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# PARTIAL REPLACEMENTS OF FINE AGGREGATE WITH POLYPROPYLENE FIBRES IN REINFORCED CONCRETE SLABS

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***Abstract:*** *Package water nylon (Polypropylene) waste seems uncontrollable in some parts of the world, where they cause harm to the environment and living organisms. Disposal of this waste has been a major problem especially in most third world countries. This paper researched into the effective use of recycled polypropylene as partial replacement of fine aggregate in concrete. Tests such as specific gravity and sieve analysis were carried out on the recycled polypropylene waste. Concrete slabs (600mm x 400mm x 50mm) and cubes (150mm x 150mm x 150mm) were made from the mixture of the recycled material at different percentages of 0%, 4%, 8%, 12% and 16%. The slabs were subjected to flexural test while the cubes were subjected to compressive strength test. Results revealed that 56.29% of polypropylene fibres were retained on the 4.75 mm sieve, the specific gravity of the material was 0.73. The compressive strength of the 4% mixture was 16.28 N/mm$^2$ while the control was 19.07 N/mm$^2$. The flexural test showed the crack width for the control as 1.79 mm, while that of 4% mixture was 2.73 mm, the 12% mixture gave the largest crack width of 6.08 mm. Deflection in the polypropylene mixes are generally higher than the control. The work concluded that at a maximum 4% mixture, the recycled waste can be used as partially replacement of fine aggregate in concrete.*
***Keywords:*** *Polypropylene fibres, Fine aggregate, Concrete slabs, crack width, Deflection*

## INTRODUCTION

*Environmental pollution is the outcome of improper waste management in highly populated countries such as Nigeria, India, Brazil, etc, where polypropylene materials are used in packaging. In these countries waste generation is high and management is somewhat poor. One of the ways to manage this waste is the re-use of waste materials itself. According to Dynaab (2014), Nylon (Polypropylene), invented in 1928 by Wallace Carothers (DuPont) is considered to be the first engineering thermoplastic, and it is a non-biodegradable material.*

*The production of conventional concrete is achieved by the use of natural materials which has been the practice for so many years and thereby leading to the reduction in the readily available construction materials on the earth surface.*

*Sachin et al. (2012) expressed the fact that, to meet the requirements of globalization, in the construction of buildings and other structures, concrete plays the rightful role and a large quantum of concrete is being utilized. River sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. In the backdrop of such a bleak atmosphere, there is large demand for alternative materials from industrial waste. Aitcin (2003) also emphasized this, stating that although High Performance Concrete (HPC) has found widespread application, its production is still limited in many countries because suitable concrete aggregate such as river sand, gravel or hard crushed aggregate are either not available or are available only in little quantity. Murali et al. (2012) also said the high consumption of raw materials by the construction sector, results in chronic shortage of building materials and the associated environmental damage.*

*According to Kamkam and Odum-Ewuakye (2006), most developing counties where more than 70% of the population lives in improvised villages, are often confronted with acute housing shortage due to their over-dependence on rather expensive imported materials. It is imperative therefore for researchers in such countries to fully exploit locally available materials to meet their housing needs.*

*Several researches are based on the use of recycled waste material in the production of concrete. Gautam et al. (2012) replaced fine aggregate with glass waste and concluded that the presence of 10% glass waste in place of fine aggregate, the compressive strength at 7 days is found to increase by about 47.75% on average. Seeni et al. (2012) in a research on the studies of partial replacement of fine aggregate with waste material from China clay industries also concluded that the waste material from china clay industries can be used as a replacement for fine aggregate. It is found that 30% replacement of fine aggregate by industrial waste give maximum result in strength and quality aspects than the conventional concrete. The results proved that the replacement of 30% of fine aggregate by* *the industrial waste induced higher compressive strength, higher split tensile strength and higher flexural strength.*

*Aggregates are the important constituents in the concrete composite that help in reducing shrinkage and impart economy to concrete production. Most of the aggregates used are naturally occurring aggregates, such as crush rock, gravel and sand which are usually chemically interactive or inert when bonded together with cement (Keerthinarayana and Srinivasan, 2010).*

*Several waste materials have been channelled into replacing fine aggregate in concrete, majority of which are to reduce the waste of used polymer materials and to solve the problem of material shortage.*

*The abundance of water packaging nylon (polypropylene) in third world countries which are disposed off indiscriminately after use is an eye sore; this material generates irritation to the environment by polluting it because of its non-degradable property.*

