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Montažni betonski izdelki – Zahteve za preskušanje v naravni velikosti v standardih za montažne betonske izdelke

Precast concrete products - Full-scale testing requirements in standards on precast concrete products

Betonfertigteile - Anforderungen an Prüfungen an Bauteilen in Originalgröbe in den Normen für Betonfertigteile

Produits préfabriqués en béton - Exigences pour les essais en vraie grandeur dans les normes sur les produits préfabriqués en béton

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This Technical Report was approved by CEN on 19 April 2004. It has been drawn up by the Technical Committee CEN/TC 229.

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Foreword

This document (CEN/TR 14862:2004) has been prepared by Technical Committee CEN/TC 229 “Precast concrete products”, the secretariat of which is held by AFNOR.

Introduction

Any product standard will require a certain amount of testing as part of the evaluation of conformity. The tests may be part of initial type testing or part of production control. It may be tests on materials, dimensions etc. Or it may be tests on the finished product.

The following types of testing may be involved as a part of either initial type testing or production control, [1]:

a) tests to establish directly the ultimate resistance or serviceability properties of structural parts. Test results are treated as absolute values valid for the group from which the sample was taken;

b) tests to obtain specific material properties using specified testing procedures;

c) tests to reduce uncertainties in parameters in load or load effect models;

d) tests to reduce uncertainties in parameters used in resistance models. Test results are defined as the ratio between measured and calculated values and statistical rules are applied to the ratio;

e) control tests to check the identity or quality of delivered products or the consistency of the production characteristics;

f) tests carried out during execution in order to obtain information needed for part of the execution;

g) control tests to check the behaviour of an actual structure or of structural members after completion.

Testing of full-scale products may be involved in all types of test except type (b).

Testing methods may or may not leave the tested product fit for further use (non-destructive or destructive testing). However, apart from checks on geometrical properties, full-scale testing will usually damage the tested product so that it cannot be used in a structure.

Tests of type (a) do not take into account prior knowledge as easily as type (d) tests. It means that the most effective use of full-scale testing will be (effectively destructive) tests of type (d).

The aim of the report is to assist the standard writers in CEN/TC 229 regime in preparing requirements on full-scale testing in product standards. Initial type testing of a product requires the producer to establish relevant properties of the product. This is often done by means of calculation models given in a standard, but in some cases full-scale testing may be used effectively to reduce uncertainties in these calculation models, maintaining the intended reliability.

The main statistical rules to be followed in this process are given in Eurocode – Basis of structural design (prEN 1990). The report illustrates how these rules may be applied in a product standard.

A practical example concerning hollow core slabs is also given. The test results used in this example were made available from Spenncon AS Hønefoss, Norway.

1 Scope

This document gives guidelines on how full-scale tests may be incorporated in product standards as a tool to reduce incertainties in resistance models.

This document also gives guidelines to designers setting up a proper test programme as part of the initial design of a component.

2 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 1168, *Precast concrete products - Hollow core slabs for floors.*

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

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

EN 13369, *Common rules for precast concrete structures.*

ISO 12491:1997, *Statistical methods for quality control of building materials and components.*

RILEM TC40-TPC3:1985, *Flexural and shearing tests on prefabricated concrete elements, Materials and structures, Vol. 18, No 108.*

3 Terms and definitions

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

3.1
accompanying test
test to determine a material property by direct or indirect methods

3.2
biased sampling
a selection of units, taken from a lot according to a selection plan

3.3
full-scale test
test performed on a finished product to determine directly the properties of the product. Properties may include behaviour, stiffness, strengths etc. of the product subjected to relevant actions

3.4
initial type testing
a procedure to demonstrate compliance of a product with the requirements applying to the product. The procedure may utilise calculation and standard materials testing and it may be assisted by full-scale tests on the product

3.5
random sampling
a selection of units, taken at random from a lot. Each unit of the lot has the same chance of being selected

3.6
resistance model
a formula used for calculation of a product property

3.7
prior knowledge
existing knowledge about the properties of a product and their dependence on geometry, materials, production process etc

3.8
product family
a type of product usually corresponding to one product standard, e.g. prestressed hollow core floor slabs

3.9
product group
a collection of products with such characteristics that all products can be attributed the same value of a chosen property. The grouping may depend on the property. Hollow core floor slabs with the same dimensions and concrete strength may be a group with respect to shear strength

3.10
production control
a production control system is a quality system to ensure that the product put on the market meets the requirements of the relevant standard and complies with the specified or declared values

4 The role of full-scale testing

4.1 Design using existing calculation models

Design of products according to Eurocode 2 (EN 1992-1-1), is normally based on resistance models giving the product properties as a function of the geometry and the properties of the material used in the product. The resistance model normally expresses the mean value of the property when the mean values of the parameters are inserted in the model. It is usually assumed that the same model express the characteristic value or the design value of the property if characteristic values or design values of the parameters are inserted in the model.

