

Structural Integrity Assessment of Office Building Development in FCT-Abuja, Using Non-Destructive Testing Method

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Abstract: This paper present structural integrity assessment of the remodelled office building for the National Directorate of Employment (NDE), Abuja. Structural and the architectural drawings were reviewed. Visual inspections, soil investigation, and in-situ concrete testing were carried out. However, to identify structural flaws and the type of reinforcement bar used; structural elements were measured, photographed were taken, Ground Penetrating Radar (GPR) was used to assessed the reinforcement in all the structural elements (columns, beams and slabs). A total station survey of the structure utilizing structural Non- Destructive Test Unmanned Aerial Vehicle (NDTUAV) was used to create the as-built plan for the building. The elevations inside the construction area were surveyed to determine the slope's orientation in order to assess the effects of wetting on the building foundation. There was no indication of structural fatigue on the structural components at the time of the visit. The structural members' in-situ compressive strength tests were satisfactory. The geotechnical investigation yielded the permissible soil carrying capacity between the range of 96.63 kN/m² to 278.76 kN/m². The structural members were constructed based on accepted engineering principles and the structural components were found to comply with the design specification. As a result, the structure is safe, reliable, and passed the structural integrity assessment.

Keywords: Concrete Strength, Rebound Hammer Value, Integrity Test, Soil Bearing Capacity

1. Introduction

Structural assessment of an existing building structure made up of reinforced concrete that host a large number of people and other equipment with a view to evaluating its performance is very crucial [1]. Consequences of collapse building structure cannot be underestimated as a bungalow that collapses on the tenant of the building cannot be regarded as a small loss. Neither will a multi-storey building that collapse with no human casualty be regarded as no loss as both involve loss of properties and human casualty. It has been observed that a number of structures are built with foundations that are not appropriate for the soil conditions.

Although, due to inadequate land space, some structures are built on land that have no good bearing capacity to support the structure. The consequence of the above is that, when the soil conditions change, the soil may no longer bear the full weight of the foundation, [2], which may lead to structural collapse. It was reported by Ayedun, et'al [3] that, owners and stakeholders in failed structure often die of high blood pressure or other related diseases associate with high blood pressure.

Nigeria does not have a history or record of natural disasters like earthquake in the past as compared to other countries of the world except in 2016 where an earth tremor was reported in some part of norther Nigeria. Despite the absence of earthquake, the collapse of building structures in

the last ten (10) years especially in Nigeria has called for active methods for evaluating the structural integrity of reinforced concrete buildings. Ironically, the country has had its share of man-made disasters as it was reported that most of the causes of building collapse in Nigeria are attributed to structural defect, poor design, abuse of building codes, use of substandard construction materials, poor workmanship and corruption, among others [4-6]. Ede [7] and Olagunju [8] reported that, poor maintenance culture of our building structures contributes to the crisis of building collapse in Nigeria which was supported by Fagbenle and Oluwunmi [9], Babalola [10] and Etim [11]. It was also reported that lack of assessing the structural integrity of a reinforced concrete building led to four collapses that included residential buildings in 2006 in Ebute Metta, Lagos, Lagos state where 37 lives were lost [12]. It was reported by Adegoroye [13] that in 2006, the Nigerian Industrial Development Bank building collapsed, and that collapsed claimed two (2) human lives and twenty-three (23) sustain various degrees of injuring [12]. In 2007, Oloyede, Akinjare, & Omoogun [12] reported that two-storey building collapsed along Okegbogbo Street in which one live was lost and fifteen other people sustained serious degrees of injuries.

It is worthy to note that structural integrity assessment of reinforced concrete structure is anticipated to detect the problem in the building structure before its failure and recommendation will be given to prevent unnecessary collapse.

There are two basic methods of assessing the structural integrity of any structural element. The methods are; Destructive Test Method and Non-Destructive Test (NDT) method. The Destructive Test Methods used in assessing the quality of concrete have several disadvantages such as; cost in implementation of the test, delay in carried the exercise,

strength properties of a concrete specimen depend on its size and shape, just to mention but few. In order to overcome the disadvantages state above, NDT was developed [14, 15], for use, as it imparts little or no damage to concrete, although it usually requires sampling or removing a small amount on the building structures.

Most accidents of building collapse in Nigeria could have been averted or minimized if quality control measures were taken through NDT during the construction of new buildings as well as structural checkups for existing ones. Thus, this research evaluated the structural integrity of an existing office building for the National Directorate of Employment (NDE), Abuja that has been subjected to various conditions including high temperature, wind, rain and cold weather over the years using NDT Method (Rebound Hammer and Ultrasonic Pulse Velocity Test) to ascertain the safe use of the structure.

1.1. Aim of the Investigation

Amsalco Suites Limited of Adetokumbo Ademola Wuse II, Abuja requested for structural integrity assessment to determine the status of its proposed building, with a view to ascertain the reliability of the entire structural elements for the purpose of remodeling the structure.

1.2. Site Location

The building is located at plot 1076, cadastral zone, Sestor B18, Gudu District, Abuja with coordinate N09.00088, E07.47525 at an elevation of 477m above sea level as shown in the Google map (see Figure 1a), while Figure 1b shows the back view of the NDE building.

