Case Study of RCC Structure with the help of Non Destructive Testing

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Abstract - *Testing on concrete is necessary as to evaluate its quality to make sure it is of sufficient strength and durability so as to stand for coming years. NDT helps us to monitor the health of concrete and is much needed for examination of the concrete structure. Generally due to ageing, weathering effects, overloading, chemical attacks, temperature variations, the structure deteriorates and fails to give trouble free service throughout its service life with or without little maintenance hence decreasing its life.*

This paper is a case study of various NDT done on a building whose age was 20 years and was located far away from any industrial or chemical plants. Various NDT methods like ultrasonic pulse velocity test, carbonation test, rebound hammer test and half-cell potential test were used to access the quality of structure. These tests were done to find the voids and cracks in the structural elements. The depth of carbonation was checked whether it is less than the cover concrete or not to make sure the reinforcements does not corrode. Finally, based on the results, the structural elements requiring repairs were identified.

***Key Words*: Non Destructive Test, Rebound Hammer Test, Ultrasonic Pulse Velocity, Carbonation Test, Half Cell Potential Test**

1. INTRODUCTION

NDT is a way to evaluate structural integrity with minimum cost and easy techniques. It is possible to inspect and/or measure the materials or structures without destroying their surface texture, product integrity and future usefulness. The field of NDT is a broad, interdisciplinary field that plays a critical role in inspecting that structural component and systems perform their function in a reliable fashion. NDT are routinely applied in industries where a failure of a component can lead to serious economic loss. The use of NDT to interpret concrete quality has been growing in the recent 2-3 decades in India.

The standard life of a structure used to be 60-70 years but now has been significantly reduced due improper construction practices, poor quality of materials, severe exposure conditions, etc.

Knowing the grade of concrete and its age, NDT helps us establish the following:

- Homogeneity of concrete
- Cracks, voids and other imperfections
- Changes in concrete with passage of time
- Suitable repair strategies if results raise doubts about concrete quality
- Damage due to fire, chemical attack etc.

2. METHODOLOGY

2.1 Ultrasonic Pulse Velocity Test

Principle:- Each material has a typical ultrasonic velocity which can be attained by testing those materials in the lab or field. Ultrasonic pulses travel faster in denser material and slower in materials with cracks or voids in it.

This instrument works on the principle of passing high frequency sound waves through the body of the concrete & measuring the time taken. Distance of path length divided by the time taken provides velocity of the waves through the concrete member being tested.

Depending on the velocity, the quality of concrete as regards homogeneity can be judged.

The concrete surface is thoroughly cleaned & dried. The instrument is calibrated before taking readings. Coupling medium such as grease is applied to the probes, and reading is taken for the pulse velocity at the location. Appropriate correction factor wherever desired are applied for the presence of steel.

Methodology:-

1. Assess single sided, double sided, etc on the structural elements
2. Clean the concrete surface thoroughly (with plaster or without plaster)
3. Apply grease on the concrete surface where test has to be conducted
4. Press probes on the surface of the structural element to remove air gaps
5. Note down the distance between two probes
6. Read the time taken for ultrasonic pulse to reach from one probe to another

7. Calculate velocity from distance and time (V=L/T)
8. Repeat the test on multiple areas of the element if necessary
9. Test at different members of the structure

Factors Affecting:-

1. Readings taken with or without plaster
2. New/old structure
3. Single sided or double sided access
4. Grade of concrete
5. New + old material (jacketed columns)

Understanding Results:-

1. The estimated strength may vary from actual strength up to about +/- 15% or so
2. In order to confirm the findings of the tests, core tests may be conducted on selected samples of elements, if necessary
3. The IS code 13311 (Part 1) 1992 gives velocity
4. However, the code does not give any interpretation of UPV in terms of strength. Hence, the IS code grading should be taken only as guidelines

2.2 Carbonation Test:-

Principle:- Carbonation occurs due to combined action of atmospheric CO2 and moisture causing reduction in the level of alkalinity of concrete. Concrete, being basically a porous material undergoes carbonation process with ageing. As the protective cover of the concrete carbonates completely, the corrosion reaches steel reinforcement, rapidly accelerating the process of corrosion in steel. The change of color of concrete to pink indicates the concrete is in good health whereas if no color change takes place, it is suggested that the concrete is carbonation affected.

