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Rehabilitation of RCC Frame Building: Case Study of School Building AT Bhimora

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Abstract: The purpose of rehabilitation is providing the deteriorated strength of existing structural member. The present study is focused on the rehabilitation of an existing school building, finding deficiencies, providing appropriate rehabilitation and obtaining performance of a rehabilitated RCC Building. G+1 RCC school is considered a case study for Rehabilitation. Rebound hammer test and Ultrasonic pulse wave test is performed as a part of primary inspection of school building. It helps to ensure the deficiency structural members. Other aim of this work is to understand various structural damages and their remedial measures of that deterioration. As per the recent strength of member's suitable method will be suggested for various deteriorated structural member. After identifying structural member, suitable rehabilitation method will be adopted. For experimental work, one RC beam is cast and it will be wrapped with FRP (Fiber Reinforced Plastic) to know it will gain the original strength of concrete or not.

Keywords: building, rehabilitation, structural deterioration, NDT Testing, RCC structure

I. INTRODUCTION

As the time passes strength of concrete will be reduced due to corrosion, carbonation, alkali acid attack, earthquake, and different environmental condition. Structure can be deteriorated due to various reasons like quality of concrete ingredient, poor workmanship, poor maintenance, structural design problems, various loadings acting on structure. For structural strength improvement, it is essential to get an idea about the reasons of distress. According to these reasons and amount of deterioration most appropriate strength improvement technique will be adopted. To overcome these damages, repair, rehabilitation and retrofitting are the different methods for structural health improvement.

Present work is focused on rehabilitation of RCC frame building. For finding current condition of concrete and recent strength of concrete Non Destructive test is conducted. As per the results of NDT testing and visual inspection of building appropriate rehabilitation method will be adopted for various deterioration of building.

In present study, L. M. Vora Uttarbuniyadi vidhyalay Kanya chhatralay At. Bhimora, near chotila, is selected as case study site. This government school building was constructed in 1982.

II. CONCEPTS OF REPAIR, REHABILITATION, AND RETROFITTING

- 1) *Repair:* This is process to regain the architectural shape of building to resume the functioning of building as it functions at the time of construction. Repair does not effect to structural strength but only improvement in outer surface of building member. For achieving the goals of repairing, it is essential to consider the several factors distressing the building member.
- 2) *Rehabilitation:* Structural rehabilitation is to upgrading deteriorated strength of building member up to its original strength. It is found in study almost in the all cases structural strength improvement by rehabilitation is always cheaper than the demolishing and construction of new building of same attributes.
- 3) *Retrofitting:* Retrofitting is the process in which structure is newly designed for new purpose. It is necessary to improve the performance of structure due to deterioration or which have crossed their estimated lifespan. Retrofitting is also termed as reconstruction.

III. STEPS OF REHABILITATION

A. Preliminary Vulnerability Study

- 1) School building is situated on hard rocky soil strata.
- 2) This school building is G+1 RCC framed building situated on column footing.
- 3) About 200 students are living and studying under this school building
- 4) So many cracks on exterior wall of the building, cracks at the lintel level of building on first floor of building.
- 5) Many chajjias are deteriorated due to weathering of concrete and corrosion of concrete.
- 6) Main steel in Slab is corroded and due to this corrosion slab starts deflection.

- 7) Beam have flexural crack of 2mm at the first floor
- 8) Lintel level beam over the window is deteriorated and steel dia is reduced to 5 mm dia due to corrosion of the steel.
- 9) About 80% chhajjas have problem spalling of concrete.

According to the results of this Preliminary study, we can decide further repair or rehabilitation work process.

B. Determination of Causes of the damage of components

For the various deterioration of structural members, it is important to find the root cause for the damage. It's too easy and safe to rehabilitate the building after finding the real cause of the damage.

- 1) There is one structural crack in beam due to overloading on member
- 2) There are Corrosion of steel at lintel level due to Corrosion of steel at lintel level
- 3) Almost all the outer walls have weathering effect and permeability problem, hence plaster will be deteriorated.
- 4) All the reinforcement corrosion problems have the same reason is carbonation

C. Detailed Investigation

Here Non- Destructive testing methods are used for evaluation of structural members. NDT is favorable because this will measure recent strength of existing building without causing damage and also this will not take too much time for testing of the structure.

1) Rebound Hammer Test

Schmidt rebound hammer is works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. There is a theoretical relationship concrete strength and rebound number of hammer. Columns and beams was tested for measuring the strength of the member.



Figure 1 Rebound hammer Test apparatus

Table 1 Rebound Hammer test Result

Rebound Value	Number of Readings (In %)
0-10	0
0 – 20	16
20 – 30	76
Above 30	8

Table 2 Interpretation of Rebound Value

Average Rebound Value	Quality of Concrete
0-10	Very Poor
10 – 20	Poor
20 – 30	Fair
Above 30	Good

As the result shows 76% members have fair strength. Hence repairing is required.

