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# Reliability Comparison of Schmidt Rebound Hammer as a Non-Destructive Test with Compressive Strength Tests for different Concrete Mix

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## Abstract-

One of the most important concrete properties for structural concrete design or re-design is the compressive strength, it gives information on the characteristics of concrete. This strength measure is obtained through standardized crushing tests on cast cubes, the cubes are produced alongside the construction of concrete elements on site however they are not available for strength testing of existing buildings hence the need for non-destructive test methods. Schmidt's Rebound Hammer is a non-destructive test which is used to assess the compressive strength of concrete using rebound index. Surface hardness test was done on different concrete mix and compared with cube compressive strength tests. The changes in one variable explained by the change in a related variable as given by the R-squared are 93.79%, 99.42%, 86.8%, 1% and 98.5% for Mix 1, 2, 3, 4 and 5 respectively. It is noted that for proper result from non-destructive tests, more than one should be implored and the model calibration should be based on actual compressive strength.

**Key words:** Rebound Hammer; Non-destructive test; Compressive Strength; Concrete.

## 1. Introduction

The recent collapse of buildings under construction generated renewed interest in testing concrete in place; not for collapse investigation, but for determining whether concrete is strong enough for form stripping and ultimately structural use. It is becoming obvious how ineffective existing practice of testing the compressive strength of cubes is with respect to modern concrete construction having in mind concrete structures are built hastily because of advancement in technology and sometimes 28 days seems too long to wait for cube strength results in the face of present pace of concrete construction, more so cube strength is not always an accurate representation of the in-place strength. To overcome these shortcomings, considerable research has been done to develop reliable methods of testing concrete in-place though acceptance of these methods has been limited.

Codes and standards still give preferences to the testing of concrete cubes & cylinders, but contractors are beginning to rely more on the rapid in-place tests to decide when forms can be safely removed. ACI report 306, published in 1978, [1] recommends use of in situ testing to determine in situ strength and to indicate when forms and reshores may be pulled. In the 20th century, our day to day activities has been characterised under rapid technology development. The best of concrete technology can only be seen with in depth knowledge of concrete materials through its choice, proportioning, mixing, compaction and curing. To ensure structural safety and reliability, all the above processes on concrete has to be accompanied with advance testing technologies [2].



Modern concrete construction has developed greatly during the past 60 years, but one aspect has remained essentially unchanged; the use of moulded cylinders & cubes tested in compression to determine the strength value of concrete in a structure [3, 4, 5, 6]. Recently, however, the testing of concrete in place has become more widespread in advanced countries. Methods are five types: rebound, maturity, pulse velocity, penetration and resistance pull-out. Concrete is a product of an infinite combination of suitable materials and to attain its full potential, effectiveness of curing procedures and consolidation is key. There are lots of environmental degrading factors that can be a threat to its good durability property, in view of this; test methods needs to be situated to check the in-place properties of concrete from time to time. For a continuous evaluation during service life, non-destructive properties check must be used so as not to have a negative effect on the function of the structure [7].

With respect to concrete, non- destructive test can be simply defined to tests that do not have any effect on the concrete and function of a structure. For some, they are tests that do less damage to the structure than drilling of cores. A list of Non Destructive tests methods includes Pull-Out test (lock-test and capo-test), Internal Fracture test, Break-off test, Pull-Off test, Penetration resistance test, Surface Hardness, Screed test, Dynamic response, Ultrasonic pulse velocity, Acoustic emission, Radiograph, Radiometric, Carbonation depth, Surface permeability, Half-cell potential, Thermography, Resonance Frequency etc [8, 9, 10, 11, 12]. Strength estimation in existing constructions are made possible through various alternatives using Non-destructive tests and destructive tests DT (cores) [13, 14, 15, 16]. Non-destructive testing methods differ to each other due to what each is used for; the quality of concrete in its entirety are determined with dynamic/vibration methods like ultrasonic pulse velocity and resonance frequency. Some other ones which test the compressive strength of concrete are surface hardness, penetration, pull-out and rebound. Schmidt Rebound Hammer can be used for numerous things as shown in figure 1 below [17, 18, 19]; factors that can significantly influence it are also included [20]. Concrete has been a regular building material and there is no act on its strength optimization by engineers and other specialists until 1900. Advancement and strength improvement has given a new meaning to “high strength”. The American Concrete Institute defined high strength concrete as concrete with compressive strength not less than 41 MPa [21]. Tests on compressive strength are made at 28 days traditionally but in recent times, high rise structures construction schedule allows that structural elements in lower floors are not subjected to full loadings for a year or more, as a result of this, compressive strength can be based on 56 or 90 days result making use of strength gained after 28 days. At 90 days, concrete is reported to attain upper strength limit of 172 to 207 MPa with some estimates for very special materials ranging as high as 731 MPa [22]. The aim of this study is to evaluate the in-place compressive strength of different concrete mixes using Non Destructive Evaluation (NDE) or Non Destructive techniques (NDT). This study test the reliability of Non Destructive Technique, formulate empirical relationship between Non Destructive Evaluation (NDE) test on normal and high strength concrete (HSC) and generate Correlation curves for different methods employed.

