Repair and Rehabilitation of an Institutional Building: A Case Study

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Abstract - *Structures have a certain service life. This life depends on various provisions. But due to various factors like ageing, leakage, fire, chemical attacks, carbon from the air, faulty design, etc., the service life is reduced. Also, both steel and concrete are adversely affected. Hence, it is necessary to inspect the condition of these structures from time to time. The purpose of paper is to present various tests carried during structural audit as well as to justify the advanced materials and method of repair and rehabilitation of old structures subjected to deterioration due to corrosion.*

Key Words: **Structural audit, rehabilitation, corrosion, repairs, CFRP laminates.**

1. INTRODUCTION

In India, there are numerous old structures which have decreased its quality because of common and man-made conditions, however the future utilization of such decayed structure is proceeded. It might threaten people and creatures. So suitable activity should be actualized to improve the exhibition of structure and re-establish the ideal capacity of structure. Subsequently convenient Structural Auditing of such sort of structures is important to know the condition of structures just as fixes/recovery to re-establish the quality when exposed to harm. The requirement for Repair and Rehabilitation of structures incorporates different standards relying on the kind of harm happened in the structures. These incorporate spalling of structural members, settlement, spalling of non-structural elements, spillages in the structure, updating of existing structure for extra powers and changed utilitarian necessities.
C. B. Shah School is considered as a contextual investigation for repair and rehabilitation. The site is situated in Ratansinghnagar, Sangli. The structure is developed in 1970's. This paper identifies with different parameters of structural audit and flexibility of the strategy rehabilitation of members subjected to corrosion, therefore giving clear and point by point data in regards to the repair method for the particular problem incurred in the structure.

2. STRUCTURAL AUDIT

Structural audit is a procedure to assess the condition of building to ensure the safety of the occupants. It helps in identifying the members of the building that need immediate repairs. The School building was 50 years old. According to the Bye- Laws No. 77, the structure should have a structural audit once in 3 years, for buildings ageing more than 30 years. Therefore, a regular checking was mandatory. Thus, the structural audit was carried out by licensed government consultants.

2.1 Causes of structural audit

[1] Deterioration of members
[2] Seepage from the top floor
[3] Spalling of concrete
[4] Exposed reinforcement
[5] Moss formation
[6] Flexural cracks

2.2 Non-Destructive tests

The strength and quality of the structural components can be determined by use of Non- Destructive tests and Destructive tests. There are various instruments available to determine at what extent the damage has been caused to the components.

A] Half- Cell Potential Test

This test determines the possibility of corrosion occurring in the member. Results are based on Copper-sulfate electrode, used as reference electrode. ASTM C876 provides a guideline on measurement of potential values.

Table -1: Relationship between the potential values and probability of corrosion

Measured Potential (mV CSE)	Probability of steel corrosion
>-200	Lesser than 10% (Initial Phase)
-200 to -350	10% to 90% (Transit Phase)
<-350	Greater than 90% (Final Phase)

Table -2: Observations of Half-Cell test

Sr. No.	Description	Potential Value (mV)	Remark
1	Beam - 01	-250	Transit Phase
2	Beam - 02	-220	Transit Phase

B] Ultrasonic Pulse Velocity Test

This method is considered as one of the most efficient method to examine the homogeneity of the concrete. UPV is determined using following relation,

$$V = L/T$$

where,
V = Pulse Velocity in longitudinal direction
L = Path Length in mm
T = Time taken to travel the length

Table -3: Observations of Ultrasonic Pulse Velocity Test

Beam No.	Method of transmis-sion	Path length [mm]	T (μs)	Pulse Velocity (kmps)	Concrete Quality
Beam 01	Direct	260	77	3.37	Medium
Beam 02	Direct	250	78	3.20	Medium

C] Rebound Hammer Test

This test is taken to measure the surface hardness of the concrete. The test procedure was carried according to guidelines provided in IS 13311:1992 (Part II).

Table -4: Observations of Rebound Hammer Test

Sr. No.	Description	Strength (N/mm^2)
1.	Beam - 01	19.50
2.	Beam - 02	24

2.3 Partially Destructive Tests

A] Carbonation Depth Test

This test determines the depth of carbonation in concrete. The depth of carbonation is estimated by the change in color profile. Carbonation of concrete is a process through which the carbon dioxide from the air penetrates into the concrete and reacts with calcium carbonates. In the presence of moisture, CO_2 changes into dilute carbonic acid which attacks the steel and increases the acidity of the concrete, thus leading to corrosion of embedded steel.
In this test, phenolphthalein solution is used as indicator. Carbonation depth is accessed when solution is sprayed on core and concrete appears to be colorless indicating carbonation in concrete.

