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Non-Destructive Testing of Fully Recycled Aggregate Concrete Bricks Prepared by Compression Casting Technique

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ABSTRACT. *This research study aims to investigate the quality and strength of fully recycled aggregate concrete (RAC) bricks made by using Compression Casting Technique (CCT). Standard size RAC bricks were manufactured using 70% recycled coarse and 30% recycled fine concrete aggregates with 15% cement content by weight of total aggregates. Three values of casting pressure (i.e., 25, 30 and 35 MPa) were studied. Recycled concrete aggregates (fine and coarse) required for this study were produced by crushing of tested concrete samples having compressive strength range of 3000 to 4000 psi. Both destructive and non-destructive testing were performed on RAC bricks. Among NDT, ultrasonic pulse velocity test was performed to assess the quality of RAC bricks and based on results, a correlation between compressive strength and UPV test values is proposed. In addition, Schmitt hammer test was also performed, and their values were compared with laboratory tested samples. Results have highlighted that Schmitt hammer and UPV test can be consider as convenient and reliable way to assess the strength and quality of RAC bricks in the field.*

Keywords: Concrete, C&D waste, recycling, casting technique, NDT

1. INTRODUCTION

Annual production of concrete is 4.4 billion tons globally, but this figure is expected to rise to over 5.5 billion tons annually by 2050 [1]. Environmental issues like global warming, depletion of natural resources and concrete waste management are getting significance importance due to large production of concrete in construction industry worldwide. In Pakistan, production of Construction and Demolition (C&D) waste is 6 million tons approximately which is the 30% of total solid waste production as per the study of 2016 [2]. Pakistan is third largest brick producing country in South Asia with annual production of 45 billion bricks [3]. During their manufacturing process in kiln, huge amount of smoke is produced which causes environmental pollution. Since the raw material for making burnt clay bricks is soil, its continuous production on large scale results in the loss of top fertile soil that leads towards agricultural related problems.

In the construction sector, recycling the C&D waste is the most feasible and promising option that can reduce the adverse environmental effects of construction industry. In last three decades, significant research work on concrete containing recycled aggregate commonly known as Recycled aggregate Concrete (RAC) has been done and review articles on the properties of RAC have been published [4, 5]. Presently, main focus of research on RAC is on its applications in construction industry. In the research investigation presented in this paper, standard size bricks (226 mm [Length] x 113 mm [width] x 75 mm [height]) with minimum compressive strength of 13.8MPa were manufactured using fully RAC and Compression Casting Technique (CCT). Keeping in view the requirement of field testing to determine the quality of bricks, Non-Destructive Tests (NDT) including Schmitt hammer and ultrasonic pulse velocity (UPV) were employed to evaluate compressive strength and quality of prepared RAC bricks, respectively. Besides NDT, destructive compressive strength tests were also performed.

2. MATERIALS AND METHODS

In this research work, commercially tested samples (concrete cubes & cylinders) available in Concrete Laboratory of Civil Engineering Department UET Lahore having compressive strength ranges from 3000 psi (21 MPa) to 4000 psi (28 MPa) were used to produce Recycled Concrete Aggregate (RCAs). The complete process of production of RCAs is shown in Fig-1. Tests were performed to determine the density, compressive strength and quality of RAC bricks.

