EFFECT OF CRUSHED COCONUT SHELL AND POLYETHYLENE TEREPHTHALATE AS PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE

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ZARIA, NIGERIA

APRIL, 2018

DECLARATION

I declare that the work in this dissertation entitled. **'Effect of Crushed Coconut Shell and Polyethylene Terephthalate as Partial Replacement of Coarse Aggregate in Concrete'**. has been carried out by me in the Department of Civil Engineering. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Okwe Ogah ADIKPE

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Name of Student Signature Date

CERTIFICATION

This Dissertation entitled **EFFECT OF CRUSHED COCONUT SHELL AND POLYETHYLENE TEREPHTHALATE AS PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE** by Okwe, Ogah ADIKPE meets the regulations governing the award of the degree of Masters in Civil Engineering of the Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to God Almighty, in you I live, move and have my being.

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ABSTRACT

This study investigates the suitability of crushed coconut shell (CCS) and polyethylene terephthalate (PET) as partial replacement of coarse aggregate in concrete. The PET was crushed mechanically to sizes between 0-10mm while the CCS was crushed manually to sizes between 12.7-19.5mm. Various tests were carried out to ascertain the physical and engineering properties of the aggregates used in this study. Sieve analysis was carried out on all the various aggregates used in this study and it was observed that when combined it gives us an all in aggregate distribution which is ideal for concrete construction. Flakiness and elongation tests were also carried out and it was observed that CCS and PET have a flakiness index of 100% as compared to gravel with a flakiness index of 19.54%. PET had the highest elongation index of 67.35%, gravel with 29.48% and CCS in between with 28.24%. Specific gravity of all the aggregates used in this study was found out with PET, river sand, gravel and CCS having specific gravities of 1.32, 2.64, 2.70 and 1.38 respectively. Aggregate impact and crushing value tests were carried out on the aggregates with PET, gravel and CCS having AIV values of 0.3125%, 26.57% and 3.62% and ACV values of 2.29% and 28% for CCS and gravel respectively. This study was narrowed to 50% replacement of conventional coarse aggregate with varying percentages of CCS and PET from 0%, 10%, 20%, 30%, 40%, to 50%. Which led to 9 different mixes labelled A to I respectively. Slump test was carried out on the fresh concrete to ascertain its workability while compressive strength and water absorption tests were carried out on the various samples with different percentage replacement of CCS and PET. From the study it was observed that a mix percentage of 50% gravel, 20% CCS and 30% PET (sample F) and 50% gravel, 20% CCS and 30% PET (sample G) of gave us a compressive strength value of 18.4 N/mm^2. Also it was observed that with increase in CCS content there was increase in compressive strength for up to 30% CCS and with decrease of percentage of PET from 50% to 20% there was increase in the compressive strength up to 18.4N/mm^2. Also, Sample F has a lower water absorption capacity of 3.99 than G which has a water absorption capacity of 4.48 but both fall within the range specified for average absorption. It was can be concluded that samples F and G are viable and sustainable construction alternatives to conventional concrete and can be used in road drainage, gutter, slabs, kerbs, canal linings, blinding, low traffic road pavements, stone pitching, embankment, base for flexible pavements and minor concrete works in general.

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ABBREVIATIONS

CCS Crushed Coconut Shell

PET Polyethylene Terephthalate **EFFECT OF CRUSHED COCONUT SHELL AND POLYETHYLENE TEREPHTHALATE AS PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE**

CHAPTER ONE

INTRODUCTION

1.0 Preamble

Concrete is the prime Civil Engineering construction material. Conventional concrete consists of cement (11%), fine aggregates (26%), coarse aggregates (41%), water (16%) and air (6%) (Al-Kourd and Hammad, 2013). Two billion tons of aggregate are produced each year in the United States and production is expected to increase by more than 2.5 billion tons per year by the year 2020. Similarly the consumption of the primary aggregate was 110 million tonnes in the United Kingdom in the year 1960 and reached nearly 275 million tonnes by 2006 (Reddy, Aruna and Fawaz, 2014). According to Kambli and Mathapati (2014) far more concrete is produced than any other man-made material. According to Muhammad and Muhammad (2015), the estimated usage of concrete worldwide is about 11 billion metric tons every year. Alternative sources of materials are needed for sustainable development.

In view of this, so many waste materials have been used in concrete with different levels of success. These materials are called green materials due to their low energy costs. The resulting concrete is termed green concrete. Such materials include but not limited to: coal ash, rice –husk ash, wood ash, natural pozzolans, silica fume are used to reduce the use of Portland cement in concrete. Also, foundry sand, core butts cupola slag, post-consumer glass, glass reinforced plastic, construction and demolition waste, have been used as replacement for fine and coarse aggregates in concrete (Naik and Moroconi, 2005).

Two of such materials that can be considered and studied for use in concrete are plastic and coconut shell. According to Europe Plastics (2015), Plastics are non-biodegradable, synthetic polymers derived primarily from petro-fossil feedstock and made-up of long chain hydrocarbons with additives and can be moulded into finished products. The world's annual consumption rate of plastic material has increased from 204 million tons in 2002 to 299 million tons in 2013. Moreover, production and consumption of polymers and plastics will be constantly growing in next year. According to Manish, Vikas, and Agarwal, (2014) in the last 60 years, plastic has become a useful and versatile material with a wide range of applications. Its uses are likely to increase with on-going developments in the plastic industry. In future, plastic could help to address some of the world's most pressing problems, such as climate change and food shortages.

Polyethylene has been used by various researchers as replacement for fine and coarse aggregate in concrete with encouraging results. Tapkire, Patil and Kumavat, (2014) used recycled plastic aggregate in concrete and noticed a 15% reduction in the weight of the cube was noticed when plastic waste was used. They strongly recommended the use of recycled plastic aggregate in concrete as a viable option for waste disposal. This research and many others show the potential of recycled plastic and polyethylene as conventional aggregate replacement in concrete.

About 54 billion nuts of coconut are produced per annum (Reddy *et al*., 2014). Indonesia was the highest producer of coconut followed by Philippines and India with an annual production value of 19.5 million metric tonnes, 15.3 million metric tonnes and 10.9 million metric tonnes respectively (FAO, 2010). In Africa, Tanzania is the highest producer of coconut and maintains the 11th position in the world, followed by Ghana and Mozambique producing 0.57 million metric tonnes, 0.32 million metric tonnes, and 0.27 million metric tonnes respectively. According to Uwubanmwen, Okere, Dada and Eseigbe, 2011), Nigeria is the 5th major producer of coconut in Africa. It produced a total of 1.09 million metric tonnes of coconut between 2004 and 2008. Osei (2013) did an experimental assessment on coconut shells as aggregate in concrete. The results of his study showed that concrete produced by replacing 18.5% of the crushed granite by coconut shells can be used in reinforced concrete construction. He concluded that the use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost measure.

This study aims to use polyethylene terephthalate (PET) and crushed coconut shell (CCS) as partial replacement of coarse aggregate in concrete which could increase the number of viable alternatives to conventional concrete.

1.1 Statement of Problem

According to Ayuba, Latifah, Abdullah and Suleiman, (2013) one of the major issues in municipal waste management in the FCT Abuja is the high volume of non-degradable fractions; polyethylene even after 13 years of burial the polyethylene waste are same as the day initially buried. The cost of recycling polyethylene is higher than the cost of producing new polyethylene which makes it non profitable to consider recycling. The manufactures have a high preference for polyethylene as such use it mostly for the packaging of their products, which are in high demand such as drinks, water and other food product. The use of glass bottles which are usually recycled and reused by the manufacturing companies is being phased out. As such currently this has been a source of great concern because of the high volume of polyethylene ending up in the landfill.

The use of polyethylene terephthalate and crushed coconut shell as coarse aggregate in concrete may provide an alternative to conventional concrete. With the increasing use of plastic in our society, and the effects it is having in our environment, alternative methods of disposal is desperately needed in order to reduce the effect of pollution thus having a clean environment. Coconut shell on the other hand is mostly regarded as waste or fuel for fire which is an underutilization of its potential. Its usefulness in the construction industry has been researched and can be further explored. However, concrete produced using polyethylene terephthalate and crushed coconut shell must have the necessary engineering performance characteristics to meet the standard code of practice specifications.

1.2 Justification

According to Muhammad and Muhammad, (2014), recycling has many benefits which include but not limited to conservation and protection of valuable resources and protection of the environment, promotion of a clean and healthy environment, elimination of non-bio-degradable waste, reduction and elimination of landfill spaces, growth of local industries, curtailing of hazardous waste concerns. With increasing exploitation of natural aggregates in developing countries and rising cost of building materials and construction, it is necessary to look for alternative sources of aggregates. Also the method of extraction of these aggregates is a cause for environmental concern. Hence the need for substitute materials which will aid in the reduction of landfill costs, saving in energy, and protecting the environment from possible pollution effect, reduction in cost of production of concrete. This study will make use of polyethylene terephthalate and coconut shell as partial replacement of aggregate in concrete as a viable alternative to produce economic, environmentally friendly concrete.

1.3 Aim and Objectives

The aim of this research is to study the properties of concrete in which the coarse aggregates is partially replaced with waste of polyethylene terephthalate and crushed coconut shell. This overall aim will be achieved by the following specific objectives:

1. To determine the workability of fresh concrete of the various mix proportions of coarse aggregate in concrete and compare it with control mix.

2. To carry out density, compressive strength test and water absorption tests on the various concrete cubes.

3. To check the suitability of concrete containing PET and CCS for general construction purposes by comparing it to the standard code of practice and specifications.

1.4 Scope and Limitations

This research is limited to studying the density, compressive strength and water absorption properties of concrete with polyethylene terephthalate and crushed coconut shell as coarse aggregate.

CHAPTER TWO

LITERATURE REVIEW

2.1 Plastics

According to Nella (2014), the Nigerian plastics and packaging sector with over 3,000 companies and a production capacity of over 100,000 tons per year had a growth rate of 23.8% in 2013. Also, most ECOWAS countries depend on Nigeria for their plastic needs, given the country's competitive advantage in the area of sourcing raw materials. Polyethylene demand in Nigeria currently stands at 80million metric tons representing 30million metric tons increase over a 5 year period.

Muhammad *et al.* (2014) stated that 'the recycling process involves processing used materials into new products to prevent the waste of potentially useful materials, reduce air pollution due to incineration and water pollution due to land filling by reducing the need of conventional waste disposal, reduce consumption of fresh materials, reduce usage of energy, and lowering emissions of greenhouse gases. Recycling is a key component to modern waste management and it is also the third component of the "Reduce, Reuse, Recycle" waste hierarchy'.

Scott, (2004) described waste minimization as a process that involves reducing the amount of waste produced in society and helps eliminate the generation of harmful and persistent wastes, supporting the efforts to promote a more sustainable society. Waste minimization involves redesigning products and/or changing societal patterns, concerning consumption and production, of waste generation, to prevent the creation of waste while to reuse is to use an item again after it has been used. That includes conventional reuse where the item is used again for the same function and new-life reuse where it is used for a different function. By taking useful products and exchanging those, without reprocessing, reuse help save time, money, energy, and resources. In broader economic terms, reuse offers quality products to people and organisations with limited means, while generating jobs and business activities that contribute to the economy. Recycling is a process to change (waste) materials into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from Land filling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to plastic production.

2.1.1 Polyethylene Terephthalate (PET)

Casanova-del-Angel and Vázquez-Ruiz. (2012) wrote a research article on manufacturing light concrete with PET aggregate. The authors concluded that, recycling PET to manufacture coarse aggregates and substitute natural aggregates should begin to spread as soon as possible, as stony materials are fast depleting, and access to quarries is becoming more and more complicated. PET aggregate produces good quality mixtures with lower volumetric weight and mechanical behaviour similar to that of natural concrete with adequate granulometry. The water/cement ratio is lower for light concretes than for natural concretes. Light concretes may be used for various applications such as light slabs for homes within hot areas. Deformations of light concrete are lower than natural concrete and from the point of statistical analysis; it has been found that there is a higher consistency for light concrete mixtures than for natural concrete mixtures.

Kim, Yi, Kim, Kim and Song (2010) observed that plastics have low bonding properties which results in reduction in compressive, tensile and flexural strength. So to improve the bonding strength the PET fibres can be modified into one of the several patterns like crimped, twist or cramped patterns.

Brajesh (2016) carried out a study on the use of recycled polyethylene terephthalate (PET) as construction material. The author concluded that based on researches, experimental works and scientific reports, plastic wastes and especially recycled PET may be applied for modifications of bituminous concrete mix of flexible pavement and also in building concretes. Research studies proved that the properties of flexible pavements were improved, resulting in better performance and stability of road pavement by use of PET in bituminous concrete. The addition of polymer fibres in concrete, works as a reinforcement which in turn improves the performance and strength of concrete. This solves the problem of safe disposal of waste plastic materials can be easily solved by utilizing them as a construction material in an eco-friendly way.

Nibudey, Nagarnaik, Parbat and Pande, (2013) carried out a research on the strength and fracture properties of post consumed waste plastic fibre reinforced concrete in order to optimize the size of fibre appropriate for use in concrete. It was discovered that the use of post-consumer plastic aggregates in concrete improve its ductility. Different percentages of plastic fibre were added to conventional concrete from 0.5% to 3.0% by weight of cement. The maximum percentage increase in compressive strength, split tensile strength and flexure strength occurred at 1% of fibre content with values of 5.26%, 15.47% and 17.32% for aspect ratio of 35 and 7.35%, 24.91% and 24.105% for aspect ratio of 50 respectively in comparison to the control concrete.

