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Health Assessment Of Reinforced Concrete Structures - A Case Study

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ABSTRACT: *It is often necessary to test concrete structure to determine its suitability for which it is designed. Ideally such testing should be done without damaging the concrete. The test available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test. The range of properties that can be assessed using non-destructive tests and partially destructive tests is quite large and includes such fundamental parameters as density, elastic modulus and strength as well as surface hardness and surface absorption, and reinforcement location, size and distance from the surface. As is been worked on assessment of in place concrete strength of R.C.C residential buildings of different age groups and elevated storage reservoirs of ages 25 yrs .and 30 yrs. respectively, it is been found that the use of NDT techniques are much reliable and can well be fit to assess the quality of concrete structures. In this paper the field investigation for strength assessment and hence resolving the doubts of quality of construction of an existing structure has been presented based upon nondestructive testing.*

1. INTRODUCTION

Any structure that is in use for which it is intended to, shows some structural disorder, requires to be assessed for its quality, structural integrity and in place concrete compressive strength. Standing structure can not be assessed by conventional methods adopted to evaluate structural integrity and in place concrete compressive strength same as by testing standard specimens up to failure. Hence for structures, standing decades together, an efficient system of assessment of structure for in place strength is urgently required. It is also true to the new structures, as more and more clients and their consultants are well aware of the quality assurance in booming infrastructure sector in India. Non Destructive Testing (NDT) has the potential of becoming an effective tool for quality assurance and damage assessment.

2. NON-DESTRUCTIVE METHODS

The objective of a non destructive test is to obtain an estimate of properties of material by measuring certain quantities which are empirically related to it. To make a strength estimation, it is necessary to know the relationship between the result of the non destructive test and strength of material. The accuracy of interpretation of results depends directly on the correlation between strength of material and measured quantity. Thus, the user of NDT should have an understanding of what quantity is measured by the test and how this quantity is related to the strength of material. Test methods range widely in reliability and complexity. Hence, appropriate experience is necessary in selection of the proper tests and correct interpretation.
The following NDT techniques are generally employed -

1. Schmidt's Rebound Hammer test for assessing the concrete compressive strength.
2. Ultrasound pulse Velocity tests for establishing quality of concrete.
3. Coring for taking out concrete cores for laboratory testing for determining compressive strength.
4. Rebar locator tests for locating reinforcement bars and for determining their diameters and spacing.
5. Carbonation test for determining the depth of carbonation of concrete.
6. Half- cell potential test for determining the likelihood of corrosion.
7. Determination of chloride contents of concrete

In the present paper, health assessment methods such as A) Rebound Hammer and B) Ultrasonic Pulse Velocity are closely scrutinized to explore some fundamental aspects of R. C. structure health monitoring.

2.1 Rebound Hammer Method

This method is explained in IS:13311 (part2):1992.

Principle of test:

When the plunger of the rebound test hammer is pressed against the surface of the concrete the spring controlled mass rebounds and the extent of such rebounds depends upon surface hardness of the concrete. The rebound is then be related to the compressive strength of concrete.

Factors affecting the Rebound Number

i. Type of cement
ii. Type of aggregate
iii. Concrete moisture condition
iv. Curing and age of concrete
v. Presence of surface carbonation etc.

2.2 Ultrasonic Pulse Velocity

This method is explained in IS 13311 (part 1):1992 , which involves measurement of the time of travel of electronically generated mechanical pulses through the concrete . The ultrasonic pulse velocity method could be used to establish:

a) Homogeneity of concrete
b) Presence of cracks & voids
c) Changes in structures of the concrete
d) The quality of the concrete in relation to standard requirement
e) The values of dynamic elastic modulus of the concrete

The principles behind the Ultrasonic Pulse Velocity is that the pulses are generated by an electro-acoustical transducer, when pulse is induced into the concrete from a transducer , it undergoes multiple reflections at the boundaries of different material phase within the concrete. A complex system of waves is developed which include longitudinal, shear and surface waves. The receiving transducer detects the onset of longitudinal waves which is the fastest.

