

MEMO 65 A
TSS 25 L
ANCHORING DESIGN
DESIGN

Date: 04.10.2011
Last rev.: 13.10.2020
Dok. nr.: K3-10/60

Sign.: ML
Sign.: JB
Contr.: SSS

ANCHORING DESIGN FOR TSS 25 L

CONTENTS

PART 1 – BASIC ASSUMPTIONS	2
GENERAL	2
STANDARDS	2
QUALITIES	3
DIMENSIONS AND CROSS SECTION VALUES.....	4
Steel constructions	4
Concrete constructions	5
LOADS	6
PART 2 – ANCHORING OF TSS25 L	7
STATIC MODELS AND EQUILIBRIUM CALCULATIONS.....	7
CONCRETE CONE FAILURE REGARDS TO R_1 , R_2 og R_h	9
CONCRETE PARAMETERS, CEN/TS 1992-4-2:2009,pkt 6.2.5.1	10
ANCHORING OF FORCE R_1	10
ANCHORING OF FORCE R_2	11
ANCHORING OF FORCE R_h	11
LIFTING CAPACITY - 1200 kg	Feil! Bokmerke er ikke definert.
CAPACITY OVERVIEW.....	12
PART 3 – EXAMPLE: LOCAL REINFORCEMENT AROUND RECESS IN LANDING	13
STATIC MODELS AND EQUILIBRIUM CALCULATIONS.....	13
LOCAL REINFORCEMENT	15

PART 1 – BASIC ASSUMPTIONS

GENERAL

The following calculations of anchorage of the units and the corresponding reinforcement must be considered as an example illustrating the design model.

It must always be checked that the forces from the anchorage reinforcement can be transferred to the main reinforcement of the concrete components. The recommended reinforcement includes only the reinforcement necessary to anchor the unit to the concrete.

In the vicinity of the unit the element must be designed for the force R_1 .

STANDARDS

The calculations are carried out in accordance with:

- Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings.
- Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings.
- Technical Specification CEN/TS 1992-4-1:2009 Design og fastenings for use in concrete Part 4-1: General.
- Technical Specification CEN/TS 1992-4-2:2009 Design og fastenings for use in concrete Del 4-2: Headed Fasteners.
- Technical Specification CEN/TR 15728:2016. Design and use of inserts for lifting and handling of precast concrete elements

The selected values for the NDP's in the following calculations are:

State	Concrete							Steel		
	γ_c	α_{cc}	α_{ct}	η_1	η_2	$\alpha_{\text{Early strength}}^{1)}$	γ_s	γ_{MO}	γ_{M1}	γ_{M2}
Value - Ultimate limit state (ULS)	1,5	0,85	0,85	1,0	1,0		1,15	1,05	1,05	1,25
Value – lifing		0,85	0,85	1,0	1,0	0,8				

1) Reduction factor $\alpha_{\text{Early strength}}$ is determined by the designer, indicates the minimum value of concrete strenght when lifting elements.

Table 1: NDP-s in EC-2 and EC-3.

	γ_c, γ_s	γ_1	γ_{I+h}	Global safety factor SF	Design formulas
Concrete					
Concrete failure	1,5	1,35	1,5	3,04	$SF = \gamma_c \times \gamma_1 \times \gamma_{I+h}$
Anchorage reinforcement	1,15	1,35	1,5	2,33	$SF = \gamma_s \times \gamma_1 \times \gamma_{I+h}$
Steel					
Structural steel	1,25	1,35	1,8	3,04	$SF = \gamma_s \times \gamma_1 \times \gamma_{I+h}$

Table 2: Global safety factors in CEN/TR 15728:2016.




QUALITIES

Material parameters	Concrete strength classes / reinforcement					Steel	Design formulas / references
	C30/37 (N/mm ²)	C35/45 (N/mm ²)	C45/55 (N/mm ²)	C55/67 (N/mm ²)	B 500 C (N/mm ²)	S355 (N/mm ²)	
f_{ck}	30	35	45	55			EC2, Table 3.1
$f_{ck,cube}$	37	45	55	67			EC2, Table 3.1
$f_{ctk,0,05}$	2,00	2,20	2,70	3,00			EC2, Table 3.1
f_{yk}					500		EC2, Annex C
f_{cd}	17,0	19,8	25,5	31,2			$f_{cd} = f_{ck} \times \alpha_{cc} / \gamma_c$
f_{ctd}	1,13	1,25	1,53	1,70			$f_{ctd} = f_{ctk,0,05} \times \alpha_{ct} / \gamma_c$
f_{bd}	2,55	2,81	3,44	3,83			$f_{bd} = 2,25 \times \eta_1 \times \eta_2 \times f_{ctd}$
f_{yd}					435		$f_{yd} = f_{yk} / \gamma_s$
$f_{cd,lifting}$	6,7	7,8	10,1	12,3			$f_{cd,lifting} = f_{ck} \times \alpha_{cc} \times \alpha_{Early\ strength} / SF$
$f_{ctd,lifting}$	0,45	0,49	0,60	0,67			$f_{ctd,lifting} = f_{ctk,0,05} \times \alpha_{ct} \times \alpha_{Early\ strength} / SF$
$f_{bd,lifting}$	1,01	1,11	1,36	1,51			$f_{bd,lifting} = 2,25 \times \eta_1 \times \eta_2 \times f_{ctd,lifting} / SF$
$f_{yd,lifting}$					215		$f_{yd,lifting} = f_{yk} / SF$
E						210000	Modulus of elasticity, EC3 clause 3.2.6
G						81000	Shear modulus, EC3 clause 3.2.6
ν						0,3	Poisson's ratio, EC3 clause 3.2.6
f_u						510	EN 10025-2
f_y						355	EN 10025-2
f_{yd}						338	$f_{yd} = f_{yk} / \gamma_{MO}$
$f_{sd, weld}$						262	$f_{sd, weld} = f_u / (\gamma_{M2} \times \sqrt{3} \times \beta_w)$; $\beta_w = 0,9$
f_{sd}						195	$f_{sd} = f_{yk} / (\gamma_{MO} \times \sqrt{3})$
$f_{yd, lifting}$						117	$f_{yd, lifting} = f_{yk} / SF$
$f_{sd, weld, lifting}$						108	$f_{sd, weld, lifting} = f_u / (SF \times \sqrt{3} \times \beta_w)$; $\beta_w = 0,9$
$f_{sd, lifting}$						67	$f_{sd, lifting} = f_{yk} / (SF \times \sqrt{3})$

