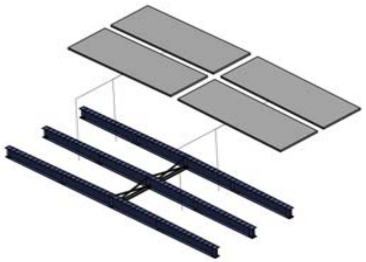
Demountable Car Parks



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Content

- Existing solutions: Sustainable or not
- What we have learn from our experiments
  - Basics of a new concept
  - Costs estimate comparison of a new solution/alternatives
  - Execution tolerances
- What has to be done to implement REDUCE concept in car parks
- Conlusions

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How sustainable is the current practice?

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Traditional steel-concrete composite structures

- Composite action through welded headed studs
  - Optimized cross-section design
  - Non-demountable connection

https://www.astron.biz/en/

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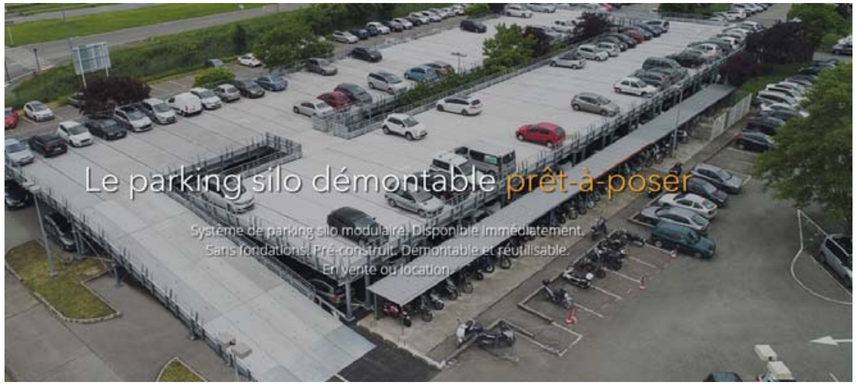
Car park designed for reuse



https://www.parkup-systems.com/le-concept/

https://www.steelconstruction.info/images/2/23/B3_Fig13.png

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Motivation to study car parks

- Short pay-off time.
- Suitable for prefabrication – “simple plan” situation.
- Simple building to consider for reuse – installations minor investment (can be embedded in structural component.

Main challenges for sustainable car parks

- Structural efficiency, no waste of materials
  - Composite interaction
- Fast execution/demounting, reuse
  - Large prefabricated elements
  - Connection between steel sections and concrete (?) floor decks
- Stable market and suitable business model
- Standardization

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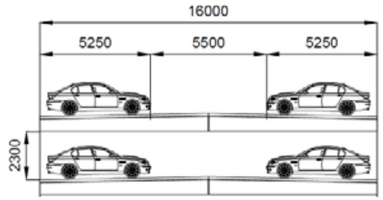
Layout of a car park



