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Structural Audit of Building by Destructive and Non-destructive Testing

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Abstract: ***Since the earliest ages of human development, civil engineering provides various tools in fulfilling the needs of humans in the form of eminent structures. These structures may be residential, industrial or commercial. Every building has its own life span and within this life span it should stand firmly on its position. Now-a-days, some buildings are collapsing before completing their life span. This may cause danger to the people staying in there. Therefore it is necessary to investigate the present condition of the structure to evaluate performance of the building with the help of structural audit. Structural audit helps to save life and property. This paper brings out the basic information about the structural audit, process of auditing and methods in practice in this process. This has been brought in detail along with the case study where author of the paper was directly involved in auditing process.***

Keywords: Structural audit, process of auditing, methods in practice, non-destructive testing methods

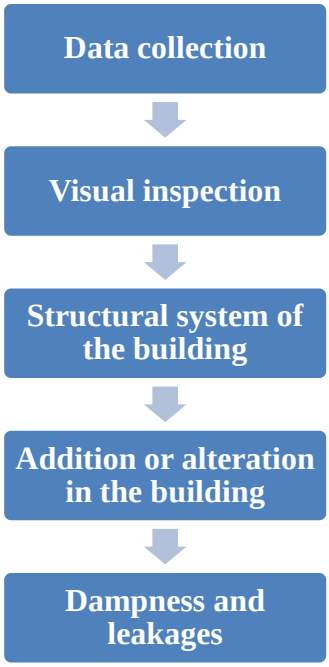
1. Introduction:

"The structural audit is the inspection or examination of the building, to evaluate the resistance in order to improve its suitability, safety and efficiency." Audit and periodic structural diagnosis for the health of existing buildings is, therefore, extremely important to find the current serviceability and structural capacity of the structures ensures that the building and its facilities are safe and have no risks. Analyze and suggest the appropriate repairs and the necessary adaptation measures so that the buildings have a better performance in their useful life. The structural audit is performed by an experienced and licensed structural consultant. The extent of the damage to the building depends on the quality of the construction work. Building damage can be the result of several factors, such as fire damage, chemical attack, corrosion of structural steel, frost action, etc. during the useful life of the structure. Therefore, this research plays a very important role in the search for the current service capacity of the structure and the scope for future development.

2. Purpose of structural audit

Structural audit helps to check the existing condition of the structure by finding critical areas that should be repaired instantly for improving life cycle of building. It also suggests preventive and corrective measures and predicts the expected future life of the building.

3. **Stages in carrying structural audit**



4. Non-destructive and Destructive testing

In addition to visual inspection, the actual strength and quality of a concrete structure must be verified with non-destructive testing. A series of non-destructive tests (NDT) is available for concrete members to determine the concrete's current strength and quality. Some of these tests are very useful to assess damage to RCC structures subjected to corrosion, chemical attack and fire. These tests have been put under four categories depending on the purpose of test as under:

Concrete strength	**Chemical attack**	**Corrosion potential assessment**	**Homogeneity and integrity Assessment**
Rebound hammer test	Carbonation test	Half-cell method	Ultrasonic pulse velocity
Ultrasonic pulse velocity test	Chloride test	Permeability test	
Core sampling and testing	Sulphate test		

5. Core Testing

The core test is a destructive method to evaluate the strength of concrete. In this method, the cylindrical core samples are taken from existing structures. The cores are visually inspected and tested in the laboratory to verify their compressive strength. It is preferable to test the cores in wet conditions.

Figure: Core testing of concrete (Source: theconstructor.org)

6. Rebound Hammer test

The rebound hammer test is used to determine the compressive strength of concrete and to determine the uniformity of concrete

Figure: Rebound Hammer (Source: indiamart.com)

7. Method of testing

1. The test should be performed on a smooth surface, free of honeycomb. In the case of a rough surface, the stain is smoothed by rubbing with silicon carbide stone.

2. Take the rebound hammer for the test, remove the plunger from the locking position by pressing the plunger on the surface and slowly push against the surface to be tested holding the plunger perpendicular to the test surface.

3. By pressing the plunger against the concrete surface, the spring loaded mass called hammer of a fixed amount of energy is loaded and released against the plunger and the bounces. The rebound due to the grip will be measured on the scale graduated by the pilot. The reading on the scale is called the bounce number. A higher bounce number indicates a stronger concrete.