## 2. Materials and Methods

The materials used in this study are fine and coarse aggregate, silica fumes, Superset Cement and Conplast® SP430 Superplasticizer. The fine and coarse aggregate are gotten from the southwest zone of Nigeria. Elephant Portland cement brand was used for this research due to its fast setting characteristic, it combines three good properties of early setting, early strength and unique latter strength.

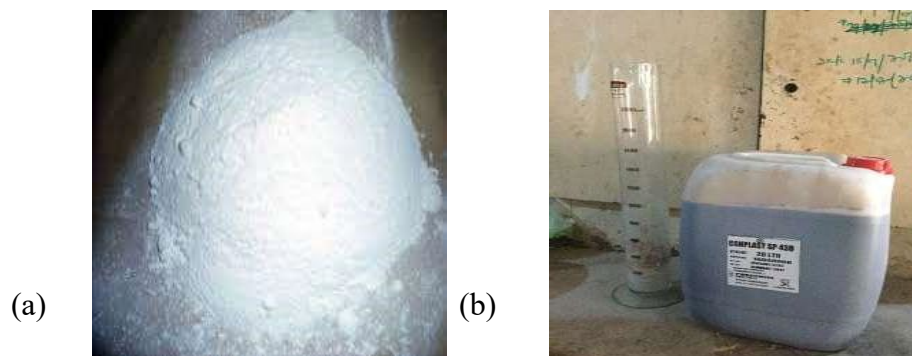


Figure 2: (a) Silica Fume (b) Conplast® SP430 Superplasticizer

Conplast® SP430 (G) a Liquid type superplasticizer was used. It complies with BS: 5075 Part 3 and ASTM-C-494 Type 'F' [23, 24] as high range water reducing admixture and Type G at high dosage. It has specific gravity 1.20 to 1.22 at 300°C and no Chloride content as per IS: 9103-1999 and BS: 5075. Silica fume was used as a cement replacement for one of the mix ratio in this experiment. Silica fume can be used in different dosages between 1 and 20% of the cement weight. The dosage used in the mix design of this research was 10%. Thirty cubes were cast and tested with Schmidt Rebound Hammer at ages of 7, 14 and 28 days as shown in Figure 3. On the same specimens' compression test were conducted on digital compression testing machine of high capacity. The Mix design for each of the mix ratios involving all materials used is as presented in Table 1 below.



Figure 3: Schmidt Rebound Hammer Test points.

Table 1: Mixes for different Concrete Mix

Mix Ratio	Water Cement Ratio	Cement (Kg)	Admixture Dosage		Aggregate Weight (kg)	
			Super plasticizer	Silica Fume	Coarse Aggregate	Fine Aggregate
1:2:4	0.5	6.94	-	-	27.77	13.87
1:3:6	0.6	4.86	-	-	29.16	14.58
1:1.5:3	0.3	8.84	2.5	-	26.51	13.25
1:1.25:2.5	0.4	10.23	2.25	-	25.58	12.79

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1:1:2	0.25	12.15	2.25	10	12.15	24.3
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## 2.1 Rebound tests

A standard Schmidt rebound hammer type N was used in the test according to the BS EN 12504-2 [25]. The reading is very sensitive to local variations in the concrete, especially to aggregate particles near to the surface. Therefore several readings at each test location were taken and average recorded. BS EN 12504-2 recommends not less than nine readings taken over an area not exceeding 300mm square, with the impact points no less than 25mm from each other or from an edge. The use of a grid to locate these points reduces error.

