RESEARCH ARTICLE

INTERNATIONAL RESEARCH JOURNAL OF MULTIDISCIPLINARY TECHNOVATION

Asian Research Association

DOI: 10.54392/irjmt2441

Evaluation of Structural Stability of Four-Storied building using Non-Destructive Testing Techniques

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DOI: https://doi.org/10.54392/irjmt2441

Received: 20-02-2024; Revised: 20-04-2024; Accepted: 23-05-2024; Published: 08-06-2024

Abstract: This paper mainly dealt with the evaluation of the structural stability of four storied building using non-destructive on-destructive testing methods. During the construction stage, there are many tests available to assess the excellence of concrete. The quality of concrete mainly depends on the quality of materials, concrete grade, and water-cement ratio. In the case of existing structures, to check the quality of concrete destructive tests are not possible, meanwhile, concrete quality will be assessed by using non-destructive testing (NDT) techniques such as rebound hammer, ultrasonic pulse velocity (UPV) etc. In this present study, an attempt has been made to check the quality of concrete in an existing four-storied building using non-destructive testing methods such as rebound hammer test and ultrasonic pulse velocity test. Moreover, the stability of the structure was also assessed. Non-destructive testing method was chosen since existing information of the structure was unavailable. Test results showed that the basement (B1) was susceptible to corrosion, and the compressive strength was not in the recommended range. Ultrasonic pulse velocity (UPV) results also proved that the average quality of the concrete was poor. Hence, significant suggestions were given for necessary retrofitting measures to improve the stability of the structure.

Keywords: Non-Destructive Testing, Ultrasonic Pulse Velocity, Rebound Hammer, Compressive Strength, Structural Stability

1. Introduction

The non-destructive tests like rebound hammer and ultrasonic pulse velocity tests can improve the accuracy of concrete strength examinations performed by support vector machines (SVM) algorithm. Comparing this to a single testing approach produces more trustworthy estimates [1]. Fibre-reinforced concrete's compressive force, lively modulus of bounciness, and Poisson's relation may all be accurately determined using ultrasonic beat speed and rebound hammer tests. While ultrasonic pulse speed is more successful in ageing concrete, rebound hammer testing is better suited for more mature concrete [2]. Combining the non-destructive methods of rebound number with ultrasonic pulse speed allows aimed at precise prediction of the compressive force of concrete structures, closely matching actual findings [3]. Rebound mallet and ultrasonic pulse speed remain two non-destructive challenging techniques that are useful for keeping an eye on the structural integrity of reinforced concrete buildings. While ultrasonic beat speed remains more successful in cutting-edge ageing concrete, ricochet hammer testing remains better suited for early-age concrete [4]. When paired with concrete density, impact ricochet hammer and ultrasonic beat speed techniques can enhance the estimation of concrete strength, emphasizing the important influence of formwork material on surface hardness [5]. Without appreciably lengthening testing times or raising costs, ultrasonic pulse speed and booming incidence examination are also efficient non-destructive testing techniques for identifying production flaws in concrete [6]. For evaluating the quality and homogeneity of the concrete matrix ultrasonic pulse velocity (UPV) test will be effective and infrared thermography can detect delaminations. Furthermore, the compressive force of concrete can be assessed by rebound hammer testing [7]. Rebound hammer testing dramatically reduces strength for high-volume hover ash concrete, although ultrasonic pulse speed testing reveals comparable compressive strength between fly ash concrete and ordinary concrete on altogether eternities [8]. Non-destructive testing for assessing the safety of structures is made possible by the multi-variation equation, which can efficiently connect the concrete compressive force and ultrasonic pulse speed values [9]. While rebound hammer testing is insufficient for forecasting steel corrosion in reinforced concrete structures, the SonReb model is the greatest dependable non-destructive testing technique aimed at predicting concrete compressive force [10]. When used in conjunction with Response Surface Methodology, ultrasonic beat speed is the greatest effective non-destructive test for deciding the compressive force of concrete [11]. The ultrasonic pulse velocity approach and the surface hardness method exhibit partial sensitivity to elements influencing abrasion resistance, whereas the initial surface absorption method remains greatest sensitive non-destructive technique for evaluating abrasion resistance of concrete slabs [12]. When comparing separate methods to determine the concrete compressive force, the SonReb method yields the most accurate results [13] by combining ultrasonic pulse speed and ricochet hammer tests. When compared to experimental results, artificial neural networks (ANN) methods can reliably and robustly forecast the concrete crushing strength of current structures [14]. Concrete strength variability, core number, NDT technique quality, and uncontrollable factors all affect the quality of the non-destructive strength evaluation of the material [15]. Unlike other non-destructive tests, ultrasonic pulse speed is a valid technique for deciding the static modulus of elasticity of thermally damaged concretes [16]. When making decisions about structural development and budget allocation, non-destructive testing methods container remain used to evaluate the real force of existing structures efficiently [17]. In comparison to traditional proportional integral controllers, the suggested artificial neural network controller offers better load frequency control in multi-area power systems [18]. The accuracy of non-destructive testing can be increased by using correlation curves for the modulus of bounciness and compressive strength of ready-mixed concrete in Rio de Janeiro [19]. The concrete quality, and strength of older and newer constructions can also be ascertained by non-destructive testing techniques [20]. Various authors have suggested using rebound hammers and ultrasonic tests to gather data about structures. This present study mainly aims towards the use of non-destructive challenges to assess the structural integrity of a four-storied residential building.

