

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI
DEPARTMENT OF CHEMISTRY**



**TITLE: THE USE OF LOW LINEAR DENSITY POLYETHYLENE IN THE
PRODUCTION OF LLDPE-SAND-STONE COMPOSITES.**

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FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF
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BY

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DECLARATION

I hereby declare that this thesis submitted to the Department of Chemistry, is the result of my own work towards the MPhil degree in Polymer Science and Technology and to the best of my knowledge, it neither contains any material previously published by another person nor material which has been accepted for the award of any other degree or diploma at any institution or University, except where due acknowledgement has been made in the text.

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ABSTRACT

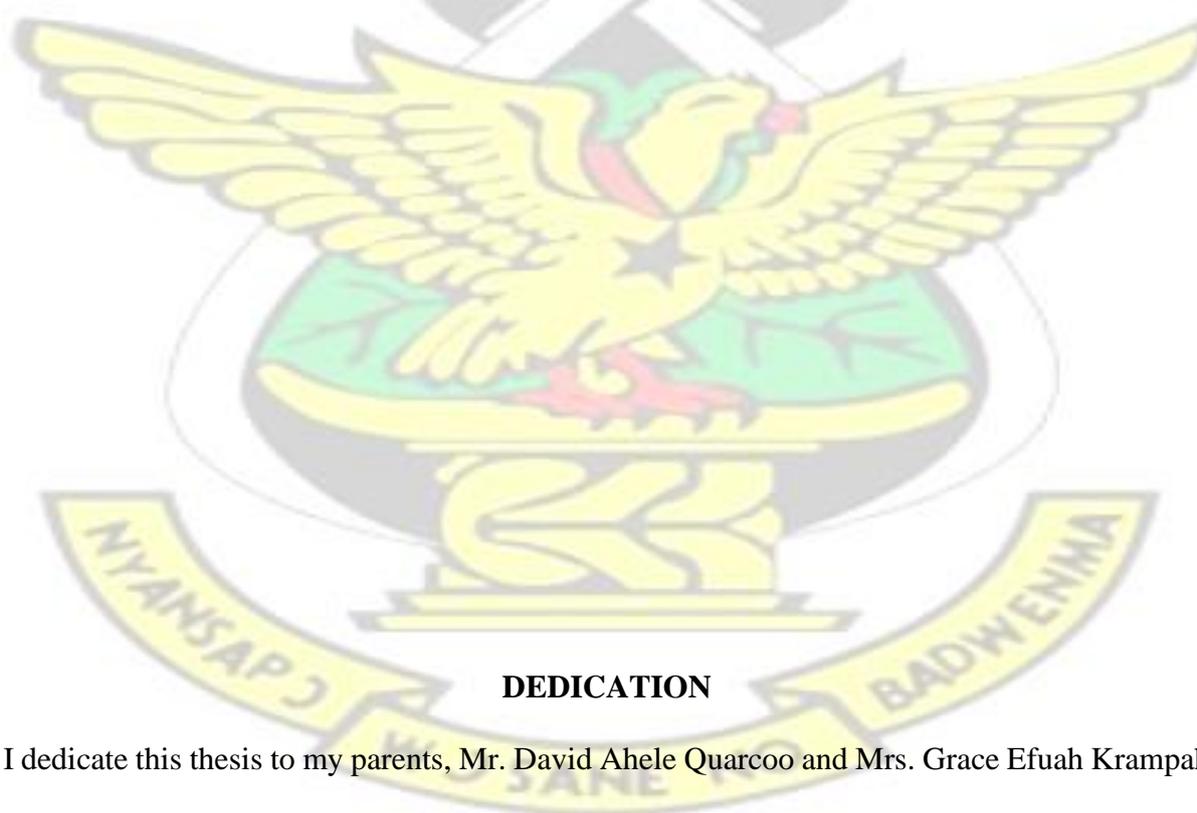
The efficient management of plastic wastes is a great challenge for most developing countries. This study examined the effect of melt blending a waste low linear density polyethylene film popularly called “sachet water” into sand and granite and forming a composite of different ratios. The polymeric material was shredded and melted in an aluminium pot at a temperature range of 110 °C - 120 °C and added to granite and sand in ratios of 9 %, 12.5 %, 14 %, 25 % and 28.5%. Studies involved determining the effect of sulphuric acid, water and sodium carbonate on the composite material. The mechanical properties determined were the compressive strength on the composite materials produced. The impact strength was also determined on the composite material. FTIR analyses were carried out on all the initial compounds used and the final composite product formed. The compressive strength of the composite block increased as the weight of the polymeric material was increased. As the ratios of the polymeric material was increased in the composite from 9 % to 25 %, the compressive strength of the polymeric composite increased for both 7 days and 28 days. The most compatible and suitable composite material produced was at 25 % loading of the polymeric material and at 28.5 % loading of the polymeric material the compressive strength reduced from the maximum peak. The composite material had maximum impact strength of 80.442J.

