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Performance Evaluation of Retrofitting of Reinforced Concrete Structures

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Abstract -*Every building is built is to serve for some particular purpose, even after its service life is completed. The structure is required to get repaired in order to keep the structure in serviceable condition so that it fulfills its desire purpose, for which time to time maintenance and repair work are necessary. The maintenance work is done periodically to avoid the building from degrading and hence preventing it from nonfunctioning or ill functioning. The Reinforced cement concrete components are mainly responsible for taking the load and hence are vital elements in any building structure.*

An investigation of existing commercial building, which is 19 years old, is conducted. The building was not in use for major time and was poorly constructed. It requires retrofitting of its various elements such as columns, beams, slabs and walls. The purpose of retrofitting is to bring their strengths up to target strength, by using section enlarging method and jacketing method. The section-enlarging method is used for retrofitting of columns and jacketing method is used for retrofitting of beams. A proposed estimate is calculated with is about Rs. 6,57,042.00/-. Extended life of the building is about 45 years. Annual worth of the extended life period of building is about Rs. 6,00,000/- per year. The Schmidt hammer experimental result shows that modifying an existing building can boost its strength. Also, quality of concrete is in between Fair to Good for the building. The percentage increase in strength of the building before and after retrofitting is 57.75%. This investigation a structural test was carried out to determine the efficacy of a retrofitting approach for reinforced concrete buildings that combined the jacketing and section-enlarging reinforcing methods. The valuation of building is increased by 75% with retrofitting. The annual life cycle cost of the building is Rs. 34,51,342-

Key Words: *Retrofitting, Repair, Rehabilitation, Retrofitting, Distress, Deterioration, NDT Methods, Rebound Hammer, etc.*

1. INTRODUCTION

The retrofitting is the process of repairing existing structures, such as buildings, commercial building structures, bridges, and historic buildings, to make them more resistant to seismic pressures like earthquakes and volcanic eruptions, as well as other natural calamities including landslides, tsunamis, floods, and thunderstorms The main objective of retrofitting RCC structural elements is to restore the structural integrity of the degraded concrete element. It also aids in the prevention of additional concrete damages' The reason for the concrete element's weakness could be due to design faults or poor building construction technique. . There can also be additional origin for the damage, such as the violent behavior of hazardous toxic and dangerous chemicals.

The required ability to the structure might be restored after the correct retrofitting process is applied and specified, and it fully depends on the type and severity of the damage suffered. Outside plate bonding, grouting, outer post-tensioning, section extension, and fiber constructed reinforced polymer materials are some of the techniques used in the repair retrofitting process. Buildings and engineering structures may require rebuilding and restoration if they have been damaged to the extent where they are no longer fit for general usage The structure cannot sustain a subsequent sequence of the same action or unforeseen unintentional acts with high reliability, and hence the risk of lives and thus the increase in structural and content damage would be excessive. To exclude the disaster in future calamities like earthquake, the retrofitting plays a key role in the structural fundamentals.

1.1 Need of Retrofitting

There are a variety of obstacles that structural members face, all of which must be addressed. Some of the more typical issues include:

a) Cracks in the structure
b) Deterioration of concrete structures
c) An excessive amount of loading
d) Design or construction errors
e) Improvements to the loads of structural system
f) Subsurface tremor impacts
g) Honeycombs corrode because of absorption

1.3 Methods of Retrofitting of Buildings

The retrofitting of buildings has some common techniques which are listed below

A. Local Retrofitting
B. Global retrofitting

The sub methods of Local and Global retrofitting are as follows:

a) New Shear Wall Addition
b) Steel Bracing Addition
c) Technique of Wall Thickening
d) Method of Base Isolation
e) Technique of Mass Reduction
f) Method of Jacketing
g) Fiber Reinforced Polymer (FRP)
h) Technique of Epoxy Injection
i) Bonding by External Plate

1.4 Factors Affecting in Selection of Retrofitting of Building Methods

When choosing a building retrofitting approach, keep the following points into consideration:

- Concrete strength at present condition
- Ease of access to work regions
- The intensity of strength to be increased.
- Cost of construction as well as maintenance.
- Time factor.
- Issues with site clearance.
- Effect of Earthquake consideration.
- Surrounding environmental aspect.