DIMENSIONS AND CROSS SECTION VALUES

Steel constructions

Tube : CFRHS 50x50x5, L=245 mm. Cold formed S355

Cross section values (NS-EN 10219-2)	B mm	H mm	S mm	Weight kg/m	A mm ²	$I \cdot 10^{-6}$ mm ⁴	$W_{ely} \cdot 10^{-3}$ mm ³	A_v mm ²
 Standard cross section	50	50	5,0	6,56	836	0,270	10,82	400
 Reduced cross section	50	50	5,0	6,56	756	0,225	9,97	400
 Rotated (45°) cross section during lifting.	70,7	70,7	5,0	6,56	836	0,270	8,66	400

Steelplate welded to tube CFRHS 50x50x5	B mm	H mm	A mm ²	W_{ely} mm ³	W_{ply} mm ³
Steelplate 80x80x10	80	80	800	-	-
Steelplate 30x170x15	30	15	450	1125,000	1687,50

Concrete constructions

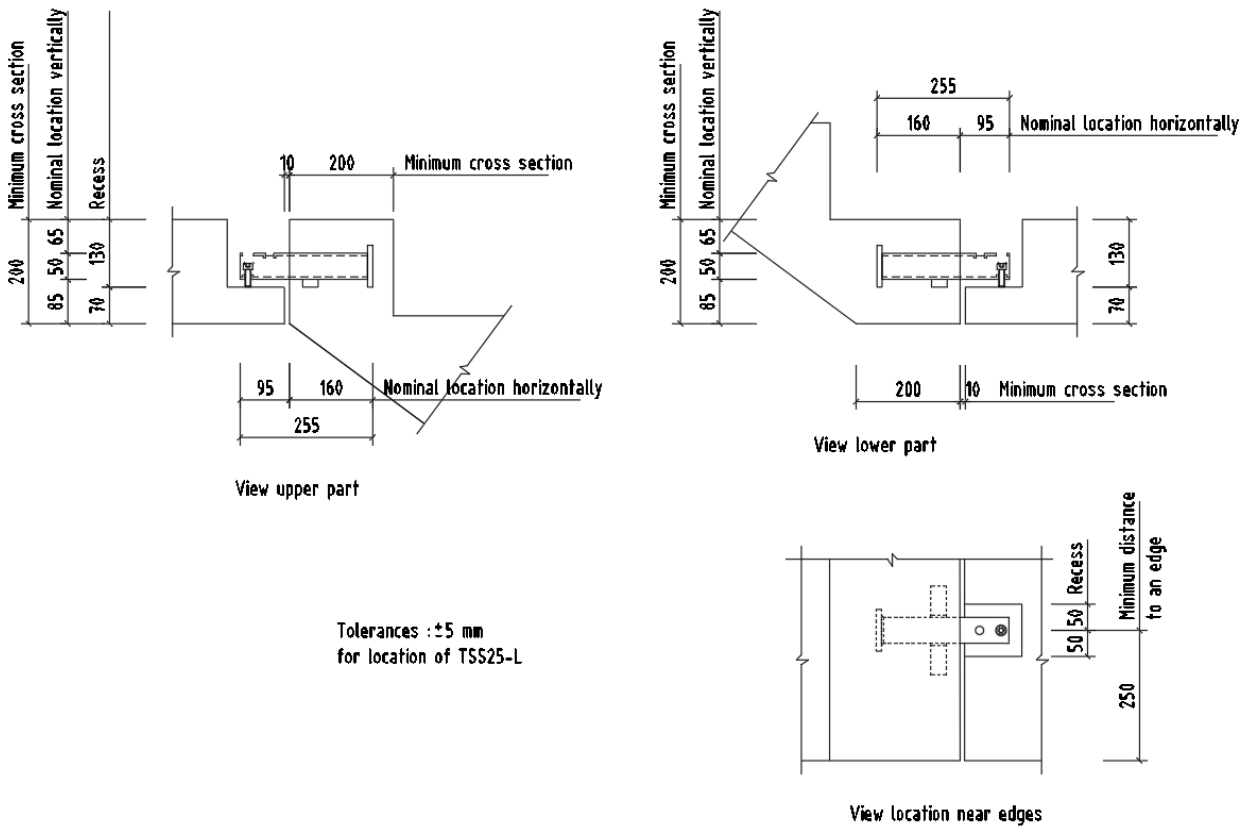


Figure 1: Minimum cross sections for stair- and repos elements

LOADS

Ultimate limit state (ULS)

Vertical ultimate limit state load: $F_{Ed} = 25 \text{ kN}$.

Horizontal ultimate limit state load (friction force): $H_{Ed} = 0,15 \times F_{Ed} = 0,15 \times 25 \text{ kN} = 3,75 \sim 4 \text{ kN}$.

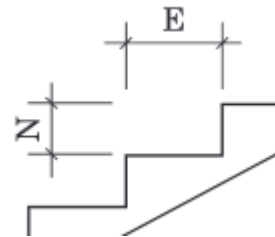
The horizontal load (H_{Ed}) is an assumed friction force at support, included in design of the unit, and in the calculation of the vertical equilibrium reaction forces. It is not a capacity that can be utilized for transfer of forces in design purpose

Lifting

Loads during lifting of stair are calculated in 5 cases. Those cases depends of various combinations of stair slopes (Various combinations of width of steps and height of rises).

