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Assessment of Concrete Quality of Reinforced Concrete Structural Elements of University Buildings using Schmidt Hammer

Akingbonmire, Samuel. L.
Department of Civil Engineering, The Federal University of Technology, Akure, NIGERIA

ABSTRACT: *The quality of concrete in reinforced concrete structures can be tested either by destructive or non-destructive technique. For structures under use, non-destructive technique is preferred simply because the method affords little or no destruction of the structural elements under investigation. Schmidt Rebound Hammer test, which is one of the commonest non-destructive tests was used to assess the reinforced concrete structural elements of two University Hostels labelled A and B. From the investigation of the concrete quality according to IS 13311-2:1992, it was discovered that for the selected elements considered in Hostel A, 89% of the ground floor columns are of fair hard concrete and 11% are of good concrete layer; 67% are of very good layer while 33% are of good layer for slab and 3% of the beams are of fair quality concrete while the rest are of good qualities. However, for Hostel B, 8% of the ground columns are of good hard concrete, 78% are of fair hard layer and 13% are of poor concrete layer, while 56% are of good hard layer and 44% are of very good layer for slab and 51% are of good hard layer and 49% are of very good layer for beams. Because of the variability of the quality of concrete of the assessed structural elements, more non-destructive tests like ultrasonic pulse velocity test, infrared thermography, concrete tester and surveyor should be conducted. As well, durability tests on the concrete like chloride penetration test, carbonation test, and petrographic analysis should be carried out in order to ascertain the durability of the concrete elements as failure of this may directly or indirectly affect the serviceability of the buildings.*

KEYWORDS: r*einforced concrete, non-destructive techniques, Schmidt rebound hammer.*

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I. INTRODUCTION

As specified in [1], the basic aim of the design of any structure is to make sure that the structure is fit for its purposes throughout its life span. This, therefore, can only be achieved if many factors are considered accordingly right from the conception stage to the construction stage. This means that structures must be well designed and constructed by professionals so as to achieve the basic aim. The design should accommodate all the principles of structural design requirements such as the limit states (ultimate and serviceability), durability, fatigue, fire resistance and lightning. The design engineer must make sure that the structure is safe **vis-à-vis** the applied loads [2]. These loads may either be dead or live. The dead load includes the self- weight of the structure and any permanent material placed on it such as tiles, roofing materials and walls. However, the live loads are any other loads apart from dead loads which include the weight of the occupants such as the people, furniture and goods; snow loads, etc. [3]. All these loads must be taken care of during the planning stage of the structure. When these are observed and applied accordingly, the structure is safe *ceteris paribus.* After the construction and the structure is in use for a longer period, it tends to deteriorate over time and if not well managed on time, an undesirable and unpalatable occurrence called collapse may happen.

Collapse of buildings are so prevalent especially in Nigeria. When a building collapses, there may be loss of lives and properties. For example, in 2019, Lagos State, Nigeria, had the highest rate of building collapses, about 43 incidents (59% were existing, 41% under construction) [4]. This accounted for 39.53% of the total numbers of collapsed buildings in Nigeria. Even in year 2020, the COVID-19 era, an ongoing eight story building under construction in Yardua drive in Owerri, Imo State collapsed trapping about 40 workers (Fig. 1). Members of the Red Cross assisted in rescuing some of the trapped workers. Some of the survivors stressed that the pillars (columns) were not enough to carry the weight of the building and that cracks were noticed before the day of collapse which was promptly reported but was neglected ignorantly by the engineers in charge of the site.

Fig. 1: 2020 Owerri building collapse [5]

In the world, there are numbers of cases of collapse. Examples are the collapse of Xinjia Express Hotel, China, killing 29 people (Fig. 2) and Caprigliola collapse, Italy [6] causing only minor injuries to two truck drivers (Fig. 3). The low traffic volume was due to the Corona Virus quarantine. Many factors have alluded to building collapse. Incorrect materials selection, design errors, poor construction, chemical attack, poor supervision, inadequate quality control, external factors, etc. are some of the causes [7]. Apart from these, poor maintenance culture especially in the developing world is a disease that needs cure, as noted by [8], [9], [10] and [11]. Therefore, there is a need to constantly monitor and maintain the health of structures.

Fig. 2: 2020 Xinjia express hotel Collapse [12]

Fig. 3: Caprigliola bridge [13]

II. LITERATURE REVIEW

2.1 NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) has widely been adopted by engineers as preference is given to sparing the structure in use during testing than to destroy the tested member [14]. This is the major objectives of NDT. It affords the evaluation of the structure without destroying the serviceability of the part of the structure or the whole system. Apart from being less expensive and safe, NDT also reduces environmental risk [15]. To test for the integrity of structures, several NDTs are available. They are visual testing, surface hardness testing, ultrasonic testing, penetrant testing, magnetic particle testing, radiographic testing, Eddy current testing, thermal infrared testing, acoustic emission testing, etc. [16], [17]. However, for this investigation, surface hardness testing (Schmidt hammer test) was used.

2.2 THE SCHMIDT REBOUND HAMMER

The Schmidt rebound hammer (Fig. 4) is a common equipment used for several purposes. As given in [18], it is used to determine concrete uniformity, indicate areas where the quality of concrete is poor and to assess the strength of concrete, only if a correlation is generated between compressive strength and rebound index.

