



Effects of waste ceramic aggregate on compressive strength of cement mortar

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Abstract

In Bangladesh, the cost of building materials is increasing gradually, available raw materials of construction are not sufficient to meet up the needs of the country. For that we have to find out cheaper and waste materials (such as ceramic waste) to reuse for construction. The study was conducted to observe the physical properties of waste ceramics and compressive strength of ceramics mortar for different curing ages. The study was done to check the probability of using waste ceramics instead of natural aggregates (sand). The fineness modulus of ceramics aggregates was 2.94. Ceramic aggregate absorbs 5.89% moisture whereas sand absorbs 14.33%. Generally, finer the aggregate shows greater the compressive strength. Though the fineness modulus of ceramics was greater than that of sand, it possessed higher compressive strength because of its self-strength. The ratio of mortar mixture was (1:2) and (1:3) for different curing periods both sand and ceramics samples. The compressive strength of sand and ceramic mortar was 2603 psi and 3500 psi respectively at the ratio of (1:2) for 3 days curing. On the other hand the compressive strength of sand and ceramics mortar was 2340 psi and 3075 psi respectively at the ratio of (1:3) for 3 days curing. Between the sand and ceramic mortar, the compressive strength of ceramic mortar was found maximum at 28 days curing period. It can be concluded that recycled ceramic aggregates will be used in comparatively low load bearing, low cost temporary and medium category farming etc. concrete structure.

Key words: Waste ceramics, mortar, fineness modulus, compressive strength, curing

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Introduction

The ceramic waste from ceramic and construction industries has a major contribution to the concrete production. The major sources of ceramic waste are ceramic industry, buildings construction and buildings demolition. In ceramic industries, a significant part of the losses in the manufacturing of ceramic elements is not returned to the production process. In building construction, ceramic waste is produced during the transportation of ceramics materials to the building site due to inconvenience transport and also during the execution of several construction elements (facades and partition walls, roofs, and precast joist slabs) and

on subsequent works, such as the opening of grooves. This waste is regionally deposited in dumping grounds, without any separation or reuse (Correia et al., 2006). Recent advances in construction engineering have made the design of safe structures possible and attracted an increasing attention to the use of concrete for its beneficial properties. Along these lines, the use of ceramic wastes in concrete has been widely investigated. Porcelain ceramic is a new generation of ceramics that is highly heat resistant and offers a great resistance against pressure. It was found that porcelain tile waste was able to increase concrete compressive

strength by up to 41%. Additionally, porcelain was found capable of increasing tensile and flexural strengths by up to 41% and 67%, respectively (Keshavarz and Mostofinejad, 2009). The strength of concrete depends on the quality of fine aggregates. The quality of fine aggregates depends on the sources of collection, size and gradation of the aggregates. The ceramic fine aggregates improve concrete quality with their proportion (Jackiewicz-Reka et al., 2015). Ceramic waste can be used widely in the production of concrete due to its some favorable properties such as durability, hard and highly resistance to chemical and physical degradation (Jimenez et al., 2013). Ceramic wastes as a construction material can be a viable solution not only for pollution problems control, but also as an economical option in the design of buildings, rice drying ground etc. This paper presented the use of ceramic materials from different resources as partial replacement of conventional materials and focusing on the making of mortar.

Materials and Methods

To carry out the study, the materials used were cement, sand, waste ceramic and water. Ordinary Portland cement was used throughout this experiment. The initial setting time of the cement was 1 hour and 10 minutes and final setting time was 4 hours and 25 minutes. In this experiment, dry and clean sand was used which was collected from local market having fineness modulus of 2.77. Debris ceramics which were collected from crockery shop of Mymensingh town. The water used for the experiment was supplied tap water, free from all dirt (BS 3148, 1980).

Preparation of materials: Crushed ceramics which is termed as fine aggregate was prepared from the broken and waste ceramics. These were cleaned and crushed into aggregate by hammer keeping on a stone surface with proper safety. Then the broken ceramics was sieved and graded in different sizes. Aggregate passed through ASTM sieve #8 (Sieve opening 2.36 mm) was used as fine aggregate (Figure 1 & 2).



Figure 1. Ceramic aggregates.



Figure 2. Preparation of ceramic mortar.

Physical properties of ceramic aggregate: Laboratory tests carried out on the ceramic aggregates include water absorption test, specific gravity, particle size distribution and water cement ratio. Water absorption test was performed on ceramic fine aggregate by keeping the samples immersed in water and removing the excess water on the surface of the samples after 24 hours, and measuring the saturated weight. After that, the samples were kept in the oven by maintaining $100\pm 5^{\circ}\text{C}$ for 24 hours. Oven dry weight of the samples was recorded and the water absorption capacity was evaluated. For particle size distribution, ceramic aggregates were sieved by using the ASTM #4, #8,

#16, #30, #50 and #100. Using sieve shaker, sieve series with aggregates was shaken around 4 to 5 minutes and then aggregate retained on individual sieve was measured and recorded.

