

# A Conceptual Study On Structural Audit Practices For Bungalows Using NDT Methods

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**Abstract-** This study presents a conceptual analysis of structural audit practices for bungalows using Non-Destructive Testing (NDT) methods. Structural Health Monitoring (SHM) plays a crucial role in assessing the integrity of buildings by detecting potential damage such as material degradation, cracks, and other structural anomalies. In residential structures, especially bungalows, the application of NDT methods like Ultrasonic Pulse Velocity (UPV), rebound hammer testing, and core concrete sampling provides valuable insights into the condition of concrete without causing damage. These techniques ensure effective, cost-efficient maintenance of buildings while extending their lifespan. The research highlights the growing adoption of NDT methods in residential building maintenance, particularly in regions like Pune, India, where many bungalows are decades old. By combining different NDT techniques, engineers can create a detailed evaluation of a structure's condition, guiding repair and reinforcement decisions. As these methods evolve, there is a shift toward predictive maintenance, with machine learning and AI integration offering the potential for more accurate assessments and earlier detection of degradation. This study also discusses the potential for sustainable practices, such as reusing concrete materials, supported by the data gathered from NDT methods. The findings suggest that NDT can significantly improve the management and longevity of bungalow structures while reducing environmental impacts associated with demolition and new construction.

**Keywords-** Structural Health Monitoring, Non-Destructive Testing, NDT Methods, Bungalows, Predictive Maintenance, Ultrasonic Pulse Velocity, Concrete Testing, Structural Audits, Remote Sensing, Data Analytics..

## I. INTRODUCTION

Structural Health Monitoring (SHM) has gained significant importance in the field of civil engineering, especially for assessing the condition of buildings and infrastructures[1]. SHM involves the continuous or periodic monitoring of structural components to detect potential issues such as degradation, crack formation, and material

deterioration. This process ensures the safety, longevity, and durability of structures, ultimately reducing the risk of catastrophic failures. In the context of bungalows, which are typically low-rise residential structures, SHM provides an effective means to assess the integrity of the building while maintaining minimal disturbance to the occupants. Non-destructive testing (NDT) methods play a pivotal role in SHM by providing valuable insights into the structural condition without causing damage to the building[2]. Common NDT methods include Ultrasonic Pulse Velocity (UPV), rebound hammer tests, and core concrete sampling[3]. These techniques, when applied correctly, offer valuable data regarding concrete strength, uniformity, and internal cracks, making them indispensable in structural audits. As of 2025, the global construction industry has increasingly adopted these methods, recognizing their potential to extend the life of residential buildings while optimizing maintenance costs.

### 1.1 NDT Methods and Their Role in Structural Audits

Non-Destructive Testing (NDT) methods have revolutionized the way structural audits are conducted, especially in residential buildings such as bungalows[4]. NDT techniques allow engineers to evaluate the condition of materials and components in a non-invasive manner, ensuring minimal disruption to the building. Among the most widely used NDT methods, Ultrasonic Pulse Velocity (UPV) testing measures the speed of ultrasonic pulses passing through concrete to determine its strength and detect voids, cracks, and other irregularities[5]. The rebound hammer test, on the other hand, provides a quick and easy way to assess the surface hardness of concrete, which can be correlated to compressive strength. Core concrete testing, though slightly invasive, allows for the extraction of concrete samples to assess the in-depth condition of structural components. By combining these techniques, engineers can create a comprehensive profile of the building's condition. A structural audit incorporating these methods enables building owners and engineers to make informed decisions regarding necessary repairs or reinforcements[6]. The growing awareness of these benefits has made NDT a standard practice in residential building maintenance, particularly in regions like Pune, India, where

