NRI INSTITUTE OF INFORMATION SCIENCE & TECHNOLOGY BHOPAL

DEPARTMENT OF CIVIL ENGINEERING

LAB MANUAL

NON DESTRUCTIVE LAB

NON DESTRUCTIVE TESTING LAB

LO	LAB OUTCOMES
LO1	Rebound hammer handling , calibration , usage can be learnt in this lab
LO2	Ultra pulse velocity meter can be studied.

REBOUND HAMMER TEST

1. Objective And Principle

Objective:

The rebound hammer method could be used for:
(i) assessing the likely compressive strength of concrete with the help of suitable corelations 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.

Principle:

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.

2. Apparatus Required

Fig. 1: 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.

S. No.	Application	Approx. Impact Energy required for Rebound hammer (Nm)
1	For Testing Normal Weight Concrete	2.25
2	For light-weight concrete or small and impact sensitive parts of concrete	0.75
3	For testing mass concrete for example, in roads, air field pavements and hydraulic structures	2.25

Table 1 : Impact Energy for Rebound hammer for different Applications.

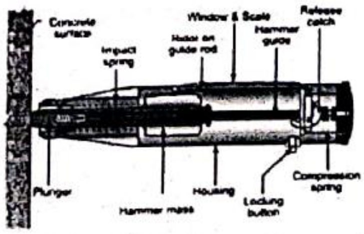

Fig. 2: Schematic of Rebound Hammer

3. Reference

IS-13311 (Part 2):1992 (Reaffirmed- May 2013) "Non Destructive Testing of Concrete-Methods of Test (Rebound hammer)".

4. Procedure

Checking of Apparatus

- 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 5000 N/mm^2. The supplier/manufacturer of the rebound hammer should indicate the range of readings on the anvil suitable for different types of rebound hammers.

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/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 300mm.

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.

Test Procedure

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

5. Influence Of Test Conditions:

- 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 ofcarbonation of concrete.

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 super sulphated cement can give 50 percent lower strength than that with ordinary Portland cement.

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 light weight aggregates require special calibration.

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 over estimate the strength of concrete.

A wet surface will give rise to under estimation 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.

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.

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. It is possible to establish correction factors by removing the carbonated layer and testing the concrete with the rebound hammer on the uncarbonated concrete.

6. Interpretation Of Result

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 4.2.
2. 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 microcracking, flaws or heterogeneity across the cross-section, rebound hammer indices will not indicate the same.
3. 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 ±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.

ULTRASONIC PULSE VELOCITY METER

1. Objective And Principle

Objective

The ultrasonic pulse velocity method could be used to establish:

(i) the homogeneity of the concrete,
(ii) the presence of cracks, voids and other imperfections,
(iii) changes in the structure of the concrete which may occur with time,
(iv) the quality of the concrete in relation to standard requirements,
(v) the quality of one element of concrete in relation to another, and
(vi) the values of dynamic elastic modulus of the concrete.

Principle

The ultrasonic pulse is generated by an electroacoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes longitudinal (compressional), shear (transverse) and surface (rayleigh) waves. The receiving transducer detects the onset of the longitudinal waves, which is the fastest.

Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic properties, pulse velocity method is a convenient technique for investigating structural concrete.

The underlying principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of poorer quality, lower velocities are obtained. If there is a crack, void or flaw inside the concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making the path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

2. Apparatus Required

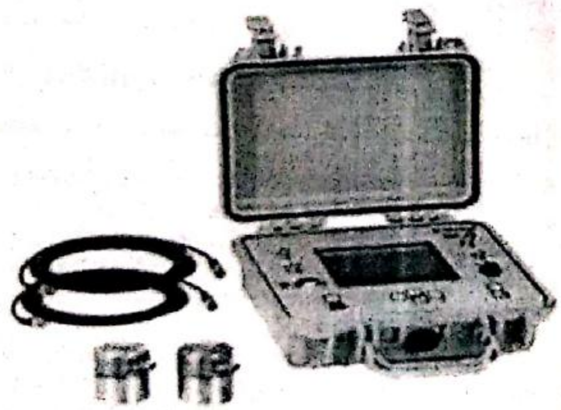

Fig. 1: Ultrasonic Pulse Velocity Meter

The apparatus for ultrasonic pulse velocity measurement shall consist of the following:
a) Electrical pulse generator,
b) Transducer - one pair,
c) Amplifier, and
d) Electronic timing device.

