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Indian Standard

NON-DESTRUCTIVE TESTING OF CONCRETE — METHODS OF TEST

PART 2 REBOUND HAMMER

(First Reprint JUNE 1995)

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

There are occasions when the various performance characteristics of concrete in a structure are required to be assessed. In most of the cases, an estimate of strength of concrete in the structure is needed, although parameters like overall quality, uniformity, etc, also become important in others. The various methods that can be adopted for *in-situ* assessment of strength properties of concrete depend upon the particular aspect of strength in question. For example, if the load-carrying capacity of structural ensemble is to be assessed, carrying out a full-scale load test as per IS 456 : 1978 'Code of practice for plain and reinforced concrete (*third revision*)' or IS 1343 : 1980 'Code of practice for prestressed concrete (*first revision*)' is the most direct way; on the other hand when the actual compressive strength of a concrete in the structure is to be measured, core testing as per IS 516 : 1959 'Method of test for strength of concrete' is more reliable. However, both these methods are relatively cumbersome and the latter method may leave the structure damaged locally in some cases. Use is, therefore, made of suitable non-destructive tests, which not only provide an estimate of the relative strength and overall quality of concrete in the structures, but also help in deciding whether more rigorous tests like load testing or core drilling at selected locations are required.

There are various such non-destructive testing methods which can be broadly classified as those which measure the overall quality of concrete, for example dynamic or vibration methods like resonance frequency and ultrasonic pulse velocity tests; and those which involve measurement of parameters like surface hardness, rebound, penetration, pull-out strength, etc, and are believed to be indirectly related to the compressive strength of concrete. In addition, radiographic, radiometric, nuclear, magnetic and electrical methods are also available. Since such non-destructive tests are at best indirect methods of monitoring the particular characteristic of concrete and the measurements are influenced by materials, mix and environmental factors, proper interpretation of the results calls for certain degree of expertise. It is more so, when the data on the materials and mix proportions used in the construction are not available as is often the case.

In view of the limitations of the method for predicting the strength of concrete in the structure, it is preferable that both ultrasonic pulse velocity given in Part 1 of the standard and rebound hammer method are used in combination to alleviate the errors arising out of influence of material, mix and environmental parameters on the respective measurements. Relationships between pulse velocity, rebound number and compressive strength of concrete are obtained by multiple regression of the measured values on laboratory test specimens. However, this approach has the limitation that the correlations are valid only for the materials and mix proportions used in the trials. The intrinsic difference between the laboratory test specimens and *in-situ* concrete, for example surface texture, moisture condition, presence of reinforcement, etc, also affect the accuracy of results. The correlation is valid only within the range of values of pulse velocity, rebound number and compressive strength employed and any extrapolation beyond these is open to question. The rebound hammer test is not intended as a substitute for standard compression test, but as a method for determining the uniformity of concrete in the structure and comparing one concrete with another.

Because of the above limitations, the combined use of these two methods is made in another way. In this, if the quality of concrete is assessed to be 'excellent or good' by pulse velocity method, only then the compressive strength is assessed from the rebound hammer indices, and this is taken as indicative of strength of concrete in the entire cross-section of the concrete member. When the quality assessed is 'medium', the estimation of compressive strength by rebound indices is extended to the entire mass only on the basis of other colateral measurements, for example, strength of site concrete cubes, cement content in the concrete or core testing. When the quality of concrete is doubtful, no assessment of concrete strength is made from rebound indices.

In most of the situations, the records of the original materials or mix proportions used in the structure are not available. Therefore, considerable improvisation has to be done in evolving the testing scheme and use is made of comparative measurements made on adjoining portions of the structures or even other structures in the vicinity of the one in question. In doing so, an approach is taken that the same materials and similar mix proportions and level of workmanship were employed for the two

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Indian Standard

NON-DESTRUCTIVE TESTING OF CONCRETE — METHODS OF TEST

PART 2 REBOUND HAMMER

1 SCOPE

This standard covers the object, principle, apparatus and procedure of rebound hammer test method. In addition, influence of test conditions and some general guidance on the interpretation of test results are also given.

NOTE — In view of the limitations of each method of non-destructive testing of concrete, it is essential that the results of tests obtained by one method should be complimented by other tests and each method should be adopted very carefully.

2 REFERENCES

The following Indian standards are necessary adjuncts to this standard.

IS No.	*Title*
516 : 1959	Method of test for strength of concrete
8900 : 1978	Criteria for rejection of outlying observations

3 OBJECT AND PRINCIPLE OF TEST

3.1 Object

The rebound hammer method could be used for:

i) assessing the likely compressive strength of concrete with the help of suitable co-relations between rebound index and compressive strength,

ii) assessing the uniformity of concrete,

iii) assessing the quality of the concrete in relation to standard requirements, and

iv) assessing the quality of one element of concrete in relation to another.

NOTE — The rebound hammer method can be used with greater confidence for differentiating between the questionable and acceptable parts of a structure or for relative comparison between two different structures.

3.2 Principle of Test

When the plunger of rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index.

4 APPARATUS

4.1 The Rebound Hammer

It consists of a spring controlled mass that slides on a plunger within a tubular housing. The impact energy required for rebound hammers for different applications is given in Table 1.

