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Utilization of Waste Groundnut Shell Ash in Zero Cement Concrete

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Abstract

Currently, geopolymer concrete serves as an excellent alternative to traditional plain cement concrete, as it is produced without using ordinary Portland cement. Different source materials such as fly ash, rice husk ash, metakaolin, red mud etc. are preferred to act as the main source for geopolymer production. In this work, a new innovative waste material such as groundnut ash is utilized as the source material for the manufacture of geopolymer concrete by considering the strength, economical and availability aspect and 10 M concentration of sodium hydroxide and sodium silicate gel is used as alkaline liquid activators. During and after the harvest of groundnut, its shells are used for burning purposes and then its ash is dumped into the landfills as a waste material which pollutes the land and groundwater to a great extent. A better solution for the above issue is to utilize groundnut shell ash in concrete to enhance its performance through waste management process. Here, fly ash is partially replaced by groundnut shell ash in the proportion of 5%, 10%, 15%, and 20%. Glass fiber is added to know the best outcome of the partial replacement of groundnut shell ash. Geopolymer concrete is cast in the form of tile size of 230 mm x 230 mm x 16 mm and it is cured in hot air oven for 6 h at 80°C. This work explains in detail about the constituents used to prepare Geopolymer concrete with partial replacement of groundnut shell ash (GSA) and experimental testing related to its strength, thermal performance and potential application.

Keywords: Alkaline activators, fly ash replacement, geopolymer concrete, groundnut shell ash, sodium hydroxide, sodium silicate gel, sustainable construction materials, waste material utilization

INTRODUCTION

Concrete is the most versatile and durable construction material globally and is fundamental to any construction project. Cement is the second most consumed material globally, surpassed only by water. The production of cement requires substantial energy and results in significant carbon dioxide emissions, with the production of one ton of cement releasing an equivalent amount of carbon dioxide.

Ignition of non-renewable energy sources to work is the biggest source and other is to compound the procedure of calcinations of limestone into lime in the bond furnace which creates CO_2. The concrete business contributes about 5% of worldwide carbon dioxide discharges. Therefore, it is essential to find an alternative material to Portland cement. Geo-polymer concrete, one of the best alternatives for OPC for sustainable development. Waste management by the utilization of fly ash using Ash to Asset technique. Strength of geo-polymer was correlated under four different curing conditions. Hot air

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curing gives better strength and thermal property. As there is no standard mix design for geo-polymer, several trials have been carried out, and adequate strength has been attained in 1:1.26 mix.

The specimen used for insulation purpose with lesser density. At 80°C, increase in compressive strength of about 20.71%, 21.16%, and 81.74% are achieved. Geopolymer concrete exhibits outstanding mechanical properties. In the production of concrete, groundnut shell ash (GSA) is utilized as a partial replacement for cement. GSA/OPC concrete is commonly employed in the construction of masonry walls and for laying mass foundations. The specific gravity of groundnut shell ash is 2.08, which, while lower than the 3.15 specific gravity of cement, is within the recommended range of 1.9–2.4 for pulverized fuel ash.

The compressive strength of GSA/OPC concrete ranges from 29 MPa at 40% replacement to approximately 70 MPa at 10% replacement on the 28th day. Partial replacement of less than 10% creates good tendency for pozzolanic activity. Groundnut shell is a by-product from agricultural waste which is also cheaper than Ordinary Portland Cement [1–3].

The research report discussed the formulation of mix proportions and evaluated the short-term properties of geopolymer concrete made from low-calcium fly ash. It specifically analyzed the performance and strength characteristics of reinforced structural beams and columns composed of this geopolymer concrete. The findings demonstrated that heat-cured, low-calcium fly ash-based geopolymer concrete achieved high compressive strength, exhibited very little drying shrinkage, had low creep rates, and showed exceptional resistance to various environmental factors. Additionally, the reduction of one ton of carbon dioxide emissions translates to earning one carbon credit, which is worth approximately 20 Euros, thus providing economic benefits. In tests where specimens were exposed to 5% sulfuric acid and hydrochloric acid, geopolymer cements maintained stability with weight losses between 5 and 8%. In contrast, Portland cement deteriorated considerably, and calcium aluminate cement experienced weight losses ranging from 30 to 60%. Geo-polymer is an innovative and eco-friendly construction material which acts as a good alternative to Portland cement. Based on the rate of absorption and particle size distribution of the groundnut shells, it is better to use it as the replacement for Fine aggregate [4–6].

