Comparison between Destructive and Non-Destructive Test on Concrete

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Abstract: Compression strength is the most important factor in concrete structures, and there are two methods to evaluate that compressive strength, destructive and non-destructive method. This work presents a study on the deference and comparison between Destructive (compressive strength test) and a Non-Destructive Method (Rebound Hammer and Ultrasonic test) for testing the compressive strength of concrete.The investigations aimed to develop the method of assessment the strength of concrete of both non-destructive tests with greater accuracy. Destructive method, to determine the strength of the in-situ concrete, and also destructive testing (DT), includes methods where the material is broken down in order to determine its mechanical properties. From the obtained results it is observed that the Rebound Hammer readings increased with the compressive strength of concrete. And the Ultrasonic pulse velocity were greatly influenced by the cements and aggregate, extent of moist curing and presence of flaws and voids in concrete, more than their influence on the measured strengths. This demonstrates the limitation of using ultrasonic pulse velocity tests for estimating compressive strength of concrete. Combined use of Ultrasonic pulse velocity (UPV) and Rebound Hammer tests for assessment of concrete strength in structures with greater reliability.

Keywords: Destructive Test (DT), Non-Destructive Test (NDT), Rebound Hammer Test, Compression Test, Ultrasonic Test, Compressive Strength of Concrete

1. Introduction

The combination of cement, fine aggregate, coarse aggregate, water, mineral admixtures and chemical admixtures in their relative proportion will produce a composite building material which is named by concrete. In a comparison between concrete and alternative building materials, concrete is relatively cheap, and easily available. One more advantage of concrete is when it is fresh state it can be molded to form any required shape or size. Thus, it is very important to check or test the quality of concrete that is used in structures after the concrete gets hardened to find whether the concrete is suitable for its designed position in the structure or not. The most beneficial property of concrete alongside the durability is compressive strength. Determining compressive strength of concrete for existing concrete structures is the main mission for civil engineers, so for that purpose there are two methods to determine and estimate the compressive strength of concrete, which are non-destructive tests (NDT) and destructive tests (DT).

The destructive testing (DT) method is performed by crushing and destroying the cast sample. The main disadvantage of the destructive testing methods is the length of time it takes for the results to be ready, the equipment and the power required (Samson & Moses, 2014). The DT of concrete is not always appropriate method to find compressive strength of concrete and concrete structures because it affects the durability and lifespan of concrete.

Non-destructive testing (NDT) as it is clear from its name refers to a test that doesn't deteriorate the intended performance of the element, member or structure under the test. The NDT method is the only method to find the strength of existing concrete structures, and to judge the quality of concrete. The NDT method is direct and easy tool to find in situ compressive strength of concrete. The NDT test methods include rebound hammer, ultrasonic pulse velocity (UPV) test, penetration test, radiography test, sonic integrity tests etc. One of the challenging and virgin areas in testing civil engineering materials and structures is to establish relationship between the results from DT and NDT (Joshi, 2011). The aim of this research is to compare concrete compressive strengths measured using destructive method and those measured using the NDT and to develop regression equation relating them.

2. Materials and Methods

According to British specifications (116:1983 188:part B.S.) the standard concrete cubes dimensions must be taken as (100mm ×100mm×100mm) to know the compressive strength of the concrete mix and different reconstruction. The compressive strength of a concrete cube can be determined by taking the ratio of failure load to the effective area. Three concrete mixtures tested (1:2:4), (1:1.5:3) and (1:1:2), with different water cement ratio ranging (from 0.35 to 0.55), these mixtures has been renamed as symbols (A,B,C) respectively, for each mixtures 3 cubes was molded with the dimensions (10cm×10cm ×10cm) and after the completion of the treatment period (28 days in water tank) for non-destructive test cubes were tested by Schmidt hammer and tested by ultrasonic and after that for destructive test the same cubes were used to get the compressive strength.

2.1. Ultrasonic Pulse Velocity Method

A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time T of the pulse to be measured.
Longitudinal pulse velocity (in km/s or m/s) is given by:

$v = L/T$ -----------------------------(1)
where :
v is the longitudinal pulse velocity,
L is the path length,
T is the time taken by the pulse to traverse that length.
In 1945, Long under- took further investigations along these lines and reported on the instrument and technique that resulted from their work which led to the development of the Soniscope (Cheesman & Lislie, 1949).

In 1951, Whitehurst used this Soniscope to carry out some investigations and thus, published a tentative classification for using pulse velocity as an indicator of quality. This is as shown in the Table below (Whitehurst, 1966).

