IPHA Technical Seminar 2015

October 21-22, Malmö - Sweden

Slim floor construction with hollowcores

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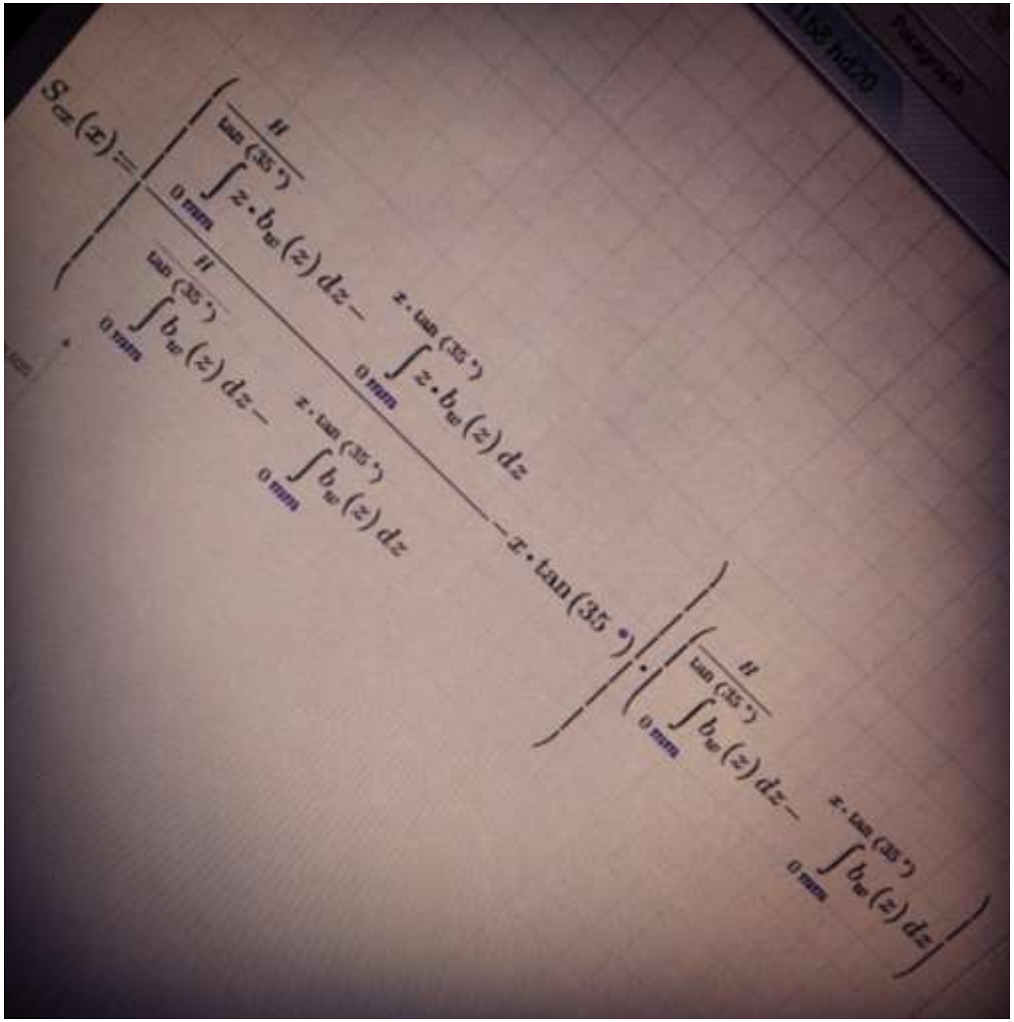
INTERNATIONAL PRESTRESSED HOLLOWCORE ASSOCIATION

in cooperation with StruSoft

How to design...



First moment of area for shear calculation according to EN1168

What is a slim floor construction?

- **Flexibility (Architectual approach)**
  - Very little interference of structural system

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  - Possibility to redesign the floor plan depending on need
    - Multi-purpose buildings (offices, laboratories, meeting rooms, etc)

