SLIM FLOOR DESIGN - UPDATE

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- Scandinavian concept of Slim Floors
- Interaction of floor components
- Mechanical model for making allowance for interaction – behaviour of non-ductile connections
- Parameters that govern the resistance design – shear interfaces, forms of cross-section in beams and slab units
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- Verified methods of strengthening the decking capacity
- Effects of openings in the floor
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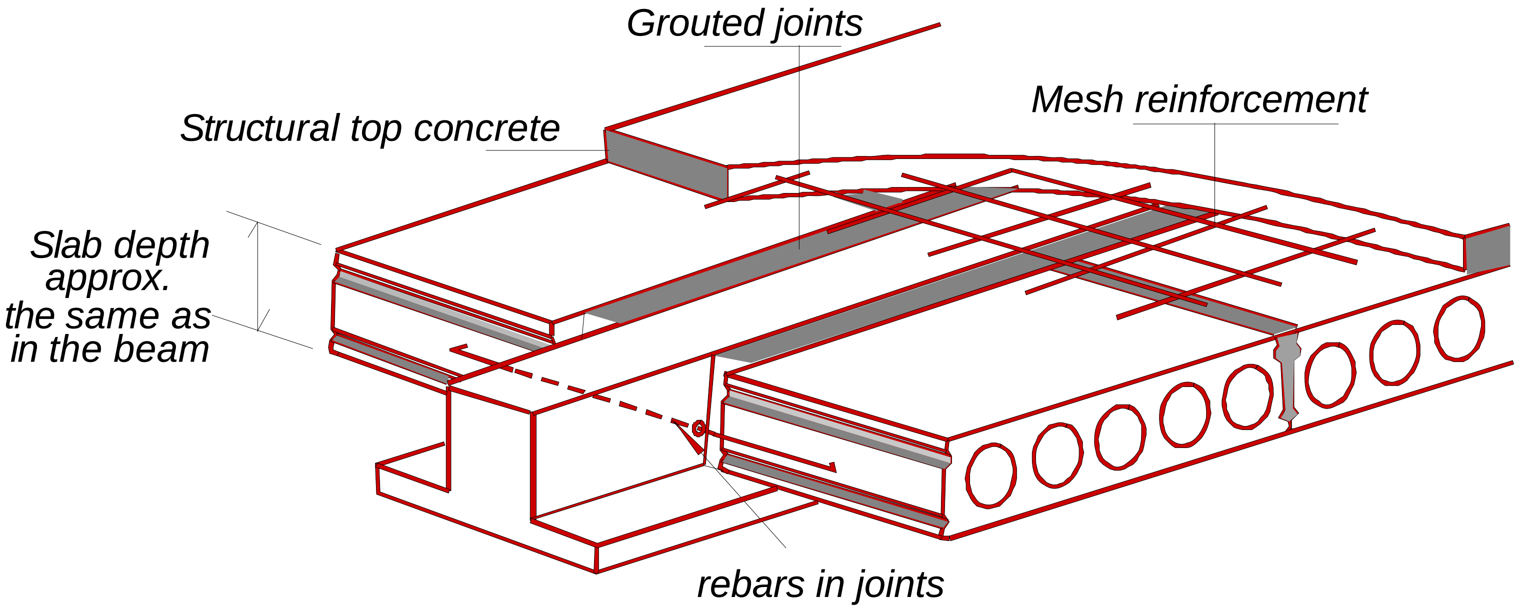
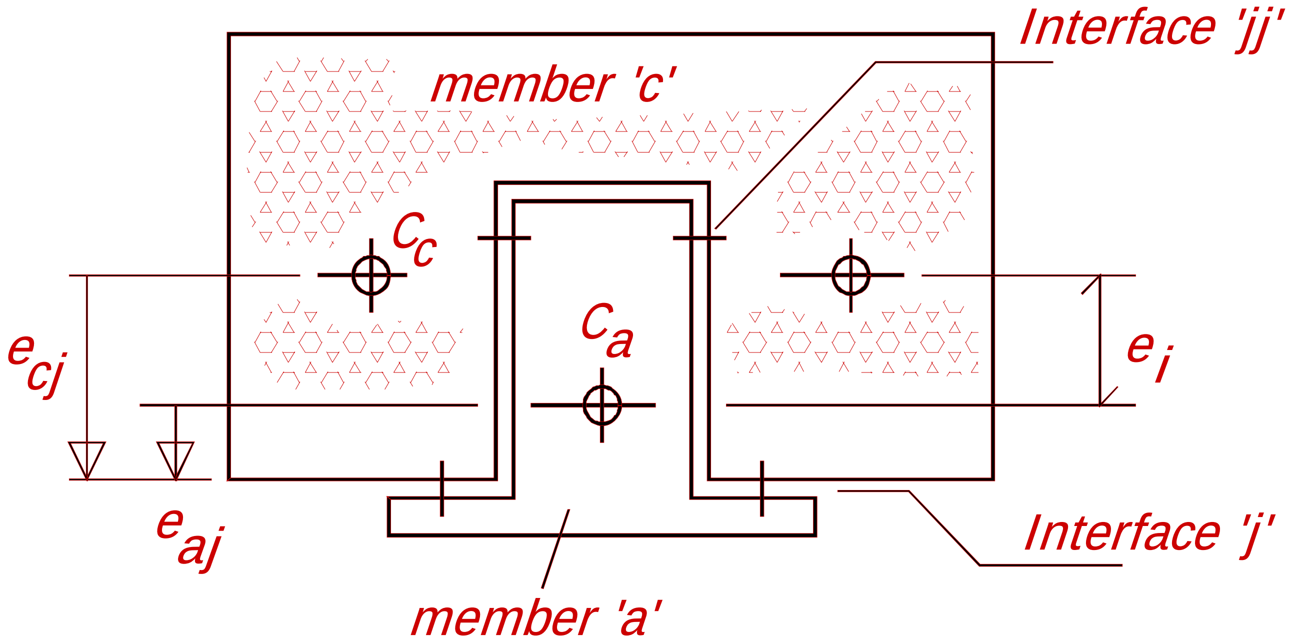
Scandinavian Concept of Slim Floors



No ductile shear connection between beam and decking

Characteristics of composite interaction: deteriorating efficiency with increasing load

