Evaluation on Scrap Glass Incorporated Geopolymer Interlocking Blocks

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ABSTRACT

An effort has been made to produce economical and environmentally friendly geopolymer interlocking blocks by activating fly ash and ground granulated blast furnace slag (GGBS) with sodium hydroxides and silicates. Scrap glass and crushed stone sand are blended to produce fine aggregates. Seven mix ratios of crushed stone sand and scrap glass were used: S_0=100%:0% S_1= 90%: 10%, S_2=80%: 20%, S_3= 70%: 30% S_4= 60%: 40% S_5=50%: 50% S_6:=60%:40. Eighty-four interlocking blocks 230 mm x 200 mm x 110 mm in size were cast to be preserved at ambient temperature for 28 days. The density, strength in compression, and water absorption of the interlocking blocks were then evaluated. Three layers of interconnecting blocks were used to produce prisms that measured 600 mm long, 375 mm high, and 200 mm wide. Blocks and prisms provided with 70% crushed stone sand and 30% scrap glass had the optimal characteristics.

KEYWORDS: Crushed stone sand. flyash, GGBS, Interlocking blocks, Scrap glass,

1. INTRODUCTION

Time and material consumption are inescapable during the entire construction of any project. The usage of mortar to bond blocks in each layer and between neighbouring layers is avoided by enhancing the quality of construction and the assortment of developments of traditional blocks in order for them to be joined to the nearby blocks with a shear key and locking mechanism.

Interlocking blocks with appropriate self-locking technologies can be found in an extensive range of dimensions and forms on the market. Sand and stone dust were employed for producing interlocking blocks in the past, and Ordinary Portland Cement (OPC) was the predominant binding ingredient. (1-3). There is an increasing urge to substitute natural river sand with other types of trash that offer analogous mechanical and physical characteristics as an outcome of the price increase and the depletion of natural river sand sources. Waste glass is one of these materials, and the viability for use in mortar and concrete has been investigated by numerous researchers. Glass waste with a concentration of less than 30% may be used as a practice while creating concrete by adding the right proportion of admixture to achieve the required workability and air content (4-5).

The ideal proportion for consumption as aggregates in concrete is 50% of glass elements. Scrap glass can also be exploited to substitute cement by about 20% without conceding its strength characteristics, and it can also be employed to substitute fine aggregates by up to 20% because blends comprising 20% scrap glass aggregate possess durability potentials comparable to those of traditional blends (6-8).

While the strength characteristics were good up to a certain extent and subsequently the workability declined when paired with fragmented glass as aggregates, another investigation also confirmed that scrap glass residue could replace cement up to 20%. Given its enhanced workability and greater durability, 10% is the ideal substitute rate for both cement and aggregates. Cement mortar can be produced by blending scrap glass and clay brick powder with cement at an ideal 15% (9). It is possible to create geopolymer mortar with a potential in compression that varies from 40 MPa to 50 MPa by partially substituting fly ash and perlite for scrap glass fine aggregate (10-12).

Conversely, the production of cement releases greenhouse gases into the atmosphere, posing serious environmental risks and playing a major role in global warming. So, the researchers are exploring more sustainable and environmentally friendly alternatives to OPC. It was investigated whether industrial trash and byproducts might be advantageously applied as cement substitutes. The effects of GGBS, fly ash, micro silica, and other pozzolanic constituents on the durability characteristics and long-term characteristics of mortar and composites were partially studied in conjunction with OPC. It emerged that each of these elements has benefits as well as disadvantages when incorporated into cement. Additionally, it emerged that the previously mentioned components performed optimally when applied in little amounts. The two main issues facing the housing sector are cutting down on construction time and exploiting fly ash as a raw material for interlocking blocks. (18-20) To address the aforementioned challenges, numerous developments are taking place worldwide. Additionally, the ingredients mentioned above were found to be effective when applied in small amounts. Despite its formidable resistance to the alkali-silica reaction, fly ash has a detrimental influence on the interlocking blocks' durability characteristics (21).