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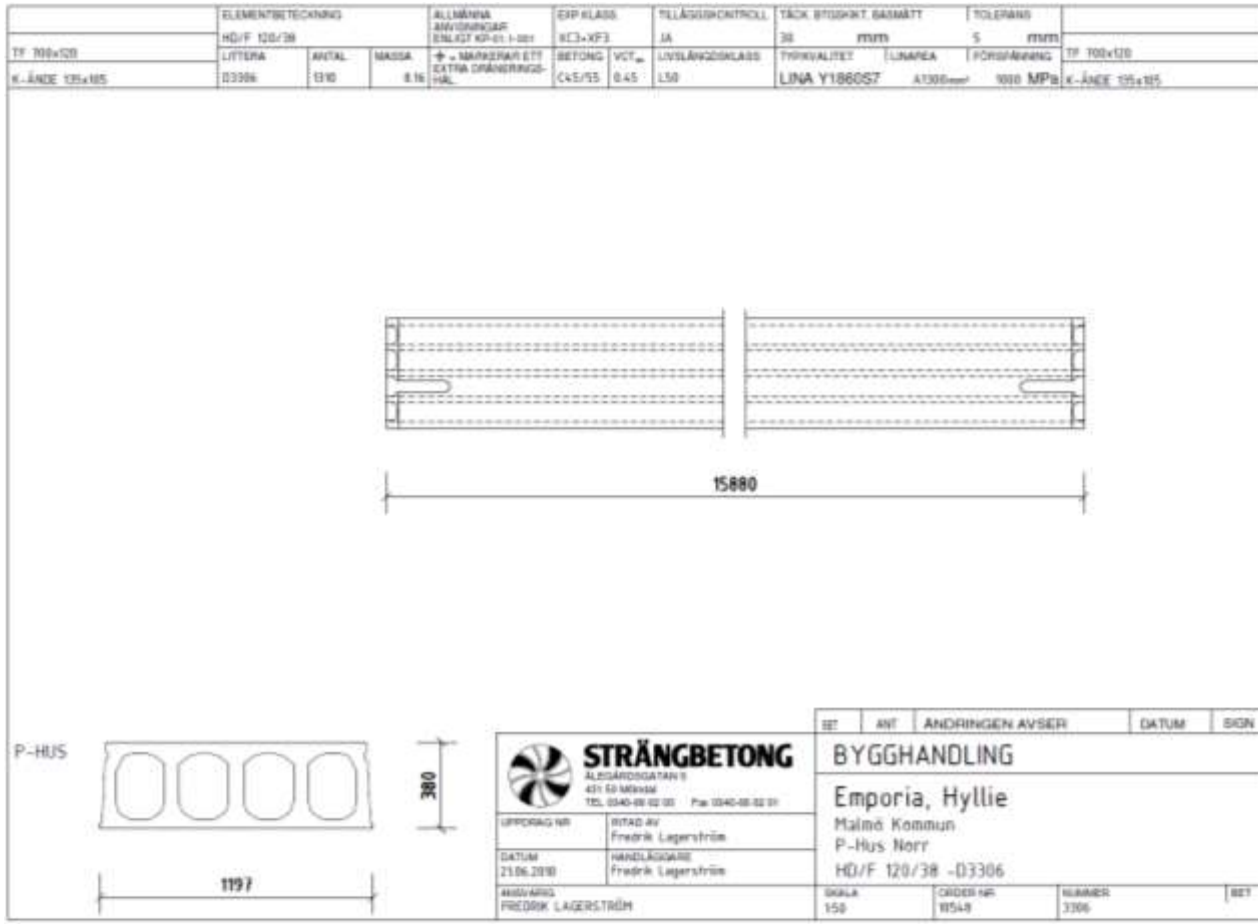
What is a slim floor construction?

- **Flexibility (Architectual approach)**
  - Very little interference of structural system
  - Possibility to redesign the floor plan depending on need
    - Multi-purpose buildings (offices, laboratories, meeting rooms, etc)
  - Long spans, fewer columns
- **Cost-efficient design**
  - Long spans
  - Fewer elements to calculate
  - Focus on the difficult areas and let the bulk calculations be done faster.
- **Cost-efficient manufactury and assembly**
  - Long spans
  - Fewer elements to cast, transport and assemble
  - Fewer lifts with the crane – minimize time for expensive cranes

What is a slim floor construction?

- **Cost-efficient design**
  - Fewer elements to calculate



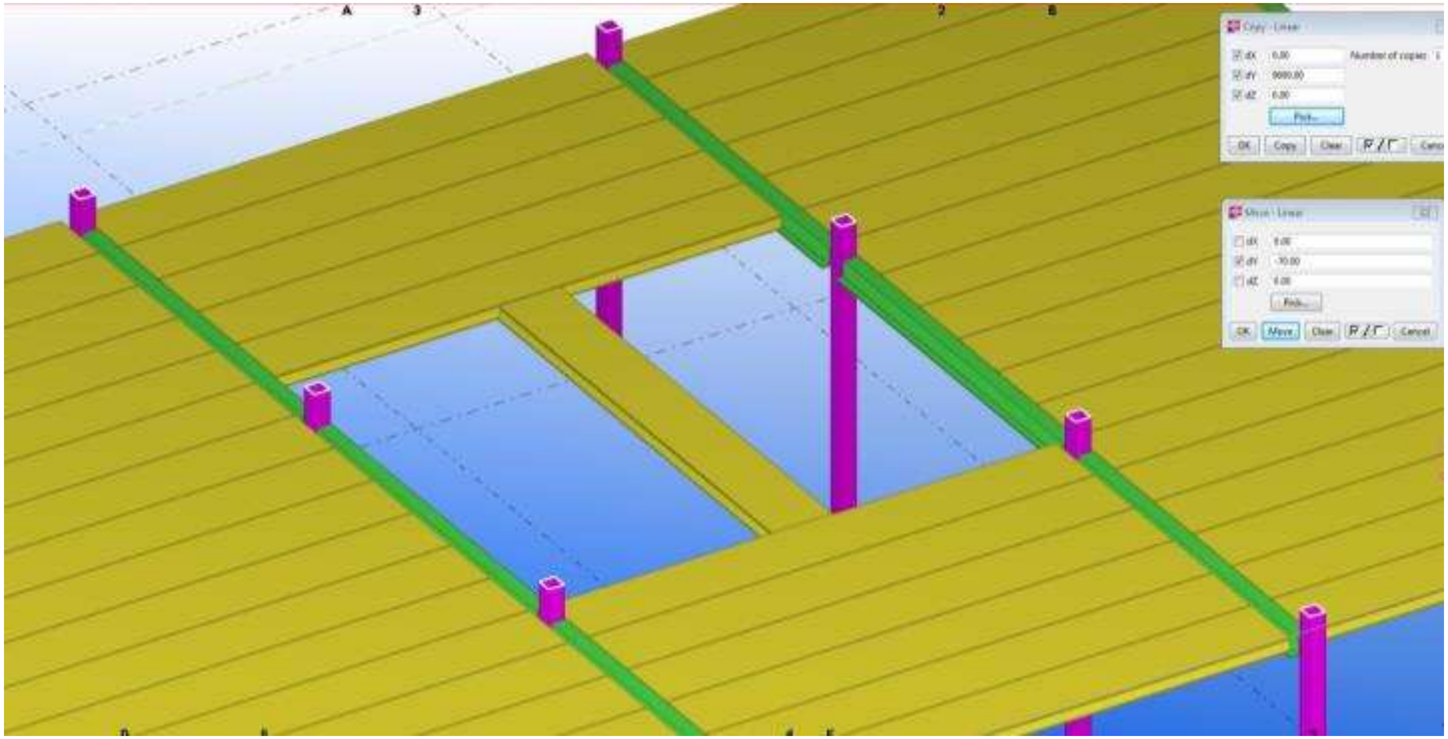
What is a slim floor construction?

