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A case study – Structural stability of 14 years old college building using NDT technique

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ABSTRACT

Reinforced concrete is extensively used as a construction material for its application, ease of construction and low cost. Deterioration of concrete is a natural phenomenon and has started exhibiting in a large number of structures an efficient approach is required in dealing with such problems. Identification of the causes of distress and consequent repair/ rehabilitation strategy at optimum cost is carried out by monitoring the structure. Structural health monitoring can be achieved by Non-destructive evaluation techniques. NDT is well known for assessing the in-situ strength of concrete without causing any damage to the structure.

Keywords*— NDT, Ultrasonic pulse velocity, Visual Inspection*

1. INTRODUCTION

Non-Destructive Testing (NDT) is a wide group of analysis techniques used in Science and Industries to evaluate the properties of a material component on the system without any damage. The term Non-Destructive Examination (NDE), Non-Destructive Inspection (NDI) and Nondestructive Evaluation (NDE) are also commonly used to describe this technology NDT does not permanently alter the article being inspected. It is a highly valuable technique that we can save money, efforts and time in product evaluation. NDT measurement technique has been used for more than two decades for concrete quality evaluation and assessing concrete compressive strength. During this period, the advantages of its use and the factors influencing the test results have been widely reported.

2. SYSTEM MODEL

Before attempting any repair procedure, it is necessary to have a planned approach to investigate the condition of concrete and reinforcement. While the diagnosis of damage or deuteriation in some cases is reasonably straight forward, it may not be so in many cases. Particularly difficult are cases in which the cause and effect phenomenon cannot be readily explained or when prognosis in terms of long term performance of the restored structure is to be made. This will require a thorough technical inspection and an understanding of the behavior of the structural component, being tested. Inspection calls for detailed mapping of affected areas, documentation of types and location of symptoms and their history and photographic evidence. It may also include environmental factors, which are likely to accelerate the damage process. A comprehensive inspection data helps in making an effective strategy for repair and rehabilitation.

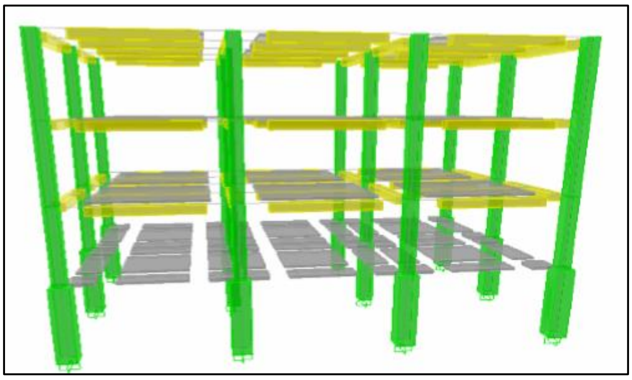

Fig. 1: 3D Modelling of the proposed floor of right section

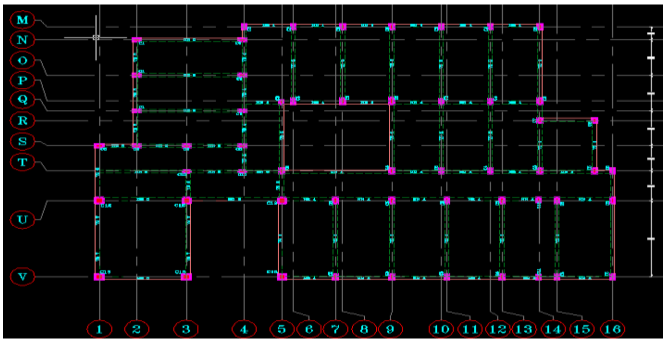

Fig. 2: First-floor columns and beams

3. PREVIOUS WORK

Concrete normally provides excellent protection to reinforcing steel. Notwithstanding this, a large number of cases have been reported in which corrosion of reinforcement has caused damage to concrete structures within a few years from the time of construction. One of the most difficult problems in repairing a reinforced concrete element is handling corrosion damage. Reinforcement corrosion caused by carbonation is arrested to a great extent through repairs executed in a sound manner. However, the treatment of chloride- induced corrosion is more difficult and more often the problem contributes even after extensive repairs have been carried out. It variably re-occurs in a short period of time. Repairing reinforcement corrosion involves a number of steps namely removal of carbonated concrete, cleaning of reinforcement, application of protection coat, making good the reduced steel area, applying a bond coat and cover replacement. Each step has to be executed with the utmost care. When chlorides are present in concrete it is extremely difficult to protect reinforcing steel from chloride attack, particularly in the case where chlorides have entered through materials used in construction residing in the hardened concrete. For such case, new technologies are available which require a specialist to execute the job.

