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CHALLENGES OF USING NON-DEGRADABLE WASTE MATERIAL POLYSTYRENE PACKING IN REINFORCED CONCRETE DESIGN AND CONSTRUCTION

BEN NGENE, GIDEON BAMIGBOYE, and OSATO ASEMOTA

Dept of Civil Engineering, Covenant University, Ota, Nigeria

Weight and Environmental concerns are two elements that have made the search for alternative materials of construction critical in today's construction industry. The importance of finding a solution to the problem has given rise to the use of non-degradable materials. This study examines the challenges of making such material as polystyrene used in product packaging a part of the structural element in construction. Such adventure it is envisaged reduced the volume and number of landfill sites in Nigeria where air pollution arising from dump sites affects the health of citizens. To achieve this aim, Styrofoam was used as a partial replacement for coarse aggregate (granite) by volume. The replacement was carried out in varying percentages of 10, 20 and 30% Styrofoam concretes respectively with a concrete mix ratio of 1:1:2. The result obtained showed that concrete produced using Styrofoam as the alternative aggregate possess lesser values of compressive strength when compared with the control of conventional concrete without Styrofoam. The optimal percentage of a replacement for Styrofoam concrete was 10% with a compressive strength of 21.33 N/mm^2 while the control concrete had a compressive strength of 33.26 N/mm^2. The loss of strength of Styrofoam concrete is compensated by the reduction of the requirement for landfill sites and the attendant pollution generated while the concrete can be used for non-structural elements in construction.

Keywords: Environment, Non-degradable waste, Air-pollution, Compressive strength, Styrofoam concrete, Conventional concrete.

1 INTRODUCTION

Zhang (2011) defined concrete as a man-made "stone" which is produced by the combination of materials, granular coarse and fine aggregates, cement and water in a standardized ratio, after which the mix is consequently coagulated and hardened. As concrete is a composite material and is made of various components, its properties and characteristics are functions of the aggregated properties of each constituent or component as well as the proportions in which each component is combined (Bamigboye *et al*. 2017). Mamlouk and Zaniewski (2006) described aggregates as a granular material such as sand, gravel, crushed stone, blast-furnace slag that generally occupies roughly 60-75% of the total volume of concrete. The issue of waste management has local, national and international dimensions and arises due to the inefficiencies of municipal solid waste management strategies adopted as stated by (Otitoju 2014). The word "Styrofoam" is a commercial name ascribed to a material known technically as expanded polystyrene or polystyrene foam. Polystyrene is produced from styrene, which can be found in naturally occurring substances or can be synthesized from petroleum by-products such as benzene according to Friend (2005). Polystyrene is a vinyl polymer and can be defined according to its chemical structure, as a long hydrocarbon chain, consisting of a phenyl group attached to every other carbon atom. Expanded polystyrene (EPS) however, can be described as polystyrene in the form of raw beads being steam-heated, causing expansion (Ismail *et al*. 2003). Production and use of Styrofoam (expanded polystyrene) have considerably harmful effects on the environment, according to the Environmental Protection Agency and Styrofoam is the fifth largest source of hazardous waste in the United States (Kuruppu and Chandratilake 2012). This is due to the difficulty experienced in the recycling of Styrofoam as a result of its lightweight and the high economic costs of transporting and degreasing the petroleum-based material. Also, on the weight side of the argument, the construction of high-rise buildings and other structures, the cost of construction of a foundation can usually be attributed to the large amounts of the dead loads incident on it, due to the self-weight of the structural members. It is therefore important to investigate the production of lightweight concrete which may possess the same strengths as structural normal weight concrete and may be produced using alternative materials as aggregates. Conventional aggregates are naturally occurring materials and are obtained from the environment. The process of aggregate extraction is harmful to the environment and may contribute to damaging geological phenomena such as landslides and erosion. According to the Cement and Concrete Institute Australia (2008), there is a critical shortage of natural aggregates for the production of new concrete. On both weight and environmental fronts, the case for alternative lighter and sustainable material cannot be over-emphasized.

The objectives of the study, therefore, is to determine the suitability of Styrofoam as aggregates for the production of structural concrete and also the percentage of coarse aggregate required to be replaced with Styrofoam for optimal concrete strength after 28 days of curing. The scope of the work is limited to comparing the compressive strength of conventional concrete and that produced using Styrofoam as coarse aggregate. The use of alternative aggregates in the production of concrete contributes to sustainable construction, observed by Kuruppu and Chandratilake (2012). The partial or full replacement of natural aggregates mitigates the need for quarrying and consequently, the environmental impact of aggregate extraction is eliminated. Therefore, the use of waste Styrofoam as alternative aggregates for the production of lightweight concrete is a practical means of diverting materials which would have otherwise been disposed of, into useful products.

