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Utilization of Freshwater Mussel Shells in the Production of Alkali Activated Composites

Chitra Shijagurumayum and Thokchom Suresh

Ph.D. Scholar, Department of Civil Engineering Manipur Institute of Technology, Takyel, Imphal, Manipur
Faculty, Department of Civil Engineering Manipur Institute of Technology, Takyel, Imphal, Manipur
E-mail: chitras10shij@gmail.com, thoks1966@gmail.com

Abstract—*Duck mussel (Anodontaanatina) is a type of freshwater edible mussel which is also found in rivers flowing in the north east regions of India. X-ray fluorescence analysis of the shells of duck mussel reported the presence of very high percentage of calcium oxide, lower value of silicon dioxide and very little percentage of aluminium oxide. In this research, ground powdered form of the shells was used to replace ground granulated blast furnace slag (GGBS) partially in the production of alkali activated composites (AAC). The ground shells of the mussels were prepared by boiling, crushing, grinding and sieving through IS sieve size of 75 micrometre. The trial mix used in this work was in a proportion of 40% replacement of GGBS by mussel shells. The physical and mechanical properties studied were bulk density, compressive strength and quality test using ultrasonic pulse velocity (UPV) method. These properties were compared with those AAC produced using GGBS activated using activator solution having Na_2O of 10% and SiO_2 of 10% by weight of GGBS. Furthermore, the test samples were exposed to elevated temperatures of 300˚C, 600˚C and 900˚C. After exposure, the weight loss and compressive strength was determined. The compressive test results obtained both through destructive and non-destructive test shows that AAC produced using 100% GGBS were higher. However, it is noted that the water absorption, apparent porosity and sorptivity values of the specimens made incorporating shells were lower, which isadvantageous to increase water tightness property.*

1. Introduction

Alkali activated composites(AAC) are alumino silicate polymers which has been gaining much attention in recent years. Precursors such as fly ash having low content of calcium and the AAC produced using such precursors are often termed as geopolymers. Ground granulated blast furnace slag (GGBS) has comparatively higher content of calcium and their reaction with alkaline solutions leads to the formation of C-A-S-H gel($Cao-Al_2O_3-SiO_2-H_2O$).[1,2]

The use of various kinds of seashells as a partial to full replacement of cement, fine aggregate and coarse aggregate has been studied by various researchers.[3-5] Duck mussel is a type of freshwater edible mussel and has reported the presence of high percentage of calcium oxide. Fresh duck mussel shells are shown in Figure 1.

Figure 1: Duck mussel

The objective of the present study is to develop alkali activated composites based on GGBS and ground shells of duck mussels and make a comparative study on their properties.

2. Experimental program

The materials used for the present experimental investigations are GGBS and powdered shells of duck mussels. The activating solution used was a mixture of sodium silicate, sodium hydroxide flakes and water.[6] The chemical composition of GGBS and grounded shells in percent mass are given in Table 1.

Table 1: Chemical composition of GGBS and Mussel shells (% mass)

Chemical composition	GGBS	DM
SiO_2	35.01	1.40
Al_2O_3	17.13	0.57
Fe_2O_3	1.10	0.80
TiO_2	0.54	-
CaO	36.58	95.73
MgO	6.61	0.16
K_2O	0.62	0.06
Na_2O	0.27	0.42
SO_3	1.69	0.26
P_2O_5	-	0.13
MnO	0.36	0.33

3. Preparation of specimen

Two types of test specimens were made. GB is the specimen made by taking only 100% GGBS as the binder. The other sample was prepared by replacing 40% of binder with grounded shells and it is represented as DM. For both the samples, the activator used was a mixture of sodium silicate, sodium hydroxide flakes and water. The Na_2O and SiO_2 was maintained at 10% of the weight of the binder. The specimens were prepared by mixing in a non-absorbent container and casted into moulds of size 50 mm cube.

4. Test conducted

The tests conducted on the specimens werewater absorption, apparent porosity, sorptivity, compressive strength. In addition, the specimens were exposed to elevated temperatures upto 900˚C. The effect of the elevated temperatures on the specimens such as change in surface texture, loss in weight and relative strengths of the specimens were found out with respect to the initial strength of the unexposed samples.

5. Results and discussions

5.1 Water absorption and apparent porosity

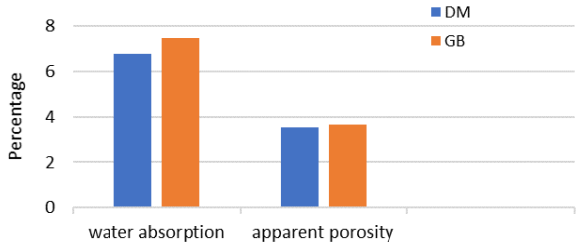

Figure 2: Chart showing water absorption and apparent porosity of the two specimens

The results of water absorption and apparent porosity are presented in Figure 2. The water absorption of samples GB were more than those of DM samples by just 0.7%. Higher water absorption indicates higher porosity. Thus in the case of apparent porosity, GB samples with higher water absorption exhibited higher apparent porosity by 0.14%.