Interaction of floor components
Composite interaction theory

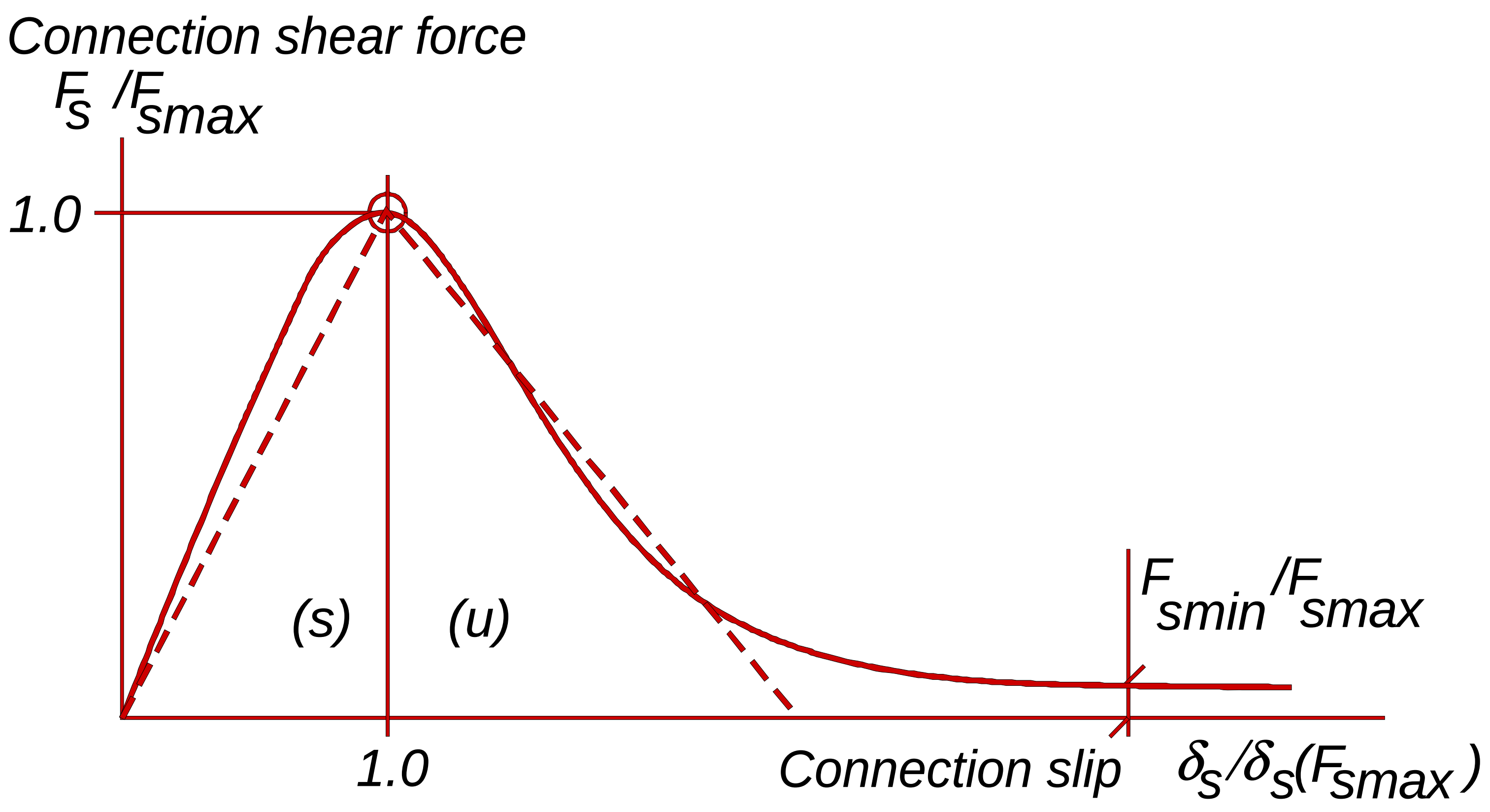


-Only one connection interface is required for composite interaction

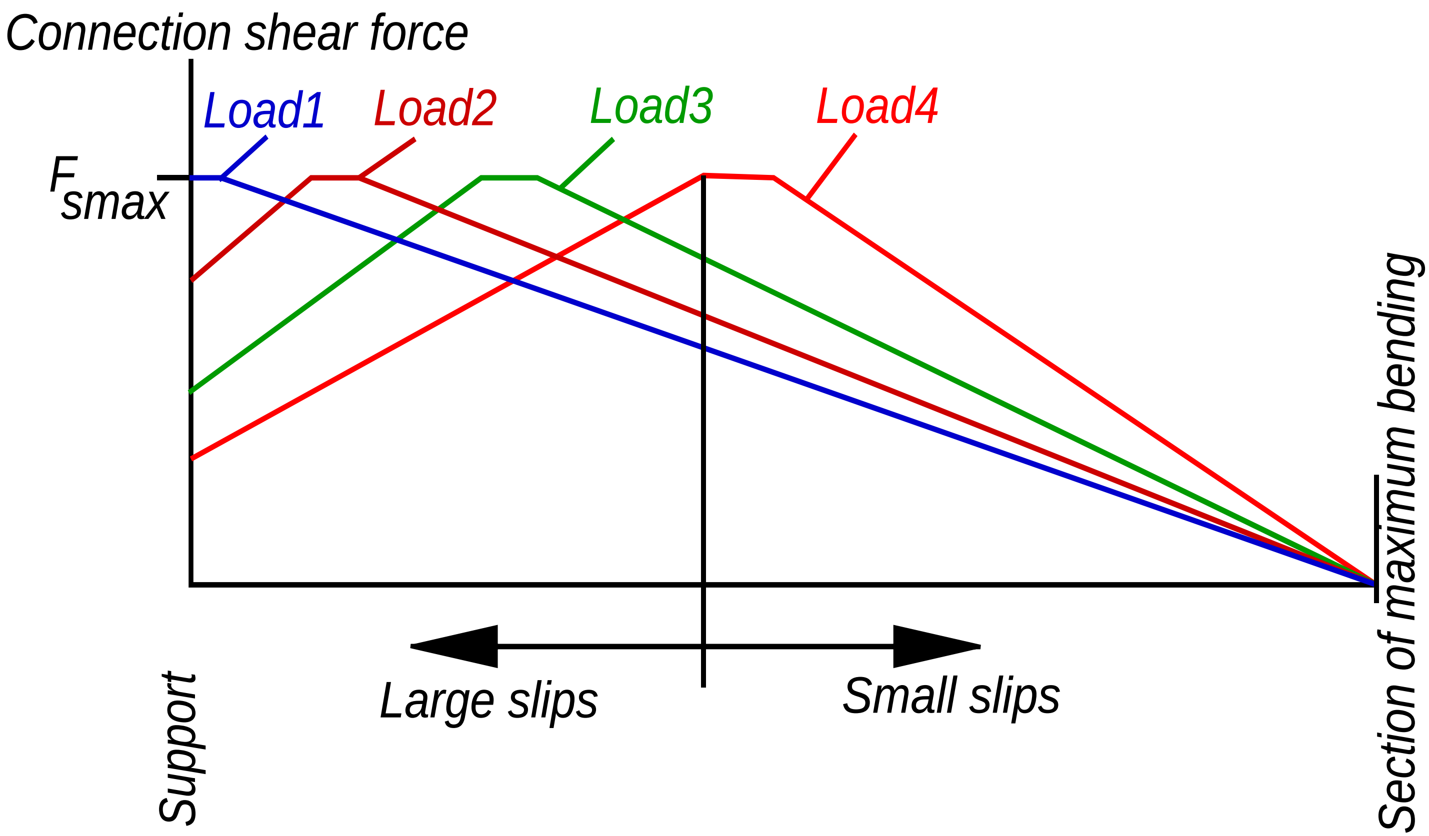
-There can be one or more interfaces, however

-The locations are not important for development of interaction, but they have importance for the behaviour of hollow core slabs

Background to Non-Ductile Connection Behaviour: Shear Force – Slip characteristics