The maximum vertical lifting load is 8 kN (Lifting anchor M16, maximum weight of stair element : $4 \times 8 = 32 \text{ kN} = 3,26 \text{ tons}$)

Load situation	Width of step (E) (mm)	Height of rise (N) (mm)	The angle of the stairs (°)	$F_{V, \text{lifting}}$ (kN)	$F_{H, \text{lifting}}$ (kN)
case 1	400	110	15,38	7,71	2,12
case 2	250	185	36,50	6,43	4,76
case 3	380	120	17,53	7,63	2,41
case 4	200	210	46,40	5,52	5,79
case 5			0	8,00	0,00
case 6 ¹⁾			0	12,00	0,00



1) Case 6 applies to TSS25 L with reinforcement to achieve lifting capacity up to 12 kN

Maximum loads :

- $F_{V, \text{Lifting}} = 8,00 \text{ kN}$ (Vertical)
- $F_{H, \text{lifting}} = 5,79 \text{ kN}$ (Horizontal)
- $F_{V, \text{Lifting, reinforcement}} = 12,00 \text{ kN}$ (Vertical) , see page 13.
- $F_{H, \text{lifting, reinforcement}} = 8,69 \text{ kN}$ (Horizontal)

PART 2 – ANCHORING OF TSS25 L

STATIC MODELS AND EQUILIBRIUM CALCULATIONS

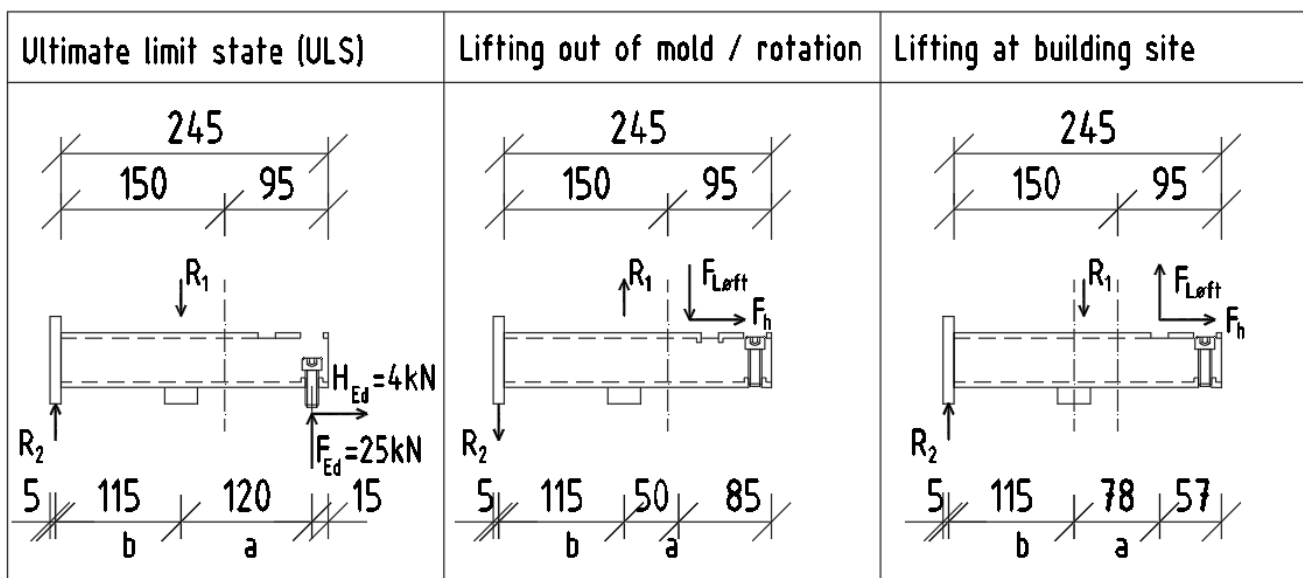


Figure 2: Static models

Load case regarded figure 2	Load (F_{Ed} or $F_{Lifting}$)	a (mm)	b (mm)	R_1 (kN)	R_2 (kN)
Ultimate limit state (ULS)	25	120	115	39,56	14,56
Lifting at building site	8	78	115	13,43	5,43
Lifting out of mold/rotating the element	8	50	115	11,48	3,48
Reinforced anchor Lifting at building site.	12	78	115	20,14	8,14
Reinforced anchor Lifting out of mold/rotating the element	12	50	115	17,22	5,22

