Danish Steel Day 2017

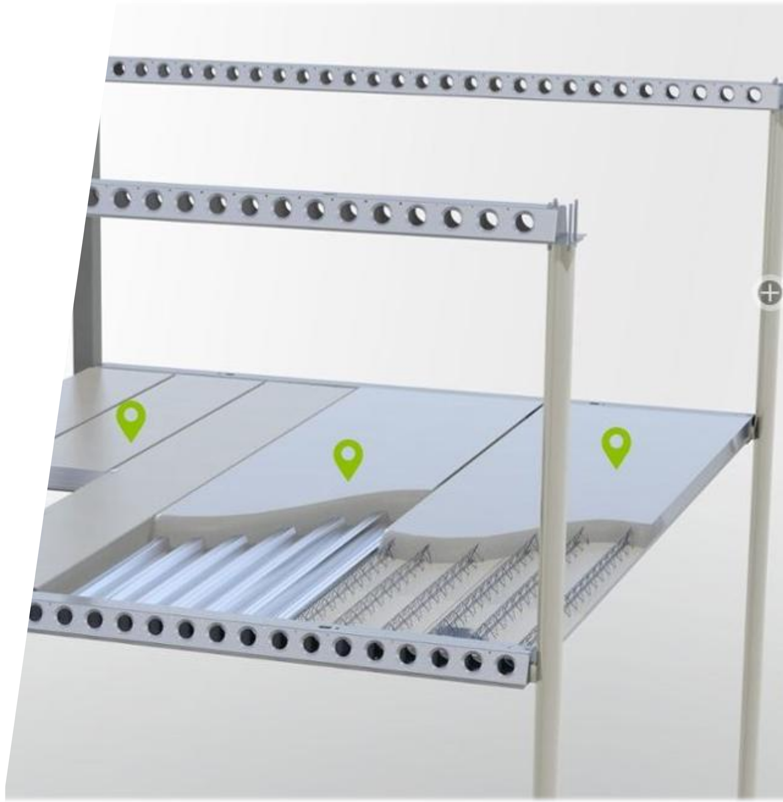
DELTABEAM® Frame

Kompositsøjler

DELTABEAM® Frame

Presentation Content

- Introduction
- Frame Options
- Fire resistance of composite columns
- Connections
- Robustness
- Assembly and Casting
- System Benefits



Introduction

Frame Options

DELTABEAM® Frame

Main Components of the frame

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Trusses, Steel Columns, Anchor Bolts

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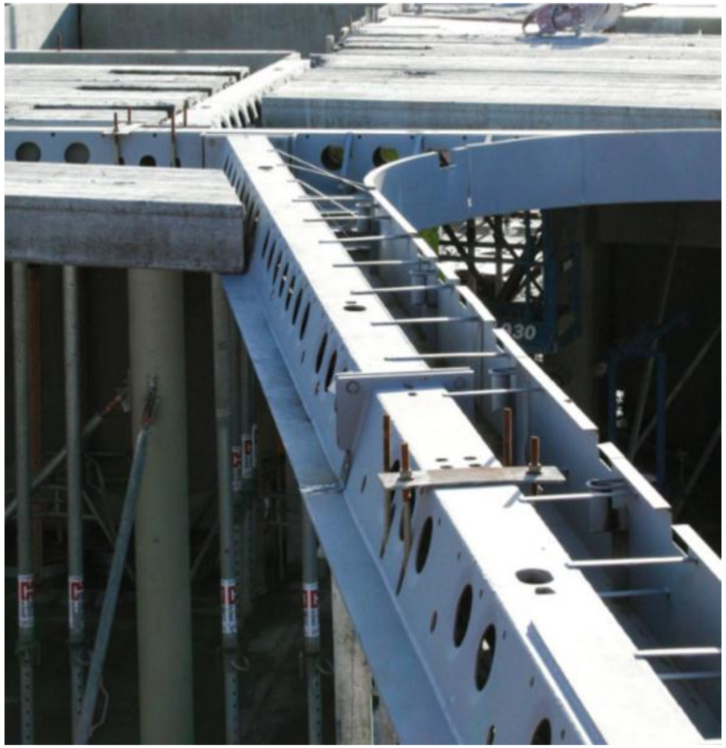
Trimmer beams, Formworks



DELTABEAM® Frame

Non standard structures and solutions

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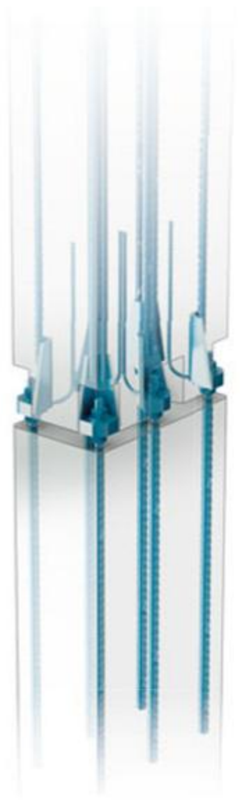
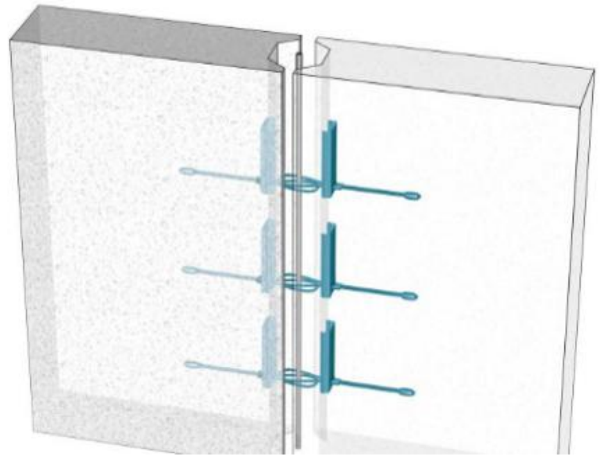
Concrete connections





