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## Review on Repairs and Rehabilitation of Civil Structures

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**ABSTRACT:** Reinforced cement concrete (RCC) as a construction material has come into use for the last one century . In India RCC has been used extensively in the last 50-60 years. During this period we have created large number of infrastructural assets in terms of buildings, bridges ,sports stadium etc. which are lifeline for the civilized society. These have been created with huge investment of resources .We cannot even dream of recreating such assets out of limited national resources. It is therefore ,essential to maintain them in functional condition .Since, deterioration of RCC is a natural phenomenon and has started exhibiting in large number of structures a systematic approach is needed in dealing with such problems . Identification of the causes of deterioration and consequent repair/rehabilitation strategy at optimum cost needs a scientific evaluation and solution .Information regarding to this development review of repairs and rehabilitation of civil structure like high rise buildings (column , beam etc ) In current scenario of building research repair and rehabilitation play a vital role it serves important in building applications . It acts as an inevitable solution in maintaining the integrity of structures. Repairs and rehabilitation of heritage building has greater importance of world notably in the developed countries.

**KEYWORDS:** Rehabilitation , Retrofitting, sustainable Development

### I. INTRODUCTION

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-storey 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. The periodical structural auditing and diagnosis for health of existing buildings is thus utmost important for finding the present serviceability and structural viability of structures. The structural audit must be carried out following auditing norms, methods of non-destructive testing and code provisions. The structural auditing will help to implement maintenance and repair work timely which leads to prolonged life of the building and safety of the occupants. In India there are many old buildings which have reduced strength in due course of time. If further use of such deteriorated structure is continued it may endanger the lives of the occupants and surrounding habitation. Appropriate actions should then be implemented to improve the

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performance of structures and restore the desired function of structures. Thus, it is utmost 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. To act more responsible and pre-emptive towards the dilapidated buildings, the municipal corporation must issue notices to the buildings and co-operative societies which are more than 30 years old to carry out mandatory structural audit and submit the audit report. Structural audit should highlight and investigate all critical areas and recommend immediate remedial and preventive measures. It should cover the structural analysis of existing frame and find critical elements for all types of loadings. It also helps in delivering a strong building structure with cost effective solutions and appropriate maintenance program. This paper deals with study of different parameter of structural audit including visual inspection, non-destructive testing, core sampling and testing. It also emphasizes on different repairs and retrofitting measures to be used for buildings after structural audit. Structural Audit is an overall health and performance check-up of a building like a doctor examines a patient. It ensures that the building and its premises are safe and have no risk. It analyses and suggests appropriate repairs and retrofitting measures required for the buildings to perform better in its service life. Structural audit is done by an experienced and licensed structural consultant. 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. Except in extreme cases, most of the structures require restoration to meet its functional requirements by appropriate repair techniques.

The word 'repair' normally conveys small and ordinary repairs, which are not of structural significance. But the aim of rehabilitation is to restore a distressed structure back to its original durability.

- 1) **Selection of case study**
- 2) **Data collection**
- 3) **Identification Of problem**
- 4) **Selection of Suitable solution like method or test for solve the problem**
- 5) **Feasible or not**

## II. LITERATURE REVIEW

1) Wael W. El-Dakhkhni<sup>1</sup>, Ahmad A. Hamid and Mohamed Elgaaly, 13th wcee August 1-6, 2004 Paper No. 3093 "Seismic retrofit of masonry infill walls using advanced composites." The authors state that the strength, stiffness and ductility of masonry infill walls needs to be in design as the interaction between panel and frame dramatically changes the dynamic characteristics of composite structures under lateral loads. They tested the specimens under prisms loaded normal, parallel to bed joints, direct shear conditions. They conclude as, In engineered masonry FRP walls supply the compressive strength stabilizing out-of-plane buckling, confine in-plane tensile failure, and increase load carrying capacity, more energy dissipation, apparent post peak strength, minimize the anisotropic behavior due to joints.