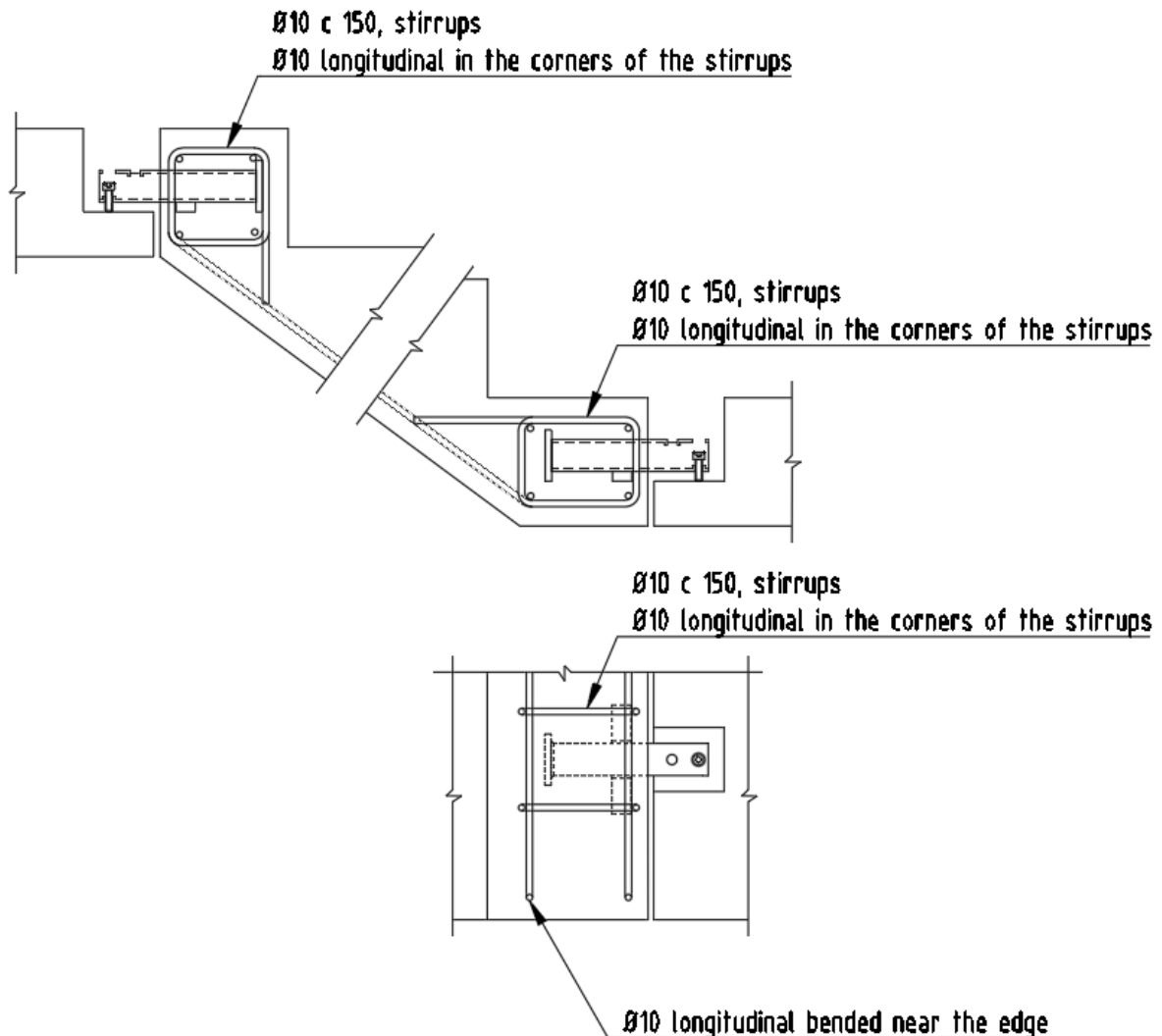


Figure 3: Minimum reinforcement

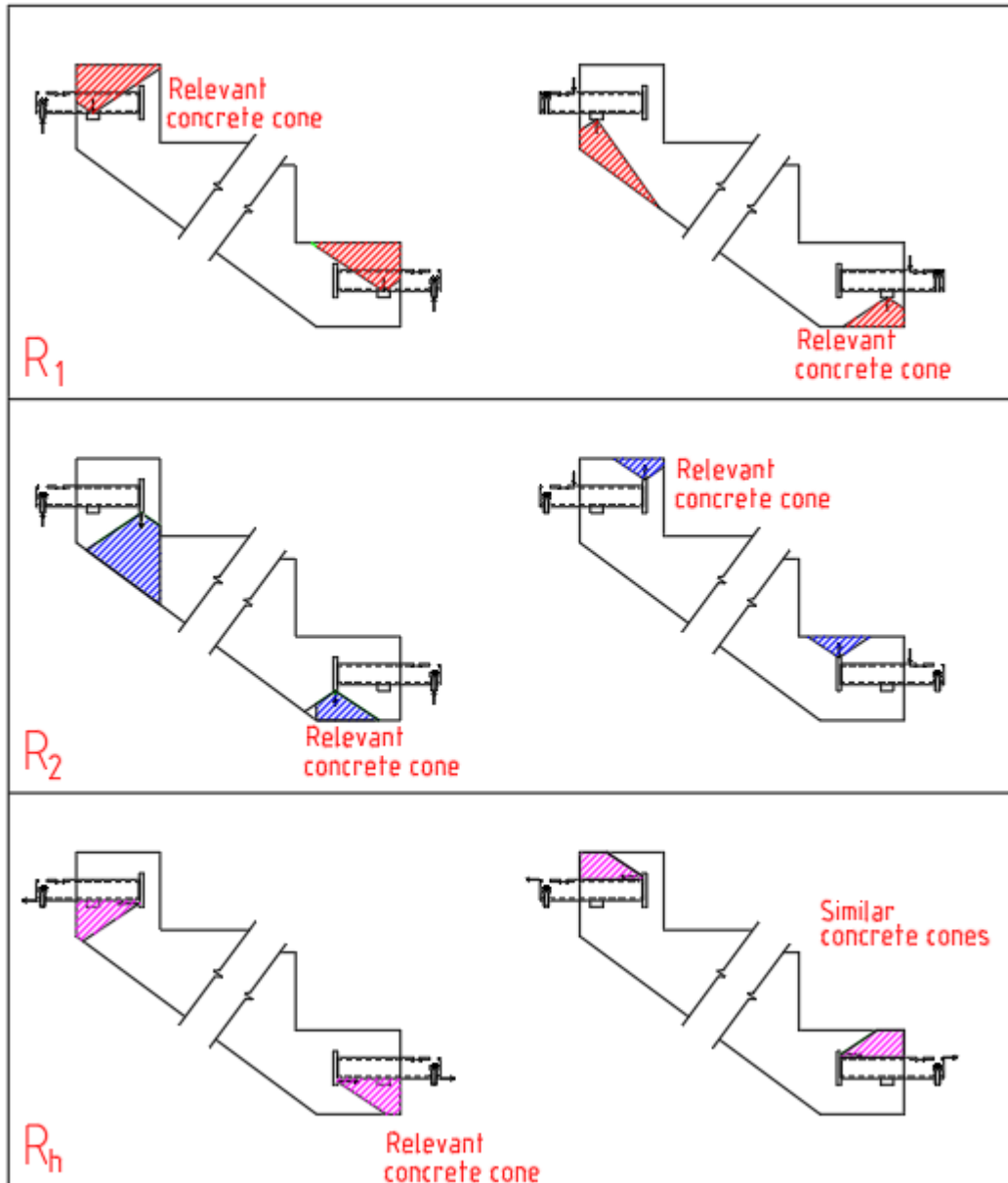
Anchoring of TSS25-L is calculated according to the rules given in Technical Specification CEN / TS 1992-4-2: 2009.

TSS25-L has steelplate welded to the main tube which activates the concrete in the conditions written above.

