

Structural Assessment and Performance Evaluation of Structural Integrity and Providing Remediation Strategies

Saurabh Subhash Tambe¹, Dr. V. A. Patil²

PG Student, Department of Civil Engineering, B. R. Harné College of Engineering and Technology, Vangani,
Maharashtra, India¹

Principal, Department of Civil Engineering, B. R. Harné College of Engineering and Technology, Vangani,
Maharashtra, India²

ABSTRACT: This study presents the structural assessment of a G+7 reinforced concrete (RCC) building located in Seismic Zone III (Thane, India) to evaluate its safety and serviceability. The analysis was performed using STAAD Pro, considering dead, live, seismic (IS 1893:2016), and wind loads (IS 875 Part 3). Structural adequacy was verified through Demand-to-Capacity (D/C) ratios as per IS 456:2000, with all values within permissible limits. Non-destructive testing using the rebound hammer method estimated in-situ concrete strength. Results from deflection, shear, and bending moment analysis indicate satisfactory performance. The building is structurally stable, requiring structural repairs for improved durability.

KEYWORDS: Structural Assessment, Staddpro, Non-destructive and Destructive Tests, Utilization Report, Wind and Seismic Analysis Structural Audit and Rehabilitation Technique.

I. INTRODUCTION

Structural assessment and performance evaluation is the technical survey of the structure to check its strength and stability. Audit is the first step in repairing procedure of the building. Structural audit was first introduced by Indian society of structural engineers. An audit is a systematic and independent examination of various things; Structural Auditing is nothing but the overall health and performance check-up of building. This process to create awareness in the residents and owners of building towards the health examination of existing concrete buildings. Audit of structure are very important to perform safely and have no risk. It analyses and suggests appropriate repairs and retrofitting measures required for the structure. Structural audit is done by an experienced and licensed structural consultant. The Audit helps to highlight & investigate all the critical areas and whether the building needs immediate attention. It covers the structural analysis of the existing frame and highlight the weak structural areas for static, wind & earthquake loads. If the building has changed the user, from residential to commercial or industrial, this should bring out the impact of such a change. As per mention in Clause 75A- The society shall cause to undertake the structural audit of the building as follows, A Norm According to the model BYE-LAW NO. 77 for co-operative housing societies, it is mandatory that if the age of a building is 15 to 30 years, a structural audit must be carried out once in five years and for buildings older than 30 years it should be carried out once in three years. One may, however, go for it even earlier if one suspects the condition of the building to be bad. Perhaps monsoon/ post monsoon is the best time to commission a structural audit since the seepage is more evident at that time.



Figure: - 1 Front view of building

II. LITERATURE REVIEW

B.H Chafekar, O.S Kadam, K.B Kale, S.R Mohite, P.A Shinde, V.P Koyle [1]: “Structural Audit” (2013) This paper covers structural audit of overall structure. According to the authors, the frame is heart of building. It is designed by structural engineer with the help of bye-laws provided for the structure.

A.B Mahadik, M.H. Jaiswal [2] “Structural audit of buildings” (2014) research India publication This paper deals to create awareness amongst the civil engineers, residents, and owners of building towards the health examination of existing concrete buildings called as Structural Audit.

Patil S.R, Professor Sayyed G.A. [3]: “Structural Audit” (2015) paper presents structural audit as a preliminary technical survey aimed at assessing the general health and safety of civil engineering structures, particularly reinforced concrete (RCC) buildings.

Malik Arooj and Gopendra Yadav [4]: “Comparison of Destructive and Non-Destructive Testing of Concrete” (2017) The paper provides a review and comparative analysis of destructive (DT) and non-destructive testing (NDT) methods used to evaluate the quality and compressive strength of concrete.

Ashwin Salunke, Dr. Santosh Patil [5]: “Structural Health Monitoring and Auditing of RCC Building” (2020) ijert.org. In this paper, authors were tried to find out the faulty mechanism in structure to prevent the failure of structure.

