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INVESTIGATION OF THE EFFECT OF GRANULATED POLYMER (POLYVINYLCHLORIDE) WASTE MATERIAL AS AN ADDITIVE ON PROPERTIES OF CONCRETE

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ABSTRACT: *In this study, an attempt was made to experimentally evaluate the effect of granulated polymer (PVC pipes) waste as additive on and physical properties of concrete. Total of one hundred and thirty (130) specimens were cast. The production of the specimen consists of sixty (60) specimens with the size 100 x 100 x100 mm. Different amount of granulated polymer (0, 5%, 10%, 15% and 20%) of total weight of fine aggregate were added to other constituents of the concrete mix. The grain size of sand ranges from 0.15 to 4.75mm, with the percentage passing of sieve 0.15 and 4.75mm are 0% and 98.4% respectively. The specific gravity of the granulated polymer was 1.10 which is lower than fine and coarse aggregate. At 28days, the average density were (2423kg/m^3,2316 kg/m^3, 2261 kg/m^3 and 2232 kg/m^3) respectively for 5%, 10%, 15% and 20% polymer content of granulated polymer were observed to be lower than that control with 0% polymer (2610 kg/m^3). Water absorption rates for varying percentage of polymer added were observed to increase with increase in polymer added. This shows that, the higher the polymer added, the higher the water absorption rate for every time taken for the observation.*

KEYWORDS: Polymer, polyvinylchloride, waste material, compressive strength, absorption capacity granulated, concrete

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INTRODUCTION

Waste plastic is one of the materials that cause pollution and damage to the environment, since it is considered a non-biodegradable material because it does not decompose and is not subject to dissolution, whether in soil or water, even after the passage of time [1]. The problems caused by burning plastic materials are the release of toxic gases, which lead to the emergence of many health problems. There is a method that can be considered economical and healthy, in order to get rid of plastic waste, which is to add plastic to concrete, either as a replacement for fine aggregate materials such as sand or coarse aggregate materials such as gravel, or adding plastic in the form of fiber [2].

The development in the construction industry all over the world is progressing. Many structures are being built, both residential and non-residential. Just like many countries, the demand for new structures in Nigeria is highly increasing [3]. Attempts have also been made by various researchers to reduce the cost of its constituent and hence total construction cost by investigating and ascertaining the usefulness of material which could be classified as local materials. Some of these local materials are agricultural or industrial waste which includes sawdust, concrete debris, fly ash, coconut shells among others which are produced from milling stations, thermal power station, waste treatment plant and so on [4].

As a result of the increase in the cost of construction materials, especially cement, crushed stone (coarse aggregate), fine sand (fine aggregate); there is the need to investigate the use of alternate building materials which are locally available [5]. Since most building construction works consist of concrete work; therefore, reduction in cost of concrete production will reduce the cost of building construction. Globally there is a resurgence of interest in this era of information revolution and environmental awareness. However, modern applications are being discovered and several are based on wood’s unique physical and mechanical properties like strength and its ease in shaping. High cost of building material has affected many Nigerians who engage in cutting corners to achieve building production leading to failure in the buildings [6]. It is therefore necessary to use alternative available local material for concrete production. Concrete is a construction material which consists of the mixture of fine, coarse aggregate, cement which proportionally mixed with certain percentage of water [5].

Concrete is one of the most important materials used in construction, and because of its suitable cost and strength, an improvement of its mechanical and chemical properties was searched by many researchers by different processes, like adding different types polymers as a ratio of water content, or adding high strength steel fibers as a ratio of cement content [7]. Some researches investigate the effect of adding low-cost materials on the mechanical properties of concrete, and because plastic material is one of the environmental pollutants, it had been used in concrete mix in some researches [7].

