Condition Assessment of Structures

Suyog Ramrao Dhawade[1], Prof. Mayur A. Banarase[2] , Dr. Prakash .S. Pajgade[3]

[1]Student of Master in Structural Engineering,
[2]Assistant Professor
[3]Professor
Department of Civil Engineering,

Prof. Ram Meghe Institute of Technology and Research, Badnera – Amravati - India

---

Abstract – The assessment plays a very important role in the maintenance and monitoring of the structure, which keep the structure to perform its functionality throughout their useful life without any interference. The condition assessment is the process of getting information and data about the existing condition of the structure. The main objective of the paper is to give the idea about the assessment of the various structures such as public building, residential building, water tank and the results which is obtained from assessment, with reference to that we can decide the methods of repair, rehabilitation, strengthening, retrofitting which helps the structure for resistance against lateral forces and wind forces, and various adverse condition. On the other hand it also deals with the explanation of different methods to adopt for monitoring of existing structure. The assessment strategy classified on the basis of types of structures, their functional uses, life span, the degree of deterioration, and their economical preservation, to signify the use of methods on the structure which is having issues regarding the functionality and adverse effects on the metabolism of the structure.

***Key Words*:** *Condition Assessment, structural monitoring, repair, rehabilitation, strengthening, retrofitting*

1. INTRODUCTION

The country development depends upon the growth and smooth functioning of infrastructure. The building, bridges, tunnels, flyover, water tank has specific function to perform in their life span. For smooth functionality of these structures, the assessment plays a vital role to keep it in useful state. The paper explains the methods of assessment and their application in the case study to rectify the present strength and defects of existing structural elements, and suggesting the immediate remedies if required. The case study includes the non- destructive testing such as visual inspection, rebound hammer test, ultrasonic pulse velocity test, carbonation of concrete, etc. The investigation of the structure gives the condition score to decide about the remedial methodology such as repair, rehabilitation, strengthening, retrofitting. The remedies help us to enable the structure to counterattack the earthquake forces deterioration due to aging, chemical forces, settlement of foundation due to variable rise in water table, etc. The technique of strengthening helps the structure to uphold for decades.

2. Case study

2.1 Condition Assessment of Public Building at Chandur Railway

2.1.1 Report of assessment

1) Name of project : Chintamani Complex (Chandur Railway)
2) Date of assessment : 1-01-2022
3) Name of client : Mr. Hariom Sharma
4) Type of structure : Public building (Frame structure)
5) Life span : 20 years.
6) Use of building : Commercial building (shops of retailing products)
7) Future requirement : Construction of two new story (G+3) and assessment of existing structural elements and earthquake resistant design

8) Requirements of clients :

- No additional increase in sizes of beams
- Comparative analysis of various strengthening techniques

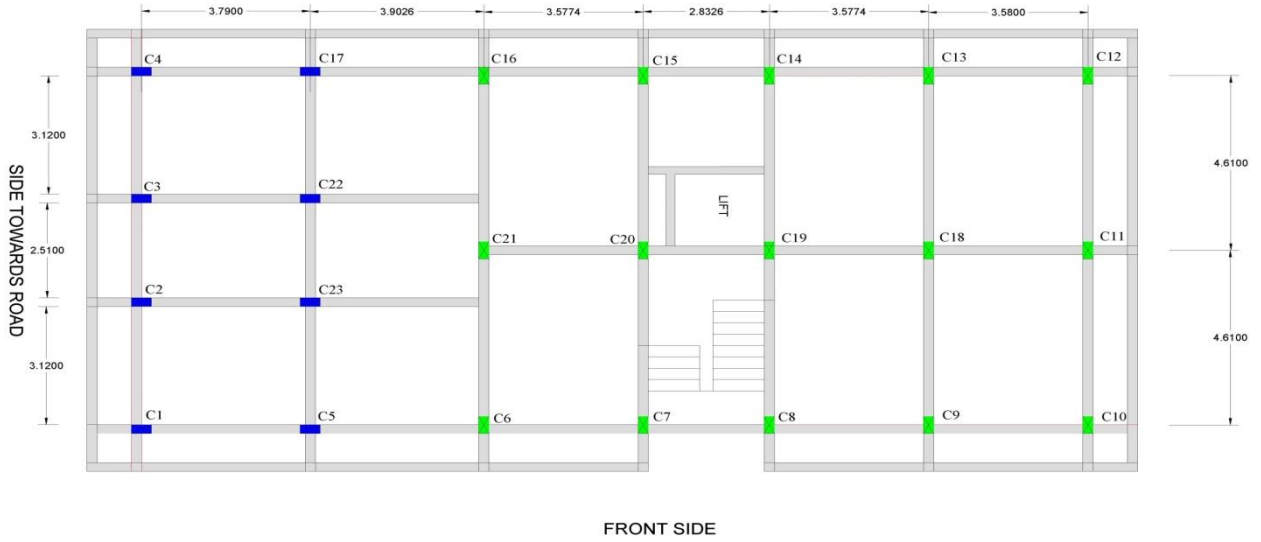


Figure 1: Floor Plan of Chintamani Complex at Chandur Railway

2.1.2 Non-destructive testing adopted at site

Type of building – Reinforced concrete framed building

1. Visual inspection

a) Observation of cracks in beams – The cracks at the ground floor slab beam of building.

Types

1) Flexural crack – These cracks are formed at bottom of middle span below N.A of the beam where flexural stresses are maximum.
2) Shear cracks – When the shear reinforcement at corners are at large spacing.

Remedies

1) Minor cracks: Repair by injecting epoxy resins and finish it by repair mortar (polymer modified mortar)
2) Flexural cracks and shear cracks: Repair by injection of low viscous grout and strengthening by F.R.P wrapping.

Figure 2: Existing condition of beam

b) Observation of cracks in column – Cracks at ground storey and first storey.

