Effect of Soda lime Silica Glass waste on the basic properties of Clay Aggregate

Md. Sagirul Islam, Nahid Sharmin, Md. Moniruzzaman, Dr. Umme Sarmeen Akhtar

Abstract—To minimize the dead load problem of high rise building it is mandatory to improve the basic properties of coarse aggregate used in structural concrete. Light expanded clay aggregate (LECA) can be the best alternative of traditional coarse aggregate because it has reduced weight and lower bulk density. The aim of this project is to improve the basic properties of light expanded clay aggregate by partial replacement of clay with soda lime silica glass sintering at high temperature. Different ratios of glass waste like 20%, 35% and 50% soda lime silica glass were incorporated respectively with clay. The sintering temperature for LECA was maintained 850ºC, 950ºC, 1050ºC and observed that the basic properties of LECA like bulk density, porosity, water absorption, compressive strength have been improved. XRD is performed to observe the phase characteristics of LECA.

Index Terms— Bulk density, Light Expanded Clay Aggregate (LECA), Cullet, XRD, Water Absorption, Soda Lime Silica Glass (SLS), Compressive Strength.

1 INTRODUCTION

UTILIZATION of solid wastes has a better impact on our environment, human body and the society. There are two advantages of utilization of solid wastes: diminishing of disposal problems and preservation of natural raw materials. [2]. In general, crushed brick or stone is used as coarse aggregate into structural concrete production. The weight of the conventional coarse aggregates is responsible for the dead load problem for high rise building. In this project it was tried to improve the basic properties like unit weight, bulk density, etc. of the coarse aggregate to minimize the dead load problem of high rise building. To manage this job SLS glass waste was incorporated with clay as fluxing agent to take down the softening point during sintering of coarse aggregate. During sintering the glassy phase of SLS glass produce required viscosity which entrap the released gas and make the coarse aggregate expanded and porous as well as make them lightweight.

Lightweight aggregate is characterized by low bulk density not exceeding 1200 kg/m^3 or by particle density not exceeding 2000 kg/m^3 [UNE EN-13055-1, 2003]. To reduce the weight of aggregate it is essential to reduce the bulk density of aggregate and make it porous. Expansion is required to make lightweight aggregate. A suitable expanding agent is incorporated with the whole mixture so that it releases the gases between softening point and maximum firing temperature and these gases remain trapped within the glass structure [5]. Soda lime glass has lower softening temperature and suitable to achieve the firing mass viscosity < 106.6Pa during sintering[4].

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Manufacturing quality of expanded clay aggregate depends on different factors influencing the expansion process [3]. SLS glass as fluxing agent plays a vital role to improve the expansion process during sintering. The presence of SLS glass in the aggregate mix may function as a fluxing agent and contribute to the desired vitreous microstructure. Added glass act as fluxing agent by promoting the formation of liquid phase and thus reducing the clay body maturation temperature [2]. The sintered sample is characterized in terms of bulk density, porosity, water absorption and compressive strength.

The main objective of this project is to reduce the porosity of LWA as well as to increase the mechanical strength of lightweight aggregate utilizing soda-lime silica glass waste. Mineral iron rich clay was chosen for its self bloating properties. Fe_2O_3 content of the red clay accelerates the expansion rate during sintering of LECA. Here Soda lime silica glass is incorporated to produce a glassy phase which forms a continuous three dimensional network after firing and plays a vital role to improve the mechanical strength of LECA.

2 EXPERIMENTAL STUDY

2.1 Materials

To perform the experiment clay has been collected from the local area named Mirpur, Dhaka, Bangladesh. The color of the clay is slightly reddish color due to the presence of increased amounts of iron content. Cullet or waste SLS glass was collected from different domestic and industrial area. Na_2CO_3 was used as an additive to potentially reduce the softening temperature of the glass phase and promotes expansion at even lower temperature [12].

