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Analysis of non-destructive testing methods for assessing structural integrity in distressed building (Cases Study of Lagos Island, Lagos State, Nigeria)

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Abstract

The collapse of structures in urban areas is a growing concern that demands effective and reliable methods for assessing structural integrity. The urban landscape of Lagos Island, boasts a diverse array of buildings, but many face structural distress due to factors like age, environmental conditions, poor construction practices, posing risks to occupants and the community. This research assessed the effectiveness of various Non-Destructive Testing (NDT) techniques using Schmidt/Rebound Hammer test and Ultrasonic Pulse Velocity Testing to evaluate the structural integrity of Ten (10) distressed buildings on Lagos Island, taking into account local environmental conditions and construction practices. The outcome of this research shows that the Rebound Hammer and Pulse Velocity tests provides a comprehensive understanding of the material's properties and quality. Likewise, the comparative analysis of the Rebound Hammer and Pulse Velocity tests shows that both methods offer valuable insights into the quality and integrity of concrete structures with the Pulse Velocity test showing a slightly higher consistency in results. The Rebound Hammer method readings were averagely higher by $5N/m^2$ to Pulse Velocity test readings. Therefore, Pulse Velocity test is more consistence, detects internal structural defects like cracks, voids and honeycombs homogeneity than Rebound Hammer method.

Keywords: Rebound Hammer; Pulse Velocity tests; Non-Destructive Testing (NDT); Structural defects

1. Introduction

In recent years, Lagos Island in Lagos State, Nigeria has been experiencing an increase in the number of distressed buildings, many of which have collapsed, causing loss of lives and properties. Alexander, A. and Rufus, A (2012) did research on part of Abuja that had building collapse and this menace was also experienced in the collapse of the Synagogue Church of All Nations (SCOAN) building in Lagos, 2014 and more than 100 people was killed. Other notable cases include the collapse of a 21-storey building in Ikoyi in 2021 which claimed several lives of workers including the developer Mr. Femi Osibona, and a 3-storey building in Ita-Faji in 2019. These incidents have raised concerns about the safety of buildings in Lagos Island and the need for more stringent regulations and enforcement to address this issue. Therefore, it is important to understand the structural integrity of these buildings Helal, J.Sofi, M. and Mendis, P. (2015). and the effectiveness of Non-Destructive Testing (NDT) methods in assessing their condition Aydin, F. and Saribiyik, m. (2010). The previous study of the relationship between NDT and concrete strength play a vital role to understand resulting defects of structures Ghrici, M. (2017).

This lack of standardization can lead to inconsistent results and ineffective interventions. In addition, there is lack of data on the extent of building distress in Lagos Island, making it difficult to develop effective strategies for addressing the issue. Therefore, this study explore the use of NDT methods such as visual inspection, ultrasonic testing, infrared

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thermography, and ground penetrating radar to assess the structural integrity of distressed buildings C. and Hall (1991)., and Chendo, I. and Obi,I. G, (2015)., described causes and effects of collapsed building and the remedies.

Source LABSCA 2023

Figure 1 Site of Building Collapse at Banana Island

Source Google.com

Figure 2 Site of 21 Building Collapse in Ikoyi Lagos State

Breysse et al.,(2008). Researched on the structural health monitoring of an existing building through the use of non-destructive evaluation techniques while Jerzy Z., and Zemajtis, (2008)., underscores the importance of monitoring and maintaining the structural integrity of buildings to achieve increased service life . The comparison of the Pulse Velocity tests and Impact-Echo test on slab integrity to ascertain stability by Ufuk et al., (2007).