Methodology:-

1. Identify test locations
2. Drill holes with an electric drill machine to reach the steel reinforcement rod
3. Remove dust by an air brush
4. Inject 1% phenolphthalein solution made by dissolving 1gm of phenolphthalein in 90 cc of ethanol and made up to 100 cc by adding distilled water in the hole
5. Insert litmus and observe the colour change profile to determine the depth of carbonation

Factors Affecting:-

1. Pore system of hardened concrete
2. Relative humidity (for dissolution of Ca(OH)2)
3. The concentration of CO2

Understanding Results:-

1. Carbonation progress into the cement at a rate 1mm per year (The rate may vary depending on several factors like chemical attack, method of placing concrete, homogeneity of concrete etc.)
2. Carbonation is a property which leads to corrosion of the embedded reinforcement
3. Carbonation test gives us the depth upto which carbonation has occurred
4. Based on the results we can identify whether the cover concrete is healthy or not
5. If the cover concrete is fully carbonated i.e. the carbonation has reached reinforcement, it is advisable to replace the cover concrete

2.3 Half Cell Potential Test:-

Principle:- The instrument in half cell potential test is used to measure the electrical potential between the reinforcement and the surface of concrete to predict the chances of corrosion activity. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte.

The name half-cell is derived from the fact that the one half of the cell is considered to be the reinforcement steel and the surrounding concrete. The electrical potential of the reinforcement is compared with some standard set of electrodes. One end of the wire is connected to the steel reinforcement and other end is connected to the standard electrode and readings are noted as seen in voltmeter.

Methodology:-

1. Identify test locations
2. Drill holes with an electric drill machine to reach the steel reinforcement rod
3. Establish electric contact to the reinforcement
4. Measure voltage in millivolts on the surface of concrete at multiple locations of the member
5. Test at different members of the structure

Factors Affecting:-

1. Moisture extent
2. Surface condition
3. Corrosion extent of reinforcement
4. Quality of cover concrete

Understanding Results:-

1. The half-cell potential test gives probability of corrosion and not the actual corrosion. For better understanding, ASTM has classified this into 3 categories as 10%, 50% and 90% probability

2. It is to be noted however, that a probability of corrosion of 50% or 90% does not indicate that the diameter of embedded steel has reduced by 50% or 90% respectively. It only refers to the probability of corrosion activity taking place at that location

2.4 Rebound Hammer Test

Principle:- When the plunger of the rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Methodology:-

1. Smooth clean and dry the surface
2. If the surface is not smooth, it should be rubbed off with a grinder wheel or stone
3. Point of impact should be selected and it should be atleast 20mm from the edge
4. The rebound hammer should be at right angle to the surface of concrete member
5. The plunger is then pressed against the surface and the rebound number is observed
6. Similarly several readings around the point of impact are taken and average is noted

Factors affecting:-

1. Type of cement and aggregate
2. Surface condition
3. Moisture content of concrete
4. Carbonation of concrete surface
5. Curing type and age of concrete
6. Angle of Inclination

Understanding Results:-

The rebound hammer test is a rapid method to calculate the surface hardness in terms of compressive strength of concrete by my means of the graph on the rebound hammer indicating the relationship between compressive strength and rebound number. However, this method is not suitable for honeycombed or no fines concrete. In old structures, generally where carbonation depth is upto 25mm, the rebound hammer test results are significantly affected and the strength maybe overestimated by 50%.

3. RESULTS:-

Type of Structure: RCC G + 3

Age of Structure: 20 years

Table -1: Results for Half Cell Potential Test

Total No of readings taken	30	
No. of columns tested	26	
No. of beams tested	2	
No. of slabs tested	2	
Range	**Probability of corrosion**	**No. of readings**
Over -200mv	10%	0
-200mv to -350mv	50%	30
Below -350mv	90%	0

Figure-1: Half Cell Potential Test

Table -2: Results for Carbonation Test

Total No of readings Taken	30
No. of columns tested	22
No. of beams tested	2
No. of slabs tested	6
Carbonation Depth	**No. of readings**
0-20	19
21-40	4
41-60	7

Figure-2: Carbonation Test

Table -3: Results for Ultrasonic Pulse Velocity Test

Total No of readings Taken		30	
No. of columns tested		22	
No. of beams tested		2	
No. of slabs tested		6	
Concrete Grade	**Pulse Velocity in Km/sec (Direct method)**	**Concrete Quality**	**No. of readings**
11	Above 4.5	Excellent	0
2	3.5-4.5	Good	0
3	3.0-3.5	Medium	0
4	Below 3	Doubtful	30

Figure-3: Ultrasonic Pulse Velocity Test

4. CONCLUSION

All the tests that have been performed in this case study, readings are taken without removing the plaster and thus a correction factor of 1.1 has been applied to all the readings.

Ultrasonic Pulse Velocity

The member under testing were found to be doubtful

Half Cell

All the members tested show that the there is a 50% chance of corrosion in all of them

Carbonation

It was found that 19 of the tested elements had a carbonation depth 0-20mm this was because these members were repaired previously. 4 tested members had carbonation depth 21-40mm which means that these elements were affected by carbonation with passage of time. 7 of the tested elements have carbonation depths reaching the steel reinforcement. These elements are highly unsafe and require quick repairs so as to prevent reinforcement from corrosion.

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NATIONAL CODES:

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