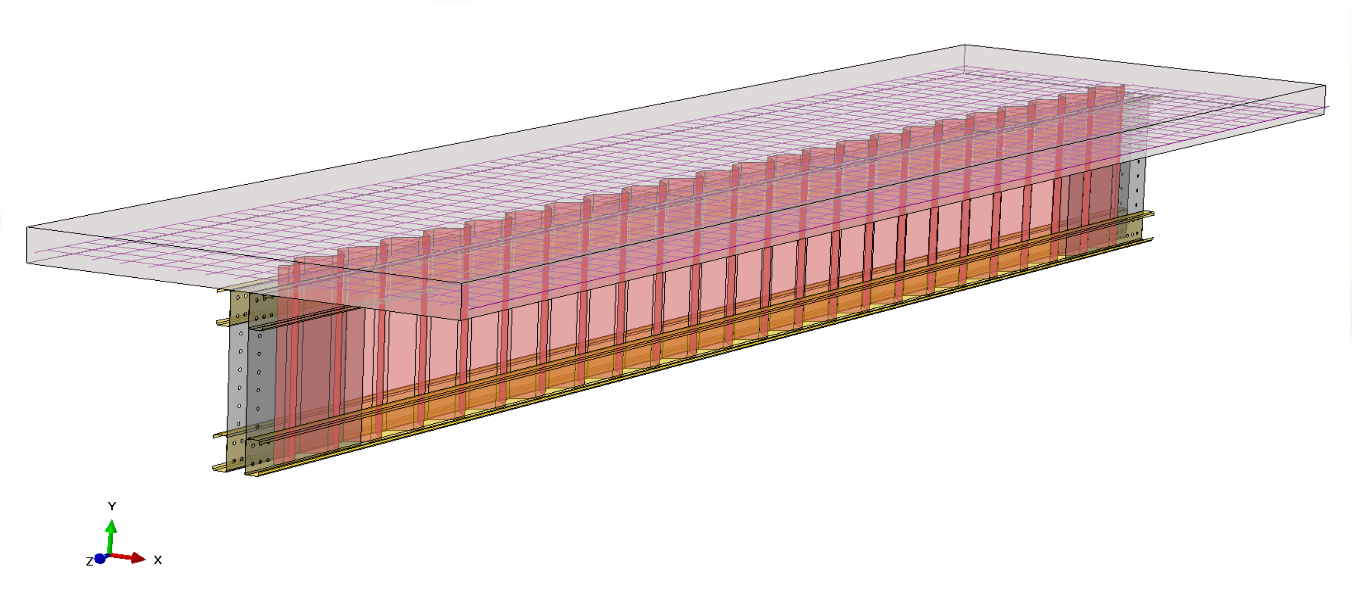
Introduction

- O3 …to investigate and validate, experimentally and numerically the proposed system

Proposal for test setup for LWT-FLOOR system

Introduction

- O4 …to validate proposed floor system through numerical parametric studies and life cycle analyses;

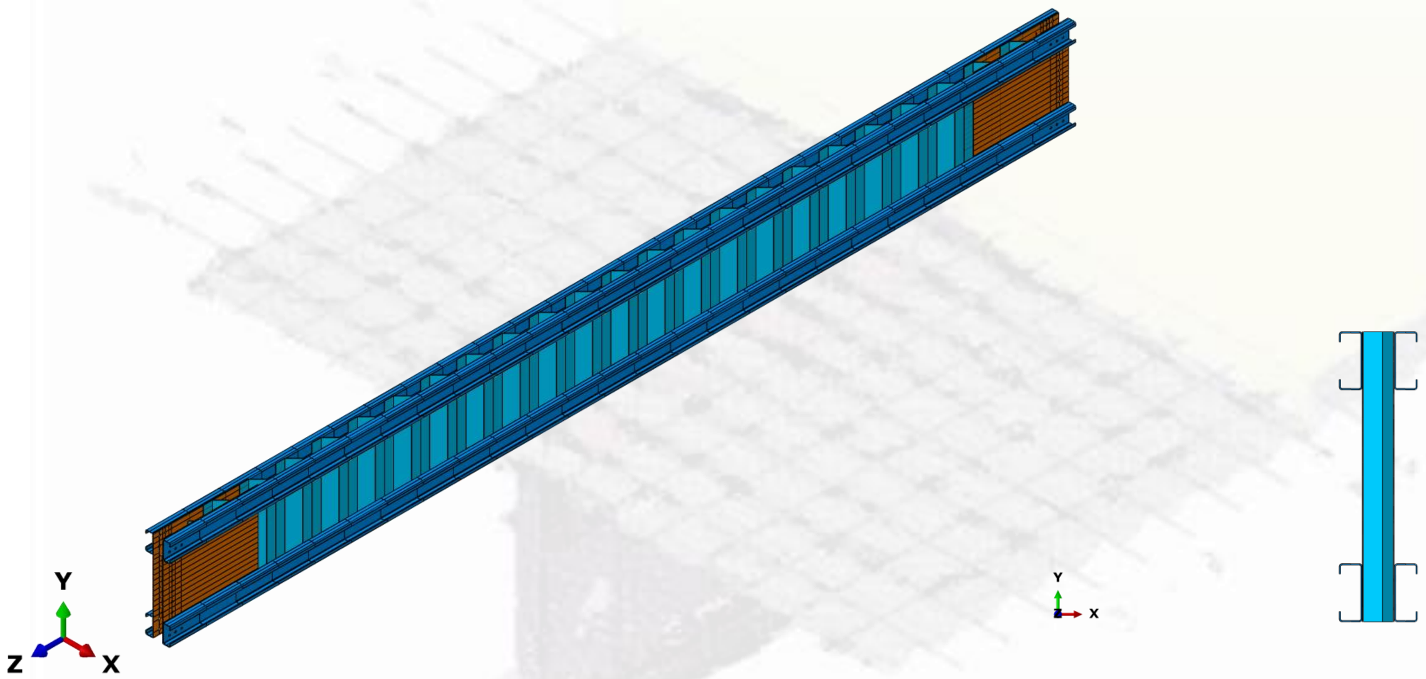


Preliminary numerical model of the LWT-FLOOR system

- O5 …to establish an analytical proposal for design recommendations for this new type of floor system