Gaps in literature review- Limited work integrates detailed structural analysis software (such as STAAD Pro or ETABS) with field investigation results for performance-based evaluation under current Indian code provisions. There is a lack of comprehensive audit frameworks that combine condition assessment, analytical modelling, seismic evaluation, and repair decision-making in a single systematic methodology. Additionally, few studies provide quantitative safety evaluation using demand-to-capacity (D/C) ratios or utilization factors of existing structural member to support repair or strengthening recommendations. Focus on region-specific challenges, such as climatic effects, aging urban infrastructure, and seismic vulnerability in rapidly developing Indian cities. Wind, earthquake, or alteration loading and changes can be tested, so to avoid structural collapse due to overloading. Therefore, there is a clear need for research that integrates on-site inspection, non-destructive testing, and computer-based structural analysis using Indian Standard codes, while developing a structured and replicable methodology that can be practically adopted by practicing engineers for reliable structural audit and safety evaluation.

III. OBJECTIVE

The objective is to design Modelling of structure with software to assess the damage to the existing structures under distress and suggest the remedial measures for strengthen or repairs and rehabilitation. To find demand to capacity ratio of existing beams and columns and find relationship between compressive strength and rebound number. To identify

any alteration and addition in the structure, misuse which may result in overloading and wind, earthquake, or alteration loading and changes can be tested, so to avoid structural collapse due to overloading, Shear force, bending moment, deflection diagram can be check for structure, length/span and determine the load and moment carrying capacity of the members using IS: 456:2000 to get idea of capacity of members. To assess the damages of existing structures under distress and suggest the remedial measures for strengthen the existing structures.

IV. SCOPE OF WORK

The scope of this project covers the complete structural assessment, performance evaluation, and remediation planning for a G+7 RCC building in Thane, India, using STAAD Pro software as the primary analysis and design tool. The key tasks undertaken include structure assessment and analysing performance and deflection. This is crucial for controlling stress and managing load distribution for ensuring structural integrity. Cost-Effective: Develop an economical solution for structural repair and maintenance through optimization of material usage without compromising safety and performance. This also involves appropriate rehabilitations methods for overall project cost.

V. METHODOLOGY

The analysis of structure will be conducted using software-based approach with combination of STADD and visual inspection. process begins with the preparation of architectural and structural plans to identify critical areas and performing load assumptions based on the building’s intended use. A preliminary inspection, including visual inspection and tapping observation, is conducted to detect defects such as cracks, seepage, and spalling. Suitable non-destructive tests are then recommended to evaluate the structural condition. The structure is modelled and analysed using STAAD Pro to determine the response under different loads and to calculate the Demand-to-Capacity ratio of structural members. The load carrying capacity is assessed as per IS 456:2000, and distressed members are identified. Based on the results, appropriate repair, strengthening, and rehabilitation measures are suggested, and a structural audit report is prepared with supporting test results and documentation.