2) Yogendra Singh, Ratnesh Kumar, and Putul Haldar, Earthquake resistant design and construction practices in India. (<http://nidm.gov.in/idmc2/PDF/Abstracts/EQ-A1.pdf>) The authors have examined the design and constructional practices in India. They conducted field survey in Delhi city, falling in seismic zone III and have recorded observation as, poor detailing of beam-column joints. The present OMRF and SMRF practices followed, with capping on the design period results in double or more design factor value. They conclude that though the BIS code provisions fall in line with worldwide codes they are not enforced in practice and detailing, which endanger the structure's performance during earthquake.

3) Prof. Dr.D.K.Kulkarni., Mr. Teke Sudhakar. S. Health Assessment Of Reinforced Concrete Structures - A Case Study, (IOSR-JMCE) ISSN: 2278-1684, PP: 37-42, [www.iosrjournals.org](http://www.iosrjournals.org). There are two distinct types of tests, and

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they are No-destructive and partially destructive. The authors have chosen two tests, from 7 as referred, (ND), viz. Schmidt's Rebound Hammer test for assessing the concrete compressive strength, and Ultrasound pulse Velocity tests for establishing quality of concrete. They had the task of ascertaining strength of concrete. These help in assessing level of damages weaknesses, deterioration, corrosion, that has taken place in past life of the structure. On such assessment the apt method of strengthening, retrofitting can be proposed and future life of the structure can be estimated. Health assessment of structures is essential to ascertain the strength which is an indicator for the durability in lieu of aging, weathering, corrosion, damage etc. effects.

4) M. J. Monteiro, Prof. N. J. Pathak, Structural Soundness of Buildings, IJESSE V. 04, No 06 SPL, October 2011, pp. 677-680. The authors are describing two NDT's and two Partially destructive tests, viz. RH, UPV, Carbonation and core sampling tests. They express need of evaluation of structure periodically for: Assessing the load carrying capacity of building and of earthquake resistance (As per revised codal provisions) in old structures, and structural soundness periodically, as well as checking feasibility of change in occupancy, for construction of additional floors, for structural modifications, or placing higher capacity equipments on building. The authors opine and state the rule, "According to the model bye-law no. 77 for co-operative housing societies, it is mandatory that if the age of a building is 15 to 30 years, a structural audit must be carried out once in five years and for buildings older than 30 years it should be carried out once in three years."

5) Stephen P. Leatherman, Arindam Gan Chowdhury, and Carolyn J. Robertson (2007) Wall of Wind Full-Scale Destructive Testing of Coastal Houses and Hurricane Damage Mitigation. Journal of Coastal Research: Volume 23, Issue 5: pp. 1211 – 1217. The author opines, "Conducting research to better understand simultaneous hurricane-induced wind, rain, and debris effects on the built environment will lead to innovative design technologies that can mitigate hurricane wind damage". They used Wall of Wind testing apparatus developed by the IHRC. Concluded that, "Experimenting with such full-scale destructive testing, performance-based evaluation, and failure-mode analysis, innovative mitigation techniques will be developed. Wall of Wind experimentation has the potential for revolutionizing our building and retrofitting practices."

6) Vilcekova S., Sedlakova A., Kapalo P., Culakova M., Burdova E. K., Geletka V. Analysis of environmental and Social Aspects in Low Energy House – case study, 13<sup>th</sup> SGEM Geo-Conference, ISSN 1314-2704, June 16-22, 2013, 555 - 562 pp. The authors set their aim of the innovations as not only energy saving but also reduce costs and preserve natural resources. The application of technologies for energy conservation, are insulation of facades, roofs and floors to those that are used systems for renewable energy sources. Using the basic form and enclosure of a building to save energy while enhancing occupant comfort, the significant part of the total energy is energy used in the extraction, processes and transportation of materials used in building structures". They conclude that, the innovation they aimed at was successful in reducing environmental impacts, in view of environmental and social aspects.