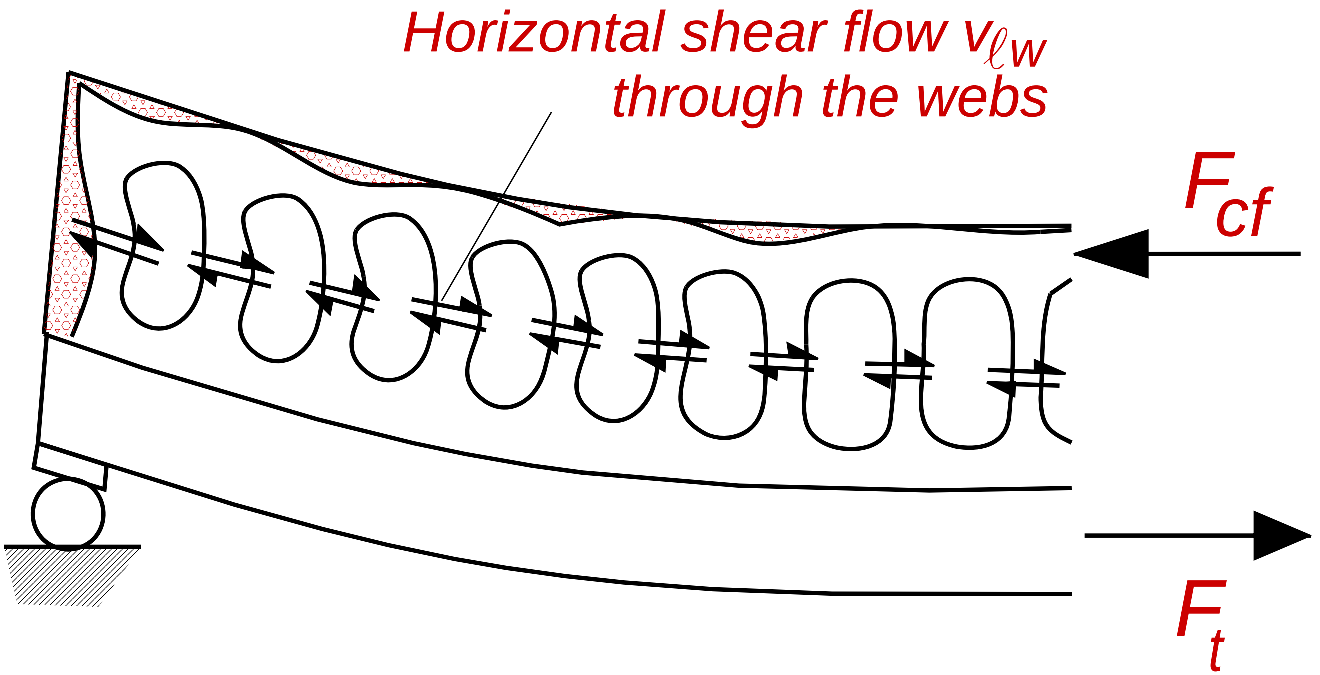


Background to Non-ductile Connection Behaviour: Zip-flyer effect



Beam loads: *Load1* ≤ *Load2* ≤ *Load3* ≤ *Load4*

MECHANICAL MODEL FOR THE EFFECTS OF 'FLEXIBLE SUPPORTS'



F_{cf} and the horizontal shear flow, ***$v_{\ell w}$***, develop due to composite interaction i.e. due to adaptation into a common curvature = the curvature of the composite system

PARAMETERS THAT GOVERN THE RESISTANCE DESIGN OF HCU'S

- Shear interfaces between the web of the beam and ends of the HCUs
  - The characteristics of the interfaces influence the maximum longitudinal shear forces that are induced to the webs of the HCUs
- Geometry of the supporting beam
  - Influences the extent of the unit shear flow
- Geometry of the HCUs
  - Thickness of the webs, ovality of the voids
  - Thickness of the upper hull in the HCUs

Summary of the floor tests carried out in Europe

- Tests in Finland: 20 full-scale floor tests, 1 smaller scale test and 1 test for demonstrating the transfer of load from the slabs to the beam (single sided long slabs, short steel beam with high loads). The beam types include concrete, composite and steel sections and a representative collection of slab sections with depths between 265 ... 500 mm

- Tests in Germany: 2 smaller scale tests, 2 floor tests with slabs of smallest depth. 4 new tests that are similar with those done in Finland. Slab depths 250 ... 265 mm

- Tests in France: 2 tests that are similar with those done in Finland. Slab depths 265 mm

- Tests in Sweden: 1 set of tests for demonstrating the load transfer from slabs to a composite slim floor beam.

- **General:** majority of the tests carried out involve slabs with depth less than 300 mm, but now also deeper slabs up to 500 mm have been tested

Additional verification for the mechanical model and effect of shear interfaces: latest tests in Finland

- In 2005 three new floor tests were made:
  - Beam: WHQ steel section (top hat), HCUs: 4-voided 500 mm deep section
  - Beam: PC inverted T-section (ledger beam) with smooth web interfaces, HCUs: 4-voided 500 mm deep section
  - Beam: Composite Deltabeam, HCUs: 4-voided 500 deep deep section
  - Span of the beams: 7200 mm, span of the decking slabs: 9900 mm, core infill length = depth of the voids
- In 2006 one additional test; Beam: PC inverted T-section (ledger beam) with smooth web interfaces, HCUs: 4-voided 400 mm deep section. Span of the beams: 4800 mm, span of the decking: 8900 mm

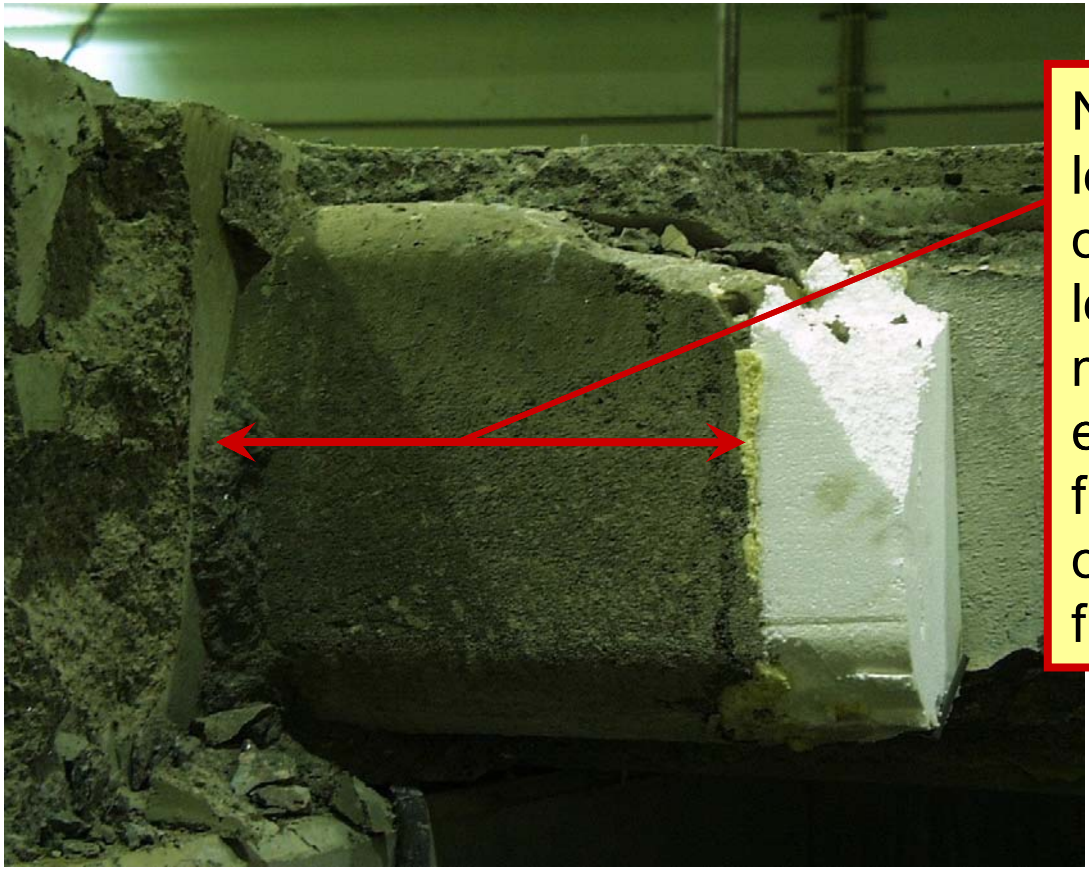
Web interfaces in PC-beams: **no keying** for reducing the efficiency of connections