*Several approaches have been thought of and put into practice on how to manage/control this particular type of waste. In that case, after use, where does it go? Where is it supposed to go? How has it been managed? What is the outcome of the on-going methods of management? Are the questions to be asked?*

*Adetunji and Ilias (2010) while carrying out research on waste generated from polypropylene sachets gave the report that almost every nook and cranny in Nigeria is littered with sachet water nylon, popularly called "pure water", the large volume of which in ordinary parlance, constitutes pollution and termed negative externality or economic 'bad' in economics. This is as a result of millions of used sachets being thrown on daily basis onto the streets of virtually every city, town, and village in Nigeria. This is a fact as majority of the populace rely on the consumption of water packaged in this form because it is associated with ease of access and cost of purchase is somewhat affordable by the majority. The most beneficial way of managing this waste is the recycling which is still at the verge of development in some countries of the world. Poor waste management such as burning is practised in some countries and one of the most effective ways of controlling waste is the reduction of waste. Burning of waste particularly inorganic waste leads to the emission of harmful substances into the atmosphere which is highly detrimental to the life of living things. This is similar to the explanation made by Adetunji and Ilias (2010) that, in the case of sachet water, it is not only the litterbugs (or the pure water consumers) that are affected but also the non-consumers and the entire environment. This is because burning the packaging lowers the quality of the air that both the consumers and non-consumers breathe in, gives off stench, and causes harm through the release of toxic gases and smoke. It also causes environmental problems such as acidification, eutrophication, the greenhouse effect (or global warning), smog, and ozone loss.*

*Waste products of polymers are made from inorganic compounds which makes them vary in characteristics. This was also confirmed by Veera (2010), who stated that "Each waste product has its specific effect on properties of fresh and hardened concrete". Waste materials of polymer are lightweight materials; this limits their application to some extent depending on the technique of use, for this reason, structures constructed to carry loads should also not be light to the degree at which it will not serve its function.*

*Due to rapid industrialization and urbanization in most third world countries, lots of infrastructure developments are taking place. This process has in turn led to the question of how mankind will solve the problem of population growth. The problems defined are acute shortage of constructional materials, increased dumping of waste products (Suganthy et al. 2013). Hence in order to overcome the above said problems waste products should be employed as construction material.*

*Replacing fine aggregate in the concrete with waste materials such as water packaging nylon could be an alternative to the materials used as fine aggregate in concrete. Since up to approximately 80 percent of the total volume of concrete consists of aggregate, aggregate characteristics significantly affect the performance of fresh and hardened concrete and have an impact on the cost effectiveness of concrete, (Hudson 1999).*

*River sand, which is one of the constituents used in the production of conventional concrete, has its price increasing with time due to several factors such as distance and location, cost of dredging, and so on, thereby making it a scarce commodity, (Shetty 2009) also stated that, in years to come, natural sand will be exhausted or costly, hence there is the need for manufactured or artificial sand. As a result of this, there is large demand for alternative materials from industrial waste. The focus of this research is based on the addition of recycled polypropylene as fine aggregate in concrete mixes and to examine the properties and performance of reinforced concrete slab under axial loads.*

## *METHODOLOGY*

### *Sieve analysis*

*The polypropylene fibres were obtained from shredded water pack made from nylon, the sieve analysis of the shredded waste material was also carried out.*

***Figure 1:** Recycled Polypropylene fibres*

*The sieve used was that of AASHTO specified. 500g of the recycled nylon material was measured on the digital scale and poured into the sieve no 1 (top sieve). It was shaken for about 5- 7 minute, the shaken continued until there are no more particles passing through the sieves. The mass of samples retained in each sieve was measured and results were recorded. Figure 1 showed the shredded polypropylene fibres.*

***Specific gravity***

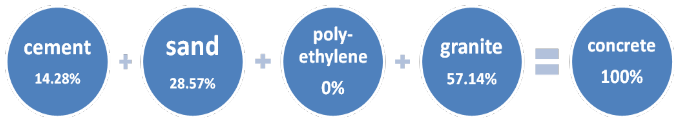
*The specific gravity of the recycled nylon following the standard of ASTM D 854-00 standard test for specific gravity of soil solids by water pycnometer was carried out. The specific gravity was calculated using the equation below.*