Cast in-situ car park

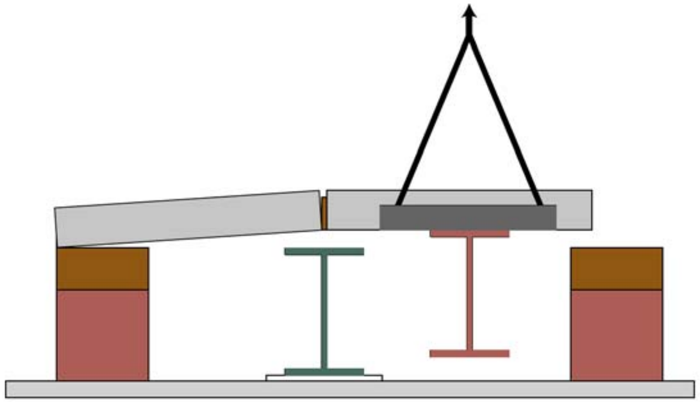
Prefabricated car park

Demounting of composite slab – a longitudinal cut

Concrete cutting saw

Metal cutting saw

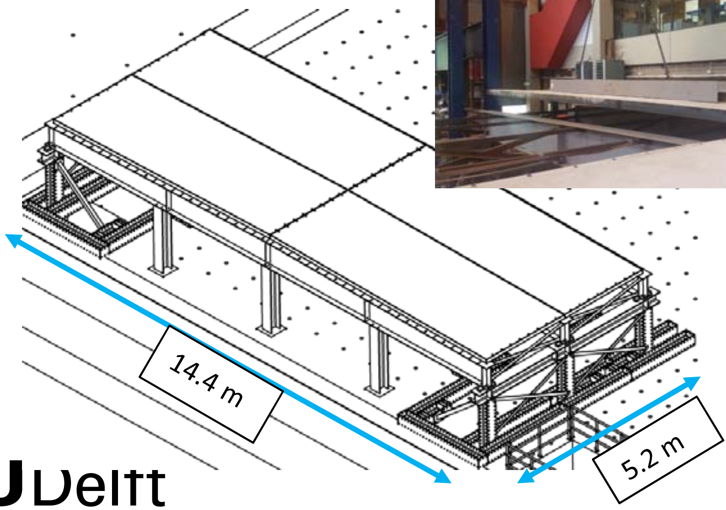
Demounting of the composite slab – detaching



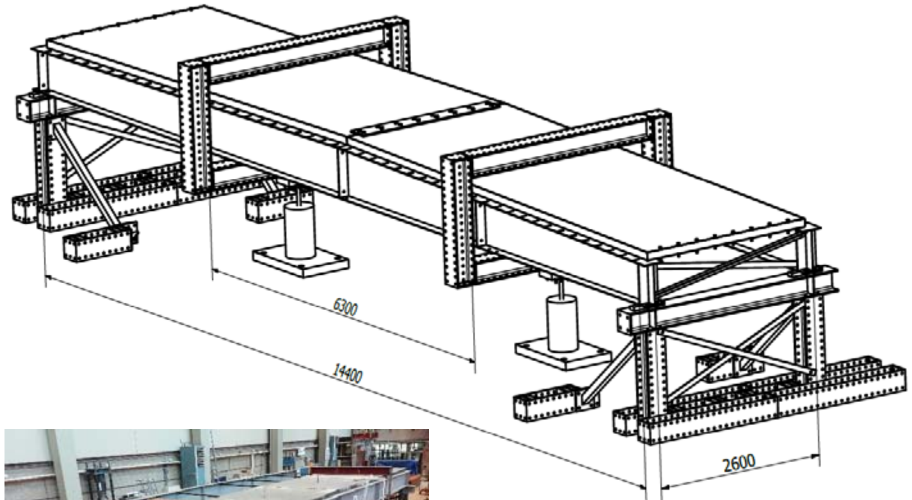
Steel beam-metal decking interface

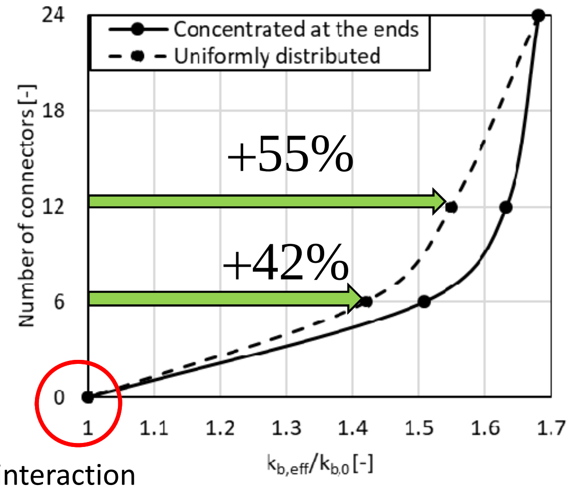
Pre-casted “large concrete” decks

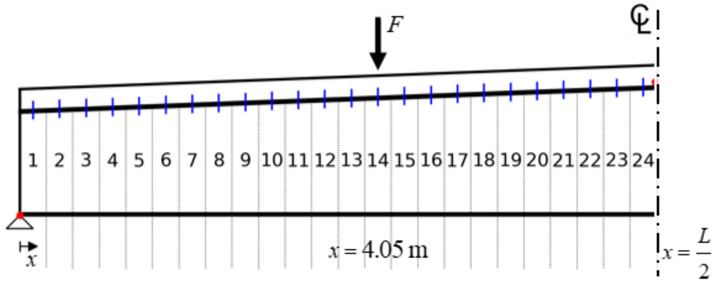
- Mock-up of two bays of one floor of a car park building
  - Tapered steel beams
  - Large prefabricated concrete decks