3. Reference

IS-13311 (Part 1):1992 (Reaffirmed- May 2013) "Non-Destructive Testing of Concrete- Methods of Test (Ultrasonic Pulse Velocity)"

4. Procedure

1. In this test method, the ultrasonic pulse is produced by the transducer which is held in contact with one surface of the concrete member under test. After traversing a known path length L in the concrete, the pulse of vibrations is converted into an electrical signal by the second transducer held in contact with the other surface of the concrete member and an electronic timing circuit enables the transit time (T) of the pulse to be measured. The pulse velocity (V) is given by:

$$V = L/T$$

2. Once the ultrasonic pulse impinges on the surface of the material, the maximum energy is propagated at right angles to the face of the transmitting transducer and best results are, therefore, obtained when the receiving transducer is placed on the opposite face of the concrete member (direct transmission or cross probing). However, in many situations two opposite faces of the structural member may not be accessible for measurements. In such cases, the receiving transducer is also placed on the same face of the concrete members (surface probing). Surface probing is not so efficient as cross probing, because the signal produced at the receiving transducer has an amplitude of only 2 to 3 percent of that produced by cross probing and the test results are greatly influenced by the surface layers of concrete which may have different properties from that of concrete inside the structural member. The indirect velocity is invariably lower than the direct velocity on the same concrete element. This difference may vary from 5 to 20 percent depending largely on the quality of the concrete under test. For good quality concrete, a difference of about 0.5 km/ sec may generally be encountered.
3. To ensure that the ultrasonic pulses generated at the transmitting transducer pass into the concrete and are then detected by the receiving transducer, it is essential that there be adequate acoustical coupling between the concrete and the face of each transducer. Typical couplants are petroleum jelly, grease, liquid soap and kaolin glycerol paste. If there is very rough concrete surface, it is required to smoothen and level an area of the surface where the transducer is to be placed. If it is necessary to work on concrete surfaces formed by other means, -for example trowelling, it is desirable to measure pulse velocity over a longer path length than would normally be used. A minimum path length of 150 mm is recommended for the direct transmission method involving one unmoulded surface and a minimum of 400 mm for the surface probing method along an unmoulded surface.
4. The natural frequency of transducers should preferably be within the range of 20 to 150 kHz. Generally, high frequency transducers are preferable for short path lengths and low frequency transducers for long path lengths. Transducers with a frequency of 50 to 60 kHz are useful for most all-round applications.
5. Since size of aggregates influences the pulse velocity measurement, it is recommended that the minimum path length should be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for concrete in which the nominal maximum size of aggregate is between 20 to 40 mm.
6. In view of the inherent variability in the test results, sufficient number of readings are taken by dividing the entire structure in suitable grid markings of 30 x 30 cm or even smaller. Each junction point of the grid becomes a point of observation.
7. Transducers are held on corresponding points of observation on opposite faces of a structural element to measure the ultrasonic pulse velocity by direct transmission, i.e., cross probing. If one of the faces is not- accessible, ultrasonic pulse velocity is measured on one face of the structural member by surface probing.
8. Surface, probing in general gives lower pulse velocity than in case of cross probing and depending on number of parameters, the difference could be of the order of about 1 km/sec.

5. Influence Of Test Conditions

Influence of Surface Conditions and Moisture Content of Concrete

Smoothness of contact surface under test affects the measurement of ultrasonic pulse velocity. For most concrete surfaces, the finish is usually sufficiently smooth to ensure good acoustical contact by the use of a coupling medium and by pressing the transducer against the concrete surface. When the concrete surface is rough and uneven, it is necessary to smoothen the surface to make the pulse velocity measurement possible.

