# EMPIRICAL STRENGTHS OF CONCRETE ROOF SLABS AFTER 34 YEARS SERVICE IN NIGERIA

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*ABSTRACT*

***This paper examines the strengths of four reinforced concrete roof slabs which have been in service for over 34years. The non-destructive test hammer was used to obtain data for the empirical determination of the practical strengths of the existing structures. A total of 110 tests were performed on each slab at 11 points which were evenly spread across the slab. The results were compared with those from standard compressive strength machine in the laboratory, and subjected to statistical analysis. The final results showed that the lowest slab compressive strength was 14 N/mm$^2$ below the minimum concrete grade of 25N/mm$^2$; and percentage defective was 29.5% more than the allowable 5% in BS8110:1997. From this work their safety has not only been assessed, the scientific basis for the increase in the number of floors for standing completed buildings has also been demonstrated.***

## 1.0 INTRODUCTION

The testing of existing structure is usually related to an assessment of structural integrity or adequacy [1]. Structural health monitoring is a systematic method for non-destructive evaluation of a structure [2]. The testing of roof slabs in this work demonstrated a system of non-destructive testing of structure using the rebound hammer.

Both the electronic and print media have reported the collapse of many buildings constructed with reinforced concrete in Nigeria. Some lives have been lost in addition to the loss of the structures themselves. In the words of Okereke and Anyanwu [3], "In fact between 1971 to date, there have been no less than 50 reported cases of collapsed buildings involving the loss of no fewer than 300 lives and millions of Naira". The collapses have not been restricted to old buildings. Those under construction have not been spared. The strengths of old and new concrete, being the main local site manufactured construction material should therefore be subjected continually to close examination in order to locate the place of stresses, among the critical causes of the devastating failures. In this way stakeholders will be able to respond to the challenges before they become uncontrollable. Reinforced concrete is made up of concrete and steel. Thus when they are combined, the steel is expected to provide tensile strength and probably some shear strength while the concrete which is, strong in compression protects the steel to give durability and fire resistance. [4].

No longer are loads treated as known with precision or strengths of structures and materials regarded as similarly fixed. Both are acknowledged to fluctuate in magnitude and treated accordingly in design processes and specification [5].

On the application of load, the ratio between stress and stains is approximately linear at first and concrete behaves almost like an elastic material with virtually a full recovery of displacement if the loads are removed. Eventually, the stress curve is no longer linear and the concrete behaves more and more as a plastic material [4].

With given proportions of aggregates, the compressive strength of concrete depends primarily upon age, cement content and water/cement ratio, an increase in any of these factors producing an increase in strength [6].

The unbridled importation of sub-standard materials and local production of poor quality materials [3] gives credence to the notion that many, building failures have been attributed to bad materials and workmanship during construction. Some had to do with a refusal to adhere to given specifications. The collapses which occurred in old buildings were attributed to an increase in the number of floors and hence an increase in the live loads after construction. The purpose of this paper is to demonstrate the empirical approach to the establishment of the practical strength of structures that have been standing for a long time after successful construction processes. It not only shows how to assess the safety of such a structure but also provides a scientific basis for any increase in the number of floors of a building.

## 2.0 MATERIALS AND METHODS

The professional specifications for testing whole structures, finished parts of structures or structural components to ensure that they have the required standards of serviceability and strength have been used to execute the work at hand. They include those of CP110, British Standard, Code of Practices for the structural use of Concrete (1972) [8] and BS8110 (1997), Structural use of Concrete, Code of Practice for design and construction [7].

If the results of check tests show that the quality of concrete is inadequate or show some other defects, the Engineer may require full loading tests to be done [8].

To carry out the check tests, the electromagnetic measuring device, gamma radiography, ultrasonic tests, cutting cores out of the existing structure for crushing or the rebound hammer test may be used [1]. The readily available equipment which has been used for the test was the rebound hammer.

The tests were done on the four roof slabs of the Faculty of Engineering workshops of the Cross River University of Technology, Calabar.