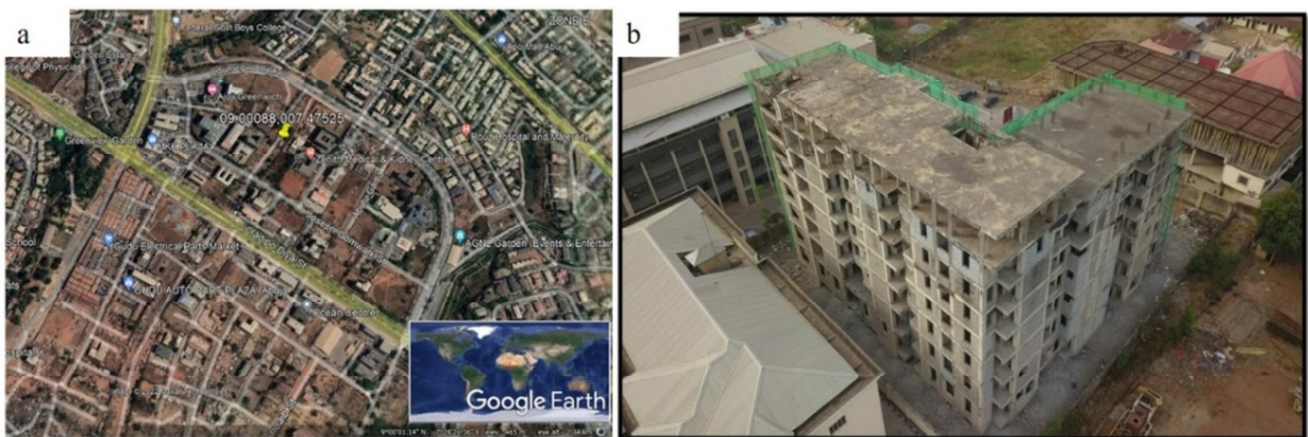


Figure 1. (a) Earth map showing location of NDE buildings (Source Google Earth) (b) The back view of the NDE building.

2. Methodology

A number of tests including site visit were carried out in order to analyzed the structural integrity of the targeted structure which is the National Directorate of Employment (NDE) building.

2.1. Site Visit

On March 24, 2022, the team visited the construction site. A thorough physical inspection of the building was carried out. The subsequent actions were taken to fully assess the issue and create a final test protocol. Visual evaluation was done to look for structural flaws such as

structural distress and deformation, and material deterioration. The potential impact of non-structural elements on building services was also evaluated. In general, the relevant documents were reviewed, the entire structure was visually assessed, the strength of the structural components (such as the slabs, beams, columns, and foundations) were evaluated, and soil sample for testing was done.

2.1.1. The Land Use of the Area

The land is used for commercial purposes.

2.1.2. General Terrain

The area is relatively flat with no mining activities and an existing pond seen close to the building. There is also no existing gully, or stream close to the building.

2.1.3. Relevant Documents

At the time of the visit, soil and concrete cube test results were not available for scrutiny. However, structural drawings were assessed; the document shows that the structural elements such as slabs, beams, columns, and foundations were properly designed.

2.1.4. Visual Inspection of the Structure

The building was framed structure. In order to determine the types of structural defects; such as, structural distress and deformation, as well as material deterioration, a thorough visual inspection of the structure was conducted.

2.2. Compressive Strength Test

Some of the common methods that are employed in assessing the in-situ strength of concrete include Rebound Hammer Test (RHT), Ultrasonic Pulse Velocity Test (USPVT) and others. This research uses these two-method due to the fact that every method has its own limitation and hence using multiple methods will provide more reliable data for predicting the strength of a concrete [16].

2.2.1. Rebound Hammer Test

The Rebound Hammer Test was carried out with the view of assessing the in-situ strength of the structural members. In practice, the results from these tests are dependent upon the surface condition and moisture content of the concrete as well as the ratio of aggregate to cement paste. Prior to testing, a grinding stone was used to smooth the test surface, and then a rag is used to remove all dust from the tested area. Figure 2 (a) shows how the test was carried out. The test procedure based on ASTM C805/C05M [17] for Rebound Hammer was adhered to for accurate result.

2.2.2. Ultrasonic Pulse Velocity Test

Ultrasonic scanning is a recognized non-destructive evaluation to qualitatively assess the homogeneity and integrity of concrete. The test was based on the EN-12504-4 [18] specification. With this technique, the qualitative assessment of concrete strength and its gradation at different locations of the structural members can be assessed. Figure 2 (b) shows how the test was carried out.



Figure 2. (a) Testing one of the internal column using Rebound hammer (b) Testing the internal column using Ultrasonic Pulse Velocity.

2.2.3. Geotechnical Investigation

An underground investigation was conducted to evaluate the condition of the foundation soil. Three (3) trial pits were carefully excavated to collect soil samples for laboratory tests (See Figure 3). Disturbed soil samples were obtained using a special coring machine and transported to the Nigerian Building and Road Research Institute material testing laboratory in Abuja.

The following tests were carried out on the collected soil

sample:

1. Particle size analysis.
2. Atterberg Limit tests for the purpose of soil classification
3. Direct Shear Test
4. Laboratory Consolidation Test

All tests were carried out in accordance with relevant standards and relevant literature in the area of concrete structures and geotechnical engineering, namely [19, 20].

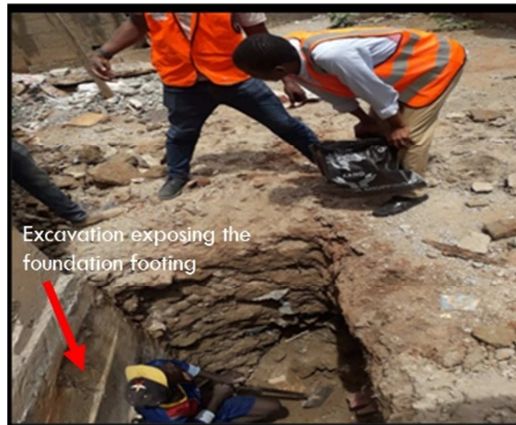


Figure 3. One of the Excavated pit for soil sample.

3. Results and Discussion

The oral interview, physical observations, soil laboratory test results, concrete strength test results, rebar sizes and depth using radar machine, and foundation analysis were all analyzed and discussed.

3.1. Oral Interview

The oral interviews conducted confirm that there were no mining activities as well as an existing pond close to the building. There was also no existing gully, or stream close to the buildings.

3.2. Physical Observation

The building is relatively in stable condition at the time of the visit. No cracks were seen on the walls, as well as structural elements of the building, except around the slanted wall section at the last floor of the building that showed exposure of reinforcement bars due to poor formwork as shown in Figure 4.