Types

1. Diagonal cracks - Load carrying capacity of column is inadequate and reinforcement is insufficient.

2. Horizontal cracks - Moment of resistance inadequate and main reinforcement not in position.

Remedies

1) Diagonal cracks and horizontal cracks: The column is R.C.C jacketed and cracks are grouted and levelled and rebar solution is applied for shear connectors.

c) Cracks in slab – At ground floor slab

Types

1) Thermal cracks – Variation due to thermal changes
2) Spalling of plaster slab – Cracks formed due to excess moisture, corrosion of reinforcement due to inadequate cover or weathering.

Remedies

1) Thermal cracks: The cracks are repaired by low viscous grout.

2) Pilling of plaster: Proper adhesive are provided on the exposed surface for proper bond with cement and high viscosity epoxy resin used for surface coating is provided on the surface.

d) Observation for corrosion of Reinforcement

1) **Column –** The ground storey level column has been corroded due to insufficient clear cover and faulty workmanship while placing concrete.
Remedies- The R.C jacketing to be done to all ground and first floor column.

2) **Beam-** The longitudinal reinforcement of front side beam on ground and first storey has affected by corrosion due to insufficient cover and inadequate confining reinforcement.
Remedies- The F.R.P jacketing to be done to all ground and first floor column.

3) **Slab** – The slab reinforcement corroded due to direct contact of moisture and other acidic components which caused because of insufficient cover and voids in the concrete.
Remedies- Remove the dust and pilled part from the slab, the exposed bars are coated with polymer and adhesive are applied to the exposed surface for proper bond with cement , after some time level it with thin mortar.

2. Rebound hammer test

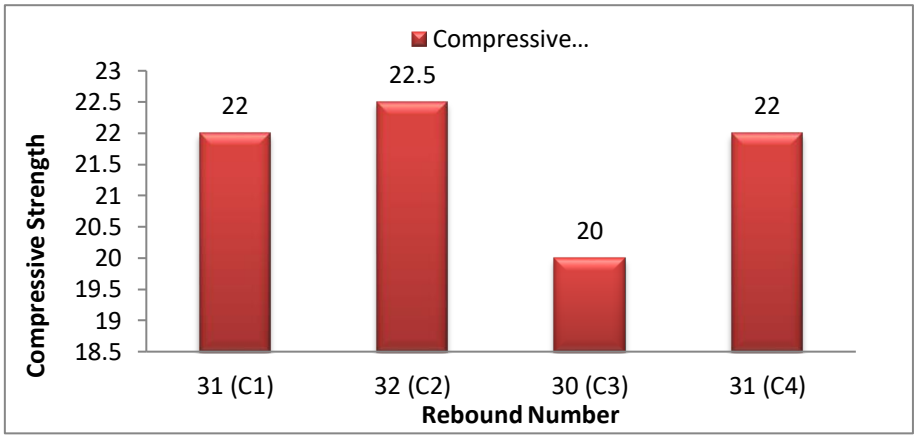
A. Ground floor north direction column (from fig no 2.1.1)

Table 1: Rebound Numbers of Ground floor North direction column

Column 1st	Column 2nd	Column 3rd	Column 4th
18	28	32	22
32	29	35	35
44	36	22	34
31	38	25	25
36	32	35	36
26	32	25	34
Avg-31	Avg-32	Avg-30	Avg-31

Table 2: Approximate Comprehensive of Ground floor North direction column

Location	Approximate Compressive strength	Quality of concrete depends on rebound value (IS 13311:1992) Part2
1st column	22 N/mm^2	30 to 40 (Good concrete)
2nd column	22.5 N/mm^2	30 to 40 (Good concrete)
3rd column	20 N/mm^2	30 to 40 (Good concrete)
4th column	22 N/mm^2	30 to 40 (Good concrete)



Graph1: Relation between comprehensive strength and rebound number

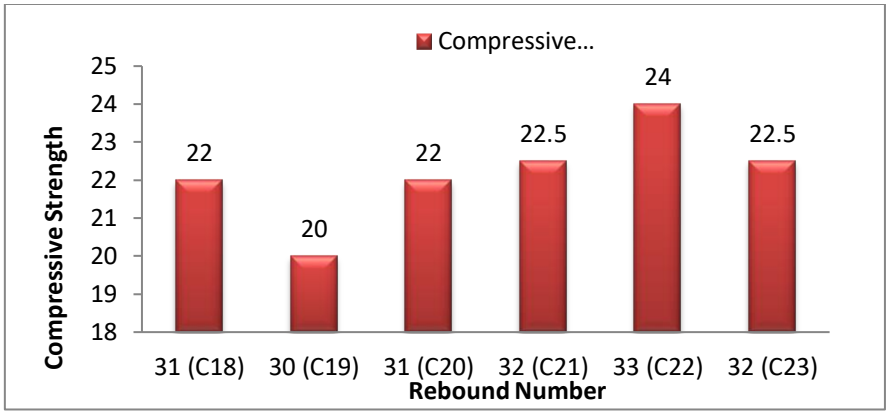
E. The interior column of the building (From fig no 2.1.1)

Table 3: Rebound Numbers of the interior column of the building

18th Column	19th Column	20th Column	21st Column	22nd Column	23rd Column
28	25	38	22	30	32
30	22	32	35	38	36
32	30	28	42	32	28
36	35	30	36	35	36
32	36	28	28	32	28
30	32	32	30	30	30
Avg-31	Avg-30	Avg-31	Avg-32	Avg-33	Avg-32

Table 4: Approximate Compressive Strength of the interior column of the building

Location	Approximate Compressive strength	Quality of concrete depends on rebound value (IS 13311:1992) Part2
18th column	22N/mm^2	30 to 40 (Good concrete)
19th column	20 N/mm^2	30 to 40 (Good concrete)
20th Column	22 N/mm^2	30 to 40 (Good concrete)
21th column	22.5 N/mm^2	30 to 40 (Good concrete)
22th column	24 N/mm^2	30 to 40 (Good concrete)
23th column	22.5 N/mm^2	30 to 40 (Good concrete)



Graph2: Relation between comprehensive strength and rebound number of the interior column of the building

Figure 3: Process of using Rebound hammer

3. Ultrasonic pulse velocity test:

1) Velocity- Travel length / Time.
2) The ultrasonic pulse velocity measures the time of travel of ultrasonic pulses which is passing through the concrete.
3) The equipment use was PUNDIT (Portable ultrasonic non-destructive digital indicating tester).
4) The direct transmission of ultrasonic pulse velocity test is adopted.

