

Products and systems  
for the protection and  
repair of concrete  
structures — Test  
methods —  
Determination of the  
durability of structural  
bonding agents

The European Standard EN 13733:2002 has the status of a  
British Standard

ICS 83.180; 91.080.40

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Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken - Prüfverfahren - Bestimmung der Dauerhaftigkeit von Klebstoffen für konstruktive Zwecke

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## Foreword

This document EN 13733:2002 has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by November 2002, and conflicting national standards shall be withdrawn at the latest by December 2002.

This standard does not supersede any other European Standard. It has been prepared by Sub-Committee 8 "Products and systems for the protection and repair of concrete structures", the secretariat of which is held by AFNOR.

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

## 1 Scope

The purpose of this European Standard is to define laboratory methods of testing to ascertain the durability of structural bonding agents in composite systems involving the bonding of hardened concrete to hardened concrete, fresh concrete to hardened concrete and steel-to-steel.

## 2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1766, *Products and systems for the protection and repair of concrete structures - Test methods – Reference concretes for testing.*

EN 12390-4, *Testing hardened concrete – Part 4: Compressive strength – Specification for testing machines.*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products – Visual assessments of surface cleanliness – Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

## 3 Principle

This standard describes a thermal cycling regime and a warm-moist environment, which are applied in turn to composite systems incorporating a structural bonding agent.

For testing the structural bonding of concrete, the specimen consists of three concrete cubes bonded in line which are then exposed to an environmental regime prior to being subjected to a compressive shear force applied in the plane of the bond line.

For testing the structural bonding of steel, two steel plates are bonded together and subjected to a cleavage force applied by the insertion of a wedge. The stressed specimen is then exposed to an environmental regime during which measurements are taken.

## 4 Equipment

### 4.1 Concrete to concrete composites (see Figures 1a) and 1b))

4.1.1 Steel mould for casting 100 mm × 100 mm × 100 mm concrete cubes.

4.1.2 Jig to ensure accurate alignment when bonding the 100 mm × 100 mm × 100 mm cubes.

4.1.3 Steel mould 100 mm × 100 mm × 302 mm for casting fresh concrete to hardened concrete specimens.

4.1.4 Compression testing machine conforming to EN 12390-4 capable of testing the bonded specimens conforming to 6.2.1 and 6.2.2 in compressive shear.

4.1.5 Test rig support to align the bonded cube assembly securely in the testing machine whilst the compressive shearing force is applied parallel to the planes of the bonds and distributed evenly between them, as depicted in Figures 1a) and 1b).

## 4.2 Steel to steel composite (see Figure 2)

- 4.2.1 2 steel plates 150 mm × 25 mm × 3,0 mm.
- 4.2.2 Steel wedge having dimensions depicted in Figure 2.
- 4.2.3 PVC tape.
- 4.2.4 Travelling microscope of magnification 15, fitted with a rule graduated in mm.

## 4.3 Environmental cabinets

- 4.3.1 Temperature controlled conditioning cabinet adjustable to within 1 °C.
- 4.3.2 Programmable temperature cabinet capable of heating to  $(+ 55 \pm 2)$  °C and cooling to  $(- 25 \pm 2)$  °C.
- 4.3.3 Climatic chamber capable of heating to  $(+ 40 \pm 2)$  °C at  $(95 \pm 5)$  % relative humidity.

## 5 Environmental regimes

### 5.1 Thermal Cycle

Thermal cycling takes place in a programmable temperature cabinet. The thermal cycling regime is depicted in Figure 3. After 15 min initial cooling from 20 °C, the cycle starts from  $- 25$  °C according to the detail given in Figure 3. Each thermal cycle consists of a cooling phase over 6 h in air at a temperature of  $(- 25 \pm 2)$  °C followed by a heating phase over 6 h in air at a temperature of  $(+ 55 \pm 2)$  °C. The cooling and the heating shall take place at a rate of 3 °C/min. One cycle lasts for 12 h and comprises the following stages :

- 333 min air storage at  $T = (- 25 \pm 2)$  °C ;
- 27 min heating in air to  $T = (+ 55 \pm 2)$  °C ;
- 333 min air storage at  $T = (+ 55 \pm 2)$  °C ;
- 27 min cooling in air to  $T = (- 25 \pm 2)$  °C.

During any interruption of the cycling the specimen shall be stored at standard climate conditions  $((21 \pm 2)$  °C/ $(60 \pm 10)$  % relative humidity).

The complete thermal cycling regime shall consist of 50 cycles.

