DELTABEAM® composite beams supporting hollow core slabs in fire case

From test to approval

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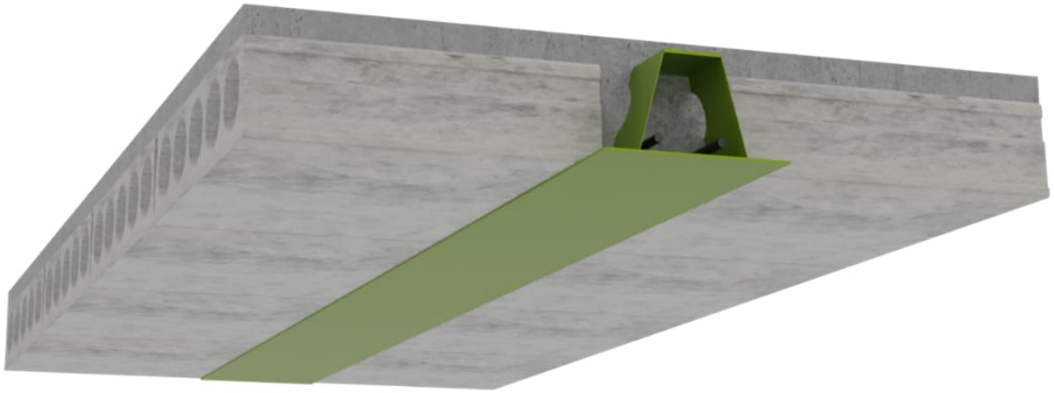
- Introduction
- Technical background
- Summary of experiments
- Contents of the approval (aBG)

Introduction

Introduction

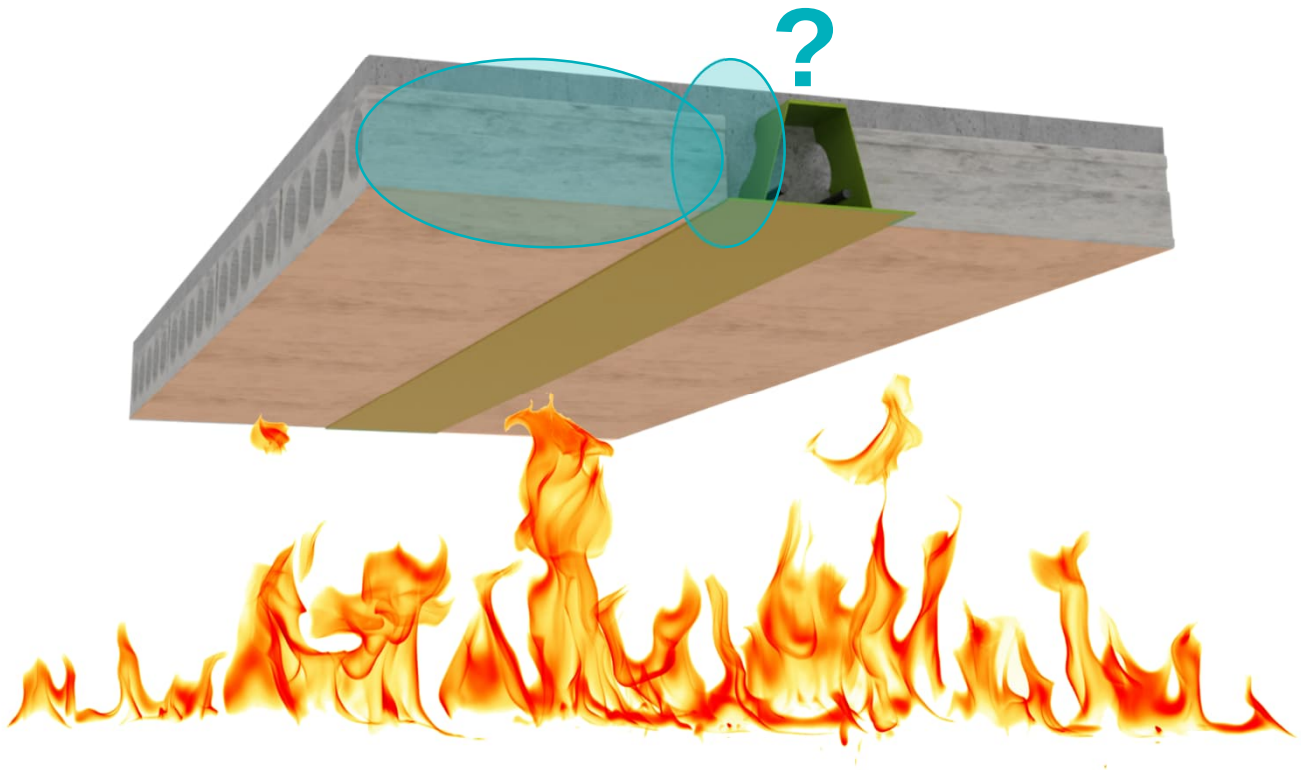
A faster, safer and more sustainable way to design and build



