INVISIBLE CONNECTORS AND ANCHORS

LIFTING CALCULATION METHOD

FIXINOX
BELGIUM / FRANCE / GULF AND MIDDLE EAST

WWW.FIXINOX.COM

INDEX

STRESS DETERMINATION ON SLEEVES, SPHERICAL HEAD ANCHORS AND FLAT HEAD ANCHORS

CALCULATION EXAMPLES:

FIXINOX
INVISIBLE CONNECTORS AND ANCHORS

Lifting calculation method

STRESS DETERMINATION ON SLEEVES, SPHERICAL HEAD ANCHORS AND FLAT HEAD ANCHORS

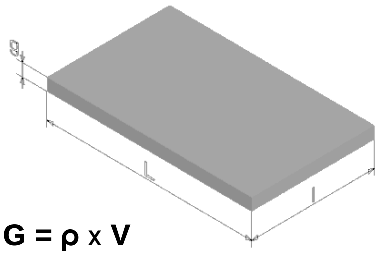
The anchor load capacity depends on multiplefactors such as:

- Deadweight of the precast concrete element "G"
- Adhesion to the mould
- Load direction, lifting angle
- Number of load bearing anchors
- Edge distance and spacing of the anchors
- Concrete strength at the time of operating: lifting or transporting
- Embedded depth of the anchor
- Dynamic forces
- Reinforcement arrangement

1. WEIGHT OF PRECAST UNIT

Prefabricated elements are composed of a higher concentration of reinforcing elements.

Total weight "G" of the precast reinforced concrete element is determined using a specific weight of: **ρ= 25 kN/m³**.



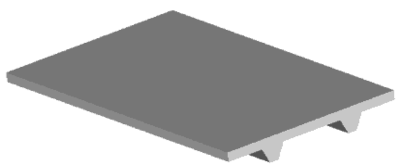
G = ρ x V
V = L x l x g
V : volume of precast (m³)
L : length (m)
l : width (m)
g : thickness (m)

2. FORMWORK ADHESION

Adhesion forces between mould and concrete depend on the type of mould used. Formwork adhesion "Ha" is calculated through the following equation:

Ha = q x A (kN)

A : area of contact between the mould and the concrete unit when starting to lift.
q : Formwork adhesion factor.
q = 1 kN/m² (for oiled steel mould).
q = 2 kN/m² (for varnished timber mould).
q = 3 kN/m² (for rough timber mould).



Special case :

For T- slabs, formwork adhesion is superior to average. An estimate can be made by multiplying the precast element weight:

H_a **= 2 x G** (double -T slabs)
H_a **= 3 x G** (ribbed elements)
H_a **= 4 x G** (coffered elements)

3. DYNAMIC FACTOR

When the movement of the precast unit is performed by lifting gear, dynamic forces that depend on the lifting gear used, appear. The lifting classes are described in DIN 15018.

	Lifting load coefficient f at lifting speed vh	
Lifting class	Up to 90 m/min	> 90 m/min
H1	1,1 + 0,002 vh	1,3
H2	1,2 + 0,004 vh	1,6
H3	1,3 + 0,007 vh	1,9
H4	1,4 + 0,009 vh	2,2

Lifting factor f is the acceleration factor. When lifting and carrying precast elements, the lifting load has to be multiplied by the "f" factor.

Class is determined by the selected lifting system (for example, class H1 for a bridge crane, class H4 for a fork-lift truck on an uneven ground).

The dynamic factor depends on the means used for the lifting. These factor depending on the type of lifting system are listed on the table below.

Lifting equipment	Lifting load coefficient f
Tower crane and fixed crane	1,2 *
Mobile crane	1,4 *
Lifting and transporting on flat ground	2 - 2,5
Lifting and transporting on uneven terrain	3 - 4

* Lower values may be appropriate in precast plants if special arrangements are made.