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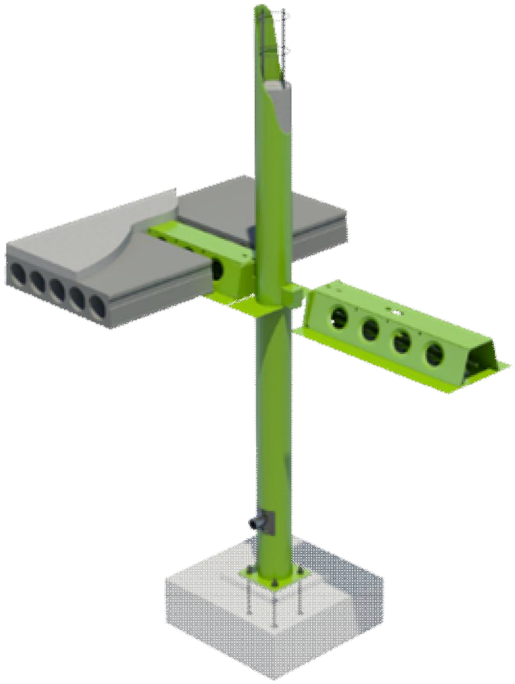
Frame Options

Continuous column and single span beam



Continuous beam and single storey column

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Frame Options- Continuous Beam

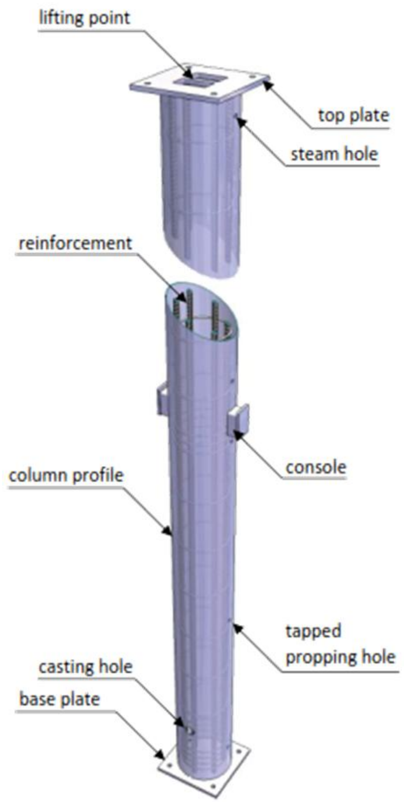
Frame Options- Continuous Column

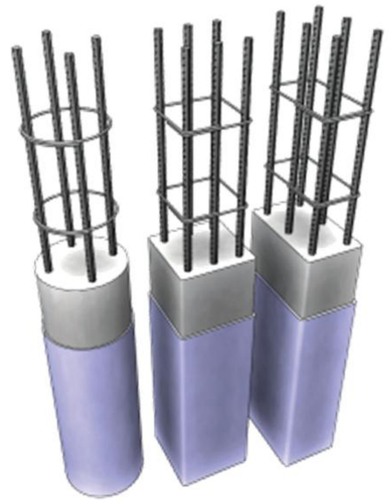
Composite column
Calculation methods for fire resistance

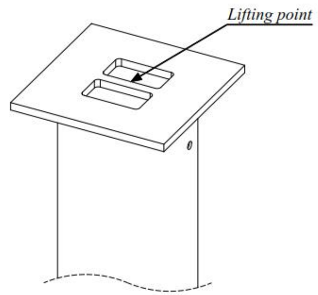
Composite Column

Main components

- Columns can be circular, square or rectangular shape
- The column consists of following parts
  - Hollow section
  - Reinforcement cage
  - Top and Bottom plate
  - Consoles
  - Lfting point
  - Other parts







Composite Column Cross section resistance

- Plastic resistance of cross section:

$$N_{pl,Rd} = A_a f_{yd} + A_c f_{cd} + A_s f_{sd}$$

$$\delta = \frac{A_a f_{yd}}{N_{pl,Rd}}$$

- Effective flexural stiffness:

$$(EI)_{eff} = E_a I_a + E_s I_S + K_e E_{c,eff} I_c$$

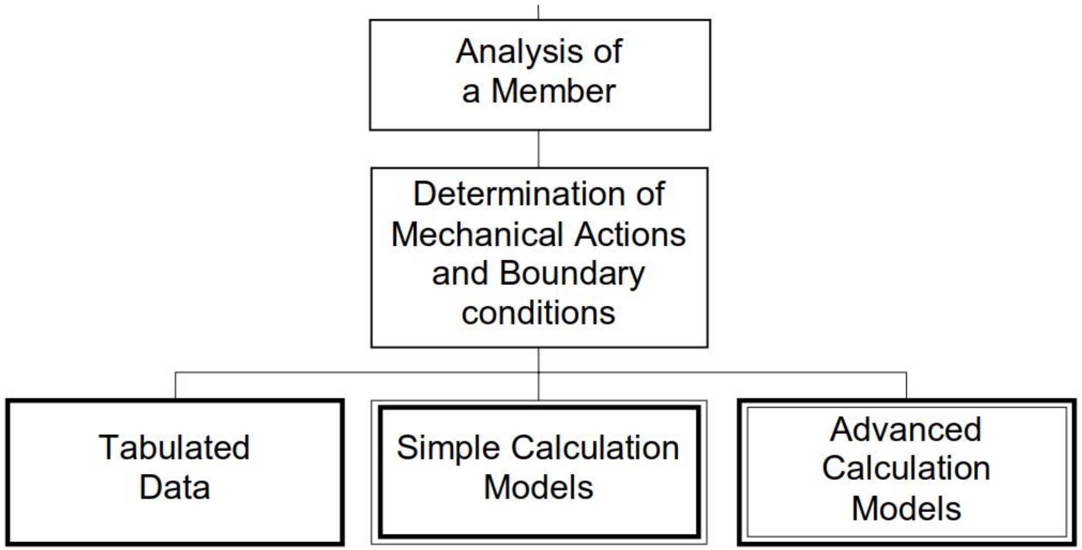
$$(EI)_{eff,II} = K_0 \left(E_a I_a + E_s I_S + K_{e,II} E_{c,eff} I_c \right)$$

$$E_{c,eff} = E_{cm} \frac{1}{1 + \left(N_{G,Ed} / N_{Ed} \right) \cdot \varphi_t}$$

