BRITISH STANDARD

BS EN
1542:1999

Products and systems for the protection and repair of concrete structures — Test methods — Measurement of bond strength by pull-off

The European Standard EN 1542:1999 has the status of a British Standard

ICS 91.080.40

National foreword

This British Standard is the English language version of EN 1542:1999.

The UK participation in its preparation was entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/8, Protection and repair of concrete structures, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 7 and a back cover.

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This British Standard, having been prepared under the direction of the Sector Committee for Building and Civil Engineering, was published under the authority of the Standards Committee and comes into effect on 15 August 1999

ISBN 0 580 32439 7

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1542

April 1999

ICS 91.010.30; 91.080.40

English version

Products and systems for the protection and repair of concrete structures — Test methods — Measurement of bond strength by pull-off

Produits et systèmes pour la protection et la réparation des structures en béton — Méthodes d'essais — Mesurage de l'adhérence par traction directe

Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken — Prüfverfahren — Messung der Haftfestigkeit im Abreißversuch

This European Standard was approved by CEN on 8 March 1999.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 1542:1999 E

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 104, Concrete (performance, production, placing and compliance criteria), 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 October 1999, and conflicting national standards shall be withdrawn at the latest by October 1999.

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, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This European Standard describes a method for determining the pull-off bond strength of repair products and systems applied to a reference concrete. The method is derived from EN 24624, Paints and Varnishes — Pull-off test (ISO 4624:1978), which is not appropriate for repair products and systems.

Contents

1 Scope

This European Standard is one of a series dealing with products and systems for the protection and repair of concrete structures. It specifies a method for measuring the tensile bond strength of grouts, mortars, concretes and surface protection systems (SPS) used for the protection and repair of concrete.

The provisions of the standard are applicable to products and systems applied to a maximum thickness of 50 mm in the test method but some products may be used in repairs where it is applied at more than 50 mm thickness.

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.

EN 196-1, *Methods of testing cement — Part 1: Determination of strength.*

EN 1504, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity.*

EN 24624:1992, *Paints and varnishes — Pull-off test* (ISO 4624:1978).

prEN 1766, *Products and systems for the protection and repair of concrete structures — Test methods — Reference concretes for testing.*

ISO 554:1976, *Standard atmospheres for conditioning and/or testing — Specifications.*

3 Principle

This Standard describes a method for measuring the tensile bond strength of repair products and systems applied to standard reference concrete specimens prepared according to prEN 1766. The method of test is by direct dolly pull-off using a dolly bonded to the surface of the repair product or system, with the test area having been defined by coring through the surface.

4 Equipment

4.1 *Mortar mixer*, in accordance with EN 196-1 or concrete mixer, (forced action pan mixer).

4.2 *Compaction tools and equipment*, for repair grouts, mortars and concretes according to EN 196-1.

The compaction method shall be in accordance with the manufacturer's instructions.

4.3 *Standard laboratory climate*, in accordance with the requirements of annex A.

4.4 *Moulds*, for producing a uniform thickness of repair product or systems on top of the reference concrete specimen, made from non-absorbent, rigid material, not attacked by cement paste or polymers, into which the reference concrete specimen shall be placed (see Figure 2).

4.5 *Vernier calipers*, accurate to not less than 0,1 mm.

4.6 *Rapid hardening two component epoxy adhesive*, or similar, as recommended by the manufacturer.

4.7 *Circular dollies*, with a diameter of $(50 \pm 0{,}5)$ mm and with a thickness of at least 20 mm if made of steel, or with a thickness of at least 30 mm if made of aluminium. On the side to which the adhesive is to be applied, the dolly shall be flat with a tolerance of 0,1 mm per 50 mm length.

The dollies shall be provided with a means for attaching the pull-off test equipment (see **4.11**) that ensures the load can be applied normal to the surface under test, without bending or shear forces being applied to the test area.

The method used for attaching the dolly to the pull-off test equipment shall normally incorporate a spherical seat, or otherwise the spherical seat shall be within the pull-off test equipment, to ensure the requirements of this subclause can be met.

4.8 *Grinding equipment*, for cleaning adhesive from the used dollies.