Later, greater attention was paid to studying geopolymer technology, which substituted 100% triggered fly ash for cement that needed to be heated to get the desired potential. To obtain the ideal blends, numerous pozzolanic materials were evaluated in permutations and triggered using catalysts, even in geopolymer technology. Even geopolymer interlocking blocks that may be exploited for non-load-bearing structures were produced containing crumb rubber as small fragments (22). In an attempt to reduce pollution and the sum of trash that is thrown in landfills, interlocking blocks were generated from plastic bottles that contained polyethylene terephthalate and polyurethane binder in a 60:40 ratio. These blocks were established to be optimal for the construction of partition walls (23-26). While scrap glass powder incorporated geocomposites are environmentally friendly options, they may open the door for future alliances with the paving sector (27-29). As an alternative masonry option for a sustainable structure, alkali-activated blocks tend to be advantageous considering that they can incorporate an enormous quantity of trash and byproducts from industries. (24). When compared to clay blocks, geocomposite blocks are said to have advantages such as being more affordable and energy-efficient (30-32). By combining recycled asphalt aggregates with a geopolymer matrix, paver blocks with the appropriate characteristics could be developed, managing excess waste and facilitating paving industrial sector decision-makers to develop an environmentally acceptable use of reclaimed asphalt surfaces (33-35). The structural strength and physical characteristics of the geocomposite block can be enhanced by the feasibility of recycling and recovering scrap block in the manufacture of a novel geocomposite block by activating it with activator solutions and industrial waste slag in it (33). As they demonstrate characteristics within the ranges appropriate for construction, fly ash could be partially substituted with leftovers such as scrap glass and dark mud for the production of geocomposite. Compared to scrap glass, the incorporation of red mud leads to enhanced flexural durability and fracture resilience characteristics (37-39). In contrast to regular clay bricks, geopolymer blocks composed of ceramic waste containing calcium and sodium hydroxide, calcium carbonate, and bentonite clay are approximately 33% more affordable (40-42). It was established that characteristics of interlocking blocks and prisms produced by exploiting fly ash, GGBS, crushed stone sand, and scrap glass have not been investigated, despite the fact that an abundance of research has been done on these elements utilizing various cement substitutes and fine aggregates. Therefore, this investigation attempts to determine the mechanical characteristics of prisms formed through the fashioned interconnecting blocks.

2. MATERIALS AND METHODS

2.1. Materials

Fly ash in compliance with IS 3812-200(13) and GGBS in compliance with BS 6699:1992 (14) are the binders exploited for the interlocking blocks. The chemicals used for activating the aforementioned binders are 0.4 times the amount of the binder and are composed of a mixture of sodium (8M) hydroxides and silicates. The combination of sodium hydroxides to silicates is 2.5:1. Crushed stone aggregate and scrap glass are blended using various proportions to produce aggregates having the largest dimensions of 4.75 mm and chips that measure 4 mm in size. Both crushed stone sand and scrap glass possess fineness moduli of 3.10 and 3.36, confined within zone 1 of IS 383-1970 (16), according to the grain size analysis experiment performed in compliance with IS 2386 – Part 1 1963 (15). For scrap glass, the specific gravity and compacted bulk density are 2.08 and 1650 kg/m^3, respectively, whereas for crushed stone sand, their numbers are 2.38 and 1720 kg/m^3. It has been determined that the aggregates crushing and impact metrics for tiny shapes are 27% and 17%, respectively.(43-45) 1452 kg/m^3 is the compacted density, whereas 0.91% represents the water absorption. GGBS and fly ash possess specific gravity values of 2.88 and 2.16, respectively. Through trial and error, the amount of water demanded to accomplish the ideal consistency of moulding interlocked blocks was established to be 17.40%, which is the additional amount needed. The components exploited are displayed in Figures 1a through 1h.

2.2 Ratios and combination designs

The density of concrete (2400 kg/ m^3) was used to determine the material quantities. It is predicted that the mix contains 20% binder and activator solutions (475 kg/m^3) and 80% aggregates (70% and 30% coarse and fine aggregate), which contain 1925 kg/ m^3. Fly ash contributes upto 80% of the binder, which consists of fly ash and GGBS. Seven mix ratios of crushed stone sand and scrap glass were used: S_0, S_1, S_2, S_3 S_4, S_5, and S_6 (S_0=100%: O%, S_1= 90%: 10%, S_2=80%: 20%, S_3= 70%: 30% S_4= 60%: 40% S_5=50%: 50% S_6 =60%:40) ,The six mix ratios that had been taken into consideration when modifying the mix ratios of scrap glass and crushed stone sand as fine aggregates. Taking into consideration their specific gravities, the volumes of fine aggregates have been determined for various proportions of crushed stone sand and scrap glass. [46,47) Table 1 lists the precise proportions of elements that have been provided for the various combinations of scrap glass and crushed stone sand as fine aggregates. Taking into account their specific gravities, the volumes of fine aggregates were calculated for various proportions of crushed stone sand and scrap glass. Table 1 summarizes the precise proportions of elements that have been provided for the various combinations.