2. Non Destructive Testing (NDT) Techniques – An Overview

In existing structures, the quality of concrete can be easily accessed by various techniques. In addition, NDT techniques are being used in evaluating the quality of plastics, composites, metals etc. The parameters such as internal voids, porosity, cracks, surface cavities, delamination, and weld quality are also assessed. Figure 1, represents the various NDT techniques currently in practice to check the quality of concrete along with its uses in different applications.

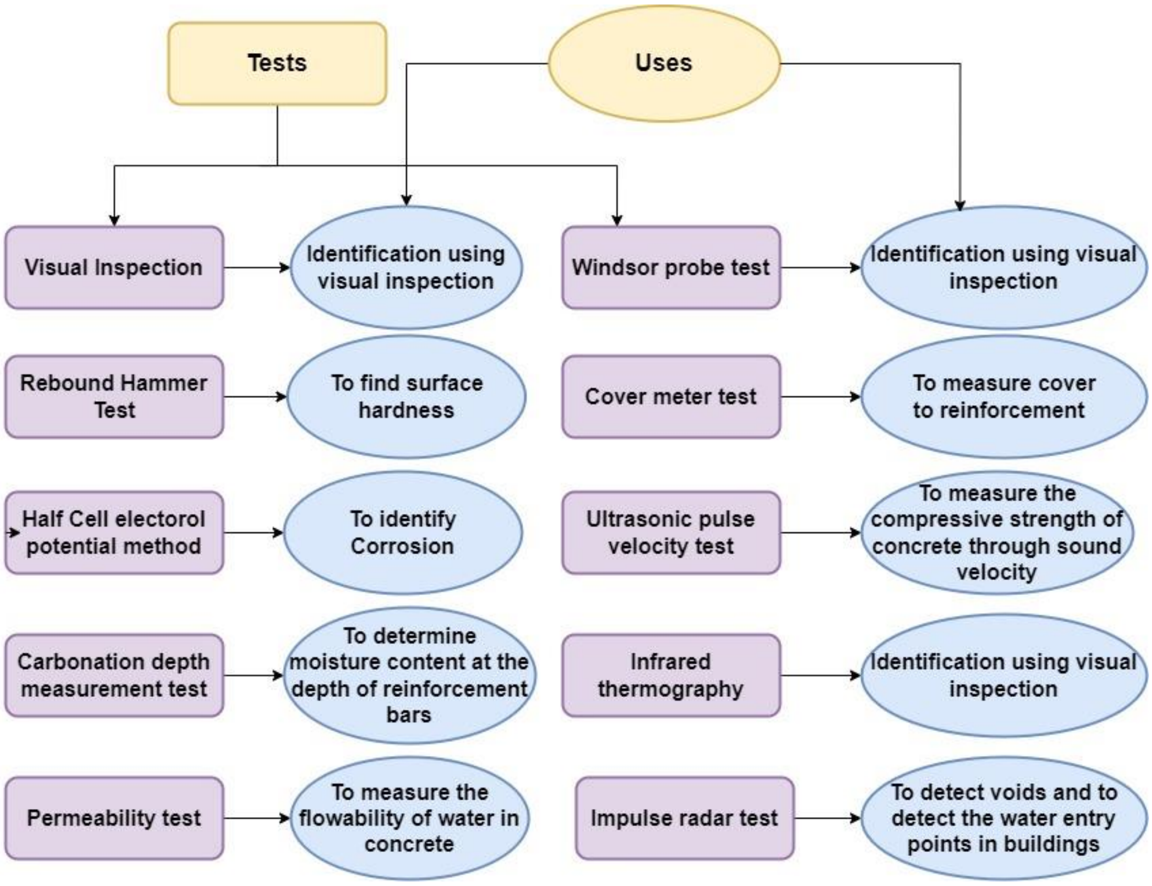

Figure.1 Various Non-Destructive Testing Techniques

3. Experimental Investigation

3.1 Rebound Hammer Test

A rebound hammer test confirming to IS 13311 (Part 2) is performed to assess the structural stability of four storied building. A few activities are to be verified before performing the test. The activities like preparation of surface to be tested, calibration of equipment, identification and marking, execution of tests, and recording results are to be ensured. Before execution, the surface of the concrete is to be cleaned and it should be free from loose particles, dust, oil, or any other contaminants that may affect the test results. Furthermore, the calibration of the equipment is to be verified and it should be within the acceptable range before proceeding with the test. Figure 2 demonstrates the testing method of structure using the rebound hammer test. A traditional test rebound hammer cannot be used to measure the concrete strength directly rather it should be calibrated for a specific concrete type and the calibration curve is shown in Figure 3 [23-27].

3.2 Ultrasonic pulse Velocity