The solution

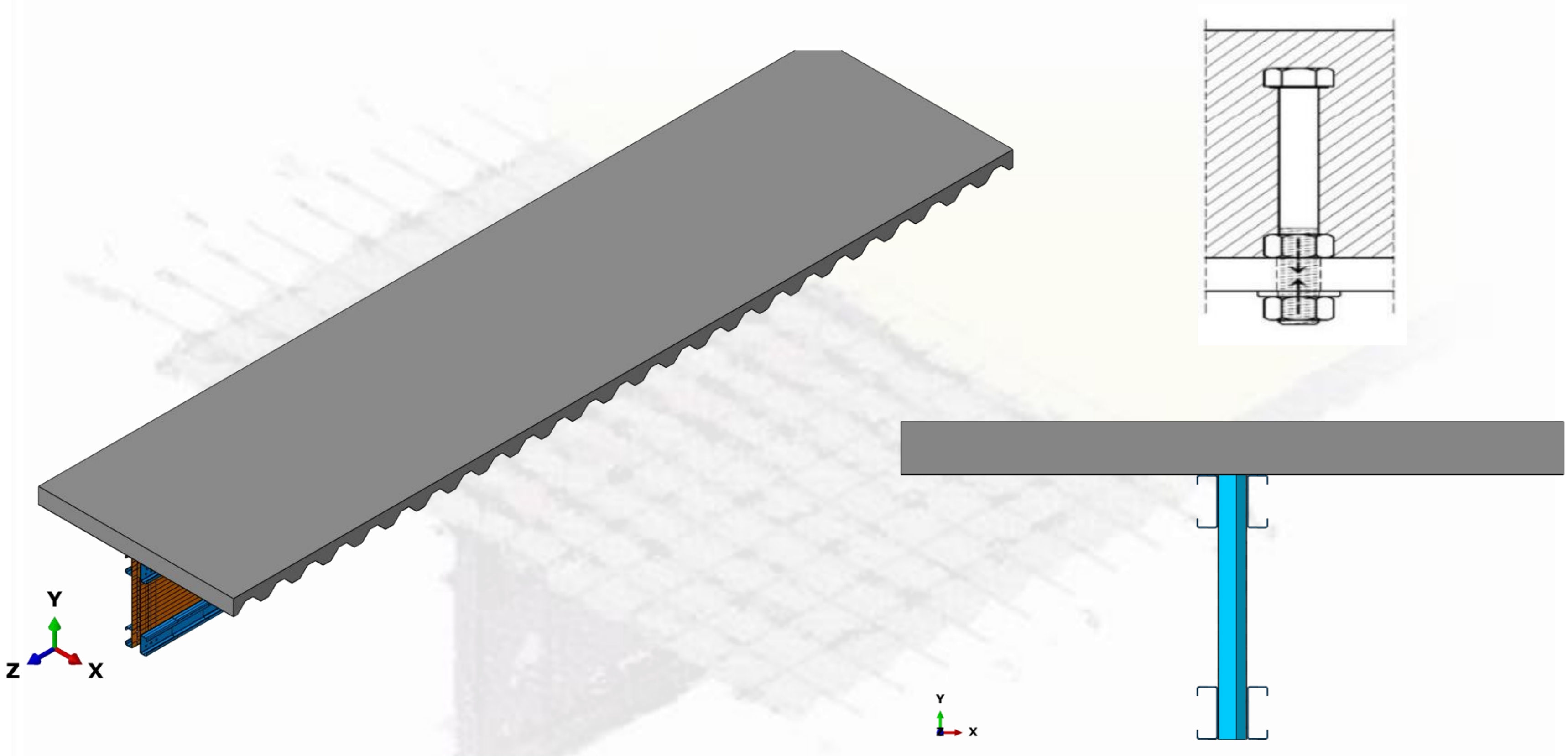
- LWT–FLOOR system



steel beam

The solution

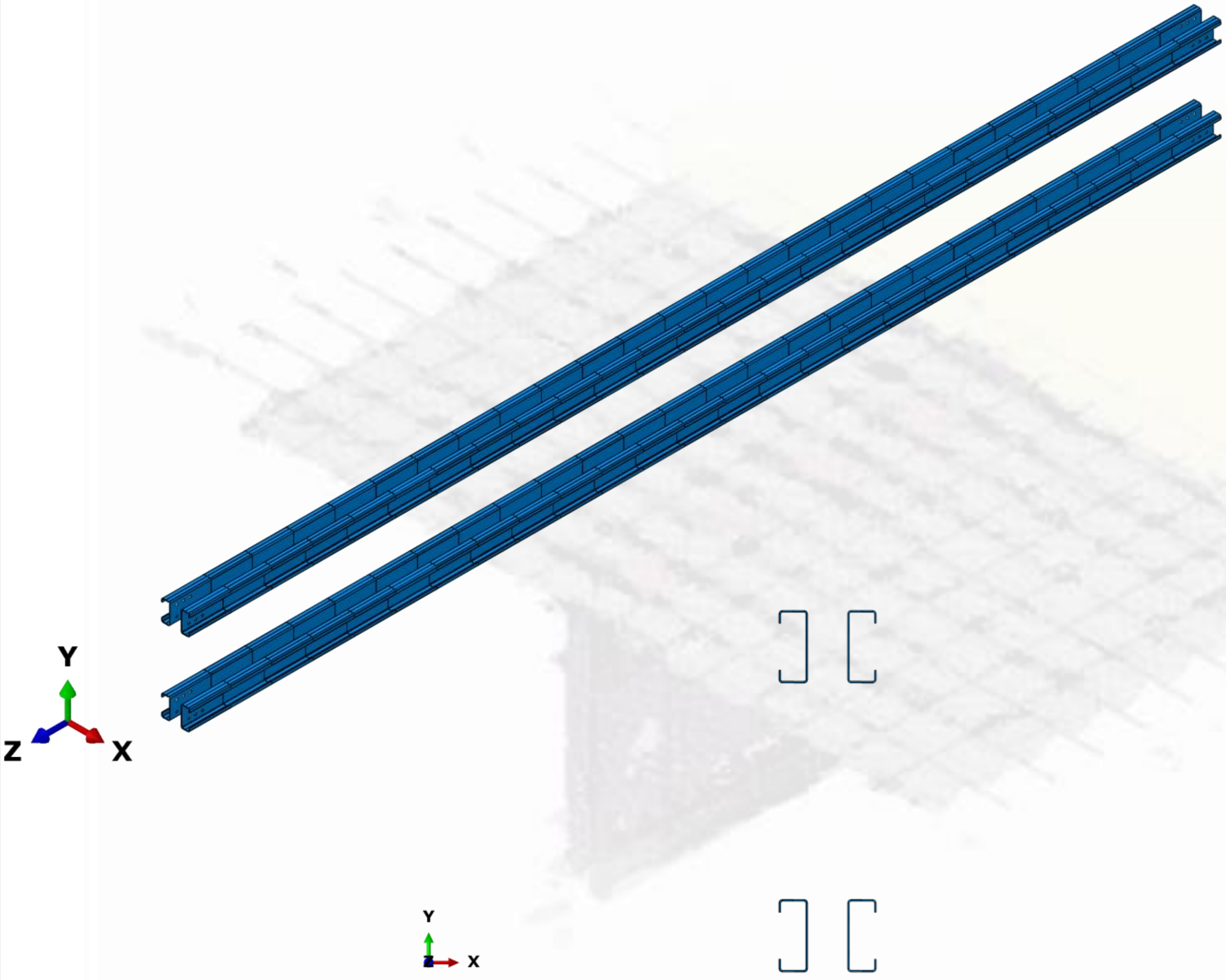
- LWT-FLOOR system



LWT-FLOOR composite system

The solution

- LWT-FLOOR system



CFS C120 profiles: S350 GD
- thickness: 2.5 mm

Shear plates: S350 GD
- thickness: 1.0 mm
- height: 400 mm

Corrugated web: S350 GD
- thickness: 1.0 mm
- height: 400 mm

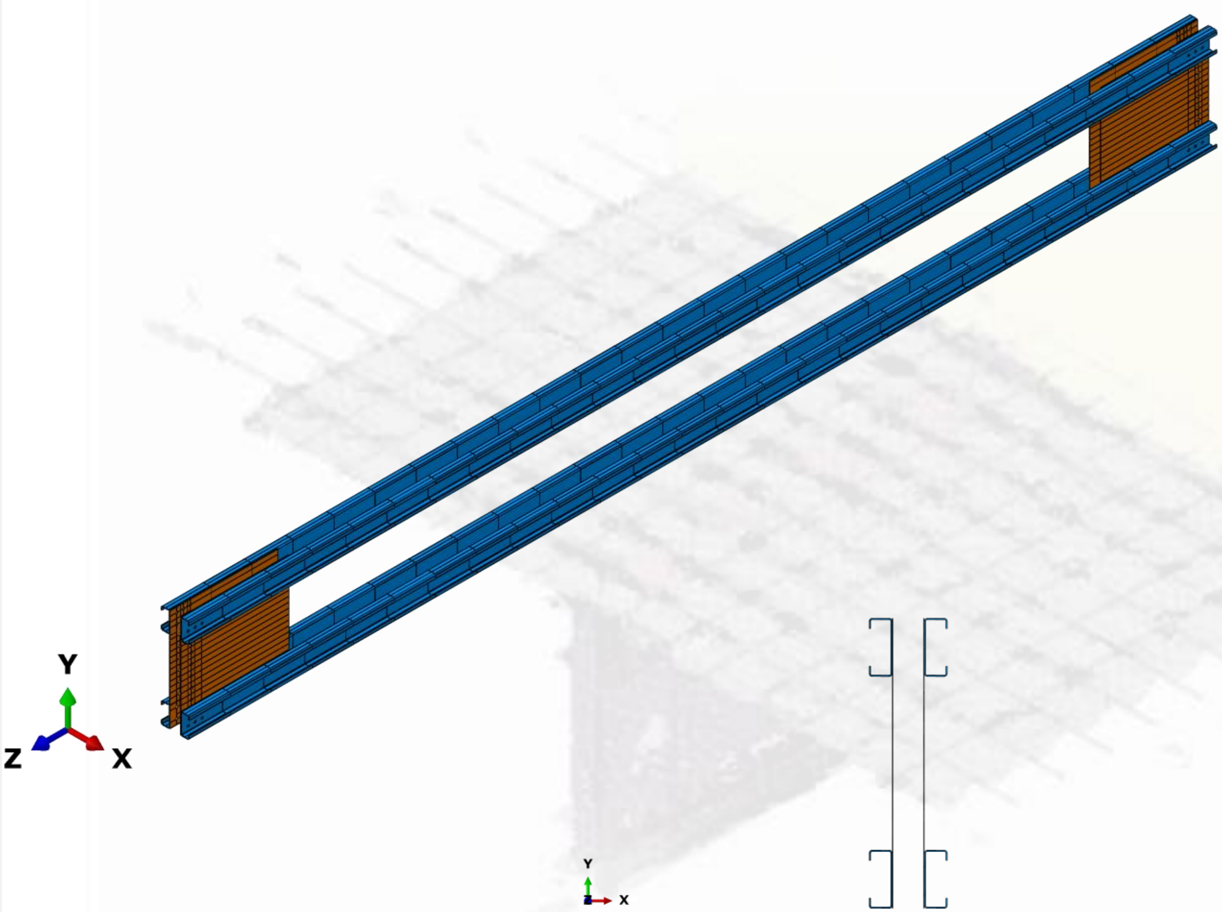
Metal sheet: S350 GD
- thickness: 1.0 mm
- eff. width: 1500 mm

