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Design and use of inserts for lifting and handling of precast concrete elements

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National foreword

This Published Document is the UK implementation of CEN/TR 15728:2016. It supersedes PD CEN/TR 15728:2008 which is withdrawn.

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Design and use of inserts for lifting and handling of precast concrete elements

Conception et utilisation d'inserts pour le levage et la manutention du béton préfabriqué - Éléments

Bemessung und Anwendung von Transportankern für Betonfertigteile - Elemente

This Technical Report was approved by CEN on 27 July 2015. It has been drawn up by the Technical Committee CEN/TC 229.

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European foreword

This document (CEN/TR 15728:2016) has been prepared by Technical Committee CEN/TC 229 “Precast concrete products”, the secretariat of which is held by AFNOR.

This document supersedes CEN/TR 15728:2008.

To ensure the performance of the precast concrete products, lifting and handling should be taken into account in the design of the product.

Inserts are used for lifting and handling of precast elements. They should meet an appropriate degree of reliability. They should sustain all actions and influences likely to occur during execution and use.

This Technical Report deals with lifting inserts cast into precast concrete elements. The intent of this document is to give information to precast product designers.

The failure of inserts for lifting and handling could cause risk to human life and/or lead to considerable economic consequences. Therefore inserts for lifting and handling should be selected and installed properly by skilled personnel according to the lifting and handling instructions.

This Technical Report based on current practices gives recommendations for correct choice and design of lifting inserts according to the lifting capacity of their part embedded in the concrete. It is based on EN 1992-1-1 (Eurocode 2), EN 1993-1-1 (Eurocode 3), CEN/TS 1992-4-1 and on published supplier’s data.

Safety levels should be determined nationally. In the Technical Report numerical values for safety factors as used in different CEN member states are given for information and are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management (Factory Production Control) applies. They may be applied in the absence of national regulations.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

1 Scope

1.1 General

This Technical Report provides recommendations for the choice and use of cast-in steel lifting inserts, hereafter called 'inserts' for the handling of precast concrete elements. They are intended for use only during transient situations for lifting and handling, and not for the service life of the structure. The choice of insert is made according to the lifting capacity of their part embedded in the concrete, or may be limited by the capacity of the insert itself and the corresponding key declared by the insert manufacturer.

The report covers commonly used applications (walls/beams/columns and solid slabs and pipes). The range of these applications is further limited to prevent other types of failure than concrete breakout failure (cone failure), bond failure, failure of reinforcement or failure in the steel insert.

Due to lack of information this report does not cover double shell walls, floor plates and beams for beam-and-block floor systems.

The safety levels are given for information and are intended for short-term-handling and transient situations.

This Technical Report applies only to precast concrete elements made of normal weight concrete and manufactured in a factory environment and under a factory production control (FPC) system (in accordance with EN 13369:2013, 6.3) covering the insert embedment.

This Technical Report does not cover:

— the design of the lifting inserts independently placed on the market;

— lifting inserts for permanent and repeated use.

This Technical Report is prepared based on the fact that the anchorage in the concrete of parts of the lifting assembly is governed by the Construction Products Regulation. Lifting accessories independently placed on the market are governed by the Machinery Directive.

1.2 Types of inserts for lifting and handling

This Technical Report applies to the embedment of lifting inserts. Devices made by the precaster may consist of smooth bars, prestressing strands, steel plates with anchorage or steel wire ropes. The system devices may be e.g. internal threaded inserts, flat steel inserts and headed inserts.

Lifting loops of ribbed bars are not covered.

1.3 Minimum dimensions

This Technical Report applies in general to inserts with a minimum nominal diameter of 6 mm or the corresponding cross section. In general, the minimum anchorage depth should be h_{ef} = 40 mm.

Wire ropes of diameter less than 6 mm are not covered.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1990:2002, *Eurocode - Basis of structural design*

EN 1992-1-1:2004, *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

EN 1993-1-1:2005, *Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings*

EN 10025-2, *Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels*

EN 12385-4, *Steel wire ropes — Safety — Part 4: Stranded ropes for general lifting applications*

EN 13369:2013, *Common rules for precast concrete products*

EN 13414-1, *Steel wire rope slings — Safety — Part 1: Slings for general lifting service*

3 Terms and definitions and symbols

For the purposes of this document, the following terms and definitions and symbols apply.

3.1 Definitions

3.1.1
concrete breakout failure
concrete cone separated from the base material by loading the insert

3.1.2
concrete breakout resistance
resistance corresponding to a concrete cone surrounding the insert or group of inserts separating from the member

3.1.3
edge distance
distance from the edge of the concrete surface to the centre of the nearest insert

3.1.4
anchorage length
for cast-in headed insert bolts and splayed inserts is illustrated in Figure 1

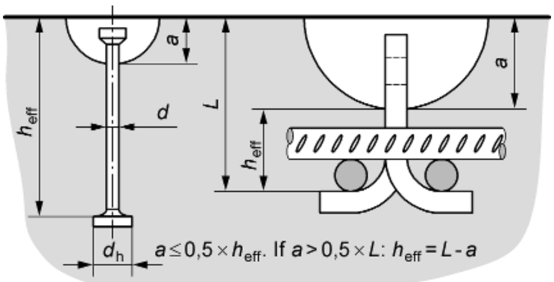


Figure 1 — Examples of anchorage length for different types of inserts

3.1.5
embedment depth
distance from the concrete surface to the farthest point of insert, measured perpendicular to the concrete surface

3.1.6
Factory Production Control
FPC
quality system satisfying the requirements in EN 13369:2013, 6.3

3.1.7
headed insert
steel insert with a head for anchorage installed before placing concrete

3.1.8
insert
steel unit cast into concrete and used for lifting of precast elements

3.1.9
insert loading
axial, shear or combined - Loads applied to the insert

3.1.10
insert resistance
load capacity (characteristic value) of the part of the insert embedded in the concrete (different from maximum working load of the insert – see 3.1.13). In this report, the wording "characteristic resistance" is sometimes used

3.1.11
lifting system
system of lifting key and appropriate insert

3.1.12
maximum working load
maximum load guaranteed by the supplier before steel failure, reduced by application of the relevant safety coefficient and marked on a lifting key or system (from Machinery Directive 2006/42/EC)

3.1.13
precaster
producer of precast concrete elements in a factory environment

3.1.14
pullout failure
failure mode in which the insert pulls out of the concrete without a steel failure and without a concrete breakout failure

3.1.15
side-face blow-out resistance
resistance of inserts with deeper embedment but thinner side cover corresponding to concrete spalling on the side face around the embedded head while no major breakout occurs at the top concrete surface

3.1.16
insert steel failure
failure mode characterised by fracture of one of the steel insert parts

3.1.17
minimum reinforcement
reinforcement required by EN 1992-1-1 or in national annex (Nationally Determined Parameter)

3.1.18
anchorage reinforcement
reinforcement designed to resist the full load in case of a concrete failure

3.1.19
supplier
manufacturer of lifting inserts brought to the market or its authorized distributor

3.2 Symbols

3.2.1 Action and resistance

E_d	design value of actions acting on a single insert;
N_{Rk}	characteristic value of resistance of a single insert;
N_{Rd}	design value of resistance of a single insert;
q_{adh}	adhesion;
$\psi_{\mathbf{dyn}}$	dynamic coefficient;
γ_{load}	partial factor for loads;
γ_{l+h}	partial factor for lifting and handling effects;
γ_c	partial factor for concrete;
γ_s	partial factor for steel.

3.2.2 Concrete and steel

A_s	stressed cross section of steel;
f_{ck}	characteristic compressive strength of concrete (strength class) measured on cylinders (150 x 300) mm;
f_{yk}	characteristic steel yield strength or steel proof strength respectively;
f_{tk}	characteristic ultimate strength of steel;
$f_{0,1k}$	characteristic strength at the 0,1 limit for prestressing steel;
$F_{p0,1}$	specified characteristic value of 0,1 % proof force, defined by prEN 10138–3:2000;
F_{min}	F_{min} is the minimum breaking force of the rope, in kilonewtons, defined by EN 13414–1;
f_{yd} and f_{cd}	design values of stress;
F_{pd}	design value of force in prestressing strand;
f_{pd}	design value of stress in prestressing strand;
F_{yd}	design value of force in wire ropes.

3.2.3 Inserts

Notation and symbols frequently used in this technical report are given below. Other notation and symbols are given in the text.

a edge distance from the axis of an insert.

$\varnothing$ diameter of insert bolt or thread diameter.

$\varnothing_h$ diameter of insert head (headed inserts).

$\varnothing_s$ diameter of reinforcing bar.

h_{ef} anchorage length (Figure 1).

4 Basis of design

4.1 General

Inserts for lifting and handling should sustain all actions and influences likely to occur during execution and use, thus preventing any structural failure (ultimate limit state). They should not deform to an inadmissible degree (serviceability limit state). Long term effects such as corrosion of the insert should be taken into account by the designer.

In the design of lifting inserts it is assumed that they are produced with ductile materials having pronounced deformations before failure. The deformability should be maintained with age and under low temperatures.

The inserts load capacity for lifting and handling should be calculated and/or tested according to the principles and design models given in this document. Embedment conditions for lifting and handling, which do not conform to these principles or design models, should be tested according to the recommendations given in Annex A and evaluated in accordance with EN 1990.

4.2 Required verifications

Ultimate limit state (ULS) and serviceability limit state design (SLS) are commonly used in present structural design. This design concept is based on partial factors.

For transient lifting and handling situations the admissible load design concept based on global factors was established in the past and is still and very often used in daily lifting insert design practice.

Both methods of verification of lifting inserts are described in the following.

4.3 Design Principles

4.3.1 Limit state design

For the inserts the following should be verified:

4.3.2 Ultimate limit state

4.3.2.1 General

In the ultimate limit state verifications are required for all appropriate load directions.

It should be shown that:

$$E_d \le R_d \tag{4.1}$$

where

E_d = design value of effect of actions with $E_d = E \times \gamma_{load}$;

E = effect of actions loading the insert;

γ_{load} = partial factor for load;

R_d = design value of resistance of the insert, with $R_d = R_k / \gamma_M$;

R_k = characteristic value of resistance;

γ_M = partial factor for material.

4.3.2.2 Servicability limit state

In service limit state the inserts should not significantly deform and the material of the insert and the corrosion protection should be selected taking into account the environmental conditions of the final structure if the insert remains in the precast element over service life in the structure.

It should be shown that:

$$E_d \leq C_d \quad (4.2)$$

where

E_d = design value of insert deformation;

C_d = nominal value, e.g. limiting deformation.

Actions should be obtained from the relevant parts of EN 1991-1 where applicable.

