# REPAIRS AND REHABILITATION OF BUILDING IN CONSTRUCTION INDUSTRY

P.V.BHOSALE[1], SUMANT KULKARNI[2],

[1](P. G. Student : Civil Engineering Department, D.Y.Patil Institute Of Engineering And Technology (DYPIET)Ambi ,Pune)

[2](Associate Professor :Civil Engineering Department, D.Y.Patil Institute Of Engineering And Technology (DYPIET)Ambi ,Pune)

**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 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-Dakhakhni1, Ahmad A. Hamid and Mohamed Elgaaly, 13th wceeAugust 1-6, 2004 Paper No. 3093 "Seismic retrofit of masonry infill walls usingadvanced 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 world wide 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. There are two distinct types of tests, and 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 forthe durability in lieu of aging, weathering, corrosion, damage etc. effects.

4) M. J. Monteiro, Prof. N. J. Pathak, Structural Soundness of Buildings, IJESE 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, 13th 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 conversation, 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 covermeter 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 covermeter 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 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 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) Rohit Newale" 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- ATaj Mahal 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 anyother 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.

#### 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.

#### 3.1.3.2 Planning Stage

Planning stage involves preparation of field documents, grouping of structural members and classification of damage as under:

i. **Preparation of Field Documents:**
ii. **Grouping of the Structural members:**

#### 3.1.3.3 Visual Inspection:

1. Visual examination of a structure is the most effective qualitative method of evaluation of structural soundness and identifying the typical distress symptoms together with the associated problems.
2. This provides valuable information to an experienced engineer in regard to its workmanship, structural serviceability and material deterioration mechanism.
3. It is meant to give a quick scan of the structure to assess its state of general health.
4. The record of visual inspection is an essential requirement for preparation of realistic bill of quantities of various repair items.
5. Experienced engineers should carry out this work as these forms the basis for detailing out the plan of action to complete the diagnosis of problems and to quantify the extent of distress.
6. Simple tools and Instruments like camera with flash, magnifying glass, binoculars, and gauge for crack width measurement, chisel and hammer are usually needed. Occasionally, a light platform/scaffold tower can be used for access to advantage.

#### 3.1.3.4 Field/Laboratory Testing stage:

**Objective:**

1. It may neither be feasible nor is the practice to conduct field/laboratory testing on every structural member in an existing distressed building.
2. The field/laboratory testing of structural concrete and reinforcement is to be undertaken, basically for validating the findings of visual inspection.
3. These may be undertaken on selective basis on representative structural members from each of the various groups based on exposure conditions as explained in the preceding sections.
2. The programme of such testing has to be chalked out based on the record of visual inspection.

**3.1.4 Considerations for Repair Strategy:**

In the Condition Survey Report, before arriving at the Repair Strategy, it shall include the following considerations:

1. Identification of the cause of problem and its source is the fundamental to the success or failure of the repair. A lack of attention at this point can put at risk the whole job.
2. For arriving at an effective and economical solution, systematic documentation of all observations is essential, which will greatly facilitate in diagnosing and making assessment of the extent of damage.
3. Available space and accessibility will determine the selection of repair method and repair strategy.
4. Accessibility to the areas identified for repairs needs consideration.
5. Depending upon the scope and scale of repairs, the repair strategy has to suit and dovetail the on-going activities in the building.
6. The prioritization of repairs and their sequencing are important components for deciding the repair strategy.
7. Major repair procedure may demand propping the structural members to relieve a part or full component of the load acting on the member. If the building requires extensive propping, vacating the building may become the pre-requisite.
8. Safety measures to prevent any immediate major mishap shall be prescribed without loosing further time.
9. The report should also include requirements on safety measures to be adopted during execution of repair jobs.

**3.2 NON DESTRUCTIVE EVALUATION TESTS:**

A number of non-destructive evaluation (NDE) tests for concrete members are available to determine in-situ strength and quality of concrete. Some of these tests are very useful in assessment of damage to RCC structures subjected to corrosion, chemical attack, and fire and due to other reasons. The term 'non destructive' is used to indicate that it does not impair the intended performance of the structural member being tested/investigated. The nondestructive evaluation has been broadly classified under two broad categories viz 'in-situ field test' and 'laboratory test'.

