

Assessment of Damaged Building by Using Retrofitting Techniques- Case Study

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Abstract:

Huge capital is invested in construction, planning and maintaining the quality of a new building. With time, old structures lose their strength and quality and thus they require restraining. Retrofitting helps in restraining of old structures by restoring their existing features and enhancing their structural capabilities. Proper assessment of damaged building to implement retrofitting techniques may help in restoring the strength and quality of old structures in lower cost and time. This paper mainly concentrates on assessment of damaged buildings by using different retrofitting techniques. Two different cases of retrofitting are presented here. The study mainly focuses on whether the total new structure is beneficial for the retrofitting of any existing structure.

Keywords-Retrofitting, Restraining, Cost analysis

I. INTRODUCTION

Decimation of any old building and rebuilding them requires considerable investment of capital. Proper estimation and management is necessary to scale down the overall cost required for retrofitting and improving the efficiency of existing buildings. Thus, it is very important to evaluate the main causes of destruction or disintegration of old buildings so as to decide the proper retrofitting technique for their refurbishment.

Retrofitting of damaged buildings is upgrading the seismic resistance of existing buildings so that they become safer under the occurrence of probable future earthquake. In retrofitting, the structure must be managed to maintain its purpose of use and enhance its safety and durability, considering the ease of retrofitting construction and post-retrofitting maintenance, as well as overall economy and environment-friendliness. Rehabilitation action include removal and rebuilding of deteriorated walls, grouting of cracks in the structural members, guniting damaged concrete surfaces, treatment against corrosion, providing additional steel reinforcement to restore tensile strength affected

by corrosion, underpinning of foundations etc. Retrofit specifically aims to enhance the capacities of building that is found to be deficient or vulnerable.

The retrofit is intended to mitigate the effect of a future earthquake.

Assessment of existing structures is an important topic for experts working in construction in most industrial countries, where rehabilitation including repairs and upgrading of construction works represent about half of all construction activities. An existing structure may be subjected to the assessment of its actual reliability in case of:

- Rehabilitation during which new structural members are added to the existing load carrying system.
- Adequacy checking in order to establish whether the existing structure can resist loads associated with the anticipated change in use of the facility, operational changes or extension of its design working life;
- Repair of a building, which has deteriorated due to time dependent environmental effects or which has suffered damage from accidental actions, for example, earthquake
- Doubts concerning actual reliability of the structure.

II. METHODOLOGY

- The study is done by analysing the data from previous research studies from various national and international journals and research papers.
- Damages are identified by actual site visit and survey from visual observation and verifying the structural development plan by actual construction.
- By proper retrofitting techniques, appropriate solutions were provided to the problems which were caused due to the damage of the building.
- Arrived to necessary suggestions and recommendations for effective application of repair and retrofitting techniques.

Sr.No	Location ID	Height L	Dia D	L/D ratio	Load (kN)	fc= load/area (N/mm ²)	Corrected Strength (N/mm ²)
1	C-19	108.5	64.2	1.7	19.75	5.98	7.7
2	C-23	124.3	64.2	1.9	39.35	12.21	15.9
3	C-30	116	64.2	1.8	46.04	13.94	18.3
			Average				17.1

The core test results indicate that the average equivalent in-situ cube compressive strength of the concrete of the column based on the balance cores is 175.1 kg/cm² which can be considered as just equivalent to M20 concrete as per the acceptance criteria provided in IS 456:2000.

III. CASE STUDY

A. Case Study- I

Name of Building: Thane Municipal Corporation School

Location: Thane

Type of Structure: RCC

Building Uses: Public

Name of Storey: G+1

Age of Construction: 30 years

1) Analysis and Interpretation of Non-Destructive Testing :

The non-destructive testing is carried out to check the condition of concrete are: core test, rebound hammer test, ultrasonic pulse velocity test, carbonation test and half-cell potentiometer test.

