Effect of Curing Types on Compressive Strength of Recycled Aggregates Concrete

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Abstract

In this research article, we analyze the effect of curing methods on compressive strength of recycled aggregates concrete prepared with 50% replacement of natural coarse aggregates as well as coarse aggregates from demolishing waste. We prepare 30 standard size cubes in six batches. In all batches 1:2:4 mix with 0.45 water cement ratio is used. One batch of the cubes is casted with all conventional aggregates. Five curing methods, i.e., water, air, gunny bags, steam and waste water are used to cure the specimens for 28 days. Our compressive strength results show that curing by gunny bags gives better strength results and helps in strength improvement of the recycled aggregate concrete. It is further observed that the compressive strength of the proposed specimens with gunny bags increases by 1.67% in comparison with compressive strength of conventional concrete specimens. Our experimental study shows that the use of demolished waste as coarse aggregates in new concrete along with appropriate curing method has promising results in terms of compressive strength.

Keywords—Green concrete, recycled concrete aggregates, curing types, compressive strength.

1 Introduction

Curing is one of the key parameters which helps concrete to attain its design strength and reduces the possibility of surface cracks. Any shortfall in this process leaves the concrete with several issues during the service life. Normally, standard water curing is done by ponding on horizontal large surface elements and by sprinkling on vertical members. Water used for this purpose should be potable. Nevertheless, in most of the areas, availability of potable water is either difficult or expensive. Bore water in many areas is also not usable for curing. Gray water and waste water might contain material that may affect the concrete properties.

On the other hand, growing population and migration from rural areas to city centers have posed a problem of accommodation everywhere in the world. To meet this requirement, high-rise buildings are a good option. But the space problem, particularly in city centers, is another issue which needs to be addressed. A solution of this problem is to demolish the old structures to erect new high-rise buildings. Demolishing old structures results in potential quantum of the construction waste. Although, type and quantity of this waste is different from region to region, but it has posed serious problems everywhere. Generally, this waste goes in landfills near the city bounds, but the space problem as mentioned earlier, forces the relevant persons to leave the material either nearby the construction site or it goes to cultivable space which in turn damages the agriculture land. This process poses a serious issue in a country like Pakistan, as agriculture is the back bone of the country's economy.

The best solution to deal with this type of waste is using it in new construction. Although, good quantity of this waste may be used in floors, footpaths, etc., but the residual quantum turns out to be huge. Therefore, using it in new concrete as coarse aggregate is one of the best options to reduce its management and to develop new material for concrete. The process not only reduces the waste management, but also saves the cultivable lands and the natural sources of the aggregates. In addition, it also reduces the adverse effects on the environment caused by quarrying of the aggregates and reactions due to deposition of the waste.

This research work investigates the concrete strength using standard size cylinders cast with partial replacement of coarse aggregates from demolishing waste and

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cured with different methods of curing. The curing of the specimens is proposed to be done by covering with gunny bags, sprinkling water, using waste water, steam curing and open-air curing. Additionally, specimens are cured by fully immersing in potable water. These specimens are treated as control specimens. The results of the proposed specimens are compared with those of control specimens.

2 Literature Review

Usage of demolishing concrete as coarse aggregate in fresh concrete has remained active since past few decades. Different scholars around the world have studied the material from different perspectives. Memon et al. [1] reviewed the recent developments about the use of the material. Recycling techniques have considerable impact on the final strength of concrete using it [2]. The properties of aggregates and concrete at fresh and hardened states have also been studied by the scholars. Old mortar attached with the aggregates demands more water to ensure workability of the concrete. Cracked particles, age, construction environment affect concrete at both fresh and hardened states.

Mechanical properties and elastic behavior of concrete using demolishing waste [3] and flexural stress-strain behavior [4] shows that the material has promising effect on strength and elastic behavior when used in new concrete.

