World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.218

NDT OF RC BEAMS WITH OLD CONCRETE AS PARTIAL REPLACEMENT OF NATURAL COARSE AGGREGATES BY REBOUND HAMMER

Mahboob Oad*[1], Abdul Hafeez Buller[2], Bashir Ahmed Memon[1] and Noor Ahmed Memon[1]

[1]Dept. of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah Pakistan.

[2]Post Graduate Student, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah Pakistan.

Article Received on 11/03/2018 Article Revised on 01/04/2018 Article Accepted on 22/04/2018

***Corresponding Author**
Mahboob Oad
Dept. of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology, Nawabshah Pakistan.

ABSTRACT

Need of residential and commercial space particularly in city centers around the world is growing every day. Therefore, pace of construction of high rise buildings is increasing at faster rate. Space constraints require demolishing of short height buildings to erect high rise buildings. This leads to huge quantum of demolishing waste. One way of treating this waste is to use it in new construction. Strength evaluation of concrete is the key parameter to ensure the quality of concrete. Destructive testing for evaluation of concrete strength is time consuming. Nondestructive testing on other hand provides easy and economical solution to the problem. Therefore, this research paper presents nondestructive testing of reinforced concrete beams made with 50% replacement of natural coarse aggregates with coarse aggregates from old concrete by rebound hammer test method. 96 reinforced concrete beams are cast and tested. The compressive strength obtained from rebound hammer test is then converted into flexural strength using ACI formulation. Comparison of obtained results with results of control specimen shows reliability of non-destructive testing for beams made with old concrete as partial replacement of coarse aggregates.

KEYWORDS: Reinforced Concrete, Green Concrete, Old Concrete, Non-destructive Testing, Rebound Hammer.

1. INTRODUCTION

Vertical expansion of infrastructure in construction industry has become the need of the day due to increasing demand of residential and commercial space particularly in city centers around the world. This in many areas requires demolishing of short height buildings to build high-rise structures. This process leads to huge quantum of the demolishing waste. Proper treatment of this waste has become another issue to be dealt properly. Among several methods available to deal with this waste, its reuse in new construction is one which got attention of the scholars. This not only solves the problem of treatment of demolishing waste to some extent but also help to preserve natural sources of the material used in new construction. Different components of demolished waste have been proposed and used by various scholars in new construction. Good quantity of demolished waste is utilized as filling material in floors. For load bearing members demolished waste is used as full or partial replacement of aggregates. Various scholars have suggested various doses of demolished waste as partial replacement of fine and coarse aggregates. In a review paper published by Memon[1] recent development on use of demolished concrete as coarse aggregates is presented. Oad[2] and Memon[2] and several other scholars have studied the use of old demolished concrete as replacement of natural coarse aggregates in new concrete. 50% dosage of coarse aggregate from old concrete has been reported as optimum in literature. Because with 50% dosage; strength reduction of new concrete is least. Although several research outcomes are available for use of this new material in literature yet its use is limited mainly due to the reason that its behavior is still not completely understood. This motivates for the research presented in this paper.

Strength is the key parameter among several others in determining the quality of concrete. Strength of concrete is best evaluated by laboratory testing. But the method is time and capital intensive. Also, direct laboratory testing of build structures is not possible. Therefore, alternatives in the form of numerical evaluation and non-destructive testing are opted. Also, almost all of the design codes and material testing codes provide methods for use of the non-destructive testing. Among non-destructive test methods Ultrasonic Pulse Velocity, Rebound Hammer etc. are commonly used. These methods are not only reliable but also are easy to operate.

In a research on the study to review the use, limitation and understanding of the results from non-destructive methods, Helal et al.[4] conducted research to review the non-destructive methods. Based on their study the authors augmented inadequacy of methods with the lack of understanding of the methods. Whereas if the methods are appropriately used will give the good insight of the parameters being studied.

In a research presented by Sanchez and Tarranza,[5] the authors used rebound hammer to test concrete cubes in two groups. A group of cubes was cured by immersing continuously in brackish water, whereas the second group was cured by cyclic drying and wetting in brackish water. After curing cubes were tested by rebound hammer and compared with the results of third group of cubes cast and cured in conventional way. Based on the results the authors observed that although the rebound hammer results were lesser than the results of conventionally cured and tested cubes yet the non-destructive testing gives fairly reliable results.