4. The test can be carried out on a horizontal, vertical or inclined surface. It is desirable to take 10-12 readings on the area to be tested

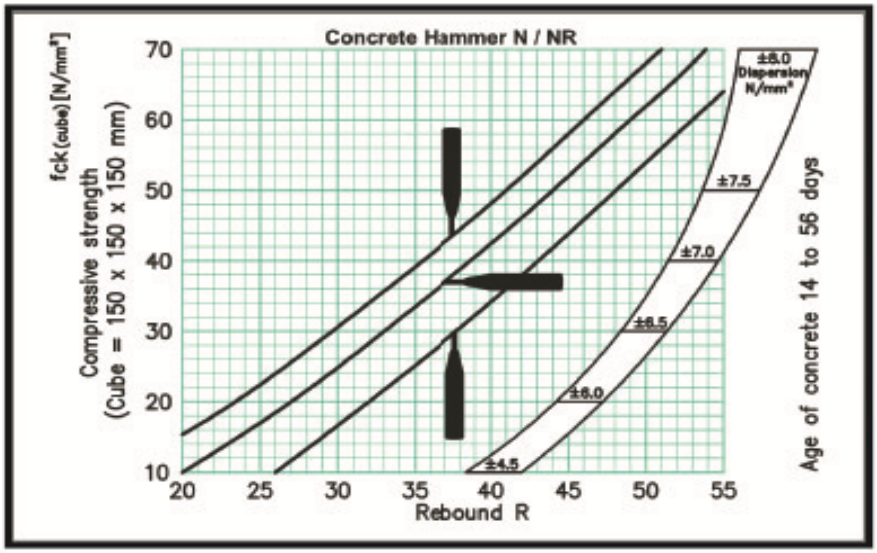
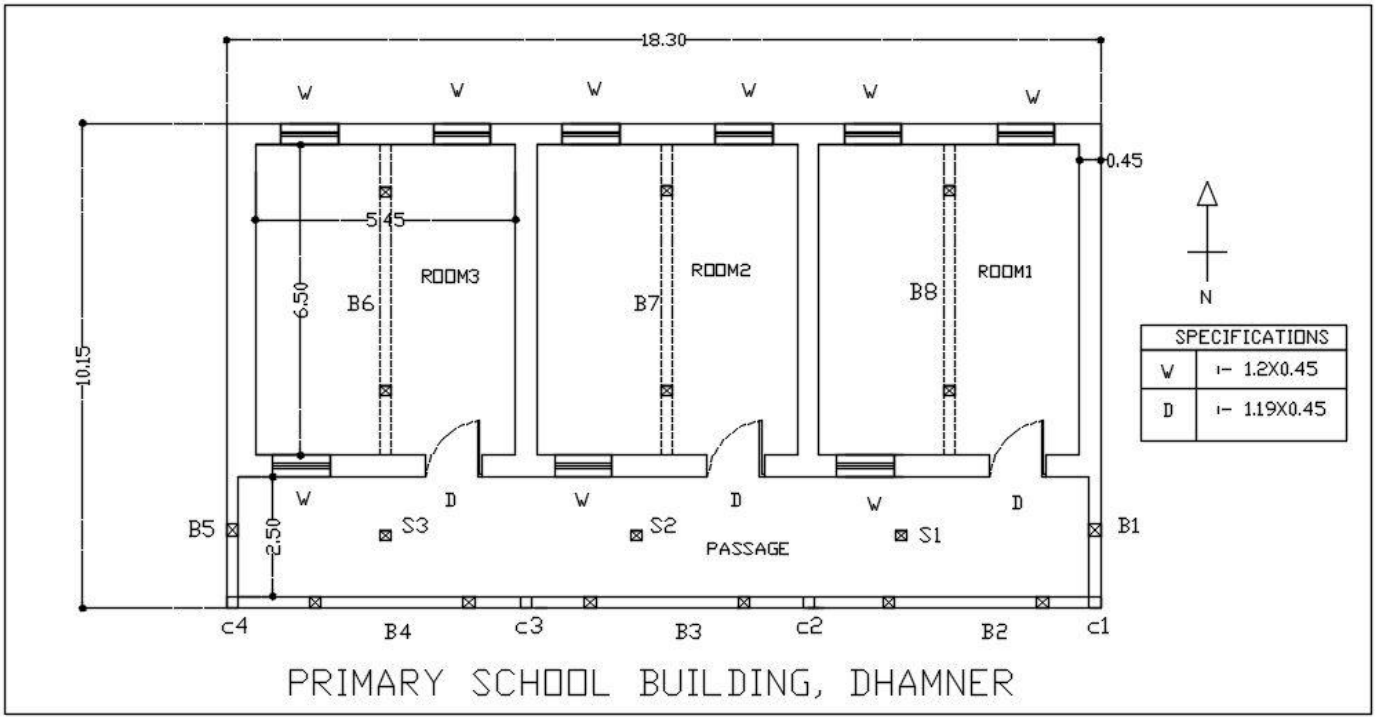


Figure: Rebound Hammer Graph (Source: engineersdaily.com)

Structural Audit Report

Name of the work: Condition assessment of School building at Dhamner, Tal- Koregaon. Dist- Satara (MH)

Preamble: As per the reference, a single storied school building consisting of a partially load-bearing type structure and partially load bearing plus RCC frame type structure exists at Dhamner, Tal. Koregaon, Dist. Satara. Due to the old construction of the building, there are major cracks in the walls of the building as well as there are leakages during the rainy season, hence serviceability of building is affected. So the department of Applied Mechanics was consulted for checking the structural condition of the building and give recommendation for the proposed extension under Unnat Bharat Abhiyan. Government College of Engineering has adopted this village for overall technical development of village.



