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Non-Destructive Evaluation of Reinforced Concrete Frames

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Abstract: As subcontinent is a seismically prone region, it has been hit by a number of earthquakes. Method of quantifying the strength of structures after such extreme events should be developed. Structures are usually demolished and reconstructed after such events without knowing the remaining life of the structure. So a method is required to find the remaining stiffness and strength of structures. In this research, effort has been done to find the strength of different parts of structures and developing a model on the basis of the data obtained. Two concrete frames with opening were undergone quasi-static loading. Rebound hammer test (RHT) was performed on the critical points on the structures. After performing RHT, cores were obtained from the from the points where RHT was performed. These cores were tested under Universal testing machine (UTM) to find the actual compressive strength. Relation between the two variables was obtained and a model was developed on the basis of determination coefficient.
Keywords: Rebound hammer test, Non Destructive Evaluation, Compressive strength, Reinforced concrete.

I. INTRODUCTION

Subcontinent due to its activeness seismically is vulnerable to earthquakes of different level. Extreme events of such type induce long term durability issues in the concrete structure which compromises the strength of the structures . So far, only visual observation or Non-destructive testing (NDT) technique is practiced to determine the extent of damage post a disaster. But this observation does not give us the complete details of the extent of damage. There is a dire need to develop an efficient technique to precisely model the damaged structure to have a deep insight into the mode of cracking and reason behind strength reduction or complete failure. An instrument was developed by Earnst Schmidt at the end of decade of 1950’s which works on a principle of rebound of the concrete’s surface. Strength judgement methods on the basis of the rebound of the surface a specimen were used in 1930’s[1]. This hammer works rebound from the surface of the metal. Hardness of the surface is given by stroking the surface with the hammer and rebound from the surface gives the hardness of the material’s surface [2]. Research work has been done to find relation among the destructive testing and rebound hammer test but reliability using this equipments is still a big issue. In one of the research, effort were made to provide possible solutions for developing relationship among the two values. Cubes of different mixes but almost of the same density were used by them. It was concluded that maturity, state of stress and moisture content have a strong influence on the test results. It was found that if such factors are not included in the test, there may be a variation of 70 percent among the field data and data obtained from RHT [3]. RHT alone is not that realiable to give a measure of the strengths of the sample. This test should be carried out with another NDT or destructive tests to give reliable results or find relation among the NDT and destructive testing [4] Research has been done using DIA on ninety six samples. Seventy two cylinders were used to find the tensile and compressive strength with different mixtures and contained dolomite and gravel as aggregate. Six vertical sections and eighteen horizontal sections were used for DIA of the samples. The horizontal section were driven from three section, that is top, centre and bottom while the vertical sections were extracted from the centre of the cylinders as shown in Fig 1 [5].

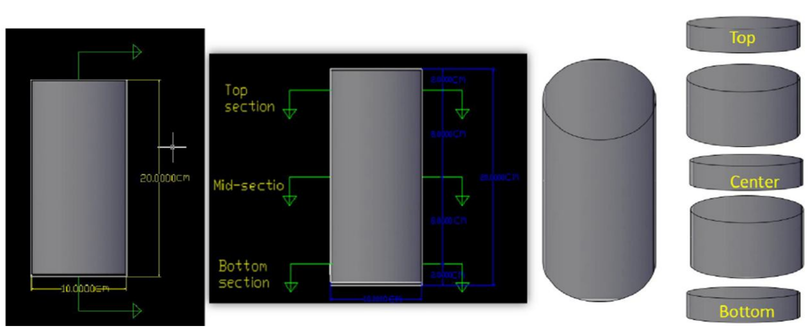

Figure 1: Location of vertical and horizontal sections (Ragab M. Abd El-Naby et al. 2017)

It was concluded that DIA gives us a good measure of uniformity, and quality of concrete. Results that were obtained from the tensile measurements have shown to have a good agreement with the results that were obtained from DIA. The images were analyzed in three steps:

Fig. 2 shows that the image of the samples were taken with a camera in a jpg format. These images were then converted into autocad file. After that output file was generated which contains the geometric properties of the aggregates.

