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Dimenzioniranje in uporaba transportnih sider za betonske polizdelke - Elementi

Design and Use of Inserts for Lifting and Handling of Precast Concrete - Elements

Bemessung und Verwendung von Transportankern für Betonfertigteile

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

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Design and Use of Inserts for Lifting and Handling of Precast Concrete - Elements

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Bemessung und Verwendung von Transportankern für Betonfertigteile

This Technical Report was approved by CEN on 2 March 2008. It has been drawn up by the Technical Committee CEN/TC 229.

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Contents

Page

Foreword

This document (CEN/TR 15728:2008) has been prepared by Technical Committee CEN/TC 229 “Precast concrete products”, the secretariat of which is held by AFNOR.

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.

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 all lifting inserts cast into precast concrete elements i.e. lifting parts developed and produced at the precasting plant as well as lifting inserts as part of a system supplied by a manufacturer of lifting systems. 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.

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) and on published supplier’s data.

In the Technical Report numerical values for partial safety factors 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.

1 Scope

1.1 Scope / 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) and the range of these applications is further limited to prevent other types of failure than concrete breakout failure (cone failure), failure of supplementary reinforcement or failure in the steel insert. A basic supposition is that the concrete is demonstrably uncracked during all lifting situations.

The limitation in scope is used to obtain simple design models. Further information may be found in [1].

The recommended safety levels 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 13369:2004, clause 6.3) covering the insert embedment.

This Technical Report does not cover :

— The design of the insert itself (for inserts manufactured by insert suppliers).

— The lifting key that hooks on to the embedded lifting insert as a component between the insert and the lifting machinery (crane, excavator…), nor its compliance with the embedded insert. These components, when brought to the market separately, are covered by the Machinery Directive (98/37/EC).

— Lifting inserts for permanent and repeated use.

This report is not an interpretation of the Machinery Directive.

1.2 Types of inserts for lifting and handling

This Technical Report applies to the embedment of lifting inserts made by the precaster for his own use as well as lifting inserts forming part of lifting systems brought to the market by a lifting system supplier, see tables 8.3 and 8.6. Devices made by the precaster may consist of smooth bars, prestressing strands and 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, nor wire ropes of less than 6 mm.

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 ℓ_a = 40 mm.

2 Normative references

The following referenced documents are indispensable for the application of this document. 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 10025-2:2004, *Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels*.

EN 10138-3, *Prestressing steels — Part 3 : Strand* [1)].

EN 12385-4:2002, *Steel wire ropes — Safety — Part 4 : Stranded ropes for general lifting applications*.

EN 13369:2004, *Common rules for precast concrete products.*

EN 13414-1:2003, *Steel wire rope slings — Safety — Part 1 : Slings for general lifting service*.

CEN/TR 14862:2004, *Precast concrete products — Full-scale testing requirements in standards on precast concrete products*.

3 Definitions and symbols

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

3.1 Definitions

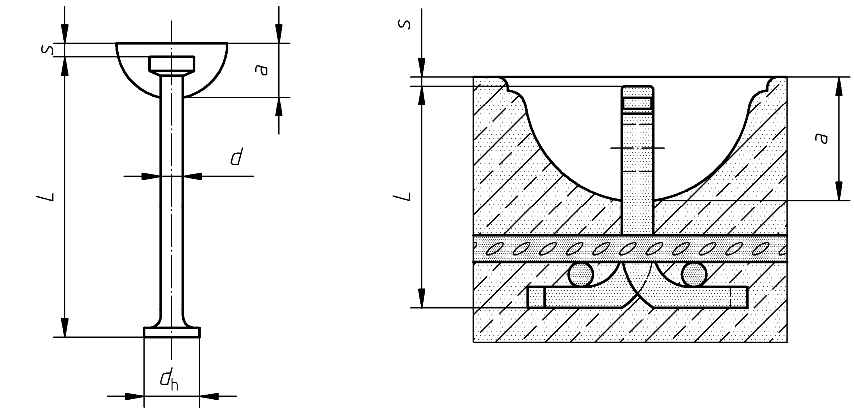
3.1.1
concrete breakout failure
concrete cone separated from the base material by loading the insert