Fig. 4: Schmidt rebound hammer

The equipment has a steel loaded hammer in which when pressed against the member to be tested at a right angle either upwards or downwards, vertical or horizontal, strikes the steel plunger in it. The rebound number or index is read on a linear scale at the back of the instrument while the hammer is still in the position of impact. As a rule, ten readings were taken on the member. The average of these is used as the rebound number of the concrete. Any reading that was differing by more than six units from the average of the ten readings was discarded. When two or more readings differed from the average by six units, the entire sets of the readings were discarded and ten new readings were taken afresh. The rebound number is affected by so many factors such as the smoothness of the surface of the concrete, the age of the concrete, the temperature, the moisture content, surface carbonation, aggregate, air voids, steel reinforcement and calibration of the rebound hammer [19]. For example, the higher the carbonated surface, the higher the rebound number. Also, the higher the moisture content of the concrete, the lower the rebound number and with a rough surface, the rebound number will be low while giving high rebound number with a smooth surface concrete. The quality of concrete as given by [20] (Table 1) classified concrete quality into poor, fair, good and very good concrete depending on their respective rebound number or index.

Table 1: Concrete quality with corresponding rebound number [20]

Average Rebound Number	Quality of concrete
Above 40	Very Good hard concrete
30 – 40	Good concrete
20 – 30	Fair concrete
Below 20	Poor concrete

III. METHODOLOGY

The two University Hostels, labelled A and B, that were considered for the investigation are as shown in Figs. 5 and 6 respectively. Both were built around the same time in 2010.

Fig 5: View of Hostel A

Fig. 6: View of Hostel B

Hostel A has 72 columns, 44 first floor beams and 18 slab panels while Hostel B has 161 columns, 89 beams and 32 slab panels. The procedure of [21] was followed strictly for the application of the rebound hammer for collection of the rebound numbers. Ten readings were taken by the rebound hammer on each structural element (Figs. 7 and 8).

Fig. 7: Field investigation on a column

Fig. 8: Field investigation on a beam

IV. RESULTS AND DISCUSSIONS

For Hostel A, Fig. 9 is the plot of rebound number for the columns and Fig. 10 shows the concrete qualities of the columns. From these plots, the average rebound number is 26.08 and their standard deviation is 2.95. The minimum and maximum rebound number is 20.40 and 34.40 respectively. Using [20] classification, 89% of the ground floor columns are of fair hard concrete and 11% are of good concrete layer. With these, it is suggested that proper check-up should be done on the columns by using more NDT methods and compare the results accordingly.