The world is facing a waste crisis from the most problematic plastic produced today: polyvinylchloride or PVC, commonly called vinyl. For years, abandoned products made of PVC have been a leading cause of dioxin in incinerators when they are burned. As more PVC products are being disposed of, the community now suffers an impending PVC waste problem. World production of PVC today is more than 20 million tonnes per year - up from three million tonnes in 1965 – which corresponds to about one-fifth of the total plastic production. Since the 1960s, PVC has been used very commonly in all types of products [8]. Considering that the lifespan of the PVC products is about 30–40 years, a significant increase

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in PVC waste generation is expected in the near future Although there have been some research studies reported on using steam gasification or pyrolysis to convert PVC to other products product [8]. It is of little doubt that large quantities of PVC wastes will need to be disposed of as solid waste. It is also expected that a significant amount of PVC waste will be derived from construction and demolition (C&D) activities [8]. The possibility of recycling these PVC wastes is therefore of genuine interest [8]. This social awareness necessitates an urge to develop new methods to recycle PVC wastes. Recycling PVC wastes to replace river sand for concrete production can be one of the environmentally friendly methods because there is a great demand for concrete worldwide, especially in developing economies such as China, and river sand has recently become a scarce natural resource [8].

Statement Problem

Waste plastic is one of the materials that cause pollution and damage to the environment, since it is considered a non-biodegradable material because it does not decompose and is not subject to dissolution, whether in soil or water, even after the passage of time. The problems caused by burning plastic materials are the release of toxic gases, which lead to the emergence of many health problems. There is a method that can be considered economical and healthy, in order to get rid of plastic waste, which is to add plastic to concrete, either as a replacement for fine aggregate materials such as sand or coarse aggregate materials such as gravel, or adding plastic in the form of fiber. Researchers are developing methods to get rid of plastic wastes without causing harm to human health and to the environment. Traditional concrete often suffers from limitations in tensile strength and durability, especially under extreme environmental conditions. The research seeks to determine how granulated polymers can enhance these properties. The cement industry is a significant contributor to carbon emissions. The research aims to reduce reliance on traditional cement by identifying effective polymer additives that can maintain or improve concrete performance. Many concrete mixtures can be challenging to work with, leading to inconsistent quality. Investigating polymer additives can help improve workability and ease of handling, addressing issues in application. Concrete is often vulnerable to environmental factors such as moisture, chemicals, and temperature fluctuations.

Significance of the Study

Granulated polymers can improve concrete's mechanical properties, such as tensile strength, flexibility, and durability. Understanding these enhancements helps in designing stronger and more resilient structures. Incorporating polymers can contribute to sustainable construction practices. By reducing the amount of traditional cement used, this approach can lower carbon emissions associated with concrete production. The addition of granulated polymers may enhance the workability and flow of concrete mixtures, making them easier to handle and apply. This can lead to improved application techniques and reduced labor costs. Polymers can enhance concrete's resistance to water, chemicals, and temperature variations, leading to longer-lasting infrastructure, particularly in harsh environments. By optimizing the properties of concrete, granulated polymers could reduce maintenance costs and extend the lifespan of concrete structures, resulting in long-term economic benefits. Research into polymer additives fosters innovation in the construction industry, encouraging the development of new materials and techniques that can lead to improved building practices. Investigating these additives aids in establishing guidelines and standards for their use, ensuring safety and performance in concrete applications.

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METHODOLOGY

Materials used:

Materials and Method

This chapter explains the raw materials and methods used to develop the mixture, as well as acceptable mixing and testing procedures.

Materials

The materials used in the study include; cement, granulated polymer (PVC), sand, granite, and water. This is shown in Figure 1.

