fib Symposium2025
Antibes - France
Concrete Structures :
extend lifespan, limit impacts

16-18 June, 2025

Experimental investigations to identify challenges in design of prefabricated concrete structures for disassembly and reuse

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and

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Reuse of prefabricated concrete components

- Reuse of prefab. components as strategy to mitigate environmental impact of concrete
- Standard prefab. systems were not conceived for reuse

→ Specific need for purpose-designed connections for disassembly

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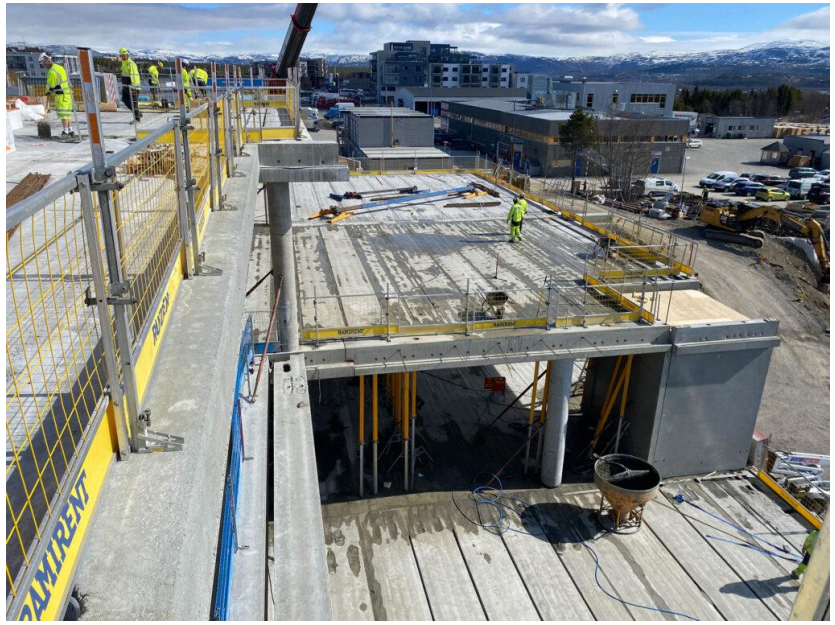

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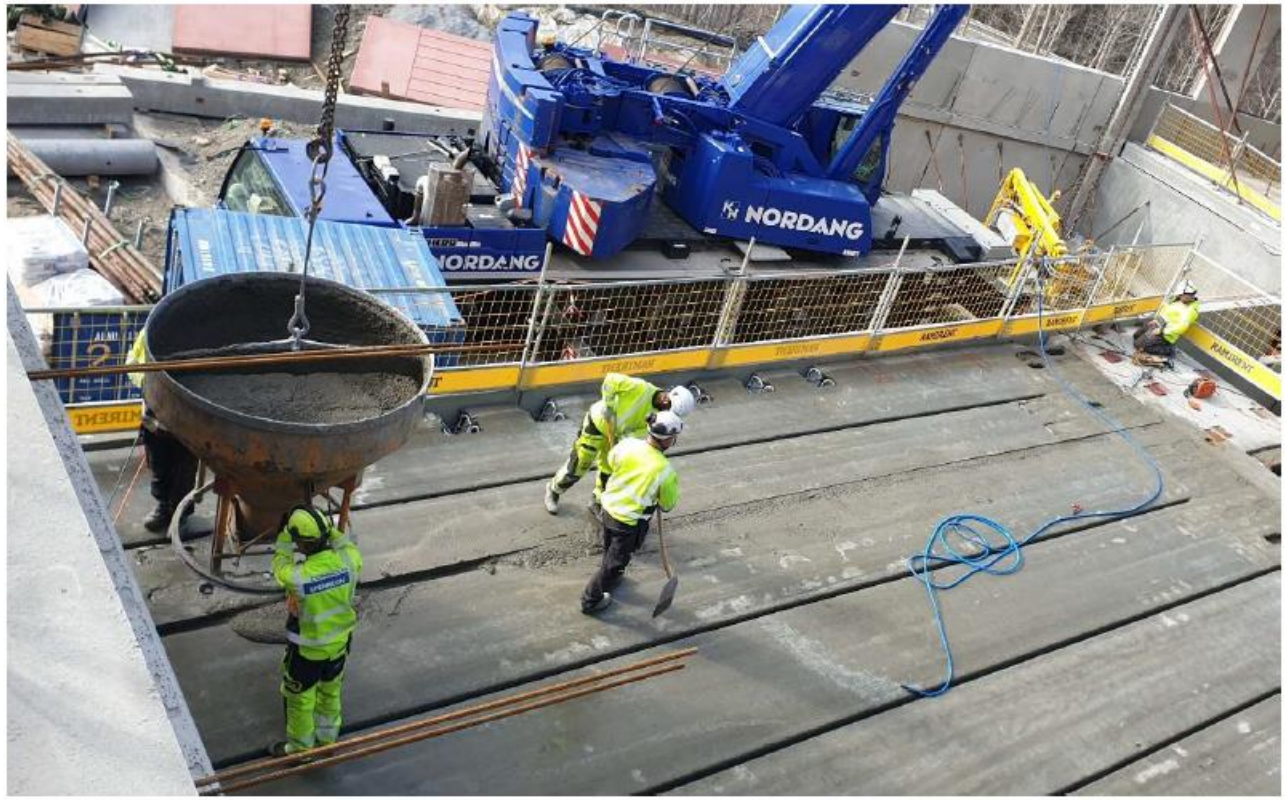
Motivation and objective