2. Methods

The present study describes a comprehensive experimental investigation carried out on the analysis of NDT methods for assessing the structural integrity of a distressed building. The testing exercise was conducted with the technical assistance of the Lagos State Material Testing Laboratory (LSMTL) using a rebound hammer and ultrasonic pulse velocity techniques. The buildings under investigation manifested visible signs of distress, and the obtained results and observations from the field-testing exercise are presented in this report. Likewise, the results were given qualitative interpretations according to EN 12504-2:2004 as seen in the tables below:

Table 1 Qualitative Interpretation of Rebound hammer test

Average Rebound number	Quality of Score
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor concrete
0	Delaminated

Table 2 Qualitative Interpretation of Ultrasonic Pulse Velocity test

UPV value in m/sec (V)	Concrete quality
V > 4000.0	Excellent
V = 3500 – 4000	Good to very good, Slightly porosity nay exist
V = 3000 – 3500	Satisfactory but loss of integrity is suspected
V = 2500 – 3000	Poor and loss of integrity exist
V = 2000 – 2500	Very poor and low integrity
V < 2000 and reading fluctuating	No integrity, large voids suspected

2.1. Research Location

The Lagos Island (Figure 3), situated in the Lagos State of Nigeria, presents a diverse and dynamic portrayal of the bustling urban region. It holds the distinction of being one of the city's oldest precincts, and its populace is marked by a confluence of various ethnicities, cultures, and socioeconomic strata.

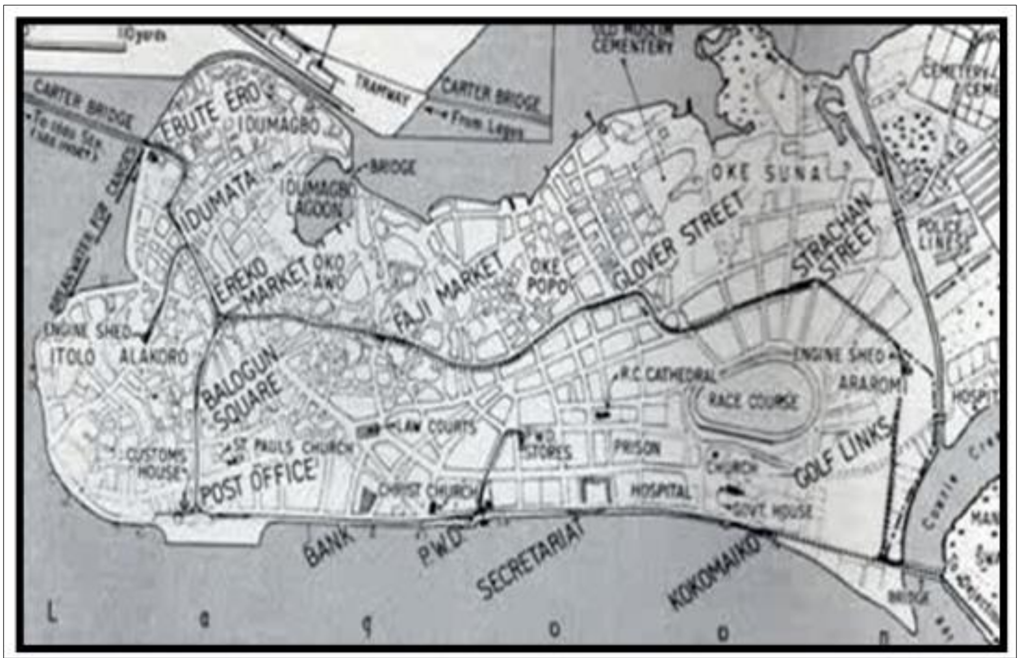

Figure 3 Map of Lagos Island

2.2. NDT Assessment

The research was limited to examination of Ten (10) several structures within Lagos Island buildings who has requested for the service of Lagos State Material Testing Laboratory (LSMTL) to ascertain the integrity of their buildings which are in deterioration stages to predict their lifespans and make decisions about their maintenance and repairs. The methodology adopted is as follows:

Identifying the buildings/structures that are in deterioration stages by locating the correct address as indicated in their invitation letter and payment receipts.

