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Comparative Study of Non-Destructive Testing Techniques using UPV & Rebound Hammer in Retrofitting

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ABSTRACT: Lifespan of a structure can range from 50-75 years depending on the usage of it. Throughout its lifespan, a structure may confront various threats ranging from minor cracks to extreme structural failure which can endanger its integrity and durability. To eliminate or reduce such threats a structure is retrofitted using various techniques. To understand and pick a method of retrofitting, the structure has to be studied and examined for its properties, composition and overall health. With the help of Non-Destructive Testing (NDT), we can investigate the structure and its components for better understanding of the condition it is in. While there are various NDT methods, the most commonly used methods are Ultrasonic Pulse Velocity (UPV) testing and Rebound Hammer Test. We use Rebound Hammer to test the surface hardness of the concrete and Ultrasonic Pulse Velocity test to calculate the density and homogeneity of the concrete. In this study, we have tried to understand the benefits of these methods as well as carried out a comparative analysis of these techniques to conclude their respective pros and cons. This study will give a thorough analysis and provide a conclusion telling which is a better NDT method for analyzing structural elements.

KEYWORDS: Retrofitting, Non-Destructive Testing, UPV, Rebound Hammer.

I.INTRODUCTION

Retrofitting is one of the most important methods of construction and civil engineering to enhance performance, safety, and longevity of structures. This adaptation is highly crucial for the improvement of currently underperforming older buildings and infrastructure to meet the contemporary standards and codes with the help of changing environmental and regulatory challenges. Retrofitting refers to any change made on a building, from the structural strengthening, wherein major components such as beams, columns, and foundations are strengthened in order to add load-bearing and seismic resistance capacity to the building. There is also seismic upgrading that can be undertaken to make the buildings more resistant to earthquakes or quakes, especially in seismically active areas. Retrofitting is one alternative option to full demolition and reconstruction, as it allows the preservation of architectural, cultural, or historical landmarks but enhances the functionality of these monuments. Self-healing concrete presents transformative benefits in retrofitting because it contains healing agents in the form of bacteria or microcapsules activated by a stress-induced reaction that heals the material autonomously upon the development of cracks. The advantages of retrofitting materials, which would include self-healing concrete, comprise increased durability as the ability to self-heal reduces further deterioration and protracts the lifespan of the structure.

Non-destructive methods like Rebound Hammer and Ultrasonic Pulse Velocity (UPV) must be selected for retrofitting the concrete structure. These techniques do allow the investigation of existing concrete conditions without causing any damage, and therefore safe and efficient assessments are possible.



Fig. 1 - Rebound Hammer

The Rebound Hammer test measures the surface hardness of concrete, which is an indirect measure of the compression strength of the concrete. The rebound hammer employs a spring-loaded action for impacting the surface of the concrete and measuring the rebound distance. Information gathered aids in assessing uniformity and integrity of concrete including possible retrofitting requirements. It values quick assessment and portability, allowing effortless use on-site.