Shear connectors:
- in pairs
- M12
- height: 84 mm
- quality: 8.8

Concrete slab:
- C25/30
- eff. width: 1500 mm
- height: 120 mm

The solution

- LWT-FLOOR system



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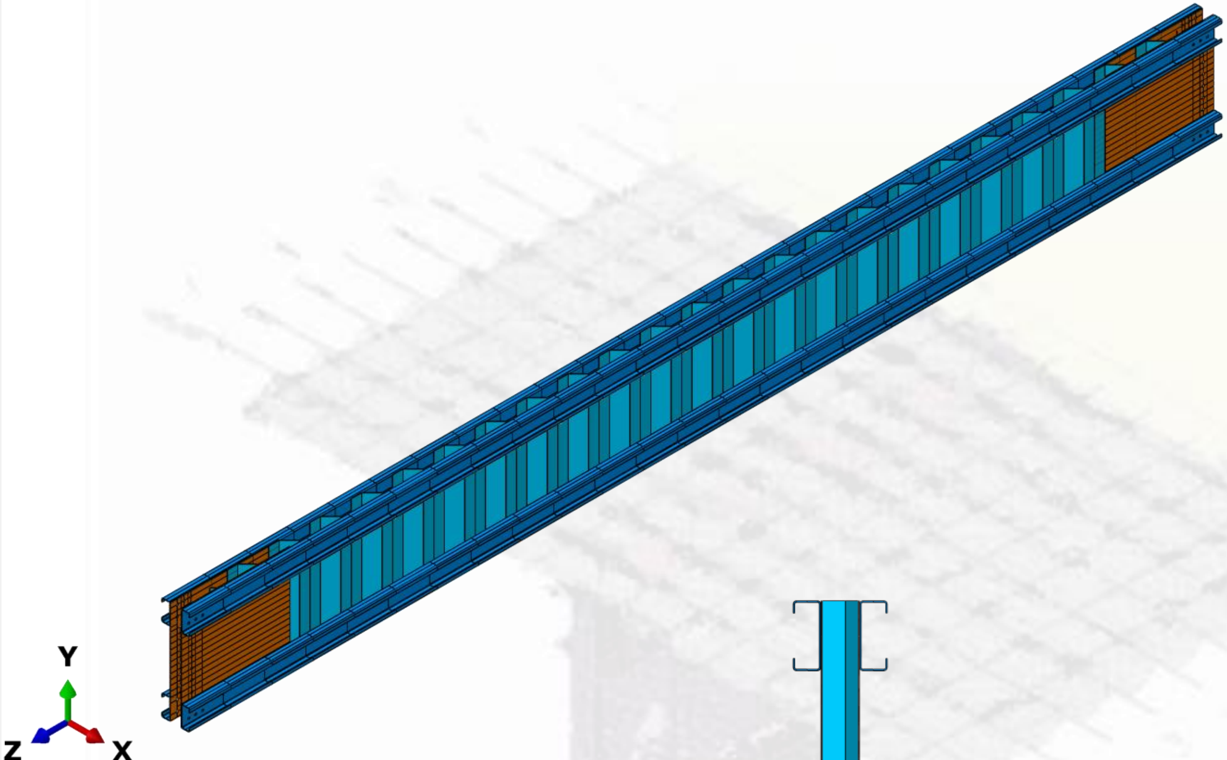

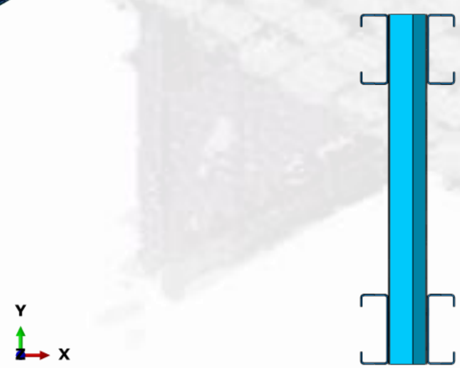

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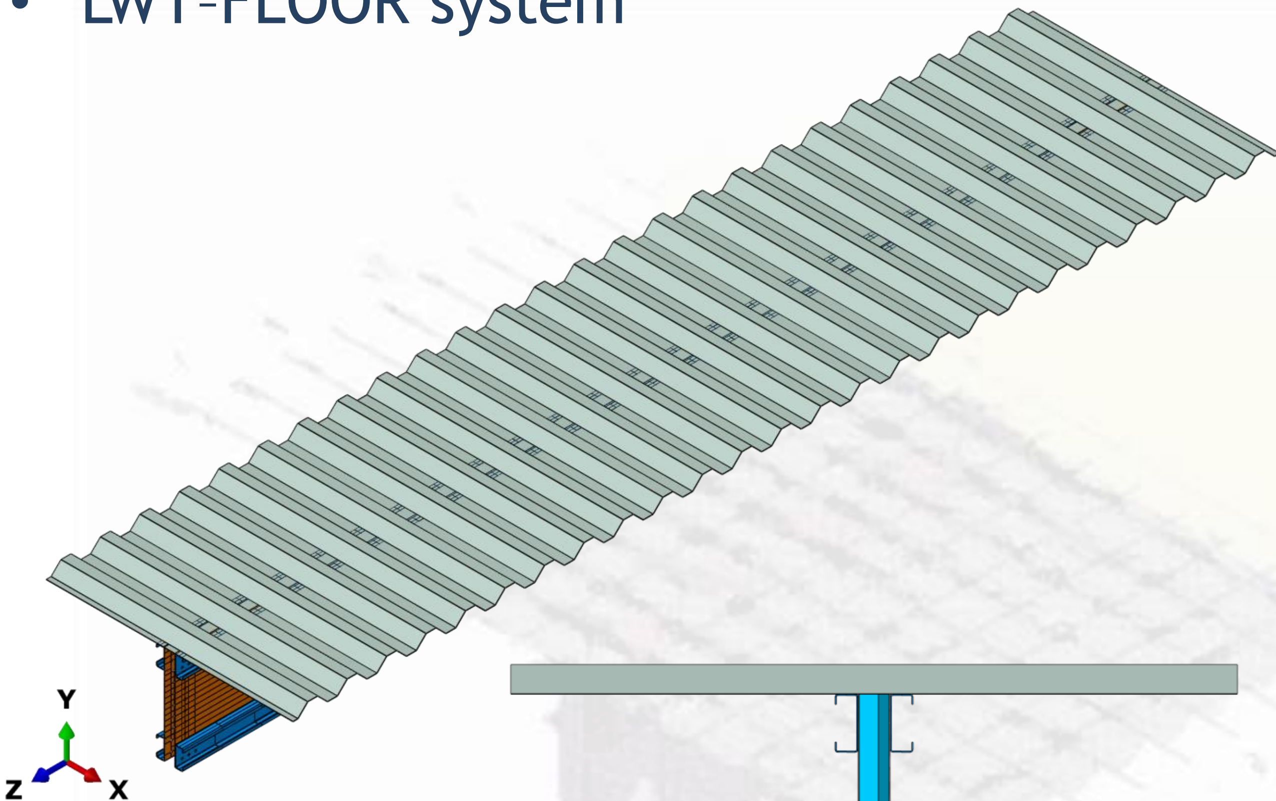