2.2 Sample preparation

To make LECA, The waste SLS glass was first crushed for 1 hour using a grinder and then sieved with 100 micron sieve size using sieve shaker. SL S glass powder was blended with red clay in three ratios like 20%, 35% and 50% using ball mill.

5 wt% Na_2CO_3 was also added with the mixture during ball milling. Adequate amount of water was added to maintain the standard consistency which helps to make better handmade granulation of raw LECA. The granular size of LECA differs from 4.75 to 20 mm. Chemical analysis of clay, SLS glass and Lightweight aggregate were carried out using gravimetric method. The boiling water method described in ASTM C20 [7] was used to perform bulk density and water absorption tests. The mineralogical composition of clay and lightweight aggregate were achieved using an X-ray Diffractometer technique (XRD: PAN Analytical "X" Pert Pro XRDPW 3040). The crushing resistance was measured using Carver Laboratory Press,(Model C: 5576-956).USA. Muffle furnace, (Model No: l3/11/C6), Nabertherm, Germany was used to fire LECA granules at high temperature. Grinder,(Model:D-55743), FRITSCH, USA was used to grind SLS glass waste into powder form. Ball Mill, (Model:G-90, LOVATO), UK was used to blend the mixture homogenously.

Fig.1. Light weight Clay Aggregate.

In order to know the vital role of raw materials used in processing LECA, it's first necessary to determine their chemical composition. The result of a chemical analysis of raw materials and LECA is illustrated in the Table I.

TABLE 1
CHEMICAL COMPOSITION OF RAW MATERIALS AND LEC A (WT%)

Parameters	SLS Glass	Red Clay	LECA
SiO_2	68.62	53.60	61.05
Al_2O_3	1.59	24.79	15.74
Fe_2O_3	0.41	7.07	6.10
CaO	9.55	0.24	3.92
MgO	3.05	0.65	2.52
Na_2O	13.83	1.31	5.62
K2O	0.63	1.89	2.67
LOI	--	9.58	0.75

2.3 Method

At first SLS glass waste was collected from different source and then grinds it into powder form and sieved through 100 micron mesh. To get a homogeneous mixture for LECA, clay was milled, sieved through 100 micron and blended with glass powder in a ball mill for 6 hours. After ball milling adequate amount of water was mixed with the mixture. The wet mix was granulated by hand to make granular size LECA. After granulation the raw LECA is air dried and then oven dried for 24 hours in a laboratory oven at 110°C. After that the drying LECA granules were fired in Muffle furnace at 1000°C where heating rate was 10°C/min. is maintained. The soaking period was maintained 30 minutes during firing. After firing the granules were cooled at room temperature and stored.