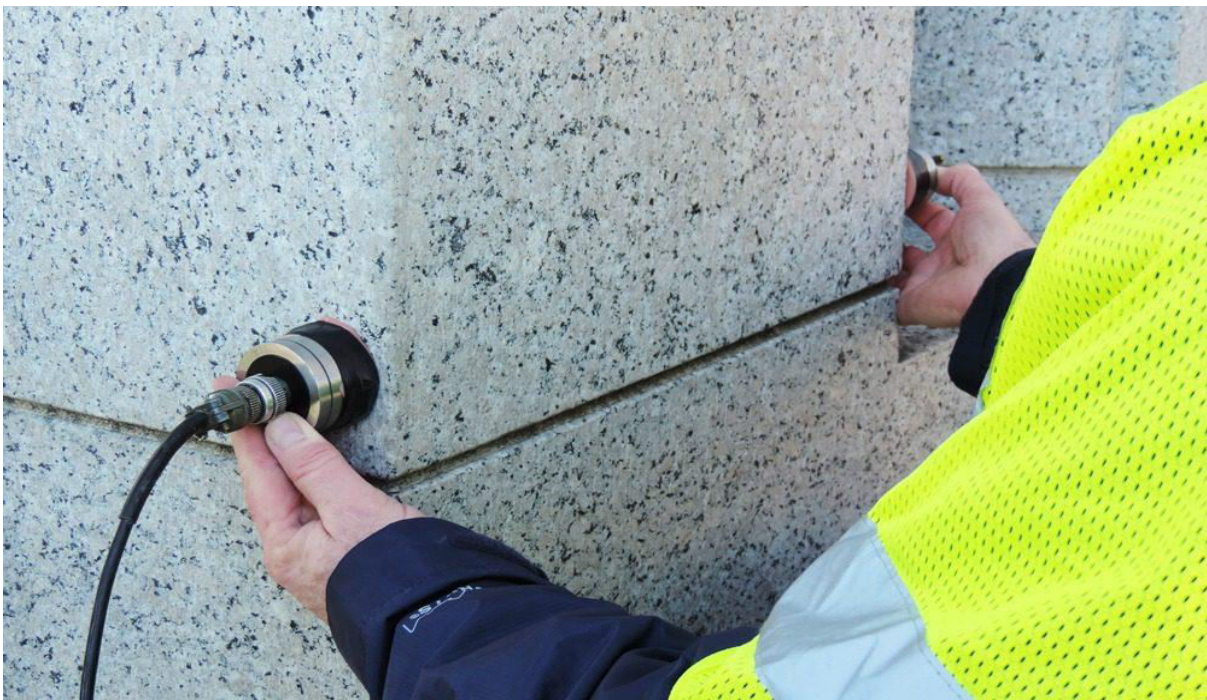


Fig. 2 - Ultrasonic Pulse Velocity

While UPV works by transmitting ultrasonic waves through the concrete and measuring the time it takes for these waves to travel between sensors. This method offers insight into material density, elastic properties, and picking up internal defects like cracks, voids, or delaminations. In this regard, UPV is important in determining concrete quality and deterioration extent that's necessary when selecting the right retrofitting strategy. All these NDT techniques together enhance the retrofitting process considerably by furnishing reliable information regarding the state of concrete structures.

I.1 OBJECTIVES:

1. Assess the effectiveness of UPV and Rebound Hammer techniques in evaluating the structural integrity of existing concrete elements before retrofitting.
2. Investigate the ability of UPV and Rebound Hammer to detect hidden defects or anomalies, such as voids or cracks, that may affect retrofitting strategies.
3. Examine the correlation between UPV and Rebound Hammer results to establish a reliable relationship for interpreting data in the context of retrofitting.
4. Provide guidance on selecting the appropriate NDT method based on retrofitting needs and conditions.
5. With an overview of present studies of structural audits examining faults and damages we can produce a self-healing concrete grout with desired properties

II. LITERATURE REVIEW

II.1 Retrofitting case studies.

J. Bhattacharjee (2016): The study discusses the critical issues surrounding the deterioration of reinforced concrete (RCC) structures, which can arise from factors such as corrosion, environmental conditions, and lack of maintenance. It highlights the necessity for effective repair, rehabilitation, and retrofitting methods to ensure the longevity and safety of these structures, aligning with sustainable development goals. It emphasizes the importance of adopting modern materials and techniques, such as polymers and advanced admixtures, to enhance the durability and performance of RCC. Various case studies are presented, showcasing successful rehabilitation projects that illustrate the practical application of these innovative methods. Furthermore, the study advocates for regular maintenance and proactive strategies to address potential deterioration before it escalates into significant structural issues. By integrating sustainable practices in the repair and retrofitting processes, the construction industry can contribute to environmental conservation while ensuring the resilience of infrastructure. Overall, the work underscores the vital role of effective management of RCC structures in promoting sustainable development in the built environment.