1.5 Advantages of Retrofitting of Buildings

The followings are the benefits of the retrofitting of building technique:

a) This approach is employed to keep the structure's concrete foundation from eroding.
b) It optimizes the structure of the building stability and safety measures.
c) Building's retrofitting makes them more flexible and suitable for current and future activities, as well as making them more comfortable to withstand loading.
d) Aids in the prevention of structural damage to inhabitants.
e) Buildings that have been restored are much more environmentally efficient and produce fewer carbon emissions from their activities.
f) The procedure contributes in strengthening residents' abilities to keep themselves safe in the earthquake zone.

1.6 Disadvantages of Retrofitting of Building

Other than the advantages, retrofitting also has several disadvantages, such as:

a) The worker's knowledge must be compatible with the retrofitting methods used.
b) Entry to the construction site is banned due to the risk that the building is still operational.
c) Binding problems may occur between the old concrete and the new surface layer.
d) As concrete has a higher strength than old masonry structures, the strength of covered concrete should be specified with caution.

2. RESEARCH METHODOLOGY

2.1 Objectives of the Study

1. To study different old buildings.
2. To prepare the questionnaire for the visual inspection of the building,
3. To identify the locations for retrofitting and replacement of items and suggest method of retrofitting,
4. To prepare estimate of retrofitting and replacement as per current DSR of PWD.
5. To find the extended life of the building and annual worth of the extended life period of building.

2.2 Methodology of the Study

The different phases of this project of work are shown in the below.

a) Review the existing literatures on retrofitting of the buildings,
b) Select different old buildings for conducting study with respect retrofitting,
c) Preparing information sheet of building which includes name of owner, location, year of construction, area, drawings, etc.
d) Preparing questionnaire for the visual inspection of the building which includes structural components, doors and windows, water supply and drainage system, etc.
e) Identifying the locations for retrofitting and replacement of items and suggesting method of retrofitting and quantify the replacement of items.
f) Preparing estimate of retrofitting and replacement as per current DSR of PWD,
g) Estimating expenses per unit area,
h) Finding the extended life of the building and annual worth of the extended life period of building,
i) Interpretation of results and conclusion.

2.3 Old Building for Study

Table -1: Old Building for Study

Sr. No.	Project	Description	Location
1	APMC Market Yard	Commercial Building	Dindori

3. PERFORMANCE ANALYSIS

3.1 Project 1: APMC Market Yard, Dindori

Table -2: Detail Information of APMC Market

Name of Building	APMC Market Yard
Name of Owner	Zilla Parishad, Government of Maharashtra
Type of Building	Commercial Building
Location	APMC Market Dindori Subyard, Vani, Taluka – Dindori.
Type of Structure	RCC G + 1 Structure
Year of Construction	2002
Age of Building	19 Years
Plot Area	154.37 sq. m
Parking Area	11.61 sq. m
Total Built-up Area	138.94 sq. m
Total Carpet Area	111.48 sq. m

Fig -1: APMC Market Yard Site

3.2 Visual Observation of Building

Table -3: Visual Observation of APMC Market Yard

Sr. No.	Description	Current Status	Remarks
1	Foundation Strata	Level Condition	NA
2	Structural Element - Column	Poorly Damaged	Need to be Retrofit
3	Structural Element - Beams	Poorly Damaged and Green Algae	Need to be Retrofit
4	Structural Element - Slab	Green Algae due to excess water	Need to be Retrofit
5	Walls, Plaster and Flooring	Cracks in Walls	Need to be Retrofit
6	Doors and Windows	Corroded	Need to be Retrofit
7	Water Supply System	Broken	Need to be Retrofit
8	Masonry Walls	Green Algae	Need to be Retrofit
9	Electrical System	NA	NA
10	Lift	NA	NA
11	Test Recommendation	--	Rebound Hammer Test