Observations: Accordingly, the author visited the site on 17-10-2018 to get a preliminary idea of the building. During the visit following observations were made.

1. According to school/ Grampanchayat authorities, the existing single storey building is around 132 years old and is founded on Black cotton soil.
2. Foundation is rested on 7'-8'on Black cotton soil, constructed in year 1886. Murum/Rock is available after 60'-70' depth below ground level.
3. Signs of heavy leakages are observed for almost in all rooms on soffit of slab and passage too.
4. Walls on North side near to slab are also showing heavy signs of leakages.
5. Plaster is collapsed at one location above window in room no 1 (Karyalaya) and exposed rubble masonry inside it. Mortar in rubble masonry is also collapsed at two locations, seems lost its strength totally.
6. Also Rubble wall on North side is observed to be declined/swayed near to floor slab especially in Room no 1, probably due to losing its strength.
7. Slab is having projection of 6" in all 4 sides of building outside of wall.
8. Passage has 4 columns of 230mmx230mm and floor beams which are structurally in deteriorated condition by showing cracks and honeycombing of concrete.
9. Bottom cover (plaster) is already collapsed at 2-3 beams, whereas for all 4 beams cover concrete is totally detached and also showing horizontal cracks at the level of tension reinforcement..
10. In Room no 2, plaster (soffit) of slab is observed detached from slab concrete, probably due to corroded reinforcement.
11. In passage beams at 2-3 beams tension reinforcement and stirrups are found in exposed condition and is in heavily corroded condition.
12. Uneven settlement of flooring is occurred approximately before 2-3 years, due to swelling of Black cotton soil for these 3 rooms.
13. Columns are also found cracks to almost all columns on various faces.
14. Reinforcement in slab is found in heavily corroded and in exposed condition.

From the visual observations it was felt that a detailed structural assessment is necessary for estimating the capacity of the structure. So it was decided to carryout non-destructive tests to assess the probable strength of concrete and actual reinforcement in the structural members.

Due to the unusual structural configuration of the building a second visit was felt necessary. So, author visited the site on 24-10-2018 to carry out the non-destructive testing. Rebound hammer was used to assess the strength of various structural members. Slab reinforcement had got exposed at two places when plaster was being removed for hammer testing and was helpful in observing the slab detailing. The beams and columns were exposed at few locations to confirm the reinforcement details.

Fig. Visual observation and Non-destructive testing

Test Results: Typical sections were selected on slab panels, few columns and beams and were tested by rebound hammer to assess the strength. From these tests it has been found that the quality of concrete and quality of construction is moderate. Honey-combing was observed at different locations

The test results are as given below.

Sr.No	Member	Avg. Compressive Strength "Mpa"	Minimum Compressive Strength "Mpa"
01	Slab (Passage)	22.77	14
02	Column (Passage)	19.22	15.44
03	Beams	16.33	10.22

Looking at the quality of materials, quality of construction and age of the building it can be concluded that the concrete in slabs, columns and beams is likely to be of grade M10 and below in column and beams whereas for slab it is likely to be of M15 grade.

From the top extension of the columns the reinforcement in the columns was evident. The beams and slabs were exposed at some locations to observe the reinforcement details. The steel used is mild steel in all members. The details of reinforcements observed were as below.

Beams: Main Steel 16.27 mm dia in a highly corroded condition.

Distribution steel – 7.02 mm dia in a highly corroded condition.

Vharanda Columns: Size- 230×230 mm having 6-12 mm dia bars distributed equally on all faces. Lateral ties could not be observed.

Structural Analysis: After ascertaining the strength of the materials it was now necessary to assess the existing capacity of the structure. This was done through structural analysis and design. The analysis was carried out manually considering the proposed additional load of extension. The loading conditions were taken as per IS: 875. The existing capacity of structural members was evaluated knowing the strength (through the NDT) and reinforcement.

Recommendations:

Based on the information furnished, tests carried out and subsequent analysis the following recommendations are made.

(a) Slab of the three rooms are in a deteriorated condition with heavily corroded reinforcement.

(b) Strength of the concrete in the slab is likely to be of M15 grade and beams of these rooms are likely to be of grade M10 or below.

(c) Actual strength of the steel is not likely to be near the designated value due to heavy corrosion.

(d) As exposed steel is corroded due to heavy leakage, it is likely that the unexposed steel in the slab and beam is also corroded.

(e) About most of the locations, concrete seems to be lost its strength totally.

(f) Also rubble masonry seems to be in structurally unstable condition.

(g) Most of locations, strength of concrete is below norms with large variation in strength.

Remark:

Looking into importance factor of school building, age of structure and existing condition of the structure, it is recommended that school building under consideration is unserviceable and unsuitable for its intended use. It is not safe to use this building.

Conclusion

The structural audit of the old buildings is very important and highly responsible job. It is important to carry out the periodical structural audit of the buildings by professional experts and take remedial measures through recommendations provided in audit report. The effective implementation of auditing improves the life span of structure, prevents deterioration of building leading to sustainability.

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