

Review on Structural Audit Repair and Rehabilitation of Building

Siddiqui Adil Mujeeb Siddiqui, Prashant Murlidhar Kulkarni

M. E Student, Department of Structure Engineering, Trinity College of Engineering and Research, Pune, India

Professor, Department of Structure Engineering, Trinity College of Engineering and Research, Pune, India

ABSTRACT: The life cycle of building can be broadly divide into four phases i.e. architectural planning, structural design ,construction ,maintenance.In most of building at most care is taken in first three cases but maintenance is forgotten. Ignorance to maintenance causes severe structural distress in building over period of time. Most of the building constructed in last 23 to 30 years is in severe structural distress and needs to repair, hence these building needs a periodical survey from structural point of view to assess from structural health. Based on this survey a decision regarding the structural health of building and repair required can be taken.This paper with methods of estimating the audit of existing structures whose life has crossedthe age of 30 years.Such an investigation can be carried out using the following methods: a) Visualexamination b) Non Destructive Testing c) Partial Destructive Testing.This paper covers the study of Structural Auditing of Residential Building .Now a days structural Auditing is necessary because of poor quality of construction, carelessness in supervision during constructionuse of poor quality of materials, carelessness by labours during work because of such reasons the quality of the building goes down and then automatically life of the building goes down.Now a days life of the building comes 60 years from 100 years because of such reasons we need to do Structural Auditing of the building after 15 years to check whether it is safe or not if not then remedial measures to be provided . Now while performing the audit of a residential building and we will conduct non-destructive testing on this building like Rebound hammer and ultrasonic Pulse velocity meter test after getting test results we will decide the building is safe or not and if it is not safe then remedial measures will be provided to increase life of the building.A collapsed mechanism has increased and today's Structures are getting collapsed before there service life is completed. Therefore, it is advisable to monitor it periodically by taking a professional opinion. Structural Audit is a preliminary technical survey of a building to assess its general health as a civil engineering structure. It is usually initiated as the first step for repair. In this Paper a Root Cause of a faulty mechanism of structure and a preventive measures to overcome a failure of this structures.The paper brings out the present state of concrete structures & the major areas where improvement is neededduring its service life stage for sustainable development & also the method of carrying out Repair, Rehabilitation.The purpose of the paper is to gain fundamental and practical understanding on concrete repair and rehabilitation of the structures. Large number of reinforced concrete (RC) structure are deteriorating, often prematurely, and need remedial measures to reinstate their safety and/or serviceability. Consequently, the need for repair and protection has grown considerably in recent years. While costs associated with repair of deteriorating concrete structures can be substantial, costs resulting from poorly designed or executed repairs may be even higher. Repair methods need to be designed with consideration for the anticipated or desired remaining service life of the structure. A distinction must be made between repairs intended to stop deterioration fully and those merely aimed at slowing down deterioration processes for a limited period of time. During the research for our paper relevant repair methods for damaged concrete structures will be discussed, focussing on design methods. The paper will be initiated with various sites nearby Pune inspection and repairs will be examined. Then the respective repairs will be studied and classified into cracks, corrosion of concrete reinforcement, seepage and deterioration of surface coating. With the help of journals and publications a detailed study will be done on the causes for each repair and a suitable rehabilitation method will be suggested for each repair site by comparing various methods. This paper will consist of studies of various repairs along with pictures, referred case studies and other references.

KEYWORDS: Structural audit, Structural Engineering, NDT method, Structural Evaluation Program

I. INTRODUCTION

Large stocks of existing structures and infrastructure are deteriorated with use and time and might have passed their design life and require retrofitting and rehabilitation. The cost of retrofitting various infrastructures is estimated in the lakhs of rupees. To overcome the ill effects caused by these deteriorated buildings Repair and Rehabilitation works are carried out from time to time. Many of the existing structures were designed to codes that have since been modified and upgraded. Change in use or higher loads and performance demands require modifications and strengthening of