4.9 *Steel wire brush* and *soft-bristled brush.*

4.10 *Diamond core drill and barrel*, that enable the drilling of a $(50 \pm 1{,}0)$ mm cylinder through the repair product and system. The core barrel should have a cutting edge that stands proud of the cylinder by $(1{,}5 \pm 0{,}5)$ mm (to reduce lateral forces being applied to the test area).

4.11 *Pull off test equipment*, complying with EN 24624 with a pulling capacity sufficient to cause tensile bond failure of the specimen. The accuracy shall be within ±2 %. (A capacity of 10 kN is sufficient for most applications). The pull-off equipment shall be capable of applying the load according to **3.1** of EN 24624:1992 and shall be provided with a measurement device that displays the exerted force by an analogue or digital system. The measurement device shall retain the reading of maximum force exerted.

4.12 *Concrete test specimens*, of dimension 300 mm × 300 mm × 100 mm, with a maximum aggregate size of 8 mm or 10 mm and prepared with a grit-blasted surface, according to prEN 1766. The strength grade shall be in accordance with EN 1504 series.

5 Preparation

Unless the repair product or system is intended to be used on horizontal surfaces only, as advised by the manufacturer, the application shall be to a vertical surface.

5.1 Preparation of the surface for application of the product

The repair product or system shall be applied to the grit-blasted surface of the reference concrete specimen (see **4.12**) in either the dry or wet condition, as defined in annex A.

To ensure the grit-blasted surface of the reference concrete specimens is free from contamination, it shall be cleaned using the steel wire brush (see **4.9**) under running water immediately before the final conditioning and applying the repair product or systems, as follows:

— for a wet surface, the reference specimen shall be stood upright for 30 min;

— for a dry surface the reference specimen shall be conditioned for seven days in the standard laboratory climate (see **4.3**) and immediately before applying the product, the test specimen shall be cleaned again using the soft-bristled brush.

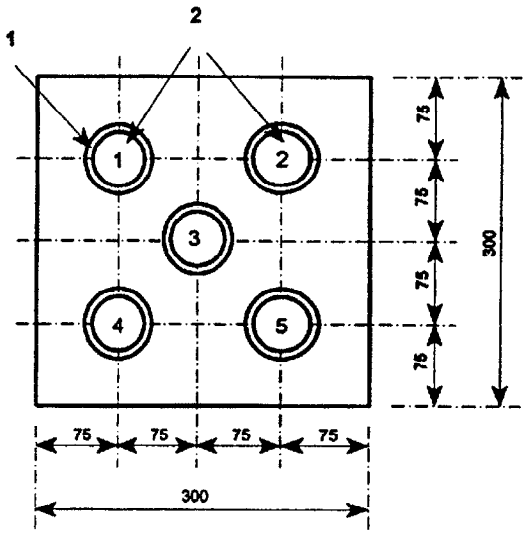
Following cleaning and conditioning, the bottom surface of the test specimen shall be indelibly marked and then the specimen placed on blocks, inside a mould (see **4.4**) if required. The grit-blasted and cleaned surface shall then be secured in a vertical position (unless the product is intended to be used for application to horizontal surfaces only).

5.2 Number of test specimens

A minimum of one test specimen is required for each repair product or system, from which five bond tests shall be carried out. The arrangement of the test areas, the sequence of tests and the numbering system to be employed is shown in Figure 1. The minimum acceptable number of tests giving a normal type of failure is three (see **7.6**).

NOTE Owing to the risk of some results being invalidated, due to abnormal types of failure, additional test specimens should be prepared, thereby avoiding delays if repeat testing is required.

