Structural Integrity of A 2-Storey Building Using None Destructive Testing Method

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Abstract

The paper assessed the condition of the existing two-storey building of six classrooms in Government Girls Day Secondary School, Gumel, Jigawa State. The method of Non Destructive Testing (NDT) using a rebound hammer was adopted. Five structural elements (slabs, beams, columns, staircases and foundations) were assessed. The cumulative average strength of the five structural elements was 32.7 RN. Results revealed that despite signs of physical defects on the building such as cracks, exposed column reinforcement bars, etc. it was still considered safe for use. The study recommended that to prevent the building from deteriorating further, periodic structural assessment and good maintenance practice should be carried out. This is to prolong the life span of the building and prevent any threat to the building users and third parties.

Keywords: *Non-destructive test, Rebound hammer, structural integrity, structural components*

Introduction

Many structures are built with foundations that are inappropriate for the soil conditions existing on a given site. Sometimes due to the lack of suitable land, structures are built on land that has the insufficient bearing capacity to support the structure. At times if the soil conditions change, it may no longer be able to bear the full weight of the foundation, (Akash, Amit and Chaitanya 2012), which may result in its collapse.

The collapse of building structures in the last few decades particularly in Nigeria has called for effective methods for evaluating the structural integrity of these buildings. However, the destructive test methods used in evaluating the quality of concrete have several demerits such as cost, delay, etc. To overcome the drawbacks, Non Destructive Test (NDT) was developed (Sajeev, Sudhir and Saleem 2013). None destructive methods like rebound hammer test and ultrasonic pulse velocity test do not damage buildings but allow for a safe inventory of structural conditions.

An assessment of buildings or reinforced concrete structures, particularly important structures that host a large number of people like bridges, hospitals, schools, stadia, etc is imperative. These types of structures should be monitored on regular basis, in case they bear any damage due to disaster, either man-made or natural (Jimada, 2015). A study by Okereke (2014) found that in Nigeria several quality control organizations including public organizations such as The Nigerian Industrial Standard (NIS) did not have well-equipped research laboratories for testing materials. Some existing facilities are obsolete or not functional for confirming the strength, safety or otherwise of the built structures.

Nigeria does not have a history of natural disasters compared to other countries of the world except in 2016 where an earth tremor was reported in part of Kaduna State. Ironically the country has had its share of man-made disasters (Falobi, 2009). The collapse of buildings for example which was recorded in the country's big cities of Lagos, Abuja, Port Harcourt and more recently was a church in Uyo in 2016, where the serving governor narrowly escaped being hurt (Etim, 2016).

Lagos has recorded four cases (including residential buildings) in 2006 with two of such collapses in Ebute Metta that claimed 37 lives (Oloyede, Omoogun and Akinjare 2010). Adegoroye (2006) reported that in 2006, the Nigerian Industrial Development

Bank building collapsed, claiming two human lives and injuring 23. In 2007, a two-storey building collapsed along Okegbogbo Street; another two six-storey buildings along Imam Ligali Street in Lagos Island collapsed, affecting two other six-storey buildings. The incidence leads to the injury of fifteen persons and claimed the life of one person (Akinjare, Oloyede & Omoogun, 2010).

Daily (2016) reported a collapse of a three-storey building (under construction) meant for the department of Architecture in Kano state University of Science and Technology, Wudil, with casualties. These and many accidents in Nigeria could have been averted or minimised if quality control measures were taken via NDT during the construction of new buildings as well as structural check-ups for existing ones. Thus, this research assessed the structural integrity of an existing 2-Storey building in Government Girl's Secondary School (G.G.S.S.) Gumel L.G.A. of Jigawa State Using NDT Method (Rebound Hammer) to ascertain the safe use of the structure.

Methodology

Instrument

The instrument used in carrying out this research was Rebound Hammer. The Schmidt rebound hammer is an instrument used in obtaining the Rebound Number (RN) of concrete elements which is related to its strength. The manufacturer of the instrument used in this research called it "Classic Concrete Hammer." and it has percussion energy of 2,207 Nm (0.0225 Kg) and model number IK0663. The instrument weighs 1.8kg and it came with the abrasive stone, conversion chart and operation manual.

The Schmidt Rebound Hammer method was selected for the assessment after considering factors such as the availability, availability of the calibration charts (for converting the RNs to compressive strength), the accuracy desired, economic considerations and lastly the practical limitation to access test points. So also, simplicity, portability of the rebound hammer was considered.