4.3.3 Admissible load design

The design of lifting inserts may be carried out on the basis of allowable loads, since the manuals of the lifting insert suppliers normally only provides admissible loads for their inserts. This concept is based on global safety factors and requires that the action E does not exceed the admissible resistance R_{adm}.

It should be shown that:

$$E \leq R_{adm} \quad (4.3)$$

where

E = effect of actions loading the insert;

R_{adm} = admissible load on the insert provided by the supplier.

The admissible resistance of lifting inserts according to this technical report is:

$$R_{adm} = R_k / \gamma \quad (4.4)$$

where

R_k = characteristic value of resistance;

γ = global safety factor, factor to cover uncertainties in action and resistance.

4.4 Verification

4.4.1 General

The verification of the resistance should be for all actions and load directions. The method used for verification may be ultimate limit state and service limit state (partial factors), or admissible load design (global safety factors).

4.4.2 Partial factor method (Ultimate limit state)

4.4.2.1 Partial factors for actions

Partial factors for actions to be used are given in EN 1990:2002, Annex A.

In the absence of National provisions the for partial factor γ_{load}, globally taking into account model uncertainties for dead load and live load, i.e. self-weight, adhesion, form friction and dynamic actions the following value is recommended:

$\gamma_{load} = 1,35$

4.4.2.2 Partial factors for resistance

In the absence of National provisions the partial factors given for steel failure in Table 1 and for concrete and anchorage failure in Table 2 are recommended.

Table 1 — Partial safety factors γ_s for steel failure

Insert material	γ_s	γ_{l+h}	Reference standards for steel strength [a]	Minimum ductility ratio, $k = f_{tk}/f_{yk}$	Design values f_{yd}, f_{pd}, F_{yd}
Structural solid steel	1,25	1,8	EN 10025–2	1,10	$f_{yd} = f_{yk} / (\gamma_s \times \gamma_{l+h}) = f_{yk} / 2,25$
Reinforcing steel (smooth bars)	1,15	1,8	National Standards or information by the producers.	1,15	$f_{yd} = f_{yk} / (\gamma_s \times \gamma_{l+h}) = f_{yk} / 2,07$
Prestressing strand	1,15	1,8	prEN 10138–3:2000, National Standards or information by the producers.	1,10	$F_{pd} = F_{0,1k} / (\gamma_s \times \gamma_{l+h}) = F_{0,1k} / 2,07$ or $f_{pd} = f_{0,1k} / (\gamma_s \times \gamma_{l+h}) = f_{0,1k} / 2,07$
Wire rope	1,15	1,8	EN 12385–4 or EN 13414–1	1,54	$F_{yd} = F_{min} / (\gamma_s \times \gamma_{l+h}) = F_{min} / 2,07$
[a] See also 6.4.					

Recommended values of the partial factor for failures in the load transfer between the insert and the concrete are given in Table 2. These values assume that an FPC system is used to control that concrete is uncracked in the vicinity of the insert.

Table 2 — Partial safety factors for concrete and anchorage failure

Precast element	γ_c, γ_s	γ_{l+h}	Design values
Concrete	1,5	1,5	$f_{cd} = f_c / (\gamma_c \times \gamma_{l+h}) = f_c / 2,25$
Anchorage of reinforcement	1,15	1,5	$f_{yd} = f_y / (\gamma_s \times \gamma_{l+h}) = f_y / 1,75$

4.4.2.3 Global safety factor method

Values for the global safety factor γ from different Nations for the different verifications are given in Table 3. For comparison the global factors are compared with the partial factors for the partial factor method of 4.4.2.2 using the following approach:

$\gamma = \gamma_{load} \times (\gamma_s \times \gamma_{l+h})$ for steel failure (4.5a)

$\gamma = \gamma_{load} \times (\gamma_c \times \gamma_{l+h})$ for concrete or anchorage failure (4.5b)

Table 3 — Global safety factors γ used in different National provisions and MD 2006/42/EC

Verification of		4.3.3	Fascicule 65 (France)	VDI/BV-BS 6205 [a] (Germany)	Conc. Elem. Book, C5 2013 edition (Norway)	PCI (for information: USA)	Machinery Directive 2006/42/EC [a]
Inserts	Structural steel	3,0 [b]		3 [f]	3,04 [b]		4 [c]
	Reinforcing steel (smooth bars)	2,8 [b]	2,35 [b]		2,80 [b]		
	Prestressing strands	2,8 [b]			2,80 [b]		
	Wire ropes	2,8 [b] 4,3 [c e]		4 [f]	2,80 [b] 4,30 [c e]	4 [c]	5 [c]
Concrete	Concrete failure	3,0		2,5 or 2,1 [d]	3,04	4	
	Anchorage reinforcement	2,3 [b]			2,33 [b]	4 [c]	

a The Machinery Directive 2006/42/EC includes a dynamic factor. VDI/BV-BS 6205 assumes this factor to be 1,3.

b Verification for f_{yk}, $f_{0,1k}$ *or* $f_{0,2k}$ (yield strength), $F_{p0,1}$ (force at 0,1 limit).

c Verification by calculation for f_{tk} (tensile strength), F_{min} (tensile force).

d γ = 2,1 might be applied if lifting inserts are installed in precast elements under plant specific and continuous inspection.

e 2,8 × k = 2,8 × 1,54 = 4,3.

f Verification by calculation for f_{tk} (tensile strength), or verification by testing for R_k (characteristic value of the insert).

5 Actions on inserts

5.1 General

Generally actions should be taken from EN 1991-1.

The forces acting on an insert should be calculated for all relevant loading situations taking into account the product properties, the position of the inserts, condition of the form, lifting equipment, number and length of the ropes, chains or straps and the static system. In some cases it might be necessary to take into account the deformations of the precast element during lifting and handling.

5.2 Effect of lifting procedures on load directions

Inserts for lifting and handling may be subjected to loads acting in different directions during operation. As examples information on slabs and wall elements are given.

The lifting equipment should allow statically determinate load distribution to the inserts (see Figure 2 and Figure 4). To ensure that all inserts carry their required part of the load, sliding or rolling couplings between the lifting wires or chains should be used when there are more than two lifting points. In a statically indeterminate system the load distribution on the inserts depends in most cases on the unknown stiffness of the ropes and the position of the insert (see Figure 3). Therefore only the statically determinate part of a system should be used in calculating the actions on the inserts.

a) **b)**

Figure 2 — Examples of handling equipment for slabs

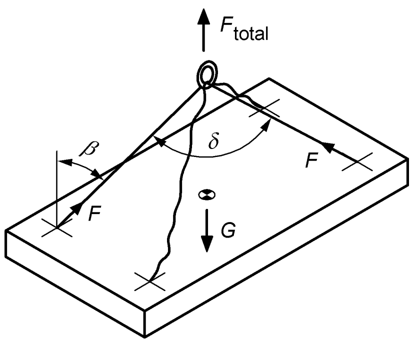
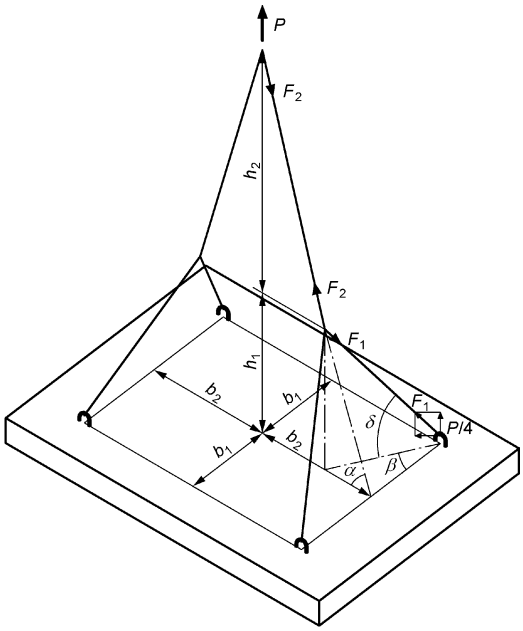


Figure 3 — Statically indeterminate system, only two inserts loaded

$$\tan\alpha = \frac{h_1 + h_2}{b_2}$$

$$\tan\beta = \frac{h_1 / \tan\alpha}{b_1} = \frac{h_1}{b_1 \times \tan\alpha}$$

$$\tan\beta = \frac{h_1 \times b_2}{b_1 \times (h_1 + h_2)}$$



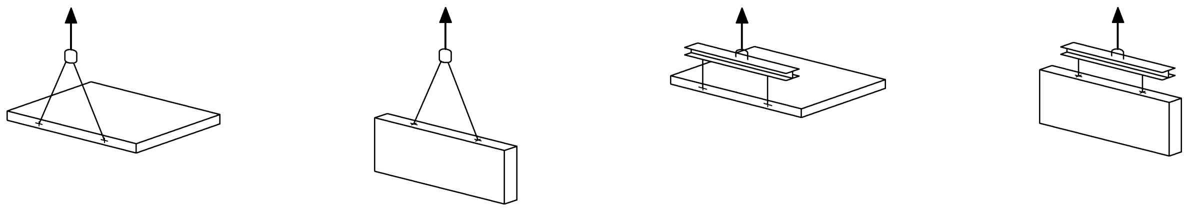
$$\tan\delta = \frac{h_1}{b_1 / \cos\beta} = \frac{h_1 \times \cos\beta}{b_1}$$

$$F_1 = \frac{P/4}{\sin\delta} = \frac{P}{4 \times \sin\delta}$$

$$F_2 = \frac{P/2}{\sin\alpha} = \frac{P}{2 \times \sin\alpha}$$

Figure 4 — Example of statically determinate lifting of a slab and resolution of forces

Depending on the equipment used during lifting the inserts may be subjected to combined parallel and transverse shear load (Figure 5a), combined tension and parallel shear loads (Figure 5b), transverse shear loads (Figure 5c) or axial tensile loads (Figure 5d).



a) **b)** **c)** **d)**

Figure 5 — Examples of loads on lifting inserts for walls

Shear loads acting on inserts may be assumed to act without a lever arm, if the design of the inserts and its key avoids significant concrete crushing in front of the insert during loading. If this condition is not satisfied the lever arm should be taken as the actual distance between the shear force and the concrete surface plus 3/4 of the nominal diameter of the insert.

5.3 Actions from adhesion and form friction

Adhesion and form friction will act on the precast element when it is removed from the form. The values should be taken from National provisions. In the absence of National provisions the values for the combined effect of adhesion and form friction q_{adh} given in Table 4 may be considered.

For some types of uneven form surfaces (structured matrixes, reliefs, structured timber etc.) the forces may be much larger than given in the table, and should be considered separately. The forces may be close to zero if the concrete does not come in contact with the form at all, for example if the concrete is poured on a layer of bricks that has been laid out on the form bottom. Large vertical – or nearly vertical – form surfaces may create extensive friction forces due to undulations in the form. Prestressed components will usually have a camber caused by the prestressing force, and will therefore have lower friction against the vertical sides of the form.