Fig -1: Carbonation test sample of Beam 02

Table -5: Observations of Carbonation Depth test

Sr. No	Description	Carbonation Depth (mm)
1.	Beam - 01	07
2.	Beam – 02	05

B] Core test

To accurately determine the compressive strength and to inspect interior of concrete, core test is carried out. Core shall be prepared and tested according to IS 516. The core diameter should not be less than the three times the maximum size of aggregate. H/D ratio should be within 0.95 to 2. Greater H/D ratio will lead in reduction of strength.

Fig -2: Core sample of Beam 01

Table -6: Observations of Core test

Sr. No	Description	Equivalent cube strength (MPa)
1.	Beam - 01	15.00
2.	Beam - 02	18.55

2.4 Outcomes from Structural Audit

[1] Corrosion of reinforcement due to seepage of water.
[2] Percentage of corrosion is greater than 10%.
[3] Concrete grade loss.
[4] Rehabilitation is necessary wherever required.

3. REHABILITATION OF STRUCTURE

It was observed that, corrosion is the root cause of damage. When corrosion is initiated, oxygen demand is increased in the embedded steel. Then the corroded steel tries to gain oxygen by pushing the concrete nearby, leading to spalling of the concrete. During this procedure the diameter of the bar is increased in the form of rust layer. Therefore, this corrosion process should be stopped as soon as possible before neck formation and then to sudden failure of bar. It is advised that, the structure should be rehabilitated when the bar increases its diameter more than 10% in form of rust, Also, preventive measures should be adopted to stop the corrosion, when the half-cell potential values are in transit phase before they enter in to final phase of corrosion.
Procedure adopted for repair and rehabilitation is as follows:

[1] Cover concrete was removed up to reinforcement.
[2] Rust remover, SP Rustclean was applied to the corroded steel to remove the corroded portions of the steel and to stop the further process of corrosion.
[3] Potholes and spalled areas were filled with repair mortar, SP Durocon 49. SP Durocon 49 has strength up to 40 N/mm2 at 28 days of curing.
[4] Beams were applied with Carbon Fibre Reinforced Polymer (CFRP) laminates to increase the flexural strength and stiffness of the member.
[5] For proper anchoring of the laminates, U shape CFRP wraps were provided.

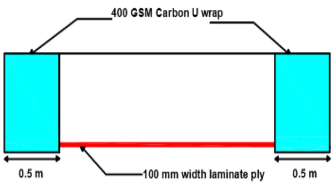

Fig -3: Side view of strengthening diagram

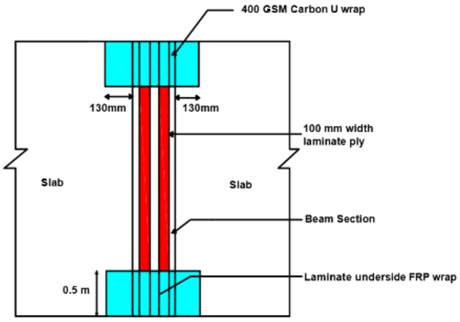

Fig -4: Bottom view of strengthening diagram

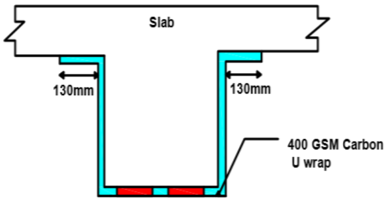

Fig -5: Front view of strengthening diagram

Fig -6: After strengthening

3. CONCLUSIONS

Repair and rehabilitation of structures is necessary to avoid abrupt failure. Timely maintenance of structures should be worked out in order to maintain the safety and structural integrity of old buildings. Repairs are costly and thus repairs and rehabilitation should be done with identifying the root cause of the damage. In the case study, various tests on damaged beam have been conducted to determine the quality of the material. These tests proved the deterioration of concrete. Also, corrosion of steel was confirmed as the potential values of beam lied in between -200 mV to -350 mV. These values indicate that the probability of corrosion was up to 90%. Thus for repair and rehabilitation due to corrosion, method described above can be utilized.

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