Table 1: Concrete quality and pulse velocity

GENERAL CONDITIONS	PULSE VELOCITY (M/S)
EXCELLENT	Above 4570
GOOD	3660 - 4570
QUESTIONABLE	3050 - 3660
POOR	2130 - 3050
VERY POOR	Below 2130

Currently, ultrasonic testing is extensively employed to estimate defects in concrete structures. It combines an easy test procedure and accuracy, at a relatively low cost (Jones & Gateld, 1960). This technique can detect areas of internal cracking, internal delamination, and relative strength parameters (Kaplan, 1958).

Figure 1: The ultrasonic device during calibration.

2.2. Rebound Hammer method

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. There is little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. However, within limits, empirical correlations have been established between strength properties and the rebound number. Further, Kolek has attempted to establish a correlation between the hammer rebound number and the hardness as measured by the Brinell method.

The rebound (Schmitz) hammer is one of the most popular non-destructive testing (NDT) methods used to test the strength of concrete. This is due to its relatively low cost and simplicity in use (Luke, 2012). Although the non-destructive testing (NDT) results are much quicker compared to the destructive methods, they are more of an approximation than exact compressive strength values

(Aguwamba & Adagba, 2012). In as much as the rebound hammer results are quicker, and do not destroy the surface of concrete tested, there is no established relationship between the compressive strength obtained using NDT and DT (Aguwamba & Adagba, 2012).

Figure 2: Schmidt Hummer device

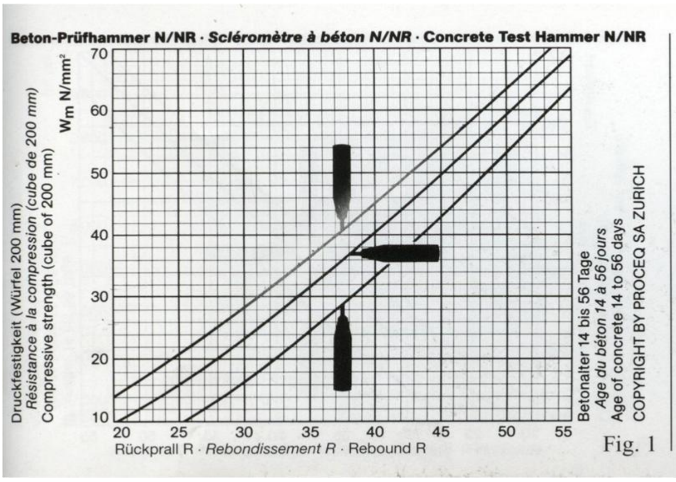

Figure 3: Rebound Hammer graph

Figure 4: The cubic sample during tested by rebound hammer

2.3. Destructive test

The compressive strength of a concrete cube can be determined by taking the ratio of failure load to the effective area, therefore by shedding loads on until failure occured by using compressive strength machine, the rate of standard load is 3 KN/sec.

Figure 5: Compressive strength machine for crushing cubes in destructive test

3. Results and Discussions

The different concrete mixes were prepared with different W/C ratio and curried for 28 days. Hammer test and ultrasonic velocity were measured at the same time and the cubes were tested destructively in compressive and compressive strength of each cube was recorded.

Table 2: Results of destructive and non-destructive test (concrete mix 1:2:4)

		Concrete mix 1:2:4			
Water cement ratio (W/C)	Average of rebound hammer test (MPa)	Average of Ultrasonic Test (MPa)	Average of compressive strength of Destructive test (MPa)	Percentage difference of hammer test with Destructive test	Percentage difference of Ultrasonic test with Destructive test
0.45	30	50.27	54.36	44.81%	7.5%
0.5	25	30.21	34.59	27%	9.7%
0.55	20	27.45	31.55	36%	12.9%

The above table and Fig.6 show the result of compression strength for cubes with concrete mix (1:2:4). Both rebound hummer and ultrasonic results are less than the destructive test, and the amount of difference in rebound hummer results when it is compared with the destructive test in which the results are much more than the difference of the ultrasonic and destructive test, as it is clear in Fig.7.