- Dry connection solutions often proposed as Dfd solutions: e.g. bolted joints
- Maintaining classical wet joints solutions relying on grouting concrete ensures:
  - adequate force transfer
  - constructability with regard to construction tolerances
  - Minimisation of adaptation costs
- **Objective**: Propose a Dfd solution for hollow core slabs (HCS) with wet joints and validate in full-scale mock-up



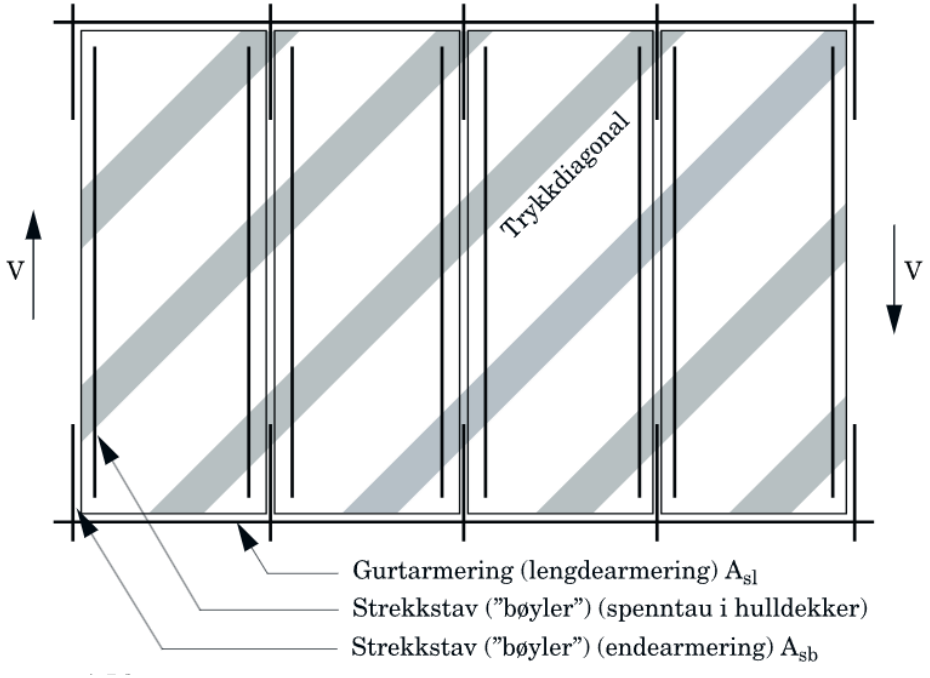
Figur 1 Dagens utførelse av fugebetong (foto: Vegard Alme Ulstein, Spenncon)