structuralelements. Concrete construction is generally expected to give trouble free service throughout its intended design life. However, these expectations are not realized in many constructions because of structural deficiency, material deterioration, unanticipated over loadings or physical damage. Premature material deterioration can arise from a number of causes, the most common being when the construction specifications are violated or when the facility is exposed to harsher service environment than those expected during the planning and design stages. Physical damage can also arise from fire, explosion as well as from restraints, both internal and external, against structural movement. Except in extreme cases, most of the structures require restoration to meet its functional requirements by appropriate repair techniques. The human body becomes deteriorated upon ageing. To a certain extent, the problem can be remedied by taking necessary preventive steps at the appropriate time. This is exactly the case with buildings. As time passes, the condition of buildings also becomes deteriorated. Unless corrective measures are taken, it may so happen that the safety of the building itself may be jeopardized. There are other factors that necessitate renovation. These are accidents, environmental factors, alteration to structures, etc. The construction associated with already-constructed structures is called renovation. Some people call the process of rehabilitation "Forensic Engineering." The role of the engineer is just like that of a doctor trying to diagnose the disease of a patient and then recommending corrective treatment. Maintenance of constructed structures includes preventive care, repairs, and rehabilitation. Rehabilitation of structures is a multi-disciplinary activity. The concerned engineer should know the design aspects, environmental factors, construction procedure, and about building materials. The rehabilitation of existing structures is a more complicated and sophisticated assignment than new construction

1.1 PRESENT REPAIR PRACTICES-OVERVIEW

Since 1950s, the construction activity in India has been increasing geometrically without matching increase in the availability of quality inputs, in terms of materials and skilled workmen. The gap between the quality planned and the quality achieved continues to become wider. The factors contributing to damages/distresses in buildings have, thus, become intrinsic right from the construction stage. Often these are concealed under external renderings and the defect takes time to manifest itself.

Why Repair of structures arise?

1. Understanding gap between Quality Planned and Quality achieved in past, present.
2. We do take cube test but How far its significance is taken during progress of work how far is the co-relation maintained with such results.
3. Construction documents have specifications and instructions but they remain on paper sometime due to lack of understanding.
4. Procedures for Periodic Inspections of building and maintenance are not followed or maintained.
5. Budget estimates are prepared by un-experienced engineer or someone else.
6. Buildings remain several years without any attention.

Construction documents contain adequate specifications and instructions required to execute quality works. However, they remain as written document without achieving the desired level of results, because of lack of understanding of their significance by the field engineers. Standard cube test results are taken as a measure of quality in the construction. Whereas the factors such as method of placing, compaction and curing of concrete, which have significant influence on the quality achieved in the hardened concrete, are given scant attention. Many a times, the quality of concrete as placed and hardened in position has no correlation to the cube test results, which are used for quality control measures. Procedures, mandatory or otherwise, for periodic inspection of buildings and structures and documenting defects, like cracks, excessive deflections, corrosion of reinforcement etc., in logical manner, and recording of structural repairs already carried out, are generally not followed or maintained. In some buildings, only visual inspection is carried out for preparing maintenance budget estimates and this exercise is often left to the engineers who have no experience in such problems.

1.2 CAUSES OF DETERIORATION OF STRUCTURES

A structure becomes deteriorated for the following reasons

Site Selection and Site Development Errors:

Failures often result from unwise land use or site selection decisions. Certain sites are more vulnerable to failure. The most obvious examples are sites located in regions of significant seismic activity, in coastal regions, or in flood plains. Other sites pose problems related to specific soil conditions such as expansive soils or permafrost in cold regions.

Design Errors:

These failures include errors in concept that lack of structural redundancy, failure to consider a load or combination of loads, deficient connection details, calculation errors, misuse of computer software, detailing problems including selection of incompatible materials, failure to consider maintenance requirements and durability, inadequate or inconsistent specifications for materials or expected quality of work and unclear communication of design intent.

Construction Errors:

Such errors may involve excavation and equipment accidents; improper sequencing; inadequate temporary support; excessive construction loads; premature removal of shoring or formwork; and non-conformance to design intent.

Material Deficiencies:

While it is true that most problems with materials are the result of human errors involving a lack of understanding about materials, there are failures that can be attributed to unexpected inconsistencies in materials.

Operational Errors:

Failures can occur after occupancy of a facility as the result of owner/operator errors. These may include alterations made to the structure, change in use, negligent overloading and inadequate maintenance.

1.3 CONDITION SURVEY AND NON-DESTRUCTIVE TESTING

✓ Objective:

1. It is examination of concrete for the purpose of identifying and defining area of distress.
2. Identify cause of distress and sources.
3. Assess extent of distress due to corrosion, fire, earthquake, any other reasons.
4. Assess residual strength of structure and inhabitability.