No keying = smooth web interfaces

Erection of the floor

Disassembled after test

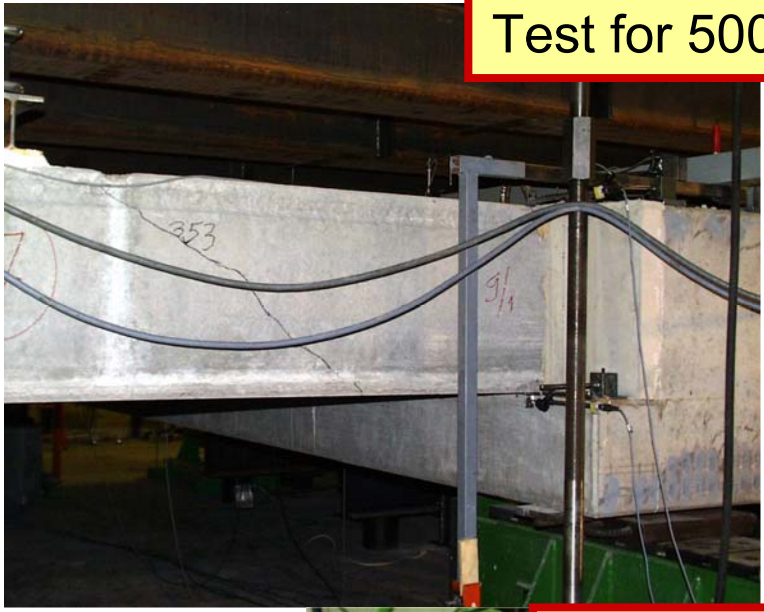
Typical condition of core infill

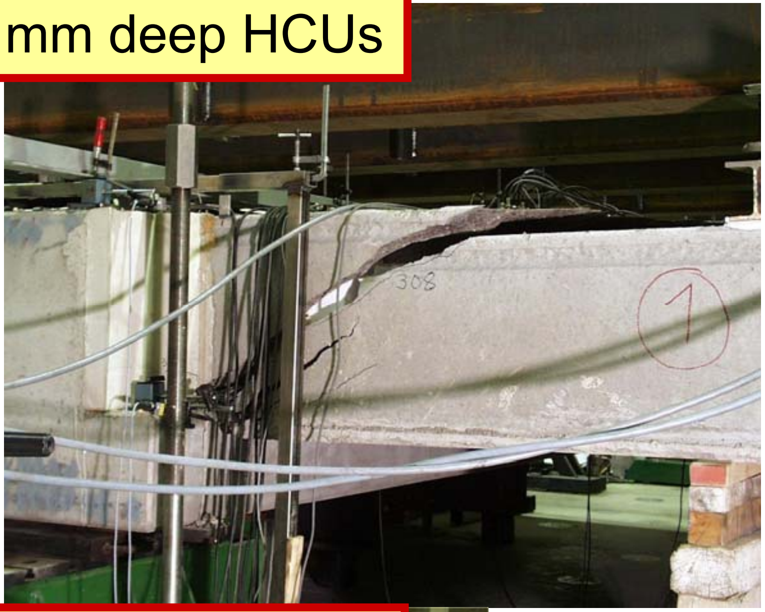


Nominal infill length = depth of the voids for long infill = the maximum that can efficiently be filled without opening the cores from above

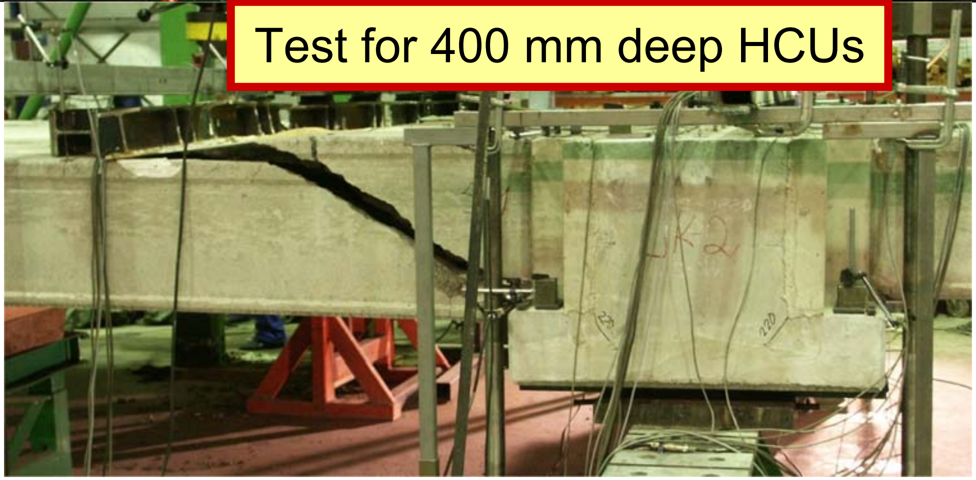
Failure Mode in All Tests: Shear-Tension Failure in the Slabs nearest to Supports

