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
- Conclusions
How sustainable is the current practice?
Traditional steel-concrete composite structures

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

https://www.astron.biz/en/
Car park designed for reuse

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

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

- Fabrication and execution deviations
  1300 measurements

- Deformations during construction
  FEM

- Speed of construction

Hole clearance
Hole clearance design

Alignment
• Longitudinal
• Transversal
Longitudinal direction

Based on measurements and FE results:
- Hole clearance 12mm
- Hole spacing
- Deck
- Beam
- Deformation
- End-slip

Hole spacing ± $\Delta_{\text{deck}}$
300 mm ± $\Delta_{\text{beam}}$
end slip
Transversal direction

Measurements:
- Connector c.t.c distance
- Beam spacing
  - Construction braces

Theoretical \( \pm \Delta_{\text{deck}} \)

Theoretical \( \pm \Delta_{\text{beams}} \)
Ensuring composite shear interaction
Resin-injected bolted connections
New material – old idea
## Cost estimate inputs

**Table 1. Materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>/kg</td>
<td>2</td>
</tr>
<tr>
<td>Hot dip galvanizing</td>
<td>/kg</td>
<td>0.25</td>
</tr>
<tr>
<td>Angle profile (L120x120x10)</td>
<td>/m</td>
<td>10</td>
</tr>
<tr>
<td>Hole (beam, angle or sheeting)</td>
<td>/unit</td>
<td>1</td>
</tr>
<tr>
<td>Concrete</td>
<td>/m²</td>
<td>15</td>
</tr>
<tr>
<td>Reinforcement mesh</td>
<td>/m²</td>
<td>10</td>
</tr>
<tr>
<td>Fire protection</td>
<td>/m²</td>
<td>25</td>
</tr>
<tr>
<td>Profiled sheeting</td>
<td>/m²</td>
<td>20</td>
</tr>
</tbody>
</table>

**Table 2. Connectors**

<table>
<thead>
<tr>
<th>Connector</th>
<th>Unit</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M20 Injection bolt 8.8</td>
<td>/unit</td>
<td>3</td>
</tr>
<tr>
<td>M20 Coupler 10.8</td>
<td>/unit</td>
<td>3.1</td>
</tr>
<tr>
<td>M20 Bolt 8.8</td>
<td>/unit</td>
<td>0.75</td>
</tr>
<tr>
<td>Washer</td>
<td>/unit</td>
<td>0.75</td>
</tr>
<tr>
<td>Stud and ceramic ferules</td>
<td>/unit</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total connector price</strong></td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td>Injectable connector</td>
<td>/unit</td>
<td>7.6</td>
</tr>
</tbody>
</table>

**Table 3. Manufacturing**

<table>
<thead>
<tr>
<th>Task</th>
<th>Unit</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting and reinforcement installation</td>
<td>/m²</td>
<td>15</td>
</tr>
<tr>
<td>Decking for profiled sheeting slabs</td>
<td>/m²</td>
<td>10</td>
</tr>
<tr>
<td>Formwork and angle-profile installation for prefabricated decks</td>
<td>/m²</td>
<td>60</td>
</tr>
<tr>
<td>Connector installation</td>
<td>/unit</td>
<td>1</td>
</tr>
<tr>
<td>Stud welding</td>
<td>/unit</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 4. In-situ work**

<table>
<thead>
<tr>
<th>Task</th>
<th>Unit</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin injection (resin, labour, consumables, release agent)</td>
<td>/unit</td>
<td>2.50</td>
</tr>
<tr>
<td>Prefabricated deck installation (crane, operator, fuel, 2 workers)</td>
<td>/deck</td>
<td>185</td>
</tr>
</tbody>
</table>

**Table 5. Transport**

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport 3.6m wide deck</td>
<td>/unit</td>
<td>750</td>
</tr>
<tr>
<td>Transport less than 3m wide deck</td>
<td>/unit</td>
<td>500</td>
</tr>
</tbody>
</table>
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%
Shear connectors for optimal design

Re-useable structure
Plastic design, at ULS prove elastic behaviour

Force per shear connector (kN) vs. Slip (mm)
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.
It's the same old story: after assembling an IKEA-like structure, there is always a part left over.