Yang et al[6] in their research work studied flexural performance of the concrete beams with polyethylene fiber reinforced strain-hardening cement-based composites with particular reference to thickness of the fiber applied. They used 20 mm and 40 mm thick fibers. The experimental results showed them that the beams with proposed material gave better performance than the conventional concrete beams.

In a research work conducted by Tameemi and Lequesne[7] the authors used hybrid concrete. The proposed concrete contained steel fiber reinforcement and had capability of self-compaction. The authors used four different dosages of steel fiber reinforcement from 0.5% to 1.5%. Based on the results the authors observed that up to cracking, properties were not affected even with presence of the fiber, however post-peak slope in compression and post-cracking tensile and flexural strength increased with increase in dosage of steel fiber.

Saleem et al[8] in their research work used non-destructive testing by UPV and rebound hammer to evaluate existing concrete structures. The authors studied an eight-year-old half-built structure to evaluate concrete strength and quality for future expansion of the building. Base on the results from UPV and rebound hammer testing the authors concluded that the quality of concrete was reasonably good for expansion except for one column in basement for which they proposed strengthening of it prior to new construction.

Shang, Yi and Yang[9] in their research work used rebound hammer testing to test big mobility concrete of C20 to C50 grade. Using rebound hammer results the authors established the curve defining correlation between rebound hammer number and compressive strength. The comparison of the results with those from literature and conventional testing proved the reliability and effectiveness of the curve developed for the purpose.

To renew the licensing of typical structures like nuclear power plants, strength evaluation of the infrastructure is the key parameter. To this end Hemant et al[10] used rebound hammer testing to evaluate the concrete strength of a nuclear power plant and a project under modification. The obtained results showed good reliability of the non-destructive test methods.

This research article is focused on reuse of demolishing waste in RC beams and non-destructive testing of the same by rebound hammer. The beams are cast by 50% replacement of natural coarse aggregates with coarse aggregates from old demolished concrete. 50% replacement is chosen based on the recommendations of Oad et al[2] and Memon et al[3] A total of 96 RC beams of 150 mm x 150 mm x 900 mm in size are prepared. Two number four bars are used in both tension and compression zones along with #3 stirrups at 150 mm center to center all along the length of beam to reinforce the beams. Two concrete mix ratios i.e. 1:2:4 and 1:1.5:3 with 0.54 water cement ratio are used to cast the beams. 7- and 28-day water curing is used 50% beams in each mix ratio. Similar methodology is adopted to prepare the reinforced concrete beams with 100% natural coarse aggregates. These beams are treated as control specimen and are used to compare the results. On completion of curing all the beams are tested using digital rebound hammer. Standard tables and graphs provided with the equipment are then used to obtain the compressive strength followed by conversion of the same in to flexural strength by ACI formulation. The obtained results are discussed in relevant section. The comparison shows good reliability on non-destructive testing for RC beams prepared by 50% replacement of natural coarse aggregates with coarse aggregates from old demolished concrete.

2. MODEL TESTING AND RESULTS

To prepare the beams old demolished concrete is collected from Nawabshah city in shape of large blocks. These blocks are then hammered down to approximate 1-inch size. Screening of the obtained aggregates is done manually to separate the cracked particles, followed by sieve analysis with 1-inch maximum size. Sieve analysis of natural coarse aggregate is done in similar fashion. Batching of ingredients of concrete i.e. OPC, hill sand and coarse aggregates is done by weight batching. Two mix ratios 1:2:4 and 1:1.5:3 with 0.54 water cement ratio are adopted for casting of the specimen as these two ratios are commonly used in construction industry. The beams are cast in eight groups with equal number of beams in each group. The first group is prepared using 1:2:4 mix 50% coarse aggregates from demolished old concrete and cured for 7-days. The second group of beams is prepared as first but cured for 28-days. Group three and four are cast with same parameters as group one and two but 1:1.5:3 concrete mix. Group five to group 8 of beams are prepared in similar fashion as group one to four but with all-natural coarse aggregates. These beams are treated as control specimen and are used to compare the results of proposed reinforced concrete beams.