Fig -2: Visual Observation of Slab

Fig -3: Visual Observation of Beams

3.3 Questionnaire Survey for Visual Inspection of the Building

Table -4: Questionnaire Survey for Visual Inspection of the Building

Sr. No.	Question	Answer
1	Construction Year	2002
2	Age of the building	19 years
3	Front elevation	Poorly Damaged and Green Algae
4	Side elevation	Cracks in Walls
5	Internal Condition	At ground floor level on the landing there was a vertical crack, which was hairline extending upwards inside the slanted portion of the ceiling
6	External Condition	Poorly damaged
7	Has previously had major alterations	No
8	Is there any problem of leakage?	Yes. Due to poor quality of construction
9	How many people are live in this apartment?	About 90
10	Is there any falling of ceiling plaster?	Yes, happened already.
11	Can you recommend an expert to look into this further?	Yes. We required.

3.4 Locations for Retrofitting and Methods of Retrofitting

Table -5: Locations and Methods of Retrofitting

Sr. No.	Location for Retrofitting	Methods of Retrofitting
1	Structural Element - Column	Section-Enlarging Reinforcing Method
2	Structural Element - Beams	Jacketing Method
3	Structural Element - Slab	Section-Enlarging Reinforcing Method
4	Walls, Plaster and Flooring	Cavity wall insulation, internal or external insulation, and cladding of external and internal surfaces.
5	Doors and Windows	Replacement high-performance doors and windows
6	Water Supply System	Replacement with PVC pipes
7	Masonry Walls	Grouting

3.5 Justification

A. Expenses Per Unit Area: -

a) Built-up Area = **538.66 sq. m**

b) Total Cost of Retrofitting = **Rs. 6,57,045.00**

c) Cost per unit area = **Rs. 1219.78.00/sq. m**

d) Annual Worth of Retrofitting considering 45 years of extended life & 8% of interest rate = Rs.52,563.00/-

B. Annual Life Cycle worth of the Building: -

a) Considering the cost of construction @ Rs.14,458.50.00/Sqm (i.e.Rs.1350.00/Sqft), Life of Building = 100 Years and rate of interest = 8%
Cost of Building = Rs.78,24,575.00
Annual Worth of building due to retrofitting = Rs.6,46,312.00
b) SIR (Saving to Investment Ratio) =
= 6,46,312.00/52,563.00 = 12.30
As the ratio is high hence the additional investment on retrofitting is justified.