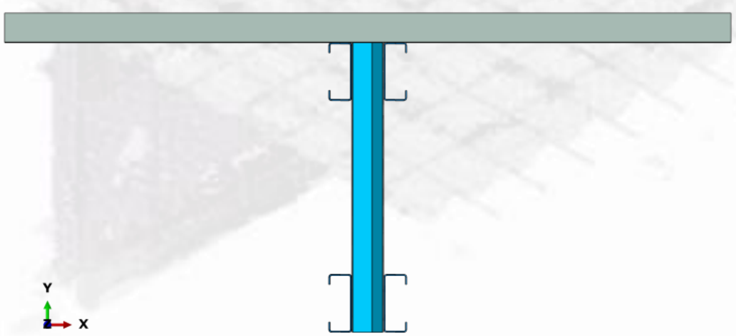

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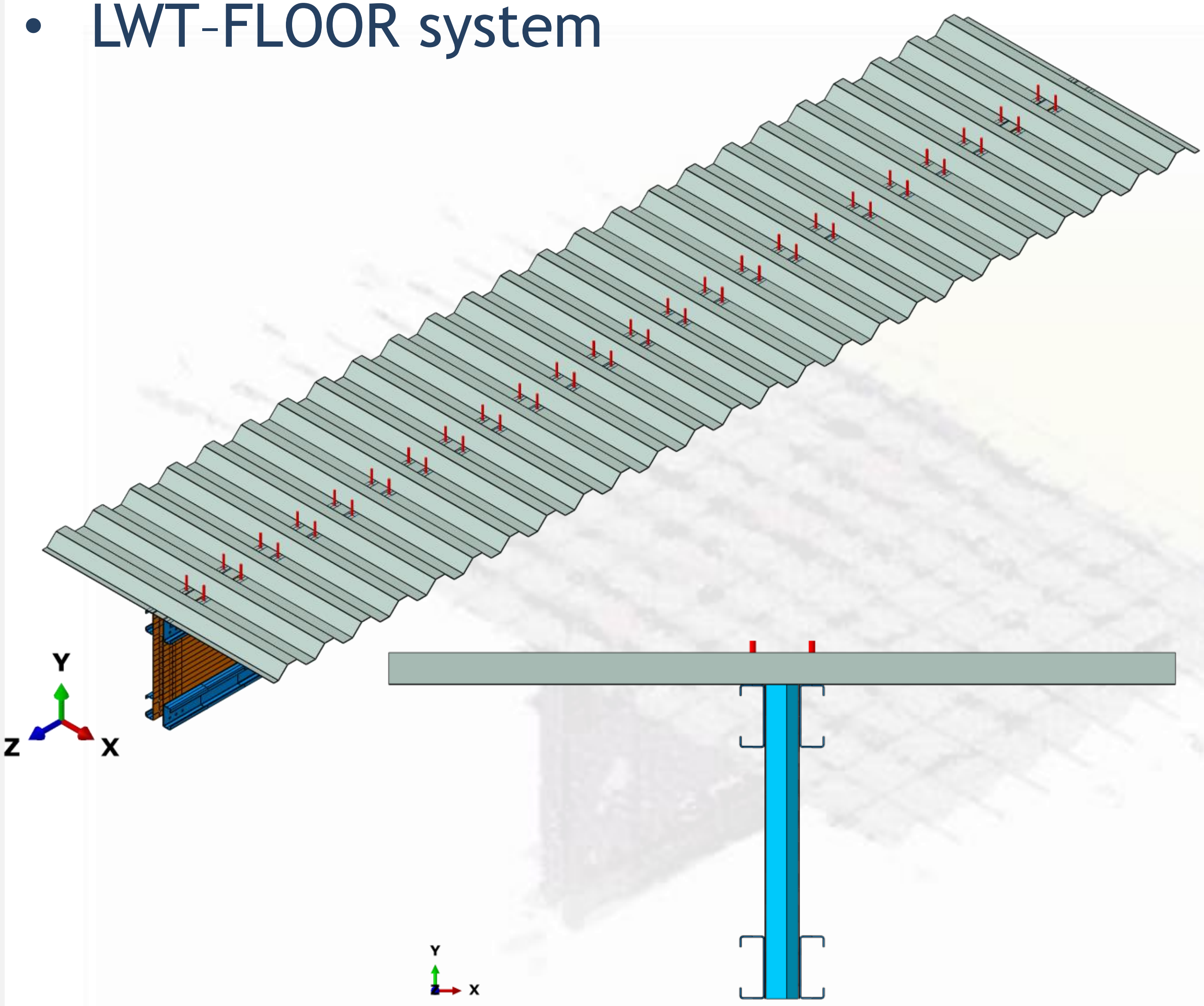

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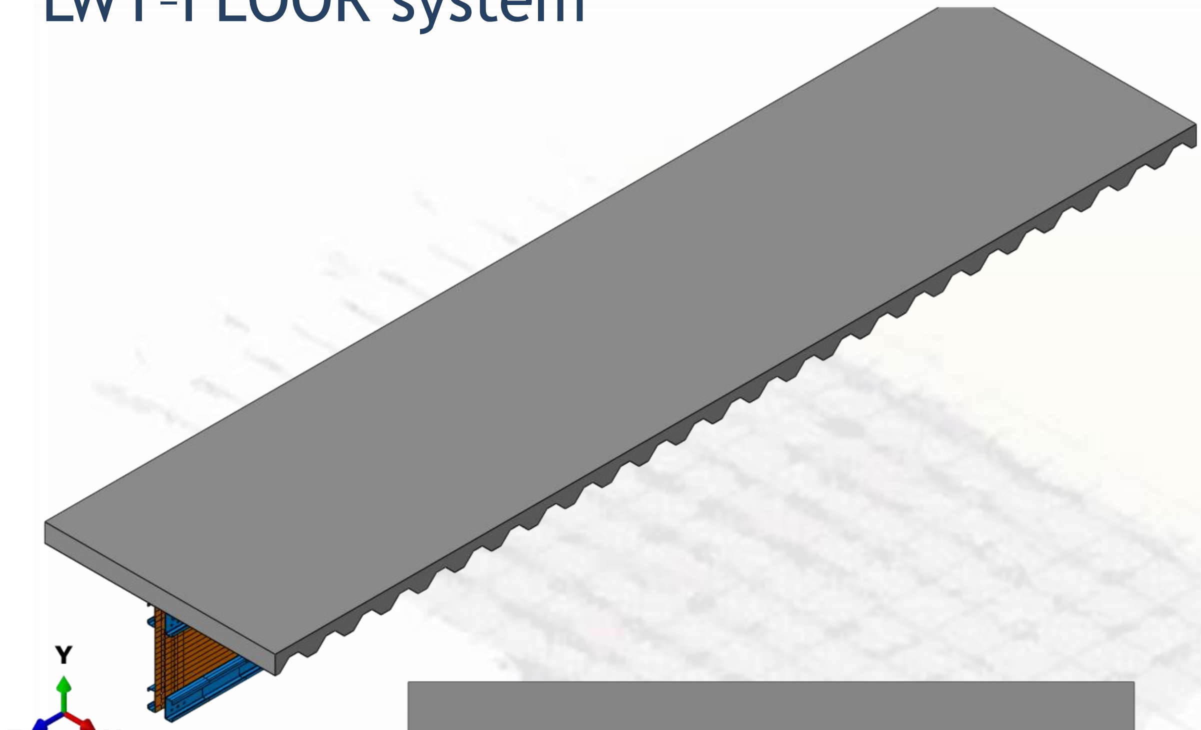