A. Pulse velocity for concrete:

Table 5: Pulse velocity for concrete of various columns

Sr.no	Location	Size	Pulse velocity	Concrete condition
C1	Front elevation exterior column.	230x450	3535 m/s	Questionable
C20	Intermediate column at ground storey.	230x450	3413 m/s	Questionable
C21	Intermediate column at first storey.	230x450	4476 m/s	Good
C15	Front column west side of building at first storey.	230x450	4285 m/s	Good
C11	Front column on south west side of building at ground storey.	230x450	3362 m/s	Questionable
C3	Front column on north side of building at ground storey	230x450	4583 m/s	Good

B. In-situ quality criteria of concrete:

Table 6: Pulse velocity of concrete and its compressive strength

Sr.no	Length	Pulse velocity	Classification	Compressive strength (IS 13311:1992) Part1 (table no:2)
C1	0.45 m	3.5km/sec	Medium	20 TO 25 N/mm^2
C20	0.45 m	3.4km/sec	Medium	20 TO 25 N/mm^2
C21	0.45 m	4.47 km/sec	Very good	30 TO 35 N/mm^2
C15	0.45 m	4.28 km/sec	Very good	30 TO 35 N/mm^2
C11	0.45 m	3.3km/sec	Medium	20 TO 25 N/mm^2
C3	0.45 m	4.58 km/sec	Very good	30 TO 35 N/mm^2

Figure 4: Process of using Ultrasonic pulse velocity test

4. Carbonation test:

1. 1% phenolphthalein solution sprayed on exposed fresh surface.
2. Unaffected by carbon dioxide having surface colour pink.
3. Coloured surface represents there is still Ca (OH)2 present in it.
4. The depth of carbonation can be determined as:
 d = coloured surface to the edge of specimen.
5. The carbonation depth is approximately equal to square root of time
 1mm for 1 year, 3mm for 9 years.

Figure 5 Phenolphthalein solutions on concrete surface

5. Rebar locator:

1) Rebar locator is used for locating the number of bars in particular column and beam.
2) It also helps to determine the diameter of bars and clear cover.
3) With the help of rebar we can get the clear idea about existing reinforcement of structure without destructive testing.

Figure 6: Position of reinforcement in the column

After the load calculation the structure is design for earthquake Zone 3

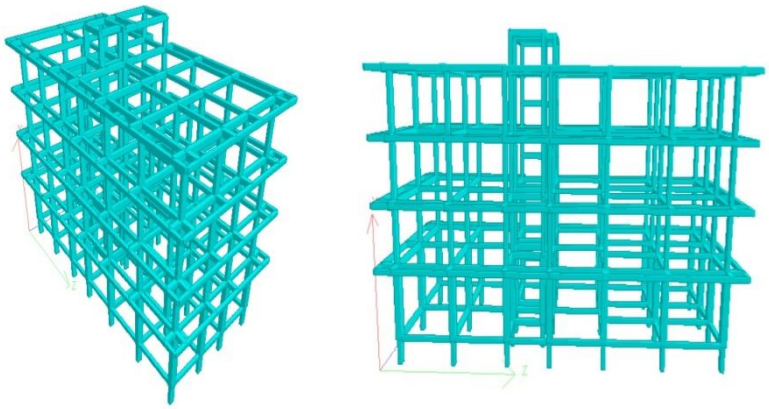


Figure 7:3D View of RC Frame of building at Chandur Railway

2.1.3 After the design in STAADPRO the beam which are having less moment of resistance than required are F.R.P jacketed

Table No. 7: FRP Jacketing to the beam

Sr. No	Floor	Beam No	Dimension	M.R Of Existing Beam	M.R Required	M.R By 1893:2002 by RCC Jacketing	Number Of Wrap	M.R Of Wrap Beam
1	Ground Floor	B12	230x380mm	61.02 KN-m	65 KN-m	108.50 KN-m (300x450mm)	1	69.39 KN-M
2	Ground Floor	B4	230x380mm	61.02 KN-m	65 KN-m	108.50 KN-m (300x450mm)	1	69.39 KN-M
3	1st Floor	BT4	230x300mm	37.54 KN-m	41.56 KN-m	88.17 KN-m (300x380mm)	1	48.90KN-M
4	1st Floor	BT6	230x300mm	37.54 KN-m	41.56 KN-m	88.17 KN-m (300x380mm)	1	48.90KN-M
5	1st Floor	BT8	230x300mm	37.54 KN-m	41.56 KN-m	88.17 KN-m (300x380mm)	1	48.90KN-M
6	1st floor	BT21	230x300mm	28.31KN-m	32.53 KN-m	88.17 KN-m (300x380mm)	1	35.77KN-M
7	1st floor	BT22	230x300mm	28.31KN-m	32.53 KN-m	88.17 KN-m (300x380mm)	1	35.77KN-M
8	1st floor	BT25	230x300mm	28.31KN-m	32.53 KN-m	88.17 KN-m (300x380mm)	1	35.77KN-M

