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Use of Non-Destructive Tests (NDT) To Assess the Concrete Strength of aConcrete Structure: A Case Study

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ABSTRACT

The quality of concrete can be judged by its compressive strength. Non-Destructive Tests (NDT) are necessary to assess the compressive strength of structural members in an existing building like the one understudy (Emmanuel Egboga building, University of Ibadan, Oyo State, Nigeria). The purpose of this research work is to investigate the strength of this building which has shown cracks of different nature, to ascertain the safety of the building.

The method adopted consists of reconnaissance survey to observe the occurrence of any crackand location of structural elements in the building. A device invented by Schmidt (a roman) called Schmidt Concrete Test Hammer was used to determine the residual strength of the structural members (which are beam, column, floor slab) of the building understudy.

The results of the reconnaissance survey revealed that most of the cracks occurred at the walls and only two of the cracks occurred at the first floor column and ground floor walkway slab. The results of the non-destructive test (NDT) indicated that, the average strength of the structural elements varies between 36.8N/mm^2 and 48.2N/mm^2 respectively, this is within acceptable limit, it is therefore satisfactory.

The concrete evaluation of Emmanuel Egboga building is necessary for the proper diagnosis of successful rehabilitation work. However, urgent rehabilitation of the building by the university authority is the best action for the safety of the building.

KEYWORDS: *Concrete, Compressive Strength, Non-Destructive Test, Structural members, Cracks.*

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I. INTRODUCTION

Determination of the structural strength of a building involves the use of two methods, which are destructive and non-destructive test. The destructive test involves taking a sample of the structural element and testing in a laboratory to determine its compressive strength while the non- destructive test is about using instruments to determine the strength of a structural element without being destroyed, hence, not tampering with the overall stability of the structure. Thisinvestigation is basically to ascertain the compressive strength of the concrete using non-destructive method with the use of Schmidt Hammer.

The composition of concrete, as a composite material, are cement, sand, aggregate, water, mineral admixtures, and chemical admixtures. From usual experience in concrete testing, the results often generated from NDT are usually affected by parameters like aggregate type and size, age of concrete, moisture content, and mix proportions. NDT is a convenient test for structural members or concrete that has been into practice for many years.

In 1948, Schmidt developed the Schmidt rebound hammer test (RHT). This device is universally used because of a hardened steel hammer impacted on the concrete by a spring. The RHT is a convenient NDT, the surface of hardened concrete is struck with the hammer, and concrete compressive strength is estimated via the surface hardness rebound value.Non-destructive testing is one of the most powerful and reliable tools. The essence of conducting non-destructive test for condition assessment of the RCC structures has grown considerably in recent times, due to increase in number of structures,showing signs of distress. The standard life of RCC frame structure is considered to be 60 - 80 years. (Kumavat et al. 2014).

Emmanuel Egbogah building is the building built by Dr. Emmanuel Egbogah, in the University of Ibadan, and was commissioned by Mr. Henry OdeinAjumogobia (SAN), the former honourable minister of state for energy (petroleum), on 20th of December, 2008. (Student's information handbook, 2009).The Non Destructive Testing is being fast, easy to use at site and relatively less expensive. It can also be used totest actual structure instead of representative cube sample, test any number of points and any locations, assess the structure for various distressed conditions,detect cracks, voids, fractures, honeycombs and week locations, assess overall stability of the structure, scanning for reinforcement location, stress locations.(Kumavat*et al.*, 2014).

The occurrence of cracks in Emmanuel Egboga building is a sign of deterioration of the service life of the structure as a whole whichwas the reason for the assessment of the strength (Non-destructive test) carried out on the structural member of the building.

II. METHODOLOGY

Area of Study

The study on the investigation of the causes and solutions to cracks in buildings was undertaken in Emmanuel Egboga building, University of Ibadan. The University of Ibadan is the oldest Nigerian university, and is located five miles (8 kilometers) from the center of the major city of Ibadan in western Nigeria.

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The building is a two storey and housed the Department of Civil Engineering and Chemical Engineering. It is located at Latitude 7.43^{o}N and Longitude 3.88^{o}E. Figure 1 shows the location of the study area.

Figure 1: Map of University of Ibadan, showing Emmanuel Egboga building

Source: www.ui.edu.ng/content/ui-google-maps

The steps below shows the operation carried out in sequentially at site.

i. Reconnaissance survey: The building inspection was carried out to diagnose the cracks in the building, by looking at the whole building from a distance, walking round the building, and observation of each room to locate the structural member and taking photograph of the cracks, and their location in the building.

ii. Desk study: Desk study was performed using the architectural design plan to:

- Check the layout of the building and location of each structural member
- It was also used to create design manifest (See Table 1), and the readings were converted using table of conversion for Rebound Hammer Readings. (See Tables2 and 3 respectively).