Muhammad and Muhammad (2015) checked the suitability of recycled plastic as partial replacement of coarse aggregate in concrete. Coarse aggregate from plastic was obtained by heating the plastic pieces at required temperature and crushed to required size of aggregate after cooling. Their experimental results shown that plastic aggregate have low aggregate crushing value (2.0 as compare to 28 for natural aggregate), low specific gravity(0.9 as compare to 2.74 for natural aggregate), and low density value(0.81 as compare to 3.14 for natural aggregate), as compare to natural coarse aggregate. Based on 20% substitution of natural coarse aggregate with plastic aggregate, there was increase in workability and increase of 28% in compressive strength but decrease in split tensile strength and modulus of elasticity.

Patil, Mali, Tapkire and Kumavat, (2014) carried out an experiment considering innovative techniques of waste plastic used in concrete mixtures. A total of forty-eight specimens and six beams and cylinders each for M20 grade of concrete with different volume percentages of plastic (0%, 10%, 20%, 30%, 40%, 50%) were cast. Their main objective was to determine specific gravity, water absorption, and abrasion value, crushing strength, impact test of two replacement levels by volume of aggregates. Their results showed that the modified concrete mix, with addition of plastic aggregate replacing conventional aggregate with up to 20% gives strength within the permissible limit. Also their results showed that modified concrete cast using plastic aggregate as partial replacement of coarse aggregate shows 10% replacement was satisfactory to Indian standard (IS) codes. And the density of concrete reduced after 20% replacement of coarse aggregate in the concrete.

Kathe, Gangurde, and Pawar (2015) carried out a study on the properties of green concrete using plastic waste. They used plastic waste as replacement for fine aggregates. They concluded that natural sand can be replaced with plastic waste by 10 to 20% to achieve green concrete. Sand can also be replaced up to 30% in the members of building which do not carry high load. Also they showed the advantages of the use of plastic wastes such as polyvinyl chloride (PVC), polypropylene (PP), polyethylene in concrete because it reduces the environmental issues and minimizes the difficulties of dumping the major plastic waste, which they said would help to tackle the increasing pollution. Finally they concluded that the use of plastic waste is cost effective.

Raghatate (2012) carried out a research on the use of plastic bags in concrete to improve its properties. Concrete with varying percentages of plastic were tested for compressive strength. It was observed that with addition of 1% of plastic there was 20% reduction after curing for 28 days, there was an increase of up to 0.8% in the split tensile strength which shows the possibility of increment of tensile strength of concrete.

Muhammad and Muhammad (2015) based on comprehensive review of several papers, made the conclusion that plastic waste can be successfully used in concrete. Reduction in density and compressive strength was reported by all the research papers reviewed.

Sahil and Sahil (2015) used crushed plastic polyethylene terephthalate (PET) bottles as replacement for natural sand in concrete. It was observed that at 2% replacement of sand with crushed PET, there was a 12% increase in the compressive strength of the concrete, as compared to the conventional concrete. Also after 2% replacement, the compressive strength begins to decrease and reaches a minimum at 6%. They concluded that concrete with waste PET fibre can be used as an effective plastic waste management practice in the future.

Elzafraney, Soroushian and Deru, (2005) worked on development of energy-efficient concrete buildings using recycled plastic aggregates. High-density polyethylene, polyvinyl chloride and polypropylene were used as coarse aggregate in concrete mixtures to alter and improve the thermal properties of buildings. Two similar retail buildings were designed and constructed one with normal concrete and the other with high content of recycled mixed plastics. Recycled plastic concrete in combination with energy efficient building design techniques proved to be of tremendous value in lowering the cooling and heating loads of the buildings and also in enhancing the comfort level of the buildings.

Baldenebro-Lopez *et al*, *(*2014) researched on the influence of continuous plastic fibres reinforcement arrangement in concrete strengthened. They found a better performance of the continuous PET fibre reinforcement than that of the short, discontinuous one; the continuous PET samples presented a great increase in the concrete properties in 150% of the maximum load in bending.

Irwan, Faisal, Othman, Wan-Ibrahim, Asyraf, Annas and Parvesh, (2014), worked on a comparative study of compressive and tensile strength of recycled ring waste pet bottle (RPET) fibre. They found ultimate tensile strength of RPET concretes were greater as compared to normal concrete.

Fernando, Montedo, Gleize and Roman, (2012) experimented on use of PET fibre in concrete and had concluded that, at 28 days, the concrete flexural toughness and impact resistance increased with the presence of PET fibres, except for the 0.05 % volume sample. Also, no significant effect of the fibre addition on the compressive strength and modulus of elasticity were observed. Their research also showed that an increase in porosity has occurred at 365 days for the fibre reinforced concrete, as determined by MIP (mercury intrusion porositimetry).

Bakri, Ruzaidi, Norazian, and Mohammad, (2007) worked on the effects of HDPE plastic waste aggregate on the properties of concrete. They carried out tests on compressive strength, flexural strength, water absorption, analysis DSC and slump and concluded that the PC is suitable for non-structural usage. As for cost analysis, the results showed that the Polymer Concrete was more cost effective than conventional concrete."

Bhogayata, Shah, Vyas and Arora, (2012) studied the environment friendly disposal of shredded plastic bags in concrete mix to be use in construction industry. Different test results were analyzed after testing on 48 x concrete cubes(150mm x 150mm x150mm) prepared from varying percentage of polyethylene fibres (0.3, 0.6, and 0.9 to 1.2% of volume of concrete) with conventional concrete material to prepare mixes. Two type of plastic bag fibres were used, one cut manually (60mm x 3mm) and another shredded into a very fine random palettes. Cubes were tested for 7 and 28 days compressive strength and compaction. They concluded that good workability was shown by the mix added with shredded fibres due to its uniform and higher aspect ratio evenly sprayed in the mix. Addition of plastics up to 0.6% is considered suitable after which reduction in compressive strength and compaction is seen affected. They observed that strength loss was less in concrete having shredded fibres of plastic as compare to hand cut macro fibres. Their research focus was only on comparative study of compressive strength but no work was carried out on other concrete properties like tensile strength, modulus of elasticity and density of concrete."

Chowdhury, Maniar and Suganya (2013) carried out a research on the use of polyethylene terephthalate waste as building solution. They replaced 0.5%, 1%, 2%, 4%, and 6% of traditional fine aggregate with PET fibres. They observed that concrete with PET fibres reduces the weight of concrete substantially and thus can be used to make light weight concrete based on unit weight. The reduction in bulk density was found to be directly proportional to plastic aggregate replacement and was attributed to a low unit weight of plastic. The compressive strength increased up to 2% replacement of the fine aggregate with PET bottle fibres and then decreased for 4% and 6% replacements. The split tensile strength gradually increased up to 2% replacement of the fine aggregate with PET bottle fibres and it decreased for 4% and 6%. The flexural strength of samples with

PET bottle fibre as fine aggregate gradually increased with the increase in the replacement percentage but it could decrease further as it was somewhat the same for the 4% and 6%. They concluded that introducing PET makes concrete ductile thus increasing its ability to deform before failure. This is a desirable quality especially in situations where concrete is subjected to harsh condition like expansion and contraction or wear and tear.

Suganthy, Dinesh and Sathish, (2013) investigated the application of pulverized fine crushed plastic (produce from melting and crushing of high density polyethylene) as replacement of fine aggregate in concrete with varying known percentages. Their main focus was on optimum replacement of natural sand by pulverized plastic sand. The results showed increase in water/cement ratio with increase replacement of sand with plastic particles to achieve desired 90mm concrete slump. They have also observed from the results that gradual decrease in strength of concrete specimen for plastic replacement up to 25% but afterward the decrease in strength is rapid which shows suitable replacement up to 25% of sand with plastic pulverized sand. They have also concluded after testing of specimen (having different proportion of plastic replacement) for ultimate and yield strength that both strength decreases with increase replacement of sand with pulverized plastic particles.

Khilesh (2014) this study presents the results of addition of waste plastics along with steel fibres with an objective to seek maximum use of waste plastic in concrete. Two different categories of mix were casted in cubes (150mm x 150mm x 150mm), one with varying percentages of plastic wastes (0.2%, 0.4%, 0.6%, 0.8% and 1% weight of cement) and another mix of plastics waste/steel fibres (0.2/0.1, 0.4/0.2, 0.6/0.3, 0.8/0.4 and 1/0.5 % by weight of cement) to study the compressive strength at 7 and 28 days strength. The combine mix of plastic waste and steel fibres has shown more strength as compared to concrete mix prepared only with plastic waste. He has reached to conclusion that a plastic waste of 0.6% weight of cement when used with steel fibre of 0.3 % (weight of cement) has shown the maximum compressive strength. This study has really focused on addressing the issue of reduced compressive strength with addition of plastic waste. Steel fibres when used along with plastic wastes will affect all the properties of concrete but the researcher only focused on compressive strength property which is insufficient to give clear picture of concrete behaviour.

Ismail and Al-Hashmi, (2007) conducted comprehensive study based on large number of experiments and tests in order to determine the feasibility of reusing plastic sand as partial replacement of fine aggregate in concrete. They conducted tests on concrete samples for dry/fresh density, slump, compressive and flexural strength and finally toughness indices on room temperature. They have collected waste plastic from plastic manufacture plant consist of 80% polyethylene and 20% polystyrene which was crushed (varying length of 0.15-12mm and width of 0.15-4mm). Concrete mix were produce with ordinary Portland cement, fine aggregate (natural sand of 4.74mm maximum size), coarse aggregate (max size below 20mm) and addition of 10%, 15% and 20% of plastic waste as sand replacement. Their test results indicate sharp decrease in slump with increasing the percentage of plastic, this decrease was attributed to the presence of angular and non uniform plastic particles. In spite of low slump however, the mixture was observed with good workability and declared suitable for application. Their tests also revealed the decrease in fresh and dry density with increasing the plastic waste ratio; however increase was reported in dry density with time at all curing ages. Decrease in compressive and flexural strength was observed by increasing the waste plastic ratio which can be related to decrease in adhesive strength between plastic waste particles with cement. However, load-deflection curve of concrete containing plastic waste showed the arrest of propagation of micro cracks which shows its application in places where high toughness is required. The study has shown good workability in spite of low slump but w/c content kept constant in all samples. They should have reduced the water content in order to improve the strength when workability was not an issue.

Mathew, Varghese, Paul and Varghese, (2013) investigated the suitability of recycled plastic as partial replacement to coarse aggregate in concrete mix to study effect on compressive strength, modulus of elasticity, split tensile strength and flexural strength properties of concrete. Coarse aggregate from plastic was obtained by heating the plastic pieces at required temperature and crushed to required size of aggregate after cooling. Their experimental results showed that plastic aggregate have low aggregate crushing value (2.0 as compare to 28 for Natural aggregate), low specific gravity (0.9 as compare to 2.74 for Natural aggregate), and density value (0.81 as compare to 3.14 for Natural aggregate), as compare to Natural coarse aggregate. Their test results were based on 20% substitution of natural coarse aggregate with plastic aggregate. Increase in workability was reported when slump test for sample was carried out. Volumetric substitution of natural aggregate with plastic aggregate was selected best in comparison with grade substitution. At 400 centigrade temperature Plastic coarse aggregate shown considerable decrease in strength as compare to normal concrete. An increase of 28% was observed in compressive strength but decrease in split tensile strength and modulus of elasticity was observed. They recommended that with use of suitable admixture at 0.4% by weight of cement will improve the bonding between matrix and plastic aggregate; however they demand more research to address the tensile behaviour of concrete prepared with 20% plastic aggregate.

Ghernouti, Rabehi, Safi and Chaid (2014) carried out partial replacement of fine aggregate in concrete by using plastic fine aggregate obtained from the crushing of waste plastic bags. Plastic bags waste was heated followed by cooling of liquid waste which was then cooled and crushed to obtained plastic sand having finesse modulus of 4.7. Fine aggregate in the mix proportion of concrete was replaced with plastic bag waste sand at 10%, 20%, 30% and 40% whereas other concrete materials remain same for all four mixes. In fresh properties of concrete it was observed from the results of slump test that with increase of waste content workability of concrete increases which is favourable for concrete because plastic cannot absorb water therefore excessive water is available. Bulk density decreases with increase of plastic bags waste. In harden state, flexural and compressive strength were tested at 28 days and reductions in both strengths with increasing percentage of plastic bag waste sand in concrete mix. Plastic waste increases the volume of voids in concrete which on other hand reduce the compactness of concrete simultaneously speed of sound in concrete is also decreased. Strength reduction in concrete mix was prime concern; however they recommend 10 to 20% replacement of fine aggregate with plastic aggregate. Use of admixtures to address the strength reduction property of concrete with addition of plastic aggregate is not emphasized.

2.2 Crushed Coconut Shell

Muhammad *et al*. (2014) stated that coconut shell is a discarded by-product which is salvaged for biomass purpose to dry food or substance. The food being dried with coconut shell will also come along with the unique coconut flavour. Also, they stated that coconut shell, a part of coconut fruit produce items such as handicrafts items, charcoal for cooking, bangles, bird feeder, bowls, shelter, musical instruments, small animal homes and even a weapon of choices for octopus in Australia.

Chanap (2012) observed that many works have been devoted to use of other natural fillers in composites in the recent past years. Also, coconut shell filler is a potential candidate for the development of new composites because they have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the composites made with these filler more weather resistant and hence more suitable for application as construction materials. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content.

According to Himanshu and Naveen (2015), the possibility of developing structural light weight concrete from coconut shell, would be a tangible addition to the construction industry because of their suitability as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production. From their experiments, concrete with crushed coconut shell as coarse aggregate had an average compressive strength of 12.44 MPa while conventional concrete had a compressive strength of 19.36 MPa. They concluded that though concrete containing crushed coconut shell is lacking in adequate compressive strength when compared to conventional concrete, it is still suitable in instances where low strength economical concrete is needed. Also the resulting concrete can be categorized as light weight concrete.

