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SHORT COMMUNICATION

Condition Assessment of Existing RCC Building Using Non-Destructive Testing

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ABSTRACT

The growing importance of maintaining and extending the functional lifespan of reinforced concrete structures has resulted in an increased emphasis on non-destructive testing techniques as essential tools for evaluating structural conditions. Non-destructive testing procedures offer a notable benefit in assessing the uniformity, homogeneity, ability to withstand compression, durability, and degree of corrosion in reinforcing bars within reinforced concrete structures. This study aimed to evaluate the existing condition of partially constructed residential buildings in Rewari district, located in the state of Haryana. The reinforced concrete structure of the building had been completed eight years ago, however, the project was abruptly stopped. Prior to recommencing the construction, it is important to assess the present state of the structure in order to evaluate the deterioration in Reinforced Cement Concrete (RCC). The building's state was evaluated by visually inspecting the building, conducting on-site examinations, and analyzing samples in a laboratory. The findings emphasize the assessment of the robustness and durability of concrete to ascertain the degree of deterioration and degradation in the structure. The study incorporates visual inspection, and non-destructive evaluation utilizing different instruments to evaluate the corrosion condition of reinforcing bars. In addition, selected RCC columns, beams, and slabs undergo chemical testing. It has been observed that the strength results and chemical results were within permissible limits.

Keywords: Condition Assessment; Visual Inspection; Distressed Condition; NDT Methods; Chemical Tests

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1. Introduction

The durability and safety of existing RC buildings depend on various factors such as material quality, construction practices, exposure conditions, and maintenance. Over time, these structures may exhibit distress such as cracks, corrosion of reinforcement, spalling, and reduced load-carrying capacity. Traditional visual inspections alone are insufficient to comprehensively evaluate their condition. Non-destructive testing methods (NDT) offer a non-invasive way to assess the integrity of concrete and identify hidden defects. By utilizing NDT techniques, engineers and researchers can gain valuable insights into the structural health, material properties, and potential vulnerabilities of existing buildings. This information helps in decision-making regarding repairs, strengthening, and maintenance of the structures. The process of evaluating the integrity of a structure involves finding any significant bending or deformation in its structural components, misalignment, damage caused by impact, extensive cracking, deterioration of concrete, or loss of steel section that requires a thorough structural examination before any repairs can be made. It is important to take into account degradation processes such as freeze-thaw and sulphate assault since they might indirectly contribute to the corrosion of the reinforcement when evaluating the situation [1–4].

The imperative for conducting comprehensive structural condition assessments of buildings, especially those constructed with reinforced concrete, arises from the intrinsic vulnerability of structures to various degradation mechanisms over time. The primary concern driving the need for structural condition assessment is the assurance of public safety. By identifying and addressing deterioration at an early stage, engineers can implement targeted maintenance and rehabilitation strategies to mitigate further damage and enhance the overall durability of the structure. Understanding the condition of a building's structure allows for the implementation of cost-effective maintenance practices. Conducting structural condition assessments promotes the longevity of existing structures, reduces the demand for new construction, and minimizes the environmental impact associated with demolition and reconstruction. Regular structural condition assessments ensure compliance with govt. regulations, mitigating legal liabilities, and safeguarding against potential legal actions resulting from structural failures [1].

Understanding the complex and multifaceted deterioration mechanisms affecting reinforced concrete structures is fundamental to the development of effective structural condition assessment strategies. These mechanisms, driven by environmental, material, and loading factors, contribute to the degradation of structural components over time. A comprehensive examination of these deterioration mechanisms provides the context necessary for selecting appropriate non-destructive testing (NDT) methods and interpreting assessment results accurately. Many non-destructive evaluation (NDE) tests for concrete members are available to determine in-situ strength and quality of concrete. Some of these tests are very useful in the assessment of damage to RCC structures subjected to corrosion, chemical attack, and fire and due to other reasons. The term 'non-destructive' is used to indicate that it does not impair the intended performance of the structural member being tested/investigated. The nondestructive evaluation has been broadly classified under two broad categories viz 'in-situ field test' and 'laboratory test' [5–7].

The present work focuses on the condition assessment of an existing 8-year-old residential building. The present study aimed to examine the deterioration that occurred during the period when the construction was halted after the completion of the reinforced concrete (RC) frame structure. The initial condition assessment of the structure involves a visual inspection to identify surface damages, flaking, coloration, and local weaknesses. In the second phase, various in-situ non-destructive tests were done and samples were taken for laboratory testing to conduct compressive strength measurements, carbonation measurements, and chemical tests. Finally, analysis of the results from various non-destructive testing (NDT) methods was combined to assess the quality of the structures.

2. Methodology

The structure considered for the present work was an RCC building located in Rewari, Haryana, India as shown in **Figure 1**. The original plan was a building with G+7 floors. Construction was commenced in 2014; but was halted after the construction of G+2 floors. Currently, the remaining work is planned to be resumed for completion. Before proceeding with the remaining construction, the owner decided to assess the current condition, quality, and durability of the structure. The typical floor plan of the building is shown in **Figure 2**.

Figure 1. Front view of the building.