Effect of curing on properties of concrete and alternative methods to improve the same has also remained active area of research among the scholars. To this end, Abel-Hey et al. [5] used different curing methods to check the strength of recycled aggregate concrete. The authors observed that curing by paint gives better results than other methods of curing. Zhao et al. [6] tested self-compacting concrete for analyzing effects of initial curing and different curing conditions. The test results revealed that at least 7-days water curing is necessary for optimum strength of the product. Compressive and tensile strength of self-compacting concrete with fly ash and with silica fume under different curing conditions have also been studied by Yazicioglu et al. [7]. The test results of the specimens cured for early, medium and standard (28-day) curing showed that after standard water curing, air-tight curing condition gives better results than open-air curing of the samples.

Weather conditions during concreting and curing also contribute towards the final strength of the product. Optimum weather conditions seldom exist, therefore, either the timing of concreting is adjusted, or additional measures are used to ensure the least effects of weather on concreting. Nevertheless, curing is a continuous process over certain period. Therefore, weather conditions must be considered during the period. Effects of hot weather on strength and durability of beam and slab models cast with OPC and silica fume have been studied by Ibrahim et al. [8] by using burlap covering and curing compounds. They initially used water curing followed by curing compounds and observed that initial curing period plays a vital role in durability and strength of concrete. Zayed et al. [9] also concluded that water curing gives best results for high strength concrete reinforced with polypropylene fibers and curing by different methods up to 90 days. On the other hand, Al-Jabri et al. [10] used waste water from car service stations in the production of high strength concrete. The authors argued that although the pH, TDS and other parameters of water were higher than those of tap water, but they were in the same range as specified by ASTM. In addition, the strength and water absorption of 28-days cured samples were comparable with those of the control specimens prepared with tap water. The effect of improper moist curing on flexural strength of beams was studied by Raha et al. [17]. The author reported that the strength can drop by even 39% due to improper curing.

Effect of different curing conditions, i.e. standard water curing, curing in dry oven and curing at temperatures higher than room temperature was studied by Wadatalla et al. [11] for high strength concrete. The authors observed a good correlation between the strength and other properties of the concrete for all curing methods. In a comparative study on curing methods [12], the authors used water, air and film coating for curing and observed that water curing gives good strength to concrete even if curing prolonged up to 56 days. In a separate study by Akeem et al. [13], density and strength of concrete were studied under different curing conditions. Among six different methods, authors observed weak correlation between the parameters with air curing of the specimens. The similar conclusion was made by Boakye et al. [14] for compressive strength of pulverized coper slag concrete. The authors also concluded that strength drop is observed with increase in the dosage of coper slag.

Steam curing is one of the methods adopted for this purpose and has been successfully used for pavers and curb blocks. The same has been used by Ramezanianpour et al. [15] for 36 samples which resulted in a good improvement in the strength. Based on the observations, they introduced a curing cycle for optimum strength for pre-cast industry. Liu et al. [16] also observed an improvement in concrete strength

(a) Large blocks of old concrete

(b) Recycled coarse aggregates

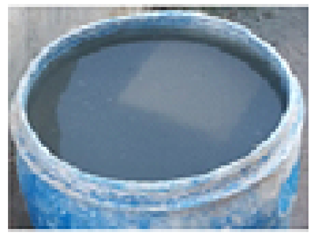
Fig. 1: Large blocks of old concrete, and recycled coarse aggregates

with fly-ash when cured for 13-hour by steam curing. From the literature review, it is obvious that a myraid of research gaps exist. In addition, the effect of the curing methods on green concrete developed with demolishing concrete as coarse aggregates has not been well studied.

3 Material & Testing

The demolished concrete in the form of large blocks was collected from the demolishing of two-story residential building situated in the downtown of Nawabshah city. These blocks were manually crushed to obtain coarse aggregates of maximum size equal to 25 mm. Unwanted substances and cracked particles were manually removed followed by washing of the aggregates. Both natural and recycled aggregates are then sieved in accordance with ASTM provisions to obtain well graded aggregates. Water absorption and specific gravity of both the aggregates are evaluated. The obtained results are given in Table 1.