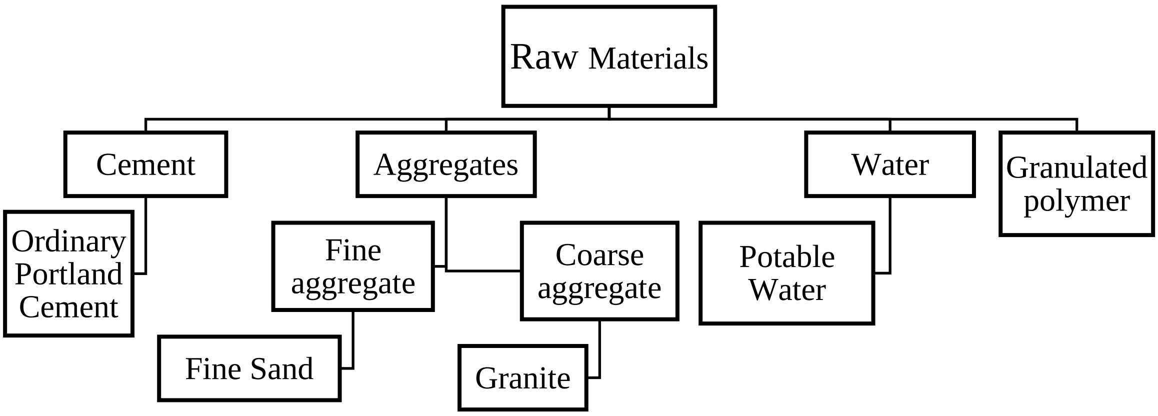

Figure 1: Hierarchy Chart for the Raw Materials used

Fine Aggregate

Sand is one of the main components of concrete, and it exists in abundance as the surface along rivers, oceans, lake banks and arid areas. Fines/sand is the accumulation of mineral material particles produced by decay. The fine aggregate (fine sand) used in the concrete mix was collected from University of Ilorin ongoing construction site in Ilorin, Kwara State. The sand was sieved according to BS 933 Part 1 (1997) to remove larger aggregates and organic pollutants.

Coarse Aggregate

It is the basic building component of concrete. The coarse aggregate (manually crushed) used was granite with maximum nominal size of 19mm and sourced locally from a University of Ilorin ongoing construction site in Ilorin, Kwara State.

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Cement

Portland cement (OPC) of Dangote 3X (42.5R grade) brand is widely used in Nigeria's construction industry. Cement that complied with BS 12: 1991 specifications was used for the concrete mix.

Water

The water used in the concrete must be clean and free of chemical contamination to avoid adverse reactions that may weaken the concrete. This study used potable tap water supplied to the University.

Granulated Polymer Waste

This was obtained from dumpsite building. The details of the granulated polymer PVC are the X-ray diffraction results on PVC powder material shows that the major elements are Nacrite, Gypsum, Orthoclase and astonite, with some minor minerals like Illite, Muscovite and Tobermorite. The CaO, SiO_2 and Al_2O_3 in PVC-powder are almost same as that in cement.

METHODS

Determination of Physical Properties of Aggregates

Properties of Aggregate

When the starter is weathered or artificially ground, it will form natural aggregates. These are inert fillers. They provide economic benefits from the total cost of concrete on the construction site and have a significant impact on the final performance of the concrete mixture. Aggregate has a major impact on the water demand of the mixture. Aggregate ensures the volume stability of hardened concrete. The properties of aggregate tested for are as follows:

- Particle size distribution;
- Specific gravity;
- Absorption capacity;
- Bulk density; and
- Slump test.

Particle size distribution

This is the distribution of different particle sizes in the aggregated sample. This is done to determine the quality of the concrete. The size of the aggregated particles varies from one type of aggregate to the same type of aggregate. In this test, the particle size distribution of the fine aggregate is determined by sieve analysis (BS812-103, 1985). This was obtained using Equation 1.

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$$Percentage\ passing\ on\ each\ sieve = \frac{weight\ of\ total\ sample - weight\ retained}{total\ weightof\ sample} \times 100\% \quad (1)$$

Specific Gravity Test of the Aggregates (BS 812-2) 1995

The specific gravity of a solid is the ratio of the weight of a certain volume of matter to the weight of an equal volume of water; in fact, it indicates how much heavier (or lighter) the material is than water. This was obtained using Equation 2.