The use of waste LLDPE films carries the advantage and cheap means of using it in lightweight construction works and is an alternative way to utilize plastic waste

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DEDICATION

I dedicate this thesis to my parents, Mr. David Ahele Quarcoo and Mrs. Grace Efuah Krampah Aduku Quarcoo; to my Pastor, Reverend Stephen Yaw Darko and to my beautiful wife, Mrs. Wilhemina Afia Owusuaa Quarcoo and to each and every person who has offered me advice, love, care and support throughout this programme.

I love you all.

KNUST



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LIST OF ABBREVIATIONS

WHO.....World Health Organization

UNEP.....United Nations Environmental Programme

FTIR.....Fourier Transform Infra-Red

EPDM.....Ethylene Propylene Diene Monomer

ASTM.....American Society for Testing and Materials



CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The Seventh Millennium Development Goal “Ensure Environmental Sustainability” is among other incentives set to reduce the number of people in the world who do not have access to basic sanitation by half in the year 2015. Basic sanitation refers to the lowest-cost technology that can certify safe and hygienic excreta removal and a healthy environment (WHO, 2009).

In some parts of the developing world, solid waste management is considered part of the sanitation issue. In countries where a functioning waste management system already exists the term sanitation involves mainly waste water and human excreta, not solid waste.

The reason for the different terminology lies, at least partly, in the fact that when solid waste is not being taken care of but dumped in rivers and on other places or burning or incinerating leads to sanitary problems. Sanitation plays a great part in the development of a country since it affects all sectors of the economy. (Revised Environmental Sanitation Policy, 2007)

Numerous waste materials generated from manufacturing processes, service industries and municipalities are increasingly becoming an environmental concern in most developing countries in Africa as far as the disposal of these waste materials is concerned.

The amount of solid waste is ever increasing due to increase in human population, developmental activities, and changes in lifestyle and socio- economic conditions. Plastic waste is a significant portion of the total municipal solid waste. Consumption of plastic products has increased dramatically over the past few decades. (Achilias *et al.*, 2008)

Solid waste management is one of the major environmental concerns in the world. Landfills are becoming scarce and the cost in building landfill sites are increasing. As a result of this, waste utilization has become an attractive utilization to disposal of waste materials. (Siddique *et al.*, 2008)

The purpose of waste management is to reduce the effects of the wastes on the environment and human health, as well as recapture resources from the waste (Zurbrugg, 2002). Waste management methods vary a lot between developed and developing countries, and also for urban and rural areas. In urban areas, it gets more urgent to manage the produced waste when societies grow and space gets more limited. Solid waste dumped indiscriminately lead to spreading of diseases, unpleasant odors, pollution of soil and water. Incinerated waste containing plastics releases carbon dioxide to the atmosphere and contributes to climate change. (Wikner, 2009)

Plastic is one of the most useful materials. However, after food and paper waste, plastic waste is the third major constituent in municipal and industrial waste. (UNEP, 2009) The production of more plastic waste is mainly due to increased use of plastic packaging materials, in the form of plastic shopping bags and polyethylene terephthalate (PET) bottles. Fortunately, plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in an environmentally friendly way. In most of the situations, plastic waste recycling could also be economically viable, as it generates resources, which are in high demand. Plastic waste recycling also has a great potential for resource conservation and greenhouse gas (GHG) emission reduction. Some developed countries have already established commercial level resource recovery from waste plastics (UNEP, 2009).