Figure 4. Exposed reinforcement bars at the last floor of the building.

3.3. Compressive Strength Test

3.3.1. Rebound Hammer

The assessment of columns, beams, and slab sections revealed that many of the tested members had good rebound values (See Figure 5 – 7). The quality of concrete may be interpreted as shown in the Table 1.

Table 1. Average Rebound number and quality of concrete [22].

| Average Rebound Number | Quality of Concrete |
|------------------------|----------------------|
| >40 | Very good hard layer |
| 30 to 40 | Good layer |
| 20 to 30 | Fair |
| < 20 | Poor concrete |
| 0 | Delaminated |

At the column, a total of one hundred and forty five (145) points on the building were identified and tested. Figure 5 shows the quality of the selected critical column at different floors in the building which ranges from 33.20 – 37.40 Average Rebound Numbers (RNs). According to the table for Standard Rebound Rating of Concretes by Anand & Ankush [21], the quality of the concrete layers is good which indicate that majority of the concrete strengths are within acceptable bounds. The column marked 1C2 at the first floor with an Average RN 37.40 is the strongest element of all the twenty nine (29) columns tested while the column marked 4C4 at the fourth floor with an average RN 33.20 is the least element.

At the beam, a total of one hundred (100) points on the building were identified and tested. Figure 6 shows the quality of the selected critical beams at different floors in the building which ranges from 33.80 – 37.60 Average Rebound Numbers (RNs), indicating that majority of the concrete strengths of the beams are within acceptable bounds as reported by Anand & Ankush [21]. The beam marked 0BM1 at the ground floor with an Average RN 37.60 is the strongest

element of all the twenty (20) beams tested while the beam marked 4BM4 at the fourth floor and beam marked 5BM3 at the fifth floor with an average RN 33.80 were the least element.

Similarly, at the slab panels, a total of eighty (80) points were identified and tested. Figure 7 shows the quality of the selected critical slab panels at different floors in the building ranges from 32.80 – 38.00 Average Rebound Numbers (RNs), indicating that the concrete strengths of the slab panels are good according to Anand & Ankush [21]. The slab panel marked 1SL4 at the first floor with an Average RN 38.00 is the strongest element of all the sixteen (16) panels tested while the slab panel marked 6SL1 at the sixth floor with an average RN 32.80 was the least element.

3.3.2. Ultrasonic Pulse Velocity

Based on the guidelines as reported by Kumar, M. J. et'al, [22] in Table 2, the result shows that the concretes are of good quality (See Figure 8, 9 and Figure 10).

Table 2. Classification of concrete by the ultrasonic pulse velocity test [21].

| Range of ultrasonic pulse velocity results (km/s) | Classification of concrete |
|---|----------------------------|
| >4.5 | Excellent |
| 3.5 – 4.5 | Good |
| 3.0 – 3.5 | Medium |
| <3.0 | Doubtful |

| | | | | | | | | | | | | | | | |
|--|--------------------|--|----|----|----|----|--------------|---------------------|-----|----|----|----|----|---|--------------|
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| NON DESTRUCTIVE TEST | | | | | | | | | | | | | | | |
| LOCATION : Plot 1076, cadastral zone, Sestor B18, Gudu District, Abuja | | | | | | | | | | | | | | Date : 27/04/22 | |
| PROJECT: STRUCTURAL INTEGRITY TEST OF NATIONAL DIRECTORATE OF EMPLOYMENT (NDE), ABUJA NIGERIA. | | | | | | | | | | | | | | Con. Grade : 25 | |
| CLIENT: Eldov Consultants Nigeria Limited of Suite A13, Saham Plaza, 10 Alexander Crescent, Wuse 2, Abuja | | | | | | | | | | | | | | 1st, 2nd, 3rd, 4th, 5th & 6th Floors | |
| S/N | Column Mark | VALUES OF REBOUND NUMBER FOR SOME SELECTED CRITICAL COLUMNS | | | | | | | | | | | | Average Rebound Values | |
| | | FIRST FLOOR | | | | | | FOURTH FLOOR | | | | | | | |
| 1 | 1C1 | 34 | 38 | 34 | 38 | 40 | 36.80 | 16 | 4C1 | 32 | 34 | 40 | 37 | 39 | 36.40 |
| 2 | 1C2 | 37 | 40 | 36 | 33 | 41 | 37.40 | 17 | 4C2 | 36 | 31 | 36 | 32 | 40 | 35.00 |
| 3 | 1C3 | 37 | 32 | 39 | 33 | 32 | 34.60 | 18 | 4C3 | 33 | 36 | 41 | 36 | 34 | 36.00 |
| 4 | 1C4 | 38 | 34 | 36 | 40 | 37 | 37.00 | 19 | 4C4 | 38 | 30 | 32 | 31 | 35 | 33.20 |
| 5 | 1C5 | 30 | 37 | 34 | 30 | 38 | 33.80 | 20 | 4C5 | 32 | 32 | 40 | 32 | 39 | 35.00 |
| | | SECOND FLOOR | | | | | | FIFTH FLOOR | | | | | | | |
| 6 | 2C1 | 40 | 32 | 34 | 36 | 38 | 36.00 | 21 | 5C1 | 30 | 35 | 34 | 37 | 41 | 35.40 |
| 7 | 2C2 | 38 | 37 | 35 | 40 | 30 | 36.00 | 22 | 5C2 | 34 | 40 | 36 | 33 | 32 | 35.00 |
| 8 | 2C3 | 38 | 31 | 35 | 35 | 38 | 35.40 | 23 | 5C3 | 37 | 35 | 30 | 41 | 30 | 34.60 |
| 9 | 2C4 | 35 | 33 | 32 | 37 | 36 | 34.60 | 24 | 5C4 | 32 | 32 | 38 | 33 | 34 | 33.80 |
| 10 | 2C5 | 30 | 38 | 40 | 37 | 31 | 35.20 | 25 | 5C5 | 38 | 32 | 40 | 30 | 32 | 34.40 |
| | | THIRD FLOOR | | | | | | SIXTH FLOOR | | | | | | | |
| 11 | 3C1 | 35 | 32 | 35 | 38 | 35 | 35.00 | 26 | 6C1 | 33 | 37 | 34 | 32 | 36 | 34.40 |
| 12 | 3C2 | 35 | 38 | 33 | 35 | 38 | 35.80 | 27 | 6C2 | 37 | 30 | 37 | 30 | 38 | 34.40 |
| 13 | 3C3 | 33 | 36 | 34 | 32 | 36 | 34.20 | 28 | 6C3 | 35 | 37 | 32 | 34 | 37 | 35.00 |
| 14 | 3C4 | 33 | 36 | 33 | 31 | 35 | 33.60 | 29 | 6C4 | 34 | 36 | 41 | 30 | 39 | 36.00 |
| 15 | 3C5 | 35 | 35 | 36 | 32 | 35 | 34.60 | | | | | | | | |
| REMARKS: | | | | | | | | | | | | | | | |
| Conducted by | | Mr. Sylvanus Okhomeh | | | | | | | | | | | | | |
| Checked by | | Engr. Miraj A. M. | | | | | | | | | | | | | |
| Approved by | | Engr. Dr. Jibrin Sule | | | | | | | | | | | | | |