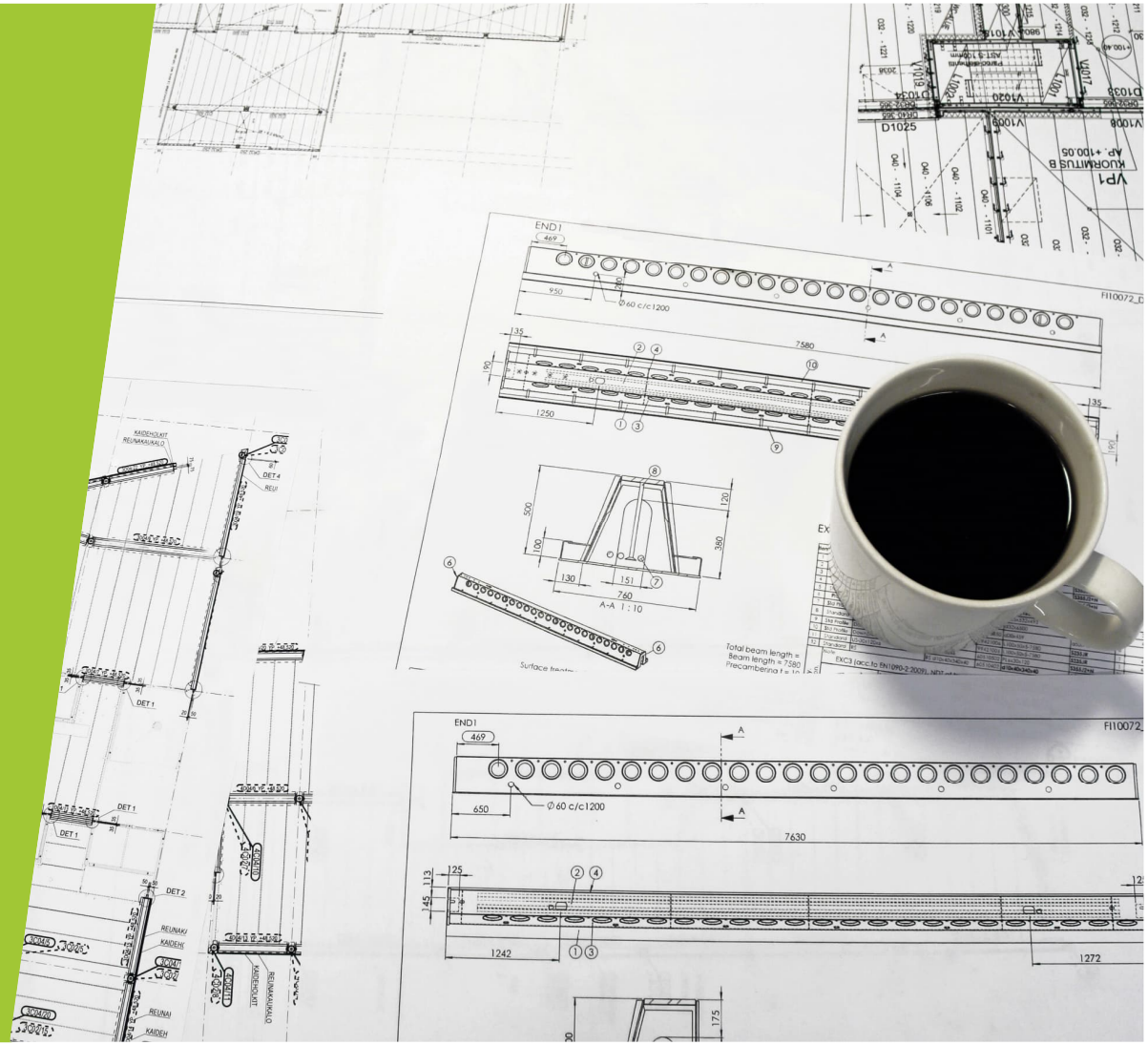
Peikko DELTABEAM® in combination with prestressed hollow core slabs