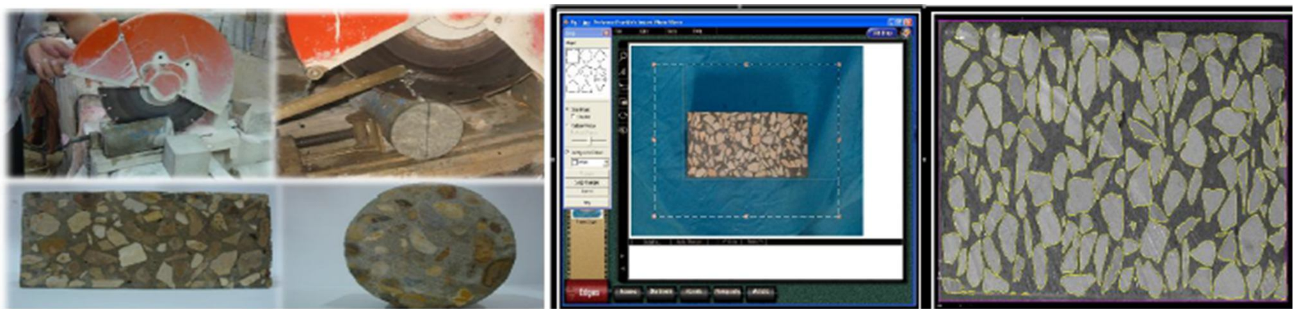

Figure 2: Final Converted Image “DXF” File (Ragab M. Abd El-Naby et al. 2017)

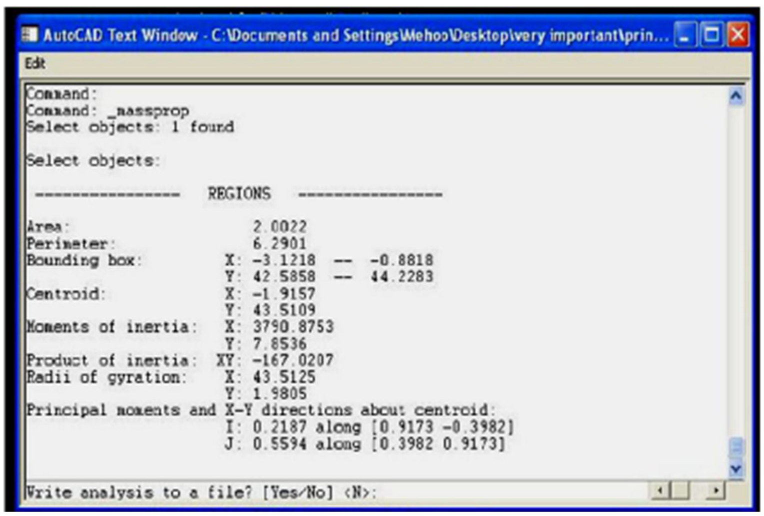

Figure 3: Calculated output of aggregate from Autocad (Ragab M. Abd El-Naby et al. 2017)

Figure 3 shows the file generated that provided geometrical properties of aggregates using image analysis.

In a research conducted on Rebound hammer technique, 288 cubes of dimension of one hundred and fifty mm were prepared according the procedures followed in India. Cubes were prepared using different mixes. For each mix, 4 cylinders were casted and 3 out of the 4 cylinders were tested using rebound hammer while 1 out of the 4 cylinders were tested using compression machine. These samples were taken out of the molds after 24 hours ensuring proper setting of the concrete. The results showed that value of UPV increase with increment in the age of the concrete but there was a slight change in the values. On the other hand, as the concrete gets old, Rebound hammer tests shows an increase so this technique gives an approximate value of the compressive strength of the concrete. For a better analysis of the strengths a comparative study of both the tests give better results as shown in Figure 4 [5].

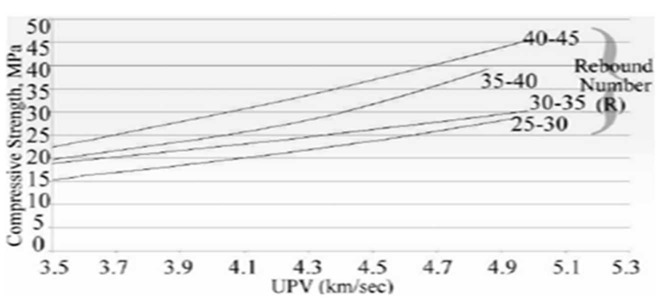

Figure 4: Co-relation between UPV, RN and Compressive strength (Akash Jain et al. 2019)

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Image processing is widely used to find the strength of concrete nowadays. And tests performed in collaboration with the image processing include Rebound Hammer test, Ultransonic pulse velocity test, scanning electron microscopy, etc. This research focused on employing ANN and IP together for finding the mechanical properties of concrete, including compressive strength,E and max deflection. They performed NDT to find the concrete strength basically [7]. In one of the research, 5 parameters were studied(curing, water/cement ratio, amount of cement, compression and additive), 96 cylinders were constructed; Before conduction of the test, pictures of the samples were taken and tests were carried out. After that stress-strain relations were developed for the samples. After every 2 minutes data from LVDTs and load cell were obtained. The fc, Ec and max deflection values were determined from graphs. Apart from these 96 samples, 40 samples of the same specimen and same composition were built to the check the reliability of the test. Both the methods were used to carrying out the test. Relation between the tests were found out. These methods used in finding the properties of concrete [7].