2 MATERIALS AND METHODS

Ordinary Portland cement with grade 42.5N, which is in line with the requirement of ASTM C150 (2007) was used. The fine aggregates used were natural sharp river sand obtained from river Ogun. The sand is free of silt or any deleterious materials and did not contain particles exceeding 5mm in size as shown in Figure 1a. Graduated granite with a maximum size of 20 mm was then used as a coarse aggregate, the supply was free of dust and other impurities as shown in Figure 1b. The Styrofoam used was procured from packaging for electronics such as air conditioners, laptops, and the likes. It was then carefully shredded into coarse aggregate sizes, to be used as a partial replacement for granite at various percentages as shown in Figure 1c. The water utilized for the concrete mixing have the following properties: It is free from harmful amounts of acids, soils, alkalis or other inorganic or organic impurities; It does not contain iron, vegetable matter or any other type of substances which are likely to have inauspicious effects on concrete or reinforcements; It is potable. The plasticizer used in the experimental procedure is

Conplast SP430. It complies with Type ‘F’ as a high range water reducing admixture. Sieve analysis was carried out on both the fine and coarse aggregates to determine aggregates grading in line with ASTM C136 (2007). The water used for the experimental procedure was potable and was observed to be free from organic or inorganic impurities, which might likely have harmful effects on the resulting concrete. The mix ratio adopted for the study is 1:1:2. Batching by volume was adopted for this study with 0.45 water-cement ratio. The specimens produced were classified into groups and sub-groups based on the material used for replacement, the percentage of replacement and the curing duration as follows Group 1(GRP1), which serve as control specimens in which conventional aggregates are used for concrete production, Group 2(GPR2), consists of specimens produced with 10% coarse aggregates replacement with Styrofoam by volume, Group3 (GPR3) consists of the specimens produced with 20% coarse aggregate replacement with Styrofoam by volume and Group 4(GPR4) consists of the specimens produced with 30% coarse aggregate replacement with Styrofoam by volume. The fresh concrete tests carried out on the concrete produced were a slump and compaction factor. The water-cement ratio of each mix was constant at 0.45 and a super-plasticizer was utilized in adequate proportions for each group mix. The fresh concrete was filled in 150x150x150mm cubic molds Figure 1d, while the specimens were de-molded after 24hrs and cured in water for 28 days in line with ASTM C31 (2015). The compressive strength of specimen was tested on the bearing surface of the Universal Testing Machine (UTM) in line with ASTM C39 (2003), which has a loading capacity of 100 tones without eccentricity and a uniform rate of loading of 550 kg/cm^2 per minute, which is applied until failure of the cube.

(a) Fine aggregate used.

(b) Coarse aggregate used.

(c) Styrofoam used as a replacement for granite.

(d) The casting of the specimen.

Figure 1. Fine (a) and Coarse (b) aggregates, Styrofoam (c) and Cast Concrete Specimen (d) Samples

3 RESULTS AND DISCUSSION

3.1 Sieve Analysis

Figures 2 and 3 show the sieve analysis results of both the fine and coarse aggregates to ascertain the particle size distribution of aggregates used. From the results obtained the aggregates are well graded.

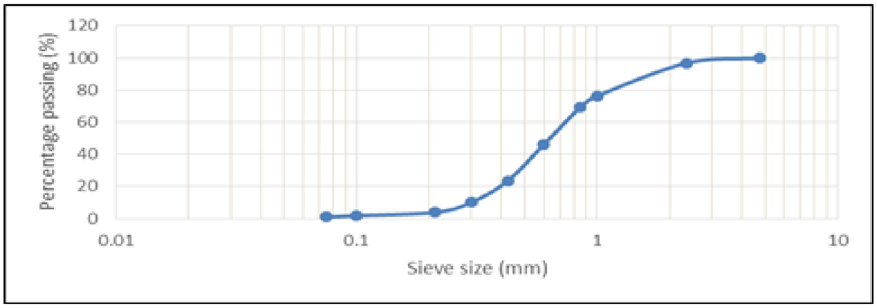

Figure 2. Particle size distribution curve for Fine aggregates.

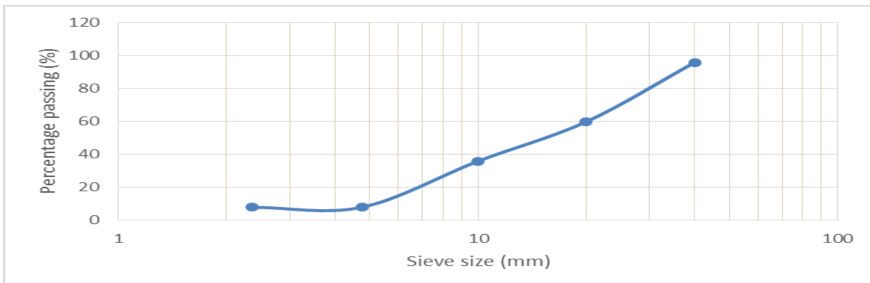

Figure 3. Particle size distribution curve for coarse aggregates.

