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Review of the Properties of Lightweight Aggregate Concrete Produced from Recycled Plastic Waste and Periwinkle Shells

Anthony N. Ede[1,a*], Praise O. Gideon[1,b], Akpabot I. Akpabot[1,c], Solomon O. Oyebisi[1,d], Oluwarotimi M. Olofinnade[1,e] and David O. Nduka[2,f]

[1]Department of Civil Engineering, Covenant University, Ota, Ogun state, Nigeria

[2]Department of Building Technology, Covenant University, Ota, Ogun state, Nigeria

[a]anthony.ede@covenantuniversity.edu.ng, [b]praise.gideon@stu.edu.ng, [c]akpabot.akpabot@covenantuniversity.edu.ng, [d]solomon.oyebisi@covenantuniversity.edu.ng, [e]rotimi.olofinnade@covenantuniversity.edu.ng [f]david.nduka@covenantuniversity.edu.ng

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Abstract. As the world population continues to increase, so does the demand for raw materials to produce basic needs of human race. One of the areas where this pressing demand for means of production is evident is in the production of concrete materials for building construction and infrastructure. The source of constitutive materials for concrete production, such as cement and aggregates are fast shrinking across the nations of the earth and there is an urgent need for substitutes that will guarantee the availability of this essential material to the built environment sector of the economy. One of the trending approach is the adoption of waste materials as replacement for some of the constitutive materials of concrete. This research reviews past works on the use of recycled plastic waste and periwinkle shells for the production of lightweight aggregate concrete. The results of this review showed that the adoption of reduced percentage of waste plastic in concrete leads to acceptable strengths for lightweight concrete, economy, efficient energy and good crack resistance. The use of periwinkle shell is beneficial for satisfactory strengths for normal aggregate concrete and for lightweight aggregate concrete, good resistance to heat and economy. This approach is sustainable as a means of recycling and will facilitate the actualization of the sustainable development goal "Responsible Production and Consumption", (SDGs 12). There is a prospective that combining these two waste materials will lead to improvement towards achieving sustainable concrete.

Introduction

Generally, the world generates millions of tons of solid waste annually of which a significant percentage consist of non-biodegradable materials. The idea of the use of waste plastic has evolved due to the rate of its improper disposal and its availability as it is one of the most used materials for packaging consumable goods which are often disposed carelessly after use. The rate at which waste plastic is recycled is less than the rate at which they are produced. Annually, Nigeria alone generates over 32 million tons of solid waste out of which only about 20% to 30% is collected [1]. Plastic is a non-biodegradable material; hence it requires a lot of time to decompose. Recycling of these waste plastic for use as replacement of aggregates in concrete seems to be an innovative idea as it is a method of disposing the material properly and at the same time utilizing it. The recycling of waste plastic in concrete production reduces the cost of the constituent material substituted, such as cement, sand or aggregate. Periwinkle shell is also another waste material considered as it is usually found close to river shores and other places where they are discarded after the extraction of the edible part. Periwinkle shells become wastes after the edible portion have been removed and the shells are usually dumped in the soil. Periwinkle is a non-degradable waste material which constitutes a nuisance to the environment if it is not appropriately handled.

The need to substitute constituent components of concrete has been on the increase in the recent times due to the pressing needs for the conservation of depreciating natural materials and sustainability across the nations of the world [2,3,4]. Aggregates constitutes a large percentage of materials used in concrete production. The environmental implication of this is that the processes of sourcing these materials have effect on the ecosystem ranging from global warming, air and noise pollution due to blasting, drilling and other methods used to obtain these materials. Aggregates can be classified based on sizes as fine or coarse. They could be further subdivided into light weight and heavy weight when considerations shift to the specific densities. For the purpose of this review work, only light-weight aggregates will be considered.

Brief Overview of Concrete Constituent Materials

Concrete is a composite material, comprised of water, aggregate (typically a rocky or sandy material) and a binder (typically Portland cement or asphalt), which holds the mix together. Many types of concrete are available, determined by the formulations of binders and the types of aggregate used to suit the desired application. These variables determine strength, density, as well as chemical and thermal resistance of the finished product. Concrete is one of the major materials in construction [5,6]. It is a combination of fines which are cement (11%), fine aggregates (26%), and coarse aggregates (41%), water (16%) and air (6%) in their specified proportions [7]. The coarse aggregate comprise a larger percentage of aggregates used. Over the years, there has been a great change in the cost of construction which has been as a result of rise in price of aggregates. This has necessitated a surge in the search for substitute materials for replacement.