✓ Stages of condition survey:

- Prioritize distressed elements according to seriousness for repairs.
 - a) Preliminary inspection
 - b) Planning
 - c) Visual Inspection
 - d) Field and laboratory testing.

1. Preliminary inspection:

1. History of structure from client, owner, occupants, General public in building.
2. Note records, previous repairs history and expenses done for the same.
3. All possible data and information.
4. Practical restriction and safety requirements.
5. Extent and quantum of survey work.
6. Time required (survey and execution).
7. Advise immediate safety measures.

Information gathering:

1. Period of construction.
2. Construction details (drawings, arch, structural).
3. Exposure conditions.
4. Designed and present use of structure.
5. Previous changes in use.
6. Record of structural changes if done.
7. Record of 1st occurrence of defect.
8. Details of repairs carried out previously.
9. Previous reports etc.
10. Details from owner, photographs.

2. Planning survey:

1. Field documents.
2. Plans and actual observations each room-wise.
3. Previous report, advise if any and implementation done as per report.
4. Grouping of structural elements (external, interior etc.)
5. Exposure conditions.

The data to be collected are:

1. Assumptions made in the design and verification of design calculation.
2. Quality of materials used in the construction.
3. Result of soil investigations, ground water analysis.
4. Quality control and method of construction.

3. Visual Indications of Distress Conditions:

1. Formation of cracks in the structure in different patterns
2. Peeling of plasters
3. Spalling of concrete
4. Yielding of steel
5. Rusting of exposed steel

4. Tests to be done:

The following tests are to be conducted on the samples taken from the structure and on the structural members.

1. Testing of concrete for ascertaining the compressive strength
2. Sampling and testing of subsoil
3. Chemical analysis of subsoil water
4. X ray diffraction tests on concrete
5. Hammer or ultrasonic tests on concrete
6. Permeability tests
7. Vibration studies.

1.4 OBJECTIVES

1. To recognize the types of structural defects.
2. To identify any signs of material deterioration.
3. To identify any signs of structural distress and deformation.
4. To identify any alteration and addition in the structure, misuse which may result in overloading.
5. To identify any signs of material deterioration.
6. To identify any signs of structural distress and deformation.
7. To identify any alteration and addition in the structure.

II. LITERATURE REVIEW

Rajendra P. Srivastava et.al.(1) (1999) -This article performs two types of analysis using Dempster-Shafer theory of belief functions for evidential reasoning. The first analysis deals with the impact of the structure of audit evidence on the overall belief at each variable in the network, variables being the account balance to be audited, the related transaction streams, and the associated audit objectives. The second analysis deals with the impact of the relationship (logical "and" and "algebraic relationship") among various variables in the network on the overall belief. For our first analysis, we change the evidential structure from a network to a tree and determine its impact.

Constantinos A. Balaras et.al.(2) (2005) – A total of 349 residential building audits were performed in seven European countries to collect data on the degradation of building elements (architectural and installations). The buildings cover typical architectural typologies, sizes, constructions and installations, at different states of deterioration. The data was collected based on a standardized methodology for building audits. Follow up analysis revealed the most

important influencing factors on the deterioration of existing residential buildings throughout Europe and estimated service lives of various building architectural elements and electromechanical installation..

B.H Chafekaret. al.(3) (2013-14) - Before going in detail about the structural audit is necessary to know about the structure. A structure is a system of inter connected elements to carry loads safely to underground earth. The health examination of concrete building called as structural audit. The author shows different methods in paper:

A.B. Mahadik et.al.(4) (2014) –This paper deals to create awareness amongst the civil engineers, residents and owners of building towards the health examination of existing concrete buildings called as Structural Audit. The need of structural audit is for maintenance

and repairs of existing structures whose life has exceeded the age of 30 years to avoid any mishaps and save valuable human life. The concrete is widely used as construction material being inexpensive, easy for construction, applications and because of it high strength-cost ratio. More than ever, the construction industry is concerned with improving the social, economic and environmental parameters of sustainability. In India, from 1980 onwards the infrastructure industry witnessed stepping up of public investment and growth in infrastructure industry which results in construction of new multi-stories concrete apartments which are now in the age of thirty plus years. There are many buildings during this period and earlier have reduced strength in due course of time because of structural deficiency, material deterioration, unexpected over loadings or physical damage. If, further use of such deteriorated structure is continued it may endanger the lives of occupants and surrounding habitation. There is demand of appropriate actions and measures for all such building structures to improve its performance and restore the desired functions of structures which may leads to increase its functional life

