British Standard

BRITISH STANDARD

BS EN
12188:1999

Products and systems for the protection and repair of concrete structures — Test methods — Determination of adhesion steel-to-steel for characterization of structural bonding agents

The European Standard EN 12188:1999 has the status of a British Standard

ICS 91.080.40

National foreword

This British Standard is the English language version of EN 12188:1999.

The UK participation in its preparation was entrusted by Technical Committee B/517, Concrete, to Subcommittee B/517/8, Repair and protection of concrete, 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.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 11 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 September 1999

ISBN 0 580 32578 4

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD **EN 12188**

NORME EUROPÉENNE

EUROPÄISCHE NORM **May 1999**

ICS 91.080.40

English version

Products and systems for the protection and repair of concrete structures — Test methods — Determination of adhesion steel-to-steel for characterization of structural bonding agents

Produits et systèmes pour la protection et la réparation des structures en béton — Méthodes d'essais — Détermination de l'adhérence acier sur acier pour la caractérisation des produits de collage structural

Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken — Prüfverfahren — Bestimmung der Klebewirkung an Stahl für die Charakterisierung der Eigenschaften von Klebstoffen für konstruktive Zwecke

This European Standard was approved by CEN on 16 April 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 12188:1999 E

Contents

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 November 1999, and conflicting national standards shall be withdrawn at the latest by November 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.

NOTE This European Standard should be read in conjunction with EN 1504-1 and prEN 1504-4.

1 Scope

This European Standard describes a method for the characterization of structural polymer based bonding agents for use in applications such as steel plate structural bonding for the strengthening of concrete structures. It involves the determination of the slant shear strength and the pull-off strength.

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

EN 1542, *Products and systems for the protection and repair of concrete structures — Test methods — Pull-off test*.

3 Principle

The slant shear strength shall be determined using steel prism halves glued together with the bonding agent.

The bond planes shall be inclined at various angles to the longitudinal axis of the prisms.

The complete prisms shall be tested in axial compression.

NOTE Stresses which occur in a joint made with a structural bonding agent can be resolved into normal stress, s. The object of the test methods described in this standard is to determine the relationship between s and t which meets the criterion $f(s,t) = 0$, i.e. to determine the shape of the failure envelope which represents failure of the adhesive agent in the bonded joint.

For the purposes of this standard, the failure envelope is defined by three straight lines on a plot of normal stress against shear stress at failure as shown in Figure 1. Conventionally, s values are plotted as abscissae and t values as ordinates.

Failure of a bonding agent is governed by its strength parameters: coefficient of friction, cohesion and resistance to separation:

- the coefficient of friction m is the numerical value of the slope of the inclined lines in Figure 1;
- the cohesion c is the shear capacity at $s = 0$;
- the resistance to separation f_t is the pull-off strength e.g. the tensile capacity at $t = 0°$.

As these values are constant for a particular material, the shape of the failure envelope can be used to characterize a material.

The failure envelope can be explained as follows:

- sliding failure occurs when numerical values of shear stress $|t|$ meet the inequality $|t| \geq c - ms$;
- separation failure occurs when the tensile stress exceeds the pull-off strength: $s \geq f_t$.

As noted above and as can be seen from Figure 1, the failure envelope is formed by three straight lines. Stress fields within the area containing the origin do not cause failure.

As an option it is possible to extend the test to include a slant shear test in tension to fully complete the failure envelope in Figure 1.

4 Terms and definitions

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

4.1
compressive stress (s_0)
the ratio of the compressive force (F) to the surface area (A_c) of the cross-section of the test specimen is:

$$s_0 = \frac{F}{A_c} \qquad \text{(MPa or N/mm}^2\text{)}$$

4.2
normal and shear stress
the normal stress (s) and shear stress (t) are the stresses at the inclined section of the test prism (see Figure 2b) in which:

$$s = s_0 \cos^2 q \qquad \text{(MPa or N/mm}^2\text{)}$$

$$|t| = s_0 \cos q \sin q \qquad \text{(MPa or N/mm}^2\text{)}$$

where:

q denotes the angle from the cross-section of the test prism to the inclined section, (see Figure 2a).