Function and design of longitudinal joints between HCS

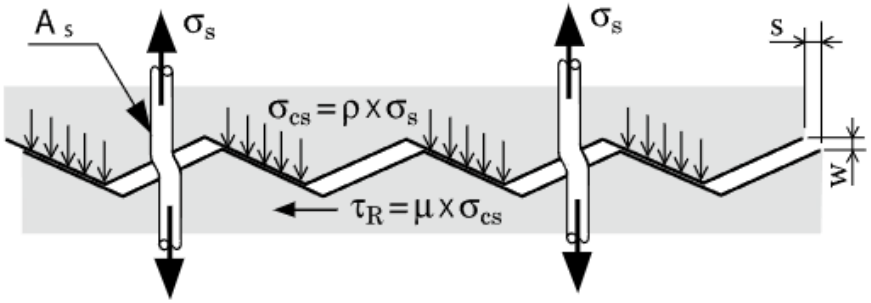
- Primary function: Ensure structural force transfer and continuity through diaphragm action.
- Design usually governed by horizontal shear capacity
  - Contribution from adhesion and friction forces
- Grouted joints in precast floors are typically assumed to crack in service due to restraint forces.

→ Shear resistance is assumed to rely on friction only

  - Normal stress and reinforcement across joint.



Betongelementboken, 2016



Betongelementboken, 2016

Adhesion and Grout Removal: Prior experiences

- Despite assumption of cracked joints in design, adhesion forces between grout and HCS surfaces an be significant

→ Complicates disassembly

→ Increases time, cost, and risk of damage

- Example: Volda (Norway) swimming hall slab (2023)
  - ~15 min/m with chisel hammer to remove standard grout
- Adhesion increases with improved execution quality
  - Today: flowable concretes, pre-wetting, better curing & frost protection

→ **Adhesion-lowering agents as solution**

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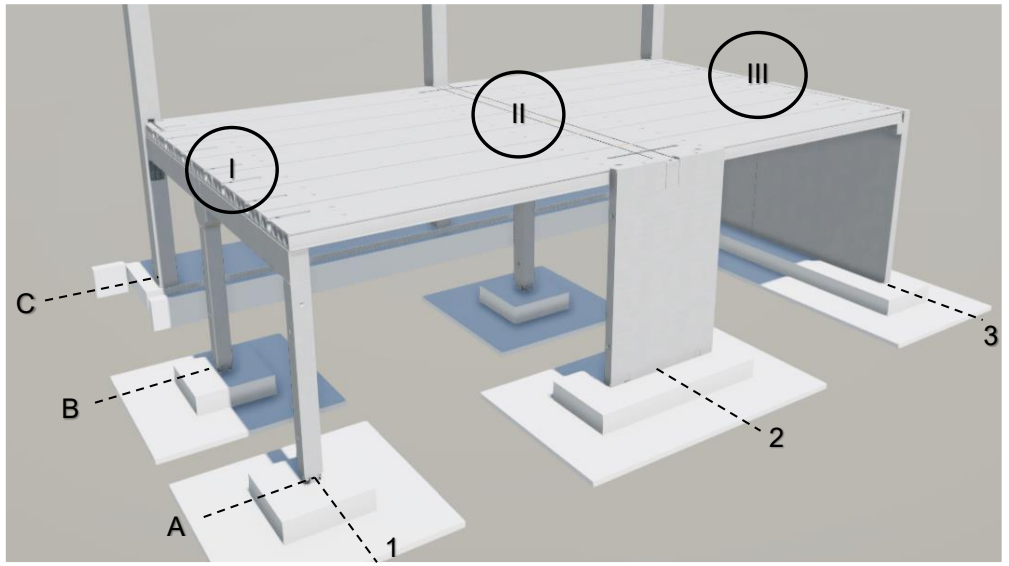
Figur 3 Fjerning av fugestøp fra utsagede hulldekker fra Volda Symjehall, 2023 (foto: Vegard Alme Ulstein, Spenncon)