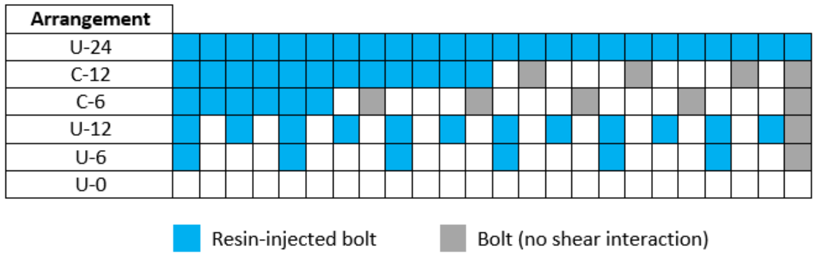


Mechanical behaviour

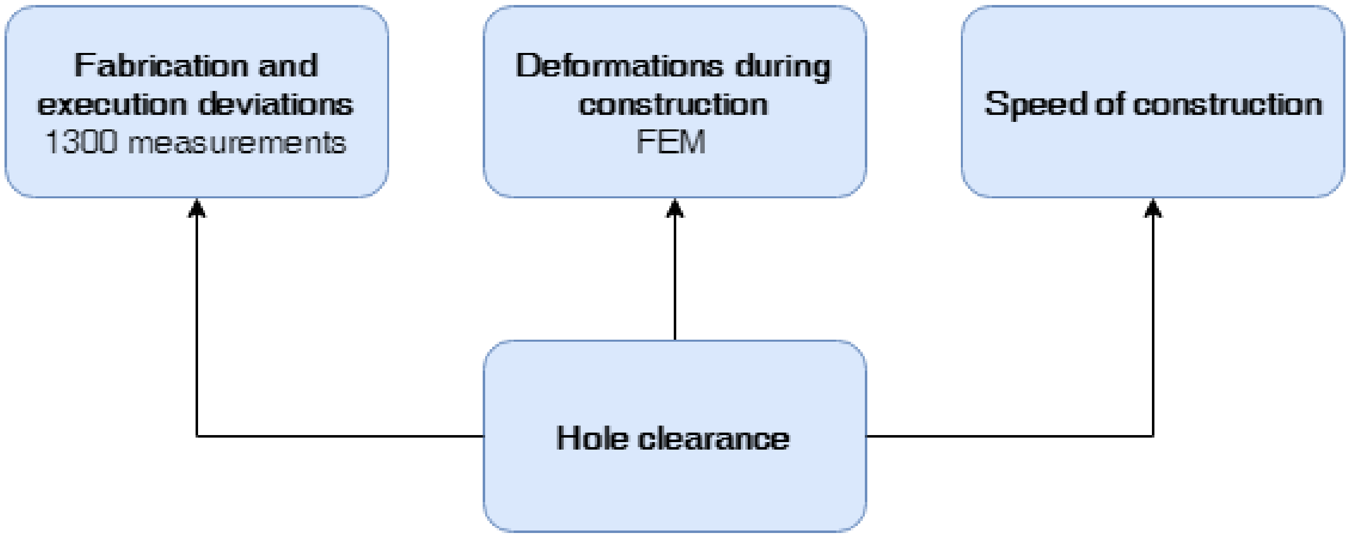








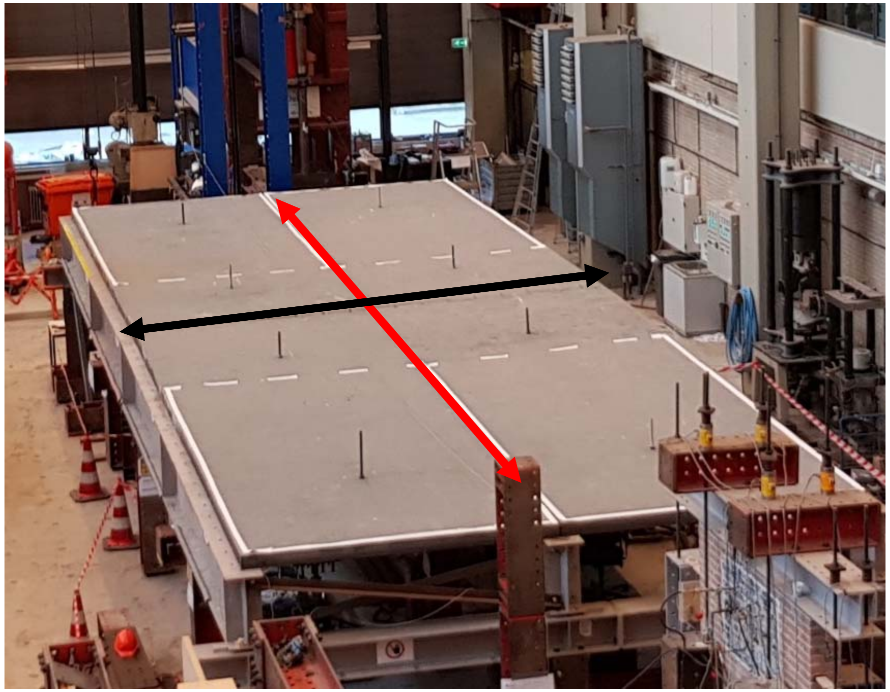
Hole clearance design



Hole clearance design

Alignment

- Longitudinal
- Transversal



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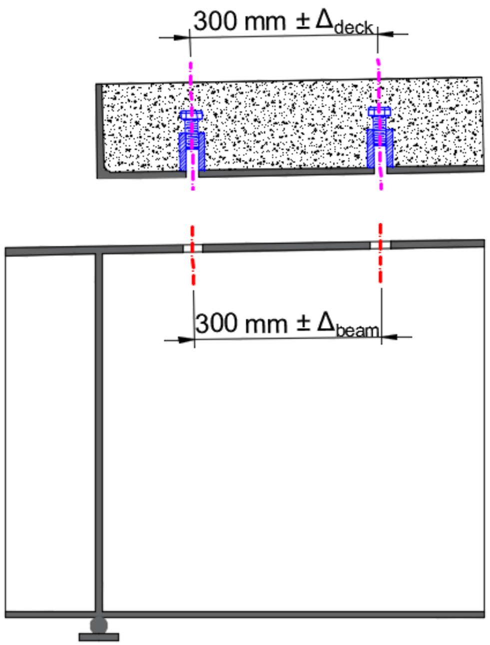