4.3
pull-off strength
the maximum tensile stress carried by the bonded joint in a pull-off test as shown in Figure 3

4.4
separation failure
a mode of failure where the failure occurs along a failure plane in such a way that the material on each side of the failure plane moves perpendicular to the failure plane

4.5
sliding failure
a mode of failure where the failure occurs along a failure plane in such a way that the material on each side of the failure plane moves parallel to the failure plane

4.6
slant shear strength
the compressive strength of a scarf-jointed test prism where failure occurs along the inclined bonded joint

5 Test method

The failure envelope of the bonding agent (see Figure 1) shall be determined from the testing of the scarf-jointed prisms and from pull-off tests such that the failures occur entirely in the bonding agent.

5.1 Sliding failure

Test prisms having inclined bonded joints, where q is equal to 50°, 60° and 70°, shall be tested in compression until failure (see Figure 2a). The slant shear strengths and the failure modes shall be observed and recorded. The corresponding values of s and t shall be plotted in a (s ; t) co-ordinate system, and a straight line fitted by applying regression analysis technique. From the position of this line the coefficient of friction, m, and the cohesion, c, shall be determined.

5.2 Separation failure

The dollies shall be tested in tension by pull-off test until failure, (see Figure 3). The pull-off strength represents the resistance against separation f_t.

6 Equipment

Compression testing machine, for testing scarf-jointed prisms shall be of a type capable of providing a constant stress rate between 0,1 MPa per second and 1,0 MPa per second. The testing apparatus for conducting the pull-off test shall be in accordance with EN 24624.

Vernier gauge, for measuring joint thickness.

7 Slant shear test

7.1 Test specimens

The test specimens shall be bonded steel prisms meeting the following requirements.

7.1.1 *Dimensions*

Prismatic steel specimens having a square cross-section of 40 mm by 40 mm and a length of 160 mm shall be used. Each of the test prisms shall consist of two identical semi prisms produced from the 40 mm × 40 mm × 160 mm steel prism by a saw cut at an angle of q to the transverse axis of the prism [see Figure 2a)]. The sawn surfaces shall be degreased using a suitable degreasing agent, for example acetone, and then shall be prepared by grit blasting. The intent is to achieve a roughness sufficient to ensure a failure within the bond plane of the adhesive (see **7.2.5**). Immediately on completion of grit blasting any surface dust shall be removed and the adhesive applied immediately.

7.1.2 *Number of specimens*

For each set of prescribed testing conditions a minimum of three specimens shall be tested for each of three angles.

7.1.3 *Preparation*

Sets of two identical semi-prisms shall be bonded with the adhesive agent and clamped together to achieve a 1 mm to 2 mm thick bond line with no entrapped air voids. Appropriate spacers shall be used to control the thickness of the bonding agent.

The steel-to-steel bonding shall be carried out in accordance with the specification given by the manufacturer. After hardening, excess bonding agent shall be cut away. For each test prism the thickness of the bonding joint shall be determined as the average of the joint thicknesses measured at the mid-points of the four sides of the prism. The bonding agent shall be cured in accordance with the recommendations of the manufacturer.

7.1.4 *Temperatures*

The resin and hardener component of the bonding agent shall be conditioned to a test temperature of (21 ± 2) °C, (60 ± 10) % relative humidity before mixing.

7.1.5 *Tolerances of the geometry*

Tolerances of the dimensions of the semi-prisms shall not be greater than ±0,1 mm. Each of the long faces of the bonded test prisms shall lie between two parallel planes 0,20 mm apart.

7.2 Test procedure

7.2.1 *Temperature*

The test prisms shall be maintained at the temperature specified for not less than 16 h before testing commences. Testing shall be carried out at (21 ± 2) °C, (60 ± 10) % relative humidity unless any other temperature condition is agreed.

7.2.2 *Extreme temperatures*

For testing at extremes of environmental conditions, alternative conditioning and testing temperatures shall be used.

7.2.3 *Loading procedure*

The loading procedure shall be in accordance with the specification for the testing machine.

The scarf-jointed prisms shall be loaded according to the standard procedures for testing cylinders for compressive strength. The rate of axial stress shall be between 0,5 MPa/s ($N/mm^2/s$) and 1,0 MPa/s ($N/mm^2/s$) (see Figure 2).

7.2.4 *Failure modes*

Various failure modes are possible for the scarf-jointed prisms. The failure modes achieved shall be described and reported.

An acceptable failure mode will pass entirely through the adhesion agent. A test of a scarf-jointed prism shall be rejected if a sliding failure occurs at the interface between the steel surface and the adhesion agent. However, it is acceptable if not more than 10 % of the sliding area takes place at the interface.

