

# Structural Audit and Repair of Commercial Building

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**Abstract :** Structural Audit is an overall health and performance medical examination of a building like a doctor examines a patient. It ensures that the building and its premises are safe and don't have any risk. It analyses and suggests acceptable repairs and retrofitting measures needed for the buildings to perform better in its service life. The project is to detect the faults and the problems which are likely to cause threat to the building structure. The visual inspection is done to detect the visual cracks in columns, beams, slabs and walls of any sign of deterioration. The other methods are Destructive and Non-destructive testing method (NDT). In this project we are auditing the structure by Non-destructive testing method, in which it includes Rebound hammer test, Ultra sonic pulse velocity test and Half-cell test; in Ultra sonic test we performed it for columns C1, C2, C3, etc. After examining the defects and faults of the structure, we have to prevent for deterioration with special repairing methods. The method used in our project for repairing are Grouting for filling up the cracks, slab strengthening by micro concrete, jacketing for beams and column, waterproofing of terrace slab and plastering work for walls. Different suitable materials were used for different methods of repairing such as micro concrete which is one type of non-shrinkage material used as concrete in strength of slab and jacketing, cement mortar (1:6) for plastering, etc. Therefore the above methods are used and reading of NDT are carried out before and after repair for better understanding of change in strength after repair. Also the estimated material cost for repairing work is calculated.

**IndexTerms – Non-destructive testing, Grouting, jacketing.**

## I. INTRODUCTION

**Structural Audit:** The life cycle of a building can be broadly divided into four phases i.e. architectural planning, structural design, construction and maintenance in most of the building. The life of the building plays an important role the architectural planning, structural planning and construction are the stages which are primary stages and all possible care is taken during the execution. The secondary stage that is maintenance of the structure is least considered. Maintenance of the structure increases the healthy life of the building. The first structural audit was presented by the Indian Structural Engineers. From the year 1975 the construction industry has been set up and the growth of the infrastructural has been increased. Due to the increase in the population and the people migrating from the village to the cities has increased the population in metropolitan cities and with the limited space available therefore the height of the building has to be increased and the number of people living in this building is more than its actual design consideration. Due to this the load on structural is increased and the settlement of the building takes place. Due low quality of construction material, improper construction technique the failure of building is increased.

**Repair:** It is the technical aspect of rehabilitation. Refers to modification of a structure partly or wholly which is damaged in appearance or serviceability. In other words, to put something that is damaged, broken, or not working correctly, back into good condition or make it work again. Poor design, poor construction, poor maintenance, incorrect usage, new environmental influences or an intended increase of the loading or extension of the structure's lifespan can make repair and/or strengthening necessary. The main purpose of repairs is to bring back the architectural form of the building so all services begin operating and therefore the functioning of building is resumed quickly. The objective of any repair ought to be to provide rehabilitation – which implies a repair applied comparatively low price, with a restricted and inevitable degree of amendment with time and without premature deterioration and/or distress throughout its intended life and purpose. To achieve this goal, it is necessary to consider the factors affecting the durability of a repaired structural system as part of a whole, or a component of composite system.

## II. OBJECTIVE

The objectives of Repair in building are:

- To restore it back to its original standards.
- To improve the facilities depending upon the development that is taking place in the building.
- To improve the aesthetical appearance to the structure.
- To increase the strength of the structural member.
- Life of the building structure increases.

## III. LITERATURE REVIEW

P.C. Sharma et.al, studied a Dome Of Church which is situated at Delhi. They carried out the structurally audit, repair and restoration. Some silent features of the structure are as follows: Period of construction- 1835, investigation carried out in 1996-17, Type of construction- Brick masonry dome structure in lime surkhi mortar with embedded steel section at horizontal bands at few locations in the dome. Visual observation were taken which consists of extensive spelling of plaster in soffits of the outer most dome, cracks on soffits of the outer most dome along the construction joints and along the vertical, ribs, few bricks have fallen out from horizontal and vertical joints exposing the embedded steel. The geometry of the dome was determined using WILD T100 Electronic theodolite. Rebound hammer test were performed and the average compressive strength were assessed. The Core test of both bricks and mortar were taken to evaluate the properties like compressive strength, water adsorption and density. The core

test revealed the compressive strength of the masonry was 3.20 MPa which shows that the bricks are generally not affected strength wise.