## 3. Results

Table 2: Mean Cube Strength of Concrete mixes with Age

Mix Ratio	Fcu (Mpa)		
	7days	14days	28days
Mix 1	9.44	15	15.44
Mix 2	10	12.69	14.89
Mix 3	27.93	28.22	28.77
Mix 4	22.78	28.89	30.22
Mix 5	27	34	38.89

Table 3: 7th Day Summary of Surface Hardness Test on Concrete Mixes

Mix Ratio	Compressive Strength (fcu)			Surface Hardness Test (Rebound Number-R)		
	Average Value [MPA]	Standard Deviation [MPA]	Coefficient of Variation	Average Value	Standard Deviation	Coefficient of Variation
Mix 1	9.44	2.29	24.3	15.15	2.512	16.57
Mix 2	10	2.36	23.6	15.56	3.26	20.97
Mix 3	27.9	0.79	2.83	20.14	2.56	12.72
Mix 4	22.8	1.57	6.89	20.63	2.58	12.53
Mix 5	27	0.92	3.41	20	2.5	12.5

Table 4: 14th Day Summary of Surface Hardness Test on Concrete Mixes

Mix Ratio	Compressive Strength (fcu)	Surface Hardness Test (Rebound Number-R)
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	Average Value [MPA]	Standard Deviation [MPA]	Coefficient of Variation	Average Value	Standard Deviation	Coefficient of Variation
Mix 1	15	6.29	41.93	17.86	2.58	14.49
Mix 2	13	1.57	12.08	18.37	2.16	11.77
Mix 3	28.22	3.93	13.93	25.36	1.66	6.53
Mix 4	29	0.79	2.73	25.47	2.58	10.13
Mix 5	34	0.75	2.21	28.3	2.43	8.59

Table 5: 28th Day Summary of Surface Hardness Test on Concrete Mixes

Mix Ratio	Compressive Strength (fcu)			Surface Hardness Test (Rebound Number-R)		
	Average Value [MPA]	Standard Deviation [MPA]	Coefficient of Variation	Average Value	Standard Deviation	Coefficient of Variation
Mix 1	15.44	1.1	7.12	19.13	2.13	11.13
Mix 2	14.89	0.31	2.08	20.7	2.66	12.87
Mix 3	28.8	0.16	0.56	27.8	2.07	7.44
Mix 4	30.22	1.57	5.2	26.42	2.57	9.73
Mix 5	38.89	0.55	1.41	31.89	1.97	6.13

#### 4. Discussion

The coefficient of variation of the individual readings obtained on different mix ratios, with the apparatus in a vertical position facing down varied from 6.13% to 20.97%, being the average value 11.6% (see Tables 3, 4 and 5). If the readings were separated into normal strength concrete and high strength concrete, the average values would be 14.60% and 9.58 %, respectively. These values indicate a decrease of the coefficient of variation as the concrete strength increases. BS 1881: Part 202 [17] indicates that the coefficient of variation for individual readings of hardness surface tests varies from 2% to 15%, being typically around 10%. The values obtained in the investigation reported here are in the upper zone of the range presented by BS 1881: Part 202 because of the non-homogeneity of the concrete achieved in laboratory conditions.

