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# Structural Audit Of 30 Years Old Building

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***Abstract***— *In India, safety of old buildings is one of the major issues. As the strength of old buildings get reduced in due course of time it creates structural defects such as material deterioration, unexpected over loading, structural deficiency or physical damages and if further use of such deteriorated structure is continued it may leads to severe loss of life and property. As Structural Audit of old building is mandatory as per municipal authorities and Government of Maharashtra has made "Structural Audit" of all old building compulsory. The main objective of present work is to adopt Structural Auditing of 30 years old building which is situated at Nagpur (Maharashtra) with Schmidt's Hammer Test, Ultra Pulse Velocity Test, Cover Meter Test, Half-cell test, pH test including Visual Inspection And Assessing the stability and safety of the structure to withstand for its remaining life by diagnosis and root cause of the problems with remedial measures. Based upon above test is observed that The quality of concrete is medium and good at maximum locations and Doubtful at few location and corrosion has started in reinforcement and well within the acceptable limit. Hence, it is recommended to repair damaged areas as per the methodology, specifications and locations.*
***Keywords***— *Structural Audit, Structural Engineering, NDT method, Structural Evaluation Program*

## I. Introduction

Structures are assemblies of load carrying elements capable of safely transferring the superimposed loads to the foundations. As the structure gets older and older as time goes, in this due course of time old structure have reduced strength due to physical damages, material deterioration, unexpected over loading or structural deficiency. In the event that further use of such damaged structure is sustained it may leads to severe loss of life and property. We all agree that every life is precious and every building is, in a way, a national asset, therefore, there is need of periodical maintenance and checkup to prevent future damages. Structural Audit is a preliminary technical survey of a building to evaluate the strength so as to improve its appropriateness, safety, efficiency. The Structural Audit highlights & investigates all the critical areas of the building and additionally suggests if building needs immediate attention. The Structural Audit is carried out by appointing a Structural Engineer who examines the structure by visual inspection and if needed the Non Destructive Tests are carried out according to requirement of structure. The standard procedures for nondestructive testing (NDT) of concrete structures is established to qualify and quantify the material properties of in-situ concrete without causing damage. The range of properties that can be assessed using non-destructive techniques is large and includes fundamental parameters of the concrete such as density and elastic modulus in addition to strength. Other properties which can be assessed include surface absorption, concrete surface hardness, and moisture condition as well as reinforcement location, cover and corrosion risk. Government of Maharashtra has made "Structural Audit" of all old building compulsory as per the amendment to MMC ACT 1888 incorporating a new section 353 B enforcing from 13/2/2009. As per by-laws of Co-operative Housing society and clause no 77. Structural Audit is mandatory for all housing society buildings as per corporation directive and as follows:-

| **Age of the Building** | **Structural Audit (Compulsory)** |
|---|---|
| 15 to 30 years | Once in 5 years |
| Above 30 years | Once in 3 years |

The main objective of present work is to adopt Structural Auditing of 30 years old building which is situated at Nagpur (Maharashtra) with Schmidt's Rebound Hammer Test, Ultra Pulse Velocity Test, Cover Meter Test, Half-cell test, pH test including Visual Inspection And Assessing the stability and safety of the structure to withstand for its remaining life by Diagnosis and root cause of the problems with remedial measures.

## II. Methodology

*A.* Visual Observation

Visual inspection is one of the most important step in non-destructive tests. Visual inspection include for instance cracks, pop-outs, color change, spalling, disintegration, surface blemishes, weathering, staining and lack of uniformity. From Visual Inspection, Engineer is able to gather information which is helpful to know health of the structure and allow formulation of a subsequent testing program.

*B.* Rebound Hammer Test

In 1948, Ernst Schmidt a Swiss Engineer developed a device for testing concrete, based upon rebound principle when a hammer strikes concrete. There is a metallic rod in Rebound hammer to which spring is attached. When The body of the instrument is pushed toward the concrete surface, the spring controlled mass rebounds and the extent of such rebound is an indication of hardness of concrete and therefore the rebound is taken to be related to the compressive strength of the concrete. For taking a measurement, keep the instrument perpendicular to the test surface. The test thus can be conducted horizontally on vertical surfaces and vertically upwards or downwards on horizontal surfaces. IS 13311 part II 1992 gives a standard test method for Rebound Hammer Test.

