BS 1881 : Part 202 : 1986
UDC 666.972.017 : 691.32 : 620.1

British Standard

Testing concrete

Part 202. Recommendations for surface hardness testing by rebound hammer

Essais du béton
Partie 202. Essai de la dureté superficielle au marteau à rebonds — Recommandations

Prüfverfahren für Beton
Teil 202. Empfehlungen für Oberflächenhärteprüfung mit dem Riickprallhammer

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Foreword

This Part of BS 1881 has been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee. It supersedes BS 4408 : Part 4 : 1971 which is withdrawn. All aspects of testing concrete are being included as Parts of BS 1881, from sampling fresh concrete to assessing concrete in structures. Part 201 gives general guidance on the choice of non-destructive test methods and should be consulted for advice on methods which complement the measurement of surface hardness or are useful as alternatives.

At present, no fundamental relationship has been found between surface hardness and strength or any other measurable property of concrete. The surface hardness tests described in this Part are different in principle from the hardness tests used for metals. Surface hardness tests can, however, be used to give an approximate indication of concrete quality and they are useful in a number of applications. The guidance given in this Part is intended to ensure that they are used to the best advantage and that valid information is derived from test results.

This Part now covers rebound testers only, principally of the spring-loaded type, as the identation testers dealt with in BS 4408 : Part 4 are no longer in common use.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

4 Factors influencing the measured hardness of a concrete surface

4.1 Concrete strength

4.1.1 General. It is possible to produce empirical relationships between the strength of concrete and its hardness which are influenced by the factors described in **4.1.2** to **4.1.6.**

4.1.2 Type of cement. The effect of differences between Portland cements of different fineness on the correlation with strength is relatively small, not exceeding 10 %. Concretes made with high alumina cements **can** give strengths 100 % higher than a calibration obtained on Portland cement would indicate. Supersulphated cement concretes can give 50 % lower strengths than a calibration obtained for Portland cement would indicate.

4.1.3 *Cement content* Concrete with 8 high cement content will give lower rebound hammer readings than concrete of the same strength but 8 lower cement content. However, the error in strength estimation resulting from a change in cement content is unlikely to exceed 10 %.

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 aggre gates and aggregates with unusual properties require special calibrations.

4.1.5 *Type of curing and age of concrete.* The relationship between hardness and strength varies 8s 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 4.5).

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.

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 **may also** give more variable results.

Tests on cut surfaces are likely to give more variable results which 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 if results are compared. In such cases separate **calibrations are** necessary.

4.3 Type of concrete

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

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** % is typical for structural concrete, although some types of concrete can give greater differences,

4.5 Carbonation

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 may have a significant effect at earlier ages. Carbonation affects the surface layer which ceases to be representative of the concrete within an element.

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 have to be rigidly mounted, e.g. by clamping them firmly in a heavy testing machine. For some structural members the slenderness or mass may 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.

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 it is consistent and normal to the surface. Corrections for a given direction are **usually** supplied with the hardness tester. It is desirable that they should be checked experimentally.

4.8 Other factors

Other factors which **are** known to influence hardness readings **are** proximity of the test are8 to 8 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 20 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 may give different rebound numbers and all tests should be made 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 made on typical concrete surfaces with **all** of them to determine the magnitude of the differences to be expected between

Recommendations

1 Scope

This Part of BS 1881 gives recommendations on the use of rebound hammers for testing the hardness of concrete. It describes the areas of application of rebound hammers, their accuracy, the calibration procedure, the procedure for obtaining a correlation between hardness and strength, the conditions of the concrete and its testing which influence results, the method of testing concrete in situ and the reporting of results.

NOTE. The titles of publications referred to in this standard are listed on page 5.

2 Definitions

For the purposes of this Part of BS 1881 the definitions given in BS 2787 and BS 6100 : Part 6 apply, together with the following.

2.1 surface hardness. A property of a concrete surface measured in terms of the proportion of the energy returned to a standard mass striking the surface, or a plunger in contact with the surface, with a fixed initial energy.

2.2 location. A region of concrete that is being assessed and that for practical purposes is assumed to be of uniform quality.

2.3 hardness reading. A single measurement of hardness at a point on the concrete surface.

2.4 **hardness** test. A set of hardness readings at a location.

3 Applications

3.1 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 the devices 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 may 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 change 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 may 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 % confidence limits on the estimation of the strength of concrete in situ will be better than ± 25 % 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 3.2 to 3.5.

3.2 Checking the uniformity of concrete

Hardness measurements can be used in the production of concrete where it may 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.

3.3 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 a small number of proof load tests or destructive tests can be supplemented by simple but numerous hardness tests.

3.4 Determining the properties of the surface of the concrete which 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 which govern abrasion resistance have been shown to correlate reasonably well with those characteristics which 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*.

3.5 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 clause 7. General guidance on the assessment of concrete strength in structures is given in BS 6089.

*For example, R. G. Chaplin. Abrasion resistant concrete floors. In: *Adv. in concrete slab technol., 532-534. 1980.*

them. Rebound numbers obtained by using any one rebound hammer should be converted to strength values using only the correlation established for that device.

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 which have given satisfactory performance are commercially available. The use of any other device should be avoided unless extensive tests have shown it to give satisfactory performance.

In most rebound hammers a mass propelled by a spring strikes a plunger in contact with the surface, however, in the pendulum type the mass may move under the action of gravity alone and strike the surface directly. The face of the plunger which 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 is available giving different impact energies and areas of contact applicable to lightweight concrete, normal structural concrete and mass concrete. The principles governing hardness testing which are outlined in this Part 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 most frequently used and is appropriate for normal structural Concrete. The apparatus should include a steel reference anvil on which the rebound hammer can be checked.