*Specific gravity,* $$G_s = \frac{W_0}{W_0 + (W_A - W_B)}$$

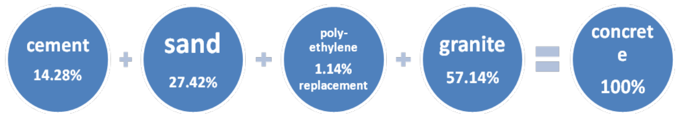
*where:* $W_0$ = *weight of sample of oven-dry soil,* $W_A$= *weight of pycometer filled with water + sample,* $W_B$= *weight of pycometer filled with water*

***Preparation of test specimen***

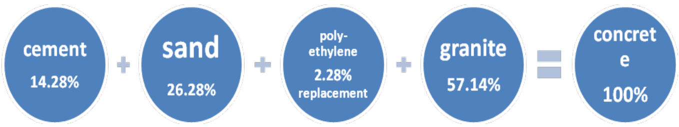
*The concrete specimens were made from the combination of different percentages of the polypropylene material. The different proportions are 0%, 4%, 8%, 12% and 16%. Each percentage of polypropylene is represented with two samples of slabs of size 600 x 400 x 50 mm. The casting of the slabs was carried out with thorough mixing of the concrete using concrete mixer. The mixed concrete was placed into the corresponding formwork and compacted; the formwork was removed after 24 hours of setting. The concrete slabs from each sample mix were cured by wetting daily and test was carried out on them after 28 days of curing.*



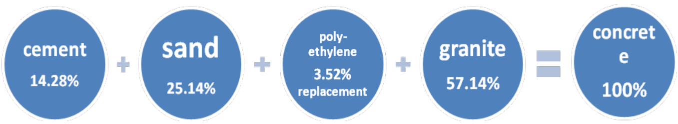

*a) 0% replacement of fine aggregate*



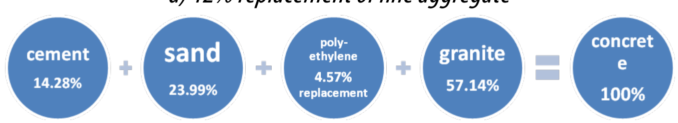

*b) 4% replacement of fine aggregate*




*c) 8% replacement of fine aggregate*




*d) 12% replacement of fine aggregate*




*e) 16% replacement of fine aggregate*

***Figure 2:*** *The detail mix ratios*

*A mix ratio of 1:2:4 was used with water cement ratio of 0.75. The water cement ratio was used due to the high absorption of water by the polypropylene mixture in concrete. The first mix was with 0% of the polypropylene material. The batching by weight process was used. The size of granite used was ½ inch (12mm) and the local fine aggregate popularly called sharp sand was used. Measurements of individual materials were carried out for each mix before pouring into the concrete mixer. The mass of the fine aggregate was measured for and the percentage of polypropylene to be used was subtracted from the mass of fine aggregate for all corresponding percentages. The detail mix ratios are shown in Figure 2.*

***Compressive strength test***

*Concrete cubes for each mix ratio were cast and subjected to compressive forces to determine the compressive strength of the concrete after 28days. This is done by applying compressive axial load to the moulded cubes at a rate which is mild and continuous until failure occurred.*

***Flexural strength test***

*Flexural strength test was carried out on the concrete slabs after 28days. This test determines the bending strength of the concrete.*

***Figure 3:*** *Slab specimen undergoing 3 points loading*

*The slabs were placed under the universal testing machine and subjected to a third point loading (Figure 3). It was subjected to continuous loading until failure occurred. Crack lengths and widths were measured and the deflection with increasing loads was determined.*

***RESULTS AND DISCUSSION***

***Sieve analysis results***

*The test was carried out on the recycled polypropylene material and the result is shown in Figure 4. From the result obtained, 56.29%, 20.28%, 16.48%, 5.83%, 0.88%, 0.23% of the recycled material was retained in 4.75 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, 150 µm* *diameter sieves, respectively. Greater percentage of the polypropylene grain was retained in the 4.75 mm sieve; this showed that the material can be used as partial replacement for fine aggregate in concrete since the standard size for fine aggregate in concrete is 4.75 mm or less.*