Table 1: Rebound Rating for Concretes

Quality of Concrete	Average Rebound Number (RN)
Very good hard layer	40- above
Good layer	30 – 40
Fair	20 – 30
Poor Concrete	20 below
Delaminated	0

Source: Anand and Ankush (2007)

Visual Inspection

Before conducting the NDT, a visual inspection of the building was carried out in accordance with the International Atomic Energy Agency, (IAEA, 2014) and Mahadik & Jaiswal (2014) procedure for NDT. All the building elements (foundation, walls, roofing, staircases, etc.) were carefully examined. Equipment used in recording the data obtained in the visual inspection includes measuring tape, markers, torchlight, calculator and camera. Note pad and pencil were also used in sketching some details. (Usually, the decision to conduct a test or not depends on the outcome of visual inspection).

Based on the physical condition of the building and nature of deterioration on it such as crack, presence of rust marks, plumbing and roof leaking etc. further investigation was carried out using the NDT where the quality rating of concrete as shown in Table 1 was used as the basis.

Test Procedures using Classic Concrete Hammer

In investigating the building, a total of twenty (20) points on the building were identified and tested as follows:

1. Foundation (sub-divided into four, namely: rear, front, left and side views representing points 1-4)
2. Staircase (left and right sides staircases, representing points 5-6)
3. Beam (four beams, representing points 7-10)
4. Column (eight columns, four for 1st floor and four for ground floor representing points 11-18)
5. Arch (two arches one for the 1st floor and the other for the ground floor, representing points 19-20)

The test procedure based on ASTM C805/C05M for Rebound Hammer was followed. The procedures in the rebound hammer manual were carefully studied and complied with before, during and after conducting a series of tests to ensure the validity of the result. More importantly, all safety measures outlined in the manuals to safeguard the user, the instruments and third parties were strictly adhered to.

Pits were marked and dug (as shown in Plate I) from the outer side of the building to access the foundations to be tested. The investigation was conducted based on the following chronological sequence:

Plate I: Pits to access the foundation

The digging was conducted carefully so as not to cause any damage to the foundation or any part of the building. The digging did not exceed the bottom of the foundations and the test surface areas prepared were at least 150 mm (6 in) in diameter each as recommended by the test manuals.

After that, the classic concrete hammer was used for the test using test anvil which is approximately 150 mm (6 in) diameter by 150 mm (6 in) high. The anvil made of steel having a hardness number of 5000 N/mm^2 as recommended by the test manual of the instrument. The instrument was found to be in perfect working condition; however, instead of 5000 N/mm^2 equivalents to 45 Rebound Number (RN), the hardness number of the anvil was 4800 N/mm^2 corresponding to 44 RN or rebound index on the appropriate classic concrete hammer graphics and the relevant curve. The adjustment was made and applied to all the readings taken from the test (i.e. one is added to all the RNs obtained for each recorded impact of the hammer).

The instrument was held at 90 degrees (perpendicular) to the area tested. It was gradually pushed toward the test surfaces until the hammer impacted. The pressure was maintained on the instrument and the button to lock the plunger in its retracted position. The RN was read on the scale and recorded. Four readings were taken on each point from the foundations, columns, arches, beams and staircases. No two impact tests were closer together than 25 mm and no test was made on wet or irregular surfaces. Where the concrete surfaces found not to be smooth, clean, irregular or with loose particles, the abrasive stone (delivered with the instrument) was used to ensure all the unwanted things on the concrete area to be tested were removed.

Impressions made on the surface of the concrete members were noted, and where the impact crushed or broke through a near-surface air void, the readings were disregarded and another one taken. As recommended by the test manuals, the test was not conducted on areas exhibiting honeycombing, cracking, high porosity or area with visible deformation. The test was also not conducted directly over reinforcing bars. The points of impacts were made to be at least 20mm away from the edge of the foundation and other concrete members, so also, from the previous points of impact. The pits dug for the investigation were backfilled after all the necessary information from the foundations were taken for further computations and analyses. Accordingly, the removed plasters were replaced after the tests.

The data collected for Classic Concrete Hammer tests for each element is computed using the formula: Characteristic Strength = [Average Strength – (1.64 x Standard Deviation)] (Jimada, 2015).

For rebound hammer results, all measurements of strength and deficiency as well as the initial C30 grade for the concrete are in N/mm^2. In the same vein, the entire rebound values were measured in numbers, computed and tabulated. Grading of the concrete strength was done using the following Table 2 to Table 6.