Fine aggregates are those that pass through 4.7mm BS sieve which could be quarry dust or river sand free from clay. Sand is the product of natural or artificial disintegration of rocks and mineral. Coarse aggregates are either gravel or crushed stone. They make up 40%-45% of the concrete mixture, and they represent sizes greater than 6.5mm [7]. The qualities of parent rocks and the kind of smasher utilized in crushing the parent rock decides the shape of coarse aggregate which could be either angular, rounded, flaky, elongated or sporadic. Generally, aggregates are cheaper than cement and concrete with high percentage of aggregates are always economical [8]. Over the years, there has been a great change in the cost of construction which has been as a result of rise in price of aggregates so the search for substitutes materials to replace the usual as increased as well.

The most desirable property of concrete is the compressive strength and the compressive strength of concrete is greatly influenced by the type of aggregate adopted [8]. For that, concrete is classified mainly on the basis of the type of aggregate used. Heavy concrete is made up of heavy weight aggregates like barite, limonite, magnetite, hematite, iron, etc.; normal concrete has normal aggregates such as sand, gravel, crushed stone and light weight concrete is made of light weight aggregates such as shale, clay, slag, slate, foams and a lots of combination of waste materials that are beginning to find applications in concrete technology[9]. One of the advantages of using periwinkle and waste plastic as aggregates in concrete is that both are less dense, i.e., they weigh less so reduce the self-weight of the concrete.

Lightweight aggregates are those which are less dense that the conventional aggregates used in concrete production. The benefits of using light-weight aggregates over the dense aggregates ranges from the reduction in self-weight of the concrete as well as reduction in cost which is an important factor to take into consideration during construction. According to [10], the use of light weight aggregates is seen from a view of conserving energy as well as cost.

Various studies have shown that the partial addition of plastic aggregates can significantly improve some properties of concrete because plastic has high toughness, good abrasion, low thermal conductivity and high heat capacity [11]. Plastic Aggregate is also significantly lighter in weight than natural aggregate and this results in lower densities of the produced concrete and therefore leads to the production of lightweight concrete [11]. The use of waste plastic in concrete can reduce the self-weight of concrete and therefore beneficial in the design of earthquake-resistant buildings [11]. It is one of the intelligent material combinations to enhance efficiency and sustainability [12,13].

Periwinkle shells also known as sea shells are mostly found around riverine or marine areas. They are often obtained after the edible part has been eaten. They are known for the offensive odour which causes air pollution in the environment. From previous studies, they have been used for various purposes because of the hard nature of their shell. Also, they are almost readily available in the Nigerian, especially around the coastal region in the southern part of the country [14]. Recently, studies have focused more on how this non degradable shells can be utilized suitably in the construction industry, especially in concrete production.

Review of Past Works on Concrete Produced from Periwinkle Shells and/or Recycled Plastic Waste (PET)

