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Case Study of Structural Rehabilitation of Multi Storey Residential Building

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Abstract - *Although the RCC structures are designed as per codes not always constructed properly using correct techniques and methods. As a result, the structures start showing signs of distress which requires repair and rehabilitation work. In this project, a case study of (G+7) multistoried building whose ground floor was damaged due to the flood of 2006 has been represented. The repair strategy was to assess the quality of structural members of the ground floor of the building with the help of Non-Destructive and Semi Destructive Tests such as Rebound Hammer, UPV and Concrete Core Test. All the flood-affected members were tested and proper treatment to each of them was applied such as anticorrosion coating, injection grouting, micro concreting and also jacketing of columns at ground level. Strict quality control in materials and workmanship was adopted. All the rehabilitation work was done to increase the durability and service life of the building. After the engagement of all the professionals and cooperation of the residents for rehabilitation work was carried out. Some of the recommendations and conclusion have also been given to prevent further damage and to increase the service life of the building.*

Key Words: *Rehabilitation, Repair, Non-Destructive Testing, Injection Grouting, Micro concreting, Jacketing*

1. INTRODUCTION

Rehabilitation is concepts of evaluation of existing structures; strength, durability and deficiencies, destructive & non-destructive testing, damaged structures & deterioration mechanisms, materials, criteria & techniques for repairing and strengthening of concrete structures.

Concrete is the most commonly used & versatile construction material possessing several benefits over steel & other construction materials. However, very often one came across with some defects in concrete. The defects may noticeable themselves in the form of cracks, exposure of reinforcement, spalling of concrete, excessive deflections or other marks of distress

1.1 GENERAL CAUSES FOR FAILURE/DEFECTS IN STRUCTURE:

The following are the major causes of failures of concrete structures:

- Damages triggered due to fire, floods, earthquakes etc.
- Chemical deterioration & marine environments.
- Damages caused due to abrasion, wear & tear, impact, dampness, etc.
- Movement of concrete produced due to the settlement of foundation, thermal expansion, etc.
- Structural deficiency due to faults in construction, use of inferior & substandard materials, poor workmanship & negligence in quality control & supervision.
- Structural deficiency result from faulty design & detailing as well as wrong assumptions in the loading criteria.

2. PROBLEM SUMMAY

The need to improve the ability of an existing building to withstand from weathering action, chemical attack, embedded metals, alkali-aggregate reactivity, fire, due to overload, seismic forces, etc. arises usually from the evidence of damage and poor behaviour. These type of structures are deteriorated with use and time and other various factors and might have passed their design life and require repair and rehabilitation. Therefore, the solutions for RCC structure or structural elements are essential and for this different techniques are used.

Strength assessment of an existing structure is required to cover all the criteria in which maintenance is required. Thus, some numbers of non-destructive and semi-destructive techniques in the existing structures are used for assessment of concrete structure and to predict the cause of deterioration of the concrete. Some reasons of deteriorations are ageing of concrete, flood and leakages in the sewer pipes and pumping network.

3. AIM

In this project, after performing various Non-Destructive and Semi- Destructive tests, and Gravity Load analysis in ETABS we have provided remedial treatment to increase the service life of the building.

4. OBJECTIVES

- Increase service life of the building
- Decrease the maintenance cost of building
- Enhance the safety of people

5. METHODOLOGY

- Perform Non Destructive tests, namely; Rebound Hammer test, Ultrasonic Pulse Velocity test and Semi Destructive test, namely; Concrete Core test
- Interpretation of results obtained from NDT testing
- Gravity load analysis in ETABS
- Remedial measures for rehabilitation of the building