The use of groundnut shells in concrete reduces its workability due to the shells' high water absorption. Both the density and compressive strength of the concrete decrease as the groundnut shell content increases. Groundnut shell ash can be used as a partial replacement for cement in Sand Crete blocks, achieving satisfactory compressive strength at a 20% binder quantity. However, the setting time of composite binder Sand Crete blocks increases with higher ash content. Additionally, the compressive strength of Sand Crete blocks for a given mix ratio decreases as the groundnut shell ash content increases. Partial replacement up to 20% gives satisfactory compressive strength. Increase in groundnut shell, decreases the density and compressive strength of concrete [7–9].

Glass fiber are often used for its strong mechanical strength. Fumed silica and Glass fiber acted synergistically in enhancing the mechanical and thermal insulating performance. Glass fiber enhances the mechanical and thermal insulating performance. The results show that high flexural modulus and low thermal conductivity are achieved.

It is used in various fields such as heat insulation, sound insulation, and optoelectronics. It impacts the physical, thermal, and chemical properties of the composite, offering high mechanical strength and low thermal conductivity.

The main problem identified are of Groundnut is available in both rural and urban areas of Tamil Nadu as a waste product. During and after the harvest of groundnut, its shells are used only for burning purposes, then its ash is dumped into the landfills which pollutes the environment. Better solution is to utilize groundnut shell ash in concrete is to enhance its performance through waste management process. This experimental study aimed to assess the strength of concrete with varying proportions of groundnut shell ash (GSA) replacing cement, from 0% to 30% in 5% increments. The concrete mix followed a 1:2:4 ratio by weight, with a water–cement ratio of 0.6. Test specimens included concrete cubes (150 × 150 × 150 mm), cylinders (150 × 300 mm), and prisms (100 × 150 mm). These were evaluated for compressive, flexural, and split tensile strengths at 7, 14, and 28 days. Results indicated that a 10% replacement of cement with groundnut shell ash achieved the highest overall strength values compared to other replacement levels. Specifically, a 15% replacement showed the highest compressive and split tensile strengths, although it did not surpass the flexural strength achieved with other percentages [10, 11].

MATERIAL COLLECTION

The raw materials used in this project work are fly ash, sodium silicate solution, sodium hydroxide flakes and superplasticizer. These materials are mostly collected from Tuticorin Thermal Power Plant and the liquid solutions of required Molarity are purchased from Madurai Chemical Shop. The cost of sodium hydroxide was Rs.60 kg^{-1}, the cost of sodium silicate solution was Rs.25 kg^{-1} and the fly ash was available at free of cost. Table 1 and Figure 1 represent the chemical composition and SEM image of fly ash F type.

Table 1. Chemical composition of Class F type.

Chemical Compound	Percentage
SiO_2	52.15
Al_2O_3	27.71
Fe_2O_3	5.09
CaO	0.51
MgO	1.01
TiO_2	3.94
K_2O	1.46
Na_2O	0.27
CuO	0.24
LOI	6.80