After completion of curing time, all the beams are tested using digital test hammer for compressive strength. On each beam 5 readings are taken in standard manner then average of the 5 readings is taken as the reading of the beam. Compressive strength obtained from graphs provided by the vendor of the equipment are also averaged for the beams. Table 1 gives rebound number and associated strength results for 1:2:4 mix 7-days and 28-days cured beams made by 50% replacement of natural coarse aggregates with coarse aggregates from old concrete. Table 2 gives details of the results for 7- and 28-days cured beams but made with rich mix (1:1.5:3 ratio). The results of control specimen (100% natural aggregates) for both 1:2:4 and 1:1.5:3 concrete beams cured for 7- and 28-days are given in tables 3 and 4. Figure 1 gives graphical representation of rebound number vs. strength of reinforced concrete beams. In this figure sub-plot (a) shows trend between rebound number and strength for beams made using 1:2:4 mix and cured for 7-days with control specimen prepared using same mix and curing time. Sub-plot (b) defines same parameters but for 28-days cured beams of 1:2:4 mixes. Similarly, sub-plots (c) and (d) show relationship of already discussed parameters for 1:1.5:3 mix beams cured for 7- and 28-days respectively.

Table 1: Rebound number and strength values for 1:2:4 mix RC beams with 50% RCA.

1:2:4 mix, 0.54 w/c ratio (50% RCA)							
#	7 Days curing				28 Days curing		
	R	Comp. Str. (Avg)			R	Comp. Str. (Avg)	
		psi	N/mm^2			psi	N/mm^2
1	30.5	2600	17.93		33.6	3150	21.72
2	31.4	2720	18.76		32.2	2900	20.00
3	30.0	2528	17.43		34.8	3245	22.38
4	30.2	2573	17.74		34.8	3245	22.38
5	30.1	2546	17.56		35.1	3266	22.52
6	30.5	2611	18.01		35.6	3352	23.12
7	31.1	2712	18.70		35.4	3329	22.96
8	31.3	2742	18.91		36.2	3464	23.89
9	30.5	2611	18.01		35.8	3385	23.34
10	30.6	2628	18.12		35.9	3406	23.49
11	29.7	2485	17.14		39.3	3889	26.82
12	29.6	2467	17.01		35.8	3465	23.90
Avg:	**30.46**	**2601.92**	**17.94**		**35.38**	**3341.33**	**23.04**

Table 2: Rebound number and strength values for 1:1.5:3 mix RC beams with 50% RCA.

1:1.5:3 mix, 0.54 w/c ratio (50% RCA)							
#	7 Days curing				28 Days curing		
	R	Comp. Str. (Avg)			R	Comp. Str. (Avg)	
		Psi	N/mm^2			psi	N/mm^2
1	33.0	3031	20.90		38.0	3770	26.00
2	31.5	2725	18.79		38.5	3858	26.61
3	30.5	2600	17.93		38.3	3796	26.18
4	29.7	2485	17.14		38.8	3845	26.52
5	30.1	2546	17.56		38.5	3858	26.61
6	29.6	2467	17.01		38.1	3761	25.94
7	28.5	2385	16.45		39.2	3912	26.98
8	28.7	2432	16.77		39.7	3952	27.26
9	28.1	2272	15.67		39.6	3945	27.21
10	29.3	2420	16.69		39.4	3921	27.04
11	30.4	2600	17.93		38.6	3869	26.68
12	31.2	2722	18.77		38.2	3792	26.15
Avg:	**30.05**	**2557.08**	**17.64**		**38.74**	**3856.58**	**26.60**

Table 3: Rebound number and strength values for 1:2:4 mix RC beams with 0% RCA.

