FOREWORD

(Formal clauses to be added later)

Testing plays an important role in controlling the quality of cement concrete work. Systematic testing of the raw materials, the fresh concrete and the hardened concrete, is an inseparable part of any quality control programme for concrete. This helps achieve a higher efficiency of the materials used and greater assurance of the performance of the concrete, in regard to workability, strength and durability. The test methods used should be simple, direct and convenient to apply. This standard was prepared with this objective in view.

This standard was first published in 1959. In this first revision, it was decided to review and update the various existing test methods of concrete. The revision of the standard is being brought out taking into consideration the latest international practices and developments in this field in the country, and also introduced certain new test methods wherever required. In the process, the various existing test methods covered in IS 516:1959 ‘Methods of tests for strength of concrete’ have been revised taking into consideration primarily the corresponding ISO standards while also examining the other best practices world over and in the country. In addition, test methods for determination of additional properties have been included in areas such as permeability, initial surface absorption, corrosion of reinforcement, carbonation of concrete (field test), accelerated carbonation test, creep of concrete and flexural strength and toughness parameters of fibre reinforced concrete. Also, for better understanding and implementation, some of the other test methods which were spread over in number of other Indian standards have been brought together under the fold of IS 516 as its various parts, such as the splitting tensile strength, ultrasonic pulse velocity test, rebound hammer test, pull out test for bond in reinforced concrete, and determination of water soluble and acid soluble chlorides. This is with a view to making the standard complete in all respects, and rendering it a
comprehensive source of provisions for testing of concrete and reference in other Indian Standards.

In this revision, IS 516 is split into 12 parts. The other parts in the series are:

- Part 1   Testing of strength of hardened concrete
- Part 2   Properties of hardened concrete other than strength
- Part 3   Making, curing and determining compressive strength of accelerated cured concrete test specimens
- Part 4   Sampling, preparing and testing of concrete cores
- Part 5   Determination of drying shrinkage and moisture movement of concrete samples
- Part 6   Determination of creep of concrete cylinders in compression
- Part 7   Determination of modulus of elasticity
- Part 8   Wear Resistance
- Part 9   Pull out test for bond in reinforced concrete
- Part 10  Method for determination of Portland cement content of hardened hydraulic cement concrete
- Part 11  Determination of water soluble and acid soluble chlorides in hardened mortar and concrete

This standard (Part 5) specifies non-destructive test methods for use on hardened concrete. 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.

This standard (Part 5/Section 4) covers the procedure of rebound hammer test method for determination of a rebound number of hardened concrete using a spring-driven steel hammer. The significant changes in this standard include:

a) Procedure for developing correlation between compression test of concrete and rebound hammer have been elaborated and have been given for both cube compressive strength and core compressive strength.

b) More details on the equipment and the very fine anvil have been included.

c) The clause on influence of test conditions have been elaborated with the inclusion of more factors.

d) The use of a combination of rebound hammer and ultrasonic pulse velocity have been emphasized for proper interpretation of the results.

This test method shall be applicable as and when published, in place of the corresponding IS 13311 (Part 2):1992 ‘Methods of non-destructive testing of concrete: Part 2 Rebound hammer’, which shall be superseded after the publication of this standard.

In reporting the result of a test or analysis made in accordance with this standard, is to be rounded off, it shall be done 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 specified value in this standard.
1 SCOPE

This standard covers the object, principle, apparatus and procedure of rebound hammer test method for determination of a rebound number of hardened concrete using a spring-driven steel hammer. In addition, influence of test conditions and some general guidance on the interpretation of test results are also given.

NOTE – The test method is not intended as an alternative for the compressive strength determination of concrete, but with suitable correlation, it can provide an estimate of in situ strength.

2 REFERENCES

The standards listed below contains provisions which through reference in this text, constitutes provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

<table>
<thead>
<tr>
<th>IS No</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>516 Part 1</td>
<td>Hardened Concrete — Methods of Test</td>
</tr>
<tr>
<td>Part 5/Sec 1 : 2018</td>
<td>Testing of strength of hardened concrete (under preparation)</td>
</tr>
<tr>
<td>IS/ISO 16269 : 2016</td>
<td>Non-destructive testing of concrete Section 1 Ultrasonic pulse velocity testing (first revision)</td>
</tr>
<tr>
<td></td>
<td>Statistical interpretation of data Part 4 : Detection and treatment of outliers</td>
</tr>
</tbody>
</table>
3 OBJECT AND PRINCIPLE OF TEST

3.1 Object

The rebound hammer method could be used for:

a) assessing the likely compressive strength of concrete with the help of suitable co-
relations between rebound index and compressive strength developed in accordance with 5.2,
b) assessing the uniformity of concrete,
c) assessing the quality of the concrete in relation to standard requirements, and

d) 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. Based on the rebound distance of the spring-controlled
mass after it impacts the plunger or based on the ratio of the hammer speed after impact
to the speed before impact, a Rebound Number is produced. Rebound Number produced
based on two measurement principles are not comparable. 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, recording paper or an electronic display
and is designated as the rebound number or rebound index.

4 APPARATUS

4.1 The Rebound Hammer

It consists of spring-loaded steel hammer that strikes the metal plunger in contact with the
concrete surface when released.

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)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Application</th>
<th>Approximate Impact Energy Required for the Rebound Hammers, Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>a)</td>
<td>For Testing normal weight concrete</td>
<td>2.25</td>
</tr>
<tr>
<td>b)</td>
<td>For light-weight concrete or small and impact sensitive part of concrete</td>
<td>0.75</td>
</tr>
</tbody>
</table>
4.2 Abrasive Stone

It consists of medium-grain texture silicon carbide or equivalent material.

