Demountable Precast Concrete Systems

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Reuse of Steel Structures and the Circular Economy
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1. Introduction

2. Demountable Shear Connections

3. Laboratory Tests

4. Design Procedure

5. Conclusions
Aspects of Design for Deconstruction (DFD):

- Use demountable mechanical connections and dry joints
- Use modular design and a standard structural grid
- Use prefabrication
- Provide access to all parts, particularly connections
- Provide tolerances for assembly and disassembly
- Use a minimum number of connectors
- Design robustly to withstand repeated use
Modular design

- Planning grid: Multiple of the basic module (m)
- Basic module: m=1.5 m (UK)  m=1.35 m (Continent)
- The size of all elements should respect the planning grid (beam, slab, spacing of connectors)

http://www.understandconstruction.com/steel-frame-structures.html
Modular design

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[Diagram of modular design]

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Introduction
Example Module: 1.35 m

Avenue Leclerc office building
Boulogne-Billancourt, 2016
Architects: Grégoire Zündel, Irina Cristea
Introduction
Example Module: 1.35 m

Medienbrücke, München, 2012
Architect: Otto Steidle

Thyssenkrupp Headquarter,
Essen, 2010
JSWD Architekten, Chaix & Morel
et Associés
Introduction

Example Module: 1.35 m

ILB building, Potsdam, 2017
Architect: Jürgen Engel

Imtech building, München, 2014
Prasch buken partner architekten
Introduction

Example Module: 1.35 m

DHPG building,
Bonn, 2013
Schmitz Architekten

Deutsche Börse, Eschborn,
2010
Jürgen Engel
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Demountable Shear Connections


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Demountable Shear Connections

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• High-strength bolted connections
• Prefabricated slab elements
• Oversized holes in the steel beam
• Pretension or epoxy resin injection
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Part 2: Laboratory Tests

Laboratory Tests

Push out tests

• Standard EC4 push-out tests
• 4 Prefabricated slabs
• HEB260 Beam
Laboratory Tests
Push out test results

Laboratory Tests
Push out test results

11/10/2019

Laboratory Tests
Push out test results
Summary (Push-out Behaviour)

- Bolt shear failure
- Higher strength
- Lower stiffness
- Sufficient deformation capacity (>6 mm)
- Non-ductile behaviour
- Demountable
- Reusable
• 2 full-scale beam tests on 6.3 m beams
• IPE 360
• 2 Prefabricated slabs
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• IPE 360
• 2 Prefabricated slabs
Beam test results

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Serviceability Limit State

1. Check the deflection

\[ \delta = \frac{5}{384} \cdot \frac{qL^4}{EI_{y,eff}} \leq \frac{L}{250} \]

Second moment of area:
Rigid connection:
\[ I_{y,eff} = I_{y,a} + I_{y,c} \cdot \frac{A_c A_a}{A_c + n A_a} \cdot a^2 \]
Flexible connection:
\[ I_{y,eff} = I_{y,a} + I_{y,c} \cdot \frac{A_c}{n} + \frac{A_c}{n A_s} + \left( \frac{E_a}{k_{sc} / s_{sc,eq}} \right) \left( \frac{n}{L} \right)^2 \left( \frac{A_c}{n} \right) \cdot a^2 \]

\[ k_{sc} : \] Shear connection stiffness (from test)
\[ s_{sc,eq} : \] Equivalent spacing

EN1994-1-1, Annex A.3

(3) The stiffness of the shear connector, \( k_{sc} \), may be taken as \( 0.7 P_{Rk} / s \), where:
- \( P_{Rk} \) is the characteristic resistance of the shear connector;
- \( s \) is the slip, determined from push tests in accordance with Annex B, at a load of \( 0.7 P_{Rk} \).
Serviceability Limit State

2. Check occurring end slip

\[ \bar{s} = M \frac{S_k}{I_{y,eff}} \frac{s_{sc,eq} \pi}{k_{sc} L} \leq \frac{0.7 P_{Rk}}{k_{sc}} \]

\[ S_k = \frac{a}{E_a} \left( \frac{\left( \frac{k_{sc}}{s_{sc,eq}} \right) \left( \frac{L}{\pi} \right)}{A_c + n A_a} + A_c A_a \right) \]
Ultimate Limit State

Non-ductile behaviour

EC4 does not allow equidistant spacing → Standardisation and modular design?

Substitute the load-slip behaviour with and equivalent ductile headed stud shear connection.

Introduction of a reduction factor $k_{\text{flex}}$:

$$P_{\text{R,eff}} = k_{\text{flex}} \cdot P_{@6\text{mm}}$$

Definition of $k_{\text{flex}}$ based on the shape of the load-slip curve and the slip distribution.

This way, $P_{\text{R,eff}}$ can be used for EC4 like $P_{\text{Rd}}$. 

$k_{\text{flex}} \approx 0.76 - 0.80$
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Conclusions

- The developed systems are suitable for demountable composite beams.

- The tests showed, that the damage occurs in the replaceable elements.

- With the developed equations, **Eurocode 4 standard design procedure remains applicable.**

- In addition, the slip must be controlled at SLS. (Equations are given.)