Figure 5. Average rebound hammer value of the selected critical column at different floors in the building.

| | | | | | | | | | | | | | | | |
|--|------------------|---|----|----|----|----|--------------|---------------------|------|----|----|----|----|--|--------------|
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| NON DESTRUCTIVE TEST | | | | | | | | | | | | | | | |
| LOCATION : Plot 1076, cadastral zone, Sestor B18, Gudu District, Abuja | | | | | | | | | | | | | | Date : 27/04/22 | |
| PROJECT: STRUCTURAL INTEGRITY TEST OF NATIONAL DIRECTORATE OF EMPLOYMENT (NDE), ABUJA NIGERIA. | | | | | | | | | | | | | | Con. Grade : 25 | |
| CLIENT: Eldov Consultants Nigeria Limited of Suite A13, Saham Plaza, 10 Alexander Crescent, Wuse 2, Abuja | | | | | | | | | | | | | | Ground , 1st 3rd, 4th, 5th Floors | |
| S/N | Beam Mark | VALUES OF REBOUND NUMBER FOR SOME SELECTED CRITICAL BEAMS | | | | | | | | | | | | Average Rebound Values | |
| | | GROUND FLOOR | | | | | | FOURTH FLOOR | | | | | | | |
| 1 | 0BM1 | 30 | 38 | 40 | 38 | 42 | 37.60 | 14 | 4BM1 | 35 | 31 | 37 | 40 | 32 | 35.00 |
| 2 | 0BM2 | 42 | 31 | 41 | 30 | 37 | 36.20 | 15 | 4BM2 | 35 | 33 | 40 | 36 | 37 | 36.20 |
| 3 | 0BM3 | 33 | 31 | 41 | 39 | 32 | 35.20 | 16 | 4BM3 | 33 | 40 | 33 | 38 | 35 | 35.80 |
| 4 | 0BM4 | 33 | 37 | 32 | 42 | 30 | 34.80 | 17 | 4BM4 | 32 | 33 | 38 | 30 | 36 | 33.80 |
| 5 | 0BM5 | 34 | 32 | 41 | 30 | 42 | 35.80 | | | | | | | | |
| | | FIRST FLOOR | | | | | | FIFTH FLOOR | | | | | | | |
| 6 | 1BM1 | 31 | 41 | 31 | 40 | 33 | 35.20 | 18 | 5BM1 | 33 | 32 | 35 | 38 | 32 | 34.00 |
| 7 | 1BM2 | 33 | 32 | 37 | 38 | 35 | 35.00 | 19 | 5BM2 | 34 | 37 | 34 | 40 | 31 | 35.20 |
| 8 | 1BM3 | 36 | 41 | 32 | 34 | 40 | 36.60 | 20 | 5BM3 | 30 | 32 | 35 | 38 | 34 | 33.80 |
| | | THIRD FLOOR | | | | | | | | | | | | | |
| 9 | 3BM1 | 34 | 40 | 36 | 33 | 40 | 36.60 | | | | | | | | |
| 10 | 3BM2 | 33 | 36 | 32 | 40 | 33 | 34.80 | | | | | | | | |
| 11 | 3BM3 | 34 | 37 | 32 | 37 | 35 | 35.00 | | | | | | | | |
| 12 | 3BM4 | 33 | 37 | 32 | 34 | 40 | 35.20 | | | | | | | | |
| 13 | 3BM5 | 35 | 35 | 36 | 32 | 35 | 34.60 | | | | | | | | |
| REMARKS | | | | | | | | | | | | | | | |
| Conducted by | | Mr. Sylvanus Okhomeh | | | | | | | | | | | | | |
| Checked by | | Engr. Miiraj A. M. | | | | | | | | | | | | | |
| Approved by | | Engr. Dr. Jibrin Sule | | | | | | | | | | | | | |

Figure 6. Average rebound hammer value of the selected critical beam at different floors in the building.