older bungalow structures are common[7]. Looking ahead, the future of structural audits in bungalows using NDT methods holds immense promise. While traditional methods primarily focus on detecting current damage, emerging trends in SHM are shifting towards proactive, predictive maintenance. The integration of advanced data analytics and machine learning with NDT could offer deeper insights into the behavior of materials over time, leading to more precise predictions regarding the remaining lifespan of structural components[8]. Additionally, advancements in remote sensing and drone technology could make it easier to conduct structural audits in hard-to-reach areas, enhancing the overall efficiency and accuracy of the audit process. For bungalows in particular, the widespread use of NDT can lead to more sustainable building practices, as it allows for timely interventions without costly demolition or extensive repairs[9]. As more data is gathered and analyzed from residential buildings, it is likely that a more standardized approach to structural health monitoring will emerge, making it easier for engineers to assess buildings at various stages of life. In 2025, it is anticipated that a holistic, data-driven approach will not only improve the accuracy of structural audits but also streamline decision-making processes for repairs and maintenance[10].

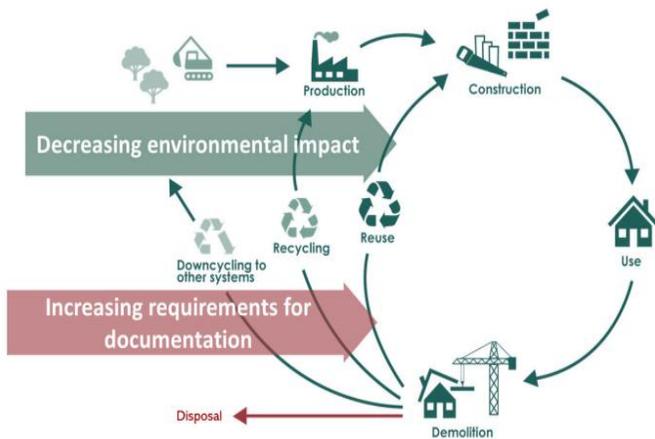
## II. RELATED WORK

### 2.1 Structural Audit and Non-Destructive Testing (NDT) Techniques in Civil Engineering

Patryk Kot et al. (2021) This study reviews recent advancements in NDT techniques for Structural Health Monitoring (SHM), including radar, infrared, fiber optics, and acoustic methods[11]. It emphasizes challenges like data interpretation and promotes AI integration and technique hybridization to improve accuracy and automation in civil infrastructure assessment. P. B. Mohite et al. (2025) The paper presents a comprehensive review of structural audit and retrofitting techniques for aging infrastructure[12]. It discusses various audit methods, retrofitting solutions, challenges, and future directions, focusing on enhancing structural safety and sustainability through literature, case studies, and technological innovations. Lakshadeep Bhagwanrao Gade et al. (2022) The authors highlight the importance of structural audits for aging buildings (30+ years) to prevent collapse[13]. They stress NDT-based assessments and recommend retrofitting methods such as beam and column strengthening and slab jacketing, following standard norms and code provisions to extend building lifespan. Lisbeth M. Ottosen et al. (2024) This paper explores the reuse of structural concrete components using NDT methods to document mechanical properties, heterogeneity, and reinforcement corrosion[14]. It identifies a lack of structured documentation and suggests

combining NDT with AI to enable safe reuse of components in the circular economy. Yasser El Masri et al. (2020) The study reviews six NDT techniques for thermodynamic diagnostics of building envelopes, including GPR, LiDAR, ultrasound, and photogrammetry[15]. It identifies gaps in accurate characterization and proposes hybrid workflows for building energy modeling and automation in large-scale envelope audits to enhance energy performance.