Table 4 — Examples of values for adhesion and form friction, q_{adh}

Formwork and condition	q_{adh} [a]
Asymetrically prestressed elements	0 to 0,6 kN/m²
Oiled steel mould, oiled plastic coated plywood	1 kN/m²
Varnished wooden mould with planed boards	2 kN/m²
Oiled rough wooden mould	3 kN/m²

[a] The area to be used in the calculations is the total contact area between the concrete and the form.

The values given here may be minimum values. Individual consideration should be carried out.

The values of Table 4 are valid only if suitable measures to reduce adhesion and form friction are taken e.g. casting on tilting tables or vibrating the formwork during the demoulding process.

The actions E_d for demoulding situations in ULS should be determined from:

$$E_{d,adh} = (G + q_{adh} \times A_f) \times \gamma_{load} \quad (5.1a)$$

or in case of admissible load design:

$$E_{adh} = (G + q_{adh} \times A_f) \quad (5.1b)$$

where

G = weight of the precast concrete element;

A_f = form area in contact with concrete;

γ_{load} = partial factor for loads (self-weight, adhesion, form friction and dynamic actions).

5.4 Dynamic actions

During lifting and handling the precast elements and the lifting devices are subjected to dynamic actions. The magnitude of the dynamic actions depends on the type of lifting machinery. Dynamic effects should be taken into account by the dynamic coefficient ψ_{dyn} given in National regulations. In the absence of National Regulations the values of Table 5 may be considered. Other dynamic influences than covered by Table 5 should be based on special provisions or engineering judgement.

Table 5 — Influence of dynamic actions on site

Dynamic influences	Dynamic coefficient (ψ_{dyn})
Tower crane, overhead crane and portal crane	1,2 [a]
Mobile crane	1,4 [a]
Lifting and moving on flat terrain	2 – 2,5
Lifting and moving on rough terrain	3 – 4

[a] In precasting factories and if special provisions are made at the building site lower values may be appropriate.

The actions E_d for lifting situations should be determined from Formula (4).7a):

$$E_{\mathrm{d,dyn}} = \psi_{\mathrm{dyn}} \times G \times \gamma_{\mathrm{load}} \tag{5.2a}$$

or in case of admissible load design:

$$E_{\mathrm{dyn}} = \psi_{\mathrm{dyn}} \times G \tag{5.2b}$$

The actions E_d or E to be used in the design of the lifting insert and it's anchorage should be the largest of $E_{d,adh}$ or $E_{d,dyn}$ in ULS, and E_{adh} or E_{dyn} in admissible load design.

5.5 Combined actions

Combined actions on lifting devices will in most cases be tension and shear.

If concrete is the governing parameter: $(N_{Ed} / N_{Rd,c})^{1,5} + (V_{Ed} / V_{Rd,c})^{1,5} \leq 1,0$.

If steel is the governing parameter: $(N_{Ed} / N_{Rd,s})^2 + (V_{Ed} / V_{Rd,s})^2 \leq 1,0$

If concrete is governing for one type of failure and steel for the other: $(N_{Ed} / N_{Rd})^{5/3} + (V_{Ed} / V_{Rd})^{5/3} \leq 1,0$

Here N_{Rd} and V_{Rd} are the smallest capacities of steel, welds or concrete.

6 Design of lifting inserts and anchorage in concrete by calculation

6.1 General conditions

For most common applications, present practice and available general information, the load capacity of inserts can be expressed in a design model. This model is described in 6.3. The model is not universally applicable. Limitations on the range of validity are used to exclude situations where failures other than concrete break out failure, bond failure, failure of anchorage reinforcement or steel failure of the insert. Limitations on the range of validity are the following:

1) Fields of application

The most common fields of application are:

1) a) walls and other linear elements (such as beams and columns), where the insert is typically long compared to the edge distance (the smallest distance from the insert to a concrete surface parallel to the insert) see 6.4;

2) b) slabs and pipes, where the edge distance is large while the possible length of the insert is limited by the thickness of the element – see 6.5.

2) Anchorage reinforcement is provided in the region of the insert if the concrete capacity is not sufficient.

Minimum reinforcement is typically provided according to EN 1992-1-1. Although provided for other reasons the reinforcement may also act as a safeguard against failure in the concrete around the insert. If minimum reinforcement is not provided complementary reinforcement should be provided

Anchorage reinforcement is designed specifically to transfer the full load on the insert to the concrete element as a whole. The suggested models for design of the reinforcement are in accordance with the rules given in EN 1992-1-1.

3) Minimum characteristic strength of concrete.

It is recommended that the concrete strength (at the time of lifting) is at least 15 MPa measured on cubes, side length 150 mm (or 12 MPa measured on cylinders).

4) Factory Production Control (FPC).

It is assumed that the precaster applies a Factory Production Control system according to the requirements in EN 13369:2013, Clause 6. It is furthermore assumed that the inspection scheme for finished product inspection includes a check that no harmful cracking has occurred in the neighbourhood of the inserts at the time of delivery.

5) Handling procedures.

Lifting design should correspond to the actual handling situations. Handling procedures as described in EN 13670:2009, 9.4, should include allowable lifting angles and handling situations. The precaster should provide an information system for these requirements. See Clause 8.

6.2 Types of inserts covered

6.2.1 Inserts independently placed on the market

All inserts shown in Figures 6 to 11 are commercially available.

All these standard lifting systems consist of an insert embedded in the concrete element and a matching unit (key) that connects to the insert (Figures 6 to 11). The crane hook or hook of a lifting sling attaches to the key. The combination of components from different systems is prohibited.

In many cases different types of cast-in-inserts belong to the same system. This can be confirmed by checking the marking of the lifting system.

Headed bolts and spread anchors transfer axial load to the concrete through mechanical interlock at the built-in end while shear load is transferred more or less directly between the recessed lifting key and the concrete at the top end.

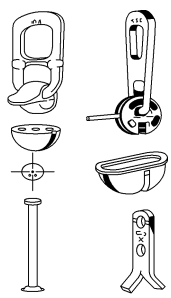


Figure 6 — Headed bolts and spread anchors

These inserts maintain the possibility of shear transfer directly from the lifting key to the concrete, while the axial load is transferred to the concrete through a separate reinforcement bar to be threaded into a hole in the insert.

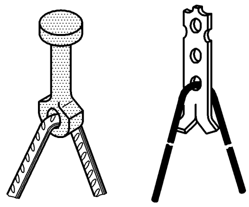


Figure 7 — Anchors with additional rebar

These inserts may utilize a simpler, threaded key to transfer the load to the insert. The axial load is transferred to the concrete through a bonded rebar either in the form of a separate bar threaded into a hole or as a built in rebar (e.g. waved anchors) included in the system. The corresponding key may or may not be suitable for transfer of shear forces.

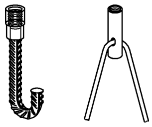


Figure 8 — Anchor systems with threaded sockets

These inserts may have an extended bearing area at the built-in end of the insert. They are intended for use in slabs and pipes to sustain axial load and shear load.

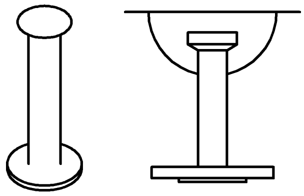


Figure 9 — Short versions of headed bolts and spread anchors

Inserts intended for use in slabs and pipes with short embedment lengths and large bearing areas that are also suited for supporting the necessary minimum reinforcement. Axial load as well as shear load may be accommodated.

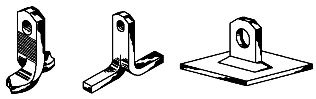


Figure 10 — Short versions of headed bolts and spread anchors

A threaded socket mounted on a plate providing a bearing area for axial load. The corresponding keys are usually not suited for transfer of shear, but special options exist.

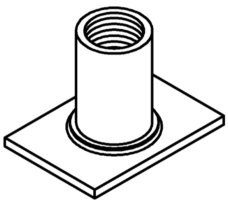


Figure 11 — Plate sockets

6.2.2 Inserts made by the precaster

In addition to the commercially available inserts the precasters may produce their own lifting devices as welded units, or made from smooth bars, prestressing strands or steel wire ropes. Necessary information on the handling of the element considered in the design, e.g. lifting hook dimensions, should be given in handling specifications.

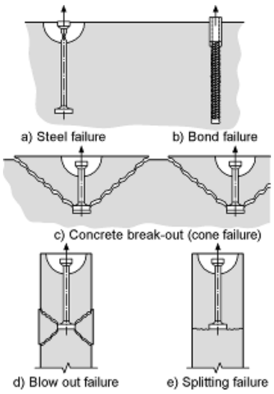
Lifting loops should only be used if the lifting angle is approximately the same in all lifting and handling situations. Furthermore, the lifting angle should be kept within the limits indicated in 6.4.2.

6.3 General design

6.3.1 Failure modes

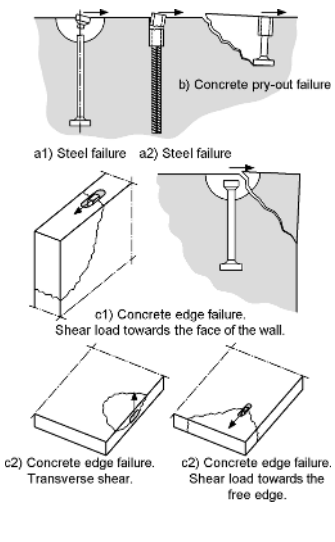
It is common practice to classify the failure either as tensile or shear failure (see Figure 12 and Figure 13). Practically all handling will include at least once a situation with skewed lifting, hence there will be a combination of tension and shear.

Concrete failures can be prevented by adding reinforcement in the vicinity of the lifting insert. The interaction between the concrete and the reinforcement for this kind of action is rather complex, and varies with the geometry of the element in the vicinity of the lifting insert and the lifting system.



Concerning c): With large edge distances it may be unreinforced. With small edge distances reinforcement should be provided.

Figure 12 — Failure modes for lifting inserts under tensile loading



Pry-out failure may be prevented by increasing the length of the insert.

This edge failure is prevented by adding reinforcement.

Concrete edge failure for transverse loads should always be prevented by reinforcement. Also the handling procedure should be considered.

Concrete edge failure towards the free edge should preferably be prevented by changing the handling procedure, but reinforcement may always be added.