A relation was set up in one of the researcher among the strength of brick and rebound no. Ten different types of bricks from different manufacturers were selected and each of the brick was hit ten times by the hammer being used. The hammer was struck ten times when held in horizontal direction and the same amount of time when held vertically. The specimens were then tested for their compressive strength in the compression testing machine. Regression analysis of the models were carried out and it was found that the variability of R2 lies in between 0.87 and 0.96. This high value of determination coefficient indicates that this test can be performed to check the strength of bricks as well besides concrete and stone [8].

In one of the research, three different algorithms were developed. One for RH test value only, second for UPV test value and the third one was developed for the combined value of the two. The targeted value was set for all the three algorithms. The remaining ten values were used to check the accuracy of the data, after training the software by entering the eighty five values of the samples as an output [9].

Concrete mixes were prepared for two specified strengths of M20 and M25. The age of concrete cubes were considered for standard 28 days for compressive strength by Compressive Testing Machine, and Rebound number by rebound hammer. For each specimen, six reading were taken with a rebound hammer . The points where the reading was to be taken was marked and divided into equal number of grid spacing. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the Rebound Values were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained. The concrete mix proportion was made for Mix Design of M20 & M25 Grade of concrete were tested by Nondestructive testing (Rebound Hammer) and Destructive testing (Compression Testing Machine). It was observed that the change in strength of concrete for 7^{th} and 28^{th} was not significant [10].

II. MATERIALS AND REVIEW METHODS

A. *Model Description*

Two infilled frames were built with opening as shown in Fig. 5 and Fig. 6. These frames were subjected to loading prior to the test conducted in this research. After the application of load, Rebound hammer test was used to find the strength of the critical points and Regression analysis was performed to find the strength of the intermediate points.

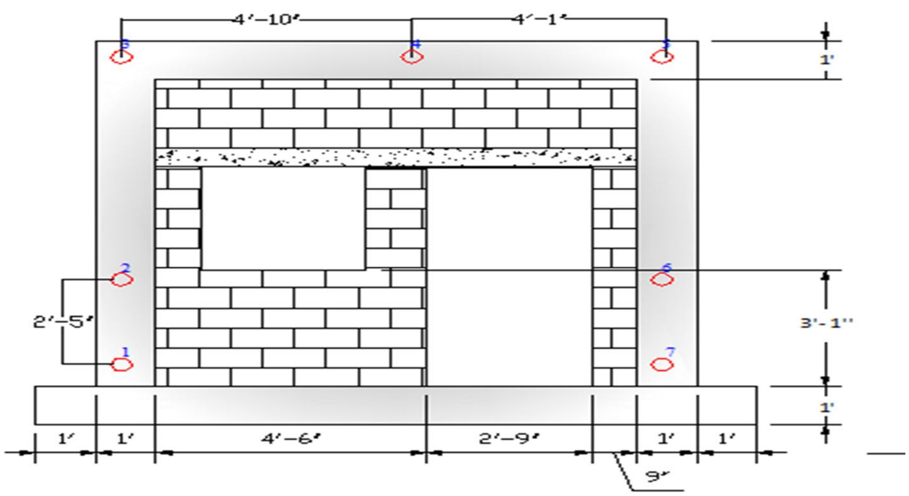

Figure 5: Infilled frame with window and door as opening (frame-I)