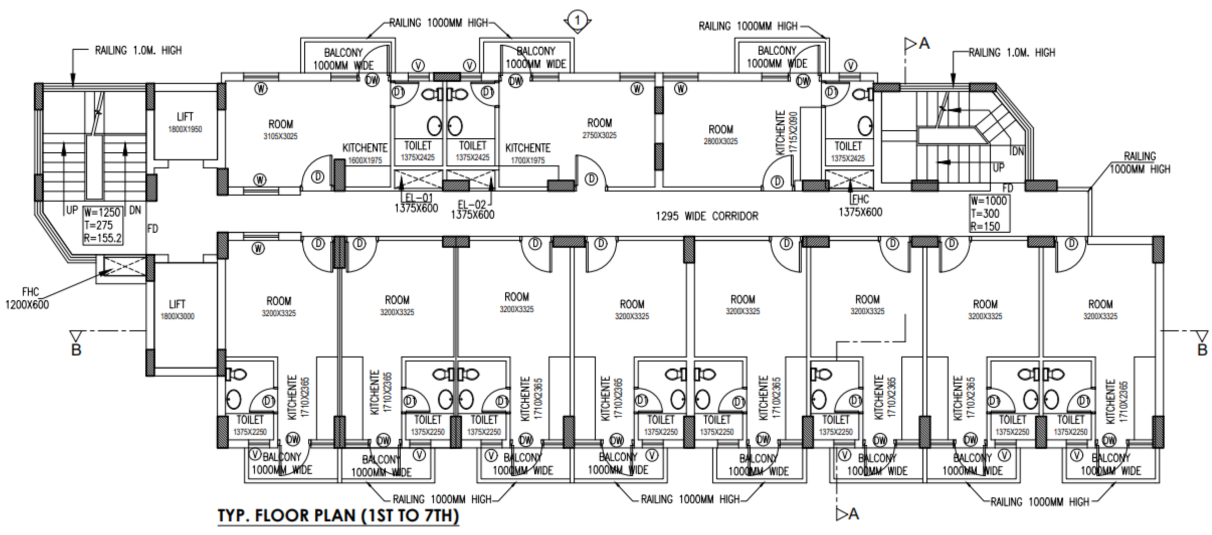


Figure 2. Typical floor plan of the building.

The condition assessment of the building was done by carrying out various non-destructive tests on RCC structural elements of the buildings on the stilt floor, 1st floor, and 2nd floor. A test plan was prepared based on the preliminary visual inspection, in which locations of sample elements for testing were decided and marked on the drawing as shown in **Figure 3**. **Figure 4** shows the non-destructive tests including ultrasonic pulse velocity (UPV) test, rebound hammer test, concrete core compressive strength test, carbonation test, half-cell potential measurement test, and chemical test for chloride and sulfate performed on the different locations of the building.

2.1. Visual Inspection

A visual inspection was conducted to identify surface damages, flaking, coloration, and local weaknesses. A test plan was prepared based on the findings of this inspection. The locations of sample elements for testing were marked on structural drawings (e.g., **Figure 3**) to ensure systematic coverage of the stilt floor, 1st floor, and 2nd floor.

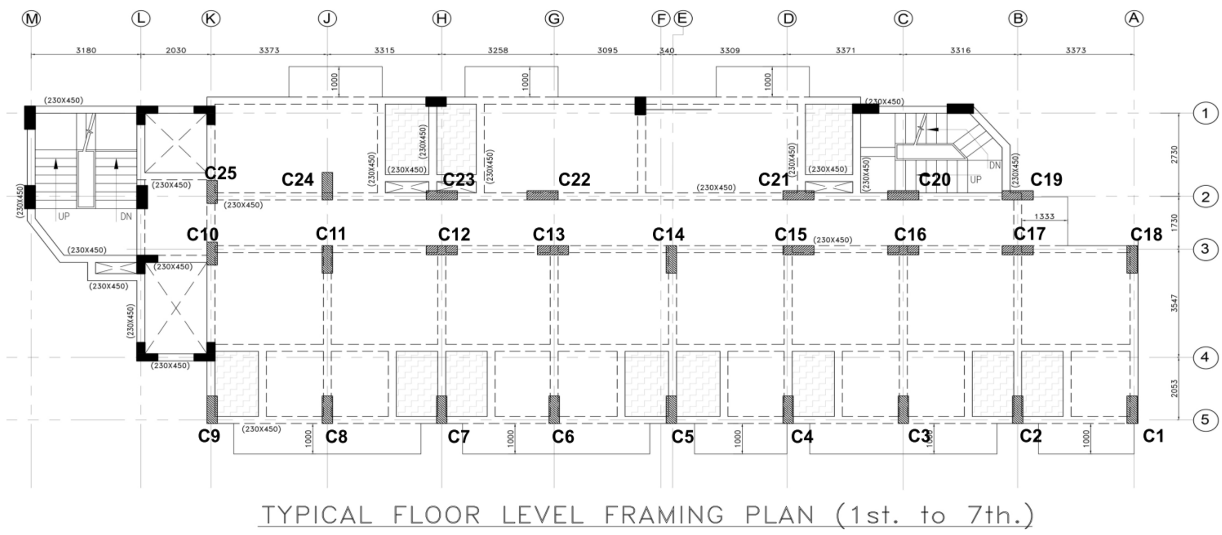


Figure 3. Typical Framing plan with ID marking.