**3.2.1.1 Rebound Hammer Test:**

The operation of Rebound Hammer (also called Schmidt's Hammer) is illustrated in Fig 3.3. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back.This test is conducted to assess the relative strength of concrete based on the hardness at or near its exposed surface and to identify relative surface weaknesses in cover concrete and also can be
used to determine the relative compressive strength of concrete. Locations possessing very low rebound numbers will be identified as weak surface concrete and such locations will be identified for further investigations like corrosion distress, fire damage and/or any other reason including original construction defects of concrete.

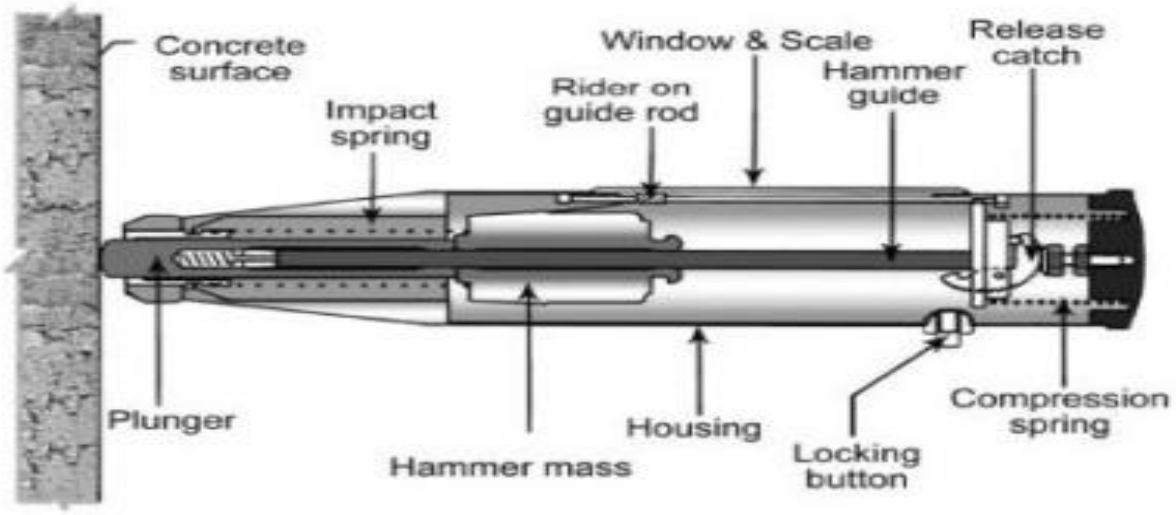


**Fig 01 Rebound Hammer Test**

**3.2.1.2 Ultrasonic Pulse Velocity (UPV) test**

Ultrasonic scanning is a recognised non-destructive evaluation test to qualitatively assess the homogeneity and integrity of concrete. With this technique, following can be assessed.

1. Qualitative assessment of strength of concrete, its gradation in different locations of structural members and plotting the same
2. Any discontinuity in cross section like cracks, cover concrete delamination etc
3. Depth of surface cracks.

This test essentially consists of measuring travel time, 'T' of ultrasonic pulse of 50-54 kHz, produced by an electro-acoustical transducer, held in contact with one surface of the concrete member under test and receiving the same by a similar transducer in contact with the surface at the other end.