An ultrasonic pulse test confirming to IS 13311 (Part 1) test is conducted to assess the structural stability of the structure. The necessary accessories like transducers, cables and coupling materials are to be ensured. The surfaces of the concrete should be cleaned to ensure good contact with the transducers. If necessary, a coupling agent (such as petroleum jelly or water-based gel) can be ensured and proper transmission of ultrasonic waves between the transducers and the material being tested. The couples between transducers are ensured and there should be no air gaps between the transducers and the material. The additional transducer is detained in interaction with the other superficial of the concrete associate and converts the vibration pulse into an electrical signal after it has travelled a known path length (Q) in the concrete. This allows the transportation time (T) of the beat to be slow using an electric judgement circuit, which yields the pulse velocity (V).

4. Results and discussion

4.1 Prediction of compressive strength by rebound hammer test

Table 1 demonstrations the compressive strength values which are observed in various locations of the existing structure. The test is carried out by rebound hammer method at various points in structural elements like basement column, basement beam, second-floor column, third-floor column and third-floor slab. Test results revealed that the points P1, P3, P4, P9, P12, TF1, TF2, TF3, TF4, TF5 and TF6 were less than 30 N/mm2 which is lower than the values obtained for other points. Moreover, more cracks are observed in aforesaid locations. Corrosion has occurred in reinforcement in those places that result in spalling of concrete. The strength of the locations will be improved with necessary repair and rehabilitation methods that result in improvement in the service life of the structure. Test results are graphically represented in Figure 5.

