International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 3 | Issue: 4 | Jul - Aug 2022 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v3i4.32

Strength Properties of Clay Based Geopolymer Concrete Using Spent Filter Sand as Fine Aggregates

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ABSTRACT
The high cost of construction materials around the globe has encouraged researchers to make findings on the use of materials within their locality for infrastructure development. This will reduce both construction cost, and environmental pollution caused by manufacturing materials such as Portland Limestone Cement (PLC) which comes with CO2 emission. Hence, this study examined the strength properties of clay based geopolymer concrete made with spent filter sand as fine aggregates. The strength properties of the concrete were tested after curing for 7, 14, 21, and 28 days. The results showed that, the clay soil is under class C ash (sum of acidic oxide equals 55.83%). The highest compressive strength, split tensile strength and flexural strength in 28 days are respectively; 30.33 N/mm2, 6.41 N/mm2, and 6.30 N/mm2. There was good strength development as the curing days increased generally. Hence, the use of SFS in clay based geopolymer concrete did not compromise the strength of the concrete but instead improved the tensile strength and flexural strength by more than 100%.

Keywords: geopolymer concrete; clay soil; spent filter sand; compressive strength; flexural strength

INTRODUCTION
Background of the Study
The usage of concrete around the globe is steadily increasing on daily bases due to the high quest for better shelters by the humans. Concrete is a very vital construction material that is been used in almost all types of structures due to its outstanding characteristics of durability and ease of production. The binder conventionally used in concrete production is the Portland Limestone Cement (PLC), hence, it has a very high demand. However, the production of PLC comes with some serious environmental challenges that are unbearable. The volume of carbon dioxide emitted in to the environment during the manufacturing process of PLC is high based on the calcination of the materials used, which also comes high energy consumption and it is capital intensive. Hence, researchers have encouraged the application of locally available pozzolanic materials that can be used to partially or wholly replace PLC for concrete production that are more environment friendly. So much work has been done by different researchers to ensure advancement in the process of manufacturing PLC or production of a greener alternative to drastically reduce the level of CO_2 emission from the cement industry which can be more environment friendly (Habert et al., 2010). A potential solution to this issue of pollution in the environment from cement production process which is required for, on daily basis, is the use of a more environment friendly cement such as the geopolymer cement (Habert *et al.,* 2011).

Geopolymer is a concrete binder that is produced from source materials containing silica and aluminium oxides by a way of activation with an alkaline solution in a geopolymerization reaction at an elevated temperature. The geopolymer cement has low energy requirements, and it also has good resistance to fire and acid attack, and more environment friendly than PLC (Mustafa Al Bakri et al 2011). Davidovits (1999) made an assertion that, cementing materials can be produced by using alkaline solution activate source materials containing aluminum, silicon in a polymeric reaction. Such materials include; fly ash, clay and rice husk which he called. Pozzolans such as fly ash, with high content aluminum and silicon are activated by alkaline solution which acts as a total replacement for PLC in concrete (Palomo et al., 1999). Application of palm oil fuel ash as source material for geopolymer concrete production was investigated by Yabefa et al 2022 with striking results. Clay is a very useful material for construction works for its pozzolanic properties enables it to be used as partial replacement material for PLC in concrete production. Water treatment plants that uses river bank filtration process usually remove iron and manganese in portable water treatment process by aeration and sand filtration. After a while, the sand becomes saturated and it is disposed of to become a nuisance in the environment and replaced with new sand, and there is sparse literature on the use of spent filter sand in concrete works. Hence, this study intends to examine the strength properties of a clay based geopolymer concrete produced with SFS as fine aggregates.

MATERIALS AND METHODS
The various materials and methods in conducting the test for this study are discussed here in detail.