L. Miranda, J. Milosevic, R. Bento (2017): This case study investigates the retrofitting of rubble stone masonry walls in historic Lisbon buildings using grout injection. The goal was to develop an effective grout composition to enhance the mechanical properties of these walls. Researchers created a grout with a 1:1 mix of cement and hydraulic lime, 0.2% super-plasticizer, and a water/binder ratio of 0.45, achieving good flowability and a compressive strength of 27 MPa. Two masonry specimens, S1 and S2, were tested in their original state and then repaired with grout injection before being retested under static cyclic loads. The retrofitted specimens, SR1 and SR2, demonstrated significant performance improvements. Failure analysis revealed a mix of flexural and shear cracking in the strengthened specimens. While SR1 and SR2 showed similar maximum lateral resistance, SR1 experienced some strength loss in areas lacking grout. The effectiveness of grout injection was most notable in SR1, which received more grout. The study concludes that grout injection is advantageous for masonry walls with a voids index of 2-15%. Overall, the research highlights the potential of grout injection for repairing historic masonry structures in earthquake-prone areas like Lisbon, providing valuable insights for conservation efforts, particularly for mixed masonry-reinforced concrete buildings, which make up about 30% of the city's building stock.

Anna ANZANI, Luigia BINDA, Maurizio LUALDI, Cristina TEDESCHI, Luigi ZANZI (2006):

In this study, researchers investigated the use of grout injection for repairing and strengthening historic masonry structures, emphasizing the lessons learned from the earthquakes in central Italy in late 1997. They highlighted the importance of thorough investigation prior to applying this technique. Non-destructive methods are vital for assessing the effectiveness of the injection process. Specimens of three-leaf stone masonry walls were tested and repaired through

injection. High-frequency radar measurements were conducted beforehand to evaluate the fracture conditions. The effectiveness of the grout injection was assessed using various non-destructive techniques both before and after the repair. Sonic velocity measurements were taken horizontally, and surface measurements were performed to compare different testing geometries. The repair involved injecting inorganic mixtures into cracks and joint spaces. Non-destructive evaluations, including sonic measurements and ground-penetrating radar surveys, were used to gauge the success of the injections. The results indicated that sonic velocity measurements were particularly responsive to grout injection, showing a significant increase in velocity post-injection. These non-destructive testing (NDT) methods are essential for refining injection techniques and monitoring grout penetration and diffusion during repairs. Additionally, high frequency radar measurements can optimize injection point locations by identifying areas of macro fractures, smaller cracks, and compact material within the masonry walls.

II.2 Rebound Hammer.

J. C. Agunwamba, T. Adagba (2012): This study compares two non-destructive testing methods: the rebound hammer and ultrasonic pulse velocity. Both methods are used to estimate the strength of concrete. The ultrasonic pulse velocity test is influenced by the age of the concrete, with strength increasing as the concrete matures. We prepared 150×150×150 mm sample cubes using mix designs of 1:2:4 and 1:3:6, with a constant water-cement ratio of 0.45. Testing was conducted at 7, 14, 21, and 28 days. The slump values ranged from 62 to 78 mm. The study examines the relationship between the rebound hammer results and compressive strength, comparing them to those obtained from ultrasonic pulse velocity measurements. It was observed that the rebound hammer shows less sensitivity to changes in concrete strength as it matures, with minimal gains in surface hardness beyond 7 days. There was no significant difference between the results from the two methods, indicating that either method can be used for estimating in-situ strength.