Test for 500 mm deep HCUs



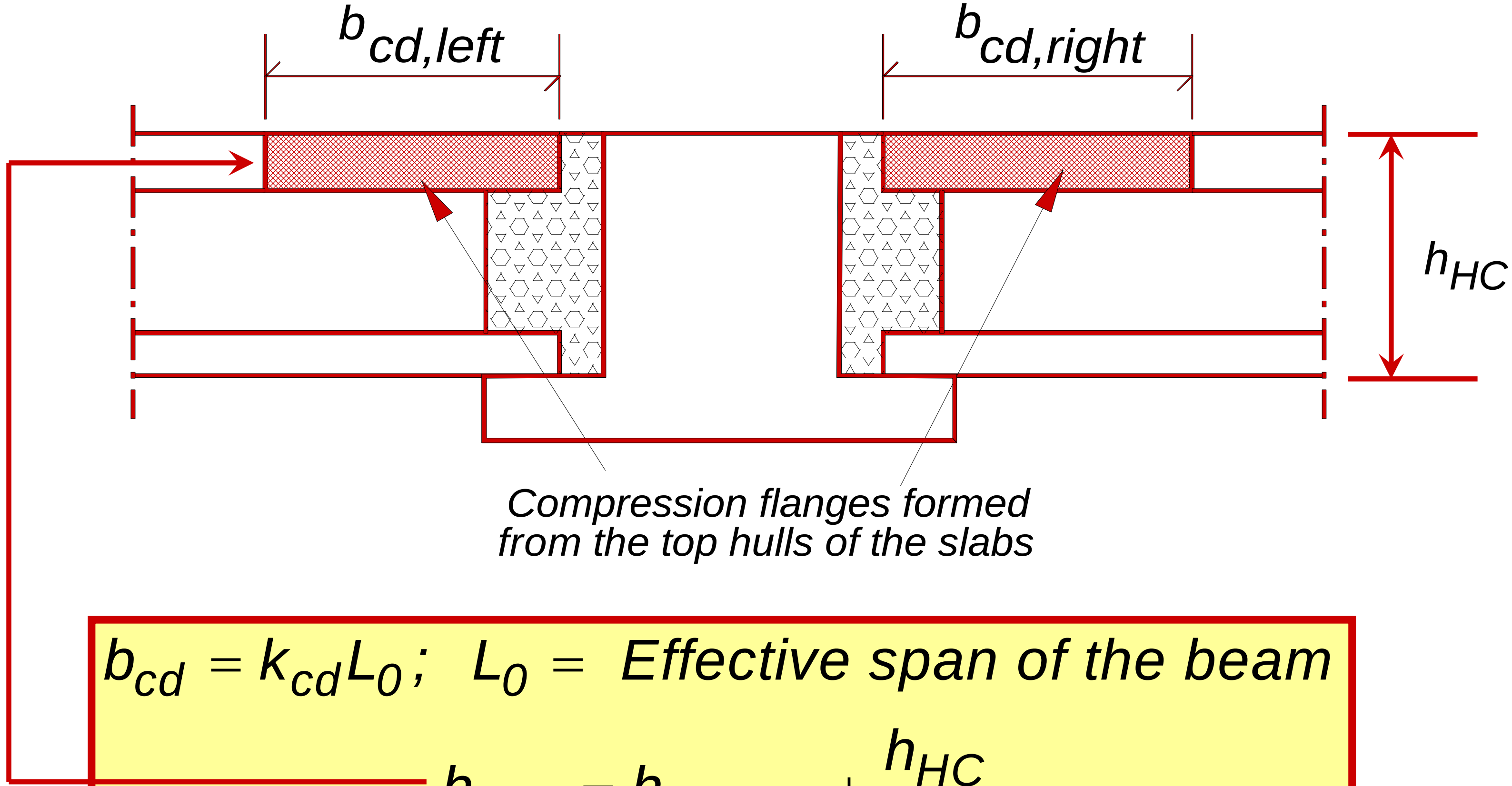


Test for 400 mm deep HCUs



k_{cd}-values for the design method: Effective composite section

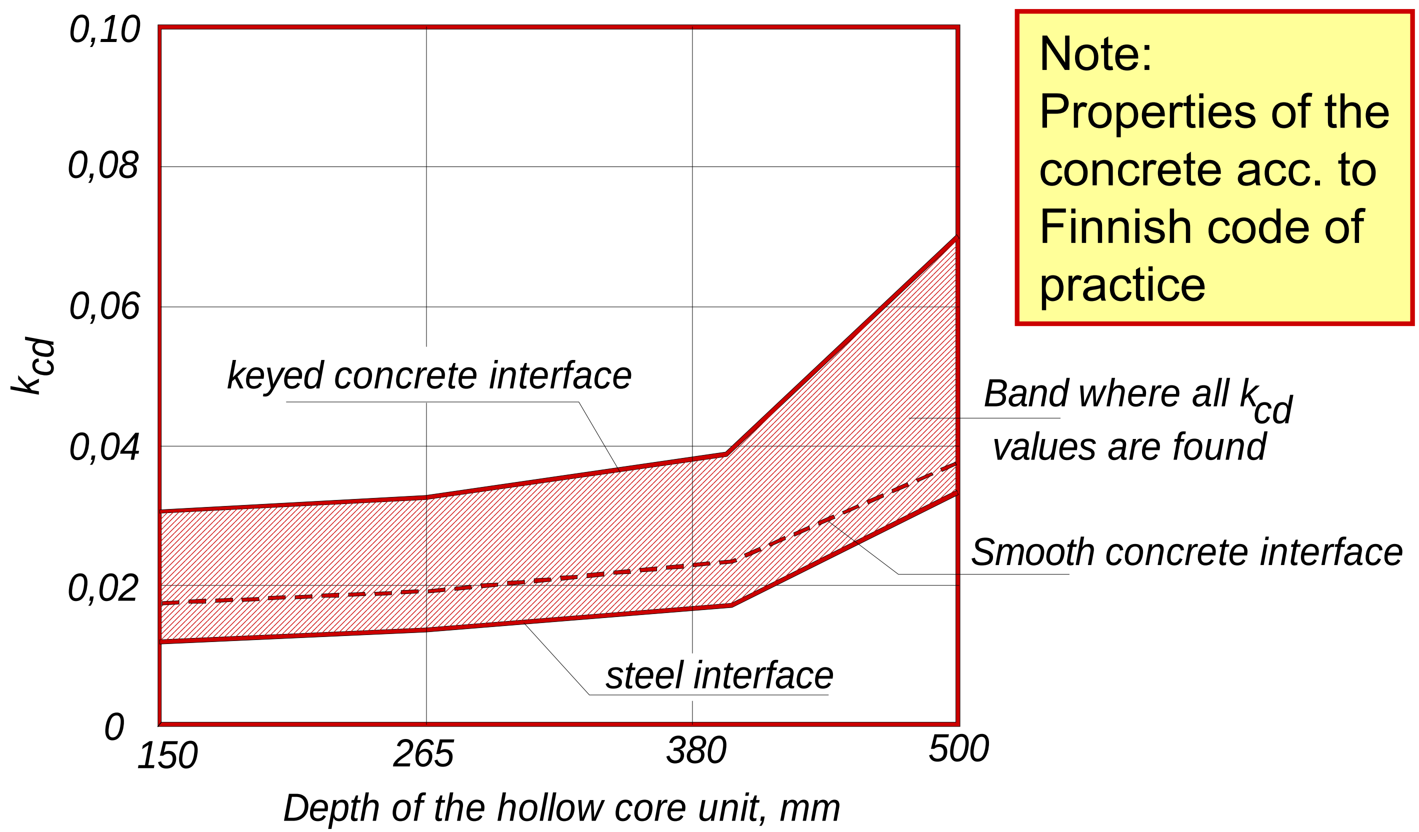
The design widths are based on the floor tests



$$b_{cd} = k_{cd} L_0 ; \quad L_0 = \text{ Effective span of the beam}$$

$$h_{cf,d} = h_{cf,nom} + \frac{h_{HC}}{80}$$

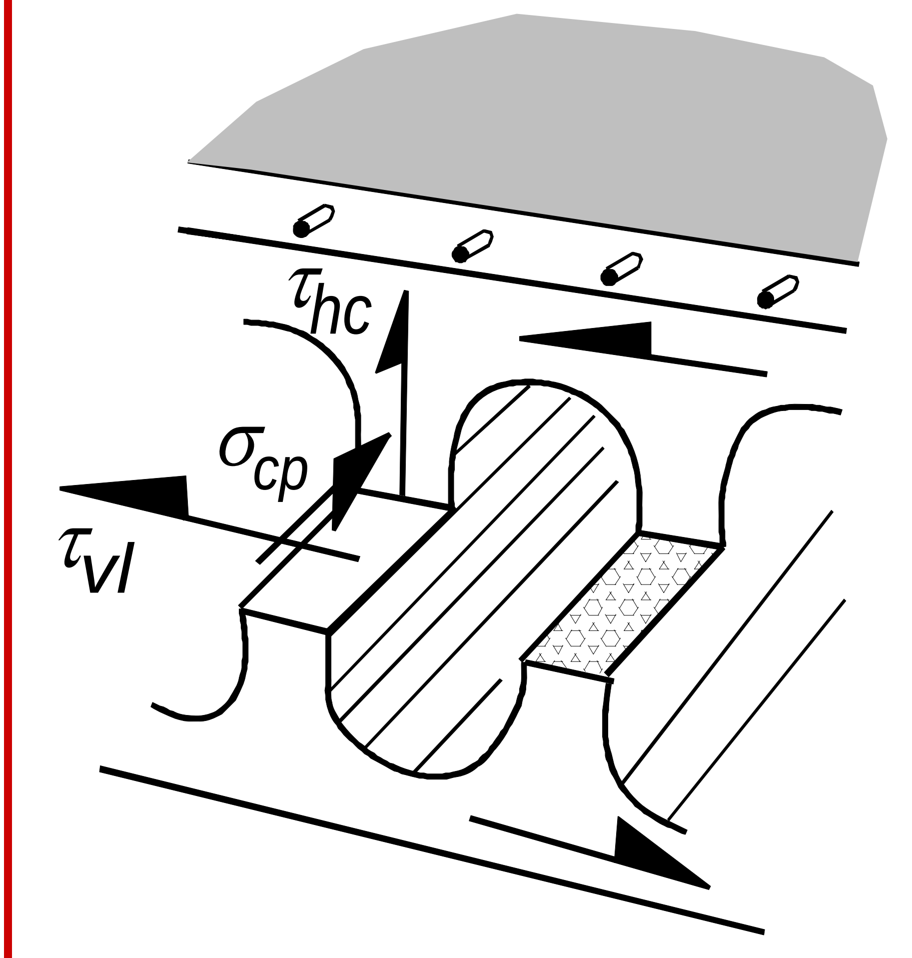
Range of k_{cd}-values: the effect of interface characteristics is obvious