The following are the detailed ND test analysis and interpretation:

The core test results on columns of the existing school building are tabulated as follows:

TABLE I
CORE TEST

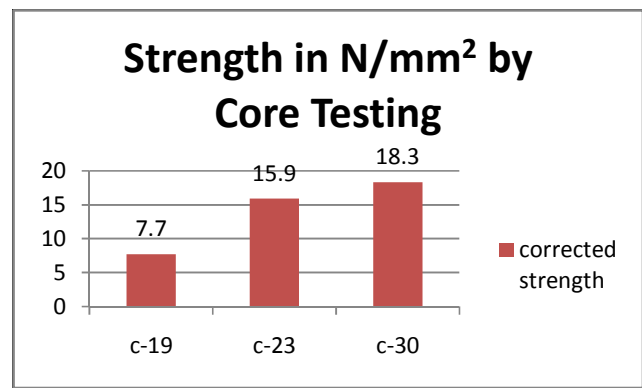


Fig.1 Bar chart showing core test results

2) Rebound hammer test and Ultrasonic pulse velocity analysis :

The rebound hammer test and ultrasonic pulse velocity on columns of existing school building are tabulated as follows:

Sr. No	Location ID	Average corrected rebound no.	In-situ compressive strength(N/mm ²)	Direct UPSV(Km/sec)	Concrete quality grading
1	C-19	32	15.5-24.5	2	Doubtful
2	C-25	36	20.5-29.5	2.6	Doubtful
3	C-24	37	22.0-31.0	2.9	Doubtful
4	C-23	33	16.5-25.5	2.7	Doubtful

Sr. No	Location ID	Average corrected rebound no.	In-situ compressive strength(N/mm ²)	Direct UPSV(K m/sec)	Concrete quality grading
5	C-22	30	13.5-22.5	-	-
6	C-23	37	22.0-31.0	3.2	Medium
7	C-24	36	20.5-29.5	2.8	Doubtful
8	C-13	37	22.0-31.0	2.5	Doubtful

3) Observation:

Internal observation:

Ground floor:

- Columns C-1,C-9,C-17,C-19,C-22 are observed with corrosion cracks.
- Columns C-9,C-12 is observed with seepage cracks.
- Beams B-28,B-32,B-33 are observed with corrosion cracks. Column C-17 is observed with honey combing.
- Beams B-6,B-28,B-33 are observed with seepage marks.
- Staircase landing bottom is observed to be damaged and steel is exposed.

First floor:

- Beam B-11, B-18, B-21, B-26 are observed with separation cracks. Beams B-33,B-16, B-17 are observed with corrosion cracks.
- Columns C-27,C-28,C-30 is observed with corrosion cracks.
- Columns C-14,C-26,C-28 are observed with separation cracks.

External observation:

The external faces are identified in the form of vertical panels which are marked in the attached drawing:

Panel-1

There are no any structural distresses observed.

Panel-2

Ground and 1st floor walls are observed with cracks.

Panel-3

Ground floor chajja cover is removed.

Panel-5

Ground floor chajja is observed with corrosion cracks. Ground and 1st floor is observed with separation cracks

Panel-6

Corner column is observed with corrosion cracks. Wall is observed with seepage marks.

Panel-7

1st floor chajja is observed with corrosion cracks.

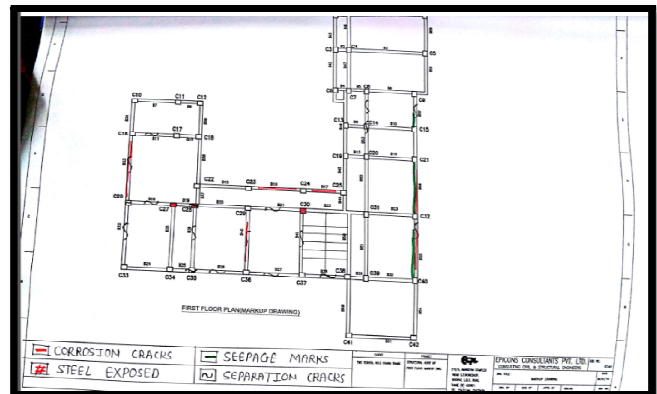


Fig.2 Drawing of school building

Considering all the above, as well as other observations, the following comprehensive remedial measures are recommended:

- All the corrosion distresses shall be attended to by using the application of the single patch polymer modified mortar in patchwork after removing loose concrete, cleaning the reinforcement, protecting, grouting, augmenting the reinforcement as per the manufacturer's specification.
- The more important members like columns with corrosion distresses all over the entire length, shall be jacketed from foundation level from all the four sides using 75mm thick micro-concrete. This shall be particularly done to all the corners columns, so that building remains in robust condition.
- The separation cracks shall be treated using polymer modified using standardized procedure.