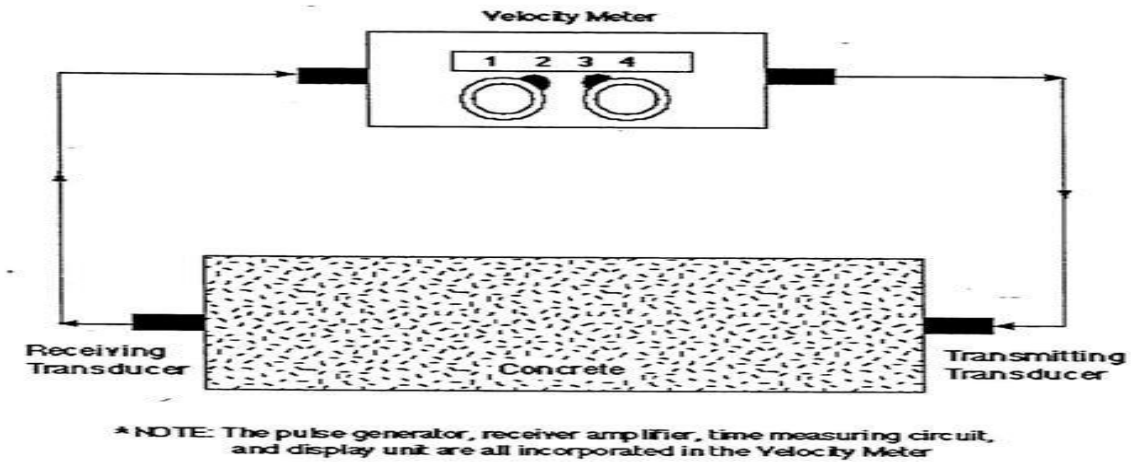


**Fig.-2 Ultrasonic Pulse Velocity (UPV) test**

**3.2.1.3 Penetration Resistance ('Windsor Probe' and 'PNR Tester')**

This technique offers a means of determining relative strengths of concrete in the same structure or relative strength of different structures. Because of the nature of equipment, it can not, and should not be expected to yield absolute values of strength. '**Windsor Probe'**, as commercially known, is penetration resistance measurement equipment, which consists of a gun powder actuated driver, hardened alloy rod probe, loaded cartridges, a depth gauge and other related accessories.

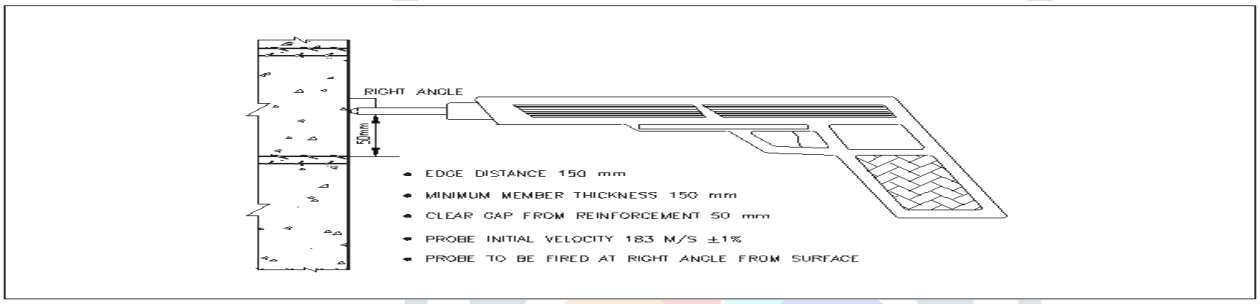


**Fig 03 Penetration Resistance Test**

**3.2.1.4 Pullout (LOK) Test**

The fundamental principle behind pull out testing with LOK-test and CAPO test is that test equipment designed to a specific geometry will produce results (pull-out forces) that closely correlate to the compressive strength of concrete. This correlation is achieved by measuring the force required to pull a steel disc or ring, embedded in fresh concrete, against a circular counter pressure placed on the concrete surface concentric with the disc/ring.

Pull out tests are used to:

a. Determine in-situ compressive strength of the concrete.
b. Ascertain the strength of concrete for carrying out post- tensioning operations.
c. Determine the time for removal of forms and shores based on actual in-situ strength of the structure.
d. Terminate curing based on in-situ strength of the structure.