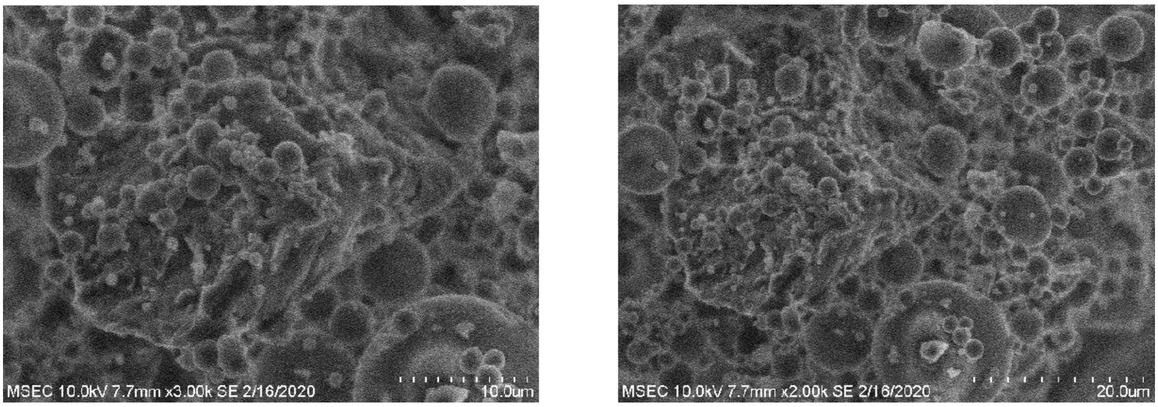

Figure 1. SEM image of class F Fly ash.

Table 2 shows the properties of fine aggregate. Table 3 represents the comparative analysis of GSA and OPC. Figure 2 depicts the SEM image of Groundnut shell ash.

MIX DESIGN

As there is no specific mix design procedure for Geopolymer concrete, trial and error method is followed to predict the optimum mix design for Geopolymer tiles. Several trials is made and the suitable mix is fixed based on the target strength achieved. Table 4 shows the mix design for tiles.

Table 2. Properties of fine aggregate.

Property	**Value**
Specific gravity	2.67
Size	<2.36 mm
Source	River sand

Table 3. Chemical composition of GSA and OPC.

Constituent	**% composition (GSA)**	**% composition (OPC)**
Fe_2O_3	1.80	4.65
SiO_2	16.21	22.00
Al_2O_3	5.93	5.03
MgO	6.74	2.06

Table 4. Mix design for Tiles.

Materials	**Quantity(G)**
Fly Ash	572.75
Fine Aggregate	721.665
Sodium Hydroxide	65.29
Sodium Silicate	163.8
15% GSA	85.91
0.5% Glass Fiber	7.18