A condition survey is an examination of concrete for the purpose of identifying and defining the area of distress while it is referred in connection with the survey of concrete and embedded reinforcement that is showing some degree of distress, its application is recommended for all buildings and structures. The system is designed to be used for recording the history of the project from its infection to completion and subsequent life.

Stages for carrying out a Condition survey, largely depend on field conditions, user habits, maintenance, etc., and have a direct relation with the pattern of distress, whether localized or spread over. Condition survey of a building/structure is generally undertaken in four different stages to identify the actual problem so as to ensure that a fruitful outcome is achieved with minimum efforts and at the least cost.

A program has to evolve to obtain as much information as possible about the distressed structure at a reasonable cost and in a reasonable time. Accordingly, the information required from the owner/client has to be listed out. Even though many construction details and other related information may not be available with the owners or clients at as much as information and details as much as possible be gathered during the preliminary site visit. Before undertaking a condition survey of a building or structure the following essential information is required and be obtained from the clients/owners:

a. Period of construction; b. Construction details including architectural, structural and as-built drawings; c. Exposure conditions of structure; d. Designed use vis-à-vis present use of structure; e. Previous changes in use, if any f. Record of structural changes made if any; g. Record of the first occurrence of detoriation, if any h. Details of repairs, if carried out in the past; I. Reports of previous investigations or condition surveys if any; j. The apparent cause of distress as could be ascertained from the owner/client; k. Photographs of distressed portions of structures.

4. PROPOSED METHODOLOGY

Generally, in-situ non-destructive evaluation of concrete is to have an overall idea of the quality of the concrete. In some cases, a sufficiently accurate estimate of the quantitative value of concrete strength is required for assessment of the load carrying capacity of a structural member. The need for such an estimate may arise during evaluation of change in usage of structure, modification or extension of the original structure or damage due to fire, earthquake, etc.

There are the various methods available in Non-destructive testing but the selection of the test depends on the type of structure and defects in structure so before adopting the test one should go through about the structure. Normally these Non-destructive testing doesn't require much time to set up the testing equipment all the testing equipment are readily available in the market but before using the instrument should be calibrated and then it should be used otherwise the results will not be accurate. The nondestructive testing of concrete has great technical and useful importance. These techniques have been grown during recent years especially in the case of construction assessment. All available methods for evaluating in-situ concrete are limited, their reliability is often questioned, and the combination of two or more techniques is emerging as an answer to all these problems. The combination of several techniques of nondestructive testing is often implemented empirically, combining two techniques most often used to enhance the reliability of the estimate compressive strength of concrete; the principle is based on correlations between observed measurements and the desired property. The compressive strength of concrete is usually the most sought-after property. This leads to the development of a method that combines index rebound hammer and the ultrasonic pulse velocity UPV.

4.1 Visual inspection

Visual Inspection The most significant of all non-destructive tests is visual testing. It can often provide valuable information to an engineer. A visual test may be related to structural serviceability, workmanship and material deterioration and it is predominantly important that the engineer is able to distinguish between the various distresses features which may be encountered. These include disintegration, cracks, colour change, pop-outs, staining, spalling, weathering, surface stains and lack of uniformity. Extensive data can be gathered from visual examination to provide a primary indication of the condition of the building and allow the making of a subsequent testing series. The visual inspection must not be confined only to the building being investigated. It should also include neighboring buildings, the surrounding environment. This is possibly the most difficult part of the whole structural investigation or any investigative works since what appears to one may not be the same to another. The benefits and significance of a visual study should not be underestimated. Often the omission of what appears to be insignificant evidence can lead to a wrong conclusion being made. The advantage of a trained eye is best described by Sherlock Holmes when he wrote: "I see no more than you but I have trained myself to notice what I see."

4.2 Schmidt's Rebound Hammer test

The aim of rebound hammer tests is usually to find a relationship between surface hardness and compressive strength to be able to estimate the strength of concrete with an acceptable error. To find a reliable method for strength estimation one should study all the influencing factors that can have any effect on the hardness measurement, and also that can have any effect on the variability of the strength of the concrete structure examined. The estimation should be based on an extensive study with the number of test results high enough to provide an acceptable reliability level.