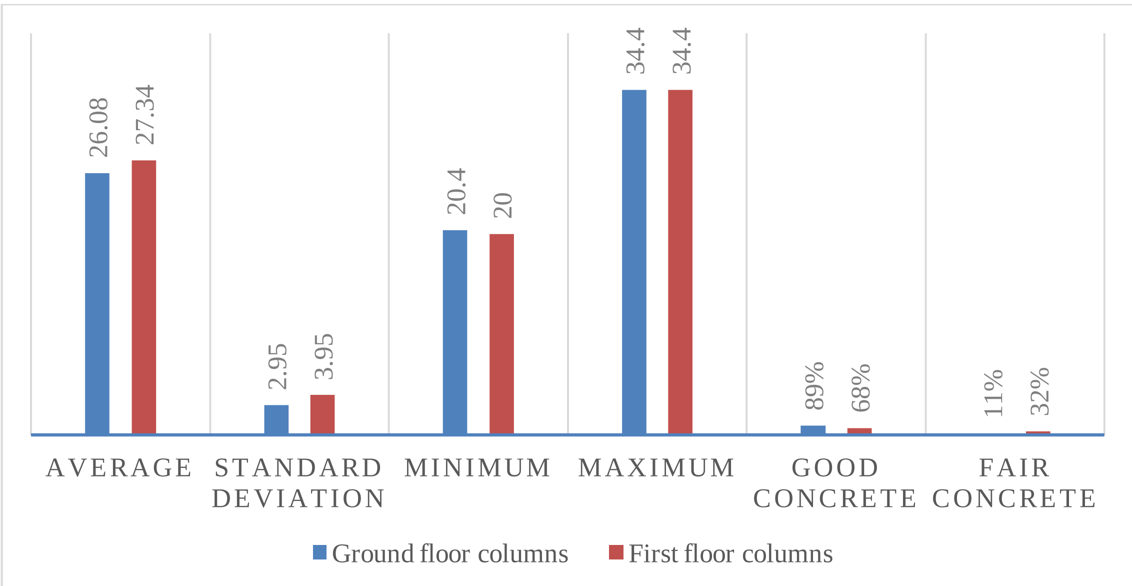

Fig. 9: Rebound number plot for ground and first floor columns for Hostel A

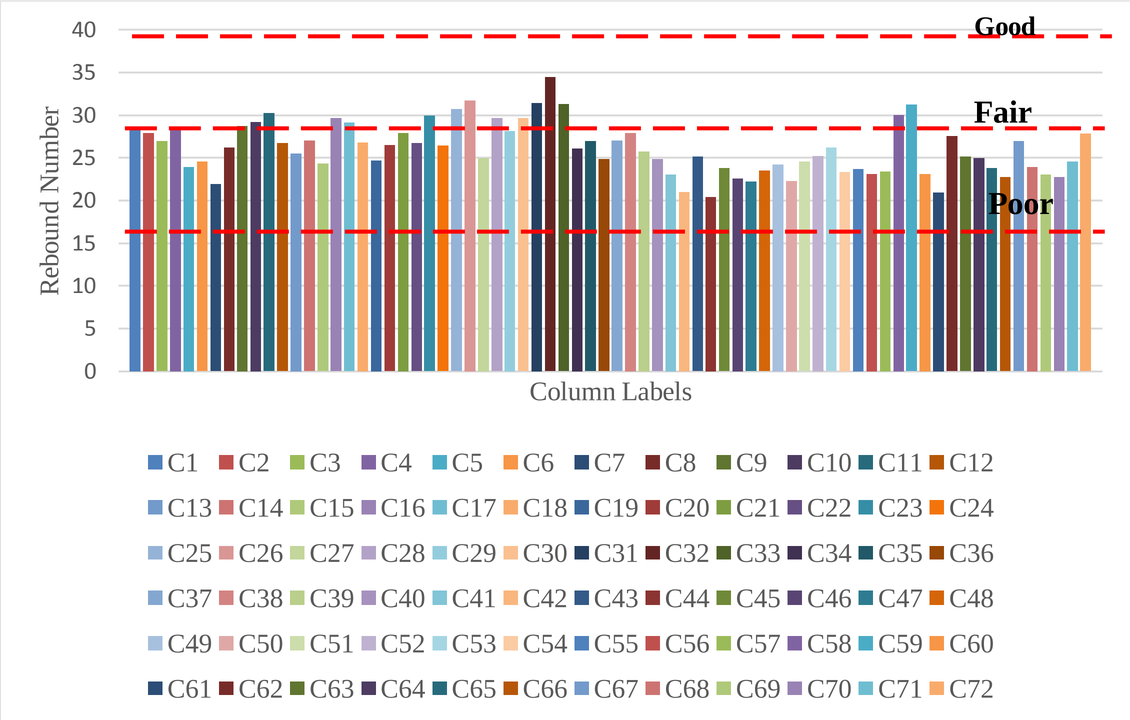

Fig. 10: Concrete qualities for ground floor columns for Hostel A

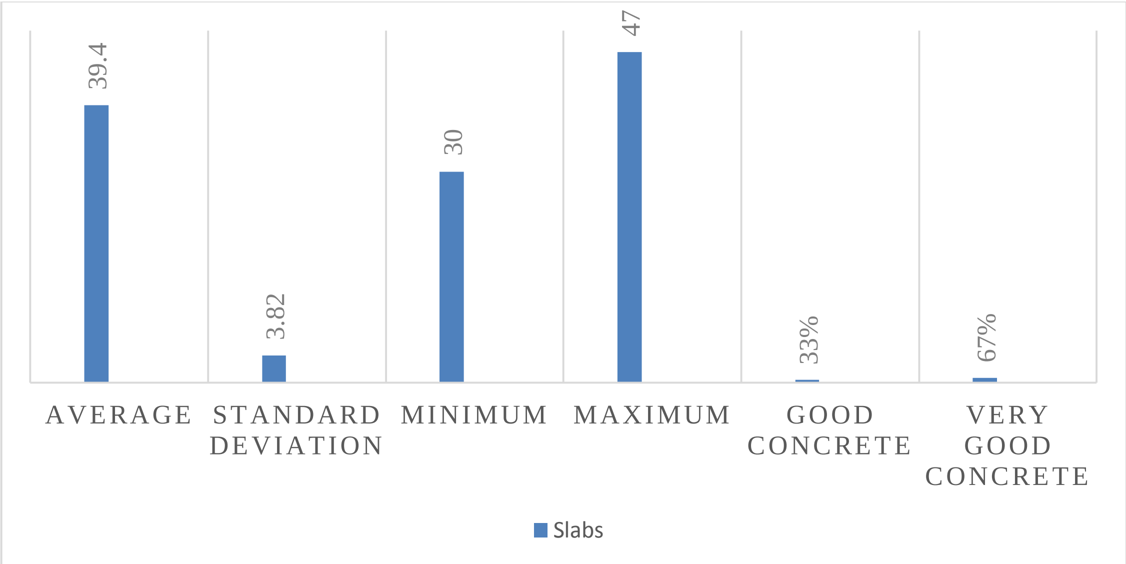

Fig. 11: Rebound number plot for slabs of Hostel A

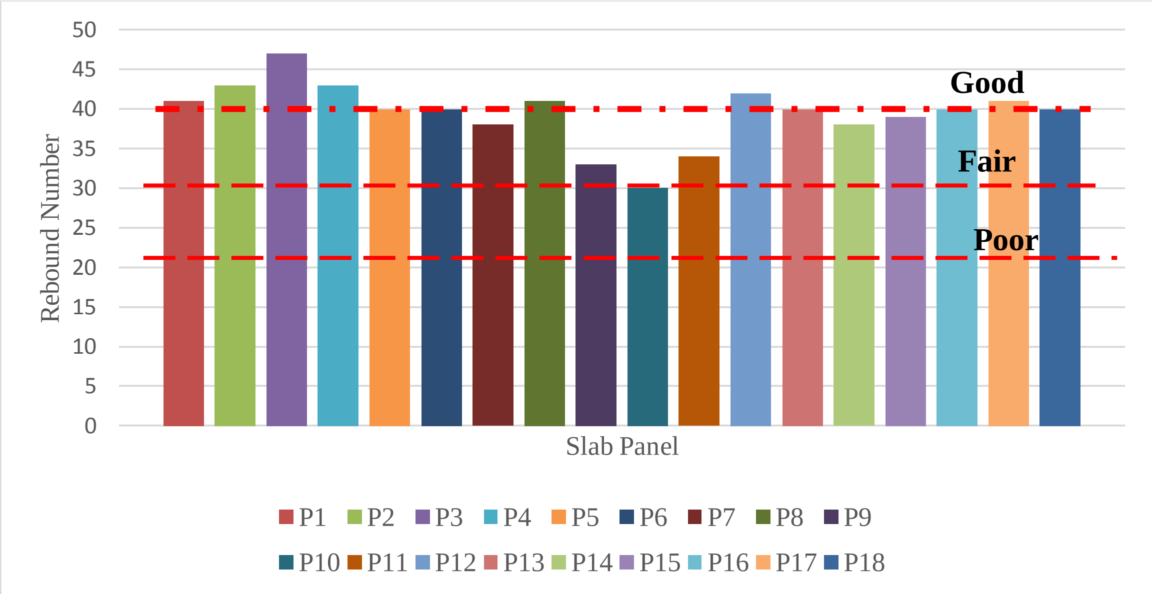

Fig. 12: Concrete qualities for Slab of Hostel A

As shown in Figs. 11 and 12, the panels of the slabs have their average rebound number to be 39.4 while their standard deviation is 3.82. Fig. 12 reveals that the slab panels are excellent as 67% are of very good layer while 33% are of good layer. The concrete of the slab is of high compressive strength judging by these rebound number values. However, for the selected beams, in Figs. 13 and 14, the minimum and the maximum rebound values are 24.0 and 38.0 respectively, while having their average as 32.9 and standard deviation as 3.07. Similarly, it can be observed that only 3% of the beams are of fair quality concrete while the rest are of good qualities. This shows that the concrete qualities of the beams are in line with the required standard and the beams can still fulfil their intended purposes. However, comparing the qualities of the concrete of the columns, beams and slab (Fig. 15), the concrete qualities of the slab panels are far better than both the concrete qualities of the beams and columns, with the columns giving the worst strength, though fair.