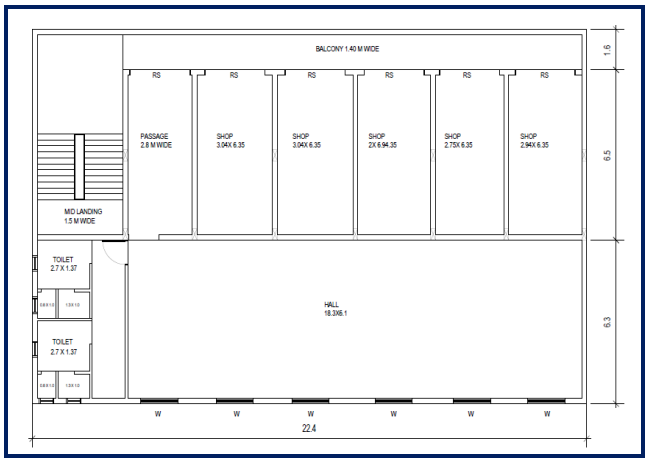

Fig -4: First Floor Plan of the APMC Market

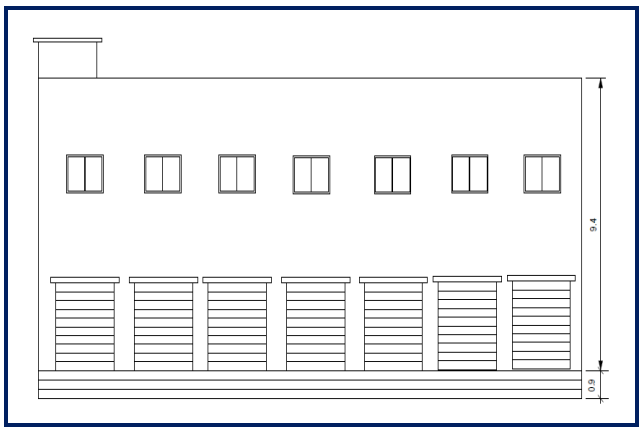

Fig -5: Elevation of the APMC Market

3.6 Rebound Hammer Test Results before Retrofitting

a) **Structure: -** RCC G + 1
b) **Instrument details: -** Rebound Hammer
c) **Code of Reference: -** IS 13311 Part (1) and (2): 1992, BS 1881: Part 203: 1986.

Table -7: Rebound Hammer Test Results (Column - Ground Floor)

Sr. No.	Member (Ground Floor)	Avg. Char. Comp. Strength (MPa)	Remark
1	Column C1	14	Fail
2	Column C2	16	Fail
3	Column C3	10.5	Fail
4	Column C4	Fail	Fail
5	Column C5	16	Fail
6	Column C6	12	Fail
7	Column C7	28	Passed
8	Column C8	19.5	Fail
9	Column C9	Fail	Fail
10	Column C9 (A)	15.5	Fail
11	Column C10	24	Passed
12	Column C10 (A)	16	Fail
13	Column C11	25	Passed
14	Column C11 (A)	19	Fail
15	Column C12	20.5	Passed
16	Column C12 (A)	18	Fail
17	Column C13	18.5	Fail
18	Column C13 (A)	19.5	Fail
19	Column C14	18	Fail
20	Column C14 (A)	17.5	Fail
21	Column C15	34	Passed
22	Column C15 (A)	27.5	Passed
23	Column C16	15.5	Fail
24	Column C16 (A)	22	Passed
25	Column C17	Fail	Fail
26	Column C18	14.5	Fail
27	Column C24	11.5	Fail
28	Column C25	19	Fail
29	Column C26	14	Fail
30	Column C31	13	Fail
31	Column C32	11	Fail

Table -8: Rebound Hammer Test Results (Column - First Floor)

Sr. No.	Member (First Floor)	Avg. Char. Comp. Strength (MPa)	Remark
1	Column C1	11.5	Fail
2	Column C2	15.5	Fail
3	Column C3	11	Fail
4	Column C4	16.5	Fail
5	Column C5	13.5	Fail
6	Column C6	15.5	Fail
7	Column C7	24.5	Passed
8	Column C8	19	Fail
9	Column C9	18	Fail
10	Column C10	24.5	Passed
11	Column C11	17.5	Fail
12	Column C12	17.5	Fail
13	Column C13	11	Fail
14	Column C14	15.5	Fail
15	Column C15	17.5	Fail
16	Column C16	23	Passed
17	Column C17	24	Passed
18	Column C18	18	Fail
19	Column C19	25.5	Passed
20	Column C20	13	Fail
21	Column C21	14.5	Fail
22	Column C22	Fail	Fail
23	Column C23	11	Fail
24	Column C24	10.5	Fail
25	Column C25	Fail	Fail
26	Column C26	13.5	Fail
27	Column C27	14	Fail
28	Column C28	10.5	Fail
29	Column C30	18	Fail
30	Column C31	20.2	Fail
31	Column C32	10	Passed
32	Column C33	Fail	Fail
33	Column C34	Fail	Fail
34	Column C35	Fail	Fail
35	Column C36	14.5	Fail
36	Column C37	13	Fail
37	Column C38	13.5	Fail

Table -9: Rebound Hammer Test Results (Beams and Slabs)

Sr. No.	Member (Ground Floor)	Avg. Char. Comp. Strength (MPa)	Remark
1	Beam B47	26	Passed
2	Beam B56	35	Passed
3	Beam B66	21	Passed
4	Slab S5	35	Passed
5	Slab S10	42	Passed
6	Slab S12	33	Passed