2.2. Ultrasonic Pulse Velocity

The Ultrasonic Pulse Velocity (UPV) test is utilised to assess the overall integrity of the concrete. This test is frequently used to assess the uniformity of concrete, find cracks within the concrete structure, locate areas of incomplete filling, and analyze the deterioration of concrete. An Ultrasonic Pulse Velocity Test was conducted on the accessible sample locations of Reinforced Concrete (R.C.) Beams, Slabs, and Columns. Both direct and indirect scanning techniques were employed at the site. The tests were conducted using the Proceq PL-200 equipment produced by M/s. Proceq, a Swiss-based business. The rebound hammer test and ultrasonic pulse velocity test were performed as per Indian standard code IS:13311-1992 (Part 1)[8].

2.3. Rebound Hammer Test

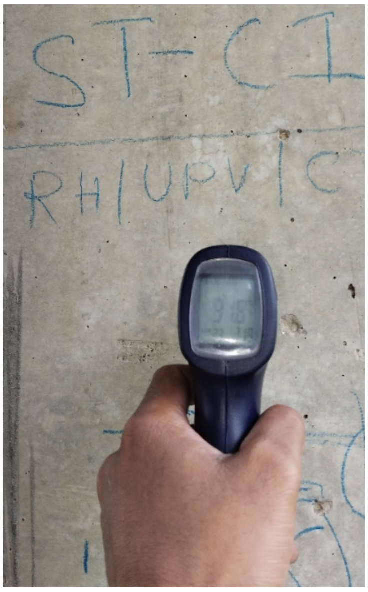
The rebound hammer test is a fast and efficient method used to evaluate the integrity of concrete by quantifying the surface hardness of a specific structure. The rebound number is a quantitative indicator of the mean compressive strength of the concrete surface. A series of rebound hammer tests were performed on various locations of reinforced concrete (R.C.) slab panels, beams, and columns. The rebound hammer test was conducted as per Indian Standard code IS:13311-1992 (Part 2)[9].

2.4. Half Cell Potentiometer

A test was done to measure the potential difference in half-cells on randomly selected accessible places of reinforced concrete (RC) components. The purpose of the test was to determine the extent of corrosion in the reinforcing bars. The experiment was conducted utilising a copper-copper sulphate solution in a half-cell. The test was conducted according to IS: 516-2021 (Part-5)[10].

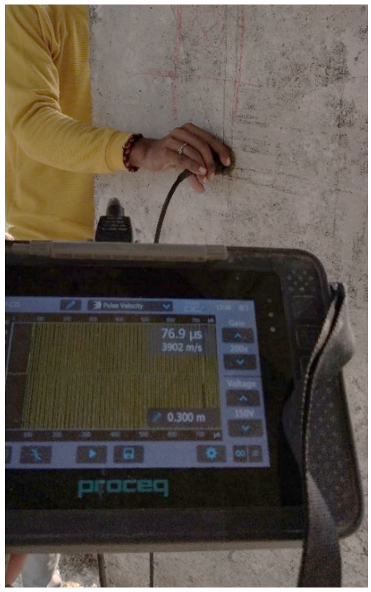
2.5. Carbonation

In order to evaluate the degree of carbonation, which refers to the reduction of alkalinity in the cover concrete that is crucial for preventing potential corrosion of the steel. The test was conducted on the extracted concrete core samples. The uncovered region was subsequently saturated with the sample solution containing a diluted ethyl alcohol solution of Phenolphthalein as an indicator, to assess the level of carbonation[11].



(**a**) Concrete temperature measurement

(**b**) Rebound hammer



(**c**) UPV test

(**d**) Half-cell potential measurement

(**e**) Concrete core cutting

(**f**) Concrete core samples

Figure 4. In-situ non-destructive testing on the concrete.

3. Results and Discussion

3.1. Rebound Hammer Test

The rebound hammer test was carried out on the column and beam/slab of the building and results have been presented in **Figures 5** and **6**, respectively. It was observed from the test results that the compressive strength varied from 25 MPa to 40 MPa; whereas the average values for stilt, 1st and 2nd floor were 35 MPa, 39 MPa, and 38 MPa respectively. Considering the over-estimation in surface strength due to carbonation hardening, the estimated compressive strength can be taken 20–30 MPa. Average compressive strength for columns is 30 MPa whereas for slab and beam it was 32 MPa. The compressive strength of concrete can be estimated to be in the range of 25–30 MPa.