The assumptions for the calculations are as follows :

- a) Non-cracked concrete structure for the force R_1 and for the horizontal forces H_{Ed} and $F_{H, lifting}$.
This assumption requires reinforcement to be applied to the boundary zones as shown in Figure 3.
The required reinforcement is determined from the largest calculated amount of reinforcement in the following three points:
 - 1) EC2, section 9.3.1.1 notice to (1), Minimum reinforcement at TSS25-L corresponding to reinforcement $\text{Ø}10 \text{ c } 150 \text{ mm}$. (20% increase of load R_1 .)
 - 2) EC2, section 9.3.1.1, determined by formula $A_{s, min} = 0.26 (f_{ctm} / f_{yk}) bd$
 - 3) EC2, section 9.3.1.2 (1)
- b) Cracked concrete structure for the force R_2

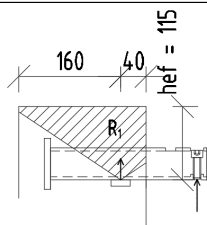
CONCRETE CONE FAILURE REGARDS TO R_1 , R_2 og R_h



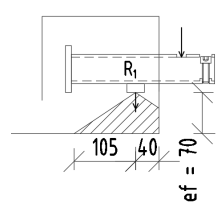
CONCRETE PARAMETERS, CEN/TS 1992-4-2:2009, pkt 6.2.5.1

Parameters	Strenght classes of concrete				Design formulas / references
	C30/37 (N/mm ²)	C35/45 (N/mm ²)	C45/55 (N/mm ²)	C55/67 (N/mm ²)	
$f_{ck,cube}$	37	45	55	67	EC2, Tabell 3.1
Non-cracked K_{1,γ_c} (N/mm ^{1.5})	48,3	53,2	58,8	64,9	CEN/TS 1992-4-2, 6.2.5.1 (5) - $K_{1,\gamma_c} = 11,9/1,5 \times \sqrt{f_{ck,cube}}$
Non-cracked $K_{1,SF}$ (N/mm ^{1.5})	23,8	26,3	29,1	32,1	CEN/TS 1992-4-2, 6.2.5.1 (5) - $K_{1,SF} = 11,9/SF \times \sqrt{f_{ck,cube}}$
Cracked K_{1,γ_c} (N/mm ^{1.5})	34,5	38,0	42,0	46,4	CEN/TS 1992-4-2, 6.2.5.1 (6) - $K_{1,\gamma_c} = 8,5/1,5 \times \sqrt{f_{ck,cube}}$
Cracked $K_{1,SF}$ (N/mm ^{1.5})	17,0	18,8	20,8	22,9	CEN/TS 1992-4-2, 6.2.5.1 (6) - $K_{1,SF} = 8,5/SF \times \sqrt{f_{ck,cube}}$

ANCHORING OF FORCE R₁

CEN/TS 1992-4-2, Figure 4, $s_1 = 83$ mm (two forces) distance to nearest egde $a_1 = 40$ mm 0 if $a_1 > 1,5 \times h_{ef}$ Distance to egde $a_2 = 160$ mm 0 if $a_2 > 1,5 \times h_{ef}$ Distance to egde $b_1 = 0$ mm 0 if $b_1 > 1,5 \times h_{ef}$ $h_{ef} = 115$ mm Actual projected area $A_{CN} = 85600$ mm ²		Area of anchoring $A_n: b = 30$ $l = 40$ $A_n = 1200$	
Anchoring depth $h_{ef} = 115$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 119025	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$	

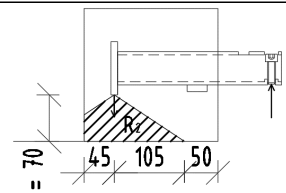
Parameters	Strenght classes of concrete				Design formulas / references	
	C30/37	C35/45	C45/55	C55/67		
$N_{Rd,c}^0$	59,5	65,6	72,6	80,1	$N_{Rd,c}^0 = K_{1,\gamma_c} \times h_{ef}^{1.5}$	
$N_{Rd,c,SF}^0$	23,5	25,9	28,7	31,6	$N_{Rd,c,SF}^0 = K_{1,SF} \times h_{ef}^{1.5} \times \alpha_{early\ strength}$	
Non-cracked $N_{Rd,c,non-cracked}$	42,8	47,2	52,2	57,6	$N_{Rd,c,non-cracked} = N_{Rd,c}^0 \times A_{CN} / A_{CN}^0$	$R_{1,ULS} = 39,56$ kN, capacity OK for B30
Max. compressive stress σ_c	207,200	252,000	308,000	375,200	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} / \gamma_c$	
Non-cracked $N_{Rd,c,SF,non-cracked}$	16,9	18,6	20,6	22,8	$N_{Rd,c,SF,non-cracked} = N_{Rd,c,SF}^0 \times A_{CN} / A_{CN}^0$	$R_{1,lifting} = 13,43$ kN, capacity OK for B30
Max. compressive stress σ_c	81,9	99,6	121,7	148,2	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} \times \alpha_{early\ strength} / SF$	Notice: Lifting capacity B30 : 800 kg

CEN/TS 1992-4-2, Figure 4, $s_1 = 83$ mm (two forces) distance to nearest egde $a_1 = 40$ mm 0 dersom $a_1 > 1,5 \times h_{ef}$ Distance to egde $a_2 = 105$ mm 0 dersom $a_2 > 1,5 \times h_{ef}$ Distance to egde $b_1 = 0$ mm 0 dersom $b_1 > 1,5 \times h_{ef}$ $h_{ef} = 70$ mm Actual projected area $A_{CN} = 42485$ mm ²		Area of anchoring $A_n: b = 30$ $l = 30$ $A_n = 900$	
Anchoring depth $h_{ef} = 70$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 44100	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$	

Parameters	Concrete				Design formulas / references	
	C30/37	C35/45	C45/55	C55/67		
$N_{Rd,c,SF}^0$	11,2	12,3	13,6	15,0	$N_{Rd,c,SF}^0 = K_{1,SF} \times h_{ef}^{1.5} \times \alpha_{early\ strength}$	Case : Lifting out of mold
Non-cracked $N_{Rd,c,SF,non-cracked}$	10,8	11,9	13,1	14,5	$N_{Rd,c,SF,non-cracked} = N_{Rd,c,SF}^0 \times A_{CN} / A_{CN}^0$	$R_{1,lifting} = 11,48$ kN, capacity OK for B35
Max. compressive stress σ_c	81,9	99,6	121,7	148,2	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} \times \alpha_{early\ strength} / SF$	Notice: Lifting capacity B30 : 700 kg