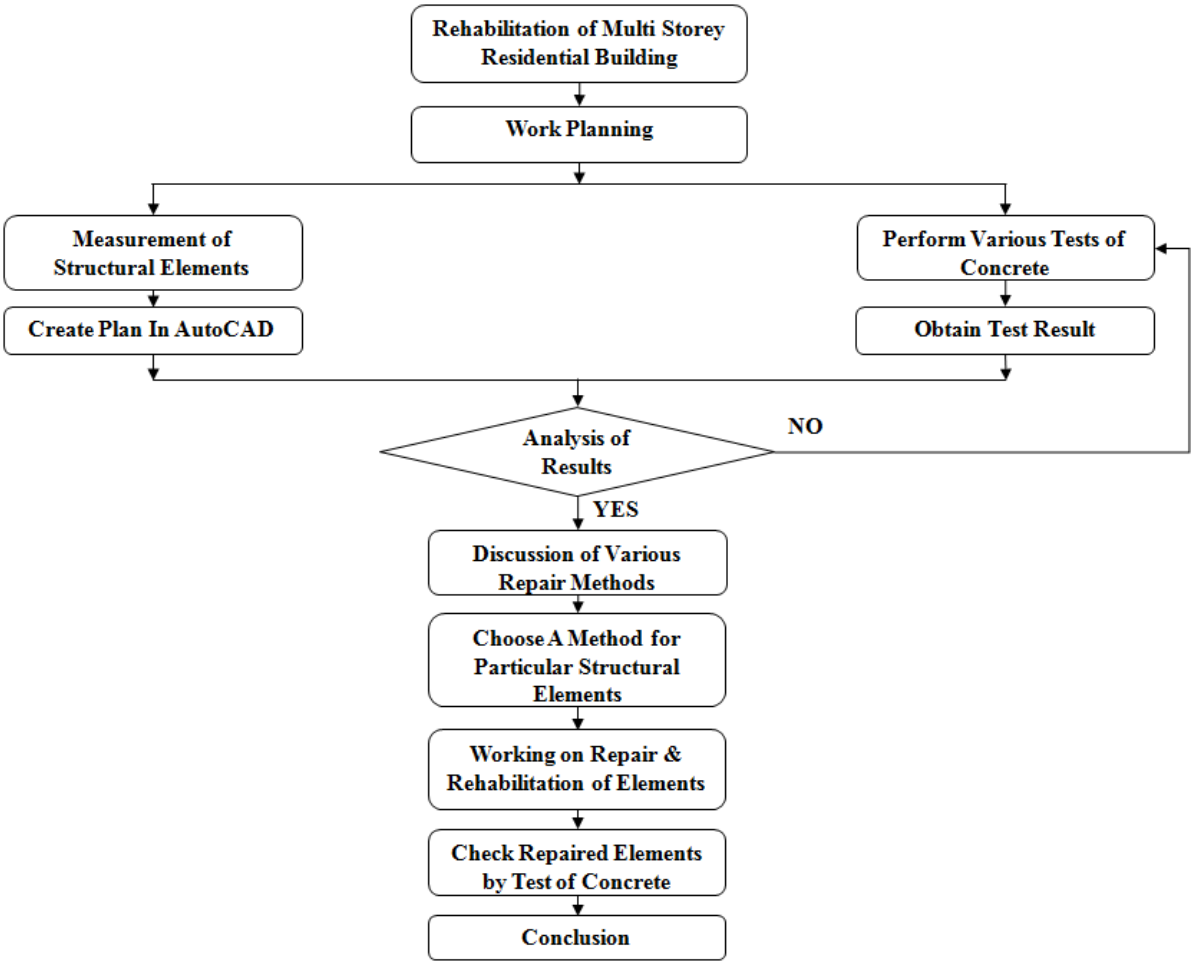


Figure 1 Process of Completion Project

6. PROBLEM SPECIFICATION

- As Akshar Plaza I is located at the bank of River Tapi, it is vulnerable to the flash floods caused due to excess rainfall and surface runoff.
- The existing condition of the building shows signs of deterioration of ground floor columns due to ageing, leakage in sewer pipes and weathering action.
- Surat is a prone to flooding as it occurs almost every year. With the beginning of the month of September, Surat becomes prone to a huge natural disaster - the flood. The climatic records of Surat states the fact that from the year 1849 itself the city is experiencing yearly flood situations.