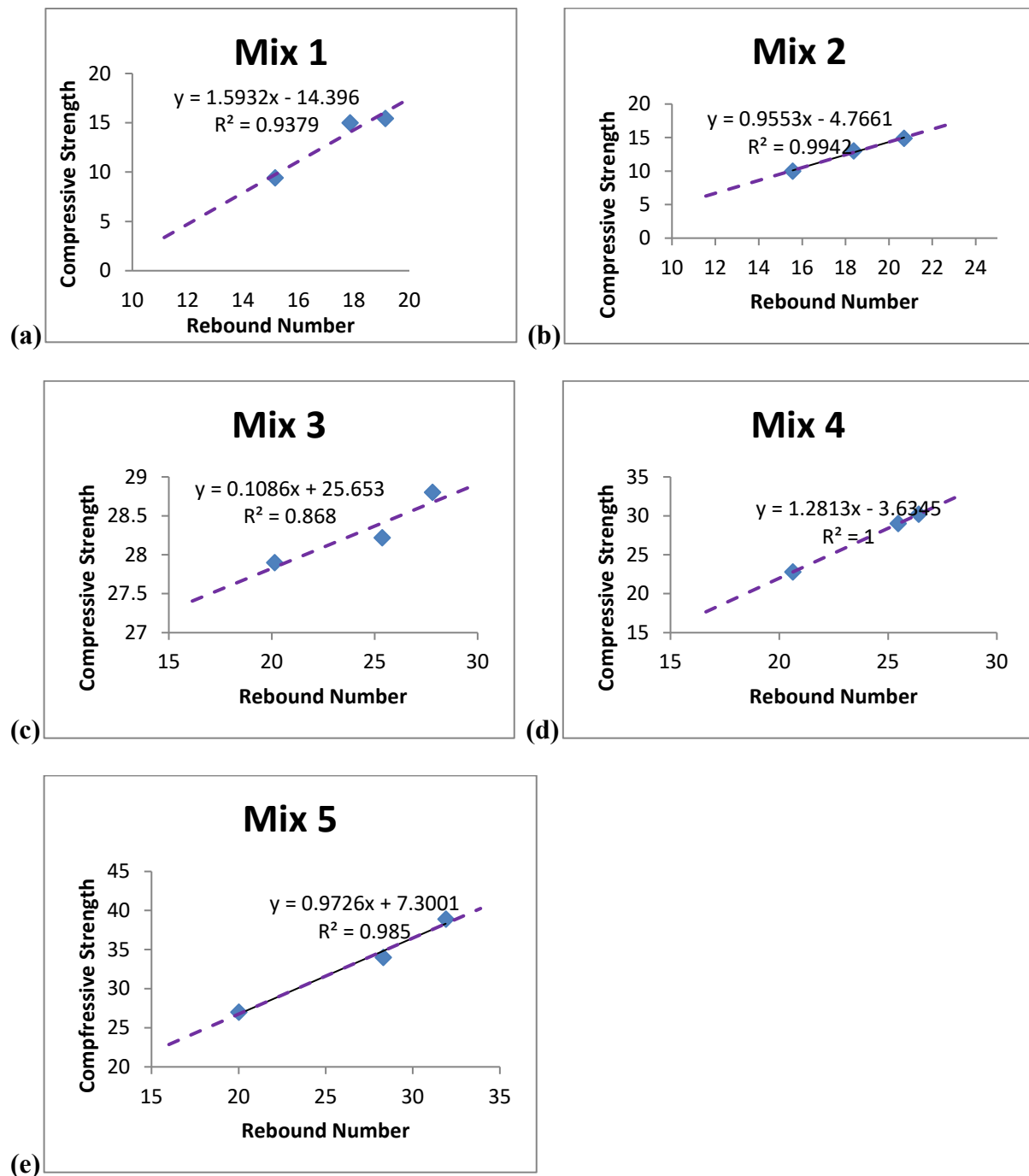


Figure 4: Average Values of Compressive Strength versus Rebound Number for Normal Concrete Strength of different Mixes.

Fig. 4a & b shows two graphs of the results presented in Tables 3-5. The results show that a relationship between compressive strength and rebound number is possible for normal strength concrete. Similarly to Fig. 4c, d & e shows the relationships between average compressive strength and average values of rebound number for high strength concrete. As for normal strength concrete, the results show that a relationship between compressive strength and rebound number is possible for high strength concrete. For this concrete, the results are closer

to the correlation line when compared with graphs of Fig. 4a & b for normal strength concrete. Aggregates petro-graphical properties have been proved to affect the rebound numbers and NDTs generally is influenced by the mix ratio of concrete and its placing method. It should be noted that for a proper use and application of Schmidt hammer test, concrete cube test is an effective basis for its calibration. As presented in Figure 4 above, relationship between the compressive strength and Rebound Hammer number was carried out using linear regression, the charts are showing the R-squared and Regression equation. The linear regression R-squared of Compressive strength versus rebound hammer is 0.9379, 0.9942, 0.868, 1 and 0.985 for Mix 1, 2, 3, 4 and 5; this indicates the percentage of the changes in one variable explained by the related variable change. This difference can be explained by how Schmidt hammer test applied. Concrete laboratory samples and used concrete in the field differs in rigidity, it is advisable that concrete cubes should be held by compression machine in order to be fixed. Thus at a limited surface, a variety of rebound numbers are recorded and errors could not be prevented. Many researchers believe that best result could not derived by only one NDT method. They suggest that using combined NDT is preferred.

## 5. Conclusions

The main conclusions derived from this investigation are as follows:

1. As a result of the investigations empirical relations between the compressive strength of the thirty tested concretes with similar compositions and the parameters determined by the surface hardness method have been established.
2. The obtained results show that even slight differences between the compositions of the concretes may lead to significant errors in non-destructive strength estimations when one uses correlation curves determined for other “similar” concretes. Therefore it is advisable to determine exact correlations for each of such concretes.

Schmidt hammer test and ultrasonic test are very convenient and can be executed anywhere but these tests have their own limitation and these limitations may result in unavoidable errors which can't be eliminated totally. Applying proper correction factor is a must to get the reliable results. Schmidt hammer test results should be calibrated according to specific condition of concrete. It is essential to develop a prior correlation relationship between actual compression strength of the concrete and the NDTs. As a result of these, some destructive tests seems unavoidable in order to calibrate the model.

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