The materials used include clay soil obtained from Wilberforce Island, Bayelsa State and burnt in an uncontrolled environment, and processed to have smaller particle size passing the 90-micron sieve size. Chemicals used include NaOH) and Na_2SiO_3. The spent filter sand (SFS) were obtained from the Niger Delta University water treatment plant, and the granites were obtained from the Amassoma market. Clay soil isan abundant material on Earth, which is pozzolanic in nature. The sodium hydroxide solids were in pellets form with 99% purity, obtained from a local supplier in Aba, Abia State. The NaOH pellets were dissolved in distilled water to prepare the solution. Figure 1 shows the preparation of the NaOH solution. Sodium silicate solution was also obtained from local supplier from Lagos. Figure 2 shows the particle size reduction process of the clay soil while the chemical analysis of clay soil and sodium silicate solution are presented in Table1 and 2 respectively by mass. The clay soil can be grouped under class C ($SiO_2 + Al_2O_3 + Fe_2O_3$ = 55.82%) in accordance with ASTM 618. Also, the specific gravity and bulk density of the clay soil are 2.17 are 1700kg/m^3 respectively. The specific gravity of spent filter sand was 2.59 which is in accordance with IS: 2386 (part 3) 1963.

FIGURE 1: NaOH solution

FIGURE 2: clay soil

TABLE 1: Chemical Analysis of clay soil

S/No.	Chemical Composition (%)	Clay
1.	Silicon dioxide (SiO_2)	38.10
2.	Aluminum oxide (Al_2O_3)	15.20
3.	Calcium oxide (CaO)	0.59
4.	Magnesium oxide (MgO)	0.40
5.	Ferric oxide (Fe_2O_3)	2.52
6.	Sulfur trioxide (SO_3)	1.52
7.	Potassium oxide (K_2O)	2.40
8.	Sodium oxide (Na_2O)	0.36

TABLE 2: Chemical Analysis of sodium silicate (Na_2SiO_3)

S/No.	Property	Na_2SiO_3
1.	Na_2O	15%
2.	SiO_2	30%
3.	H_2O	55%

Mix proportions and Samples preparation

The proportion for aggregates used in the study was 77%. The NaOH to Na_2SiO_3 ratio by mass used was 2.5, the concentration of NaOH solution was 10M, the alkaline activator to geopolymer solid ratio used was 0.45 and the water to binder ratio was 0.1. the concrete moulds used include; cube (100mm), cylinders (100mm by 200mm), beams (100mm by 100mm by 500mm). The fresh concrete was cast on the moulds and allowed for 24 hours' rest period before demolding, and then, oven cured at 60^{0}C for 6 hours. Then, the samples were then kept at ambient temperature for 7, 14, 21, and 28 days before testing. Table 3 presents the mix proportion for this study. Figure 3 presents the fresh clay based geopolymer concrete mixture.

TABLE 3: Mixed Proportion for clay based geopolymer concrete

S/NO	Materials	Mass kg/m^3
1.	Coarse Aggregate (granites)	1346
2.	Fine Aggregate (SFS)	612
3.	Clay soil	408
4.	Sodium Silicate Solution (Na_2SiO_3)	103
5.	Sodium hydroxide (NaOH) (10M)	41
6.	Extra water	41

FIGURE 3: Fresh geopolymer concrete

Compressive Strength of Clay based Geopolymer Concrete

The compressive strengths of the hardened concrete is shown in Table 4. it shows the variation of strength with different curing durations. The strength of the concrete increased at different days. The average compressive strength of the three consecutive cubes crushed in 7, 14, 21, and 28 days respectively, are 15.00 N/mm^2, 24 N/mm^2, 25 N/mm^2, 30.33 N/mm^2. Figure 4 presents the graphical illustration of the compressive strength variation with time.

TABLE 4: Compressive strength

S/No	Curing Duration days	Compressive Strength (N/mm^2)	Average compressive strength (N/mm^2)
1	7	14 15 16	15.00
2	14	24 25 23	24.00
3	21	24 25 26	25.00
4	28	33 28 30	30.33

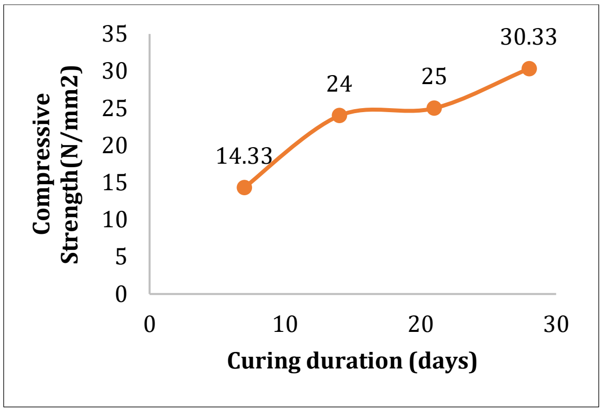

FIGURE 4: Compressive Strength

Split Tensile Strength

The split tensile strengths of the concrete at the different curing days is shown in Table 5. It shows that, the strength of the concrete increased with curing duration. The average split tensile strengths of the concrete at 7, 14, 21, and 28 days are; 2.90, 5.10, 5.31 and 6.41N/mm^2 respectively. There was 121% increase of strength from 7 to 28 days. Figure 5 shows the variation of the split tensile strength with time.