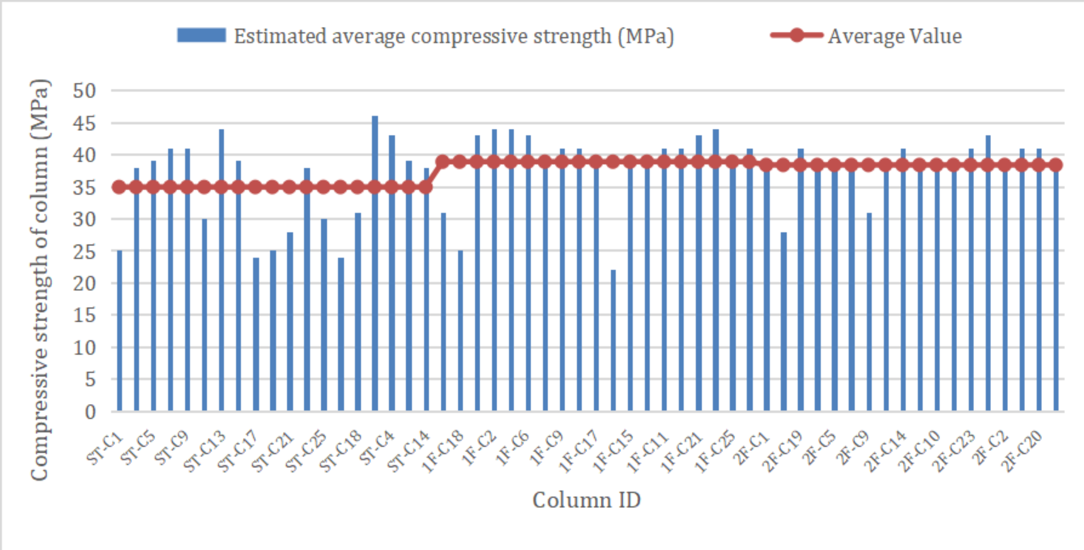


Figure 5. Rebound Hammer test results for columns.

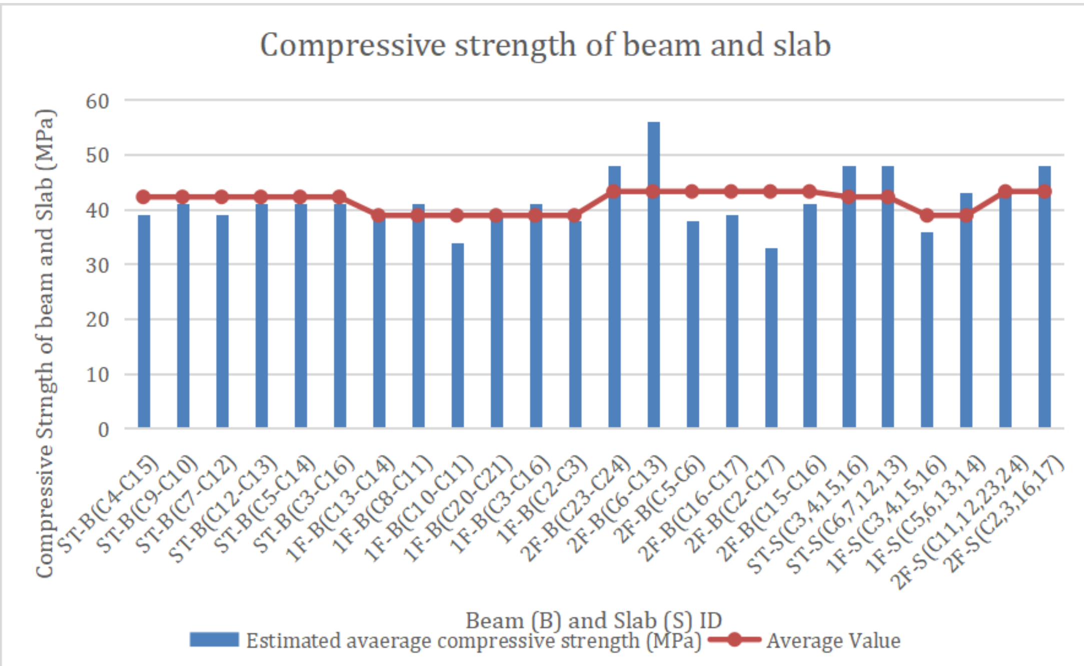


Figure 6. Rebound Hammer test results for slabs and beams.

3.2. Ultrasonic Pulse Velocity Method

The UPV test was conducted on the different elements of the selected structures and the results were interpreted in terms of quality since the velocity signifies the quality of the particular specimens or elements. The results of UPV in the form of quality have been shown in **Figure 7**. The value of Ultrasonic Pulse Velocity value was in the range of 2.86 to 4.43 Km/s. Around 80% of the test results were above 3.75 Km/s, which is classified as "Good" concrete quality for concrete of above M25 grade as per IS: 516 [7]. The remaining 20% results were in the doubtful conditions which signify the poor quality.