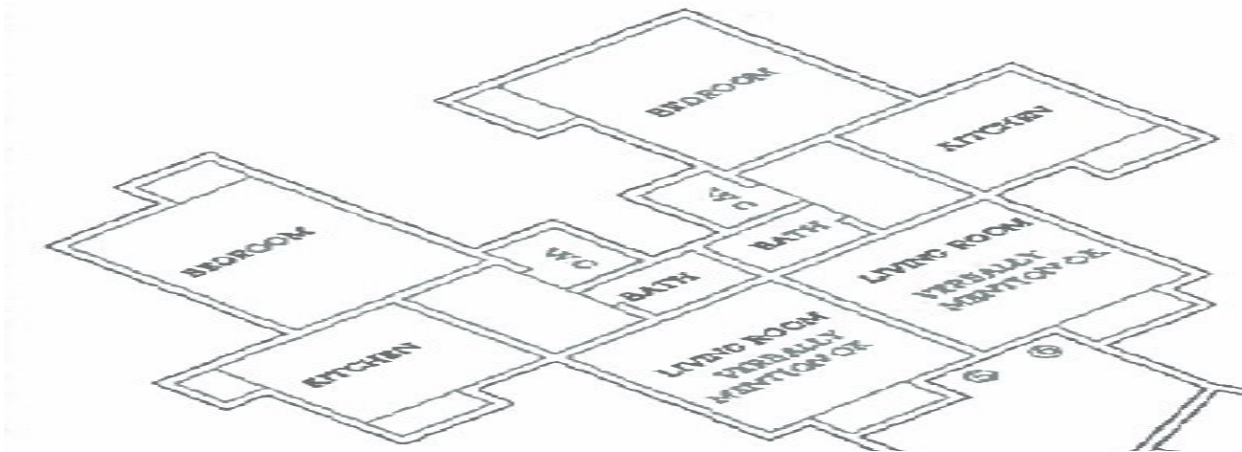


Figure: - 2 Ground floor plan

Table: - 1 Structural report

Sr. No	Type of element	Section
1	Name of building	Purushottam Park, Thane, India
2	No. of storey and seismic zone	G+7 floor, zone-III
3	Floor height	3
4	Column	600 mm x 600 mm
5	Beams/Slabs	300 mm x 450 mm/ slab 150-200mm
6	Concrete Grade and density	M25 and 25 kN/m ³

7	Steel Grade	415
8	Total DL (Structure)	7200kN
9	Only 25% of LL is considered	600kN
10	Design Wind Speed (V_z)	$44 * 1.0 * 1.02 * 1.0 * 1.0 = 44.88$ m/s
11	Design Wind Pressure	$0.6 * V_z^2 = 0.6 * (44.88)^2 = 1210$ N/m ² = 1.21 kN/m ²
12	Design Horizontal Seismic Coefficient: $A_h = (Z/2) \times (I/R) \times (S_a/g)$	$A_h = (0.16/2) \times (1/4) \times 2.5 = 0.05$
13	Structural repairs	No repairs found to be taken place.
14	Tenantable repairs	No repairs found to be taken place.
15	Roof/waterproofing	No repairs found to be taken place.
16	Plumbing	No repairs found to be taken place.
17	Internal plaster	We have observed minutely during the physical survey that the flats were found to have few cracks and leakages at few locations but seepages were found at many locations. Few cracks may be superficial which does not have any dangerous signs.
18	External plaster	It was observed that the external facade of the structure was found to have many cracks and there may be chances that the depth of cracks might have damaged structural member (R.C.C) which could be the reason of corrosion in the reinforcement.
19	Plumbing	The plumbing condition of the structure was observed to have leakages running through a few places especially at junctions and the joints between the washroom, toilet, and kitchen therefore, it needs to be rectified/replaced at an earliest possible to avoid water seeping and deteriorating R.C.C members and finally start corrosion of reinforcement, which will be the source of damage to the existing society building.
20	Drain lines/chambers	The drain lines found in good condition.
21	Doors and windows.	Doors and windows were noted to be in working condition.
22	Column steel exposure.	Column and Wall reinforcement was exposed at a small surface area.
23	Uneven settlement in the flooring and gaps in-between.	Flooring of the structure was noted to be in average condition.
24	Skirting and flooring.	Observed to be in usable condition.
25	Foundation settlement	There was no foundation settlement observed
26	Deflections/Sagging	No deflection or sagging was noticed during the time of survey.
27	Major cracks in column and beams.	The structure was found to have slightly major/minor cracks.
28	Seepage/Leakages	It was noted that the structure exhibited seepages/leakages at many places.
29	Staircase column	Cracks in Column, Slab, Beam and Wall. Seepage in waist slab and wall was noticed which needs to be repaired to avoid furthermore damages due to delay of the restoration.
30	Lift walls	As per the observation it was noted that the walls