For well over a decade now, Ghana is still grappling with the proper disposal and management of its Municipal Solid Waste (MSW), especially plastic waste. Over the years, traditional waste

disposal techniques including land filling and open air combustion have been rendered incapable of dealing with the ever increasing volumes of plastic waste generated in the various municipalities and urban centres. Waste plastics choke gutters, rivers and fill beaches and roadsides.

The absence of efficient solid waste management and disposal methods is not peculiar to Ghana only, but many other developing countries as well. In several African countries, including, South Africa, Mauritania, Rwanda, Kenya and Uganda, the frustration and difficulties associated with the use and proper disposal of plastics have culminated in the adoption of very strict state laws which completely ban the use of plastic carrier bags or impose higher levies on plastic importers (Bashir, 2013).

Some limited studies have been reported on the use of recycled plastic, mainly polyethylene, in the manufacture of polymer-modified bitumen or asphalt cement. For instance, some researchers have reported that, the use of recycled polyethylene from shopping bags is useful in asphaltic (bituminous) construction and yields pavement structure which showed reduced permanent deformation in the form of rutting and reduced low-temperature cracking (Vasudevan *et. al*, 2012; Noor, *et. al*, 2011).

Waste plastics, mainly used for packaging are made up of Polyethylene (PE), Polypropylene (PP) and Polystyrene (PS). Their softening points vary between 110°C and 140°C and do not produce any toxic gases during processing. The process of modifying bitumen with plastics promotes value addition to the waste plastics and helps to dispose of them through an ecofriendly recycling strategy.

1.2 Problem Statement and Hypothesis

Many parts of the world face serious problems of managing the generation and disposal of plastic wastes (Katchy, 2000; Charrier, 1990; Bhatnagar, 2004; Gruenwald, 1992; Hensen, 1997; Piringer & Baner, 2008; Allcock *et al.*, 2003). Ghana as a nation is still grappling with the problem of managing its plastic waste. This is as a result of the poor attitude of Ghanaians towards proper disposal of plastic waste. This causes serious environmental challenges with its attendant health challenges. The government recently considered putting a ban on plastic products. The metropolitan area of Kumasi generates about 1 100 ton of solid waste per day. (Wikner, 2009) It is assumed that 70 % of the waste produced is collected. (Wikner, 2009) The rest of the solid waste is indiscriminately dumped in rivers or drainage systems or burned. (Wikner, 2009)

Composite materials comprising of waste plastics and aggregates need to be developed to solve the problem of plastic waste.

1.3 Main Objective

The aim of this study is to prepare a polymer composite with low linear density polyethylene specifically “sachet water bags” by melting together with sand and granite.

1.4 Specific Objectives

- To determine the chemical and mechanical properties of initial and final products by using different tests including FTIR, compressive tests, impact tests, effect of acid, effect of base and effect of water.
- Review potential techniques for preparing low linear density polyethylene composites as a waste management strategy

- Establish the suitability of using the polyethylene as a binder for concrete works in place of cement.