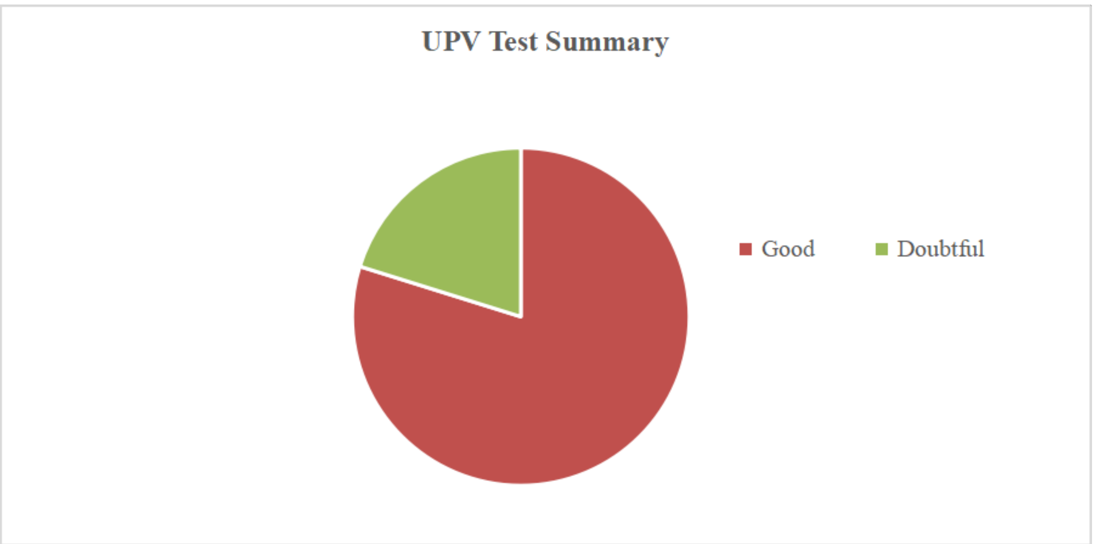


Figure 7. UPV test results.

3.3. Half-Cell Potential Test

A half-cell potential test was performed to assess the probability of corrosion in the reinforcement steel bars. The test results were depicted in **Figure 8** and results vary from −127 mV to −328 mV. Approximately 71% of the investigated locations showed a 50% likelihood of corrosion (with uncertainty), while 30% of the locations had a 10% probability of corrosion. The 90% probability of corrosion had zero percentage of the investigated locations as shown in **Figure 8**.

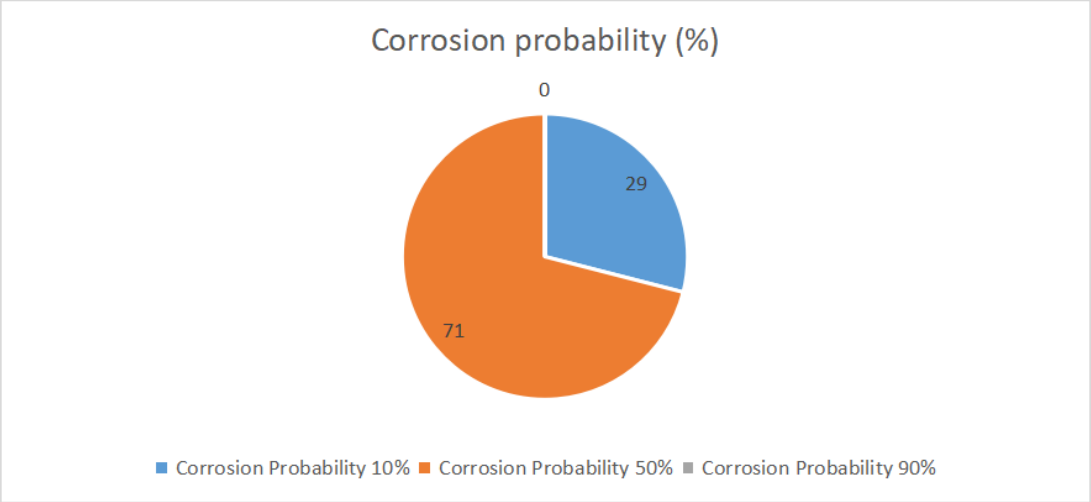


Figure 8. Corrosion probability.

3.4. Carbonation Depth Measurements

Figure 9 shows the carbonation depth of the different structural components. For columns, the test results range varied from 16mm to 33 mm. Considering the concrete cover of 40 mm for columns, it is assessed that cover depth of 50 to 75% has been carbonated and at this stage, reinforcement steel bars not vulnerable to corrosion.

The carbonation depth for slabs and beams ranges from 14 to 30 mm. Given the nominal concrete cover of 15 to 20 mm, it is expected that the reinforcement steel bars are susceptible to corrosion, since nearly the entire depth of the cover concrete has undergone carbonation.