		were found to be in average condition
31	Underground tank	In usable condition. However, Cracks in Plaster were observed.
32	Lift room	Found in average condition.
33	Terrace	During the survey it was noted that the plaster was cracked a few locations and seepage was observed.
34	Parapet at terrace	Cracks were observed.
35	Common areas	Found in Average Condition
36	Toilet blocks and dry balcony	Found to have seepage running through which can lead to deflection and sagging of the beams and slabs.
37	Terrace waterproofing	During the survey the terrace waterproofing was found in average condition.
38	Brief description of repairs to be done	Given below
	I] Water proofing	Yes
	II] External plaster	Yes
	III] Structural repairs	This repair is only expected but after removing the existing plaster we may be able to ascertain whether the structural member is damaged or not. at this stage structural member is sound enough to withstand at its stability without any danger to the society.
	IV] Column jacketing	At present it is not required
	V] Slab recasting	Not required
	VI] Beam recasting	Not required
	VIII] Evacuation during repair	No needed
	IX] Propping	During the time of repair, it is required to avoid any untoward incidents (sliding and settlement movement of existing structure)
39	Classification of building	C2-B
	1] C1	To be evacuated demolition immediately
	2] C2-A	To be evacuated and or partial demolition requiring major structural repairs.
	3] C2-B	No eviction only structural repairs
	4] C3	No eviction needs minor repairs

VI. RESULTS

Table: - 2 Destructive and non-destructive test results

Sr. No	Types of tests	Findings	Range as per IS code
1]	Ultrasonic pulse velocity test	3.5	Velocity Criterion for concrete quality grading as per Table2 of IS-13311 (Part 1):1992.
	Excellent		Above 4.40 km/s
	Good		3.75 10 4.40 km/s
	Doubtful		3.0 to 3.75 km/s
	Poor		Below 3.0 km/s

2]	Rebound Hammer Test	30.6 N/mm ²	More than 15 N/mm ² concrete is good IS 13311 Part [2]: 1992 Reaffirmed 2013.
3]	Half Cell Potential Test	231 (-MV)	Half-Cell Potential Test Criteria as per ASTM-C876-15.
4]	Harden Concrete Carbonation Depth Test	55mm (Depth)	46.8% of carbonation.
5]	Concrete Core Compressive Test	27.2 N/mm ²	More than 15 N/mm ² concrete is good IS 13311 Part [2]: 1992 Reaffirmed 2013.

Table: - 3 Compressive test result

Location/ID Mark	Core HT (mm)	Core Dia (mm)	Core Wt (kg)	Area (mm ²)	Max Load (KN)	Actual comp strength (N/mm ²)	Corrected Comp Strength (N/mm ²)	Equivalent Comp Strength (N/mm ²)
GF/C-4	75.69	67.63	0.634	3592.7	81.58	22.71	21.74	27.2

Table: - 4 Ultra sonic pulse velocity result

ID	Location	Travel Path (mm)	Travel Time (μs)	Actual Velocity (km/sec)	Corrected Velocity (km/sec)	Surface Condition
C-1	Ground	400	227.5	1.76	1.76	Dry
C-2	Ground	400	169.7	2.36	2.36	Dry
C-3	Ground	400	163.6	2.44	2.44	Dry
C-4	Ground	400	156.7	2.55	2.55	Dry
C-5	Ground	400	134.8	2.97	2.97	Dry
C-6	Ground	400	131.7	3.04	3.04	Dry
C-7	Ground	400	169.8	2.36	2.36	Dry
C-8	Ground	400	108.4	3.69	4.19	Dry

Table: - 5 Rebound hammer test result

ID	Location	Avg. Rebound index	Comp Strength (N/mm ²)	Direction	Surface
C-1	Ground	33.5	26.8	Horizontal	Dry
C-2	Ground	40.0	36.2	Horizontal	Dry
C-3	Ground	39.0	34.8	Horizontal	Dry
C-4	Ground	35.0	29.0	Horizontal	Dry
C-5	Ground	36.0	30.4	Horizontal	Dry
C-6	Ground	35.0	29.0	Horizontal	Dry
C-7	Ground	35.5	21.7	Vertical Up	Dry
C-8	Ground	40.5	36.9	Horizontal	Dry

