



BSI Standards Publication

## Testing concrete in structures

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Part 2: Non-destructive testing — Determination of rebound number

## National foreword

This British Standard is the UK implementation of [EN 12504-2:2021](#). It supersedes [BS EN 12504-2:2012](#), which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/517/1, Concrete production and testing.

A list of organizations represented on this committee can be obtained on request to its committee manager.

The UK committee draws users' attention to informative [National Annex NA](#), appended at the back of this document, which offers guidance on the use of this standard.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2021.

### Amendments/corrigenda issued since publication

Date	Text affected
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English Version

## Testing concrete in structures - Part 2: Non-destructive testing - Determination of rebound number

Essais pour béton dans les structures - Partie  
2 : Essais non destructifs - Détermination  
de l'indice de rebondissement

Prüfung von Beton in Bauwerken  
- Teil 2: Zerstörungsfreie Prüfung -  
Bestimmung der Rückprallzahl

This European Standard was approved by CEN on 14 June 2021.

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## European foreword

This document ([EN 12504-2:2021](#)) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by SN.

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of an identical text or by endorsement, at the latest by January 2022, and conflicting national standards shall be withdrawn at the latest by January 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes [EN 12504-2:2012](#).

The following amendments have been made in comparison to the former edition:

- a recommendation that two different reference anvils are used for calibrating the equipment.
- the allowable range of results has been tightened.

This document is based on the International Standard ISO 1920-7, *Testing of concrete – Part 7: Non-destructive tests on hardened concrete*, and reference has been made to ASTM C805, *Standard Test Method for Rebound number of hardened concrete*.

This document has been framed around the use of a Type N, spring driven steel hammer, originally designed by Schmidt.

This document is one of a series on testing concrete.

[EN 12504](#), *Testing concrete in structures*, consists of the following parts:

- Part 1: *Cored specimens – Taking, examining and testing in compression;*
- Part 2: *Non-destructive testing – Determination of rebound number;*
- Part 3: *Determination of pull-out force;*
- Part 4: *Determination of ultrasonic pulse velocity.*

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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## 1 Scope

This document specifies a method for determining the rebound number of an area of hardened concrete using a spring-driven hammer.

NOTE 1 The rebound number determined by this method can be used to assess the uniformity of concrete *in situ*, to delineate zones or areas of poor quality or deteriorated concrete in structures.

NOTE 2 The test method is not intended as an alternative for the compressive strength determination of concrete (EN 12390-3), but with suitable correlation, it can provide an estimate of *in situ* compressive strength. For the assessment of *in situ* compressive strength, see EN 13791.

NOTE 3 The hammer can be used for comparative testing, referenced against a concrete with known strength or against a concrete which has been shown that it has come from a defined volume of concrete with a population verified as conforming to a particular strength class.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (ISO 6508-1)*

## 3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

## 4 Principle

A mass propelled by a spring strikes a plunger in contact with the surface of the structure or specimen to be tested. The test result is expressed as a number in terms of the rebound distance of the mass. A number may also be obtained in terms of the energy or velocity differential before and after impact of the mass.

## 5 Apparatus

### 5.1 Rebound hammer

Consisting of a spring-loaded hammer mass which, when released, strikes a plunger in contact with the surface to be tested. The rebound distance of the hammer mass from the plunger or other rebound values shall be measured.

NOTE Several types and sizes of rebound hammers are commercially available for testing various strength classes and types of concrete. Each type and size of hammer can only be used with the strength classes and types of concrete for which it is intended.

### 5.2 Reference anvil

Steel reference anvil for verification of the hammer, with an impact area having a hardness of minimum 52 HRC when tested in accordance with EN ISO 6508-1 and a mass of  $(16 \pm 1)$  kg and a diameter of approximately 150 mm.

Other anvils may be used if it can be demonstrated that the readings are within the tolerance given in [7.3](#).