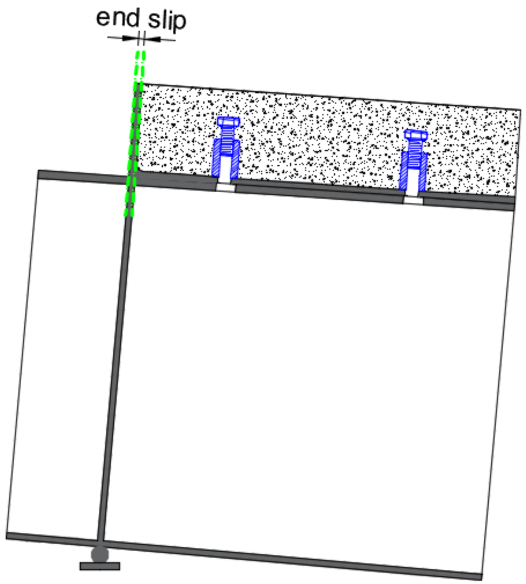
Longitudinal direction





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

Based on measurements and FE results

Hole clearance 12mm

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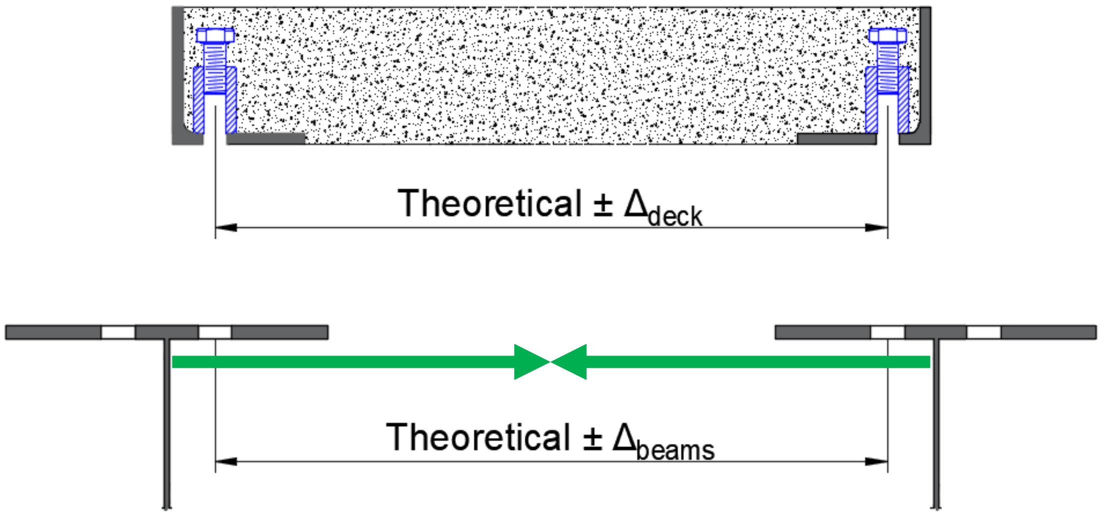
Transversal direction



