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Health Assessment of Structures

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ABSTRACT: Every need of mankind has a structure associated with it. For e.g. - educational buildings such as schools and colleges, commercial buildings such as offices and manufacturing plants, transportation such as roads and bridges and many others. The recent rise in collapse of structures in major metropolitan cities such as Mumbai has put the spotlight on irregularities in construction, improper maintenance and illegal alterations carried out in structures. Carrying out regular inspection of the structures that we inhabit will help to mitigate these threats and prevent any major accidents causing physical or psychological agony and preventing any disruption in our day to day activities. This paper aims to highlight the importance of carrying out structural auditing, various methods used for rectifying commonly found defects and includes the audit report of an institutional building situated in Navi Mumbai.

KEYWORDS: Structural Audit, Structures, Metropolitan, Maintenance

I. INTRODUCTION

As structures grow old, the materials used during their construction may start to deteriorate due to various reasons such as general wear and tear, Ageing, Weathering, etc. Health assessment of structures refers to the regular inspection of structures to identify various defects that have cropped up and to suggest various repair methods to rectify them. This ensures that the structure remains serviceable throughout its design period and may also increase the life of the structure beyond it. This is also referred as structural audit. It is carried out in 4 phases, namely – Preliminary inspection, Planning, Visual inspection and Field testing.

India is developing at a very rapid pace. As important it is to develop new structures, it is also important to maintain the old and ageing structures to avoid any mishaps or loss of life if a structure collapses. In some cases, these old structures represent the history of an area or are of cultural significance which necessitates their upkeep. These structures, if well maintained, will spawn a sprawling tourism industry, thus generating more revenue for the government. So one can conclude that structural auditing and repairs, as an industry, will help by not only ensuring the safety of old structures and their inhabitants but by also increasing their value, thus helping them to generate more revenue and bring prosperity to their owners.

According to Bye-law no. 77 of the Maharashtra co-operative housing society bye laws, “The society shall cause to undertake the structural audit of the building as follows :

- 1) For buildings aged between 15 to 30 years.. . once in 5 years
- 2) For buildings aged more than 30 years .. . once in 3 years.”

Paper is organized as follows. Section II presents the Literature survey for the published works. Section III gives a brief about the methodology adopted for carrying out the structural audit. Section IV includes the audit report for an institutional building. Finally, Section V presents conclusion.

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II. LITERATURE REVIEW

Multiple research papers were studied to establish a sound knowledge of the various aspects involved in the field of structural auditing. Some of the highlights are given below: -

