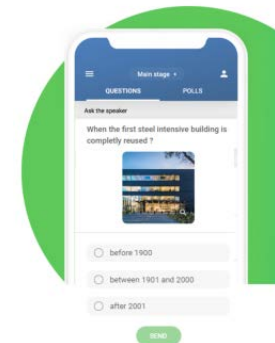
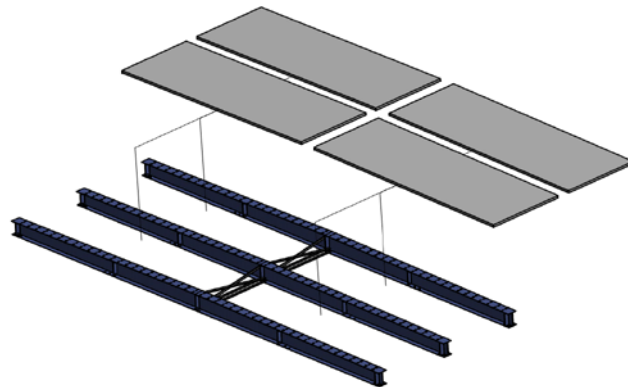




Tekniska lösningar för återanvändbara stålkonstruktioner (samverkanskonstruktioner)



M.Veljkovic, Dep. Engineering Structures
Steel and Composite Structures

Stålbyggnadsdagen, online 22 oktober 2020



Content



- Existing solutions: Sustainable or not. 
- “Circularity in construction”, how old is that phrase?
- Circularity of steel construction sector, case study examples, NL
- What have we learned from TUD experiments?
- What do you think about the future? 

HOW SUSTAINABLE IS THE CURRENT PRACTICE IN CONSTRUCTION SECTOR?



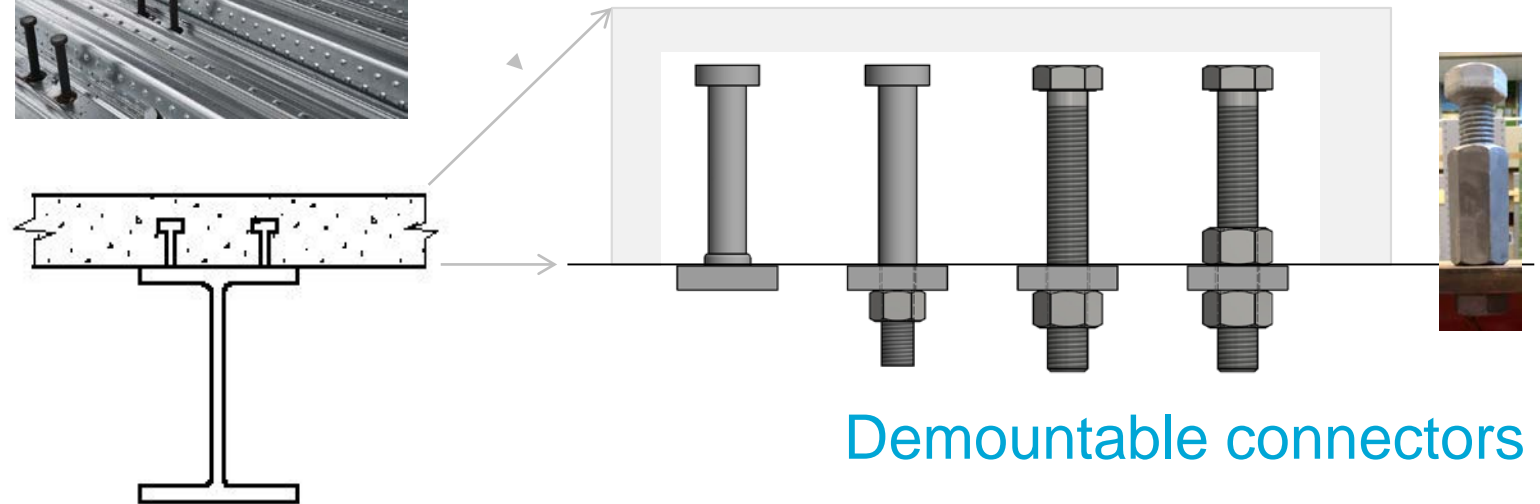
- Construction sector:
 - **23% of CO₂ emission globally** ¹
 - **36% of the waste generated (EU)** ²



