

# Seismic Analysis Using NDT Techniques a Case Study on Commercial Building, Mumbai

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**Abstract**— Tata press building is a G+ 3 story structure located at Prabhadevi, Mumbai. This building was constructed in 1970's. Earlier the building was used as a printing press and now as a Head office for ICICI Lombard. The structure has a flat slab system with internal circular columns and rectangular column beam frame arrangement on the periphery. This building was reaching its design life and was observed to be heavily distressed. Structural audits and other tests were carried out to know the actual condition of the building. The building is currently undergoing repairs.

This study aims at estimating the total amount of distresses in the building, in depth knowledge of the tests carried out to understand the condition of structural members, interpretation of the results, methodology of repairs suggested to increase the strength and durability of the building. Remedial measures, additions and alterations to be made in the building to make it structurally sound and making sure it fulfills the criteria of latest IS codes for seismic behavior.

Pre repair and post repair analysis using Etabs. A structural model based on the inputs and test results is developed in Etabs for predicting the seismic behavior of the building. Various repair and retrofitting methods are discussed in this study and the best suited ones were used for the repair works. The methods suggested are easy, simple economically feasible and efficient. A comparative study of behavior of building before repairs and post repairs is also presented in this paper.

**Keywords**— Repair; Retrofitting; NDT; Seismic Analysis

## INTRODUCTION

Reinforced Concrete Has Been Used As A Construction Material Since A Century. For The Past 50 To 60 Years Reinforced Concrete Is Being Widely Used In India. We Have Been Extensively Using Concrete For The Construction Of Buildings, Stadiums, Bridges As Infrastructural Assets. Keeping Them In Working Condition And Maintaining Their Functionality Is Need Of The Hour.

Unlike Other Materials Even Concrete Undergoes Deterioration And It Is Considered To Be A Natural Phenomenon. And This Phenomenon Is Generally Due To Chemical Attack, Alkali Aggregate Reaction, Embedded Metals, Due To Overloading, Fire Or Seismic Forces.

This deterioration may also arise because of its use, time and expired its design life and may require rehab and repair. Also 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 structural elements. Inadequate performance of this type of structures is a major concern from public safety standpoint.

These reasons of deteriorations DUE TO DESIGN ERROR AND AGEING and detailing can be reanalyzed. The entire process is divided into 3R's repair, rehabilitation and retrofitting. Terms Repair, Rehabilitation and Retrofitting are explained in brief below:

### A. Repair:

Repair deals with the architectural aspects of the building and its functionality. Its main purpose is to make services working as early as possible. However repair does not deal with the structural strength parameters nor has a role in strengthening of structural members. Hence considering its durability is important and has been discussed in further chapter.

### B. Rehabilitation

Rehabilitation of a structure involves the upgrading or changing of purpose of, its use, design goals or regulatory requirements. Rehabilitation is cheaper for improvements in building than demolishing or reconstructing a new building in the space available.

### C. Retrofitting:

The engineering which involves in modifying the existing buildings for structural behavior without hampering its basic intent of use is termed as retrofitting. It is necessary to improve the performance of structures facing loss of strength due to degradation or which have crossed their anticipated lifespan. The realization of retrofitting depends on the authentic causes and measures adopted to prevent its further deterioration. This development includes retrofit, repair, reconstruction and renovation wherever required. A proper load path has to be analyzed by a structural engineer and a decision has to be taken if any additional member like shear walls, etc needs to be added.

#### Origin of Deterioration:

1. Drying Shrinkage
2. Temperature stresses
3. Absorption of moisture by concrete
4. Corrosion of reinforcement.
5. Aggressive action of chemical
6. Weathering action
7. Poor design or Errors in design
8. Errors in earlier repairs
9. Overloading
10. External influences such as earthquake, wind, fire, cyclones etc.

#### D. Repair Methodologies

The decision on method of repair can be taken only after economical and technical evaluations considering the likely service life after repairs. After the preliminary investigations, evaluation of extent of distress is done a proper repair methodology is to be developed. This methodology should include available methods of repair and materials for repair works. Following are the type of repair methodologies which are commonly used.

- Grouting or crack repair.  
Firstly the holes are drilled in structure in line of cracks and also around hollow spots. These holes can be staggered for long length of cracks. Hole spacing can be modified as per site requirements. G.I. pipes (12to20mm diax200mm) with PVC nozzles or one end threaded are fixed in the holes with rich cement mortar. All the cracks around pipes are sealed with cement mortar
- Cleaning and passivating of corroded steel reinforcement.  
Corroded steel reinforcement can be cleaned by using a wire brush which can be a mechanical wire brush or hand used. The reinforcement can also be cleaned with sand blasting
- Patch repairs.  
Firstly the damaged part of unsound concrete is removed by light tapping. The dirt, oil or grease if any is cleaned out. The part to be repaired is scrubbed with stiff bristle brush. The surface to be repaired is cleaned with water and dried. Then the patch mortar is applied (this patch mortar is available in various types and the best suit can be used)
- Polymer treatment.  
This method of repair is similar to that of patch repairs. In polymer treatment method a special type of concrete is used which consists of polymers such as resins etc.
- Water proofing  
Waterproofing is a similar process as like normal new waterproofing. But during the repair works the old waterproofing layers are removed and the surface is cleaned and made ready for new layer of waterproofing. Generally the waterproofing has a life of 10 years the process of waterproofing has to repeat.
- Shotcrete  
Shotcrete method consists of two process i.e dry process and wet process. In the dry process the cement and moist aggregate are mixed and then placed into the device and sprayed. The water wets the other ingredients