Sophiya Sunny Pulickal et.al, prepared a safety audit on MS Excel and 19 major elements were selected for the study. The audit was implemented in SSH International, Kuwait. For the collection of data for the audit, physical checks/inspections were done. Safety engineers, safety officers and others involved in addressing the safety at the workplace were contacted. Safety records, safety logs, safety registers, minutes of safety meetings, etc. were assessed. The factors that could affect the health and safety of the workers at the site were then ranked based on their criticality. The audit score for the consultancy was 79%. Out of the 19 audits elements, 6 elements were ranked as the primary and secondary causes of accidents. The improper usage of the following 6 elements could affect the Health and the safety of the construction personnel at the aforementioned construction site. The six elements were the following: Amenities/Sanitation, Electrical Works, Excavations, Tools and equipment, Fire protection and hot works, and Personal Protective Equipment's (PPE's). The practical implication of the audit is that the actual work-site conditions could be taken into account through the audit, and based on the happenings at the work-site, suggestive measures could be given.

Girish Joshi et.al, has taken into consideration Structural Audit, Repair & Rehabilitation of an RCC G+4 building at Pune. The age of building is 24 years, which was constructed in Aug 1987 and has been effected by weathering effect. The condition survey of the building was carried out which include an examination of concrete for identifying and defining area of distress. Condition survey included the following stages i.e., preliminary inspection, planning, visual inspection & field and laboratory testing. Further visual inspection of site has been carried out which include any observations of cracks, spelling, seepage etc. and are noted. Technical test carried out on different RCC structures by Ultrasonic pulse velocity. The reading were recorded which were evaluated further for remedial measures.

Kalpesh R. Kolhe, et.al, performed the case study related to Assessment of Damaged building by Retrofitting on Thane Municipal Corporation School and Scottish chemical Industries, Mumbai. Retrofitting of damaged buildings is upgrading the seismic resistance of existing buildings so that they become safer under the occurrence of probable future earthquake. The study is done by analyzing the data from previous research studies from various national and international journals and research papers. Damages are identified by actual site visit and survey from visual observation and verifying the structural development plan by actual construction. By proper retrofitting techniques, appropriate solutions were provided to the problems, which were caused due to the damage of the building. Arrived to necessary suggestions and recommendations for effective application of repair and retrofitting techniques.

Abhinandan Kale1 et.al, carried out Structural Audit on an educational building in Pune. Various methodology and investigation are done includes Virtual inspection as follows Any settlement in the foundation, Detect dampness in wall, Visual cracks in columns, beams, slab and walls. Any sign of material deterioration and the various addition and alteration made. On site at Sant. Tukaram Maharaj Vidyalay School at Pune, NDT test was carried out i.e., rebound hammer test. The repair should be carried out as per the standard procedure mentioned in their respective code. The maintenance work should be carefully carried out as per mentioned. The present status of the building is satisfactory. The restoration work for the building will require major repairs for the structural members which could prove dangerous as well as very costly. In spite of this remaining member of the building needs major upgradation.

Basit Bashir Dar et.al, considered a building in Kupwara district, Jammu and Kashmir for audit. The building is G+4 having no. of apartment 12 and was constructed in 1987. 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, the Structural audit, repair and restoration of this building become mandatory. Whereas for structural auditing different NDT method like rebound hammer test and ultra sonic pulse velocity test were carried out and the data and results is analyzed accordingly. After NDT, the data was collected and distress in RCC member was due to following reasons: Inadequate thickness of cover concrete, highly permeable and porous concrete and Carbonation of concrete. Most distressed portions were chajjas along with lintel/beam, which is directly exposed to marine atmosphere and frequent alternate wetting and drying. Seepage observed in roof slab was due to leakage from pipe line.