Measurements:

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

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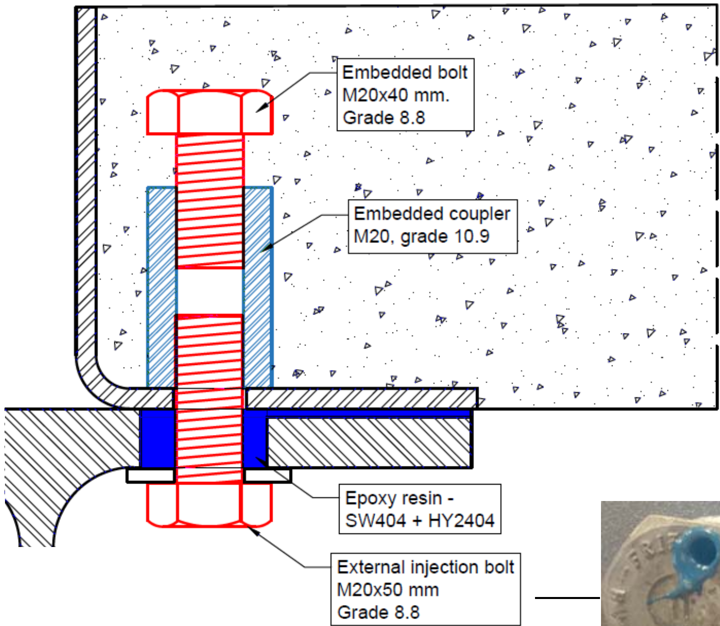
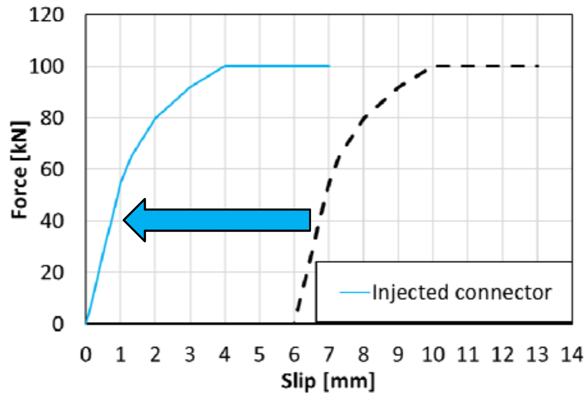
Ensuring composite shear interaction





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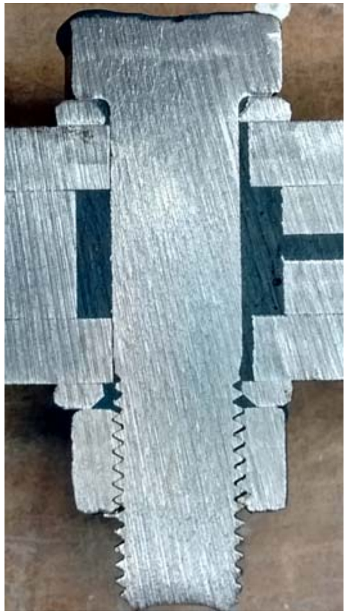
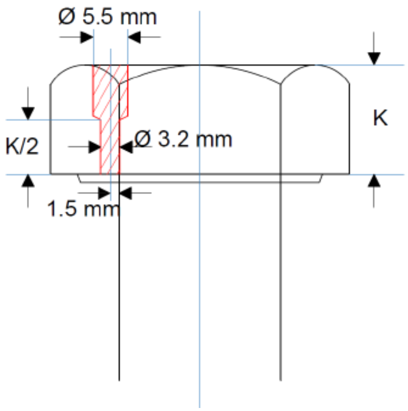
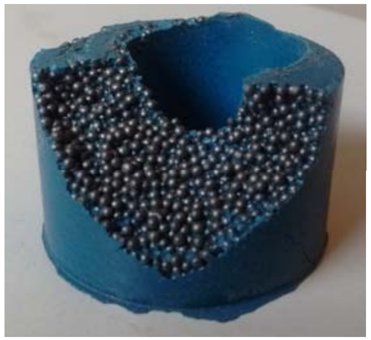
Resin-injected bolted connections
New material – old idea