- a) *Ultrasonic pulse Velocity test:* Direct method and indirect method are used here for UPV testing. To reduce reflection at the boundaries grease used as liquid coupling material. According to elastic modulus and concrete strength, ultrasonic pulse velocity is influenced. The results of UPV testing are as following:

Table 3 UPV Test Result

Pulse Velocity (km/s)	Number of Readings (In %)
0.0-1.0	4
1.0 – 2.0	88
2.0 – 3.0	4
3.0 – 4.0	4

Table 4 Interpretation of UPV Value

Pulse Velocity	Number of Readings (In %)
Below 3.0	Doubt Full
3.0 -3.5	Medium
3.5 - 4.5	Good
Above 4.5	Excellent

As the result shows 88% members have doubt quality of Concrete.

- b) *Rebar Locator*: Rebar locator is equipment which is to find reinforcement spacing, diameter, clear cover in concrete member. 16mm dia bar is found throughout all columns and beams. at some places diameter of bar is increased to 20mm due to corrosion of bar.

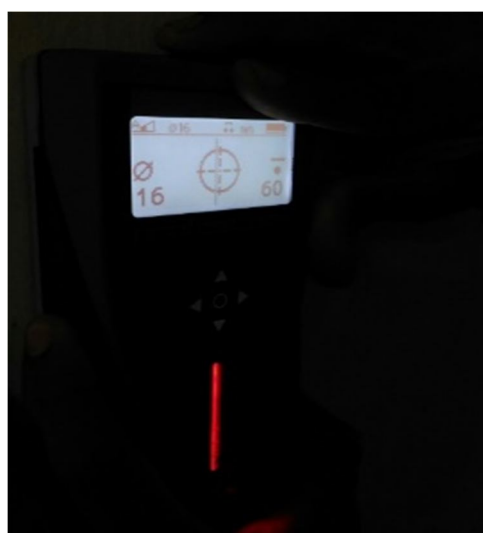


Figure 2 Rebar Locator Test Apparatus

- c) *Carbonation Test*: Carbonation refers to reaction between carbon dioxide and alkalis in pore solution of the cement paste. As a result, the pH of the pore solution decrease and this will also decrease the passive coating on reinforcing steel. In present study, we have tested the place where corrosion is occurred in concrete member. At almost all the deteriorated members are gives positives result of carbonation test. It becomes colorless at all the places.

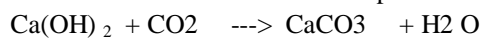


Figure 3 Phenolphthalein liquid used for carbonation test



Figure 4 Concret remains colourless



IV. EXPERIMENTAL WORK

Experimental work has been conducted to accomplish the objective of this research work. At the primary stage, a beam of size 230mm x 300mm x 2000mm was cast of M-20 concrete grade.

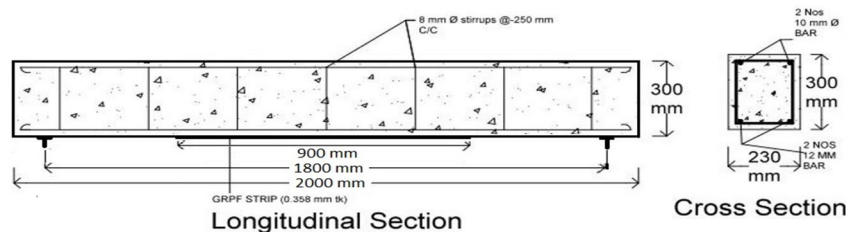


Figure 5 Beam Configuration



Figure 6 Steel Arrangement

Test of beam was carried out in our laboratory. Testing arrangement is shown in figure.



Figure 7 Crack Pattern after loading

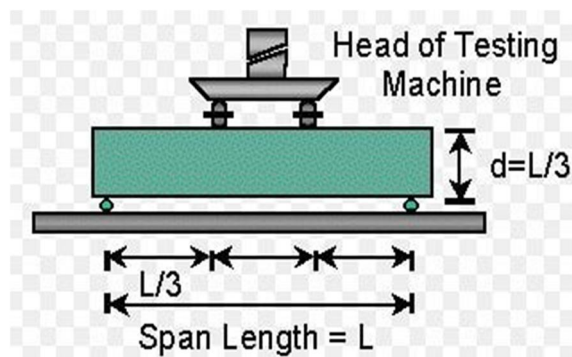


Figure 8 Two Point Load Testing Arrangement

Two point loads were applied on beam of 2m through hydraulic jack of capacity 1000KN. A dial Gauge is provided to measuring middle span deflection while applying load.

Grade of concrete	Design load (In KN)	Experimental load (In KN)
M – 20	50 KN	68

Then beam was wrapped by 0.358mm thick GRPF sheet. 900mm long GRPF sheet was attached at the bottom side of the beam. Redwoop Flexoplus material is used as adhesive material for wrapping of beam. Wrapped beam been cured for 24 hours at room temperature.



Figure 9 Loading Arrangement



Figure 10 Crack Pattern after Loading

Grade of concrete	Design load (In KN)	Experimental load (In KN)
M – 20 (wrapped)	62.5	81.6

As the result shows strength of the beam is increased 20% compared to simple RCC beam.

V. REPAIR STRATEGY

The following approach is adopted for rehabilitation of building.