Table: - 6 Mean compressive strength

Parameter	Value
Number of data points (n)	8
Sum of rebound (r)	294.5
Sum of strength (fc)	243.4
Sum of (r*fc)	9041.8
Sum of r ²	10889.75
Mean compressive strength	30.42 n/mm ²

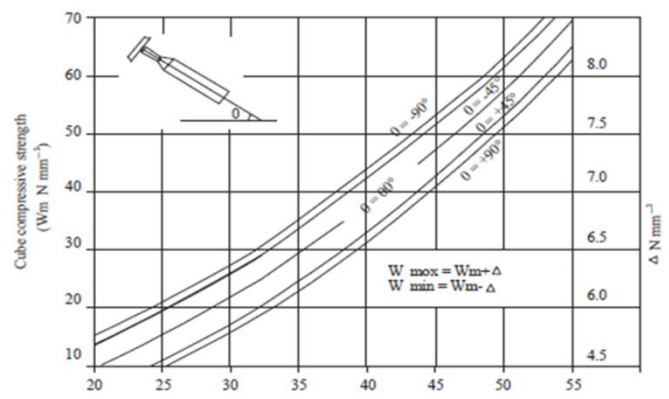
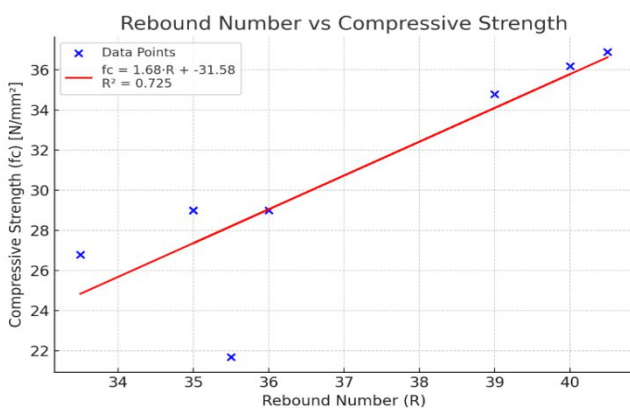


Figure: - 3 Rebound number and compressive strength

Table: - 7 Half-Cell potential test

Sr. No	ID mark/Location	Half-cell potential value (-MV)
1	GF/ C-1	232
2	GF/ C-2	258
3	GF/ C-3	246
4	GF/ C-4	235
5	GF/ C-5	206
6	GF/ C-6	216
7	GF/ S-1	234
8	GF/ C-7	222

Shear force and bending moment - Columns: upto 150.2 kN minimum shear force: 109.4 kN, Beams: upto 50.3 kN minimum shear force: 18.3 kN. Maximum BM in beams: 120 kNm, Maximum BM in columns: 170 kNm. All beam deflections < 20 mm → SAFE, All column deflections < 20 mm → SAFE.

Beams: - Maximum D/C Ratio: 0.93, Average D/C Ratio: 0.73, Columns: - Maximum D/C Ratio: 0.88, Average D/C Ratio: 0.60, All values < 1 → Columns/Beams are safe. Overall structure: - Maximum D/C Ratio: 0.93, Average D/C Ratio: 0.67, Global structure utilization is within safe limits.