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

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

[1)] Presently under preparation

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



$$\ell_a = 1{,}25(L + s - a) \leq L + s$$

$$\ell_a = 1{,}25(L + s - a) \leq 0{,}85L + s$$

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)
a quality system satisfying the requirements in EN 13369, clause 6.3

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

3.1.8
insert
a 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 key
lifting tool to couple to the embedded insert

3.1.12
lifting system
system of lifting key and appropriate insert

3.1.13
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 Directive 98/37/EC, 4.1.1)

3.1.14
precaster
producer of precast concrete elements in a factory environment

3.1.15
pullout failure
a failure mode in which the insert pulls out of the concrete without a steel failure and without a concrete breakout failure

3.1.16
side-face blow-out resistance
the 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

3.1.17
insert steel failure
failure mode characterised by fracture of one of the steel insert parts

3.1.18
minimum reinforcement
reinforcement required by EN 1992-1-1 or in national annex (Nationally Determined Parameter)

3.1.19
supplementary reinforcement
reinforcement designed to resist the full load in case of a concrete failure

3.1.20
complementary reinforcement
reinforcement provided to avoid brittle failure

3.1.21
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
ψ_{dyn}	dynamic coefficient
γ_G	partial factor for dead load
γ_Q	partial factor for live load
γ_c	partial factor for concrete
γ_s	partial factor for steel

3.2.2 Concrete and 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_{uk} characteristic steel ultimate tensile strength

A_s stressed cross section of steel

3.2.3 Inserts

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

c edge distance from the axis of an insert

d diameter of insert bolt or thread diameter

d_h diameter of insert head (headed inserts)

d_s diameter of reinforcing bar

ℓ_a anchorage length (Figure 1)

4 General design principles

4.1 General principles

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.

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

4.2 Partial factors

4.2.1 Partial factors for actions

In the absence of National provisions the following factors are recommended:

γ_G = 1,15 (partial factor for dead load) ;

γ_Q = 1,5 (partial factor for live load, i.e. adhesion, friction and dynamic actions).

4.2.2 Partial factors for resistance

In the absence of National provisions the partial factors given in Tables 1 and 2 are recommended.

Recommended values of the partial factors γ_s for characteristic resistance of steel based on characteristic ultimate values (R_{uk}, f_{uk}) are given in Table 1. For solid steel loops, steel wire ropes and prestressing strands the partial factor γ_s is based on the characteristic resistance of the loop including effects of the lifting hook.

Recommended values of the partial factor γ_c 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 1 — Partial factors γ_s for steel failure

Type of insert	$f_{uk} \le 800 N/mm^2$ and $f_{yk}/f_{uk} \le 0.8$	$f_{uk} > 800 N/mm^2$ or $f_{yk}/f_{uk} > 0.8$
Solid steel lifting systems	Max(1,5; 1,2 f_{uk}/f_{yk})	1,7
Solid steel (smooth bars) lifting loops *)	2,0	-
Steel wire ropes	-	1,8
Prestressing strands	-	1,8
*) The material for smooth bar lifting loops should be at least equivalent to S235J2+N.		

Table 2 — Partial factors γ_c for concrete failure

Loading in	Certified FPC
Tension	1,5
Shear, combined tension and shear	1,5

5 Actions on inserts

5.1 Actions

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). 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