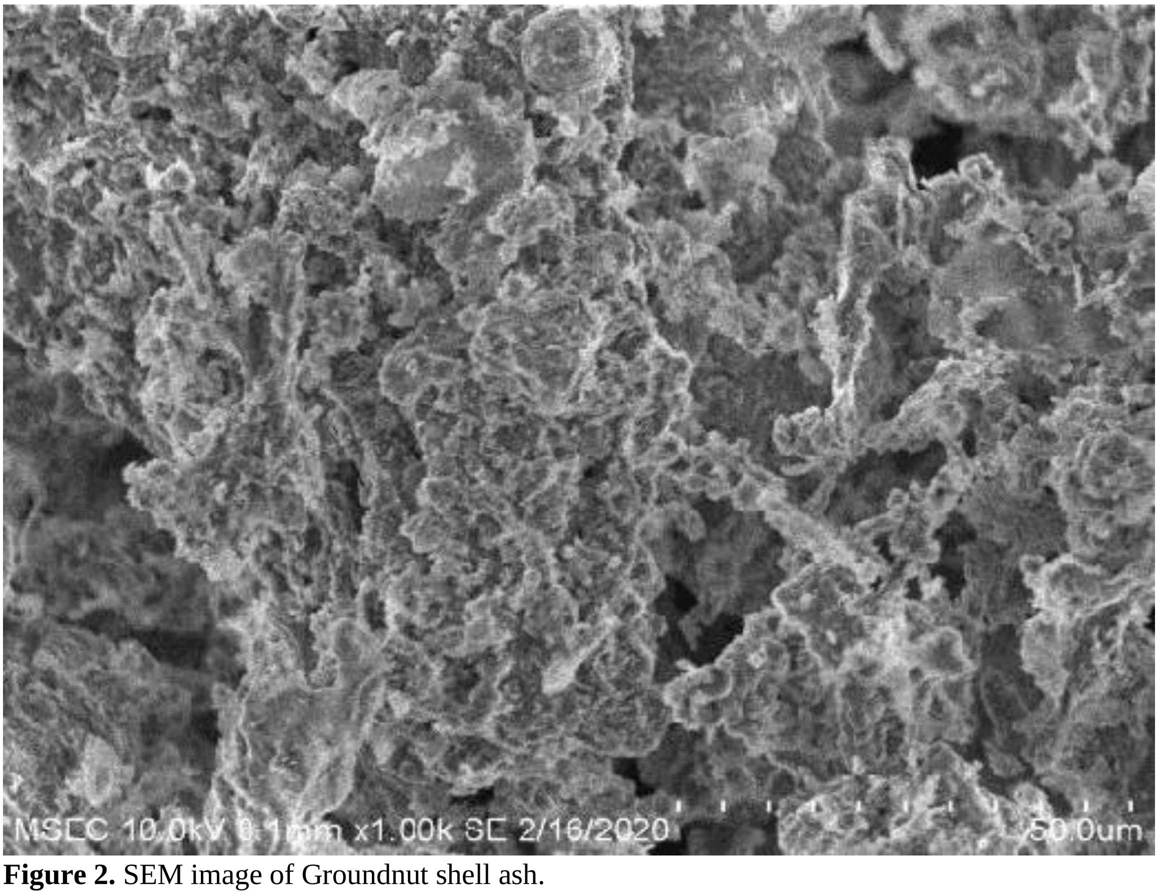

Figure 2. SEM image of Groundnut shell ash.

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EXPERIMENTAL WORK

The tiles are prepared using the optimized mix and casted in the tile mold of size 23 mm × 230 mm × 16 mm. In the above mix, fly ash is replaced by Groundnut shell ash by various proportions like 5%, 10%, 15% and 20%. Glass fiber is added as an additive to the best outcome of the Groundnut shell as replacement. The performance of the Groundnut shell ash based Geopolymer tiles is determined by conducting the following experimental tests such as Dry density test, Bending strength, Water absorption test, Impact resistance test and Surface abrasion test

Dry Density Test

Dry density test is carried out for all the proportions of the tiles such as 5%, 10%, 15%, 20% replacement of fly ash by Groundnut shell ash. Table 5 shows the dry density of all the proportions of Groundnut shell ash based Geopolymer tile. Figure 3 represents the dry weight taken using weighing balance. The tiles are made in the similar dimension of 230 × 230 × 16 (mm).

Table 5. Dry density of the tile.

Sample	**Weight of the Tile (kg)**	**Dry Density**
(Replacement)		**(kg m^{-3})**
Control mix	1.76	2083.65
GSA 5%	1.87	2208.38
GSA 10%	1.76	2075.46
GSA 15%	1.82	2225.98
GSA 20%	1.68	1986.85
GSA 15% + G.F 0.5%	1.80	2209.09

Figure 3. Tile weighted on a weighing machine.

Tile Flexure Test

Table 6 shows the bending strength of the tile and it is tested by using Tile flexure testing machine. Tile flexure strength indicates the withstand capacity of the tile against the heavy load. The following table clearly shows the strength of the tile gradually increases with the replacement of fly ash by Groundnut shell ash up to 15% replacement. Further replacement reduces the strength. So 15% replacement of Groundnut shell ash is recommended and 0.5% of Glass Fiber is added as an additive to the mix and tiles are casted. It further increases the strength of the tile. Figure 4 shows the breakage of tile during the Tile flexure test and Figure 5 indicates the pictorial representation of the Tile flexure test results.

Table 6. Tile flexure strength.