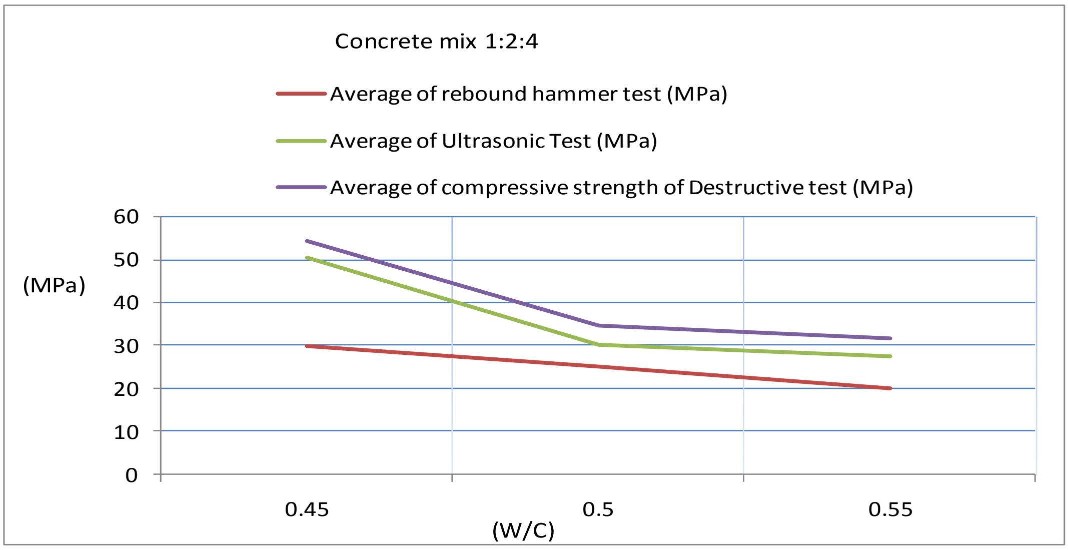

Figure 6: Destructive and nondestructive results for mix 1:2:4

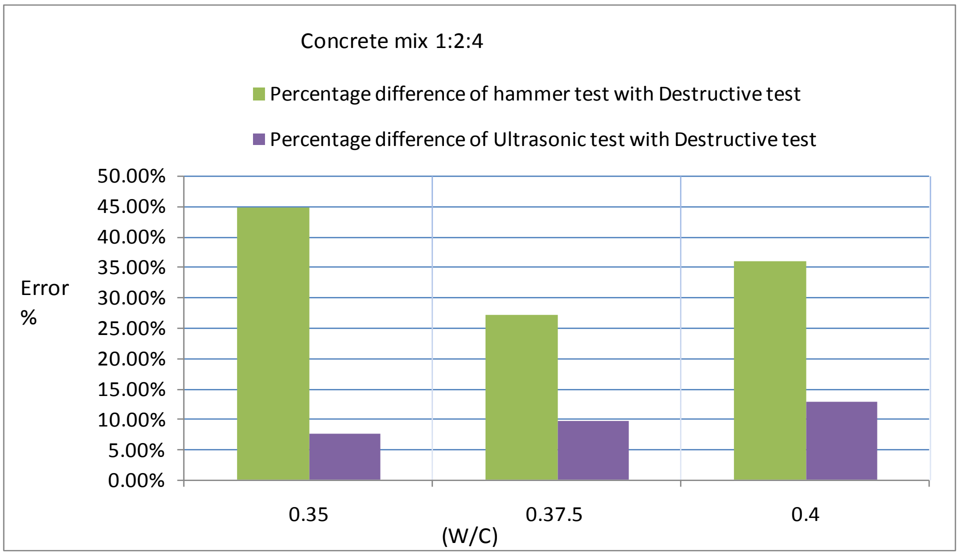

Figure 7: Error percentage for hammer and ultrasonic results for mix 1:2:4

Table 3: Results of destructive and non-destructive test (concrete mix 1:1.5:3)

Concrete mix 1:1.5:3					
Water cement ratio (W/C)	Average of rebound hammer test (MPa)	Average of Ultrasonic Test (MPa)	Average of compressive strength of Destructive test (MPa)	Percentage difference of hammer test with Destructive test	Percentage difference of Ultrasonic test with Destructive test
0.4	40	47.45	50.65	21%	6.32%
0.45	32	44.33	47.55	32.7%	6.77%
0.5	30	37.89	41.89	28.4%	9.5%

Both above table and Fig.8 show the result of compression strength for cubes with concrete mix (1:1.5:3). Both rebound hummer and ultrasonic results are less than the destructive test. Fig. 9 shows the amount of difference in rebound hummer results when it is compared with the destructive test range from 21 to 28 % and the difference of the ultrasonic and destructive test range from 6 to 9%.