Composite Column Fire Design

Calculation Methods

- Tabulated Data
- Simple calculation models:
  - Annex H
  - Simple Method
- Advanced/General Method



Composite Column Fire Design

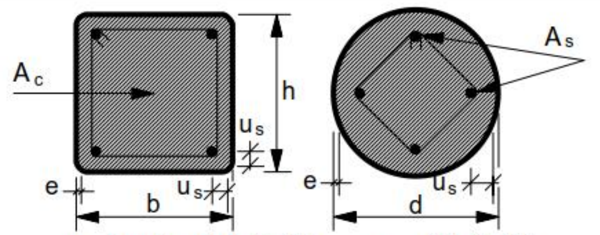
Tabulated DATA

$$\eta_{fi,t} = \frac{E_{fi,d,t}}{R_d}$$; load level for fire design,

For Rd calculation following values must be taken:

- Steel grade S235
- Tube thicknes up to 1/25 b or d
- Reinforcement ratio up to 3%
- Concrete strenght as in normal temperature
- Buckling length $2xL_{fi}$
- Valid for braced frames
- $L \leq 30d\ (or\ b)$

Table 4.7: Minimum cross-sectional dimensions, minimum reinforcement ratios and minimum axis distance of the reinforcing bars of composite columns made of concrete filled hollow sections



	steel section: (b / e) ≥ 25 or (d / e) ≥ 25	Standard Fire Resistance				
		R30	R60	R90	R120	R180
1	Minimum cross-sectional dimensions for load level $\eta_{fi,t} \leq$ 0,28					
1.1	Minimum dimensions h and b or minimum diameter d [mm]	160	200	220	260	400
1.2	Minimum ratio of reinforcement $A_S / (A_C + A_S)$ in (%)	0	1,5	3,0	6,0	6,0
1.3	Minimum axis distance of reinforcing bars u_S [mm]	-	30	40	50	60
2	Minimum cross-sectional dimensions for load level $\eta_{fi,t} \leq$ 0,47					
2.1	Minimum dimensions h and b or minimum diameter d [mm]	260	260	400	450	500
2.2	Minimum ratio of reinforcement $A_S / (A_C + A_S)$ in (%)	0	3,0	6,0	6,0	6,0
2.3	Minimum axis distance of reinforcing bars u_S [mm]	-	30	40	50	60
3	Minimum cross-sectional dimensions for load level $\eta_{fi,t} \leq$ 0,66					
3.1	Minimum dimensions h and b or minimum diameter d [mm]	260	450	550	-	-
3.2	Minimum ratio of reinforcement $A_S / (A_C + A_S)$ in (%)	3,0	6,0	6,0	-	-
3.3	Minimum axis distance of reinforcing bars u_S [mm]	25	30	40	-	-

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Composite Column Fire Design

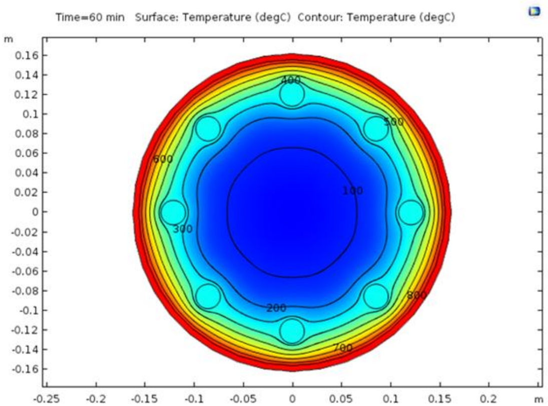
Annex H

$$N_{fi,Rd} = N_{fi,cr} = N_{fi,pl,Rd}$$

where:

$$N_{fi,cr} = \pi^2 \left[E_{a,\theta,\sigma}\, I_a + E_{c,\theta,\sigma}\, I_c + E_{s,\theta,\sigma}\, I_s\right] / \ell_\theta^2$$ and

$$N_{fi,pl,Rd} = A_a\, \sigma_{a,\theta} / \gamma_{M,fi,a} + A_c\, \sigma_{c,\theta} / \gamma_{M,fi,c} + A_s\, \sigma_{s,\theta} / \gamma_{M,fi,s}$$



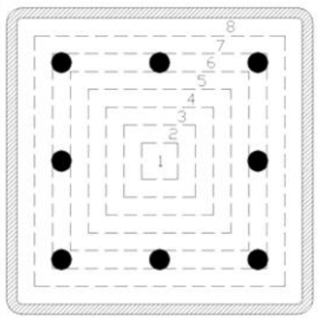
Strain	$N_{fi,cr}$ (kN)	$N_{fi,pl,Rd}$ (kN)
0,005	3148	335
0,001	2327	670
0,002	1957	1215
0,0025	1913	1474
0,0028	1887	1623
0,0029	1417	1703
0,002833	1679	1675

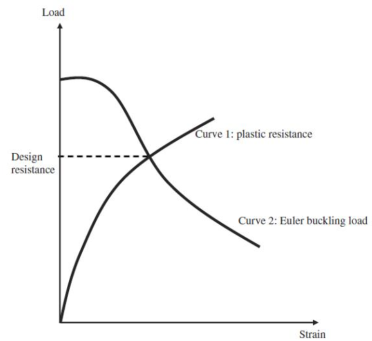
Thus $N_{fi,cr} = N_{fi,pl,Rd}$ at about 1675 kN

i.e. $N_{fi,Rd} = N_{fi,cr} = N_{fi,pl,Rd} = 1675$ kN

The axial resistance after 90 minutes is 1675 kN

Layer	Outer side length, d_o (mm)	Inner side length, d_i (mm)	Temperature
1	35	0	124°C
2	70	35	134°C
3	105	70	164°C
4	140	105	221°C
5	175	140	303°C
6	210	175	415°C
7	245	210	577°C
8	280	245	814°C
Steel			953°C





Composite Column Fire Design

Annex H

Validity range:

- buckling length in fire $l \leq 4.5m$
- 140 mm $\leq$ depth b or diameter d $\leq$ 400 mm
- $C$20/25 $\leq$ concrete grades $\leq$ $C$40/50
- percentage of reinforcing steel $\leq$ 5%
- standard fire resistance $\leq$ 120min
- **relative slenderness $\boldsymbol{\lambda \leq 0.5}$**

Composite Column Fire Design

Simple method

$$N_{fi,Rd} = \chi \, N_{fi,pl,Rd}$$

(4) The design value of the plastic resistance to axial compression in the fire situation is given by:

$$N_{fi,pl,Rd} = \sum_j \left(A_{a,\theta}\, f_{ay,\theta}\right)/\gamma_{M,fi,a} + \sum_k \left(A_{s,\theta}\, f_{sy,\theta}\right)/\gamma_{M,fi,s} + \sum_m \left(A_{c,\theta}\, f_{c,\theta}\right)/\gamma_{M,fi,c}$$

(5) The effective flexural stiffness is calculated as

$$(EI)_{fi,eff} = \sum_j \left(\varphi_{a,\theta}\, E_{a,\theta}\, I_{a,\theta}\right) + \sum_k \left(\varphi_{s,\theta}\, E_{s,\theta}\, I_{s,\theta}\right) + \sum_m \left(\varphi_{c,\theta}\, E_{c,sec,\theta}\, I_{c,\theta}\right)$$

$\varphi_{i,\theta}$ is the reduction coefficient depending on the effect of thermal stresses.

Project FRISCC – Future Annex H

Fire resistance of innovative and slender concrete filled tubular composite columns

$$N_{fi,pl,Rd} = A_a f_y(\theta_{a,eq}) + A_c f_c(\theta_{c,eq}) + A_s f_s(\theta_{s,eq})$$

where:

A_i is the area of part *i* of the cross-section;

f_i is the maximum design strength of part *i* at the temperature $\theta_{i,eq}$;

$$(EI)_{fi,eff} = \varphi_{a,\theta} E_a(\theta_{a,eq}) I_a + \varphi_{c,\theta} E_c(\theta_{c,eq}) I_c + \varphi_{s,\theta} E_s(\theta_{s,eq}) I_s$$

where:

$\varphi_{i,\theta}$ is the reduction coefficient depending on the effect of thermal stresses of part *i*. The values of these coefficients are given in (5);

Project FRISCC – Future Annex H

Fire resistance of innovative and slender concrete filled tubular composite columns

- Concrete core:

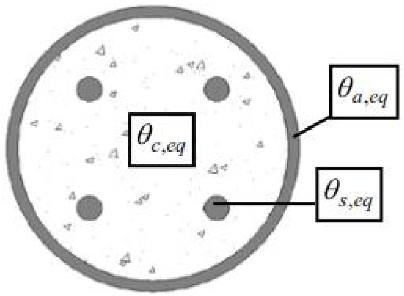
$$\theta_{c,eq} = 81.801 - 5.046 \cdot t_{fi} + 0.003 \cdot t_{fi}^{2} - 15.07 A_m / V + 0.331 (A_m / V)^2 - 0.875 \cdot t_{fi} \cdot A_m / V + 7.428 \cdot t_{fi}^{0.842} \cdot (A_m / V)^{0.714}$$

- Steel tube:

$$\theta_{a,eq} = -824.667 - 5.579 \cdot t_{fi} + 0.007 \cdot t_{fi}^{2} - 0.009 \cdot t_{fi} \cdot A_m / V + 645.076 \cdot t_{fi}^{0.269} \cdot (A_m / V)^{0.017}$$

- Reinforcing bars:

$$\theta_{s,eq} = \beta_3 \cdot \left(t_{fi} / u_s^2\right)^3 + \beta_2 \cdot \left(t_{fi} / u_s^2\right)^2 + \beta_1 \cdot \left(t_{fi} / u_s^2\right) + \beta_0$$



where:

t_{fi} is the duration of fire exposure;

A_m/V is the section factor;

u_s is the axis distance of the reinforcing bars to the concrete surface.

Project FRISCC – Future Annex H

Fire resistance of innovative and slender concrete filled tubular composite columns

(5) The flexural stiffness reduction coefficients $\varphi_{i,\theta}$ for the different components of the cross-section are given hereafter:

- Concrete core: $\varphi_{c,\theta} = 1.2$ (for secant modulus), or $\varphi_{c,\theta} = 0.8$ (for tangent modulus)

- Steel tube:

CHS
$\varphi_{a,\theta} = 0.75 - 0.023 \cdot (A_m / V)$
SHS
$\varphi_{a,\theta} = 0.15 - 0.001 \cdot (A_m / V)$
RHS & EHS
$\varphi_{a,\theta} = 0.012(\ell_\theta / B)$

where:

B is the shorter dimension of a rectangular or elliptical cross-section;

ℓ_θ is the buckling length of the column in the fire situation.

- Reinforcing bars:

CHS & SHS
$\varphi_{s,\theta} = 0.8 - 0.002 \cdot t_{fi}$
RHS
$\varphi_{s,\theta} = 0.7$
EHS
$\varphi_{s,\theta} = 0.95$

where:

t_{fi} is the duration of fire exposure.

Project FRISCC – Future Annex H

Fire resistance of innovative and slender concrete filled tubular composite columns

- Field of application:

For CHS columns:

$$5 \leq A_m / V \leq 30$$
$$10 \leq D / t \leq 60$$
$$5 \leq \ell_\theta / D \leq 30$$

For SHS columns:

$$5 \leq A_m / V \leq 35$$
$$5 \leq B / t \leq 40$$
$$5 \leq \ell_\theta / B \leq 30$$

For RHS columns:

$$10 \leq A_m / V \leq 45$$
$$5 \leq B / t \leq 20$$
$$5 \leq \ell_\theta / B \leq 30$$
$$H / B = \{1.5,\ 2,\ 3\}$$

For EHS columns:

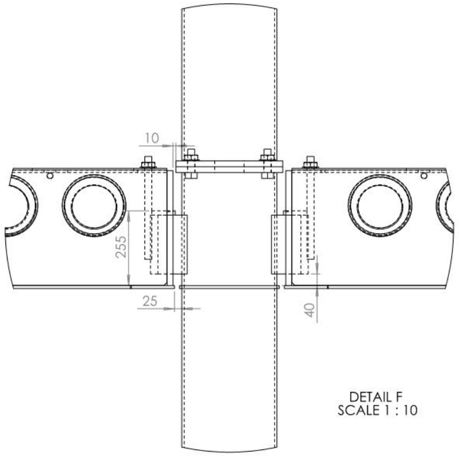
$$10 \leq A_m / V \leq 30$$
$$5 \leq B / t \leq 20$$
$$5 \leq \ell_\theta / B \leq 30$$
$$H / B = 2$$

- The percentage of reinforcement should be lower than 5 %.
- For concentrically loaded unreinforced CHS and SHS columns with relative slenderness $\bar{\lambda}$ over 0.5, a minimum amount of 2.5 % of reinforcement is required.
- The relative load eccentricity e / D, e / B or e / H should be lower than 1.
- The method can be used for fire exposure times ranging between 30 and 240 minutes.
- It is considered that differential axial displacements may occur between the outer steel tube and the concrete core, i.e., “slip” is considered at the top end of the columns.
- This calculation model shall only be used for columns in braced frames.