For cranes with precision lifting, such as those in manufacturing plants the lifting load coefficient is f = 1.1 ÷ 1.3

In the precast factory:

for de-mould f = 1.1
for pitch and transport f = 1.3

On site:

for pitch/transport/install f = 1.5
when transporting suspended precast elements over uneven terrain, the lifting load coefficient used is f > 2.

INVISIBLE CONNECTORS AND ANCHORS

Lifting calculation method

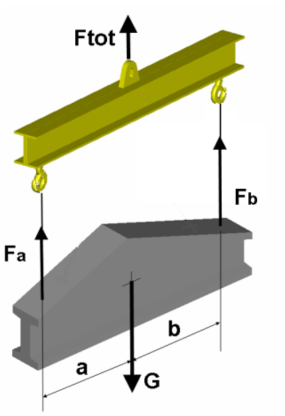
4. ASYMMETRICAL LOAD DISTRIBUTION

The load of each anchor depends on the embedded position of the anchor in the precast unit and also on the transporting mode.

$$F_a = \frac{F_{tot} \times b}{(a + b)}$$

$$F_b = \frac{F_{tot} \times a}{(a + b)}$$

F_{tot} : Total load



Note: To avoid tilting of the unit during transport, the load should be suspended from the lifting beam such that its centre of gravity is directly below the crane hook.

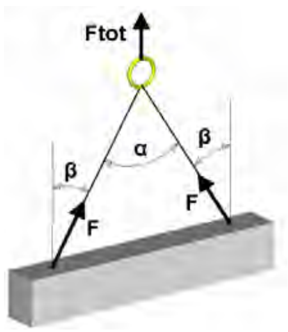
5. SPREAD ANGLE FACTOR

The cable angle ß is determined by the length of the suspending cable. We recommend that, if possible, ß should be kept to ß ≤30°. The tensile force on the anchor is increased with a spread angle factor z.

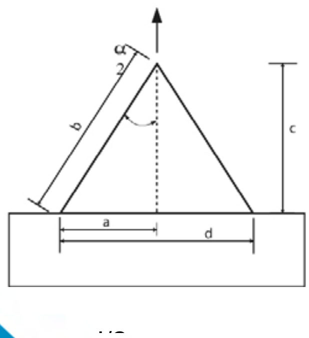
Note : If no lifting beam is used during transport, the anchor must be embedded symmetrically to the load.

$F = \frac{z \times F_{tot}}{n}$ where : $z = \frac{1}{\cos ß}$ spread angle factor.

n : number of load bearing anchors



α = 2 x ß



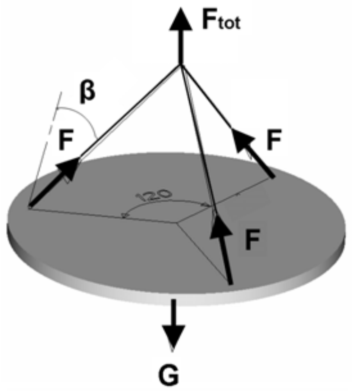
Cable angle ß	Spread angle factor z
0°	1,00
7,5°	1,01
15,0°	1,04
22,5°	1,08
30,0°	1,16
37,5° *	1,26
45,0° *	1,41

* preferred ß ≤30°

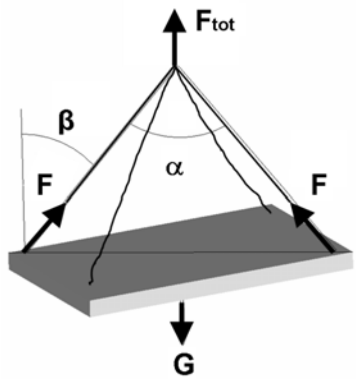
Ratio a/b	Angle (degree α)	Spread angle factor
0,000 < a/b < 0,259	0 < α < 30	1,04
0,259 < a/b < 0,383	30 < α < 45	1,08
0,383 < a/b <0,500	45 < α < 60	1,16
0,500 < a/b <0,608	60 < α < 75	1,26
0,608 < a/b <0,707	75 < α < 90	1,41