- **Cost-efficient design**
  - Fewer elements to calculate
- **Cost-efficient manufactury and assembly**
  - Fewer elements to cast, transport and assemble
  - Fewer lifts with the crane for larger area of construction

Emporia, Malmö, Sweden (Strängbetong 2008-2011)

How to slim down a structure

- **The solution with large open areas are often appealing to architects**
  - ...so they often want even more openings, and walking bridges.



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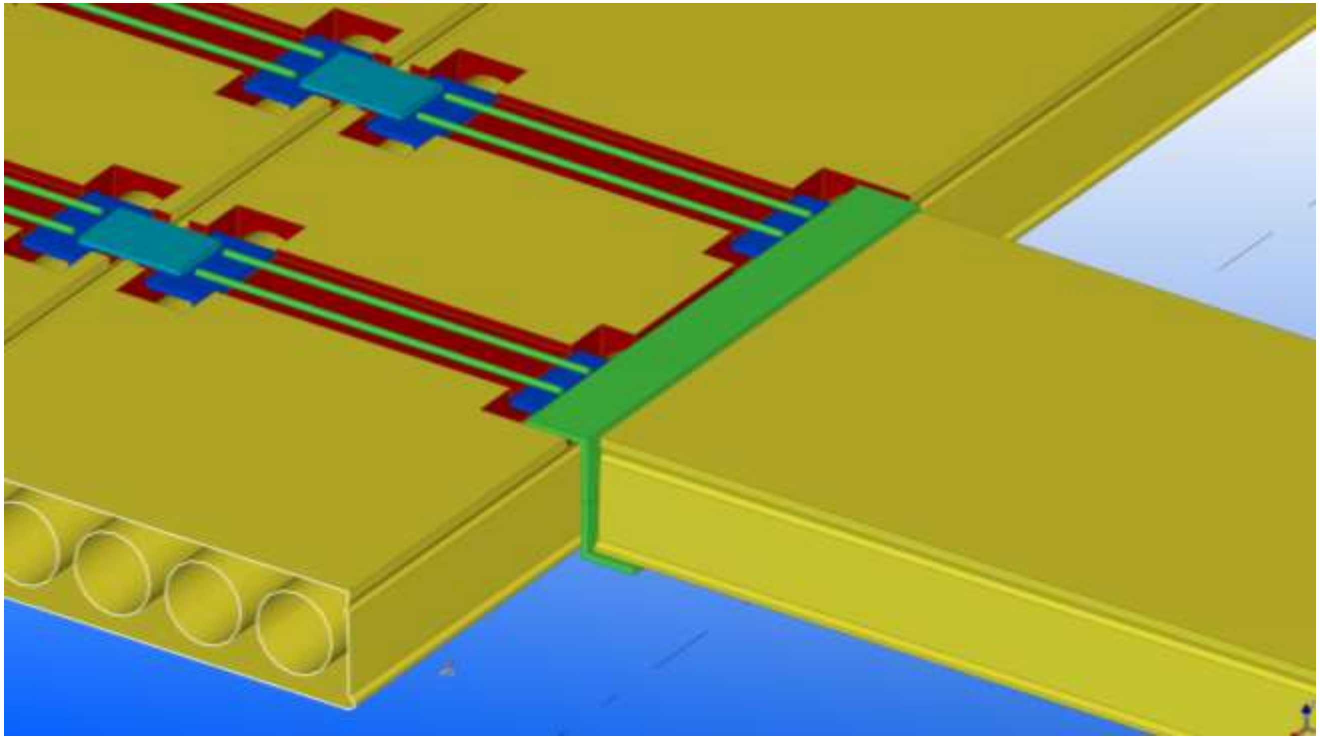