Introduction

A faster, safer and more sustainable way to design and build



Technical background

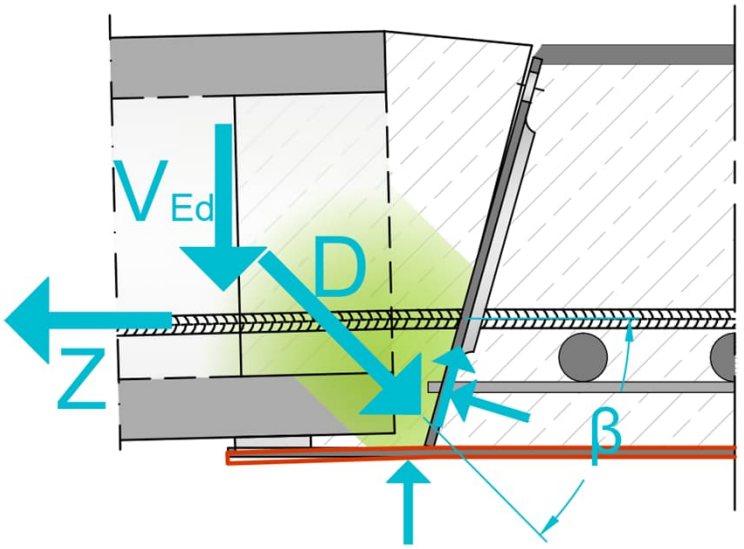


Technical background

Hollow core slabs supported on DELTABEAM®

Shifted direct support

- Bottomplate temperature >900°C
- Direct support is no longer provided→ Support reaction shifted towards web
- Load transfer to the beam through the concrete grout
- Strut-and-tie model
- Straight connecting reinforcement



Technical background

Hollow core slabs supported on DELTABEAM®

Flexible support in fire case

Ambient temperature

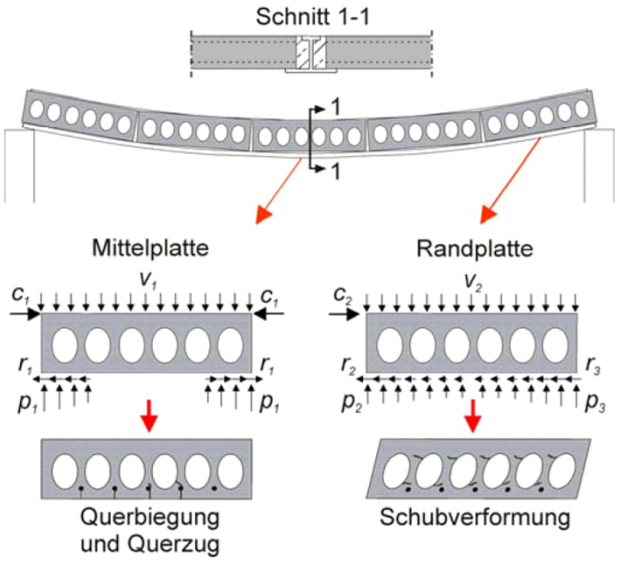
- Vertical shear resistance reduced when supported on flexible beams

Fire case

- No negative effect known
- No code regulations available
- Germany: Beam deflection limit in fire case ≤ L/100

Important note

- Forced displacement “c2”, not a load displacement !
- Cracking reduces stiffness and stresses



From: „Zum Tragverhalten von Spannbeton-Fertigdecken bei biegeweicher Lagerung“, Roggendorf, 2010, Fig 2.11

Summary of the experiments

Summary of experiments

Test program for investigating the system behavior in the event of a fire

- Flexible support
- Shifted direct support

- Shear tests on individual slab elements
  - Behaviour of the slab elements under combined stress of vertical shear, horizontal forced displacement and elevated temperature
- System tests
  - Behaviour of a slab system from DELTABEAM® and hollow core slabs
  - Load transfer mechanisms
  - Vertical shear resistance of slabs

Summary of experiments

Boundary conditions for the shear tests on individual slabs

Objective:

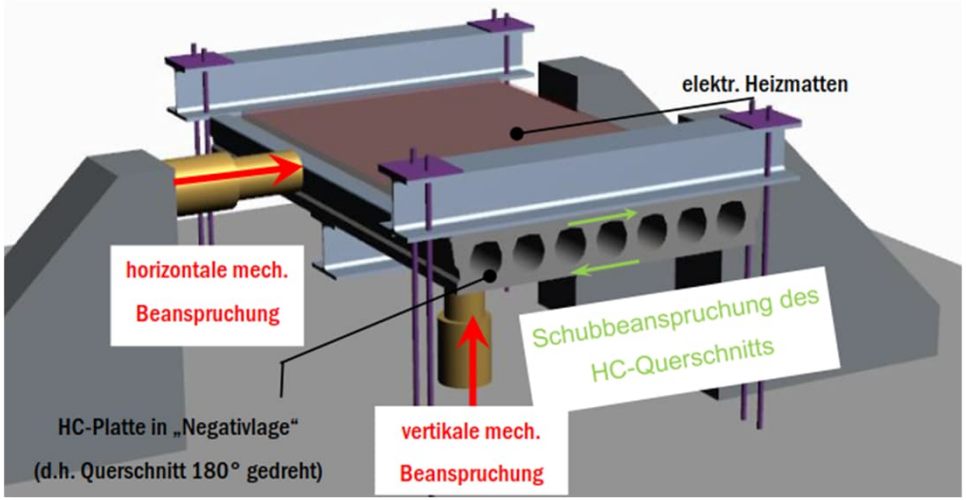
- Investigation of slab element behaviour under combined loading
- Calibration of FE models

Execution:

Bottom side of the slabs – electric heating mats

Apply vertical shear force and horizontal displacement up to failure

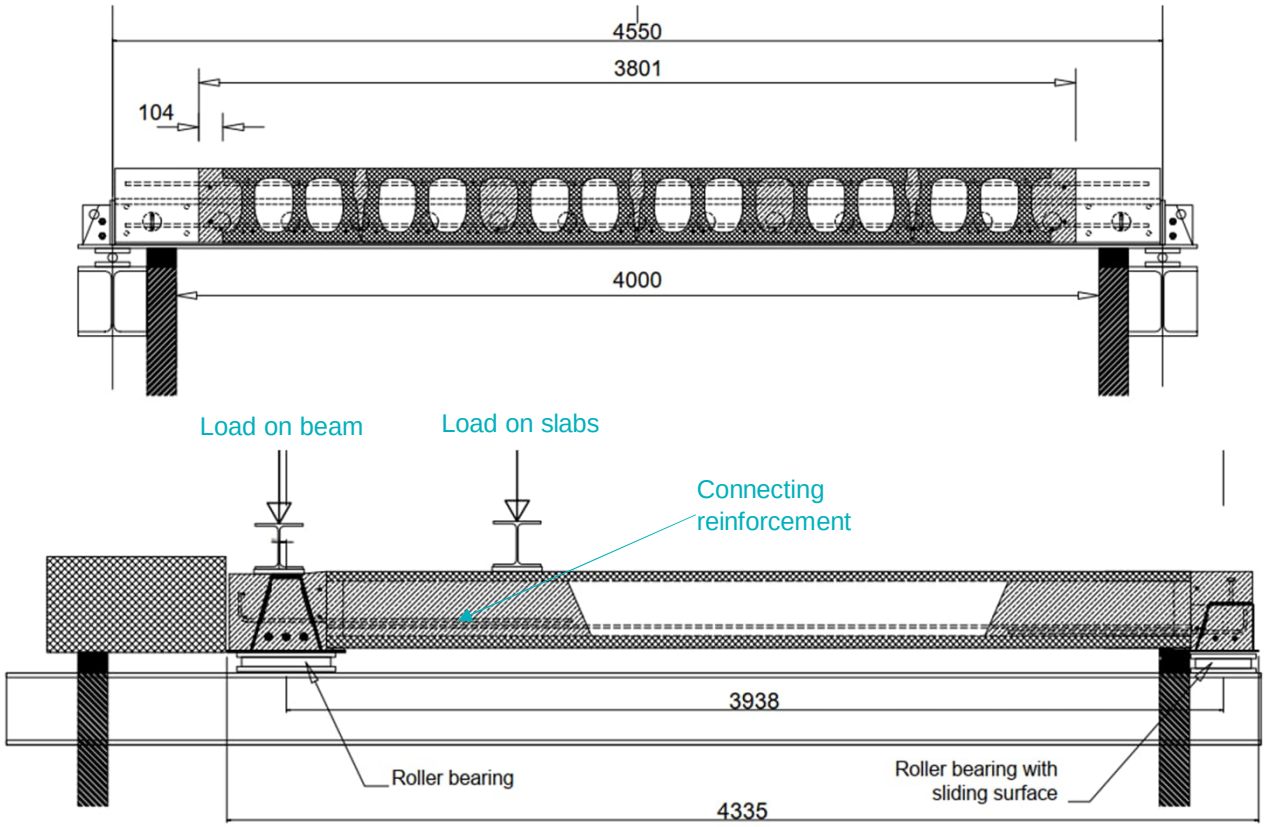
Investigation of different slab element geometries