The specific gravity (SG) $= \frac{GL(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$ (2)

Where: GL= Specific gravity of the liquid used i.e. for water = 1.00

M_1= mass of empty cylinder (g)

M_2= mass of empty cylinder + dry soil (g)

M_3= mass of empty cylinder + dry soil + liquid (g)

M_4= mass of empty cylinder + liquid only (g)

Bulk Density (BS 812-2) 1995

It is the weight of aggregate carried by a unit volume container when it is filled or compacted under specified conditions. The bulk density or specific gravity of the aggregate provides valuable information about the shape and classification of the aggregate. This was obtained using Equation 3.

Weight of empty container = w

Weight of container + aggregate = W_1

Volume of container = V

$$Bulk\ Density(SSD) = \frac{(W_1 - W)}{V}\ kg/m^3 \quad (3)$$

Water Absorption Capacity (BS 933, 1997)

Some aggregates are porous and absorbent. The porosity and absorption rate of the aggregate affect the water/cement ratio, thereby affecting the workability of concrete. This was obtained using Equation 4.

Absorption capacity % = $\frac{W_2 - W_1}{W_1} \times 100\%$ (4)

Weight of dry sample = $w1$

Weight of water and sample= W_2

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RESULTS

Particle Size Distribution

The particle size distribution charts for Sand, Granite and Polymer are shown in Figures 2-4respectively.

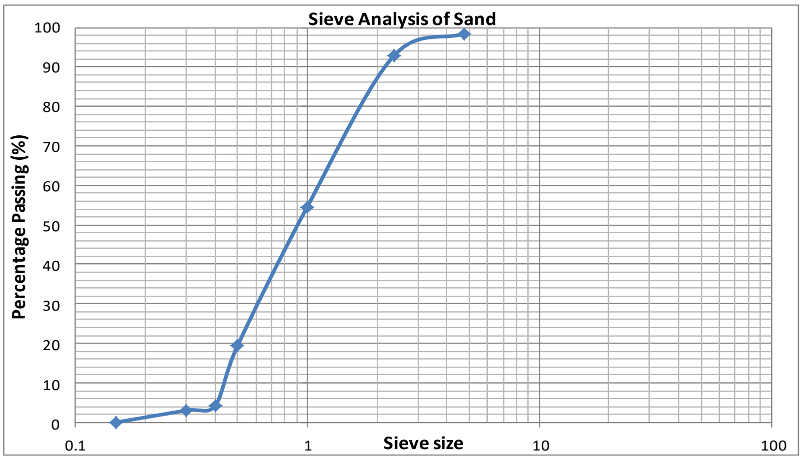

Figure 2: Particle Size Distribution for Sand

In Figure 2, the grain size ranges from 0.15 to 4.75mm, with the corresponding percentage passing being 0% and 98.4% respectively. The sand can be classified as medium grading fine aggregate with fineness modulus of 2.74 based on BS EN 12620:2002 requirement.

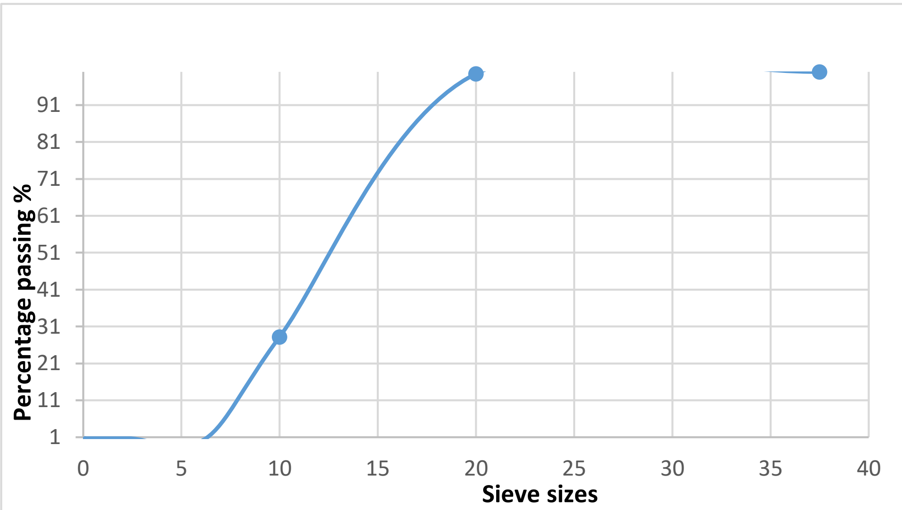

Figure 3: Particle Size Distribution for Coarse Aggregate

From Figure 3, the graph shows that sieve grain size ranges from 0.075mm to 37.5mm with percentage passing of 0.7% and 100% respectively. According to BS 882:1992, it satisfied the grading requirement for coarse aggregate with fineness modulus of 5.69.

