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Mehanski preskusi za ponapenjalne sisteme

Mechanical tests for post-tensioning systems

Mechanische Prüfungen für Spannverfahren it nachträglichem Verbund

Essais mécaniques concernant les procédés de précontrainte par post-tension

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Mechanische Prüfungen für Spannverfahren it nachträglichem Verbund

This European Standard was approved by CEN on 3 November 2003.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Foreword

This document (EN 13391:2004) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2004, and conflicting national standards shall be withdrawn at the latest by August 2004.

This European Standard was prepared by Working Group 1 of CEN/TC 250/SC 2 "Design of concrete structures". The standard supplements ENV 1992-1-1, ENV 1992-2 and the "European Technical Approval Guideline of post-tensioning kits for prestressing of structures (these are commonly called Post-Tensioning Systems)", ETAG 013.

Annex A is informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies the test procedures for the anchorages and couplings of post-tensioning systems. This standard is to be used in conjunction with the relevant European Standards ENV 1992-1-1 and ENV 1992-2 and others for pertaining to prestressed concrete structures.

The test results should be used for the acquisition of the Technical Approval of the specified post-tensioning system.

For unbonded tendons additional tests and requirements are needed and these are not covered in the present scope of this standard.

2 Normative references

Not applicable.

3 Terms, definitions and symbols

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

3.1 Definitions

3.1.1
Anchorage
mechanical device, usually consisting of several components designed to reliably and safely retain the force in the stressed tendon and to transmit it to the concrete. Anchorages can be either of the two types specified below:

- Stressing anchorage: an anchorage located at the end of a tendon which can be used for stressing. It is exposed until grouting has been carried out and the anchorage sealed.

- Fixed anchorage: an anchorage which is not used for tendon stressing.

3.1.2
Anchorage zone
local zone in the structure through which the prestressing force is transferred to the structure via the anchorage

3.1.3
Bursting reinforcement
reinforcement in the anchorage zone to resist transverse tensile forces due to the introduction of prestressing force into the structure

3.1.4
Coupling
device to join tendons

3.1.5
Duct (sheathing)
enclosure in which the prestressing steel is placed and which temporarily or permanently allows relative movement between the prestressing steel and surrounding concrete. The remaining void within the duct can

be subsequently filled with cementitious grout or other suitable material to protect the prestressing steel against corrosion

3.1.6
Prestressing
controlled generation of permanent forces and deformations in a structural concrete member to counteract the stresses arising from dead and live loads and/or due to shrinkage etc.

3.1.7
Post-tensioning system
arrangement of tendon and anchorages to carry out post-tensioning

3.1.8
Tendon
one or a number of prestressing steel elements e.g. wire, strand, bar, etc. Tendons can be either:

— Bonded: following stressing the tendon is grouted, thereby creating bond between the prestressing steel, grout, duct and concrete; or

— Unbonded: bond between tendon and concrete is prevented with the tensile force of the stressed tendon being permanently transferred to the concrete by the anchorages and deviators only

3.1.9
Tendon-anchorage assembly
connection between tendon and anchorage

Symbols

A_{pk} characteristic cross-sectional area of the tendon

A_{pm} actual mean cross-sectional area of the tendon

F_{pk} characteristic ultimate resisting force of prestressing steel of tendon; $F_{pk} = A_{pk} \times f_{pk}$

F_{pm} calculated ultimate resisting force of prestressing steel of tendon; $F_{pm} = A_{pm} \times f_{pm}$

F_{Tu} measured ultimate force of tendon-anchorage assembly

F_{u} measured ultimate force in load transfer test

max F upper force in the dynamic load test with tendon-anchorage assembly

min F lower force in the dynamic load test with tendon-anchorage assembly

ΔF force range in the dynamic load test; ΔF = max F – min F

f_{ck} characteristic compressive strength of concrete at 28 days

$f_{ck,o}$ minimum characteristic compressive strength of concrete at which full prestressing is planned on site

$f_{cm,e}$ mean compressive strength of concrete of specimen at final test to failure in the load transfer test

$f_{cm,o}$ mean compressive strength of concrete at which full prestressing is planned on site

f_{pk} characteristic tensile strength of prestressing steel

f_{pm} actual mean tensile strength of prestressing steel used for test (mean of the result of minimum three tests)

t time

w crack width measured in the load transfer test

ε_{Tu} elongation of prestressing steel on free length of tendon at ultimate force F_{Tu}

4 Tests and requirements for post-tensioning anchorages

4.1 General

4.1.1 Purpose

It is the purpose of the test procedures to standardize the required mechanical tests for post-tensioning systems. The stipulated requirements pertain to the described tests. Figures are given in annex A.