The manufacturer's instructions and any other equipment shall be used to ensure the longitudinal axis of the plunger is perpendicular to the surface of the anvil at impact.

Different hammers with the same rebound value on the reference anvil may not give identical results on site if the rebound value obtained lies above the normal working range of the hammer.

NOTE 1 An improved verification can be obtained by additionally using an anvil with a lower hardness that provides a second rebound value within the normal working range of the hammer ( $30 < R < 60$  or  $30 < Q < 70$  where  $R$  is the rebound distance and  $Q$  is the energy or velocity measurement depending on the type of hammer used). This will ensure that different hammers obtain similar results.

NOTE 2 If the smaller anvil is used for daily verification checks on site, it is important to verify the hammer on the reference anvil at regular intervals.

### 5.3 Abrasive stone

A medium-grain texture silicon carbide stone or equivalent material.

## 6 Test location

### 6.1 Selection

Concrete elements to be tested shall be at least 100 mm thick and fixed within a structure. Smaller elements or specimens may be tested provided they are rigidly supported. Areas exhibiting honeycombing, scaling, rough texture, or high porosity should be avoided.

In selecting an area to be tested, the following factors should be considered:

- a) the strength of the concrete;
- b) type of surface (e.g. formed or unformed);
- c) type of concrete (e.g. normal or lightweight);
- d) moisture condition of the surface;
- e) carbonation (if appropriate);
- f) direction of test;
- g) other appropriate factors.

A test location should be approximately 300 mm × 300 mm.

### 6.2 Preparation

Using the abrasive stone, grind heavily textured or soft surfaces, or surfaces with loose mortar, until they are smooth and free of loose material. Smooth-formed or trowelled surfaces may be tested without grinding.

Remove any water present on the surface of the concrete.

## 7 Procedure

### 7.1 Preliminary preparation

7.1.1 Use the hammer in accordance with the manufacturer's instructions for its operation.

**7.1.2** Before a sequence of tests on a concrete surface, clean the impact surfaces of the reference anvil and plunger. Perform at least five impacts on the steel reference anvil and record the readings from the next five impacts. If the readings from the last five impacts are not within  $\pm 3$  of the value given by the manufacturer, clean and/or adjust the hammer in accordance with the manufacturer's instructions and repeat the above.

**7.1.3** The hammer shall only be operated at a temperature within the range 0 °C to 50 °C.

## **7.2 Operations**

At the time of the test, the hammer shall meet the requirements defined in [7.1.2](#).

Hold the hammer firmly in a position that allows the plunger to impact perpendicularly to the surface being tested.

Gradually increase the pressure on the plunger until the hammer impacts (see [7.1.1](#)).

After impact, record the rebound number based on the rebound distance and/or energy or velocity measurements.

Examine each impression made on the surface after impact and if the impact has crushed or broken through a near-to-surface void, discount the result.

Take a minimum of nine valid readings to obtain a reliable estimate of the rebound number for a test location.

Record the position and orientation of the hammer for each set of readings.

Ensure that no two impact points are closer than 25 mm and none are within 25 mm of an edge.

**NOTE** It is preferable to draw a regular grid of lines 25 mm to 50 mm apart and take the intersections of the lines as the test points.

## **7.3 Reference checking**

After performing the tests, take five readings using the steel reference anvil. If the readings are not within  $\pm 3$  of the value given by the manufacturer, clean and/or adjust the hammer according to the manufacturer's instruction and repeat the test.

## **8 Test result**

The rebound number of the test location shall be taken as the median of all the readings, adjusted if necessary to take into account the orientation of the hammer in accordance with the manufacturer's instructions. The rebound number shall be expressed as a whole number.

If more than 20 % of all the readings differ from the median by more than 25 % the entire set of readings shall be discarded.

**NOTE** If more than one hammer is to be used, a sufficient number of tests can be made on similar concrete surfaces with all hammers, to determine the variation in the results obtained.

