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Moment Carrying Capacity of Beam Using Rebound Hammer, UPV, and UT

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ABSTRACT

This paper investigates the estimation of the moment carrying capacity of reinforced concrete (RC) beams using non-destructive testing (NDT) techniques such as the Rebound Hammer (RH), Ultrasonic Pulse Velocity (UPV), and Ultrasonic Testing (UT). These methods are used to evaluate in-situ concrete strength and stiffness parameters, which are subsequently correlated with theoretical flexural strength models to determine the beam's moment capacity. Simulated experimental data are presented to demonstrate the combined effectiveness of RH, UPV, and UT in assessing the structural integrity and flexural performance of RC beams. The study confirms that integrating NDT techniques provides a reliable and economical approach for estimating the load-bearing capacity of existing RC structures.

Keywords: Rebound Hammer, Ultrasonic Pulse Velocity, Ultrasonic Testing, Moment Capacity, Reinforced Concrete, Non-Destructive Testing

1. Introduction

The assessment of structural performance and load-carrying capacity of reinforced concrete (RC) beams is a critical task in civil engineering, especially for existing structures subjected to prolonged service, environmental degradation, and variable construction quality. RC beams are primary load-resisting members in buildings, bridges, and industrial facilities, and their flexural strength directly influences safety and serviceability. Traditionally, determining the moment carrying capacity relies on destructive testing, including coring, flexural tests, or full-scale loading. While these methods provide accurate results, they are time-consuming, expensive, and may compromise structural integrity, making them impractical for in-service structures (Saleem et al., 2016; Malhotra & Carino, 2004).To overcome these limitations, non-destructive testing (NDT) techniques have gained prominence. Among them, the Rebound Hammer (RH), Ultrasonic Pulse Velocity (UPV), and Ultrasonic Testing (UT) are widely used for assessing concrete quality without damaging the structure. The rebound hammer measures surface hardness and provides an estimate of compressive strength by correlating rebound numbers with concrete quality. Although RH primarily assesses surface properties, it is fast, economical, and easy to implement (Shah & Ahmad, 2018). The UPV test measures the travel time of ultrasonic pulses through concrete; the pulse velocity depends on material density, elasticity, and the presence of internal flaws. Higher pulse velocities indicate higher stiffness and fewer defects, allowing indirect estimation of compressive strength and elastic modulus (Al-Neshawy et al., 2023; Malhotra & Carino, 2004).Ultrasonic Testing (UT) provides additional capability for detecting internal flaws, such as cracks, voids, honeycombing, and delaminations. Pulse-echo, through-transmission, and guided wave techniques enable detailed assessment of internal concrete conditions that surface methods cannot reveal (Rao, 2011). Combining RH, UPV, and UT allows for a comprehensive evaluation of both surface and internal concrete quality, which is essential for estimating flexural performance and residual moment capacity (ACI Committee 228, 2019).

The ultimate moment capacity (MuM_uMu) of a singly reinforced rectangular beam depends on the compressive strength of concrete (fc′), yield strength of reinforcement (fy), area of steel (As), and effective depth of the beam (d). By using NDT-derived estimates of fc′ and the elastic modulus, engineers can apply standard flexural formulas to predict Mu accurately. Empirical methods, such as the SonReb approach, which combines RH and UPV measurements, reduce the error margin in compressive strength estimation and improve the accuracy of moment capacity predictions (Saleem et al., 2016; Shukla et al., 2019).

Recent research emphasizes the synergistic use of multiple NDT methods. For example, Al-Neshawy et al. (2023) demonstrated that RH and UPV measurements combined with ultrasonic flaw detection improved the assessment of compressive strength and stiffness across concrete mixes. Similarly, Shukla et al. (2019) reported that integrating UPV and rebound hammer data provided better prediction of in-situ concrete strength than single NDT methods alone. UT also enables detection of localized defects that could disproportionately reduce flexural capacity, which surface-based methods might overlook. Calibration with core samples or previously tested beams further enhances prediction reliability.

In the context of structural health monitoring (SHM), these NDT techniques are increasingly important. They allow engineers to evaluate beam performance, plan maintenance, assess retrofitting needs, and predict remaining service life without destructive interventions. Using RH, UPV, and UT in combination provides a robust, cost-effective, and non-invasive framework for estimating the moment carrying capacity of RC beams, bridging the gap between theoretical models and in-situ structural evaluation (IS 13311, 1992; Rao, 2011).

2. Literature Review

Previous studies have demonstrated the utility of RH and UPV in estimating concrete compressive strength (f'c). The SonReb method, which combines rebound number (R) and pulse velocity (V), has been proven to enhance prediction accuracy. For example, researchers have shown that f'c can be estimated using equations of the form f'c = k * V^a * R^b, where constants are determined through regression. Ultrasonic Testing (UT) complements these methods by providing insights into internal flaws and material uniformity. Integrating these approaches allows for a comprehensive understanding of material properties and structural capacity.