2.1.3 After the design in STAADPRO the column which are having less reinforcement than required are R.C.C jacketed

Table No. 8: R.C Jacketing to the column

Column No	Existing Column Size		Existing steel	Stirrups Details	Required Size		Required steel	Stirrups Details	Actual Steel Required	No Of Bar
	L	B			L	B				
1	230	450	905	6 mm @150mm	380	600	1824	8mm-130mm	**919**	16X4,12x2
2	230	450	905	6 mm @150mm	380	600	1606	8mm-130mm	**701**	12x6
3	230	450	905	6 mm @150mm	380	600	1606	8mm-130mm	**701**	12x6
4	230	450	905	6 mm @150mm	380	600	1824	8mm-130mm	**919**	16X4,12x2
5	230	450	905	6 mm @150mm	380	600	1824	8mm-130mm	**919**	16X4,12x2
6	230	450	905	6 mm @150mm	380	600	1538	8mm-130mm	**633**	12x6
7	230	450	905	6 mm @150mm	380	600	1824	8mm-130mm	**919**	16X4,12x2
8	230	450	905	6 mm @150mm	380	600	2371	8mm-130mm	**1466**	16X6,12x2
9	230	450	905	6 mm @150mm	380	600	1824	8mm-130mm	**919**	16X4,12x2
10	230	450	1131	6 mm @150mm	380	600	1824	8mm-130mm	**693**	12x6

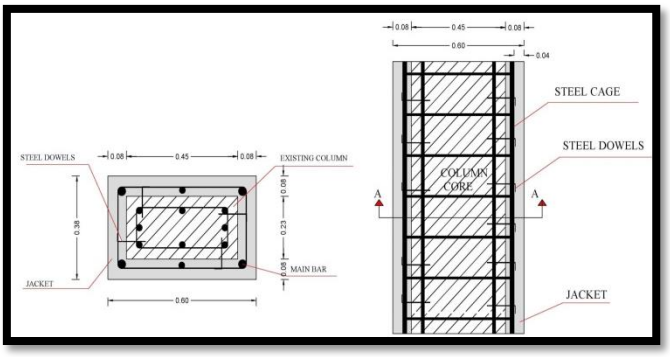


Figure 8: Cross Section of RCC Jacketed Column

2.2 Condition assessment of residential building at Amravati city

5.2.1 Report of assessment

1) Name of project : Om Niwas (Amravati).
2) Date of assessment : 15-02-2022
3) Name of client : Mr. Shubham Rithe
4) Type of structure : Frame Structure
5) Life span : 15 Years.
6) Use of building : Residential Building
7) Future requirement : Assessment of the existing structural element and design according to is 1893-2016 for Zone 3 and rectify defects if any.
8) Requirements of clients:
   - No additional increase of size for upper stories.
   - Economical techniques for strengthening.
   - No use of destructive equipment while assessing the structure.

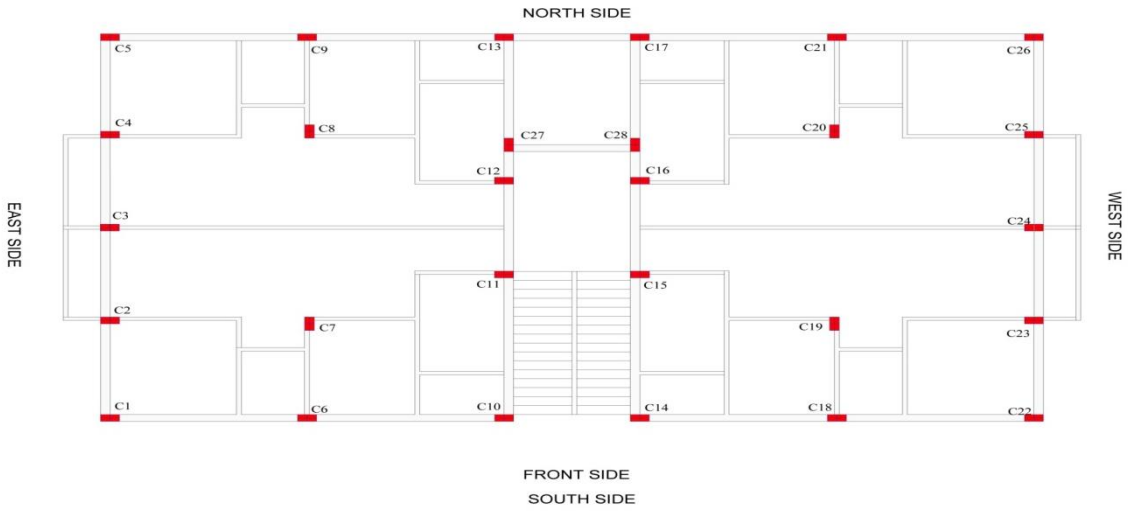


Figure 9: Floor Plan of Residential Building in Amravati city

5.2.2 Non-destructive testing adopted at site

Type of building – reinforced concrete framed building

Description of assessment items:

1. Visual inspection

A. Observation of cracks in beams – The cracks at the first and second story of building.

Types

1) Flexural crack – These cracks are formed at bottom of middle span below N.A of the beam where flexural stresses are maximum.

Remedies

1) Minor cracks: Repair by injecting epoxy resins and finish it by repair mortar (polymer modified mortar)

2) Flexural cracks and shear cracks: Repair by injection of low viscous grout and strengthening by F.R.P wrapping

Figure 10: Flexural Cracks in the Beam

B) Observation of cracks in column – Cracks at ground storey and first storey

Types-

1) Horizontal cracks - Moment of resistance inadequate and main reinforcement not in position.

Remedies-

1) Horizontal cracks: The column is R.C.C jacketed and cracks are grouted and levelled and rebar solution is applied for shear connectors.

C. Observation of cracks in slab – at ground floor slab

Types-

1) Thermal cracks: Variation due to temperature changes

Remedies-

1) Thermal cracks : The cracks are repaired by low viscous grout

D. Observation for corrosion of Reinforcement –

1) **Column –** the ground and first storey level column has been corroded due t0 insufficient clear cover and faulty workmanship while placing concrete.
   Remedies: The R.C.C jacketing to be done to all ground and first floor column.
2) **Beam-** the longitudinal reinforcement of east sided beam on first and third story has affected by corrosion due to insufficient cover and inadequate confining reinforcement.
   Remedies: The F.R.P. jacketing to be done to all ground and first floor column.