Figure 13 — Failure modes for lifting inserts under shear loading

6.3.2 Design procedures

One of three design procedures should be used:

a) using standardized commercially available lifting accessories and inserts with load capacity tables for the insert which are based on generally accepted verifications taking into account, concrete and anchorage reinforcement:

— — no additional design is required;

— — alternatively the anchorage reinforcement can be designed according to 6.3.4;

b) using precaster's own lifting assembly and insert:

— — capacity tables for the insert, concrete and anchorage reinforcement based on testing according to Clause 7;

c) using precaster's own lifting assembly and insert:

— — design models according to 6.3.2, 6.3.3 and 6.3.4;

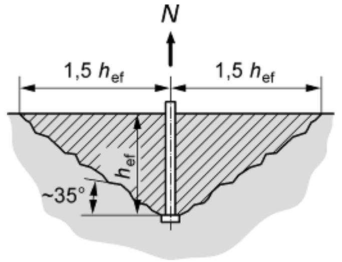
— — the concrete failure is based on the conservative assumption that there is no interaction between the concrete and the anchorage reinforcement, except for the situations described in EN 1992-1-1. In all other cases the anchorage reinforcement should be designed for the full load on the insert;

— — the tension and shear load capacities are generally found separately, and the total capacity is calculated using an interaction formula as given in 5.5.

6.3.3 Unreinforced concrete

6.3.3.1 Tensile load

Inserts with an anchor plate or similar device creating compressive concrete stresses will be governed by a concrete cone failure – see Figure 14. Capacity calculation formulas are given in CEN/TS 1992-4-2:2009, Clause 6. Headed inserts are commercially available (see 6.3.2 a), but are also in many cases made by the precasters.



$$N_{\mathrm{Rd,c}} = N^0_{\mathrm{Rd,c}} \times \frac{A_{\mathrm{c,N}}}{A^0_{\mathrm{c,N}}} \Psi_{\mathrm{s,N}} \times \Psi_{\mathrm{re,N}} \times \Psi_{\mathrm{ec,N}}$$

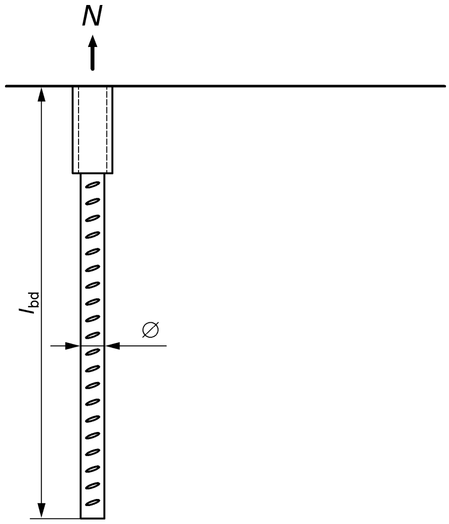
where

$$N^0_{\mathrm{Rd,c}} = \frac{k_{\mathrm{N}}}{\gamma_{\mathrm{c}} \times \gamma_{\mathrm{1+h}}} \times \sqrt{f_{\mathrm{c,cube}}} \times h_{\mathrm{ef}}^{1,5} \left[\mathrm{N,mm}\right]$$

Recommended k_{N} = 11,9

Figure 14 — Concrete cone failure in tension

Inserts without anchor foot will be governed by bond failure. Capacity formulas for anchoring of steel reinforcement (ribbed bars, strands) are given in EN 1992-1-1. See Figure 15.



$$N_{\mathrm{Rd,c}} = \pi \cdot \varphi \cdot l_{bd} \cdot f_{bd} / \sum \alpha$$

$$\sum \alpha_{\mathrm{unreiforced}} = \alpha_1 \cdot \alpha_2$$

$$\sum \alpha_{\mathrm{reinforced}} = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4$$

Material factors

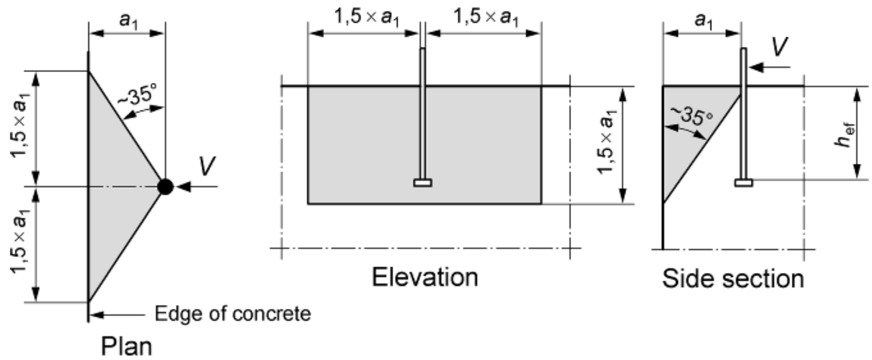
$\gamma_{\mathrm{c}} \cdot \gamma_{\mathrm{l+h}}$ and $\gamma_{\mathrm{s}} \cdot \gamma_{\mathrm{l+h}}$

Figure 15 — Bond failure in tension

6.3.3.2 Shear load

Concrete edge failure

The shear capacity of an insert near the concrete edge will be governed by spalling or splitting – see Figure 13c. Capacity formulas are given in CEN/TS 1992-4-2:2009, Clause 6. (see Figure 16)



$$V_{\mathrm{Rd,c}} = V^0{}_{\mathrm{Rd,c}} \times \frac{A_{\mathrm{c,V}}}{A^0{}_{\mathrm{c,V}}} \times \psi_{\mathrm{f,V}} \times \psi_{\mathrm{s,V}} \times \psi_{\mathrm{h,V}} \times \psi_{\mathrm{ec,V}} \times \psi_{\mathrm{,N}} \times \psi_{\mathrm{re,V}}$$

where

$$V^0{}_{\mathrm{Rd,c}} = \frac{k_{\mathrm{V}}}{\gamma_{\mathrm{c}} \times \gamma_{\mathrm{1+h}}} \times \varphi^{\alpha} \times l_{\mathrm{f}}^{\beta} \times \sqrt{f_{\mathrm{c,cube}}} \times a_{\mathrm{a_1}}^{1,5} \quad \textbf{[N, mm]}$$

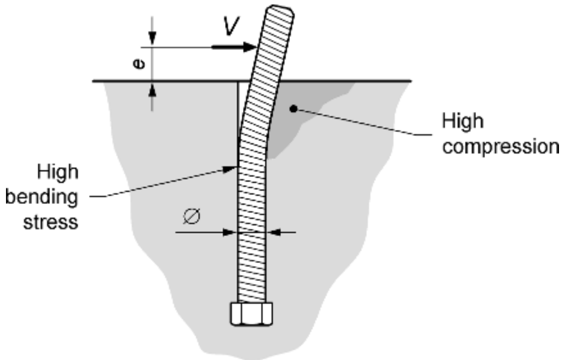
$l_{\mathrm{f}} = \min\left(h_{\mathrm{ef}}; 8 \times \varphi\right)$ Recommended $k_{\mathrm{v}} = 2,3$

Figure 16 — Concrete edge failure in shear

Local concrete crushing / steel bending failure

If the concrete edge failure is prevented by local reinforcement and/or large edge distances, the capacity may be governed by local crushing of the concrete combined with bending of the steel insert.

Capacity formulas are given in fib bulletin 43:2008: "Structural connections for precast concrete buildings", 8.2.



Provided e = 0:

$V_{\mathrm{Rd,c}} = \varphi^2 \times \sqrt{f_{\mathrm{cd}} \times f_{\mathrm{yd}}}$

with material factors

$\gamma_{\mathrm{c}} \times \gamma_{1+\mathrm{h}}$ and $\gamma_{\mathrm{s}} \times \gamma_{1+\mathrm{h}}$

Figure 17 — Local crushing and flexural failure

Commercially available inserts

The inserts described in Figures 6 to 11 will normally be lifted with a specially developed lifting key in order to avoid bending of the insert and damage to the concrete. The shear load will then be transferred directly to the concrete and/or behave partly according to the shear-friction theory. These inserts can be designed according to Figure 17. However, design by testing will normally result in higher capacities, but may result in larger deformations. See also Figure 21.

6.3.4 Reinforced concrete

6.3.4.1 Tensile load

Headed inserts (with anchor foot)

The concrete cone failure capacity can be increased by adding a plate to the anchor foot as shown in Figure 18. The capacity formulas will be the same as given in Figure 14, but with h_{ef} replaced by (h_{ef}+u).

Additional transverse reinforcement instead of the added plate will have the same effect.

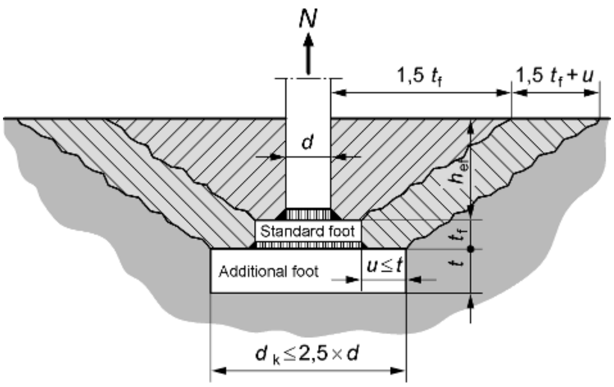


Figure 18 — Effect of large foot

If the concrete capacity is not sufficient – see Figure 12c – anchorage reinforcement should be provided. The reinforcement should be designed for the full load on the insert – see Figures 15 and 19.

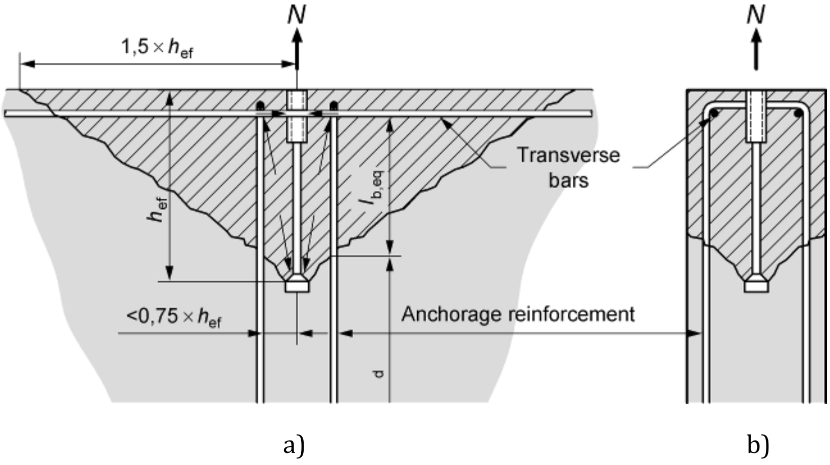


Figure 19 — Anchorage reinforcement

Inserts without anchor foot and anchorage reinforcement

The capacity of such inserts will determined by bond failure. The capacity can be increased by transverse reinforcement welded to the main bar or hooks on the main bar. Capacity formulas are given in EN 1992-1-1:2004, Clause 8 see Figure 15.

6.3.4.2 Shear load

Concrete edge failure

If the concrete capacity is not sufficient – see Figure 13c – reinforcement shall be provided. The reinforcement should be designed for the full load on the insert – see Figure 20.