- iv. The seepage leakages originate from toilet sunk shall be stopped by identifying the source by elimination procedure in the sequence of checking external plaster cracks along with tile joints.



Fig.3 Showing slab breaks with exposed steel shows in red mark



Fig. 4 Showing corner column shows corrosion cracks

4) Different Techniques used for strengthening of structure:

Polymer Modified Mortar:

Polymer mortar is composite material in which aggregate is bound together in a dense matrix with a polymer binder. The best known and most widely used polymer used in this site is epoxy resins. For larger repair areas with thickness excess of 50mm, this is better option as repair material.

Jacketing:

Jacketing is the most popularly used method for strengthening of building columns. The most common types of jackets are steel jacket, reinforced concrete jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc.

The main purposes of jacketing are:

1. To increase concrete confinement by transverse fibre reinforcement, especially for circular cross-sectional columns,
2. To increase shear strength by transverse fibre reinforcement,
3. To increase flexural strength by longitudinal fibre reinforcement provided.

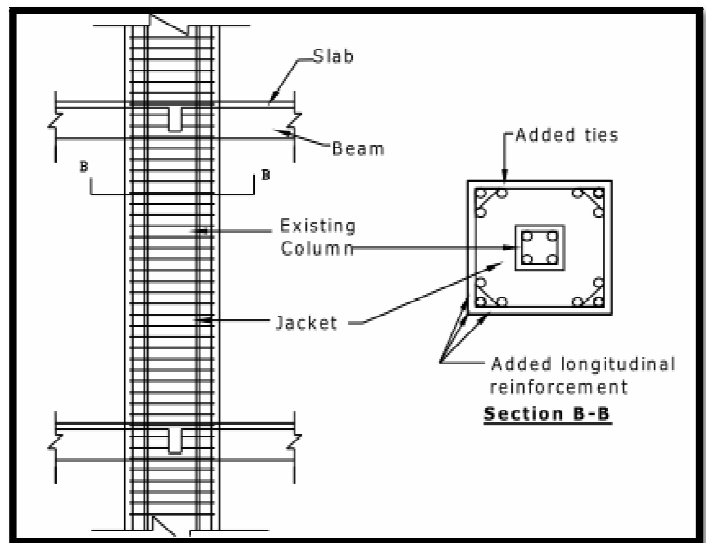


Fig. 5 Showing jacketing of column

B. Case Study- II

Primary Data:

Name of Building: Scottish chemical industries

Location: Mumbai

Type of structure: RCC

Building Uses: Commercial

Name of Storey: 2

Age of Construction: 15 years

1) Analysis of Non-Destructive Testing:

The non-destructive testing carried out to check condition of concrete are: Core Test, Rebound Hammer Test, Ultrasonic Pulse Velocity Test, Carbonation Test and Half-cell Potentiometer Test. The following are the detailed ND test analysis.

Table 1. Results of Chemical Tests on columns and beam

Test Location				Chemical Test Results	
Sr. No.	Location ID	Level	Element Type	pH	CL(kg/m ³)
1	A8-A9	G	Beam	8	0.480
2	A10-A11	G	Beam	7	0.600
3	A5	G-1	Column	7	0.600
4	B8	G-1	Column	9	0.480
5	B3	G-1	Column	9	0.480
Notes: permissible limits as per IS 456:200					
pH	Not less than 8				
CL(kg/m ³)	For PCC, maximum 3.0kg of chloride per m ³ of concrete. For RCC, maximum 0.6 kg of chloride per m ³ of concrete.				

Table 2. Results of Ultrasonic Thickness Gauge Test on columns and beam

Sr. No.	Member	Truss ID	Angle section as per drawing	Standard thickness	Thickness obtained from Vernier Calliper (mm)	Thickness Loss (%)
1	Vertical ISA Member	B4-A4	75x75x6	6.00	4.93	17.83
2	Truss Bottom Cord	B3-A3	75x75x8	8.00	7.11	11.13
3	Truss Diagonal Member	B6-A6	50x50x6	6.00	5.29	11.83

2) Observation:

- Beam A10, A11, B1, B2 are observed with corrosion cracks.
- Slab B14, A15 are observed with separation cracks.
- Column A5, B3, B8 of first floor is observed with separation and corrosion cracks.
- Truss B4-A4, B3-A3 are totally damaged due to corrosion. Hence, here we have to demolish these trusses for strengthening.