Figure 11: Slab Plaster Pilling and Reinforcement Corroded

2. Rebound Hammer Test –

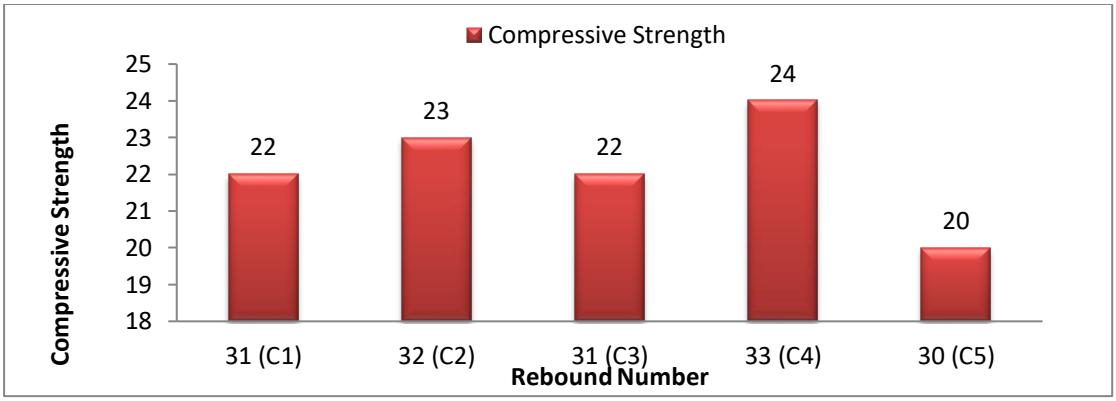
A. The ground floor column in east direction front to the playground (from fig no 2.2.1)

Table 9: Rebound Hammer the ground floor column in east direction

Column 1st	Column 2nd	Column 3rd	Column 4th	Column 5th
25	32	31	33	32
35	35	33	34	33
30	26	31	34	29
28	32	30	33	32
38	34	31	35	29
32	28	32	32	28
Avg-31	Avg-32	Avg-31	Avg-33	Avg-30

Table 10: According to the rebound numbers the approximate compressive strength

Location	Approximate Compressive strength	Quality of concrete depends on rebound value (IS 13311:1992) Part2
1st column	22 N/mm^2	30 to 40 (Good concrete)
2nd column	23 N/mm^2	30 to 40 (Good concrete)
3rd column	22 N/mm^2	30 to 40 (Good concrete)
4th column	24 N/mm^2	30 to 40 (Good concrete)
5th column	20 N/mm^2	30 to 40 (Good concrete)



Graph 3: Relation between comprehensive strength and rebound number of Ground floor column in east direction

Figure 12: Process of using Rebound Hammer

3. Ultrasonic Pulse velocity test

A. Pulse Velocity for Concrete:

Table 11: Pulse Velocity of column

Sr. No	Location	Size	Pulse velocity	Concrete condition
C1	Front Elevation Exterior Column (East Side)	300x450mm	3435m/sec	Questionable
C11	Intermediate Column At Ground Storey	300x450mm	3416m/sec	Questionable
C12	Intermediate Column At First Storey	300x450mm	4142 m/sec	Good
C17	Side Column Of North Side Of Ground Floor	300x450mm	3932 m/sec	Good
C26	Side Column On North Side Of Third Floor	300x450mm	4032 m/sec	Good
C6	Side Column On South Side Of First Floor	300x450mm	3925 m/sec	Good
C22	Side Column On South Side Of Second Floor	300x450mm	3425m/sec	Questionable
C24	Rare Column On West Side Of Ground Floor	300x450mm	3245m/sec	Questionable

B. Insitu quality criteria of concrete:

Table 12: Approximate Compressive strength of column

Sr. No.	Length	Pulse velocity	Classification	Compressive strength (IS 13311:1992) Part1
C1	0.45 m	3.435 KN/m	Medium	20 to 25 N/mm^2
C11	0.45 m	3.416KN/m	Medium	20 to 25 N/mm^2
C12	0.45 m	4.142 KN/m	Good	25 to 30 N/mm^2
C17	0.45 m	3.932 KN/m	Good	25 to 30 N/mm^2
C26	0.45 m	4.032 KN/m	Good	25 to 30 N/mm^2
C6	0.45 m	3.925 KN/m	Good	25 to 30 N/mm^2
C22	0.45 m	3.425 KN/m	Medium	20 to 25 N/mm^2
C24	0.45 m	3.245 KN/m	Medium	20 to 25 N/mm^2