- Identifying different NDT methods to be conducted on the structure or building.
- Determination of the potential factors contributing to the structural degradation.
- Evaluating the extent of the damage incurred and ascertaining its fitness for future utilisation.
- Non-Destructive Testing methods used in this study were Schmidit/Rebound hammer test and UPV testing.

3. Results and Discussion

During the visual inspection of the distressed buildings, several observations were made, some interior and exterior walls of 85% buildings tested showed multiple cracks and fissures, some of which appeared to be quite deep. The cracks were observed to be more severe at the corners and edges of 85% of buildings tested. Ninety percentage (90%) of buildings tested also displayed signs of water damage, with discoloration and staining visible on several of the walls. In some areas, the painting finish of the exterior walls had begun to peel away, revealing the underlying block work. Furthermore, several windows were found to be broken or missing, and the roof showed signs of wear and tear, with several shingles missing or damaged. These observations indicate that 85% of buildings are in a state of disrepair, and further investigation is necessary to assess its structural integrity which result in the use if rebound hammer and ultrasonic pulse velocity.

(Source Field)

Figure 4 Distressed Building with Concrete Spalling off from Slab and Beam

Figure 5 Building Showing Different Cracks Pattern (Source Field)

Based on the outcome of the visual and Non-Destructive test carried out on the building using UPV and Rebound Hammer techniques which shows its present condition and the summary of the Average Pulse Velocity (APV) and Average Rebound Hammer (ARH) results (Figures 6 to 15) revealed the structural status of the buildings assessed.

The summary of results of Building 1 is as presented in Figure 6. Rebound hammer test revealed that 92% of ground floor columns tested has strength above $25N/mm^2$ and such were rated good. Likewise, 87% on the first floor columns are remarked good as they have strength above $25N/mm^2$. The UPV test revealed that 86% of ground floor columns and 81% of first floor columns tested have strength above $25N/mm^2$ and such were rated good.

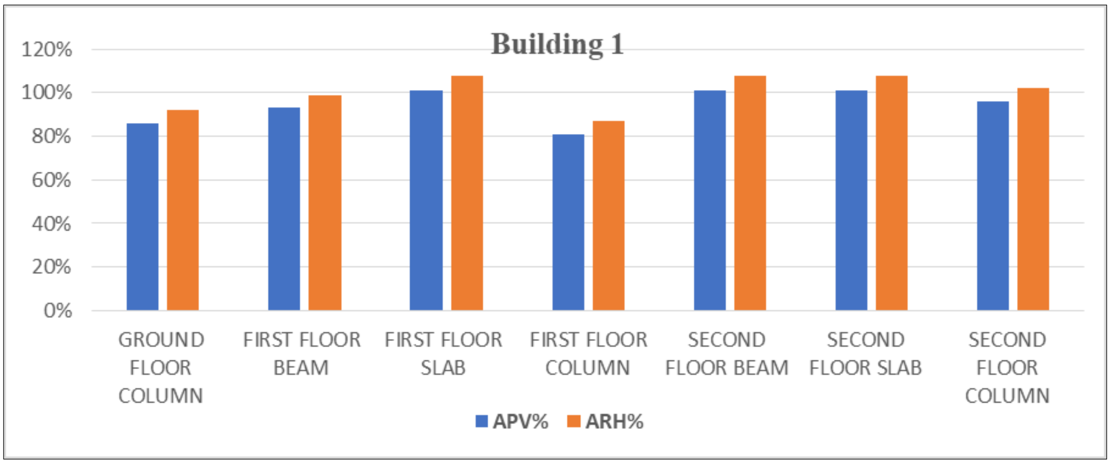

Figure 6 APV and ARH of Building 1

Results obtained from Building 2 revealed that 92% of ground floor columns tested using Rebound hammer test (Figure 7) has strength above $25N/mm^2$ and such were rated good. Likewise, 97% on the first floor columns are remarked good as they have strength above $25N/mm^2$. UPV test revealed that 89% of ground floor columns and 93% of first floor columns tested have strength above $25N/mm^2$ and such were rated good.