Akash Jain, Ankit Kathuria, Adarsh Kumar, Yogesh Verma, Krishna Murari (2013): Non-destructive testing (NDT) of concrete is crucial for both practical and engineering applications. In recent years, there has been increased attention on using NDT to assess the quality of damaged concrete structures. NDT is valuable for reducing labour involved in testing and preparing work, especially when dealing with minor structural damage where drilling into concrete to assess strength is not feasible. The rebound hammer is effective for detecting changes in building material properties over time, such as the hydration of cement. This study aims to develop a method that combines different non-destructive tests to assess concrete strength with greater accuracy. Rebound hammer readings increase in correlation with the concrete's compressive strength, and the strength can be estimated using rebound hammer compression charts. The ultrasonic pulse velocity test is another method used to estimate concrete's compressive strength. By analyzing the correlation between rebound numbers and ultrasonic pulse velocity, we can determine the compressive strength more precisely. The ultrasonic pulse velocity is significantly affected by factors such as the type of cement, aggregate, and the extent of moist curing, while the presence of voids in the concrete also plays a critical role in the measured strength.

Dr. R. Rajeshguna, M. Hari Sathish Kumar, M. Anbalagan (2017): Steel fiber reinforced concrete is a crucial material composed of hydraulic cement, fine aggregate, and coarse aggregate, with the addition of steel fibers to enhance its properties. These fibers help control cracking, limit crack propagation, and improve both strength and durability. The rebound hammer test is significant as it measures concrete hardness based on the energy absorbed during a collision. In this study, the Schmidt rebound hammer is used to assess the uniformity of concrete. This paper examines the impact of fiber volume fraction on concrete. We found that concrete with a higher fiber volume fraction shows greater compressive strength compared to conventional concrete, as measured by the rebound hammer. With a fiber aspect ratio of 60, the optimal compressive strength was achieved with a 1% fiber volume fraction. The addition of steel fibers improves the compressive strength and durability of concrete. We observed a linear relationship between the rebound hammer readings and fiber volume fraction. The addition of fibers reduces concrete brittleness, preventing the specimens from crumbling; instead, they are held together by the fibers, which contribute to the concrete's improved performance.

II.3 Ultrasonic Pulse Velocity.

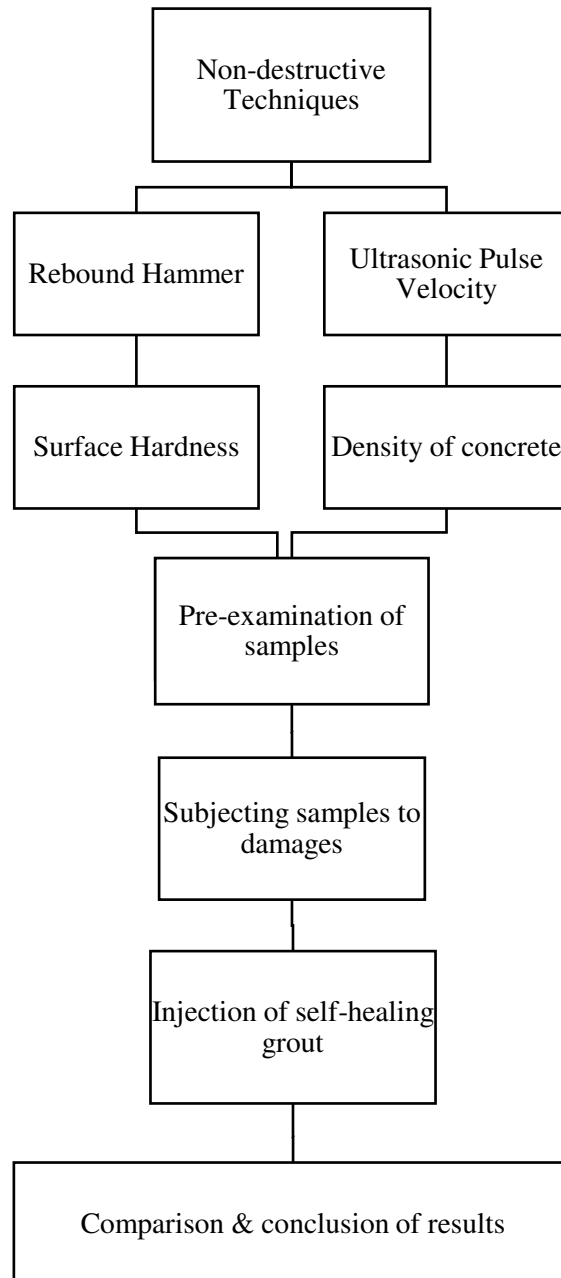
Kenneth C. Hover (2019): This study compares NDT test results with 3-day compressive strength of drilled cores across 12 instances over 15 years. The research shows how changes in within-batch and cross-curing concrete have an