### 5.2 Warm-moist environment

The warm-moist environmental regime shall consist of six months exposure to an environment maintained at  $(+ 40 \pm 2)$  °C,  $(95 \pm 5)$  % relative humidity).

During any interruption to the regime the specimen shall be stored at standard climate conditions  $((21 \pm 2)$  °C/ $(60 \pm 10)$  % relative humidity).

## 6 Preparation of test specimens

### 6.1 General

For applications involving bonded plate reinforcement six specimens of hardened concrete to hardened concrete and six specimens of steel-to-steel shall be produced for testing associated with each environmental regime.

## EN 13733:2002 (E)

For applications involving bonded mortar or concrete six specimens of either hardened concrete to hardened concrete or fresh concrete to hardened concrete shall be produced for testing associated with each environmental regime.

For each environmental regime three specimens shall be tested. A further three specimens shall be maintained at standard climate conditions ( $(21 \pm 2) ^\circ\text{C}$ ,  $(60 \pm 10) \%$  relative humidity) for control purposes.

### 6.2 Concrete to concrete composites

#### 6.2.1 Production of the hardened concrete to hardened concrete specimens

Concrete cubes of dimensions  $100\text{ mm} \times 100\text{ mm} \times 100\text{ mm}$  shall be cast and cured in accordance with EN 1766.

On one cube, two of the formed faces to be bonded and on two cubes, the formed face to be bonded, shall be gritblasted in accordance with the requirements of EN 1766. Immediately prior to bonding these gritblasted surfaces shall be vacuumed to remove any dust.

Mix the components of the adhesive to be tested and apply an even layer approximately 1mm thick to each of the prepared concrete surfaces in accordance with the manufacturer's instructions. Bond the three cubes together to produce a specimen with a bond line approximately 1mm thick as shown in Figure 1. It is necessary to use a jig to ensure accurate alignment of adherents.

Allow the adhesive to cure for at least 7 days at  $(+ 21 \pm 2) ^\circ\text{C}$ ,  $(60 \pm 10) \%$  relative humidity.

#### 6.2.2 Production of the fresh concrete to hardened concrete specimens

Concrete cubes of dimensions  $100\text{ mm} \times 100\text{ mm} \times 100\text{ mm}$  shall be cast and cured in accordance with EN 1766.

On two of the cubes, the cast face to be bonded shall be gritblasted in accordance with the requirements of EN 1766. Immediately prior to bonding this gritblasted surface shall be vacuumed to remove any dust.

The components of the adhesive shall be mixed and an even layer approximately 1 mm thick applied to the prepared concrete surfaces in accordance with the manufacturer's instructions. Place the two cubes at a separation of  $(102 \pm 0,2)$  mm in the  $100\text{ mm} \times 100\text{ mm} \times 302\text{ mm}$  mould. The concrete shall be poured into the central  $100\text{ mm} \times 100\text{ mm} \times 100\text{ mm}$  volume and carefully compacted by hand in accordance with EN 1766.

The complete assembly shall be cured for at least 28 days at  $(+ 21 \pm 2) ^\circ\text{C}$ ,  $(60 \pm 10) \%$  relative humidity.

### 6.3 Production of steel-to-steel composite specimens

Degrease one side of each steel plate using a suitable degreasing agent and then gritblast to grade Sa 2.5 according to ISO 8501-1. The gritblasted surface shall then be vacuumed to remove any dust. Glue PVC tape (12,5 mm wide) on one end of the plate so that the wedge can be inserted there (see Figure 2).

Mix the components of the adhesive and apply an even layer approximately 0,5 mm thick to each of the prepared steel surfaces in accordance with the manufacturer's instructions. Bond the steel plates together in a suitable jig (for example, see Figure 4) in order to achieve a glueline thickness of  $(0,65 \pm 0,05)$  mm.

Allow the adhesive to cure for at least seven days at  $(+ 21 \pm 2) ^\circ\text{C}$ ,  $(60 \pm 10) \%$  relative humidity, before inserting the wedge at a rate of 50 mm/min to its full depth of 25 mm in a suitable compression testing machine.

## 7 Test procedures

### 7.1 Testing of the concrete-to-concrete specimens

After the specimens have undergone the appropriate environmental regime, they shall be conditioned for 24 h at  $(21 \pm 2) ^\circ\text{C}$  and  $(60 \pm 10) \%$  relative humidity. The test and control specimens shall then be tested in shear as



shown in Figures 1a) and 1b). Load shall be applied at a rate of  $(60 \pm 20)$  kN/min. The load at failure in kN and the position of failure shall be noted in each case.