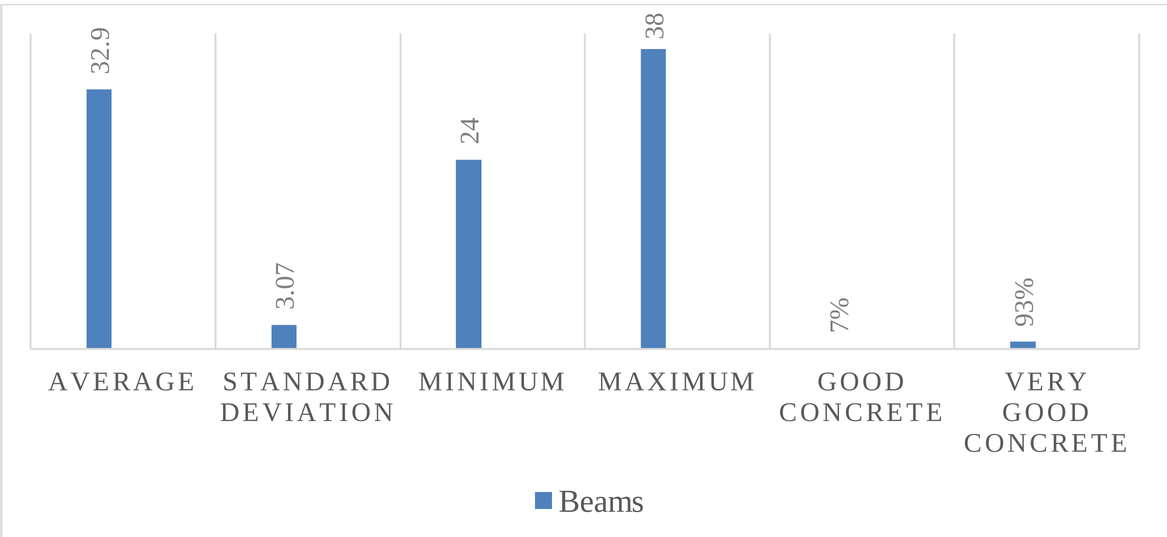

Fig. 13: Rebound number plot for first floor beams of Hostel A

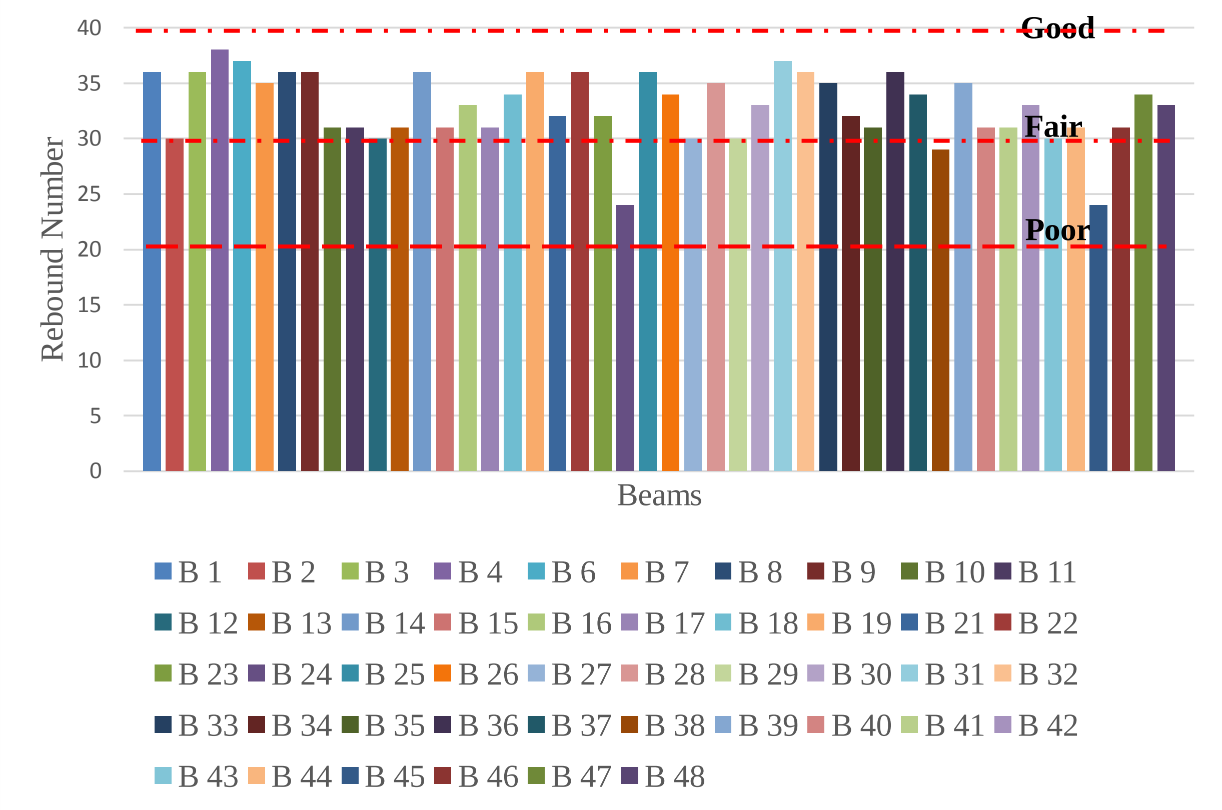

Fig. 14: Concrete qualities for first floor beam labels of Hostel A

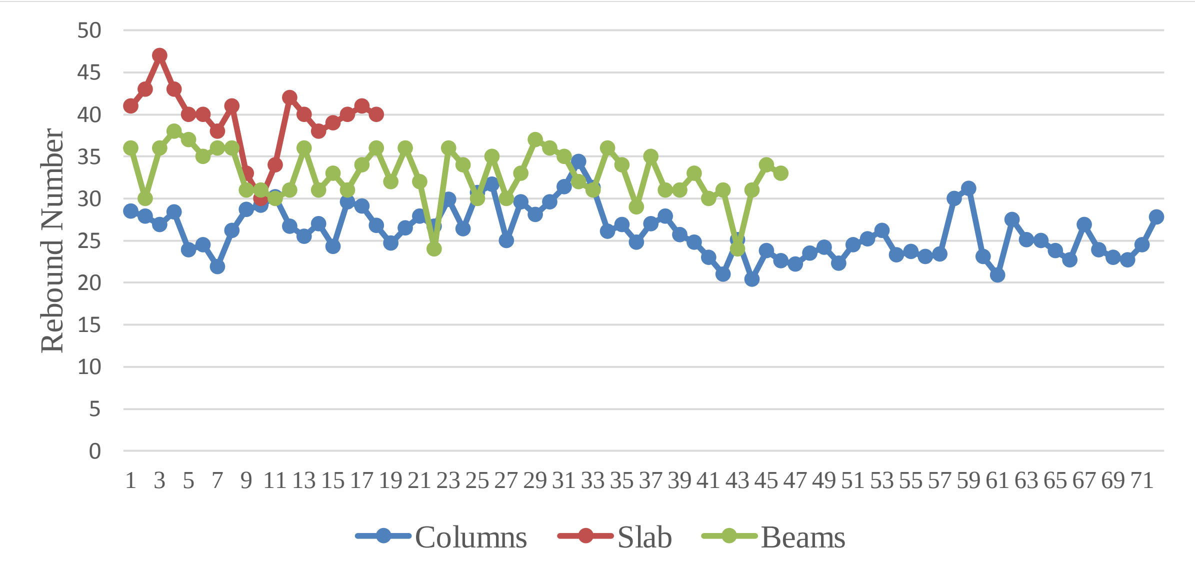

Fig. 15: Comparison of Rebound Numbers for Columns, Slab and Beams of Hostel A

However, for Hostel B, Fig. 16 depicts the plot of the rebound number columns. The average rebound number is 24.5 with a standard deviation of 3.8. The minimum and maximum rebound number is 13.4 and 33.0 respectively.

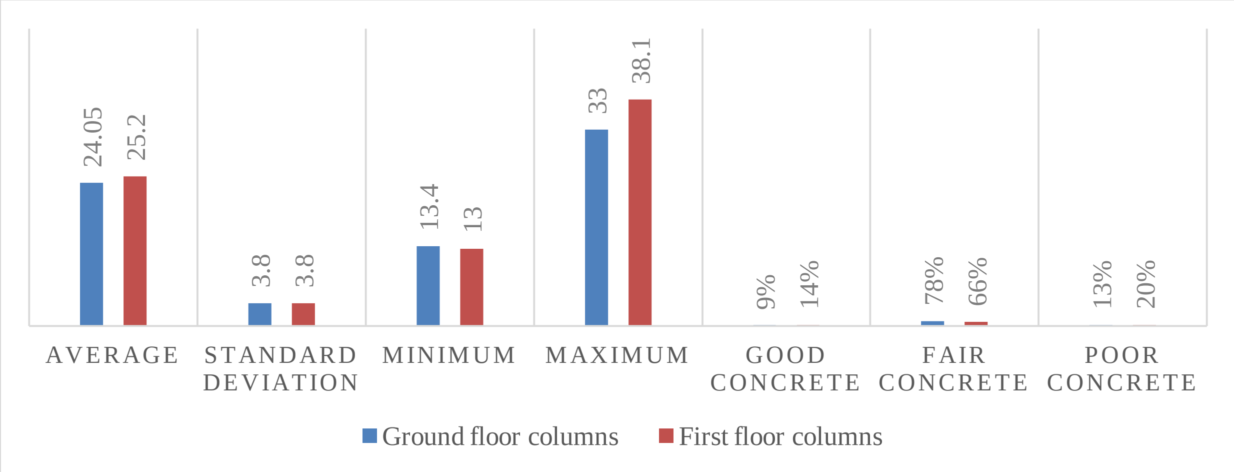

Fig. 16: Rebound number plot for ground and first floor columns for Hostel B

With [2] and Fig. 17, it is observed that only 8% of the ground columns are of good hard concrete, 78% are of fair hard layer and 13% are of poor concrete layer. The differences in the quality of concrete of the columns imply that regular non-destructive test should be carried out for prompt maintenance so that the building will still be fit throughout the working life. Similarly, as for the slab, the average rebound number is 28.8 for the slab while their standard deviation is 3.44. The minimum rebound number is 30.00 while the maximum rebound number is 47.00. It is observed from Fig. 18 that the slab has 56% good hard layer and 44% very good layer. All the panels of the slabs give excellent results. For the first floor beams, the average rebound number is 29.3 while the standard deviation is 2.57. The minimum rebound number is 22.00 while the maximum rebound number is 35.00. From Fig. 19, the beams have 51% fair hard layer and 49% very good hard layer.