## **9 Test report**

The report shall include:

- a) a reference to this document, including its year of publication;
- b) identification of the concrete structure/element;
- c) identification of test location(s);

- d) the type and identification of the rebound hammer;
- e) description of preparation of test location(s);
- f) details of concrete (if known) and its condition;
- g) date/time of performance of the test;
- h) rebound number (median of test result readings) adjusted for hammer orientation (if appropriate) for each test location;
- i) any deviation from the standard test method e.g. presence of water on surface (see [6.2](#)), temperature outside acceptable range (see [7.1.3](#));
- j) a declaration by the person technically responsible for the test that it was carried out in accordance with this document, except as noted in item i).

The report may include:

- k) individual rebound hammer readings, if required;
- l) specification of the rebound hammer, if known.

## **10 Precision**

There are no precision data available for this test.

## Bibliography

- [1] [EN 12390-3](#), *Testing hardened concrete – Part 3: Compressive strength of test specimens*
- [2] [EN 13791](#), *Assessment of in-situ compressive strength in structures and precast concrete components*
- [3] ISO 1920-7, *Testing of concrete - Part 7: Non-destructive tests on hardened concrete*
- [4] ASTM C805, *Standard Test Method for Rebound Number of Hardened Concrete*

## **National Annex NA** (informative)

### **Guidance on the application of surface hardness testing by rebound hammer**

#### **NA.1 General**

The testing of concrete by hardness methods is not generally considered to be a substitute for other well-established methods but only as a useful preliminary or complementary method. Hardness measurements provide information on the quality of the surface layer (about 30 mm deep) of the concrete only.

The attention of the user is drawn to the fact that rebound hammers give a measure of the surface hardness of the concrete only, and that the relationship to any other property of the concrete is empirical.

No single correlation with strength or any other measurable property applies to all concrete, and a calibration for a specific set of circumstances is necessary if acceptable accuracy is to be obtained. It might be possible to apply well-established and documented correction factors for a number of influences, but it is doubtful whether, if a large number of correction factors were required, the estimate of the property would be sufficiently accurate. It is possible that the simultaneous changing of two or more influences would result in an interaction affecting the results in a way different from predictions based on the sum of their separate actions.

The accuracy with which a property of the concrete might be estimated from a hardness test will not be better than the confidence limits of the correlation derived between that property and hardness readings. If the specimens used for deriving the correlation do not exactly represent the concrete to be tested, additional errors will be introduced into the results. It is unlikely that 95 per cent confidence limits on the estimation of the strength of concrete in situ will be better than  $\pm 25$  per cent under ideal conditions. The use of universal calibrations, such as those produced by the manufacturers of rebound hammers, can lead to serious errors and should be avoided.

Examples of cases where hardness methods are particularly useful are given in [NA.2.1](#) to [NA.2.4](#)

#### **NA.2 Typical applications for the measurement of concrete hardness**

##### **NA.2.1 Checking the uniformity of concrete**

Hardness measurements can be used in the production of concrete where it might be desirable to establish the uniformity of products or similar elements in a structure in situ at a constant age, temperature, maturity and moisture condition. Hardness measurements can also be used to define areas of different quality prior to testing by other methods, possibly using destructive tests.

##### **NA.2.2 Comparing a given concrete with a reference in terms of a specific requirement**

A hardness value may be set to determine the handling and transport of units, the removal of temporary supports from structural members, etc. The critical hardness should be established on the basis of a proof load or past experience of performance. In acceptance testing or quality control procedures, simple but numerous hardness tests can supplement a small number of proof load tests or destructive tests.