Because the velocity of the pulses is independent of the geometry of the material through which they pass and depends only on its elastic properties. When quality of concrete in terms of density , homogeneity and uniformity is good, higher velocities are obtained. In case of poorer quality of concrete lower velocities are obtained. In general the velocity criterion are as shown in table No.1.

Table No.1.

Sr. No	Pulse Velocity (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

Factors affecting the pulse velocity

i. Surface condition and moisture content
ii. Temperature of concrete
iii. Micro cracks in concrete
iv. Water cement ratio
v. Age of concrete
vi. Presence of steel reinforcement
vii. Type of aggregate

3. CASE STUDY

3.1 General Information

In a prime locality of Gargoti, (kolhapur) a G + II storied institute building was under construction a couple of years before. The grade of concrete used was M20. The floor system consisted of beam slab construction. Part of the first floor slab and beams were cast on a particular day. The cube test results yielded lower values and the concrete failed to achieve the acceptance criteria. It was decided to perform non-destructive tests to estimate the properties of concrete in the structure. Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

3.2 Scope of work

The quality of the concrete was to be evaluated by performing Non-destructive Testing. In order to assess the quality of concrete, the following methods of testing were employed:

(i) Ultrasonic Pulse Velocity test as per IS:13311 (Part 1).

(ii) Rebound Hammer test as per IS:13311 (Part 2)

3.3 Visual Inspection & Selection of Spots for Testing.

Ultrasonic Pulse Velocity test :- (Fig. 1.)

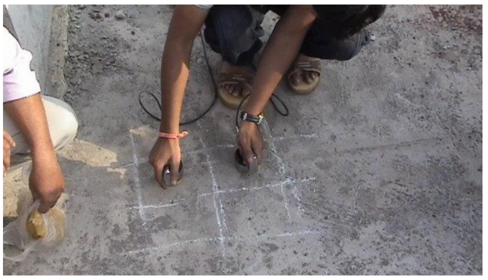

Fig. 1.

Rebound Hammer test :- (Fig.2)

Fig. 2.

Apparently no abnormality in concreting was observed at the 1st floor. At different parts of the floor slab and beam, spots were selected for performing the NDT work.

Rebound Hammer tests were performed on the floor slab by holding the hammer vertically down. Readings were taken also on beam sides with direction of hammer horizontal. All these locations were assessed by USPV tester. Majority of the observations were surfaces probing whereas for beam sides cross probing was adopted.

3.4 Summary of Observations & Interpretation of Results

In view of the limitations of the methods for predicting the strength of concrete in the structure, it is preferable that both ultrasonic pulse velocity and rebound hammer methods be 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 regression analysis of the measured values on laboratory test specimen.

For the structure under investigation a detailed NDT scheme was adopted and the summery of observation is mentioned below-

Concrete at 1st floor level

Rebound Hammer & USPV readings were noted at 10 spots on a number of slab panels and beams.

Jist of observation on 1st floor

Slab and beams –

Rebound Hammer –

Direction of hammer ↓i.e. held vertically downwards

Rebound index = 23.17

Direction of Hammer →i.e. held horizontal

Rebound index= 33.84

USPV-

USPV (surfaces) = 2.05 km/s

USPV (cross) = 4.1 km/s

3.5 Correlation Between compressive Strength of concrete & NDT Parameters viz. Rebound Index & USPV

In an attempt to develop correlation between USPV & Rebound index with compressive strength, cubes were casted of same grades and cured and left to meet with the site conditions.

A total of 4 cubes each of M20 Grades concrete were obtained for testing in the laboratory.

As per IS:13311 (part 2), the cubes were tested by Rebound hammer by holding them in compression testing machine under a fixed load of 7 N/mm^2. Rebound Number or indices for horizontal position were obtained. About 9 readings on each of the two faces of the cubes were noted.

Values of Rebound indices, USPV and compressive strengths of the cubes are presented in table 2.

Table 2: Results of Destructive and Non-destructive tests on cube specimens.