Durgalaskshmi (2015) carried out replacement of coarse aggregate with coconut shell up to 30% and cement with fly ash up to 30%. From the experimental results and discussion 10% replacement of concrete materials by fly ash, stone dust and coconut shell was found to be 32 N/mm^2 at 28 days which is good in comparison with other combinations which makes it useful for the low strength concrete mixes and cost-effective building construction.

Tukiman and Mohd (2009) did a technical review of the combination of coconut shell and grained palm kernel to replace aggregate in concrete. Five different concrete mixes with different combinations of natural material namely 0%, 25%, 50%, 75% and 100%. Coarse aggregate retained on 5mm sieve and fine aggregate passing through 2.36mm sieve were used. They concluded that the grained palm kernel shell and coconut shell has potential as light weight aggregate and it is cost effective.

Jyoti and Singh (2015) did an experimental study on strength characteristics of M25 concrete with partial replacement of coarse aggregate with coconut shell and cement with fly ash. They carried out a partial replacement of 10%, 20% and 30% of coarse aggregate by coconut shell while simultaneously replacing cement with 20% fly ash content. They concluded that an increase in percentage replacement of coconut shell reduces compressive, tensile and flexural strength of concrete decreases its density, increases its workability, and is suitable for light weight construction. Also they saw that permeable voids and water absorption increases with increase in coconut shell replacement.

Kaur and Kaur (2012) did a review on the utilization of coconut shell as coarse aggregates in mass concrete. They concluded that coconut shell use in concrete can help in waste and pollution reduction. Also coconut shell concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly. Also, coconut shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.

Kamal and Singh (2015) did an experimental study on the characteristics of M25 concrete with partial replacement of coarse aggregate by coconut shell from their research it was observed that coconut shell has more resistance against crushing, impact and abrasion in comparison to crushed granite. It is a light-weight aggregate, produces increased slump with increase in coconut shell thus increased workability although there was decrease in compressive strength of the concrete as the percentage of coconut shell increased.

Sreenivasulu, Praveen, Satish, Harsha, Mahesh, and Kumar. (2014) carried out a laboratory investigation on coconut shell in concrete for the aim of getting a viable alternative low cost building material. They inferred from the results of their experiments that coconut shells can be used as full replacement of crushed granite or other conventional aggregates in concrete construction. Also there is no need to treat the coconut shell before use as an aggregate except for water absorption. Also, they observed that coconut shell concrete is showing 65% compressive strength in comparison to that of normal concrete. Also coconut shell exhibits more resistance against crushing, impact and abrasion when compare to normal concrete. They concluded that coconut shell can be used instead of crushed granite for light weight structures.

Kakade and Dhawale (2015) studied the properties of lightweight aggregate concrete by using coconut shell. Three different concrete mixes with different coconut shell content 0%, 25% 50%. From their experiments, they concluded that coconut shell aggregates have higher water absorption because of higher porosity in its shell structure. The aggregate impact value of coconut shell are much lower compared to crushed stone aggregate which indicates that this aggregates have good absorbance to shock. Also, after 28 days the fresh concrete density and hardened concrete density (under SSD condition) using coconut shell was found to be in the range of 1975 kg/m^3 - 2111 kg/m^3 and 1880 – 1930 kg/m^3, the 28 days compressive strength of coconut shell concrete was found to be 21.31 for 25% replacement by coconut shell aggregate under full water curing and it satisfies the requirement for structural lightweight concrete.

Parag and Sandhya (2014) investigated the effect of replacement of coarse aggregate with coconut shell at 10%, 20%, 30% and 40%. Three different concrete mixes namely M20, M35 and M50 grades. They concluded that coconut shell has potential as lightweight aggregate in concrete and it can reduce the cost of material cost in construction. Also, it can be used in rural areas and places where coconut is abundant and where conventional aggregates are costly. Also, they are more suitable as low-strength giving lightweight aggregate when used to replace common coarse aggregate in concrete production.

Reddy, Aruna and Shaik, (2014) carried out experimental analysis on the use of coconut shell as coarse aggregate. They replaced coarse aggregate with coconut shell by volume, replacing 25%, 50%, 75% and 100% of coarse aggregate with coconut shells. Tests were conducted on the cast specimen after 28 days. The flexural strength for coconut shell concrete was 5.36N/mm^2, 4.32 N/mm^2, 2.4 N/mm^2, for specimens replacing 25%, 50%, 75% but in the case of 100%, the specimen failed under its self weight. Also the compressive strength of 25% coconut shell concrete was obtained as 24 N/mm^2 while that of 50% was 22.62 N/mm^2. The splitting tensile strength of coconut shell concrete was obtained as 2.48 N/mm^2 for 25% and 2.22 N/mm^2 for 50% coconut shell concrete. They concluded that coconut shell concrete of 25% coconut shell content shows properties similar to nominal mix and 50% replaced coconut shell concrete shows properties similar to light weight concrete which can be used as filler materials in framed structures, flooring tiles, thermal insulating concrete and so on.

Kambli and Mathapati (2014) investigated the effect of replacement of coarse aggregate with coconut shell at 10%, 20%, 30% and 40%. Three different concrete mixes namely M20, M35 and M50 grades. They concluded that coconut shell has potential as lightweight aggregate in concrete and it can reduce the cost of material cost in construction. Also, it can be used in rural areas and places where coconut is abundant and where conventional aggregates are costly. Also, they are more suitable as low-strength giving lightweight aggregate when used to replace common coarse aggregate in concrete production.

Avula and Joshua (2015) did a study on the behaviour of bamboo as reinforcement with coconut shell as aggregate in concrete in compression members with different lengths. They observed that the stiffness of the column decreased with the replacement of coarse aggregate, stiffness of the column with bamboo reinforcement was lesser than the column with coconut shell aggregate and steel reinforcement, the ultimate load carrying capacity for the column of 1m length with coconut shell aggregate and steel reinforcement was about 86% of the column with conventional aggregate and steel reinforcement and coconut shell with bamboo reinforcement was about 63%.

Kanojia and Jain (2015) did a review on the performance of coconut shell as coarse aggregate in concrete. They observed that coconut shell can be grouped under lightweight aggregate because 28-day air-dry densities of coconut shell aggregate concrete are less than 2000 kg/m^3 actual density of coconut shell is in the range of 550-650 kg/m^3. They concluded that coconut shell concrete can be used in rural areas.

It has been seen from various literatures that these materials have been used as replacement for concrete. However, this study aims at combining the polyethylene terpephthalate and crushed coconut shell as replacement of coarse aggregate in concrete in order to study its properties and see if there is any advantage in such a combination. If such an advantage is discovered, it will lead to stronger and durable concrete.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

1. Dangote Ordinary Portland Cement 42.5N sourced from the open market.

2. Fine aggregate (river sand): sourced river sand was obtained from Funtua local government, Katsina State.

3. Coarse aggregate (gravel, polyethylene terephthalate [PET] and crushed coconut shell [CCS]): the gravel was obtained from a quarry site in Zaria along Kaduna-Zaria highway, Kaduna State. Sizes of 12mm and 19mm were used for this research.

The polyethylene terephthalate was obtained from Pepsi bottling company, Idu industrial layout, Abuja. The used PET bottles were mechanically crushed to sizes not more than 10mm.

The crushed coconut shell was obtained from a coconut seller in Sabo market, Zaria Kaduna State. The coconut shell was hand crushed using a hammer with 82.6% passing through sieve size of 25.4mm.

4. Water.

3.2 Methods

3.3 Cement

The following tests listed below were carried out to check the properties of the cement to ensure that the cement used meets the standard requirements for ordinary Portland cement as specified by BS-EN 196:1995.

3.3.1 Consistency of Cement

It's a method of determining the water to cement ratio that would give reasonable workability of concrete. The test was carried out in accordance with the procedures outlined in BS EN196-3:1995, and the result is shown in Table 3.1 and the details are in appendix A1.

Table 3.1: Consistency of cement

No of trials	Water content (%)	Penetration depth (mm
First trial	30	5.5
Second trial	30	5.5
Third trial	30	5.5
Average	**30**	**5.5**

3.3.2 Initial and Final Setting Time

The initial and final setting times of concrete are tests that monitor the transition of the hydration of cement from fluid state to solid state. Both tests were carried out in accordance with the procedures outlined in BS EN196-3:1995 and the average results are shown in Table 3.2 while the full results are in appendix A1.

Table 3.2: Initial and final setting time of cement

Initial setting time	119 minutes
Final setting time	189 minutes

3.3.3 Soundness of Cement

This is the property of cement that shows its resistance to volume expansion after it has set; in other words it goes a long way to determine the degree of disrupting the mortar or concrete when used in construction. This test was conducted in accordance with the procedures outlined in BS EN196-3:1995 and the result is presented in appendix A1.

3.4 Tests on Aggregate

The physical and mechanical properties of aggregates play a very important role in the overall properties of fresh and hardened concrete. These series of tests were carried out in order to categorize our materials in terms of their physical and mechanical properties especially the CCS and PET comparing them with code specifications. These tests include:

3.4.1 Particle size distribution test

The essence of size distribution analysis is to have a well graded aggregate which have direct influence on producing workable concrete. The particle size distribution test was carried out in accordance with BS 812-103.1:1985 and the results are shown in Tables 3.4, 3.5, 3.6 and 3.7 and the details in appendices B1, B2, B3 and B4.

Table 3.3: Sieve Analysis of Crushed Coconut Shell.

Sieve size (mm	% passing
38.1	100
25.4	82.60
19.50	42.77
12.7	6.64
9.52	1.05
6.25	0
Pan	0

Table 3.4: Sieve Analysis of Polyethylene Terephthalate

Sieve size(mm)	% Passing
38.1	100
25.4	100
19.50	100
12.7	97.7
9.52	86.7
6.35	2.32
1.18	0.77
0.600	0.62
0.300	0.46
0.150	0.31
Pan	0

Table 3.5: Sieve Analysis of Gravel

Sieve size (mm	% passing
38.1	99.15
25.4	86.30
19.50	53.66
12.7	24.8
9.52	14.80
6.35	4.65
Pan	0

Table 3.6: Sieve Analysis of River Sand

Sieve size (mm	% Passing
4.75	92.42
2.36	86.44
1.18	76.80
0.60	51.86
0.30	10.31
0.15	0.99
Pan	0
Total	

3.4.2 Flakiness/Elongation Test

Flakiness and elongation tests are carried out in order to classify the shape and suitability of the aggregate in concrete with respect to its workability and strength. The more flaky and elongated the aggregate is, the less suitable it is for constructional purposes, especially in high performance concrete. Three tests were done for each of the coarse aggregates. The flakiness test was done in accordance with BS 812-105.1:1990 and the elongation test was done in accordance with BS 812-105.2:1990 and the results are shown in Tables 3.8-3.12 and the details in appendices C1, C2, C3, C4 and C5.

3.4.2.1 Flakiness Test

Table 3.7: Flakiness Test on Gravel

	Flakiness Ind (%)
Sample 1	25.8
Sample 2	16.57
Sample 3	16.24
Average	19.54

Table 3.8: Flakiness Test on CCS

	Flakiness Ind (%)
Sample 1	100
Sample 2	100
Sample 3	100
Average	100

PET

Flakiness index 100%

3.4.2.2 Elongation Test

Table 3.9: Elongation Test on Gravel

	Elongation Index (%)
Sample 1	26.46
Sample 2	26.65
Sample 3	35.34
Average	29.48

Table 3.10: Elongation Test on CCS

	Elongation Index (%)
Sample 1	23.24
Sample 2	33.06
Sample 3	28.42
Average	28.24

PET 60%

3.4.3 Specific Gravity of Fine and Coarse Aggregate

This test was carried out on the fine aggregate (river sand) and the coarse aggregates (gravel, crushed polyethylene terephthalate and crushed coconut shell). In each test, three sample tests were carried. The tests were carried out in accordance with BS 812 part 2 and the results are shown in Table 3.13 and full result in appendix D4

Table 3.11: Specific Gravity of Aggregates.

	PET	River san	Gravel	CCS
Specific gravity	1.32	2.64	2.70	1.38

3.4.4 Aggregate Crushing Value

The aggregate crushing value gives relative measure of resistance of an aggregate sample to crushing under gradually applied compressive load. The test was performed with size aggregates passing 12.5mm sieve and retained in 10mm sieve. It was done according to BS 812: part 110:1990 and the results are shown in Table 3.14 and full results in appendix E1.

Table 3.12: Aggregate Crushing Value of Coarse Aggregates.

Material	ACV
Coconut Shell	2.29%
Gravel	28%
Polyethylene Terephthalate.	Test procedure n compatible with t material

3.4.5 Aggregate Impact Value

The aggregate impact value gives relative measure of resistance of aggregate to sudden shock or impact. It was done according to BS 812: part 112:1990 and the results are shown in Table 3.15 and full results in appendix E2.

Table 3.13: Aggregate Impact Value of Coarse Aggregates.

Material	AIV
Gravel	26.57%
Coconut Shell	3.62%
Polyethylene Terephthalate	0.3125%

3.5 Concrete Mix Design

A mix design ratio of 1:2:3 that is, one part cement, 2 parts fine aggregate and three parts coarse aggregate was used in this study. This research will be limited to 50% replacement in order to see if the properties of concrete improve with the addition of PET to CCS in concrete at the specified replacement percentage. The replacement value for 50% of the conventional coarse aggregate with PET and CCS was chosen because, other research (Kaur and Kaur, 2012) have been done with coconut shell as replacement of coarse aggregate in concrete with encouraging results.

In all of the mixes, a water/cement ratio of 0.43 was used. Using the method of absolute volume, the mix ratio and the water cement ratio, the weights of the various constituents were obtained. The detail calculations and weights of the different samples are given in appendix F.