1:2:4 mix, 0.54 w/c ratio (0% RCA)							
#	7 Days curing				28 Days curing		
	R	Comp. Str. (Avg)			R	Comp. Str. (Avg)	
		psi	N/mm^2			psi	N/mm^2
1	31.5	2777	19.15		35.5	3338	23.02
2	31.2	2722	18.77		35.8	3465	23.90
3	30.8	2668	18.40		35.6	3352	23.12
4	30.6	2645	18.24		35.3	3307	22.81
5	30.1	2546	17.56		35.5	3338	23.02
6	31.3	2737	18.88		35.9	3413	23.54
7	31.1	2711	18.70		36.2	3478	23.99
8	31.1	2711	18.70		36.7	3564	24.58
9	29.6	2467	17.01		36.5	3509	24.20
10	29.8	2501	17.25		36.4	3494	24.10
11	29.3	2420	16.69		36.6	3527	24.32
12	30.4	2600	17.93		36.1	3451	23.80
Avg:	**30.57**	**2625.42**	**18.11**		**36.01**	**3436.33**	**23.70**

Table 4: Rebound number and strength values for 1:1.5:3 mix RC beams with 0% RCA.

1:1.5:3 mix, 0.54 w/c ratio (0% RCA)							
#	7 Days curing				28 Days curing		
	R	Comp. Str. (Avg)			R	Comp. Str. (Avg)	
		psi	N/mm^2			psi	N/mm^2
1	33.0	3031	20.90		38.7	3819	26.34
2	29.6	2467	17.01		38.9	3827	26.39
3	29.8	2514	17.34		38.2	3781	26.08
4	29.3	2420	16.69		38.6	3802	26.22
5	29.2	2404	16.58		38.7	3819	26.34
6	29.1	2388	16.47		38.6	3802	26.22
7	30.1	2546	17.56		39.2	3912	26.98
8	30.2	2573	17.74		39.6	3949	27.23
9	29.7	2485	17.14		39.4	3915	27.00
10	29.3	2420	16.69		39.5	3932	27.12
11	29.1	2388	16.47		38.6	3802	26.22
12	29.5	2447	16.88		39.1	3862	26.63
Avg:	**29.83**	**2506.92**	**17.29**		**38.93**	**3851.83**	**26.56**

Table 5 gives the details of minimum, maximum and average values of rebound number and compressive strength for all beams. From this table it can be observed that average strength values of 7-days cured beams of 1:2:4 mixes observed 0.89% reduction in strength in comparison to the control specimen of same mix and curing, whereas 28-days cured beams of same mix observed 2.7% loss of strength when compared with control specimen of same mix and curing. Both reductions are less than 5% and may be treated as negligible. Comparison of rich mix beams made by 50% replacement of natural coarse aggregates with aggregates from old concrete with control specimen shows increase in strength of 2% for 7-days cured beams and 0.12% increase for 28-days cured beams respectively. Although the results are different in trend than those of normal mix beams but it might be because of better coarse aggregates than those used in normal mix. However, it need more study to get proper insight of the behavior of rich mix beams. Based on the available results it is clearly observed that the variation in strength is not much. Hence use of coarse aggregates from old concrete shows promising effect on the strength.

The compressive strength discussed above is the direct measure of strength by rebound hammer, whereas the flexural strength of reinforced concrete beams is one of the important parameter therefore compressive strength obtained by rebound hammer tests is then converted to flexural strength using numerical expression given by ACI committee[11] and is reproduced as under for the purpose of clarity of reading.

$$f_s = 0.94 f_c^{0.5}$$

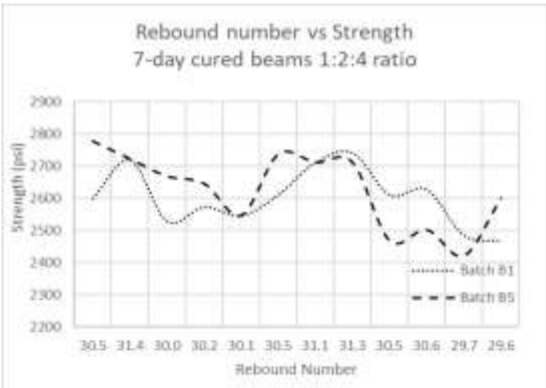
Where, f_s is flexural strength and f_c is compressive strength of concrete. Using above expression, flexural strength of all beams is evaluated and average values of each group of beams are tabulated in table 6. From this table it may be observed that 7-days cured 1:2:4 mix beams observed 0.45% increase in the flexural strength as compared to control specimen of same type. Whereas, 28-days cured beams of same mix observed 1.39% increase in comparison of the control specimen of same mix and curing. It is further observed from this table that 7-days cured beams of rich mix observed 1.02% reduction in flexural strength in comparison to control specimen of rich mix cured for same duration. Whereas, 0.05% reduction in flexural strength values for 28-days cured rich mix beams is recorded in comparison to control specimen. The last column of table 6 gives percentage value of flexural strength with respect to compressive strength. From this column it is observed that percentage value of flexural strength remained in the range of 18% to 22%. The upper limit is slightly higher than the percentage value of flexural strength reported in the literature. This shows better performance of coarse aggregates from old concrete. From the obtained results reliability of rebound hammer testing is witnessed.