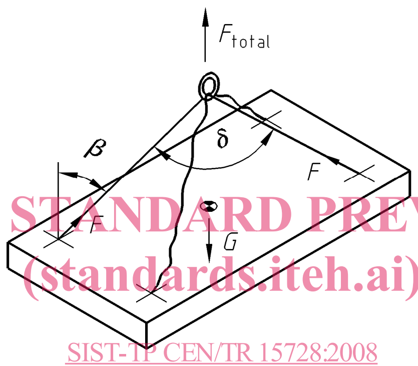


Figure 3 — Statically indeterminate system, only two inserts loaded

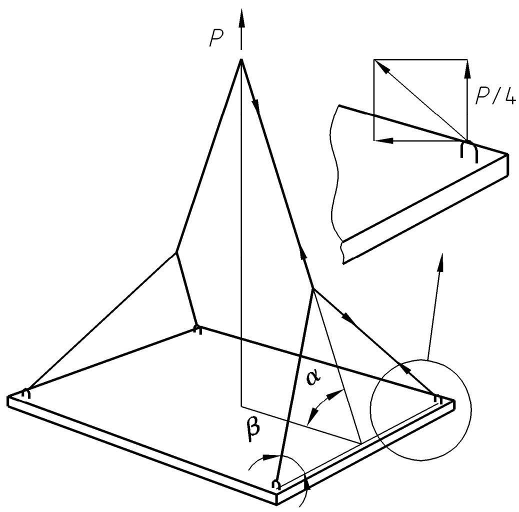
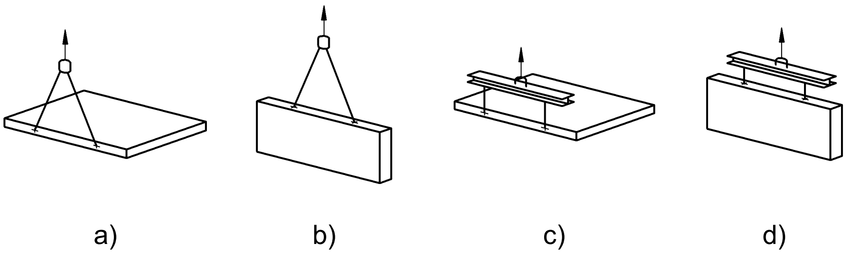


Figure 4 — Example of statically determinate lifting of a slab and resolution of forces

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).



Key

a) Combined parallel and transverse shear load

b) Combined tension and parallel shear load

c) Transverse shear load

d) Axial load

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 half the nominal diameter of the insert.

5.3 Actions from adhesion and form friction

Adhesion and form friction will occur when the precast element is removed from the formwork. 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 3 may be considered. General values for form friction are difficult to assess and friction should be avoided as far as possible.

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 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 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 3 — Examples of values of q_{adh}

Formwork and condition	q_{adh} *)
Oiled steel mould, oiled plastic coated plywood	1 kN/m^2
Varnished wooden mould with planed boards	2 kN/m^2
Oiled rough wooden mould	3 kN/m^2
*) The area to be used in the calculations is the total contact area between the concrete and the form.	

The actions, E_d, for demoulding situations should be determined from:

$$E_d = \gamma_G \cdot G + \gamma_Q \cdot q_{adh} \cdot A_f$$

with

G = weight of the precast concrete element ;

A_f = form area in contact with concrete ;

γ_G and γ_Q are partial safety factors for permanent and variable actions respectively.

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 4 may be considered. Other dynamic influences than covered by Table 4 should be based on special provisions or engineering judgement.

Table 4 — Influence of dynamic actions on site

Dynamic influences	Dynamic coefficient (ψ_{dyn})
Tower crane and portal crane	1,2 x)
Mobile crane	1,4 x)
Lifting and moving on flat terrain	2 – 2,5
Lifting and moving on rough terrain	3 – 4
x) 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 Equation (5.3):

$$E_d = \gamma_G \cdot G + (\psi_{dyn} - 1)\gamma_Q \cdot G$$

6 Choice of inserts

Having determined the actions on the insert for all relevant load combinations the task remains to choose an appropriate insert and relevant reinforcement.

The insert load capacity depends on the field of application. The designer has three options in choosing the appropriate lifting arrangement :

1) The recommendations given by the insert suppliers may be used directly. This option is further described in clause 7;

2) The design charts provided in clause 8 may be used;

3) Tests may be carried out specific to the intended application as outlined in clause 9.

Figure 6 indicates which option could be appropriate in a given situation.

7 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 Annex A;

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 clause 8 or clause 9.

Information given by the supplier should conform to Annex B.

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