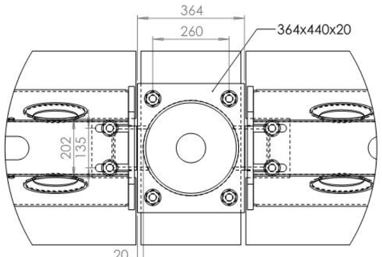
Connections
Overview

Robustness

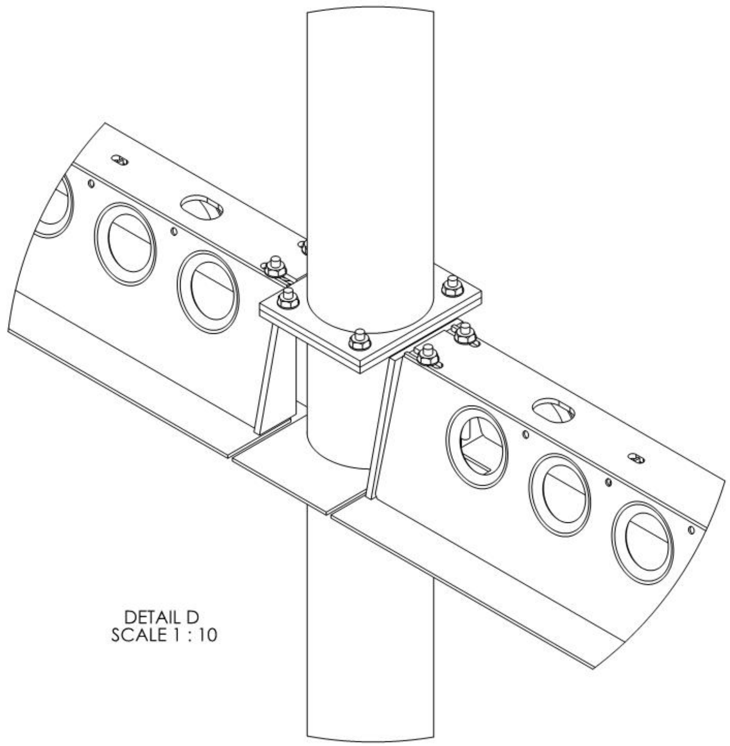
DELTABEAM® Frame - Connections



DETAIL F
SCALE 1 : 10



DETAIL E
SCALE 1 : 10



DETAIL D
SCALE 1 : 10

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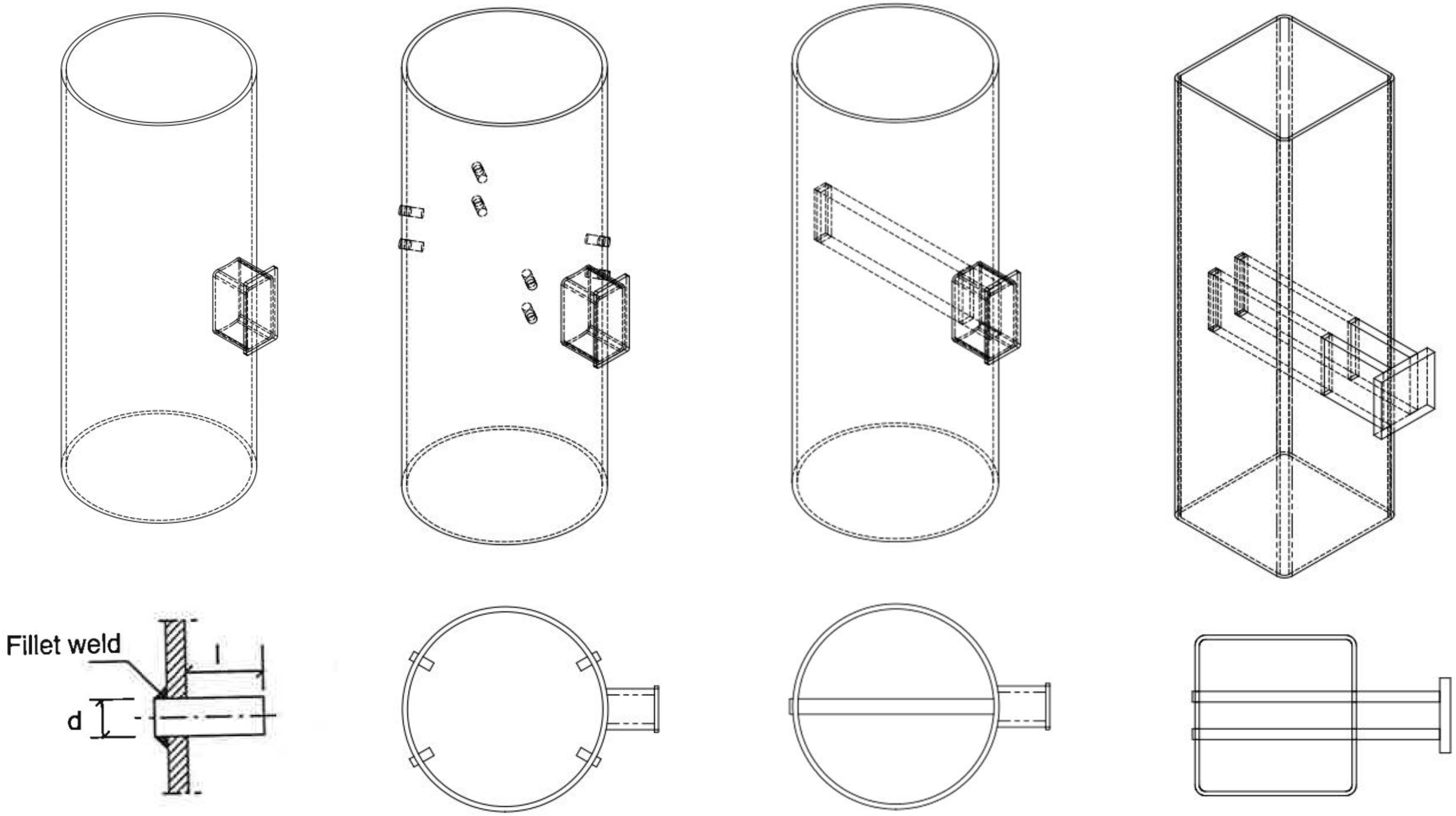
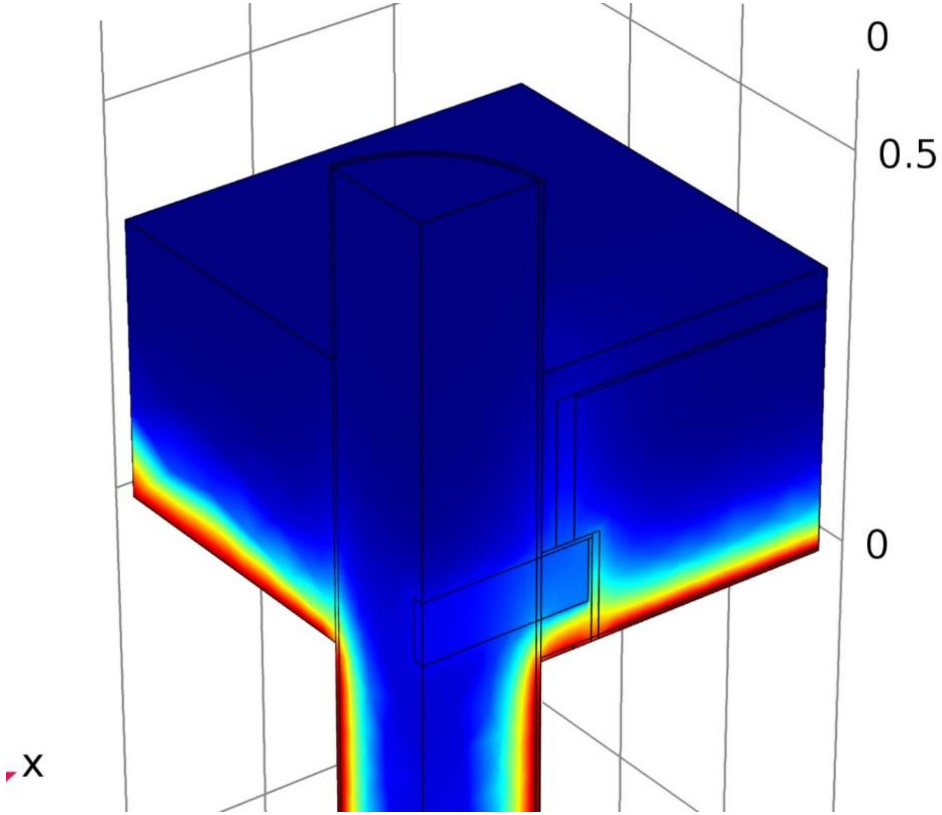
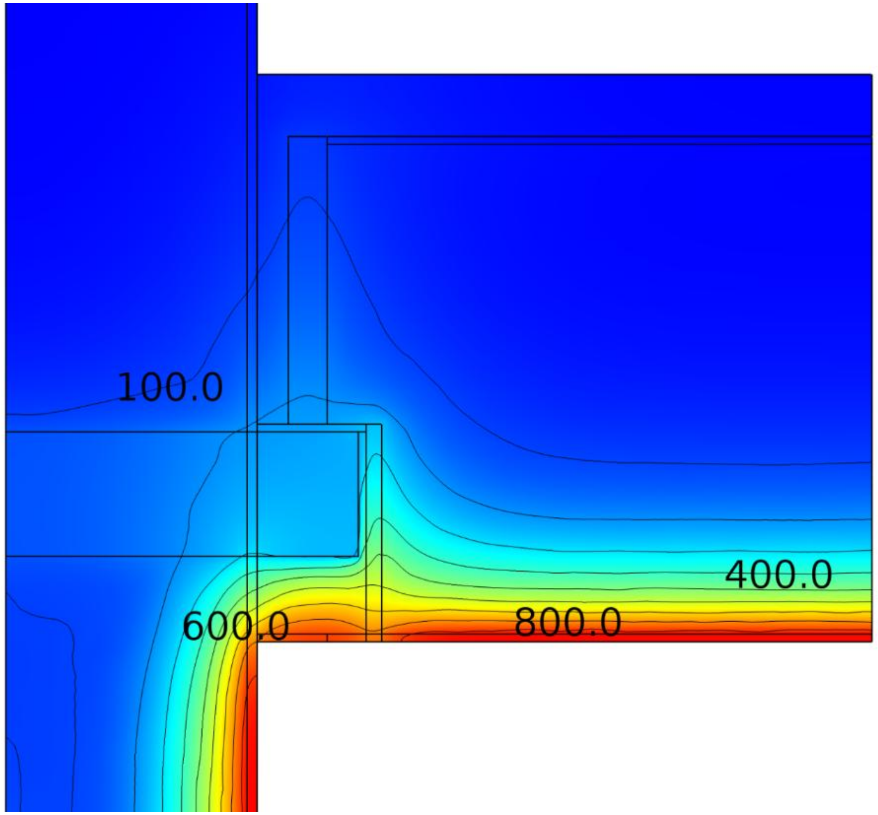
DELTABEAM® Frame – Connection details