7. TEST RESULT

7.1 REBOUND HAMMER TEST RESULT

Table 1 Rebound hammer test result

SITE ADDRESS:- Sahnip park, Nr.Divya Shoes, Adajan			REPORT NO:- 1								
RESULT OF REBOUND HAMMER TEST											
GROUND FLOOR											
SR NO.	MEMBER	LOCATION IDENTIFICATION	REBOUND HAMMER READING						AVG. READING	CUBE COMPRESSIVE STRENGTH	QUALITY OF CONCRETE
			1	2	3	4	5	6			
1	COLUMN	A1	25	19	20	22	23	20	21	0	FAIR
2	COLUMN	A2	38	36	34	30	32	32	35	19.2	GOOD LAYER
3	COLUMN	A3	44	42	40	38	38	38	40	23.9	GOOD LAYER
4	COLUMN	A4	23	20	22	19	20	21	21	0	FAIR
5	COLUMN	A5	30	30	33	31	36	30	28	15.1	FAIR
6	COLUMN	A6	26	25	24	28	25	20	24	14.3	FAIR
7	COLUMN	A7	36	36	35	31	32	33	34	19	GOOD LAYER
8	COLUMN	A8	36	33	32	35	36	31	34	19	GOOD LAYER
9	COLUMN	A9	44	40	42	43	42	40	42	28.7	HARD LAYER
10	COLUMN	A10	33	35	38	36	32	35	35	19.2	GOOD LAYER
11	COLUMN	B1	37	36	32	36	36	35	35	19.2	GOOD LAYER
12	COLUMN	B2	20	26	21	22	23	24	23	13	FAIR
13	COLUMN	B3	31	34	36	33	35	36	34	19	GOOD LAYER
14	COLUMN	B4	28	27	23	30	28	25	27	14.9	FAIR
15	COLUMN	B5	20	18	20	15	15	16	18	0	POOR
16	COLUMN	C1	25	22	29	28	27	24	26	14.7	FAIR
17	COLUMN	C2	25	26	23	22	21	29	24	14.3	FAIR
18	COLUMN	C3	36	33	32	35	36	31	34	19	GOOD LAYER
19	COLUMN	D1	36	36	35	31	32	33	34	19	GOOD LAYER
20	COLUMN	D2	20	21	25	26	28	30	24	14.3	FAIR
21	COLUMN	D3	44	42	40	38	38	38	40	23.9	GOOD LAYER
22	COLUMN	D4	25	19	18	22	17	20	19	0	POOR
23	COLUMN	E1	44	40	43	42	41	40	42	28.7	HARD LAYER
24	COLUMN	E2	26	25	24	28	25	20	24	14.3	FAIR
25	COLUMN	E3	37	36	32	36	36	35	35	19.2	GOOD LAYER
26	COLUMN	E4	25	22	29	28	27	24	26	14.7	FAIR
27	COLUMN	E5	25	12	20	20	23	19	20	0	POOR
28	COLUMN	E6	33	35	38	36	32	35	35	19.2	GOOD LAYER
CA	COLUMN	E7	28	27	19	25	23	20	19	0	POOR
30	COLUMN	E8	31	34	36	33	35	36	34	19	GOOD LAYER

31	COLUMN	E9	20	20	20	21	18	17	20	0	POOR
32	COLUMN	E10	28	27	23	36	28	25	27	14.9	FAIR
33	COLUMN	E11	36	33	32	35	36	31	34	19	GOOD LAYER
34	COLUMN	E12	30	34	33	31	36	30	28	15.1	FAIR

NOTE:-Test results are location specific. Rebound hammer test use only for relative strength evaluation not for absolute strength.

Table 2 Criteria for quality of concrete by rebound number

Average Rebound Number	**Quality of Concrete**
> 40	Very Good Hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor Concrete
0	Delaminated

7.2 ULTRASONIC PULSE VELOCITY TEST RESULT

NOTE:- Test Results Are Location Specific

Following remarks are applicable for 'direct method' as per IS 13311 (part2) 1992

1. Velocity below 3.0 km/sec indicates **'DOUBTFUL'** quality concrete.
2. Velocity between 3.0 to 3.5 km/sec indicates **'MEDIUM'** quality concrete.
3. Velocity between 3.5 to 4.5 km/sec indicates **'GOOD'** quality concrete.
4. Velocity above 4.5 km/sec indicates **'EXCELLENT'** quality concrete

Table 3 Ultrasonic pulse velocity result

SITE ADDRESS:- Sahnip park, Nr.Divya Shoes, Adajan						**REPORT NO:- 1**	
RESULT OF ULTRASONIC PULSE VELOCITY TEST							
GROUND FLOOR							
SR NO.	**MEMBER**	**LOCATION IDENTIFICATION**	**METHOD APPLY**	**DISTANCE (mm)**	**TRANSIT TIME (µsec)**	**U.P.V (Km/Sec)**	**CONCRETE QUALITY GRADING**
1	COLUMN	A1	Direct	584.2	393	1.5	Doubtful
2	COLUMN	A2	Direct	508	190	2.7	Doubtful
3	COLUMN	A3	Direct	762	576	1.3	Doubtful
4	COLUMN	A4	Direct	393.7	225.8	1.7	Doubtful
5	COLUMN	A5	Direct	482.6	300	1.6	Doubtful
6	COLUMN	A6	Semi-Direct	419.1	120.4	3.5	Good
7	COLUMN	A7	Indirect	406.4	198	2.1	Doubtful
8	COLUMN	A8	Direct	482.6	220	2.2	Doubtful
9	COLUMN	A9	Direct	584.2	190	3.1	Satisfactory
10	COLUMN	A10	Direct	431.8	98	4.4	Excellent