#### IV. METHODOLOGY

To check the health of the structural, the structural audit is performed and to do so the following procedure was carried out:

- a) Study of architectural and structural drawings, design criteria, design calculations, structural stability certificate of the existing structure.
- b) If architectural and structural drawings are not available, these drawings should be prepared by an engineer.
- c) Visual Inspection of structure to be investigated.
- d) Various NDTs were performed and the defects were located to overcome the problems.
- e) Various structural members were repaired by using different repairing techniques.
- f) The cost required for repairing using micro concreting was calculated.
- g) The strength of repaired members was investigated again by using NDTs.

##### 1. Rebound Hammer Test:

The method of using the hammer is explained. With the hammer pushed arduous against the concrete, the body is allowed to move far from the concrete till the latch connects the hammer mass to the plunger. The plunger is then held perpendicular to the concrete surface and also the body pushed towards the concrete. The hammer will be utilized in the horizontal, vertically overhead or vertically downward positions similarly as at any intermediate angle provided the hammer to the surface. The position of the mass relative to the vertical, however, affects the rebound number due to the action of gravity on the mass in the

hammer. This movement extends the spring holding the mass to the body. When the utmost extension of the spring is reached, the latch releases and the mass are pulled towards the surface by the spring. The mass hits the shoulder of the plunger rod and rebounds as a result of the rod is pushed arduous against the concrete. During rebound the slide indicator travels with the hammer mass and stops at the maximum distance the mass reaches when rebounding. A button on the side of the body is pushed to lock the plunger into the retracted position and the rebound number is read from a scale on the body. Maximum distance the mass reaches after rebounding. A button on the side of the body is pushed to lock the plunger into the retracted position and the rebound number is read from a scale on the body.

## 2. Ultrasonic Pulse Velocity Test:

UPV methods can be considered as one of most promising methods for evaluation the concrete structures once it makes possible an examination of material homogeneity. The tests can also be used to explore the relation between the concrete qualities with the compressive strength. The main plan is to explore the actual fact that ultrasonic speed waves are a perform of the fabric density, which is correlated with the compressive strength. The relation isn't invariably trustworthy once there are plenty of variables that have an effect on the concrete strength like the water/cement quantitative relation, the size and type of aggregate, the molding procedure, the specimen size and the cement type. A pulse of longitudinal vibrations is produced y an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the electrical device employing a liquid coupling material like grease or cellulose paste, it undergoes multiple reflections at the boundaries of the various material phases inside the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to achieve the receiving electrical device are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic temporal arrangement circuits change the transit time T of the pulse to be measured. Longitudinal pulse velocity (in km/s or m/s) is given by:

$$V = L/T$$

where,

V is the longitudinal pulse velocity,

L is the path length;

T is the time taken by the pulse to traverse that length.

Sr. No.	Pulse Velocity (Km/s)	Concrete Quality
1	> 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	< 3.0	Doubtful

## 3. Half Cell Test:

The instrument measures the potential and therefore the electric resistance between the reinforcement and also the surface to evaluate the corrosion activity as well as the actual condition of the quilt layer throughout testing. The electrical activity of the steel reinforcement and also the concrete leads them to be consider collectively half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell measure derives from the actual fact that the one half the battery cell is taken into account to be the steel reinforcing bar and therefore the encompassing concrete. The electrical potential of the surface of steel reinforcing bar is measured with a copper sulphate reference conductor on the surface. Practically, this is achieved by connecting a wire from one terminal of a meter to the reinforcement and another wire to the sulphate reference conductor. Then typically readings taken are at grid of one x one m for slabs, walls and at 0.5 m c/c for Column, beams.