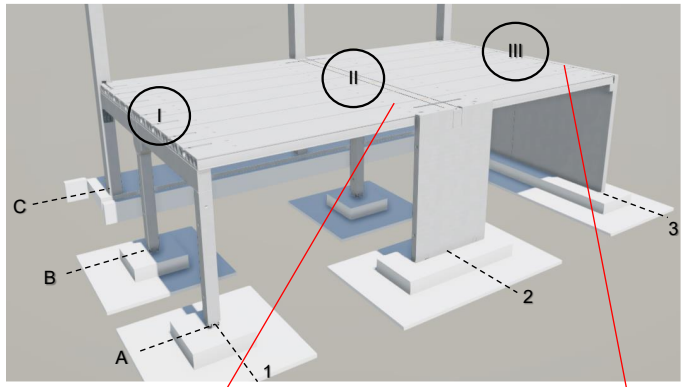
Mock-up description

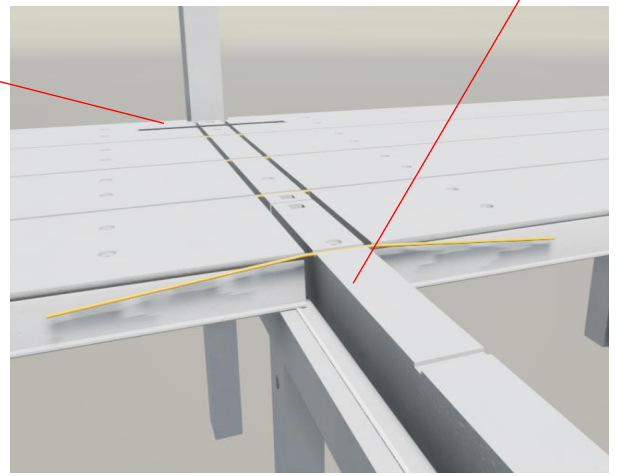
- Planned and executed by Spenncon A.S. (Hønefoss, Norway)
- Hollow-core slabs (HCS) spanning two bays
- Supported by rectangular beam (1), inverted T-beam (ITB) (2), and a wall with nib (3)
- Vertical loads → transferred to columns + walls (axes 3 and A)
- Horizontal loads → resisted by diaphragm action and moment-resisting columns (1C, 2C)



HCS Support Connections and Detailing

- Rebars in longitudinal joints between HCS crossing connection II to ITB for continuity
- Threaded rods embedded in slots in connection III transfer force to wall
- Steel plates welded across end joints of the HCS to tie components together



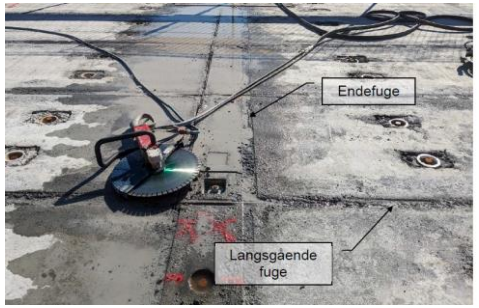


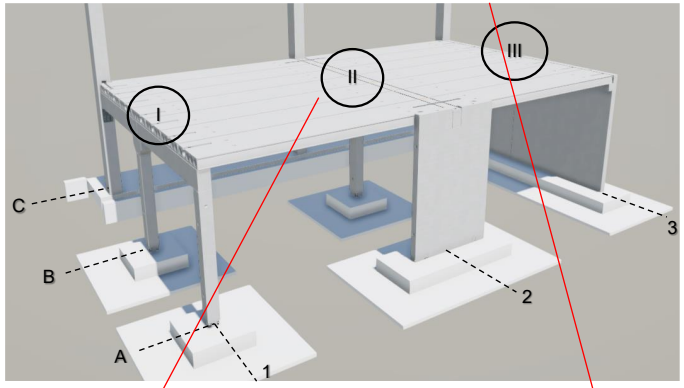
Joint between HCS and ITB (connection II)