Figure 13:Ultrasonic Pulse Velocity Test

4. Rebar locator:

Figure 14: Position of reinforcement in the column

After the load calculation the structure is design for earthquake Zone 3

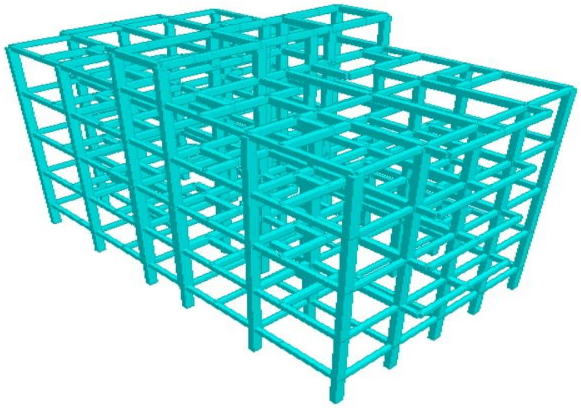


Figure 15: 3D View of RC Frame of building at Amravati

2.1.3 After the design in STAADPRO the beam which are having less moment of resistance than required are F.R.P jacketed

Table No. 13: FRP Jacketing to the beam

Sr.No	Floor	Beam No	Dimension	M.R of Existing Beam	M.R By Required	M.R By R.C.C Jacketing	Number of Wrap	M.R By FRP Wrapping
1	Ground Floor	B21	300x380 mm	67.34 KN-m	72.52 KN-m	111.64 KN-m (380x450mm)	1	90.75 KN-m
2	Ground Floor	B18	300x380 mm	67.34 KN-m	72.52 KN-m	111.64 KN-m (380x450mm)	1	90.75 KN-m
3	1st Floor	BS65	230x300 mm	37.56 KN-m	41.56 KN-m	88.17KN-m (300x380m)	1	47.63KN-m
4	1st Floor	BS67	230x300 mm	37.56 KN-m	41.56 KN-m	88.17KN-m (300x380m)	1	47.63KN-m
5	1st Floor	BS61	230x300 mm	60.25 KN-m	66.68 KN-m	111.64KN-m (380x450m)	1	76.86 KN-m
6	2ndFloor	BT67	230x300 mm	37.56 KN-m	41.56 KN-m	88.17KN-m (300x380m)	1	47.63KN-m
7	2ndFloor	BT61	300x380 mm	60.25 KN-m	66.68 KN-m	111.64KN-m (380x450mm)	1	76.86 KN-m
8	2ndFloor	BT62	300x380 mm	60.25 KN-m	66.68 KN-m	111.64KN-m (380x450mm)	1	76.86 KN-m

2.1.3 After the design in STAADPRO the column which are having less reinforcement than required are R.C.C jacketed

COLUMN NO	EXISTING COLUMN SIZE		EXISTING STEEL	STIRRUPS DETILS	REQUIRED SIZE		REQUIRED STEEL	STIRRUPS DETILS	ACTUAL STEEL REQUIRED	NO OF BAR
	L	B			L	B				
C7	300	450	1068	6 MM @ 150MM C/C	450	600	2380	8MM-130MM C/C	**1312**	16x4, 12X2
C8	300	450	1053	6 MM @ 150MM C/C	450	600	2160	8MM-130MM C/C	**1107**	12x6
C10	300	450	1068	6 MM @ 150MM C/C	450	600	2160	8MM-130MM C/C	**1092**	16x4, 12X2
C11	300	450	1353	6 MM @ 150MM C/C	450	600	2160	8MM-130MM C/C	**807**	16X4
C12	300	450	1408	6 MM @ 150MM C/C	450	600	2160	8MM-130MM C/C	**752**	16X4

5.3 Report of Assessment of Water Tank

5.3.1 Report of assessment

1) Name of project : Elevated Service Reservoir (Wasni khurd).
2) Date of assessment : 31-03-2022
3) Name of authority : Maharashtra Jeevan Pradhikaran, Subdivision, Achalpur
4) Type of structure : Water tank.
5) Capacity of water tank : 20000 lit.
6) Life span : 14 years.
7) Use of building : Distribution of water throughout the village.
8) Future requirement : Assessment of ESR and checks for resistant to lateral forces.
9) Requirements of authority :
   - Only staging elements sizes should be revised, if any change in design.
   - After assessing the reservoir, if it fails then whole structure is constructed as a new.
   - No uses of destructive equipment while assessing the tank.

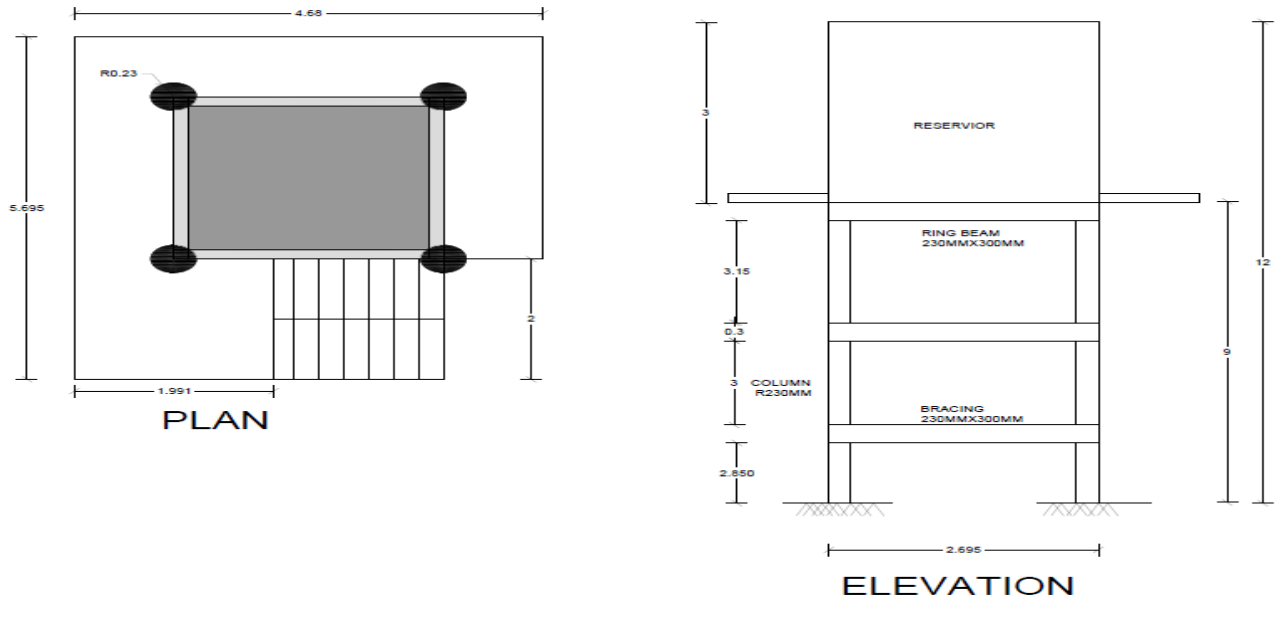


Figure 16: Plan and elevation of Water Tank

2.3.2 Non-destructive testing adopted at site

Type of building – Reinforced concrete framed building

1. Visual inspection

a) Observation of cracks in beams – The cracks at the 1st level bracing.