### **NA.2.3 Determining the properties of the surface of the concrete that have a direct influence on its performance**

The assessment of the wearing quality of a concrete floor can be based on its hardness. The characteristics of a concrete surface that govern abrasion resistance have been shown to correlate reasonably well with those characteristics that determine rebound hammer readings. Hardness measurements for this purpose should not be made earlier than 14 days nor later than 3 months after laying the concrete. Appropriate specialist publications contain broad relationships between rebound number and abrasion resistance.<sup>1)</sup>

### **NA.2.4 Estimation of strength of concrete in structures**

The estimation of strength should be made with considerable care. A procedure for relating strength and rebound hammer reading is given in [NA.6](#). General guidance on the assessment of concrete strength in structures is given in PD CEN/TR 17086.

## **NA.3 Method of obtaining a correlation between strength and rebound number**

The most convenient method of producing a correlation between strength and rebound number is by tests in which both measurements are made on concrete cubes. It is difficult to ensure that cubes accurately represent the structure to be tested, and more reliable results might be obtained if a correlation is made using cores. In this case, hardness tests should be made on the concrete in situ at proposed core positions, and cores subsequently cut and tested for strength.

The test specimens used for correlation should be of as large a mass as possible. If cubes are used for this purpose, 150 mm cubes are preferred to 100 mm cubes. Unless there is sufficient evidence to support a general correlation, the constituent materials used in the manufacture of test cubes to be used to establish a correlation should be the same as the concrete to be examined. The most satisfactory way of carrying out hardness tests on cubes is by holding them in a compression testing machine under a load corresponding to a stress between 7 MPa and 10 MPa if the impact energy is about 2.2 N·m. The load should be increased for testing with devices of greater impact energy and can be decreased with devices of lesser impact energy.

To prepare a correlation between rebound number and strength, it is necessary to test a number of specimens that encompass the likely range of strength expected in the structure. The reliability of the correlation is increased by increasing the number of specimens. The method of varying the strength should be chosen in relation to the purpose for which the correlation is used. If it is intended to monitor the development of strength in a structure, then it would be appropriate to test correlation specimens at different ages. If it is proposed to monitor the quality of the concrete in a structure, it would be appropriate to vary the mix proportions of the concrete.

Correlation specimens should represent the structure to be tested as closely as possible; all the factors given in [NA.4](#) should be considered. Where cubes are used as the specimens, nine readings should be taken using the rebound hammer on each of two moulded and opposite side faces. The points of impact on the specimen should not be nearer an edge than 25 mm and should be not less than 25 mm from each other. The same point should not be struck more than once. A correlation curve should be constructed from the mean rebound number and strength for each test specimen. The equation for this curve can be determined by any standard curve fitting procedure.

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1) Chaplin, R G. Abrasion resistant concrete floors. In: *Adv. In Concrete Slab Technology*, pp. 532-534, 1980, and Sadegzadeh, M & Kettle, R. Indirect and non-destructive methods for assessing abrasion resistance of concrete. In: *Magazine of Concrete Research*, Vol. 38, No. 137, Dec 1986.

## **NA.4 Factors influencing the measured hardness of a concrete surface**

### **NA.4.1 Concrete strength**

#### **NA.4.1.1 General**

It is possible to produce empirical relationships between the strength of concrete and its hardness that are influenced by the factors described in [NA.4.1.2](#) to [NA.4.1.6](#)

#### **NA.4.1.2 Type of cement**

The effect of differences between CEM I cements of different fineness on the correlation with strength is relatively small, not exceeding 10 per cent. Concretes made with calcium aluminate cements can give strengths 100 per cent higher than a calibration obtained on Portland cement would indicate. Some less common cements can give 50 per cent lower strengths than a calibration obtained for Portland cement would indicate.

#### **NA.4.1.3 Cement content**

Concrete with a high cement content will give lower rebound hammer readings than concrete of the same strength, and hence the same or similar water to cement ratio, but a lower cement content. The error in strength estimation resulting from a change in cement content is unlikely to exceed 10 per cent.

#### **NA.4.1.4 Type of aggregate**

Although many normal weight aggregates give similar correlations between concrete strength and hardness, these should not be assumed unless supporting test evidence is available.