6. COUNTING LOAD BEARING ANCHORS

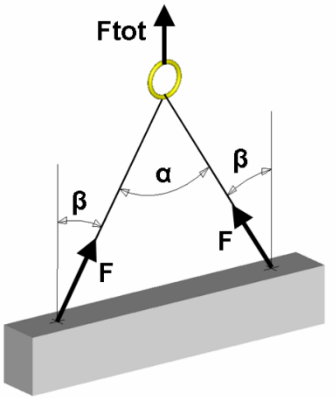
n = 3



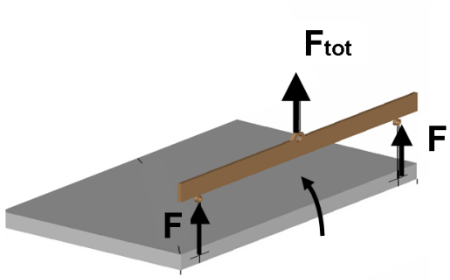
n = 2
only two anchors take over the load bearing



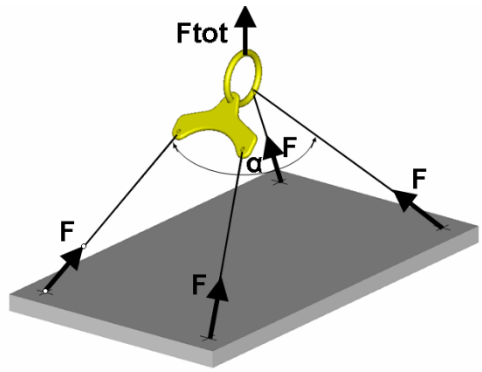
n = 2



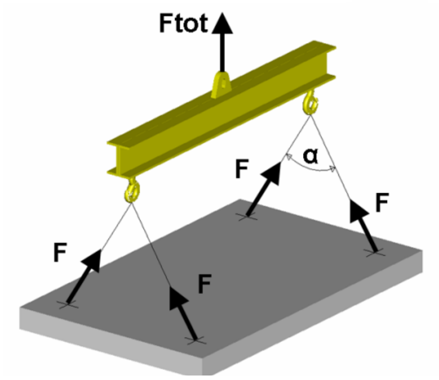
n = 2



n = 4

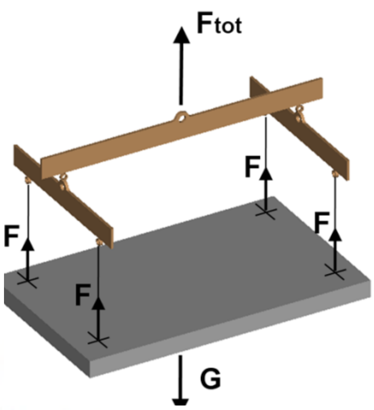


n = 4



The compensated lifting slings ensure equal load distribution.

A perfect static weight distribution can be obtained through the use of a lifting beam and two pairs of anchors set out symmetrically.



n = 4

A perfect static weight distribution can be obtained using a crossed spreader beam, which avoids angled pull.

7. DETERMINATION OF TOTAL LOAD "F $_{TOT}$"

Total load of precast unit for calculating the anchor is determined through the following equation:

- When de-mould $F_{tot} = G + Ha$
- When pitching $F_{tot} = \frac{G}{2}$
- When de-mould and pitching $F_{tot} = \frac{(G + Ha)}{2}$
- When transporting $F_{tot} = G$

8. DETERMINATION OF ANCHOR LOAD "F"

The load on each load bearing anchor is calculated with the following formula:

- When de-mould $F = \frac{(F_{tot} \text{ x f x z})}{n} = \frac{(G + Ha) \text{ x f x z}}{n}$
- When pitching $F = \frac{(F_{tot} \text{ x f x z})}{n} = \frac{(G/2 \text{ x f x z})}{n}$
- When de-mould and pitching $F = \frac{(F_{tot} \text{ x f x z})}{n} = \frac{[(G + Ha)/2] \text{ x z})}{n}$

During tilting, the concrete element remains supported on the ground, only the half of the forces have to be taken into account.
In the situation of pitching, load carrying capacity of sockets and anchors is limited to 50% of the axial load.