Detail used on Malmö Arena, Malmö, Sweden (Strängbetong 2007-08)

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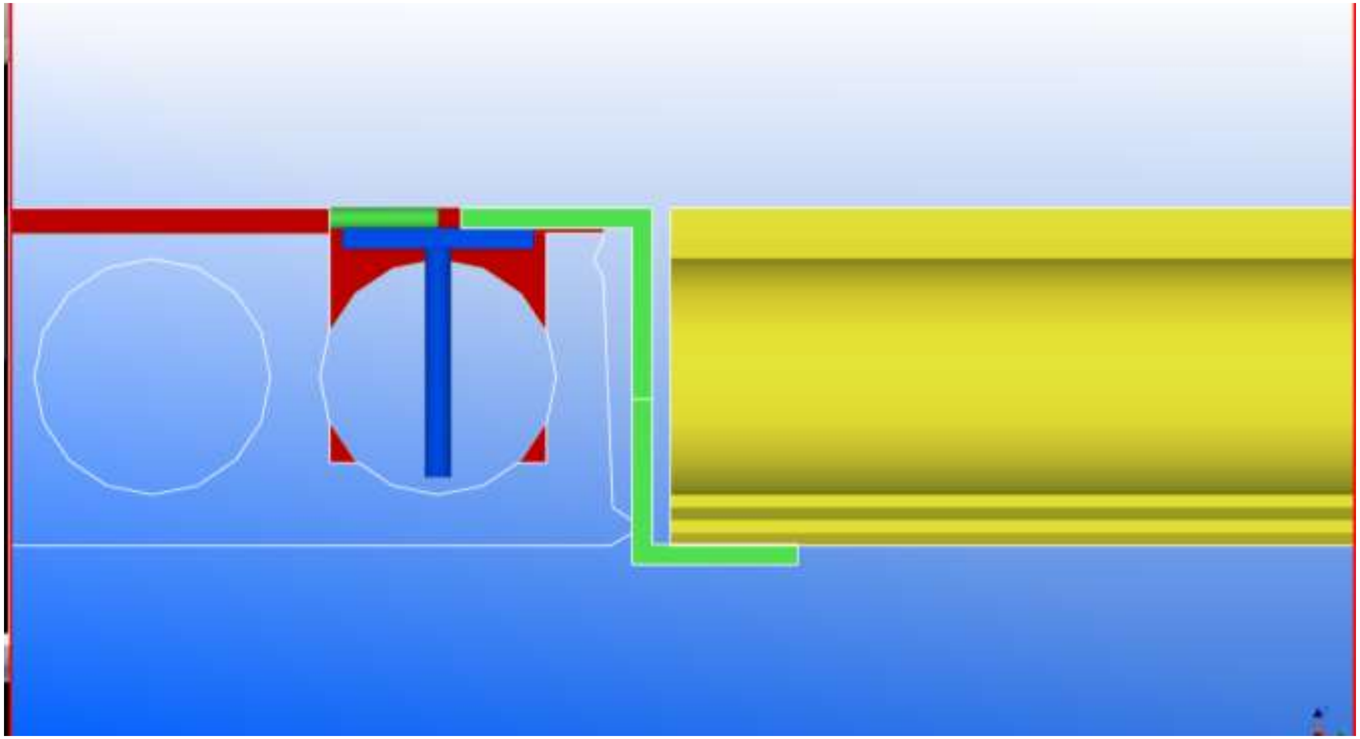


Detail used on Malmö Arena, Malmö, Sweden (Strängbetong 2007-08)