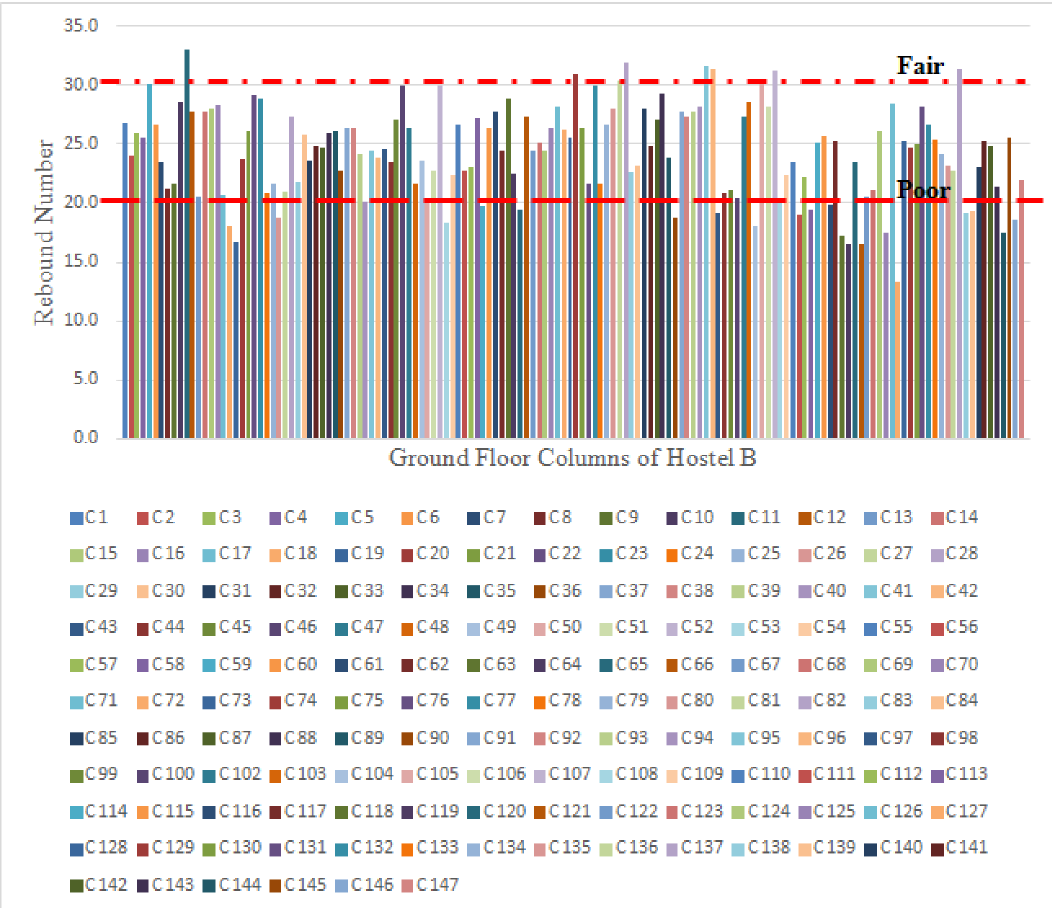

Fig. 17: Concrete qualities for ground floor columns of Hostel B

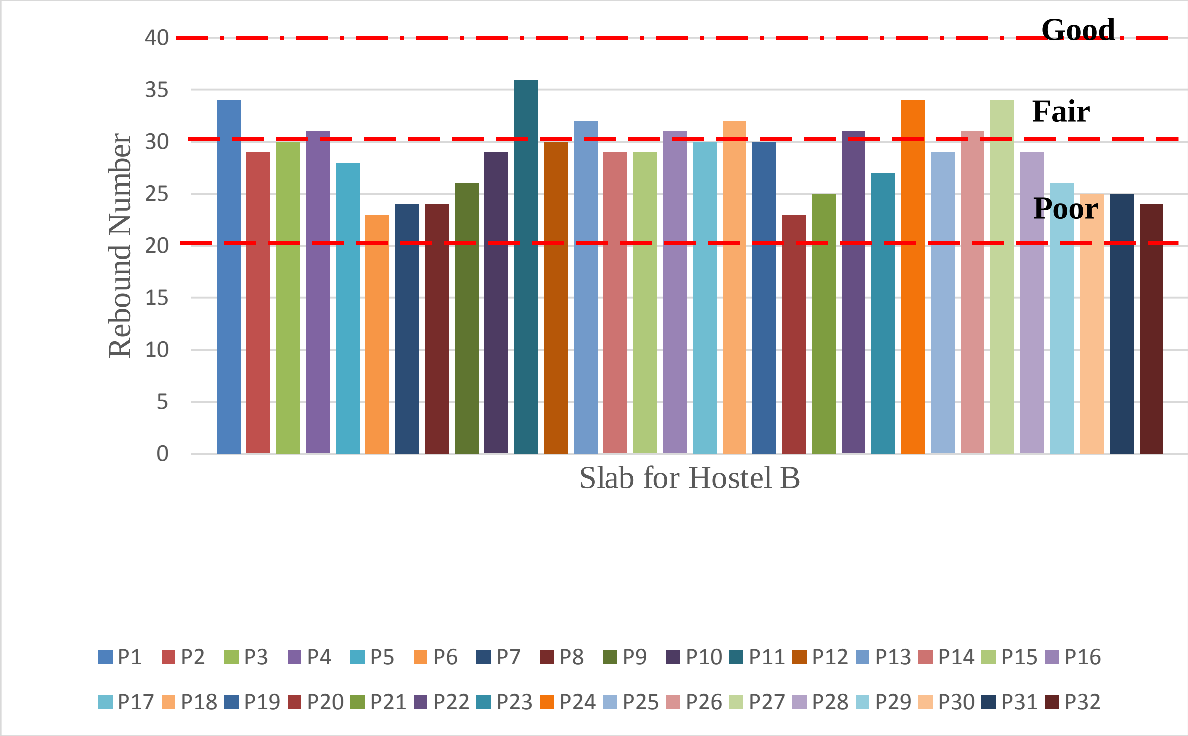

Fig. 18: Concrete qualities for Slab of Hostel B

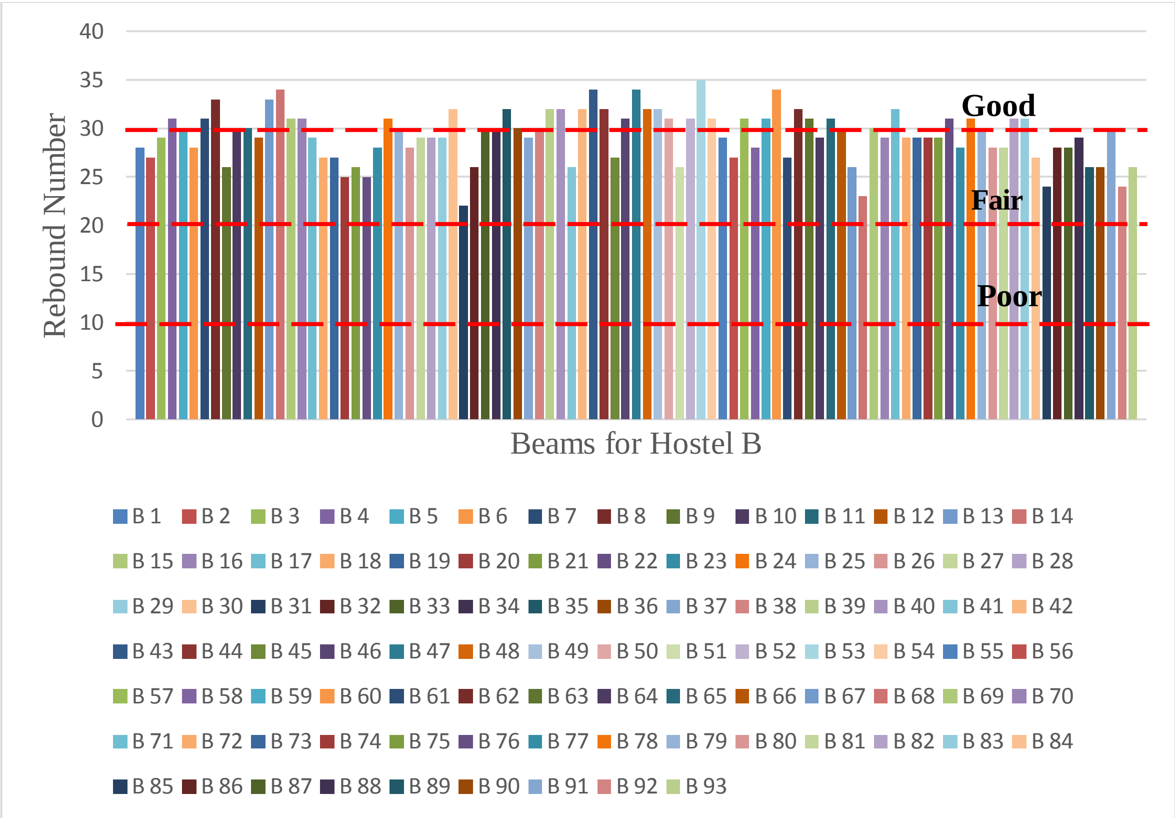

Fig. 19: Concrete qualities for Beams of Hostel B

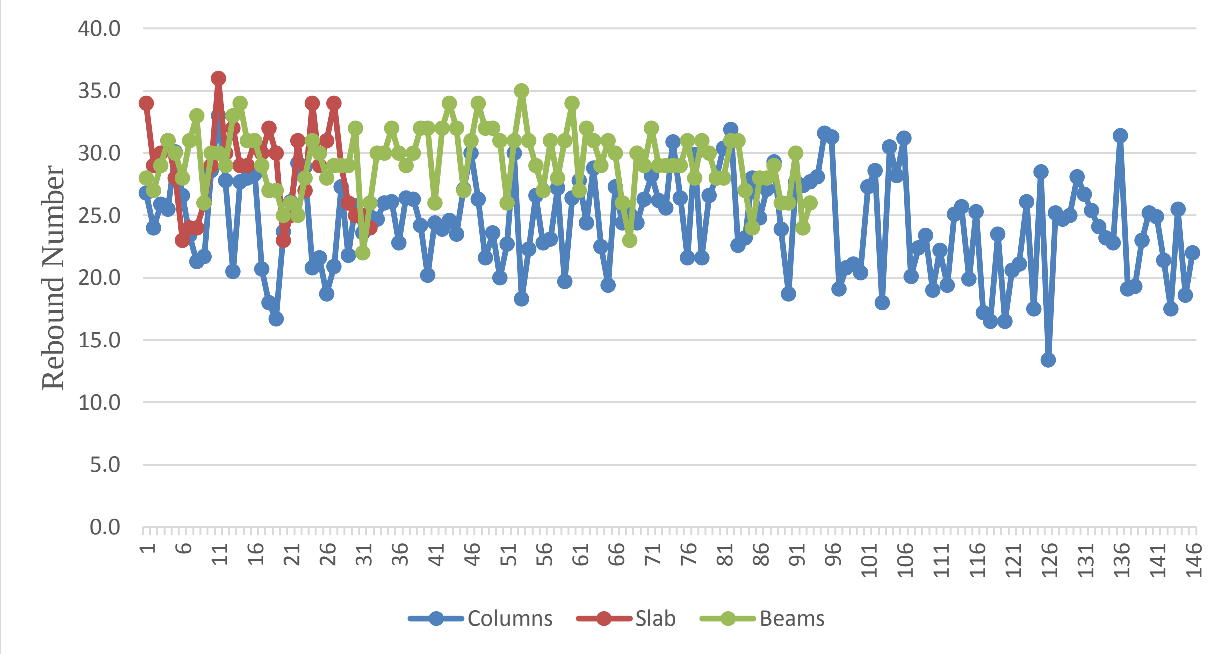

Fig. 20: Comparison of Rebound Numbers for Columns, Slab and Beams for Hostel B

Considering Fig. 20, which gives the comparison of the rebound number for the structural elements considered in Hostel B, it can be seen that the slab panels give better rebound number than the beams and the columns. Meanwhile, by comparing the rebound number for the two Hostels as shown in Fig. 21, the rebound values for slab in Hostel A are far better than all other elements.