## 7.2 Testing of steel-to-steel specimens

Immediately prior to commencement of the environmental regime the crack length shall be measured on both sides of each test and control specimen to an accuracy of  $\pm 0,1$  mm using, for example, a travelling microscope. The test specimens shall be placed immediately into the environmental chamber or cabinet, and measurements taken after 24 h, and then at 24 h intervals until the crack length has stabilised. Thereafter, measurements shall be taken at 7 day intervals until the end of the environmental regime. At each measurement the position of the crack (i.e. within the adhesive or at an interface) shall be noted.

## 8 Test report

### 8.1 Concrete to concrete composite specimen

The report shall include the following information for each determination:

- a) a reference to this test method standard;
- b) name and address of the test laboratory;
- c) identification number and date of the test report;
- d) name and address of the manufacturer or supplier of the product;
- e) name and identification marks or batch number of the product;
- f) date of supply of the product;
- g) date of preparation of the test specimens and any deviation from the prescribed method of preparation;
- h) conditions of storage of prepared specimens prior to test;
- i) date of test and details of the test equipment used, including the make, type and capacity and the calibrations details or the identification number of the apparatus;
- j) the compressive shear load at failure expressed in  $\text{N/mm}^2$ ;
- k) the rate of application of load;
- l) the mode of failure;
- m) any observation regarding delamination, cracking etc.;
- n) precision data;
- o) date of test report and signature.

### 8.2 Steel-to-steel composite specimen

The report shall include the following information for each determination:

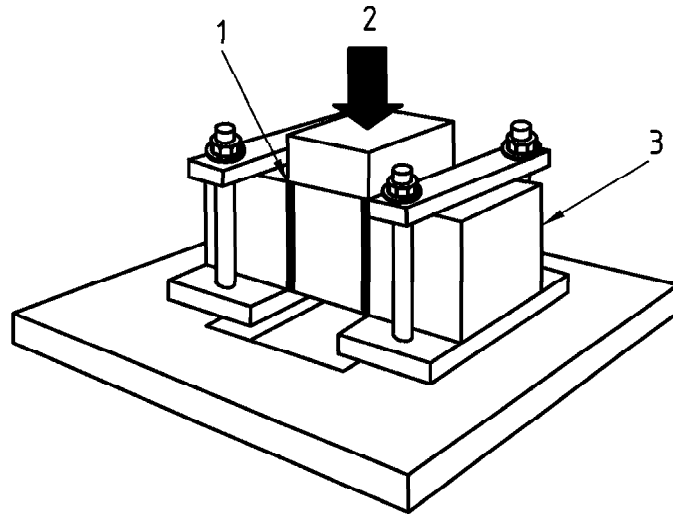
- a) a reference to this test method standard;
- b) name and address of the test laboratory;
- c) identification number and date of the test report;

- d) name and address of the manufacturer or supplier of the product;
- e) name and identification marks or batch number of the product;
- f) date of supply of the product;
- g) date of preparation of the test specimens and any deviation from the prescribed method of preparation;
- h) conditions of storage of prepared specimens prior to test;
- i) date of test and details of the test equipment used, including the make, type and capacity and the calibrations details or the identification number of the apparatus;
- j) the fracture energy for each specimen shall be determined and plotted against time (log hours):

$$G_{ic} = \left( \frac{E_s d^2 h^3}{16} \right) \left[ \frac{3(a + 0,6 h)^2 + h^2}{((a + 0,6 h)^3 + ah^2)^2} \right]$$

where

- $G_{ic}$  is the fracture energy expressed in kN/m;
- $E_s$  is the elastic modulus of the steel test plates in kN/m<sup>2</sup>;
- $d$  is the wedge thickness in m;
- $a$  is the crack length in m;
- $h$  is the steel test plate thickness in m;
- $d, a$  and  $h$  shall be measured to an accuracy of  $\pm 0,1$  mm;
- k) the initial and any change in crack position, i.e. within the adhesive or at an interface;
- l) the mode of failure, if any;
- m) any observations regarding delamination, corrosion, etc should be noted;
- n) precision data;
- o) date of test report and signature.