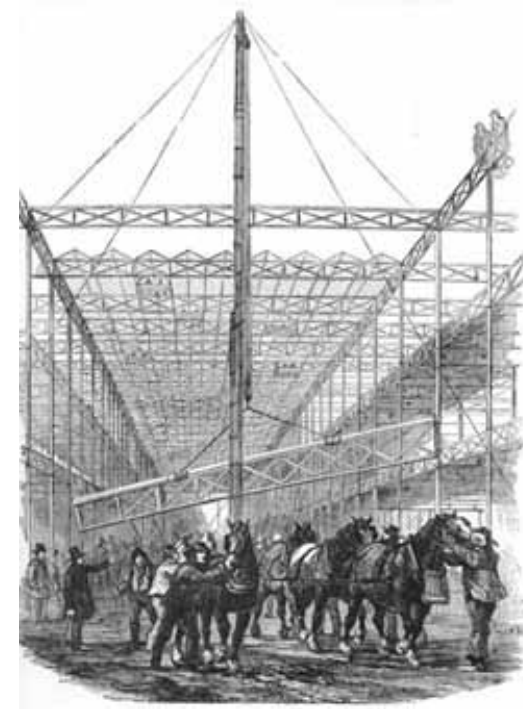
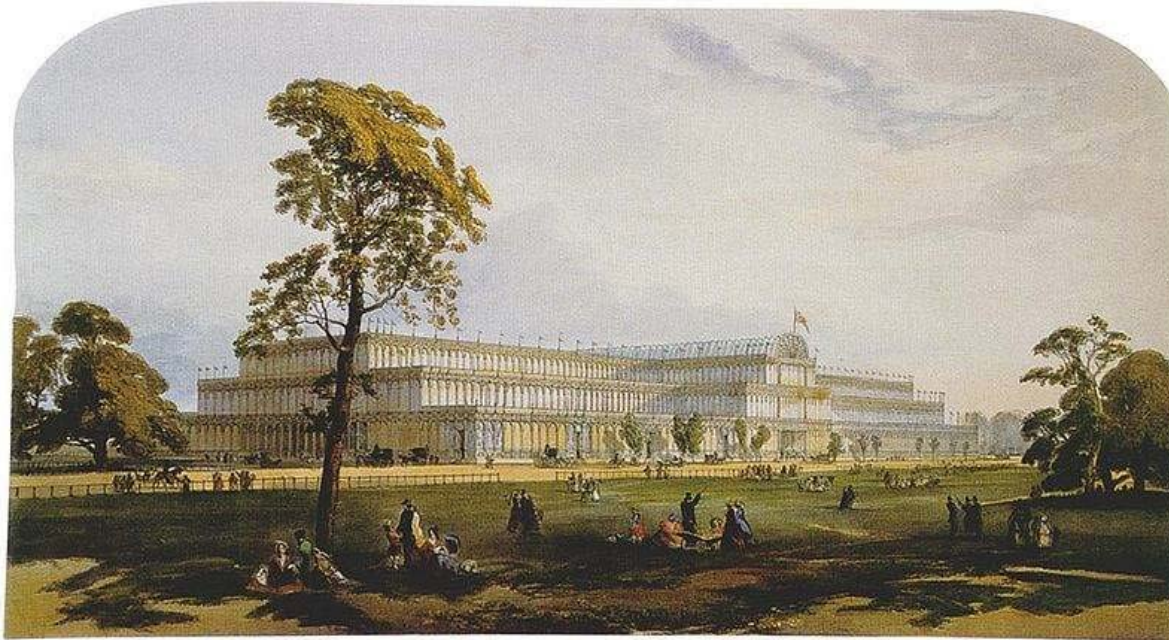
Source: BCSA. Data generated from TRADA/BCSA/WRAP analysis

TRADITIONAL STEEL-CONCRETE COMPOSITE STRUCTURES VS. DEMOUNTABLE

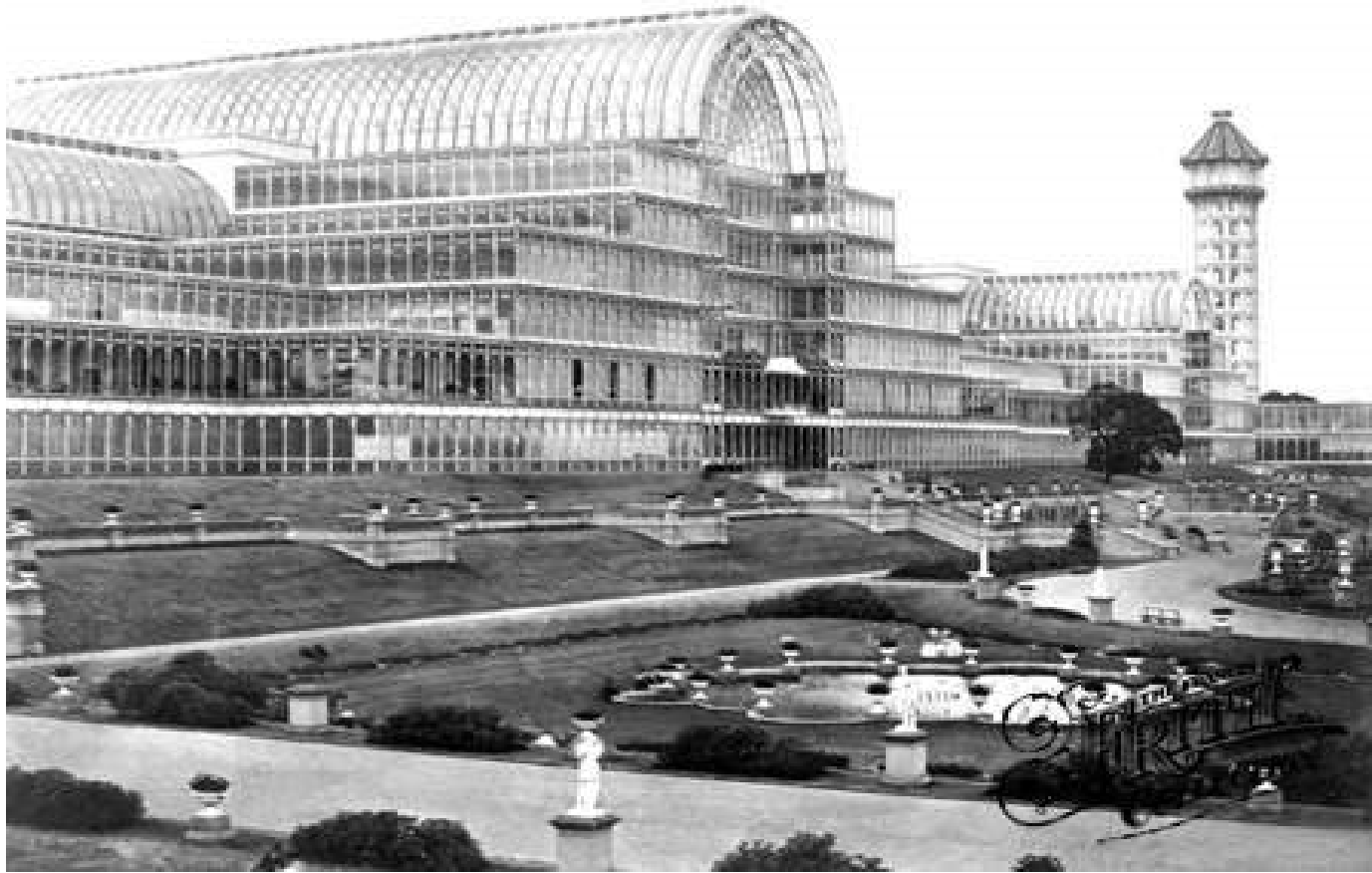
- Composite action through welded headed studs
 - Optimized cross-section design
 - Cast in-situ, non-demountable connection