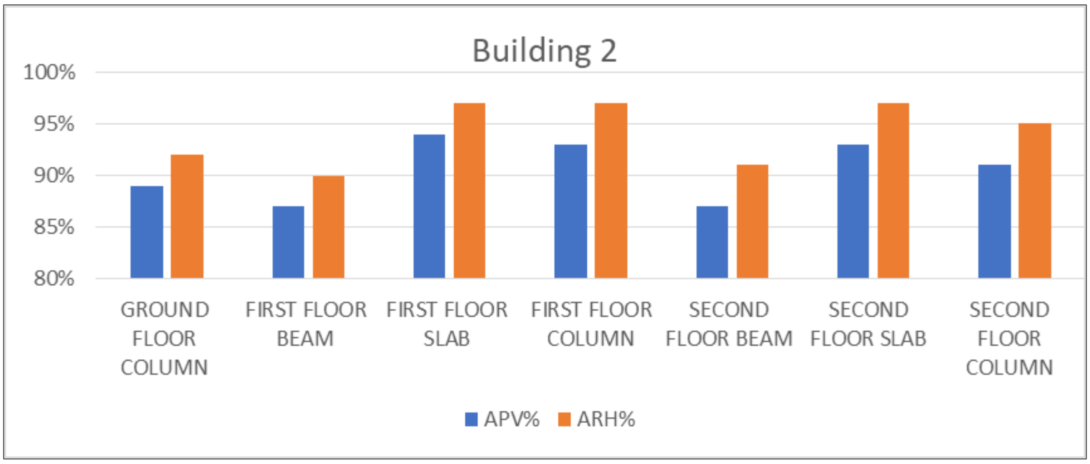

Figure 7 APV and ARV of Building 2

Figure 8 shows the summary of all test results. Rebound hammer test revealed that 94% of ground floor columns tested has strength above $25N/mm^2$ and such were rated good. Likewise, 98% on the first floor columns are remarked good as they have strength above $25N/mm^2$. UPV indicated that 91% of ground floor columns and 94% of first floor columns tested have strength above $25N/mm^2$ and such were rated good.

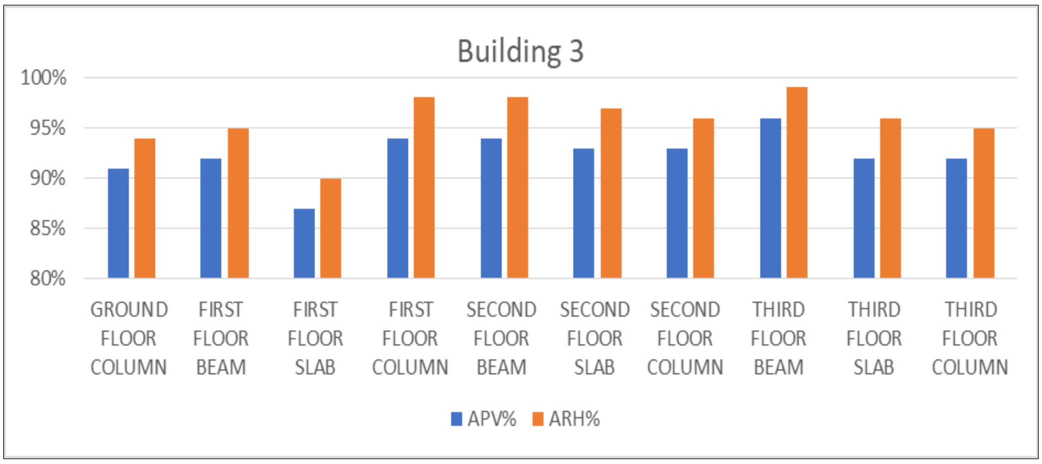

Figure 8 Summary of tests for building 3

Figure 9 shows the summary of all test results. Rebound hammer test revealed that 68% of ground floor columns tested has strength above 25N/mm^2 and such were rated good. Likewise, 34% on the first floor columns are remarked delaminated as they have strength below 25N/mm^2. UPV test revealed that 65% of ground floor columns and 33% of first floor columns tested have strength above 25N/mm^2 and such were rated poor.