TABLE 5: Split Tensile strength

S/No	Curing Duration days	Split tensile strength (N/mm^2)	Average compressive strength (N/mm^2)
1	7	2.95 2.80 2.95	2.90
2	14	5.14 5.15 5.00	5.10
3	21	5.33 5.30 5.31	5.31
4	28	6.42 6.39 6.41	6.41

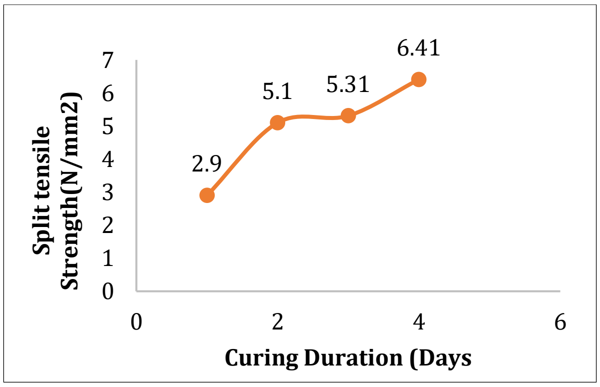

FIGURE 5: Split tensile strength

Flexural Strength

The flexural strength of the concrete increased as the curing duration increased, as presented in Table 6. It shows the flexural strengths of the three different samples tested in each day after the curing age and, the average flexural strength was recorded. The flexural strengths at 7, 14, 21 and 28 days are 1.31, 3.84, 4.19 and 6.30 N/mm^2 respectively. It was observed that, there was an increase of 381% from 7 to 28 days.

TABLE 6: Flexural Strength

S/No	Curing Duration days	Flexural Strength (N/mm^2)	Average Flexural Strength (N/mm^2)
1	7	1.24 1.44 1.24	1.31
2	14	3.84 4.18 3.51	3.84
3	21	3.84 4.18 4.54	4.19
4	28	7.47 5.30 6.12	6.30

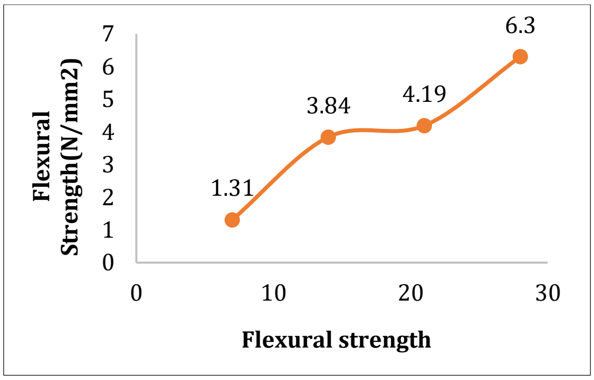

FIGURE 6: Flexural strength

CONCLUSIONS

This study was concluded as follows based on the findings of the research.

- Spent filter sand (SFS) can be used with Clay soil as a source material for geopolymer concrete production.
- Clay soil can be grouped under class C ash (i.e. sum of acidic oxide = 55.82%,).
- The strength properties of the concrete increased generally with increase in curing days from 7 - 28 days reaching a maximum compressive, split tensile and flexural strengths are 30.33N/mm^2, 6.41N/mm^2, 6.30 N/mm^2 respectively
- Road pavements which require materials with good tensile strength property can have some relief in this studied geopolymer concrete.

RECOMMENDATIONS

The following recommendations are made.

- The strength behavior of geopolymer concrete using spent filter sand needs to be studied using different ratios of SPS and normal river sand in the mixture.
- The effect of calcination temperature of the clay soil on the mechanical properties of the concrete needs to be investigated.
- Government should encourage the use of this technology to enhance the construction of low-cost housing units.

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