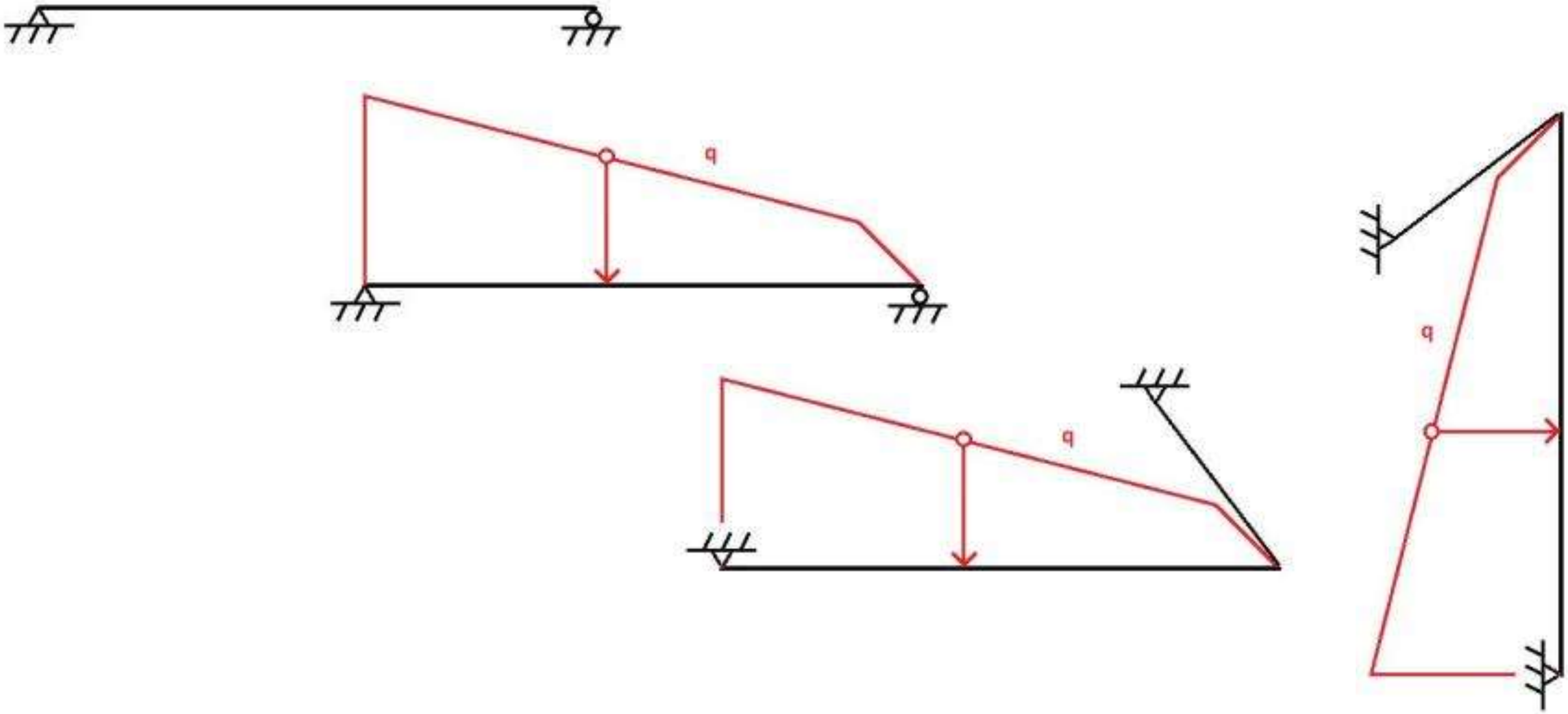
Simplify, if possible!

- **Oriels or glassed in balconies**
  - In Sweden we very rarely use prestressing wires in the top!

Kv. Kronolotsen 2, Malmö, Sweden (Strängbetong 2007-2008)

Other areas where hollowcores can be used

- **Retaining walls**



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Echo, South Africa

Other areas where hollowcores can be used

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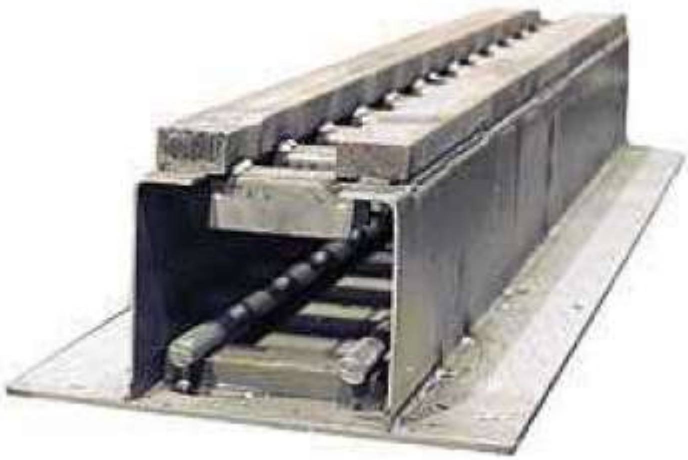
Different types of steel beams in use

- **Regular hot rolled steel sections**

Different types of steel beams in use

- **SWT beam**
  - Flange beam that is filled with concrete in-situ



Different types of steel beams in use

- **SWT beam**
  - Flange beam that is filled with concrete in-situ
  - Connections to the hollowcores are welded to the beam web

Kv. Kronolotsen 2, Malmö, Sweden (Strängbetong 2007-2008)

Different types of steel beams in use

- **VSAB – IQB-beam**
  - Flange beam that is welded and filled with concrete in the beam-factory

SCA, Gothenburg, Sweden (Strängbetong 2015)

Different types of steel beams in use

- **VSAB – IQB-beam**
  - Flange beam that is welded and filled with concrete in the beam-factory
  - Connections to hollowcores with stirrups

SCA, Gothenburg, Sweden (Strängbetong 2015)

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Different types of steel beams in use

