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Structural Audit of an Old Building

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ABSTRACT

In India there are infinite old structures that are at the verge of damages. There are many buildings which have reduced their strength due to time passes, due to deterioration of concrete from structural element, due to development of cracks. The structure is a combination of load carrying members, damages in members cause failure of structure and it is harmful for living beings. To prevent old structure from failure the technique is adopted know as Non-Destructive Testing (NDT). With the help of non-destructive testing auditing of an old structure is get easier. NDT examine the total health of an infrastructure in order to check strength and stability of building. NDT is a bunch of various testing consist of Ultrasonic pulse velocity test (UPV), Rebound hammer test (RHT), Half-cell test, etc. Conducting NDT on building and analyzing testing result decide to repair building as per IS code, technique like grouting, Retrofitting, etc. to increase strength and stability of building. In this project structural has to be done on old structure which is situated at Nagpur. Audit done by NDT consist of Ultra-sonic pulse velocity test, Rebound hammer test, Half-cell test. After analyzing all test result including visual inspection it is found that structure need to repair and retrofitted to make it safe and stable for all static loadings. Column jacketing also provide to structure.

1. INTRODUCTION

A civil infrastructure is a model of linked, associated element that form together a system which can carry the external loads on it. As time goes structure get older and lessen its strength due to unpredictable load on it, deterioration of materials or physical damages. Use structure with this defect it may cause dangerous loss of property and livings as well. That's why we have to maintain and scrutinize structure to prevent structure from future damage. To control this problem a structural audit, have to do after 15 or 20 years to know the condition of building and materials used. Structural audit ensure that the building is guarded and haven't dangerous. Structural audit consists of testing like Ultrasonic pulse velocity test, rebound hammer test, pH test, etc. from this test result come to know the quality of concrete, strength of concrete and condition of reinforcement. According to this we can strengthening and modify structural element to regain its capacity and withstand longer. Use of structural auditing in future can help in limiting damages to structure and life as well. This paper covers the study and type of tests conduct for structural Auditing of an old structure.

2. OBJECTIVE OF PROJECT

- To assess the condition of existing building with the help of NDT.
- To find the Critical areas which need repairs, rehabilitations and retrofitting etc.
- To suggest corrective and preventive remedial measures along with specifications for repairs, rehabilitation & retrofitting the structure.
- To analyse the structure using software (Staad Pro).
- To save human lives and life of structure.

3. METHOD USED FOR ANALYSIS-

Study of Architectural and Structural Drawings, Designs Criteria of Existing Structure

- Visual Inspection
- Non-Destructive Testing
    - Ultrasonic pulse Velocity
    - Rebound Hammer Test
    - Core Sampling and Testing
    - Cover Meter
- Preparation of Structural Assessment and Audit Report
- Post Structural Assessment and Audit
- Repairs and Strengthening of the Structure etc.
- Retesting of the Existing Structure after Repairs and Strengthening with Non-Destructive Testing.