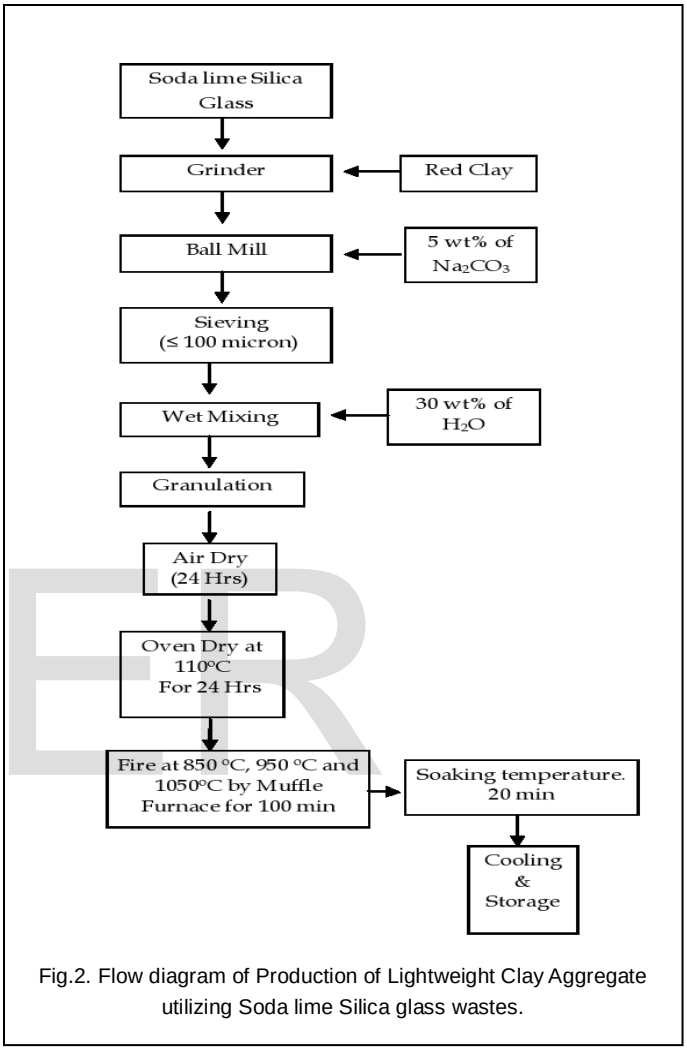

Fig.2. Flow diagram of Production of Lightweight Clay Aggregate utilizing Soda lime Silica glass wastes.

3. RESULT AND DISCUSSION

Bulk Density is one of the basic properties of light weight aggregate. To determine the bulk density of clay aggregate dry weight, soaked weight and suspended weight of clay aggregate has to be determined. The bulk density was calculated through the equation BD= (S-D)/(P-D) kg/m^3, where, S=Soaked weight, P=Suspended weight and D=Dry weight of the clay aggregate.

This decrease of bulk density in samples suggests that more gases were generated and trapped by the viscous melt of glassy phase. Consequently expansion made by the entrapped gases increase the volume of LECA and the bulk density is decreased. In fact, as expansion percentage increases the pore size of LECAs increases, resulting in a decrease of bulk density[6]. Fig.2 shows that at 950°C, the bulk density of LECA

decreases than the firing temperature 950°C and 1050°C due to the initialization of expansion.

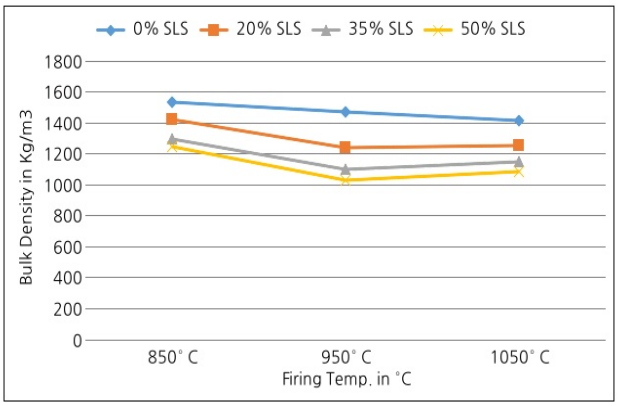

Fig.3. Decreasing of Bulk Density with the Increase of Glass Content and Firing Temperature.

At 950°C the high expansion is observed and at 1050°C temperature the expansion rate decreases due to the entrapped gases are released from LECA. The entrapped gases make expansion from 950°C to 1050°C and at 1050°C temperature the expansion collapse due to the lower viscosity of glassy phase on outer shale. So therefore firing temperature and content of glass has a better effect on the bulk density of LECA.

To determine the water absorption of fired expanded clay aggregate was oven dried at 110°C for 24 hours and after that the weight of dried sample was recorded and the dried sample was emerged into the water for 24 hours.

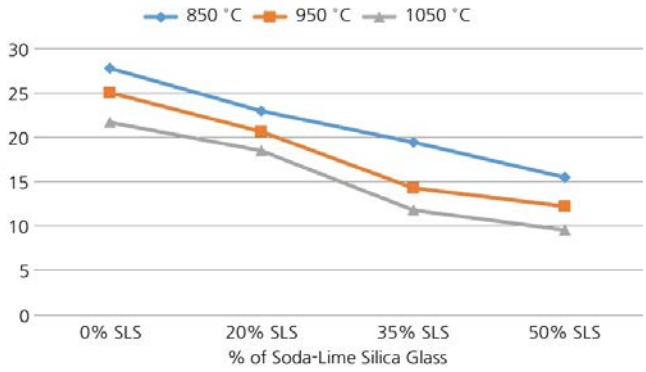

Fig.4. Effect of incorporated SLS glass percentage on the Water Absorption.