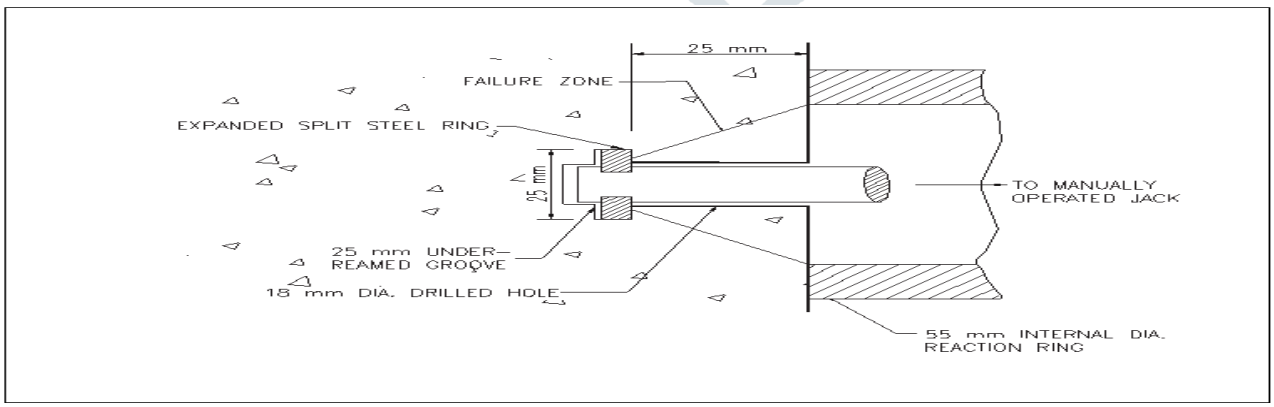


**Fig 04 Pullout (LOK) Test**

**3.2.1.5 Core Sampling and Testing**

A direct assessment of strength can be made by core sampling and testing. Cores are usually cut by means of a rotary cutting tool with diamond bits. In this manner, a cylindrical specimen is obtained, usually with its ends being uneven, parallel and square and sometimes with embedded pieces of reinforcement. The cores are visually described and photographed, giving specific attention to compaction, distribution of aggregate, presence of steel etc. The core should then be soaked in water, capped with molten sulpher to

make its ends plane, parallel, at right angle and then tested in compression in a moist condition as per BS 1881: Part 4: 1970 or ASTM C 42-77. The core samples can also be used for the following:

- Strength and density determination
- Depth of carbonation of concrete
- Chemical analysis
- Water/gas permeability
- Petrographic analysis
- ASHTO Chloride permeability test

Following are the factors, which affect the compressive strength of extracted concrete cores:

- Size of Stone Aggregate
- Presence of transverse reinforcing Steel
- Height/Diameter Ratio
- Age of Concrete
- Strength of Concrete
- Drilling Operations
- Site Conditions

**3.2.2 Chemical Tests:**

Chemical analysis of concrete can provide extremely useful information regarding the cause of causes of failure of concrete.The tests most frequently carried out are listed below:

**3.2.3 Corrosion Potential Assessment:**

1. Cover-Meter/ Non-destructive method for measuring Profo-meter Thickness of cover concrete (In-situ Test) - Reinforcement diameter - Reinforcement spacing.
2. Half Cell Method
3. Resistivity Measurement
4. Permeability
5. Initial Surface An indicator of surface permeability

**3.2.4 Fire Damage Assessment:**

1. Differential Thermal Assessment of qualitative & quantitative Analysis(DTA)(Lab Test) composition of sample of concrete
2. 2. X-ray Diffraction
3. To determine the extent of deterioration(XRD)(Lab Test) in concrete subjected to fire

**3.2.5 Structural Integrity/Soundness Assessment**

1. Radiography:
2. Impact-echo test:
3. Dynamic Testing of Structures:

**1.2.6 Interpretation and Evaluation of Test Result Data**

Establishing the problem, the probable causes and factors influencing the deterioration requires careful studies and analysis of the information gathered in the investigation stage which should be tabulated on a specific proforma to be prepared depending on the type of test data, information available for analysis.