4. TOOLS

- **Tools used for visual inspection**
  - **Magnifying Glass**: With the help of Magnifying glasses, we can observe Surface Texture, Cracks, Crack Width and corrosion effect on magnifying scale to get magnified view of deteriorations.
  - **Measuring Steel Tape**: When the dimensions are not available due to unavailability of drawings, we can use the steel tape to take measurement of structural components.
  - **Bar Detector**: Bar detector is used to measure the cover and spacing of reinforcement in structural element.
  - Digital Camera: Digital camera is used to record the distressed location in structure. It is very useful to detect the R.C.C. defects, plaster cracks, pipe damages, tree growth, water seepage, algae growth, paint discoloration etc.
  - **Recording Sheets and Sketches for Site Use:** All the measurement should be record on the sheets along with sketch of building plan. Drawing should be prepared to locate the defects in the building along with specific legend. The detail investigation was carried out on different member of the structure and we have observed Reinforcement exposed at various locations, corrosion, major cracks, minor cracks, honeycombing, deterioration of concrete etc. the documentation of damage concrete members have been shown as follows.
- **REBOUND HAMMER TEST (As per IS 13311 part II: 1992)**
  For testing concrete device has been developed on rebound principled which measure rebound height of diamond hammer. To perform the test plunger is extended from the body of instrument, which causes a latch mechanism to grab hold of hammer. The body of instrument is then pushed towards the Concrete surface. The combination of gravity and spring forces, propel the hammer. The rebound distance is measured on a scale by the slide indicator. The rebound distance is expressed as a rebound number, which is percentage of the initial extension of the spring.
- **ULTRASONIC PULSE VELOCITY TEST (As per IS 13311 part I: 1992)**
  The ultrasonic pulse velocity measurement technique involves determination of velocity of ultrasonic pulse through solid material. The velocity of these pulses depends upon the density and elastic properties of the material. The quality of some materials is sometimes related to their elastic stiffness so that measurement of ultrasonic pulse velocity in such material can often be used to indicate their quality as well as to determine their elastic properties
- **HALF CELL POTENTIOMETER TEST**
  Half-cell potentiometer test is used to indicate the probability of corrosion activity associated with steel which is embedded in concrete. The copper/ copper sulphate or silver/silver chloride electrode are used for half-cell. The measurement consists of by making direct electrical connection to the reinforcing bar. Half-cell makes electrical contact with concrete by means of porous plug and sponge. One end of wire is connected to steel reinforcement (positive connection) and other end is connected to the standard electrode (Negative connection). If the bar is corroded the electron would tends to flow from bar to the half-cell. The readings are noted as seen on voltmeter. More negative value indicated higher is the bar corrosion. Half-cell does not measure the rate of corrosion it gives an idea of probable corrosion. This method is mostly used to assess the durability of reinforce concrete member where the reinforcement corrosion suspected.
- **MODELLING AND DESIGNING**

  ❖ **DESIGN OF R.C.C. COLUMN JACKETING**

  STEP 1]

  The details of existing column:
  Column Size = 230x450mm
  Grade of concrete = M15 (As per Rebound Hammer Graph)
  Grade of steel = Fe-415 N/mm^2
  Load on column = 1450 KN

  STEP 2]

  Calculation of load carrying capacity of existing column
  Pu = 0.4 x fck x Ac + 0.67 x fy x Asc
  Pu = 0.4 x 15 x 230 x 450 + 0.67 x 415 x (π/4x12^{2}x8) -- (Assume)
  Pu = 0.4 x 15 x 230 x 450 + 0.67 x 415 x 905
  Pu = 872KN [87.2 T.]

STEP 3]
Actual Load coming on column
Pa = 145.0 T.
Net load for column jacketing
Pj = Pa – Pu
Pj = 145.0-87.2
Pj = 57.8 T.

STEP 4]
According to the provisions provided in 8.5.1.2 (a) IS 15988:2013, Concrete strength shall be at least 5 Mpa greater than the strength of existing concrete
Thus, taking fck = 25 N/mm^2
fy = Fe-500 N/mm^2
And assuming Asc = 0.8 % Ac
PJ = 0.4 x fck x Acj + 0.67 x fy x 0.8% Asj
57.8x10^{4}x1.5 = 0.4 x 25 x Acj + 0.67 x 500 x 0.008 x Acj
57.8x10^{4}x1.5 = 12.68 Acj
Acj = 68375.39 mm^2
According to IS 15988:2013
Acj = (3/2) x A'cj
Acj = (3/2) x 68375.39
Acj(req) = 102563.08 mm^2

STEP 5]
Minimum jacket thickness shall be 100mm as per 8.5.1.2.c of IS 15988:2013
But assume 125mm thickness of jacket
Thus, the new size of column:
As per IS 15988:2013- 8.5.1.2 minimum B = 230+125+125 = 480mm
D = 450+125+125 = 700mm
Ac (provided) = (480 x 700) – (230 x 450)
Ac (provided) = 232500mm^2
Thus, Ac (provided) > Ac (req) - - - - (Hence OK)
Asj = 0.8% Ac
Asj = 0.008 x 232500
Asj = 1860mm^2
But According to IS 15988:2013
As = (4/3)A's
As = (4/3) x 1860
As = 2480mm^2
Assuming 16mm dia. Bars
Thus, No. of bars = Asj / As
As = π/4 x (16)^2
As = 201 mm^2
Thus, No. bars = 2480 / 201 = 12.33 nos. say = 14 Nos.
Thus, provide 14 nos.16ø vertical bars for jacketing.