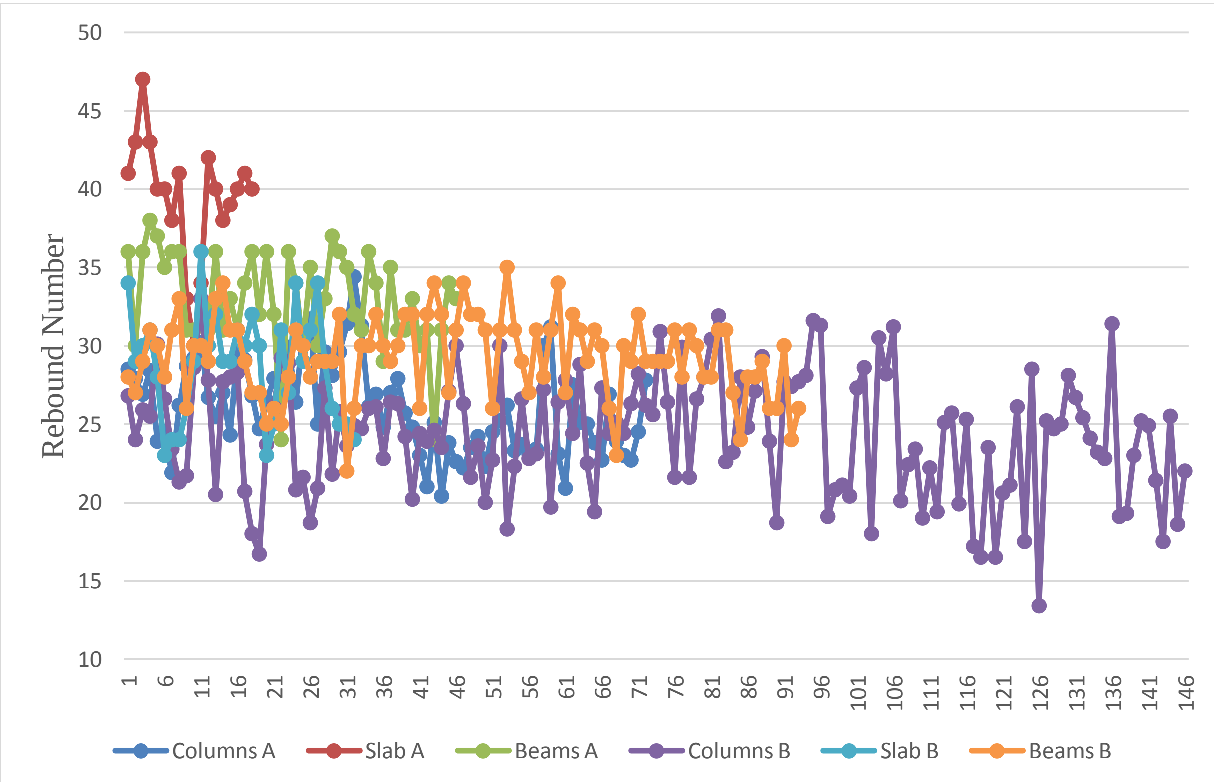

Fig 21: Comparison of Rebound Numbers for Columns, Slab and Beams for Hostel A and B Hostel B

V. CONCLUSION

In this investigation, Schmidt Rebound Hammer was used to examine the concrete qualities of two University Hostels, and the following conclusions are made:

1. Non-destructive technique is a fast method of assessing the quality of structural elements of reinforced buildings.
2. For comparison, alternate non-destructive equipment like ultrasonic pulse velocity test, infrared thermography, impact echo testing, concrete tester and surveyor should be used.
3. Among the structural elements of the two hostels, the rebound number for slab in Hostel A is higher than others while the columns in Hostel B gave lowest rebound values.
4. The rebound value of beams in Hostel B gave excellent rebound values than Hostel A because 51% of the beams are of good hard layer and 49% very good layer while in Hostel A, 3% of the beams are of fair quality concrete while the rest are of good qualities.
5. Judging from the rebound values of the structural elements of the two Hostels, the concrete qualities are generally fair but quick attention should be given to those elements that gave low rebound values so that the structural integrity of the buildings can be sustained to a high degree.

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