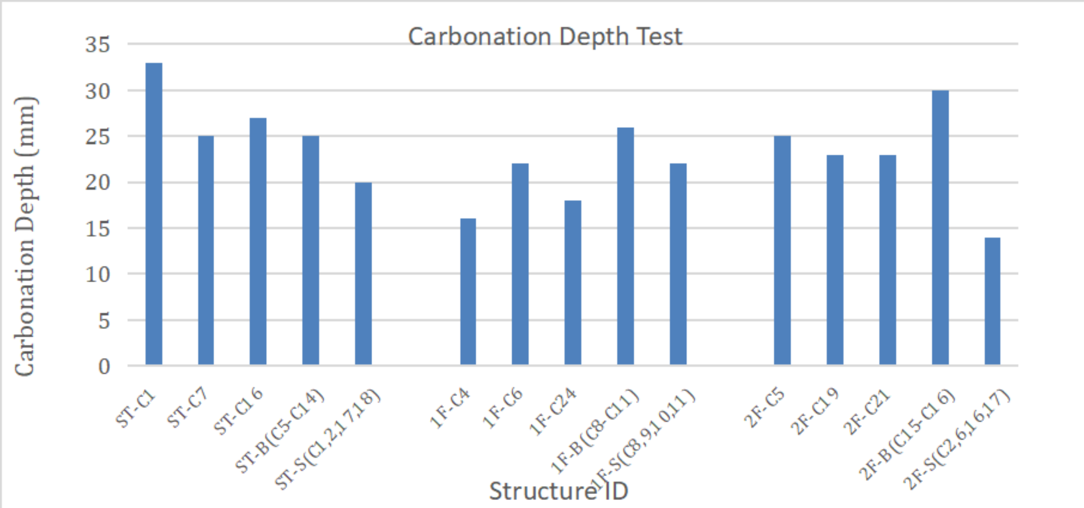


Figure 9. Carbonation depth of the different samples.

3.5. Chemical Testing on Hardened Concrete

3.5.1. Determination of Sulphate

The sulphate determination test is conducted to measure the amount of sulphates in concrete and results have been shown in **Figure 10**. High concentrations of sulphates cause the deterioration of concrete due to the chemical interaction between calcium and the excessive sulphates. The sulphate content in concrete is quantified as a percentage relative to the weight of the concrete. The permissible limit for the test is 4.0%. Sulphate (as SO_3) content % by weight of cement is 1.43 to 2.16%, which is within the specified limits 4%[8].

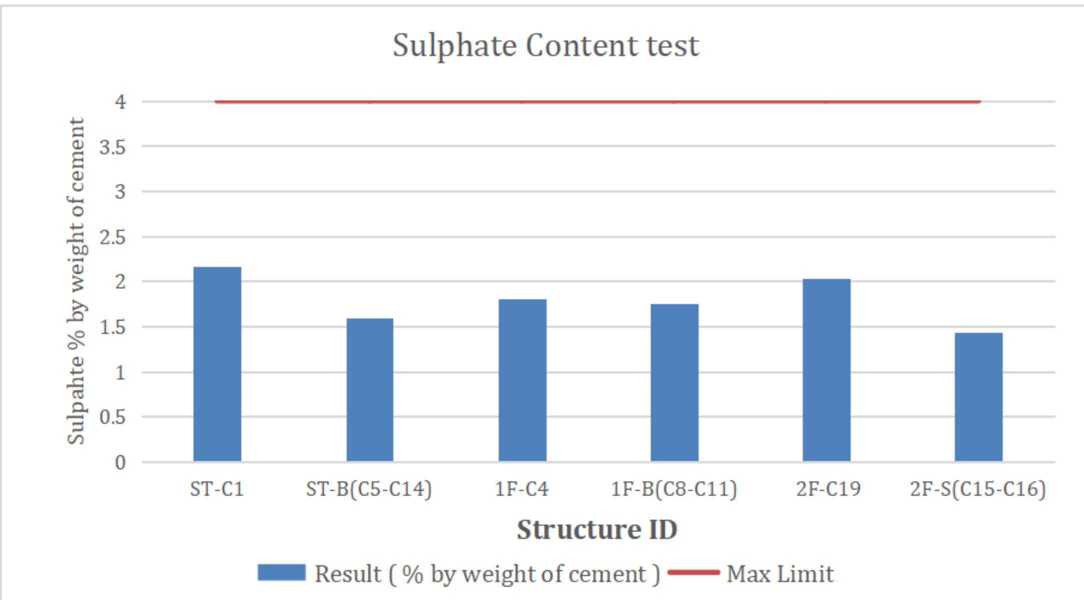


Figure 10. Sulphate content test.

3.5.2. Determination of Chloride

The chloride determination test is conducted to determine the amount of chlorides present in concrete. High levels of chlorides result in the corrosion of reinforcement bars. The permissible limit for the test is 0.6 kilogrammes per cubic centimetre. Chloride content in concrete , as results shown in **Figure 11**, ranges from 0.13 to 0.2 kg/m^3, which is within the specified limits of 0.6 kg/m^3 [8].