7) Sivasubramanian K, Jaya K.P, Neelemegam M. Cover-meter for identifying cover depth and rebar diameter in high strength concrete IJCSE V. 3, No 3, 2013 "The present work focuses on identifying the capabilities and the limitations of using cover meter in high strength concrete". Ascertaining the cover depth is important to implement durability standards to the structure under construction. In cases where concrete core extracts are to be taken the identification of the rebar locations becomes essential to avoid cutting of the reinforcement bars. To determine these aspects it becomes necessary to apply non-destructive testing methods. Hence, rebar locators or the cover meter used in the site. It shall be noted that these results are obtained under laboratory conditions. Hence, the results will be unreliable in field conditions.

8) Bhattacharya Shubhamoy, Nayak Sanket, Datta Sekhar Chandra, (IJDRR, V-7, March 14) A critical review of retrofitting methods for unreinforced masonry structures. The authors state that URM buildings are common in Himalayan region and Indian subcontinent. They observed that these buildings cannot withstand the lateral load imposed by the earthquake and often fail in brittle manner. They have collected information on various types retrofitting

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methods. On analyzing they concluded that this study will provide useful guidance to policy makers, planners, designers, architects, and engineers, to choose proper methodology.

9) Sachin Rambhau Shelke "Structural Health Monitoring and Audit, Repair and Rehabilitation of Building in Construction Industry". Structures are assemblies of load carrying members capable of safely transferring the superimposed loads to the foundations. Their main and most looked after property is the strength of the material that they are made of. Concrete, as we all know, is an integral material used for construction purposes. Thus, strength of concrete used, is required to be 'known' before starting with any kind of analysis. In the recent past, various methods and techniques, called as Non-Destructive Evaluation (NDE) techniques, are being used for Structural Health Monitoring (SHM). The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of the specimen nor the structure from which it is taken. However, one problem that has been prevalent within the concrete industry for years is that the true properties of an in-place specimen have never been tested without leaving a certain degree of damage on the structure. For most cast-in-place concrete structures, construction specifications require that test cylinders be cast for 28-day strength determination. Usually, representative test specimens are cast from the same concrete mix as the larger structural elements. Unfortunately, test specimens are not an exact representation of in-situ concrete, and may be affected by variations in specimen type, size, and curing procedures. The rebound hammer test is classified as a hardness test and is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges.

10) Vivek Kumar Yadav "Repairs And Rehabilitation of R.C.C. Structures by Fiber Reinforced Plastic- A Review"  
The purpose of the paper is to highlight the methods of repair and rehabilitation to be undertaken for structures with defects and deficiencies that necessitate rehabilitation. Repair and Rehabilitation methods currently used are reviewed on the basis of present knowledge and the merit of a holistic system approach. This paper focuses on visible symptoms of the problem rather than on visible and invisible problems as well as the possible causes behind them. This paper focuses about the repair materials and the techniques are essential for the satisfactory performance of the repaired structure.

11) Ankur Gupta "A Case Study' On Repair Rehabilitation & Retrofitting of RC Framed Structure  
The building material mainly reinforced concrete is being used comprehensively for innumerable forms of construction developments. However, the deterioration of Reinforced Concrete structures is acknowledged as a foremost problem. To one side, it requires regular maintenance and on other side many structures call for widespread repair, rehabilitation & retrofitting. With the passage of time, as these structures develop older, we discover in them certain dilapidation or weakening with subsequent distress revealed in the form of delamination, cracking, corrosion and splitting etc. Such worsened structures can be repaired, rehabilitated and retrofitted by means of several sorts of admixtures & new repair materials. The purpose of this paper is to suggest methods of repair, rehabilitation and retrofitting of RC framed structures with the help of a case study where the author was involved at every stage. In the case study of the structure involved the focus was made on the determination and correlation of the results of various non-destructive tests for the purpose of suggesting suitable sustainable measures for the rehabilitation of the structures.

12) Manish Kumar "Structural Rehabilitation, Retrofitting and Strengthening of Reinforced Concrete Structures"  
Reinforced cement concrete is getting extensively used for construction of different type of structures for the last one century. During this period, we have constructed many structures like buildings, bridges, industrial structures, pavement, water tanks etc. using this construction material. These structures have been created with huge investment of resources. It is essential to maintain those structures in functional condition. Since deterioration in RCC Structures is a common and natural phenomenon it is required to have a detailed plan, methodology for structural repair and rehabilitation shall be in place for dealing such issues. It is important to know exact reason of distress, type of distress and correct method of repair concrete structures. The different methods of repair are described in paper according to distress category which can be refereed for repair. Major finding of the study is that to protect our structure we need to

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have maintenance frequency and correct material to be chosen for repair. Also workmanship during repair needs to be taken utmost care for quality repair.