Table 5: Minimum, maximum and average values of rebound number and strength for all batches.

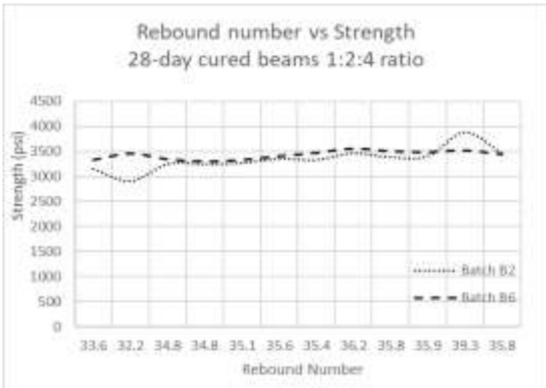
Batch	Ratio	Curing	% of RCA	Rebound Number			Strength (MPa)		
				Minimum	Maximum	Average	Minimum	Maximum	Average
G1	1:2:4	7-days	50	29.6	31.4	30.46	17.01	18.91	17.94
G2	1:2:4	28-days	50	32.2	39.3	35.38	20.00	26.82	23.04
G3	1:1.5:3	7-days	50	28.1	33.0	30.05	15.67	20.90	17.64
G4	1:1.5:3	28-days	50	38.0	39.7	38.74	25.94	27.26	26.60
G5	1:2:4	7-days	0	29.3	31.5	30.57	16.69	19.15	18.11
G6	1:2:4	28-days	0	35.3	36.7	36.01	22.81	24.58	23.70
G7	1:1.5:3	7-days	0	29.1	33.0	29.83	16.47	20.90	17.29
G8	1:1.5:3	28-days	0	38.2	39.6	38.93	26.08	27.23	26.56

Table 6: Flexural strength from NDT results by ACI 318-99.

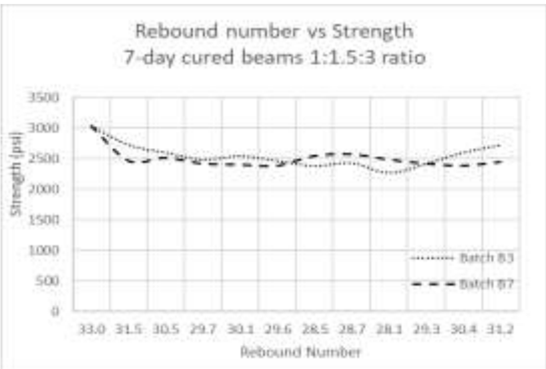
Batch	Ratio	Curing	% of RCA	Compressive Strength (MPa)	Flexural Strength (MPa)	% value with Comp Strength
G1	1:2:4	7-days	50	17.94	3.9819	22.19
G2	1:2:4	28-days	50	23.04	4.5124	19.58
G3	1:1.5:3	7-days	50	17.64	3.9474	22.38
G4	1:1.5:3	28-days	50	26.60	4.8478	18.23
G5	1:2:4	7-days	0	18.11	3.9998	22.09
G6	1:2:4	28-days	0	23.70	4.5761	19.31
G7	1:1.5:3	7-days	0	17.29	3.9085	22.61
G8	1:1.5:3	28-days	0	26.56	4.8448	18.24



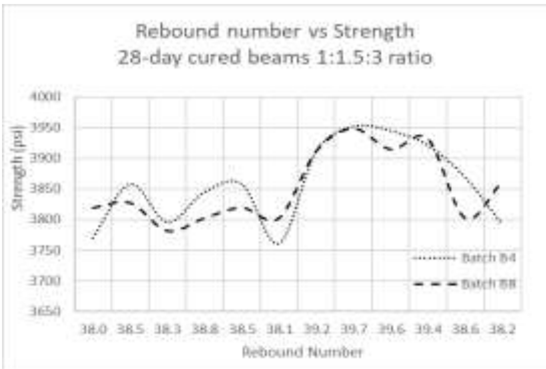
(a) 7-days cured beams, 1:2:4 mix.