From: „Gutachtliche Stellungnahme zur beigeweichen und indirekten Auflagerung von Spannbetonhohlplatten aus Slim-Floor-Trägern „Deltabeam“ im Brandfall – Abstimmung Validierungsversuche“, Cyllok, Pessel, Hothan, Häßler, 2018

Summary of experiments

System fire tests

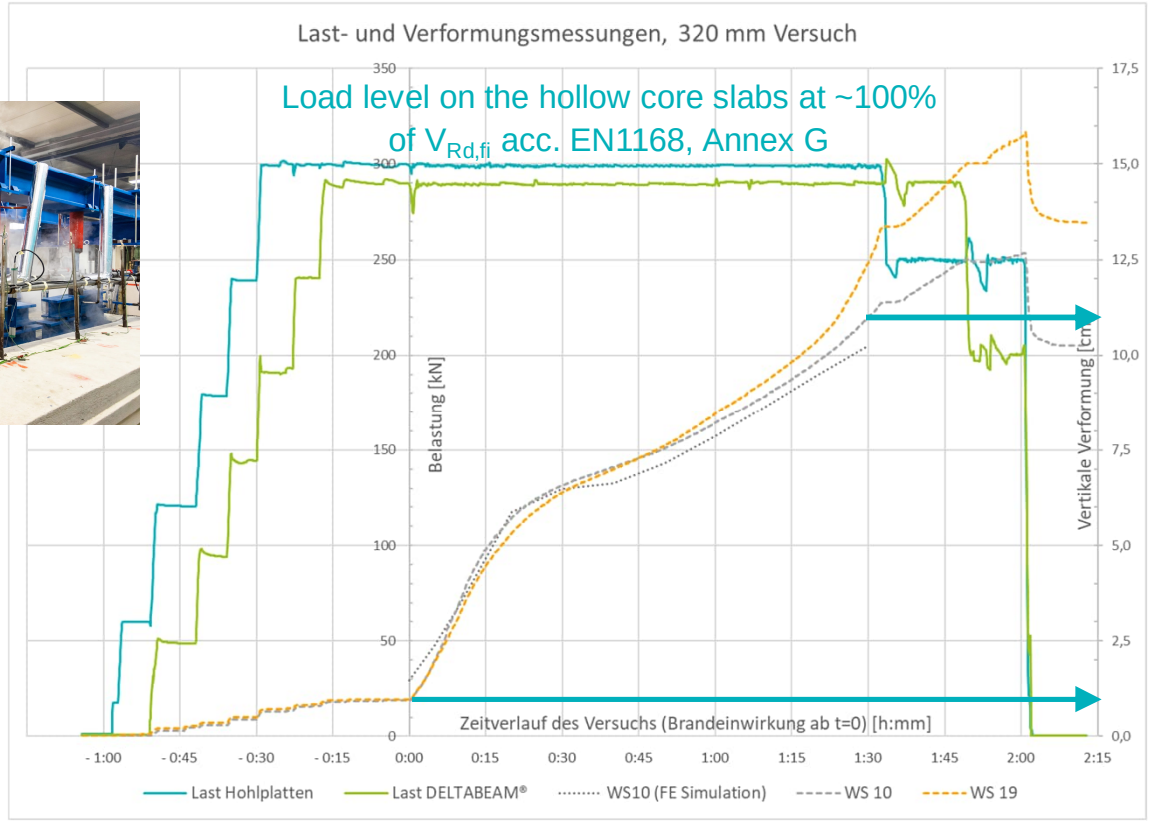


Sections of the system fire tests (D32-300 mit A32V)

Summary of experiments

System fire tests

Load and displacement measurements in the A32V test



110 mm ≙ L/41
(calculated:
103 mm ≙ L/44)

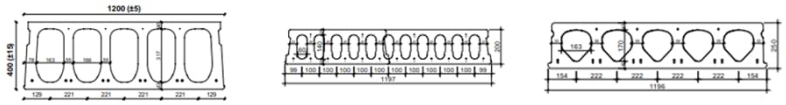
11,6 mm ≙ L/399
(calculated:
14,6 mm ≙ L/312)

Contents of the approval (aBG)

Contents of the approval (aBG)

Boundary conditions of the aBG

- Design recommendations for support of HCS on DELTABEAM® in fire case
- DELTABEAM®
  - All cross-sections of the German DELTABEAM® approval
  - 180mm to 700mm beam height
- Prestressed hollow core slabs
  - All cross-sections according to standard
  - Slab heights of 200mm to 400mm