A Schmidt hammer was used to assess the strength of the structural elements (See Plates2 and 3 respectively). The strength of each structural member was obtained by taking the average of seven recorded values of Schmidt Hammer Reading. The Non-Destructive Schmidt Hammer Test conducted on the building under appraisal comprises of the basement, ground, first, and second floor. The summary findings were presented in Table 4.

The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness generates the rebound which is directly related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

The rebound reading on the indicator scale has been calibrated by the manufacturer of the rebound hammer for horizontal impact, that is, on a vertical surface, to indicate the compressive strength. When used in any other position, appropriate correction as given by the manufacturer is to be taken into account.

iii. Data analysis: Descriptive statistical analysis was used to analyze the data obtained from the investigation of cracks.

III. RESULTS AND DISCUSSION

Emmanuel Egboga building has 53 rooms, and four floors, which are basement floor, ground floor, first floor, and second floor as shown in Figure 2. The structural frame members consist of 129 beams, 92 columns, and 240 walls in total. It is covered at the roof with aluminium roofing sheets, and contains roof gutter for proper drainage. It also contains retaining wall that links the basement floor to the ground floor.

Plate 1: Front View of Egboga Building

The observations on the cracks were that the cracks appeared due to drying shrinkage, movement due to creep, architectural design fault, foundation settlement, low density/ non-uniformity of a column at the second floor.

One of the cracks appeared at the Second Floor, Wing B, Room 3, Column 1(Grid 4A)

First observation was the wrong dimension (260 × 600mm) instead of 300 × 600mm on the plan. Also, the compressive strength at the crack side is very low, which is 23.3 N/mm^2 (i.e Grid 4A, as shownTable 1), indicating low density of concrete at this side of the column and non-uniformity.The concrete in question is not sufficiently dense, and may be due to poor mix design, bad water cement ratio, poor grading of aggregates, improper compaction and inadequate curing. **Solution:** In order to avoid exposure and corrosion of the reinforcement, which can render the column unsafe, crack in question, could be repaired by removing all loose and damaged part of the concrete, cleaning reinforcement of all rust, and re-concreting the affected area by guniting (that is, depositing concrete under pneumatic pressure).

Table 1: Rebound Hammer Readings on Second Floor Columns

S/NO	POSITION/LOCATION	DIRECTION OF TEST	REBOUND HAMMER READING(AVERAGE)	COMPRESSIVE STRENGTH (N/mm^2)
1	Grid 2A	→	44	50.4
2	Grid 3A	→	36	33.6
3	Grid 4A	→	30	23.3
4	Grid 5A	→	42	45.9
5	Grid 6A	→	42	45.9
6	Grid 7A	→	44	50.4
7	Grid 8A	→	44	50.4
8	Grid F2	→	40	41.6
9	Grid F3	→	54	60.0
10	Grid F4	→	38	37.5
11	Grid F5	→	36	33.6
12	Grid F6	→	44	50.4
13	Grid F7	→	38	37.5
14	Grid F8	→	36	33.6
15	Grid C3	→	38	37.5
16	Grid C4	→	44	50.4
17	Grid C5	→	38	37.5
18	Grid C6	→	34	30.0

19	Grid C7	→	40	41.6
20	Grid 7D	→	54	60.0
21	Grid 6D	→	48	60.0
22	Grid 5D	→	42	45.9
23	Grid 4D	→	48	60.0
24	Grid 3D	→	42	45.9
	Average compressive strength			44.3