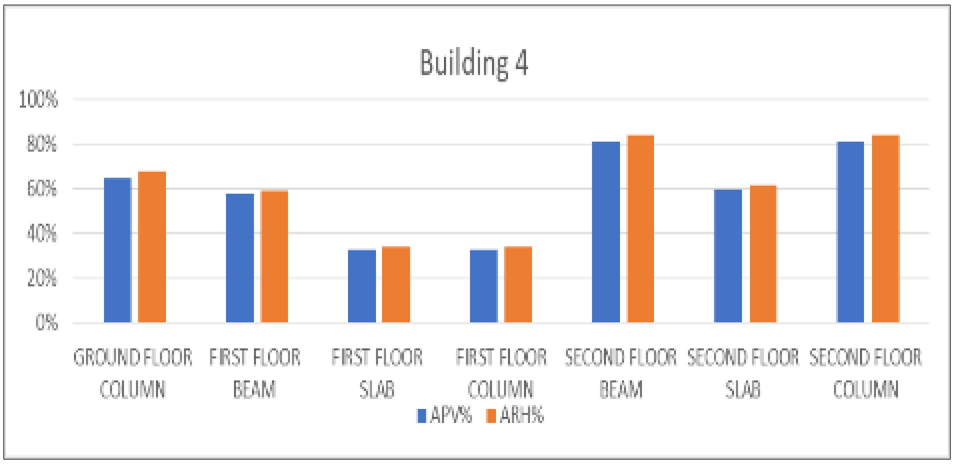

Figure 9 Summary of tests for building 4

Figure 10 shows the summary of all test results. Rebound hammer test revealed that 84% of ground floor columns tested has strength above 25N/mm^2 and such were rated good. Likewise, 66% on the first floor columns are remarked fair. Ultrasonic Pulse Velocity test revealed that 80% of ground floor columns and such was rated satisfactory and 64% of first floor columns tested have strength above 25N/mm^2 and such were rated poor.

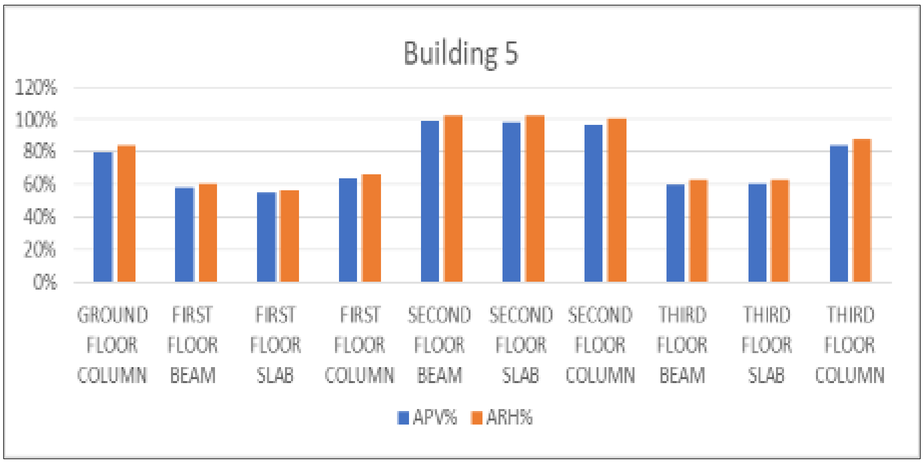

Figure 10 Summary of tests for building 5

Figure 11 shows the summary of all test results. Rebound hammer test revealed that 89% of ground floor columns tested has strength above 25N/mm² and such were rated very good. Likewise, 97% on the first floor columns are remarked very good as they have strength above 25N/mm². Ultrasonic Pulse Velocity test revealed that 89% of ground floor columns and 95% of first floor columns tested have strength above 25N/mm² and such were rated very good.