1.5 Justification

In a work carried out by Osei Bonsu (2013) it was shown that the various percentages of plastic waste generated at Independence Hall at KNUST were as follows:

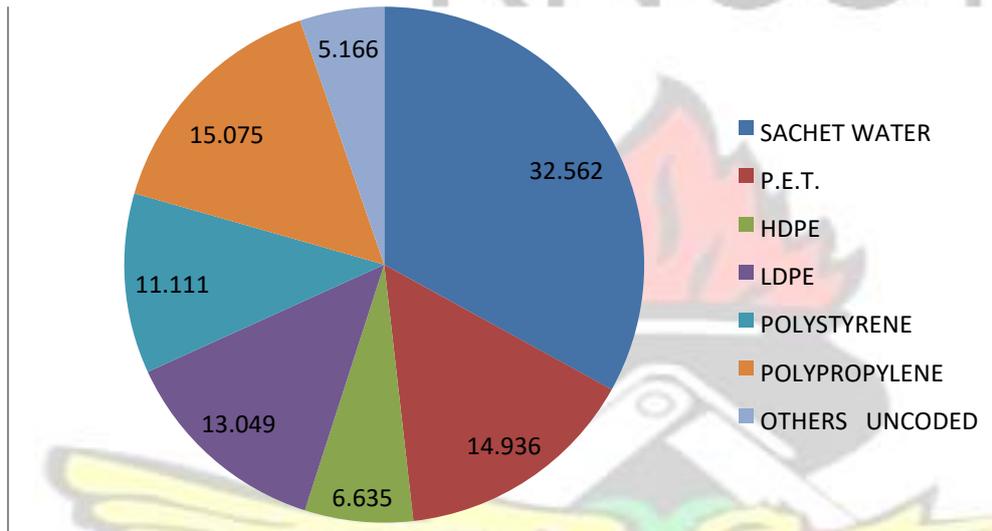


Fig 1.1 Percentage of waste plastics generated at Independence Hall, KNUST Kumasi (Osei Bonsu Eric, 2013)

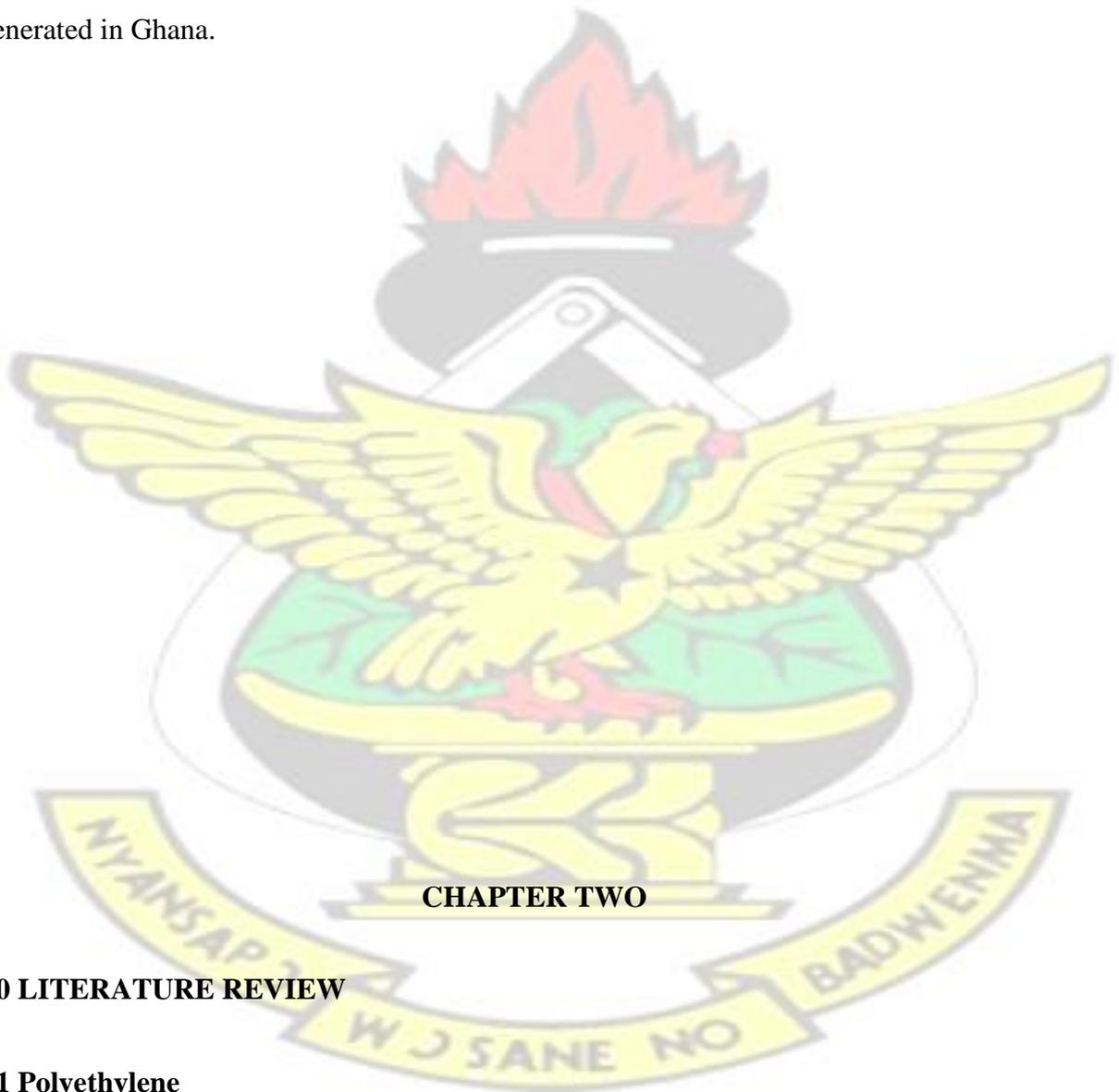
It can be seen that waste generated from sachet was the highest. From this work, it can be extrapolated that the highest amount of plastic waste generated in Ghana comes from polyethylene water sachet which is causing an environmental nuisance which has caused the government of Ghana to consider banning the use of polyethylene in the country.