7.2.5 *Calculation of the slant shear strength*

The slant shear strength (s_0) shall be calculated for each specimen by dividing the load at failure by the cross-sectional area of the prism and expressing the results in units of MPa (N/mm^2). The determination of μ and c shall be carried out by linear regression analysis.

The mean slant shear strength of scarf-jointed prisms having equal values of angle q of joint shall be calculated to the nearest 0,1 MPa for the purpose of the determination of the coefficient of friction m and the cohesion c, to be found by regression analysis.

The stresses s and t with respect to an angle q between the cross-section and the joint shall be calculated by means of the formulae given in **4.2**. Table 1 presents values of s/s_0 and t/s_0 with respect to the angle q.

Table 1 — Values of normal stress s and shear stress t in a bonded joint of a scarf-jointed prism in relation to the slant shear strength s_0 and with respect to the angle q between the cross-section and the joint

q	s/s_0	t/s_0
50°	0,413	0,492
60°	0,250	0,433
70°	0,117	0,321

8 Pull-off test

8.1 Test specimens

The test specimens shall include cylindrical dollies meeting the following requirements.

8.1.1 *Dimensions*

Cylindrical steel dollies shall be used in accordance with EN 1542. The diameter shall be 20 mm but 50 mm is preferred where an appropriate tensile testing machine is available. The height of the dolly shall not be less than 50 % of the diameter.

8.1.2 *Preparation*

Dollies shall be prepared in accordance with EN 1542.

The dollies shall be bonded to massive steel plates with the adhesive agent in such a way that the bonded joints have horizontal positions. The thickness of the steel plate shall be at least as thick as the height of the dolly. Alternatively, the test may be performed on the top flange of an I-beam of similar geometry and with the dolly positioned immediately above the web of the beam.

The steel-to-steel bonding shall be carried out in accordance with the specification given by the supplier. For each test dolly the thickness of the bonding joint shall be maintained uniform over the area of the joint and be measured by means of a vernier gauge. After hardening, excess bonding agent is cut away. The joint thickness shall be determined as the average of the joint widths measured along the edge of the dolly at the end-points of two diameters perpendicular to each other. The bonding agent shall be cured in accordance with the recommendations of the manufacturer.

8.1.3 *Tolerance of the geometry*

Tolerances of the dimensions of the test dollies shall be in accordance with EN 1542.

8.2 Test procedure

The pull-off test shall be conducted in accordance with EN 1542.

9 Test report

The following information shall be included in the test report:

a) name and address of the testing laboratory, and the place at which the tests were performed if different from the laboratory address;

b) date and identification number of the test report;

c) name and address of the client;

d) purpose of the test;

e) date of receipt and complete identification of the samples of bonding agents to be tested;

f) description and marking of the specimens;

g) description of the preparation of the specimens, including full details of any priming system used and thickness (or mass) of primer or bonding agent applied;

h) date of the test performance;

i) any deviations from or additions to the test method, and any omissions, together with other information of importance for the interpretation of the observation and the evaluation of the test result;

j) observations (for example failure modes) and test results, using SI units;

k) inaccuracy or uncertainty of the test result;

l) signed and dated by the person responsible for the technical content of the test report;

m) reference to this European Standard.

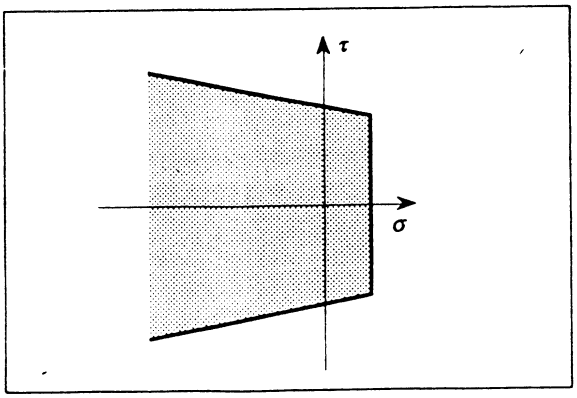

Figure 1 — Typical failure envelope for a material under a stress field of normal stress *s* and shear stress *t*

The shaded open space in the diagram represents combinations of normal stress *s* and shear stress *t* which will not lead to failure of the bonding agent.