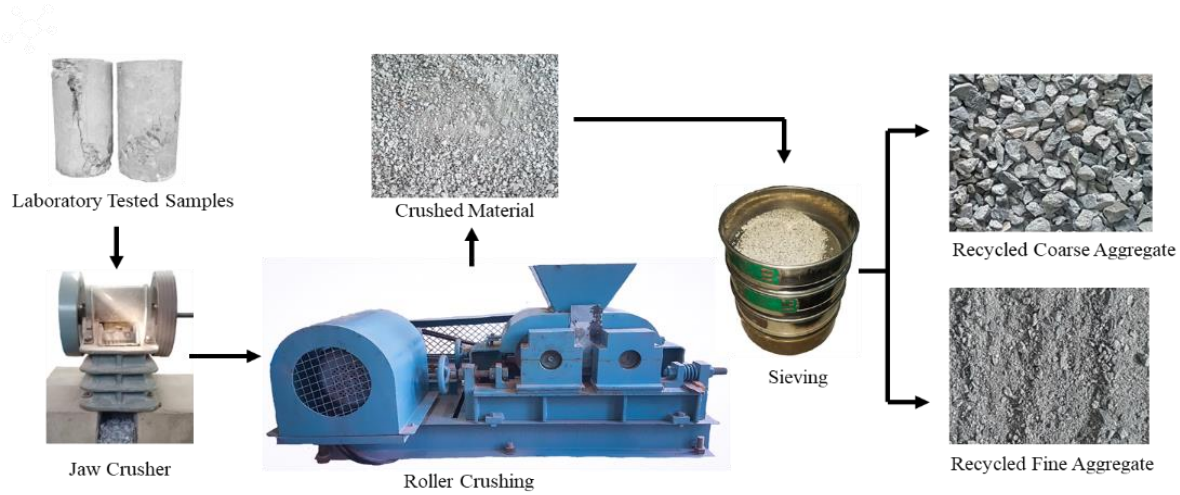

Fig-1: Production Process of Recycled Concrete Aggregates

2.1 Concrete Mix and Preparation of Bricks

Based on the findings of previous research [6] a RAC mix containing 70% RCAs and 30% fine RCAs with 15% cement content [by weight of total aggregates] was used in this study. The coarse RCAs were used in SSD condition and three different casting pressures were adopted. Considering the requirement of material fresh properties with respect to brick manufacturing by CCT, water to cement ratios of 0.3, 0.35 and 0.4 were selected. Detail of concrete mixes is given in Table-1, where designation RACB-70C30F is used for bricks prepared using RAC containing 70% coarse RCAs and 30% fine RCAs. Specially designed steel moulds were used to manufacture bricks under high pressure. This complete process of brick manufacturing is shown in Fig-2.

Fig-2: Manufacturing process of RAC Bricks

Table-1: Concrete mixes

Mix Designation	RACB-70C30F								
Cement Content	15% by total weight of aggregates								
w/c ratio	0.3			0.35			0.4		
Casting Pressure (MPa)	25	30	35	25	30	35	25	30	35
Superplasticizer	1% by weight of cement								

3. RESULTS AND DISCUSSION

3.1 Density

Density is one of the most basic parameters that classify the quality of RAC. After manufacturing of bricks by CCT, density of bricks was determined after 28 days of curing. For this purpose, weight and dimensions of bricks were measured. The value of density of RAC bricks are shown in Fig-3.

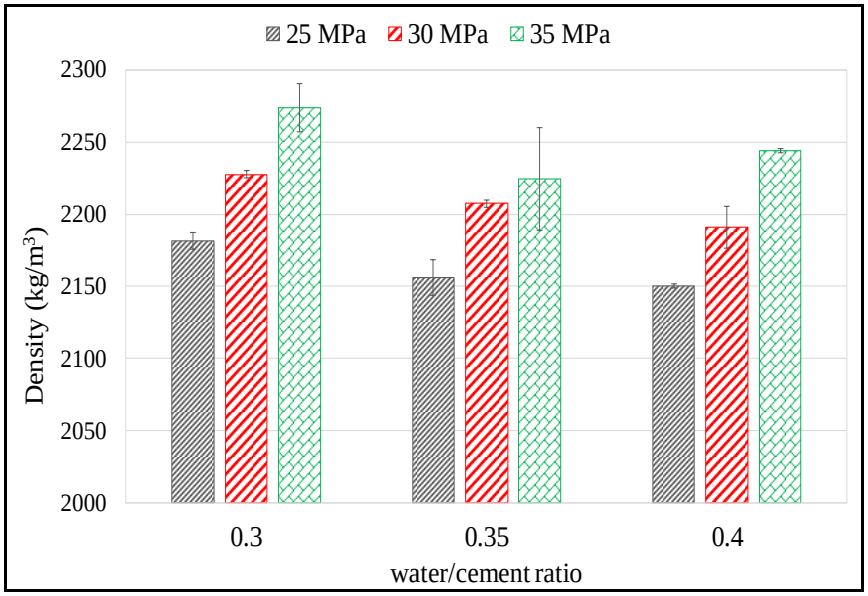

Fig-3: Density of RAC Bricks

It was noticed in these results that with the increase of applied casting pressure from 25 MPa to 35 MPa, the density of resulting RAC bricks was increased and this observation was true for all w/c used in this study. Among different bricks prepared, the maximum density was exhibited by RAC brick having w/c of 0.3 and prepared under casting pressure of 35 MPa while least value of density was attained by RAC brick having w/c of 0.4 under casting pressure of 25 MPa.

3.3 Rebound Hammer Test

Rebound hammer is a non- destructive test (NDT) which is used to determine the uniformity in the compressive strength of concrete member. This test gives surface strength of samples. The average of six values of rebound number was taken for each brick following ASTM C805 [7] and compressive strength was determined. For comparison, destructive testing (DT) in compression was also conducted. Compressive strength results of DT and NDT tests are shown in Fig-4. From these results, an average factor of 1.56 as ratio of DT to NDT values was found which can be employed in field to predict the compressive strength of RAC bricks based on NDT value.