Types

1) Shear cracks – When the shear reinforcement at corners are at large spacing.

Remedies

1) Minor cracks: Repair by injecting epoxy resins and finish it by repair mortar (polymer modified mortar)
2) Shear cracks: Repaired by epoxy mortar and finish it by rich mix.

b) Observation of cracks in column – Cracks at 2nd and 3rd level

Types

1. Diagonal cracks - Load carrying capacity of column is inadequate and reinforcement is insufficient.
2. Horizontal cracks - Moment of resistance inadequate and main reinforcement not in position.

Remedies

1) Diagonal cracks and horizontal cracks: The column cracks are filled by low viscous grout and then wrapping of fiber reinforced polymer around the column.

c) Observation of cracks in slab – At first floor slab

Types

1) Thermal cracks – Variation due to temperature changes.

Remedies

1) Temperature cracks: The cracks are repaired by low viscous grout and level it by putty.

d) Observation for corrosion of reinforcement –

Column – The 1st level column has been corroded due to insufficient clear cover and faulty workmanship while placing concrete.

Remedies

1. The R.C.C jacketing to be done to all ground column.

Figure 17: Shear cracks in the beam

2. Rebound hammer test –

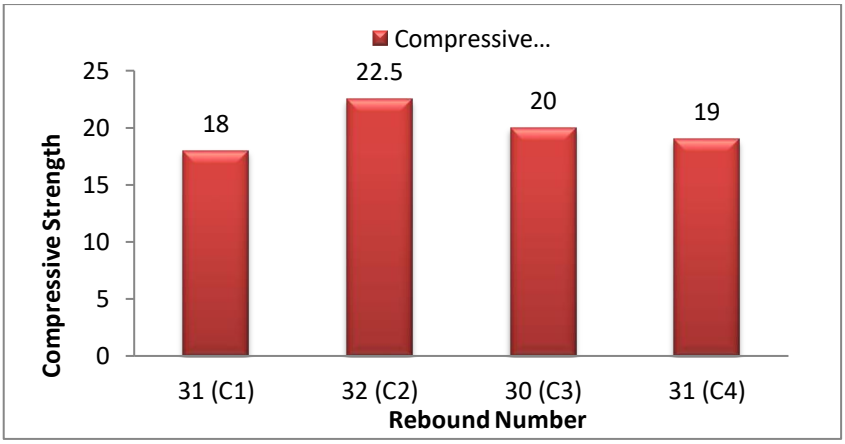
A. The 1st level column in north direction column (from fig no.2.3.1)

Table 14: Rebound Numbers of 1st level column in north direction column

Column 1st	Column 2nd	Column 3rd	Column 4th
30	32	30	31
28	33	29	26
29	34	32	30
28	29	28	26
29	28	35	31
26	30	30	28
Avg-31	Avg-32	Avg-30	Avg-31

Table 15: Approximate Comprehensive of 1st level column in north direction column

Location	Approximate Compressive strength	Quality of concrete depends on rebound value
1st column	18 N/mm^2	20 to 30 (Good concrete)
2nd column	22.5 N/mm^2	30 to 40 (Good concrete)
3rd column	20 N/mm^2	30 to 40 (Good concrete)
4th column	19 N/mm^2	20 to 30 (Good concrete)



Graph4: Relation between comprehensive strength and rebound number of 1st level column in north direction column

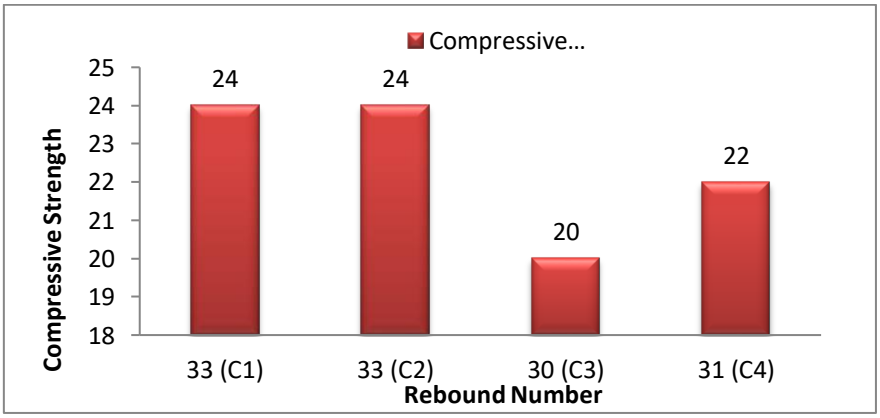
B. Bracing rebound number

Table 16: Rebound Numbers of the bracing

CSB1	CSB2	CTB1	CTB2
32	35	30	28
30	36	32	32
36	33	28	30
36	30	30	34
Avg-33	Avg-33	Avg-30	Avg-31

Table 17 : Approximate Compressive strength of the bracing

Location	Approximate Compressive strength	Quality of concrete depends on rebound value (IS 13311:1992) Part2
2nd level bracing CSB1	24N/mm^2	30 to 40 (Good concrete)
2nd level bracing CSB2	24N/mm^2	30 to 40 (Good concrete)
3rd level bracing CTB1	20N/mm^2	30 to 40 (Good concrete)
3rd level bracing CTB2	22N/mm^2	30 to 40 (Good concrete)



Graph5: Relation between comprehensive strength and rebound number of Bracing

Figure 18: Process of Rebound hammer test

3. Ultrasonic Pulse velocity test

A. Pulse Velocity for Concrete:

Table 18: Pulse velocity for concrete of various columns

Sr. No	Location	Size	Pulse velocity	Concrete condition
C1	1st level column	230mm	3446m/sec	Questionable
C2	1st level column	230mm	3986 m/sec	Good