- **Peikko Delta beam**
  - Flange beam that is filled with concrete in-situ

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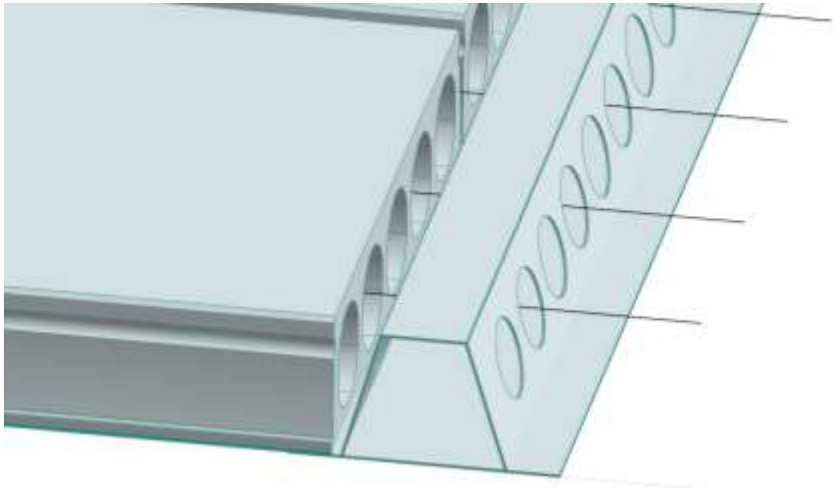
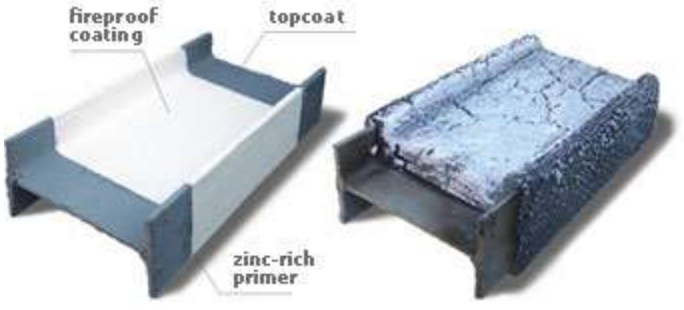


Using the knowledge of IPHA seminars in the design - Fire design

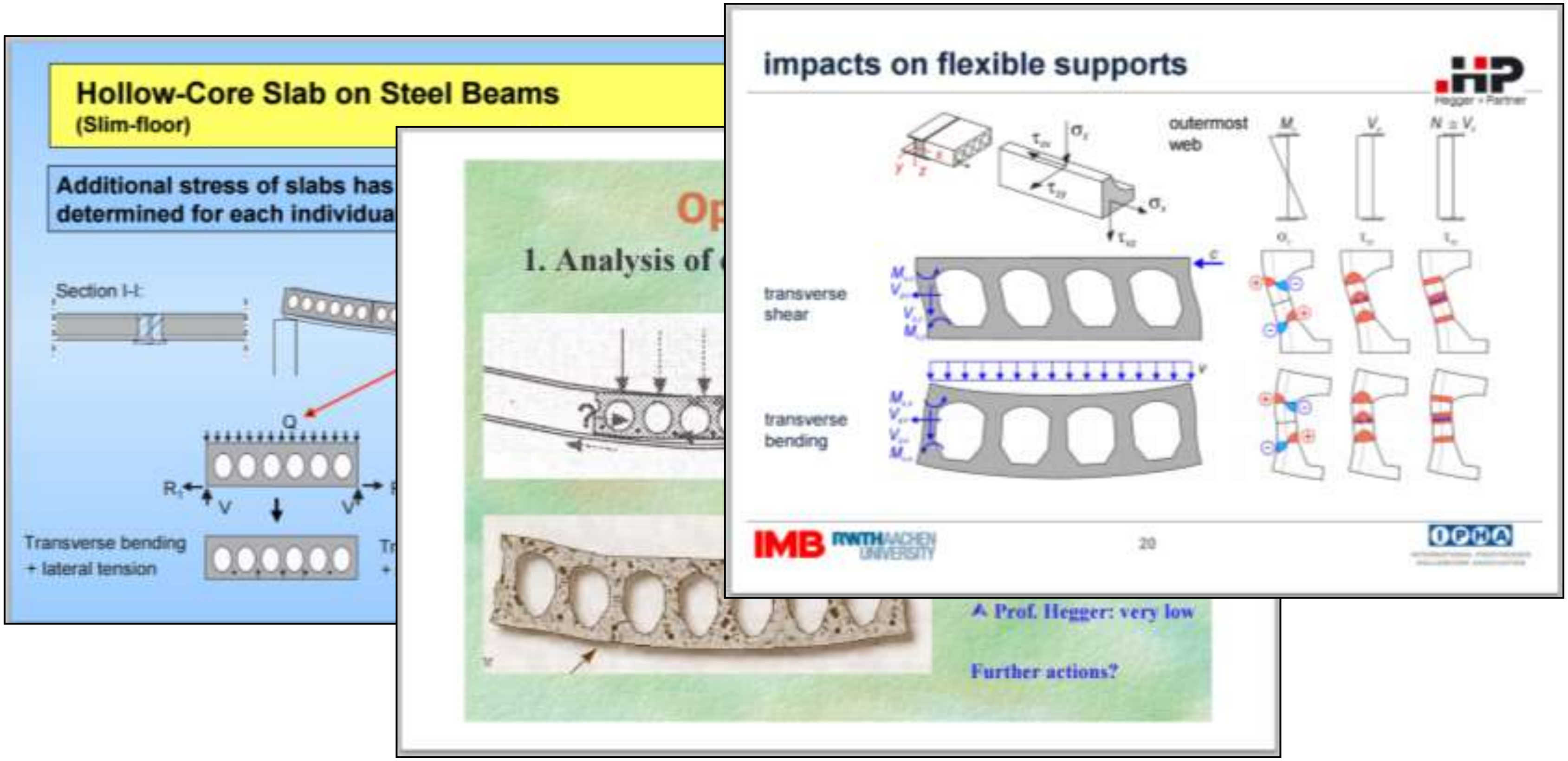
- **EN1168 and EN1992-1-2**
- **IPHA technical seminar 2013 in Epernon, France**
- **Fire protection of exposed steel**
  - Concrete cast in and around the steel
  - Gypsum
  - Fire paint