To cast the standard size cubes ($150\,mm \times 150\,mm \times 150\,mm$), ordinary Portland cement, natural coarse aggregates, recycled coarse aggregates, and hill sand are mixed in 1:2:4 proportion with 0.45 water cement ratio. The natural coarse aggregates are replaced in 50% proportion, as the strength loss with this dosage is least in comparison to conventional concrete [18]. Total 30 cubes were prepared in six batches as shown in Table 2. Batch B1 was casted from all conventional aggregates and treated as control specimens to check and compare the results of other curing methods. The cubes of batch B2 were cured in standard fashion by fully immersing in potable water. The strength results of the cubes cured in open air, by gunny bags, by steam and by waste water are also compared with the strength results of batch B2. After casting, the cubes were cured by five different methods mentioned in Table 2 for 28 days. Figure 2 shows the curing arrangement of the cubes. After the curing time elapsed, the weight of the cubes were determined. All the cubes were then tested in universal testing machine for compressive strength by gradually increasing the load till failure. Figure 3 shows the testing of a cube. The weight and strength results of the cubes are given in Table 3 - Table 8.

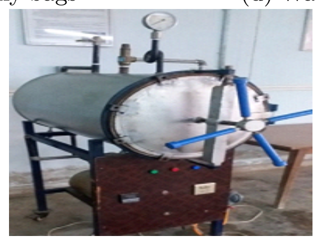


(a) Ponding

(b) Open air

(c) Gunny bags

(d) Waste water



(e) Steam

Fig. 2: Different curing arrangements

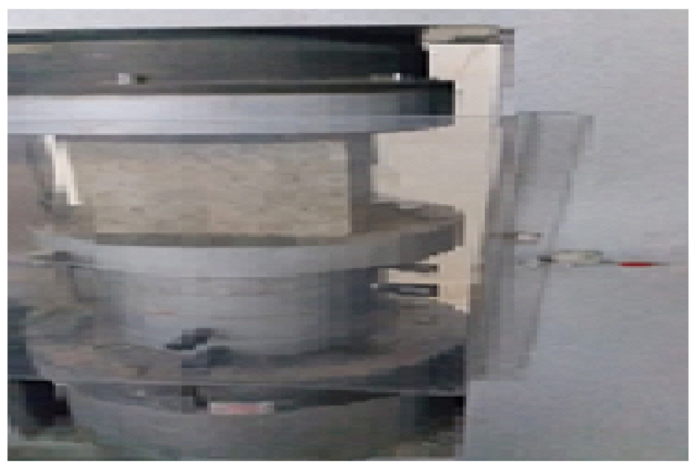


Fig. 3: Testing of the cube

4 Results & Discussion

Test results of water absorption and specific gravity presented in the previous sections are compared in

SNO.	Material	Weight in Water (gm)	Saturated Weight	Oven Dried weight	Specific gravity	Water Absorption (%)
1	CA	690	1114	1097	2.63	1.17
2	RA	676	1138	1077	2.33	5.61

TABLE 1: Water absorption and specific gravity of aggregates

SNO.	Batch #	Recycled Aggregates (%)	Natural Aggregates (%)	No. of cubes	Curing method
1	B1	0	100	5	Potable water
2	B2	50	50	5	Potable water
3	B3	50	50	5	Open Air
4	B4	50	50	5	Gunny bags
5	B5	50	50	5	Steam
6	B6	50	50	5	Waste Water

TABLE 2: Details of cubes

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.94	866.232	38.2
2	8.842	852.622	39.1
3	8.876	831.943	37.5
4	8.82	747.49	35
5	8.817	812.302	36

TABLE 3: Batch B1

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.94	866.232	38.2
2	8.842	852.622	39.1
3	8.876	831.943	37.5
4	8.82	747.49	35
5	8.817	812.302	36

TABLE 4: Batch B2

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.334	660.14	30.9
2	8.123	587.98	26.7
3	8.453	574.94	25.5
4	8.543	756.49	28.6
5	8.123	612.9	36

TABLE 5: BATCH B3

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.74	770.23	34.25
2	8.771	908.62	39.98
3	8.743	870.94	38.58
4	8.62	747.49	37.1
5	8.763	889.3	39

TABLE 6: Batch B4

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.709	710.23	31.2
2	8.552	587.62	29.1
3	8.517	798.94	30.5
4	8.596	629.49	28.8
5	8.467	671.3	27