ANCHORING OF FORCE R_2

CEN/TS 1992-4-2, Figure 4, $s_1 = 0$ mm (one force) distance to nearest edge $a_1 = 45$ mm $h_{ef} = 70$ mm Actual projected area $A_{CN} = 31500$ mm ²		Area of anchoring A_n : $b = 10$ mm $l = 15$ mm $A_n = 150$ mm ²			
Anchoring depth $h_{ef} = 70$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 44100	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$			
Concrete strength classes					
Parameters	C30/37	C35/45	C45/55	C55/67	Design formulas / references
$N_{Rd,c}^0$	28,3	31,2	34,5	38,0	$N_{Rd,c}^0 = K_{1,IC} \times h_{ef}^{1,5}$
$N_{Rd,c,SF}^0$	11,2	12,3	13,6	15,0	$N_{Rd,c,SF}^0 = K_{1,SF} \times h_{ef}^{1,5} \times \alpha_{earlystrength}$
Cracked $N_{Rd,c,cracked}$	14,1	15,6	17,2	19,0	$N_{Rd,c,cracked} = 0,7 \times N_{Rd,c}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	148,000	180,000	220,000	268,000	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 6,0 \times f_{ck,cube} / \gamma_c$
Cracked $N_{Rd,c,SF,cracked}$	5,6	6,2	6,8	7,5	$N_{Rd,c,SF,cracked} = 0,7 \times N_{Rd,c,SF}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	58,5	71,1	86,9	105,9	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 6,0 \times f_{ck,cube} \times \alpha_{earlystrength} / SF$



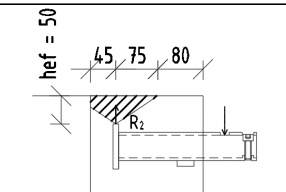
R_2

$h_{ef} = 70$

45 105 50

$R_2, ULS =$	14,56	kN
Notice : C30/37 for $F_{Ed} <$	24,27	kN
$R_2, lifting =$	5,43	kN, capacity OK for C30/37
Notice: Lifting capacity C30/37 :	800	kg

CEN/TS 1992-4-2, Figure 4, $s_1 = 0$ mm (one force) distance to nearest edge $a_1 = 45$ mm $h_{ef} = 50$ mm Actual projected area $A_{CN} = 18000$ mm ²		Area of anchoring A_n : $b = 10$ mm $l = 15$ mm $A_n = 150$ mm ²			
Anchoring depth $h_{ef} = 50$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 22500	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$			
Concrete strength classes					
Parameters	C30/37	C35/45	C45/55	C55/67	Design formulas / references
$N_{Rd,c}^0$	6,7	7,4	8,2	9,1	$N_{Rd,c}^0 = K_{1,IC} \times h_{ef}^{1,5} \times \alpha_{earlystrength}$
$N_{Rd,c,SF}^0$	3,77	4,16	4,60	5,08	$N_{Rd,c,SF}^0 = 0,7 \times N_{Rd,c}^0 \times A_{CN} / A_{CN}^0$
Cracked $N_{Rd,c,cracked}$	3,77	4,16	4,60	5,08	$N_{Rd,c,cracked} = 0,7 \times N_{Rd,c}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	58,5	71,1	86,9	105,9	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 6,0 \times f_{ck,cube} \times \alpha_{earlystrength} / SF$



R_2

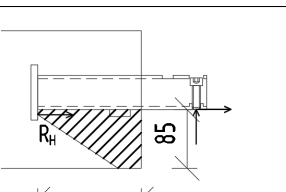
$h_{ef} = 50$

45 75 80

Case : Lifting out of mold	
$R_2, lifting =$	3,48 kN, capacity OK for C30/37
Notice: Lifting capacity C30/37 :	800 kg

ANCHORING OF FORCE R_H

CEN/TS 1992-4-2, Figure 4, $s_1 = 0$ mm (one force) distance to nearest edge $a_1 = 85$ mm, $a_2 = 77,5$ mm $h_{ef} = 150$ mm Actual projected area $A_{CN} = 38250$ mm ²		Area of anchoring A_n : $b = 30$ mm $l = 75$ mm $A_n = 2250$ mm ²			
Anchoring depth $h_{ef} = 150$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 202500	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$			
Concrete strength classes					
Parameters	C30/37	C35/45	C45/55	C55/67	Design formulas / references
$N_{Rd,c}^0$	88,7	97,8	108,1	119,3	$N_{Rd,c}^0 = K_{1,IC} \times h_{ef}^{1,5}$
$N_{Rd,c,SF}^0$	35,0	38,6	42,7	47,1	$N_{Rd,c,SF}^0 = K_{1,SF} \times h_{ef}^{1,5} \times \alpha_{earlystrength}$
Non-cracked $N_{Rd,c,non-cracked}$	16,7	18,5	20,4	22,5	$N_{Rd,c,non-cracked} = N_{Rd,c}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	207,200	252,000	308,000	375,200	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} / \gamma_c$
Non-cracked $N_{Rd,c,SF,non-cracked}$	6,6	7,3	8,1	8,9	$N_{Rd,c,SF,non-cracked} = N_{Rd,c,SF}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	81,9	99,6	121,7	148,2	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} \times \alpha_{earlystrength} / SF$



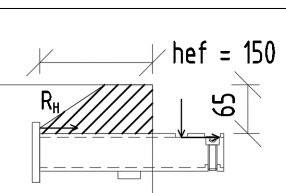
R_H

$h_{ef} = 150$

85

$H_{Ed, ULS} =$	4,0	kN, capacity Ok for C30/37
$F_{H,lifting} =$	5,79	kN, capacity Ok for C30/37
Notice: Lifting capacity C30/37 :	800	kg