CRYSTAL PALACE, HYDE PARK 1851-1854



CRYSTAL PALACE, SYDENHAM 1854-1936



REUSE OF STEEL STRUCTURES

CS1-NL



1942

1958

20XX



2015



DESIGN FOR DEMOUNTABILITY: DISTRIBUTION CENTER, SCHIPHOL AIRPORT

- 100% circular design (2016):
 - Steelframe : bolted connections
 - Cladding :screwed connections
 - Precast flooring not structurally connected to steel frame

-> 100% demountable + re-useable

Moreover further facilitate re-use:

- Modular dimensions
- Material passport for future re-use



DEMOUNTABLE COURTHOUSE AMSTERDAM

CS3-NL

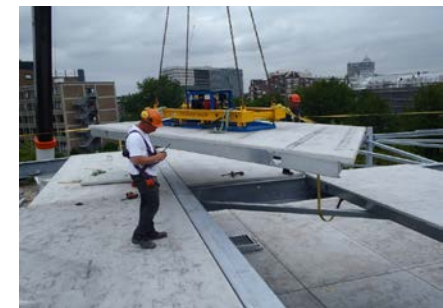
100% circular design:

- Steelframe : bolted connections
- flooring: demountable connection
- -> 100% demountable + re-use- able
- Lease model : Contractor retains ownership



TEMPORARY PARKING LEIDEN

CS4-NL



Tata Steel Quantum demountable flooring system

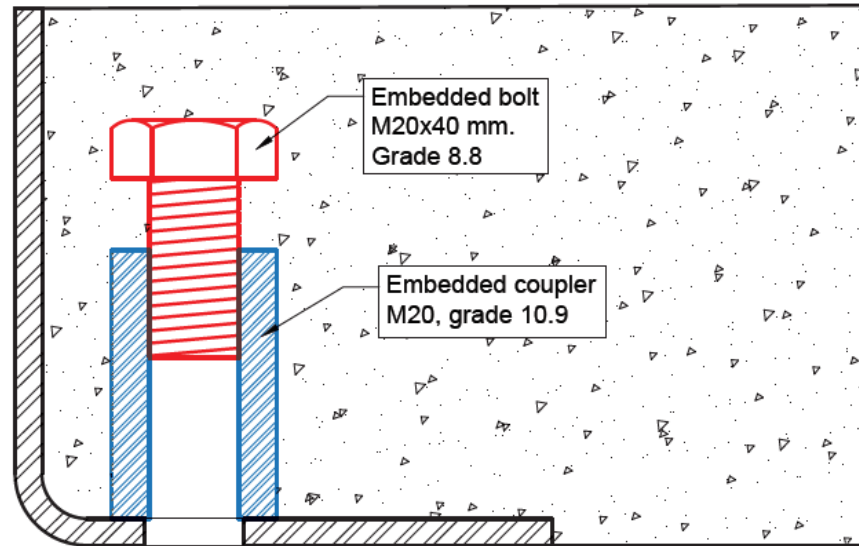
TECHNICAL SOLUTION FOR SUSTAINABLE COMPOSITE FLOOR SYSTEMS

Large prefabricated concrete deck (2.7 x 8 m x 0.15 m)

