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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 Anwendung von Transportankern für Betonfertigteile - Elemente

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

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 COMMITTEE FOR STANDARDIZATION
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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

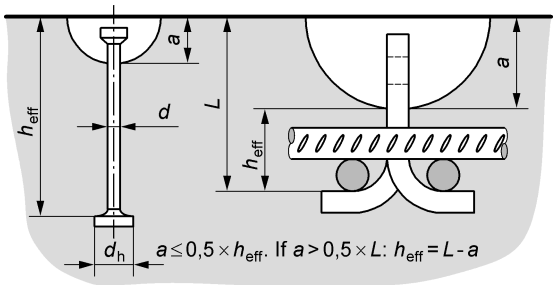

Figure 1 — Examples of anchorage length for different types of inserts

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;
ψ_{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:

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

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:

$$E_d \leq C_d \tag{4.2}$$

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:

$$E \leq R_{adm} \tag{4.3}$$

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:

$$R_{adm} = R_k / \gamma \tag{4.4}$$

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	$f_{yd} = f_y / (\gamma_s \times \gamma_{l+h}) = f_y / 1{,}75$