4.3 Verifying Anvil

It consists of a steel cylinder with 150mm diameter and 150 mm height. The HRC hardness value of the impact area shall be 64 to 68. The supplier/manufacturer of the rebound hammer should indicate the range of readings on the anvil suitable for different types of rebound hammers.

5 CHECKING OF APPARATUS

5.1 It is necessary that the rebound hammer is checked against the testing anvil as per 4.3 before commencement of a test and after completion of test to ensure reliable results.

NOTE – A properly operating rebound hammer and a properly designed anvil should result in a rebounder number recommended by the manufacturer. Verification on the anvil does not guarantee that the hammer will yield repeatable rebound numbers at other points on the scale.

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

Relationships between rebound number and concrete strength that are provided by instrument manufactures shall be used only to provide indications of relative concrete strength at different locations in a structure. To use this test method to estimate strength, it is necessary to establish a correlation between rebound number and strength for a particular concrete and particular apparatus by any method given below.

5.2.1 Correlation Between Compressive Strength of Concrete and Rebound Number (using cube compressive strength)

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 correlation shall be derived on project specific concrete cubes for all bigger projects. The general correlation can be derived from concrete cubes used in smaller projects in a region with similar materials including cement type and same shall be repeated every year. For bigger projects atleast three cubes each for three different concrete grades shall be cast and tested for establishing the correlation. Cube specimens should be wet cured for 27 days and they should be removed from wet storage and kept in the laboratory atmosphere for about 24 hours before testing. The concrete cube specimens are held in a compression testing machine under a fixed load, measurements of rebound number taken using the particular hammer / hammers for which conditions are to be established and then the compressive strength determined as per IS 516 (Part 1). The fixed load required is of the order of 7 N/mm$^2$ 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. 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 25 mm and should be not less than 25 mm from each other. The same points must not be impacted more than once.

5.2.2 Correlation Between **Equivalent Cube Compressive Strength of Concrete Cores and Rebound Number** (using core compressive strength)

To establish correlation between rebound number and strength for a particular concrete and particular apparatus, rebound numbers measured on the structure can be correlated with the few core strengths measured on the structure on corresponding members. At least two replicate core shall be taken from at least six locations with different rebound numbers. The test conditions and surface conditions of the locations where strengths are to be estimated using developed correlation shall be similar to the locations used for development of correlation. For smaller projects the number of core may be limited to six. The locations where these test are conducted and cores are taken should have ultrasonic pulse value greater or equal to 3.75 km/sec, when tested as per IS 516(Part 5/Sec 1).

**NOTES**
1. Predetermined curve prepared for similar concrete in the same region may be used for rough estimation of strength of structural members tested for cases where correlation cannot be developed neither by cube compressive strength nor in-situ core strengths.
2. Different instruments of the same type may give rebound numbers differing from 1 to 3 units. Therefore, tests should be made with the same instrument in order to compare results. If more than one instrument is to be used, perform comparative tests on a range of typical concrete surfaces so as to determine the magnitude of the differences to be expected in the readings of different instruments.

For readings to be compared, the direction of impact must be the same or established correlation factors shall be applied to the readings. In the absence of data, manufacturer correlation for direction effect can be adopted.

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 off 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 25 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 (preferably) 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.

**NOTE** – Digital angle gauges are available that can be attached to the body of the instrument to allow quick measurement of the angle with respect to horizontal. However, correlation taking into account the direction effect can also be developed between equivalent cubes compressive strength of concrete
cores (minimum six nos.) with rebound number in vertically upward or downward direction for the specific project.

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/ISO 16269:2016 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. The effect of age can be ignored for concrete above 14 days 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 overestimate of strength which in extreme cases can be up to 50 percent. The carbonation depth shall be checked in cases where the age of concrete is more than six months and same shall be reproduced in the test
It is possible to establish correction factors by removing the carbonated layer and testing the concrete with the rebound hammer on the uncarbonated concrete.

7.1.6 Influence of vertical distance from the bottom of concrete placement.

The influence of vertical distance from the bottom of concrete placement on the rebound number is very significant. Generally, a higher rebound number is observed near the bottom of concrete placement as during compaction concentration of aggregates will be higher at the bottom.

7.1.7 Influence of surface conditions used in development of correlation between compressive strength and Rebound Number

The direct correlation between rebound numbers and strength of wet cured and wet tested cubes is not recommended. 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. The ratio of dry tested cube to wet tested cube in compression is generally about 1.05.

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 can be up to ±25 percent depending upon correlation curve and methodology adopted for establishing correlation between rebound index and likely compressive strength. 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.

Because of the various limitations in rebound hammer test, the combined use of ultrasonic pulse velocity (UPV) test [IS 516 (Part 5/Sec 1)] and rebound hammer test is must for proper interpretation. If the quality of concrete assessed by ultrasonic pulse velocity method is 3.75 Km/sec or above, only then the in-situ compressive strength assessed from the rebound hammer test is valid. This shall be taken as indicative of strength of concrete in the entire cross-section of the concrete member represented by the both tests. In case the quality assessed by UPV is 'medium', the estimation of in-situ compressive strength by rebound indices shall be extended to the entire mass only on the basis of other collateral measurements, for example, strength of site concrete cubes, cement content in the concrete or core testing. In cases the quality of concrete assessed by UPV is doubtful, no assessment of concrete strength shall be made from rebound hammer test.
9 TEST REPORT

The report shall include:

a) Date/period of testing;
b) Identification of the concrete structure/element;
c) Location of test area(s);
d) Identification of the rebound hammer;
e) Details of concrete and its condition;
f) Date/time of performance of the test;
g) Test result and hammer orientation for each test area; and
h) The details of carbonation of the tested area in case the structure is more than 6 months old.

NOTE – The report can include individual rebound hammer readings, if required.