Light to Heavy Loads



DELTABEAM® Frame - Fire Design

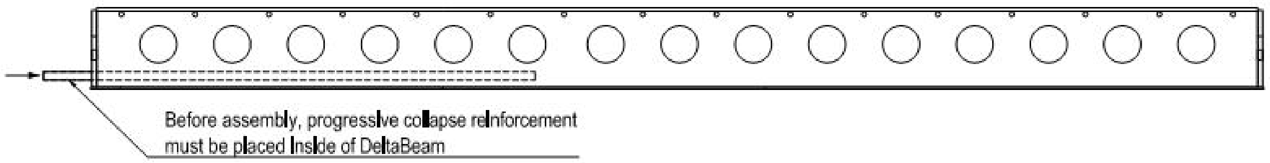




DELTABEAM® Frame - Robustness

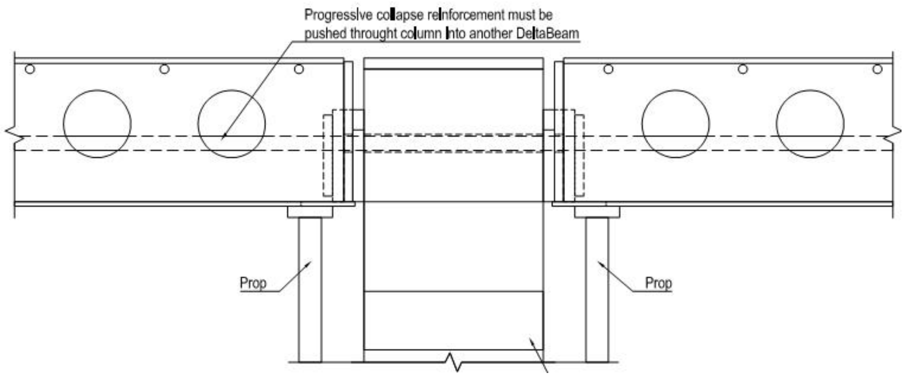
Picture 2

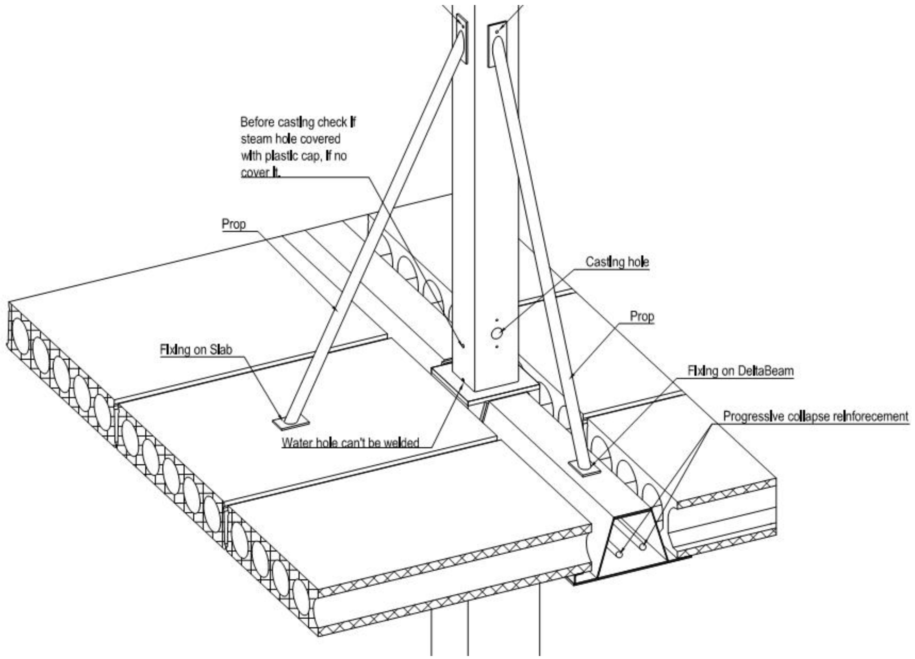
TEMPORARY PLACING PROGRESSIVE COLLAPSE REINFORCEMENT IN DELTABEAM



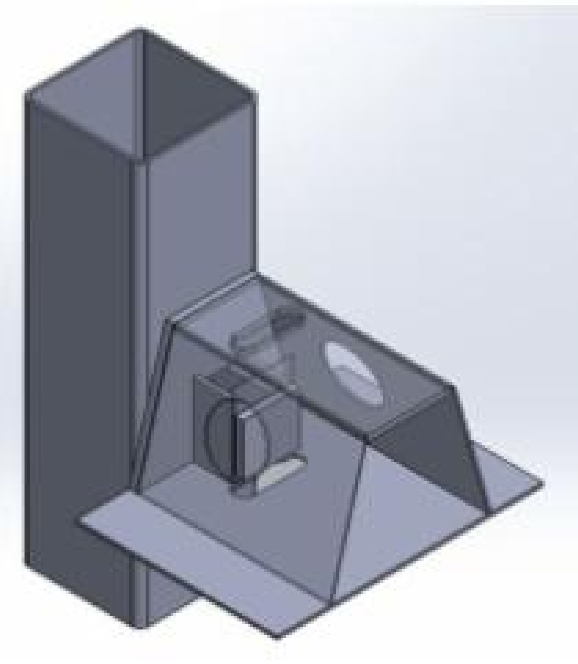
Picture 4

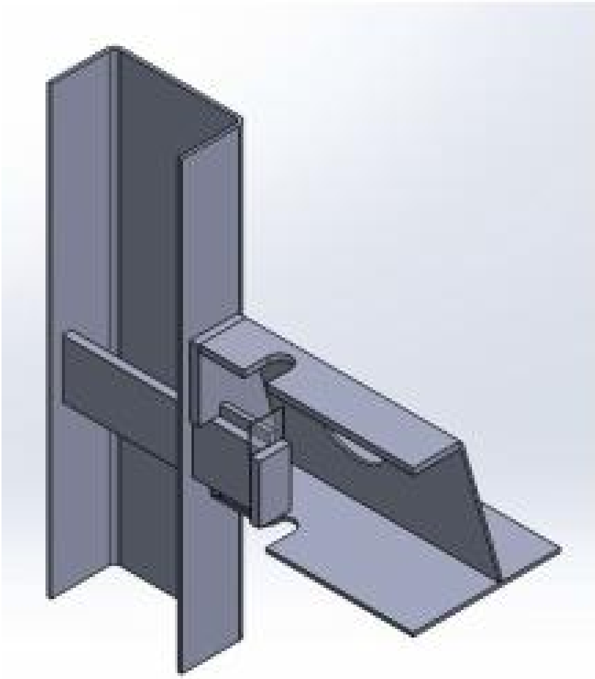
Pushing reinforcement throught both deltabeams





DELTABEAM® Frame - Robustness





Assembly and Casting

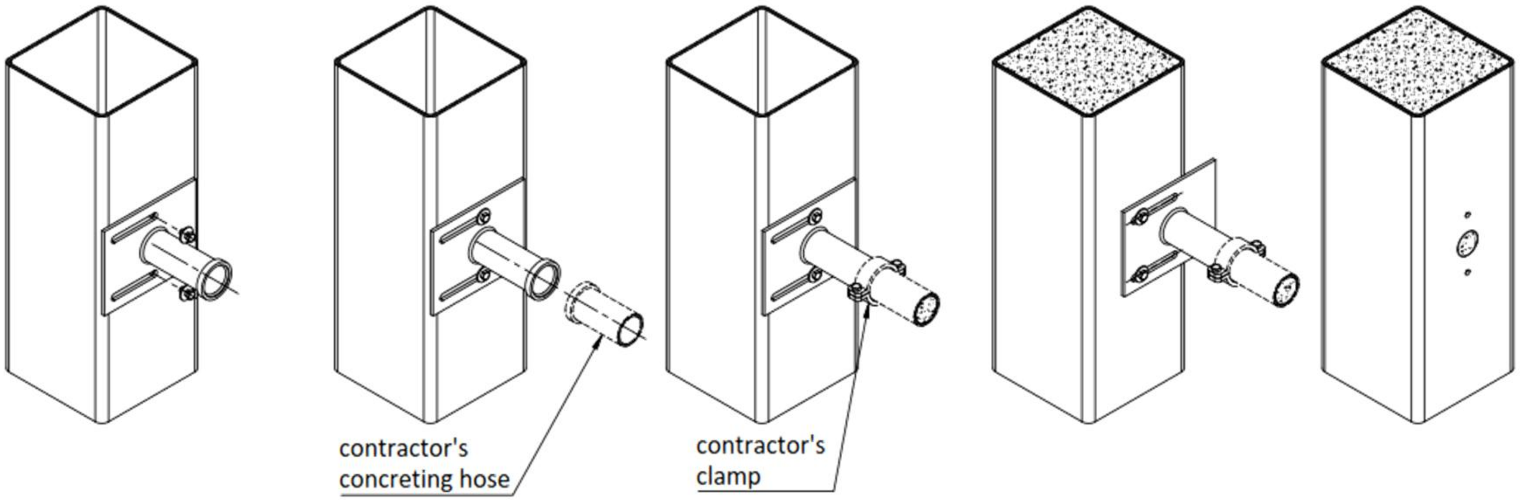
System Benefits

Assembly

- DELTABEAMS can be propped or not propped.
- Columns in most cases are propped.
- For continuous columns, props are usually required only in first floor. If beams are not propped, columns may require to be propped in other floors.