The design strength parameters for the materials are normally found by reducing the characteristic strength obtained from materials testing by a partial safety factor. In the initial type testing of a product, these design strength parameters are used together with nominal dimensions of the product in the resistance model to determine the design value of the property. The producer can then declare a design property less than or equal to the calculated design value.

It is noted that partial safety factors may change from country to country. The design value of a property for a specific product may therefore also be different from one country to the next.

Following initial type testing, the continuous production is monitored by production control to make sure that the declaration (and its assumptions) is fulfilled. The production control relies primarily on checking the process, including tests on materials etc. The finished product is checked for geometry, appearance etc. The resistance model used in initial type testing is usually taken for granted.

4.2 Design assisted by testing

The resistance models available in Eurocode 2 (EN 1992-1-1), may not be adequate for initial type testing of a number of products within the regime of CEN/TC 229. A model may intend to cover a large spectrum of products, and the model should be safe for the whole spectrum. The model may therefore become conservative for some of the products within that spectrum. In other cases the uncertainty on the model may in general be large.

Full-scale testing may in such cases support the initial type testing in two different ways:

— tests (of type (a)) may be used to determine directly the property of a specific product ("single property determination"), e.g. the shear strength of a hollow core floor slab with specified dimensions and materials. The tests may yield a number [kN/m] for the mean value and a number for the characteristic value. These properties will be different for different variants of a product family. Although the approach may sometimes be useful, it often becomes economically unfeasible because the product family may contain so many variants, that the cost of testing is prohibitive. Furthermore, the design value of the property depends on a partial safety factor that is not known, unless the property depends on the strength of only one material. Declaration of a design value for the property may therefore not be easy;

— tests (of type (d)) may be used to improve inadequate resistance models ("determination of resistance model"). The result is a revised resistance model to determine the mean values of the property for a product family. For example, an improved formula to determine the mean value of the shear strength of hollow core floor slabs as a function of the actual dimensions and actual material strengths of the test specimens.

When a revised resistance model is found, initial type testing continues in the same way as if the resistance model was taken from Eurocode 2. It means that design properties are calculated by the revised formula (using nominal values for dimensions and design values for material strengths). The producer can declare properties less than the calculated design values. Different declarations will appear due to variations in the partial safety factors.

The production control procedures will contain the same items as if calculation by Eurocode 2 was used in initial type testing. New items may have to be added, if the revised resistance model is sensitive to parameters that are not monitored as part of the normal production control.

5 Specification of full-scale testing requirements.

A product standard may include requirements on full-scale testing and such requirements should be specified with the same degree of stringency as is normally used when calculations are specified. It means that the following three subjects shall be dealt with:

— **why** are full-scale testing to be considered (Objectives and planning);

— **how** can a relevant full-scale test be performed (Test method);

— **what** are the consequences of the results of the test (Interpretation).

These subjects are interrelated. A test method is relevant only if it produces information about the objectives. The planning shall foresee the interpretation phase and the interpretation of course is linked to the objectives.

The **why** and **what** issues are natural parts of the product standard itself, while the **how** issue may be treated either in a separate standard or in the product standard itself.

Clauses 6, 7 and 8 in the present document outline the considerations to be dealt with by the standardisation body with respect to objectives, planning and interpretation. The outline is supported on two annexes:

— Annex A containing a brief summary of the statistically based procedure described in EN 1990:2002 to determine a resistance model. The procedure is illustrated by an example dealing with shear strength of hollow core floor slabs;

— Annex B contains a list of items to be covered in the specification of a full-scale test in a CEN/TC 229 product standard. Text that can be used independently of the product is given to the extent possible.

6 Objectives

If a standardisation body decides to introduce provisions on full-scale testing, the body shall specify directly those subjects that full-scale testing is supposed to clarify. The need for full-scale testing will often be associated with initial type testing, where resistance models are needed. The existing models, however, may be too conservative or otherwise insufficient for calculation of product properties. A possible reason for such conservatism could be that the model is intended to be safe within a larger range of parameters than needed for the specific product.