After soaking water the soaked weight of sample was recorded. The difference between the soaked and dry weight is calculated as % of water absorption of the sample. "Fig".4 shows that the sharp decrease of water absorption with increasing glass content incorporated and firing temperature. The water absorption of LECA is between 10-15% for 35 to 50% glass content incorporated at 950°C to 1050°C. Expansion increases the porosity of LECA. Although expansion occurs from 950°C to 1050°C, the concentrated glassy phase due to the heavy replacement of clay with the glass waste decreases the pore size of the outer shale of LECA. The applicability of LWAs for concrete production is strongly affected by water absorption where high water absorption is not desirable.

Crushing Resistance of lightweight aggregate is determined according to EN 13055-1 method which is a potential way to assess the strength of lightweight aggregate. According to the method the lightweight aggregates were sieved with the sieving fraction 4-22 mm and put them into a steel container of one liter volume. Then the LECA were compacted by vibration and compressed by 20 mm with a steel piston with a cross section area of 100 cm^2.The total time of the compression process was maintained 100 second. The crushing resistance was calculated by dividing the maximum recorded load by the area of the piston. But this method is not applicable to LECA produced in small quantities in a laboratory. Another method named as single pellet uniaxial compression test is fast and more appropriate method to determine the crushing resistance

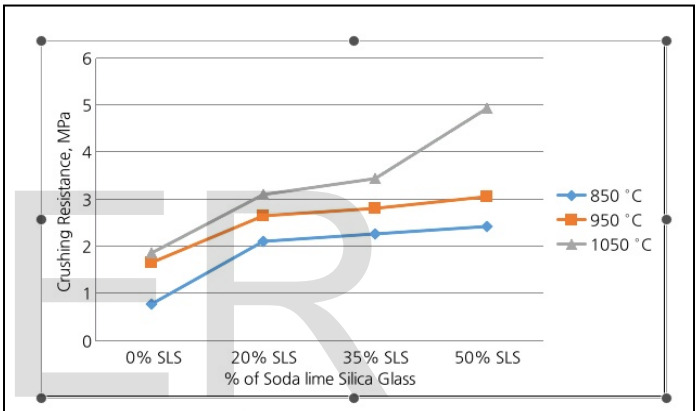

Fig. 5. Crushing resistance of LECA determined by single pellet uniaxial compression test method.

of laboratory made small quantities LECA. In this method single pellet strength is determined by uniaxial compression between two parallel rigid platens. Compression was performed with a constant displacement of 2 mm per minute until a crack ruptured the sample at least two larger pieces. The diameter of every aggregate was measured between the highest and lowest point with a caliper [8]. The crushing resistance of LECA was calculated according to the following equation.CR = $F_{crit.}/A$. Where, $F_{crit.}$=The applied load at failure and A= is the area of load distribution. The whole process is completed by Hydraulic Press: WEBER PRESSEN, Germany. The addition of waste glass considerably contributed to vitrification and enhanced the strength development by closing the internal pores with glassy phase, especially during firing [2].

"Fig".5 shows that the sharp increase of crushing strength of LECA at 1050°C with 50% SLS glass content. SLS glass content contributes high viscosity glassy phase during sintering at 950°C and Fe_2O_3 of red clay accelerates the release of expansive which are entrapped by high viscous glass melt and

consequently expansion occurs and bulk density decreases. From 950ºC to 1050ºC, the alkali oxide like Na_2O of SLS glass helps to reduce the viscosity of SLS glass melt. When the viscosity of SLS glass melt reduces the entrapped gases are escaped through creating capillary pores of LECA. Consequently the core structure becomes porous which make LECA lightweight. On the other hand glassy phase creates glass melt shade over the outer shell of LECA which decreases the open pores of LECA which decreases the water absorption rate. So therefore it could be illustrated as that SLS glass reduces the number of interconnected pores on outer shale which decreases the water absorption rate of LECA. The increased amount of SLS glass creates high viscosity glassy phase which increases the crushing resistance as well as reduces the water absorption rate. So therefore it is revealed that crushing resistance of clay aggregate is greatly depended on the amount of waste glass addition and firing temperature.