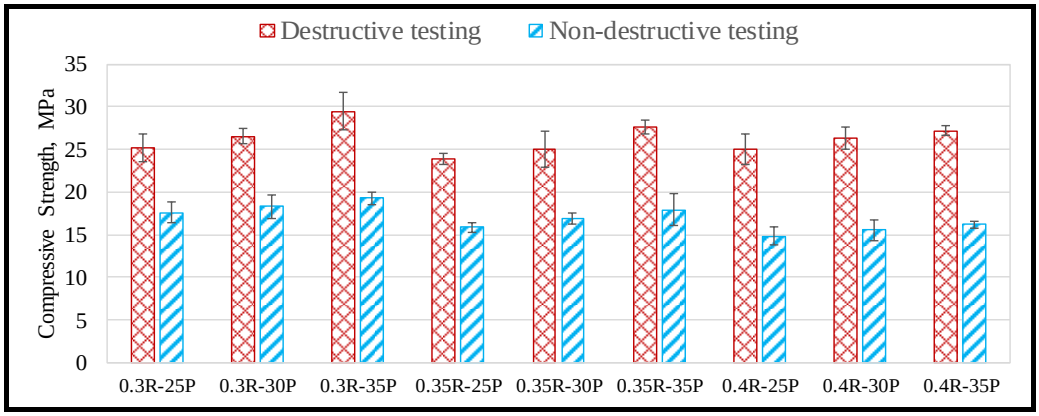

Fig-4: Compressive strength of RAC bricks (R is for w/c & P is for casting pressure)

3.2 Ultrasonic Pulse Velocity Test

UPV test was performed to determine the quality of RAC bricks with respect to their internal structure. For each case, three samples of bricks were tested. Standard UPV Test apparatus available in Civil Engineering Department UET Lahore was used to perform this test. The results are presented in Table-2, where the qualitative assessment of RAC bricks based on UPV value was done following the guidelines provided by Feldman [8]. It is observed in Table-2 that quality of all bricks was in the range of good to excellent.

Table-2: Results of UPV tests

w/c ratio	Casting Pressure	Sample	Time (sec 10^{-6})	Distance (m)	Velocity (m/s)	Average Velocity	Quality of Brick
0.4	35 MPa	A1	54.2	0.23	4244	4275	Very Good
		A2	53.7	0.23	4283		
		A3	53.5	0.23	4299		
	30 MPa	B1	56.9	0.23	4042	4083	Very Good
		B2	56.3	0.23	4085		
		B3	55.8	0.23	4122		
	25 MPa	C1	59.4	0.23	3872	3876	Good
		C2	59.3	0.23	3879		
		C3	59.3	0.23	3879		
0.35	35 MPa	D1	52.7	0.23	4364	4384	Very Good
		D2	52.3	0.23	4398		
		D3	52.4	0.23	4389		
	30 MPa	E1	59.4	0.23	3872	3903	Good
		E2	58.6	0.23	3925		
		E3	58.8	0.23	3912		
	25 MPa	F1	59.8	0.23	3846	3825	Good
		F2	60.4	0.23	3808		
		F3	60.2	0.23	3821		
0.30	35 MPa	G1	51.5	0.23	4466	4528	Excellent
		G2	50.2	0.23	4582		
		G3	50.7	0.23	4536		
	30 MPa	H1	55.7	0.23	4129	4159	Very Good
		H2	54.8	0.23	4197		
		H3	55.4	0.23	4152		
	25 MPa	I1	57.3	0.23	4014	3959	Good
		I2	58.2	0.23	3952		
		I3	58.8	0.23	3912		

3.3 Correlation between UPV and Compressive Strength

Based on the results of UPV tests and compressive strength obtained in this study, a correlation between UPV and f_c' as shown in Fig-5 has been proposed which could be employed in the field to predict the compressive strength of RAC bricks based on UPV value.

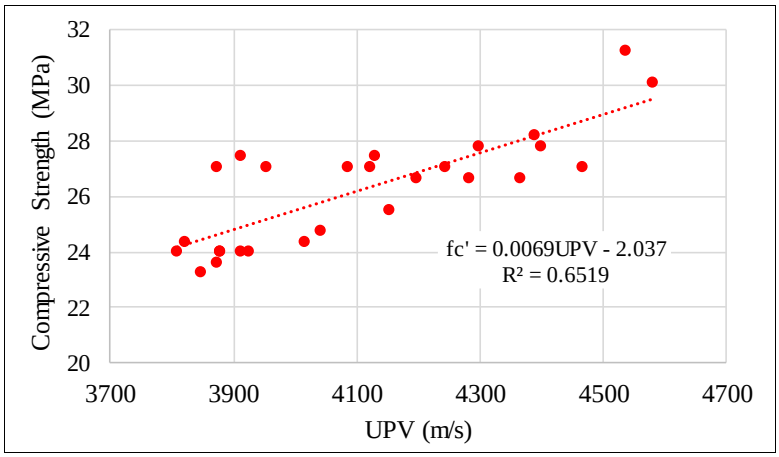

Fig-5: Co-relation between UPV and fc'

4. CONCLUSIONS

In this study non-destructive and destructive testing of fully RAC bricks were carried out and results obtained made it possible to draw the following conclusions:

- Density and compressive strength of RAC bricks are increased with the increase of casting pressure during their manufacturing.
- Increase in w/c ratio of mix results in detrimental effect on the mixture fresh state as well as on compressive strength.
- For fully RAC bricks prepared and tested in this study, a factor of 1.56 exists to determine the compressive strength of bricks based on strength determined by rebound hammer.
- An equation is proposed to determine the compressive strength of RAC bricks on site based on UPV value which could be considered a good tool for quality control Engineers.

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