Table 1 Impact Energy for Rebound Hammers for Different Applications

(*Clause* 4.1)

Sl No.	Application	Approximate Impact Energy Required for the Rebound Hammers (Nm)
i)	For testing normal weight concrete	2·25
ii)	For light-weight concrete or small and impact sensitive parts of concrete	0·75
iii)	For testing mass concrete, for example in roads, air-fields pavements and hydraulic structures	30·00

5 CHECKING OF APPARATUS

5.1 It is necessary that the rebound hammer is checked against the testing anvil before commencement of a test to ensure reliable results. The testing anvil should be of steel having Brinell hardness of about 5 000 N/mm². The supplier/manufacturer of the rebound hammer should indicate the range of readings on the anvil suitable for different types of rebound hammers.

5.2 Procedure of Obtaining Correlation Between Compressive Strength of Concrete and Rebound Number

The most satisfactory way of establishing a correlation between compressive strength of concrete and its rebound number is to measure both the properties simultaneously on concrete cubes. The concrete cube specimens are held in a compression testing machine under a fixed load, measurements of rebound number taken and then the compressive strength determined as per IS 516 : 1959. The fixed load required is of the order of 7 N/mm² when the impact energy of the hammer is about 2·2 Nm. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimise the size effect on the test result of a full scale structure. 150 mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2·2 Nm), whereas for rebound hammers of higher impact energy, for example 30 Nm, the test cubes should not be smaller than 300 mm.

If the specimens are wet cured, they should be removed from wet storage and kept in the laboratory atmosphere for about 24 hours before testing. To obtain a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes and the strength of dry tested cubes on which rebound readings are taken. A direct correlation between rebound numbers on wet cubes and the strength of wet cubes is not recommended. Only the vertical faces of the cube as cast should be tested. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20 mm and should be not less than 20 mm from each other. The same points must not be impacted more than once.

6 PROCEDURE

6.1 For testing, smooth, clean and dry surface is to be selected. If loosely adhering scale is present, this should be rubbed of with a grinding wheel or stone. Rough surfaces resulting from incomplete compaction, loss of grout, spalled or tooled surfaces do not give reliable results and should be avoided.

6.2 The point of impact should be at least 20 mm away from any edge or shape discontinuity.

6.3 For taking a measurement, the rebound hammer should be held at right angles to the surface of the concrete member. The test can thus be conducted horizontally on vertical surfaces or vertically upwards or downwards on horizontal surfaces. If the situation demands, the rebound hammer can be held at intermediate angles also, but in each case, the rebound number will be different for the same concrete.

6.4 Rebound hammer test is conducted around all the points of observation on all accessible faces of the structural element. Concrete surfaces are thoroughly cleaned before taking any measurement. Around each point of observation, six readings of rebound indices are taken and average of these readings after deleting outliers as per IS 8900 : 1978 becomes the rebound index for the point of observation.

7 INFLUENCE OF TEST CONDITIONS

7.1 The rebound numbers are influenced by a number of factors like types of cement and aggregate, surface condition and moisture content, age of concrete and extent of carbonation of concrete.

7.1.1 *Influence of Type of Cement*

Concretes made with high alumina cement can give strengths 100 percent higher than that with ordinary Portland cement. Concretes made with supersulphated cement can give 50 percent lower strength than that with ordinary Portland cement.

7.1.2 *Influence of Type of Aggregate*

Different types of aggregate used in concrete give different correlations between compressive strength and rebound numbers. Normal aggregates such as gravels and crushed rock aggregates give similar correlations, but concrete made with lightweight aggregates require special calibration.

7.1.3 *Influence of Surface Condition and Moisture Content of Concrete*

The rebound hammer method is suitable only for close texture concrete. Open texture concrete typical of masonry blocks, honeycombed concrete or no-fines concrete are unsuitable for this test. All correlations assume full compaction, as the strength of partially compacted concrete bears no unique relationship to the rebound numbers. Trowelled and floated surfaces are harder than moulded surfaces, and tend to overestimate the strength of concrete.

A wet surface will give rise to underestimation of the strength of concrete calibrated under dry conditions. In structural concrete, this can be about 20 percent lower than in an equivalent dry concrete.

7.1.4 *Influence 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.

7.1.5 *Influence of Carbonation of Concrete Surface*

The influence of carbonation of concrete surface on the rebound number is very significant. Carbonated concrete gives an over-estimate of strength which in extreme cases can be up to 50 percent. It is possible to establish correction factors by removing the carbonated layer and testing the concrete with the rebound hammer on the uncarbonated concrete.

8 INTERPRETATION OF RESULTS

8.1 The rebound hammer method provides a convenient and rapid indication of the compressive strength of concrete by means of establishing a suitable correlation between the rebound index and the compressive strength of concrete. The procedure of obtaining such correlation is given in **5.2**. In general, the rebound number increases as the strength increases but it is also affected by a number of parameters as mentioned in **7.1**.

It is also pointed out that rebound indices are indicative of compressive strength of concrete to a limited depth from the surface. If the concrete in a particular member has internal micro-cracking, flaws or heterogeneity across the cross-section, rebound hammer indices will not indicate the same.

As such, the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is $\pm$ 25 percent. If the relationship between rebound index and compressive strength can be checked by tests on core samples obtained from the structure or standard specimens made with the same concrete materials and mix proportion, then the accuracy of results and confidence thereon are greatly increased.

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situations, any significant difference in the ultrasonic pulse velocity or rebound indices between them must be due to some inherent differences in the overall quality. If the nominal grades of concrete or mix proportions are known to be different in either case, suitable allowance is made for the same in interpretation of results.

The test results on ultrasonic pulse velocity and rebound indices are analysed statistically and plotted as histograms and the lower fractiles of results are taken for assessing the quality or 'characteristic' strength of concrete, in line with the current limit state concepts of design.

The composition of the technical committee responsible for the formulation of this standard is given at Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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