ID	Location	Avg. Depth (mm)	Total Depth (mm)	Carbonation (%)
C-1	Ground	22	55	40.0
C-2	Ground	26	58	44.8
C-3	Ground	28	60	46.7
C-4	Ground	24	52	46.2
C-5	Ground	26	50	52.0

C-6	Ground	28	56	50.0
S-1	Ground	25	52	48.1
C-7	Ground	30	58	51.7

Table: - 8 Carbonation result

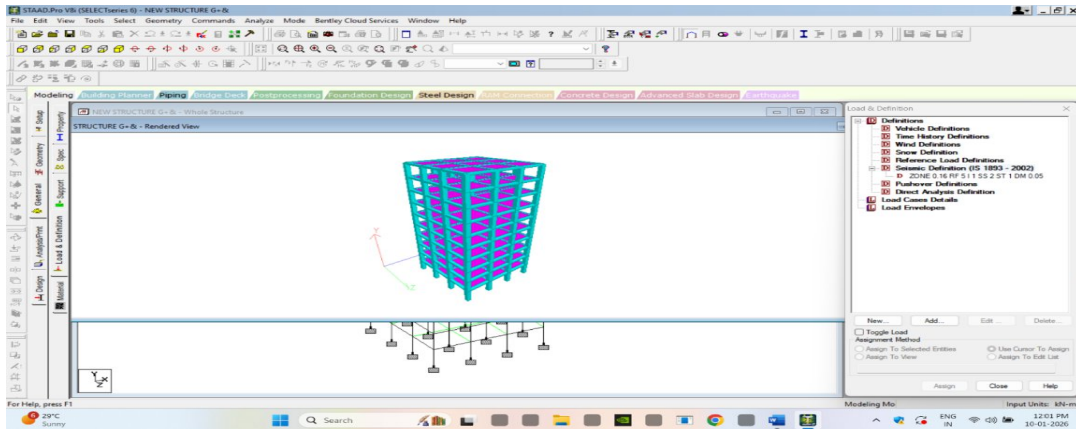


Figure: - 4 3D Render View and Slab panel point.

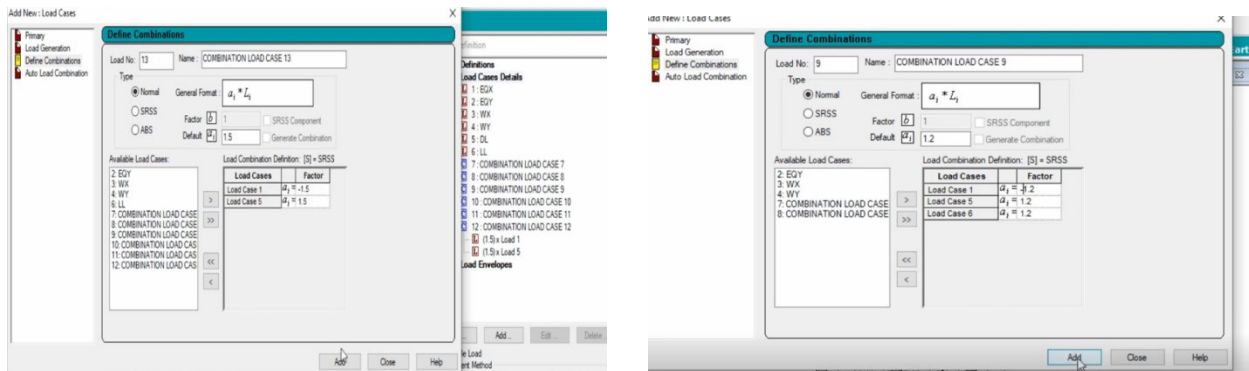
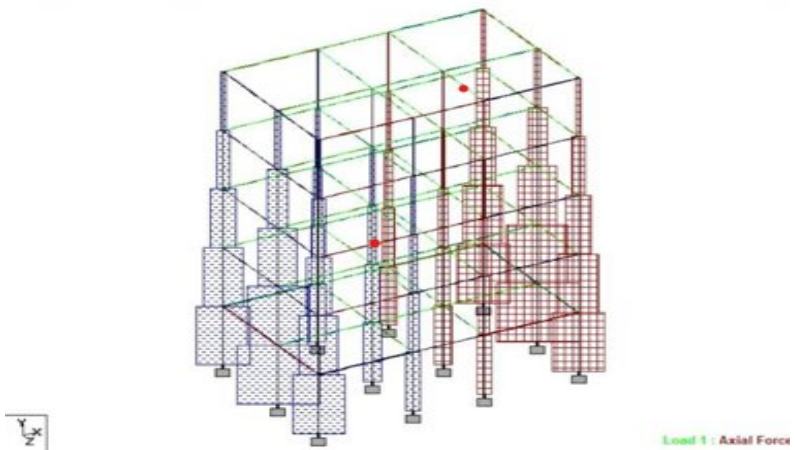