The concrete industry significantly relies on limited natural resources such as water, gravel, sand, and crushed rock. While natural aggregates are considered abundant on a global scale, certain regions are experiencing shortages due to excessive extraction for construction purposes (Ioannidou et al., 2017)[16]. Furthermore, the production of cement consumes raw materials equivalent to approximately 626 kg per capita—an amount even greater than average human food consumption (Scrivener, 2018)[17]. Cement manufacturing is also responsible for nearly 6% of global anthropogenic greenhouse gas (GHG) emissions (IEA WBCSD, 2009)[18]. These facts underscore the substantial environmental impact of concrete production and reinforce the urgency for adopting a circular economy (CE) framework. Transitioning to CE in the concrete sector can be approached through three primary strategies: (a) narrowing material loops by reducing resource input and minimizing waste; (b) slowing loops by extending the usage phase of materials; and (c) closing loops through the recycling and reuse of materials at the end of their lifecycle (Baldassarre et al., 2004)[19]. This study particularly emphasizes the third strategy—closing loops—by focusing on the reuse of structural concrete elements such as beams, columns, and load-bearing walls. These components can be selectively deconstructed from donor buildings and reused in new structures, effectively replacing newly cast concrete elements. Compared to conventional recycling of concrete into aggregates, this approach offers significantly greater potential for conserving embodied carbon (Eberhardt, 2019)[20]. Moreover, it presents a promising solution to the growing scarcity of natural construction materials. Reusability, in this context, refers to the extent to which a recovered structural element can perform similarly in its second life as it did in its original application. The central focus of this paper is on evaluating the in situ reusability of such structural concrete components.



**Figure 1:** Life Cycle Flow of Building Materials Highlighting Environmental Impact, Documentation Needs, and End-of-Life Options[21]

The EU requires a 70% recovery rate for construction waste, but most buildings lack deconstruction-friendly designs and reuse guidelines. This paper explores how Non-Destructive Testing (NDT) methods can efficiently assess concrete component reusability in donor buildings, supporting early planning and circular economy practices[22].

### III. NDT METHODS AND THEIR ROLE IN STRUCTURAL AUDITS

Non-Destructive Testing (NDT) methods are invaluable tools in structural audits, particularly for evaluating the integrity of concrete in residential buildings like bungalows[23]. These techniques allow engineers to assess the condition of a structure without causing damage, making them ideal for use in aging infrastructure. Below are three commonly used NDT methods for structural audits:

#### *Ultrasonic Pulse Velocity (UPV)*

Principle:

Ultrasonic Pulse Velocity (UPV) is an NDT method used to assess the quality and integrity of concrete. The method involves sending ultrasonic waves through the concrete material, which travel at varying speeds depending on the material's density and uniformity[24]. The time it takes for the ultrasonic pulse to travel through the concrete is measured and used to calculate the pulse velocity. This velocity is indicative of the concrete's overall quality, including its strength, homogeneity, and the presence of defects.

Application:

- **Concrete Strength Assessment:** UPV is used to estimate the compressive strength of concrete by evaluating how fast sound waves pass through the material[25]. The higher the pulse velocity, the denser and stronger the concrete is likely to be. This is especially useful for identifying weak zones in the structure that may be prone to cracking or failure.
- **Detection of Voids and Cracks:** UPV can detect voids, cracks, or other internal defects within the concrete. If there is a large void or crack, the ultrasonic pulse will travel slower, indicating areas where repairs may be needed[26].

Example in Bungalows:

In older bungalow structures in Pune, UPV is commonly used to assess the condition of concrete used in walls, beams, and foundations[27]. Since many of these bungalows were built decades ago, UPV helps engineers identify whether the concrete has deteriorated or suffered from issues such as settling or cracking. This technique is non-invasive and can be applied to structures without causing any damage, making it ideal for regular audits of residential properties.

#### *Rebound Hammer Test*

Principle:

The rebound hammer test, also known as the Schmidt Hammer test, is a non-destructive technique that measures the surface hardness of concrete. The hammer has a spring-loaded plunger that strikes the concrete surface and rebounds[28]. The extent of the rebound is measured and correlates with the compressive strength of the concrete. A harder surface will result in a higher rebound value, which typically indicates stronger concrete.

Application:

- **Surface Hardness Measurement:** The primary purpose of the rebound hammer test is to assess the surface hardness of concrete[29]. The rebound value can provide an indication of the material's compressive strength, which is essential for determining the overall structural integrity of a building.
- **Quick and Non-Invasive:** The test is fast, simple, and can be performed on-site with minimal disruption to the building's occupants[30]. It is particularly useful for large-scale structural assessments where rapid results are needed.

