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Structural Audit of 30 Years Old Building with Structural Strengthening

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Abstract - *In India, Safety of old buildings for human habitation have emerged as prime concerns. As Prevention is better than cure, Structural audit is an important technique to check their safety and they have no risk. Structural Audit of old building is mandatory as per municipal authorities. It is process of analyses of building and this process includes the evaluation and interpretation of test data which helps the structural auditor to understand the condition of any existing structure and highlight and investigate all the critical areas which demand immediate attention and suggest an appropriate repairs and retrofitting measures needed for the buildings to perform well in its service life. 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 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 by recommending strengthening and then retesting after strengthening is done to check the required strength which is expected. On the basis of retesting on existing structure before strengthening and after strengthening with Nondestructive test, it is observed that the desired strength which is expected is still not achieved by the structure so it is recommended to do RCC jacketing to few columns which are found weak based upon the readings and visual observations.*

***Key Words*: Structural Audit, Non Destructive Testing, Grouting, Strengthening**

1. INTRODUCTION

Nowadays, there is demand of NDT method for old building structures with repairs and retrofitting to enhance its performance and restore the desired strength of the structures which may leads to increase in its functional life. As the time passes, structures become older, we find certain degradation or deterioration in structure with resultant distress showed in the form of cracking, splitting, delaminating, corrosion, carbonation, voids, honeycombing etc. Such weakened structures can be restored and retrofitted by utilizing different kinds of admixtures and modern repair techniques. NDT method would not only locate a defect, but it would also be used to measure strength, durability and overall quality of concrete. NDT method is very useful in monitoring long term changes in concrete properties from which an estimate of strength, durability and elastic behaviour of material are obtained. The condition and behaviour of the structural system depends on its quality of maintenance as a building grows old, ageing, use or misuse and exposure to the environment can greatly affect the health of the structure. 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 Hammer Test, Ultra Pulse Velocity 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 by recommending strengthening and then retesting after adopting strengthening is done to check the required strength which is expected.

2. METHODOLOGY

2.1 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, voids, honeycombing ,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.

2.2 Rebound Hammer Test

Since 1940, Rebound hammer test is the most common method used for checking the strength of concrete. In 1948, Ernst Schmidt a Swiss Engineer developed a device for testing concrete, primarily 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 pressed strongly and steadily against the concrete surface, the combination of gravity and spring force, propel the hammer and the rebound distance is expressed as rebound number, which is measured on a scale by slide indicator. The extent of such rebound is an indication of the hardness of concrete. The rebound distance is the percentage of the initial extension of spring 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.

The results taken by Rebound Hammer is significantly affected by factors such as Cement type, Aggregate type, moisture content and surface conditions, curing, age of concrete, Surface carbonation.

The Rebound Hammer Test is used to determine the uniformity of the concrete, quality of concrete in relation to standard requirements, the compressive strength of concrete. IS 13311 part II 1992 gives a standard test method for Rebound Hammer Test.

Table -1: 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

2.3 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 are placed on the smooth concrete surface 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 surface are applied with coupling medium such as petroleum jelly, grease to have good coupling. 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.

$$V=L/T$$

V= Pulse Velocity

L=Path Length

T= Transit Time

The results taken by Ultrasonic Pulse Velocity test may be affected by factors such as Surface conditions and moisture content, Aggregate Type, Cement type, Reinforcement Bar, Type of mix, water cement ratio, Stress, Path length.

The Ultrasonic Pulse Velocity test is used to determine Homogeneity of the concrete, Quality of concrete in relation to standard specified requirement, the presence of voids, cracks and other imperfections, changes in the concrete with time due to age of concrete, fire, frost or chemical attack.

Table -2: 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 -2: Ultrasonic Pulse Velocity Test

3. 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 viscosity solvent free epoxy grouting required or high molecular thermo set polymer grouting) as per methodology and specification given as follows:

3.1 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/Cm2 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.

3.2 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/Cm2 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.

3.3 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.

3.4 Micro Concrete

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

Fig -3: Strengthening to Column

4. RESULTS

4.1 Rebound Hammer Test

Table -3: Rebound Hammer Test Results

Sr. No.	Description	No. of Points	Rebound Hammer Test		
			Max.	Min.	Average
Basement					
1.	Column	315	33.55	24.66	29.19
2.	Beam	108	35.33	30	32.66
First Floor					
3.	Column	270	34.22	21.11	27.66
Second Floor					
4.	Column	99	33.11	28.88	30.99
5.	Slab	9	31..11	31..11	31.11
Third Floor					
6.	Column	90	36	25.77	30.88
Fourth Floor					
7.	Column	108	36.66	28.22	32.44
8.	Beam	9	26.22	26.22	26.22
9.	Slab	9	23.77	23.77	23.77
Fifth Floor					
10.	Column	126	35.11	23.77	29.44
11.	Beam	9	25.77	25.77	25.77
Sixth Floor					
12.	Column	81	34.22	25.55	29.88
13.	Beam	9	28.88	28.88	28.88
Seventh Floor					
14.	Slab	36	24.22	28	26.11