Conventional concrete cubes were moulded to serve as control to determine the acceptable performance criteria. Varying percentages of polyethylene and coconut shell were used to replace 50% of the coarse aggregate. The polyethylene terephthalate and coconut shell proportions were varied from 10% up to 50%. The various mix proportion of coarse aggregates are given in Table 3.14.

Table 3.14: Percentage Replacement of Gravel with PET and CCS.

Sample	**Mix Proportions of Coarse Aggregate**		
	Gravel	PET	CCS
A	100%	0%	0%
B	0%	0%	100%
C	0%	100%	0%
D	50%	50%	0%
E	50%	40%	10%
F	50%	30%	20%
G	50%	20%	30%
H	50%	10%	40%
I	50%	0%	50%

3.5.1 Preparation of concrete cubes

The mixing was done by a concrete mixer in the Civil Engineering laboratory and properly compacted in three layers with 25 blows and properly vibrated. A total of 189 cubes were cast. The details of these procedures are clearly outlined in BS 1881-108:1983.The cubes were left in the mould for twenty four hours then removed, weighed and put in the curing tank. The cubes were labelled from A to I with respect to the percentage of replacement of the coarse aggregate with PET and CCS respectively.

3.6 Tests on concrete

The basic properties of fresh and hardened concrete were tested in order to study the behaviour of concrete with CCS and PET. These tests include:

3.6.1 Slump test

This test was carried out on fresh concrete to ensure the workability of concrete with focus on the test samples with CCS and PET. The test was carried out in accordance with BS 1881-102:1983 and the result is shown in Table 3.19 and shown in plate I.

Table 3.15: Result of slump test

Sample	**Mix proportion of coarse aggrega**	**Slump val (mm)**
A	100% Gravel, 0% PET, 0% CCS	25
B	0% Gravel, 0% PET, 100% CCS	25
C	0% Gravel, 100% PET, 0% CCS	30
D	50% Gravel, 50% PET, 0% CCS	25
E	50% Gravel, 40% PET, 10% CCS	24
F	50% Gravel, 30% PET, 20% CCS	25
G	50% Gravel, 20% PET, 30% CCS	27
H	50% Gravel, 10% PET, 40% CCS	25
I	50% Gravel, 0% PET, 50% CCS	22

Plate I: Slump Test carried out at the Structural Laboratory Civil Engineering Department, Ahmadu Bello University, Zaria. Source: Author’s fieldwork 2017.

3.6.2 Density of Concrete

This test was done to check the density of concrete with CCS and PET in order to compare it with the code specifications and the nominal concrete mix. This test was carried out in accordance with BS 1881-114:1983 and the result is shown in Table 3.20 and the full results shown in appendix H.

Table 3.16: Density of concrete samples

Mix Proportion	**Average density (kg/m^3)**			
	Period of curing (days)			
	1	7	14	28
A	2,568	2,661	2,539	2,560
B	2,094	2,089	2,103	2,089
C	1,649	1,738	1,644	1,743
D	2,080	2,252	2,079	2,015
E	2,217	2,311	2,222	2,267
F	2,275	2,304	2,356	2,316
G	2,070	2,126	2,148	2,099
H	2,090	2,049	2,168	2,123
I	2,252	2,360	2,252	2,291

3.6.3 Compressive Strength Test

This test was done to check the compressive strength of concrete with CCS and PET in order to compare it with the code specifications and the nominal concrete mix. This test was carried out in accordance with BS 1881-116:1983 and the result is shown in Table 3.21 and full results shown in appendix J.

Table 3.17: Compressive Strength of Concrete Samples

Mix proportio	**Average compressive strength (N/mm^2) M 25; w/c ratio – 0.42**						
	Period of curing(days)						
	1	2	3	4	7	14	28
A	10	17	20	22	23.	24.	24.
B	4.	5.	9.	11	16.	17.	17.
C	2.	4.	5.	5.7	6.1	6.4	7.0
D	6.	8.	10	10	11.	13.	16.
E	6.	9.	11	12	15.	15.	16.
F	5.	8.	12	13	14.	16.	18.
G	7.	8.	12	13	14.	16.	18.
H	3.	5.	8.	9.	9.6	13.	14.
I	3.	5.	5.	7.	10.	11.	16.

3.6.4 Water Absorption Test

This test was carried out for the purpose of accessing the durability characteristics of concrete with CCS and PET as compared with code specifications and the control mix. This test was carried out in accordance with BS 1881- 122:1983 and the result is shown in Table 3.22 and full results in appendix K.

Table 3.18: Water Absorption Property of the Various Concrete Samples

Mix proportions	Water absorption (%
A	4.52
B	1.79
C	12.86
D	5.45
E	3.43
F	3.99
G	4.48
H	4.90
I	5.72

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Preamble

The results of all the tests carried out in chapter three are discussed in this chapter to make deductions and conclusions.

4.2 Tests on Cement

The tests listed in Table 4.1 below were conducted on Dangote Ordinary Portland cement and the summary given below.

Table 4.1: Physical Properties of Dangote Brand of OPC

Parameters tested	Test result	Code Specifications BS EN196-3:1995
Standard consistency	**30%**	**26-33%**
Initial setting time	**119 minutes**	**≥ 45 minutes**
Final setting time	**189 minutes**	**< 600 minutes**
Soundness	**0.5 mm**	**≤ 10mm**

From the results given above, it could be clearly seen that the cement has satisfied the physical requirements as specified in BS EN196-3:1995 and BS 12:1996.

4.3 Tests on Aggregates

The following tests were carried out on the aggregates. The results are reported in chapter three while the full results are in the appendix.

4.3.1 Sieve Analysis

Sieve analysis was carried out on gravel, CCS and PET in accordance with BS 812-103.1:1985. The results of the sieve analysis are presented in tables 3.4 to 3.7 for CCS, PET, gravel and river sand.

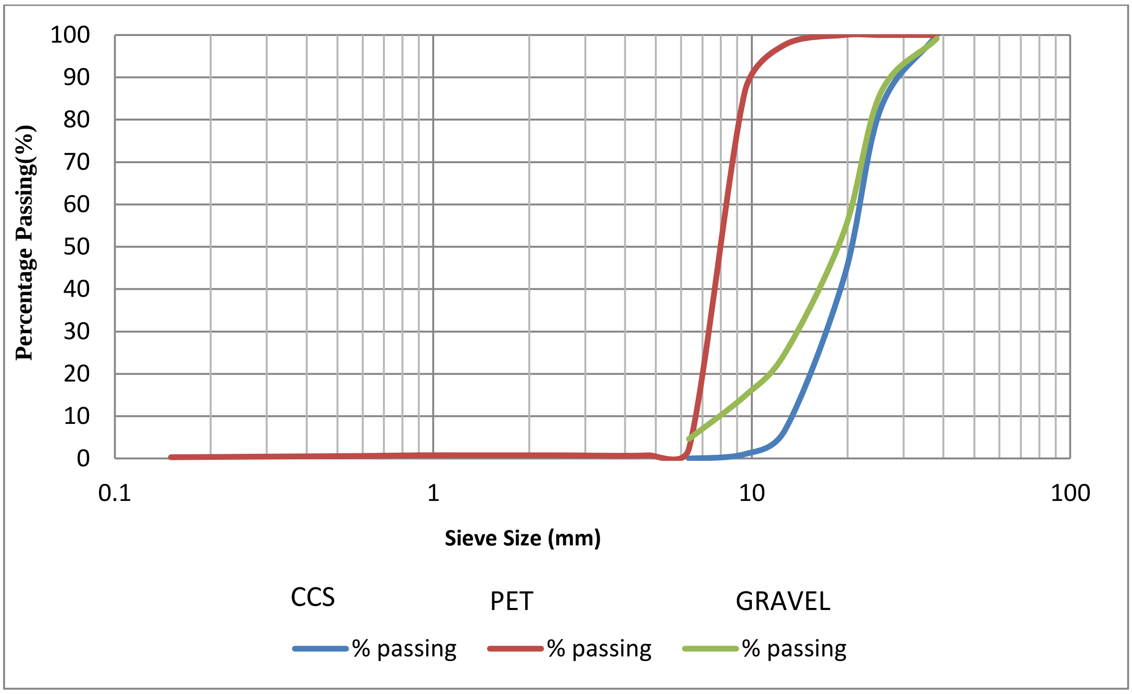

Figure 4.1: Particle Size analysis of CCS, PET and Gravel.

4.3.1.1 Crushed Coconut Shell (CCS)

From the sieve analysis of the crushed coconut shell, it can be seen that a sizable amount of the aggregate was retained on sieves 19.50mm and 12.7mm which is seen in the steep gradient in the Fig 4.1 above.

4.3.1.2 Polyethylene Terephthalate (PET)

Fig 4.1 shows a steep gradient between sizes 9.52mm and 6.35mm and a discontinuity between 6.35mm and 1.18mm which shows that 86.7% of the PET is made up of aggregates of a narrow size range between 9.52mm and 6.35mm, which shows that crushed PET is largely homogenous in size.

CCS has aggregate sizes predominantly within 12.7mm-19.5mm and PET predominantly within 6.35mm-9.52mm. The combination of these aggregates will give us a well graded aggregate mixture as can be seen from Fig 4.1. This implies higher workability for fresh concrete and reduction in honey combing.

4.3.1.3 Gravel

From Fig 4.1, it can be seen that the aggregate is well graded although there is a gap in size of aggregate between 19.5mm and 12.7mm which can be seen from the steepness in the graph.

4.3.1.4 River Sand

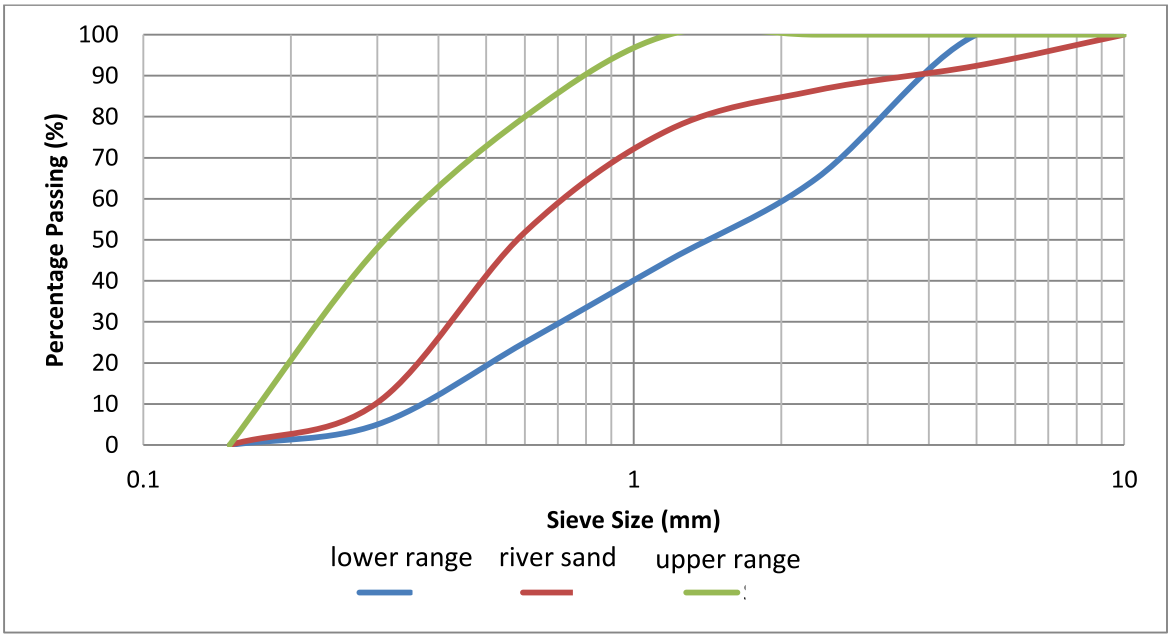

Fig 4.2: Particle Size Analysis of River Sand showing upper range and lower range for fine aggregate in accordance with BS 882.

From fig 4.2, it can be seen that the aggregate is well graded indicating its suitability for construction purposes as can be seen from the curve. Also it falls within the acceptable range for fine aggregate in concrete.

In conclusion when the coarse and fine aggregates are combined it gives us an all in aggregate representation which meets the requirement for all in aggregate as specified in BS 882:1992. This shows its suitability in concrete production.

4.4 Flakiness and Elongation Test

4.4.1 Flakiness Test

Flakiness test was carried out on the gravel, CCS and PET, in accordance with BS 812-105.2:1990. According to BS 882:1992, the flakiness index requirement for coarse aggregate in concrete is that it should not exceed 40%. If it does, it is not suitable for engineering purposes. The result of this test is reported in Tables 3.8 and 3.9 on and the full results are presented in appendices C1 and C2.

Table 4.2: Flakiness Index of Aggregates

Material	Flakiness index	Code Requirement (BS 882:1992)
Gravel	**19.54%**	**<40% satisfactory**
CCS	**100%**	**> 40% not satisfactory**
PET	**100%**	**> 40% not satisfactory**

CCS and PET have a flakiness index of 100% which shows that all the aggregates have a thickness of less than 0.6 of their mean sieve size. When compared to gravel which has a 19.54% which is less than the maximum flakiness index as specified by BS 882:1992.

4.4.2 Elongation Test

Elongation test was carried out on the gravel, CCS and PET, in accordance with BS 812-105.2:1990. According to this code, the elongation index requirement for coarse aggregate in concrete is that it should not exceed 40%. If it does, it is not suitable for engineering purposes. The result of this test is reported in Tables 3.10 – 3.12 and the full results are presented in appendices C3-C5.