CEN/TS 1992-4-2, Figure 4, $s_1 = 0$ mm (one force) distance to nearest edge $a_1 = 65$ mm, $a_2 = 57,5$ mm $h_{ef} = 150$ mm Actual projected area $A_{CN} = 29250$ mm ²		Area of anchoring A_n : $b = 30$ mm $l = 75$ mm $A_n = 2250$ mm ²			
Anchoring depth $h_{ef} = 150$	A_{CN}^0 (for $N_{Rd,c}^0$ or $N_{Rd,c,SF}^0$) = 202500	Reference projected area $A_{CN}^0 = (3 \times h_{ef}) \times (3 \times h_{ef})$			
Concrete strength classes					
Parameters	C30/37	C35/45	C45/55	C55/67	Design formulas / references
$N_{Rd,c}^0$	88,7	97,8	108,1	119,3	$N_{Rd,c}^0 = K_{1,IC} \times h_{ef}^{1,5}$
$N_{Rd,c,SF}^0$	35,0	38,6	42,7	47,1	$N_{Rd,c,SF}^0 = K_{1,SF} \times h_{ef}^{1,5} \times \alpha_{earlystrength}$
non-cracked $N_{Rd,c,SF,non-cracked}$	5,1	5,6	6,2	6,8	$N_{Rd,c,SF,non-cracked} = N_{Rd,c,SF}^0 \times A_{CN} / A_{CN}^0$
Max. compressive stress σ_c	81,9	99,6	121,7	148,2	CEN/TS 1992-4-2, 6.2.4 (2) $\sigma_c = 8,4 \times f_{ck,cube} \times \alpha_{earlystrength} / SF$



R_H

$h_{ef} = 150$

65

Case : Lifting out of mold	
$F_{H,lifting} =$	5,79 kN, capacity ok for C45/55
Notice: Lifting capacity C30/37 : 700 kg, C35/45=750 kg	

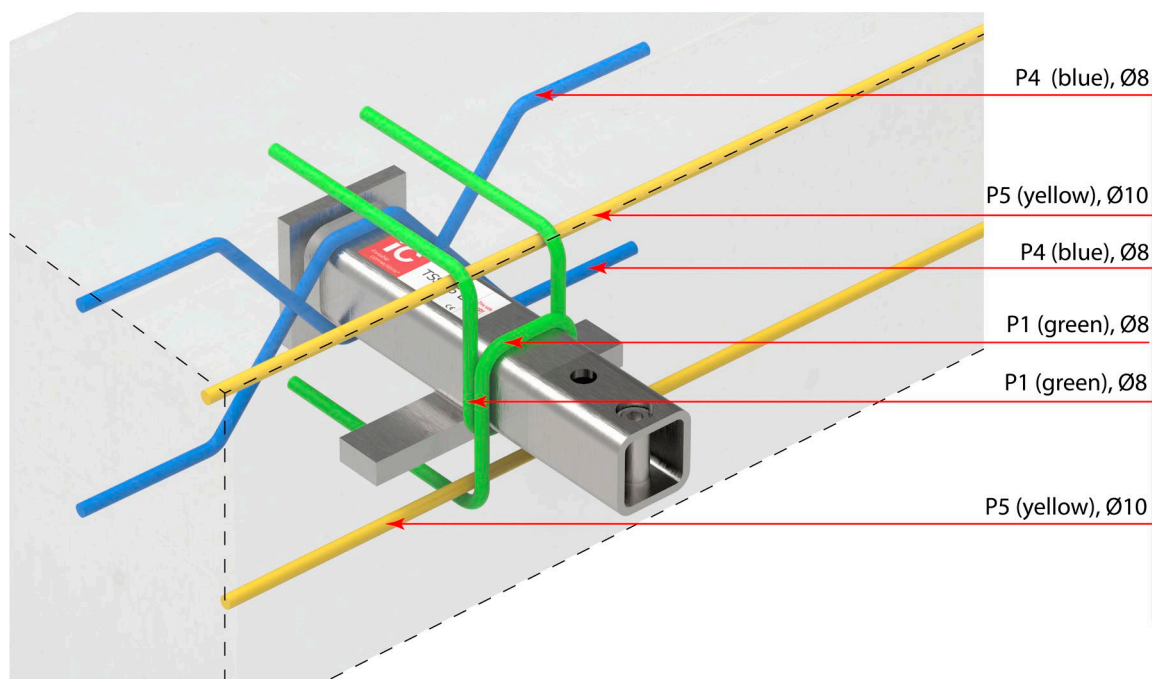
REINFORCEMENT FOR LIFT FROM 800 kg -1200 kg

Note : It is recommended a reinforcement for both forces R_1 (20,15 kN) and R_2 (8,15 kN).
The force R_h is taken care of by 2 Ø10 c150 stirrups (See fig 3)

Necessary cross section to maintain the force R_1 (20,15 kN) : $A_{slifting} = R_1 / f_{yd, lifting} = 20150 / 215 = 93,9 \text{ mm}^2$
ie. Ø8 mm stirrup, $A_s = 50,26 \times 2 = 100,52 \text{ mm}^2$

Force R_2 : The same cross section as R_1
You can choose to use the same reinforcement in R_1 and R_2

Reinforcement guidance :



CAPACITY OVERVIEW

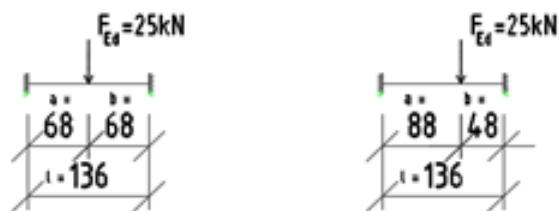
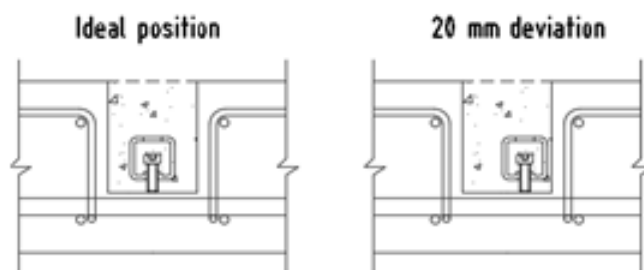
Load case	Concrete strength classes			
	C30/37	C35/45	C45/55	C55/67
Ultimate limit state (ULS)	< 23 kN	25 kN		
Lifting out of mold / rotating the element	700 kg	750 kg	800 kg	800 kg
Lifting at building site	800 kg	800 kg	800 kg	800 kg
Reinforced lifting connection	1200 kg	1200 kg	1200 kg	1200 kg