Grade of concrete	Rebound Hammer	USPV Results (km/s)	Compressive Strength (Mpa)
	Hammer Direction (→)	Cross Probing	Compressive Strength (Mpa)
M 20	29.06	4.02	27.08
M 20	30.35	4.1 2	31.73
M 20	29.78	4.21	32.14
M 20	31.18	4.17	30.52

Based on the procedure outlined in Is-13311 (part 1) and (part 2) relationships between compressive strength and USPV and Rebound numbers have been developed using regression shown in figures 3 to 4. from the relevant correlation curves, most likely cube compressive strength of concrete has been obtained after allowing for necessary corrections.

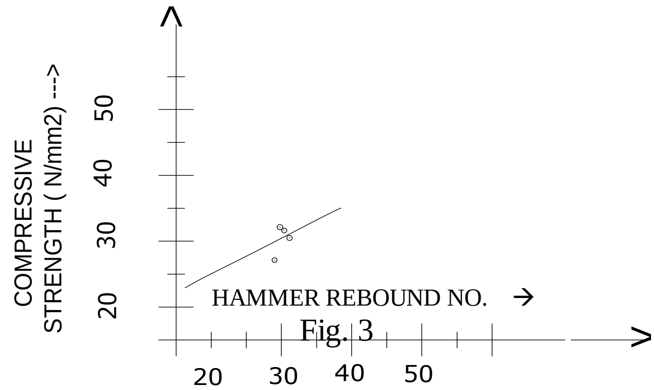

Fig. 3

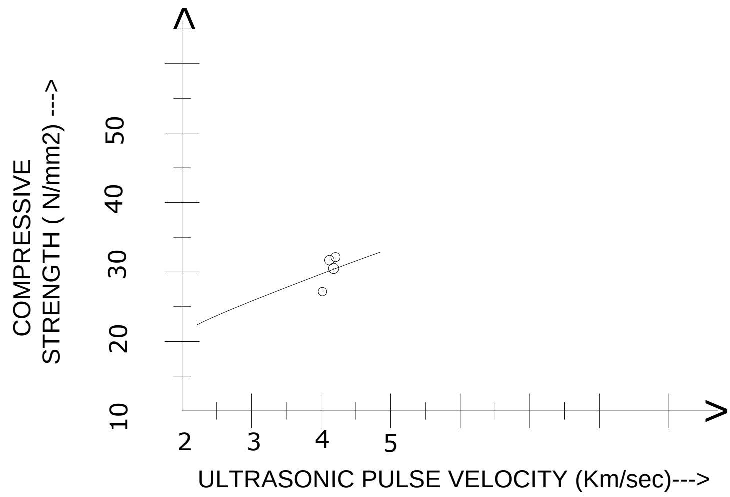

Fig. 4.

Using these relationships, the compressive strengths of concrete have been evaluated from the observations taken on the actual structure.

3.5.1 Compressive Strength from Rebound indices

1st Floor concrete, Grade adopted M20

Average value of Rebound number with hammer held horizontal = 33.84(→)

From the correlation developed between rebound numbers and compressive strength, compressive strength was obtained as 32.58 MPa. (Fig. 5.)

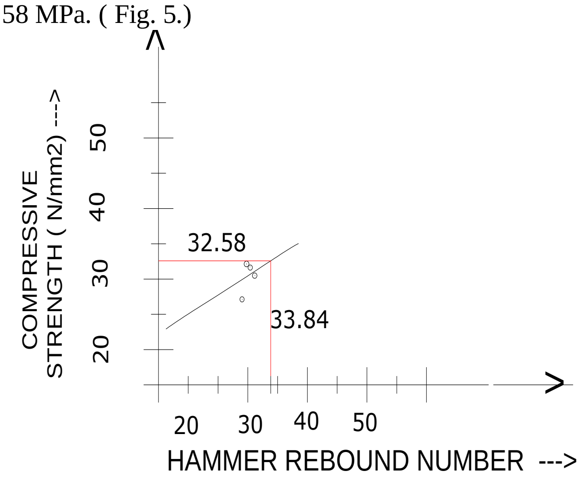

Fig. 5.

3.5.2 Compressive Strength from USPV

Observations on concrete at 1st floor level

The average value of USPV for cross probing of 1st floor concrete was obtained as 4.1 km/s which as per IS:13311 (part 1) can be considered as good quality concrete.