Joint between HCS and wall nib (connection III)

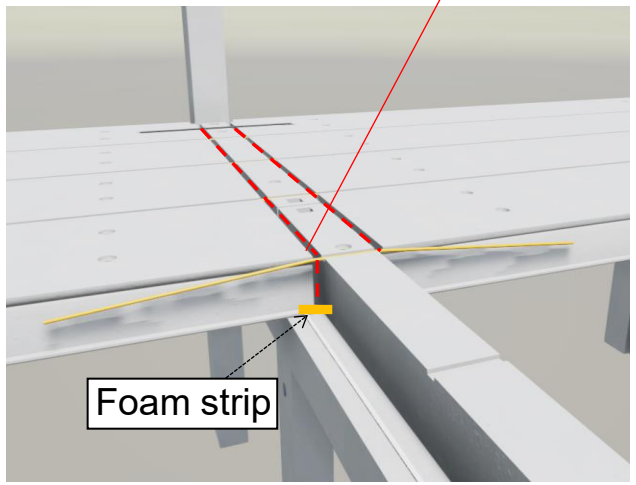
Disassembly considerations

- Cutting required through grout, rebars and threaded rods
- Threaded rods cut → new slot in HCS needed for reuse
- Existing sleeves in wall can be reused unless geometry misaligns
- 80 mm foam strip on top of HCS support prevents adhesion and damage during cutting
- **Adhesion-reducing agents**

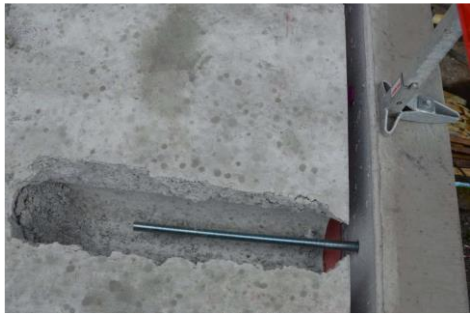




Joint between HCS and wall nib (connection III)



Joint between HCS and ITB (connection II)



Adhesion-Reducing Products

- Seven products by Master Builders Solutions tested, based on prior laboratory study
- Application areas:
  - Longitudinal HCS side surfaces
  - Contact surfaces on supporting walls, and the ITB
  - Untreated reference zones for comparison
- Application process
  - Performed by Master Builders under open roof and dry weather
  - Low-viscosity liquids applied with pressure sprayers
  - Two thin layers on dry concrete
  - Drying time: ~15 minutes before 5-day storage prior to assembly

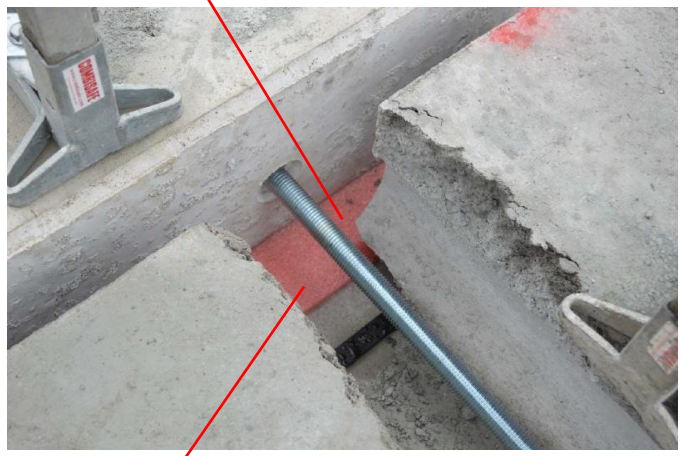
Application of the adhesion-reducing products on lateral surfaces of HCS.

Application on lateral surfaces of ITB.