**TABLE I.** REBOUND CRITERIA FOR QUALITY OF CONCRETE GRADING

| **Average Rebound** | **Quality of Concrete** |
|---|---|
| >40 | Very Good hard layer |
| 30-40 | Good |
| 20-30 | Fair |
| <20 | Poor concrete |
| 0 | Delaminated |

Fig. 1. Rebound Hammer Test

*C.* Ultrasonic Pulse Velocity Test

The strength of concrete in ultrasonic pulse velocity test is assessed by measuring the velocity of an ultrasonic pulse passing through it. The ultrasonic testing method is based on the use of equipment composed of transducers which produce and receive the ultrasonic wave. The time taken by pulse to travel from the transmitting to receiving transducers is measured by a timing circuit. A better quality of concrete is indicated by higher velocity while if the surface is not uniform and consist of cracks it is indicated by lower velocity.
The pulse velocity in concrete will be represented in Km/sec or M/s. IS 13311 (Part I) 1992 gives a standard test method for Ultrasonic Pulse Velocity Test.

**TABLE II** VELOCITY CRITERIA FOR QUALITY OF CONCRETE GRADING

| **Pulse Velocity** | **Quality of Concrete** |
|---|---|
| Above 4.5 Km/Sec | Excellent |
| 3.5 - 4.5 Km/Sec | Good |
| 3.0 - 3.5 Km/Sec | Satisfactory |
| Below 3.0 Km/Sec | Doubtful |


**Fig Ii** Ultrasonic Pulse Velocity Test

*D.* Half Cell Test

Half Cell Potential Test is an important method for assessing the severity of corrosion activity in concrete structures. The method of half-cell potential measurements normally involves measuring the potential of an embedded reinforcing bar relative to a reference half-cell normally a copper/ copper sulfate placed on the concrete surface. Half Cell Potential Test offers a rapid and non-destructive way for corrosion assessment. The Half cell test is helpful in checking the severity of corrosion which destroy the passive protective film of steel bar. The risk of corrosion gets higher when potential is greater. ASTM C876 - 91 gives a standard test method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete.

**TABLE III** RISK OF CORROSION AGAINST POTENTIAL DIFFERENCE READING

| **Half-cell potential (mv) relative to Cu-Cu sulphate Ref. Electrode** | **% chance of corrosion activity** |
|---|---|
| Less than -200 | 10% |
| Between -200 to -350 | 50% (uncertain) |
| Above -350 | 90% |

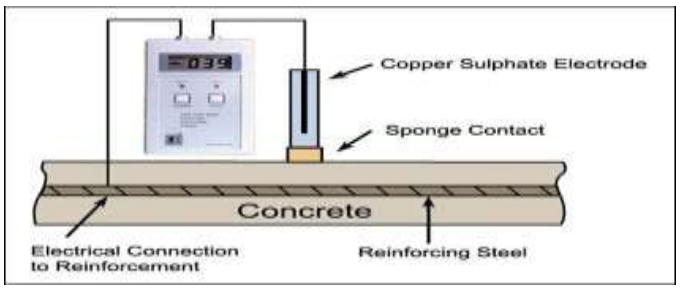


Fig. 2. Half Cell Test

(Image source-http://civil-online2010.blogspot.com/2010/09/half-cell-electrical-potential-method.html)

Half Cell Test is used for assessment of the durability of reinforced concrete members where corrosion of reinforcement is observed.

*E.* Cover Meter Test

A cover meter is a device designed specifically for determining the "cover" to reinforcement bars in concrete, location of embedded rebars and estimation of size of embedded rebars. Cover is defined as being the distance from a given surface of a concrete element to the nearest part of a reinforcement bar or other embedded item. Knowing the diameter of the bar and their location is essential to understand the bar spacing and their placement, in existing structures where there are no structural drawings available. The cover thickness is important to estimate the extent of corrosion. Cover meter is important to ensure longer life for the structure.