In general, pulse velocity through concrete increases with increased moisture content of concrete. This influence is more for low strength concrete than high strength concrete. The pulse velocity of saturated concrete may be up to 2 percent higher than that of similar dry concrete. In general, drying of concrete may result in somewhat lower pulse velocity.

Influence of Path Length, Shape and Size of the Concrete Member

As concrete is inherently heterogeneous, it is essential that path lengths be sufficiently long so as to avoid any error introduced due to its heterogeneity. In field work, this does not pose any difficulty as the pulse velocity measurements are carried out on thick structural concrete members. However, in the laboratory where generally small specimens are used, the path length can affect the pulse velocity readings.

The shape and size of the concrete member do not influence the pulse velocity unless the least lateral dimension is less than a certain minimum value, for example the minimum lateral dimension of about 80 mm for 50 kHz natural frequency of the transducer. Table 1 gives the guidance on the choice of the transducer natural frequency for different path lengths and minimum transverse dimensions of the concrete members.

Influence of Temperature of Concrete

Variations of the concrete temperature between 5 and 30°C do not significantly affect the pulse velocity measurements in concrete. At temperatures between 30 to 60°C there can be reduction in pulse velocity up to 5 percent. Below freezing temperature, the free water freezes within concrete, resulting in an increase .in pulse velocity up to 7.5 percent.

Influence of Stress

When concrete is subjected to a stress which is abnormally high for the quality of the concrete, the pulse velocity may be reduced due to the development of micro-cracks. This influence is likely to be the greatest when the pulse path is normal to the predominant direction of the planes of such micro-cracks. This occurs when the pulse path is perpendicular to the direction of a uniaxial compressive stress in a member.

This influence is generally insignificant unless the stress is greater than about 60 percent of the ultimate strength of the concrete.

Effect of Reinforcing Bars

The pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition. This is because, the pulse velocity in steel is 1.2 to 1.9 times the velocity in plain concrete and, under certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel.

The apparent increase in pulse velocity depends upon the proximity of the measurements to the reinforcing bar, the diameter and number of the bars and their orientation with respect to the path of propagation.

6. Interpretation Of Result

1. The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. This in turn, depends upon the materials and mix proportions used in making concrete as well as the method of placing, compaction and curing of concrete.

   For example, if the concrete is not compacted as thoroughly as possible, or if there is segregation of concrete during placing or there are internal cracks or flaws, the pulse velocity will be lower, although the same materials and mix proportions are used.
2. The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc, indicative of the level of workmanship employed; can thus be assessed using the guidelines given in Table 2, which have been evolved for characterising the quality of concrete in structures in terms of the ultrasonic pulse velocity.

S. No.	Pulse velocity by Cross Probing (km/sec)	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

Table 1 : Velocity Criterion for Concrete Quality Grading.

3. Since actual values of the pulse velocity obtained, depend on a number of parameters, any criterion for assessing the quality of concrete on the basis of pulse velocity as given in Table 2 can be held as satisfactory only to a general extent. However, when the comparison is made amongst different parts of a structure, which have been built at the same time with supposedly similar materials, construction practices and supervision, the assessment of quality becomes more meaningful and reliable.
4. The assessment of compressive strength of concrete from ultrasonic pulse velocity values is not adequate because the statistical confidence of the correlation between ultrasonic pulse velocity and the compressive strength of concrete is not very high. The reason is that a large number of parameters are involved, which influence the pulse velocity and compressive strength of concrete to different extents. However, if actual concrete materials and mix proportions adopted in a particular structure are available, then estimate of concrete strength can be made by establishing suitable correlation between the pulse velocity and the compressive strength of concrete specimens made with such materials and mix proportions, under environmental conditions similar to that in the