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| NON DESTRUCTIVE TEST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| S/N | Slab Mark | VALUES OF REBOUND NUMBER FOR SOME SELECTED CRITICAL SLABS PANALS | | | | | | | | | | | | | Average Rebound Values | | | | | | | | | | | | | | | | | |
| | | FIRST FLOOR | | | | | | | FIFTH FLOOR | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1SL 1 | 33 | 30 | 32 | 35 | 38 | 33.60 | 10 | 5SL 1 | 30 | 34 | 36 | 33 | 32 | 33.00 | | | | | | | | | | | | | | | | | |
| 2 | 1SL 2 | 30 | 34 | 38 | 37 | 40 | 35.80 | 11 | 5SL 2 | 31 | 32 | 40 | 37 | 33 | 34.60 | | | | | | | | | | | | | | | | | |
| 3 | 1SL 3 | 33 | 31 | 30 | 40 | 31 | 33.00 | 12 | 5SL 3 | 32 | 40 | 33 | 39 | 36 | 36.00 | | | | | | | | | | | | | | | | | |
| 4 | 1SL 4 | 35 | 38 | 39 | 40 | 41 | 38.60 | 13 | 5SL 4 | 33 | 38 | 35 | 38 | 30 | 34.80 | | | | | | | | | | | | | | | | | |
| | THIRD FLOOR | | | | | | | SIXTH FLOOR | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 3SL 1 | 37 | 38 | 32 | 37 | 34 | 35.60 | 14 | 6SL 1 | 33 | 35 | 36 | 29 | 31 | 32.80 | | | | | | | | | | | | | | | | | |
| 6 | 3SL 2 | 34 | 35 | 35 | 34 | 34 | 34.40 | 15 | 6SL 2 | 35 | 39 | 35 | 32 | 34 | 35.00 | | | | | | | | | | | | | | | | | |
| 7 | 3SL 3 | 35 | 36 | 33 | 38 | 30 | 34.40 | 16 | 6SL 3 | 39 | 38 | 37 | 32 | 37 | 36.60 | | | | | | | | | | | | | | | | | |
| | FOURTH FLOOR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 4SL 1 | 34 | 36 | 38 | 33 | 39 | 36.00 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 4SL 2 | 39 | 40 | 37 | 35 | 33 | 36.80 | | | | | | | | | | | | | | | | | | | | | | | | | |
| REMARKS: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conducted by | | Mr. Sylvanus Okhomeh | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Checked by | | Engr. Miiraj A. M. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Approved by | | Engr. Dr. Jibrin Sule | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 7. Average rebound hammer value of the selected critical slab panals at different floors in the building.

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| PROJECT: STRUCTURAL INTEGRITY TEST OF NATIONAL DIRECTORATE OF EMPLOYMENT (NDE), ABUJA NIGERIA. | | | | | Date | | 27-Apr-22 |
| | | | | | Concrete Grade | | 25 |
| CLIENT: Eldov Consultants Nigeria Limited of Suite A13, Saham Plaza, 10 Alexander Crescent, Wuse 2, Abuja | | | | | 1st, 2nd, 3rd, 4th, 5th, & 6th Floors | | |
| S/N | COLUMN MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK | S/N | COLUMN MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK |
| FIRST FLOOR | | | | FOURTH FLOOR | | | |
| 1 | 1C1 | 4.153 | Good | 1 | 4C1 | 4.631 | Excellent |
| 2 | 1C2 | 3.964 | Good | 2 | 4C2 | 3.546 | Good |
| 3 | 1C3 | 3.771 | Good | 3 | 4C3 | 3.887 | Good |
| 4 | 1C4 | 3.765 | Good | 4 | 4C4 | 3.761 | Good |
| 5 | 1C5 | 4.007 | Good | 5 | 4C5 | 3.901 | Good |
| SECOND FLOOR | | | | FIFTH FLOOR | | | |
| 1 | 2C1 | 3.879 | Good | 6 | 5C1 | 3.980 | Good |
| 2 | 2C2 | 4.129 | Good | 7 | 5C2 | 3.664 | Good |
| 3 | 2C3 | 3.891 | Good | 8 | 5C3 | 3.987 | Good |
| 4 | 2C4 | 3.749 | Good | 9 | 5C4 | 4.120 | Good |
| 5 | 2C5 | 3.832 | Good | 10 | 5C5 | 3.659 | Good |
| THIRD FLOOR | | | | SIXTH FLOOR | | | |
| 1 | 3C1 | 4.213 | Good | 11 | 6C1 | 4.003 | Good |
| 2 | 3C2 | 3.901 | Good | 12 | 6C2 | 3.812 | Good |
| 3 | 3C3 | 3.897 | Good | 13 | 6C3 | 3.902 | Good |
| 4 | 3C4 | 3.876 | Good | 14 | 6C4 | 3.784 | Good |
| 5 | 3C5 | 4.201 | Good | | | | |
| REMARKS: | | | | | | | |
| Conducted by | | | Mr. Sylvanus Okhomeh | | | | |
| Checked by | | | Engr. Miiraj A. M. | | | | |
| Approved by | | | Engr. Dr. Jibrin Sule | | | | |

Figure 8. Ultrasonic Pulse Velocity Value of the selected critical columns at different floors in the building.


|  NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE (FEDERAL MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION) | | | | | | | |
|---|-----------|---------------------------------|-----------------------|--------------|------------------------------------|---------------------------------|--------|
| NON DESTRUCTIVE TEST | | | | | | | |
| PROJECT: STRUCTURAL INTEGRITY TEST OF NATIONAL DIRECTORATE OF EMPLOYMENT (NDE), ABUJA NIGERIA. CLIENT: Eldov Consultants Nigeria Limited of Suite A13, Saham Plaza, 10 Alexander Crescent, Wuse 2, Abuja | | | | | Date | 27-Apr-22 | |
| | | | | | Concrete Grade | 25 | |
| | | | | | Ground, 1st, 3rd, 4th & 5th Floors | | |
| S/N | BEAM MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK | S/N | BEAM MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK |
| GROUND FLOOR | | | | FOURTH FLOOR | | | |
| 1 | 0BM1 | 3.878 | Good | 1 | 4BM1 | 3.913 | Good |
| 2 | 0BM2 | 3.976 | Good | 2 | 4BM2 | 3.546 | Good |
| 3 | 0BM3 | 3.523 | Good | 3 | 4BM3 | 3.887 | Good |
| 4 | 0BM4 | 3.543 | Good | 4 | 4BM4 | 3.761 | Good |
| 5 | 0BM5 | 4.241 | Good | | | | |
| FIRST FLOOR | | | | FIFTH FLOOR | | | |
| 1 | 1BM1 | 4.126 | Good | 1 | 5BM1 | 3.983 | Good |
| 2 | 1BM2 | 3.932 | Good | 2 | 5BM2 | 4.134 | Good |
| 3 | 1BM3 | 4.241 | Good | 3 | 5BM3 | 3.815 | Good |
| THIRD FLOOR | | | | | | | |
| 1 | 3BM1 | 4.134 | Good | | | | |
| 2 | 3BM2 | 3.783 | Good | | | | |
| 3 | 3BM3 | 3.951 | Good | | | | |
| 4 | 3BM4 | 4.032 | Good | | | | |
| 5 | 3BM5 | 3.851 | Good | | | | |
| REMARKS: | | | | | | | |
| Conducted by | | | Mr. Sylvanus Okhomeh | | | | |
| Checked by | | | Engr. Miiraj A. M. | | | | |
| Approved by | | | Engr. Dr. Jibrin Sule | | | | |