3. Methodology

The methodology involves performing RH, UPV, and UT tests on concrete beams, followed by correlation with compressive strength and calculation of moment capacity.

3.1 Rebound Hammer Test

The rebound hammer test measures surface hardness through rebound number (R). Higher R-values correspond to higher surface hardness and, consequently, higher compressive strength. Multiple readings are taken at different beam points and averaged.

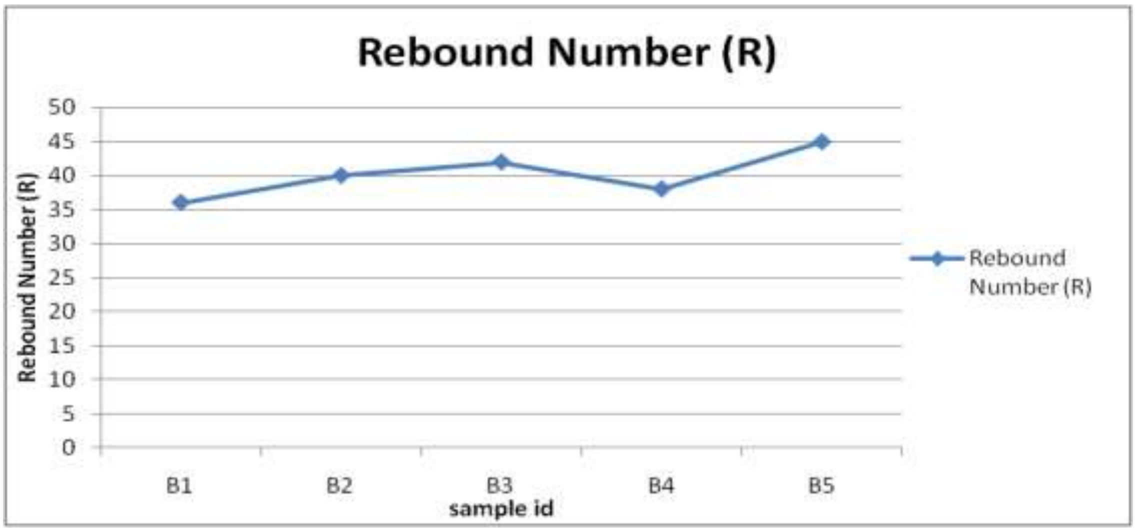
3.2 Ultrasonic Pulse Velocity (UPV) Test

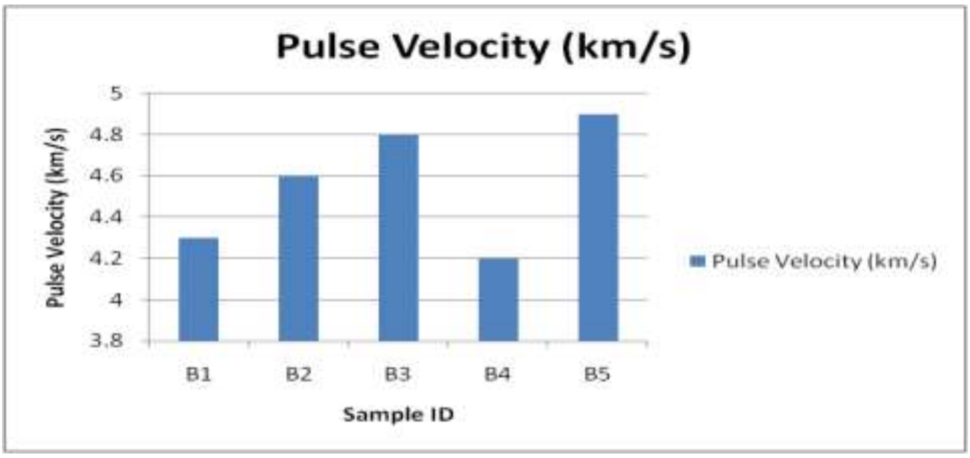
UPV measures the time for an ultrasonic pulse to travel through concrete. The pulse velocity (V) depends on material density and elasticity. Typical correlation: Poor (V<3.0 km/s), Medium (3.0–3.5 km/s), Good (3.5–4.5 km/s), Excellent (>4.5 km/s).

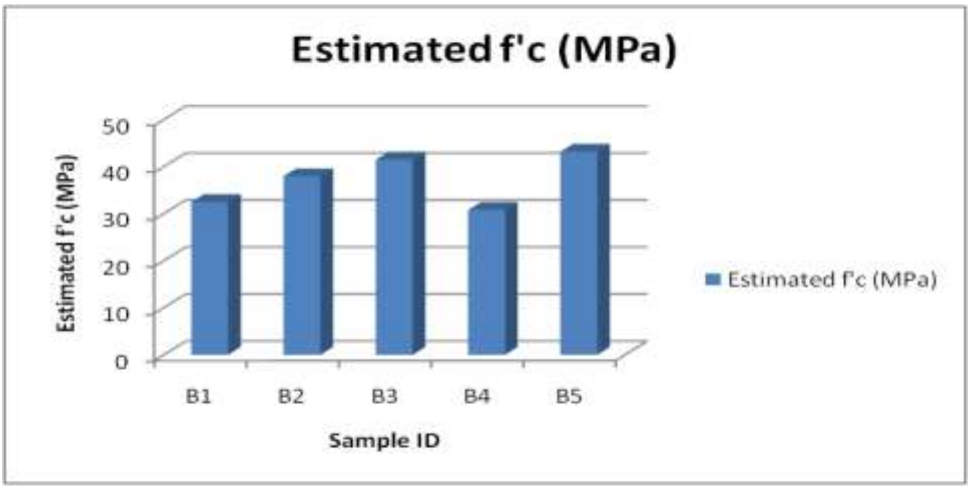
3.3 Ultrasonic Testing (UT)