The XRD pattern (Fig.6, 7, 8) show some differences among various percentage of SLS glass that mixed with red clay sample which suggests that phase transformation has take place.

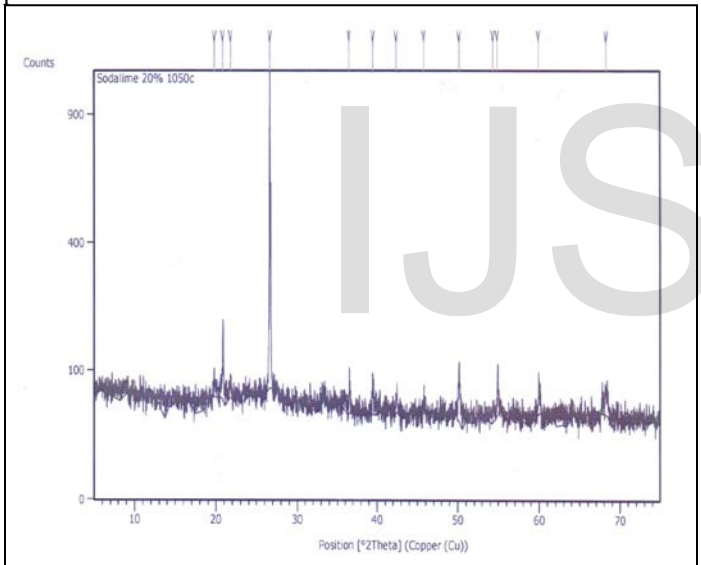

Fig.6. XRD pattern of 20% SLS glass incorporated Clay Aggregate fired at 1050ºC

The mineralogical Composition of the fired samples was determined by powder XRD. Some sharp and intense quartz peak has been observed for the 20%, 35% and 50% SLS glass incorporated LECA sample. This may be due to the re-crystallization of amorphous silica to crystalline with firing temperature. The illite peaks have completely disappeared completely at 1050ºC due to the illite structure breaking down in this range of temperature and Hematite begins to crystallize at 1050ºC reported by Escalera *et al.*[1]. The XRD pattern of prepared sample with 20%, 35% and 50% SLS glass content fired at 1050ºC confirms the presence of crystobalite, feldspar, Muscovite and quartz as major phase. Hematite phase also observed due to the presence of Fe_2O_3 rich Red clay.