Table 2: CALIBRATION FOR CONVERSION OF REBOUND HAMMER READINGS

R	α-90˚	α-45˚	α-0˚	α+45˚	α+90˚
20	14.9	13.7	10.3		
21	16.2	14.9	11.4		
22	17.4	16	12.5		
23	18.8	17.4	13.7	10.3	
24	20	18.6	14.9	10.5	
25	21.5	20	16.2	11.6	10.3
26	22.8	21.4	17.5	12.8	11
27	24.5	22.8	18.9	14	11.9
28	25.9	24.3	20.3	15.4	13.4
29	27.6	25.9	21.8	16.7	14.8
30	29.1	27.4	23.3	18.2	16.2
31	30.9	29.1	24.9	19.6	17.6
32	32.5	30.7	26.5	21.2	19.1
33	34.4	32.5	28.2	22.7	20.8
34	36.1	34.2	30	24.5	
35	38.2	36.1	31.8	26	
36	39.9	37.9	33.6	27.9	
37	42	39.9	35.5	29.6	
38	43.9	41.8	37.5	31.6	
39	46.1	43.9	39.5	33.5	
40	48.1	45.9	41.6	35.5	
41	50.4	48.1	43.7	37.5	
42	52.5	50.2	45.9	39.7	
43	54.8	52.5	48.1	41.8	
44	57	54.6	50.4	44.1	
45	59.5	57	52.4	46.3	
46	Over 60	59.2	55	48.7	
47	Over 60	Over 60	57.5	51	
48	Over 60	Over 60	60	53.6	
49				56	
50				58.8	

Source: Graduated Scale of Standard Table on Schmidt Hammer Test Reading

Table 3: TABLE SHOWING ANGLE OF IMPACT WITH ITS CORRESPONDING DIRECTION OF TEST

ANGLE OF IMPACT	DIRECTION
α-90˚	↑
α-45˚	↗
α-0˚	→
α+45˚	↙
α+90˚	↓

Source: Graduated Scale of Standard Table on Schmidt Hammer Test Reading

Rebound Hammer Reading Test

The summary of the results is shown in Table 4. The minimum compressive strength required in 28days is 25N/mm^2. The minimum compressive strength required in 1year is 31N/mm^2. The adequacy of a reinforced concrete structural element to support loads imposed on it, is determined by the compressive strength of concrete, dimension properties, reinforcement constituent and tensile strength of the reinforcement bars. For the buildings under investigation, Grade 25 concrete with 28day compressive strength of 25N/mm^2 is considered appropriate and adequate. This is expected to attain 31N/mm^2 in one year of the concrete age, and then marginally increase over the years. From the non-destructive Schmidt hammer rebound readings obtained for the structural elements, the average strength of the building varies between 36.8N/mm^2 and 48.2N/mm^2 respectively, this is within acceptable limit, it is therefore satisfactory.

Table 4: General Summary of Results for the Compressive Strength of theStructural Members

The general summary of compressive strength of the building is presented in the table below:

FLOOR	BUILDING ELEMENT	Average Compressive Strength (N/mm^2)
BASEMENT	SLAB	44.9
	BEAM	36.8
	COLUMN	36.9
GROUND FLOOR	SLAB	38.7
	BEAM	48.2
	COLUMN	38.6
FIRST FLOOR	SLAB	44.4
	BEAM	45.4
	COLUMN	39.7
SECOND FLOOR	SLAB	47.9
	BEAM	47.1
	COLUMN	44.3

Plate 2: Picture Showing the Schmidt Hammer and Schmidt Hammer Reading of Beam

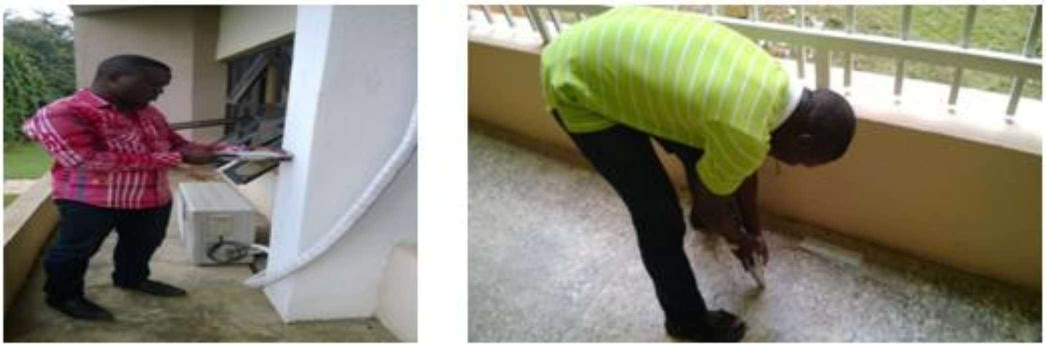

Plate 3: Picture showing Schmidt Hammer Reading of Column and Floor Slab

IV. CONCLUSION

The non-destructive tests carried out using the Schmidt hammer method shows that the basement floor, ground floor, first floor, second floor are structurally sound and will achieve its design life.

However,the findings on this building with the appearance of cracks caused by different problems, which are plaster cracks by drying shrinkage, movement due to creep, architectural design fault, foundation settlement, low density/ non-uniformity of a column should be repaired immediately by the school authorityto avoid further structural damage by these cracks as soon as possible.

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