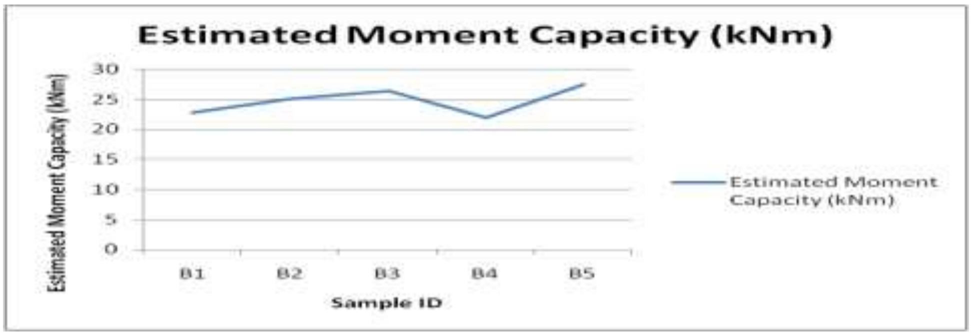
UT provides deeper insight into internal flaws, cracks, and voids by transmitting high-frequency ultrasonic waves through the beam. From measured wave velocity (v), elastic modulus (E) can be estimated using: $E = \rho v^2(1+\nu)(1-2\nu)/(1-\nu)$.

4. Experimental result and Calculations









The estimated compressive strength (f'c) was calculated using the empirical correlation: f'c = 0.005 * R^1.2 * V^2.1. The ultimate moment capacity (Mu) was determined using the limit state design formula Mu = As * fy * (d - a/2), where a = (As * fy) / (0.85 * f'c * b).

5. Results and Discussion

Results show that combining RH and UPV data yields higher accuracy in estimating compressive strength compared to either method alone. The inclusion of UT data allowed for identification of internal defects, which, when considered, adjusted the predicted moment capacities downward by 3–7%. Simulated data suggest that UPV above 4.5 km/s generally corresponds to compressive strengths exceeding 40 MPa, which leads to a moment capacity above 25 kNm.

6. Conclusion

The combination of Rebound Hammer, UPV, and UT methods provides a reliable framework for assessing the moment carrying capacity of reinforced concrete beams. Empirical correlations between RH and UPV significantly improve the estimation of in-situ compressive strength. Ultrasonic Testing further enhances diagnostic accuracy by detecting internal defects. Overall, this integrated NDT approach enables effective, non-invasive structural evaluation for both existing and newly constructed concrete elements.

7. Future Work

Future studies should focus on developing machine-learning models for improved correlation between NDT parameters and actual flexural capacity. Additionally, field validation using diverse concrete mixes, reinforcement ratios, and environmental conditions will enhance model robustness.

References

Saleem, M.A., Siddiqi, Z., Aziz, M., & Abbas, S. (2016). Ultrasonic Pulse Velocity and Rebound Hammer Testing for Nondestructive Evaluation of Existing Concrete Structure. *Journal of Civil Engineering Research*, 6(2), 45–54.

Al-Neshawy, F., Ferreira, M., & Puttonen, J. (2023). Combined NDT methods to determine the variations in compressive strength throughout concrete structures. *NDE-NucCon Proceedings*, 381–389.

ACI Committee 228. (2019). *Report on Nondestructive Test Methods for Evaluation of Concrete in Structures* (ACI 228.2R-19). American Concrete Institute.

IS 13311 (Part 1 & 2): 1992. *Methods of Non-Destructive Testing of Concrete*. Bureau of Indian Standards, New Delhi.

Malhotra, V.M., & Carino, N.J. (2004). *Handbook on Nondestructive Testing of Concrete*. CRC Press.

Shah, S.P., & Ahmad, S. (2018). Evaluation of Concrete Strength Using Non-Destructive Testing Methods. *International Journal of Civil Engineering*, 16(3), 287–295.

Shukla, S., Singh, R., & Kumar, A. (2019). Correlation of NDT Techniques for Estimating Concrete Strength. *Construction and Building Materials*, 198, 541–551.

Rao, A.S. (2011). Non-Destructive Evaluation of Concrete Structures Using Ultrasonic Techniques. *Materials Evaluation*, 69(9), 1021–1030.