Fig. 1. (a) -Fly ash (b) -GGBS (c)- crushed stone (d) -stoneaggregate

Fig.1. (e) - scrap glass (f) -processed Scarp glass (g)- NaOH (h)- Na_2SiO_3

Table 1 Mix details ((kg/m^3)

Sample ID	***Fly Ash***	***GGBS***	***Stone Aggregate***	***Crushed Stone Sand***	***Scrap Glass***	***NaOH***	***Na_2sio_3***	***Water***
S_0	273.53	69.82	1345.25	567.65	0	40.43	99.2	61.24
S_1	273.53	69.82	1345.25	511.01	50.69	40.43	99.2	61.24
S_2	273.53	69.82	1345.25	454.37	100.13	40.43	99.2	61.24
S_3	273.53	69.82	1345.25	397.73	149.57	40.43	99.2	61.24
S_4	273.53	69.82	1345.25	341.09	199.01	40.43	99.2	61.24
S_5	273.53	69.82	1345.25	284.45	248.45	40.43	99.2	61.24
S_6	273.53	69.82	1345.25	227.81	297.89	40.43	99.2	61.24

2.3 Preparation and Testing of Blocks and Prisms

One day prior to brick moulding, an 8 molar concentration of NaOH solution was made and blended with 2.5 times as much Na_2sio_3 solution. First, a mixer was put to work to add and thoroughly mix all of the dry powder and aggregate ingredients. The dry ingredients are then combined with water and alkaline liquid. After that, the combination of ingredients was put into the die section for manufacture in the hydraulically propelled interlocking block-manufacture technique. Interlocking blocks were stored in the shed at ambient temperature for 28 days to cure once the specimen was taken out of the die. Figures 2a and 2b, respectively, illustrate the block after casting and the block applied during casting.

Fig. 2. (a). Mould (b) Casting of block

A total of 84 blocks were cast, 12 for each proportion, of which 3 were examined for compression evaluation, 3 examined a water absorption evaluation, and 6 were employed for constructing the interconnecting wall prisms, which were examined for compression evaluation. Figure 3 displays the blocks that were prepared for the experiment. Prior to the compression assessment, the blocks' weight was used to evaluate their density. Additionally, the moisture absorption of the oven-dried sample following a 24-hour soaking in water was calculated and expressed as a percentage of its dry mass in Figure 4. Because of the imposed crushing load in the compression evaluation equipment, the interlocking blocks underwent a compression evaluation.

Fig. 3. Interlocking blocks

Fig. 4. Water absorption assessment

Prism compression tests were conducted in addition to evaluation on blocks. The interlocking block prism measures 600 mm in length, 375 mm in height, and 200 mm in width. As seen in Figure 5, the three interlocking prism layers were built without mortar and examined using universal testing equipment with a system interface. To fairly distribute the stress on the prism, a steel plate was positioned at the top surface. Until the prism failed, the load was being transmitted gradually at a rate of 2.5 kN/sec. The prisms' maximum displacement, ultimate load, and breaking load were recorded.

Fig.5. Prism testing

3. RESULTS AND DISCUSSION

3.1 Density

Densities were computed by dividing the masses of blocks by their volumes after they were weighed. Three blocks were weighed for each mix ratio, and the weights of each block were noted. Figure 6 displays the average densities, which vary from 1914 kg/ m^3 to 2042 kg/m^3. Block made entirely of crushed stone sand has a density of 1952 kg/ m^3. The average density values decline when 10% and 20% of the crushed stone sand is substituted with scrap glass. However, when compared to S_0 samples, the specimens' density increases when the waste glass percentage surpasses 20%. S_3 blocks with 70% crushed stone aggregate and 30% scrap glass as fine aggregates have the highest density. The density differences between the S_4 S_5 and S_6 samples are not very noticeable. According to Indian standards for a grade C solid block must have a density of at least 1800 kg/m^3 in order to be implemented in a load-bearing construction. Fly ash, GGBS, crushed stone sand, and scrap glass were exploited to make geopolymer blocks, which satisfied the density-related specifications to be used as load-carrying devices.