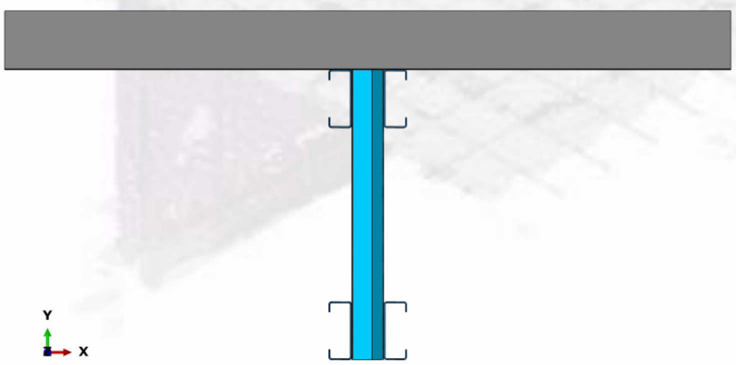

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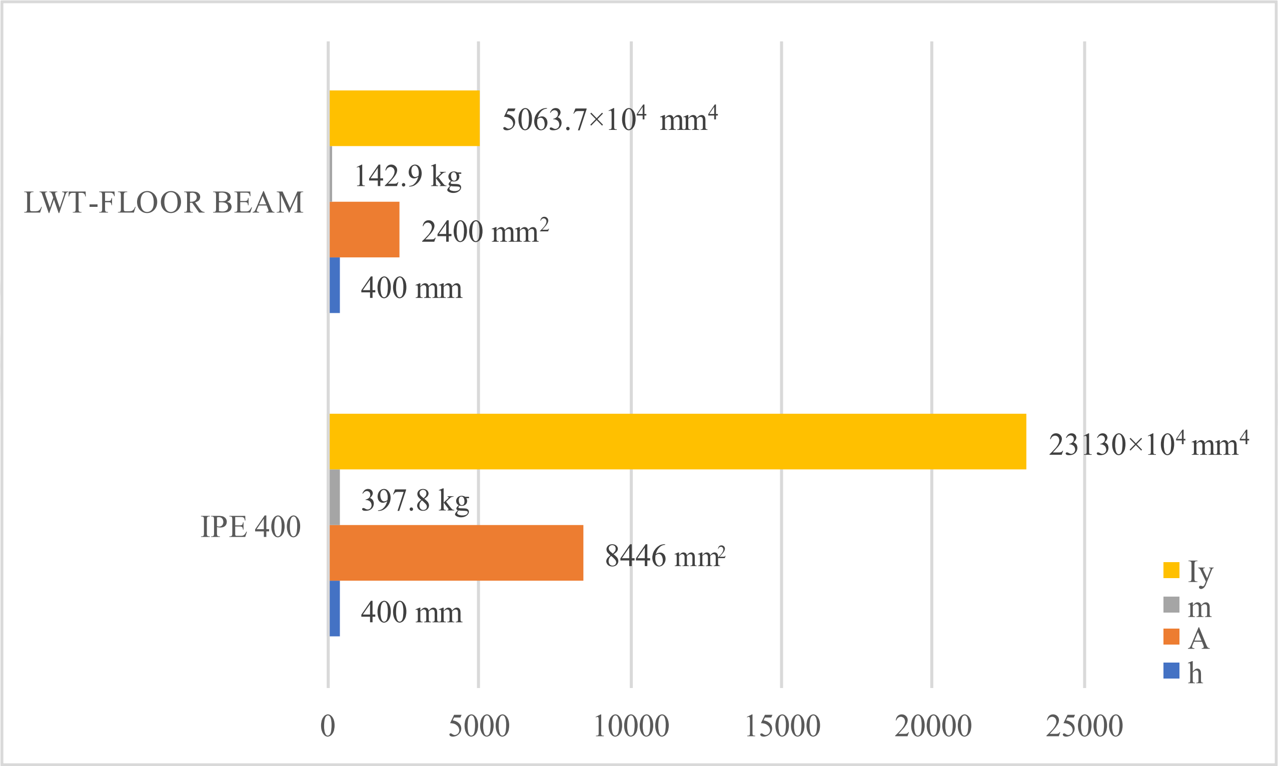
LWT-FLOOR vs. traditional systems