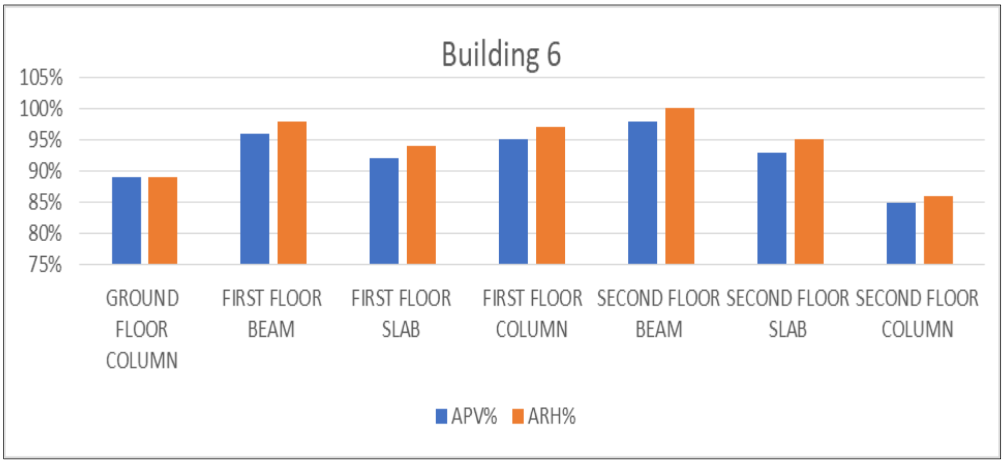

Figure 11 Summary of tests for building 6

Figure 12 shows the summary of all test results. Rebound hammer test revealed that 94% of ground floor columns tested has strength above 25N/mm² and such were rated very good. Likewise, 98% on the first floor columns are remarked very good as they have strength above 25N/mm². Ultrasonic Pulse Velocity test revealed that 91% of ground floor columns and 94% of first floor columns tested have strength above 25N/mm² and such were rated very good.