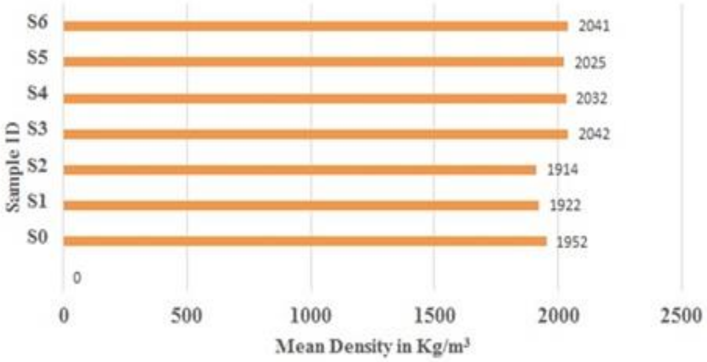

Fig. 6. Average densities

3.2 Compressive characteristics evaluation

Figure 7 provides the mean results of the evaluation in compression for each specimen that was analyzed. Three blocks have been examined for each mix fraction, and the final load was noted. It was evident from the experimental findings that the S_0 samples had an average evaluation of characteristics in compression of 2.15 N/mm^2, while the S_2 mix had the weakest average characteristics of all the mixes, 1.97 N/mm^2. Furthermore, out of all the mixes, S_2 is the only one with a lower characteristic in compression than S_0. At 28 days, the S_3 ratio exhibits its optimum compressive strength, measuring 3.55 N/mm^2. The characteristics in the compression of S_4 mix, which contains 60% crushed stone sand and 40% scrap glass, are almost identical to those of S_3. Similarly, the intensities of S_0 and S_1 mixes are nearly identical. In accordance with IS 2185:2005 (Part I)(17), the evaluation of characteristics in compression of a grade C solid load-bearing element must not be less than 3.2 N/mm^2 for individual units, and it should be at least 4 MPa for grade C . Two blocks met the grade C standards for the S_1 mix. Likewise, all blocks produced with S_3 and S_4 mixes having crushed stone sand and a 30% scrap glass ratio(70% : 30%, 60% : 40%), respectively, have an evaluation of characteristics in compression greater than 3.2 N/mm^2, making them grade C standard blocks. The compressive characteristics an evaluation of Indian standards was not met by any of the other combinations. To get around this weakness, mixes could be manufactured by raising the molarity of the NaOH solution and the proportion of GGBS. The strength data also demonstrated that all other mixes, with the exception of S_2, had higher characteristics in compression when compared to blocks made with the S_1 mix. This strength decline in S_2 is also caused by one of the blocks' lower characteristics of strength values, which has decreased the mix's average characteristics in compression.

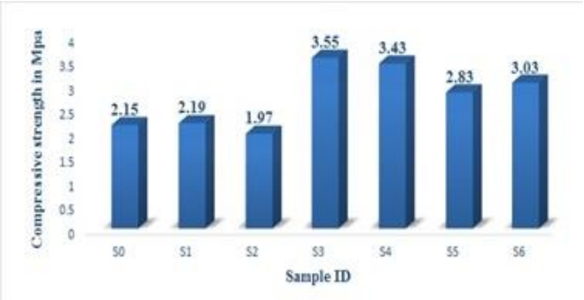

Fig. 7. Mean compression evaluation outcomes

3.3 Water Absorption

Figure 8 demonstrates the mean absorption of water values evaluated against the initial weights and the weights following soaking. According to IS 2185:2005 (Part I), the mean absorption of water of three units cannot exceed 10% by weight. The average arise for S_0 specimens is 10.58%, which is marginally greater than the Indian standard's maximum limit. The absorption for each subsequent specimen is less than 10%. The S_3 mix has the least absorption, preceded by the S4 combination. Because the blocks meet the guidelines of IS 2185:2005 (Part I), they can therefore be used. The findings are encouraging because the interlocking blocks made in the present investigation with 80% fly ash absorb less water than those made with fly ash, which has been demonstrated to have a detrimental effect on water absorption in earlier research. The mix is dense and the samples have few fissures or pores when the S_3 absorbs the least amount of water.