- 1. Malek Jedidi, KaoutherMachta, 2014, “Destructive and non-destructive testing of concrete structures”, Jordan Journal of Civil engineering, Vol.8, No. 4, pp - 432 – 441.**
This paper outlines the various methods of testing concrete and the effects of various characteristics such as W/C ratio and age of concrete on the results obtained. There are namely 2 methods of testing hardened concrete - destructive and non-destructive. Destructive methods include core testing, pull out and pull off test whereas non-destructive testing includes UPV test and rebound hammer test. Generally 2 or more types of NDT are used in conjunction with each other to get a better idea of the condition of the structure and NDT is often economical when compared to its counterpart. In the experiments conducted by the authors, it was noticed that rebound hammer test gives comparable results to destructive tests when the concrete is 28 days old. Hence it can be used to evaluate the strength of old concrete rather than young concrete. They also noted that with an increase in water-cement ratio, the pulse velocity decreases which points to increased porosity of concrete and reduction in the dynamic modulus of elasticity of concrete.
- 2. Mahadik A.B., Jaiswal M.H.,2014, “Structural audit of building”, International journal of Civil Engineering Research, Vol.-5, pp – 411-416.**
This paper gives a brief about structural auditing and outline its importance in a developing nation like ours where development in the construction and infrastructure industry is booming. Just like our human bodies need regular health check-ups after a certain point of time to identify potential health hazards that may be lurking inside, the structures that provide shelter to us and aide our lives also need to be checked periodically to determine whether they can perform their designated function safely. This can be done by first, studying the drawings of the structure in question followed by visual inspection for any signs of distress. After identifying the critical spots, testing (Destructive or non-destructive) should be carried out to determine the extent of damage and the possible repair and retrofitting measures that need to be undertaken to elongate the service life of the structure. The various repairs and retrofitting measures should be suggested taking into consideration the socio-economic factors.
- 3. Bakri Nurul, MydinAzree, 2013, “General building defects – Causes, symptoms, and remedial work”, European Journal Of Technology and Design, Vol.-3, No.-1,pp - 4 -17**
This paper analyses in detail the various commonly found structural and non-structural defects in structures and enlists the remedial measures to be taken to rectify these. It enlists the various causes of each defect and what to look out for in order to get an accurate diagnosis of the defect. The defects covered in this paper include dampness (may be due to defective DPC or excessive rain), Cracks (may be due to differential settlement or unequal thermal expansion), Peeling paint (due to poor surface preparation), Timber decay (due to biological action such as termite infestation or non-biological actions such as excessive moisture content or chemical deterioration), fungal attack (due to excessive moisture present in an area out of the reach of direct sunlight), defective plaster (due to weathering or use of substandard materials) and unstable foundation (due to improper design, overloading or use of substandard materials).
- 4. Kumar Kishor, Shriram P.,2017, “Pivotal factors causing defects in buildings – A case study in Chennai, Tamil Nadu”, International Journal of Civil Engineering and Technology, Vol. – 8, pp – 325 – 331.**
The authors of this paper have attempted to find out the major factors responsible for causing defects in a structure by enlisting some of the common causes and ranking them on the basis of “Relative Importance Index”(RII). 22 factors which would represent the research area in the best way were selected and a questionnaire was prepared. The responses to these questionnaires were collected from 50 individuals

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including contractors, managers and inhabitants of different structures to include a wide variety of views on the causes of defects. The factors in the questionnaire were ranked from 1 to 5 on the basis of most likeliness to occur. Then RII value of each factor is found based on the responses and the factors are ranked. This research was applied to 2 structures to find out the cause of deterioration. Repair methods were suggested for the same.

5. Tikate Pavan, Tande S. N., 2014, “Repair and Rehabilitation of structures”, International Journal of Engineering Sciences and Research Technology, pp – 511 -515

This paper enlists some of the common causes of failures of structures such as Site selection and site development errors, Design errors, construction errors, Material deficiencies, and operational errors along with principles of rehabilitation, namely, Elimination, Separation and Ventilation. Some of the major types of repair works highlighted in the paper include Brick wall repair, Plaster wall repairs and RCC repairs. The major issues in each type are highlighted and various repair methodologies that can be adopted are explained.

6. Kunal Kishor, KillemshtettyNamesh, 2014, “Study on control of cracks in a structure through visual identification and inspection”, IOSR Journal of Mechanical and Civil engineering, Vol.-11,pp -64-72

This paper throws light on the changing ideology of design of modern structures and also how these structures are more cracks prone as compared to the older structures. Cracks are a common occurrence in structures. They can be formed by any externally applied force or internally induced stress. They are broadly classified into two types: structural and non-structural. Cracks can also be commonly classified based on the width as follows: Thin, Medium and Wide. It is cited by the author that there are many causes of occurrence of cracks in buildings which are as follows: Moisture change, Thermal variation, Elastic deformation, Creep, Chemical reaction, Foundation movement and settlement of soil and Vegetation. There is also case study of an Institute namely O.P. Jindal Institute of Technology, Raigarh, Chhattisgarh which was open in the year 2008 and already had started showing deep cracks in the various parts of the institute building which affected the durability of the structure. The various reasons for crack development were found and suitable treatment measures were suggested based on the characterisation of cracks. The methods applied for repair of cracks are: a) sealing the external face of the crack by filling it with a suitable joint sealer; b) filling the cracks with cementitious grouts of pouring consistency; c) repairing by low viscous epoxy resin (viscosity below 200 centipoise) and other synthetic resins by injection. The author has also given various measures for controlling cracks due to shrinkage, thermal variation, creep & chemical attack and recommended the use of IS 4326-1976 for the design of structures to withstand the earthquakes.