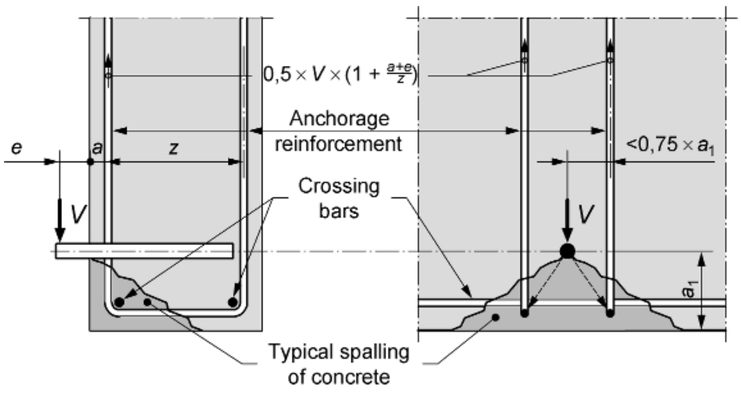


Figure 20 — Reinforcement for the prevention of concrete edge failure

Reinforcement as shown in Figure 20 may not necessarily prevent local spalling, but the insert and the reinforcement will work together and provide the required safety level. Some commercial lifting keys and inserts are specially designed for this purpose, and will within certain limitations prevent concrete spalling. The structural engineer and the precaster should pay attention to practical experience with existing lifting systems, and coordinate the choice of inserts with the expected handling situations.

Local concrete crushing / steel bending failure

The capacity is the same as described for unreinforced concrete – see 6.3.3.2 and Figure 17.

Commercially available inserts

The comments are the same as described for unreinforced concrete – see 6.3.3.2.

6.4 Lifting inserts

6.4.1 General design

The lifting insert will generally be subjected to various combinations of tension, shear and flexure – see Figure 21.

The commercial lifting systems are developed to minimize the shear forces V and the bending moment M (e = 0). Hence the lifting inserts will only be subjected to the tensile load N, and the shear forces will go directly into the concrete and / or reinforcement provided. Other lifting systems should be detailed in such a way that the bending moment M approximately = 0.

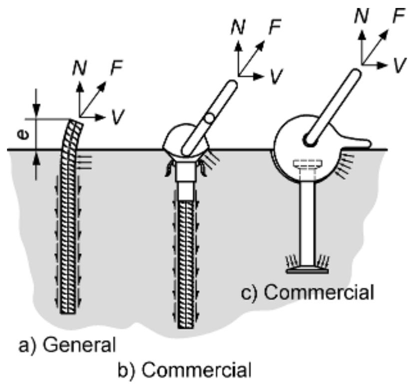


Figure 21 — Flow of forces on lifting inserts

Inserts of structural steel or massive rods / bars should be designed according to EN 1993-1-1 and EN 1993-1-8, with material coefficients $\gamma_s \times \gamma_{l+h}$ according to 4.4. The basic design formulas are:

Tension: $N_{Rd,s} = f_{yd} \times A_s$

Shear: $V_{Rd,s} = f_{yd} \times A_s / \sqrt{3}$

Flexure: $M_{Rd,s} = f_{yd} \times W_p$.

W_p is $b \times h^2 / 6$ for rectangular inserts, and $\emptyset^3 / 6$ for circular inserts.

The maximum stresses due to *N*, *V* and *M* often occurs at different locations along the insert. This should be considered when the stresses are combined, even if one of the effects may not be the maximum value. Combination of *N* and *V* – see 4.3. Combinations with *M* – see EN 1993-1-1:2005, Clause 6.

6.4.2 Lifting loops of smooth bars

Examples of typical geometry of lifting loops of smooth bars are given in Figure 22.

The material should be ductile, the elongation at rupture should be at least 15 % tested at lengths 10 × Ø. The material for smooth bar lifting loops should be at least equivalent to S235J2+N. For higher qualities the material properties concerning brittleness, especially in low temperatures, should be checked

The tensile capacity should be reduced depending on the diameter in the loop – see Table 6.

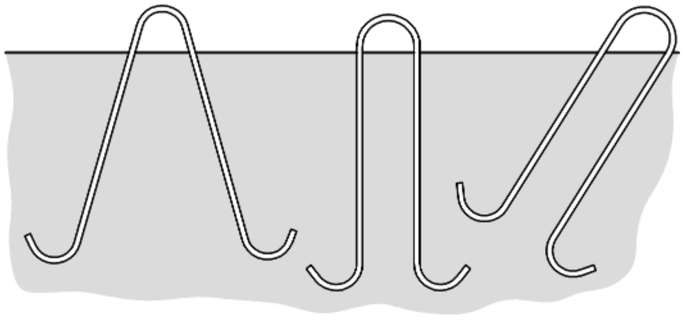
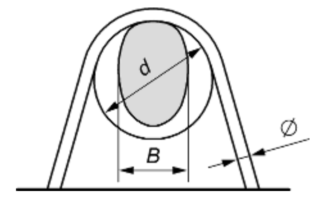


Figure 22 — Typical geometry of lifting loops of smooth bars

Table 6 — Capacity reduction factor for lifting loops of smooth bars depending on the lifting hook dimension

Bending diameter d	Hook width B	k_1	
≥ 2 × Ø ≥ 25 mm	d/2 ≤ B ≤ d	0,65	
≥ 4 × Ø (minimum for strands)		0,80	
≥ 6 × Ø		0,90	

Steel capacity for tensile loads:

$N_{Rd,s} = k_1 \times f_{yd} \times 2 \times A_s$

A_s is the cross sectional area of lifting loop = $\pi \times Ø^2/4$;

f_{yd} is according to 4.4, with material factors $\gamma_s \times \gamma_{l+h}$.

The loading angle β (the angle between the direction of the force and the axis if the insert) should not exceed 30° (see Figure 23). The effect of β on the distribution of the forces to the legs of the loop should be considered, and bending moments according to 6.4.1 should be included.

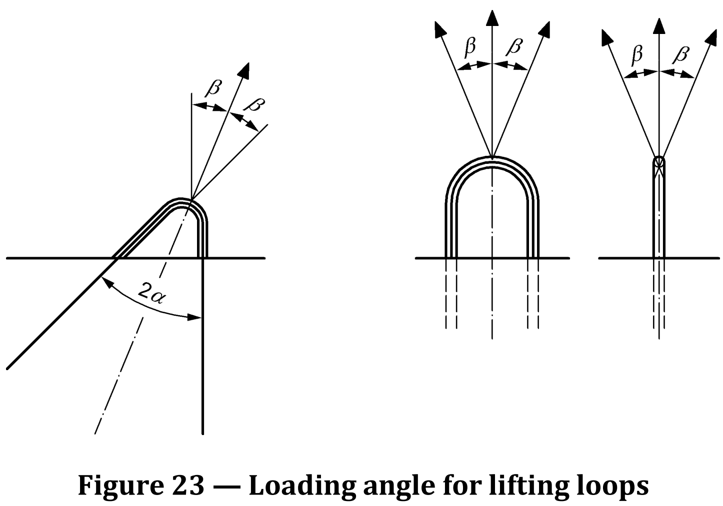


Figure 23 — Loading angle for lifting loops

The anchorage of smooth bars may be calculated according to Figure 15, but with reduced bond stress according to national regulations. A full 180° anchorage hook at the ends according to EN 1992-1-1:2004, 8.4, is recommended. The structural engineer shall consider the shape of the lifting insert compared with the lifting angle to determine the distribution of the load between anchorage legs. In extreme situations only one of the legs may be active.

6.4.3 Lifting loops of strands

Material quality should be according to prEN 10138-3:2000. Recommended diameters are from 12,5 mm to 15,7 mm 7-wire strands. Reduction factor k_1 due to bending diameter is the same as in Table 6, with the bending diameter ≥ 4 × Ø.

The shape of the strands may be adapted to the various types of elements. Prestressing strands that have been deformed before shaping should not be used. Bending of the strands during stocking or turning of elements should be avoided.

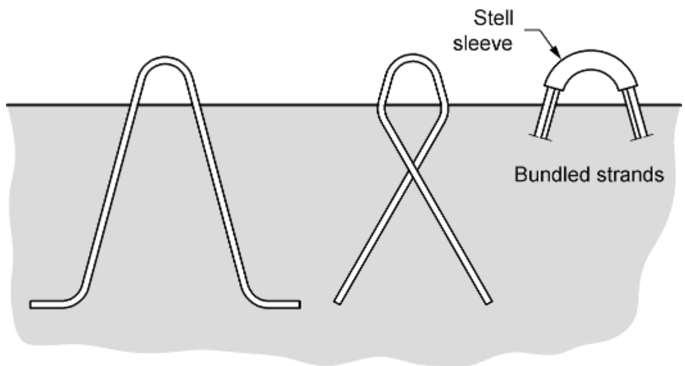


Figure 24 — Typical geometry of lifting loops of strands

Bundling of maximum four strands may be used only when provided with a steel sleeve bent together with the strands, see Figure 24.

The reduction factor k_2 for bundled strands are shown in Table 7.

Table 7 — Reduction factor for lifting loops made of bundled strands with sleeves

Number of strands	2	3	4
k_2	0,90	0,85	0,75

Steel capacity for tensile loads:

$N_{Rd,s} = k_1 \times k_2 \times f_{yd} \times 2 \times A_s$

A_s is the cross sectional area of the bundled bars in the sleeve;

f_{yd} is according to 4.4, with material factors $\gamma_s \times \gamma_{l+h.}$

In the case when a steel sleeve is used for a single strand or loop, the factor k_1 may be increased with 25 %, but k_1 should never be larger than 1,00.

The requirements regarding loading angles β are the same as for smooth bars – see Figure 23.

The anchorage of the strands may be calculated according to Figure 15, but with reduced bond stresses. The reduction factor is 1,2 / 2,25 = 0,533 (EC2, 8.4.2 and 8.10.2.3).

Commercially available lifting loops – see Annex B.

6.4.4 Lifting loops of steel wire ropes

Examples of typical geometry of lifting loops of steel wire ropes are given in Figure 25.

The shape of steel wire ropes can relatively easily be adapted to the geometry of the concrete element as well as the location of the reinforcement. Only steel wire ropes complying with EN 12385-4 should be used. Steel and fibre cores are allowed. The rope grade should be 1770 N/mm^2 or 1960 N/mm^2.

When calculating only the design relevant characteristics based on 1770 N/mm^2 should be used due to the brittleness of rope grade 1960 N/mm^2.