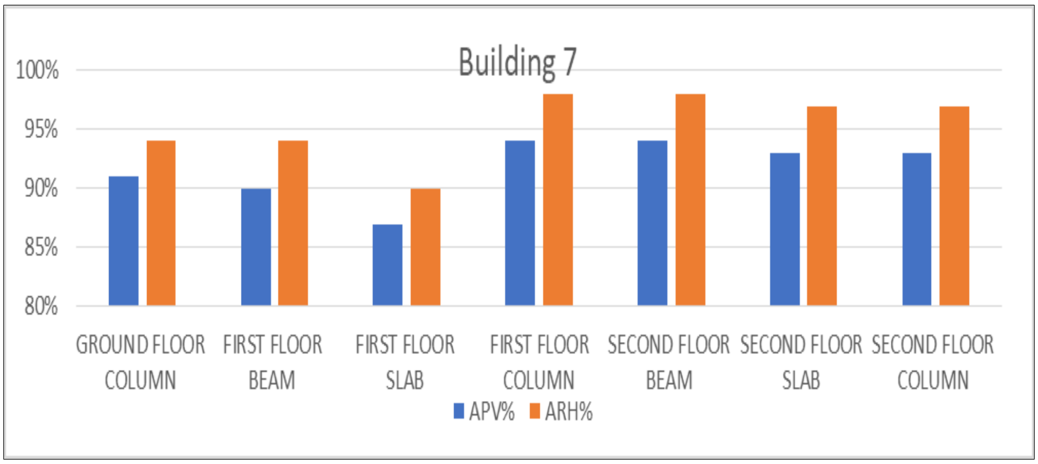

Figure 12 Summary of tests for building 7

Figure 13 shows the summary of all test results. Rebound hammer test revealed that 110% of ground floor columns tested has strength above 25N/mm^2 and such were rated very good. Likewise, 118% on the first floor columns are remarked very good as they have strength above 25N/mm^2. Ultrasonic Pulse Velocity test revealed that 95% of ground floor columns tested have strength above 25N/mm^2 and such were rated very good while 102% of first floor columns tested have strength above 25N/mm^2 and such were rated excellent.

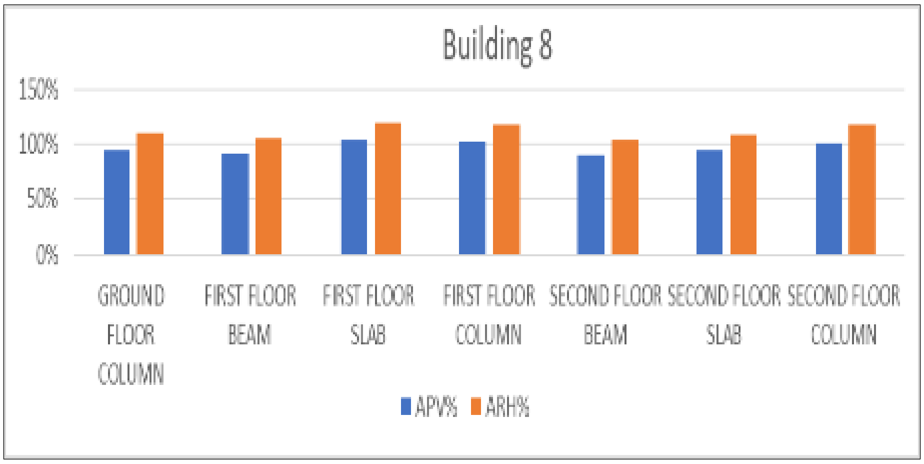

Figure 13 Summary of tests for building 8

Figure 14 shows the summary of all test results. Rebound hammer test revealed that 113% of ground floor columns tested has strength above 25N/mm^2 and such were rated very good. Likewise, 101% on the first floor columns are remarked very good as they have strength above 25N/mm^2.

Ultrasonic Pulse Velocity test revealed that 95% of ground floor columns tested have strength above 25N/mm^2 and such were rated very good while 95% of first floor columns tested have strength above 25N/mm^2 and such were rated very good.