Table 2: Quality of Foundation

S/N	Point / Location	Grade	Resistance	Average RN
1	Rear Side Foundation	C 30	28.2	35.8
2	Front Side foundation	C 30	27.0	34.5
3	Left Side foundation	C 30	28.2	34.8
4	Right Side foundation	C 30	29.2	36.8

Table 2 shows the quality of the foundation tested which ranges from 34.5 – 36.8 RNs. According to the table for Standard Rebound Rating of Concretes by Anand & Ankush (2007), the quality of the concrete layers is good. The right side of the foundation with an Average RN 36.8 is the strongest element of all the twenty tested while the front side foundation with an average RN 34.5 is the least element.

Table 3: Quality of Staircase

S/N	Point / Location	Grade	Resistance	Average RN
1	Right staircase	C 30	19.3	28.5
2	Left staircase	C 30	18.2	27.8

Table 3 above indicated that the RNs of the staircases tested ranges from 27.8 – 28.5. This showed that the quality of the concrete layers is fair (Anand & Ankush 2007).

Table 4: Quality of Beam

S/N	Point / Location	Grade	Resistance	Average RN
1	Last floor beam 1	C 30	26.2	34.5
2	Last floor beam 2	C 30	20.0	34.0
3	Last floor beam 3	C 30	20.4	34.5
4	Last floor beam 4	C 30	27.7	35.5

Table 3 showed that the RNs of the beams tested ranges from 34.5 – 35.5. According to Anand & Ankush (2007), the concrete layers are good. The last floor beam 4 is having the second-best concrete layer of all the twenty elements tested.

Table 5: Quality of Column

S/N	Point / Location	Grade	Resistance	Average RN
1	ground floor column 1	C 30	18.1	31.5
2	ground floor column 2	C 30	21.9	31.8
3	ground floor column 3	C 30	17.4	27.5
4	ground floor column 4	C 30	17.9	30.3
5	Last floor column 1	C 30	26.1	34.0
6	Last floor column2	C 30	29.4	34.5
7	Last floor column3	C 30	18.2	32.0
8	Last floor column4	C 30	26.7	34.0

It can be seen from Table 5 that the columns tested have RNs ranging from 27.5 – 34.0 This showed that the quality of the concrete layer of the ground floor 3 is the only column with a fair layer of concrete, while all the columns have good layers of concrete (Anand & Ankush, 2007). The ground floor column 3 is the individual element with the least average RN of 27.5.

Table 6: Quality of Arches

S/N	Point / Location	Grade	Resistance	Average RN
1	ground floor arch	C 30	26.7	34.0
2	Last floor arch	C 30	27.4	33.0

From Table 5, the quality of the arches tested ranges from 33.0 – 34.0 RNs. Based on the above results, the quality of the concrete layers is good (Anand & Ankush 2007).

Table 7: Rating of the Cumulative Strength of the Elements

Elements	Resistance of the concrete	Percentage (%)	Average RN
Foundation	28.8	96	35.5
Arches	27.0	90	34.6
Beams	24.0	80	33.5
Columns	22.0	73	31.9
Staircases	19.0	63	28.2

Table 7, compared the five elements cumulatively. The elements were graded according to their strengths as follows:

- **i.** Foundation: This element has concrete resistance of 28.8 which is equivalent to 93% strength as well as an average RN of 35.5. According to Table 1, this element has the best concrete layer in the building and was rated the first.
- **ii.** Beam: it has concrete resistance of 27.0 which is equivalent to 90% strength as well as an average RN of 34.6. In this regard, the element was graded second in terms of quality.
- **iii.** Arch: Beam has concrete resistance of 24.0 which is equivalent to 80% strength as well as 33.5 average RNs. This was graded as the third element in terms of quality.
- **iv.** Column: This element has concrete resistance of 22.0, equivalent to 73% strength as well as an average RNs of 31.9. The element was graded forth in terms of strength.
- **v.** Staircase: Staircase is the element with the least concrete strength (19.0) and least average RNs (28.2). The quality of the concrete according to Table1 for Standard Rebound Rating for Concretes is fair and rated the last.

Conclusion

Although the building showed some signs of physical defects, the structure is safe for use. Moreover, the broken and detached newel post, exposed reinforcement bars in some columns and recent leak stains on ceilings of the building are indications of inadequate maintenance practices. It is therefore recommended that NDT could be employed to ascertain the structural integrity of existing buildings, particularly public buildings that house a great number of people.

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