Some research work has been carried out and proven possible to modify concrete materials with plastic products like polyethylene with specific reference to polyethylene water sachet. In Ghana, the polyethylene or polyethylene bags are one major cause of environmental pollution.

Research is being carried out on the utilization of waste products like discarded tires, plastic, glass, steel, burnt foundry sand and coal combustion by products in concrete production.

The use of waste products in concrete not only makes it economical but also helps in reducing disposal problems. Efforts have been made to explore the use of plastic in concrete and asphalt concrete. The development of new construction materials using recycled plastics is important to both the construction and the plastic recycling industries. (Siddique *et al.*, 2008)

It is imperative therefore to find a way of preparing composites with low linear density polyethylene film specifically the sachet water bag films to reduce the volumes of plastic waste generated in Ghana.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Polyethylene

In its simplest form a polyethylene molecule consists of a long backbone of an even number of covalently linked carbon atoms with a pair of hydrogen atoms attached to each carbon; chain

ends are terminated by methyl groups. Typically, the degree of polymerization is well in excess of 100 and can be as high as 250,000 or more, equating to molecular weights varying from 1400 to more than 3,500,000.

Polyethylene is created through polymerization of ethene. It can be produced through free radical polymerization, anionic addition polymerization, ion co-ordination polymerization or cationic addition polymerization. This is because ethene does not have any substituent groups which influence the stability of the propagation head of the polymer. Each of these methods results in a different type of polyethylene. The process requires a highly purified ethylene feed and the operating pressure ranges from 1000 to 3000 atm and a temperature range of 120-3000°C. Temperatures exceeding 3000°C cause ethylene to decompose and are not recommended in practice (Dhib, 2002).