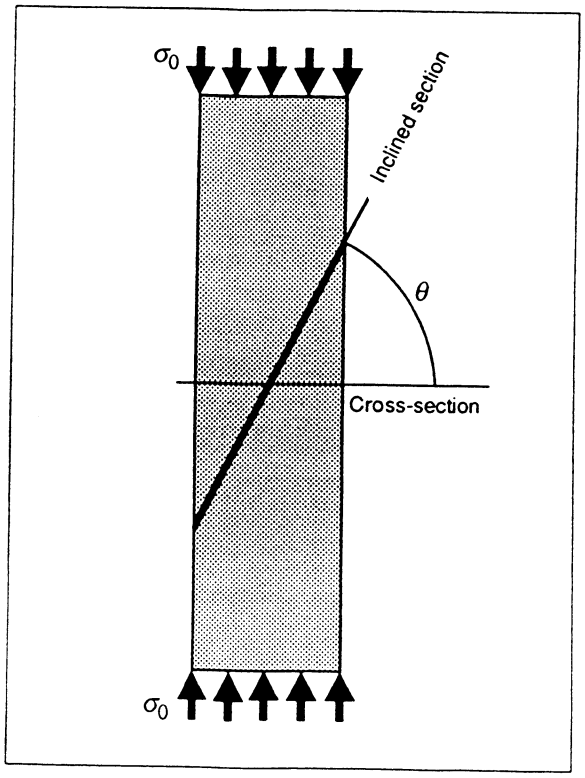

Figure 2a) — Scarf-jointed test prism in the compression

q denotes the angle from the cross-section of the test prism to the inclined section

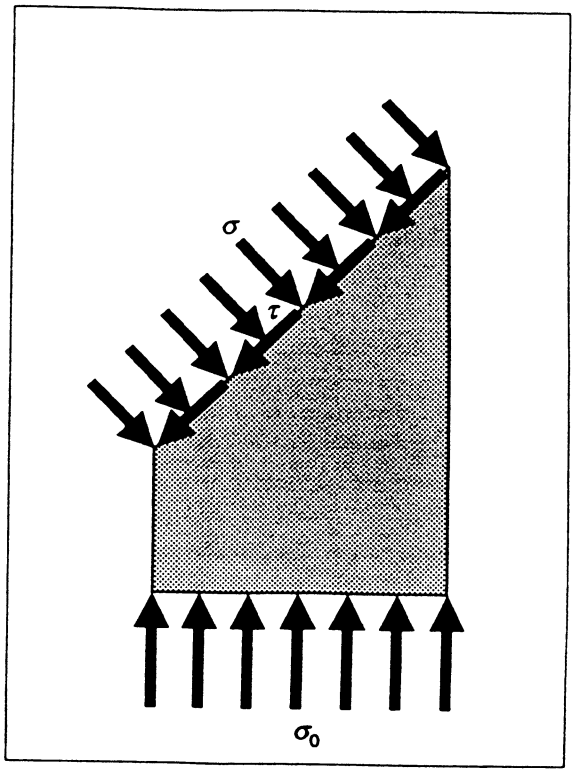

Figure 2b)

The stresses of the inclined section are normal stresses *s* and shear stresses *t*. The relationships between these stresses and the slant shear stress s_0 are given in **4.2**.

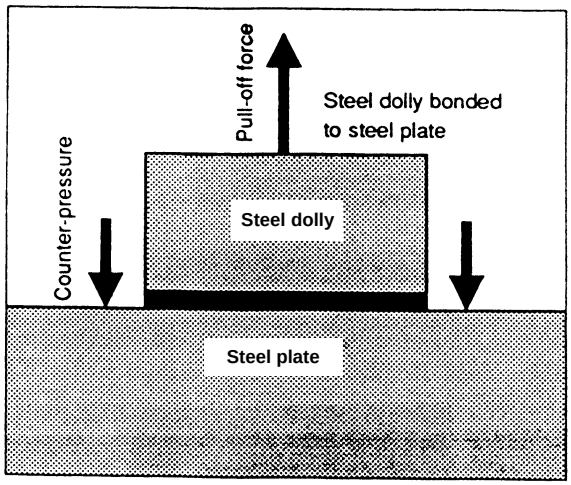

Figure 3

A circular steel dolly is bonded with the bonding agent to a steel plate. When the bonding agent is hardened the dolly is tested by a pull-off test in pure tension until failure. The pull-off strength f_t represents the resistance against separation (tensile strength of the bonding agent) and the failure mode is a separation failure.

Annex A (informative)
Bibliography

[1] EN 1504-1, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 1: Definitions*.

[2] prEN 1504-4, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 4: Structural bonding*.

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