Example in Bungalows:

For bungalow audits in Pune, the rebound hammer is often used to assess the surface hardness of concrete in exposed areas like exterior walls and columns. Since bungalows are often exposed to environmental factors such as moisture and temperature changes, which can affect the concrete's strength over time, the rebound hammer helps provide a quick check on whether surface deterioration is occurring. This test is particularly useful in the early detection of concrete degradation, which is common in older structures.

### ***Core Concrete Sampling***

#### **Principle:**

Core concrete sampling involves extracting a small cylindrical sample of concrete from the structure, typically from critical or high-stress areas like beams, columns, or foundations. The sample is then tested in a laboratory to evaluate its compressive strength, homogeneity, and other mechanical properties. This method is slightly invasive but provides the most accurate assessment of concrete's structural integrity. The extracted core sample is subjected to standardized laboratory tests to determine the material's exact properties.

#### **Application:**

- **In-Depth Structural Integrity Assessment:** Core sampling provides the most detailed data about the concrete's composition, strength, and durability. It is especially useful when other NDT methods, such as UPV or rebound hammer tests, indicate potential issues, but further investigation is required to confirm the extent of the damage[31].
- **Testing for Structural Reuse:** When assessing the possibility of reusing structural concrete elements (e.g., in the context of sustainable construction or a circular economy), core sampling is critical. It can confirm whether the material still meets the required safety standards.

#### **Example in Bungalows:**

In the context of bungalow audits, core concrete sampling is usually employed when non-invasive methods like UPV or rebound hammer tests suggest the presence of deeper cracks, voids, or deterioration. In older bungalows in Pune, core sampling is often done in key structural areas such as the foundation and load-bearing walls to evaluate the concrete's strength and assess the need for retrofitting[32]. Since the process involves removing a sample from the structure, it is typically performed in areas where there is a concern about safety or material integrity.

### **Application of NDT Methods in Bungalow Audits in Pune, India**

Pune, India, has a significant number of bungalows built in the mid-20th century that are now experiencing the effects of age, weathering, and material degradation. As these bungalows are often inhabited, performing traditional destructive testing is not feasible. NDT methods offer an ideal solution by providing accurate insights into the structural condition of these buildings without causing further damage[33]. For example, in an audit of a bungalow built in the 1970s in Pune, UPV may reveal weak concrete areas in the foundation, which would prompt further examination through core sampling. Rebound hammer testing could be used on the exterior walls to check for surface deterioration, and the results might show that repairs are needed in high-moisture areas. These combined NDT methods ensure that engineers can develop a comprehensive maintenance plan that addresses both surface and internal issues, helping to preserve the structural integrity of the bungalow while minimizing the disruption to the occupants[34]. By utilizing these three NDT methods UPV, rebound hammer testing, and core concrete sampling structural audits of bungalows can provide a thorough evaluation of the building's condition, detect potential defects early, and guide informed decisions on repairs and maintenance, ensuring the longevity and safety of the structure[35].

## **IV. METHODOLOGY**

### ***Conceptual Approach to NDT in Documentation***

NDT methods, such as UPV, rebound hammer testing, and core concrete sampling, enable non-invasive assessment of concrete properties. This study hypothesizes that NDT can document concrete quality for reuse in construction, helping minimize waste and promote sustainable practices by assessing strength, homogeneity, and suitability for future use without compromising the material's integrity.

### ***Literature Search Methodology***

A structured literature search identified relevant NDT techniques by searching key databases like Google Scholar, Scopus, and ScienceDirect. Studies published from 2010-2025 focusing on NDT for concrete assessment and reuse were reviewed. Keywords included "Non-Destructive Testing," "Concrete Reuse," and "Structural Health Monitoring." Articles were evaluated for practical application and relevance to bungalow audits and sustainable construction.

### ***Combining NDT Methods***

Combining multiple NDT techniques, such as UPV, rebound hammer testing, and core sampling, provides a comprehensive analysis of concrete. UPV and rebound hammer tests offer quick, non-invasive insights, while core sampling gives in-depth data. This combination enhances reliability, cross-verifies results, and offers both surface-level and internal assessments, ensuring accurate evaluations of structural integrity.