- When lifting $F = \frac{(F_{tot} \text{ x f x z})}{n} = \frac{(G \text{ x f x z})}{n}$

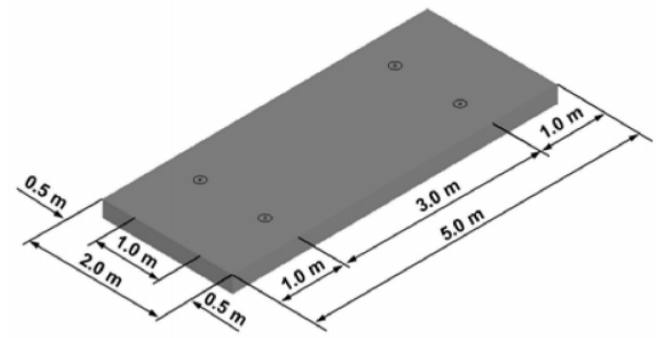
CALCULATION EXAMPLES

A. FLOOR ELEMENT

General dates	Symbol	De-mould	Mount
Concrete strength at de-mould [N/mm²]		20	
Concrete strength on site [N/mm²]			45
Weight for element [kN]	**G**	50	50
Mould area [m ²]	**A**	10	
Cable angle factor at de-mould (ß = 15,0°)	**z**	1,04	
Cable angle factor on site (ß = 30,0°)	**z**		1,16
Lifting load coefficient at de-mould	**f**	1,3	
Lifting load coefficient on site	**f**		1,3
Formwork adhesion factor [kN/m²]	**q**	1,0	
Anchor number for de-mould	**n**	4	
Anchor number for transport on site	**n**		4

Lifting calculation method

SLAB:



Dimensions: 5,00 x 2,00 x 0,20 (m^3)
Concrete strength class B45
Concrete strength at de-mould 20 N/mm^2
Weight : G= V x ρ
G= 5,00 x 2,0 x 0,2 (m^3) x 25 (kN/m^3) = 50 kN

Anchor for de-mould, for transport and montage.

SITUATION AT PRECAST FACTORY:

- The element will be taken out of the oiled steel formwork with a portal crane. There is work with an lifting beam to prevent that the angle to the concrete becomes smaller than 75º.
  The used cable angle factor will be z=1,04. Will also be taken into account: a lifting load factor f=1,3.

SITUATION AT BUILDING SITE:

- The element will be lift with the aid of a turning crane. There is work with 2 clutches and lifting beam to prevent that the angle to the concrete becomes smaller than 60º .
  The cable angle factor that must be used is z =1,16. Will also be taken into account: a lifting load factor of f =1,3

DETERMINATION OF THE LIFTING FORCE "F" PER ANCHOR:

At precast factory : Ha = q x A= 1,0 x 5 x 2 = 10 kN
Force per anchor: $F = \frac{(G + Ha) \times f \times z}{n} = \frac{(50 + 10) \times 1,3 \times 1,04}{4} = 20,28$ kN

At building site :
Force per anchor: $F = \frac{(G \times z \times f)}{n} = \frac{50 \times 1,16 \times 1,3}{4} = 18.85$ kN

CONCLUSION:

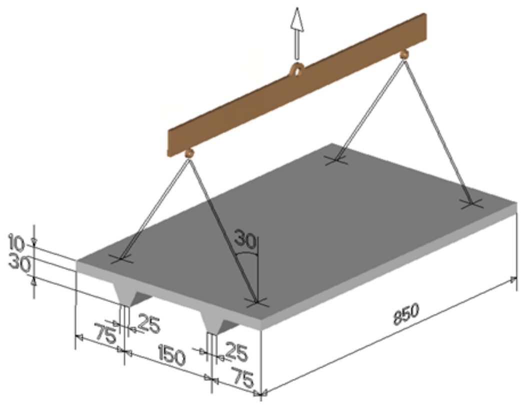
The floor element can be lifted with 4 T-Slot-anchors; Type T -25-120 in untreated, hot dip galvanized or in stainless carbon steel.