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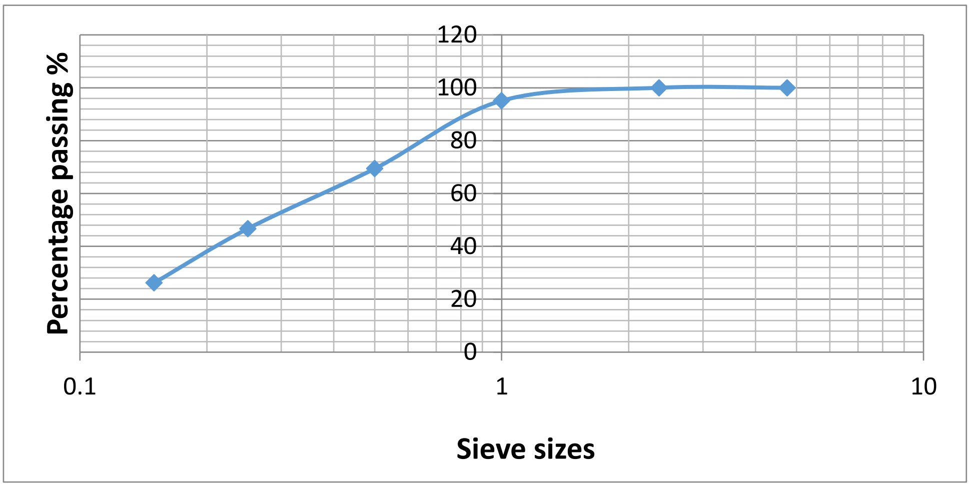

Figure 4: Particle Size Distribution for Granulated Polymer (PVC)

From Figure 4, show that the sieve grain size ranges from 0.15 to 2.36mm based on sieve sizes used for the experiment, with the corresponding percentage passing of sieve 26.2% through sieve 0.15mm. This shows that 73.8% are retained in seize size 0.15mm while the maximum grain size of granulated polymer was 2.36mm. However, there are granulated PVC sizes less than 0.15mm but no practical sieves size less than 0.15mm in the laboratory in order to get sizes below 0.15mm, this is one of the limitations of the study.

Specific Gravity

Figure 5 shows the specific gravity of sand, granite and granulated polymer (GP). Their average specific gravities 2.61, 2.76 and 1.10 respectively. The specific gravity is one of the dictating factors of bulk density. Shetty (2005) said the higher the bulk density, the higher the specific gravity. The result showed that the GP is lighter than the other two materials (sand and granite). The specific gravity of GP is comparable to that of water which is 1.0