Figure 9. Ultrasonic Pulse Velocity Value of of the selected critical beams at different floors in the building.


|  NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE (FEDERAL MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION) | | | | | | | |
|---|-----------|---------------------------------|-----------------------|-------------|----------------------------------|---------------------------------|--------|
| NON DESTRUCTIVE TEST | | | | | | | |
| PROJECT: STRUCTURAL INTEGRITY TEST OF NATIONAL DIRECTORATE OF EMPLOYMENT (NDE), ABUJA NIGERIA. CLIENT: Eldov Consultants Nigeria Limited of Suite A13, Saham Plaza, 10 Alexander Crescent, Wuse 2, Abuja | | | | | Date | 27-Apr-22 | |
| | | | | | Concrete Grade | 25 | |
| | | | | | 1st, 3rd, 4th, 5th, & 6th Floors | | |
| S/N | SLAB MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK | S/N | SLAB MARK | ULTRASONIC PULSE VELOCITY (UPV) | REMARK |
| FIRST FLOOR | | | | FIFTH FLOOR | | | |
| 1 | 1SL 1 | 3.850 | Good | 1 | 5SL 1 | 3.980 | Good |
| 2 | 1SL 2 | 4.150 | Good | 2 | 5SL 2 | 3.664 | Good |
| 3 | 1SL 3 | 3.720 | Good | 3 | 5SL 3 | 3.987 | Good |
| 4 | 1SL 4 | 3.940 | Good | 4 | 5SL 4 | 4.120 | Good |
| THIRD FLOOR | | | | SIXTH FLOOR | | | |
| 1 | 3SL 1 | 3.890 | Good | 1 | 6SL 1 | 3.780 | Good |
| 2 | 3SL 2 | 4.210 | Good | 2 | 6SL 2 | 4.100 | Good |
| 3 | 3SL 3 | 3.930 | Good | 3 | 6SL 3 | 3.976 | Good |
| FOURTH FLOOR | | | | | | | |
| 1 | 4SL 1 | 4.620 | Excellent | | | | |
| 2 | 4SL 2 | 3.890 | Good | | | | |
| REMARKS: | | | | | | | |
| Conducted by | | | Mr. Sylvanus Okhomeh | | | | |
| Checked by | | | Engr. Miiraj A. M. | | | | |
| Approved by | | | Engr. Dr. Jibrin Sule | | | | |

Figure 10. Ultrasonic Pulse Velocity Value of of the selected critical slab panels at different floors in the building.

3.3.3. Rebar Sizes and Depth Using Radar Machine

The radar method is a technology that transmits and receives high-frequency electromagnetic waves to picture the subsurface of materials. Ground Penetrating Radar (GPR) has proven to be a useful technique for the non-destructive analysis of concrete structures and it allows engineers to

quickly trace electrical conduits, detect voids, recognize reinforcing elements and quantify slab thickness, on the site. This research uses this technique to assess reinforcement in the building. The tested points were randomly selected though with emphasis on critical structural members. Table 3 – 6 shows details of the reinforcement in the building.

Table 3. Ground floor Columns.

| S/N | Test Point | Size | Reinforcement | | | Remark |
|-----|------------|------------------------|---------------|----------|-------|--------------|
| | | Columns Size (mm x mm) | Main | Stirrups | Cover | |
| 1 | C1 | 600X300 | 20YØ25mm | @ 175c/c | 25 | Satisfactory |
| 2 | C2 | 750X230 | 14YØ25mm | @ 175c/c | 25 | Satisfactory |
| 3 | C3 | 600X230 | 12YØ25mm | @ 175c/c | 24 | Satisfactory |
| 4 | C4 | 450X230 | 12YØ25mm | @ 175c/c | 26 | Satisfactory |
| 5 | C5 | 450X400 | 14YØ25mm | @ 175c/c | 25 | Satisfactory |
| 6 | C6 | NIL | - | - | - | - |
| 7 | C7 | 600x230 | 12YØ25mm | @ 175c/c | 25 | Satisfactory |
| 8 | C8 | 450x230 | 8YØ16mm | @ 175c/c | 24 | Satisfactory |
| 9 | C9 | NIL | - | - | - | - |
| 10 | C10 | 450x230 | 8YØ25mm | @ 175c/c | 27 | Satisfactory |

Table 4. First Floor columns.

| S/N | Test Point | Size | Reinforcement | | | Remark |
|-----|------------|------------------------|---------------|----------|-------|--------------|
| | | Columns Size (mm x mm) | Main | Stirrups | Cover | |
| 1 | C1 | 600X300 | 18YØ25mm | @ 175c/c | 27 | Satisfactory |
| 2 | C2 | 750X230 | 14YØ25mm | @ 175c/c | 24 | Satisfactory |
| 3 | C3 | 600X230 | 12YØ25mm | @ 175c/c | 26 | Satisfactory |
| 4 | C4 | 450X230 | 12YØ25mm | @ 175c/c | 25 | Satisfactory |
| 5 | C5 | 450X400 | 10YØ25mm | @ 175c/c | 26 | Satisfactory |
| 6 | C6 | NIL | - | - | - | - |
| 7 | C7 | 600x230 | 10YØ25mm | @ 175c/c | 25 | Satisfactory |
| 8 | C8 | 450x230 | 8YØ25mm | @ 175c/c | 28 | Satisfactory |
| 9 | C9 | NIL | - | - | - | - |
| 10 | C10 | 450x230 | 8YØ25mm | @ 175c/c | 26 | Satisfactory |