4.2.1 Working of Rebound Hammer: A demonstration of Schmidt rebound hammer is shown in figure 3. The mass of the hammer is about 1.8 kg, which is suitably used for both field and laboratory condition. Once the plunger of rebound hammer is enforced alongside the surface of concrete, a spring measured mass rebounds and the level of such rebound depends upon the concrete surface hardness. The rebound number is defined as the space of rebound is read on a graduated scale which is attached to it. Basically, the rebound space or distance depends upon the kinetic energy value of the hammer, previous to impact with the shoulder of the plunger and energy is involved during impact.

The stress-strain relationship of concrete shows the energy influenced by it. Thus, the energy engaged in low strength low stiffness concrete is more than high strength concrete and will provide lesser rebound number. Figure 3.2 shows the Rebound Hammer instrument. IS 13311 part -2-1992 as well as BS: 6089-81 and BS: 1881: part-202 explains the standard procedure for test and correlation between concrete cube crushing strength and rebound number.

Fig. 3: Rebound hammer

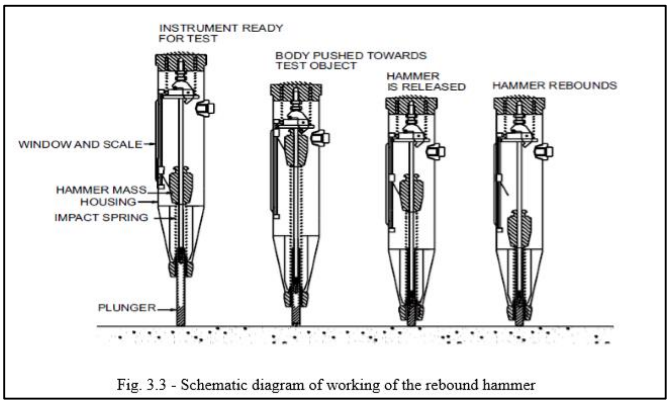

Fig. 4: Schematic diagram of working of Rebound hammer

Table 1: Quality of concrete from rebound values comparative hardness

Average Rebound	Quality of Concrete
>40	Very Good
30-40	Good
20-30	Fair
<20	Poor and/or delaminated
0	Very Poor and/or delaminated

4.3 Ultrasonic pulse velocity test

Ultrasonic pulse velocity is the most frequently used technique in which the ultrasonic pulses formed by the electro-acoustical transducer are conveyed through the concrete. In solids, along the direction of sound propagation the particle oscillates as longitudinal waves or as transverse waves which are perpendicular to the direction of sound waves. When the pulses are induced into the concrete from a transducer, at the boundaries of concrete it undergoes multiple reflections. A complex arrangement of stress waves such as longitudinal (Compressional), surface (Rayleigh) and shear (Transverse) waves are developed. Electrical signals are converted by transducers into mechanical vibrations and vice versa. Commonly used transducers are 50 kHz to 100 kHz but 20 kHz and 200 kHz are also available. The arrival of the fastest wave i.e., longitudinal waves are detected by the receiver and the materials elastic property affects the velocity of the pulses through which they pass. In certain situations, the strength and velocity of concrete are directly associated. The concrete density is the common factor; a change in a pulse velocity results in a change in the density. By increasing the water-cement ratio the density decreases, this decreases both the velocity of a pulse transmitted and compressive strength of concrete.

For investigating the structural concrete Pulse Velocity method is considered as a convenient technique. The principle of assessing the concrete quality is that higher velocities are obtained when the concrete quality in terms of homogeneity, density and uniformity is good. Lower velocities are obtained in case poorer concrete quality. If there is any discontinuity such as void, crack or flaws inside the concrete which comes in the path of transmission of the pulses, the pulse passes around the discontinuity thus making the path length longer resulting in the lower velocities.

The mix proportion of the concrete and the materials affect the values of the pulse velocity. Modulus of elasticity of aggregate and density also significantly affect the pulse velocity. Figure 3.5 shows the Portable Ultrasonic Non-destructive Indicating Tester.

4.4 Method of testing

4.41 Direct Transmission (Cross Probing) through Concrete: As shown in the figure, transducers are placed on the opposite face of the concrete element to be tested. It is most commonly used and is mostly preferred because this results in maximum sensitivity and gives a precise path length.

4.4.2 Semi-direct Transmission through Concrete: As shown in the figure, sometimes one of the faces of the concrete to be tested is not accessible, in such cases semi-direct method can be applied. In this method, the path length is not clearly defined and the sensitivity will be lesser than cross probing method.