**Key**

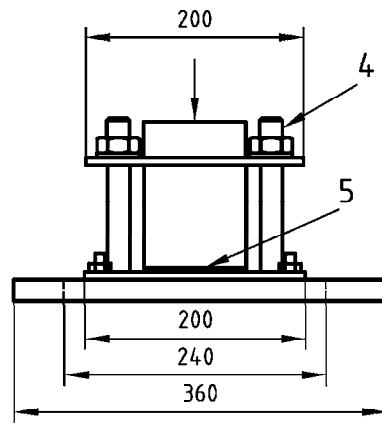
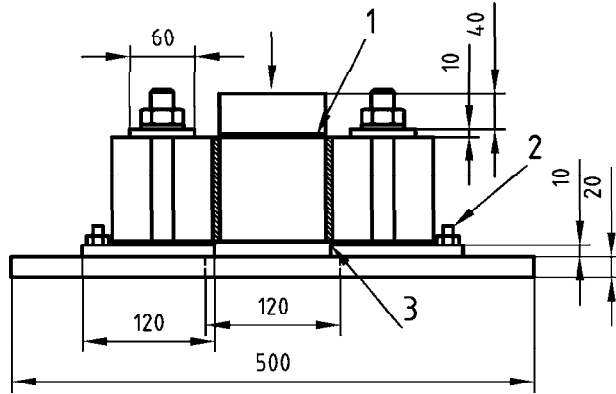
1 Bonding agent (at the agreed thickness)

2 Applied force

3 Concrete cubes

**Figure 1a) Test principle**

ELEVATION



END ELEVATION

Key

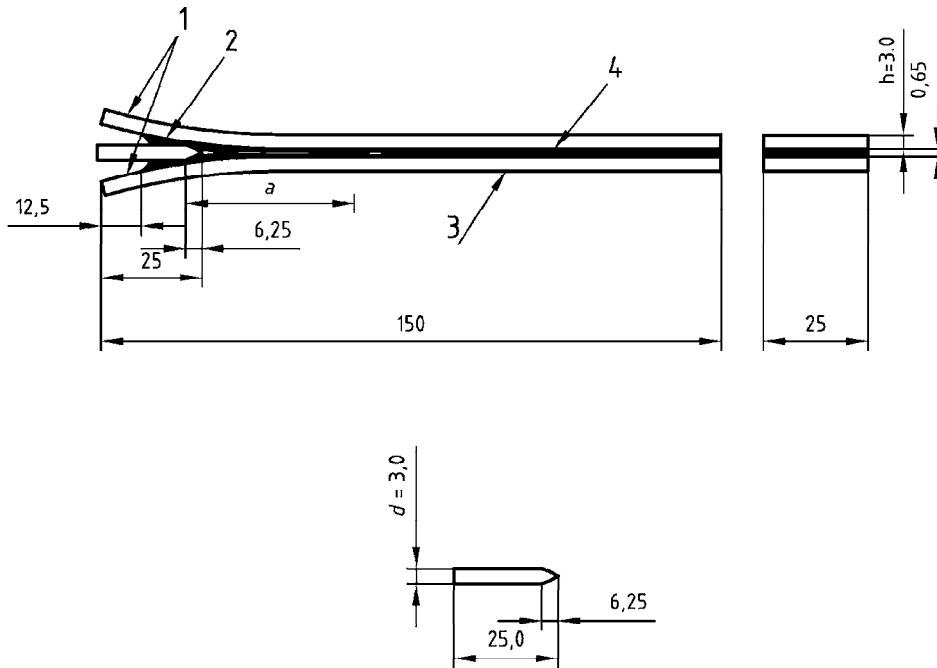
- 1 Bearing plate 3 × 10 × 100
- 4 Bolt M20

- 2 Holding down bolt M12
- 5 Bearing plate 3 × 10 × 100

- 3 Bearing plate 3 × 10 × 100

**Figure 1b) Test equipment**  
**Figure 1 — Compressive shear test**

Dimensions in millimetres  
Tolerance  $\pm 0,1$  mm



**Key**

- 1 Initial 12,5 mm debond
- 2 3,0 thick mild steel wedge
- 3 25 × 3 mm bright mild steel
- 4 Bondline