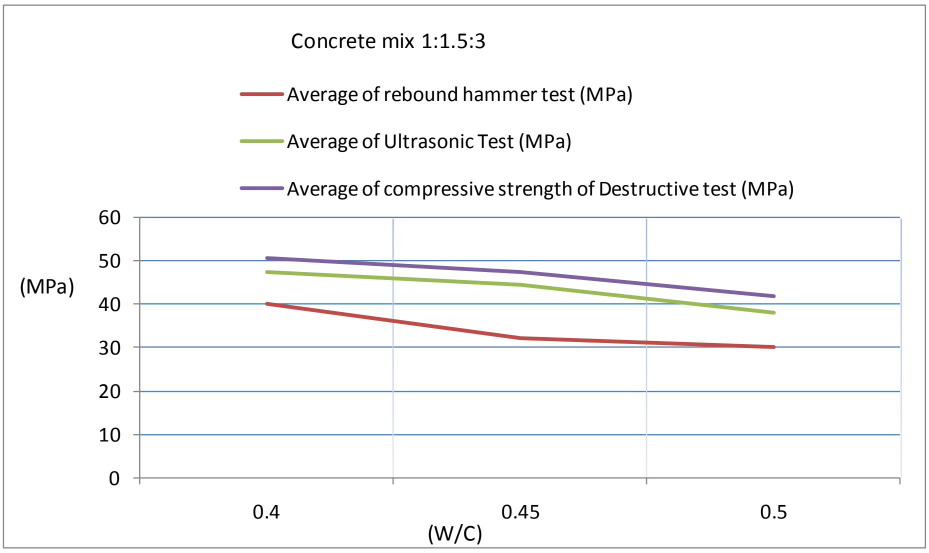

Figure 8: Destructive and nondestructive results for mix 1:1.5:3

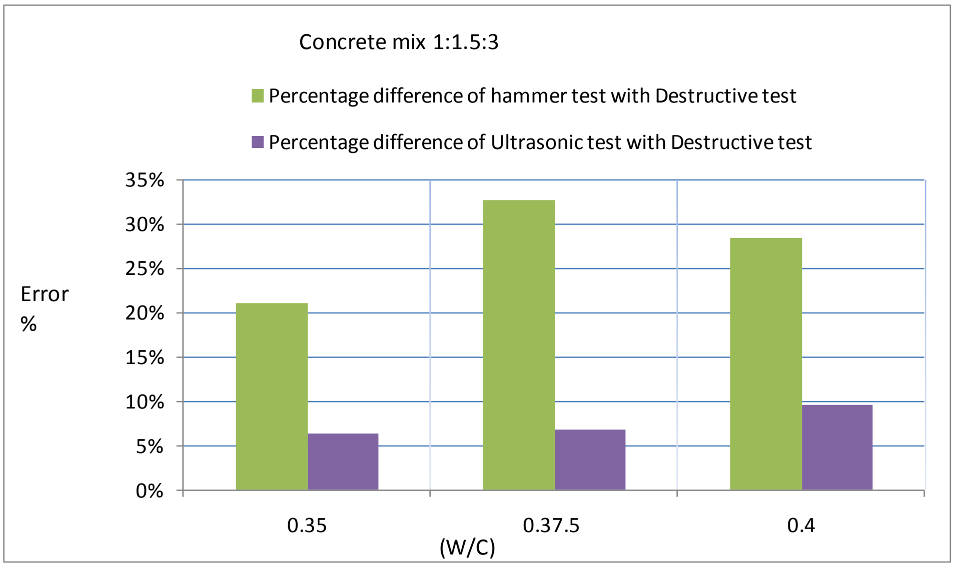

Figure 9: Error percentage for hammer and ultrasonic results for mix 1:1.5:3

Table 4: Results of destructive and non-destructive test (concrete mix 1:1:2)

Concrete mix 1:1:2					
Water cement ratio (W/C)	Average of rebound hammer test (MPa)	Average of Ultrasonic Test (MPa)	Average of compressive strength of Destructive test (MPa)	Percentage difference of hammer test with Destructive test	Percentage difference of Ultrasonic test with Destructive test
0.35	31	50.66	55.41	44.1%	8.5%
0.37.5	30	46.52	51.79	42.7%	10.2%
0.4	29	41.98	47.89	39.4%	12.3%

The above table and Fig.10 show the result of compression strength for cubes with concrete mix (1:1:2). Both rebound hummer and ultrasonic results are less than the destructive test, and the amount of difference in rebound hummer results when it is compared with the destructive test range from 39 to 44 % and the difference of the ultrasonic and destructive test range from 8 to 12%, as it is appear in Fig.11.