Mechanical property of ceramic mortar: Strength is commonly considering the most valuable property. Strength usually gives overall picture of quality of materials. Strength is of different types such as compressive strength, tensile strength, flexural strength and shear strength. In this study the compressive strength of mortar cubes were performed in three different curing ages such as 3 days, 7 days and 28 days (Figure 3).

Sand-cement and ceramic-cement mortar block were prepared using 2.78 inch cube according to following mix proportions (Table 1).



Figure 3. Curing of the cubes

Table 1. Mix proportion for sample preparation

Mixing ratio	Cement(gm)	Sand(gm)	Ceramic(gm)	Water(gm)	W/C ratio
1:2	3000	6000	-	1400	0.48
	2500	-	5000	1080	0.43
1:3	2200	6600	-	1200	0.54
	2000	-	6000	900	0.45

The mortar cubes were wiped properly before placing in the compression testing machine (Figure 4) for compressive strength test and crushing loads were recorded.



Figure 4. Compressive strength test

Results and Discussion

Physical properties of the aggregates: The results of the investigation on some physical properties of ceramic waste, and aggregates used are presented in Table 2. Recycled aggregate generally has a higher absorption but ceramic remains high clay soil and burned materials which has small particles and tiny pore space. For this reasons ceramic aggregates absorb less water than sand.

Gradation curve of sand and ceramic aggregates: Grading curves showed that the sand and ceramic waste aggregates were well graded and suitable for concrete production. Medium size of sand was found smaller for sand but for ceramic waste aggregates, medium size was found greater. Effective size of sand

was found greater for sand but for ceramic aggregates, effective size was found smaller (Figure 5 & 6).

Table 2. Physical properties of sand and ceramic aggregates.

Aggregates	F.M	Water absorption (%)	Specific gravity
Sand	2.77	14.33	2.65
Ceramic	2.94	5.89	2.84

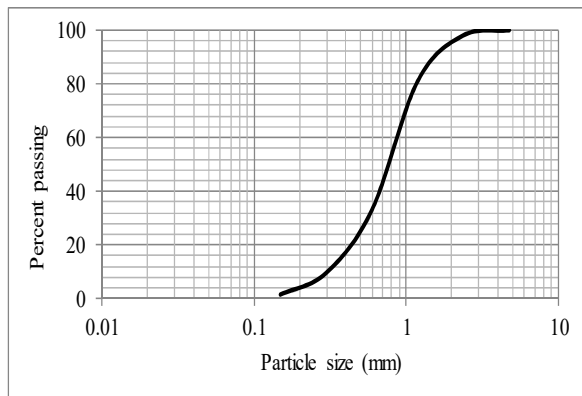


Figure 5. Gradation curve for sand aggregate.

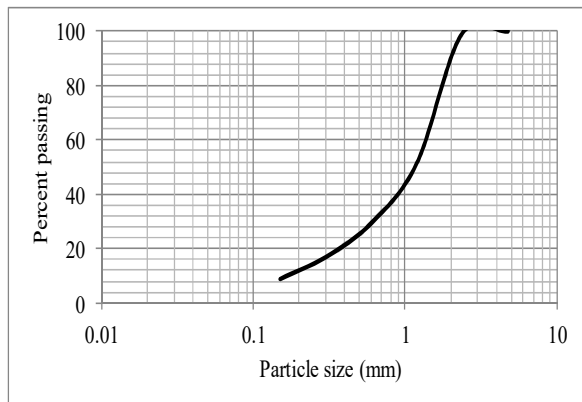


Figure 6. Gradation curve for ceramic aggregate.

Effect of curing period on compressive strength of mortar cube: The compressive strength of sand-cement mortar was increased significantly according to the curing period at a mix ratio of 1:2. The maximum compressive strength was found 5271.21 psi at 28 days curing (Figure 7). But at the same ratio and same

curing period the compressive strength of ceramic-cement mortar was found 6124.23 psi which is greater than sand-cement mortar (Figure 8).