Mock-up assembly

- Assembly took place August 2024
  - Two workers with assistance from a mobile crane
- Joint grouting with C30 concrete
  - Standard for summer joint casting in Norway
  - Weather: Humid conditions — no pre-watering applied

Placing of a HCS with the mobile crane



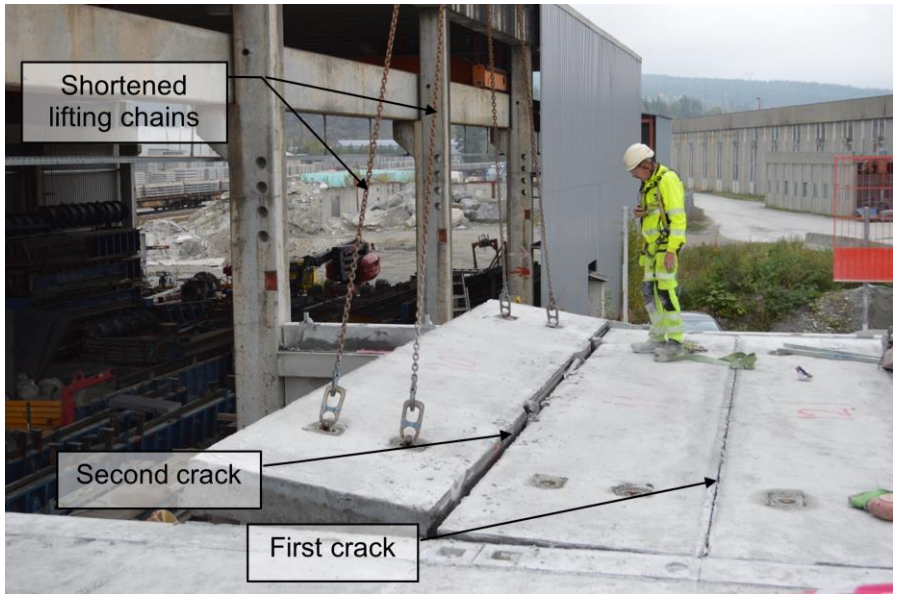
Foam strip on top of wall nib supporting the HCS in axis C before grouting .

Grouting of end joints

Finished slab

Disassembly of HCS

- > 4 weeks after assembly
- HCS removal sequence
  - Saw cutting of HCS end joints to wall nibs and ITB
  - HCS lifted with crane using embedded anchors
  - Shortened lifting chains to induce bending stress and hence controlled cracking in the nearest longitudinal joint
- Challenge and solution
  - Sometimes, unintended first cracking occurred at joint between the adjacent pair of HCS → damage risk
  - Shallow saw cuts + wedges + sledgehammer hits to induce cracking at intended joints



Reconditioning of HCS and adjacent members

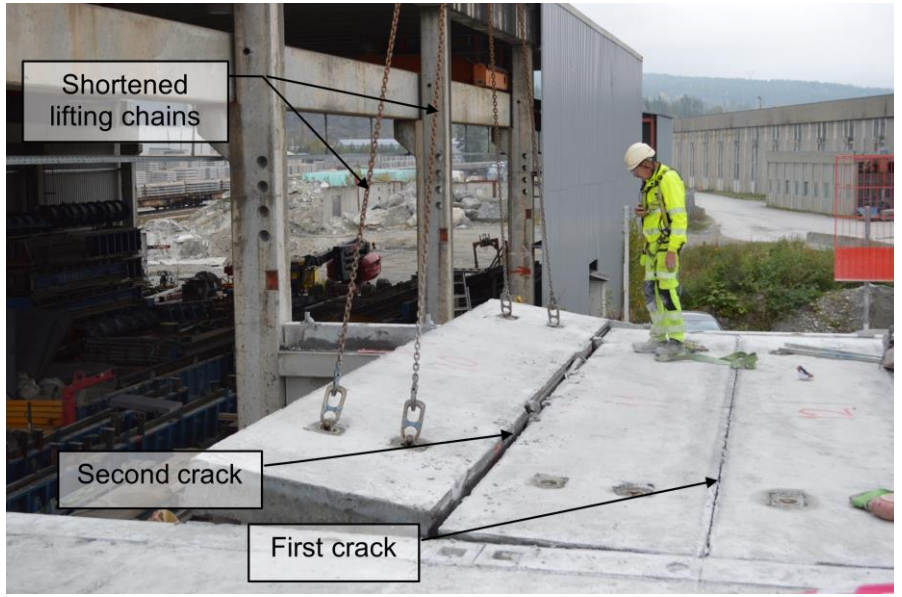
- Removal of residual grouting concrete from HCS long and short sides, ITB web, Wall nib
- Performance of adhesion-reducing products:
  - Treated HCS long sides: Easy removal, 60–85 sec/m. Large sheets detached cleanly
  - Untreated areas: Difficult removal, 200–350 sec/m. Very labor-intensive, especially at short ends
  - One product showed notably higher adhesion; others performed similarly
  - Grout on beam side edges detached easily, regardless of adhesion-lowering agents
  - Grout on the wall above nib was only easy to remove where treatment was applied