3) Different Steps involved in Restraining

Restraining involves structural interference which helps in improving the strength of components in a building that are either deteriorated or damaged. Restraining is done so the original strength of structural members can be restored. Different steps that are involved in restraining are listed below:

- Footing strengthening

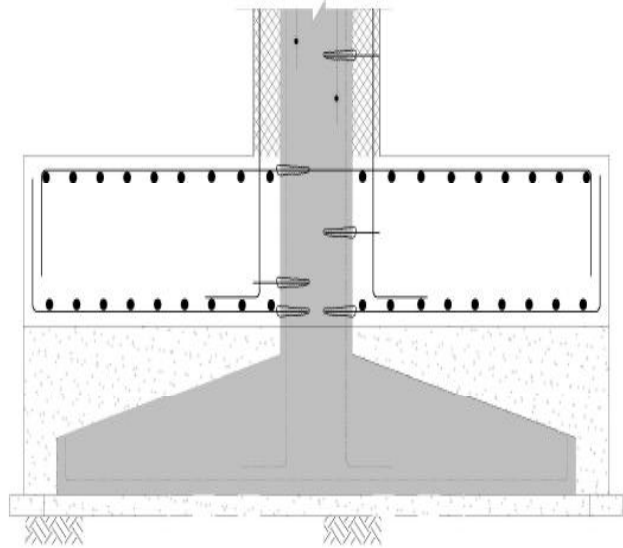


Fig. 6 Showing Footing Strengthening with Reinforcement & Concrete Jacketing

- Column strengthening

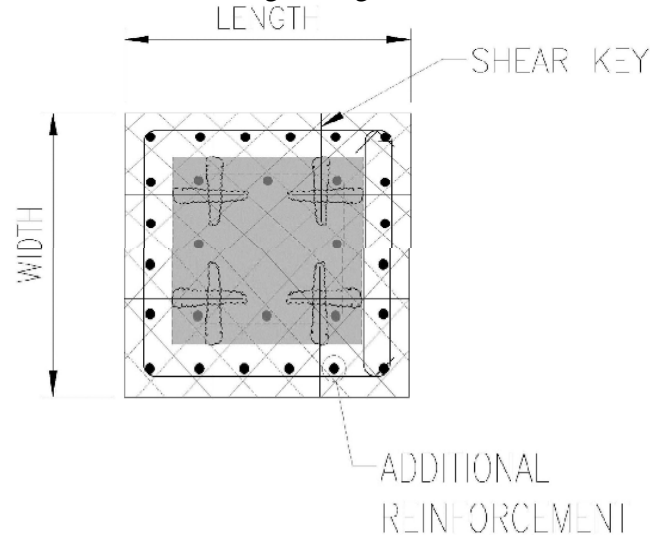


Fig. 7 Showing Column Jacketing with Reinforcement & Micro Concrete

- Chajjas:
Existing Chajjas & windows are to be demolished for proposed strengthening work.
- Truss Strengthening.



Fig. 8 Shows that footing is strengthen with extra reinforcement



Fig. 9 Showing columns with red mark shows that they are strengthen with the help of jacketing.

Unlike new construction, where adding seismic design requirements is not an over-riding cost issue, seismic retrofit of buildings is commonly expensive and disruptive. The cost of retrofit is therefore the primary determinant in selecting acceptable risk for evaluation standards and for selecting the minimum performance objective for retrofit public policy or for retrofit of individual buildings. Studies have shown that retrofit costs have large ranges, with coefficients of variation of about 100%, even when buildings are subdivided into fairly specific categories. This is not unreasonable considering that existing buildings can have a wide variety of deficiencies, with some buildings requiring far more retrofit than others. Usually the economic feasibility of retrofitting any individual building can only be determined by a building specific evaluation to determine the extent of deficiency; often descriptions of building specific at the conceptual level will provide adequate scope for cost estimating purposes. Procedures for calculating life-cycle cost-benefit ratios for seismic retrofit are straightforward. However, determination of the parameters necessary to perform such studies, including the annual probability of occurrence of various ground motions, the damage to the structure before and after retrofit, casualty rates and the monetary value of casualties, and the extent of building downtime, is difficult and require considerable engineering judgement. With few exceptions, such calculations yield benefit to cost ratios of less than one, which is often counter-intuitive. Therefore, these studies are often used only to compare alternate actions, or are accompanied by risk adverse analysis.