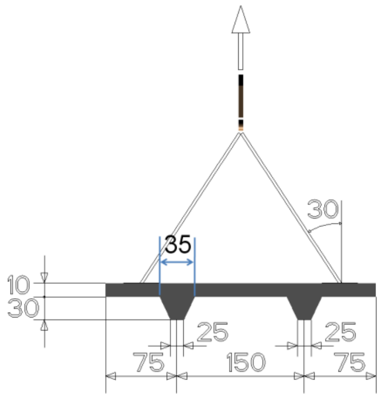
Chosen positions :
Length direction: 1/5 of the length = 1,00 m from the edge.
Transverse direction: 30% of the width = 0,50 m from the edge.

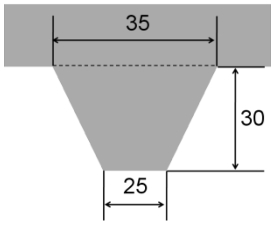
B. DOUBLE-T BEAM

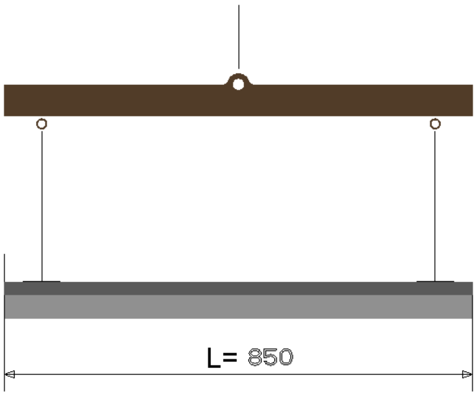
Load capacity when lifting and transporting at the manufacturing plant.

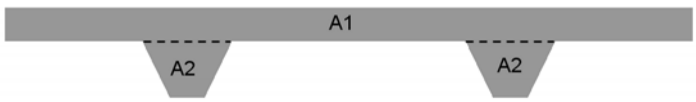
Concrete strength when de-mould	⩾25 N / mm²
Cable angle	ß = 30.0°
Spread angle factor	z = 1.16
Lifting load coefficient when transporting	f = 1.3
Lifting load coefficient when de-mould	f = 1.1
Anchor number	n = 4











L = 850 cm
A1 = 10 x 300 (cm²)
A1 = 0,1 x 3 (m²)

ρ= 25 kN/m³
A2 = [(35+25) x 30]/2 (cm²)

$$A2 = \frac{(0{,}35+0{,}25) \times 0{,}3}{2} = \frac{(0{,}6 \times 0{,}3)}{2} = 0{,}09 = 0{,}3^2\ (m^2)$$

Weight : G= V x ρ = (A x L) x ρ = (A1+A2 x 2) x L x ρ

G = [(0,3 + 0,3²) x 2] x 8.5 (m³) x 25 (kN/m³) = 102 kN

Formwork adhesion : Ha = 2 x G = 204 kN
Total load Ftot : Ha + G = 204 kN + 102 kN = 306 kN

Load per anchor when de-mould.

$$F = \frac{F_{tot} \times f \times z}{n} = \frac{306 \times 1{,}16 \times 1{,}1}{4} = 97{,}61\ kN$$

Load per anchor when transporting

$$F = \frac{F_{tot} \times f \times z}{n} = \frac{102 \times 1.16 \times 1.3}{4} = 38.45\ kN$$

USE 4 ANCHORS ALLOWABLE LOAD > 98 KN.