11	COLUMN	B1	Direct	482.6	280	1.8	Doubtful
12	COLUMN	B2	Direct	482.6	290	1.7	Doubtful
13	COLUMN	B3	Direct	482.6	270	2.8	Doubtful
14	COLUMN	B4	Direct	482.6	210	2.3	Doubtful
15	COLUMN	B5	Direct	558.8	174.6	3.2	Satisfactory
16	COLUMN	B6	Indirect	482.6	156.6	3.1	Satisfactory
17	COLUMN	B7	Direct	490.2	381	1.3	Doubtful
18	COLUMN	B8	Direct	482.6	275.3	1.8	Doubtful
19	COLUMN	B9	Direct	482.6	280	1.8	Doubtful
20	COLUMN	C1	Direct	482.6	262.1	1.9	Doubtful
21	COLUMN	C2	Direct	558.8	408.3	1.4	Doubtful
22	COLUMN	C3	Direct	558.8	250.6	2.2	Doubtful
23	COLUMN	C4	Direct	558.8	120	4.6	Excellent
24	COLUMN	C5	Direct	558.8	570	0.9	Doubtful
25	COLUMN	C6	Direct	482.6	250.9	1.9	Doubtful
26	COLUMN	D1	Direct	482.6	243	1.9	Doubtful
27	COLUMN	D2	Direct	482.6	280	1.7	Doubtful
28	COLUMN	D3	Direct	457.2	260	1.8	Doubtful
29	COLUMN	D4	Semi Direct	482.6	230	2.1	Doubtful
30	COLUMN	D5	Direct	548.2	360	1.5	Doubtful
31	COLUMN	D6	Direct	482.6	130	3.7	Good
32	COLUMN	D7	Indirect	482.6	400	1.2	Doubtful
33	COLUMN	D8	Direct	482.6	310	1.6	Doubtful
34	COLUMN	D9	Direct	482.6	155	3.1	Satisfactory
35	COLUMN	E1	Direct	419.1	145	2.9	Doubtful
36	COLUMN	E2	Direct	584.2	157.9	3.8	Good
37	COLUMN	E3	Direct	482.6	372	1.3	Doubtful
38	COLUMN	E4	Semi Direct	393.7	115	3.4	Satisfactory
39	COLUMN	E5	Semi Direct	406.4	279	1.5	Doubtful
40	COLUMN	E6	Direct	635	500	1.3	Doubtful
41	COLUMN	E7	Indirect	419.1	389	1.07	Doubtful
42	COLUMN	E8	Semi Direct	406.4	200	2	Doubtful
43	COLUMN	E9	Semi Direct	393.7	240	1.6	Doubtful
44	COLUMN	E10	Direct	495.3	190	2.6	Doubtful
45	COLUMN	E11	Semi Direct	571.5	140	4.1	Excellent
46	COLUMN	E12	Direct	419.1	350.2	1.19	Doubtful
47	BEAM	A1+B2	Direct	419.5	160	1.6	Doubtful
48	BEAM	D3+C3	Semi Direct	420.6	190	2.2	Doubtful

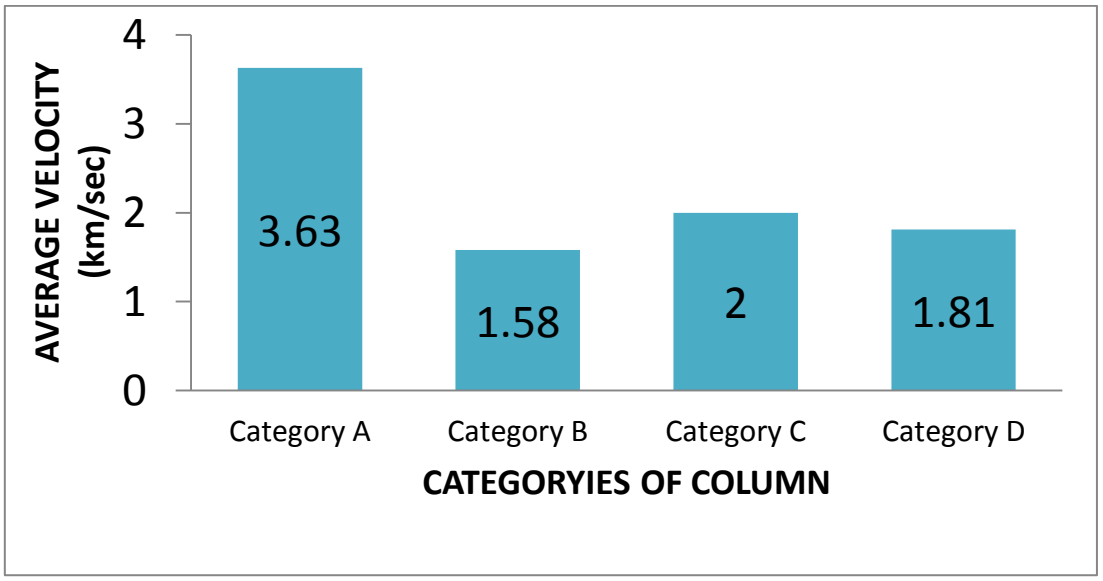
7.3 STRUCTURAL MEMBERS CAN BE DIVIDED INTO FOLLOWING CATEGORIES BASED ON THEIR CONDITIONS