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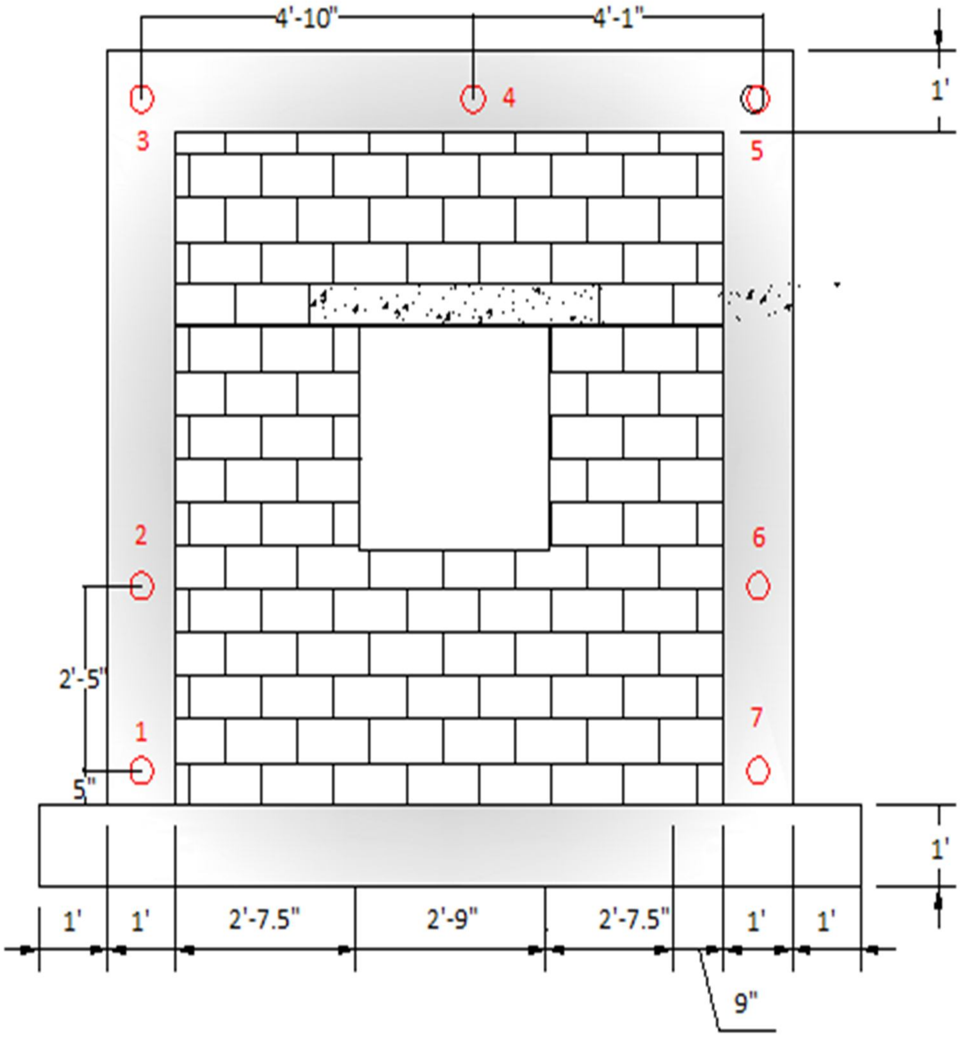

Figure 6: Infilled frame with window as opening (frame-II)

B. Material

Type-1 cement from local cement factory was used as a binding material in this research. The coarse aggregate from Basai quarry was selected for this work. Basai quarry was selected because of its irregular shaped aggregates. Irregular shape increases the binding properties of resultant concrete. The fine aggregate used in this research work was selected from Nizampur quarry because of its very excellent fineness modulus. Compression strength of concrete cylinder was determined by adopting ASTM C-39specification. Nine cylinders were subjected to uniaxial testing in UTM. Concrete cylinders wereprepared in 1:2:4 mix proportion.

C. Methods

The circles shown in the Fig. 7 and Fig. 8 are the points where the reading of Rebound hammer was taken. After the RH readings were taken, core cutter machine was used to drill out the cores of 2 inch from the frames. Size of the cores was taken as a choice due to steel incorporated in the frames. These points were chosen after detecting the concrete with a steel detector. After conforming the spots, they were marked with spray and cores were taken out of the specified points. Cores taken out of the frames were 6 inch in length. They were then tested in Universal Testing machine (UTM) to find the actual compression strength. The strength achieved from RH and Compression testing machine were compared and a regression model was developed on the basis of relation to find the strength of the strength of the remaining points using that equation and relation.

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III. RESULTS

A. Data Analysis of Rebound Hammer Test

Rebound Number gives us the hardness of the surface of the specimen. Hardness and stiffness of the concrete are implicitly related to the strength of the concrete. The compressive strength obtained from RH test performed on frame-I and frame-II are shown in tables 1-2:

Table 1: RH test results for frame-I

Core point	Reading	Avg	Comp. strenth (kg/cm2)	Comp. strenth(psi)	Shape coefficient	Final Compressive Strength including shape cofficient	Compression Test strength	Difference	RHT/CT
	19								
1	20	19	88	1251.65	1.06	1326.75	1305.34	21.41	1.02
	18								
	21								
2	19	19.67	92	1308.54	1.06	1387.05	1454.73	-67.68	0.95
	19								
	19								
3	22	20.67	107	1521.89	1.06	1613.2	1463.43	149.77	1.10
	21								
	23								
4	21	21.33	114	1621.46	1.06	1718.75	1958.01	-239.26	0.88
	20								
	19								
5	17	18.33	81	1152.09	1.06	1221.22	1421.37	-200.15	0.86
	19								
	19								
6	19	18.33	75	1066.75	1.06	1130.76	971.75	159.01	1.16
	17								
	16								
7	18	17.33	65	924.51	1.06	979.98	942.75	37.23	1.04
	18								

Shape coefficients has been used in the table because of the cube shaped frame. After computing the strengths from the manual using rebound no. they were then multiplied with shape coefficient. The value of the strengths obtained from this test are written against the actual compression test of the samples that were obtained using UTM. Difference and ration among the two values are computed and plotted in Fig 10 and Fig 12 for two forms to develop a relation.