Fig. 3. Cover Meter

*F*. pH Test

when the carbon dioxide in atmosphere in the presence of moisture reacts with hydrated cement, carbonation of concrete occurs. Carbonation process is also called as depassivation. Carbonation of concrete is associated with the corrosion of steel reinforcement and with shrinkage. The method to establish the extent of carbonation in concrete by applying a solution of 15mg Phenolphthalein & 10ml Ethanol diluted in 50ml of distilled water to a fresh fracture surface of concrete. The change of Pink color of concrete indicate carbonation free concrete while the uncolored indicated carbonation. The pH of concrete lowers when the carbon dioxide in the air comes in contact with concrete, the process is called carbonation. A standard pH meter is used to measure the pH of concrete. If pH value between 7 to 9 Concrete stats to break down and pH of the concrete below 8.6, suggesting carbonation.

Fig. 4. Depth Of Carbonation Test


Fig. 5. pH Test

## III. Results

*G.* Rebound Hammer Test

**TABLE IV** REBOUND HAMMER TEST RESULTS.

| Sr. No. | Description | No. of Points | Rebound Hammer Test | | |
|---|---|---|---|---|---|
| | | | Min. | Max. | Average |
| **Parking** | | | | | |
| 1. | Column | 135 | 24.66 | 42 | 33.33 |

| Sr. No. | Description | No. of | Rebound Hammer Test | | |
|---|---|---|---|---|---|
| 2. | Beam | 108 | 30 | 41.55 | 35.77 |
| **First Floor** | | | | | |
| 3. | Column | 9 | 35.77 | 35.77 | 35.77 |
| **Second Floor** | | | | | |
| 4. | Column | 9 | 30 | 30 | 30 |
| 5. | Slab | 9 | 31..11 | 31..11 | 31.11 |
| **Third Floor** | | | | | |
| 6. | Column | 18 | 17.77 | 22.66 | 20.215 |
| **Fourth Floor** | | | | | |
| 7. | Column | 27 | 23.33 | 30 | 26.66 |
| 8. | Beam | 9 | 21.99 | 21.99 | 21.99 |
| 9. | Slab | 9 | 23.77 | 23.77 | 23.77 |
| **Fifth Floor** | | | | | |
| 10. | Column | 63 | 14 | 35.55 | 24.77 |
| 11. | Beam | 9 | 25.77 | 25.77 | 25.77 |
| **Sixth Floor** | | | | | |
| 12. | Column | 27 | 23.14 | 26.66 | 24.68 |
| 13. | Beam | 9 | 28.88 | 28.88 | 28.88 |
| **Midlanding Of 1st And 2nd Floor** | | | | | |
| 14. | Column | 18 | 16 | 24.66 | 20.33 |
| **Midlanding Of 2nd And 3rd Floor** | | | | | |
| 15. | Column | 9 | 24.44 | 24.44 | 24.44 |
| **Midlanding Of 3rd And 4th Floor** | | | | | |
| 16. | Column | 9 | 19.55 | 19.55 | 19.55 |

*H.* Ultrasonic Pulse Velocity Test

**TABLE IV** ULTRASONIC PULSE VELOSITY TEST RESULTS.

| Sr. No. | Description | No. of Points | Ultrasonic Pulse velocity Test (Km/Sec) | | |
|---|---|---|---|---|---|
| | | | Min. | Max. | Average |
| **Parking** | | | | | |
| 1. | Column | 62 | 1.63 | 4.22 | 2.93 |
| 2. | Beam | 46 | 2.41 | 4.35 | 3.38 |
| **Third Floor** | | | | | |
| 3. | Column | 5 | 2.98 | 2.98 | 2.98 |
| **Fourth Floor** | | | | | |
| 4. | Column | 14 | 1.91 | 3.83 | 2.87 |
| **Fifth Floor** | | | | | |
| 5. | Column | 27 | 2.37 | 4.21 | 3.29 |
| **Sixth Floor** | | | | | |
| 6. | Column | 5 | 3.27 | 3.27 | 3.27 |
| **Seventh Floor** | | | | | |

| Sr. No. | Description | No. of | Ultrasonic Pulse velocity Test (Km/Sec) | | |
|---|---|---|---|---|---|
| 7. | Slab | 30 | 1.74 | 3.06 | 2.4 |

