International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 04, April-2019

A STUDY ON THE STRENGTH PROPERTIES OF LIGHTWEIGHT GEOPOLYMER CONCRETE

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Abstract*— *The present research work deals with the preliminary investigations on the development of the lightweight Geopolymer concrete (LWGPC). The objective of the study is to develop the LWGPC for the applications in reducing the thermal conductivity and reduction of the structural dead load. The scope of the study includes mix design, tests on constituents, preparation of alkaline solution and tests on the mixes for obtaining the strength properties of LWGPC. The study includes innovative usage of expanded clay aggregates, recycled plastic aggregates, recycled fly ash bricks aggregates toward the achievement of the weight reduction of the conventional GPC. The study is focused on obtaining the compressive and splitting tensile strength of the GPC specimens containing the lightweight aggregates of varying types. The results revealed that the usage of the expanded clay aggregates reduced the weight of the GPC up to 50% at the full replacement of the natural aggregates. Though the strength properties did not show a noticeable improvement, the material may be utilized for the light to medium intensity of the loads for various field applications.

Keywords*— *Geopolymer concrete, expanded clay aggregates (ECA), Recycled plastic waste aggregates (RPA), Fly ash bricks, and alkaline activators.

I. INTRODUCTION

The weight reduction of the structural material is a prime important attribute for the designers and engineers. Along with the reduced self-weight, it is expected form the material to act as the thermal barriers and improved acoustical properties. However, the lightweight materials are to be tested for the minimum strength properties also. In the present paper the conventional geopolymer concrete (GPC) is prepared with varieties of the light weight aggregate articles namely expanded clay aggregates, recycled plastic waste aggregates and recycled fly ash brick aggregates for reduction of the self-weight of the GPC. Total of eight mixes were prepared and tested. The strength properties declined due to the replacement of the natural aggregates and sand tough, the weight reduction being the central objective of the study was achieved.

II. MATERIALS AND MIXES

Total of eight mixes were prepared labelled with B1 to B8. All batches were varying with the replacement of the natural aggregates with ECA, RPA, and RFA. The geopolymer mix was containing alkaline solution of sodium hydroxide and sodium silicate. The ratio of the two liquids was maintained at 2. The solution of sodium hydroxide was prepared with 16M content made in the distilled water. The geopolymer binder was prepared with mixing the alkaline solution and ground granulated blast furnace slag. All the constituents were first dry mixed and the liquid was prepared 24 hours before the mixing. The specimens were prepared as cube and cylinders of the standard dimensions of 150mmx150mmx150mm and 150mmx300mm respectively. The ECA was added by 20% and 60% of the weight of the natural aggregates. The RPA were mixed as 50% and the RFA were added as 10% and 50%. The general properties of ECA and RPA are shown in Table 1 and Table 2 respectively. Figure 1 and Figure 2 shows the images of aggregates. Table 3 shows the density of all the batches prepared with varying combinations of the constituents.

Table 1 General ECA properties

Parameter	Values
Specific Gravity	0.90 – 1.23
Abbreviation	Polypropylene
Water absorption (24hr)	1%
max usage temperature	120 - 140°C
Density g/cm³	0.90
Ignition temperature	300 - 360°C
Humidity absorption	<0.1%
Elongation	750

Figure 1 Expanded clay aggregtes

Table 2 General RPA properties

Property	**Range**
Aggregate size	0/2 – 0/4 – 1/5 - 4/8 – 8/16… mm
Loose Bulk density	250 to 750 kg/m³
Particle density	620 to 1300 kg/m³
Porosity between grains	37 - 50 % - drainage/permeability
Water absorption	25.65 %
Impact Value	67.9%
Crushing Value	79%
LA. Abrasion Value	61.6%

Figure 2 Recycled plastic aggregates

Table 3 Mix desing details of LWGPC batches

Sr. no. batch	**Details of mix**	**Density in kg/m^3**
B1	GPC	2460
B2	GPC+20% ECA	2240
B3	GPC+50%ECA+50% RPA	1200
B4	GPC+60% ECA	1790
B5	GPC+50% RPA	1650
B6	GPC+10%RFA	1900
B7	GPC+50% RFA	1700
B8	GPC+50% ECA+100% natrual sand	2100