Table 4 Categories of structural member based on their condition

Category of members	Condition	Location Identification
A	Structural members with initial good condition and negligible effect	A10, C4, E11
B	Columns showing loss of strength due to aging and flood	A9, A6, B5, B6, D6, D9,E2, E4
C	Structural members showing loss of strength due to leakage in drainage system	A3, A4, B3, B5, D2, E1, E3
D	Columns supporting Sunk slabs	A5, A8, E5, E8, E9 ,E11, E12, D8, C5, B2

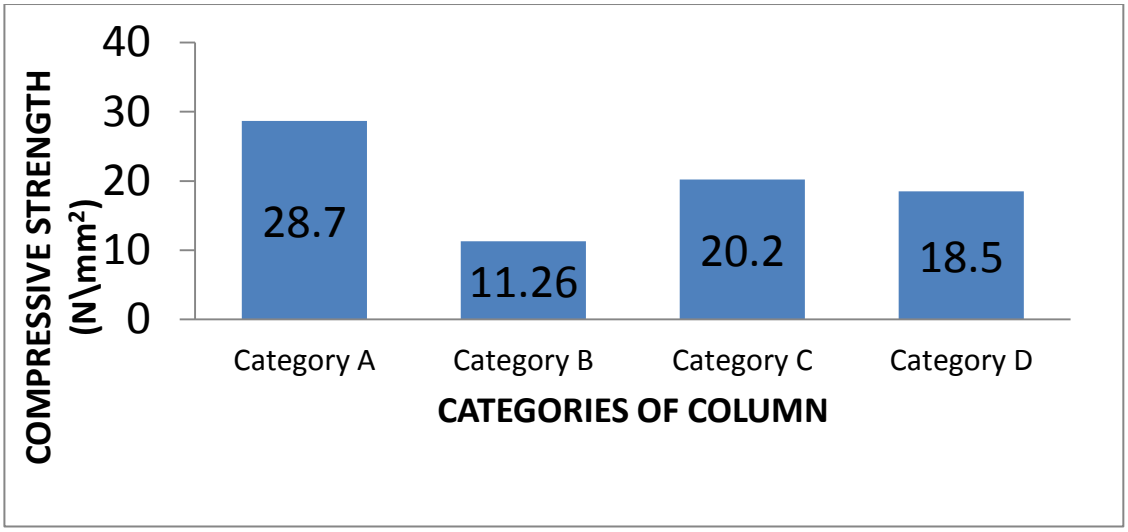
7.4 ULTRASONIC PULSE VELOCITY TEST ANALYSIS

Table 5 Analysis of UPV test



7.5 REBOUND HAMMER TEST ANALYSIS

Table 6 Analysis of rebound test



7.6 RESULT DISCUSSION

Following observations were made from the test results.

- Category D members have low strength compare to category A members, as pulse velocity obtained from UPV test is 10-15% lower for category D members.
- Bottom portion(up to 1m from ground) of category B members are weaker than top potion of the columns, as pulse velocity obtained from UPV test is 50-55% lower for bottom portion.
- Moreover, bottom portion(up to 1m from ground level) of category B members has pulse velocity 45-50% lower than category A members and this indicates flood damage.
- Category C members have low strength compare to category A members, as compressive strength obtained from Rebound Hammer test is 30% lower than average.