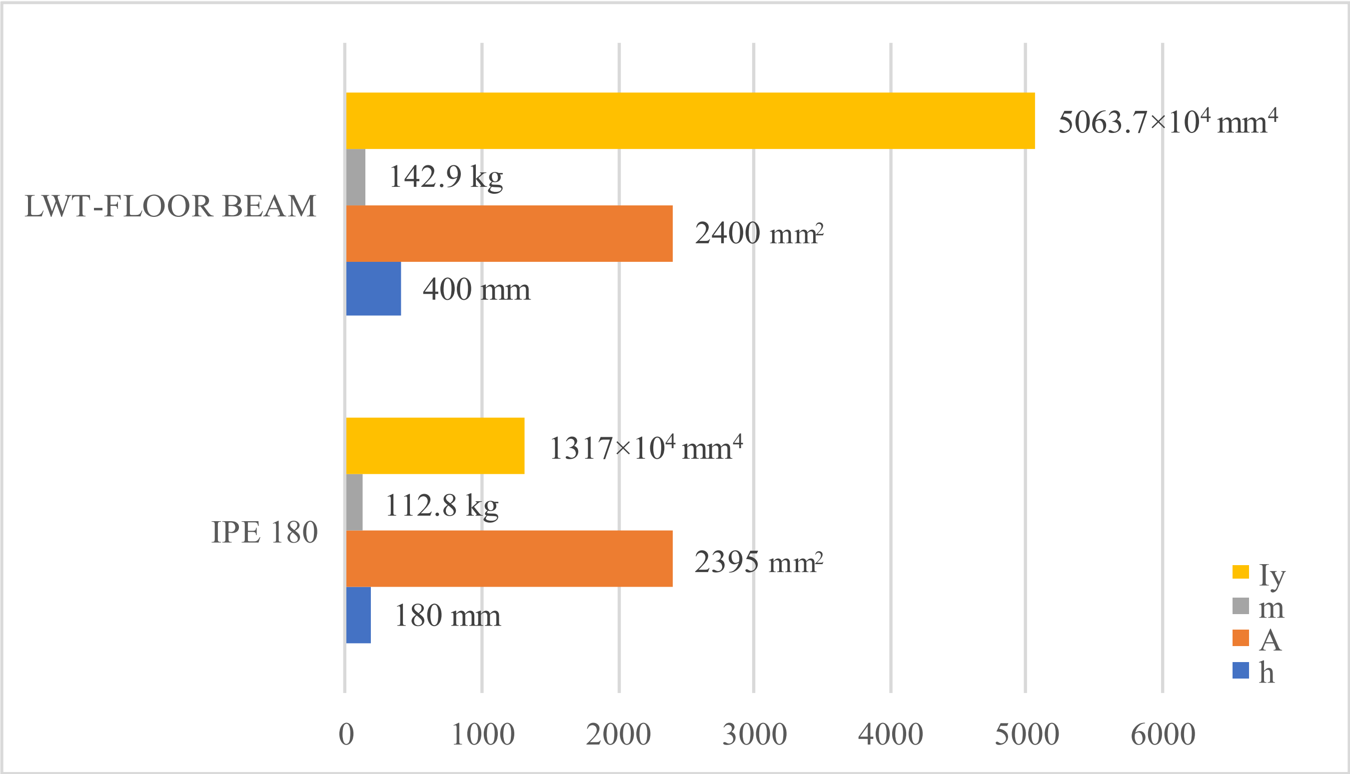
- Steel beam height



Comparison of beams with same steel beam height, h

LWT-FLOOR vs. traditional systems

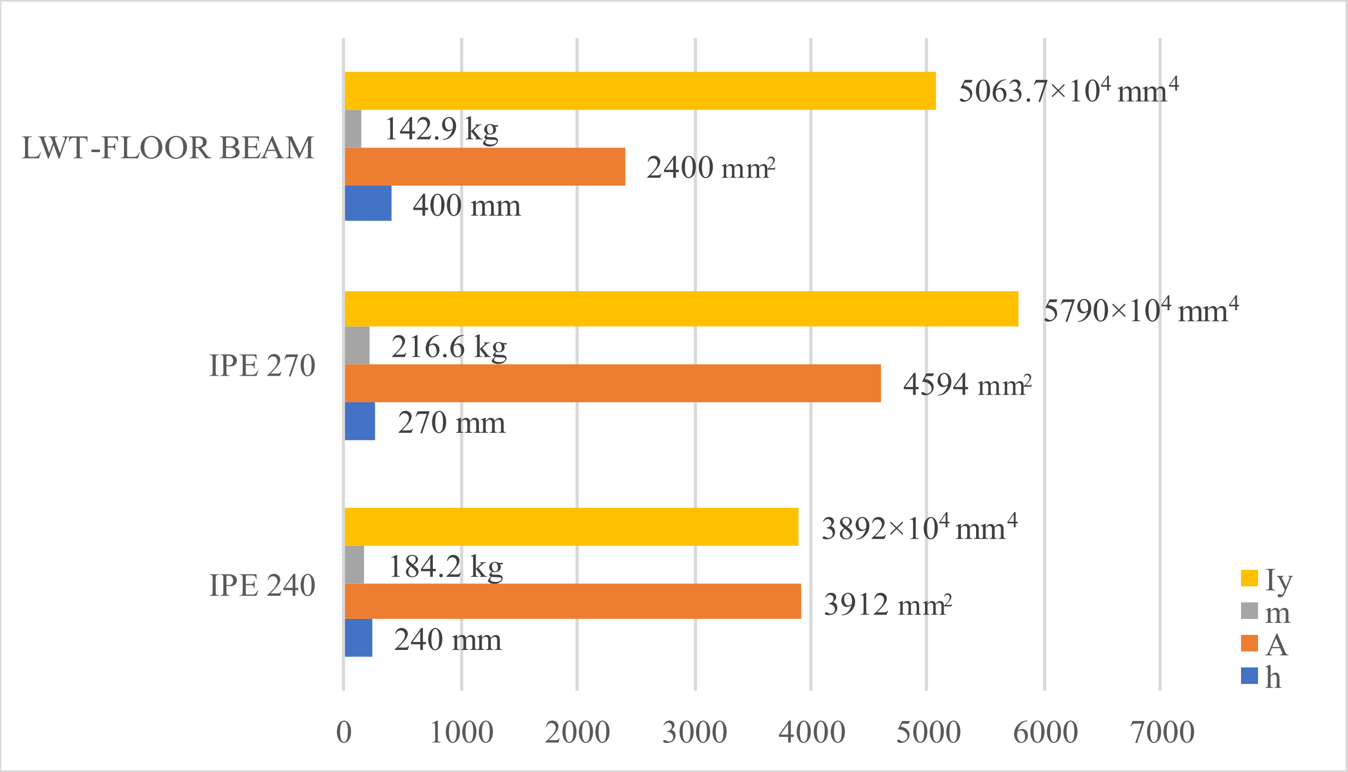
- Cross-sectional area



Comparison of beams with a similar cross-sectional area, A

LWT-FLOOR vs. traditional systems

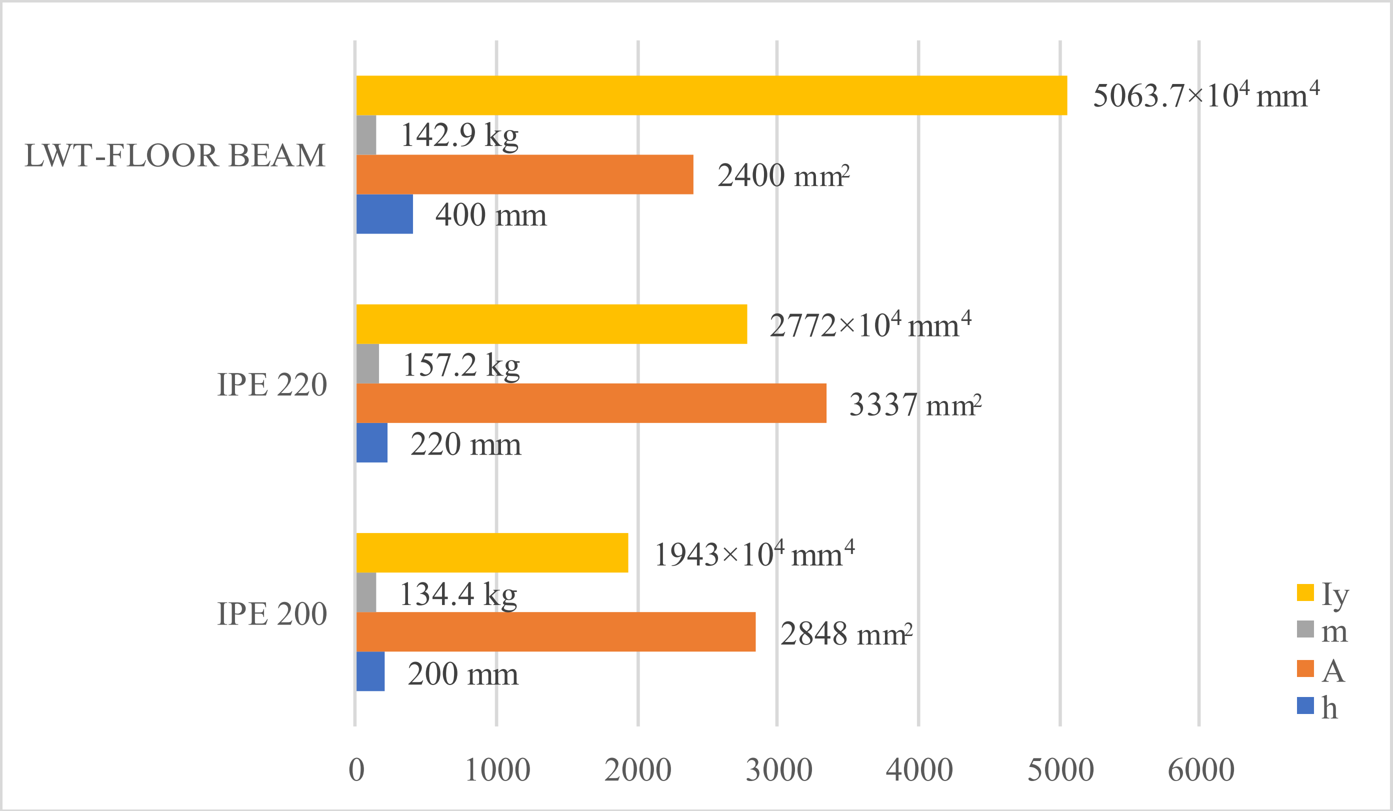
- Moment of inertia



Comparison of beams with a similar moment of inertia, I_y

LWT-FLOOR vs. traditional systems

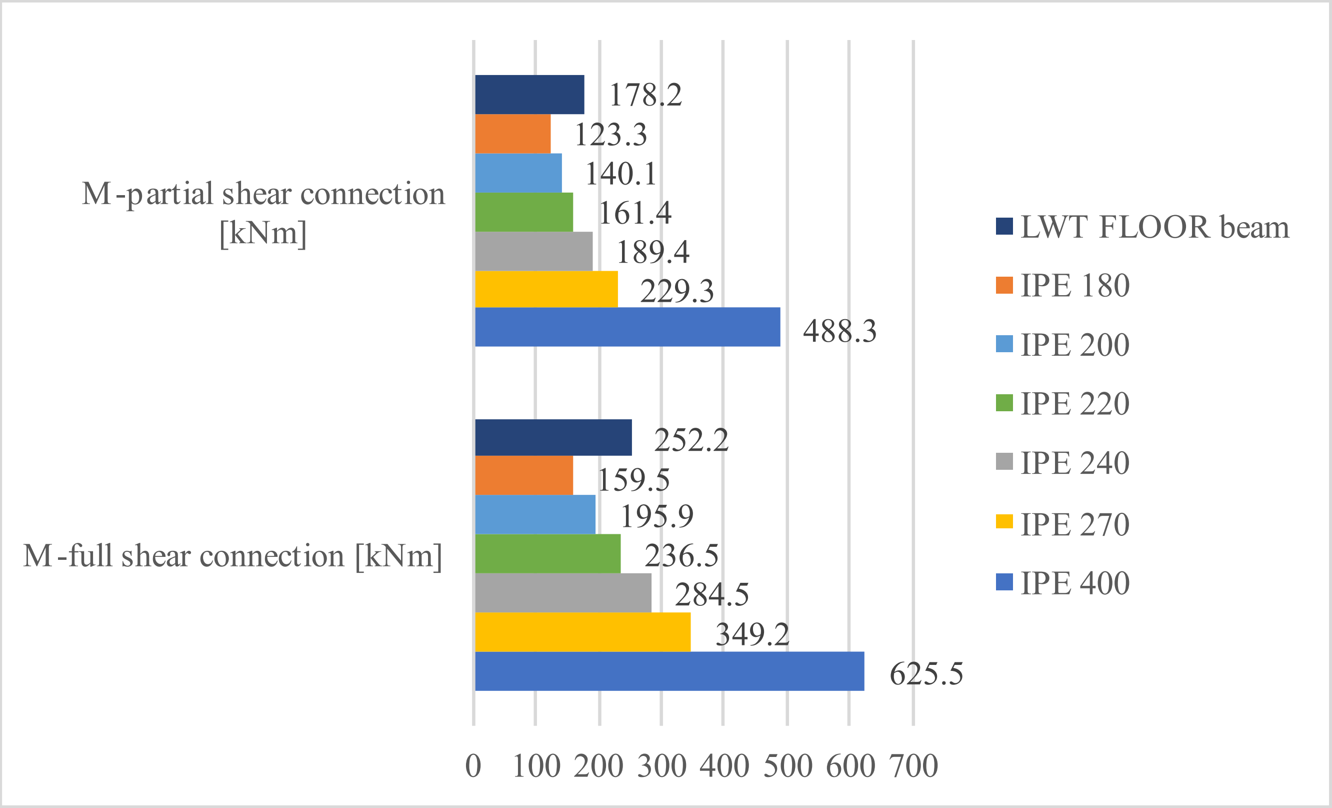
- Steel beam mass



Comparison of beams with a similar mass, m

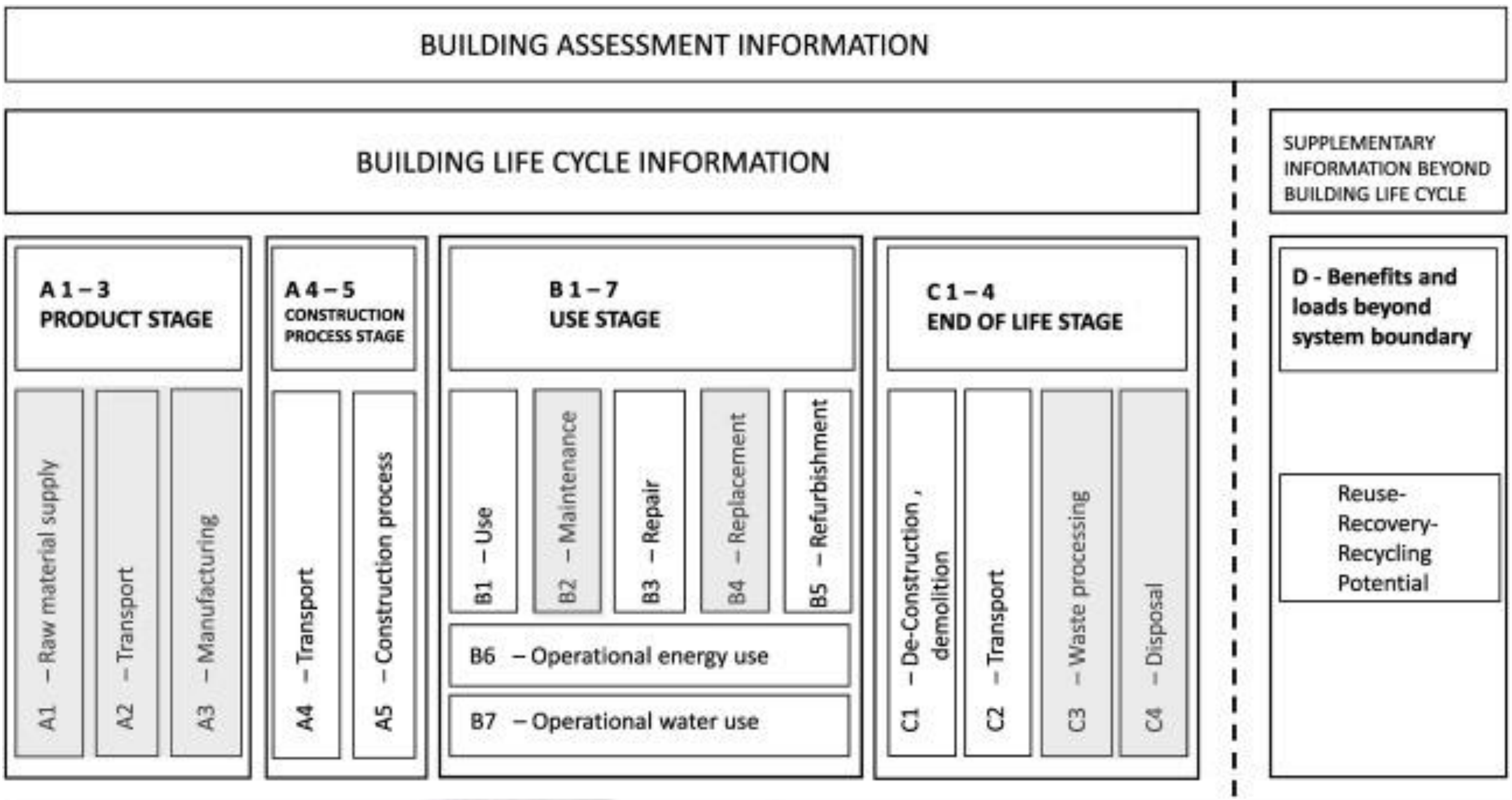
LWT-FLOOR vs. traditional systems

- Composite solution



Bending resistance for composite steel-concrete beams

Life Cycle Assessment



Modules of the building life cycle

EN 15804: *Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products*