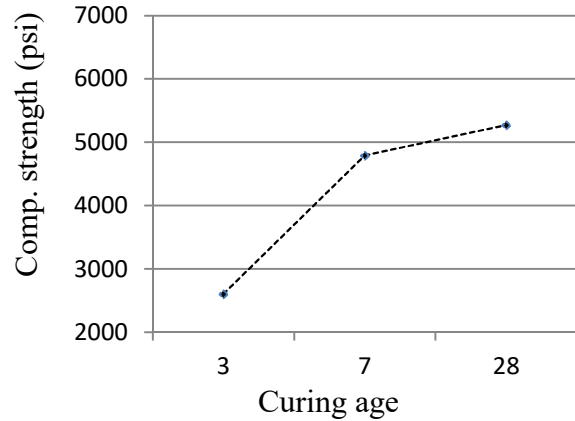


Figure 7. Relation between compressive strength of sand-cement mortar and different curing days at ratio 1:2.

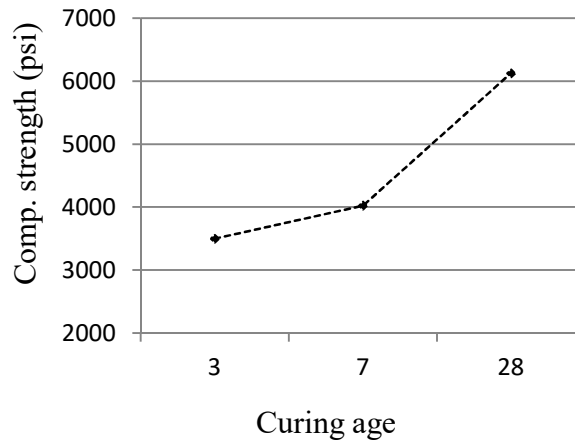


Figure 8. Relation between compressive strength of ceramic-cement mortar and different curing days at ratio 1:2.

On the other hand while mixing ratio was 1:3, at 28 days curing period the compressive strength of ceramic-cement mortar was greater than that of sand-cement mortar (Figure 9 & 10). However, at 28 days curing the compressive strength of ceramic-cement mortar is greater than that of sand-cement mortar but at

early age up to 7 days the compressive strength of sand-cement mortar was higher than ceramic-cement mortar in both mixing ratio of 1:2 and 1:3. (Figure 11 & 12).

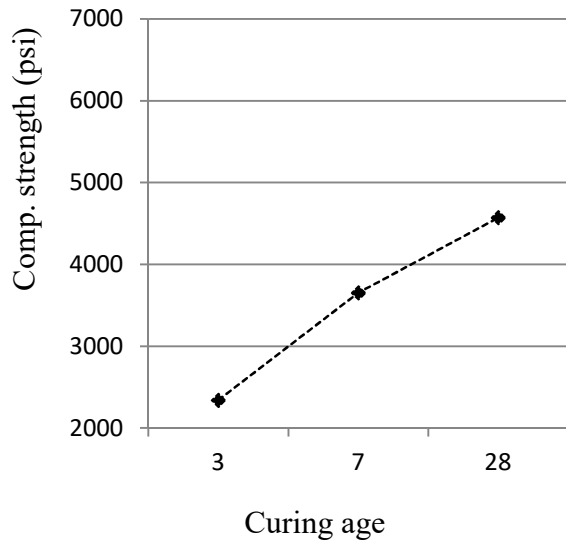


Figure 9. Relation between compressive strength of sand-cement mortar and different curing days at ratio 1:3.

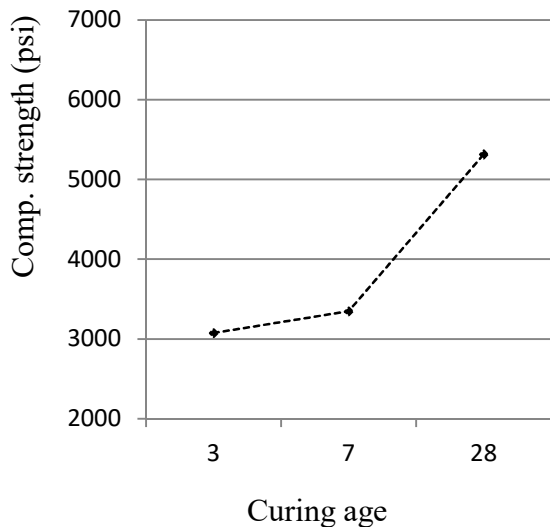


Figure 10. Relation between compressive strength of ceramic-cement mortar and different curing at ratio 1:3.