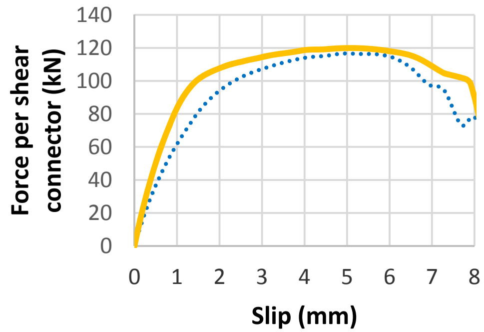



ECCS - Technical Committee 10
Structural Connections

European Recommendations for Bolted Connections with Injection Bolts







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Cost estimate inputs

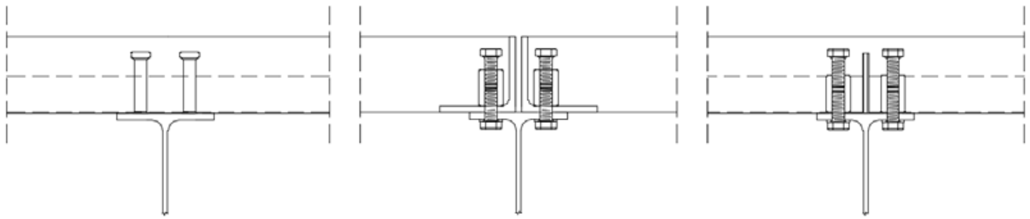
Table 1.	**Materials**	
Steel	/kg	2 €
Hot dip galvanizing	/kg	0.25 €
Angle profile (L120x120x10)	/m	10 €
Hole (beam, angle or sheeting)	/unit	1 €
Concrete	/m^2	15 €
Reinforcement mesh	/m^2	10 €
Fire protection	/m^2	25 €
Profiled sheeting	/m^2	20 €

Table 2.	**Connectors**	
M20 Injection bolt 8.8	/unit	3 €
M20 Coupler 10.8	/unit	3.1 €
M20 Bolt 8.8	/unit	0.75 €
Washer	/unit	0.75 €
Stud and ceramic ferules	/unit	0.5 €
Total connector price		
Injectable connector	/unit	7.6 €

Table 3.	**Manufacturing**	
Casting and reinforcement installation	/m^2	15 €
Decking for profiled sheeting slabs	/m^2	10 €
Formwork and angle-profile installation for prefabricated decks	/m^2	60 €
Connector installation	/unit	1 €
Stud welding	/unit	2 €

Table 4.	**In-situ work**	
Resin injection (resin, labour, consumables, release agent)	/unit	2.50 €
Prefabricated deck installation (crane, operator, fuel, 2 workers)	/deck	185 €

Table 5.	**Transport**	
Transport 3.6m wide deck	/unit	750 €
Transport less than 3m wide deck	/unit	500 €



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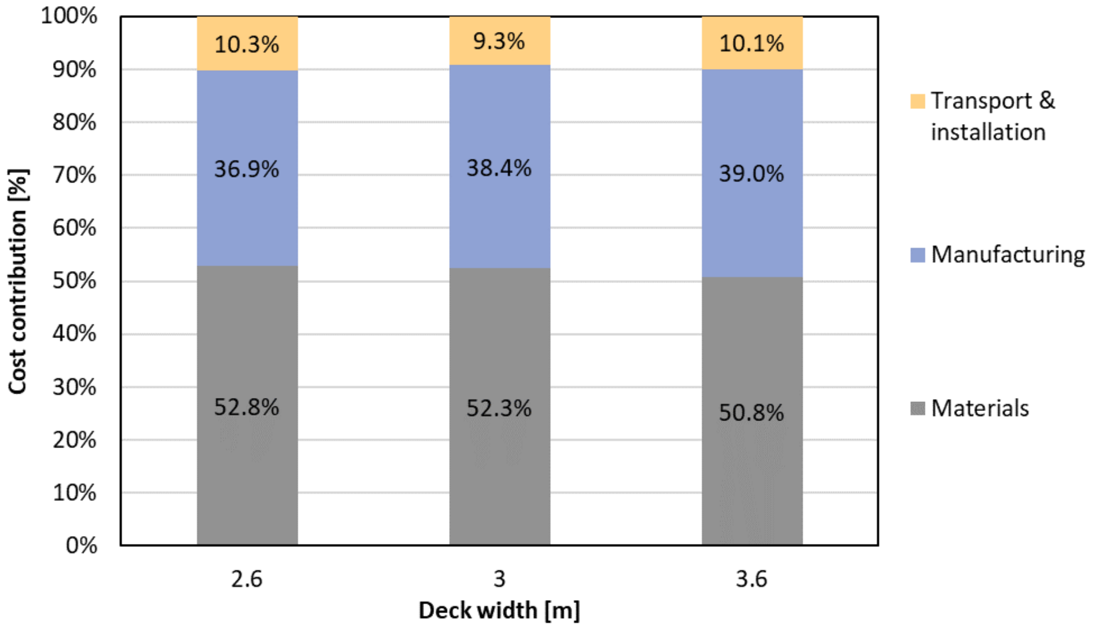
Car-park cost optimization

