RCC Structure with the help of Non Destructive Testing and Retrofitting Techniques

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Abstract- *Nondestructive evaluation of existing structures is a vital part and an active area of research in civil engineering industry. Whenever modifications in a structure or its use are proposed the process begins with the evaluation of existing condition. 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 industrial building whose age was 20 years and was located nearer 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.

Keywords- Non Destructive Test, Rebound Hammer Test, Ultrasonic Pulse Velocity, Carbonation Test, Half Cell Potential Test, Concrete Cover Meter Test

I. 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.A structure made of reinforced concrete can during its service period be exposed to various aggressive effects which can cause damage. These influences can originate in the environment or be related to the use of the structure. They can be classified in three basic groups:

- Physical
- Biological and
- Chemical effects.

The most drastic form of the physical impact leading to concrete degradation is frost action. Namely, water which is retained in pores and cracks freezes in low temperatures and exposes concrete to often very high pressures (up to 220 MPa). Detrimental frost action in foundation engineering is most frequently prevented by the proper selection of foundation depth, construction of the gravel layer below the foundations, construction of the proper drainage and construction of adequate moist and water insulation of the parts of the buildings which are in the ground.

The other forms of physical degradation of concrete and concrete structures are related to the onset of cracks due to shrinking, temperature variations and due to different thermal expansion of the aggregate and cement rock etc. In addition, one should mention exceeding the concrete bearing capacity and cyclical loading and unloading of the structure which causes onset of cracks and paves the way for other aggressive effects.

The mentioned harmful mechanisms usually attack the concrete immediately above the ground level, and very seldom higher than 50cm above it, depending on the height of the capillary rise of water. The biological effects comprise the impact of vegetation, which causes the existing cracks to widen as the root systems of trees expand.

The chemical effects causing concrete degradation are usually impacts which are a consequence of chemical reactions of aggressive compounds from the structure

environment and the constituents of the cement rock themselves. Their detrimental effects cause concrete corrosion. The following types of degradation should be mentioned here:

- Aggregate expansion,
- Salt weathering,
- Carbonation, and
- Leaching

When a concrete structure is prone to chemical actions its durability gets affected. The chemicals may cause cracking of concrete, volume change and deterioration of structure. The life of structure reduces and it can lead to failure of structures. Different types of chemical attacks and their effects on concrete structures are explained below

- Sulphate attack
- Chloride attack
- Alkali aggregate reaction
- Carbonation
- Acid attack

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

II. 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:-

- Assess single sided, double sided, etc on the structural elements
- Clean the concrete surface thoroughly (with plaster or without plaster)
- Apply grease on the concrete surface where test has to be conducted
- Press probes on the surface of the structural element to remove air gaps
- Note down the distance between two probes
- Read the time taken for ultrasonic pulse to reach from one probe to another
- Calculate velocity from distance and time (V=L/T)
- Repeat the test on multiple areas of the element if necessary
- 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:-

- The estimated strength may vary from actual strength up to about +/- 15% or so
- In order to confirm the findings of the tests, core tests may be conducted on selected samples of elements, if necessary
- The IS code 13311 (Part 1) 1992 gives velocity
- 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

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

2.2 Carbonation Test:-

Principle:-Carbonation occurs due to combined action ofatmospheric CO_2 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

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, IS 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

2.3 Half Cell Potential Test:-

Principle:-The instrument in half cell potential test is usedto 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

2.4 Rebound Hammer Test

Principle:-When the plunger of the rebound hammer ispressed 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

III. EXPERIMENTAL INVESTIGATION

Type of Structure: RCC

Age of Structure: 30 years

Table -1: Results for Ultrasonic Pulse Velocity Test

Total No of readings Taken	50	
No. of columns tested	10	
Pulse Velocity in Km/sec (Direct method)	Concrete Quality	No. of readings
Above 4.5	Excellent	0
3.5-4.5	Good	0
3.0-3.5	Medium	0
Below 3	Doubtful	30

Table -2: Results for Half Cell Potential Test

Total No of readings taken	30	
No. of columns tested	10	
Range	Probability of corrosion	No. of readings
Over -200mv	10%	0
-200mv to -350mv	50%	05
Below -350mv	90%	25

Table -3: Results for Carbonation Test

Total No of readings Taken	10
No. of columns tested	10
Carbonation Depth	No. of readings
0-20	00
21-40	03
41-60	07

Table -4: Results for Rebound Hammer Test

Total No of readings Taken	60
No. of columns tested	10
Average	Estimated Compressive Strength (N/mm²)
28.0	22

Discussion on NDT report.

The estimated compressive strength as found by Rebound hammer test appears to be over 22 N/mm². The IS code 13311 Part II,1992, mentions that the deviation between the compressive strength found by rebound hammer test and the actual compressive strength could be ±25%.

The depth of carbonation at most of the places is greater than the thickness of cover.

Corrosion of the rebars was noticed, as cracks were visible on the surface of columns. Also the half cell potential test indicates presence of corrosion. The reason for it could be attributed to :

- Gutter has not been provided at the end of the roofing sheets and now some sheets are indamaged conditions.
- Surface porosity of the concrete (though the cover thickness is adequate).

The homogeneity of concrete was found to be insufficient at most of the places. It was grossly insufficient across the cracked sections.

The trusses appeared to be badly corroded in the process shall reduction in the thickness of its members was also visible.

Crack is apparent on the RCC columns .

Suggestions:

- The span of the RCC beam (supporting the extended portion) should be reduced, so that the opening is restricted to 1.25m or so.
- The trusses and the roofing sheets of the process hall should be replaced by new trusses, portions and sheets.
- Epoxy / Polyurathane coating shall be applied to new MS trusses and purlins. This coating shall act as barrier between the corrosive elements and the steel.
- To facilitate removal of trusses; some portion of columns may also be required to be demolished.

Micro concrete viz. Rendroc RG/Emaco-S-346T or equivalent may be deployed.

- The homogeneity of concrete can be improved by injecting low viscous Monopol into all column (irrespective of results) 12mm. dia. holes, 120mm deep could be drilled at about 350-400 c/c. along the height of the columns and Monopol could be dispensed at suitable pressure say 2-5 kg/cm² (depending on site conditions).

The corrosion of the rebars could be treated by adopting following methodology.

a. Chipping out affected area of concrete.
b. Applying 2 coats of Feovert.
c. Applying 2 coats of IP NET RB
d. Applying 1 coat of NITOBOND EP
e. Applying 15mm thick polymer modified plaster with polymer modification of about 10% by wt. of cement.

The vertical portion constructed at the free end of chajjas (about 10cm. in height) should be removed to facilitate ease in draining rain water. The top of the chajjas should be provided with appropriate slope without increasing load on it. Exterior grade emulsions viz. weather shield equivalent shall be applied to the entire exterior surface. The next date for conducting structural condition assessment should be after 3 years or on having observed notable flaws, whichever occurs earlier.

Disclaimer:

The conclusion is drawn on the basis of the visual test and the non-destructive testing which stands valid for the points then taken.

NATIONAL CODES:

[1] IS13311: Part I: 1992: NDT of concrete methods of test: Ultrasonic Pulse Velocity Method
[2] IS13311: Part II: 1992: NDT of concrete methods of test: Rebound Hammer
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