6.1 Option or requirement in initial type testing

The first decision to be made by the standardisation body is whether full-scale testing is an option or a requirement:

— if given as an option the product properties may be declared based on either a resistance model, referred to or given by the standard, or on a resistance model verified by test results. The option should allow a benefit from testing;

— if given as a requirement the declared property must be based on a resistance model verified by the test results.

If available resistance models are considered sufficient there is no need for full-scale testing. If so there is no reason that a standard should require such testing, also considering that the cost of full-scale testing is generally rather high. Full-scale testing should therefore preferably be used as an option leaving the producer to decide whether money should be spent on testing or on more conservative declarations of properties.

6.2 Part of production control

In principle, the use of full-scale testing as part of production control is possible, but it may not necessarily be warranted.

Testing included in the production control process should be considered as a basis for acceptance or not acceptance of a part of the total production. This also applies to full-scale tests if they are made as part of the production control. The available number of full-scale tests, however, is likely to be small for economical reasons. An acceptance procedure based on a small number of tests becomes very unreliable. If initial type testing has been performed, it is much more relevant to consider such tests during production as further type testing.

6.3 Further type testing

If full-scale testing has been part of the initial type testing there may be good reasons to require further type testing at certain intervals. According to EN 13369, further type testing is required when major changes take place (new raw materials, new production process etc.). In practice smaller changes are made from time to time - intentionally or not intentionally. Especially changes in the production process may occur without being recognised as a change requiring new initial type testing. The standardisation body may therefore consider a maximum time limit for the validity of the initial type testing.

The further type testing may (or may not) lead to a revision of the declared properties or a new design for future production, while the result is of no consequence for the past production. It should also be noted, that validation of an earlier initial type testing may only require a few additional tests.

6.4 Technical questions to be clarified

The technical questions to be solved by testing may depend heavily on the product. Typically, strength properties for the product may be questioned.

In the normal design process, some failure modes for the product are favoured, while other modes are considered less acceptable or even unacceptable. For a beam, e.g., a bending failure is favoured, a shear failure may usually not be accepted and a spalling failure in the anchorage zone may be considered unacceptable. The protection against shear failure is often specifically designed for each individual component to obtain a bending failure at a lower load level than a shear failure, but economy may call for a small margin between the two load levels. Protection against spalling is often obtained by a more conservative approach leaving no significant doubt that this type of failure mode is unlikely.

A design process assisted by testing may therefore include a determination of the critical strength properties (e.g. the shear capacity) and a check, that failure modes considered in the actual case to be unlikely are in fact unlikely (e.g. a spalling failure). This last objective may not require a precise determination of the failure load. It may be sufficient to establish that the capacity is higher than some threshold value, which is likely to be the upper value of the action effect.

7 Planning

7.1 Groups in the product family

A product standard shall normally cover all products within a range of variations (geometry, raw materials, etc.) and resistance models given in the standard for the relevant properties shall therefore cover that range. In most cases such resistance models are available based on prior knowledge about the properties of a product family, although the models may be more or less accurate. If the model is known to be very accurate, the need for testing is non-existent. Less accurate models may also be used in the standard – most likely with a built-in margin reflecting the uncertainty. The larger uncertainty, the more the testing option is needed.

Although a model may be associated with a large uncertainty, it usually identifies the most important parameters. The model can therefore be used to separate a family of products into groups within the family that can be assumed to have (almost) the same property.

As an example, a producer of hollow core floor slabs may consider a resistance model from Eurocode 2 to give conservative shear capacity results for the range of products in his own production. The producer wants to improve the resistance model based on full-scale tests. The existing model suggests that the shear strength of a hollow core floor slab is sensitive to the slab thickness, the thickness of the webs and the concrete strength, and less sensitive to the amount of reinforcement and prestress. The producer may therefore choose to consider all slabs with the same concrete dimensions and concrete strength as one group. A test program to improve the model should consequently contain specimens from those groups that are contained in the producers production program.

A product standard, which requires or allows design assisted by testing should preferably identify the best possible resistance model, or it should identify, alternatively, the rules and limitations that shall be applied with respect to grouping. Members of the standardisation body are likely to have expert knowledge about these items and the body is therefore suited to give such guidance. Otherwise, rules of this kind are effectively decided by the producer or by a third party.