### ***Methodological Framework for Assessing Concrete Strength, Detecting Defects, and Ensuring Structural Integrity***

The methodology involves using UPV and rebound hammer tests for initial assessment, followed by targeted core sampling in critical areas. The combined results offer a comprehensive analysis of concrete strength and defects. Data is analyzed for consistency, and recommendations for repairs or retrofitting are provided, ensuring structural integrity while documenting concrete properties for potential reuse in construction.

## **V. FUTURE DIRECTIONS AND RECOMMENDATIONS**

AI and machine learning can integrate with NDT methods to enhance predictive maintenance by analyzing large datasets. AI algorithms, such as neural networks, can identify patterns in concrete degradation and predict future failures, enabling engineers to determine the remaining lifespan of structural components. By incorporating real-time data, these technologies offer more accurate maintenance schedules, optimizing repairs and preventing premature failures. This data-driven approach helps reduce costs and extend the life of building elements by proactively addressing issues before they escalate. Drones equipped with high-resolution cameras, LiDAR, and thermal sensors can enhance structural audits by capturing data from hard-to-reach areas, such as rooftops and facades. These technologies allow for quick, safe, and detailed inspections, providing insights into potential structural issues like cracks, moisture ingress, or thermal bridging. When integrated with NDT methods, drones can efficiently assess the condition of large buildings, enabling accurate diagnostics, minimizing inspection time, and improving the overall quality of structural audits while reducing manual labor and safety risks.

A standardized approach to structural health monitoring (SHM) will unify best practices in NDT, ensuring consistent and reliable assessments. Data-driven frameworks

will improve decision-making by using uniform methods for analyzing NDT results, making the audit process more transparent and systematic. This approach will optimize repair and maintenance scheduling by providing clear criteria for intervention. Standardization also allows for better data sharing and benchmarking, ensuring that similar structures are assessed under the same guidelines, leading to more accurate and efficient audits. NDT plays a vital role in promoting sustainability by enabling the reuse of concrete materials. By assessing the quality of existing concrete through non-invasive methods, engineers can determine its suitability for reuse, reducing the demand for new raw materials and minimizing waste. In addition, NDT can identify areas of a structure that can be retrofitted instead of demolished, supporting eco-friendly retrofitting practices. This contributes to the circular economy by extending the life cycle of building materials and reducing environmental impacts associated with new construction.

## **VI. CONCLUSION**

The study underscores the critical role of Non-Destructive Testing (NDT) in the structural auditing of bungalows, emphasizing its ability to assess concrete integrity without damaging the structure. Techniques like Ultrasonic Pulse Velocity (UPV), rebound hammer tests, and core concrete sampling provide complementary insights into the health of the building. The integration of these methods enables engineers to identify weak points, cracks, and other structural issues in a non-invasive and efficient manner, ensuring minimal disruption to the building and its occupants. The findings suggest that NDT methods are becoming indispensable in maintaining aging residential structures, especially in places with a high prevalence of bungalows-built decades ago. As the construction industry moves towards more sustainable practices, NDT also contributes to circular economy strategies by assessing the potential for reusing concrete materials. Looking ahead, the integration of AI and machine learning with NDT methods promises to enhance the predictive capabilities of structural audits, allowing for more proactive maintenance. These advances will likely lead to more precise maintenance schedules and cost savings for homeowners. In conclusion, NDT methods are essential for optimizing the safety, durability, and environmental sustainability of residential buildings, paving the way for smarter and more cost-effective approaches to structural health monitoring.

## **VII. FUTURE SCOPE**

The future scope of structural audits using NDT methods lies in the integration of advanced technologies such

as AI, machine learning, and remote sensing. AI can help predict future structural issues by analyzing large datasets, improving the accuracy and efficiency of maintenance schedules. Drones and high-resolution imaging can facilitate inspections in hard-to-reach areas, making audits faster and safer. Additionally, NDT methods can be standardized globally, ensuring consistent quality in structural health assessments. These developments will enhance the reliability, cost-effectiveness, and sustainability of building maintenance practices, especially for aging residential structures like bungalows.

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