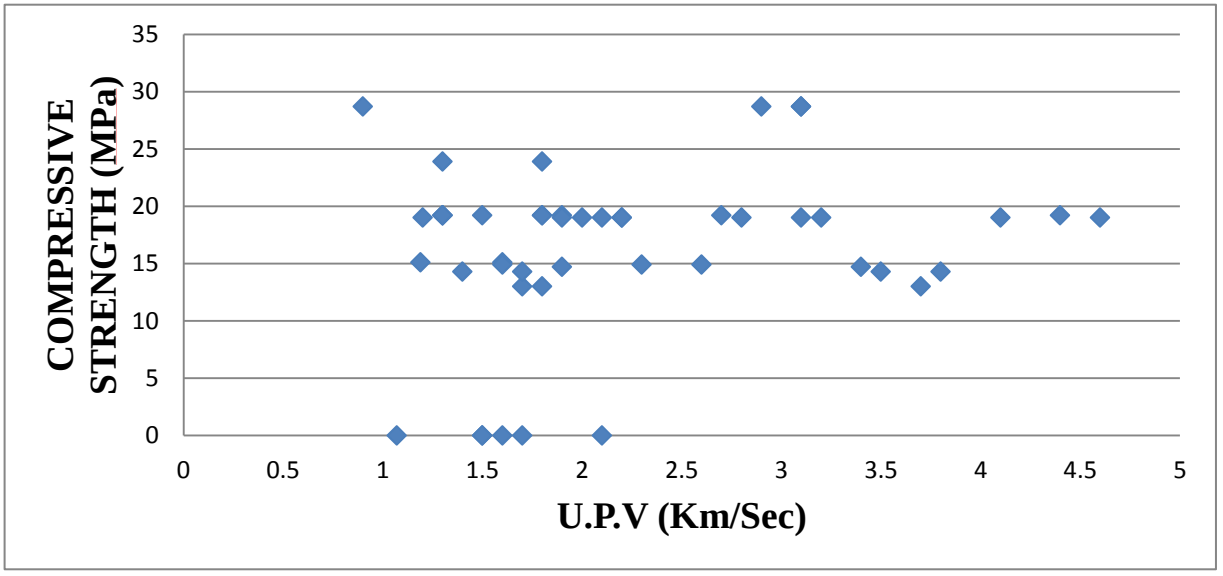
7.7 CONCLUSION OF ANALYSIS

Following conclusions are drawn based on the present project work.

- Comparative compressive strength of category A members is noted 45-50% higher than category B members.
- For category B columns compressive strength of bottom portion(up to 1m from ground level) is noted 20-25% lower than top portion(above 1m from ground level) of respective columns.
- Comparative compressive strength of category A members is noted 5-10% higher than category D members.
- As per testing results slabs and beams are found in good condition.
- These results obtained from tests will helps in performing Push over analysis which is essential for further repair and rehabilitation of the building.