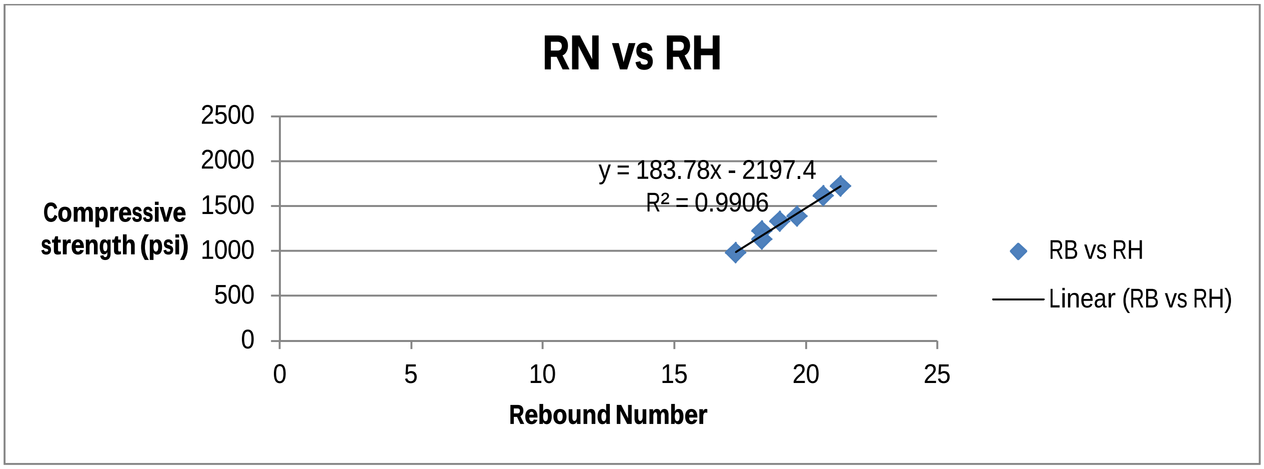

Figure 7: Regression plot of Rebound No and strength of concrete samples using rebound hammer(frame-I)

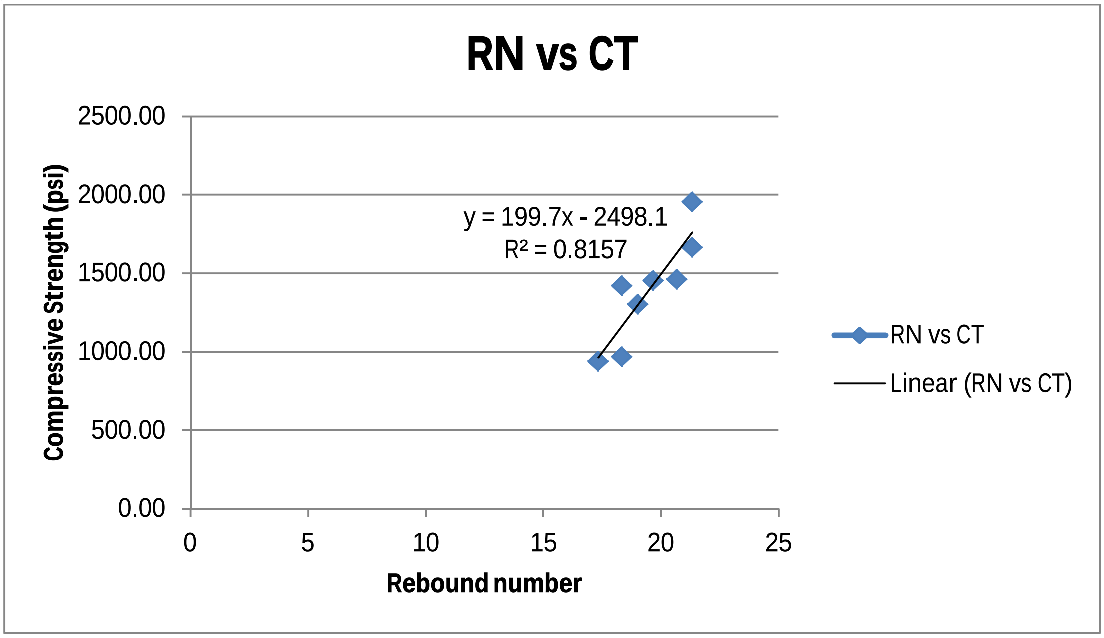

Figure 8: Regression plot of RH and strength of concrete samples data points (frame-I)

Linear model has been used on the basis of literature studied. The selection of the model was based on the value of coefficient of determination (R^2). Closer the value of R^2 to 1, the better will be the result. The model can be used to find the strength of the remaining points of the frame. Reliability of the equation developed can be used with reliability and confidence within the range of the data points.