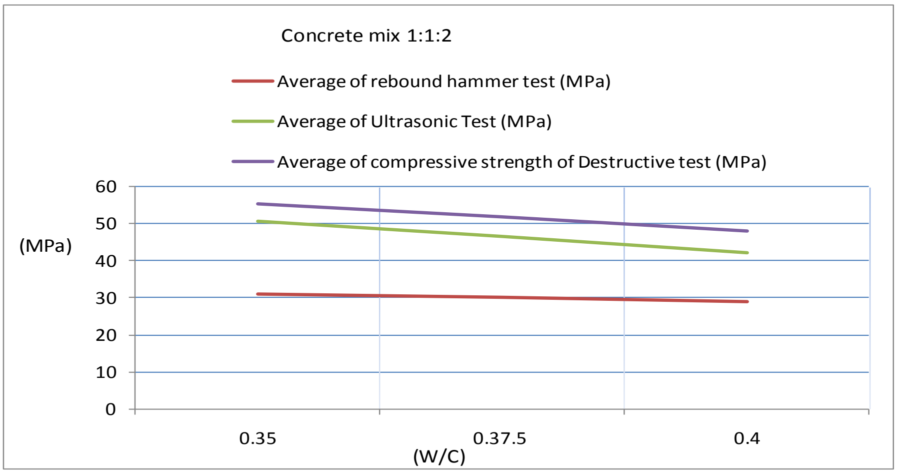

Figure 10: Destructive and non-destructive results for mix 1:1:2

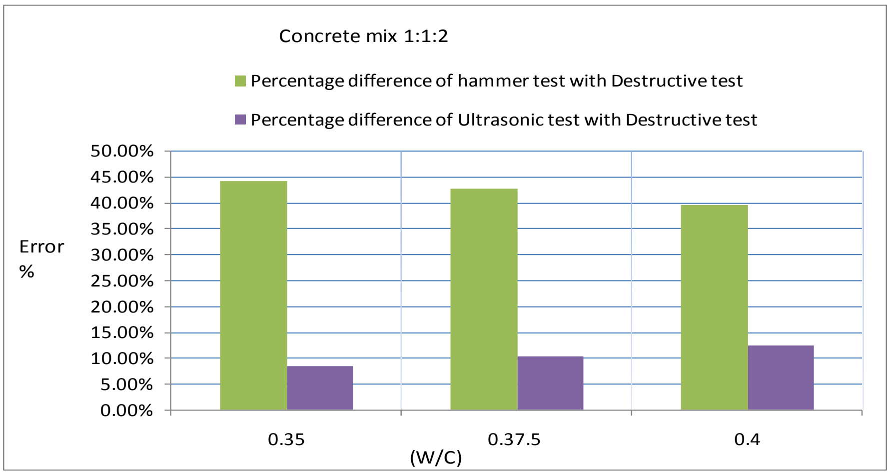

Figure 11: Error percentage for hammer and ultrasonic results for mix 1:1:2

4. Conclusion

1-The rebound hammer test can be used to evaluate the compressive strength of old concrete and not young (new) concrete.
2- The UPV increase with the increase of W/C ratio, which promotes a very important capillary porosity. Instead, UPV increases with the age of the concrete. The indirect determination of the actually strength of the concrete is an operation much delicate. It has to be carried out with the due caution from skilled workers of consolidated experience.
3- The rebound hammer method is not intended as an alternative for strength determination of concrete.
4- With reference to the Ultrasonic Pulse Velocity method, the evaluation of the resistance of the degraded concrete results of difficult solution because of the insufficient sensibility of the ultrasonic velocity in the field of the low strength.
5- In the test for all concrete mixes the results that obtained from Non-destructive (Hammer and Ultrasonic) test were less than the Destructive (compressive strength) test.
6- The Destructive test (Compressive strength test) and Non-destructive test (rebound number and ultrasonic test) were taken as the dependent and independent variable respectively.
7- From the result that obtained the ultrasonic test is more reliable than rebound hammer test because the difference between the destructive tests and non-destructive tests (ultrasonic test) is 9.29% and (rebound hammer test) is 35.12% which means the difference is much less for ultrasonic test than rebound hammer test.
8- The high difference of rebound hammer test is due to the effective of moisture content in the samples and due to the small size of the samples, where these reasons did not affected greatly for the ultrasonic test.

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