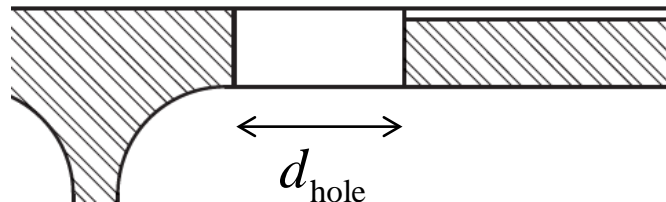
Mass ca 7 t

+

Steel beam



$d_{\text{connector}}$



d_{hole}

d_{hole} \longleftrightarrow $d_{\text{connector}}$

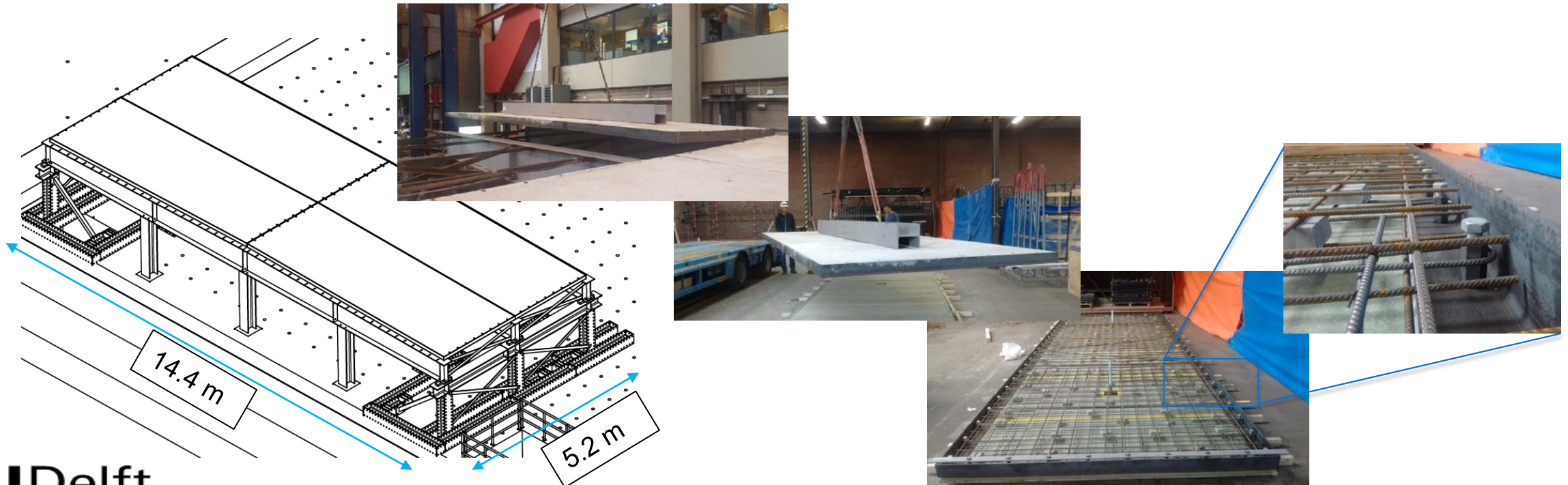
- Deviations
- Slip during execution
- Execution speed

$$d_{\text{hole}} \approx d_{\text{connector}} + (12 - 15 \text{ mm})$$

Based on Monte-Carlo simulation of member deviations

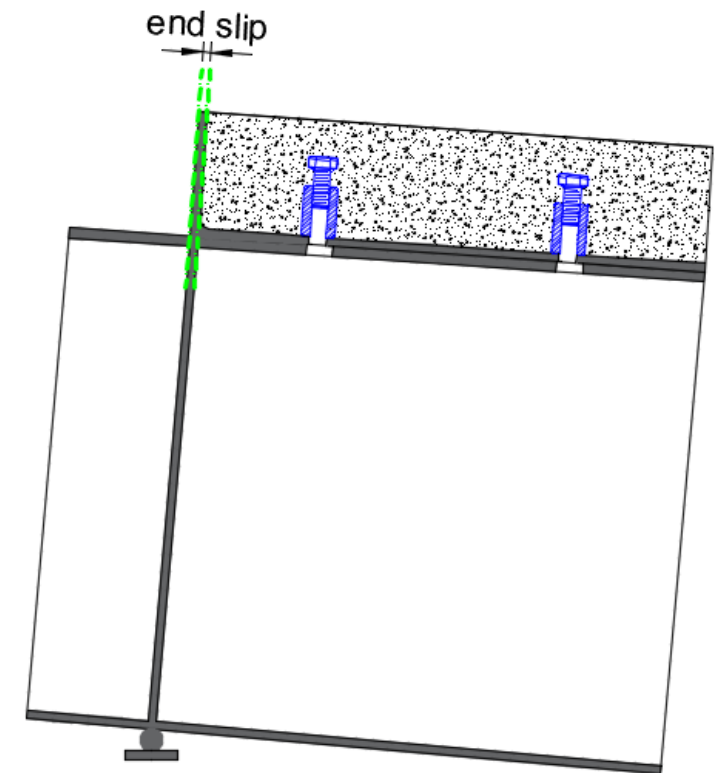
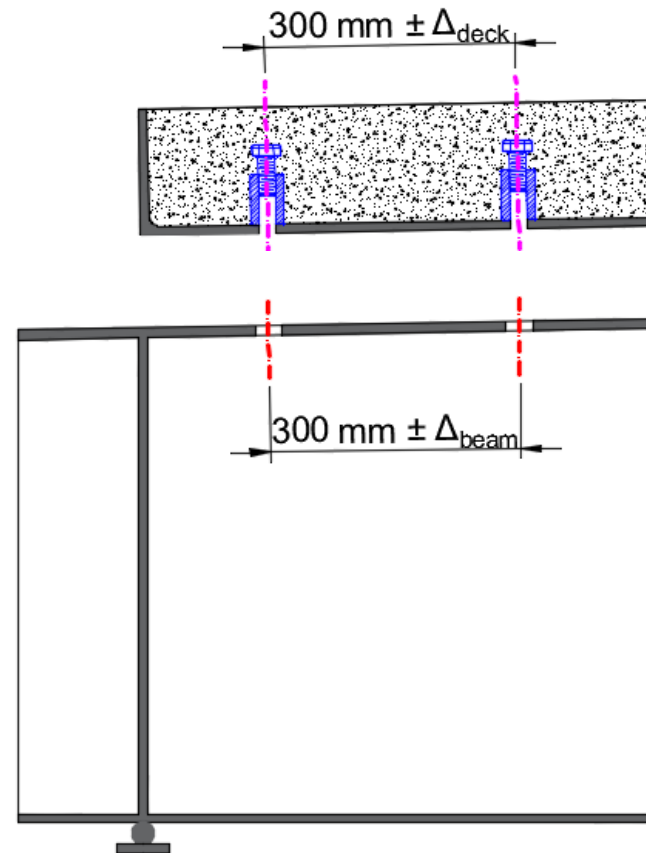
PRE-CASTED “LARGE CONCRETE” DECKS