It is essential that all possible factors be noted during an investigation, so that unusual features of the environment or the concrete can be identified and the necessary solution sought.

## 4. RESULTS AND DESCUSSIONS

**Case Study : 1 A Double Storied Load Bearing Residential Building at Panvel India**

**Sailent Features**

- Year of Construction : 1965
- Investigation done : 1998
- Types of structure : Double Storied Load Bearing structure
- Types of foundations : Spread footings
- Numbers of Quarters : 44

**Visual Observations**

- Extensive cracking and spalling of concrete in sunshades, chajja, staircase and beams etc.
- At some place reinforcement was exposed and corroded heavily .
- Major cracking observed on plastering on all faces.
- Severe seepage seen in most of the roof slab and external walls.
- Waist – slab of staircase and soffit of beams exhibited delamination over 50%

**In-Situ Evaluation and Non-Destructive Tests**

**Delam Survey**

Every column and beam was tapped by three different types of hammers .Most effective was the medium hammer . which gave , delams for 15 to 25mm depth. The hollow sound was recorded as hallow and the results of each structural member recorded on to observation sheet **.**

**Rebound Hammer Test**

- The rebound numbers measured on concrete surface Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its not feasible for this case study .

**Ultrasonic Pulse Velocity Test**

- Values of pules velocity varied in the range of from3.0 km/sec to 4.8km/sec.
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its feasible for this case study .

**Carbonation Test**

- Carbonation has taken place beyond the reinforcement level .
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its feasible for this case study.

**Case Study : 2 A Seven Storied R.C.C Residential Building at karjat India**

**Sailent Features**

- Year of Construction : 1969
- Investigation done : 2001
- Types of structure : Seven Storied R.C.C Residential Building
- Types of foundations : Spread footings
- Numbers of Quarters : 32

**Visual Observations**

- Extensive cracking and spalling of concrete in sunshades, chajja, staircase and beams . columns , balcony etc.
- At some place reinforcement was exposed and corroded heavily .
- Major cracking observed on plastering on all faces.
- Severe seepage seen in most of the roof slab and external walls.
- Waist – slab of staircase and soffit of beams exhibited delamination over 30%
- Major cracking observed on R.C.C structures like columns , beams , balcony slab etc.

**In-Situ Evaluation and Non-Destructive Tests**

**Delam Survey**

Every column, beama and slab was tapped by three different types of hammers .Most effective was the medium hammer . which gave , delams for 10 to 15mm depth. The hollow sound was recorded as hallow and the results of each structural member recorded on to observation sheet **.**

**Rebound Hammer Test**

- The rebound numbers measured on concrete surface .
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its feasible for this case study .

**Ultrasonic Pulse Velocity Test**

- Values of pules velocity varied in the range of from4.0 km/sec to5.6km/sec.
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its not feasible for this case study .

**Carbonation Test**

- Carbonation has taken place beyond the reinforcement level .
- Cost of test is low .

- Solution of problem is not life time .
- Adaptability is easily .
- Its feasible for this case study .

**Pullout (LOK) Test**

- Deermine in-situ compressive strength of concrete ..
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily .
- Its feasible for this case study .

**Core Sampling and Testing**

Strength and density determination of concrete.

**Case Study :3 A 4th Storied R.C.C commercial building at khopoli India**

**Sailent Features**

- Year of Construction : 1982
- Investigation done : 2005
- Types of structure : A 4th Storied R.C.C commercial building
- Types of foundations : Spread footings
- Numbers of shopes : 65

**Visual Observations**

- Extensive cracking and spalling of concrete in sunshades, chajja, staircase and beams . columns , balcony like verandas etc.
- At some place reinforcement was exposed and corroded heavily .
- Major cracking observed on plastering on all faces.
- Severe seepage seen in most of the roof slab and external walls.
- Waist – slab of staircase and soffit of beams exhibited delamination over 30%.
- Major cracking observed on R.C.C structures like columns , beams , verandas slab etc.