**Figure 2 — Specimen for the wedge test**

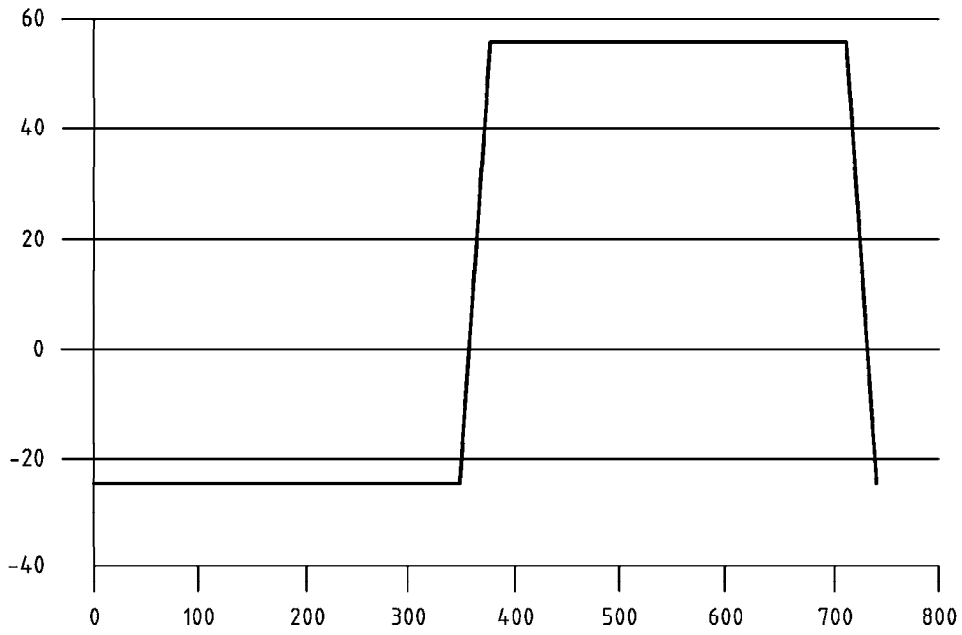
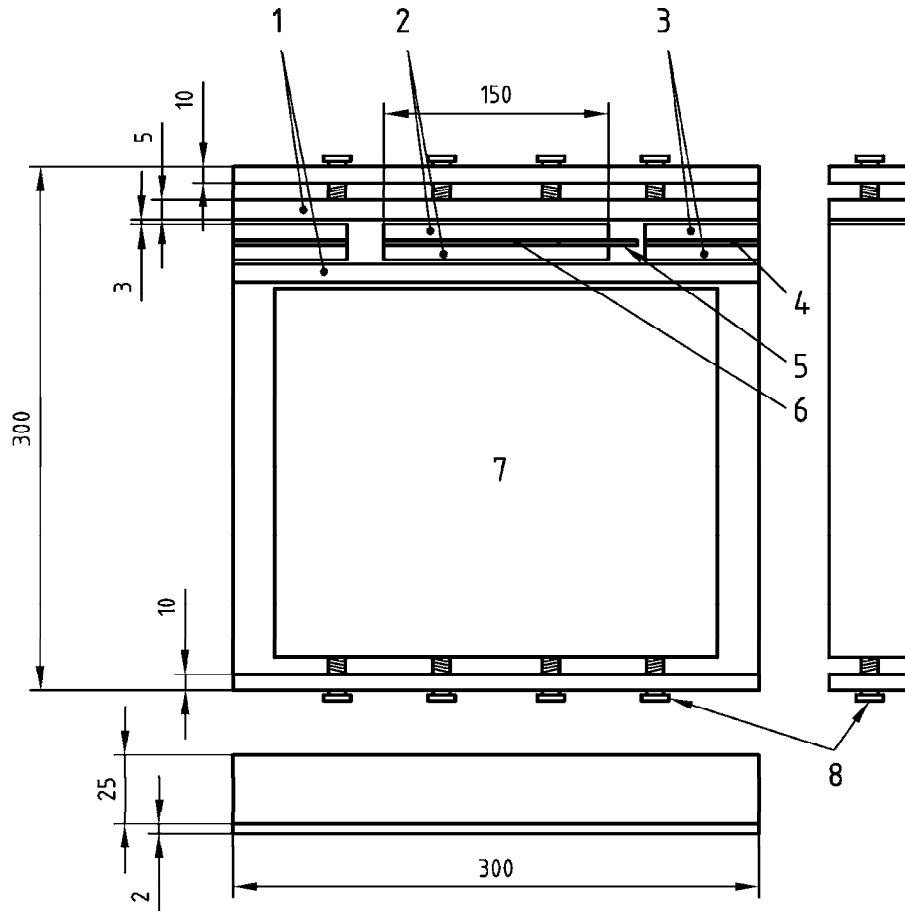


Figure 3 — Thermal Cycle

Dimensions in millimetres

**Key**

NOTE 1 Jig is shown with one joint and a large spacing block. Various joint/spacer combinations can be employed.

NOTE 2 Not to scale.

- 1 Steel spacer strip
- 2 150 x 25 x 3 steel test plate
- 3 Spacer (same thickness as steel plate)
- 4 Spacer (same thickness as adhesive layer)
- 5 Spacer between the bonded ends of the composite
- 6 Adhesive layer
- 7 Large steel spacing block
- 8 Jig tightening screws

**Figure 4 — Steel-to-steel bonding specimen jig**

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