PART 3 – EXAMPLE: LOCAL REINFORCEMENT AROUND RECESS IN LANDING

STATIC MODELS AND EQUILIBRIUM CALCULATIONS

Ideal position of the load F_{Ed} :

$$\begin{aligned}
 F_{Ed} &= 25 \text{ kN} \\
 a &= 68 \text{ mm} \\
 b &= 68 \text{ mm} \\
 l &= 136 \text{ mm} \\
 \\
 V_{z,d,K2} &= 12,50 \text{ kN} \\
 V_{z,d,K1} &= 12,50 \text{ kN} \\
 \\
 M_{Ed,1} &= 425,00 \text{ kNmm} \\
 M_{Ed,3} &= 425,00 \text{ kNmm} \\
 M_{Ed,2} &= 425,00 \text{ kNmm}
 \end{aligned}$$



20 mm deviation in position of load F_{Ed} :

$$\begin{aligned}
 F_{Ed} &= 25 \text{ kN} \\
 a &= 88 \text{ mm} \\
 b &= 48 \text{ mm} \\
 l &= 136 \text{ mm} \\
 \\
 V_{z,d,K2} &= 17,86 \text{ kN} \\
 V_{z,d,K1} &= 7,14 \text{ kN} \\
 \\
 M_{Ed,1} &= 274,05 \text{ kNmm} \\
 M_{Ed,3} &= 354,65 \text{ kNmm} \\
 M_{Ed,2} &= 502,42 \text{ kNmm}
 \end{aligned}$$



The largest shear force and the largest bending moment occur in the same section.

$$\begin{aligned}
 M_{Ed} &= 502,42 \text{ kNmm} \\
 V_{Ed} &= 17,86 \text{ kN}
 \end{aligned}$$

Assume that the entire load F_{Ed} is taken up in reinforcement without contribution from the concrete structure. The main bar is calculated for a combined loads M_{Ed} and V_{Ed} .

Reinforcement $\varnothing 20$.

Capacity for the main bar due to bending moment :

$$M_{\text{red},1 \text{ stang}} = W f_{yd} = 341,5 \text{ kNmm} < ME_d \Rightarrow 2 \text{ } \varnothing 20, M_{\text{red},1, \text{ tot}} = 683,0 \text{ kNmm, OK}$$

$$W = \pi \varnothing^3 / 32 = 785,40 \text{ mm}^3$$

$$f_{yd} = 435 \text{ N/mm}^2$$

Capacity for the main bar due to shear force :

$$V_{\text{red},1 \text{ stang}} = A_s f_{yd} / \sqrt{3} = 78,9 \text{ kN} > V_{\text{ed}}, \text{ OK} \quad \text{Capacity of 2 bars } V_{\text{ed}, \text{ tot}} = 157,72 \text{ kN}$$

$$A_s = 314,16 \text{ mm}^2$$

$$\text{Combined loads : } (V_{\text{ed}}/V_{\text{red}})^2 + (M_{\text{ed}}/M_{\text{red}})^2 \leq 1,0 \quad 0,554 < 1,0 \text{ ok}$$

Force V2 :

$$V2 = 17,86 \text{ kN}$$

$$\text{Necessary reinforcement: } A_{s2} = V2 / f_{yd} = 41,1 \text{ mm}^2, \text{ stirrup } \varnothing 8 : A_s = 100 \text{ mm}^2$$

Stabilization of the bending moment M2

Distance from V2 to the end of the $\varnothing 20$ bar, $L_2 = 120 \text{ mm}$

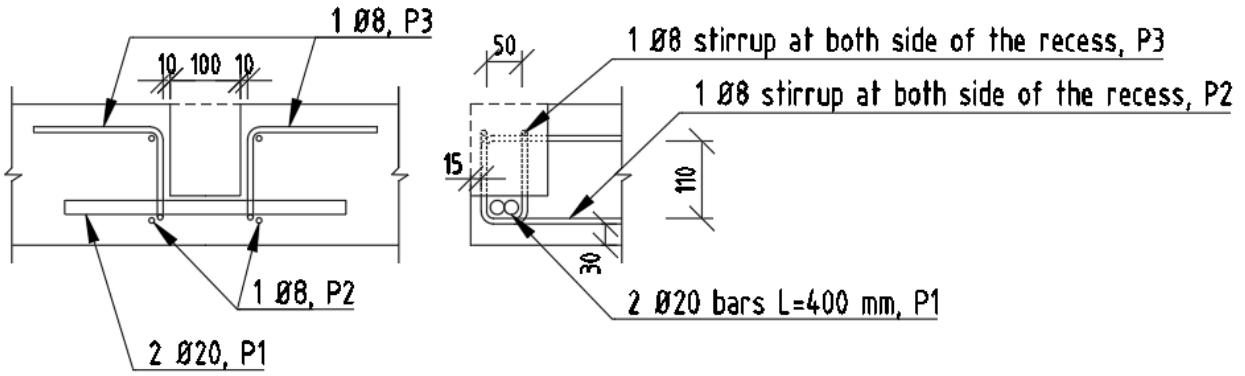
$$\text{Force : } P = M_2 / L_2 = 4,19 \text{ kN}$$

$$\text{Necessary area - concrete C30/37 : } \sigma = P / f_{\text{cd,C30/37}} = 246,29 \text{ mm}^2 \text{ (area } 10 \text{ mm} \times 25 \text{ mm)}$$

$$f_{\text{cd,C30/37}} = 17 \text{ N/mm}^2$$

The force at the end of the bar is not large enough to be a main issue in the connection, hence not dimensioning.

LOCAL REINFORCEMENT



P1	$\underline{\text{Ø}20 \text{ L} = 400}$
P2	$\begin{matrix} 310 \\ 115 \text{ } \text{Ø}8 \\ 310 \end{matrix}$
P3	$\begin{matrix} 180 \\ 135 \text{ } \text{Ø}8 \\ 135 \\ 70 \end{matrix}$

REVISION HISTORY	
Dato:	Beskrivelse:
13.10.2020	descriptive image anchoring 1200 kg
10.04.2015	First edition
08.01.2016	Included note on reinforcement ductility grade.
20.05.2016	New template
04.09.2019	Included horizontal friction force. Introduced reduced material factor $\gamma_{s,red2}$
24.01.2020	TSS25-L
27.03.2020	Include local reinforcement around recess in landing.
24.04.2020	Table – capacity overview. Small revision of text, page 6
28.09.2020	Lifing capacity – 1200 kg