- Concrete C20/25 to C50/60
- Ring anchor reinforcement 2∅14mm around each slab area

Contents of the approval (aBG)

Boundary conditions of the aBG

- Fire resistance up to 90 minutes
  - Resistance (Criterium R)
  - Compartmentation (Criterium E)
  - Insulation (Criterium I) is provided by products
- Fire exposure of top and bottom side
- Design of individual products DB und HCS must also be fulfilled

Contents of the approval (aBG)

Design

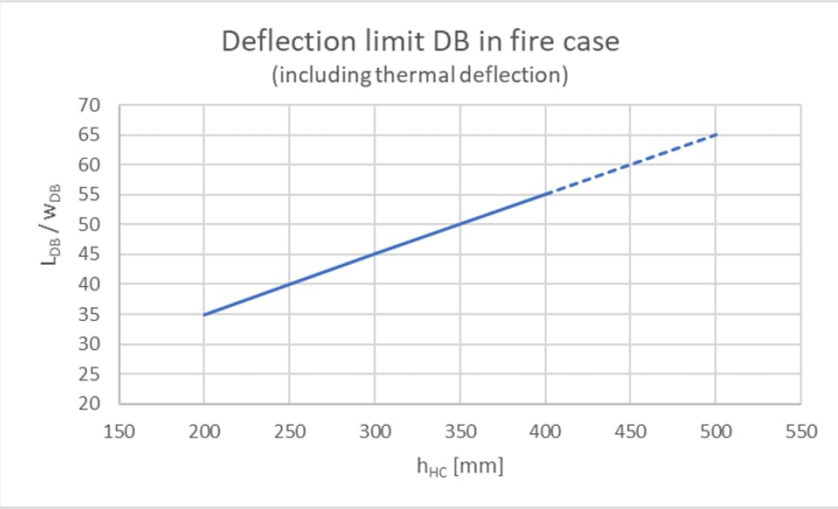
- Deflection of DELTABEAM® must be limited:
  - Basis: exceptional load combination
  - Consideration of thermal deflections
  -

$$\frac{L_{DB}}{w_{DB,fi}} \geq 35 + 30 * \frac{h_{HC} - 200}{300}$$

mit

h_{HC} Höhe der Spannbeton-Hohlplatten

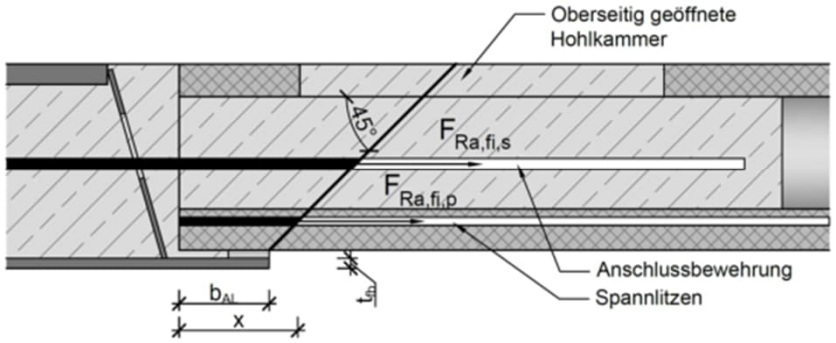
L_{DB}, $W_{DB,fi}$, h_{HC} in [mm]



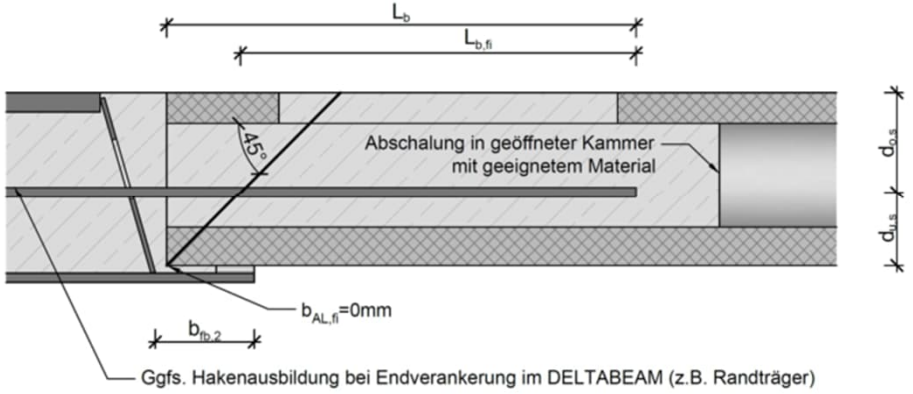
Contents of the approval (aBG)