- **Deck width 3,6 m**
  - **192.1 €/m²**
- **Benefits of composite action**

- **Steel work - 31%**
  - Design influenced steel price of 1.25€/kg
- **Manufacturing 30.5%**
- Demountable connectors 2%



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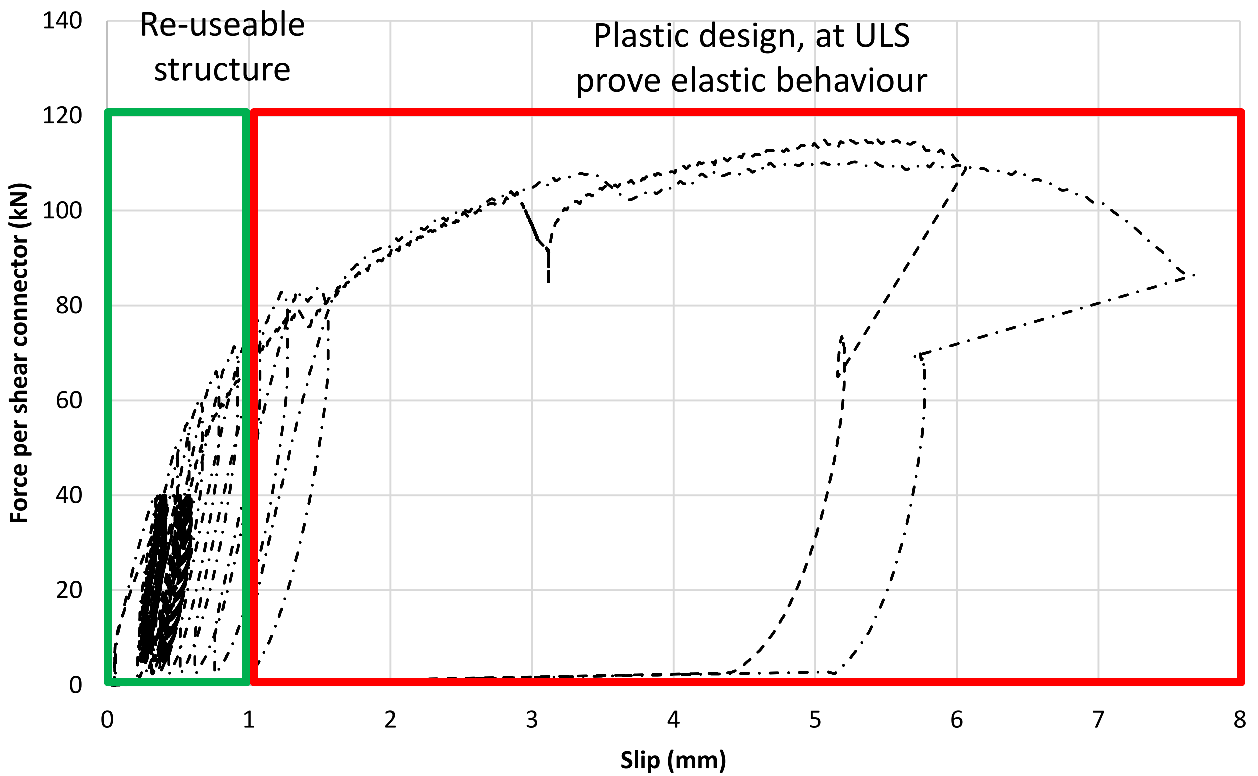
Shear connectors for optimal design