The tests were performed between 19/12/07 and 23/12/07 by a team of engineers and technicians. The construction of the workshop roof slabs was completed in 1973, 34 years ago.

### 2.1 Test Procedure

Each slab was divided into grids to provide 11 test points as shown in figure 1.0. The rebound hammer was applied to obtain ten readings at each nodal point and the average node reading was obtained. This was done for all the nodes. The compressive strengths of the concrete at the different nodes were then obtained from the chart that came with equipment.

The physical measurements of the relevant structures were made with tape. The lengths and breadths of the slabs as well as the heights from the slabs to the adjourning roofs were also made. The same procedure was repeated for the remaining 3 slabs. A total of 440 tests results were obtained from the 4 slabs tested. The structures were visually inspected for crack and other visual defects.

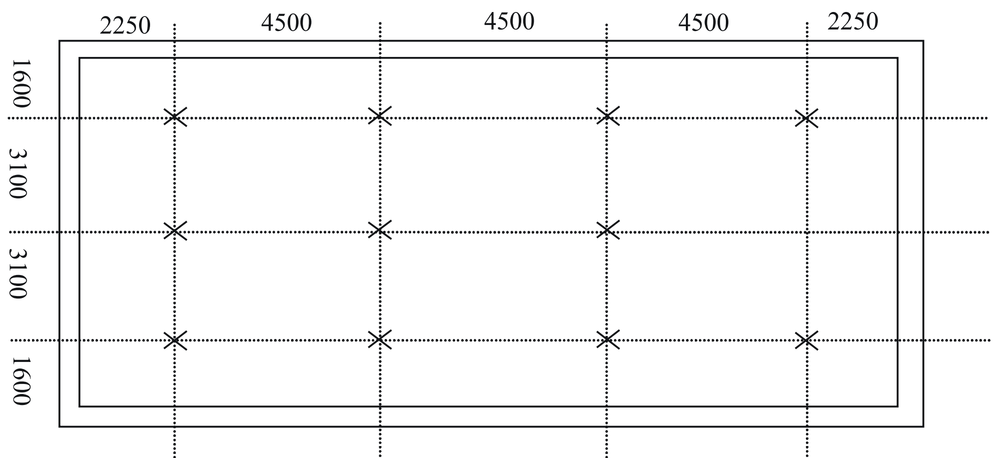


Figure 1.0: Typical slab configuration showing test positions (Not to scale)

## 2.2 Calibration

The equipment was calibrated at the materials laboratory. Five concrete test cubes were used for the test. The hammer was applied ten times on one cube and the average reading for the cube was obtained. The same procedure was adopted for the other cubes.

The five cubes were tested to failure. Their crushing strengths were then computed. The correlation coefficient of actual crushing strength of the cubes and the hammer readings was computed.

The results obtained from the equipment chart and those obtained from compressive strength testing machine in the laboratory were compared to establish equipment reliability. With a correlation coefficient of 0.92 the equipment is highly reliable [9].

Table 1.0: Laboratory cube strength tests with hammer and crushing

| S/N | LOAD ON CUBE KN A | STRENGTH OF CUBE ($N/mm^2$) B | REBOUND HAMMER NO C | CUBE STRENGTH BY HAMMER $N/MM^2$ D | B/D (%) |
|---|---|---|---|---|---|
| 1 | 430 | 19.11 | 25 | 20-22 | 91 |
| 2 | 400 | 17.78 | 26 | 24-30 | 66 |
| 3 | 500 | 22.22 | 25 | 20-22 | 106 |
| 4 | 490 | 21.78 | 25 | 20-22 | 10 |
| 5 | 590 | 26.22 | 20 | 24-30 | 97 |

Correlation coefficient obtained was 0.92

### 2.3 Test For Significance of Correlation Coefficient, r

Using Fisher's F – test, [10]

$$f = \frac{1+[r]}{1-[r]}$$

For r = 0.92,

$$f = \frac{1+[0.92]}{1-[0.92]} = 24.0$$

Critical $f_{0.05}(9,9) = 4.03$

*Since the computed f-value (24.0) is greater than the critical f-value (4.03), we reject the null hypothesis of no significant relationship and conclude that* ***there is significant relationship between cube strength and hammer strength.***