Table 2: RH test results for frame-II

Core point	Readings	Avg	Compressive strenth(kg/cm 2)	Compressive strenth(psi)	Shape coefficient	Final Compressive Strength including shape cofficient	Compression Test Strength	Difference	RHT/ CT
	16								
1	18	17.67	69	981.41	1.06	1040.29	1261.83	-221.54	0.82
	19								
	18								
2	20	18.33	81	1152.09	1.06	1221.22	1363.36	-142.14	0.90
	17								
	18								
3	20	18.33	81	1152.09	1.06	1221.22	1102.29	118.93	1.11
	17								
	18								
4	21	19.67	97	1379.66	1.06	1462.44	1638.93	-176.49	0.89
	20								
	22								
5	19	20.67	103	1465	1.06	1552.90	1456.18	96.72	1.07
	21								
	22								
6	22	21.33	114	1621.46	1.06 `	1718.75	1696.94	21.80	1.01
	20								
	18								
7	18	17.67	69	981.41	1.06	1040.29	1000.76	39.53	1.04
	17								

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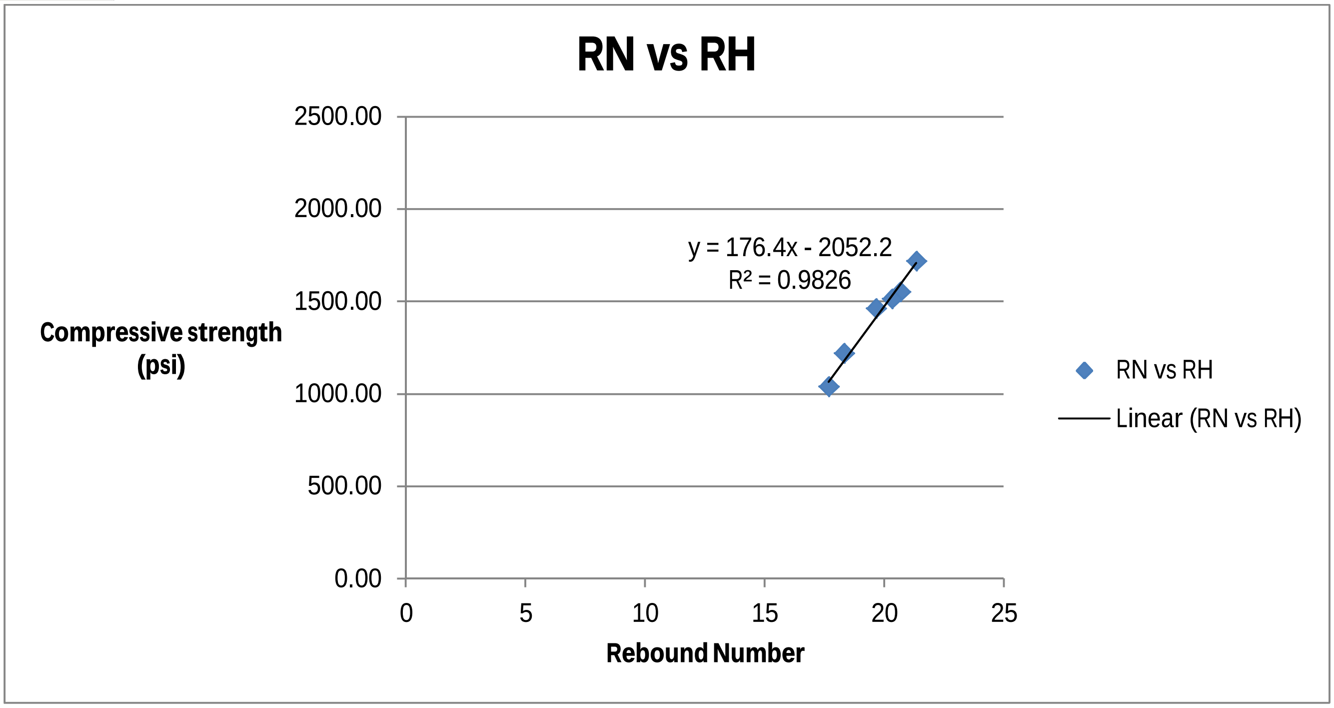

Figure 9: Regression.plot.of.Rebound no vs strength of concrete using rebound hammer(frame-II)