Table -4: Rebound Hammer Test Results Before and after strengthening

Sr. No.	Description	No. of Points	Rebound Hammer Test		
			Max.	Min.	Average
BASEMENT					
1.	Before Repair	216	33.55	24.66	29.19
	After Repair	189	34.88	28	31.44
FIRST FLOOR					
2	Before Repair	180	34.22	21.11	27.66
	After Repair	144	40.22	26.22	33.22
SECOND FLOOR					
3.	Before Repair	54	33.11	28.88	30.99
	After Repair	18	35.11	30.22	32.88

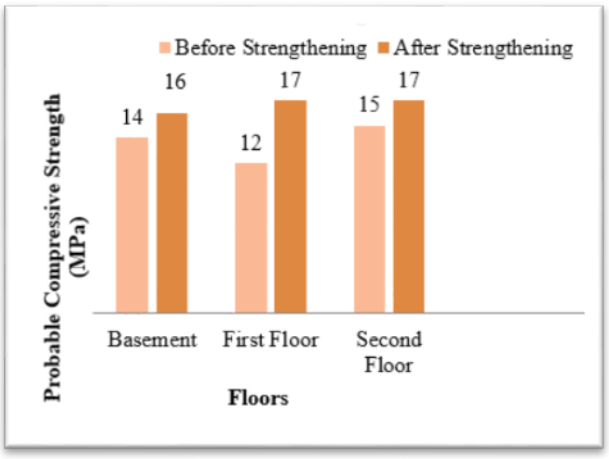

Chart -1: Comparison of Rebound Hammer Test Results

Rebound Hammer Test reading after strengthening at maximum location it is indicate that the Compressive Strength are found between M13 to M22 (Refer to IS 13311(Part II):1992).

4.2 Ultrasonic Pulse Velocity Test

Table -5: Ultrasonic Pulse Velocity Test Results

Sr. No.	Description	No. of Points	Ultrasonic Pulse velocity Test (Km/Sec)		
			Max.	Min.	Average
Basement					
1.	Column	112	3.66	2.51	3.08
2.	Beam	44	3.35	2.41	2.88
First Floor					
3.	Column	80	3.24	2.55	2.89
Second Floor					
4	Column	28	3.25	2.84	3.04
Third Floor					
5.	Column	30	3.29	2.91	3.1
Fourth Floor					
6.	Column	35	3.83	2.77	3.3
Fifth Floor					
7.	Column	46	4.11	2.37	3.24
Sixth Floor					
8.	Column	24	3.27	2.89	3.08
9.	Beam	4	2.89	2.89	2.89
Seventh Floor					
10.	Slab	28	3.06	2.14	2.6

Table -6: Ultrasonic Pulse Velocity Test Results before and after strengthening

Sr. No.	Description	No. of Points	Ultrasonic Pulse velocity Test (Km/Sec		
			Max.	Min.	Average
BASEMENT					
1.	Before Repair	112	3.66	2.51	3.08
	After Repair	82	4.12	3.03	3.57
FIRST FLOOR					
2	Before Repair	80	3.24	2.55	2.89
	After Repair	58	4.05	2.93	3.49
SECOND FLOOR					
3.	Before Repair	16	3.25	2.84	3.04
	After Repair	8	4.10	3.62	3.86

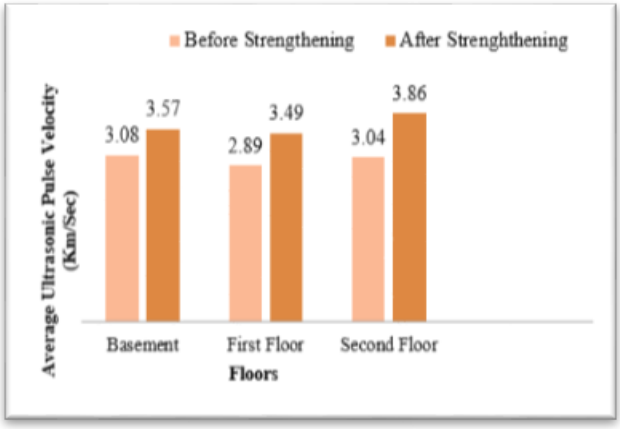

Chart -2: Comparison of Ultrasonic Pulse Velocity Test Results

5. CONCLUSIONS

As per detailed systematic inspection while conducting Structural Auditing of 30 years old building with Visual Inspection, Schmidt's Hammer Test, Ultra Pulse Velocity Test, before strengthening and after strengthening, It is observed that It is observed that the Ultrasonic Pulse Velocity Test results with direct, indirect and semi direct method found that maximum readings are between 2.51 Km/Sec to 3.66 Km/Sec (Before Strengthening) & 2.93 Km/Sec to 4.10 Km/Sec (After Strengthening) (Refer to IS 13311(Part I):1992).

It is also observed that based upon Rebound Hammer Test the Compressive Strength are founds between M11 MPa to M21 MPa (Before Strengthening) & M13 MPa to M22 MPa (After Strengthening) (Refer to IS 13311(Part II):1992).
The quality of concrete is medium and good at maximum locations and Doubtful at few locations.

According to the Visual Observation and Non Destructive Test on existing structure before strengthening and after strengthening, it is observed that the desired strength which is expected is still not achieved by the structure so it is recommended to do RCC jacketing to few columns which are found weak. As per given specifications repairs and retrofitting should be done, to maintain the building in Good condition

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