Polyethylenes as contained in pure water sachet are low linear density polyethylene materials which have as a result of their being cheap and convenient, have become more popular in West Africa. On the average, Ghanaians drink 2 sachets of water every day. The material polyethylene is a non-biodegradable material. Some of the properties of polyethylene as contained in pure water sachet include:

- coagulating on heat application whilst flowing in a solvent and heat
- good transparency and being colourless at very low temperature
- melting at a temperature of 115°C
- retention of its toughness and pliability over a wide temperature range
- flexible even before heat is applied
- not hard as a result of the irregular packing of the polymer chains
- Insoluble in most solvents but soluble on heat application in some solvents
- Low adhesive property

[Source: Shell Bitumen Handbook (1990)]

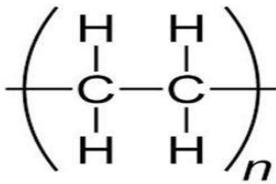


Fig. 2.1 Structure Of Polyethylene

2.1.1 Types of Polyethylene

Polyethylene is classified into several different categories based mostly on the density and the branching. Its mechanical properties depend significantly on variables such as the extent and type of branching, the crystal structure and the molecular weight. With regard to volumes, the most important polyethylene grades are high density polyethylene (HDPE), low linear density polyethylene (LLDPE) and low density polyethylene (LDPE).

2.1.1.1 High Density Polyethylene

It is made from petroleum and it has a large strength to density ratio. It has little branching giving it a stronger intermolecular force and tensile strength than LDPE. It is harder and can withstand higher temperatures. It is commonly used in the production of plastic bottles. It is the third largest commodity plastic material in the world after poly vinyl chloride and polypropylene in terms of volume. It is a thermoplastic material composed of carbon and hydrogen atoms joined together forming high molecular weight products. (Kumar and Singh, 2013)

2.1.1.2 Low Density Polyethylene

Low density polyethylene is a thermoplastic made from the monomer ethylene. It is quite flexible and tough but breakable. It can withstand temperatures of 80°C continuously and 95°C for a short time. It has more branching than HDPE thereby giving it weaker

intermolecular forces. It has a lower tensile strength and higher resilience. Its density is lower as a result of the less tightly packed molecules and less crystalline molecules because of the side branches. Low density polyethylene is so named because such polymers contain substantial concentrations of branches that hinder the crystallization process, resulting in relatively low densities. The numerous branches characteristic of low density polyethylene molecules inhibit their ability to crystallize, reducing their resin density relative to high density polyethylene. (Peacock, 2000)

2.1.1.3 Works done with Polyethylene

Punith and Veeraragavan (2007) studied the behaviour of asphalt concrete mixtures with reclaimed polyethylene as additive. They found out that the performance of polyethylene modified asphalt mixtures is better when compared to conventional mixtures.

Panda and Mazumdar (2002) researched on the utilization of reclaimed polyethylene in bituminous paving mixes. They found out that the Marshall stability, resilient modulus, fatigue life and moisture susceptibility of mixes were improved as a result of modifying asphalt cement with reclaimed polyethylene.

Navarro *et al.*, (2010) studied the effect of ground tire rubber and recycled polyethylene on the thermal and rheological properties of modified bitumen blends. They found out that the combination of both recycled polymers greatly enhanced the mechanical properties of the bitumen thermo rheological behaviour. From an environmental point of view they concluded that the use of both ground tire rubber and recycled polyethylene may contribute to solve a waste disposal problem and improve the quality of the resulting blends for roofing and waterproofing applications.

2.1.1.4 A Brief History of “Sachet”

In the 1970s and 1980s, it was common to be able to buy a cup of drinking water on the streets by drinking directly from a metal cup or plastic cup. The vendor normally scooped the water out of a larger storage vessel. Increased demand coupled with obvious sanitary shortcomings of such a system led to the packaging of water in small plastic bags in the 1990s. (Olayemi (1999), Obiri Danso *et al* (2003). In the late 1990s, new Chinese machinery that heat sealed water in a plastic sleeve effectively created the modern polyethylene that is currently sold on the streets of several West African nations.