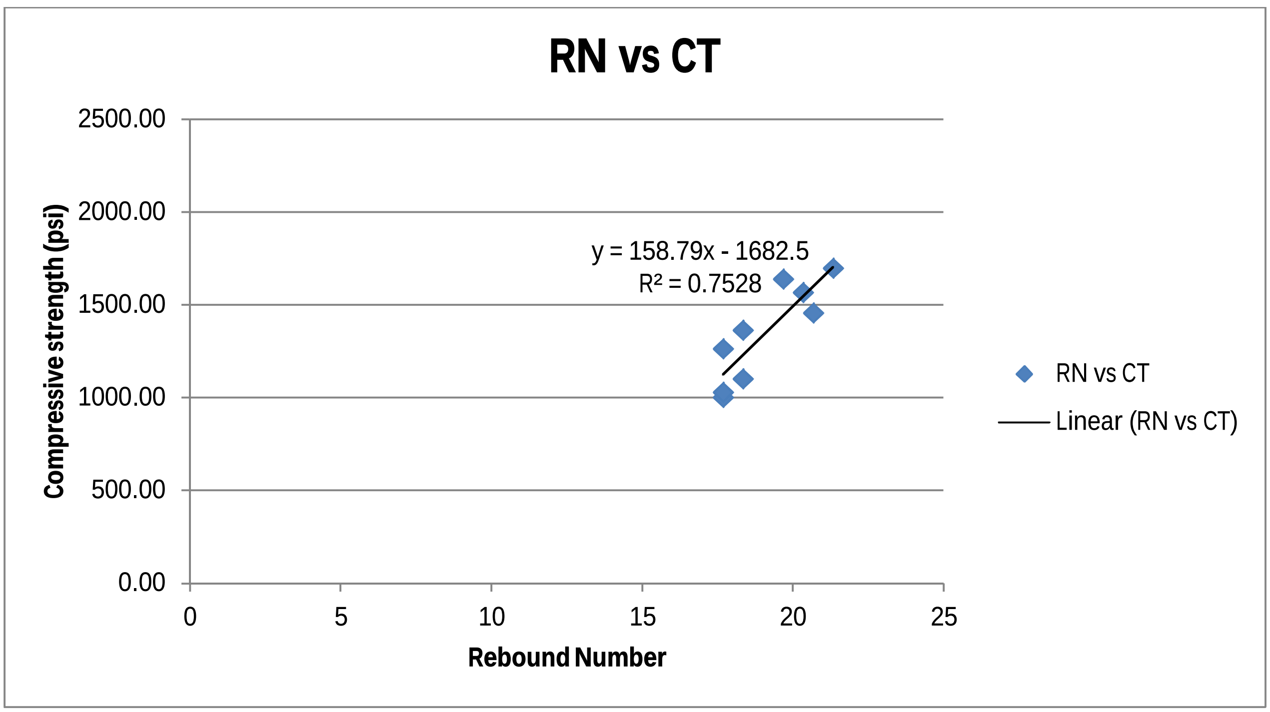

Figure 10: Regression.plot.of.RH vs strength of concrete samples.data points (frame-II)

Regression plot of rebound hammer and compressive strength of concrete are shown in Fig. 10 and Fig. 12. R^2 value for frame-II is comparatively lower than frame-I but this gives us a considerably good idea about the strength of different parts of the frames that have undergone extreme event. As mentioned earlier, that these values give us a good measure of the strength of the remaining points within the range. Range of the equation is approximately from 1000 psi to 2000 psi. All the other points can be interpolated using the equation given within the Fig. 10 and Fig. 12.

IV. CONCLUSIONS

Rebound Hammer basically gives us the measure of hardness on the surface. If high accuracy and reliability is required, this test should be incorporated with another Non-Destructive test to get better results. Results that we get from these NDT's are not exactly the same as that of compression test. As NDE tests give us a good measure of the strengths, these test should be carry out and then the decision should be made whether the structure should be demolished or is there any chance of retrofitting the structure.