Design

- Design of prestressed hollow core slabs:
  - Vertical shear resistance acc. EN 1168, Annex G
  - Resistance as for rigidly support slabs
  - Support length b_{AL} to be applied as 0mm (Anchorage length of tendons ~0mm)



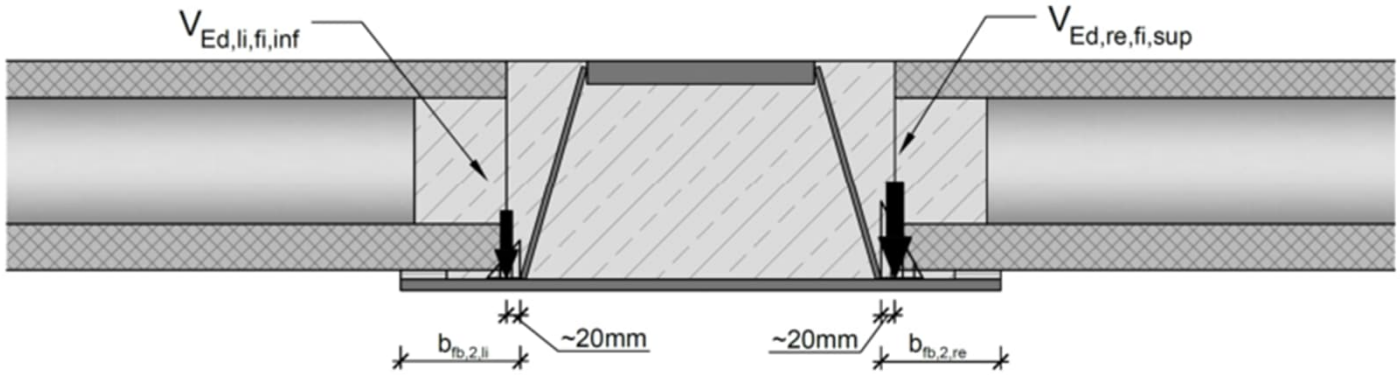
Die Auflagerlänge b_{AL} wird ab Ende Spannbeton-Hohlplatte gemessen. Im Brandfall gilt b_{AL} = 0 mm.



Contents of the approval (aBG)

Design

- Location of the resulting support reaction



Contents of the approval (aBG)

Design

– Connecting reinforcement – Part 1: Slab support

Basis: Equilibrium with friction coeff. μ_k=0,6

Factor 1,11 at β=78° (worst case)

$$A_{s,1,fi,req} = \frac{F_{s,1,fi,li/re}}{f_{sk,\theta}}$$

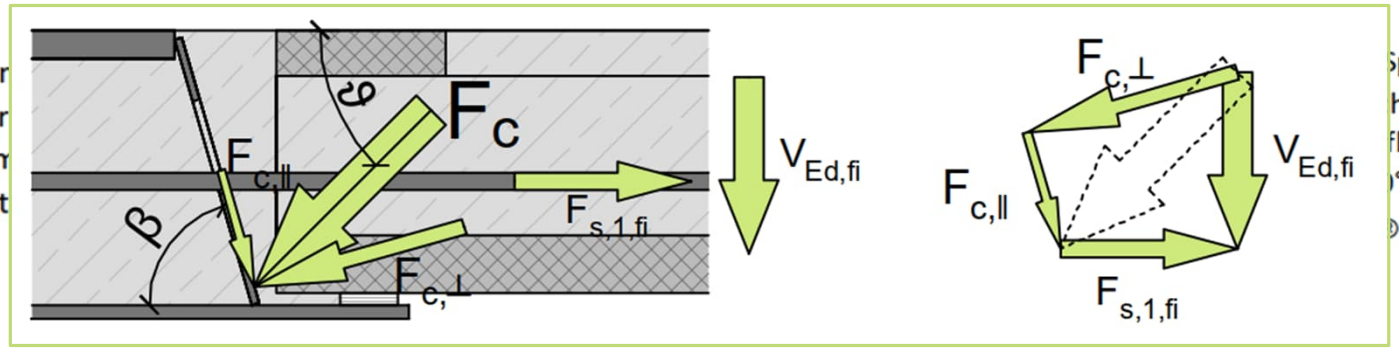
$$F_{s,1,fi,li/re} = 1{,}11 * V_{Ed,fi,li/re}$$