Ghadzali et al., [5] carried out a review on properties of concrete containing different type of waste materials as aggregate replacement exposed to elevated temperature and concluded that the materials used to replace aggregate will determine how the concrete strength will be affected during fire. From their review, they concluded that during very high/elevated temperature, the concrete strength tends to reduce drastically. Elzafraney et al., [15] presented theoretical investigation on recycled plastic aggregate in concrete to work out its performance with respect to thermal attributes and efficient energy performance in comparison with normal aggregate concrete. The aggregates used in concrete are prepared from recycled plastics to meet various requirements such as strength, workability and finish ability. It was observed that recycled plastic concrete having good insulation used 8% less energy in comparison of normal concrete. They concluded that the use of recycle plastic aggregate leads to a light weight, more economical and efficient energy performance concrete. Pramod et al., [16] investigated the use of plastic recycled aggregate as replacement of coarse aggregate in concrete experimentally. Different plastic percentages of 0%, 10%, 20%, 30%, 40% and 50% were used as replacement of coarse aggregate in concrete mixes. A decrease in density was observed above 20% replacement of the recycled plastic aggregate. Also the strength obtained at up to 20% replacement of the aggregate was within permissible limit. From the results obtained, replacement of aggregates within the range of 20% and below will be suitable in production of lightweight concrete. Saikia and Brito [11] carried out a study on waste polyethylene terephthalate as an aggregate in concrete and concluded that there is a reduction in the compressive strength of concrete as the replacement of the PET-aggregate increases and the splitting tensile and flexural strength of concrete containing any type of PET-aggregate are proportional to its loss of compressive strength. Jaivignesh and Sofi [10] carried a study on the mechanical properties of concrete using plastic waste as an aggregate and found out that the reduction of the compressive strength is as a result of the decrease in adhesive strength between the waste plastic and the cement paste. Logachandran and Kalaivani [17] carried out a review on the feasibility study of plastic wastes in concrete and concluded that recycled plastic waste can be successfully used as partial replacement of fine aggregate in concrete as it increased the compressive strength, split tensile strength and flexural strength and has excellent crack resistance property. This showed that the use of recycled plastics in concrete is an eco-friendly way of disposing the plastic waste. Adewuyi and Adegoke, [18] studied the use of periwinkle shells as coarse aggregate in concrete works. The coarse aggregate was replaced with periwinkle shell as coarse aggregate and replace in proportion of 25%, 50%, 75% and 100%. Design mix of 1:2:4 and 1:3:6 were used respectively. For the mix design of 1:2:4, the optimum strength obtained was at 25% replacement after 28 curing days which gave a compressive strength of 23.4 N/mm^2 as against the 26 N/mm^2 obtained from the control concrete. For the mix design of 1:3:6, the optimum strength obtained was at 25% replacement after 28 curing days which gave a compressive strength of 18.5 N/mm^2 as against the 21.5 N/mm^2 obtained from the control concrete. It is observed from these results that there is a slight reduction in the compressive strength upon increase in the replacement of periwinkle shell. From this research, the mixes at 1:2:4 and 1:3:6 produced acceptable strengths for normal aggregate concrete and for lightweight aggregate concrete, respectively. Falade et al., [19] investigated the properties of light-weight concrete with periwinkle shell at a high/elevated temperature and observed that there was a strength loss gradually. At a temperature of about 800 degrees Celsius per hour, the specimen lost about 24% to 40% of their strength value which was dependent on their mix proportion and curing days. A reduction in weight and loss in appearance was also noticed. This shows that concrete produced with periwinkle shows very high resistance to heat. Soneye et al., [14] carried out a study on the use of periwinkle shell as fine and coarse aggregate in concrete works. They replaced both fine and coarse aggregate with periwinkle shell at 10%, 30%, 50% and 100% respectively using a design mix of 1:2:4. From the results obtained after 56 days of curing, the compressive strength at 10% replacement of periwinkle shell as fine aggregate was 23.5 N/mm^2 as against the 24 N/mm^2 of the control concrete while that of the coarse was 23.5 N/mm^2 as against the 25 N/mm^2 control concrete. This shows a slight reduction in the compressive strength. They also achieved a saving in cost of 6.8% when 30% of periwinkle shells are used with 70% of granite as coarse aggregate. Their work proved that a 10% replacement of periwinkle shell as fine and as coarse aggregates produced concrete of acceptable strength while a 30% of periwinkle shells achieved a saving in cost of 6.8%. This shows that the adoption of periwinkle shell in concrete is both economical and sustainable.

Conclusion and Recommendation

This review considered previous works on recycled waste plastic (PET and periwinkle shell as substitute aggregates in concrete production. Different percentage of replacement of these materials gave different strength results when substituted. The adoption of reduced percentage of waste plastic in concrete showed acceptable strengths for lightweight concrete, economy, efficient energy and good crack resistance property. On the other hand, the use of limited percentage of periwinkle shell in concrete showed acceptable strengths for normal aggregate concrete and for lightweight aggregate concrete, good resistance to heat and economy. These results show that the adoption of waste plastic and periwinkle shell in concrete is beneficial and sustainable as a means of recycling, thereby reducing their negative impacts in the environment. This also helps in the actualization of the sustainable development goal (SDG) number 12: "Responsible Production and Consumption". Combining these two waste materials will yet provide more improvement towards producing sustainable concrete. It is recommended that further research could be carried out to optimize the use of both materials in the construction industry.

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