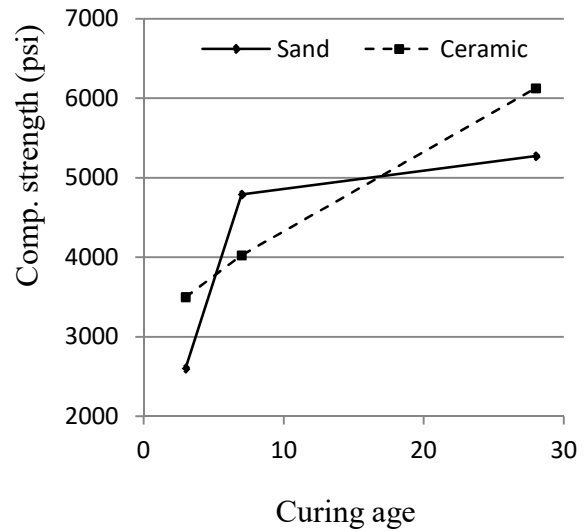


Figure 11. Relation of compressive strength between sand mortar and ceramics mortar at ratio 1:2.

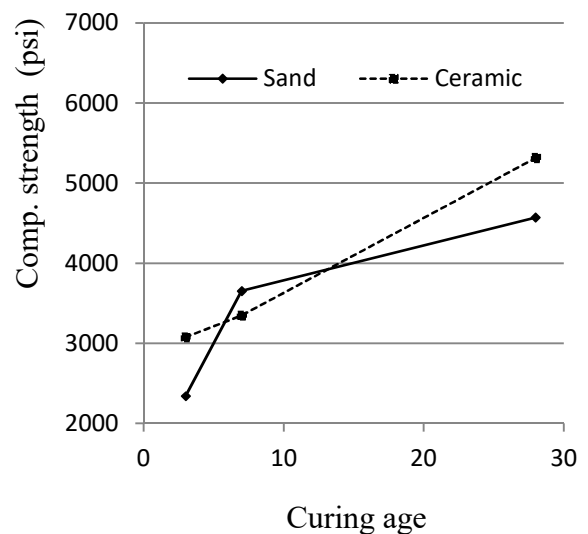


Figure 12. Relation of compressive strength between sand mortar and ceramics mortar at ratio 1:3.

Effect of mixing ratio on compressive strength of mortar cube: The compressive strength of sand-cement mortar and ceramic-cement mortar at different days of curing were found different with different mixing ratio of 1:2 and 1:3 (BS EN 12350-6, 2009) (BS EN 12390-3, 2009). The compressive strength of different mortar

cubes at a mixing ratio 1:2 was greater than mixing ratio of 1:3 (Figure 13 & 14).

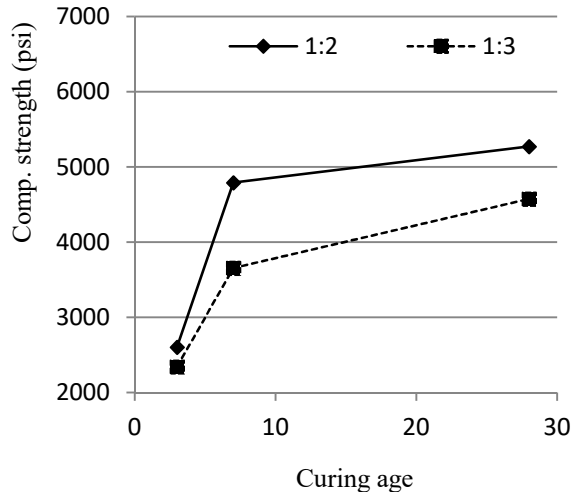


Figure 13. Compressive strength of sand mortar cube at different ratio of 1:2 and 1:3.

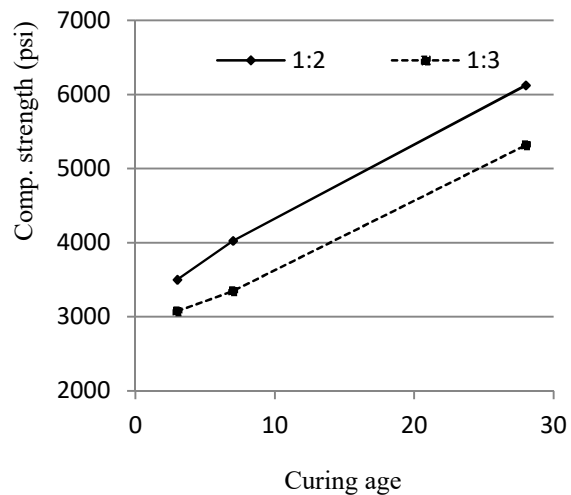


Figure 14. Compressive strength of ceramic mortar cube at different ratio of 1:2 and 1:3

Conclusions

From the study, following conclusions can be made:

1. Ceramic aggregate absorbs less water than traditional aggregate sand.

2. Compressive strength increases with the decrease in water-cement ratio.
3. Compressive strength of mortar cube made of ceramic aggregate is higher than that of sand mortar cube at different curing period.
4. Strength of ceramic mortar increases considerably during 7 to 28 days of curing.

Acknowledgement

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