impact on NDT correlations. It reveals that the links between NDT results and core strength can vary, with prediction errors around $\pm 25\%$ of the average core strength. The study used several NDT methods, including Rebound Hammer (ASTM C805), Penetration Resistance – Windsor Probe (C803), Pullout Strength (C900), and Ultrasonic Pulse Velocity (UPV) (C597). All tests used concrete from the same supplier and identical mixture ratios under consistent conditions. Over 12 case studies, NDT correlations showed uneven precision affected by concrete variability due to yearly changes in environment and raw materials. To sum up, the findings suggest that while calibrations tailored to the mixture could improve NDT result precision, people still rely on generic calibrations, which might lead to inaccuracies. The study stresses the need to develop more precise calibration methods.

Choonghyun Kang, Yongmyung Park, Taewan Kim (2023): In this study, researchers examined how Ordinary Portland Cement (OPC) mixed with Ground Granulated Blast-Furnace Slag (GGBFS) self-heals in seawater at various temperatures. Using Ultrasonic Pulse Velocity (UPV), they assessed the healing effectiveness of minerals formed during soaking. They found that higher GGBFS content and warmer seawater improved self-healing for the first 30 days. However, after this period, brucite build-up blocked further healing, leading to misleadingly high UPV readings. The research highlights the complexity of self-healing in seawater compared to freshwater, emphasizing GGBFS's role in enhancing durability and chloride resistance for marine applications. The study calls for further exploration of aggregate types and sizes to improve self-healing methods. Overall, UPV is vital for non-destructively monitoring healing processes and understanding the factors influencing self-healing in concrete.

Harshbab Singh and Rishi Gupta (2020): Traditional concrete is susceptible to cracking under stress. To mitigate this, using bacteria for self-repair without external intervention has proven beneficial, cost-effective, and environmentally friendly. This self-healing technology is advancing, but suitable carriers to protect the bacteria in concrete remain to be identified. Cellulose fiber has shown promise by reducing crack width during plastic shrinkage by up to 85% and providing an 85% water absorption rate for better internal curing. In this study, bacteria-infused mortar specimens were tested for strength using Ultrasonic Pulse Velocity (UPV) and image analysis. Five samples were tested at 14 days and another five at 28 days of curing, with additional samples assessed for compressive strength at 28 days. UPV tests, conducted per ASTM C597, estimated material discontinuities by analyzing wave travel times. Results revealed that UPV values are significantly influenced by the un-cracked matrix, with cracked samples showing decreased UPV due to increased micro cracks and macro cracks. However, after curing and the introduction of self-healing agents, UPV values indicated a remarkable recovery, demonstrating effective restoration of material integrity. This underscores the importance of UPV as a non-destructive method for real-time monitoring of concrete's self-healing capabilities.

III. PROPOSED METHODOLOGY



IV. DESIRED OUTCOMES

- To find out a feasible and efficient test to examine the concrete properties for good retrofitting.
- To understand the benefits of both of the NDT tests favourable to our project.
- With comparison of two tests, we will get more precise and dependable readings that'll aid the retrofitting process.
- As both NDT methods assess different traits of concrete, it'll help retrofit the element as per the lacks and requirements.
- We can identify the better suited testing method with respect to our project goal of efficient retrofitting.

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