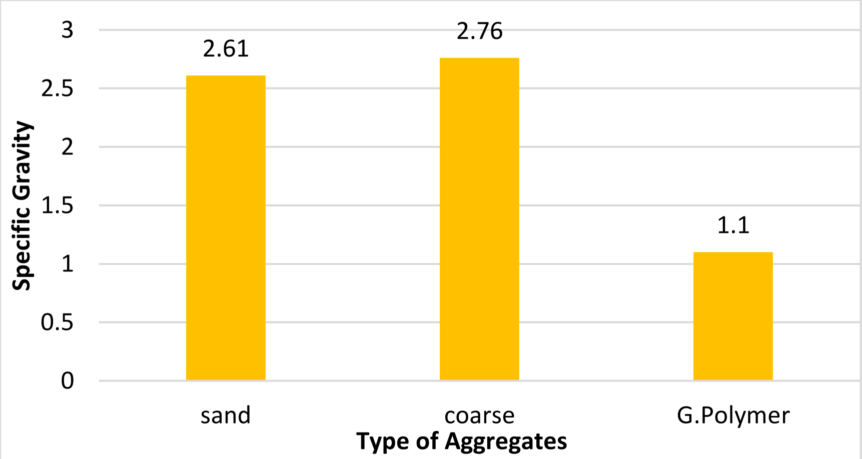

Figure 5: Average Specific Gravity for the Aggregates used

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Water Absorption Capacity

Figure 6, the water absorption capacity for the aggregates (sand and granite) were observed to be equal and more than that of granulated polymer. Shetty (2005) explained that the reason for the differences might be due to fineness and porosity of the aggregate or the rock with which the aggregates were derived from.

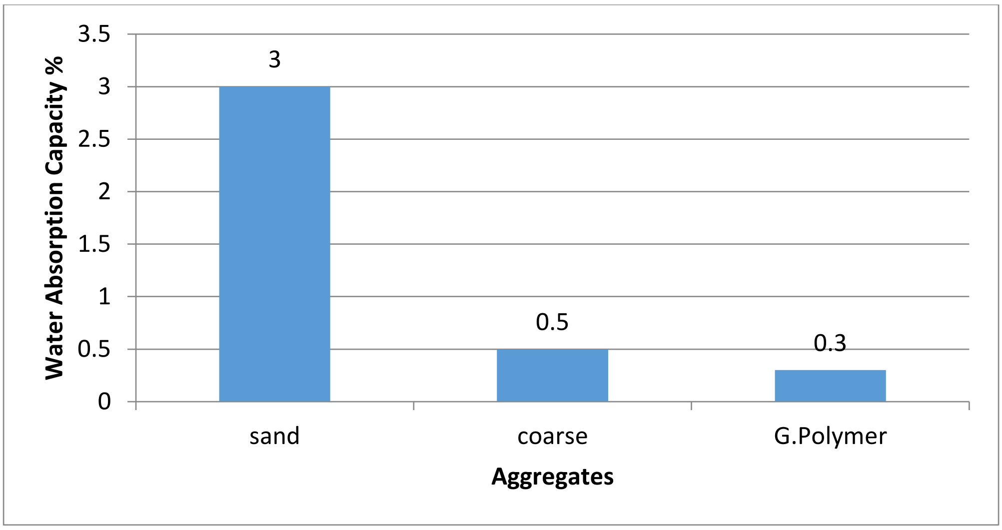

Figure 6: Average Water Absorption Capacity for the Aggregates used

Bulk Density of Aggregates

From Figure 7, it was observed that the aggregates (fine sand, granite and granulated polymer) used in the production of the concrete have average bulk density of $1652\frac{kg}{m^3}$, $1396\frac{kg}{m^3}$ and $780\frac{kg}{m^3}$ respectively. Safriat (2014) explained that a dried normal aggregate should have bulk density of not less than $1200\frac{kg}{m^3}$. Therefore, the coarse and fine aggregates are fit for the production of normal concrete.