III. TEST METHODS

The cube specimens were used to obtain the compressive strength. The compression testing machine of 2000kN capacity was used. The test was performed under the strict laboratory observations and conditions. The load values were recorded at the two different stages namely initial failure load and final failure load. Similarly the splitting tensile strength was obtained from the cylinder specimens. The cylinders were placed longitudinally and loaded in the same testing machine. The loads causing first crack and final cracks were recorded. Moreover, the crack patterns on the surface of the specimens were also studied to obtain the behavior of the material. All the tests were carried out on three specimens for each batch and an average value of the three was considered in the result analysis. Figure 3 and Figure 4 shows the test apparatus with specimens.

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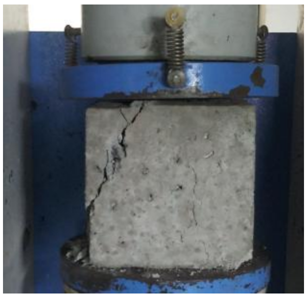


Figure 3 Compression test

Figure 4 Splitting tensile strength test

IV. RESULTS AND DISCUSSION

Compressive strength

The cubes were tested for the compression test and the results are shown in figure 5. As it can be observed form the results, the compressive strength was reduced with the replacement of the natural aggregates with the ECA and RPA and RFA in varying proportions. However, the mix containing the natural sand showed maximum strength with the replacement of the coarse aggregates by ECA and RPA. It is to be noted that the lowest strength was observed for the batch of GPC containing RFA. This is due to the fact that the RFA were found to be highly brittle and unable to resist the compression with low values of the forces.

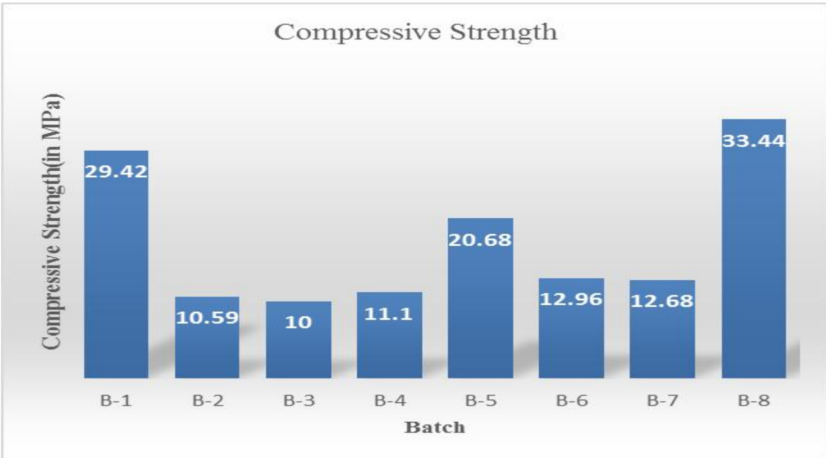
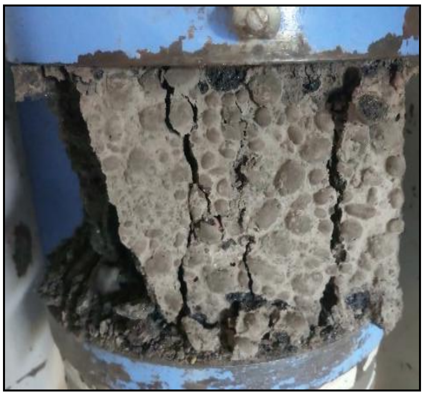


Figure 5 Effect of aggregate replacement on compressive strength of LWGPC

From the reuslts it was evident that the best combination for the LWGPC was the ECA and natural sand. That not only reduced the density by 50% compared to the GPC reference mix, but also imporved the strength. The failure patterns were also studied in the case of the cubes as shown in figure 6(a) and (b).