Fireproof coating system before and after fire exposure

Using the knowledge of IPHA seminars in the design
- Flexible support

- **Research projects 1991-95 by Matti Pajari, VTT, Finland**
- **Early software made by Dr. Gösta Lindström at Strängbetong (1996)**
- **Tracked the problem back to IPHA Technical seminar in Leuven, Belgium, 2003**
    - Previous presentations are available at the IPHA homepage > members section



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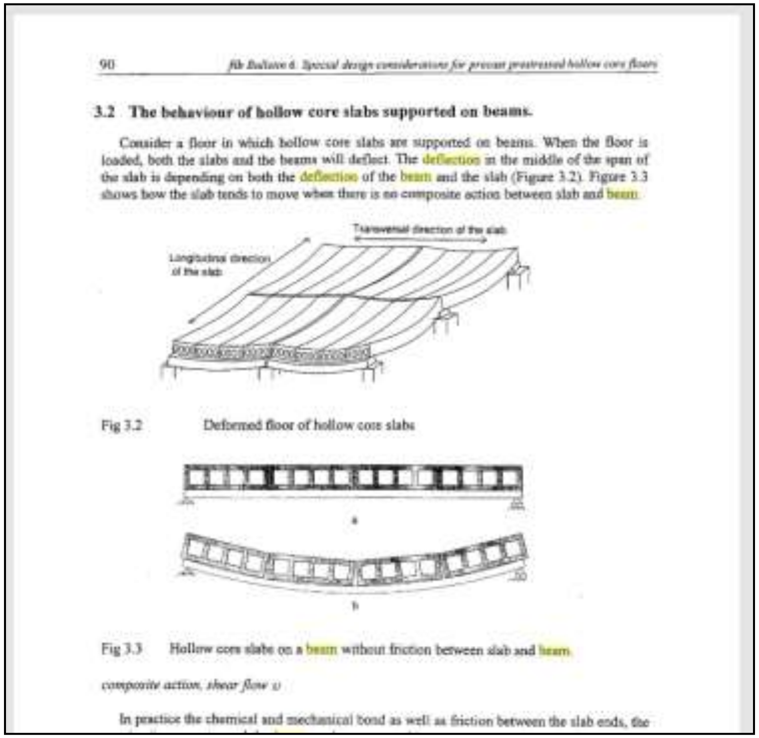
- **FIB Bulletin nr 6**


90 fib Bulletin 6. Special design considerations for precast prestressed hollow core floors

3.2 The behaviour of hollow core slabs supported on beams.

Consider a floor in which hollow core slabs are supported on beams. When the floor is loaded, both the slabs and the beams will deflect. The deflection in the middle of the span of the slab is depending on both the deflection of the beam and the slab (Figure 3.2). Figure 3.3 shows how the slab tends to move when there is no composite action between slab and beam.

Transversal direction of the slab

Longitudinal direction of the slab

Fig 3.2 Deformed floor of hollow core slabs

a

b

Fig 3.3 Hollow core slabs on a beam without friction between slab and beam.

composite action, shear flow u

In practice the chemical and mechanical bond as well as friction between the slab ends, the

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- **FIB Bulletin nr 6**
- **EN 1168, soon?**