Sample (Replacement)	**Bending Strength (MPa)**
Control mix	1.03
GSA 5%	1.09
GSA 10%	1.18
GSA 15%	**1.43**
GSA 20%	1.10
GSA 15% + G.F 0.5%	**1.57**

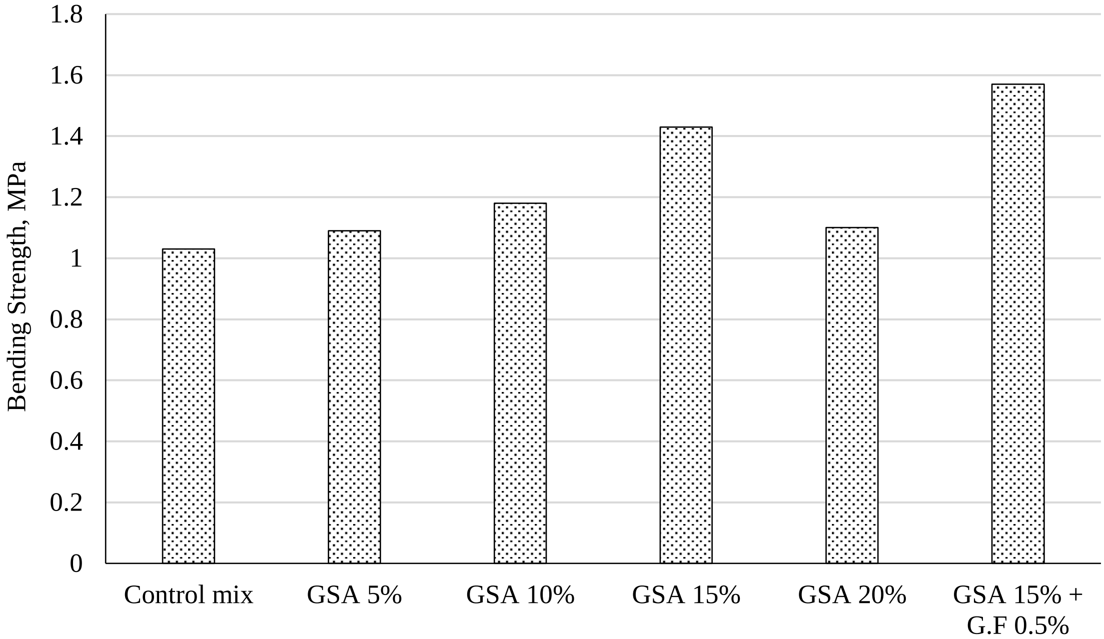

Figure 5. Tile flexure strength.

Water Absorption Test

The tiles were tested in accordance with the procedure in IS 13630–Part 2 should be immersed in cold water for 24 h to obtain its water absorption value. Figure 6 shows the water absorption process of tile and Table 7 shows its results. 15% Replacement of the Groundnut shell ash is selected as a ratio replacement for the fly ash. Since, 15% replacement of Groundnut shell ash based geopolymer tile water. absorption test values are within the acceptable range (i.e., 0–6%). Therefore, 0.5% of the Glass fiber is added to the 15% and that mixture gives most acceptable results of 3.97%.

Tile Surface Abrasion

Tile surface abrasion is tested for nine specimens with three different proportions. The average for each of the specimen is taken as the results. Figure 7 depicts the abrasion process that is carried out for mortar specimen and Table 8 gives its results.

Figure 6. Water absorption test.

Table 7. Water absorption test results.

Ratio (Replacement)	Water absorption %
Control mix	3.01
GSA 5%	3.26
GSA 10%	3.55
GSA 15%	4.01
GSA 20%	6.79
GSA 15% + G.F 0.5%	**3.97**

Table 8. Tile surface abrasion results.

Ratio (Replacement)	Average loss of thickness, mm
Control mix	2.67
GSA 15%	2.69
GSA 15% +G.F. 0.5%	**2.25**

The results of control mix sample and 15% partial replacement of the Groundnut shell ash sample gives nearly similar results. At the same time, 0.5% of glass fiber is mixed with 15% replacement of the Groundnut shell ash, it gives better results than the control mix.

Figure 7. Tile surface abrasion test.