- Bolted connection allows to release column from the crane before props are installed.
- Propping plans with required propping resistance are supplied by Peikko.
- Two methods of column casting:
  - Casting from the bottom.
  - Filling from the top.

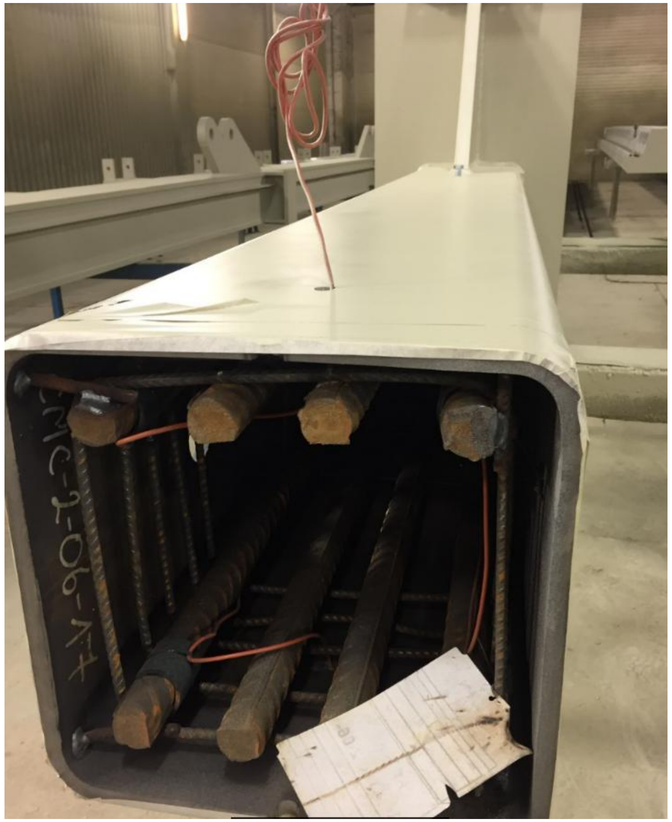
Casting from the bottom

- Casting from the bottom ensures good compaction of concrete.
- No need for concrete vibration.



Casting during the winter

Heating wires inside composite column



SLIM FLOOR

SLIM COLUMNS

LONG SPANS

INTEGRATED FIRE RESISTANCE

FAST ASSEMBLY

Thank you for your attention

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