## 3.0 DISCUSSION

The analyses of the non-destructive tests data in table 2.0 gave a maximum strength of 29.45 $N/mm^2$ with a standard deviation of 1.47$N/mm^2$ and a minimum of 14$N/mm^2$ with a standard deviation of 1.79$N/mm^2$. An engineer who must be safety conscious must examine the least strength which ranged from 20$N/mm^2$ to 14$N/mm^2$ after 34 years service. This strength fell gravely below the allowable specification of 25$N/mm^2$ after 28days for grade 25 concrete with normal weight aggregates [11]

The roof felt had deteriorated leaving the roof slab exposed with serious cracks. The summary of statistical analysis for the non-destructive strength measurements on the four slabs are presented below in table 2.0.

Table 2.0: Summary of Rebound Hammer Test Results from workshops 1 – 4.

| Workshop | Least ($N/mm^2$) | Mean ($N/mm^2$) | Standard Deviation | Coeff of Variation (%) | Visual Examination |
|---|---|---|---|---|---|
| 1 | 20 | 25.6 | 1.13 | 4.41 | Cracks, roof felt destroyed |
| 2 | 20 | 29.45 | 1.47 | 4.99 | Same as above |
| 3 | 20 | 25.64 | 1.04 | 4.06 | Same as above |
| 4 | 14 | 24.00 | 1.79 | 7.46 | Same as above |

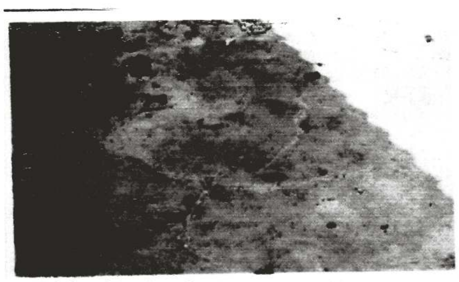

Fig. 2a: **Hairline / Random Cracks on the Roof Slab**

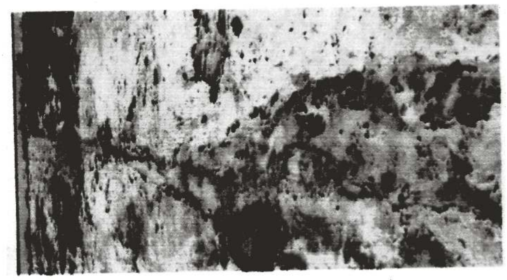

Fig. 2b: **Cracks across the Roof Slab**

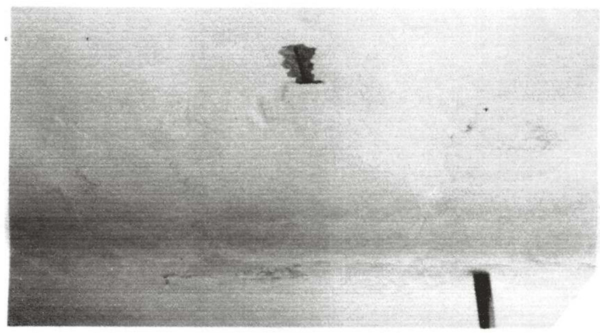

Fig. 2c: **Cracks and pealing of Concrete cover at the Soffit exposing reinforcement**

Fig. 2d: **Members of Staff of Civil Engineering Department carrying out undestructive test on Roof Slabs of Workshops 1 - 4 to determine the concrete strength**

## 4.0 CONCLUSIONS

With the least strength being $14N/mm^2$ after 34 years as against the recommended design strength $25N/mm^2$ [7], in 28 days the slabs are not safe and need to be strengthened to carry any additional load. In fact the slabs need maintenance attention urgently because they are not only very weak but also have cracks with roof felt protection which have deteriorated to nothingness.

With results like this a stakeholder is in a position to make rational choices as to whether or not to increase the load on the slabs or increase the number of floors of the buildings. All structures needing modification should be subjected to tests similar to this before alterations are attempted.

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