3.2 Slump Test Result

Slump test was carried out to determine the workability of each specimen group mix as shown in Figure 4. From test results, it was observed that the highest slump value is obtained by the group 4 specimen, which consists of concrete produced with 30% coarse aggregate replacement with Styrofoam by volume. This can be attributed to the hydrophobic nature of the Styrofoam, which would reduce the absorptive properties of the specimens and allow for more water to be available within the mix thereby increasing the slump. The lowest value of slump is attained by the group 1 specimens, which are the control group 1. This is because of the roughness of the granite surface, which increases the aggregate interlocking ability of the mix.

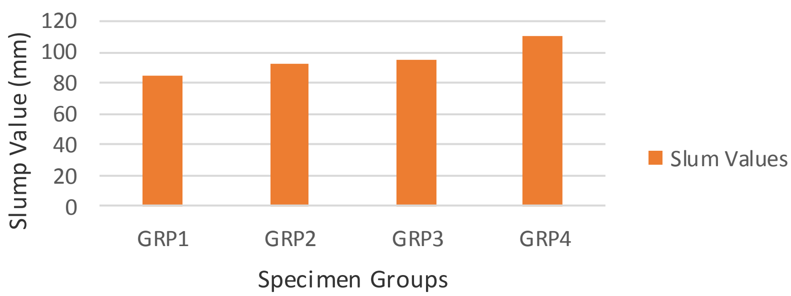

Figure 4. Slump value for each specimen.

3.3 Compressive Strength

Compressive strengths of concrete produced using Styrofoam as partial replacement of conventional aggregates were determined. The specimens produced were classified into four groups and sub-groups based on the material used for replacement, the percentage of replacement and the curing duration. Example of such grouping consists of the control specimens in which the conventional aggregates are used for concrete production. This group is further classified into the following sub-groups: GRP1-7, GRP1-14, and GRP1-28 where the numbers after the hyphen are the duration for which the specimens within each group were cured. The other groups include five for specimens produced with 10% coarse aggregate replacement with Styrofoam by volume; six for specimens produced with 20% coarse aggregate replacement with Styrofoam by volume and seven for specimens produced with 30% coarse aggregate replacement with Styrofoam by volume. It is also important to note that the following conditions were varied in the production of the specimens: curing period, the volume of granite and volume of Styrofoam. On the other hand, the following conditions were kept constant during the experimental procedure: volume of cement, the volume of sand, the volume of water, water-cement ratio, grade of cement and mix ratio.

From Figure 5, it can be observed that the highest values of compressive strengths are obtained by the group 1 specimens. The graphs show a consistent decrease in the compressive strengths of the specimen with an increase in the percentage replacement of the granite. The largest values of compressive strength Styrofoam values were obtained after 28 days of curing. It can be observed from Figure 5, that the values of compressive strength of the Styrofoam specimen are substantially smaller than those of the control specimen with the lowest value occurring at 30% replacement of coarse aggregate. This reduction can be attributed to segregation, which occurs during mixing of the Styrofoam specimens due to its hydrophobic nature. This would lead to a reduction in the bond experienced within the concrete matrix between the constituents and consequently lead to a reduction in strength.

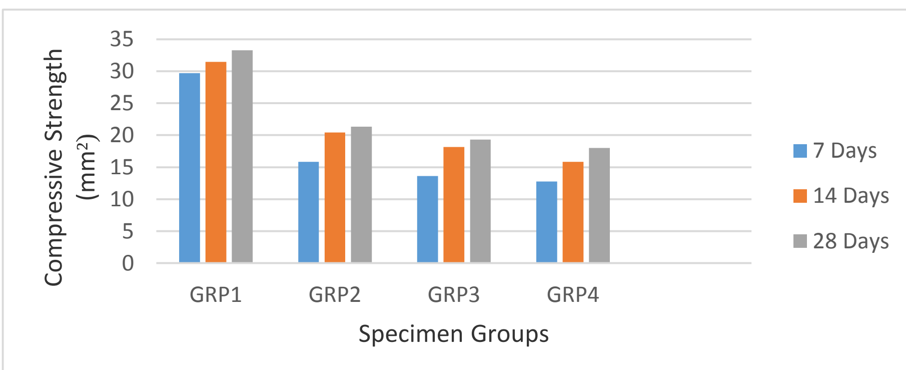

Figure 5. Bar chart showing strength development of Styrofoam specimens for control, 10, 20 and 30% coarse aggregate replacement for varying curing period.

4 CONCLUSION

The results of the experimentation provided significant information for the application of lightweight concrete in construction. The comparison between the compressive strengths of concrete produced using conventional aggregates and those produced using Styrofoam as a partial coarse aggregate replacement showed that the control specimens of conventional concrete were found to have the highest values of compressive strengths for the curing period of 7, 14 and 28 days. The optimal replacement percentage for Styrofoam as a replacement for natural granite in concrete was obtained to be 10% as this gave the highest compressive strength value of 21.33

Mpa after 28 days of curing. The values obtained at 20 and 30% were found to be considerably low and therefore not recommended to be used for structural purposes. To further improve the possibility of field application, the bond between the resulting concrete and conventional steel reinforcement need to be investigated also.

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