Environmental assesment

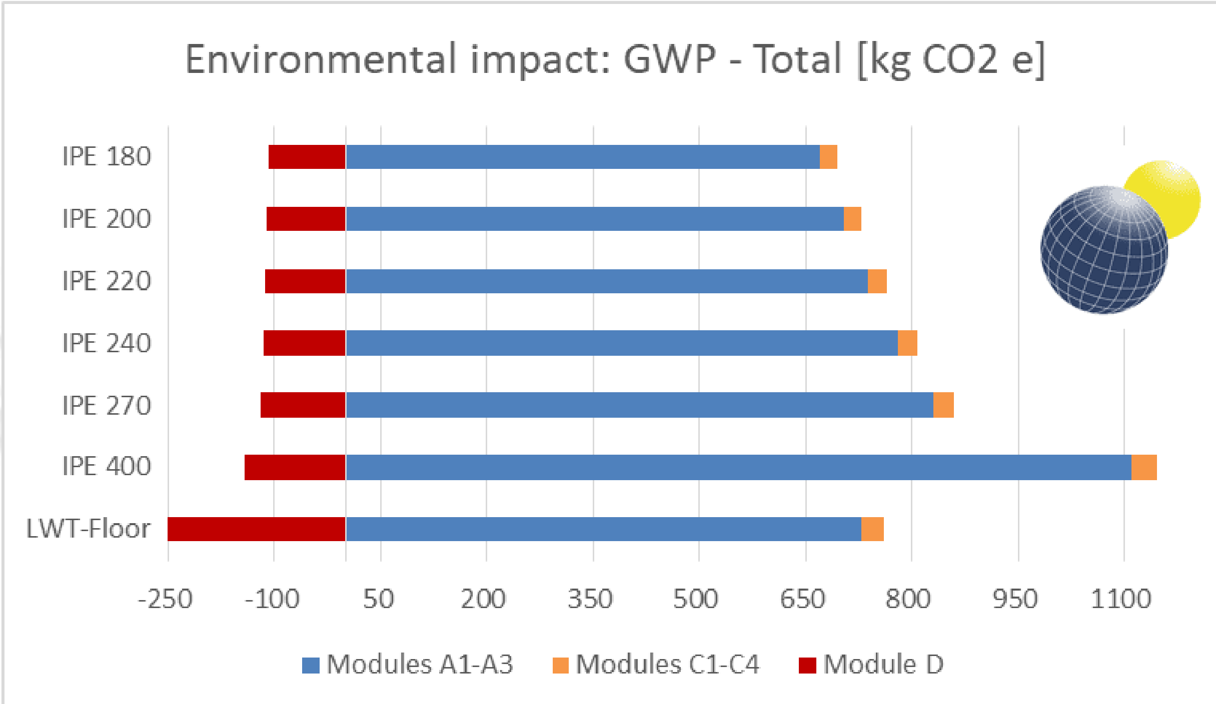
- LCA and global warming potential (GWP) evaluation are based on the modular building life cycle approach as described in the European standards EN 15978:2011, EN 15804:2013 and ISO 14044;
- Production stage phases (A1, A2, A3) and end-of-life (C1, C2, C3, C4), in conjunction with Potential environmental loads and benefits (D);

Environmental assesment

- For modules C3 and C4: 90% of steel is transformed into secondary material in a recycling plant (based on the European average), and 10% of the steel is assumed to be landfilled while the concrete is 50% recycled and 50% landfilled;
- For module D only the mass of primary steel in the components was considered to provide a benefit to avoid double counting. For the concrete, the avoided product is considered crushed aggregate.