4.1.2 Specification of system

Prior to testing, the principal details of the prestressing system shall be made known as far as they relate to the tests, e.g. by the technical report or specification of system.

4.1.3 Laboratory, testing facility

Generally, the tests shall be performed by an independent and notified laboratory. However, facilities provided by the applicant may be used, if the tests are executed under the surveillance and responsibility of such a laboratory.

4.1.4 Materials and components for the tests

All tests should be performed with the type and grade of prestressing steel and with the anchorage components as intended for application. If the anchorage to be used requires mechanical treatment of the prestressing steel, the effects of such treatment should be considered and justified.

The geometrical and mechanical properties of anchorage components as well as the tolerance range of dimensions shall be made known.

For the load transfer test the grade of concrete for the application of the post-tensioning system shall be as defined in the specifications. The grade of concrete is specified by its characteristic compressive concrete strength at 28 days, f_{ck}, this being determined in accordance with relevant standards. The minimum concrete compressive strength at which full prestress can be applied on site shall be specified. It can be defined either as the mean compressive strength $f_{cm,o}$ or as the minimum characteristic compressive strength, $f_{ck,o}$ of the concrete of the anchorage zone. These values are assumed to be related to each other by:

$$f_{ck,o} = f_{cm,o} - 8 \text{ MPa.}$$

(The properties of the concrete for the specimens are given in 4.2.3.2 and 4.2.3.3)

4.1.5 Types of test

The tests are performed according to the method of anchoring the prestressing steel. A distinction is made between:

— Anchorages formed by mechanical means: the prestressing steel is fixed to an anchorage element by means of mechanical devices such as wedges, button heads, threads, etc. Anchoring may also be achieved by forming the prestressing steel in a loop around a steel element, etc.

— Bond anchorages: the prestressing steel is anchored in the concrete before the stressing force is applied to the tendon. The anchoring may either be achieved by bond alone or partially by a mechanical device and partially by bond.

The tests pertain to tendon-anchorage assemblies and anchorage zones of bonded and unbonded, interior or exterior tendons. Couplings, which connect two tendons to form a continuous tendon, shall be tested in the same way as anchorages with mechanical means.

In carrying out a test items may also be combined, for instance:

— mechanical anchorage – coupling – mechanical anchorage.

— mechanical anchorage – anchorage by bond.

Three types of tests are to be performed: static load test, fatigue test and load transfer test.

4.2 Testing of systems with mechanical anchorages

4.2.1 Static load test with tendon-anchorage assembly

4.2.1.1 General

The aim of the test is to assess the performance of the tendon-anchorage assembly and to determine any decrease of the breaking load of the prestressing steel due to the influence of the anchorage. The test also pertains to couplers.

4.2.1.2 Test specimen

The tendon to be tested shall be assembled according to the envisaged application, using all components necessary for anchoring the tendon. Components for testing shall be randomly selected. The geometrical configuration of the individual tensile elements in the specimen shall be identical to that of the specified tendon assembly given in the European Technical Approval (ETA). The following data of the tensile elements shall be established :

— main mechanical and geometrical properties of the tensile elements, including the actual ultimate strength;

— calculated actual ultimate force F_{pm};

— mean total cross-section of tensile elements A_{pm};

— surface characteristics of tensile elements.

Relevant geometrical and mechanical properties of anchorage components shall also be determined. The free length of the tensile elements in the tendon specimen to be tested shall not be less than 3,0 m, except for bar tendons with a minimum length of 1,0 m. If more than one grade of tensile elements of the same type is to be used with the same type of anchorage, the tests shall be performed using the grade with the highest characteristic tensile strength, and/or load capacity.

4.2.1.3 Test procedure

The tendon specimen is mounted in the test rig or testing machine, observing the same geometrical configuration of the individual tensile elements in the specimen to that specified in the ETA.