Removal of concrete from longitudinal side of HCS, where adhesion-reducing products were applied

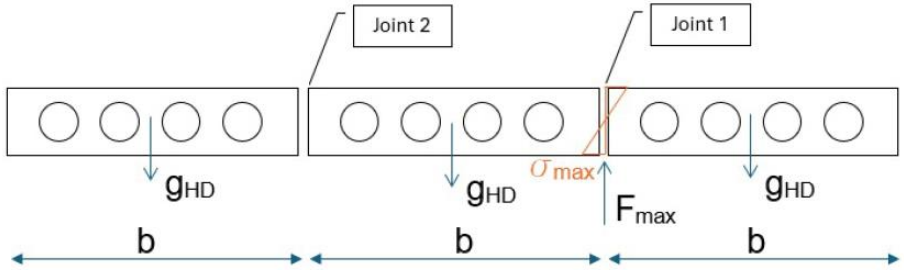
Removal from a reference area at the short end of the HCS

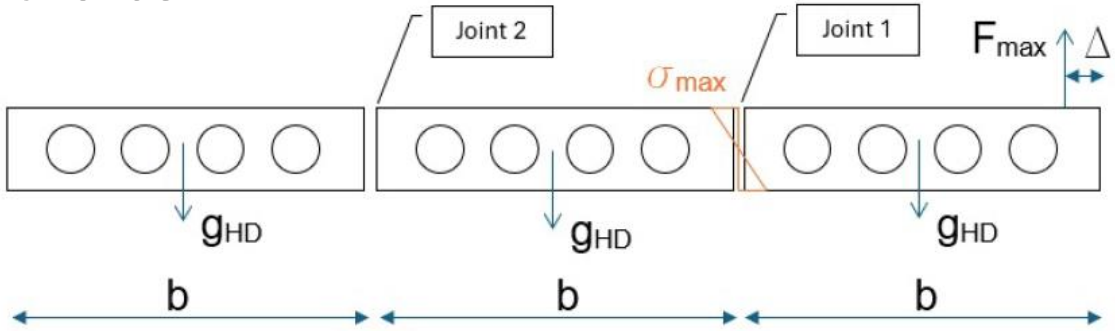
Lessons and envisaged improvements – Longitudinal joints

- Traditionally, adhesion neglected in HCS joint design
- Tests evidenced significant adhesion forces
- Adhesion-lowering products effective in cleaning phase
- Observed uncontrolled cracking during disassembly
- Reliability-based joint design to crack at predictable locations: $\sigma_{max}(F_{max}, \Delta, gH_{CS}) \geq \sigma_{R,adh}(p_{ft})$



- Same principle for disassembly relying on uplift force:





Lessons and envisaged improvements – Longitudinal joints

- Further optimisation of adhesion-lowering agents
- Tests to ensure these agents do not imply friction loss:
  - Shear-off tests to study roughness/interlock effects.
  - Consider surface indents to improve friction capacity
- Reducing adhesion by lower grouting concrete strength is questionable strategy due to several reasons, e.g.
  - Requirements to frost protection (min C30/C35 in Norway).
  - Use same concrete for adjacent connections, such as e.g. floor-wall joints → low-strength mortars unsuitable.
  - Concrete tensile strength is crucial for anchoring reinforcement in longitudinal joints and HCS slots.