V. ACKNOWLEDGEMENT

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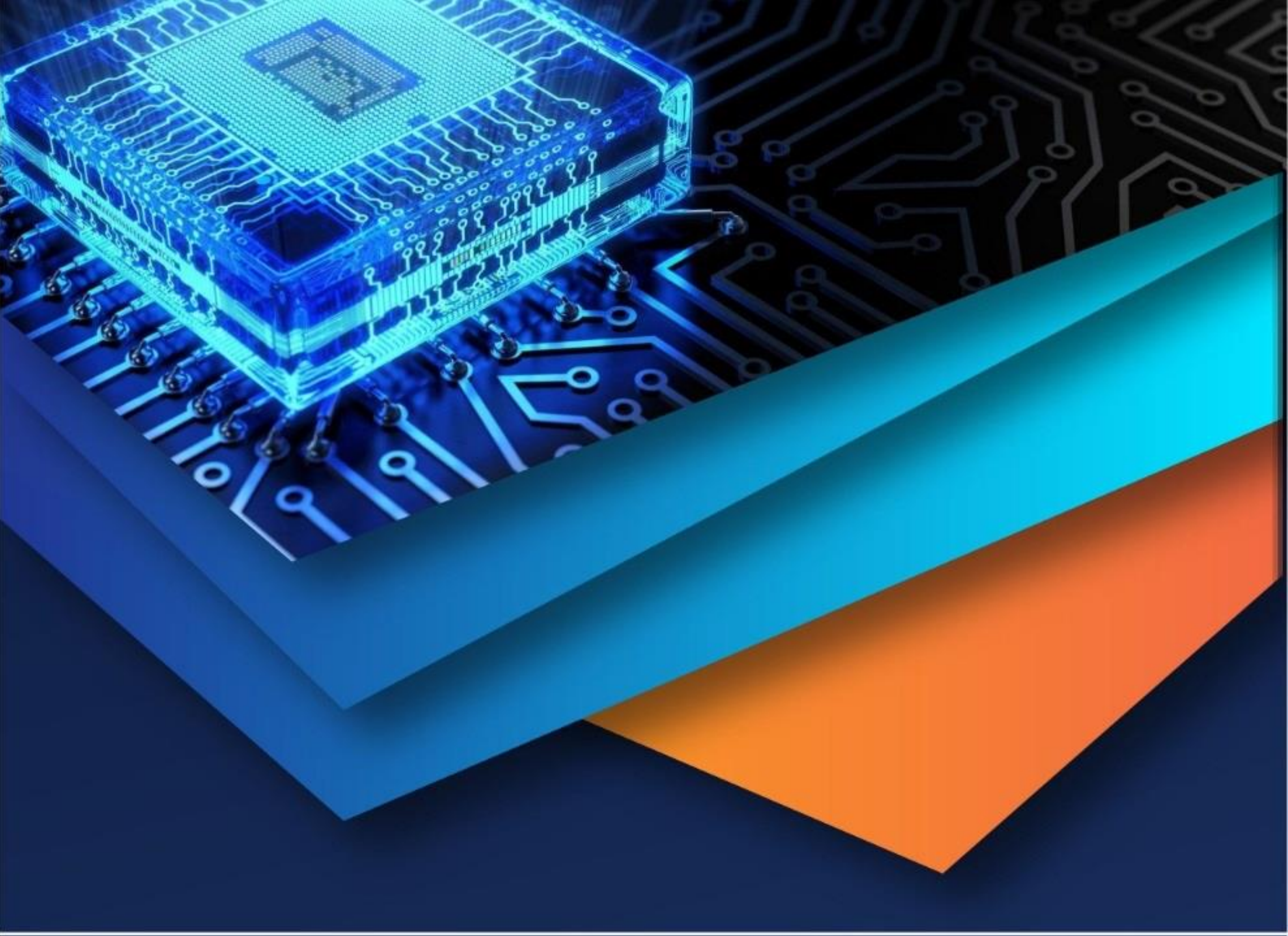
REFERENCES

[1] Malhotra, V. M. (1970). Maturity Strength Relations and Accelerated Strength Testing. Canada Mines Branch Internal Report, MPI.
[2] Kolak, J. (1958). J Kolak, 1958, "An Appreciation of the Rebound Hammer", Magazine of Concrete Research, Volume 10, Issue 28, 01 March 1958, pages 27-36. Magazine of Concrete Research, 10(28), 27–36.
[3] Brencich, A., Cassini, G., Pera, D., & Riotto, G. (2013). Calibration and Reliability of the Rebound (Schmidt) Hammer Test. Civil Engineering and Architecture, 1(3), 66–78. http://doi.org/10.13189/cea.2013.010303
[4] Akash Jain, Ankit Kathuriaa, Adarsh Kumar, Yogesh Verma, and Krishna Murari(2019), 'Combined Use of Non-Destructive Tests for Assessment of Strength of Concrete in Structure'.
[5] Ragab M. Abd El-Naby, Emad A. M. El-Dardiry and Naji A. Abo Azzom Journal of American Science 2014;10(7)
[6] Javed, M., Khan, A. N., & Magenes, G. (2008). Performance of masonry structures during earthquake-2005 in Kashmir. Mehran University Research Journal of Engineering and Technology (Pakistan)
[7] Gamze Dogan, Musa Hakan Arslan , Murat Ceylan "Concrete compressive strength detection using image processing based new test method ." Measurement 109 (2017) 137–148.
[8] Md. Roknuzzaman, Md. Belal Hossain, Md. Ibrahim Mostazid, Md. Rashedul Haque, 'Application of Rebound Hammer Method for Estimating Compressive Strength of Bricks'.
[9] Yi-Fan Shih, Yu-Ren Wang, Kuo-Liang Lin,and Chin-Wen ChenImproving,' Non-Destructive Concrete Strength Tests Using Support Vector Machines'
[10] Konapure C.G and Jagale Richardrobin.J, 'Relationship between Non-Destructive Testing of Rebound Hammer and Destructive Testing', International Journal of Current Engineering and Technology 05 Feb2015, Vol.5, No.4 (Aug 2015)
[11] ASTM Manual C-597-02
[12] Properties of Concrete by A. M. Neville (5th Edition).



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