B. In-situ quality criteria of concrete:

Table 19: In-situ quality criteria of concrete

Sr.no	Radius	Pulse velocity	Classification	Compressive strength
C1	0.23m	3.446km/sec	Medium quality	20 to 25 N/mm^2
C2	0.23m	3.986km/sec	Good Quality	25 to 30 N/mm^2

Figure 19: Ultra sonic pulse velocity test

4. Rebar Locator:

Figure 20: Rebar locator

After the load calculation the structure is design for earthquake Zone 3

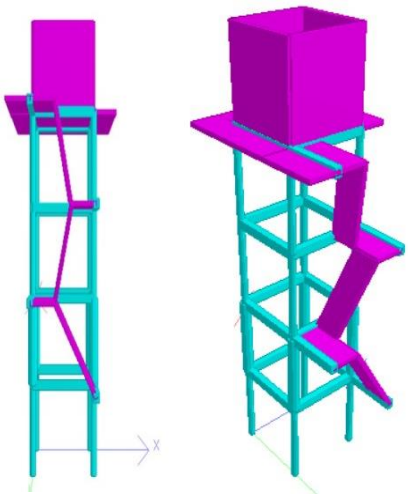


Figure 21:3D of Water Tank

2.1.3 After the design in STAADPRO the column which are having less characteristics compressive strength than required are F.R.P jacketed

Table No. 20 FRP jacketing to the column of 2nd and 3rd level

Sr. No	Floor level	Column No	Column dimension Circular	fck By NDT	fck required	Number of wrap required	Confining pressure
1	2nd Floor	CS1	Diameter 230mm	18N/mm^2	25 N/mm^2	2	26N/mm^2
2	2nd Floor	CS 2	Diameter 230mm	18 N/mm^2	25 N/mm^2	2	26N/mm^2
3	2nd Floor	CS 3	Diameter 230mm	18 N/mm^2	25 N/mm^2	2	26N/mm^2

2.1.3 After the design in STAADPRO the column which are having less reinforcement than required are R.C.C jacketed

Table No. 21 R.C.C jacketing to the column of level 1

Column No.	Existing Column size	Existing column steel	Stirrups details	Required size	Required steel	Stirrups details	Actual steel Required	No of bar
	Diameter			Diameter				
1	230	680	6 mm @150mm	380	1300	8mm-150mm	**620**	12x6
2	230	680	6 mm @150mm	380	1340	8mm-150mm	**660**	12x6

Conclusion:

1. The assessment of public building is carried out to extend two floors above and to check the existing condition of structural elements, whether they are capable of resisting the lateral forces or other natural calamities. The R.C jacketing to the ground floor columns is recommended as per the design criteria because the load carrying capacity of the ground floor column is inadequate. The cross section of non-jacketed column is 230x450mm, after designing the column for R.C jacketing it is increased by 30-40%, now jacketed cross section is 450x600 mm. The beams of the ground and first floor fails while designing the structure for earthquake forces, the moment of resistance of the existing beams is less than required. The F.R.P jacketing is recommended to the beam which is having inadequate moment of resistance.

2. The residential building is assessed to enhance resistance against lateral forces and to check deterioration of structure. The building ground and first storey columns fails while designing the structure for lateral forces, because of inadequate cross section and lack of the reinforcement to carry the load of two floors above. The R.C jacketing to the ground floor and first floor columns is recommended as per the design criteria. The cross section of non-jacketed column is 300x450mm, after designing the column for R.C jacketing it is increased by 30-40%, now jacketed cross section is 450x600 mm.

3. The beams of the ground, first and second floors fails while designing the structure for lateral forces, the moment of resistance of the existing beams is less than required. The F.R.P jacketing is recommended to the beam which is having inadequate moment of resistance.

4. After the assessment of water tank, the 1^{st} level columns are affected by corrosion of reinforcement and diagonal cracks, the R.C jacketing technique is recommended to the 1^{st} level column. The F.R.P jacketing to the 2^{nd} and 3^{rd} level columns is recommended because of its inadequate compressive strength and F.R.P material lightweight, so that the additional dead load on the foundation should not exceed. The reservoir has no point of leakages and safe while designing the tank for earthquake forces. For minor damping water proofing is suggested to the tank.

References:

1. M. K. Lim and H. Cao, "Combining multiple NDT methods to improve testing effectiveness "Journal of Construction Engineering Volume 2013 Article ID 834572.

2. Adam B. Noel, Ahmed Badway "SHM Using Wireless Sensor Networks: A Comprehensive Survey" Ieee Communication Surveys And Surveys Volume 19 N No 3, 201.

3. Hearn, G. and Testa, B. R., "Modal Analysis for Damage Detection in Structures", J. Structural Engrg., 117-10, ASCE, 1991. 20. IS13945, Repair and Seismic Strengthing of Building – Guidelines, Bureau of Indian Standars , New Delhi.

4. T. P. Meikandaan, Dr. A. Ramachandra Murthy (2017), "Flexural Behaviour of RC Beam Wrapped with GFRP Sheets". International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 2, February 2017, pp. 452–469 .

5. Consuelo Beschi, Alberto Meda and Paolo Riva, (ANIDIS RIVA-2011) "Beam-Column Joint Retrofitting with High Performance Fibre Reinforced Concrete Jacketing" ANIDIS BARIA 2011.

6. IS 13935:1993, Repair and Seismic Strengthening of Buildings—Guidelines, Bureau of Indian Standards, New Delhi, 1993.

7. IS 15988: 2013 , Seismic Evaluation and Strengthening of Existing Reinforced Concrete Building - Guidelines, Bureau of Indian Standards, New Delhi.

8. IS 1893 (Part 1):2002 , Criteria For Earthquake Resistant Design of Structures - Guidelines, Bureau of Indian Standards, New Delhi.

9. IS 10262:2009 Concrete Mix Proportioning - Guidelines, Bureau of Indian Standards, New Delhi.