Lightweight aggregates and aggregates with unusual properties require special calibrations.

#### **NA.4.1.5 Type of curing and age of concrete**

The relationship between hardness and strength varies as a function of time. Variations in initial rate of hardening, subsequent curing and conditions of exposure also influence the relationship. Separate calibration curves are required for different curing regimes, but the effect of age can generally be ignored for concrete between 3 days and 3 months old (see [NA.4.5](#)).

#### **NA.4.1.6 Compaction**

Rebound hammers are unsuitable for detecting strength variations caused by different degrees of compaction. If the concrete is not fully compacted, strength cannot be reliably estimated.

### **NA.4.2 Type of surface**

Only smooth surfaces should be tested. Surfaces obtained by casting against different formwork materials respond differently to hardness tests. Trowelled surfaces are generally harder than those cast against formwork and might also give more variable results.

Tests on cut or ground surfaces are likely to give more variable results that differ significantly from those obtained on a cast surface.

Tests on moulded surfaces are generally to be preferred. Lack of quantitative evidence on how different surfaces behave under a hardness test can lead to considerable errors when results from different surfaces are compared. In such cases, separate calibrations might be necessary.

### **NA.4.3 Type of concrete**

Hardness methods are suitable only for close textured concrete. These tests are unsuitable for open textured concrete typical of masonry blocks, honeycombed concrete or no-fines concrete.

### **NA.4.4 Moisture condition of the surface**

A wet surface gives lower rebound hammer readings than a dry surface. This effect can be considerable, and a reduction in rebound number of 20 per cent is typical for structural concrete when wet, although some types of concrete can give greater differences.

### **NA.4.5 Carbonation**

Carbonation affects the surface layer, which ceases to be representative of the concrete within an element. The effect of carbonation is to increase the hardness of concrete. Normal rates of carbonation do not significantly affect the measured hardness when the concrete is less than 3 months old. In some circumstances of high temperature and high carbon dioxide concentration, carbonation might have a significant effect at earlier ages.

### **NA.4.6 Movement of concrete under test**

The impact from the rebound hammer should not be allowed to cause noticeable vibration or movement of the concrete being tested. Consequently, small concrete specimens should be rigidly mounted, for example by clamping them firmly in a heavy testing machine. For some structural members, the slenderness or mass might be such that this criterion is not fully satisfied, and in such cases strength prediction is difficult, although comparisons between or within individual members may be made by conducting tests at points of similar rigidity.

### **NA.4.7 Direction of test**

The direction of test will influence the measured hardness. The usual directions of test are either horizontal or vertically down, but any direction of test can be used, provided that results and locations are recorded. Corrections for a given direction are usually supplied with the rebound hammer. It is desirable that they be checked experimentally.

### **NA.4.8 Other factors**

Other factors that are known to influence hardness readings are proximity of the test area to a discontinuity, the state of stress of the concrete, and the temperature of both the concrete and the hardness tester. Provided that points of impact are at least 25 mm from any edge or sharp discontinuity and extreme conditions are avoided, these effects are likely to be small in normal practical situations. Normal sizes and covers of reinforcing steel in concrete are unlikely to have a significant effect on hardness when measured as described in this standard.

Different rebound hammers of the same nominal design might give different rebound numbers. All tests should be carried out with the same device if results are to be compared. If the use of more than one rebound hammer is unavoidable, a sufficient number of tests should be carried out on typical concrete surfaces with all of them, in order to determine the magnitude of the differences to be expected between them. Rebound numbers should be converted to strength values using only the correlation established for that device.

## **NA.5 Apparatus**

Surface hardness measurements are influenced not only by the characteristics of the concrete surface but also by the design of the measuring apparatus. Several rebound hammers that have given satisfactory performance are commercially available.

For most impact hammers, the face of the plunger that strikes the concrete surface is curved, and the area in contact with the surface varies during the impact owing to the formation of a small indentation, which will normally be less than 1 mm deep and 15 mm in diameter. The results are expressed in terms of rebound number, which is a measure of the rebound distance of the mass.