Table 4.3: Elongation Index of Aggregates

Materials	Elongation index	Code Requirements (BS 882:1992)
Gravel	**29.48%**	**<40% satisfactory**
CCS	**28.24%**	**<40% satisfactory**
PET	**60%**	**>40% not satisfactory**

It can be seen that all the aggregates used in this test with the exception of PET had elongation index less than the maximum of 40% specified by BS 882:1992. PET has the highest elongation index of 67.35%, gravel with 29.448% and CCS in between with 28.24%.

4.5 Specific Gravity Test

The specific gravity of aggregate determines to a large extent the density of concrete. In other words, the lower the specific gravity, the lighter the concrete. The result of the specific gravity of the aggregates are shown in Table 3.13 with the full results shown in appendix D.

From Table 3.13, page 30 the specific gravities of PET and dried CCS from table 9 are 1.32 and 1.38 which is about 50% of the specific gravity of gravel. According to implying they can be used as light weight aggregate.

4.6 Aggregate Crushing Value

Aggregate crushing value is an indicator of resistance of coarse aggregate to sustained loading. The lower the value, the higher the resistance to sustained loading. From BS 882:1992 the aggregate crushing values for engineering and non engineering purposes are stated below:

0 – 25% - good enough for any important engineering activities

25 – 45% - general construction purposes and minor concrete works

Greater than 45%- is not useful for any important engineering activity.

The result of this test is reported in Table 3.14 and the full results are presented in appendix E1

From Table 3.14 it is observed that gravel has an ACV value of 28% which is less than 45% which shows it is suitable for wearing or non-wearing surfaces. CCS on the other hand had an ACV value of 2.29% which shows it is suitability for engineering purposes. The machine couldn't impose its load in the PET.

4.7 Aggregate Impact Value

The aggregate impact value of coarse aggregate gives us an indication of the resistance of coarse aggregates to impact or shock loading. The British standard BS 882: 1992, specifies maximum value of 25% when the aggregate is used in heavy duty floors, 30% when the aggregate is to be used in concrete for wearing surfaces and 45% when it is to be used in the other conventional construction purposes.

The result of this test is reported in Table 3.15 on page 31 and the full results are presented in appendix E2

From Table 3.15, page 31 it is observed that all the coarse aggregates used in this test satisfies the requirements as specified in the code. PET shows better resistance to impact loading than CCS and gravel.

4.8 Tests on Concrete

The tests carried out on concrete of different mixes to study the workability, compressive strength and durability of concrete in which the coarse aggregate is partially replaced with PET and CCS.

4.8.1 Slump test

This test was done in order to study the workability of the different fresh concrete mixes.

According to BS 8500-1:2002, the different types of slump include:

Not less than 0 and not more than 70mm –S1

Not less than 30mm and not more than 120mm – S2

Not less than 80mm and not more than 180mm – S3

Not less than 140mm and not more than 240mm – S4

From Table 4.4 it can be observed that for all the various concrete mixes, there was true slump although the workability was generally low.

Table 4.4: Slump Value and Type of Slump for the Different Concrete Mixes.

Sampl	**Mix proportion coarse aggregate**	**Slump value (mm)**	**Slump class accordi to I 8500-1**
A	100% Gravel, 0% PE 0% CCS	25	S1
B	0% Gravel, 0% PE 100% CCS	25	S1
C	0% Gravel, 100% PE 0% CCS	30	S1
D	50% Gravel, 50% PE 0% CCS	25	S1
E	50% Gravel, 40% PE 10% CCS	24	S1
F	50% Gravel, 30% PE 20% CCS	25	S1
G	50% Gravel, 20% PE 30% CCS	27	S1
H	50% Gravel, 10% PE 40% CCS	25	S1
I	50% Gravel, 0% PE 50% CCS	22	S1

As compared to the control mix, there was no significant increase or decrease in the workability of the concrete, hence it can be concluded that the inclusion of PET and CCS in concrete does not significantly improve or reduce the workability of concrete as can be seen from the results.

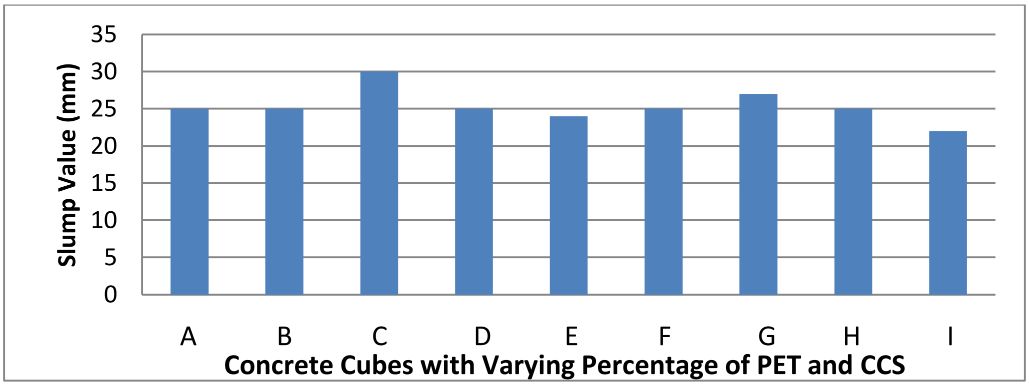

Fig 4.3: Slump of Concrete Samples.

4.8.2 Density of Concrete

This test was carried out on the hardened concrete in order to study the effect of replacement of gravel with PET and CCS on the weight of concrete. This test was carried out in accordance with BS 812 pt 2:1995. The result of this test is reported in Table 3.20 and the full results are presented in appendix H.

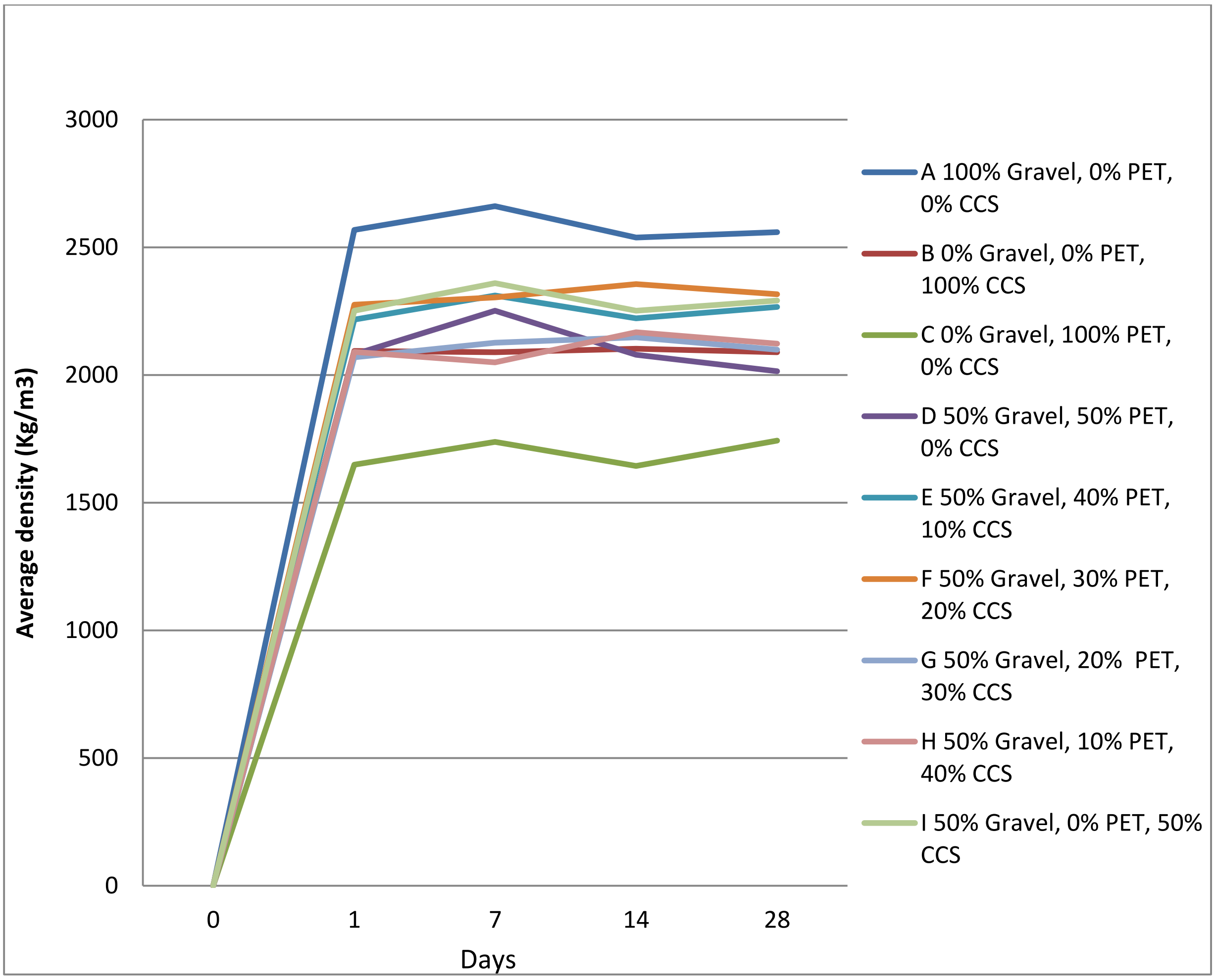

Fig 4.4: Density of Concrete Cubes

4.8.2.1 Effect of increased CCS content on density of concrete

With replacement of gravel with PET and CCS, there is decrease in the density of the concrete samples for all percentages of replacement. For samples E, F, G, H, I and B with CCS content of 10%, 20%, 30%, 40%, 50% and 100% respectively have densities of 2,267 kg/m^3, 2,316kg/m^3, 2,099kg/m^3, 2,123kg/m^3, 2,291kg/m^3 and 2,089kg/m^3 at 28 days. Also, there is no noticeable increase or decrease in density with increase in number of curing days indicating no changes in the physical properties as regards the weight of the concrete.

4.8.2.2 Effect of increased PET content on density of concrete

For samples H, G, F, E, D and C with PET content of 10%, 20%, 30%, 40%, 50% and 100% respectively have densities of 2,123kg/m^3, 2,099kg/m^3, 2,316kg/m^3, 2,267kg/m^3, 2,015kg/m^3 and 1,743kg/m^3 at 28 days. It can be seen that there is no recognizable pattern with increase in content of PET. Compared to the control mix with density of the control mix which is 2,560kg/m^3 at 28 days it can be seen that concrete with PET used as partial replacement of gravel can be used as lightweight concrete, thus giving room for possibilities in construction. Also, there is no noticeable pattern of increase or decrease of density with increase in number of curing days.

4.8.3 Compressive Strength

The compressive strength test was carried out on the hardened concrete in order to study the resistance of the concrete cubes casted from the different concrete mixes to compressive load. This test was done in accordance with BS 1881-116:1983 and the result of this test is reported in Table 3.21 and the full results are presented in appendix J.

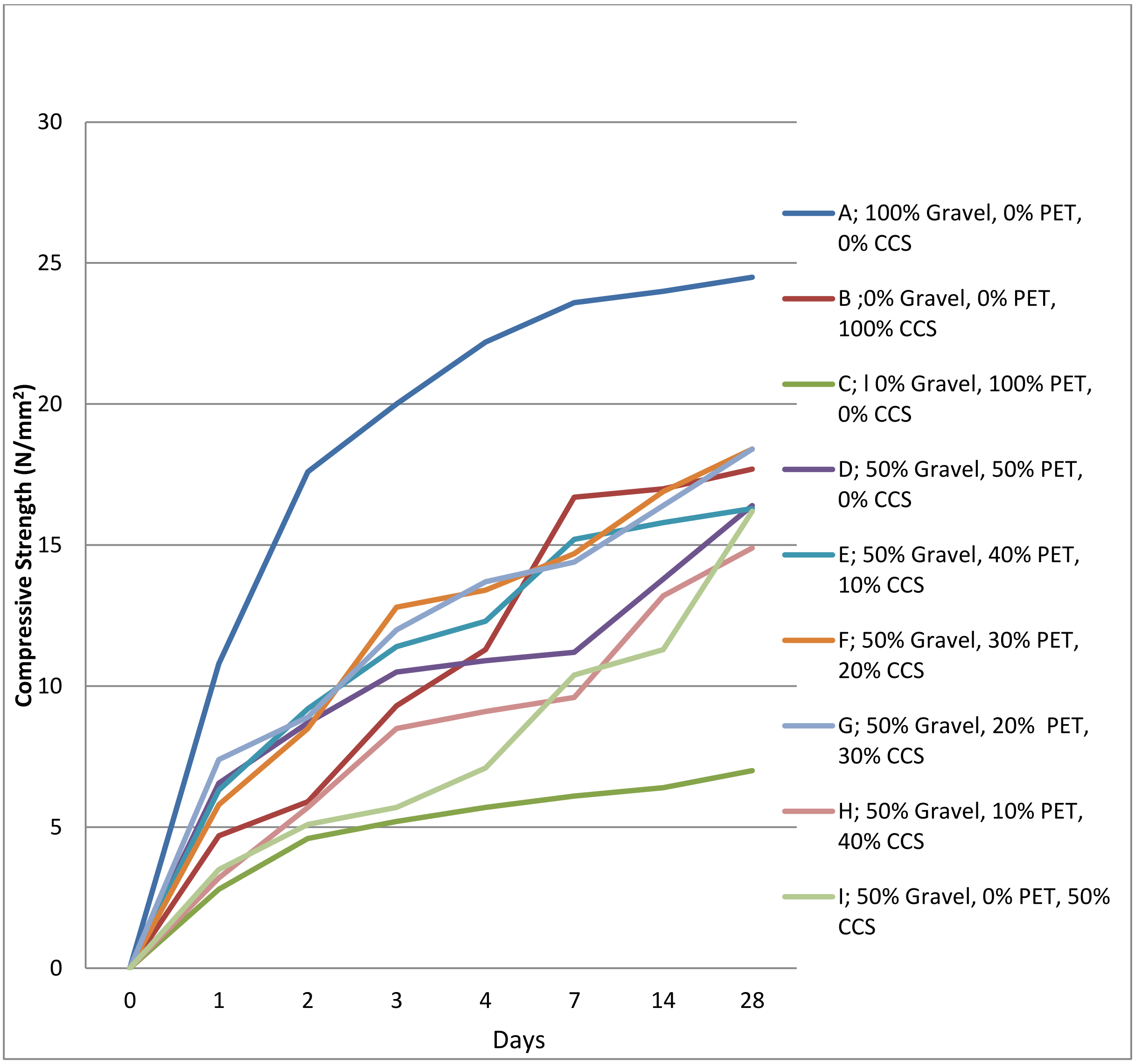

Fig 4.5: Compressive Strength of Concrete Cubes.