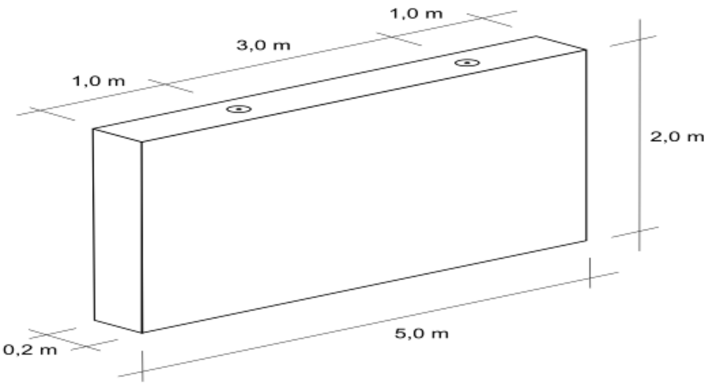
INVISIBLE CONNECTORS AND ANCHORS

Lifting calculation method

C. FACADE ELEMENT

Dimensions : 5,00 x 2,00 x 0,20 (m3)

- 4 T-Slot-anchors for de-mould
- 2 T-Slot-anchors for pitching, transport and mounting



ρ= 25 kN/m³
Concrete strength class B45
Strength at de-mould 20 N/mm²

Weight : G= V x ρ
G = 5,0 x 2,0 x 0,2 (m³) x 25 (kN/m³) = 50 kN

General date	Symbol	De-mould	Pitching	Mount
Concrete strength at de-mould [N/mm²]		20	20	
Concrete strength on site [N/mm²]				45
Weight for element [kN]	**G**	50		50
Mould area [m²]	**A**	10		
Spread angle factor at de-mould (ß = 15,0°)	**z**	1,04		
Spread angle factor at pitching (ß = 0.0°)	**z**		1,0	
Spread angle factor on site (ß = 30,0°)	**z**			1,16
Lifting load coefficient at de-mould	**f**	1,3		
Lifting load coefficient at pitching	**f**		1,3	
Lifting load coefficient on site	**f**			1,3
Formwork adhesion factor [kN/m²]	**q**	1,0		
Anchor number for de-mould	**n**	4		
Anchor number for transport on site	**n**			2

Lifting calculation method

SITUATION AT PRECAST FACTORY:

- The element will be taken out of the oiled steel formwork with a portal crane. In free storage the facade element will be brought to a vertical position. In the meantime, the element is brought in a vertical position, there is worked with a lifting beam to prevent that the angle to the concrete becomes smaller than 75º (ß = 15,0°). Hereby the element still rests on the floor so that the T- Slot-anchors only bear half of the weight. Only when the element is in a vertical position it can be lifted and the T-Slot-anchors will be loaded with the full weight. That is why the bringing of the element into a vertical position is not a normative loading. Also when de-mould and directly bringing into a vertical position with the aid of 2 T-Slot-anchors to the front side will not give a normative loading as well.
  While lifting with a lifting beam: The angle to the concrete is about 90º (ß = 0°), the used T-Slot-anchor spread angle factor will be z=1,0.
  Will also be taken into account: a lifting load factor f=1,3.

SITUATION AT BUILDING SITE:

- The element will be lifted with the aid of a turning crane. There is worked with 2 clutches and a lifting beam to prevent that the angle to the concrete becomes about 60º (ß = 30,0°). The used spread angle factor will be z=1,16.
  Will also be taken into account: a lifting load factor of f=1,3.

DETERMINATION OF THE LIFTING FORCE “F” PER ANCHOR:

At precast factory : Ha = q x A = 1,0 x 5 x 2 = 10 kN
Force per anchor: $\mathbf{F = \frac{(G + Ha) \times f \times z}{n}} = \frac{(50 + 10) \times 1{,}3 \times 1{,}04}{4} = 20{,}28$ kN

At precast factory - pitching :
Force per anchor: $\mathbf{F = \frac{(G/2 \times f \times z)}{n}} = \frac{50/2 \times 1{,}3 \times 1{,}0}{2} = 16{,}25$ kN

At building site :
Force per anchor: $\mathbf{F = \frac{(G \times f \times z)}{n}} = \frac{50 \times 1{,}3 \times 1{,}16}{2} = 37{,}70$ kN

The floor element can be lifted with 4 T-Slot-anchors; Type T -25-120 in untreated, hot dip galvanized or in stainless carbon steel.
The facade element can be lifted with 2 T-Slot-anchors type T -50-340 in untreated, hot dip galvanized or in stainless carbon steel.