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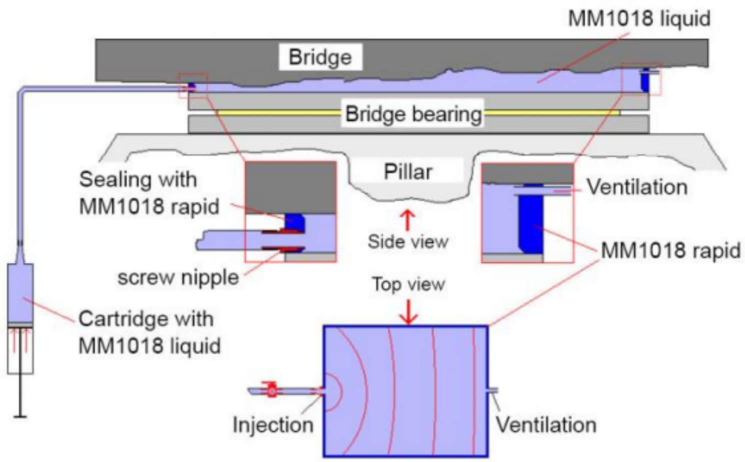
Other applications for (steel-reinforced) resin



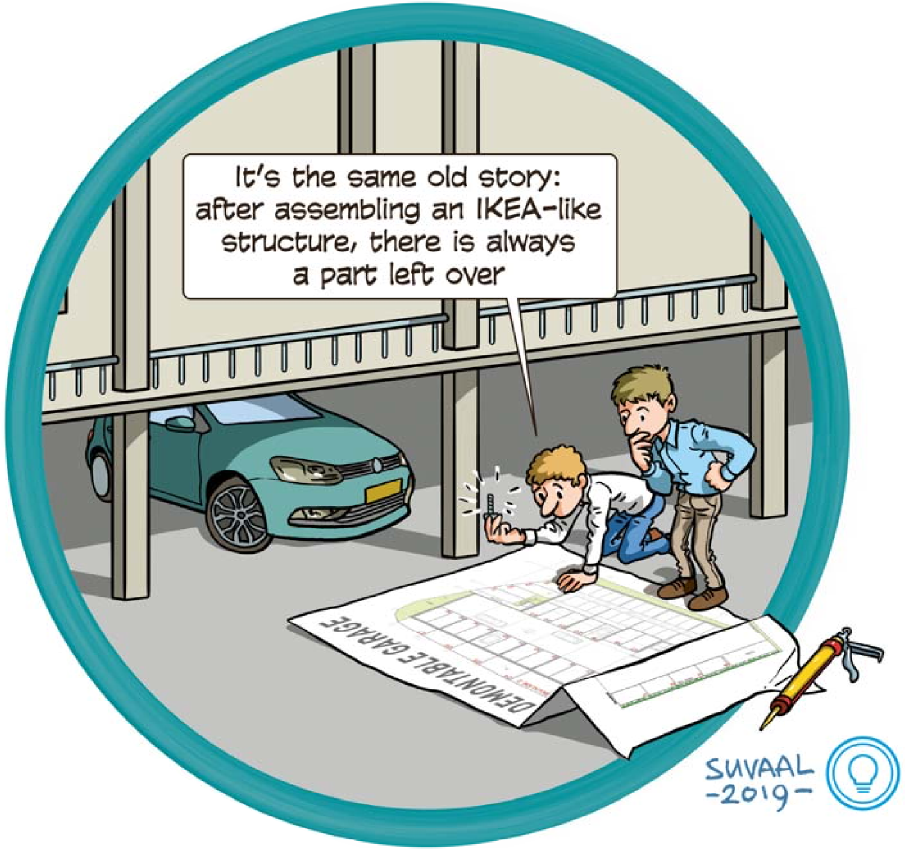
Conclusions

- Significantly oversized holes (12mm for M20 couplers) are used to allow for large tolerance for big concrete deck floor (2,6*8,0*0.15m^3)

- Reduced number of shear connectors optimized to improve the structural response.

- A novel material, steel-reinforced resin, increases the stiffness of the (bolted) connection, and to reduce the creep-deformation.

- Push-out tests and material tests are conducting to establish engineering model for design and account on long-term mechanical behaviour.



https://www.tudelft.nl/en/technology-transfer/development-innovation/research-exhibition-projects/circularity-of-constructions/