Member	Probability Of Corrosion	No. of Readings
Stilt Floor	-190	10%
Stilt Floor	-200	10%

Tests conducted	Purpose	No. Of points tested
Half-cell potential test	Determining the probability of corrosion in the embedded steel	2

### Stages of Repair:

Repair of concrete structure is carried out in the following stages:

- Removal of damaged concrete.
- Pre treatment of surfaces and reinforcement.
- Application of repair materials.
- Restoring the integrity of individual sections and strengthening of structure as a whole.

#### a) Removal of damaged concrete:

- Prior to the execution of any repair, one essential and common requirement is that the deteriorated or damaged concrete should be removed.
- Removal of defective concrete can be carried out using tools and equipment the types of which depend on the damage.
- Normally, removal of concrete are often accomplished by hand tools, or when that is impractical because of the extent of repair, it can be done with a light or medium weight power hammer fitted with a spade formed bit.
- Care should be taken not to damage the unaffected concrete portions. For cracks and other minor defects, a saw-toothed bit will help achieve sharp edges and a suitable under cut.

**b) Pre treatment of surfaces and reinforcement:**

- Complete removal of unsound material.
- Undercutting along with the formation of smooth edges. Removal of the cracks from the surface.
- Formation of a well defined cavity geometry with rounded inside corners.
- Providing, rough but uniform surface for repair.

The cleaning of all loose particles and oil and dirt out of the cavity should be carried out shortly before the repair. This cleaning can be achieved by blowing with compressed air, hosing with water, acid etching, wire brushing, scarifying or a combination. Brooms or brushes will facilitate to get rid of loose material.

**c) Application of repair materials:**

- After the concrete surface has been prepared, a bonding coat should be applied to the entire cleaned exposed surface.
- It should be done with minimum delay.
- The bonding coat may consist of bonding agents such as cement slurry, cement sand mortar, epoxy, epoxy mortar, resin materials etc.
- Adequate preparation of surface and good workmanship are the ingredients of efficient and economical repairs.

**d) Repair procedure:**

The repair of cracked or damaged structure is discussed under two distinct categories, namely ordinary or conventional procedures. A repair procedure could also be chosen to accomplish one or the other of the subsequent objective:

- To extend strength or restore load carrying capability.
- To restore or increase stiffness.
- To improve functional performance.
- To provide water tightness.
- To improve appearance of concrete surface.
- To improve durability.
- To stop access of corrosive materials to reinforcement.