Table 5. Second Floor Columns.

| SN | Test Point | Size | Reinforcement | | | Remark |
|----|------------|------------------------|---------------|----------|-------|--------------|
| | | Columns Size (mm x mm) | Main | Stirrups | Cover | |
| 1 | C1 | 600x300x300 | 16YØ25mm | @ 175c/c | 27 | Satisfactory |
| 2 | C2 | 700X230 | 14YØ25mm | @ 175c/c | 25 | Satisfactory |
| 3 | C3 | 600X230 | 10YØ25mm | @ 175c/c | 25 | Satisfactory |
| 4 | C4 | 450X230 | 12YØ25mm | @ 175c/c | 26 | Satisfactory |
| 5 | C5 | 450x400 | 12YØ25mm | @ 175c/c | 24 | Satisfactory |
| 6 | C6 | NIL | - | - | - | - |
| 7 | C7 | 600X230 | 12YØ25mm | @ 175c/c | 25 | Satisfactory |
| 8 | C8 | 450x230 | 8YØ25mm | @ 175c/c | 26 | Satisfactory |
| 9 | C9 | NIL | - | - | - | - |
| 10 | C10 | 450x230 | 8YØ25mm | @ 175c/c | 24 | Satisfactory |

Table 6. Third Floor Columns.

| SN | Test Point | Size | Reinforcement | | | Remark |
|----|------------|------------------------|---------------|----------|-------|--------------|
| | | Columns Size (mm x mm) | Main | Stirrups | Cover | |
| 1 | C1 | NILL | - | - | - | - |
| 2 | C2 | 750X230 | 14YØ25mm | @ 175c/c | 25 | Satisfactory |
| 3 | C3 | 600x230 | 12YØ25mm | @ 175c/c | 27 | Satisfactory |
| 4 | C4 | 600x230 | 10YØ25mm | @ 175c/c | 26 | Satisfactory |
| 5 | C5 | 450x400 | 12YØ25mm | @ 175c/c | 24 | Satisfactory |
| 6 | C6 | 600x300 | 10YØ25mm | @ 175c/c | 27 | Satisfactory |
| 7 | C7 | 600x230 | 10YØ25mm | @ 175c/c | 25 | Satisfactory |
| 8 | C8 | 400x230 | 8YØ25mm | @ 175c/c | 24 | Satisfactory |
| 9 | C9 | NILL | - | - | - | - |
| 10 | C10 | NILL | - | - | - | - |

3.4. Geotechnical Investigation

Soil is typically tested to determine its variability and to obtain data for specific geotechnical calculations. The following tests were carried out in the laboratory based on the client's requested.

3.4.1. Natural Moisture Content

Table 7 presents results of the natural moisture content of soils encountered on the building site under investigation. The results depict the moisture level of existing soils consistent with the rainy season encountered during the time of sample collection. Natural moisture content values ranged from 12.65 to 22.4%.

Table 7. Natural moisture content of soils.

| Trial Pit (TP) | TP1 | TP2 | TP3 |
|------------------------------|-------|------|-------|
| Natural Moisture Content (%) | 12.65 | 22.4 | 20.53 |

3.4.2. Specific Gravity of Soils

Table 8 presents results of specific gravities of soils encountered on the site. Specific gravity values ranged from 2.31 to 2.63.

Table 8. Specific gravity of soils.

| Trial Pit (TP) | TP1 | TP2 | TP3 |
|------------------|------|------|------|
| Specific Gravity | 2.31 | 2.49 | 2.63 |

3.4.3. Particle Size Distribution of Soils

According to Table 9, an examination of the particle size distribution for soil samples taken from the building under investigation reveals that the samples are coarse-grained (sandy) soils with sizable proportions of fines (silt and clay) and a negligible proportion of gravel. The trial pit soils had a sizable amount of sand in them. The silt and clay content for all three (3) trial pits was less than 15%, and the gravel content was less than 4%. Given the characteristics of these

soils, areas with excessive fines must be taken into account in order to prevent uneven settlements on the site.

Table 9. Particle Size Distribution.

| Trial Pit (TP) | TP 1 | TP 2 | TP 3 |
|-----------------|-------|-------|-------|
| Gravel (%) | 0.35 | 1.12 | 2.38 |
| Sand (%) | 87.79 | 90.94 | 84.75 |
| Silt + Clay (%) | 12.21 | 7.93 | 12.87 |

3.4.4. Atterberg Limits of Soils

The outcomes of the Atterberg limit tests for the building are shown in Table 10. According to the results of the liquid limit tests, most of the soils had liquid limits that were lower than 50% across all trial pits, indicating medium to high soil plasticity. Consequently, the soil is non-plastic (NP) in all of the trial pits.

Table 10. Atterberg Limits.

| Trial Pit (TP) | TP 1 | TP 2 | TP 3 |
|----------------------|------|-------|------|
| Liquid Limit (%) | 48.5 | 37.50 | 42.0 |
| Plastic Limit (%) | NP | NP | NP |
| Plasticity Index (%) | NA | NP | NP |
| Shrinkage Limit (%) | NA | NA | NA |

3.4.5. Classification of Soils

According to the Unified Soils Classification System (USCS), soils are coarse-grained if less than 50% pass through sieve size No. 200. Based on this criterion, most of the soil samples tested are coarse-grained soils. Results are presented in Table 11. Most soils encountered on the investigated site were classified as Clayey Sand (SC) and Silty Sand (SM), which are predominantly clayey sands or sand-silt mixtures with low to medium plasticity and generally good to poor bearing capacity as foundation materials.