The compressive strength of the concrete samples showed a rise in compressive strength from D (50% PET and 0%CCS) to F 30% PET and 20% CCS) and G (20% CCS and 30% CCS then falling at H (10% PET and 40% CCS) with an increase in I (0% PET and 50%). The optimum value of CCS and PET percentage to replace 50% of gravel in concrete can be seen to be mix F and G. Sample F (30% PET and 20% CCS) shows a steady increase in the compressive strength from 14.7N/mm^2 to 16.9N/mm^2 to 18.4N/mm^2 at 7, 14 and 28 days respectively. Sample F was able to achieve 76.7% of the compressive strength of the control mix at 28 days.

4.8.3.1 Effect of increase in CCS on compressive strength of concrete

With increase in CCS content, there was an increase in compressive strength up to 30% CCS afterwards there was a decrease at 40%. With decrease in the percentage of PET, there was decrease in the percentage of flaky and elongated aggregates in the various mixes thus resulting in higher compressive strength. However, at 40% PET and 10% CCS, the presence of voids in the mix due to inadequate fill by the PET led to a drop in the strength.

The lowest value of compressive strength of 14.9N/mm^2 was in sample H (40% CCS) with a highest value in sample F and G (20% CCS and 30% CCS) of 18.4N/mm^2. There was an increase in compressive strength up to 30% CCS.

It can be concluded that with increase of CCS content up to 30%, there is increase in the compressive strength of the concrete.

4.8.3.2 Effect of increase in PET on compressive strength of concrete

Due to the flakiness of PET, the strength of the concrete was reduced for the same strength category as the control. However, with increase of PET content up to 20%, there is increase in the strength of concrete, the strength remains the same at 30% then decreases at 40% and 50% respectively. With increase in percentage of PET, there is a more well graded aggregate profile which leads to better strength properties, but as the percentage of PET increases, the effect of the flakiness and elongation of the PET cancels out the advantage of well graded aggregates. It can be concluded that with increase of PET content up to 20%, there is increase in the compressive strength of the concrete.

4.8.3.3 Combined effect of CCS and PET on compressive strength of concrete.

With increase in the content of CCS and PET there was noticeable increase up to the 20% and 30% replacements of PET and CCS respectively. Subsequent decrease in strength was noticed when the proportions were beyond the optimum range (20-30% CCS/PET). Sample F (30% PET and 20% CCS) and sample G (20% PET and 30% CCS) gave us the highest value of compressive strength of 18.4N/mm^2. This optimum range shows us the percentage range in which the advantage of having whole in aggregate and the disadvantage of having flaky and elongated aggregates superimpose on each other to bring out the best combination which is (20-30% CCS/PET).

The samples F (30% PET and 20% CCS) and G (20% PET and 30% CCS) satisfy the requirement for C15 concrete as specified in BS 8500:2002.

4.8.4 Water Absorption Test

This test was carried out as a measure of Durability of the various concrete cubes derived from the different concrete mixes.

According to BS 1881-122:1983, and general experience has shown that the typical values of absorption of concrete are given as:

Less than 3% - Low Absorption Concrete

3-5% - Average Absorption Concrete

Greater than 5% - High Absorption Concrete.

The result of this test is reported in Table 3.22 and the full results are presented in appendix K.

Table 4.5: Classification of water absorption characteristics of concrete samples

Mix proportions	Water absorption (9	Classification according code
A	4.52	Average absorption concret
B	1.79	Low absorption concrete
C	12.86	High absorption concrete
D	5.45	High absorption concrete
E	3.43	Average absorption concret
F	3.99	Average abruption concrete
G	4.48	Average absorption concret
H	4.90	Average absorption concret
I	5.72	High absorption concrete

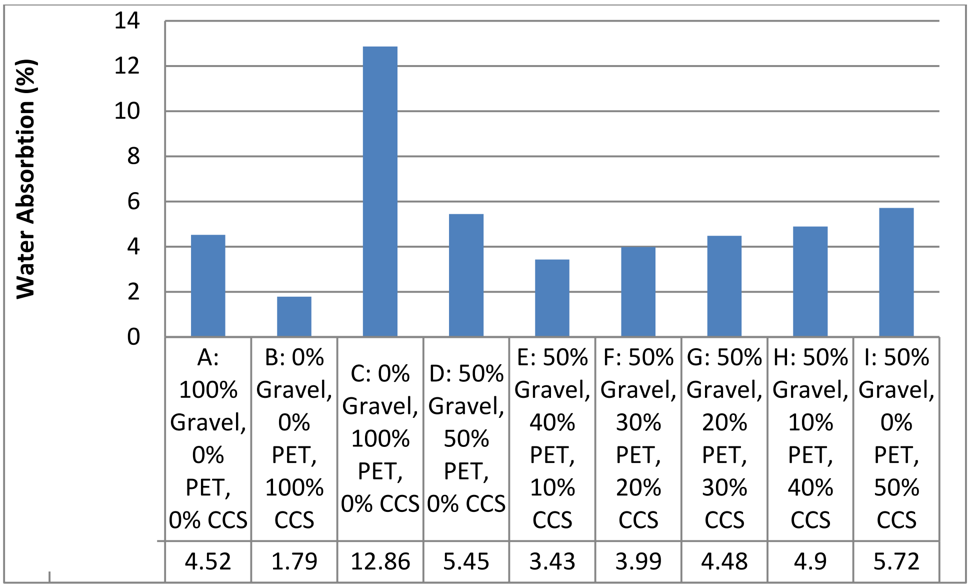

Fig 4.6: Water Absorption of Concrete Cubes.

4.8.4.1 Effect of replacement of gravel with CCS and PET on the water absorption characteristics of concrete.

From Table 4.5 it can be seen that with increase in PET content, there is increase in water absorption, indicating less durability with increase in PET content. This shows that increase in PET content leads to more voids in concrete. Sample A which has 100% gravel has a value of 4.52 which indicates an average absorption capacity while concrete with 100% CCS and PET as coarse aggregates has values of 1.79 and 12.86 which indicates low and high absorption capacities, respectively.

Samples F (30% PET and 20% CCS) and G (20% PET and 30% CCS) gave us 3.99 and 4.48 which according to BS 1881-122:1983 specifies an average absorption concrete. Also sample F shows a lower water absorption capacity than G which shows its higher durability. It can be concluded that samples with increase of PET content there is rise in the water absorption capacity of the concrete, therefore an optimum percentage of 30% PET content is recommended.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The combination of CCS and PET with gravel gives us particle sizes that adequately represent all the standard sizes specified by BS 812-103.1:1985 and satisfies the requirement for all in aggregate given in BS 882 : 1992 which is ideal for workable concrete and reduces the chances of honeycombing in concrete.

2. The specific gravity of CCS and PET are both 1.32 while that of gravel is 2.70. This implies their suitability for use as lightweight aggregates in concrete production.

3. The AIV values of gravel (26.57%), CCS (3.62%), PET (0.3125%) and ACV values for gravel (28%), and CCS (2.29%), are all less than the maximum acceptable value given in BS 882:1992 of 45% therefore the coarse aggregates with the exception of PET (extremely low values indicate flakiness) used in this study show their suitability for general construction purposes.

4. The density of concrete replaced with CCS and PET is considerably lesser than conventional concrete, which makes for easier handling and mixing.

5. Sample F has a lower water absorption capacity of 3.99 than G which has a water absorption capacity of 4.48 indicating a more desirable durability characteristic thus making it preferred to sample G.

5.2 Recommendations

1. Concrete with 50% gravel, 30% PET and 20% CCS (sample F) and concrete with 50% gravel, 20% PET and 30% CCS (sample G) can be considered as a viable alternative to conventional concrete as regards waste disposal and environmentally friendly concrete.

2. Concrete samples F and G can be used in road drainage, gutter, slabs, kerbs, canal linings, blinding, low traffic road pavements, stone pitching, embankment, base for flexible pavements and minor concrete works in general.

3. PET can be used as filler in concrete with gravel and CCS as seen in the improvement of its strength and durability characteristics.

5.3 Contributions to Knowledge

1. The flakiness and elongation tests showed that PET is flaky and elongated with a flakiness index of 100% and elongation index of 67.35%. CCS was also seen to be flaky with a flakiness index of 100%. Gravel and CCS fulfilled the requirement of elongation index of less than 40% specified in BS 882:1992 having an elongation index of 29.48% and 28.24% respectively.

2. The workability of the concrete with CCS and PET gives us a range of (22-30mm) values close to the control sample (25mm), for any percentage replacement of gravel by 50% with CCS and PET and can be categorized as S1 according to BS 8500-1:2002.

3. The compressive strength of sample F (30% PET and 20% CCS) and sample G (20% PET and 30% CCS) gives us 18.4N/mm^2 which according to BS 8500-1:2002 shows its suitability as C15 concrete.

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APPENDIX A

Tests on Cement

1. Consistency Test (10:13am – 10:30am)

Water Content: 30%

2. Penetration Depth: 5.5 mm

3. Initial Setting Time: 7mm at 1hour 59 Mins

Final Setting Time: 7mm at 1:20pm

3 Hours 7 minutes.

4. Soundness Test

Distance between two indicator points before placement in water bath	**9mm**
Distance between two indicator points after placement in water bath	9.5mm
Expansion	0.5mm
Code requirement	OPC 10mm (max)

APPENDIX B

Sieve Analysis Results for the Aggregates Used in this Study.

1. Crushed Coconut Shell

Sieve Size (mm)	Weight Retained	Weight Passing	% Passing
38.1	0	1431	100
25.4	249	1182	82.60
19.50	570	612	42.77
12.7	517	95	6.64
9.52	80	15	1.05
6.25	15	0	0
Pan	0	0	0
Total			

2. Polyethylene Terephthalate

Sieve Size (mm)	Weight Retained	Weight Passing	% Passing
38.1	0	646	100
25.4	0	646	100
19.50	0	646	100
12.7	15	631	97.7
9.52	71	560	86.7
6.35	545	15	2.32
1.18	10	5	0.77
0.600	1	4	0.62
0.300	1	3	0.46
0.150	1	2	0.31
Pan	2	0	0
Total			

3. Gravel

Sieve Analysis (mm)	Weight Retained	Weight Passing	% Passing
38.1	43	4905	99.15
25.4	635	4270	86.30
19.50	1615	2655	53.66
12.7	1427	1228	24.8
9.52	495	733	14.80
6.35	503	230	4.65
Pan	230	0	0
Total			

4. River Sand

Sieve Analysis (mm)	Weight Retained	Weight Passing	% Passing
4.75	114	1390	92.42
2.36	90	1300	86.44
1.18	145	1155	76.80
0.60	375	780	51.86
0.30	625	155	10.31
0.15	140	15	0.99
Pan	15	0	0
Total			

Sieve size (mm)	Lower Range	River sand	Upper Range
10	100	100	100
5	100	92.42	100
2.36	65	86.44	100
1.18	45	76.80	100
.6	25	51.86	80
.3	5	10.31	48
.15	0	0	0

APPENDIX C

Flakiness and Elongation Tests

Flakiness Test

1. Sieve Analysis for Gravel

Sieve Size (mm)	Sample 1	Sample 2	Sample 3
	Weight Retained	Weight Retained	Weight Retained
38.1	0	0	0
25.4	854	390	770
19.52	710	1010	1371
12.7	655	562	540
9.52	45	30	2
6.25	2	1	0
Pan			
Total	2245	1950	2720

1.1 Result of Flakiness Test for Gravel

Aperture Size (mm)	Sample 1		Sample 2		Sample 3	
	Weight Retained	Weight Passing	Weight Retained	Weight Passing	Weight Retained	Weight Passing
50 – 38.1	0	0	0	0	0	0
38.1 – 25.4	530	331	325	67	630	90
25.4 – 19.5	602	115	796	214	1105	268
19.5 – 12.7	517	128	475	90	473	70
12.7 – 9.52	29	11	25	2	1	0
9.52 – 6.25	2	0	1	0	0	0
Total						

Flakiness Index (25.8% + 16.57% + 16.24%) / 3 = 19.54%

2. Sieve Analysis for CCS

Sieve Size (mm)	Sample 1	Sample 2	Sample 3
	Weight Retained	Weight Retained	Weight Retained
38.1	0	0	0
25.4	87	55	70
19.52	150	140	180
12.7	155	170	130

9.52	7	10	5
6.25	1	1	0
Pan			
Total	425	401	405

2.1 Result of Flakiness Test for CCS

Aperture Size (mm)	**Sample 1**		**Sample 2**		**Sample 3**	
	Weight Retained	Weight Passing	Weight Retained	Weight Passing	Weight Retained	Weight Passing
50 – 38.1	0	0	0	0	0	0
38.1 – 25.4	0	87	0	55	0	70
25.4 – 19.5	0	151	0	140	0	180
19.5 – 12.7	0	154	0	170	0	130
12.7 – 9.52	0	6.9	0	10	0	5
9.52 – 6.25	0	1	0	1	0	0
Total						