STEP 6]
Design for stirrups
diameter of stirrups shall be 8mm and not less than one third of longitudinal bar diameter.
Diameter of bar = 1/3x16 = 6mm
Thus, take 8mm ø stirrups for jacketing
Spacing of stirrups is given by

$$S = \frac{fy \times d^2h}{\sqrt{fck} \times tj}$$

where, dh = diameter of stirrups & tj = Thickness of jacketing

$$S = \frac{500 \times 8^2}{\sqrt{25} \times 125}$$

S = 51.2mm
But as per IS 15988:2013 (8.5.1.2)
The spacing of ties shall not exceed the thickness of jacket or 200mm whichever is less.

Therefore, provide 125mm spacing.
Thus, provide 8mm ø@125mm c/c spacing of stirrups.

STEP 7]

Design of shear connectors
Load taken by old column = 145.0 T.
Balance load to be taken by jacketing = 57.8 T.
Neglecting shear stress taken by old and new concrete bond
Total shear force taken by shear connectors.
No. of shear connectors = Load taken for jacketing / Shear taken by one connector
Therefore, assume 12mmø bar for shear connector
Ast = $\pi/4 \times 122 = 113$ mm^2
0.45 x fy x Ast = 0.45 x 500 x 113
= 25425 N
= 25425 / 10^4
= 2.54 T.
Therefore, No. of shear connectors = $\frac{57.8}{2.54}$ = 22.63 nos. say = 24Nos.
Existing column height = 3.0m.
Therefore, spacing of shear connector by deducting beam depth = 2550/ 6 = 425 mm c/c Thus, provide 4 Nos.12ø shear connectors @425 mm c/c at each face of column.

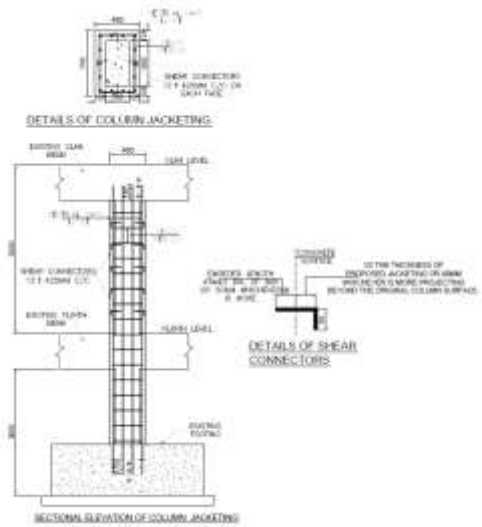


Fig.: R.C.C. Details of Column Jacketing

❖ STAAD PRO DESIGN MODEL

This chapter discusses the modelling details of residential old building using staad pro software

Dead Loads (IS-875 Part-I)

Dead load includes all permanent loads acting on structure compressing the roof, floor, and wall and foundation systems, including cladding, finishes and fixed equipment's. Dead load is the total load of all component of building that generally do not change over time. In software assignment of dead load automatically done by assign the property of the member. In load case we have the option of self-weight automatically calculate using the properties of material i.e., density. In this project following loads are taken under dead loads.

Slab Weight Calculations:
Self -weight of slab = Density of concrete x Thickness of slab
= 25x0.125
= 3.125 kN/m2
Floor Finish at Floor = 1.0 kN/m2
Total Slab weight at floor level = 4.125 kN/m2
Wall load Calculations:

Weight of wall = Thickness of wall x Height of wall x Density of Brick wall
For 230mm = 0.23 x (3.0-0.45) x 20 = 11.73 kN/m
For 115mm = 0.115 x (3.0-0.45) x 20 = 5.86 kN/m
Weight of Parapet wall = 0.115 x 1.0 x 20 = 2.3 kN/m

Live Loads (IS-875 Part-II)

Live loads are depending upon the use and occupancy of a building. Loads includes those from human occupants, furnishings, no fixed equipment, storage and construction and maintenance activities. In STAAD we assign the live load in terms of U.D.L. We have to create a load case for Live Load and select all the beams to carry such load. In this project the live load considered 2.0 kN/m2 After assigning the primary loads and generated load combination of loads are assigned. Table shows the loads and loads combinations assigned to the structure.