III. METHODOLOGY

There is no set standard to be followed for carrying out structural audit. The process followed varies from auditor to auditor. The CPWD handbook on repair and rehabilitation of RCC buildings gives a general outline for the entire process of auditing a structure, which has been adopted in the next phase for auditing an institutional building. The CPWD handbook mentions that there are 4 stages of structural auditing, namely: -

- 1) Preliminary inspection – This involves collecting and studying information about the structure to be surveyed. This helps the auditor to establish a sound knowledge about the use of structure, the exposure conditions, any deteriorations that are visible, repair works carried out in the past and the structural details. These details will help during visual inspection to identify the root cause of the defect. A preliminary site visit should be done in order to determine the quantum of work to be done and any arrangements to be made to carry out the survey smoothly.
- 2) Planning – During this phase, work sheets are prepared to take note of various defects, its location and extent of damage. Structural members are grouped as per exposure conditions and interpretation rules must be fixed to classify the damage based on observations during preliminary site visit.

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Vol. 9, Issue 2, February 2020

- 3) Visual inspection – The entire structure is observed for any signs of distress. These are noted on the worksheets. Simple tools such as flashlight, camera with flash, ladder, etc are required during this phase to aid the visual inspection.
- 4) Field/Laboratory testing – Certain representative members from each category of exposure condition are selected and various tests are carried out on them to ascertain the findings of visual inspection. These may be destructive or non-destructive in nature. The type of test to be performed is selected on the basis of the parameter to be tested.

IV. AUDIT REPORT

The structure surveyed is an institutional building of MGM college of engineering and Technology, Navi Mumbai, Maharashtra. The structure is a G+5 RCC framed structure with a partial trussed roof on the 3rd floor. The building was constructed in stages with the ground floor completing construction in 1991 and subsequent floors being added in 1994, 1998, 2010, 2016 and 2019. In the absence of structural details and drawings, it is being assumed that the building has been adequately designed and constructed for its present level of usage. The building has been inspected on a room by room basis. Certain portions are covered by false ceiling, thus preventing visual inspection. Some minor repairs have been carried out on the ground and first floor. Recently, jacketing of columns surrounding the central courtyard was undertaken while the 5th floor was being constructed as they were heavily deteriorated. Also, all classrooms have been repainted as is gathered during the inspection.