5.2 Sorptivity

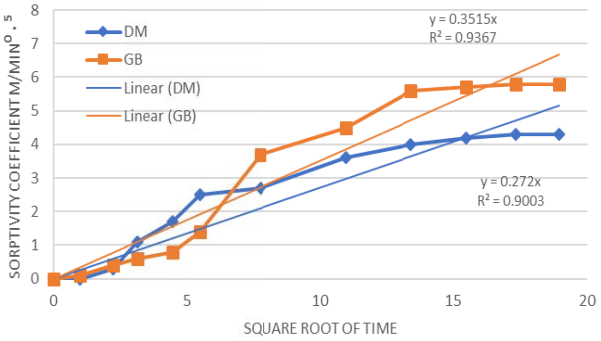

Figure 3: Sorptivity Coefficient curve

Water sorptivity is a property which indirectly indicates the durability of a specimen. Figure 3 presents the results of water sorptivity of specimens. It can be seen in the graph that the sorptivity coefficient of both the samples shows a gradual increase upto 60 minutes of the test. However, it almost shows no further increase upon reaching 120 minutes. Initially, the plot of GB and DM are almost similar. However, as the time reaches 60 minutes, GB samples tend to achieve higher sorptivity coefficient which indicated presence of more capillary pores. Saturation of such pores results in higher water absorption.

5.3 Compressive strength of unexposed samples

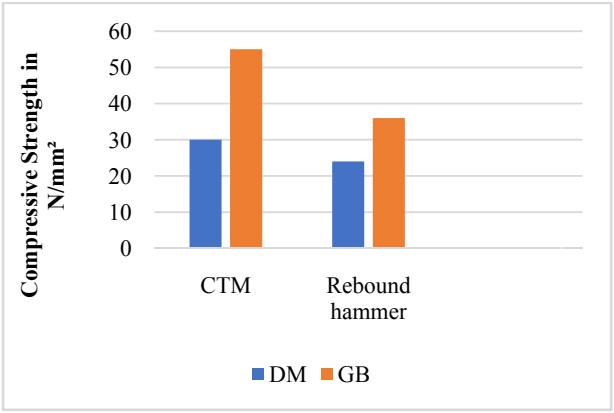

Figure 4: Compressive strength of the samples using compressive testing machine and rebound hammer

The results of compressive strength of specimens determined using both destructive as well as non destructive methods is given in Figure 4. The compressive strength of GB specimen is found to be greater than those of DM specimens in both destructive and non destructive tests.

5.4 Weight loss at elevated temperature

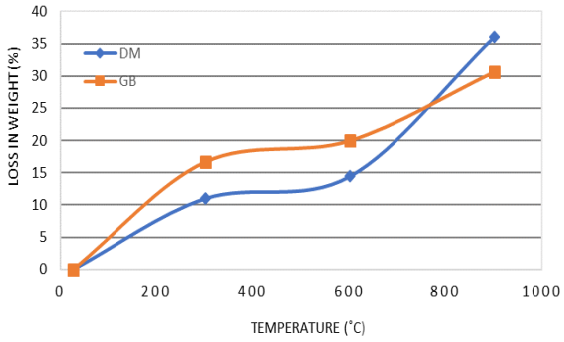

Figure 5: Weight loss of the specimens subjected to elavated temperatures

The specimens were exposed to elevated temperature and the weight loss recorded is presented in Figure 5. As it is evident from the results of water absorption and apparent porosity that GB samples have more porous structure hence it will have more weight loss at elevated temperatures. The change in weight for GB samples were more pronounced till 600˚C but

upon reaching 900˚C, DM samples exhibited greater weight loss. This sudden change may be attributed to the fact that, DM samples starts to disintegrate rapidly beyond 600ºC. GB samples though showed large surface cracks, succeeded to remain intact.

5.5 Surface texture of samples at elevated temperatures

Figure 6: Surface texture of the specimens at elevated temperature

The surface texture of the exposed samples are shown in Figure 6. It is clearly visible that GB samples maintain its shape till 600˚C but started showing large crack lines upon reaching 900˚C. On the other hand, DM samples starts losing its definite cube shape at 600˚C and starts disintegrating upon reaching 900˚.

5.6 Relative strength of exposed samples

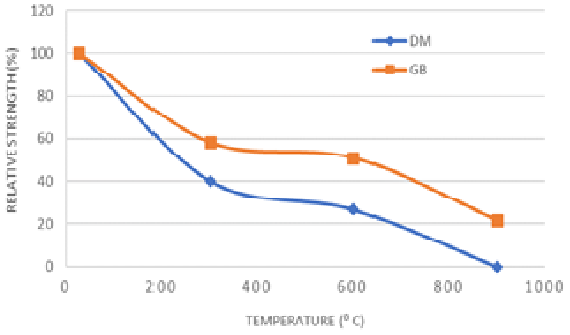

Figure 7: Relative strength of the samples after exposure to elevated temperatures

The strength loss of specimens at elevated temperature is shown in Figure 7. The loss is represented as relative to the initial strength of unexposed specimen. The relative strength of the samples significantly decreases after being exposed at elevated temperatures. DM samples failed to retain at least 50% of the strength at 300˚C. Upon reaching 600˚C, DM samples retained only 27% of its original strength and it was no longer able to show any strength at 900˚C. In the case of GB, the samples were able to retained 50% of its strength upto a temperature range of 600˚C and retained only 22% of its strength at 900˚C.

6. Conclusion

Through the limited study, it has been observed that the compressive strength obtained both through destructive and non-destructive test shows that AAC produced using 100% GGBS were higher. However, it is noted that the water absorption, apparent porosity and sorptivity values of the specimens made incorporating mussel shells were lower, which isadvantageous to increase water tightness property. Several percentage replacements can be studied further to arrive at an optimum percent replacement.

Acknowledgements

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