Type	L/C	Name
Primary	1	DL
Primary	2	LL
Combination	3	DL+LL
Combination	4	1.5(DL+LL)

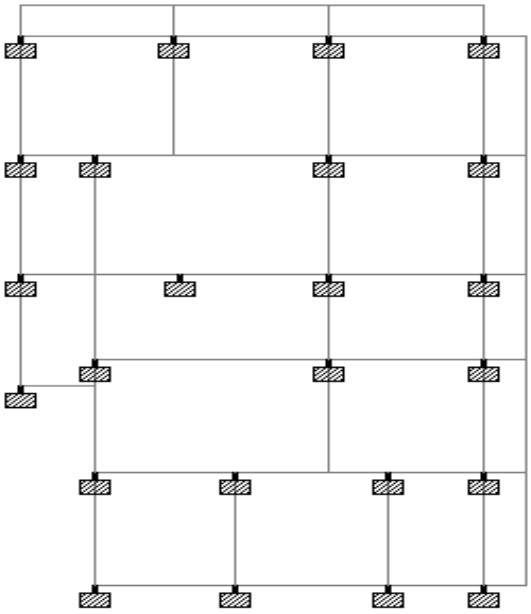


Fig.- Staad Model- Plan View

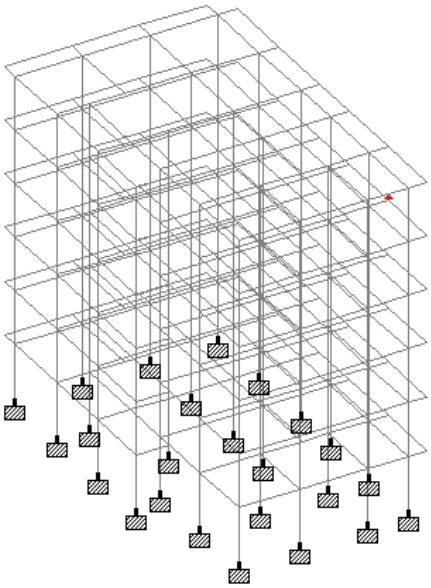
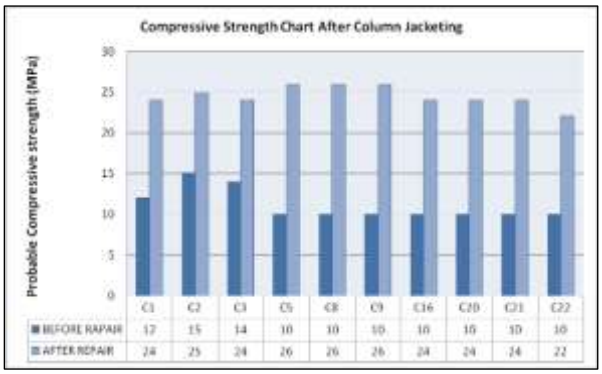