- Mock-up of two bays of one floor of a car park building
 - Tapered steel beams
 - Large prefabricated concrete decks, mass 7t



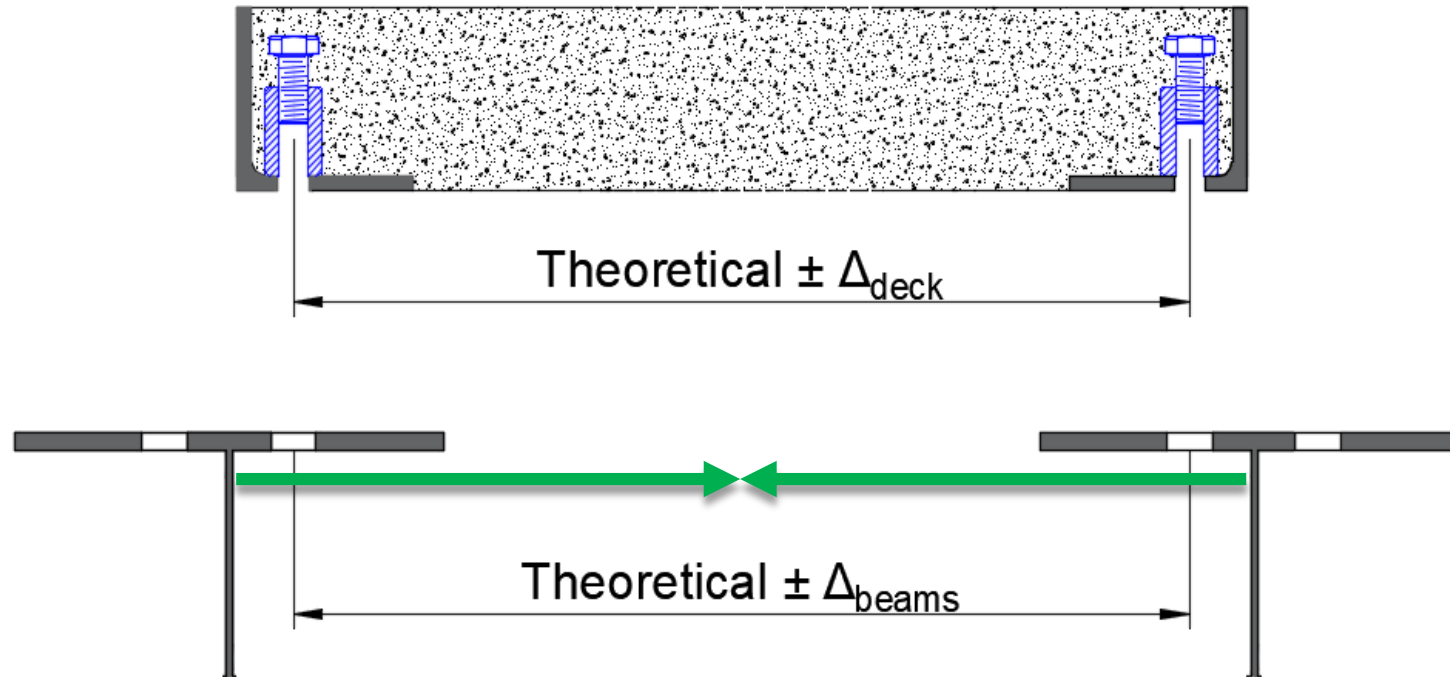
Hole alignment: Longitudinal direction

- **Hole spacing**
 - Deck
 - Beam
- **Deformation**
 - End-slip



Based on measurements and FE results **Hole clearance 12mm**

Hole alignment: Transversal direction



Measurements:

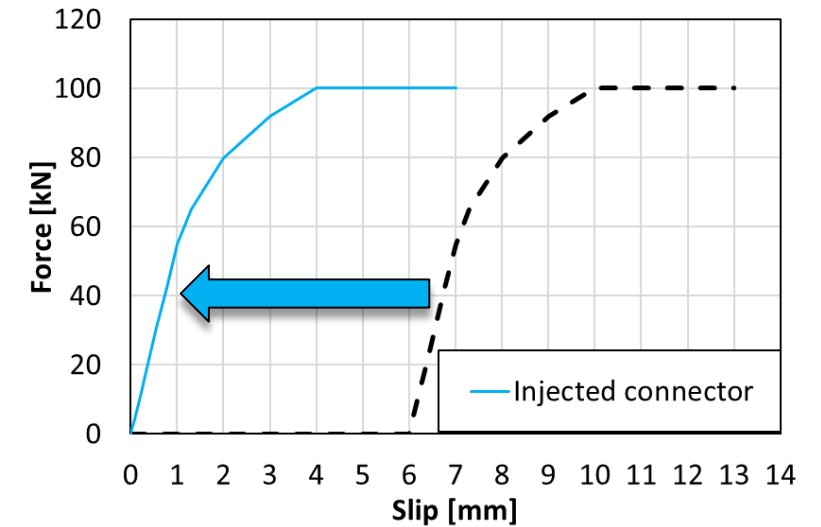
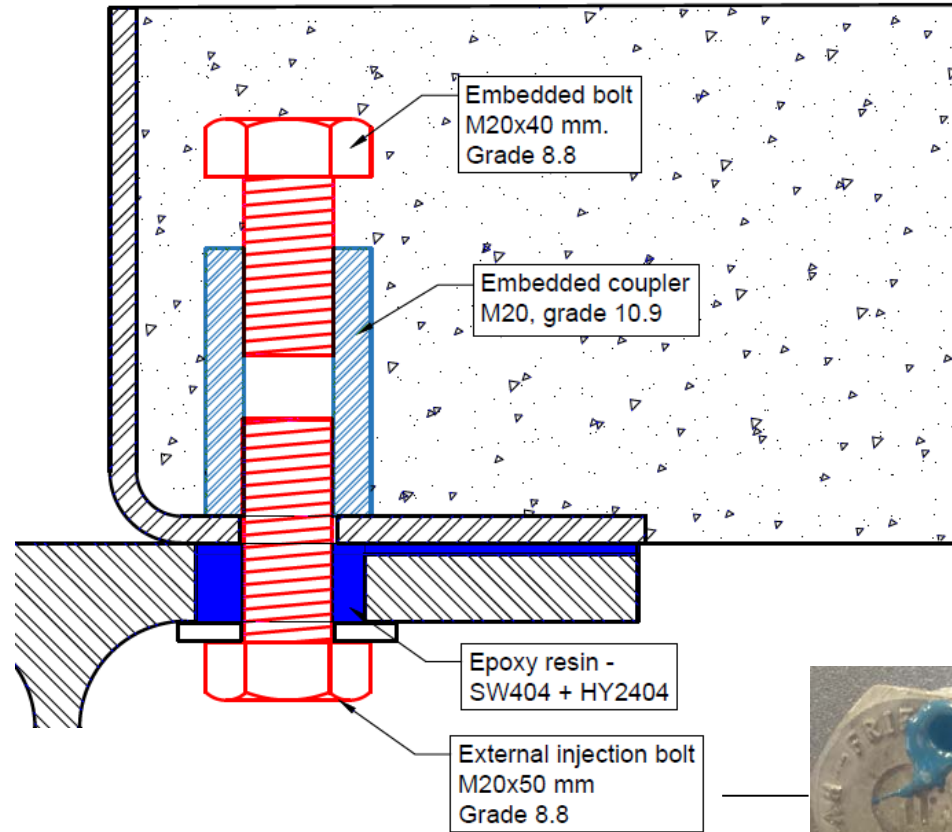
- Connector c.t.c distance
- Beam spacing
 - **Construction braces**

OPTIMIZATION OF MECHANICAL BEHAVIOUR



■ Resin-injected bolt ■ Bolt (no shear interaction)