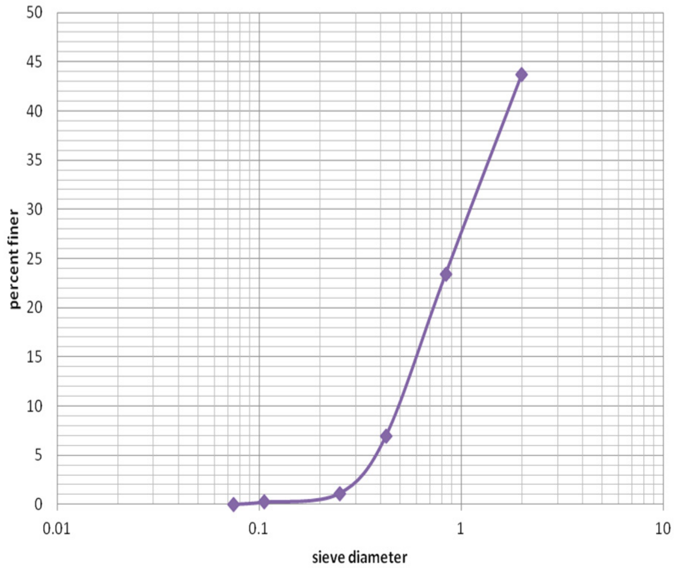



***Figure 4:*** *Grain size distribution for polypropylene materials*

### *Specific gravity*

*Result of specific gravity of the substance shows 0.73 as calculated. This indicates that the density of the material is 730kg/m³. The result of the specific gravity test shows that, the material has a low density compared to the density of the natural sand. While carrying out the test, the recycled nylon floats on water unlike the natural sand which settles under its own weight. The average specific gravity for rocks that are commonly used as fine aggregate vary from 2.6 to 2.8, the 0.73 obtained for the polypropylene fibre is low, this is because the material is a product of hydrocarbon, which naturally have low density, but using it as a partial replacement for sand in concrete is a technology that must be well researched into.*

### *Compressive strength test*

*Compressive strength being the failure load of a concrete cube or cylinder per unit area indicates the mechanical and durability properties of the concrete mix. After 28days of curing, the cubes were subjected to crushing under the Universal Testing Machine. The result revealed that control concrete cubes have a compressive strength of 19.07 N/mm² this low strength was obtained because of the high water cement ratio used in the experiment, the 4% mix gave a compressive strength of 16.28 N/mm². Although there was a general reduction in compressive strength when polypropylene fibres were added to the concrete, this is because concrete is like a chain in which aggregates are the links bonded together by cement paste, the strength of concrete is depended on the bond strength occurring within the concrete cement paste, the introduction of polypropylene fibre which is fluffy, water repellent and insoluble in the cement matrix reduces the bond strength, hence the low compressive strength obtained from all the specimen that contained the fibres. Any mix less than 4% can be used for partial replacement in concrete, especially in light weight concrete. Figure 5 showed the detail results.*

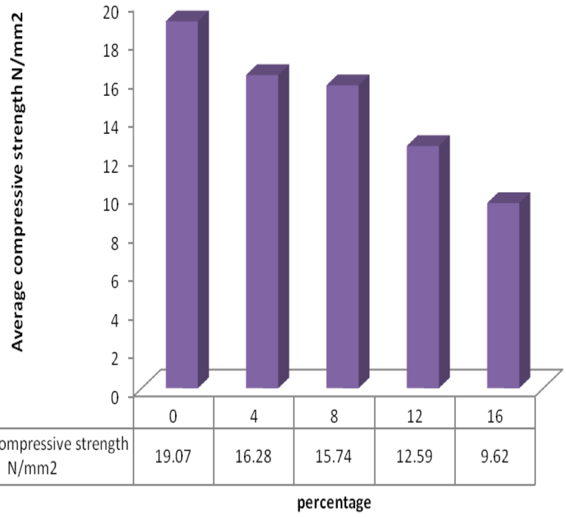



***Figure 5:*** *Compressive strength test result*

### *Flexural test*

*Reinforced concrete is very unique in it behaviour, and this has made it popular as construction material. In solid slabs; at flexural failure, concrete slabs develop hinge lines. A hinge line causes much of the reinforcement passing through it to resist the moment along it length, contributing to the safety of the slab. The largest flexural strains therefore occur at the point of load application, consequently, cracking initiates at the soffit of the region, from where the cracks then spread rapidly to the edges of the slab with increasing load to collapse ( Kankam and Odum-Ewuakye 2006).*

*In addition as reported by Kankam and Odum-Ewuakye (2006), collapse of slabs may occur either through flexural failure caused by the crushing of concrete and/or fracture of the tension bars. The modes of collapse therefore depend on the amount of reinforcement, concrete strength and the effective depth of the slab (Aalamin 2005).*