as the mixture is jetted from the nozzle at high velocity on the surface which is to be shotcrete. In the wet-mix process, all raw materials are first mixed to produce mortar or concrete. The mortar or concrete is then placed into device. The material is forced through a delivery hose to the nozzle where compressed air is injected to increase velocity.

- RCC Jacketing.

RCC jacketing is one of the prominent methods used to increase the stiffness of the member. Increase in stiffness further facilitates increase in the strength of the member. If columns in a building are slender then jacketing prevents buckling of members. Repair work and design for strengthening are based on interaction between new and old work. Plate bonding and jacketing are common methods for strengthening of structural members.

- Fiber wrap Technique.

Although reinforced concrete and masonry buildings are being constructed worldwide, there are large numbers of concrete structures that deteriorate and become unsafe. In most of the the cases the buildings designed as load bearings ones cannot resist the seismic forces and can lead to hazardous circumstances and distress in members. The use of advanced composite fibre-wrap is the new technique in the emerging market of structural rehabilitation industry. There are various types of fibres used viz : glass, aramid and carbon. This process is carried out by preparing surface, applying primer, applying saturant and then laying of sheets. This is one of the safe, easy and inexpensive methods of repair.

#### E. Case Study

ICICI Lombard occupies building commonly known as Tata Press Building off Veer Savarkar Marg, Prabhadevi. The is a Ground + 3 storied, RCC framed structure. The original Tata Press building is a G+ 3 industrial building and is aged more than 50 years. The ramp, elevator was added to access terrace slab for parking in 2012. The building is showing severe distress at various locations.

The false ceiling was opened as part of planned renovations of ground and first floor. Distress in slabs was observed and there was a local collapse of cover concrete of first floor ceiling. These incidents initiated requirement of complete structural audit of the building. As part of statutory requirements, it is necessary to conduct structural audit of buildings (15 years and above) every five years and every 3 years for buildings whose age is 30 years or more. The mode of construction of the building is cast in situ RCC flat slab supported on column heads.

The RCC beams are provided only at periphery. The internal columns are mainly circular columns. The structural audit was conducted by physical verification and light tapping of the concrete members. The visual inspection for the audit was carried out. The Nondestructive tests were carried out. UPSV, Rebound hammer, carbonation, Half-cell potentiometer and core tests.

#### F. Methodology

- Firstly the reconnaissance survey was made to get a rough idea about the distress in the building.
- It was observed that a large amount of slabs were covered with false ceilings and hence noting the visual observations was restricted.
- After vacating the entire building the false floor and ceilings were removed.
- A detailed report of the structural audit was made and the building was observed to be heavily damaged.
- In the structural audit report a few Non Destructive tests were suggested to know the severity of distress.
- The Non-destructive tests carried out were UPSV, Rebound hammer, carbonation, Half-cell potentiometer and core tests.
- After analyzing the test results the average strength of the concrete was found which was lesser than the mix design at the time of casting.
- An Etabs model was made considering the present strength of concrete and as per the physical dimensions of beams and columns.
- The model was analyzed for earthquake and wind forces.
- The repair methodology was decided based upon the model results and visual observations.
- Post repair nondestructive tests were performed to check the achieved strength after repair works.
- An Etabs model of achieved strength of concrete was made along with the alterations of structural members made in the repair process. This model was checked to see if the desired results and structural safety of the structure was achieved.

#### G. Discussions

- It has been observed that nondestructive tests help a lot in evaluating the present condition of the building although the results vary by 15 to 20 %.
- Using software for analysis of structure for the achieved concrete strengths facilitates the ease in assessment of the effects of distress on the structural behavior.
- Post repair NDT helps in understanding whether the desired strengths are achieved and also in estimating the extended design life.

- Software analysis helps in assessing seismic behavior of the building and in deciding the retrofitting methods.
- Repairs should always be done for the type of the usage of a building.
- More economical, easy and efficient repair methodologies are to be discovered for cutting down the repair time and also to nullify the probability of vacating the place for repair works.
- Such studies help in understanding the concrete properties, types of distress, structural behavior in distressed condition, wear and tear of structural members under various loads, Repair methodologies and selection of materials, Behavior of building under seismic loads and retrofitting options for the same, Interpretation of NDT results.

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