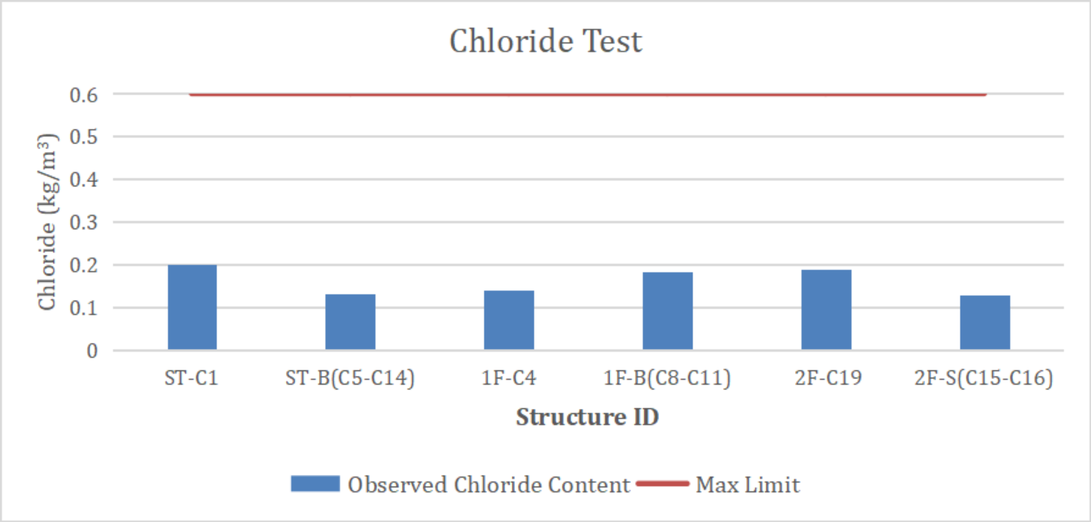


Figure 11. Results of chloride test.

3.5.3. Determination of pH Level in Concrete

The pH level of fresh concrete generally varies between 12 and 14. The pH level of concrete will markedly decrease due to the loss of alkalinity and carbonation. If the pH level in the structure falls below 10, the concrete's alkalinity will be insufficient to prevent rebar corrosion, resulting in the degradation of the building. The pH of the various specimens was within the range and thereby, there is lesser chances of corrosion. The pH of the concrete samples was in the range of 11.2 to 12.4 indicating moderate loss in alkalinity of concrete, as shown in **Figure 12**. This could not be correlated due to lesser numbers of pH and Chloride tests than carbonation tests.

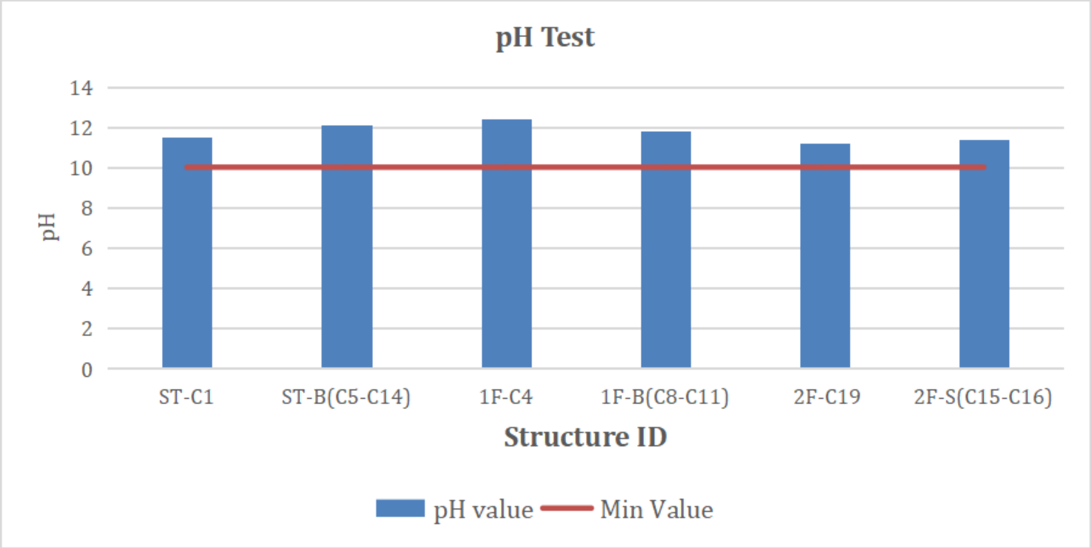


Figure 12. Variation of pH for different samples.

3.5.4. Core Compressive Strength Test

Fifteen concrete core samples were taken to assess the compressive strength of the concrete. Nine samples have been taken from the columns (three samples each floor), and six samples were obtained from the beams and slabs (two samples per level). The compressive strength of the different specimens have been shown in **Figure 13**. The average core compressive strength of column was 30 MPa and 32 MPa for slab/beam. The minimum value of core compressive strength was 15 MPa and 24 MPa and maximum core compressive strength was 36 MPa and 40 MPa, for column and slab/beam, respectively.