ENSURING COMPOSITE SHEAR INTERACTION



Overhead resin injection



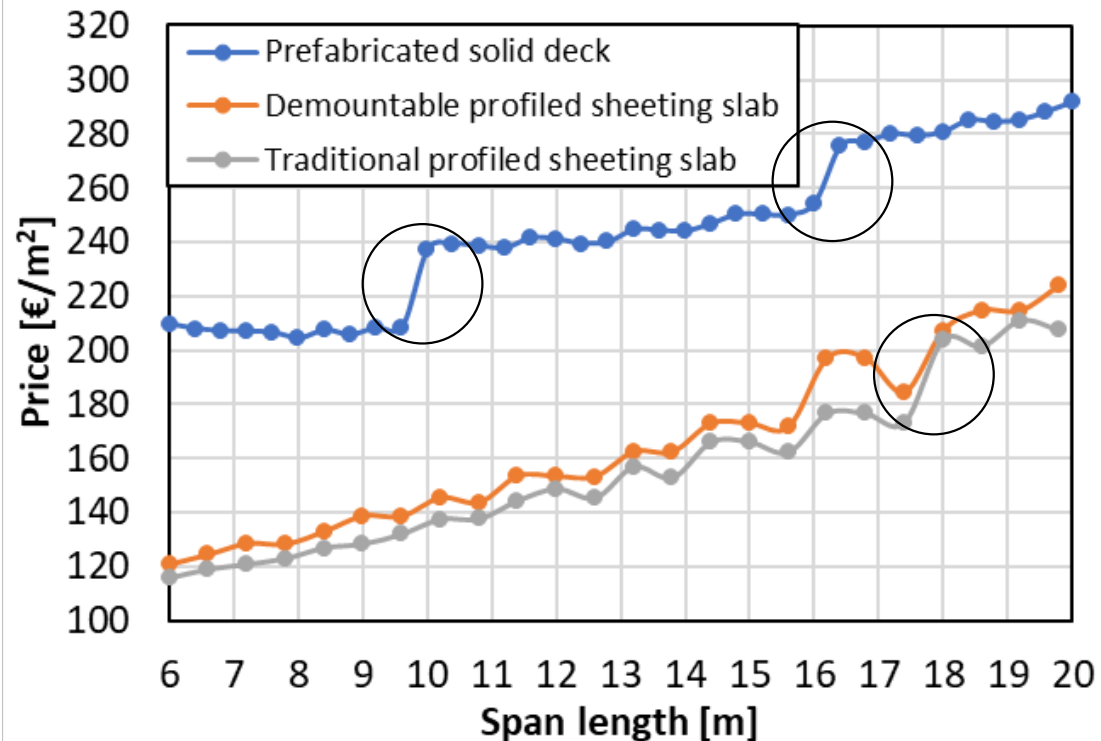
Overhead injection

- 150 bolts
- 30sec/bolt
- Minor air inclusions

Prevent adhesion



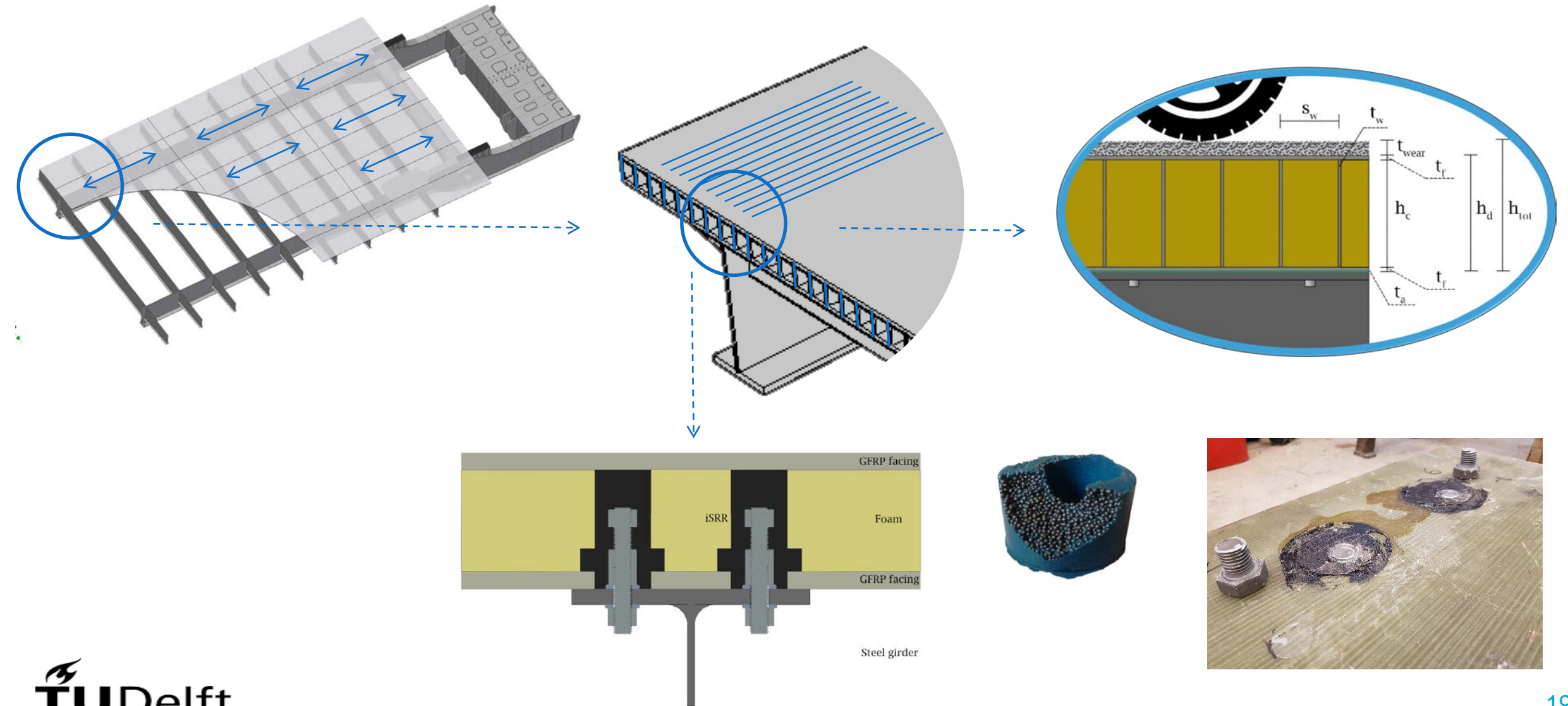
Office building – cost comparison



- Cost increase with span length
- Wider slab – most economical
- Transportation limitation
- IPE to HE