Flakiness Index = 100%

3. Polyethylene Terephthalate

Flakiness Index of 100%

Elongation Test

4.1 Elongation Test for Gravel

Aperture Size (mm)	**Sample 1**		**Sample 2**		**Sample 3**	
	Weight Retained	Weight Passing	Weight Retained	Weight Passing	Weight Retained	Weight Passing
50 – 38.1	0	0	0	0	0	0
38.1 – 25.4	25	830	0	390	76	392
25.4 – 19.5	254	464	230	730	439	934
19.5 – 12.7	285	365	283	292	330	220
12.7 – 9.52	33	8	25	6	1	0
9.52 – 6.25	2	0	1	0	0	0
Total						

Elongation Index: (26.46% + 26.65% + 35.34%) / 3 = 29.48%

4.2 Elongation Test for Crushed Coconut Shell

Aperture Size (mm)	Sample 1		Sample 2		Sample 3	
	Weight Retained	Weight Passing	Weight Retained	Weight Passing	Weight Retained	Weight Passing
50 – 38.1	0	0	0	0	0	0
38.1 – 25.4	0	87	0	55	0	70
25.4 – 19.5	30	115	61	80	70	110
19.5 – 12.7	59	92	60	110	38	92
12.7 – 9.52	4	2	4	5	2	3
9.52 – 6.25	0.6	0.4	0	1	0	0
Total						

Elongation Index: (23.24% + 33.06%+ 28.42%) / 3 = 28.24%

4.3 Elongation Test for Polyethylene Terephthalate

Aperture Size (mm)	Sample 1		Sieve Analysis	
	Weight Retained	Weight Passing	Weight Retained	Weight Passing
50 – 38.1	0	0	0	0
38.1 – 25.4	0	0	0	0
25.4 – 19.5	0	0	0	0
19.5 – 12.7	5	4	10	35
12.7 – 9.52	15	5	15	20
9.52 – 6.25	13	7	20	0
Total				55

Elongation Index 60%

Summary of Results for Flakiness Test

5.1 Gravel

	Cumulative Weight Passing From Flakiness Test	Cumulative Weight Retained From Sieve Analysis	Flakiness Index (%)
Sample 1	574	2245	25.8
Sample 2	371	1950	16.57
Sample 3	428	2720	16.24
Average			19.54

5.2 CCS

	Cumulative Weight Passing From Flakiness Test	Cumulative Weight Retained From Sieve Analysis	Flakiness Index (%)
Sample 1	425	425	100
Sample 2	401	401	100
Sample 3	405	405	100
Average			100

Summary of Results for Elongation Test

6.1 Gravel

	Cumulative Weight Retained From Flakiness Test	Cumulative Weight Retained From Sieve Analysis	Elongation Index(%)
Sample 1	597	2245	26.46
Sample 2	538	1950	26.65
Sample 3	845	2720	35.34
Average			29.48

6.2 CCS

	Cumulative Weight Passing From Flakiness Test	Cumulative Weight Retained From Sieve Analysis	Elongation Index (%)
Sample 1	93	425	23.24
Sample 2	121	401	33.06
Sample 3	108	405	28.42
Average			28.24

APPENDIX D

Specific Gravity Test

Gas Jar + Water = P

Sample (Coarse Aggregate) = B

Gas Jar + Water + Coarse Aggregate = Ps

1. First Trial of Specific Gravity Test

	Gravel	CCS	PET	River Sand
Gas Jar + Water	2.12g	2.12g	2.12g	1.6g
Sample	1g	0.36g	0.33g	0.5g
Gas Jar + Water + Coarse Aggregate	2.75g	2.22g	2.2g	1.91g
Specific Gravity	2.70	1.38	1.32	2.64

2. Second Trial of Specific Gravity Test

	Gravel	CCS	PET	River Sand
Gas Jar + Water	2.12g	2.12g	2.12g	1.6g
Sample	1g	0.36g	0.33g	0.5g
Gas Jar + Water + Coarse Aggregate	2.75g	2.22g	2.2g	1.91g
Specific Gravity	2.71	1.38	1.33	2.64

3. Third Trial of Specific Gravity Test

	Gravel	CCS	PET	River Sand
Gas Jar + Water	2.12g	2.12g	2.12g	1.6g
Sample	1g	0.37g	0.34g	0.5g
Gas Jar + Water + Coarse Aggregate	2.75g	2.22g	2.2g	1.91g
Specific Gravity	2.69	1.37	1.31	2.64

4. Summary of Specific Gravity Results.

	Gravel	CCS	PET	River Sand
First trial	2.70	1.38	1.32	2.64
Second trial	2.71	1.38	1.33	2.64
Third trial	2.69	1.37	1.31	2.64
Average	2.70	1.38	1.32	2.64

APPENDIX E

Results of Aggregate Crushing Value and the Aggregate Impact Value and of the Coarse Aggregates Used in This Study.

1. Aggregate Crushing Value of Gravel, CCS and PET.

	Gravel	CCS	PET
Total Weight Of The Material	5kg	2.5kg	-
Left Over After Filling The Cylinder	3.5kg	1.1kg	-
Percentage Passing Sieve 2.36% After Crushing	0.42kg	0.032kg	-
ACV	8%	2.29%	Test Procedure Not Compatible With The Material.

2. Aggregate Impact Value of Gravel, CCS and PET.

	Gravel	CCS	PET
Total Weight Of The Material	500g	500g	500g
Left Over After Filling The Small Cylinder	165g	362g	436g
Percentage Passing Sieve 2.36% After Crushing	89g	5g	0.2g
AIV	26.57%	3.62%	0.3125%

APPENDIX F

Summary of Concrete Mix Design

Preliminary Requirements		M25	
Maximum slump		100mm	
Maximum aggregate size		25mm	
Maximum air content		1.5%	
Maximum water content		193 kg/m^3	
Water to cement ratio		0.43	
Batch mix			
1m^3 of concrete			
Water		193 kg	
Cement		449 kg	
Fine Aggregate		742 kg	
Coarse Aggregate	Gravel	100%	1152 kg
	CCS	100%	572 kg
	PET	100%	563 kg
21 cubes were cast per sample			
1 cube= 0.15 m× 0.15 m× 0.15 m= 0.003375 m^3× 21= 0.0709m^3			
15% allowance for wastage we have 0.0709 × 1.15 = 0.082 m^3			
For 21 cubes			
Water		15.8 kg	
Cement		36.8 kg	
Fine Aggregate		60.8 kg	
Coarse Aggregate	Gravel		94.46 kg
	CCS		46.90 kg
	PET		46.16 kg
Mix ratio		**1: 2 : 3**	

Batch Mix of Various Concrete Cubes

Sample	Batch Mix (Cement: F.A: C.A)				
	Cement	Sand	Coarse Aggregate		
			Gravel	PET	CCS
A	1	2	3	-	-
B	1	2	3	-	-
C	1	2	3	-	-
D	1	2	1.5	1.5	0
E	1	2	1.5	1.2	0.3
F	1	2	1.5	0.9	0.6
G	1	2	1.5	0.6	0.9
H	1	2	1.5	0.3	1.2
I	1	2	1.5	0	1.5

F: A = Fine Aggregate

C: A = Coarse Aggregate

Mix By Mass for Various Percentages

1. Mix of Coarse Aggregates for Concrete Mix A

Material A **100% Gravel, 0% PET, 0% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	94.46
Polyethylene Terephthalate	-
Crushed Coconut Shell	-
Fine Aggregate	60.8

2. **Mix of Coarse Aggregates for Concrete Mix B**

Material B **0% Gravel, 0% PET, 100% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	-
Polyethylene Terephthalate	-
Crushed Coconut Shell	46.90
Fine Aggregate	60.8

3. **Mix of Coarse Aggregates for Concrete Mix C**

Material C **0% Gravel, 100% PET, 0% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	-
Polyethylene Terephthalate	46.16
Crushed Coconut Shell	-
Fine Aggregate	60.8

4. **Mix of Coarse Aggregates for Concrete Mix D**

Material D **50% Gravel, 50% PET, 0% CCS**	**Mass (kg)**
Water	9.38
Cement	15.30
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	23.08
Crushed Coconut Shell	-
Fine Aggregate	60.8

5. **Mix of Coarse Aggregates for Concrete Mix E**

Material E **50% Gravel, 40% PET, 10% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	18.46
Crushed Coconut Shell	4.69
Fine Aggregate	60.8

6. **Mix of Coarse Aggregates for Concrete Mix F**

Material F	**Mass (kg)**

50% Gravel, 30% PET, 20% CCS	
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	13.85
Crushed Coconut Shell	9.38
Fine Aggregate	60.8

7. **Mix of Coarse Aggregates for Concrete Mix G**

Material G **50% Gravel, 20% PET, 30% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	9.23
Crushed Coconut Shell	14.07
Fine Aggregate	60.8

8. **Mix of Coarse Aggregates for Concrete Mix H**

Material H **50% Gravel, 10% PET, 40% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	4.62
Crushed Coconut Shell	18.76
Fine Aggregate	60.8

9. **Mix of Coarse Aggregates for Concrete Mix I**

Material I **50% Gravel, 0% PET, 50% CCS**	**Mass (kg)**
Water	15.8
Cement	36.8
Coarse Aggregate	
Gravel	47.23
Polyethylene Terephthalate	-
Crushed Coconut Shell	23.45
Fine Aggregate	60.8

APPENDIX G

Tests on Concrete

Mass of Concrete of the Concrete Cubes Made From the Different Concrete Mixes.

1. Mass of Concrete Cubes Made From Concrete Mix A

A	Mass (kg)			
	Days			
S/No	1	7	14	28
1	9.15	9.20		
2	9.0	9.10		
3	8.6	8.65		
4	8.4		8.5	
5	8.6		8.7	
6	8.4		8.5	
7	8.65			8.6
8	8.45			8.6
9	8.7			8.7
10	8.6			
11	8.6			
12	9.0			
Average	8.68	8.98	8.57	8.63

2. Mass of Concrete Cubes Made From Concrete Mix B

B	Mass (kg)			
	Days			
S/No	1	7	14	28
1	6.8	6.95		
2	7	7.15		
3	6.9		7.1	
4	7.05		7.2	
5	6.95			7.0
6	6.9			7.1
7	7.5			
8	7.4			
9	6.8			
10				
11				
12				
Average	7.03	7.05	7.15	7.05

3. Mass of Concrete Cubes Made From Concrete Mix C

C	Mass (kg)			
	Days			
S/No	1	7	14	28
1	5.2	5.85		
2	5.7		5.85	
3	5.7		5.9	
4	5.6		5.75	
5	5.4			
6	5.2			
7	5.1	5.4		
8	5.5	5.5		
9	5.7			5.85
10	5.8			5.9
11	5.8			5.9
12	5.75			
Average	5.54	5.58	5.83	5.88

4. Mass of Concrete Cubes Made From Concrete Mix D

D	Mass (kg)			
	Days			
S/No	1	7	14	28
1	7.5	7.6		
2	7.4	7.6		
3	7.5	7.6		
4	7.2		7.3	
5	7.3			
6	7.4			
7	6.8		6.9	
8	6.7		6.85	
9	6.5			6.6
10	6.6			6.7
11	7.0			7.1
12	7.0			
Average	7.08	7.6	7.02	6.8

5. Mass of Concrete Cubes Made From Concrete Mix E

E	Mass (kg)			
	Days			
S/No	1	7	14	28
1	7.5	7.8		
2	7.8	7.9		
3	7.4	7.7		
4	7.3		7.4	
5	7.4		7.5	
6	7.5		7.6	
7	7.9			8.1
8	7.2			7.4
9	7.35			7.45
10	7.65			
11	7.3			
12	7.75			
Average	7.50	7.8	7.5	7.65

6. Mass of Concrete Cubes Made From Concrete Mix F

F	Mass (kg)			
	Days			
S/No	1	7	14	28
1	7.7	7.80		
2	7.6	7.75		
3	7.75		7.9	
4	7.75		8.0	
5	7.65			7.75
6	7.4			7.6
7	7.3			
8	7.5			
9	7.9			8.1
10				
11				
12				
Average	7.62	7.78	7.95	7.82

7. Mass of Concrete Cubes Made From Concrete Mix G

G	Mass (kg)			
	Days			
S/No	1	7	14	28
1	6.9	7.25		
2	6.9	7.1		
3	7.1		7.2	
4	7.2		7.3	
5	7.1			7.15
6	7.1			7.2
7	6.7			6.9
8	6.9			
9	7.1			
10				
11				
12				
Average	7.0	7.18	7.25	7.08

8. Mass of Concrete Cubes Made From Concrete Mix H

H	Mass (kg)			
	Days			
S/No	1	7	14	28
1	6.9	7.0		
2	6.85	6.9		
3	6.7	6.85		
4	7.1		7.2	
5	7.35		7.5	
6	7.15		7.25	
7	7.1			7.2
8	7.1			7.2
9	7.0			7.1
10	7.3			
11	7.2			
12	7.2			
Average	7.08	6.92	7.32	7.17

9. Mass of Concrete Cubes Made From Concrete Mix I

I	**Mass (kg)**			
	Days			
S/No	1	7	14	28
1	8.3	8.4		
2	7.9	8.0		
3	7.4	7.5		
4	7.2		7.5	
5	7.4		7.6	
6	7.3		7.5	
7	8.1			8.2
8	7.1			7.2
9	7.7			7.8
10	7.4			
11	7.35			
12	7.6			
Average	7.56	7.97	7.53	7.73

APPENDIX H

Density of Concrete of the Concrete Cubes Made From the Different Concrete Mixes.