*I.* Half cell Potentiometer Test

**TABLE V., HALF CELL POTENTIOMETER TEST RESULTS.**

| Sr. No. | Description | Half Cell Potentiometer Test | |
|---|---|---|---|
| | | Half Cell Readings (mV) | Average (mV) |
| 1 | Column No..-C1 | -291, -355, -328, -389, -249, -247 | -309 |
| 2 | Column No..-C2 | -264,-314,-234,-272,-286,-315 | -280 |
| 3 | Column No..-C8 | -232,-221,-215,-192,-237,-156 | -208 |
| 4 | Column No..-C9 | -288,-265, -222,-185,-243,-286 | -248 |
| 5 | Column No..-C11 | -194,-249,-286,-285,-186,-233 | -238 |
| 6 | Column No..-C14 | -278,-171,-264,-248,-198,-168 | -221 |
| 7 | Beam No..-B7 | -243,-249,-157,-192,-232,-271 | -224 |
| 8 | Beam No..-B12 | -279,-291,-211,-217,-247,-259 | -250 |

*J.* pH Test

**TABLE VI** PH TEST RESULTS.

| Sr. No. | Description | Potential (mV) | | |
|---|---|---|---|---|
| | | 40mm | 80mm. | pH |
| 1. | Column No..-C2 | -202 | -198 | 8.14 to 8.12 |
| 2. | Column No..-C6 | -161 | -202 | 7.63 to 8.13 |
| 3. | Column No..-C9 | -150 | -212 | 7.44 to 8.24 |
| 4. | Column No..-C12 | -169 | -220 | 7.60 to 8.38 |
| 5. | Column No..-C03 | -165 | -135 | 7.58 to 7.30 |
| 6. | Column No..-C05 | -224 | -209 | 8.47 to 8.29 |

## IV. Recommended Strengthening Scheme

On the basis of ultrasonic pulse velocity test, rebound hammer test including visual inspection it is recommended to do grouting for all the columns with Micro Fine Cement & Epoxy Resin (Non Shrink free flow low viscocity solvent free epoxy grouting required or high molecular thermo set polymer grouting) as per methodology and specification given as follows:

A. Micro Fine Cement Grout to Columns

Providing and injecting Micro Fine Cement Grout in the ratio by grouting pump at a pressure @ 3-7 $Kg/Cm^2$ or as instructed by Engineer-in-charge etc. complete by considering 200mm x 200mm c/c grid along honeycombing areas and 150mm x 150mm c/c grid along cracks.

B. Epoxy Resin Grout to Column

Providing and injecting low viscosity solvent free epoxy in the ratio by grouting pump at a pressure @ 3-6 $Kg/Cm^2$ or as instructed by Engineer-in-charge etc. complete by considering 200mm x 200mm c/c grid along honeycombing areas and 150mm x 150mm c/c grid along cracks.

C. Damaged Concrete Cracks

Open the cracks into "V" groove. Then providing and applying Epoxy + Silica Sand 1:2 mortar at the groove and finish at all heights, levels and surface etc. complete.

D. Micro Concrete

Providing and applying 50/100/150mm micro concrete as per specification or as instructed by Engineer-in-charge etc. complete.

## V. Conclusion

As per detailed systematic inspection while conducting Structural Auditing of 30 years old building with Schmidt's Hammer Test, Ultra Pulse Velocity Test, Cover Meter Test, Half cell test, pH test including Visual Inspection , It is observed that the Ultrasonic Pulse velocity results with direct and indirect method indicate the maximum readings are between 1.63 Km/Sec to 4.35 Km/Sec (Refer to IS 13311 (Part I) 1992 ''Non- Destructive Testing of concrete methods of test, Ultrasonic Pulse Velocity"). The quality of concrete is medium and good at maximum locations and Doubtful at few location. As per 13311 (Part 1) 1992 the Ultrasonic Pulse Velocity readings with indirect method gives less reading than direct methods generally by 1 km/sec and readings given are factored.

As per the rebound hammer test (refer IS 13311 part II 1992) all the readings are confirming M15 to M20 grade concrete. As per half cell potentiometer test on reinforcement it is observed that the maximum reading are between -156 MV to -291 MV which indicates corrosion has started in reinforcement and well within the acceptable limit.

As per pH and carbonation test on concrete, it is observed that the pH of cover concrete is reduced but the passive layer over the reinforcement is intact. The ph of core concrete is within acceptable limit.

Based upon all the Non-Destructive Test results it is recommended to repair damaged areas as per the methodology, Specifications and locations.

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