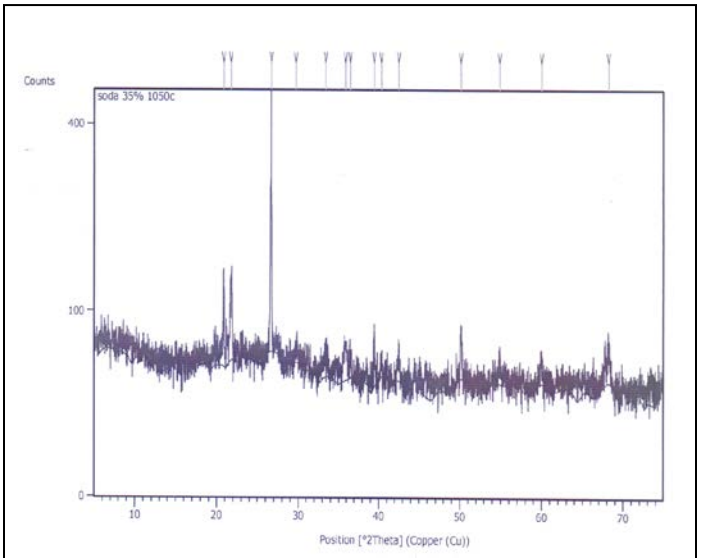

Fig.7. XRD pattern of 50% SLS glass incorporated Clay Aggregate fired at 1050ºC

Quartz (α-SiO_2) exists with a dominant peak at 27^0 2θ. As the waste SLS glass content increased a small peak of anorthite [$Ca(Al_2SiO_8)$] detected around 22^0 2θ was prominent with increased glass content reducing the overall crystalline quartz. The reduction of the crystalline quartz with the incorporation of waste glass confirmed that some of the crystalline quartz in clay fused and formed the dense fired clay body[10].

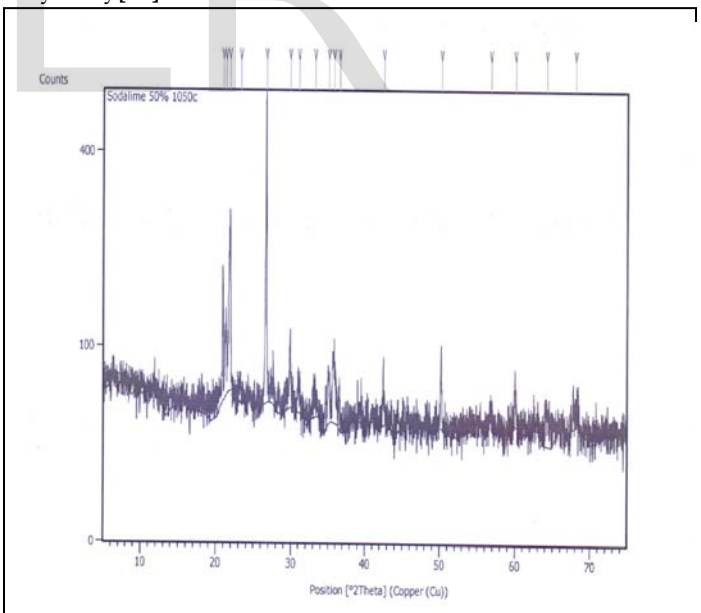

Fig.8. XRD pattern of 50% SLS glass incorporated Clay Aggregate fired at 1050ºC

" Fig."8 shows that incorporation of 50% SLS glass the phase of Tridymite(β-SiO_2) starts to be seen. The α- SiO_2 plays an important role as a back-bone in the structure fired sample with the modification of the increased glassy phase on waste glass addition[9].

As the Glass content increases the Crystobalite and Anorthite peaks result from devitrification. Glass addition increased the the number of crystalline phase like devitrite, gehlenite and wolastonite which are resulting from the devitrification of glass and sodium aluminium silicate [11]. Thus from the change of XRD pattern of fired samples it is revealed that re-crystallization of glass with the increasing amount of glass and firing temperatures is responsible to enhance the basic properties like lightweight, increased crushing resistance, reduced water absorption of fired sample.

4. Conclusion

Usually conventional bricks are crushed into different sizes to be used as coarse aggregate in high rise building. The conventional coarse aggregate is porous and holds a high volume density. Thus it causes dead load problem in high rise building and due to increased porosity it causes lower crushing resistance and high water absorption. Hence the quality of clay aggregate has been improved by minimizing the above limitation utilizing SLS glass and Red Clay.

The physical properties of LECA with SLS glass were examined. The results showed that the crushing resistance of LWA increased with the increase of waste glass addition from 20 to 50 wt.% and firing temperatures from 850ºC to 1050ºC. The values of water absorption of LWA also decreased with increases in waste glass addition and firing temperatures. The values of bulk density of LWA aggregate decreased from 950ºC because of expansion and slightly increased at 1050ºC because of collapse of LWA.

The study reveals that utilization of SLS glass waste showed some positive effects on the properties of clay aggregate like increased strength and lowering of open porosity, water absorption and weight.

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