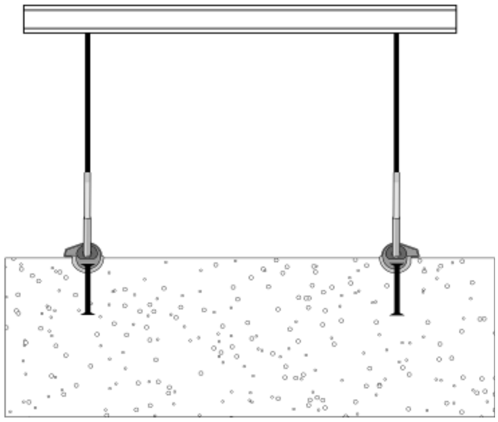
Chosen positions :
Length direction: ca. 1/5 of the length = 1,00 m from the edge.
Transverse direction: 1/4 of the length = 0,50 m from the edge.

Lifting calculation method

D. VERTICALLY PREFABRICATED BEAMS – AXIAL LIFTING

Dimensions : 5,00 x 1,00 x 0,40 (m3)

- 2 T-Slot-anchors for de-mould
- 2 T-Slot-anchors for pitching, transport and mounting



ρ= 25 kN/m³
Concrete strength class B45
Strength at de-mould 15 N/mm²

Weight : G= V x ρ
G = 5,0 x 1,0 x 0,4 (m³) x 25 (kN/m³) = 50 kN

General dates	Symbol	De-mould	Mount
Concrete strength at de-mould [N/mm²]		15	
Concrete strength on site [N/mm²]			45
Weight for element [kN]	**G**	50	
Mould area [m ²]	**A**	2	
Spread angle factor at de-mould (ß = 0.0°)	**z**	1,0	
Spread angle factor on site (ß = 0.0°)	**z**		1,0
Lifting load coefficient at de-mould	**f**	1,3	
Lifting load coefficient on site	**f**		1,3
Formwork adhesion factor [kN/m²]	**q**	3,0	
Anchor number for de-mould	**n**	2	
Anchor number for transport on site	**n**		2

SITUATION AT PRECAST FACTORY:

- The prefabricated element is lifted from the rough timber oiled mould with a tower crane and using 2 anchors. At lifting is used a lifting beam to prevent that the angle to the concrete becomes smaller than 90º. The angle to the concrete is about 90º (ß = 0°). The adhesion to mould factor is q=3.
  Spread angle factor will be 1,00. Will also be taken into account: lifting load factor = 1,3.

Lifting calculation method

DETERMINATION OF THE LIFTING FORCE "F" PER ANCHOR:

At precast factory : Ha = q x A = 3,0 x 5 x 2 = 6 kN

Force per anchor: $\mathbf{F} = \frac{\mathbf{(G + Ha) \times f \times z}}{\mathbf{n}} = \frac{(50 + 6) \times 1{,}3 \times 1{,}0}{2} = 36{,}4$ kN

At building site :

Force per anchor: $\mathbf{F} = \frac{\mathbf{(G \times f \times z)}}{\mathbf{n}} = \frac{50 \times 1{,}3 \times 1{,}0}{2} = 32{,}5$ kN

The situation at the prefab factory is for the choice of the loading class normative T-Slot-anchor: T -50 kN.

CONCLUSION :

The floor element can be lifted with 2 T-Slot-anchors type T -50-340 in untreated, galvanized or in stainless carbon steel.

Chosen positions :
Length direction: 1/5 of the length = 1,00 m from the edge.
Transverse direction: in the middle of the material thickness.