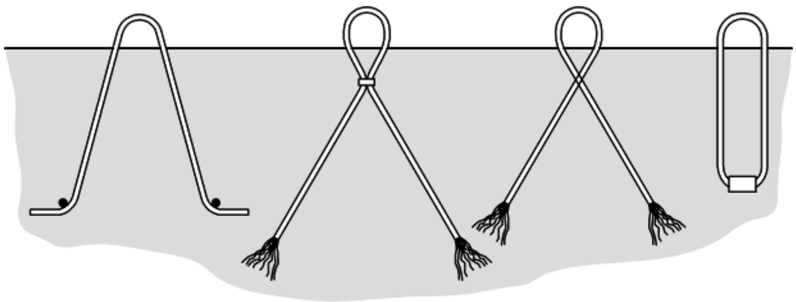


Figure 25 — Typical geometry of lifting loops of steel wire ropes

To ensure sufficient flexibility of a rope the steel, wire ropes should consist at least of the following number of wires:

d = 6 mm: Minimum 42 wires (steel wire 6 × 7);

d ≤ 14 mm: Minimum 114 wires (steel wire 6 × 19);

d > 14 mm: Minimum 186 wires (steel wire 6 × 31).

The steel wire rope is much more flexible than a solid steel bar, however, the bending rules and capacity reduction factor k_1 given in Table 6 are recommended, except if the capacity is determined by testing.

Steel capacity for tensile loads:

$$N_{Rd,s} = k_1 \times 2 \times F_{yd}$$

F_{yd} is the design tensile force of one leg, determined according to 4.2.

The requirements for loading angles in Figure 23 are not relevant. The anchorage of steel wire ropes with steel cores may be calculated according to Figure 15 with bond stresses for ribbed bars. For steel wire ropes with fibre cores the bond stress used in the design should, due to the contraction of the rope, be reduced with a factor of 0,4 to 0,9, depending also on the shape of the embedded part.

To ensure sufficient bond steel wire ropes shall be cleaned. The ends of the lifting loop made of a steel wire rope should be ferrule-secured or split. Split ends should not be taken into account in the design, but a ferrule-secured end will provide some extra anchorage.

6.5 Lifting of walls and linear elements

6.5.1 General

The choice of an appropriate insert for a wall application would typically involve:

— selection of an insert, suitable for the load direction and with sufficient resistance of the insert itself;

— checking that the concrete wall thickness is sufficient;

— checking that the available reinforcement can prevent brittle failure;

— determination of the required anchorage length for the insert;

— checking the need for anchorage reinforcement around the insert;

— checking the possible reduction in capacity due to shear load component.

6.5.2 Minimum thickness of wall or element

The thickness of the wall should be sufficient to avoid failure modes that cannot be counteracted effectively by reinforcement – see Figure 12d. Practical experience shows that the wall thickness and anchorage reinforcement required in such walls to prevent failure modes according to Figure 12e, Figure 13c1 and Figure 13c2 will be sufficient to prevent blow-out failure.

6.5.3 Anchorage reinforcement

The reinforcement should be calculated according to 6.3.4.1 and 6.3.4.2. Typical reinforcement models are shown in Figures 26, 27, 28 and 29.

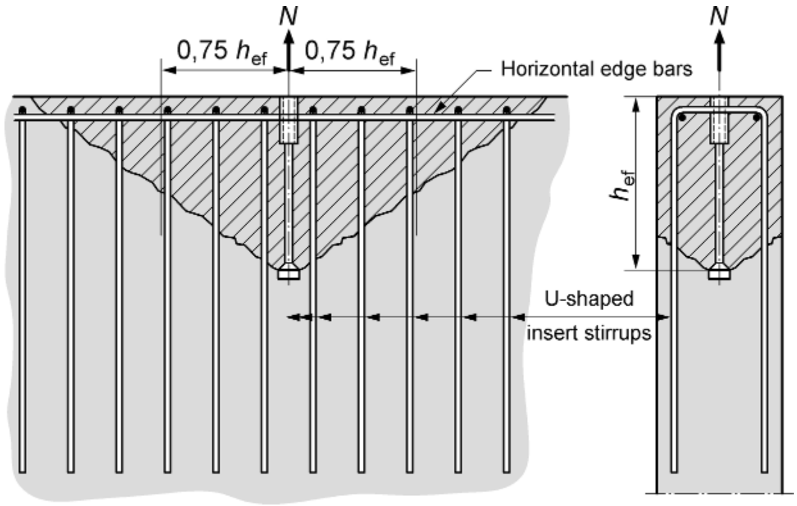
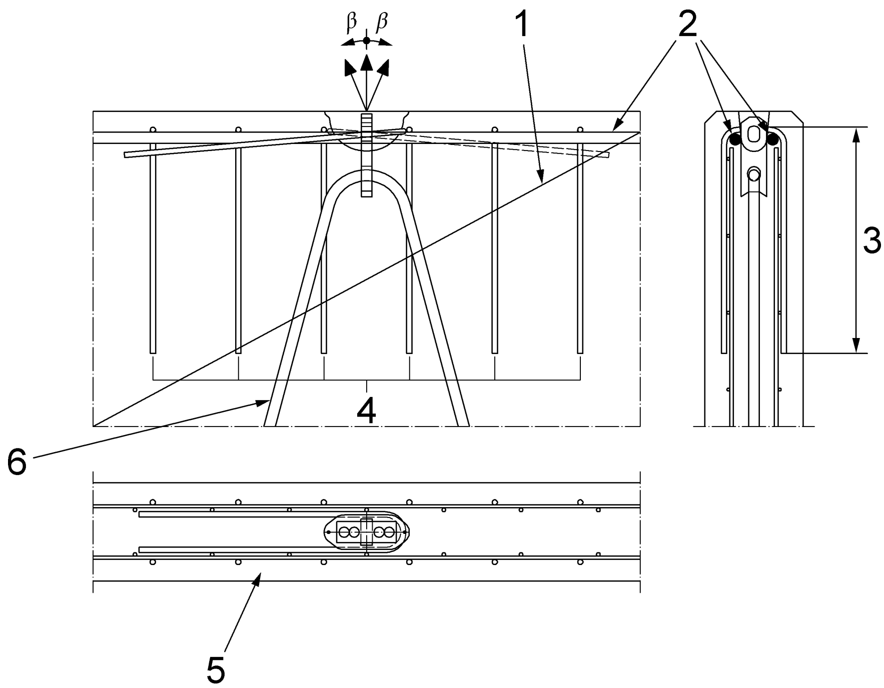


Figure 26 — Examples of anchorage reinforcement for insufficient anchorage length of the insert



Key

1 mesh reinforcement *Q*…

2 edge reinforcement

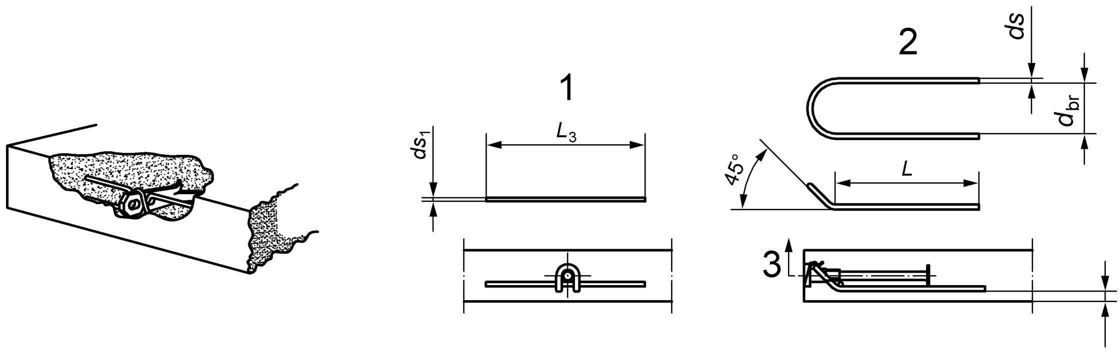
3 length of slot-in link L_1

4 slot-in link (positioned as closely to anchor as possible)

5 angled pull reinforcement as close as possible to recess

6 additional reinforcement for pull

Figure 27 — Examples of reinforcement for combined axial and shear load*



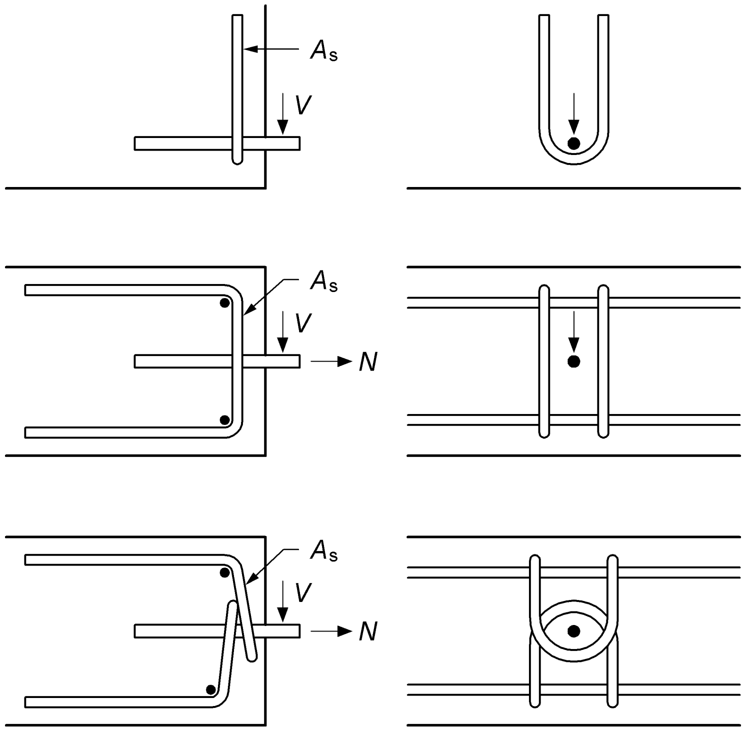
Key

1 additional reinforcement

2 radial reinforcement

3 transverse pull

Figure 28 — Examples of lifting inserts in a wall with supplementary tilting reinforcement for transverse shear loads



The lifting insert may be any type, commercial or "home made".

Figure 29 — Typical anchorage reinforcement in walls for shear and tension

6.6 Lifting of slabs and pipes

6.6.1 Minimum edge distances

The full insert load capacity is obtained only if the edge distances are large enough to allow the cone to develop fully and independently of the edge distance. This is likely to be the case if the edge distance is at least 1,5 times the length of the insert. Smaller edge distances will reduce the load capacity.

6.6.2 Anchorage reinforcement

If the concrete capacity is not sufficient, the reinforcement should be added and designed according to 6.3.4.1 and 6.3.4.2. A simple way of increasing the concrete cone capacity is to add larger steel plates to the anchor foot, or to use additional reinforcement (see Figure 30). A possible calculation model is shown in Figure 18.