System	Span	Average cost increase
Prefabricated solid slab	6m - 12m	70%
	12m - 20m	45%
Composite slab (demountable)	6m - 20m	5%

RENOVATION AND NEW BRIDGES



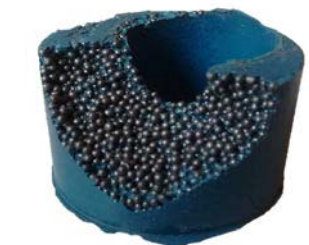
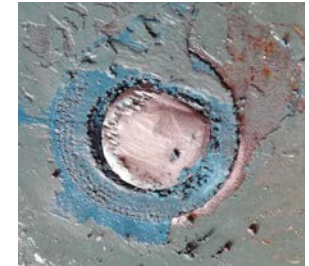
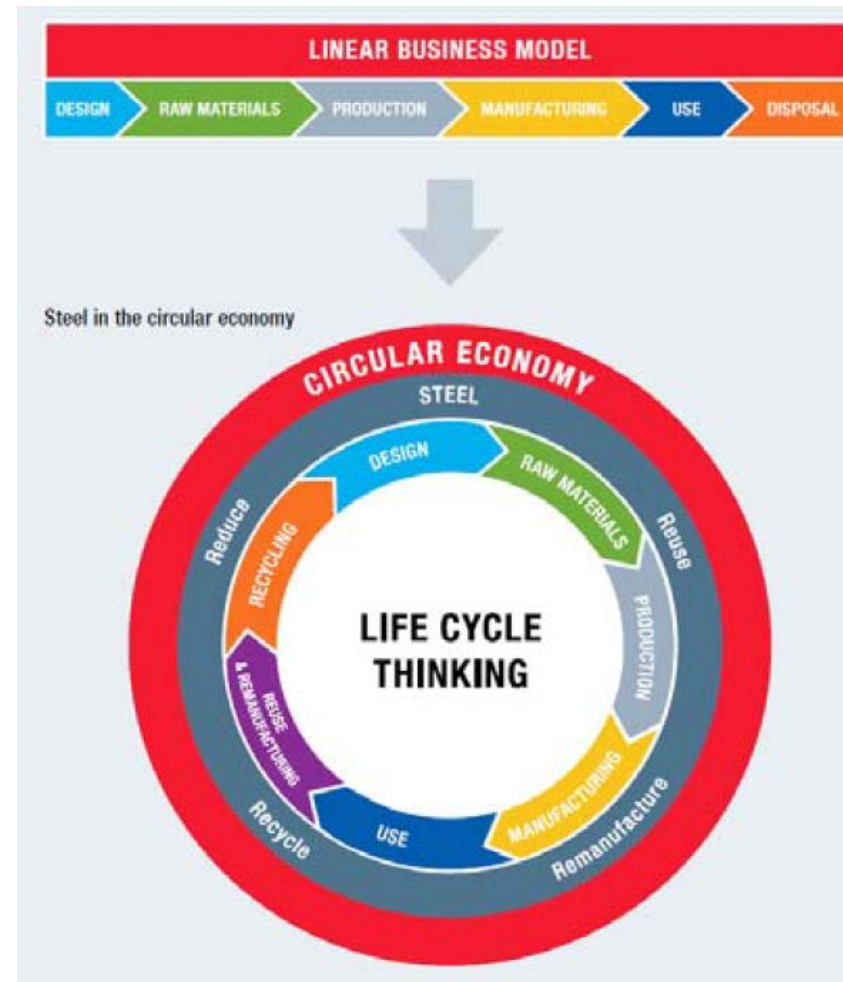
STEEL INTENSIVE STRUCTURES IN FUTURE

Expectations:

- Lower costs for maintenance
- Lower costs for investment

4R approach in design:

- **Reduce (energy and resources)**
- **Reuse (multiple lifetime)**
- **Remanufacture (restoring)**
- **Recycle (change in physical form)**



<https://www.tudelft.nl/citg/over-faculteit/afdelingen/engineering-structures/sections-labs/steel-and-composite-structures/research/research-lines/design-for-reuse/reduce/>

STOR TACK TILL:

- **Bauke Hoekstra Bonnema, Tata Steel** Ijmuiden, for case study stories
- **Martin Nijgh**, PhD candidate, for his research years at TUD, 2021 PhD
- **Marko Pavlovic**, Assit. Prof. TUD, for examples with FRP deck
- **MSc students**, TUD, for their efforts in the Stevin 2 lab and MSc thesis work

<https://repository.tudelft.nl/islandora/search/veljkovic?collection=education>

<https://repository.tudelft.nl/islandora/search/pavlovic?collection=education>

- **REDUCE PROJECT PARTNERS**, RFCS project 2016-2019

Steel Construction Institute (UK) (project coordinator), University of Luxembourg (Luxembourg), Tata Steel (NL), AEC3 (UK, Germany), Bouwen met Staal (NL), University of Bradford (UK) and Lindab S.A. (Luxembourg)