LCA results

- LCA results of the scenarios in terms of GWP – total

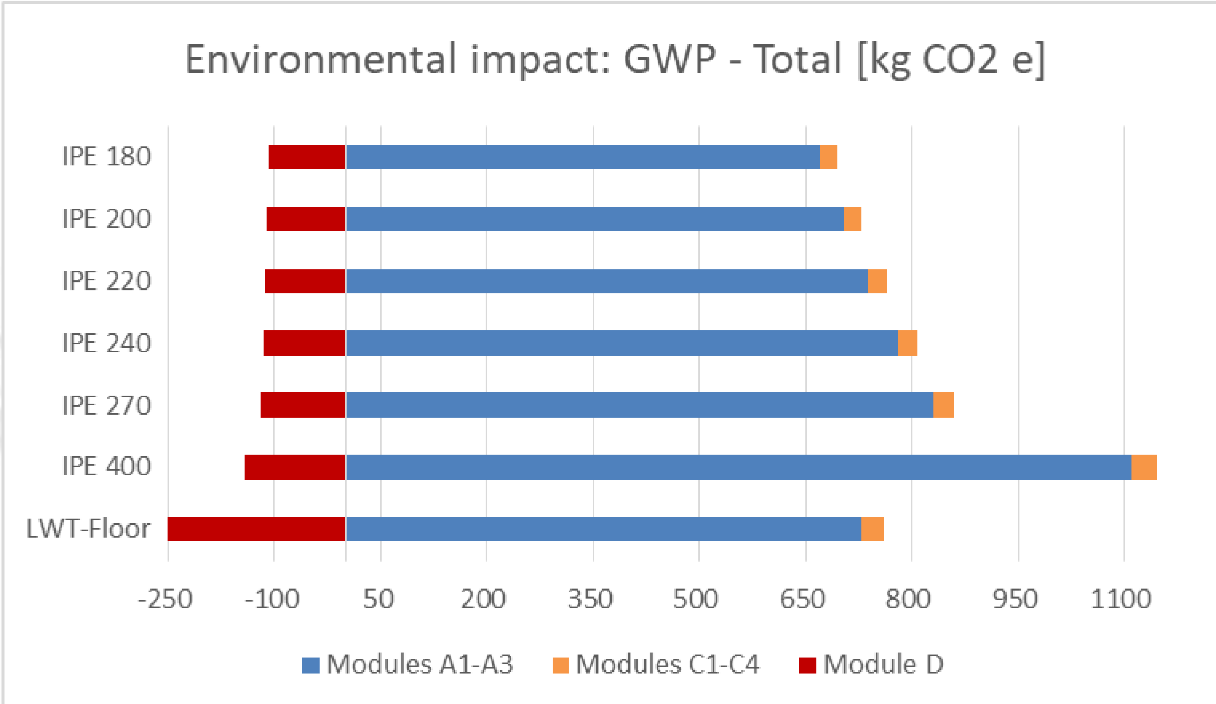


Bending resistance for composite steel-concrete beams

- For A1-A3, the emissions (GWP-total) are up to 34% smaller when LWT-FLOOR is used compared to the traditional one (IPE220-IPE400);

LCA results

- LCA results of the scenarios in terms of GWP – total

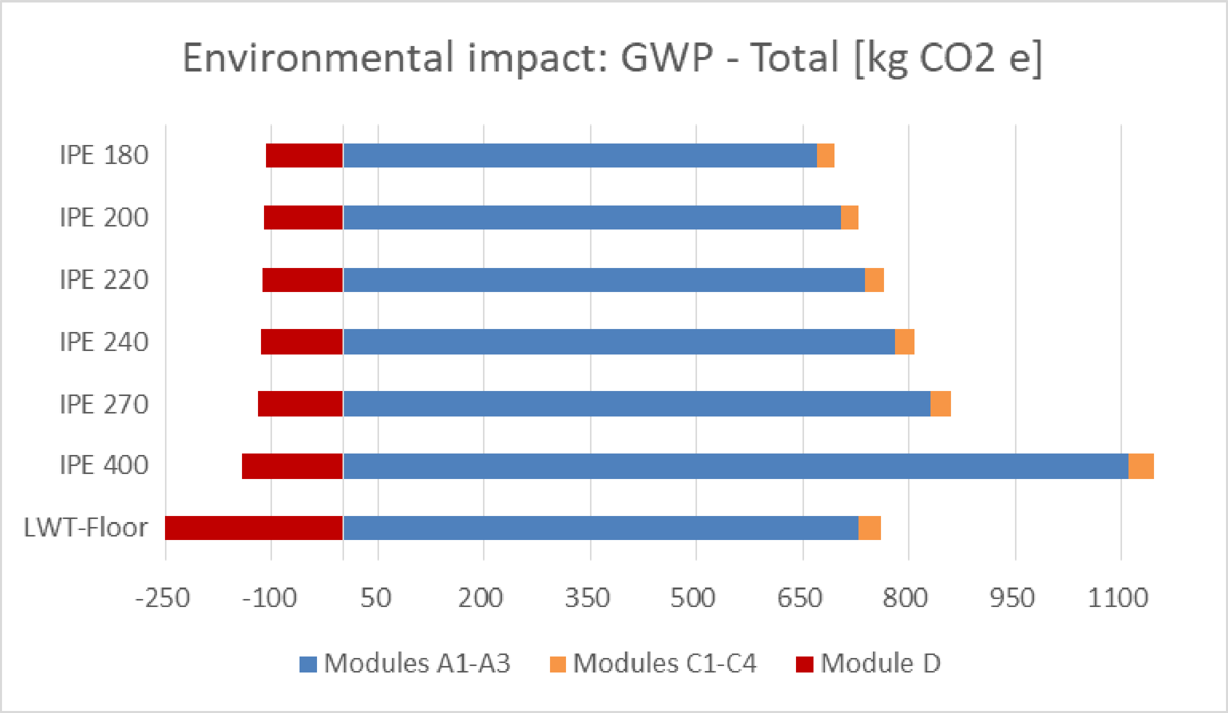


Bending resistance for composite steel-concrete beams

- For C1-C4, the emissions (GWP-total) are 9-19% smaller for the traditional steel-concrete composite floor systems, except for the floor system based on the IPE400 (10.46% more);

LCA results

- LCA results of the scenarios in terms of GWP – total

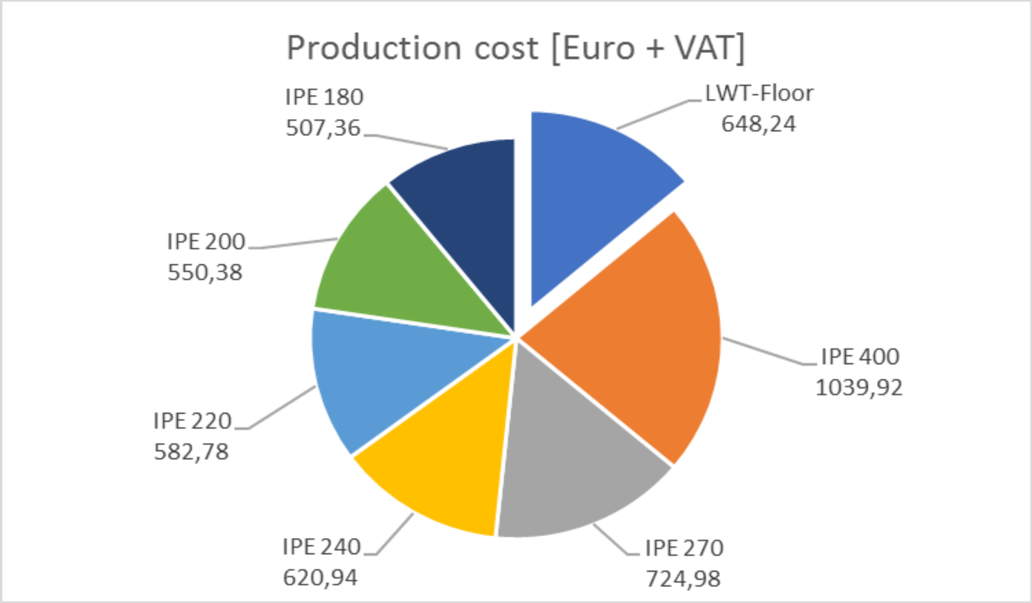


Bending resistance for composite steel-concrete beams

- The potential savings are 83%-141% higher than in the scenarios where traditional steel-concrete composite floor systems.

Economic impact

- it was considered the costs of the analysed scenarios associated with the Production stage only



Total production costs of the steel-concrete composite floor systems

- The costs of the LWT-FLOOR are above the costs of the traditional steel-concrete composite floor systems based on the IPE 180 - IPE 240 steel beams, but with 37.6% smaller than the solution based on IPE 400 steel beam.

Conclusions

- by comparing the geometrical characteristics of different composite beam configurations, it is concluded that the **LWT-FLOOR beam** has **good bending resistance with low material consumption;**
- the environmental and economic results showed that in the production stage, the environmental impact (reflected by the GWP-total indicator) is up to 34% smaller when LWT-FLOOR is used in comparison with the traditional steel-concrete composite floor systems based on the IPE 220-IPE 400 steel beams, while the costs of it are smaller with 10-37% compared to traditional steel-concrete composite floor systems based on the IPE 270-IPE 400.

Conclusions

- for the environmental impact, the GWP-total indicator shows that the potential savings by recycling the materials at the end-of-life of the composite floor systems are 83%-141% higher in the scenario where LWT-FLOOR is used than in the scenarios where traditional steel-concrete composite floor systems were studied.

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