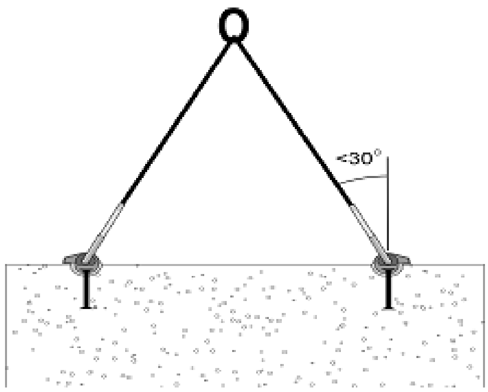
E. VERTICALLY PREFABRICATED BEAMS – INCLINED LIFTING

Dimensions : 5,00 x 1,00 x 0,40 (m3)

- 2 T-Slot-anchors for de-mould
- 2 T-Slot-anchors for pitching, transport and mounting

ρ= 25 kN/m³
Concrete strength class B45
Strength at de-mould 15 N/mm²

Weight : G= V x ρ
G = 5,0 x 1,0 x 0,4 (m³) x 25 (kN/m³) = 50 kN



Lifting calculation method

General dates	Symbol	De-mould	Mount
Concrete strength at de-mould [N/mm²]		15	
Concrete strength on site [N/mm²]			45
Weight for element [kN]	**G**	50	
Mould area [m ²]	**A**	2	
Cable angle factor at de-mould (ß = 30.0°)	**z**	1,16	
Cable angle factor on site (ß = 30.0°)	**z**		1,16
Lifting load coefficient at de-mould	**f**	1,3	
Lifting load coefficient on site	**f**		1,3
Formwork adhesion factor [kN/m²]	**q**	3	
Anchor number for de-mould	**n**	2	
Anchor number for transport on site	**n**		2

SITUATION IN THE PREFAB FACTORY:

- The prefabricated element is lifted from the rough timber oiled mould with a tower crane and using 2 anchors. At bringing in a vertical position there is worked with a spring that is used with a top angle smaller than 60º (ß = 30,0°).The used cable angle factor will be 1,16. Will also be taken into account: Lifting load factor f= 1,3. The adhesion to mould factor is q=3.

SITUATION AT THE BUILDING SITE:

- On site the element is lifted with a tower crane at an angle ß = 30,0°. In this case the cable angle factor z=1,16 and the lifting load factor is f=1,3.

DETERMINATION OF THE LIFTING FORCE FPER ANCHOR:

In the prefab factory: Ha = q x A = 3 x 5 x 0,4 = 6 kN

Force per anchor: $\mathbf{F = \dfrac{(G + Ha) \times f \times z}{n}} = \dfrac{(50 + 6) \times 1{,}3 \times 1{,}16}{2} = 42{,}22$ kN

At the building site:

Force per anchor: $\mathbf{F = \dfrac{(G \times f \times z)}{n}} = \dfrac{50 \times 1{,}3 \times 1{,}16}{2} = 37{,}70$ kN

The situation at the prefab factory is for the choice of the loading class normative T-Slot-anchor: T -50 kN.

Chosen positions:

Length direction: 1/5 of the length = 1,00 m from the edge.

Transverse direction: in the middle of the material thickness.

Lifting calculation method

INVISIBLE CONNECTORS AND ANCHORS

FIXINOX France
21 rue Jean-Pierre Timbaud – 75011 Paris
Agence Commerciale Île-de-France - Tél. +33 (0)6 22 05 27 23
Nord, Est, Sud-Est, international : +33 (0)6 88 97 07 83
Fax : +32 (0) 71 81 05 29

FIXINOX Belgium
Z.I. de Jumet Première rue, 8 - 6040 Jumet (Charleroi)
Tél : +32 (0) 71 81 05 26 • Fax : +32 (0) 71 81 05 29
info@fixinox.be

EPS Gulf & Middle East
Tél : +971-6-5251297
info@eps-gulf.com

Viva Bahria Pearl, Doha

Ibis Hotel, Dubai

Stadium, Al Ain

Cooling Tower, Doha