(b) 28-days cured beams, 1:2:4 mix.



(c) 7-days cured beams, 1:1.5:3 mix.



(d) 28-days cured beams, 1:1.5:3 mix.

Figure 1: Graphical representation of Rebound number vs. strength.

3. CONCLUSION

This research work presents the non-destructive testing of reinforced concrete beams made with 50% replacement of natural coarse aggregates with coarse aggregates from old concrete by rebound hammer. 48 RC beams are prepared using normal and rich mix concrete. In each mix 50% beams are cured for 7-days and remaining 50% for 28-days. Same number of beams with similar parameters but with 100% natural coarse aggregates is also cast to compare the results. After curing all the beams are tested using digital rebound hammer for compressive strength. The compressive strength obtained is then converted in to flexural strength using ACI formulation. The proposed beams observed 5% deviation in compressive strength in comparison to control specimen, whereas, the flexural strength remained in the range of 18% - 22% of percentage value of compressive strength. From the obtained results it is concluded that not only the coarse aggregates from old concrete can effectively be used as coarse aggregates in new concrete but also ensures reliability of rebound hammer testing for proposed reinforced concrete beams.

4. REFERENCES

1. Memon B A, "Recent Development on Use of Demolished Concrete as Coarse Aggregates", International Journal of Emerging Technology and Innovative Engineering, 2016; 2(1).
2. Oad M and Memon B A, "Compressive Strength of Concrete Cylinders using Coarse Aggregates from Old Concrete", 1st National Conference on Civil Engineering (NCCE 2013-14) - (Modern Trends and Advancements), April 28th – 29th, 2014.
3. Memon B A, Bhatti G S, "Flexural Behavior of Beam made by Partial Replacement of Natural Aggregates with Coarse Aggregates from Old Concrete", International Journal of Engineering Sciences & Research Technology, 2014; 3(5).
4. Helal J, Sofi M and Mendis P, "Non-destructive Testing of Concrete: A Review of Methods", Electronic Journal of Structural Engineering (Special Issue), 2015; 14(1).
5. Sanchez K and Tarranza N, "Reliability of Rebound Hammer Test in Concrete Compressive Strength Estimation", International Journal of Advances in Agricultural & Environmental Engineering (IJAAEE), 2014; 1(2).
6. Yang H J, Kim J S, Kim S H and Yun H D, "Flexural Performance of Reinforced Concrete Beams with a Layer of Expansive Strain-hardening Cement based Composite (SHCC)", 15 WCEE, LISBOA, 2012.

7. Tameemi W and Lequesne R, “Correlation between compressive, Flexural and Tensile Behavior of Self-Consolidating Fiber Reinforced Concrete”, Structural Engineering and Engineering Materials, SM Report No. 114, The University of Kansas Center for Research, Inc., Lawrence, Kansas, October, 2015.
8. Saleem M A, Siddiqui Z A, Aziz M and Abbas S, “Ultrasonic Pulse Velocity and Rebound Hammer Testing for Non-destructive Evaluation of Existing Concrete Structure”, Pak. Journal of Engineering and Applied Sciences, January, 2016; 18.
9. Shang H S, Yi T H and Yang L S, “Experimental Study on the Compressive Strength of Big Mobility Concrete with Non-destructive Testing Method”, Advances in Materials Science and Engineering, Hindwai Publishing Corporation, 2012.
10. Hemant S L, Limaye A M and Kakde P E, “Evaluation of Concrete Structures using Non-Destructive Techniques”, Proceedings of the 20th International Conference on Nuclear Engineering Collocated with ASME, 2012.
11. ACI Committee 318. Building Code Requirement for Structural Committee (ACI-318-99) and Commentary (318-99). Farmington Hills, MI: American Concrete Institute, 1999.