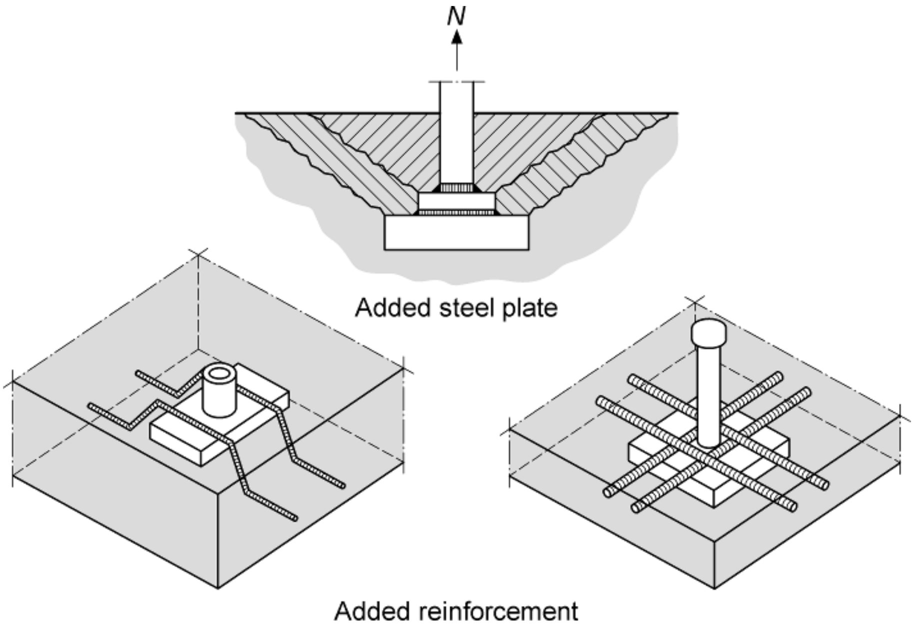


Figure 30 — Examples of increasing concrete cone capacity

7 Design of lifting inserts and anchorage in concrete by testing

7.1 General conditions

The precaster may need to do testing in three situations that are different from a statistical point of view, because the extent of prior knowledge is different. EN 1990 provides the basis when the statistical data are taken from identified and sufficiently homogeneous populations and a sufficient number of observations are available.

— In the first case the precaster wants to check that a design based on supplier information or on the recommendations in Clause 5 is valid for a specific application. Strong prior knowledge can be assumed and that may reduce the necessary testing program to 2-5 tests. EN 1990:2002, D.8.4 provides the basis.

— In the second case the precaster wants to verify a design that may be outside the range of applicability for which available information is valid. The insert to be applied may be new or it may be used outside the stipulated limits. In this case the necessary testing program is likely to be somewhat larger, because the strength of prior knowledge is somewhat debatable. EN 1990:2002, D.8.2 provides the basis.

— In the third case the precaster wants to utilize an insert for which no prior knowledge is available. The necessary testing program is likely to be large. EN 1990:2002, D.7.2 provides the basis.

When inserts are design by testing, tests should be performed and evaluated with respect to the failure modes occurring under tension and shear loading – see Figure 12 and Figure 13.

The objective of these tests is to provide reliable information on the resistance properties of a particular insert for a limited area of application. The insert might be produced by a precaster for his own use or it might be an insert as part of a system.

The testing program limited to the special application may intend to confirm an existing design model, it may intend to develop a special design procedure or it may intend to determine a resistance value for the insert. Prior know-ledge should be used as far as possible, but the effect of prior knowledge depends on the circumstances.

Testing conditions should reflect the conditions within the intended range of application and this should be documented.

7.2 Specification of specimens

7.2.1 Areas of application

A lifting insert should be tested depending on the field of its application. For example, a distinction between lifting of slabs and pipes on one side and walls and linear concrete elements such as beams and columns on the other side is generally appropriate.

The test conditions should consider:

— direction of loading of the insert (tension, shear or in combination);

— dimensions of the concrete member;

— concrete strength at the age of lifting;

— arrangement of insert(s) within concrete member (distance between inserts, edge distance, etc.);

— reinforcement.

7.2.2 Design of test specimen

Depending on the area of application, typical test specimen may be arranged as shown in Table 8 and Figures 31 to 33.

In addition the steel resistance should be tested (if included in the calculation model).

Table 8 — Typical test specimen simulating different areas of application

Application of inserts in	Type of loading		
	Tension	**Combined tension and shear**	**Shear**
Walls and linear elements	Figure 33	Figure 33	Figures 33 or 34
Slabs and pipes	Figures 31 or 32	Figure 31	Figure 34

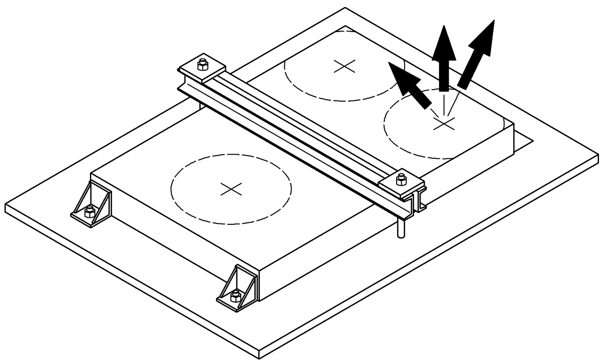
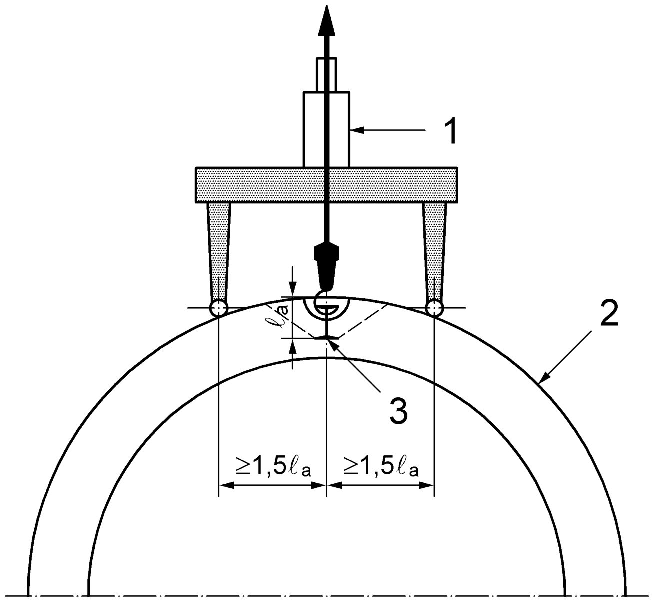


Figure 31 — Example of a test set-up for inserts under tension load and combined tension and shear load



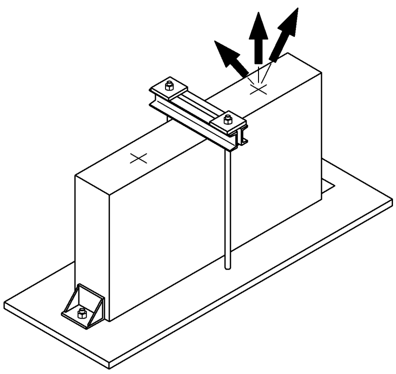
Key

1 jack

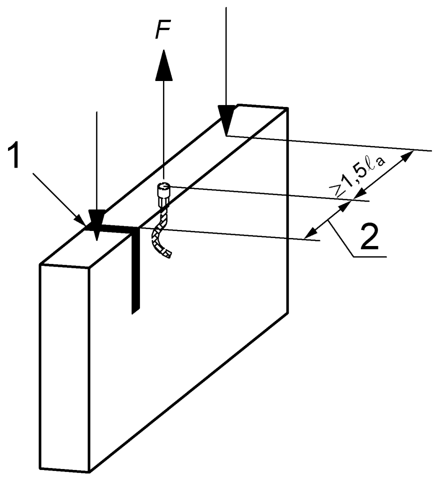
2 pipe

3 insert

Figure 32 — Example of a test set-up for inserts under tension load in a pipe



a)



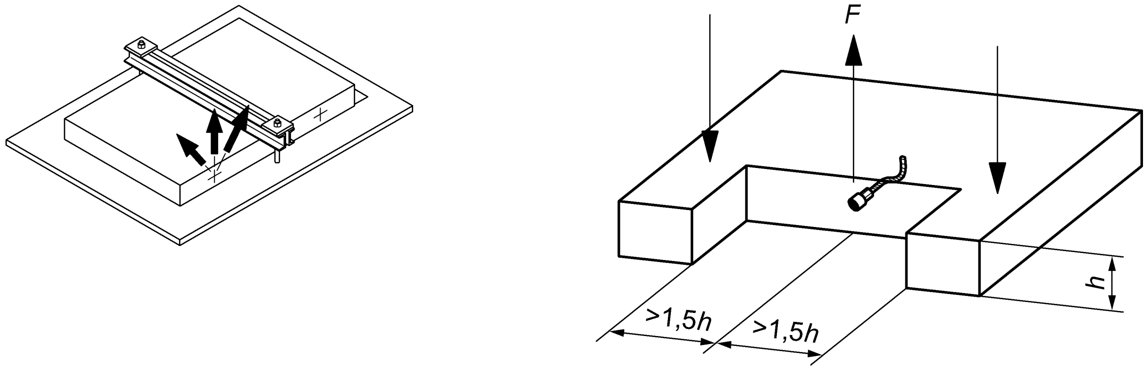
b)

Key

1 polystyrene

2 edge distance

Figure 33 — Examples of test set-ups for inserts under tension load and shear load in a wall



a) b)

Figure 34 — Examples of transverse shear test set-ups

7.2.3 Age of concrete specimen at testing

The specimen should be representative for the concrete product, i.e. cured and kept as the product and tested such that properties can be established for the relevant lifting situations. The precise history of the specimen should be known i.e. age, production, curing method, storage, etc.

Typically testing is performed at early age of the concrete. It should be noted that the tensile strength of the concrete develops slower than the compressive strength during the first days of hardening. Furthermore, it should be considered that temperatures due to heat of hydration may yield strength development of the test specimen different from that of the corresponding cubes or cylinders stored together with the specimen.

7.2.4 Specification of inserts

The testing samples should be representative of the production of the manufacturer as applied to the precast concrete element.

The lifting inserts should be installed in accordance with the intended use.

The lifting inserts to be tested should be unambiguously identified by comparison with relevant specifications and drawings.

7.3 Loading conditions

7.3.1 Load and support conditions

After the concrete specimen has been installed, the lifting insert should be connected to the test rig by means of the lifting key intended for use in practice. If the lifting insert is part of a lifting system, the lifting insert should be tested with the appropriate lifting key. In other cases the smallest high strength hook intended to be used should be used in the tests.