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1168:2005+A3

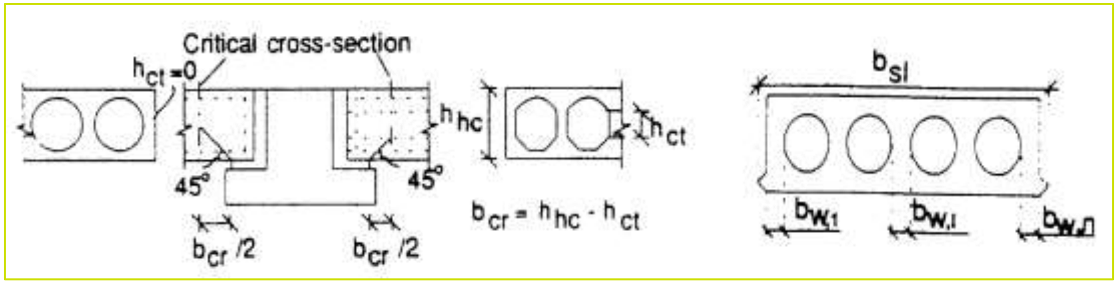
October 2011

English Version

Precast concrete products - Hollow core slabs

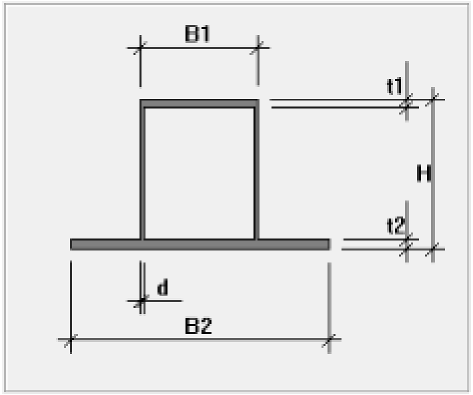
Design with regards of flexible support

- **Critical cross section**
  - Weakest section in the hollowcore web



Design with regards of flexible support

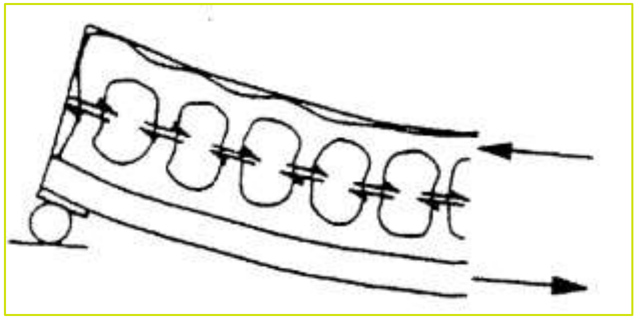
- **Critical cross section**
  - Weakest section in the hollowcore web
- **Calculate geometry properties**
  - Beam, hollowcore, joint- and topping concrete



$$I_1 = \frac{B2 \cdot t2^3}{12} + (B2 \cdot t2) \cdot \left(\frac{t2}{2} - Y_1\right)^2 + \frac{B1 \cdot t1^3}{12} + (B1 \cdot t1) \cdot \left(H - \frac{t1}{2} - Y_1\right)^2$$

$$+ \frac{2 \cdot d \cdot (H - t1 - t2)^3}{12} + 2 \cdot d \cdot (H - t1 - t2) \cdot \left(t2 + \frac{H - t2 - t1}{2} - Y_1\right)^2$$

Design with regards of flexible support



- **Critical cross section**
  - Weakest section in the hollowcore web
- **Calculate geometry properties**
  - Beam, hollowcore, joint- and topping concrete
- **Calculate forces due to geometry and loading**
- **Local effects such as prestressed strand slip and anchorage**
- **Combine into a principal stress in the web**

$$\tau_{2.top} = \frac{3 * S_{f,top} * b_2}{4 * b_{cr} * b_{w,2}}$$

$$\sigma_1 = \frac{-\alpha * \gamma_p * \sigma_p * A_p}{A_c} \qquad \tau_1 = \frac{V_{d.g,2} * S_{2x}}{I_{2x} * b_{w,2}} + \frac{V_{d.imp,2} * S_{top,2x}}{I_{top,2x} * b_{w,2}}$$

$$\tau_{2.imp} = \frac{3 * S_{f,imp} * b_2}{4 * b_{cr} * b_{w,2}}$$

$$\sigma_{ps} = \frac{\sigma_1}{2} + \sqrt{\frac{\sigma_1^2}{4} + \tau_1{}^2 + \left(\beta_f * \left(\tau_{2.top} + \beta_{top} * \tau_{2.imp}\right)\right)^2} \qquad \eta_{ULS} = \frac{\sigma_{ps}}{f_{ctd.hc}}$$

Design with regards of flexible support

- **Serviceability limit state**
  - Check of crack width
    - Check against allowed crack width and exposure class (EN 206)
  - Check of curvature of the beam
    - Compare with allowed curvature limit

Table 7.1N Recommended values of w_{max} (mm)

Exposure Class	Reinforced members and prestressed members with unbonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
X0, XC1	0,4[1]	0,2
XC2, XC3, XC4	0,3	0,2[2]
XD1, XD2, XS1, XS2, XS3		Decompression

Note 1: For X0, XC1 exposure classes, crack width has no influence on durability and this limit is set to guarantee acceptable appearance. In the absence of appearance conditions this limit may be relaxed.
Note 2: For these exposure classes, in addition, decompression should be checked under the quasi-permanent combination of loads.

$$\kappa = \frac{M_{imposed\ load}}{EI_{composite\ beam.k}}$$

Summary

- **Enter design stage early to influence architects**
  - ... to suit your production (efficiency in time and cost)
  - Reduce number of elements
    - Many small can become fewer long elements?
  - Explore possibilities to use hollowcores in other fields
    - Try to influence contractor with a type of structure that suits your production
- **Earlier research are now on the way into the standards**
  - Previous presentations are available at Hollowcore.org
  - Fire design is a major field for designers, flexible supports are the next?

...this is the last slide, I promise!

Thank you for your attention!

fredrik.lagerstrom@strusoft.com