4) **Cost Benefit study of retrofitted structure:**

In retrofitting, the structure must be designed so it is in keeping with its purpose of use and is both safe and durable, with consideration given to the ease of retrofitting construction and post-retrofitting maintenance, as well as overall economy and environment-friendliness.

IV. COST ANALYSIS:

1) Case Study – 1

Table 3. Cost analysis for case Study- 1

Area of ground floor (Sq. ft.)	13800
Area of first Floor (Sq. ft.)	9000
Total Area (Sq. ft.)	22800
Rate of Building	3000

Construction in Mumbai	
New Construction Cost	68400000
Retrofitting for GF	
40% of area to be retrofitted	5520
Retrofitting Rate for GF per Sq. Ft	3900
Cost of Retrofitting for GF (Rs)	21528000
Retrofitting for FF	
30% of area to be retrofitted(Sq. ft.)	2700
Retrofitting Rate for FF per Sq. Ft	4290
Cost of Retrofitting for FF (Rs)	11583000
Total Cost for retrofitting	33111000
Cost Saving (Rs)	35289000
Percentage Saving	52%

1) Case Study – 2

Table 4. Cost analysis for case Study- 1

Area of ground floor (Sq. ft.)	5822
Area of first Floor (Sq. ft.)	5166
Total Area (Sq. ft.)	10988
Rate of Building Construction in Mumbai	6000
New Construction Cost	65928000
Retrofitting for GF	
40% of area to be retrofitted (Sq. ft.)	5822
Retrofitting Rate for GF per Sq. Ft	7800
Cost of Retrofitting for GF (Rs)	18164640
Retrofitting for FF	
30% of area to be	5166

retrofitted (Sq. ft.)	
Retrofitting Rate for FF per Sq. Ft	8580
Cost of Retrofitting for FF (Rs)	13297284
Total Cost for retrofitting	31461924
Cost Saving (Rs)	34466076
Percentage Saving	52.27%

V. CONCLUSION

The study mainly focuses on whether the total new construction is beneficial for retrofitting of any structure. The reduction in life of strength of structure depends mostly on the quality of material and strict selection of right contractor for the construction project. Following points can be concluded from the above case studies:

1. Company must be successfully able to deal with various decision making situations successfully within two days in highly competitive construction market. The first steps that the company need to consider is whether to construct a totally new structure by demolishing the old damaged structure or retrofit the old structure and increase its strength and life.
2. After considering the retrofitting to increase strength, life and to achieve the economy by reducing construction cost, contractor selection is more important point.
3. Only experienced contractor should be selected for retrofitting as it is a special type of work and requires careful quality control.
4. The strength and life of the structure reduces due to poor contractor performance and poor quality material. It is also due to not maintaining proper guidelines given by RCC designer regarding clear cover and end cover.
5. The retrofitting of the building totally depends on the damage percentage of the structure. Availability of fund for new or retrofitting and time required to complete

- the structure for use should be considered as one of the important factor.
6. Methods to be used for retrofitting depend on damaged member type and possibility of retrofitting benefit. For very old structure, it is not possible to retrofit any member of structure. In such cases only dismantling of total old structure and construction of a totally new structure is suggested.
 7. The age of structure plays an important role while suggesting retrofitting.
 8. Retrofitting also depends on the purpose. Various financial institutions have found influence of purpose.
 9. Health and retrofitting management at construction site can be studied by performing investigation at construction site. It can be done by creating a team which comprises of project manager, site engineer, safety manager, supervisor and workers.
 10. In case study of school building, ground floor required more retrofitting than first floor parts of structural member.
 11. Chemical factory building required more retrofitting than school building as it is damaged more due to chemical attacks on structural parts.
 12. By retrofitting, as the strength and life increases, the aesthetic look and overall elevation is changed.
 13. As construction site is prone to accident, it is more important to implement safety procedure while retrofitting. Safety management at the construction site plays important role for the safety of the structure.
 14. In Second Case, special precautions are suggested to reduce the chemical pollution for safety of the structure.
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