From the correlation developed between USPV and compressive strength, compressive strength was obtained as 30 MPa. (Fig. 6.)

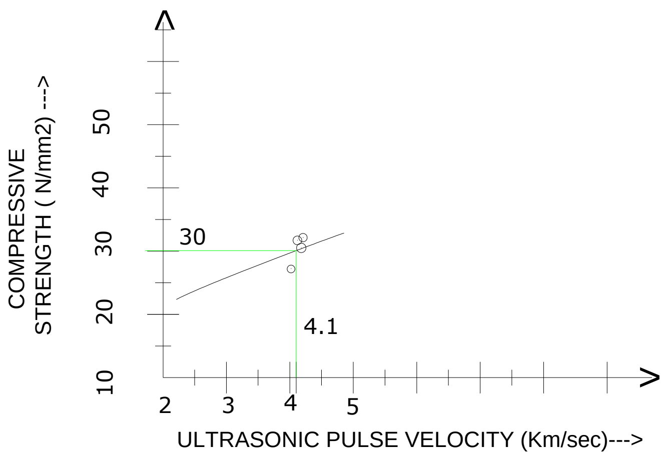

Fig. 6.

3.6 Comparison of Strength Results from Existing Models / Relationship

A classical example of this application is the SONREB method, developed largely due to the efforts of RILEM technical committees 7 NDT and 43 CND and under the chairmanship of facaoaru has been adopted in Romania. A general relationship between compressive strength of concrete, rebound hammer number, and ultrasonic pulse velocity. In accordance with the tentative recommendations for in-situ concrete strength estimation by combined non-destructive methods," RILEM committee TC 43 CND, 1983, forms the basis of SONREB technique. 'this relationship is in the form of a nomogram. By knowing the rebound number and pulse velocity, the compressive strength is estimated.

Based on the correlations developed between the Non-destructive parameters and compressive strength the most likely compressive strength of concrete at the 1st floor is mentioned here.

Estimated compressive strength of concrete investigated at 1st floor level (beams & slabs has been obtained as 32.58 MPa from rebound indices which becomes as 22.80MPa when age correction factor is applied (Age correction factor = 0.7 for 300 days) and 30 MPa from USPV.

For the building under consideration, the estimated value of the compressive strength as obtained from the nomogram (Fig. 7.) on the basis of values of rebound index (33.84) and USPV (4.1 Km/sec.) is 23 MPa. This value is well in agreement with the values obtained by statistical correlations developed from specimens tested in the laboratory.

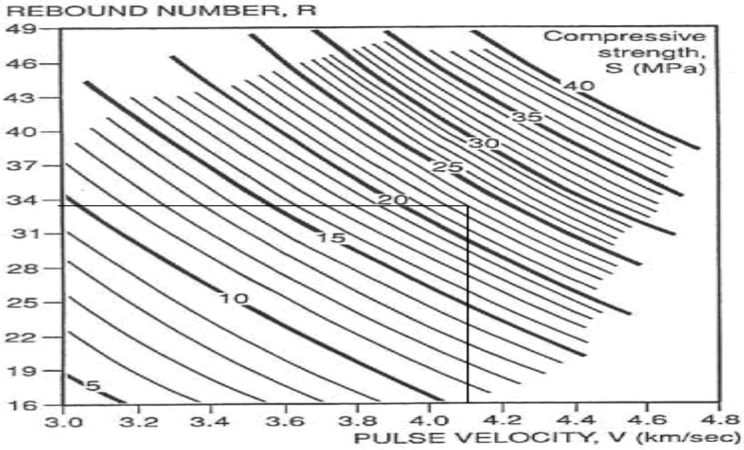

Fig. 7. ISO- Strength Curves for reference concrete in SONREB method.

4. CONCLUSION

Health assessment work may be performed on new structures if concrete fails to attain the desired strength at 28 days age. This case study deals with the health assessment work where the strength of the concrete existing in a new structure was ascertained by developing statistical correlation between NDT properties and compressive strength of concrete as per IS: 13311.

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