$$F_{s,1,fi,li/re} = \frac{1}{\tan\vartheta} * V_{Ed,fi,li/re}$$

mit

$F_{s,1,fi,li/re}$ Ber
der
ten
Bet

$f_{sk,\Theta}$

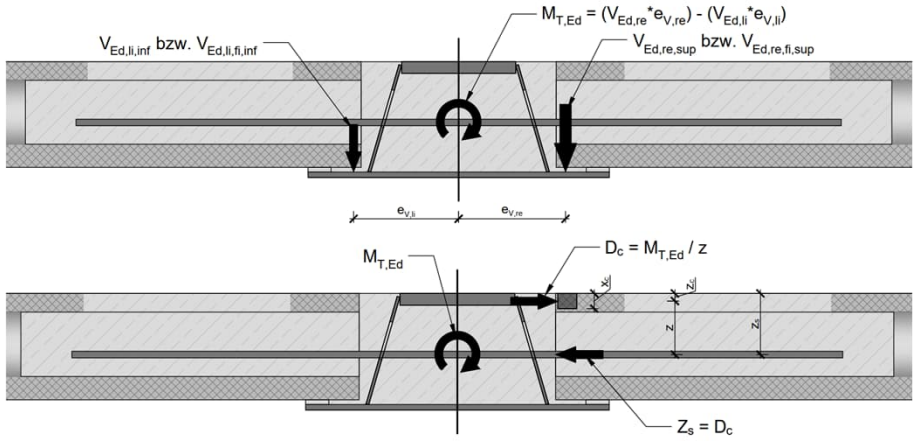


Spannbeton-
hten Flansch [kN/m]
flager-Druckkraft auf
)° - β
ϑ zur Horizontalen

Contents of the approval (aBG)

Design

- Connecting reinforcement – Part 2: Torsion



$$A_{s,2,fi,req} = \frac{F_{s,2,fi,li/re}}{f_{sk,\theta}}$$

$$F_{s,2,fi,li/re} = \frac{(V_{Ed,fi,li} * e_{fi,li}) - (V_{Ed,fi,re} * e_{fi,re})}{z}$$

mit

$F_{s,2,fi,li/re}$	Bemessungszugkraft in der Anschlussbewehrung aus exzentrischer Deckenlast [kN/m]
$V_{Ed,li/re}$	Einwirkende Auflagerkaft aus Querkraft in den Decken auf dem linken/rechten Flansch des Deltabeam [kN/m]
$e_{fi,li/re}$	Abstand der Lastresultierenden von $V_{Ed,fi,li/re}$ zum Schubmittelpunkt des Deltabeam [mm]
z	innerer Hebelarm [mm]

Contents of the approval (aBG)

Design

- Connecting reinforcement – Sum

$$A_{s,fi,req} = \max\left(\left(A_{s,1,li,fi,req} + A_{s,2,li,fi,req}\right), \left(A_{s,1,re,fi,req} + A_{s,2,re,fi,req}\right)\right)$$

mit

$A_{s,fi,req}$ erforderlicher Querschnitt der Anschlussbewehrung [cm²/m]

- This connecting reinforcement can be also applied for design of the prestressed hollow core slabs according to EN 1168, Annex G.1.3 (no combinations req.)
- Anchorage

$$l_{bd,fi} = \frac{\emptyset_s}{4} * \frac{\sigma_{sd,fi}}{f_{bd,fi}} \geq 700\ mm$$

mit

$\sigma_{sd,fi} = \frac{F_s}{A_{s,fi,req}}$

$f_{bd,fi} = 2{,}25 * 0{,}7 * f_{ctk,0.05} * \frac{f_{c,\Theta}}{f_{ck}}$

$f_{ctk,0.05}$ 5%-Quantil der Zugfestigkeit des Fugenbetons nach DIN EN 1992-1-1[18], Tabelle 3.1 [kN/cm²]

$\frac{f_{c,\Theta}}{f_{ck}}$ temperaturbedingter Abminderungsfaktor der Druckfestigkeit des Fugenbetons nach DIN EN 1992-1-2[14], Tabelle 3.1

Contents of the approval (aBG)

Design

- Interface shear between concrete grout and HCS element void is covered by aforementioned anchorage length !

Execution

- Cleaning of voids
- No installation of slab elements with cracked anchorage areas
- De-areation and compaction
- Neoprene strips flush with the outer end of the bottom flanges

QUESTIONS ?

Thank you for listening !

Oliver Beckmann, Dipl.-Ing. (FH)

R&D Engineer Deltabeam Frame

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