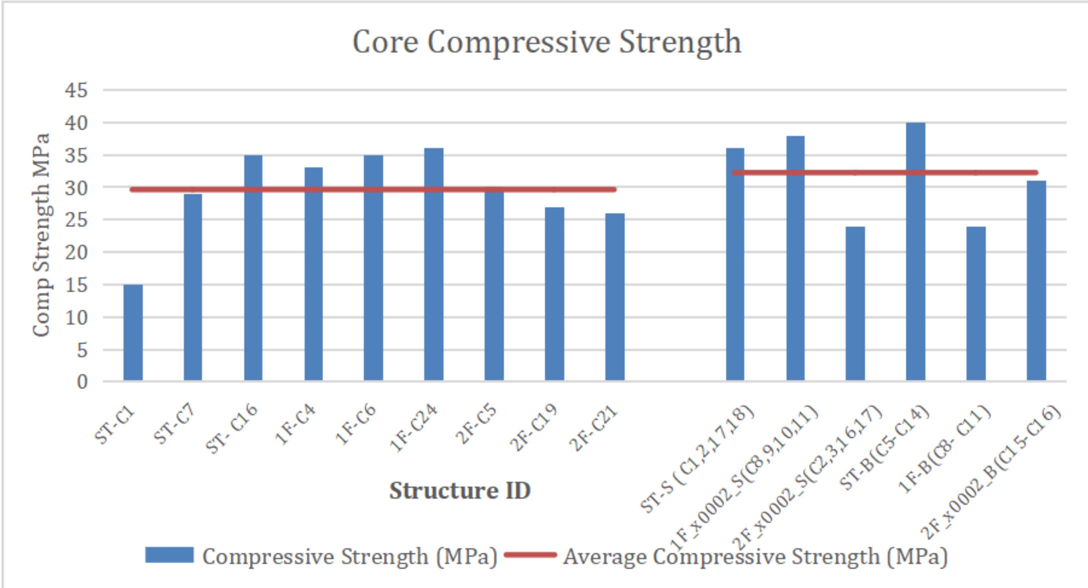


Figure 13. Compressive strength of core samples.

4. Conclusion

In the present study, assessment of a reinforced concrete building was done using the different non-destructive tests such as rebound hammer, ultrasonic pulse velocity, core test, carbonation test, pH, half-cell potential measurement and chemical test. It was found from the core compressive strength test and NDT test results, the compressive strength of the concrete was estimated to be M25. It has been reported by that design grade of concrete in the structure is M-25, so the in-situ concrete compressive strength can be considered at par with the design strength and hence satisfactory. The status of corrosion in the reinforcement steel bars, based on the NDT test can be considered satisfactory, as no location of high risk of corrosion was found during the evaluation. Chemical test results indicate that Chloride and sulfate content are within the acceptable limits and hence considered satisfactory.

Author Contributions

V.K.: Conceptualization, Data Collection and Analysis, Drafting the Manuscript, Interpretation. K.D.: Conceptual and Theoretical Guidance, Reviewing and editing drafts. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. The research was conducted in the absence of any financial relationships that could be construed as a potential conflict of interest.

References

[1] Mehta, P.K., Monteiro, P.J.M., 2017. Concrete: Microstructure Properties and Materials, 4th ed. McGraw Hill Education: Noida, India, p. 1.

[2] Devi, K., Saini, B., Aggarwal, P., 2019. Utilization of Kota stone slurry powder and accelerators in concrete. Computers and Concrete. 23(3), 189–201. DOI: https://doi.org/10.12989/cac.2019.23.3.189

[3] Torres-Luque, M., Bastidas-Arteaga, E., Schoefs, F., et al., 2014. Non-destructive methods for measuring chloride ingress into concrete: State-of-the-art and future challenges. Construction and Building Materials. 68, 68–81. DOI: https://doi.org/10.1016/j.conbuildmat.2014.06.009

[4] Lim, M.K., Cao, H., 2013. Combining multiple NDT methods to improve testing effectiveness. Construction and Building Materials. 38, 1310–1315. DOI: https://doi.org/10.1016/j.conbuildmat.2011.01.011

[5] Wang, J., Xia, Y., Zhang, C., et al., 2023. Evaluation of compressive strength of concrete durability degradation in dry and wet environments using destructive and non-destructive testing. Measurement. 223, 113702. DOI: https://doi.org/10.1016/j.measurement.2023.113702

[6] Kobayashi, C., Nishiwaki, T., Tanabe, T., et al., 2024. Non-destructive testing of reinforced concrete structures using sub-terahertz reflected waves. Developments in the Built Environment. 18, 100423. DOI: https://doi.org/10.1016/j.dibe.2024.100423

[7] Zhang, W., Liu, D., Cao, K., 2024. Prediction of concrete compressive strength using support vector machine regression and non-destructive testing. Case Studies in Construction Materials. 21, e03416. DOI: https://doi.org/10.1016/j.cscm.2024.e03416

[8] IS 13311, 1992. (Part-1 Ultrasonic pulse velocity) Non-destructive testing of concrete-Methods of test. Bureau of Indian Standard: New Delhi, India.

[9] IS 13311, 1992. (Part-2 Rebound Hammer), Non-destructive testing of concrete-Methods of test. Bureau of Indian Standard: New Delhi, India.

[10] IS 516 (Part 5/Sec1), 2018. "Hardened Concrete —Methods of Test-Non-destructive testing of concrete-methods of test", PART 1 Ultrasonic Pulse Velocity, Indian Standards. Bureau of Indian Standard: New Delhi, India.

[11] Tambara, L.U.D., Hirsch, A., Dehn, F., et al., 2024. Carbonation resistance of alkali-activated GGBFS/calcined clay concrete under natural and accelerated conditions. Construction and Building Materials. 449, 138351. DOI: https://doi.org/10.1016/j.conbuildmat.2024.138351