1. **Density of Concrete Cubes Made From Concrete Mix A**

A	**Density (kg/m^3)**			
	Days			
	1	7	14	28
1	2,711	2,725		
2	2,670	2,696		
3	2,551	2,563		
4	2,492		2,519	
5	2,551		2,578	
6	2,490		2,519	
7	2,563			2,551
8	2,504			2,551
9	2,578			2,578
Average	2,568	2,661	2,539	2,560

2. Density of Concrete Cubes Made From Concrete Mix B

B	**Density (kg/m^3)**			
	Days			
	1	7	14	28
1	2,015	2,059		
2	2,074	2,119		
3	2,044		2,103	
4	2,089		2,133	
5	2,059			2,074
6	2,055			2,103
7	2,222			
8	2,192			
9				
Average	2,094	2,089	2,103	2,089

3. Density of Concrete Cubes Made From Concrete Mix C

C	**Density (kg/m^3)**			
	Days			
	1	7	14	28
1	1,541	1,733		
2	1,689	1,733		
3	1,689	1,748		
4	1,659		1,703	
5	1,511		1,600	

6	1,629		1,629	
7	1,689			1,733
8	1,719			1,748
9	1,719			1,748
Average	1,649	1,738	1,644	1,743

4. Density of Concrete Cubes Made From Concrete Mix D

D	**Density (kg/m^3)**			
	Days			
	1	7	14	28
1	2,222	2,252		
2	2,193	2,252		
3	2,222	2,252		
4	2,133		2,162	
5	2,015		2,044	
6	1,985		2,030	
7	1,923			1,956
8	1,956			1,985
9	2,074			2,104
Average	2,080	2,252	2,079	2,015

5. Density of Concrete Cubes Made From Concrete Mix E

E	**Density (kg/m^3)**			
	Days			
	1	7	14	28
1	2,222	2,311		
2	2,311	2,341		
3	2,193	2,282		
4	2,163		2,193	
5	2,193		2,222	
6	2,222		2,252	
7	2,341			2,400
8	2,133			2,193
9	2,178			2,208
Average	2,217	2,311	2,222	2,267

6. Density of Concrete Cubes Made From Concrete Mix F

F	Density (kg/m³)			
	Days			
	1	7	14	28
1	2,281	2,311		
2	2,252	2,296		
3	2,296		2,341	
4	2,296		2,370	
5	2,267			2,296
6	2,193			2,252
7	2,341			2,400
8				
9				
Average	2,275	2,304	2,356	2,316

7. Density of Concrete Cubes Made From Concrete Mix G

G	Density (kg/m³)			
	Days			
	1	7	14	28
1	2,044	2,148		
2	2,044	2,104		
3	2,104		2,133	
4	2,133		2,163	
5	2,104			2,119
6	2,104			2,133
7	1,985			2,044
8	2,044			
9				
Average	2,070	2,126	2,148	2,099

8. Density of Concrete Cubes Made From Concrete Mix H

H	Density (kg/m^3)			
	Days			
	1	7	14	28
1	2,044	2,074		
2	2,030	2,044		
3	1,985	2,030		
4	2,103		2,133	
5	2,178		2,222	
6	2,185		2,148	
7	2,104			2,133
8	2,104			2,133
9	2,074			2,103
Average	2,090	2,049	2,168	2,123

9. Density of Concrete Cubes Made From Concrete Mix I

I	Density (kg/m^3)			
	Days			
	1	7	14	28
1	2,459	2,489		
2	2,341	2,370		
3	2,193	2,222		
4	2,133		2,222	
5	2,193		2,252	
6	2,163		2,222	
7	2,400			2,429
8	2,103			2,133
9	2,281			2,311
Average	2,252	2,360	2,252	2,291

APPENDIX I

Crushing Load of the Concrete Cubes Made From the Different Concrete Mixes.

1. Crushing Load of Concrete Cubes Made From Concrete Mix A

A	**Load At Failure (kN)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	236	407	441	518	547	556	538
Sample 2	250	403	484	448	468	513	573
Sample 3	243	378	432	540	578	551	542
Average	243	396	450	500	531	540	551

2. Crushing Load of Concrete Cubes Made From Concrete Mix B

B	**Load At Failure (kN)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	110	140	205	261	367	380	405
Sample 2	115	124	200	243	382	389	387
Sample 3	92	135	223	259	378	378	403
Average	106	133	209	254	376	383	398

3. Crushing Load of Concrete Cubes Made From Concrete Mix C

C	**Load At Failure (kN)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	68	110	124	137	146	153	164
Sample 2	56	94.5	110	119	131	137	155
Sample 3	65	106	117	128	135	142	153
Average	63	104	117	128	137	144	158

4. Crushing Load of Concrete Cubes Made From Concrete Mix D

D	**Load At Failure (kN)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	137	203	248	234	258	306	382
Sample 2	155	184	222	254	243	319	355
Sample 3	153	200	238	247	254	306	369
Average	148	195	236	245	252	310	369

5. Crushing Load of Concrete Cubes Made From Concrete Mix E

E	Load At Failure (kN)						
	Days						
	1	2	3	4	7	14	28
Sample 1	130	209	263	290	360	342	384
Sample 2	144	198	243	243	330	339	355
Sample 3	150	213	263	297	335	384	360
Average	141	207	256	276	342	355	366

6. Crushing Load of Concrete Cubes Made From Concrete Mix F

F	Load At Failure (kN)						
	Days						
	1	2	3	4	7	14	28
Sample 1	132	189	267	312	326	366	425
Sample 2	141	204	290	290	333	382	409
Sample 3	117	180	306	303	333	391	407
Average	130	191	270	301	330	380	414

7. Crushing Load of Concrete Cubes Made From Concrete Mix G

G	Load At Failure (kN)						
	Days						
	1	2	3	4	7	14	28
Sample 1	166	189	258	297	315	362	425
Sample 2	155	207	276	290	326	387	409
Sample 3	177	204	274	337	330	391	407
Average	166	200	270	308	324	380	414

8. Crushing Load of Concrete Cubes Made From Concrete Mix H

H	Load At Failure (kN)						
	Days						
	1	2	3	4	7	14	28
Sample 1	63	141	175	207	222	279	330
Sample 2	87	110	202	195	175	292	337
Sample 3	65	132	195	211	249	319	337
Average	72	128	191	204	216	297	335

9. Crushing Load of Concrete Cubes Made From Concrete Mix I

I	**Load At Failure (kN)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	90	126	128	164	245	263	310
Sample 2	72	85	110	150	220	245	416
Sample 3	74	132	146	164	236	254	366
Average	78	114	128	159	234	254	364

APPENDIX J

Compressive Strength of the Concrete Cubes Made From the Different Concrete Mixes.

Compressive Strength = $\frac{load}{area}$

Surface Area of Concrete Cubes = $length \times breadth$

Size of Concrete Cube 150mm by 150mm by 150mm

Surface Area = 0.15m × 0.15m = 0.0225 m^2

Compressive Strength = $\left(\frac{load}{0.0225} \times \frac{1}{1000}\right)$kN/$m^2$

1. Compressive Strength of Concrete Cubes Made From Concrete Mix A

A	**Compressive Strength (N/mm^2)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	10.5	18.1	19.6	23.0	24.3	24.7	23.9
Sample 2	11.1	17.9	21.2	19.9	20.8	22.8	25.5
Sample 3	10.8	16.8	19.2	24.0	25.7	24.5	14.1
Average	10.8	17.6	20.0	22.2	23.6	24.0	24.5

2. Compressive Strength of Concrete Cubes Made From Concrete Mix B

B	**Compressive Strength (N/mm^2)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	4.9	6.2	9.1	11.6	16.3	16.9	18.0
Sample 2	5.1	5.5	8.9	10.8	17.0	17.3	17.2
Sample 3	4.1	6.0	9.9	11.5	16.8	16.8	17.9
Average	4.7	5.9	9.3	11.3	16.7	17.0	17.7

3. Compressive Strength of Concrete Cubes Made From Concrete Mix C

C	**Compressive Strength (N/mm^2)**						
	Days						
	1	2	3	4	7	14	28
Sample 1	3.0	4.9	5.5	6.1	6.5	6.8	7.3
Sample 2	2.5	4.2	4.9	5.3	5.8	6.1	6.9
Sample 3	2.9	4.7	5.2	5.7	6.0	6.3	6.8
Average	2.8	4.6	5.2	5.7	6.1	6.4	7.0

4. Compressive Strength of Concrete Cubes Made From Concrete Mix D

D	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	6.1	9.0	11.0	10.4	11.5	13.6	17.0
Sample 2	6.9	8.2	9.9	11.3	10.8	14.2	15.8
Sample 3	6.8	8.9	10.6	11.0	11.3	13.6	16.4
Average	6.6	8.7	10.5	10.9	11.2	13.8	16.4

5. Compressive Strength of Concrete Cubes Made From Concrete Mix E

E	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	5.8	9.3	11.7	12.9	16.0	15.2	17.1
Sample 2	6.4	8.8	10.8	10.8	14.7	15.1	15.8
Sample 3	6.7	9.5	11.7	13.2	14.9	17.1	16.0
Average	6.3	9.2	11.4	12.3	15.2	15.8	16.3

6. Compressive Strength of Concrete Cubes Made From Concrete Mix F

F	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	5.9	8.4	11.9	13.8	14.5	16.3	18.9
Sample 2	6.3	9.1	12.9	12.9	14.8	17.0	18.2
Sample 3	5.2	8.0	13.6	13.5	14.8	17.4	18.1
Average	5.8	8.5	12.8	13.4	14.7	16.9	18.4

7. Compressive Strength of Concrete Cubes Made From Concrete Mix G

G	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	7.4	8.4	11.5	13.2	14.0	16.1	18.9
Sample 2	6.9	9.2	12.3	12.9	14.5	17.2	18.2
Sample 3	7.9	9.1	12.2	15.0	14.7	17.4	18.1
Average	7.4	8.9	12.0	13.7	14.4	16.9	18.4

8. Compressive Strength of Concrete Cubes Made From Concrete Mix H

H	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	2.8	6.3	7.8	9.2	9.9	12.4	14.7
Sample 2	3.9	4.9	9.0	8.7	7.8	13.0	15.0
Sample 3	2.9	5.9	8.7	9.4	11.1	14.2	15.0
Average	3.2	5.7	8.5	9.1	9.6	13.2	14.9

9. Compressive Strength of Concrete Cubes Made From Concrete Mix I

I	Compressive Strength (N/mm^2)						
	Days						
	1	2	3	4	7	14	28
Sample 1	4.0	5.6	5.7	7.3	10.9	11.7	13.8
Sample 2	3.2	3.8	4.9	6.7	9.8	10.9	18.5
Sample 3	3.3	5.9	6.5	7.3	10.5	11.3	16.3
Average	3.5	5.1	5.7	7.1	10.4	11.3	16.2

APPENDIX K

Water Absorption Test of the Concrete Cubes Made From the Different Concrete Mixes.

Let:

M1 be the mass of specimen before oven drying.

M2 be the mass of the specimen after oven drying.

M3= M1-M2

Absorption = $\left({}^{M3}/_{M1} \times 100\right)\%$

1. Water Absorption Test of Concrete Cubes Made From Concrete Mix A

A	M1 (kg)	M2 (kg)	M3 (kg)	Absorption (%)
1	6.8	7.1	0.3	4.41
2	6.2	6.6	0.4	6.45
3	7.15	7.35	0.2	2.7
Average				4.52

2. Water Absorption Test of Concrete Cubes Made From Concrete Mix B

B	M1 (kg)	M2 (kg)	M3 (kg)	Absorption (%)
1	8.25	8.4	0.15	1.82
2	8.90	9.0	0.1	1.12
3	8.20	8.40	0.2	2.43
Average				1.79

3. Water Absorption Test of Concrete Cubes Made From Concrete Mix C

C	M1 (kg)	M2 (kg)	M3 (kg)	Absorption (%)
1	5.2	5.9	0.7	13.46
2	5.2	5.8	0.6	11.54
3	5.15	5.85	0.7	13.59
Average				12.86

4. Water Absorption Test of Concrete Cubes Made From Concrete Mix D

D	M1 (kg)	M2 (kg)	M3 (kg)	Absorption (%)
1	6.5	6.9	0.4	6.15
2	6.8	7.15	0.35	5.15

3	6.95	7.3	0.35	5.04
Average				5.45

5. Water Absorption Test of Concrete Cubes Made From Concrete Mix E

E	**M1 (kg)**	**M2 (kg)**	**M3 (kg)**	**Absorption (%)**
1	7.3	7.55	0.26	3.44
2	7.25	7.5		3.43
3				
Average				3.43

6. Water Absorption Test of Concrete Cubes Made From Concrete Mix F

F	**M1 (kg)**	**M2 (kg)**	**M3 (kg)**	**Absorption (%)**
1	6.8	7.1	0.3	4.40
2	7.0	7.25	0.25	3.57
3				
Average				3.99

7. Water Absorption Test of Concrete Cubes Made From Concrete Mix G

G	**M1 (kg)**	**M2 (kg)**	**M3 (kg)**	**Absorption (%)**
1	6.7	7.0	0.30	4.48
2	6.7	7.0	0.30	4.48
3				
Average				4.48

8. Water Absorption Test of Concrete Cubes Made From Concrete Mix H

H	**M1 (kg)**	**M2 (kg)**	**M3 (kg)**	**Absorption (%)**
1	6.5	6.85	0.35	5.40
2	6.8	7.1	0.3	4.40
3				
Average				4.90

9. Water Absorption Test of Concrete Cubes Made From Concrete Mix I

I	**M1 (kg)**	**M2 (kg)**	**M3 (kg)**	**Absorption (%)**
1	6.9	7.3	0.4	5.80
2	7.1	7.5	0.4	5.63
3				
Average				5.72