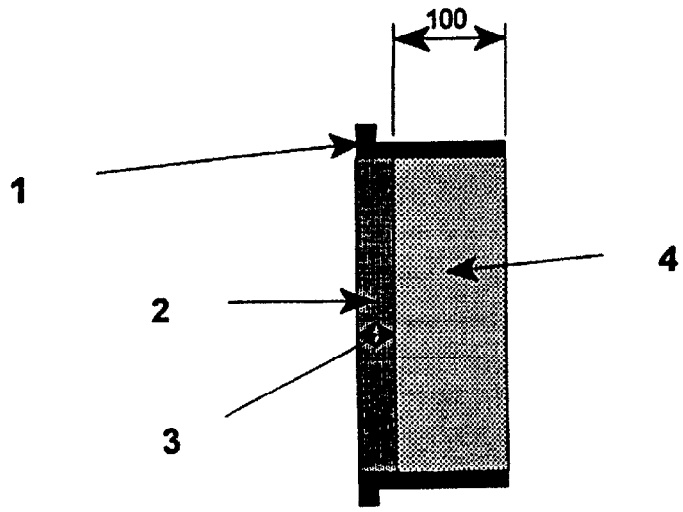
Dimensions in millimetres



Key

1 Annulus around test area, formed by coring
2 50 mm diameter steel or aluminium dolly

Figure 1 — Plan of specimen showing dolly locations



Key
1 Mould
2 Product of system
3 Thickness adjusted by fixing mould in position
4 Reference concrete specimen

Figure 2 — Section through specimen, showing mould in place

6 Procedure

6.1 Applying the repair products or system

The product or system, together with the containers and tools to be used for preparing the mix and its application, shall be placed in the standard laboratory climate (see **4.3**) for at least 24 h before use.

Unless otherwise instructed by the manufacturer, use the following mixing technique for preparing the specimens.

For PCC and cementitious mortar, use the mortar mixer (see **4.1**) set to a low speed, pouring the gauging liquid to the bowl and adding the dry ingredients, mixing for a total period of 2 min.

Where manufacturer's instructions preclude use of part bags of materials, a concrete mixer (see **4.1**) or other method recommended by the manufacturer shall be used.

NOTE It has been found that certain types of repair mortar can foam excessively under the action of the mortar mixer specified in EN 196-1. An alternative is to use a concrete mixer (see **4.1**). The air content, strength and density of the CC and PCC mixes should normally be determined to characterize the mortar under test.

6.2 Storage

The test specimens prepared in the vertical position shall be stored in this position for three days under the curing conditions specified in annex A. During the storage period, the faces of the test specimens shall be positioned at least 100 mm apart.

Any moulds (see **4.4**) shall be removed 24 h after application of the product or system of products and then returned to the vertical position, unless stated otherwise by the manufacturer.

Following the three days of vertical curing, the specimens may be laid horizontal and curing continued for the time specified in annex A.

7 Carrying out test

Following the curing period, the test specimen shall be conditioned for seven days by storage in a standard laboratory climate, as specified in annex A.

Towards the end of this seven day period, the specimen shall be prepared by fixing the dollics such that testing can take place at the end of the seventh day.

7.1 Core drilling

Fasten the core drill and test specimen so that they cannot move or become loose. The drill should be free from significant vibration and should not allow lateral movement of the coring bit. Drill with a diamond coring barrel (see **4.10**) with an axis at $(90 \pm 1)°$ to the surface. Drill through the repair product or system to a depth of (15 ± 5) mm into the concrete substrate. Remove the diamond coring barrel without damaging the test specimen.

NOTE The total drill-in depth is:

$$d_i = d_d + (15 \pm 5)$$

where

d_i is the total drill-in depth, in millimetres;

d_d is the thickness of the mortar layer, in millimetres.

7.2 Applying the dolly

Clean the dolly using the grinding equipment as necessary (see **4.8**), then degrease and dry the side of the dolly (see **4.7**) onto which the adhesive (see **4.6**) is to be applied. Apply a thin layer of adhesive to the surface of the specimen so that the adhesive forms a uniform layer between the dolly and the substrate. No adhesive shall penetrate into the clearance made by the coring barrel.

Place the dolly on the core face so that the centre of the dolly coincides with the centre of the core. Apply sufficient pressure to the dolly to expel air, carefully and immediately removing any extruded adhesive. Allow the adhesive to harden in accordance with the manufacturers instructions.

7.3 Setting the pull-off equipment

The pull off equipment (see **4.11**) and its accessories shall be used in accordance with the manufacturer's instructions.

Place the pull-off equipment concentrically over the dolly and at $(90 \pm 1)°$ to the cored surface. Secure the equipment in such a way that its position will not change during the test.