Impact Resistance Test

Impact resistance test is done to identify the withstand energy of the specimen. Impact resistance test was done by the guidelines of ACI committee544.2R.89. Table 9 shows the results of the Impact resistance test conducted for the samples of 3 proportions (control mix, GSA 15%, GSA 15% + G.F 0.5%). Here, Table 9 provides the results of impact resistance and Figure 8 shows its process. The impact test result shows that the control mix and the 15% replacement of the Groundnut shell ash samples withstands same amount of impact load. The sample with 15% Groundnut shell ash replacement and 0.5% glass fiber shows better withstand energy than the control mix.

Figure 8. Impact Resistance test.

Table 9. Impact resistance test results.

Ratio (Replacement)	Impact energy, J
Control mix	19.87
GSA 15%	19.87
GSA 15% +G.F 0.5%	**39.73**

CONCLUSION

From this project, it was found that groundnut shell ash, a waste material readily available from the oil industry, can be effectively used as a cement replacement. It contributes to making geopolymer concrete lighter and enhances its strength. Groundnut shell ash is incorporated into geopolymer mortar in varying proportions, specifically as a 5%, 10%, 15%, and 20% replacement for fly ash. After testing all the samples for bending strength test, 15% replacement of Groundnut shell ash with the addition of 0.5% glass fibre in geopolymer mortar showed better results. Therefore, 15% of Groundnut shell ash is selected for further addition and the following observations are made: Groundnut shell ash based Geopolymer tiles showed a better flexural strength of 1.57 MPa which is higher than that of the control mix. It also showed a water absorption of 3.97% which is within the acceptable limit for tiles. There was a slight decrease in the dry density which is of 2225.98 kg m^{-3}, this makes the tile lighter. GSA tile showed better abrasion effect with the loss in the thickness of 2.25 mm and also showed better resistance to impact with 39.73J impact energy. Hence, Groundnut shell ash based Geopolymer tile is found to be a better option for the roof tiles as well as floor tiles application.

REFERENCES

1. Nwofor TC, Sule S. Stability of groundnut shell ash (GSA)/ordinary portland cement (OPC) concrete in Nigeria. Adv Appl Res. 2012; 3 (4): 2283–2287p.
2. Sada BH, Amartey YD, Bako S. An investigation into the use of groundnut shell as fine aggregate replacement. Nigerian J Technol. 2013; 32 (1): 54–60p.
3. Mahmoud H, Belel ZA, Nwakaire C. Groundnut shell ash as a partial replacement of cement in sandcrete blocks production. Constr Build Mater. 2013; 1 (3): 1026–1032p.
4. Narayanan A Et Al. An experimental investigation on fly ash-based geopolymer mortar under different curing regime for thermal analysis. Energy Build. 2017; 138: 539–545p.
5. Tian J, Shafi S, Tan H, Zhao Y. Mechanical and thermal-insulating performance of silica aerogel enhanced jointly with glass fiber and fumed silica by facile compression technique. Chem Phys Lett. 2020; 739: 136950p.
6. Narayanan A et al. Development of fly ash-based geopolymer mix using parametric analysis. Int J Rec Technol Eng. 2019; 8 (1): 30543059p.
7. Gunasekara C, Law DW, Setunge S, Sanjayan JG. Zeta potential, gel formation and compressive

strength of low calcium fly ash geopolymers. Constr Build Mater. 2015; 95: 592–599p.
8. Helmy AII. Intermittent curing of fly ash geopolymer mortar. Constr Build Mater. 2016; 110: 54–64p.
9. Patankar SV, Ghugal YM, Jamkar SS. Effect of concentration of sodium hydroxide and degree of heat curing on fly ash-based geopolymer mortar. Indian J Mater Sci. 2014; 2014: 1–6p.
10. Patankar SV, Ghugal YM, Jamkar SS. Mix design of fly ash based geopolymer concrete. Proc Conf Adv Struct Eng. 2014: 1619–1634p.
11. Ramujee K, Malasani P. Performance characteristics of geopolymer concrete in acid and sulphate environment. Indian Concr Inst J. 2015; 16: 1–7p.