TABLE 7: Batch B5

#	Weight (Kg)	Loading (kN)	Compressive Strength (Mpa)
1	8.94	876.28	38.76
2	8.852	900.62	35.97
3	8.74	826.94	36.5
4	8.632	647.49	35.87
5	8.871	789.3	35.33

TABLE 8: Batch B6

Figure 4. It may be observed that water absorption of recycled aggregates is approximately 380% higher than those of the conventional aggregates. Whereas, specific gravity of recycled aggregates is 11.4% lower than that of the conventional aggregates. Both the deviations are attributed to the old mortar attached with the RCA. The average weight of all batches of the cubes is given in Table 9. The same is compared with control specimen in Figure 5. It may be observed that the average weight of the conventional concrete cubes remained higher than the recycled aggregate concrete specimens for all curing methods. Maximum weight is observed in specimens cured in waste water, whereas, the minimum weight is recorded for cubes cured in open air. The weight loss for the proposed specimens cured in the similar way to conventional concrete cubes is measured to be 1.22%. This shows that the use of demolishing waste as coarse aggregates produces lighter concrete as compared to the conventional concrete. It is further observed that the waste water curing results

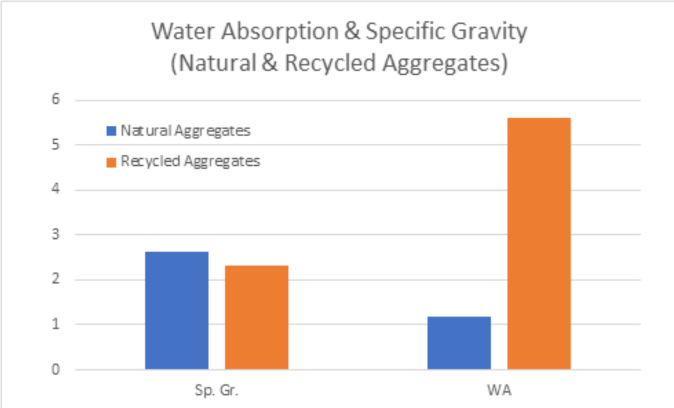


Fig. 4: WA and Sp. Gr. of NA and RCA

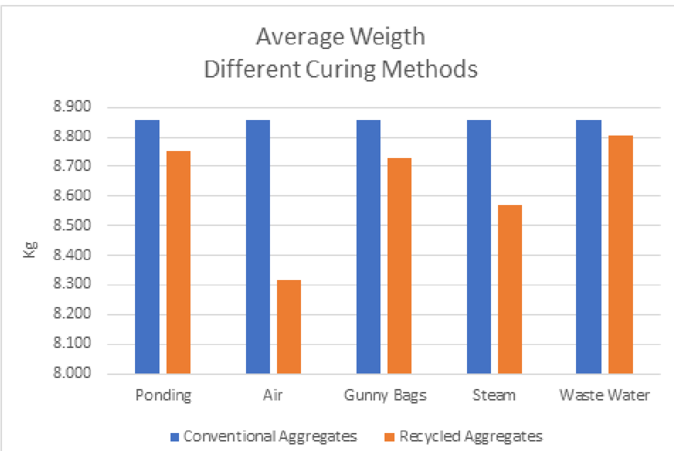


Fig. 5: Comparison of average weight

in least weight loss of the proposed specimens.