The tendon is stressed at one end with representative equipment comparable to the one used on construction site, and specified in the ETA, in steps corresponding to 0,2, 0,4, 0,6 and 0,8 of the characteristic tensile strength of the tensile elements. The load is increased at a constant rate corresponding to about 100 MPa per minute. At 0,8 level, the load is transferred from the equipment to the anchorage and test rig. It is then held constant at 0,8 level for one and two hours for internal and external tendons, respectively. For external tendons, the load is then reduced to 0,2 level. Subsequently, the load is gradually increased for both tendon types with the test rig to failure at a maximum strain rate of 0,002 per minute.

The uncertainty of values measured with the measuring equipment shall be within +1 %. Loads shall be maintained with a maximum tolerance of +2 %. The load measured in the jack shall be adjusted for estimated friction losses in the anchorages to assure that the specified load has been applied to the anchor head used for measurement.

4.2.1.4 Measurements and observations

The following measurements and observations shall be made and recorded:

— Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).

— Relative load– and time–dependent displacement Δs of the tensile elements with respect to the anchorage on at least two elements (see Figure A.1).

— Relative load– and time–dependent displacement Δr between the individual components of the anchorage on at least two components, e.g. wedges (see Figure A.1), or as applicable for other methods of anchoring the tensile elements.

— For external tendons only, deformations of one anchor head in circumferential direction Δt, and deflections of the head relative to the supporting plate Δz, (see Figure A.2), in seven measurement series as follows:

1) At 20 % level.

2) At 40 % level.

3) At 80 % level between time t_o, and t_o + 10 minutes where t_o is time when 80 % level was reached.

4) At 80 % level between time t_o + 30 minutes and t_o + 40 minutes.

5) At 80 % level between time t_o + 60 minutes and t_o + 70 minutes.

6) At 80 % level between time t_o + 120 minutes and t_o + 130 minutes.

7) At 20 % level.

— Complete load-elongation diagram, continuously recorded during the test.

— Elongation of the tensile elements ε_{Tu} on free length at measured maximum force F_{Tu}.

— Measured maximum force F_{Tu}.

— Location and mode of failure.

— Examination of components after dismantling, photographic documentation, comments, including residual deformations of the anchor head.

4.2.2 Fatigue test with tendon-anchorage assembly

4.2.2.1 General

The aim of the test is to determine the capacity of the tendon-anchorage assembly under load fluctuations, as an indication of the reliability and durability of the assembly.

4.2.2.2 Test specimen

The type of specimen corresponds to 4.2.1.2, see also Figure A.1. At least at one tendon end the anchorage with all components which deviate the tensile elements in the anchorage and at the entrance into the duct shall be provided identical to the assembly specified in ETA, with no change to their geometry, their material, and their machining. These components which deviate the tensile elements shall be kept at a fixed distance from the anchorage to duplicate the actual deviation and the relative movements to the tensile elements. If both tendon ends have such anchorage details as specified above, the specimen shall count as two tests.

If more than one grade of tensile elements of the same type is to be used with the same type of anchorage, the tests shall be performed with tensile elements using the grade with the highest characteristic tensile strength, and/or largest load capacity.

Where possible the tendon shall be tested with the complete number of tensile elements installed. However, the number of tensile elements in the tendon-anchorage assembly to be tested may be reduced as follows. For a tendon of n tensile elements, the reduced number n' of tensile elements installed for the test shall comply with:

— if $n \leq 12$: $n' \geq n/2$

— if $n \geq 12$: $n' \geq 6 + (n - 12)/3$

The tensile elements with the most severe angular deviation from the tendon axis shall be included.

The concrete strength at the start of the fatigue test shall not exceed $f_{cm,o}$

4.2.2.3 Test procedure

The test shall be performed in a tensile testing machine with the pulsator at a constant load frequency of not more than 10 Hz, and with a constant upper load of 65 % of the characteristic strength of the tensile elements. Range of loads $\Delta F = \max F - \min F$ shall be maintained constant throughout the testing, at levels corresponding to 80 MPa stress amplitude in the tensile elements for 2 million cycles. On its free length the specimen shall be without duct and filling material.

The specimen shall be tested in such a way that secondary oscillations are precluded. When assembling the specimen and fitting it in the testing machine, special care should be taken to ensure that the load is evenly distributed to all the tensile elements of the tendon.

4.2.2.4 Measurements and observations

The following measurements and observations shall be made and recorded :

— Compliance checking of the components with European Technical Approval specifications (materials, machining, geometry, hardness, etc).