Note:
Properties of the concrete acc. to Finnish code of practice

Constituents of the critical stress state in the webs of the HCUs

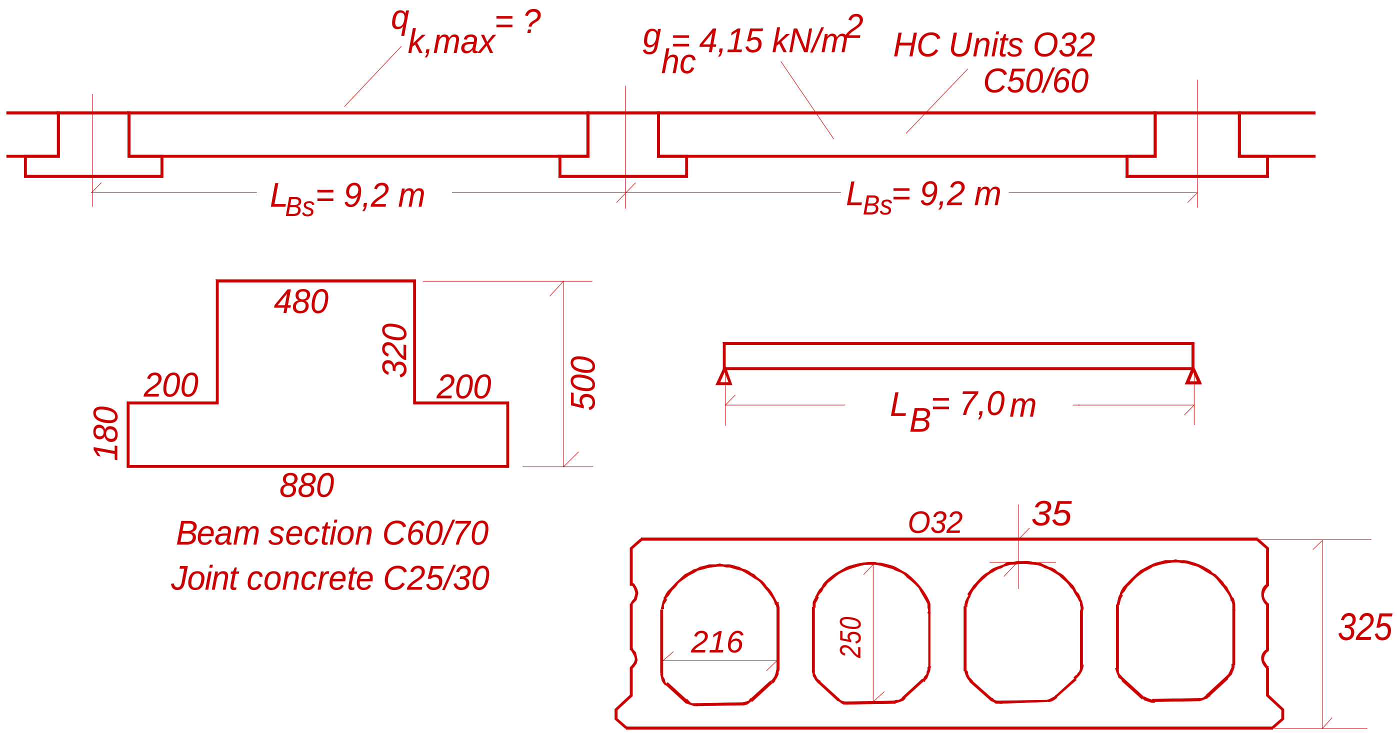
$$F_{fail} = \left(\frac{\tau_{hc}}{f_{ctd,hc,r}}\right)^2 + \left(\frac{\beta_r \tau_{v\ell}}{f_{ctd,hc,r}}\right)^2 - \frac{\left|\sigma_{cp}\right|}{f_{ctd,hc,r}} \leq 1$$



Verified methods of improving the capacity of the HC-decking

- Basic capacity is defined in relation to:
  - Short core infill, not more than *50* mm
  - No structural top concrete
  - Slabs on simply supported beams
- Increase in capacity may be achieved by reducing the horizontal shear stresses τ_{vl} efficiently and especially by:
  - Employment of long core infill reduces additional shear stresses by factor $\beta_f = 0,7$
  - Employment of reinforced top concrete does change the paths of horizontal shear flows, reducing the additional shear stresses
  - Designing the beams for continuity reduces the effective span and compression width b_{cd}