4.2 Prediction of compressive strength by ultrasonic pulse velocity test

Table 2 demonstrates the values obtained from ultrasonic pulse velocity (UPV) testing of the third-floor slab of the building. The UPV grading of TF1, TF2, TF3, TF4, and TF5 are 0.420 km/sec, 1.156 km/sec, 1.10 km/sec, 0.465 km/sec and 0.847 km/sec respectively. The UPV standards are indicative of the homogeneity of the real combination, microstructure, and presence of voids in the material. The values were calculated based on the path length of the contact area and the distance travelled by the UPV rays.

Figure 2. Testing of structure by rebound hammer test method

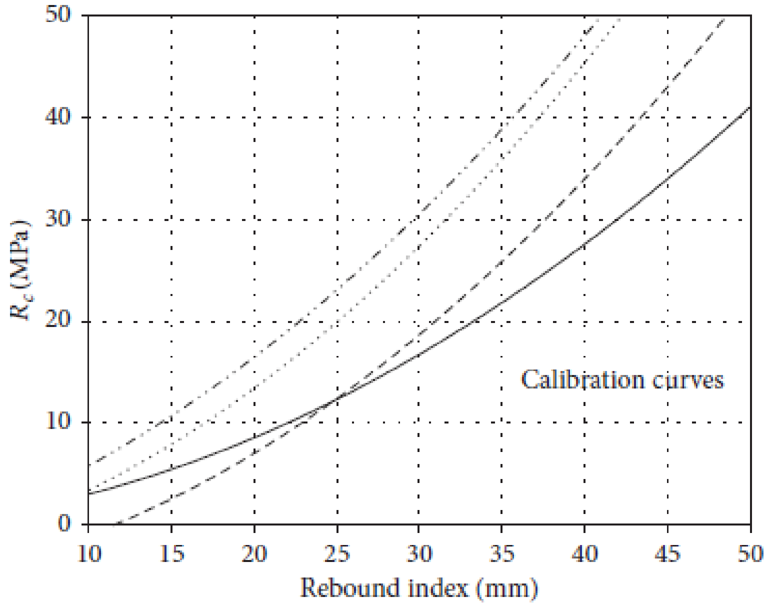

Figure 3. Rebound hammer calibration curves [23-27]

Figure 4. Testing of the structure by ultrasonic sonic pulse velocity test method