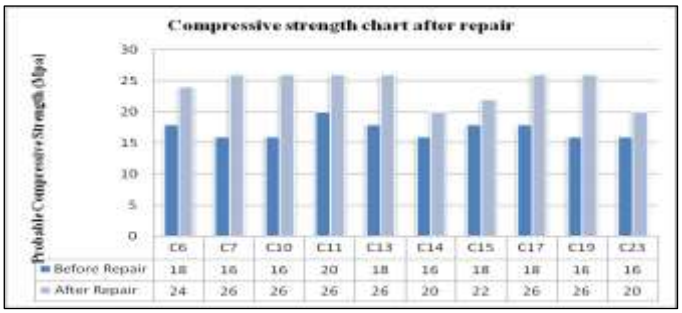
Fig. -Staad Model

5. GRAPHICAL REPRESENTATION OF RESULTS BEFORE AND AFTER NDT TESTING

5.1 Rebound Hammer Test Result

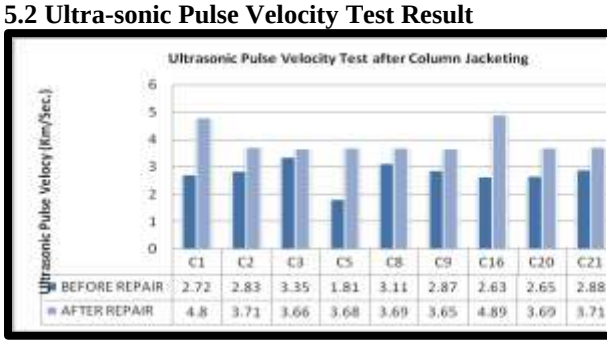


Graph 1: Comparison of Compressive Strength with Rebound

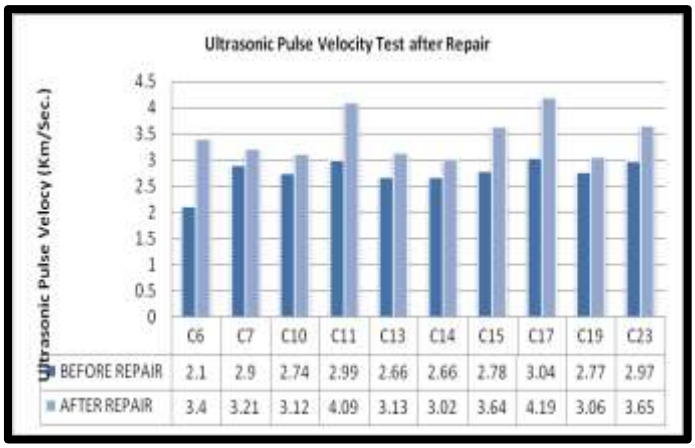


Graph 2: Comparison of Compressive Strength with Rebound

5.2 Ultra-sonic Pulse Velocity Test Result



Graph 3: Ultrasonic Pulse Velocity Test Result



Graph 4: Comparison Ultrasonic Pulse Velocity Test Result

6. CONCLUSION

- Based on NDT results, Analysis and Design following conclusions are made:
- The original grade of concrete was 20 N/mm2. Due to carbonation effect and age of concrete strength is reduced. While conducting visual inspection on existing structure we found major cracks in columns, reinforcement exposed on various locations of columns, honeycombing and seepage, deterioration of concrete observed on maximum locations. They are repaired by using epoxy grouting and micro fine cement grouting with epoxy bonding agent, polymer repair and micro concrete.
- Rebound Hammer test & Ultrasonic pulse velocity test have been performed to check the quality and compressive strength of concrete and it is found in doubtful condition at maximum locations before strengthening and found in good and excellent condition after strengthening at maximum locations.
- Half-cell potentiometer test carried out to check the probable corrosion in reinforcement and sever corrosion observed at most of the locations of columns.
- As per the pH test and depth of carbonation test it is observed that carbonation observed on various columns and pH of concrete cover is reduced and passive layer over reinforcement is not intact.
- Based on above all Non-Destructive test results it is observed that columns at ground floor are damaged and load carrying capacity is reduced. Hence, we had strengthened corresponding weak and damaged columns with R.C.C. jacketing as per methodology and specifications given.
- After repair and retrofitting of the structure retesting such as Rebound hammer test and Ultrasonic pulse velocity test have been performed to check the strength of concrete and as per the results the existing structure is safe for all static loadings.

7. FUTURE SCOPE

- Design of Jacketing for various Thickness and comparison of them.
- Comparison of different type of jacketing such as Steel Plate jacketing and R.C.C. Jacketing for same load and condition of building.
- Carbon wrapping is also the essential tool for strengthening.
- Study of repaired material used to strengthen the structure.
- Study of Effect of carbonation on concrete structure.

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