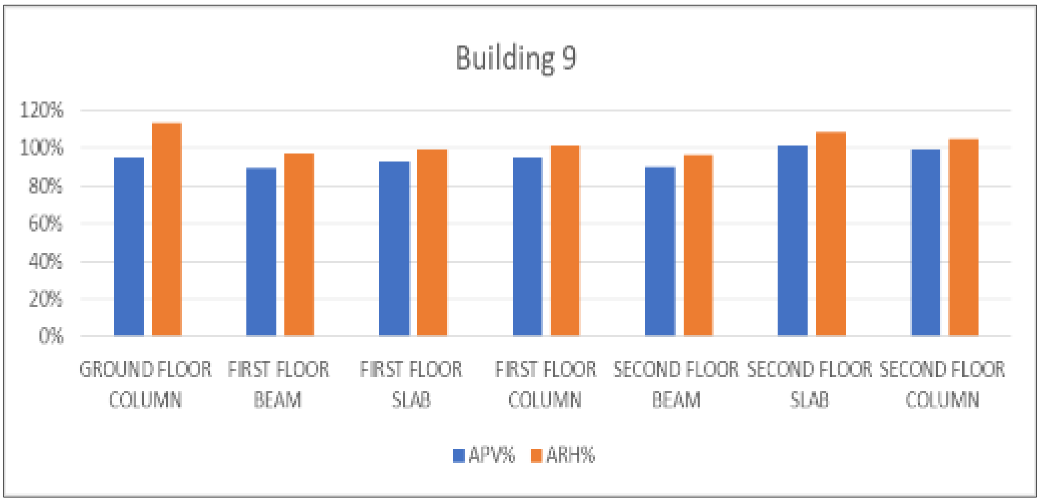

Figure 14 Summary of tests for building 9

Figure 15 shows the summary of all test results. Rebound hammer test revealed that 78% of ground floor columns tested has strength above 25N/mm^2 and such were rated fair. Likewise, 84% on the first floor columns are remarked good as they have strength above 25N/mm^2.

Ultrasonic Pulse Velocity test revealed that 73% of ground floor columns tested has strength above 25N/mm^2 and such were rated poor while 79% of first floor columns tested has strength above 25N/mm^2 and such were rated satisfactory.

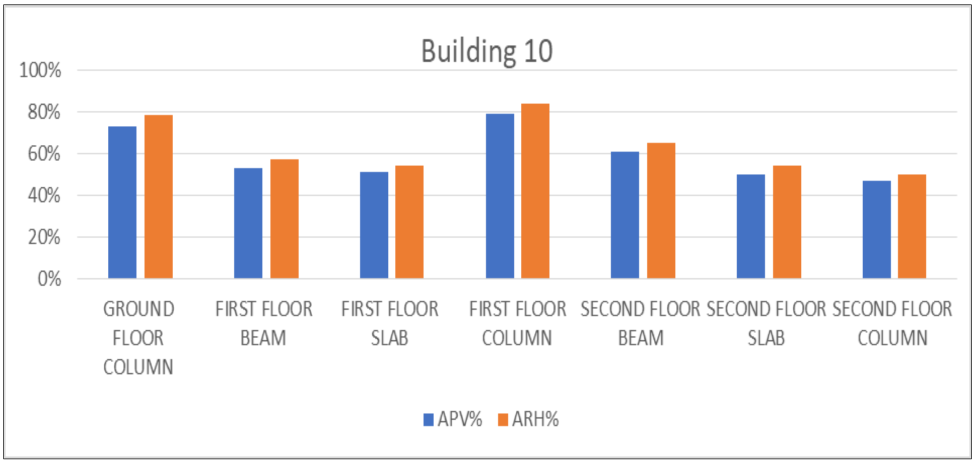

Figure 15 Summary of tests for building 10

Structural members rated poor from the test analysis should be adequately strengthened using safe and suitable strengthening method. Thus, the test results revealed that the structure is still stable and fit for habitation. The comparative analysis of the Rebound Hammer and Pulse Velocity tests shows that both methods offer valuable insights into the quality and integrity of concrete structures. However, the Pulse Velocity test demonstrates a slightly higher consistency in results, as indicated by its lower standard deviation and variance. This suggests that the Pulse Velocity method might be more reliable for assessing the uniformity and overall quality of concrete, though it is important to consider the context and specific requirements of each assessment

4. Conclusion

The statistical analysis of the Rebound Hammer and Pulse Velocity tests conducted on concrete samples provides a comprehensive understanding of the material's properties and quality. While both methods have their merits, the Pulse Velocity test appears to offer a more consistent measure of concrete integrity. These findings underscore the importance of employing multiple assessment techniques in civil engineering to ensure the accuracy and reliability of structural evaluations. This research serves as a guide in providing a comprehensive assessment of NDT methods for assessing the structural integrity of distressed buildings, including practical recommendations for their use in the field, thus, contributed to the field of civil engineering and urban development by promoting cost-effective and non-destructive assessment methods that can extend the service life of aging infrastructure. Hence, the use of these non-destructive testing methods in routine structural assessments to identify potential defects and ensure safety of concrete structures and prevent collapse so as to prevent the future loss of lives and properties.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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