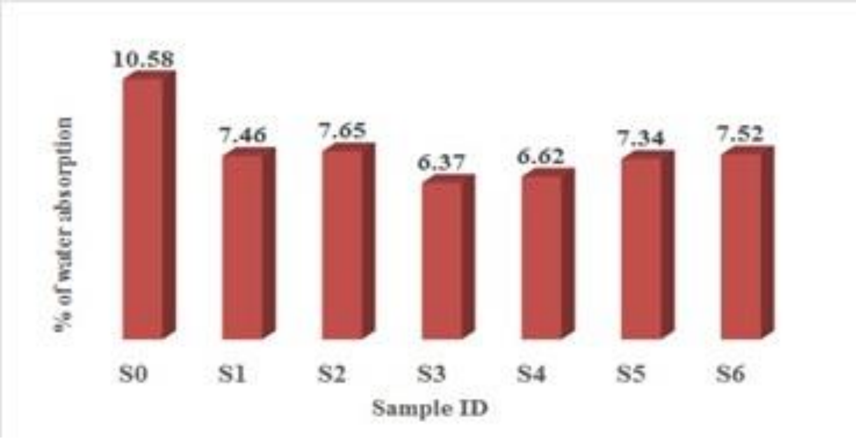

Fig. 8. Mean absorption of water

3.4 Performance of Prisms

While S_0, S_1, S_3 and S_4prisms exhibit significant deflection before attaining their optimal compressive strength, S_2, S_5 and S_6 prisms have not undergone significant deformation prior to reaching the maximum load. A compression characteristic investigation was performed on the wall prisms until they failed. For every prism, the highest possible and breaking loads, optimum deformations, and displacement under maximum load are noted, as shown in Table 2. In the early loading phases, the masonry prism's load-deflection relationships exhibit a linear trend. The prisms demonstrate inelastic behaviour once fragmenting has begun. After the peak stress, there is a very abrupt drop in strength and a minor increase in deformation in all prisms. While S_0, S_1, S_3 and S_4 prisms exhibit significant deformation prior to attaining their ultimate strength in compression , S_2, S_5 and S_6 prisms have not undergone significant deformation before reaching the ultimate load.

Table 2: Load and deflection values

Sample ID	*Linear force in kN*	*Ultimate load in kN*	*Compressive strength in MPa*	*Ultimate load displacement in mm*	*Cracking load in kN*	*Maximum displacement in mm*
S_0	95.58	150.90	1.33	8.38	128.30	9.72
S_1	80.67	113.60	1.02	7.228	59.60	7.647
S_2	92.21	136.80	1.21	2.305	113.40	2.654
S_3	209.92	261.40	2.25	5.552	227.40	6.809
S_4	139.83	184.10	1.6	7.507	159.80	8.258
S_5	153.53	183.40	1.6	3.701	162.90	3.771
S_6	133.10	170.80	1.49	2.165	90.50	3.369