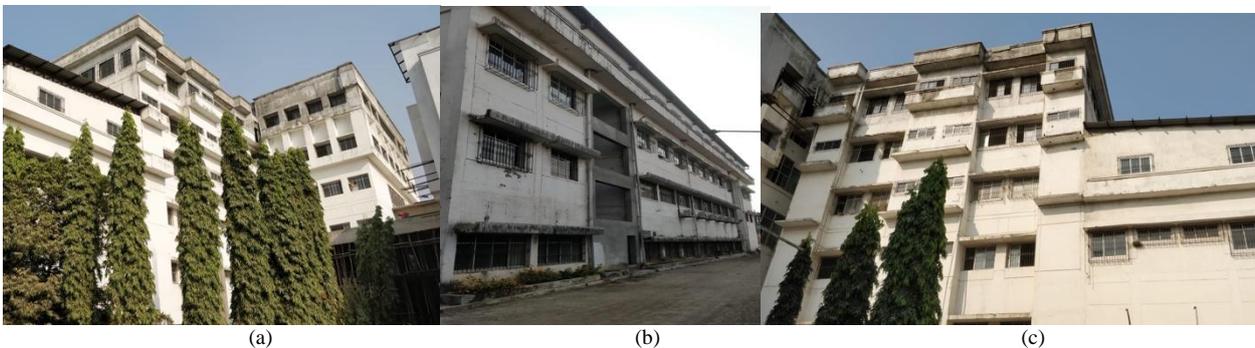


Fig. 1. External views of MGM CET (a) front view (b) Side view (c) Back view

Following are some of the observations made during the inspection: -

- 1) Many columns surrounding the central courtyard show wide longitudinal cracks. This is due to corrosion of rebar caused by inadequate protection provided to the lapping reinforcement for columns left for constructing further extensions.
- 2) Beams and corridor slabs surrounding the central courtyard show spalling of cover concrete. This is again due to corrosion of rebar as a result of non-provision of waterproofing layers during construction which led to water ingress in these members.
- 3) Some RCC Chajjas show excessive deflection and spalling of concrete. This is due to corrosion of the embedded rebar resulting in reduction in its strength.
- 4) A lot of spots having water marks have been noted in the corridor slabs, external walls and WC slabs. This indicates dampness due to inadequate waterproofing provided on these surfaces.
- 5) Termite infestation has been noted in the north west corner of the building.
- 6) Some walls show large separation cracks at joints of columns and walls.

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Vol. 9, Issue 2, February 2020



Fig. 2. Visual observations (a) Splitting of columns (b) Spalling of cover concrete in beams (c) Spalling of cover concrete in slabs (d) Deterioration of RCC chajjas (e) Dampness in WC slab (f) Termite infestation (g) Separation cracks between wall and column

NDT was conducted on a few members on every floor. Members were selected in such a way that they represent every type of exposure condition. The findings are enlisted below: -

- 1) The average readings for all members tested by Ultrasonic Pulse velocity fall in the range of 3 – 3.5 km/sec. Thus from Table 2, IS 13311(part 1), we can conclude that the concrete is of Fair quality
- 2) The average readings for Rebound hammer test fall in the range of 30 – 40. Thus, one can conclude that the concrete is of good quality.

From the above statements, one can conclude that the concrete still retains its strength and is still homogeneous in nature.



Fig. 3. NDT test (a) Rebound hammer test on slab (b) UPV test on slab (c) UPV test on staircase slab (d) Rebound hammer test on beam

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Remedial measures suggested for the same are as follows: -

- 1) Each column is to be treated differently on the basis of the classification of the damage that has been noted during the visual inspection. For major cracks continuing throughout the length of the column, Jacketing should be done to restore its strength using micro concrete. For columns showing minor cracks, the old concrete should be removed, rust on the rebar should be scraped off using a wire brush, an effective rust passivator must be applied and the patch should be sealed by polymer modified mortar. Additional rebar, if necessary, must be added.
- 2) A first floor level slab shows excessive deterioration due to spalled cover concrete on its entire span. This slab must be re-casted. For other slabs and beams showing spalling cover concrete, they must be repaired as stated in (1) by using Polymer modified mortar.
- 3) The RCC chajjas showing excessive deflection must be carefully dismantled and re-casted or may be replaced by ferrocement chajjas which are light in weight and similar in appearance.
- 4) Waterproofing layers must be replaced in the WC's and drinking water areas showing dampness in slabs. Ferrocement Chajjas may be provided along the corridors to prevent water from coming in direct contact with the corridor slab. The external walls must be replastered by using cement mortar mixed with waterproofing compounds and repainted to match the appearance.
- 5) The existing termite shelter tubes must be removed. To prevent further ingress of termites, holes should be drilled at the junction of the plinth and wall at an angle of 45° at intervals of 1 meter. These holes should be injected with anti-termite emulsion and sealed after completion of treatment.
- 6) To avoid large separation cracks, the wall and column junction must be replastered by provision of chicken mesh to hold the plaster together.

From the above observations, it can be concluded that the building requires some structural repairs but is habitable. A large part of the structure is sound. Most of the damage is concentrated around the central courtyards. Negligence during the construction phase, use of substandard materials and bad workmanship is to be blamed for majority of the deterioration.

V. CONCLUSION

This paper gives a detailed analysis of the process of structural auditing while highlighting its importance in today's world. In order to help in developing a complete understanding of the process of structural audit, an audit was conducted on an institutional building belonging to the Mahatma Gandhi Mission trust situated in Navi Mumbai, Maharashtra. It was found that the building requires some structural repairs but is habitable and there is no need for eviction.

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