4.4.3 Indirect Transmission (Surface Probing) through Concrete: Only when one face of concrete to be tested is accessible this method of pulse transmission method is used. This is the least satisfactory of all the other methods because the pulse velocity measurements identify the class of concrete only near the surface and do not offer any evidence about the deeper layers of concrete. Weaker concrete which may be lying below a strong surface can't be detected. The path length is not well defined in this method. Figure 3.7 shows different procedures of circulating ultrasonic pulses through concrete.

Table 2: Quality grading chart

Pulse Velocity (kM/sec)	Concrete Quality Grading (as per IS:13311 (Part-1)-1992)
Below 3.0	Doubtful
3.1 to 3.5	Medium
3.5 to 4.5	Good
Above 4.5	Excellent

Fig. 5: Performing ultrasonic pulse velocity test on beam

Fig. 6: Performing ultrasonic pulse velocity test onthe column

Fig. 7: Portable ultrasonic non-destructive indicating tester

5. SIMULATION/EXPERIMENTAL RESULTS

The Non-Destructive Test (NDT) for institution building comprising of G+3 floors have been conducted using Schmidt's rebound hammer test And Ultrasonic Pulse Velocity test (UPV).

Following are the result discussions for G+3 floors by Schmidt's rebound hammer test And Ultrasound Pulse Velocity test (UPV). Schmidt's Rebound Hammer Test Rebound hammer test has been carried out on beams, columns and slabs of ground, first, second and third floor and the results are tabulated which is observed to be safe.

Table 3: Test results

GROUND FLOOR					
BEAM	COMPRESSIVE STRENGTH	COLUMN	COMPRESSIVE STRENGTH	SLAB	COMPRESSIVE STRENGTH
HB-1	21.5	A-14	27	C-12	23
HB-2	23.5	A-12	29.5	C-9	21
HB-3	20.5	A-10	32.5	C-6	22.5
HB-4	21.5	A-9	26.5	C-3	21
HB-5	23	A-8	22	F-3	21.5
HB-6	21	A-6	22.5	I-2	22
HB-7	20.5	A-4	20.5	I-4	19
HB-8	18	B-4	24.5	I-7	21
HB-9	19.5	B-2	27	I-11	22
HB-10	20.5	C-2	25.5	I-15	19.5
HB-11	22.5	E-2	27.5	G-13	22.5
HB-12	21	G-2	27.5	G-10	21
HB-13	22	G-1	22.5		
HB-14	23.5	G-3	23.5		

5.1 Ultrasonic pulse velocity test

Ultrasonic pulse velocity test has been carried out on beams and columns of ground, first, second and third floor and the results are tabulated which is observed to be good and safe.

Table 4: Ultrasonic pulse velocity test

SL. NO.	MEMBER : BEAM	PULSE VELOCITY (km/sec)	CONCRETE QUALITY	ESTIMATED COMPRESSIVE STRENGTH
15	HB-15	4.05	Good	22-25
16	HB-16	3.9	Good	20-22
17	HB-17	4.22	Good	22-25
18	HB-18	4.1	Good	22-25
19	HB-19	4.25	Good	22-25
20	HB-20	4.4	Good	22-25
21	HB-21	4.12	Good	22-25
22	HB-22	4.2	Good	22-25
23	HB-23	4.01	Good	22-25
24	HB-24	4.05	Good	22-25
25	HB-25	3.92	Good	20-22
26	HB-26	3.8	Good	20-22

6. CONCLUSION

The following are the conclusions based on the study on Non-destructive testing.

Non-destructive testing methods are used to achieve information regarding the properties of a structure without damaging it. After conducting a case study on an existing building, the overall quality of construction is found to be GOOD. From Rebound hammer test results the estimated strength of in-situ concrete nearer to the surface, beams fall in the range of 20 N/sq.mm to 25 N/sq.mm, columns fall in the range of 20 N/sq.mm to 28 N/sq.mm and RC slab falls in 20 N/mm2 to 24 N/mm2. Hence the RC components are safe. From UPV test results the estimated compressive strength of concrete was found to be in the range of 18 N/mm2 to 24 N/mm2. Hence the RC components are safe. From the cover meter test, it is observed that cover concrete provided to the rebars is adequate in most of the tested RC members. It was found out that the building is structurally safe.

7. FUTURE SCOPES

- A comparative study can be carried out using Etabs with in situ tests conducted.
- A feasibility study can be carried out with extra floors.

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