**In-Situ Evaluation and Non-Destructive Tests**

**Delam Survey**

Every column, beama and slab was tapped by three different types of hammers .Most effective was the medium hammer . which gave , delams for 10 to 12mm depth. The hollow sound was recorded as hallow and the results of each structural member recorded on to observation sheet

**Rebound Hammer Test**

- The rebound numbers measured on concrete surface .
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily ..
- Its feasible for this case study .

**Ultrasonic Pulse Velocity Test**

- Values of pules velocity varied in the range of from4.0 km/sec to 5.2km/sec.
- Cost of test is high.
- Solution of problem is not life time .
- Adaptability is easily.
- Its not feasible for this case study .

**Carbonation Test**

- Carbonation has taken place beyond the reinforcement level Cost of test is high
- Solution of problem is not life time.
- Adaptability is easily .
- Its feasible for this case study .

**Pullout (LOK) Test**

- Deermine in-situ compressive strength of concrete .
- Cost of test is high .
- Solution of problem is not life time .
- Adaptability is easily.
- Its feasible for this case study.

**Core Sampling and Testing**

- Strength and density determination of concrete. Cost of test is high .
- Solution of problem is not life time.
- Adaptability is easily .
- Its not feasible for this case study .

## CONCLUSIONS

Rehabilitation of structures embroils contribution of high end technology, advanced skills and calculations. This is avery 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 recommnded for age-old buildings showing signs of decent and save human lives from failure. This paper provides comprensive 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 papers delivers its usefulness to those who as an objective of doing Repair and Rehabilitation of civil sructures .

## REFERENCES

1) Wael W. El-Dakhakhni1, 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

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)

3) Prof. Dr.D.K.Kulkarni., Mr. Teke Sudhakar. S. Health Assessment Of ReinforcedConcrete Structures - A Case Study, (IOSR-JMCE) ISSN: 2278-1684, PP: 37-

4) M. J. Monteiro, Prof. N. J. Pathak, Structural Soundness of Buildings, IJESE V. 04, No 06 SPL, October 2011, pp. 677-680. The authors are describing two NDT's and two

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:

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, 13th SGEM Geo-Conference, ISSN 1314-2704, June 16-22, 2013, 555 - 562 pp. The authors

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

8) Bhattacharya Shubhamoy, Nayak Sanket, Datta Sekhar Chandra, (IJDRR, V-7, March 14) A critical review of retrofitting methods for unreinforced masonry structures.

9) Arya Anand S., Agarwal Ankush, (dumb dia.nic.in) Simple Retrofitting Details for Improving Earthquake Resistance of Brick Masonry Buildings in NCT of Delhi .

10) Alpa Seth, 2) Sudhir K. Jain,3) THIRUPPUGAZH V. Earthquake Capacity Building.

9) Sachin Rambhau Shelke “Structural Health Monitoring and Audit, Repair and Rehabilitation of Building in Construction Industry” International Journal of Recent Research in Science, Engineering and Technology Vol. 4, Issue 3, March 2018

10) Vivek Kumar Yadav “Repairs And Rehabilitation of R.C.C. Structures by Fiber Reinforced Plastic- A Review” ISSN: 2277-9655 [Yadav* Et Al., 8(2): February, 2019]

11) Ankur Gupta “‘A Case Study’ On Repair Rehabilitation & Retrofitting of RC Framed Structure” International Journal of Innovative Research in Science, Engineering and Technology (A High Impact Factor, Monthly, Peer Reviewed Journal) Visit: www.ijirset.com Vol. 6, Issue 11, November 2017

12) Manish Kumar “Structural Rehabilitation, Retrofitting and Strengthening of Reinforced Concrete Structures” World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:10, No:1, 2016

13) Rohit Newale” Structural Audit, Repair and Rehabilitation of Building” International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Website: www.ijirset.com Vol. 6, Issue 3, March 2017

14) J. Bhattacharjee “Repair, Rehabilitation &Retrofitting Of RCC for Sustainable Development with Case Studies” Civil Engineering and Urban Planning: An International Journal (CiVEJ) Vol.3, No.2, June 2016.