Table 11. Classification of soils.

| Trial Pit | USCS | Remarks |
|-----------|------------------|---|
| TP1 | SM (Silty sand) | Silty sands or sand silt mixtures which generally have a good to poor bearing capacity value as foundation materials |
| TP2 | SC (Clayey sand) | Clayey sands or sand silt mixtures which generally have a good to poor bearing capacity value as foundation materials |
| TP3 | SC (Clayey sand) | Clayey sands or sand silt mixtures which generally have a good to poor bearing capacity value as foundation materials |

3.4.6. Direct Shear Test Results

The findings from the direct shear tests, which are shown in Table 12, reveal that the soils from the building site have medium cohesion values between 3.66 and 4.41 kN/m², which may be related to medium to high bearing capacity, and angles of internal friction between 30.9 and 42.1°.

Table 12. Shear Strength Parameters from the building site.

| Trial Pits (TP) | TP1 | TP2 | TP3 |
|--------------------------------|------|------|------|
| Cohesion kN/m ² | 3.66 | 4.07 | 4.41 |
| Angle of Internal Friction (°) | 30.9 | 42.1 | 33.3 |

3.4.7. Bearing Capacity Analysis

The ultimate bearing capacity for foundations can be evaluated using shear strength parameters obtained from in situ or laboratory tests with suitable theoretical analysis. The Terzaghi equations, which are applicable to foundations where the depth of foundation is less than the minimum width, can be used as follows:

For square footing,

$$q_u = 1.3cN_c + \gamma Z(N_q - 1) + 0.4\gamma BN_\gamma$$

Where: q_u – Ultimate bearing capacity (kN/m²)

c – Cohesion (kN/m^2)
 γ – Unit weight (kN/m^3)
 Z – Depth of footing (m)
 B – Width of footing (m)

N_c , N_q , and N_γ are bearing capacity factors dependent on the angle of internal friction (ϕ)

The ultimate bearing capacity was calculated using the results from the direct shear test on samples collected from the trial pits.

Based on partial safety factors of 1.25, 1.50 and 1.75 on γ , ϕ and c respectively, and a load factor of 3, the computations for safe, Ultimate and allowable bearing capacities were made. Table 13 presents the allowable bearing capacity for an isolated square footing assuming a width of 1.2m for the trial pits.

The result from the bearing capacity analysis of the building under investigation at 1.5m shows that the site has a lower allowable bearing pressure of 96.63 kN/m^2 and the highest value of 278.76 kN/m^2 bearing capacity.

Table 13. Allowable Bearing pressures.

| Trial Pit (TP) | q_{ult} | q_{safe} | q_{all} |
|----------------|-----------|------------|-----------|
| TP1 | 1076.17 | 289.88 | 96.63 |
| TP2 | 5033.22 | 836.28 | 278.76 |
| TP3 | 1464.28 | 359.59 | 119.86 |

3.4.8. Consolidation Test

The consolidation test (also known as the oedometer test) is the primary laboratory test used to study the settlement and expansion behaviour of soils. The consolidation test performed was a one-dimensional consolidation test and was conducted in accordance with clause 3 of BS 1377: Part 5: 1990 [23]. Table 14 shows the outcomes of the one-dimensional consolidation test. The findings demonstrate that all soil samples are highly compressible for the tested stress ranges, with maximum expected vertical settlements of about 82.8 mm and minimum vertical settlements of 57.96 mm. The result indicates that the settlements are above the tolerable limit as recommended by EN 1997-1 Eurocode 7 [24]. For serviceability limits, the maximum total settlement should not exceed 25 mm.

Table 14. Consolidation Parameters.

| Trial Pit | Depth (m) | Coefficient of Consolidation (m^2/yr) | | | Volume Compressibility (m^2/MN) | | | Remark | Settlement (mm) |
|-----------|-----------|---|---------|----------|---|---------|----------|----------------------|-----------------|
| | | 0-138 | 138-275 | 275 -550 | 0-138 | 138-275 | 275 -550 | | |
| 1 | 1.5 | 6.1 | 30 | 18 | 0.28 | 0.046 | 0.056 | High compressibility | 57.96 |
| 2 | 1.5 | 6 | 29 | 17 | 0.4 | 0.039 | 0.022 | High compressibility | 82.8 |
| 3 | 1.5 | 6.1 | 30 | 18 | 0.28 | 0.046 | 0.058 | High compressibility | 57.96 |

4. Conclusions and Recommendations

4.1. Conclusions

The structural components of the National Directorate of Employment (NDE) located at Plot 1076, Cadastral Zone, Sestor B18, Gudu District, Abuja, the Nigeria Federal Capital was inspected, analysed, subjected to structural design checks, field and laboratory testing. From the results obtained and presented, the following general judgements are made.

1. According to the USCS soil classification system, the soil is predominantly clayey sands and sand-silt mixtures with low to medium plasticity and generally good to poor bearing capacity values.
2. The soil is within the acceptable range with a lower allowable bearing pressure of 96.63 kN/m^2 and a higher allowable bearing pressure of 278.76 kN/m^2 .
3. The settlement is above the recommended limit as recommended by Eurocode 7 for serviceability limits. This is because the soils in all the trial pits are highly compressible and the settlement is within the tolerable limit.
4. The quality of the concrete layers were good (with Average Rebound Number between 30 to 40) which indicate that majority of the concrete strengths are within acceptable bounds.
5. The structural elements met the ultimate and

serviceability requirement specifications.

6. The structural components' reliability and safety were confirmed, and they passed the integrity test.

4.2. Recommendations

The following suggestions were made;

1. All exposed reinforcement should be covered to avoid further deterioration.
2. Areas with poor concreting should be amended.
3. The roof slab should be adequately protected.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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