- 1) Removal of deteriorated plaster /concrete.
- 2) Removal of corrosion on steel reinforcement by mechanical and chemical action (also provide new steel reinforcement) and further use of corrosion Inhibitor material.
- 3) Use of bond coat of acrylic polymer – cement mix to make proper bond between old and new concrete or mortar.
- 4) Repair of RCC columns, beams, slabs by polymer modified rich mortar.
- 5) Jacketing of columns with rich concrete if required.
- 6) FRP wrapping for increase strength
- 7) Crack sealing in masonry walls with polymer modified rich mortar.
- 8) Re-plaster and acrylic paint on exterior wall.
- 9) *Repair procedure:*

The repair of structural member was carried out as follows,

A. Removal of deteriorated plaster/ concrete

At the areas, where plaster/ concrete cover had spalled down e.g. Exterior wall, slab, soffit of beam, column corners and loose concrete material should be removed. The beams and slabs were supported with props before removing of deteriorated concrete. All dust and loose particles resulting from such pretreatment was removed by washing with water under pressure.

B. Removal of corrosion on steel reinforcement

Corrosion on steel should be removed first by light hammering and manual chipping. If steel corroded more than the half of the diameter of rod, then entire steel reinforcement should be replaced with new reinforcement bar of same diameter. Then one coat of rust remover was applied all around the steel rebar.

C. Use of bond coat of acrylic polymer

All surfaces prior to application of bond coat was thoroughly inspected and made free from any deleterious materials such as oil, dust, dirt etc. Use of bond coat of acrylic polymer will make proper bond between old concrete and new concrete.

D. Repair of RCC columns, beams, slabs by polymer modified rich mortar

The building was originally constructed with M-20 with minimum strength requirement of 20 N/mm². So for repairing work rich polymer modified mortar have compressive strength of minimum 25 N/mm². So that it can withstand all weathering conditions and provide proper cover to old concrete.

E. Jacketing of columns with rich concrete

Main aim of Jacketing is to increase section modulus by increasing size of the element. Columns were jacketed with new rebar and jacketing with concrete is about 75mm all around to increase its strength and stiffness and to protect reinforcement from further corrosion

F. FRP wrapping for strengthening of beam and columns

Cracks can be generated Due to design errors, overloading then design load and deterioration by weathering action. So cracks and deflection of members can be prevented by wrapping on member. Glass fiber wrapping and carbon fiber wrapping are the method according to material used for wrapping. Different wrapping pattern and method is used as per the strength requirement.

G. Crack sealing in masonry walls with polymer modified rich mortar

Before starting repairing treatment, it is necessary to remove loose dust, mortar, and concrete by wire brush. The plasticized expanding grout admixtures along with Styrene Butadiene Rubber (SBR) polymer was used for sealing of masonry wall cracks.

H. Re-plaster and acrylic paint on exterior wall

To prevent further deterioration and weathering effect re-plastering is used for slab, parapet, exterior walls. For re-plastering of member rich quality cement mortar with acrylic paint is used.

VI. DISCUSSION

TYPE OF DAMAGE	TESTING / RVS	TENTATIVE CAUSES OF DAMAGE	REMEADY	MARERIAL SPECIFICATION
External walls (W1-8, W8-15, W1-2, W2-3, W4-5, W5-6, W6-7, W15-22, W30-31, W31-32, W34-35)	RVS	Weathering effect, water permeability, efflorescence	Remove deteriorated mortar, replace damaged member (if required), plaster with good quality mortar	Plaster with rich mortar (C:S = 1:3) and REDWOOP BUTABOND SBR mixture
Bending in beam	RVS	less reinforcement, higher load,	Wrapping by Carbon Fiber reinforced plastic	Wrap FRP by using epoxy putty to fill small surface voids and make bond between concrete and wrapping material or use extra MS FLAT or I Sec.
corrosion of steel at Chhajja	RVS, Carbonation Test	carbonation of concrete, weathering effect	remove rust from steel, remove loose concrete, replace reinforcement (if required), Re-concrete with rich material	For mortar use C:S = 1:3 and use higher grade of concrete with more workability with mixing of REDWOOP BUTABOND SBR, Use Sikka CNI for protection against corrosion
Corrosion of steel and falling of concrete at beam	RVS, Carbonation test	carbonation of concrete, less clear cover, efflorescence	remove rust from steel, use steel inhibitor, remove loose concrete, replace reinforcement (if required), shotcrete with rich material,	For mortar use C:S = 1:3 and for Concrete use higher grade of concrete with more workability, Use Sikka CNI for protection against corrosion
Corrosion of steel at lintel level	RVS, Carbonation test,	Carbonation of concrete, poor workmanship, environmental effect	Remove loose concrete, remove rust from steel, use steel inhibitor, replace reinforcement (if required), shotcrete with rich concrete	Use Sikka CNI for protection against corrosion, use REDWOOP BUTABOND SBR mixing with rich concrete
strength of column	Non Destructive Test	Poor workmanship, concrete deterioration	Remove loose concrete, Fill honeycombing and cracks with REDWOOP MICROCONCRETE (RG(L))	mix well 4.75 lit water in 25 kg powder bag and pour it where required

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