7.8 COMPRESSIVE STRENGTH VS UPV

Table 7 COMPRESSION STRENGTH VS UPV



8. STRUCTURAL LAYOUT

Figure 2 Deterioration Of Concrete In Slab, Beam, Column

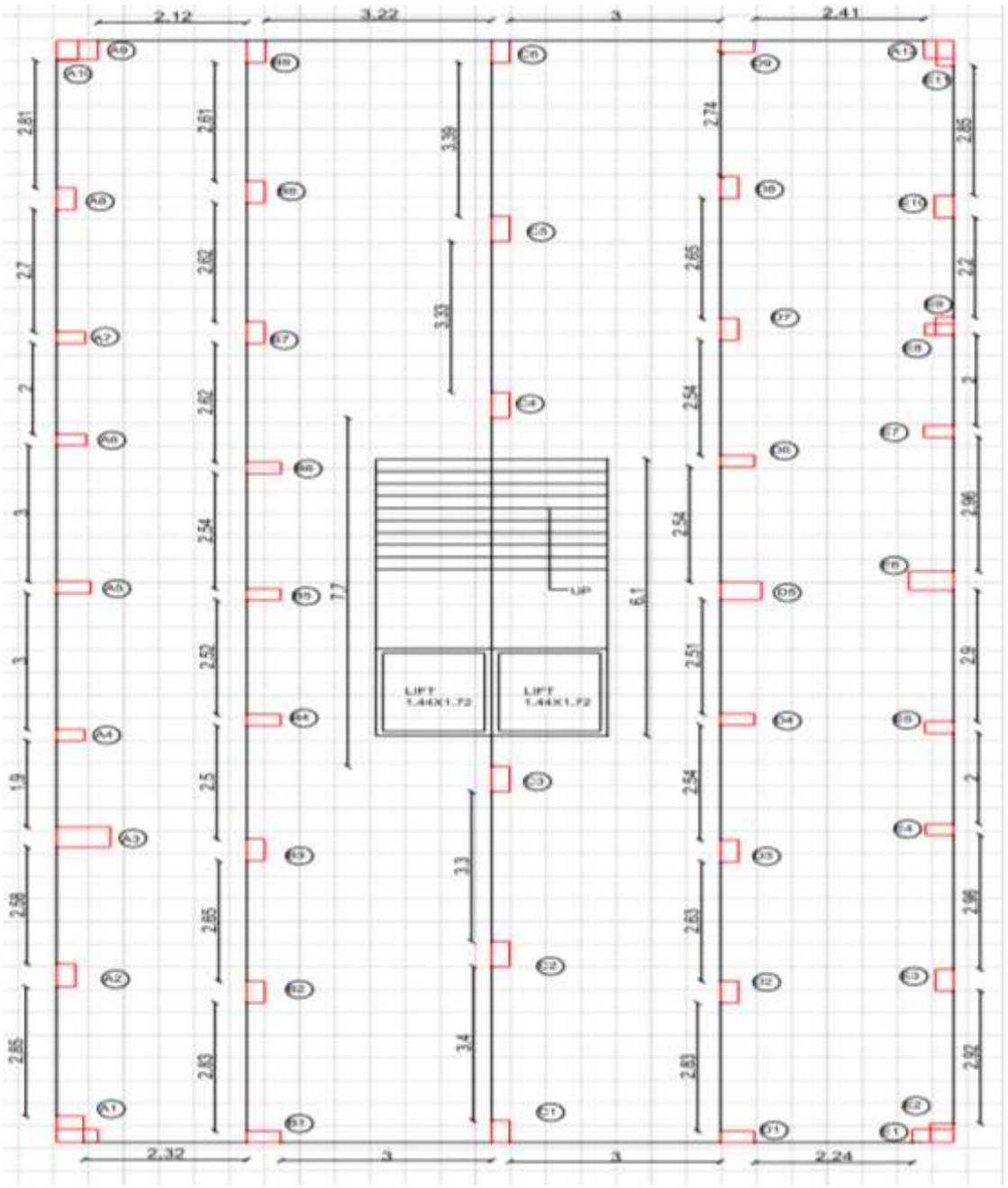


Figure 3 Structural Layout

9. GRAVITY LOAD ANALYSIS

9.1 PROJECT DETAIL

- Purpose of the building: Residential
- Shape of the building: Regular (rectangular)
- No. of stories: (G+7)
- Type of wall: Brick wall
- Height of stories: 3m. (Similar stories)

9.2 MATERIAL PROPERTIIES

- To carry out the analysis in ETABS, the properties of the materials such as concrete and steel should be defined. Similarly, various loads acting in the structure should be defined such as live load and super dead loads.
- Grade of concrete: M20
- Grade of steel: Fe 415
- Live loads: 5 kN/m^2
- SDL (floor finish): 1.5kN/m^2
- SDL (wall loads inner and outer respectively): 12kN/m^2
- Steel Percentage: 2.5% (Assumption)