Francesca Ceronia(5) (2015) - A synergic approach for the investigations of the historical building performances - with reference to both the structural behaviour and the energy performances for the space heating and cooling - is presented. The historical masonry building “Palazzo BoscoLucarelli”, located in Benevento, has been chosen as case study. The structural and energy analyses are carried out in parallel, especially during the identification of the building characteristics through tests and surveys in-situ. For the structural analysis - beyond examinations on materials – some dynamic tests have been used for better assessing a numerical Finite Element model necessary for the verification of the structure safety. Moreover, being necessary a structural refurbishment, also an energy retrofit could be realized. A rigorous evaluation procedure - aimed to guarantee the necessary reliability of numerical predictions - is performed in order to verify the technical and economical convenience of various energy retrofit solutions.

Mohammad Ismail(6) (2016) - The paper presents research findings on the deteriorating conditions of abandoned residential papers due to environmental factors of degradations. Sampling was made from two hundred and sixty-one abandoned housing papers. Structural degradations associated with the uncompleted buildings were studied. In a similar manner, a small-scale reinforced concrete structure was erected in an open and critically monitored for defects caused by environmental factors of degradations. The selected uncompleted buildings were assessed for surface salt deposits, crack formations and reinforcement corrosion. However, the small-scale structure was evaluated for performance degradations through destructive and non-destructive strength tests, steel tensile strength test and corrosion test. Results show that there is an alarming decrease in structural integrity and durability functions in abandoned reinforced concrete buildings with time. Eventually, performance-depreciation versus age graph was developed for assessing life-span limit beyond which unacceptable mechanical properties are eminent. Based on the surrounding exposure conditions, an abandoned reinforced concrete building could fail to perform acceptable designed strength functions within a period of twelve (12) years

J. Bhattacharjee(7) (2016) –The construction material mainly reinforced concrete is being used extensively for various types of construction papers. However, the deterioration of Reinforced Concrete structures is recognized as a major problem worldwide. Apart from requiring regular maintenance, many structures require extensive Repair, Rehabilitation &Retrofitting. Over a period of time, as these structures become older, we find in them certain degradation or deterioration with resultant distress manifested in the form of cracking, splitting, delaminating, corrosion etc. Such deteriorated structures can be rehabilitated and retrofitted by using various types of admixtures & modern repair materials. The paper brings out the present state of concrete structures & the major areas where improvement is needed during its service life stage for sustainable development & also the method of carrying out Repair, Rehabilitation &Retrofitting. This has been brought in details in the paper along with Case studies, where the Author of the paper was directly involved in planning and execution of the jobs.

Swapnil U Biraris(8) (2017) – Structural audit is an overall health and performance check-up of buildings .It is important to the building to check their safety and they have no risk. It is process of analyses of building And this process suggest a appropriate repairs and retrofitting measures required for the buildings to perform better in its service life structural audit is an important tool for knowing the real health status of the old buildings.

Shah I. H.(9)has stated structural audit is an important tool for knowing the real status of the old buildings. The audit should highlight and investigate all the risk areas, critical areas and whether the building needs immediate attention. If the bldg. has changed the user, from residential to commercial or industrial, this should bring out the impact of such a change. This Publication gives step by step guidelines for carrying out structural audit of old buildings.

Monteria. J., Patha,N. J(8)have estimated the soundness of existing structures whose life has crossed the age of thirty years. Concrete constructions are generally expected to give trouble free service throughout its intended design life. The deterioration of buildings can be a result of various factors including fire damage, frost action, chemical attack, corrosion of steel etc. during the life span of the structure. The investigation of soundness is thus essential for finding the present serviceability of the structure and its scope for future developments or for the change in its utilization

Balayssac J.-P., Laurens S.(10),have stated the management and maintenance of the built heritage is one of the main concerns of the owners of concrete structures. Combining NDT methods is currently considered as one of the most appropriate ways to improve the quality of the diagnosis of concrete structures. This paper describes a French paper named SENSO (Strategy of non-destructive evaluation for the monitoring of concrete structures) devoted to developing a methodology for the non-destructive evaluation of concrete based on a multi-technique approach.