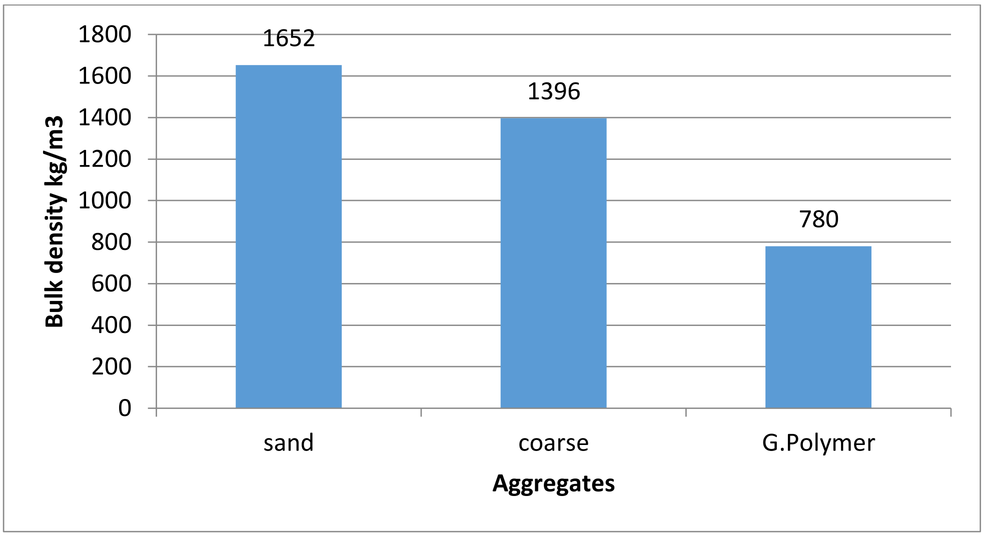

Figure 7: Average Bulk Density for the Aggregates used

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CONCLUSION

Based on the work carried out in this study, the following conclusions were drawn.

1. The grain size of sand ranges from 0.15 to 4.75mm, with the percentage passing of sieve 0.15 and 4.75mm are 0% and 98.4% respectively. The sand can be classified as medium grading fine aggregate, as it satisfies the BS EN 12620:2002 requirement.

2. The grain size of coarse ranges from 1mm to 10mm with percentage passing of 0.7% and 100% through sieve size 10mm and 1mm respectively. As accordingly to standards the sieve varies from 4.75mm to 40mm. It satisfied the grading requirement for coarse aggregate as specified by BS 882:1992.

3. The grain size of granulated polymer ranges from 0.15 to 2.36mm, with the percentage passing of sieve 26.2% through sieve 0.15mm meaning that 73.8% are retained in seize size 0.15mm while the maximum grain size of granulated polymer is 2.36mm.All the grain sizes are suitable as fine aggregates based on sizes because accordingly to the standards as it satisfies the BS EN 12620:2002 requirement.

4. The specific gravity for fine aggregates ranges from 2.52 to 2.66 with an average value of 2.61 which satisfies the British Standard, BS 812-2 (1995).

5. The Specific gravity for coarse aggregates ranges from 2.66 to 2.71 with an average value of 2.67 which satisfies the British Standard, BS 812-2 (1995).

6. The Specific gravity for the granulated polymer ranges from 1.06 to 1.18 with an average value of 1.10 which satisfies the British Standard, BS 812-2 (1995).

7. The Bulk density for fine aggregates ranges from 1632 kg/m^3 to 1672 kg/m^3 with an average value of 1652 kg/m^3, for coarse also range from 1393 kg/m^3 to 1398 kg/m^3 with an average value of 1396 kg/m^3 and granulated polymer range from 764 kg/m^3 to 788 kg/m^3 with an average value of 780 kg/m^3.

8. The Water absorption capacity for fine range from 2.6% to 3.4% with an average value of 3.0%, for coarse also range from 0.3% to 0.4% with an average value of 0.3% and granulated polymer of value from 1% to 1.5% with an average value of 1.2% which satisfies BS 882 or BS 1047.

9. The Density of granulated polymer ranges from 2376 kg/m^3 to 2385 kg/m^3 with an average of 2380kg/m^3.

RECOMMENDATION

From this study, the following findings are recommended;

i. Polymer (PVC) is available in significant quantities across the country. To prevent the wastage of this material, it can be utilized for the production of light weight, durable and cheap concrete.

ii. Polymer (PVC) can be used for partial replacement of cement in concrete production at a percentage up to 20%. This will decrease the weight of the concrete, and in turn reduce the cost.

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iii. For the sustainability of our environment, Polymer (PVC) burning must be stopped. This will help in reducing pollution of the environment.

iv. Also, further study is recommended on effect of different water/cement ratios, different mix ratios, and the reactivity of Polymer (PVC) on the strength development of Polymer (PVC) Concrete.

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