Worked example: effect of shear interfaces - keyed vs. smooth

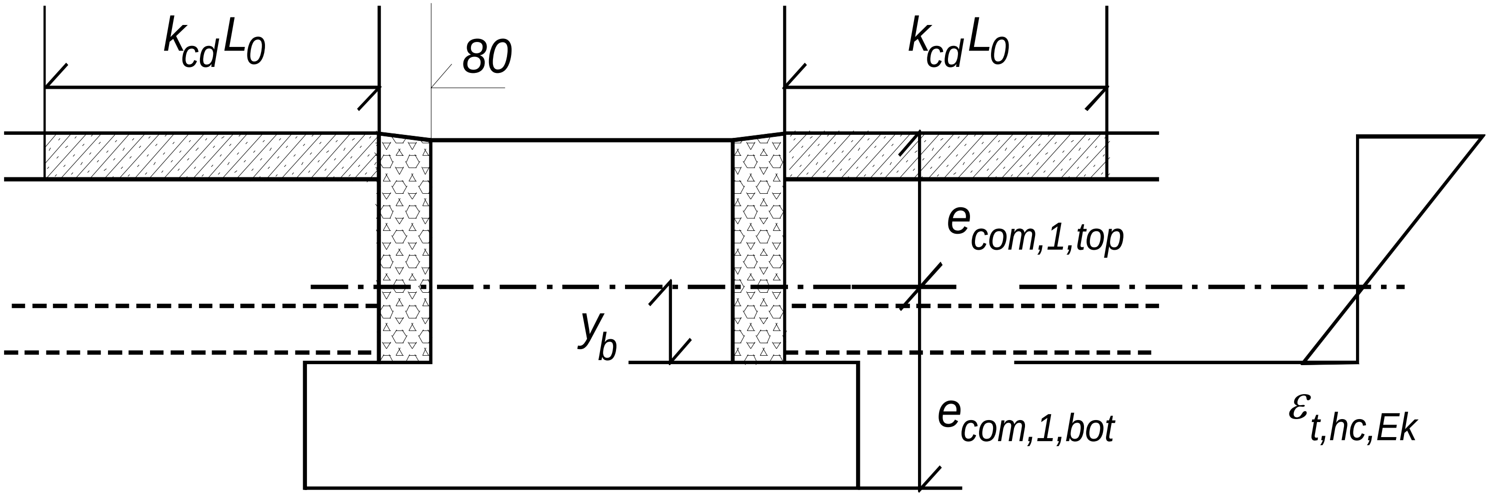


$q_{k,max}$ is evaluated assuming (1) smooth and (2) keyed web interfaces

Notation for web interfaces:
lb1 = keyed; lb2 = smooth

$k_{cd,lb1}$ = 0,0345

$k_{cd,lb2}$ = 0,0208



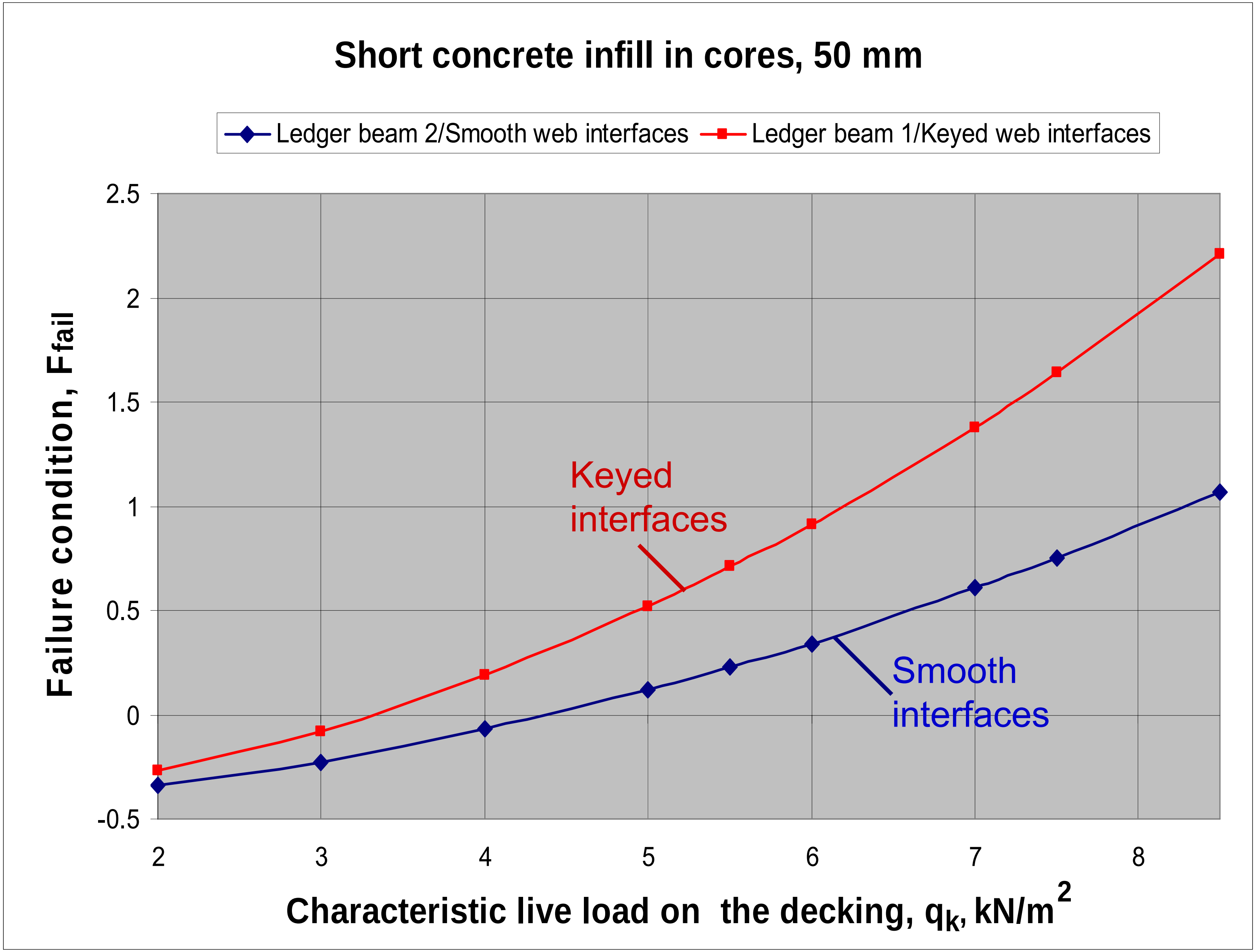
'Basic' shear stress, $\tau_{hc} = \dfrac{V_{hc.Ed} S_{hc}}{b_{w,hc} I_{hc}}$

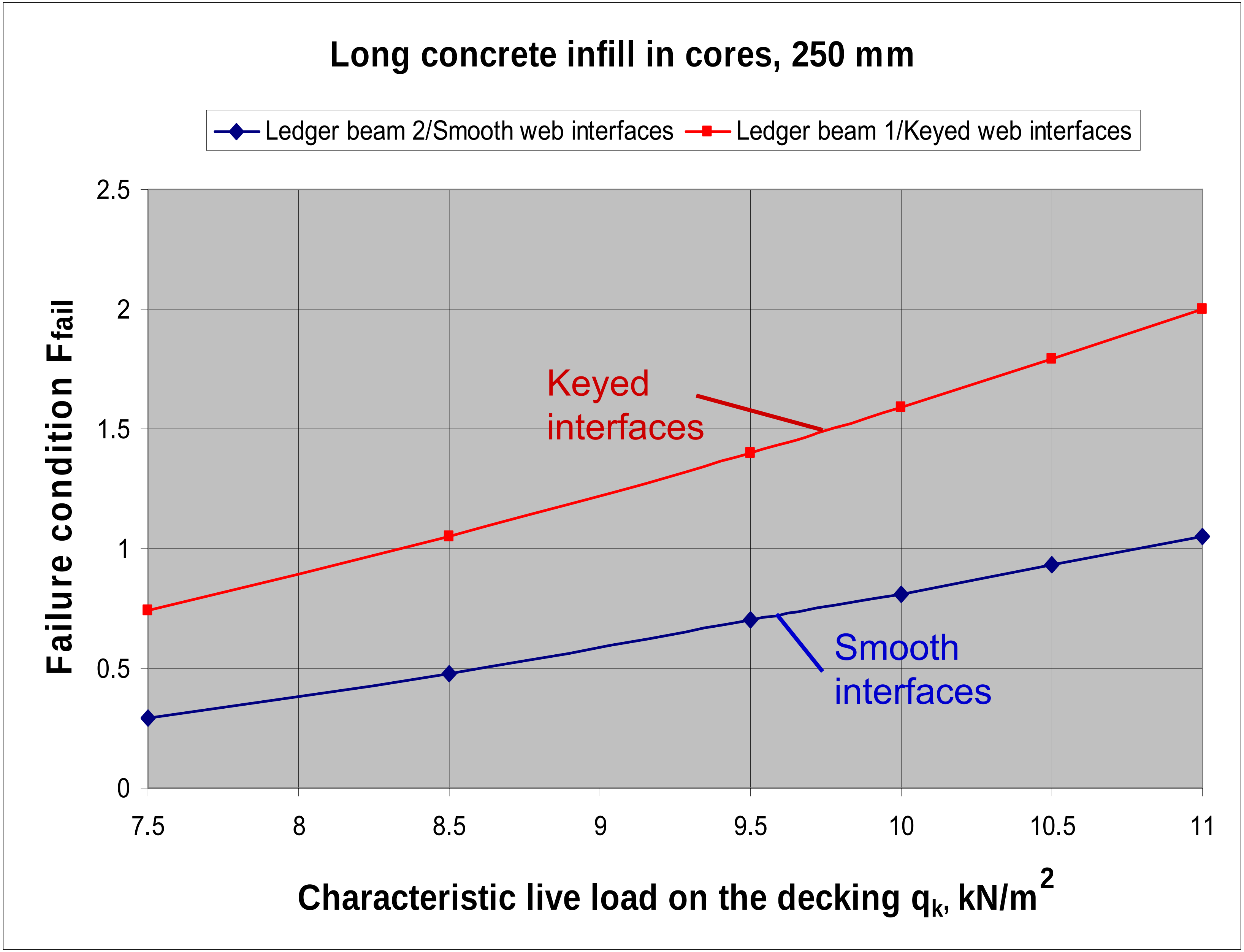
No differences in the basic shear stresses

Horizontal shear stress, $\tau_{v\ell} = 1{,}5 \dfrac{b_{hc}}{A_{v\ell}} v_{\ell w} \beta_f$

$v_{\ell w} = v_\ell^1 V_{B.Ed}$; $v_{\ell.lb1}^1 = 0{,}2682 \dfrac{1}{m}$; $v_{\ell.lb2}^1 = 0{,}1746 \dfrac{1}{m}$