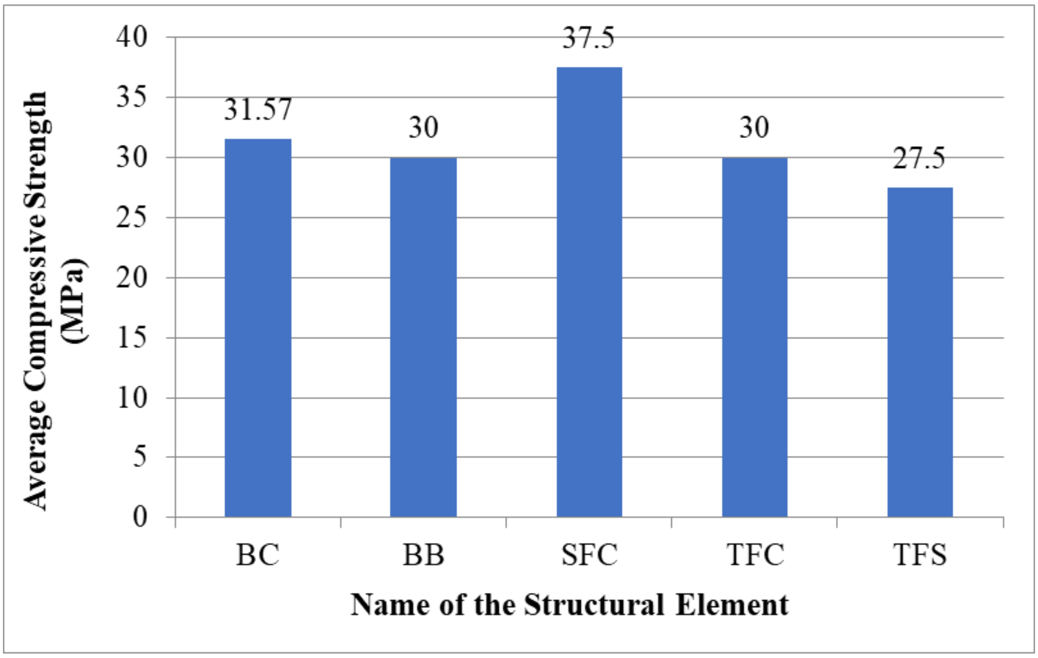

Figure 4. Average compressive strength of structural elements

Table 1. Compressive strength of structural elements at various points

S.No	Name of Structural Element	Point ID	Rebound Number	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	Basement Column (BC)	P1	31	27	31.57
		P2	35	32	
		P3	32	28	
		P4	34	29	
		P5	36	36	
		P6	37	37	
		P7	34	32	
2	Basement Beam P'1 (BB)	P'1	38	30	30
3	Second Floor Column (SFC)	P8	33	30	37.5
		P9	32	28	
		P10	42	46	
		P11	42	46	
4	Third Floor Column (TFC)	P12	32	28	30
		P13	33	30	
		P14	34	32	
5	Third Floor Slab (TFS)	TF1	28	27	27.5
		TF2	29	29	
		TF3	29	29	
		TF4	28	27	
		TF5	29	29	
		TF6	26	24	

Table 2. Non-Destructive Testing By Ultrasonic Pulse Velocity

Name of Structural Element	Point ID	Method of transmission	Path length (mm)	Time (μ sec)	Velocity (km/sec)
Third floor slab	TF1	Indirect	200	476	0.420
	TF2		200	173	1.156
	TF3		200	181.5	1.10
	TF4		200	430	0.465
	TF5		200	236	0.847

Table 3. Speed Standard for Concrete Excellence Grading IS 1311 (Part 1): 1992

Pulse velocity (km/sec)	Quality Grading of Concrete
"Above 4.5"	Outstanding
"3.5 to 4.5"	Decent
"3.0 to 3.5"	Average
"Below 3.0"	Unsure

Arrived test results are verified in accordance with IS 1311 and it was found that all the points had pulse velocity values below 3.0. This can be attributed to the fact that the concrete quality is doubtful and requires further strengthening.

5. Conclusion

Non-destructive testing is performed in the existing structure and the following observations were made.In the Basement area, the North and East side walls constructed with RR Masonry, whereas the South and West side portions are framed type structures that would lead to uneven load distribution and the proposed area of construction is lying in NE and SE area. Further, it is recommended to carry external strengthening in the basement area beam (P’1). Furthermore, corrosion in reinforcement is observed and suggested for anti-corrosion treatment. The floating column was identified in different locations that may lead to uneven distribution of loads when the structure is extra loaded. It is suggested to introduce a support column below the floating column area. In addition, strong beam and weak column conditions was observed in the existing building that will not resist any dynamic loads. The points P1, P3, P4, P9, P12, TF1, TF2, TF3, TF4, TF5 and TF6 has less than 30 N/mm2 not in the recommended range as per codal provisions. Many structural cracks are identified in beam and column elements that need strengthening by FRP Jacketing or any other retrofitting methods. Waterproofing is also required in open-to-sky portions to resist the seepage of water. It has been noticed that slab concrete quality needs to be improved where the proposed building is to be constructed. it is recommended micro concreting for strengthening, and masonry work done in column structures at roof level and the same can be replaced with RCC with necessary strengthening techniques. Vegetation’s are observed in adjacent buildings which is rooted inside the structure and the same should be removed. As concluding remarks, the suggestion has been given to the clients not to construct any structure in existing building that may lead to structural failure.

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Authors Contribution Statement

R. Saravanakumar: Conceptualization, methodology, software, validation, supervision, result analysis; K.S. Elango: Methodology, Data collection, Writing; S. Gnanavenkatesh: Conceptualization, Formal analysis, validation; S. Saravanaganesh: Conceptualization, visualization, supervision, Writing-review and editing.

Funding

This research was conducted without the aid of any financial grants.

Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Has this article screened for similarity?

Yes