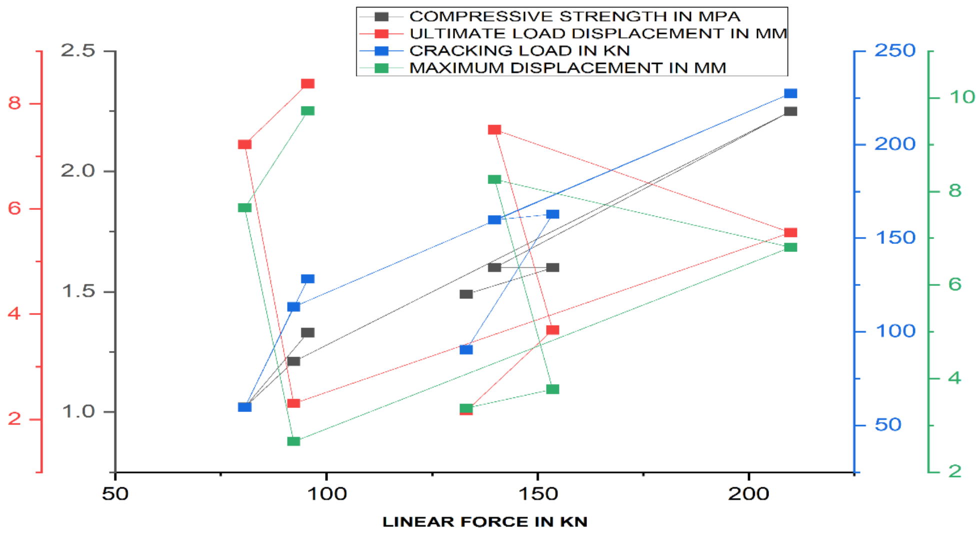

Fig. 9: Load Vs Displacement

As demonstrated in Figure 9, graphs are used to display the displacement patterns with loads.The capacity of the S_0 prism is 150.90 kN. With a load of 261.40 kN, the S_3 prism with 30% scarp glass has its optimum load- carrying capacity. The next maximum load carrying capability of the S_4 prism is followed by that of the S_5 and S_6 prisms. The S_1 prism, which has 90% crushed stone sand and 10% scarp glass, has the lowest load of 113.60 kN. The S_2 prism, which has 80% crushed stone sand and 20% scarp glass, has the next lower number, 136.80 kN. The S_3 prism has a maximum compressive stress of 2.25 MPa. The highest compressive characteristic stress for the prism S_0 samples was 1.33 MPa, whereas the optimal stresses for the S_1 and S_2 prisms remained 1.02 MPa and 1.21 MPa, correspondingly. The compressive characteristic stresses are greater than S_0 in every other prism.

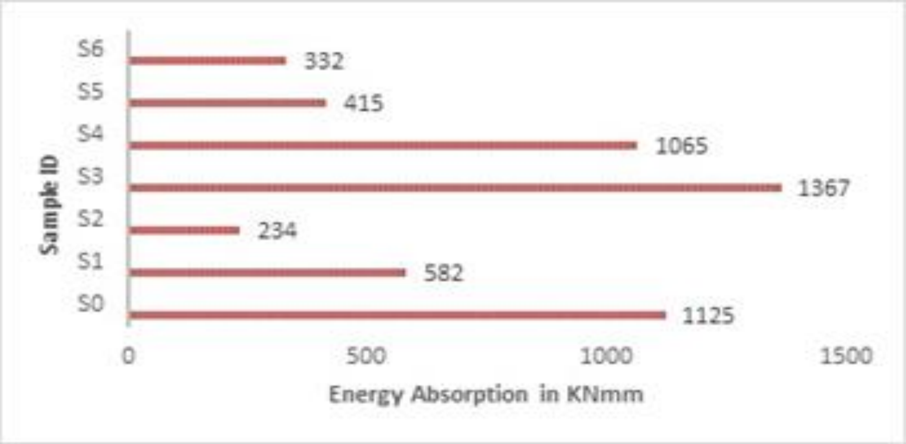

Fig. 10. Energy absorption in kNmm

As shown in Figure 10, the area bounded was computed to determine the prisms' toughness or energy-absorbing capability. S_3has the most energy-absorbing capability of any prism evaluated whereas S_0, which is made entirely of crushed stone sand, has the next-highest toughness.There is relatively minimal variation in the energy absorbing capacity of S_4 and S_0. The S_2 prism, which has the least toughness level at 237 kN.mm, is composed of 20% scarp glass and 80% crushed stone sand.

4. CONCLUSIONS

A summary of the experimental program's results is provided here: For usage as load-bearing units, geopolymer blocks composed of fly ash, GGBS, crushed stone sand, and scarp glass meet IS 2185:2005 (Part I) density standards. Maximum compressive strength and minimal water absorption were demonstrated by interlocking blocks made of 70% crushed stone sand and 30% scrap glass. According to IS 2185:2005 (Part I)'s standards for compressive strength, blocks built using S3 and S4 mixes—70% crushed stone sand and 30% scrap glass and 60% crushed stone sand and 40% scrap glass, correspondingly, with characteristic strength in compression greater than 3.2 MPa—place them in Grade C (4.0).

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