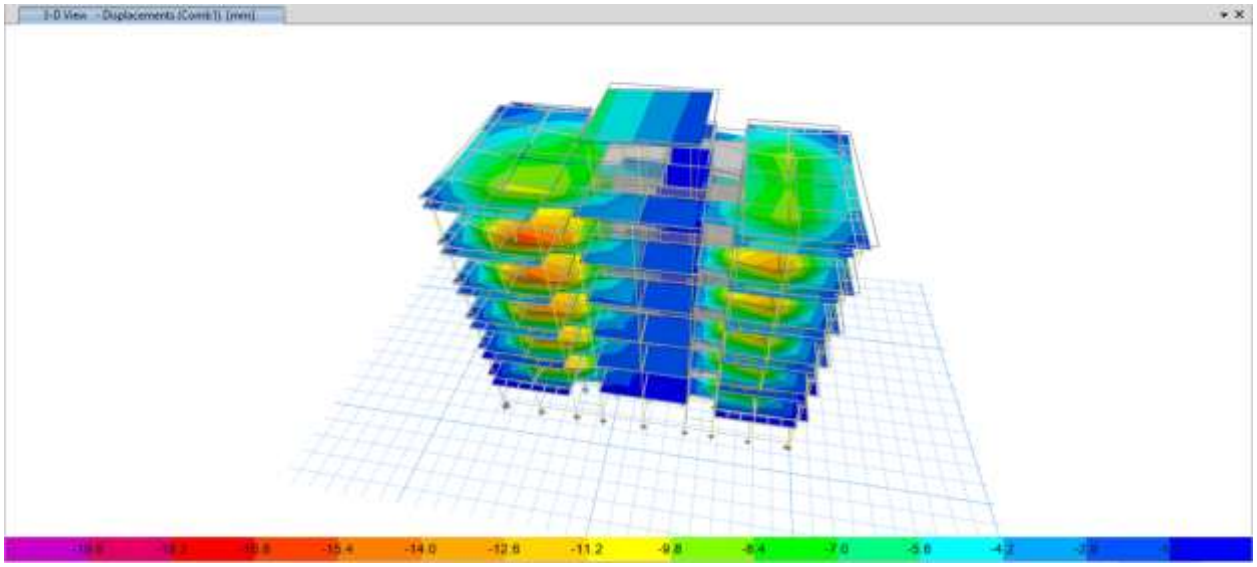


Figure 4 ETABS Analysis

Figure 5 Model for Building Repair Treatment

9.3 RESULT DISCUSSION

- **Based on the analysis of the multi-storied building, the following conclusions are made:**
- **This analysis was performed just for informational purpose.**
- **Steel data was not available, so an around 2.5% steel of total cross section of the column was considered for analysis.**
- **The analysis did not show any structural failure.**

10. REHABILITATION METHODOLOGY

10.1 TREATMENT A: INJECTION GROUTING

- Clean all surface with a wire brush.
- Clean all corroded steel bar with mild nitric acid. Apply zinc primer on a steel bar.
- Fill up the big cavity with grouting chemical.
- Put injection grouting plastic tube in the cavity or any crack.
- Apply high dose polymer treatment using SBR.
- The low viscous polymer to be injected in all crack from the above fitted plastic tube with high pressure.
- Do proper curing.

10.2 TREATMENT B: JACKETING

- Support surrounding structure with steel support.
- Clean all corroded steel bar with mild nitric acid. Apply zinc primer on a steel bar.
- Fill up the big cavity with grouting chemical.
- Apply 12mm "L" bar as shear connectors in zigzag pattern on column faces.
- Apply high dose SBR plaster with white sand and create a rough surface for proper bonding of outer new jacketing.
- Create new pad foundation of size (1.89 m x 1.89 m) 600mm thick with M:25 concrete, with two-layer mesh of 12mm @ 75mm c/c. (Top & bottom mesh) with a proper cover, at ground level.
- Erect new jacketing steel from pad foundation.
- Put extra steel of 4 nos. of 20mm tor TMT bars and 6 nos. of 12mm tor TMT vertical bars with 10mm ring @ 75mm c/c providing hook of 10 times the diameter of bar at an angle of 135 degree surrounding old column as jacketing steel.
- Do jacketing of minimum 75mm thick around old column with a minimum of M25 grade concrete.
- Treatment must be carried out up to the top of parking floor.
- Do proper curing.

10.3 TREATMENT C: MICRO CONCRETING

- Clean all surface with a wire brush.
- Put injection grouting plastic tube in the cavity or any crack.
- Apply high dose polymer treatment using S.B.R.
- The low viscous polymer to be injected in all crack from the above fitted plastic tube with high pressure.
- Apply 12mm "L" bar as shear connectors in zigzag pattern on column faces, at 2' (600mm) c/c.
- Put extra steel TMT Tor steel by welding if required with rings.
- Apply minimum 3" (75 mm) micro concrete on the old column.
- Do proper curing

10.4 TREATMENT

The following table shows the appropriate treatment:

Table 8 TREATMENT ON STRUCTURAL ELEMEN

Treatment	Column Members	Beam	Other
A	A1,A2,A9,B1,B2,C3,C4,D9,E1,E5,E10	SB1, SB3	
B	A5,A6,B3,B6,D5,B8,B9,C1,C2,D3,D6,E7	SB5	
C	A4,B4,B5,E3,C6,D1,E4,E6		BALCONY- 5,6,8

11. CONCLUSION

- **Following conclusions are drawn based on the present project work.**
- The early deterioration of concrete structure is also due to poor maintenance practices. The water supply and drainage system should be kept intact so that there is no leakage/ seepage on the walls which acts as an enemy to the structural integrity of the buildings.
- The repair/ rehabilitation of damaged structure should be carried out urgently to avoid further deterioration with time so that the life of the structure and the occupants are not jeopardized.
- Structural rehabilitation is more challenging than new concrete construction. It requires special considerations for evaluation of damage, selection of suitable material, technical specifications, and techniques for repair and quality control of material and workmanship. Therefore sufficient time and cost allocations should be made for durable rehabilitation work.

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