The test rig should be placed such that an unrestricted concrete failure is possible. The clearance l_s between insert and support of the test set-up on the specimen to avoid an influence on the concrete break-out resistance should be at least:

— in case of inserts under tension loading in general the clearance between outer perimeter of the insert and support of the test set-up $l_s \geq 1{,}5 \cdot h_{ef}$;

— in case of inserts under tension loading where other than concrete break-out failures are to be studied, the distance between support and insert may be reduced to a value of half of the insert length and the directly connected rebars;

— in case of transverse shear loading $l_S \geq 1{,}5 \cdot h$, Figure 34b.

In a combined tension and shear test the load may be applied by either one jack acting at the specified angle to the lifting insert axis or by two jacks under servo control applying simultaneously an axial tension load and a shear load, respectively. During the test the intended angle of load application should be kept constant with a tolerance of ± 2°.

7.3.2 Loading history

The insert should be loaded to failure unless the resistance of the insert is determined by attributes.

The load should be applied to the specimen according to the following procedure:

— speed of loading should not exceed 10 % of expected ultimate load per minute. In case of manual recording of test data the time includes actual time used to increase the load from one level to the next and the time spent at each load level to record displacements and to make other observations;

— the loading history should start with one loading-unloading step to a small load value (5 % of expected ultimate load to settle the set-up);

— the loading history should contain 5 loading-unloading sequences to service load level each sequence consisting of 5 load steps (if the stiffness or permanent deflections are part of the objectives).

7.3.3 Measurements

Tests should be carried out using measuring equipment for load and displacement having traceable calibration.

The load application equipment should be designed to avoid sudden increase in load especially at the beginning of the test. The measuring error of load and displacement should not exceed 3 % of measured values at ultimate load in each test.

Displacements should be recorded continuously (e.g. by means of displacement electrical transducers) with a measuring error not greater than 0,1 mm.

The displacements of the insert relative to the concrete surface at a distance of > 1,5 embedment depth in case of tension loading and > 1,5 edge distance in case of shear loading from the insert should be measured in the direction of the load application.

7.4 Test programs

7.4.1 General

The need for testing arises when prior knowledge is insufficient. It means that the need may vary from almost nothing to infinity depending on the situation. And it means that there may be more than one good solution to a given problem.

Prior knowledge may be hard core evidence like original results of earlier traceable tests. It may be state-of-the-art evaluations of test results from other sources (like the present report or design recommendations from suppliers of inserts). It may even be experience from previous successful use of an insert. From a statistical point of view the use of these various types of prior knowledge is not necessarily unambiguous and thus the need for testing is always debatable. Furthermore, it may well be more economical to compensate for uncertain design rules by over-sizing the inserts instead of doing more testing. The following recommendations should therefore be considered as guide lines for good practice rather than legal minimum requirements.

7.4.2 Tests to verify prior knowledge

The precaster will often have a certain prior knowledge about the resistance properties of an insert to be used in a certain application. The aim of testing is to fill in the remaining gaps. The typical situations would be in a range between the following two examples:

— the validity of an earlier initial type testing (ITT) is to be checked. Strong prior knowledge can be claimed and the rules given in EN 1990:2002, D.8.4 may be used requiring only a few tests;

— the precaster intends to use a “home made” insert for a limited range of applications. The insert may or may not be covered by the type descriptions in Clause 6. For the initial type testing (ITT) the precaster assumes that the load capacity of the insert within the application range may be calculated according to a certain calculation model. Tests are then used to verify that the assumed calculation model can be used or how the model may be improved. EN 1990:2002, D.8.2 describes the procedure and an example on the use of the procedure is given in CEN/TR 14862:2004.

The term “prior knowledge” is by nature a flexible concept. Furthermore, some of the descriptions given in EN 1990 may be interpretable so that different designers may reach different results from these procedures. It is therefore important that a clear and fair limitation on the range of applicability of the resulting calculation model is given.

7.4.3 Tests utilizing no prior knowledge — Determination of properties for one insert used for specific applications

This possibility may be used successfully for ITT when an insert is to be used in a very narrow range of applications. A number of tests may be used to determine the mean value and the deviation of the resistance. The characteristic resistance may then be found using ordinary statistical methods as described in EN 1990:2002, D.7.2. Prior knowledge is not needed in this case:

— the tests may be performed for only the most unfavourable situation within the range of applications in order to obtain a characteristic resistance that may then be used for the whole range;

— tests may also be performed for several situations which each represent the most unfavourable case of a group of situations within the range of applications;

— in any case the testing should cover at least the most unfavourable combination of the intended lifting and handling conditions, e.g. lowest concrete strength or loading direction with the lowest expected ultimate resistance.

The method may utilize prior knowledge on the coefficient of variation, but if a larger range of applications should be covered, it would often be more economical to develop a design model according to Annex A.

7.5 Assessment of the test results

Assessment of test results and verification of design model should be according to EN 1990:2002, Annex D.

7.6 Test report

The report should include enough information to make it possible to repeat the tests. At least the following information should be available:

7.6.1 General information

— Description and type of insert.

— Insert identification (dimensions, materials, coating, production method).

— Name and address of manufacturer.

— Name and address of test laboratory.

— Date of tests.

— Name of natural or legal person responsible for the tests.

— Type of test (e.g. tension, shear, oblique tension, short-term or repeated load test).

— Tests should be supervised and inspected by personnel with documented competence

— Number of tests.

— Test rigs, illustrated by sketches or photographs.

— Particulars concerning support of test rig on the test member.

7.6.2 Test members

— Composition of concrete. Properties of fresh concrete (consistency, density).

— Date of manufacture.

— Dimensions of control specimens, and/or cores (if applicable) measured value of compression strength at the time of testing (individual results and average value).

— Dimensions of test member.

— Nature and positioning of any reinforcement.

— Direction of casting, if horizontally or vertically.

7.6.3 Installation of the insert

— Information on the positioning of the insert (e.g. placed on the uncast face or cast face of the test member).

— Distances of inserts from edges of test member and between adjacent inserts.

— Tools employed for insert installation.

— Depth of anchorage.

— Quality and type of screws and nuts employed.

— Length of thread engagement (where applicable).

7.6.4 Measured values

— Parameters of load application (e.g. rate of increase of load, size of load increase steps, etc.).

— Displacements measured as a function of the applied load.

— Any special observations concerning application of the load.

— Ultimate load.

— Cause(s) of rupture or failure.

— Radius (maximum radius, minimum radius) and height of a concrete cone produced in the test (where applicable).

7.6.5 Evaluation report

The evaluated data should be reported and as a minimum requirement, the report should include at least the following information:

— complete product identification, explicit installation instructions, and design data;

— description of types of lifting inserts fasteners;

— constituent materials of the lifting inserts;

— insert performance data.

8 Lifting and handling instructions

The following information should be available at the precast plant and on site for each type of precast element:

— lifting keys to be used;

— weight of the precast element;

— permitted suspension points; if necessary balancing yoke;

— required number of suspension points;

— permitted storage points;

— allowable inclination of lifting wires;

— placing and support of stacks;

— maximum stacking height;

— temporary supports or stabilizing measures, if required;

— any measures for protection, if necessary (this does not have anything to do with lifting and handling, except to prevent ice forming in lifting recesses);

— allowable orientation of the element during handling.

In certain cases it might be necessary additionally to include a description of the required compensation devices the transport and erection procedures and to indicate the centre of gravity.

Annex A
(informative)

Information to be given by the insert supplier

A.1 Information on the content of an operational manual

A.1.1 General technical introduction

The introduction should contain the following:

a) short description of the lifting anchor system and its components including the connection between key and lifting inserts;

b) description of the use of the lifting system with regard to:

— — storage;

— — assembly in formwork;

— — lifting and handling precast units;

c) general specification:

— — corrosion behaviour;

— — type of marking and signing the system;

d) general field of application:

— — range of concrete unit types;

— — load directions;

e) restrictions;

f) compliance with Directive 98/37/EC, (Machinery Directive);

g) short summary of the design method and assumptions used in design.

A.1.2 Documentation of the lifting anchor

a) Available types, dimensions and sizes and their marking in figures and tables.

b) Materials.

c) Information on which keys can be used, e.g. colour code for threaded systems.

d) The characteristic resistance of the lifting anchor itself.

e) Typical application for types of concrete elements.

f) Load table, dependent of the type of key used, showing at least the insert load capacity for the minimum concrete strength in different directions.

g) Required supplementary reinforcement, shape, amount, diameter, length, depending on the lifting conditions.

h) Minimum dimensions of the concrete elements, spacing between anchors, edge distance, panel thickness, concrete cover.

i) Analysis and hints of risk and danger.

j) Restrictions.

k) Declaration of conformity for CE marking.

A.1.3 Documentation of the lifting key

The operation instruction has to fulfil the European Machinery Directive 98/37/EC. The following information should be given:

a) available types and their marking;

b) marking with identification of:

- producer;
- type and/or size;
- maximum working load e.g. colour code for threaded systems;
- fabrication number;
- year of production;

c) dimensions and sizes in figures and tables;

d) materials;

e) admissible fields of application;

f) information on which inserts can be connected;

g) restrictions in use and storage;

h) analysis and hints of risk and danger;

i) possible consequences of misbehaviour;

j) maximum working load in allowed directions;

k) description of first time usage inspection;

l) removal of the lifting device:

- lifetime definition;

— specification of possible failures;

— description of checking;

— criteria for bringing the key out of service;

— necessary measure tables;

— allowed and forbidden repair or maintenance work;

m) declaration of conformity for CE marking.

A.1.4 Documentation of accessories

a) Available types and their marking.

b) Dimensions and sizes in figures and tables.

c) Materials.

d) Description of typical application of all accessory components:

— for assembly/fixing anchors to formwork;

— for marking and signing the system;

— closing of openings;

— cleaning threads.

e) Analysis and hints of risk and danger.

f) Restrictions.

Annex B
(informative)

Use of Supplier's recommendations

The commercially available lifting systems are usually designed and optimised for defined fields of application, in some cases based on results from proprietary test programs. Catalogue material from the supplier often describes corresponding design methods. These methods may be used provided that one of the following conditions is satisfied:

1) the method is certified by an accredited third party in accordance with a relevant ETAG;

2) the method is certified by an accredited third party in accordance with a CEN product standard;

3) the method is certified by an accredited third party based on tests according to Chapter 6;

4) the method is given by national provisions.

The supplier's declaration of the product should state the method chosen. If the supplier cannot satisfy either of these conditions, or if the intended application falls outside the range of validity for the design methods recommended by the supplier, the designer should choose one of the options in Clauses 5 or 6.

Information given by the supplier should conform to Annex B.

Suppliers' catalogues may disclaim the responsibility for the use of the data. Consequently, such catalogues should not be used as a recommendation.

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[6] prEN 10138-3, *Prestressing steels — Part 3: Strand*

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BSI Group Headquarters

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