6 Method of testing

Select a rebound hammer appropriate to the type of wncrete to be tested, check that it is working correctly and check its reading on the steel reference anvil. Use it in accordance with the manufacturer's instructions that refer to its physical operation.

Choose suitable test locations in relation to the factors listed in clause 4 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 to reduce any possible effects due to differences in rigidity and segregation of the wncrete. 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.

The surface to be tested should be smooth and clean. A moulded surface is preferable but a free trowelled surface may 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 may be necessary to test a trowelled surface. If extraneous matter is present on the surface this should be removed. It may be necessary to use a grinding wheel or stone for this purpose. Rough surfaces resulting from incomplete compaction, loss of grout, 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 free water is wiped from the surface, saturated concrete can be tested satisfactorily.

Twelve readings are usually sufficient to obtain a reliable estimate of the surface hardness at a location. It is normally better to confine the readings of a test to an area not exceeding 300 mm x 300 mm rather than to take random readings over the whole structure or unit. It is preferable to draw a regular grid of lines 20 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 $\pm 15/\sqrt{n}$ % with 95 % confidence, where n is the number of readings.

The mean of each set of readings should be calculated using all the readings (including abnormally high and abnormally low results) unless there is a good reason to doubt the validity of a particular reading. The coefficient of variation of individual readings within one test is usually of the order of 10 % but is sometimes as low as 2 % or as high as 15 %. 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.

7 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 wncrete cubes. It is difficult to ensure that cubes accurately represent the structure to be tested and more reliable results may be obtained if a correlation is made using cores. In this case hardness tests should be made on the concrete in situ at proposed wre positions and cores subsequently cut and tested for strength.

The test specimens should preferably be of as large a mass as possible and 150 mm cube specimens are preferred to 100 mm cubes. The most satisfactory way of making hardness tests on cubes is by holding them in a compression testing machine under a load corresponding to a stress between 7 N/mm' and 10 N/mm^2 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 which 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 clause 4 should be considered. Twelve readings are usually sufficient to obtain a reliable estimate of the surface hardness at one location. Where cubes are used as the specimens, take nine readings using the rebound hammer on each of the two side faces accessible in the compression machine. The points of impact on the specimen should not be nearer an edge than 20 mm and should be not less than 20 mm from each other. The same point should not be struck more than once.

Construct a correlation curve 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.

Check the correct functioning of the rebound hammer from time to time using the reference anvil.

8 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 test in relation to the depth of lift of concrete will give different results owing to differences in the water-cement ratio which are caused by settlement and bleeding. BS 6089 gives an indication of the variation in concrete strength to be expected in a structure.

The interpretation of the results of surveys may be aided by the use of graphical methods. Contour plots showing zones of equal rebound number may indicate areas of abnormally high or low hardness which may then, if necessary, be subjected to further tests. When a large number of results is available from similar locations, histograms may give an indication of the variability of the concrete. For example, uniform supply of concrete and good site practice should result in a single peak with an approximately normal distribution. A distribution with a long tail may indicate poor construction and two distinct peaks may 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 1881 : Part 203 (see also BS 1881 : Part 201).

9 Report

9.1 General

The report should affirm that the hardness was determined in accordance with the recommendations given in this Part of BS 1881.

9.2 Information to be included in the test report

9.2.1 *Obligatory information.* The following information should be included in the test report:

(a) the date, time and place of test;

(b) a description of the structure and positions of the test areas and whether grid lines were used as described in clause 6 (give sketches if necessary);

(c) the details of the concrete and the conditions of test, including factors listed in clause 4 where known;

(d) the details of the rebound hammer used including the make, type and identifying number;

(e) the mean, range, standard deviation and coefficient of variation of the readings in each test;

(f) the reference anvil readings before and after the test.

9.2.2 Additional information. Where appropriate, the following information also should be included in the test report:

(a) the test results expressed in terms of the correlated property (e.g. strength), giving the source of the correlation;

(b) the results of complementary tests by methods other than hardness;

(c) the spacing of grid lines, if used.

Publications referred to

BS 1881 Testing concrete
Part 201 Guide to the use of non-destructive methods of test for hardened concrete
*Part 203 Recommendations for measurement of the velocity of ultrasonic pukes in concrete
BS 2787 Glossary of terms for concrete and reinforced concrete
BS 6089 Guide to the assessment of concrete strength in existing structures
BS 6100 Glossary of building and civil engineering terms
Part 6 Concrete and plaster

CHAPLIN, R.G. Abrasion resistant concrete floors. In: *Advances in concrete slab technology*, 532–534, 1980.

'In preparation.

This British Standard, having been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1986.

ISBN 0 580 14778 9

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The following BSI references relate to the work on this standard:
Committee reference CAB/4 Draft for comment 84/13399 DC

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Cement, Gypsum, Aggregates and Quarry Products Standards Committee (CAB/-) to Technical Committee CAB/4 upon which the following bodies were represented:

Association of Lightweight Aggregate Manufacturers
Association of Metropolitan Authoritias
British Aggregate Construction Materials Industries
British Precast Concrete Federation
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Society of Chemical Industry

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Civil Engineering Test Equipment Manufacturers' Association
British Nuclear Fuels Limited
United Kingdom Atomic Energy Authority

Amendments issued since publication

Amd. No.	Date of issue	Text affected

BS 1881 : Part 202 : 1986

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