*From the test carried out on the entire specimen (slabs), gradual increase in load showed corresponding deflection in all the specimen. With the continuous application of loads, the slabs started showing cracks gradually until the specimens can no longer resist the applied load. The control mix failed at 48 kN load with a final deflection of 3.75 mm, the 4% and 8% mix failed at 40 kN and 36 kN, final deflections were 5.8 mm and 7.5 mm respectively, while the 12% and 16% replacement failed at 34kN and 22 kN load respectively. Deflection and the extent of cracking of a reinforced concrete slab are highly dependent on its support conditions, nonlinear and inelastic properties of concrete and the surrounding structure (Gilbert 2005). The initial load at which deflection was observed; failure load and final deflection are shown in Figure 6. However, increase in percentage of recycled nylon waste led to the slab showing significant deflection at reduced load and within increased time. There was no significant recovery of the slab at complete failure because the elastic limit was exceeded.*

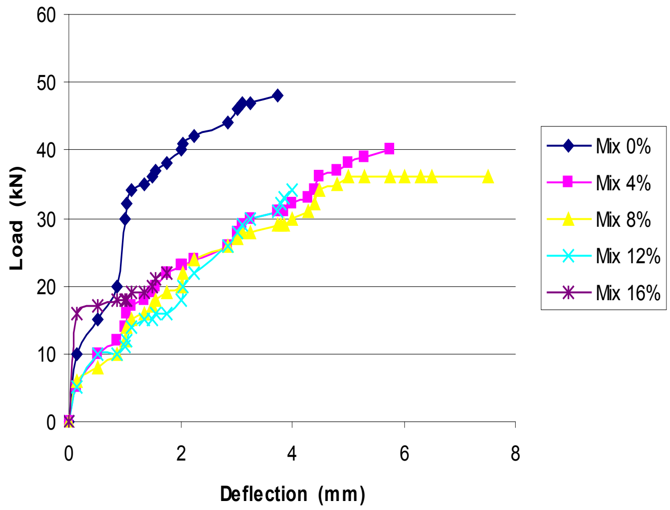



***Figure 6:*** *Deflection of samples under load*

***Cracking and failure loads***

*The crack width at the middle and the two edges were measured, and the average crack width was obtained. From Table 1, crack width was minimal and gradually increased with increase in the percentage of polypropylene fibres in the concrete, but 0% mix showed the lowest crack width of 1.79 mm, while the 12% mix gave the highest crack width of 6.08 mm. Further increments in load on the reinforced concrete slab led to disintegration between polypropylene material and other concrete materials like coarse and fine aggregates with cement. This must have been as a result of poor or loose bond between the concrete matrix, iron reinforcement and the polypropylene fibres. Ductile properties such as cracks and deformation before failure is an important stage regarding the load bearing capacity of reinforced concrete members, the unique ductile behaviour observed in the slab specimens especially the partially replaced samples was evidence by the large crack width observed.*

***Table 1.*** *Cracks at failure loads*

| Replacement Ratio % | Crack Length (cm) | Crack width (mm) Right Edge | Mid-way | Left Edge | Average Crack Width (mm) |
|---|---|---|---|---|---|
| 0. | 45.25 | 1.725 | 2.06 | 1.575 | 1.79 |
| 4. | 43.25 | 2.52 | 2.805 | 1.995 | 2.73 |
| 8. | 30.85 | 6.255 | 5.515 | 4.60 | 5.45 |
| 12. | 45.50 | 6.39 | 5.28 | 6.575 | 6.08 |
| 16. | 42.00 | 6.13 | 5.63 | 5.575 | 5.775 |

***CONCLUSIONS***

*Laboratory test were performed on all slabs and cubes that were made from the replacement of fine aggregate in varying percentage in concrete. The result showed that there is a good possibility of utilizing partially replaced aggregate in concrete for Civil engineering construction with careful consideration given to the percentage of recycled waste. The water demand for proper mix of the concrete increases as the percentage of the recycled waste increases. The weight of the cubes and slabs decreases gradually with increase in recycled waste in the mix. The difference between concrete slab and cube at 0% replacement and slabs and cubes with 4% replacement is not more. The gradual increase in parentage of recycled waste in concrete, led to drastic reduction in strength. The positive response of the concrete with 4% replacement of fine aggregate should encourage the use of such concrete in construction to aid waste management around the world. Waste commonly generated apart from polypropylene waste should be examined for their usefulness in civil engineering materials and deep study should be carried out on polypropylene use in concrete mix with more tests carried out such as response to heat, seismic activities and so on.*

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