7.4 Applying the load

Increase the load continuously and evenly at a rate of $(0{,}05 \pm 0{,}01)$ MPa/s until failure occurs. Record the load at failure and then determine the mean diameter of the specimen at the failure face as the average result of measurements taken perpendicularly to each other, across the core, using the vernier calipers (see **4.5**).

Avoid excessive fluctuations in applying the load, liable to occur for instance when using certain types of manually operated pull-off equipment.

7.5 Determination of the type of failure

From a visual assessment, determine the type of failure of the specimen. The types of failure are as follows:

A Cohesion failure in the concrete substrate;

A/B Adhesion failure between the substrate and the first layer (e.g. primer, bonding slurry or mortar);

B Cohesion failure in the first layer;

B/C Adhesion failure between the first and second layer;

C Cohesion failure in the second layer;

(Etc., as defined by the particular product or system under test)

-/Y Adhesion failure between the last layer and adhesive layer (e.g. C/Y in a two-layer repair system);

Y Cohesion failure in the adhesive layer;

Y/Z Adhesion failure between the adhesive layer and the dolly (which is Z).

If there is a combination of these types of failure, a visual inspection shall be made of the failure face to find the percentage of each type of failure, based on the surface area, for example:

A : A/B : B = 40 % : 10 % : 50 %

7.6 Validity of the test result

For each test location, the load at failure is valid for all combinations of failure type, except where an abnormal failure occurs. An abnormal failure is where the adhesive layer fails prematurely (i.e. where the surface includes part of a type Y, type Y/Z or type -/Y failure). In this event the tensile bond strength for that location shall not be calculated.

NOTE Abnormal failures may suggest the adhesive is unsuitable for use with the repair product or system under test and the manufacturer's advice should be obtained.

7.7 Calculation

For each test location yielding a normal failure, calculate the tensile bond strength, to the nearest 0,1 MPa, using the following formula:

$$f_h = \frac{4F_h}{\pi D^2}$$

where

f_h is the bond of the test specimen, in megapascals;

F_h is the failure load, in Newtons;

D is the mean diameter of the test specimen, in millimetres.

The mean tensile bond strength shall then be determined from a minimum of three normal test results. If many abnormal failures occur, as defined in **7.6**, further test specimens shall be prepared and tested until the required minimum number of results is obtained.

8 Test report

The test report shall include the following information:

a) a reference to this European Standard, including the number, title and date of issue;

b) the place, date and time of sampling and testing;

c) identification of the type, origin and designation of the repair product or system under test;

d) methods used for preparation, curing and conditioning of the specimens;

e) the thickness of repair mortar;

f) the test date, age, type and roughness of the concrete;

g) the diameter, thickness and the material of the dolly used and the type of adhesive;

h) a description of the pull-off test equipment, stating the make, type, load capacity and measurement range;

i) the failure load and the mean diameter for each location number from Figure 1;

j) the individual tensile bond strength test results, and the mean results;

k) the type of failure for each location;

l) any anomalies or points of note recorded during testing.

Annex A (normative)

Summary of temperatures and humidities for the curing, conditioning and testing of repair products and systems

A.1 Curing

A.1.1 CC (grouts, mortars and concretes)

— prepare as EN 196-1, cover in film for 24 h;

— demould after 24 h;

— cure under water at (21 ± 2) °C for 27 days.

A.1.2 PCC (grouts, mortars and concretes)

— prepare as EN 196-1, cover in film for 24 h;

— demould after 24 h and wrap in film for 48 h;

— unwrap and cure for 25 days in a standard laboratory climate of (21 ± 2) °C and (60 ± 10) % relative humidity.

A.1.3 PC (grouts, mortars and concretes)

— prepare as ISO 554;

— cure for 7 days at (21 ± 2) °C and (60 ± 10) % relative humidity.

A.2 Conditioning and testing

For specific applications, the following conditions apply:

A.2.1 Standard laboratory climate (Dry conditioning):

— take from the curing/storage environment and condition for 7 days in a standard laboratory climate of (21 ± 2) °C and (60 ± 10) % relative humidity.

A.2.2 Wet conditioning:

— Immerse for 7 days at (21 ± 2) °C, or for CC take directly for test after 28 days of immersion;

— remove all surface water by standing upright for 30 min before using for tests.

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