A.B. Mahadik and M. H. Jaiswal(4) concluded that to create awareness amongst the civil engineers, residents and owners of building towards the health examination of existing concrete buildings called as Structural Audit which help to implement maintenance and repair work timely which leads to prolonged life of the building and safety. The need of structural audit is for maintenance and repairs of existing structures whose life has exceeded the age of 30 years to avoid any mishap.

B.H Chafekar, O.S Kadam K.B Kale, S.R Mohite, P.A Shinde, V.P Koyle(3) studied that before going in detail about the structural audit is necessary to know about the structure. A structure is a system of inter connected elements to carry loads safely to underground earth. The health examination of concrete building called as structural audit. The author shows different methods in paper: E.g. Visual inspection, non-destructive test.

M.M.Sonawane, D.H.Markad, V.G.Maindad, M.B.Patil, K.D.Manwar, P.D.Mote(23). Concluded that appropriate actions should then be implemented to improve the performance of structures and restore the desired function of structures. Thus, it is almost important to perform structural audit of existing buildings and to implement maintenance/ repair work timely which will lead to prolonged life of the building and safety of the occupant.

K.R.Sonawane,Dr.A.W.Dhawale(24) concluded that The life cycle of building can be broadly divided into four phases i.e. architectural planning, structural design, and construction maintenance. In most of building at most care is taken in first three cases but maintenance is forgotten. Ignorance to maintenance causes severe structural distress in building over period of time. Regarding the structural health of building and repair required can be carried out. Such an investigation can be carried out using the following methods: a) Visual examination b) Non Destructive Testing c) Partial Destructive Testing.

III. CONCLUSION

From the consideration of all the above points we conclude that the defects of structural members are due to combined effects of carbonation, corrosion & effect of continuous drying and wetting. The result of visual survey prompt us to conclude the distress is wide spread and is an ongoing process and so needs to be stopped at this stage so as to avoid complete collapse of the structure. There for Rehabilitation of the RCC members and will constitute the following steps

1. Periodic maintenance of structures is essential.
2. Each and every problem should be properly analyzed and then the appropriate repair methods undertaken.
3. Primary design of the building reflects its performance in long run.
4. Each repair technique is suitable only for the particular application for which it is meant for.
5. Cost should not be significant planning factor in rehabilitation though it is a deciding factor.
6. Due to moisture, walls get patch off and brick walls losses its strength, so the mentioned repair works for bricks and plaster of walls is well recommended.

Structural Defects: The defects of structural members are due to combined effects of carbonation, corrosion & effect of continuous drying and wetting. The result of visual survey prompt us to conclude the distress is wide spread and is an ongoing process and so needs to be stopped at this stage so as to avoid complete collapse of the structure. There for Rehabilitation of the RCC members and will constitute the following steps

- 1) Propping the structure wherever necessary
- 2) Removing loose/disintegrated concrete
- 3) Cleaning the affected steel
- 4) Adding steel wherever necessary.
- 5) Applying Passivator coat to the steel
- 6) Applying Bond Coat and doing Polymer /Micro Concrete treatment depending on the requirements
- 7) Finishing with new plaster

The condition of the building appears to be quite bad and major structural distress is observed in some of the columns and beams of the external walls.

Micro Concrete Repairs to R.C.C. Column, Beam, etc.: In terms of restoration of extensive damages in R.C.C. micro concrete: micro concrete is a very high strength mix design concrete, its factory made product. its dry powder in grey colour more like cement constitutes cement as a one component & other's graded fine aggregate, additive in powder form & free flowing agent, because of this micro concrete can placed in less thickness & mix. Material can travel in narrow gape & having self-levelling properties, so that it provides very smooth & uniform finish. Strength equivalent to 35 m concrete can be achieved in only three day setting / placing time. After overnight setting de shuttering is possible. While doing the Structural Audit and various Non- Destructive Test [NDT] it has been concluded that the Structural Audi to fall old buildings having age more than 30 years must be necessary. Principal repairs are mostly required at various levels. Any delay in Structural repair works will result in more deterioration and maintenance will become more and more. Minor cracks should be repairs by injection of Epoxy or by using Grouting Method so that the building appears to be quite good and major structural distress is not observed in different components of building. The Effective implementation of Auditing enhances the life span of Structure present deterioration of building leading to Sustainability.

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