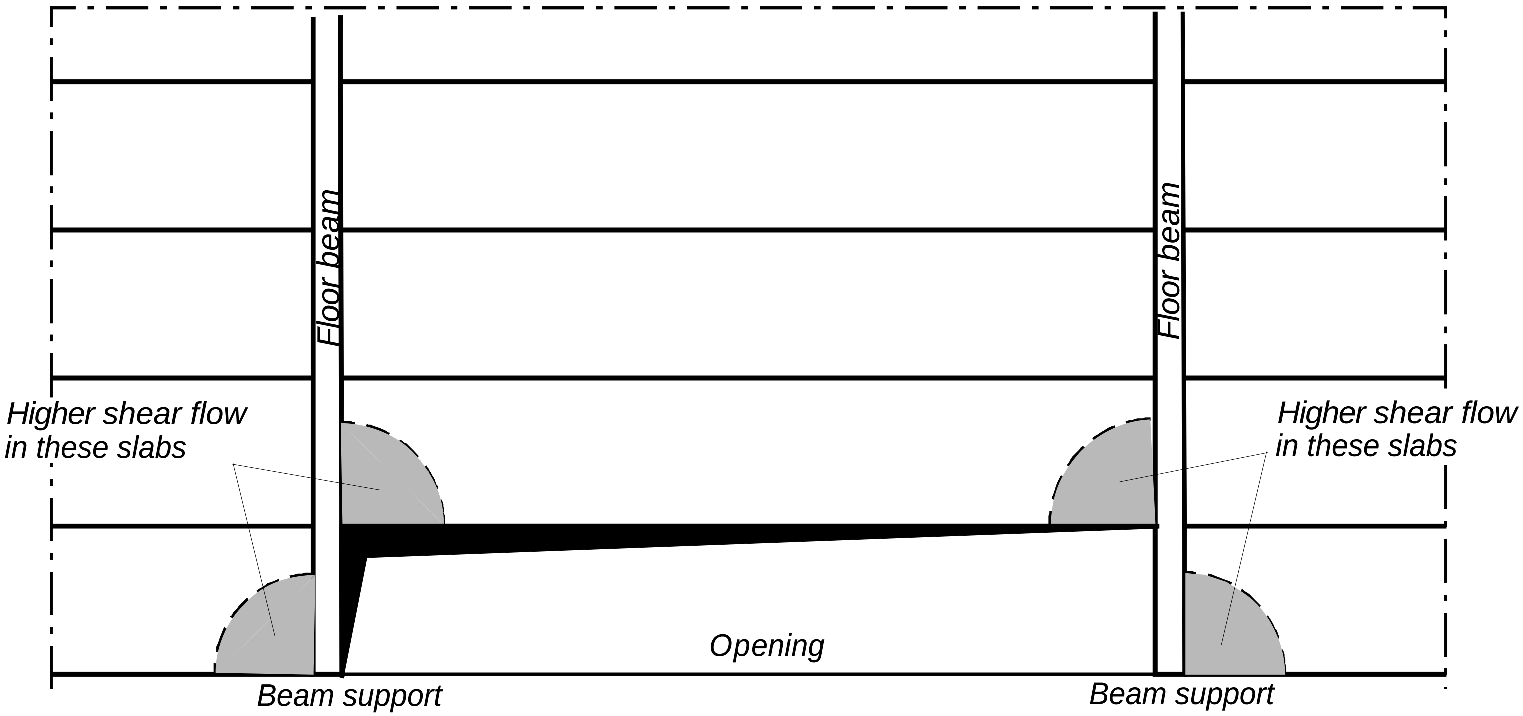
Effective compressive stress in the HCUs due to prestressing
$\sigma_{cp} = n_{strand} \sigma_{cp/\varnothing 12,5} = 1{,}001$ MPa


Short concrete infill in cores, 50 mm
Ledger beam 2/Smooth web interfaces
Ledger beam 1/Keyed web interfaces
2.5
2
1.5
1
0.5
0
-0.5
Failure condition, Ffail
Keyed interfaces
Smooth interfaces
2
3
4
5
6
7
8
Characteristic live load on the decking, qk, kN/m2



Long concrete infill in cores, 250 mm
Ledger beam 2/Smooth web interfaces
Ledger beam 1/Keyed web interfaces
Keyed interfaces
Smooth interfaces
Failure condition Ffail
Characteristic live load on the decking q_k, kN/m^2
2.5
2
1.5
1
0.5
0
7.5
8
8.5
9
9.5
10
10.5
11

Effect of Openings in the Floor

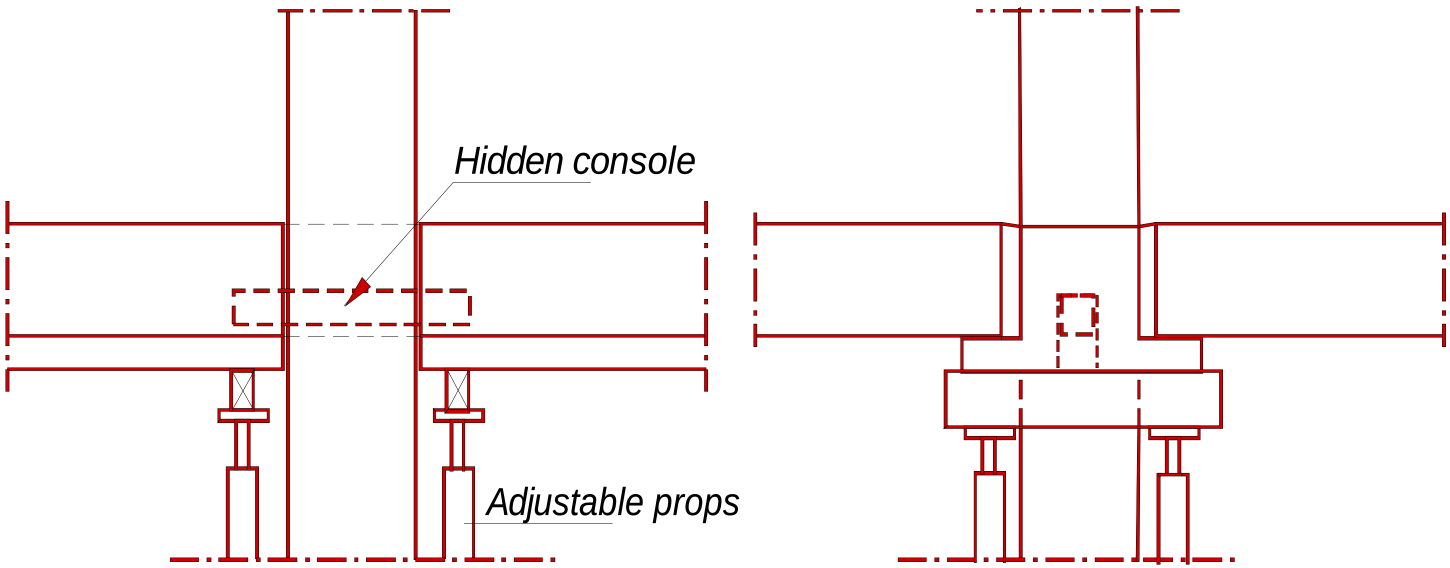


Compared to floors with no openings, higher shear flow will appear in the slabs around large openings, i.e. when there are fewer webs of HCUs to resist the effects of flexure in the floor beams

Provisions for Erection and Construction Sequence

- The erection sequence may influence the capacity of the most critical HCUs nearest to the beam supports - erection without propping along the span of the beam is the basic rule
- When propping is used, it should be taken into account in the resistance verification
- Propping is frequently required for eliminating the effects of twist of the beams - such propping is done nearest to the column, and this does not affect the basic design

Principle of propping to avoid twist of the beam around its longitudinal axis



The beams or slabs shall not be propped in a way that is contradictory to the assembly drawing, unless allowed by the designer of the slabs