(a) GPC reference cube test specimen



(b) LWGPC specimen with ECA

Figure 6 Compression tests on the cube specimens

Splitting tensile strength

The cylinders were subjected to the splitting action across the diameter of the specimens. The action of the compression on the cross section of the specimen was regarded as the load causing the cracks in the concrete. The load was gradually increased and the value of the load causing first and final crack were recorded. The resistance to the splitting action depends on the cohesive forces exist between the constituents of the mix and the binder gel of the GPC. The results of the splitting tensile strength are shown in Figure 7. From the results, it was observed that the strength reduced for the replacement of the natural sand with the ECA aggregates and increased with the combined usage of the ECA with natural sand. The response by the GPC reference batch B1 was obtained comparable to the normal cement based concrete; however the weight reduction was insignificant. The combination of ECA and RPA provided the best results for splitting tensile strength. The ECA aggregates provided better surface adhesion of the geopolymer binder gel and the presence of the RPA resisted the splitting action more effectively. The mix B3 was found the optimum combination due to the better strength and considerable reduction of the self-weight of the mix compared to the GPC reference mix.

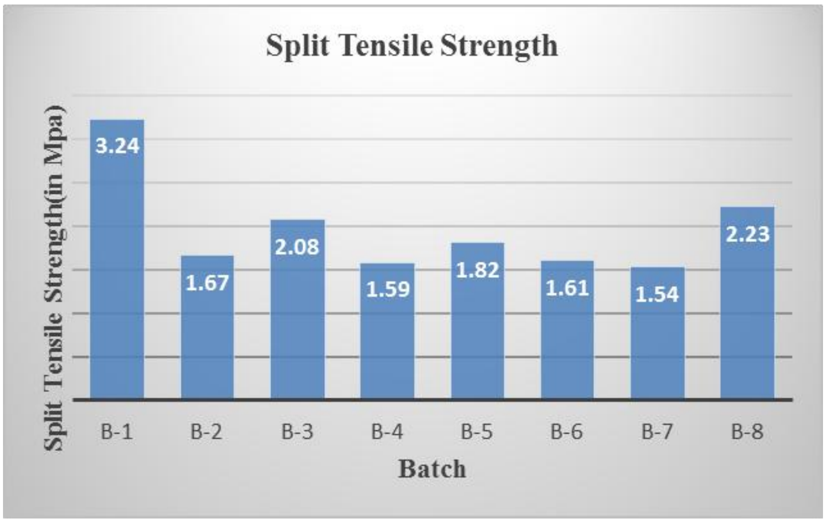
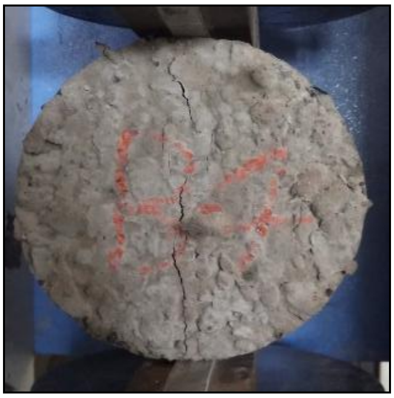


Figure 7 Results of splitting tensile strength for LWGPC

The B3 mixes showed excellent adherence capacity and reduced crack propagation along the failure plane compared to the reference GPC mixes and other batches as shown in the Figure 8 (a) and (b).



(a) Crack pattern at initial failure

(b) Crack pattern at the final failure

Figure 8 Failure patterns of varying Mix batches under splitting tensile strength

V. CONCLUSIONS

The experimental investigations revealed that the replacement of natural aggregates with ECA and RPA showed maximum reduction of the density of the GPC up to 50%. The batch B3 containing 50% ECA and 50% RPA responded with maximum resistance to the splitting tensile strength values. Though it was noticed that not all the mixes showed acceptable strength in compression, the replacement of coarse aggregates with ECA in the combination of the natural sand maintained the high compressive strength in the mix. The study showed that the combination of ECA and RPA are the most preferred replacement of the natural aggregates to obtain the light weight geopolymer concrete out of the all available mixtures and proportions. The role of RFA was found limited and the replacement of RPA did not reflect any significant change of the properties namely self-weight and strength properties. The optimum replacement of the 100% natural coarse aggregates was obtained by combination of RPA and ECA of 50% proportions of each types and exhibited good resistance to the compression and best performance for the splitting tensile strength.

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