**V. RESULTS****SITE INVESTIGATION:**

Name of Building: Sahil Hotel

Location: Khar West, Mumbai

Type of structure: G+1 RCC Building

Uses: Commercial

Floor investigated: 1st floor



Photo.5.1: Sahil Hotel

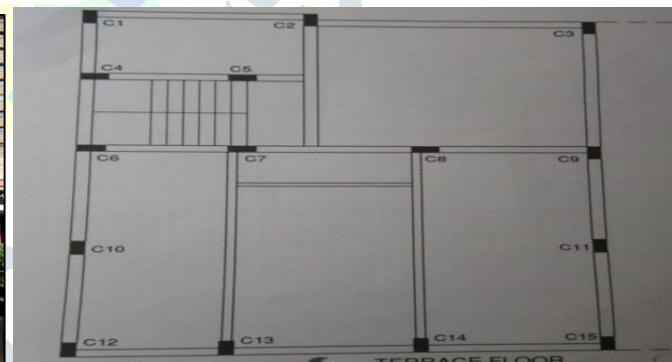
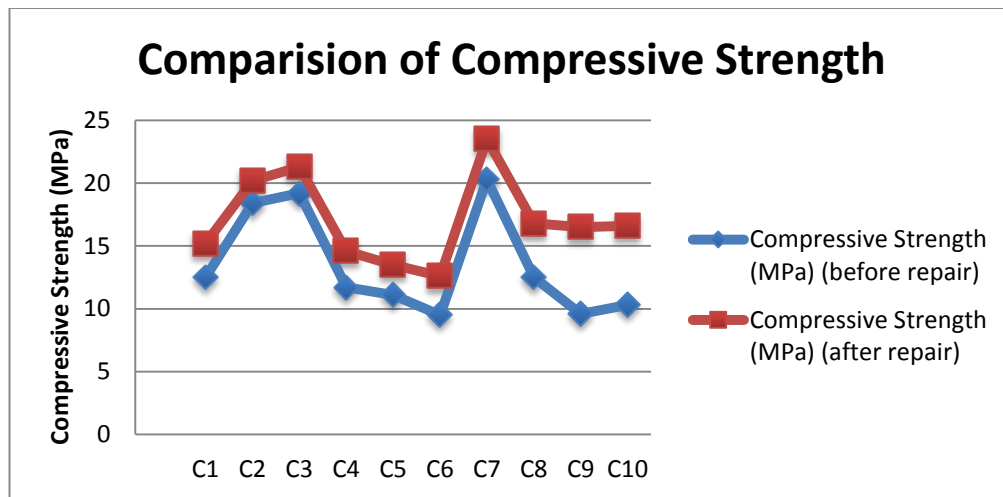
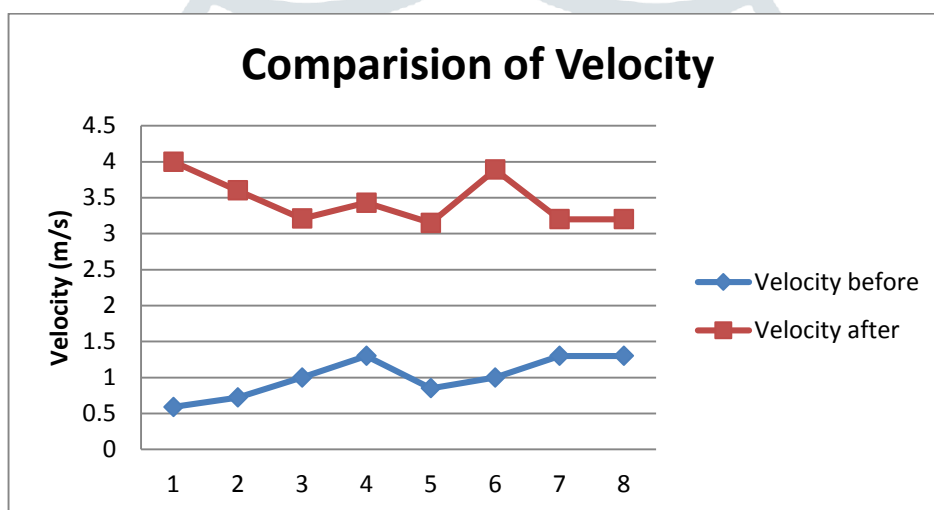


Fig 5.1: Building Plan

1. Rebound Hammer Test



2. Ultrasonic Pulse Velocity Test



3. Half Cell Test

Range	Probability Of Corrosion	No. Of Readings
Below -200 Mv	10%	1
-200 To -350 Mv	50%	1
Above -350 Mv	90%	0

VI. CONCLUSION

The structural member and non-structural member of site Sahil Hotel, Khar(W) Mumbai which is a G+1 structure was deteriorated with atmospheric agencies such as rain and wind. Structure like slab of Room 2 & 3 also fails in deflection due to overloading at terrace & due to lack of timely maintenance. By the above investigation survey, we have come to know that the structure health condition was inferior. After conducting NDT, we have concluded that the structural member or components are suffering from class 2 damage. Therefore principal repair works have been carried out to avoid further deterioration of the structures.

The repair work done on 1st floor and terrace are strengthening of column, plastering works of defected areas and water proofing, etc. Also rectifications of leakage have done in various locations at top. After repairing of structural and non structural member, the NDT was performed again to check the performance/strength of the structure against the loading conditions. Hence we conclude that the major repairing of the 1st floor and terrace of Sahil Hotel is done and the building will serve for atleast 25 years without any major defects in structural members. Therefore the structure has been repaired and restored to its original working condition.

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