The compressive strength results of all batches of the cubes are plotted in Figure 6. It can be observed that none of the strength result of the specimens in any batch deviated more than 15% than the average compressive strength of the respective batch. The maximum average strength is recorded for the curing with gunny bags. The strength recorded with this curing method is 1.85% higher than the average strength of batch B1 cubes (conventional concrete cubes cured in potable water). The comparison of average strength with respect to conventional concrete specimens cured in potable water is given in Table 10. The average compressive strength in B1 cubes (control specimens) is measured to be 37.16 Mpa. In comparison to this, concrete cubes cured by fully immersing in water observed 4.4% less strength. Similarly, RCA cubes cured in open air in waste water and by stream were observed to have 20.5%, 1.8% and 21.1% reduction in compressive strength. The RCA cubes cured by covering with gunny bags were observed to increase about 1.7% in compressive strength. While comparing the strength results of RCA cubes with those of batch B2 (RCA cubes cured by fully immersing in potable water), it is noted that the maximum strength loss is observed in steam cured cubes. The cubes cured in open air also observed strength reduction, though less than the steam cured cubes. Other two batches of the cubes B4 (Gunny bags) and B6 (Waste water) observed an increase in strength as compared to potable water cured cubes (B2). Again, it is noted that cubes cured by covering with gunny bags showed about 6% increase in strength. The compressive strength of RCA cubes cured by standard curing versus other methods of curing is illustrated in Figure 7.

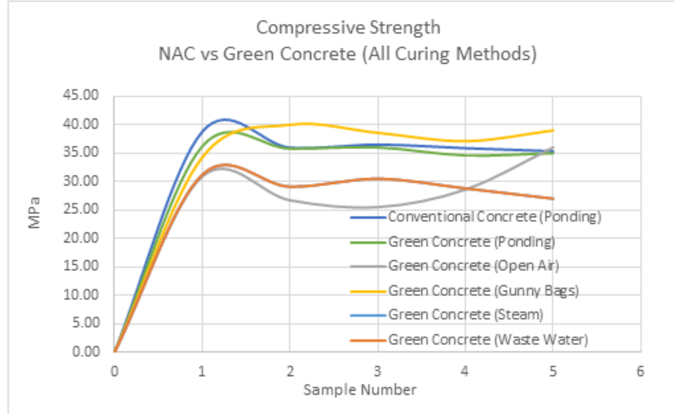


Fig. 6: Compressive strength (All curing methods)

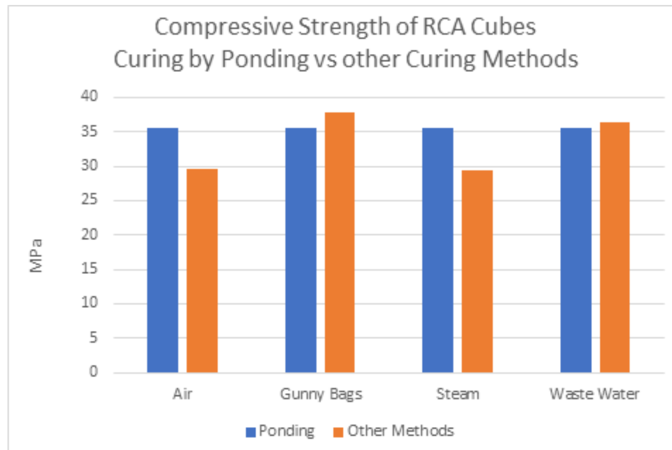


Fig. 7: Compressive strength RCA cubes

5 Conclusion

From the test results it is concluded that although standard water curing serves the purpose very well, but the improvement in both weight and compressive strength can be achieved by adopting curing of the

#	Batch	Curing Method	Recycled Aggregates (%)	Average Weight (Kg)	Weight Loss
1	B1	Potable Water	0	8.859	–
2	B2	Potable Water	50	8.751	1.22
3	B3	Open Air	50	8.315	6.14
4	B4	Gunny Bags	50	8.727	1.49
5	B5	Steam	50	8.568	3.28
6	B6	Waste Water	50	8.807	0.59

TABLE 9: Average weight of concrete cubes for different curing methods

#	Batch	Curing Method	Recycled Aggregates (%)	Compressive Strength (MPa)	Reduction
1	B1	Potable Water	0	37.16	–
2	B2	Potable Water	50	35.52	-4.41
3	B3	Open Air	50	29.54	-20.5
4	B4	Gunny Bags	50	37.78	1.67
5	B5	Steam	50	29.32	-21.1
6	B6	Waste Water	50	36.49	-1.81

TABLE 10: Average compressive strength for all curing methods

recycled aggregate concrete with gunny bags. Present study with limited number of specimens shows an increase in weight and compressive strength equal to 1.5% and 1.7% respectively.

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