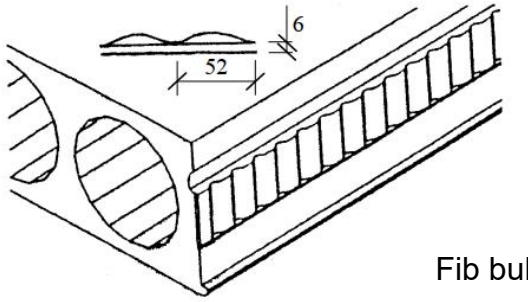


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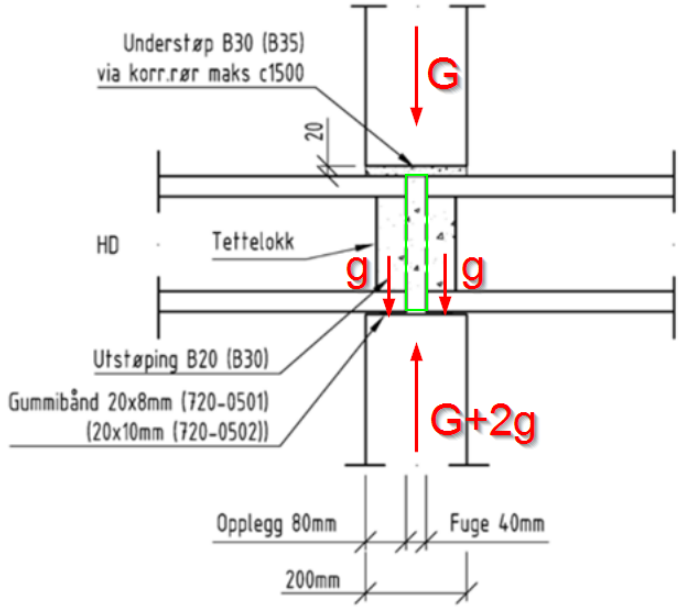
Fig. 8-65: Slab with undulated sinusoidal edge according to tests byMenegotto (1994)



Vertical force transfer across wall-HCS joint in a multistorey building

Lessons and envisaged improvements – End connections

- Adhesion behaviour characterised by surface type
- Free surfaces (not cast against formwork), e.g., wall above nib, require adhesion-reducing agents
  - Classified as “smooth” or “rough” per prEN 1992-1-1
- Formwork-cast surfaces, e.g., ITB side edge, do not require such agents
  - Classified as “very smooth” per prEN 1992-1-1
- Adhesion-reducing agents could also be applied to short ends of HCS, but risk of overspray into slits

→ Saw cutting at interface between HCS and grout is preferred option

Conclusions

- Contrary to common belief, wet joints (grouted) can be suitable for reuse
- Adhesion forces in HCS joints can significantly resist disassembly and cleaning.
- Adhesion-reducing agents provide a viable and cost-effective solution to this problem
  - Preserve the benefits of wet joints (e.g. force transfer, diaphragm action, tolerances).
  - Outperforms strategy based on low-strength mortars, which face practical limitations.
  - Recommended for “smooth” or “rough” surfaces per prEN 1992-1-1.
- Induced tensile stress (via crane/jack) enables joint separation without prior grout removal.
- Further joint design optimization potential has been identified

Acknowledgements

Special thanks to Vegard Ulme (Spenncon) who is the main developer of this study.

The study received financial support from the **Research Council of Norway** via project no 327777 **SirkBygg: Sirkulære nybygg - Design og bygging for demontering og ombruk.**

Project owner: Skanska Norway (www.skanska.no).

Project partners: Spenncon A.S., Contiga (Heidelberg Materials), SINTEF Community