A number of rebound hammers are available giving different impact energies and areas of contact applicable to lightweight concrete, normal structural concrete and mass concrete. The principles governing hardness testing that are outlined in this standard are applicable to all rebound hammers. Details of test procedure, such as minimum spacing between test positions, relate specifically to a rebound hammer giving an impact energy of about 2.2 N·m, which is the size used most frequently and is appropriate for normal structural concrete.

## NA.6 Method of testing

A rebound hammer appropriate to the type of concrete to be tested should be selected.

Suitable test locations should be chosen in relation to the factors listed in [Subclause 6.1](#) of the standard and the purpose of the investigation.

For comparative surveys, all test locations should be tested under similar conditions. When testing a number of similar elements, they should be tested at similar positions in order to reduce any possible effects due to differences in rigidity and uniformity of the concrete. If tests on a structure are to be compared with a correlation curve or other predetermined rebound number, the structure should be tested under the same conditions as those occurring when the correlation was prepared.

A moulded surface is preferable but a free trowelled surface might also be satisfactory if appropriate corrections are applied or a specific correlation is prepared. When hardness measurements are being used to assess abrasion resistance, it might be necessary to test a trowelled surface. If extraneous matter is present on the surface, this should be removed.

In those cases where a smooth surface is not available for testing, it might be necessary to rub smooth the surface using a medium-grain texture silicon carbide stone or equivalent material stone.

Rough surfaces resulting from incomplete compaction, loss of grout, and spalled or tooled surfaces will not give reliable results and should be avoided.

The moisture condition of the surface should be consistent throughout the testing and should be consistent with the moisture condition of any correlation specimens. Dry surfaces are preferred but, provided that free water is wiped from the surface, saturated concrete can be tested satisfactorily (see [NA.4.4](#)).

It is preferable to draw a regular grid of lines 25 mm to 50 mm apart and to take the intersections of the lines as test points. This procedure tends to reduce any bias by the operator. If at least 10 readings are obtained in this way, the mean rebound number is likely to be accurate within:

$$\frac{15}{\sqrt{n}} \%$$

with 95 per cent confidence, where  $n$  is the number of readings.

The coefficient of variation of individual readings within one test is usually of the order of 10 per cent but is sometimes as low as 2 per cent or as high as 15 per cent. The coefficient of variation decreases with an increase in the strength of concrete and increases with an increase in the size and amount of coarse aggregate.

## NA.7 Interpretation of results

Differences between the results of tests at different locations will give a measure of the variability of the concrete within that structure or unit. Thus, for example, the position of the test in relation to the depth of lift of concrete will give different results owing to differences in the water to cement ratio that

are caused by settlement and bleeding. BS EN 13791 indicates there will be a natural strength variation dependent on casting height due to compaction procedure and efficiency.

The interpretation of the results of surveys might be aided by the use of graphical methods. Contour plots showing zones of equal rebound number might indicate areas of abnormally high or low hardness that may then, if necessary, be subjected to further tests. When a large number of results are available from similar locations, histograms might give an indication of the variability of the concrete. For example, uniform concrete and good site practice should result in a single peak with an approximately normal distribution. A distribution with a long tail might indicate poor construction, and two distinct peaks might indicate that two qualities of concrete have been supplied. When graphical methods are being used, the results should be expressed in terms of the rebound number rather than in terms of any correlated property.

Confidence in the test results can be improved by combining hardness testing with measurements of ultrasonic pulse velocity as described in BS EN 12504-4.

## **Bibliography**

BS EN 12504-4, *Testing concrete – Part 4: Determination of ultrasonic pulse velocity*

BS EN 13791, *Assessment of in-situ compressive strength in structures and precast concrete components*

PD CEN/TR 17086, *Further guidance on the application of EN 13791:2019 and background to the provisions*



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