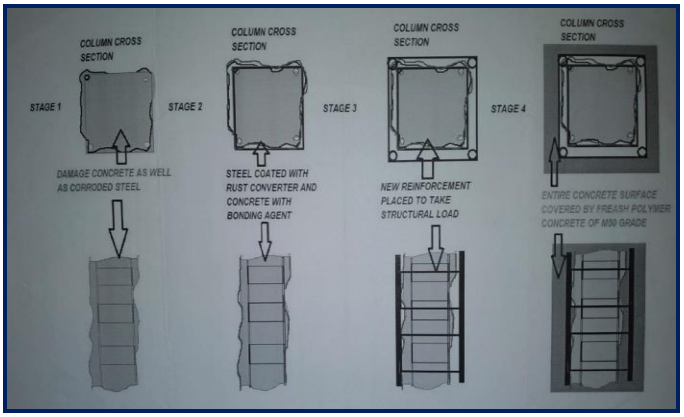

Fig -6: Cross Section of Columns before Retrofitting

3.7 Percentage Increase in Strength of Rebound Hammer Test Results before and after Retrofitting

Table -11: Percentage Increase in Strength of Rebound Hammer Test Results before and after Retrofitting (Column - Ground Floor)

Sr. No.	Member (Ground Floor)	Avg. Char. Comp. Strength before Retrofitting (MPa)	Avg. Char. Comp. Strength after Retrofitting (MPa)	% Increase in Strength
1	Column C1	14	24	71.43
2	Column C2	16	22	37.5
3	Column C3	10.5	26	147.62
4	Column C4	10	25	150
5	Column C5	16	22	37.5
6	Column C6	12	25	108.33
7	Column C7	25	28	12
8	Column C8	19.5	22	12.82
9	Column C9	9.5	22	131.58
10	Column C9 (A)	15.5	26	67.74
11	Column C10	24	24	0
12	Column C10 (A)	16	22	37.5
13	Column C11	22	25	13.64
14	Column C11 (A)	19	24	26.31
15	Column C12	20.5	22	7.31
16	Column C12 (A)	18	24	33.33
17	Column C13	18.5	22	18.92
18	Column C13 (A)	19.5	25	28.20
19	Column C14	18	25	38.89
20	Column C14 (A)	17.5	25	42.86
21	Column C15	20	25	25
22	Column C15 (A)	22	27.5	25
23	Column C16	15.5	28	80.64
24	Column C16 (A)	22	25	13.63
25	Column C17	9.5	28	194.74
26	Column C18	14.5	28	93.10
27	Column C24	11.5	22	91.30
28	Column C25	19	22	15.79
29	Column C26	14	20	42.86
30	Column C31	13	24	84.62
31	Column C32	11	22	100

4. RESULTS

i. Extended Life of the Building = **45 years.**
ii. Annual Life Cycle Cost for investment = **Rs. 52,563.00**
iii. Annual worth of the extended life period of building = **Rs. 6,46,312.00**
iv. Average percentage increase in strength of rebound hammer test results before and after retrofitting (Column - Ground Floor) = **57.75%.** And Quality of concrete in between Fair to Good for the building.

v. Valuation of the building would increase after retrofitting and its life would be 45 years.

5. CONCLUSIONS

The proposed retrofitting would add the strength to the building structure. Many of the structural elements are not in good shape partially, at present, thus the building may be termed as unsafe for its intended use. The retrofitting as suggested would make it effective and capable of handling static and dynamic loads. The retrofitting of the various beams and columns would provide good strength against seismic loading. The cost estimate of the retrofitting is Rs. 6,57,045.00. The cost of retrofitting per unit area of the comes out Rs.1219.78 per sq. m. The annual worth of the building considering its life of 100 years and rate of interest 8% is Rs.6,46,312.00, whereas the annual cost of retrofitting for 45 years and same rate of interest comes out Rs.52,563.00. The SIR is 12.30, which is quite attractive and thus it can be concluded that the investment in retrofitting is worth. The schmidt hammer experiment results show that retrofitting of structural elements of an old building enhance the strength. The investigation shows that the increase in strength of the structural elements after retrofitting is 57.75%.

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