13) RohitNewale” Structural Audit, Repair and Rehabilitation of Building”

Civil Engineering Industry is one of the oldest industries which provide a basic infrastructure to all the human beings. Structures can be any kind it can be Historical, Heritage Structure, Residential building, Commercial building or an Industrial building. Every structure has its own service life, and within this service life it should stand firmly on its position. Ex- ATajMahal in Agra in India which is one of the oldest structure and a Wonders of the World, and still stand on its position very efficiently. But this not a condition about the today’s Structures. 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.

14) J. Bhattacharjee “Repair, Rehabilitation &Retrofitting Of RCC for Sustainable Development with Case Studies”

The construction material mainly reinforced concrete is being used extensively for various types of construction projects. 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.

## III. RESEARCH METHODOLOGY

### 3.1 Condition Survey:

#### 3.1.1. Definition:

Condition Survey is an examination of concrete for the purpose of identifying and defining area of distress. While it is referred in connection with survey of concrete and embedded reinforcement that is showing some degree of distress, its application is recommended for all buildings and structures. The system is designed to be used for recording the history of the project from its inception to completion and subsequent life.

#### 3.1.2. Objective:

The objective of Condition Survey of a building structure is

- a. To identify
  - Causes of distress and
  - Their sources;
- b. To assess
  - The extent of distress occurred due to corrosion, fire, earthquake or any other reason,
  - The residual strength of the structure and
  - Its rehabilitability;
- c. To prioritise the distressed elements according to seriousness for repairs and
- d. To select and plan the effective remedy.

“Find the cause, the remedy will suggest itself”. Sometimes, the source of the cause of distress is different than what is apparently seen. It is, therefore, essential that the engineers conducting condition survey determine the source(s) of cause so as to effectively deal with it and minimize their effects by proper treatment.

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### 3.1.3.1. Preliminary Inspection:

**A. The primary objective** of the preliminary inspection is-

1. To assess and collect following necessary information for a thoughtful planning before a condition survey is physically undertaken;
2. To advise the client/owner of the building in regard to immediate safety measures, if considered necessary, to avert any mishap endangering life and structure.
3. To define the scope of work of field investigations in consultation with the Clients/Owners.

**B. Basic Information Gathering:** - A programme has to be evolved to obtain as much information as possible about the distressed structure at reasonable cost and in a reasonable time. Accordingly, the information required from the owner/client has to be listed out. Even though; many construction details and other related information may not be available with the owners/clients, yet as much as information and details as possible be gathered during the Preliminary Site Visit. Before undertaking a Condition Survey of a building/structure, the following essential information is required and be obtained from the clients/owners:

**C. Photographic Record:** It is always necessary to carry a camera with flash during such 'Preliminary inspection' and take necessary photographs of the distressed structure and its members. Preliminary Inspection and collection of data would be helpful in planning, the Condition Survey for field investigations. The symptoms of distress are related with the age of structure. This allows a reasonably sufficient understanding of the cause of distress for an experienced Rehabilitation Engineer.

## IV. CONCLUSIONS

Rehabilitation of structures embroils contribution of high end technology, advanced skills and calculations. This is a very responsible job to be done to save hazardous failure of structures due to deterioration. The success of this subject totally depends on gaining expertise in the field and day to day advancements. Rehabilitation is highly recommended for age-old buildings showing signs of decent and save human lives from failure. This paper provides comprehensive study of repair and rehabilitation of heritage buildings. The existed problems and its reported solutions are finely reviewed. An effective solution for the reported problem is formulated based on tradeoff between cost, lifetime and adaptability of the solution. This paper delivers its usefulness to those who as an objective of doing Repair and Rehabilitation of civil structures.

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