Figure: - 5 Load combination and forces



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Based on the results of present study following conclusions are drawn.

- The G+7 RCC building located in Thane (Zone III) has been analysed for combined wind and seismic effects. Seismic forces govern the structural design. Wind effects are within permissible limits. The structure is SAFE and satisfies IS 875 and IS 1893 requirements.
- Overall structure: - Maximum D/C Ratio: 0.93, Average D/C Ratio: 0.67 Member design is safe.
- Reinforcement design, slab system, OHT, and staircase is structurally sound.
- As per IS 456:2000, the maximum permissible deflection for structural members should not exceed Span/250 to Span/350 or 20mm whichever is less. For standard spans of approximately 5 meters, this corresponds to about 20 mm. The deflections observed in both beams and columns from the STAAD Pro analysis fall within this permissible limit less than 20 mm indicating that the structure meets the serviceability criteria.
- Stability of member- clear span of simply supported and continuous beam should not exceed $60*b$ or $250B^2/D$ whichever is less and in cantilever should not exceed $25*b$ or $100B^2/D$ as per IS 456.
- This study addresses the need for systematic structural performance evaluation of G+7 RCC building using staddpro software analytical modelling integrated with NDT and DT results, to verify compliance with IS codes and ensure long term safety and serviceability.

VIII. REMEDIAL MEASURES

General recommendation- Although the Demand-to-Capacity (D/C) ratios of all structural members are within permissible limits, the existing reinforcement is in average condition and may deteriorate over time due to corrosion. Corrosion, primarily caused by dampness and leakage from slabs and walls, can reduce the cross-sectional area of reinforcement, leading to increased deflection beyond allowable limits (greater than 20 mm) and potential long-term structural instability. To enhance durability and serviceability, it is recommended to implement effective waterproofing measures to prevent seepage. Areas with damaged concrete should be repaired using polymer-modified mortar after removing loose material. Corroded reinforcement, if identified during inspection, should be cleaned using a wire brush and treated with suitable rust-removing agents, followed by the application of a passivating coating. All repair and strengthening works must be carried out under the supervision of a qualified structural engineer. Additionally, leakages should be rectified promptly, vegetation growth removed, and proper flooring practices followed by replacing existing flooring rather than overlaying new layers.

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IS CODES-

- IS 456:2000- "Plain and Reinforced Concrete- Code of Practice".

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- IS 1893:2016 Part I- “Criteria for Earthquake Resistant Design of Structures”- Bureau of Indian Standards, New Delhi, India.
- IS 516 Part V- Section 1:2018 “Ultrasonic Pulse Velocity Test.
- IS 516 Part V- Section 2:2021 “Half-Cell Potential Test.
- IS 516 Part V- Section 3:2021 “Harden Concrete Carbonation Depth Test.
- IS 516 Part IV:2018 “Concrete Core Compressive Strength Test.
- IS 516 Part V- Section 4 “Rebound Hammer Test.
- IS 13311 Part 2:1992- “General Empirical Relationship Between Rebound Number and Compressive Strength.
- IS 13311:1992 Part I- “Velocity Criterion for Concrete Quality Grading as per Table 2.
- IS 875:2015 Part I, II, III- “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures” Part I- Dead Loads, Part II- Imposed Load/Live Loads, Part III- Wind Load.



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