The advent and rapid spread of polyethylene drinking water in West Africa presents a new challenge for providing sustainable access to global safe water. According to Stoler (2012) polyethylene water sachets are an unsustainable water delivery vehicle due to their overwhelming plastic waste burden. The discarded plastic sleeves have become a sanitation menace in many cities. Plastic polyethylene wrappers litter the streets and clog drains and gutters in the rainy season, increasing the likelihoods of floods and leading to subsequent public exposure to untreated sewage and a mélange of health risks. Stoler concludes that without renewed commitments to plastic recycling there will be no prognosis to how polyethylene water sachets will improve sustainable access to safe drinking water. The popularity of polyethylene in the packaging industry of the years is due to its favourable strength and thermal properties as well as its ease in recycling into other types of plastic.

2.1.1.5 Works done with Polyethylene Water Sachet (PWS)

Akinpelu *et al.*, (2013) investigated the effects of polyethylene modified bitumen on the properties of hot mix asphalt. The polyethylene was added in a grinded state as a binder modifier. The polyethylene was introduced to the mixture by melting it in bitumen used in preparing asphalt concrete mix. They found out that the modifier increases the stability, reduces the density and slightly reduces the flow of the asphalt concrete. Again, the polyethylene

modifiers offers better engineering properties and its usage as a bitumen modifier could serve as a means of managing the waste menace.

Bamidele *et al.*, (2013) conducted work on pure water polyethylene modified bitumen. In their work, they found out that Polyethylene Water Sachet influences more on the penetration of the modified sample with the increase in the viscosity of the bitumen.

Olukorede and Kehinde (2012) conducted work by replacing polyethylene water sachet with bitumen. They found out that when polyethylene water sachet is replaced with bitumen, the resistance to permanent deformation, fatigue cracking and cohesion of the modified bitumen is enhanced.

Raji *et al.*, (2009) partially replaced cement with polyethylene water sachet. They found out that as the percentage of polyethylene water sachet was being increased, the weight of the molded cubes as well as the compressive strength of the molded cube decreased. In effect, the greater the percentage of the polyethylene water sachet used, the lower the weight of the block and the lower the compressive strength.

Raji *et al.*, (2009) also studied the effect of reprocessed polyethylene water sachet on the strength and permeability of laterized concrete. They found out that replacing part of the cement with the reprocessed PWS enhances the compressive strength of the laterized concrete from 2% polyethylene water sachet up to 8% polyethylene water sachet content before it dropped.

Ohemeng *et al.*, (2014) studied the feasibility of using low linear density polyethylene as partial replacement for sand in the production of concrete pavement blocks. The plastic material was ground and used together with cement, sand and coarse aggregate in a mix proportion of 1:1.5:3(cement, sand, coarse aggregate). It was observed that as the plastic content increased,

the density, compressive strength, flexural strength and splitting tensile strength decreased. From this work it was noted that compressive strengths of 20 N/mm², 30 N/mm² and 40 N/mm² are satisfactory for pedestrian walkways, light traffic and heavy traffic situations respectively.

Akinyele and Olatomide (2014) studied the structural response of heated polymer which is polyethylene bag known as “polyethylene”. They found out that polyethylene (polymer) rod could be a very good substitute in slender concrete structures like façade because of its low crack width, non-corrosive nature and its low thermal conductivity

Adogbo and Yusuf (2013) researched on how waste polyethylene sachet can be processed for thread applications. Their results showed that waste polyethylene sachets can be used to make threads.

Bello *et al.*, (2014) investigated the strength properties of a polymer concrete using reprocessed Pure Water Polyethylene (PWS) as a binder and sharp sand as aggregate for possible replacement for conventional cement concrete in some areas of application.

In their work they mixed reprocessed PWS with sand in different polymer-aggregate percentage replacements by volume (50%-50%, 60%-40%, 70%-30%, and 80%-20%).

They concluded in their work that modifying cement formulations with polymers provides many important properties that make a variety of applications possible, including concrete patch and repair, decorative cement overlays, ceramic tile adhesives, and many others.

2.1.1.6 Polymer Concrete

Concretes in which the continuous phase is some kind of polymeric resin and the dispersed phase is some type of mineral aggregate are known as Polymer concrete. This is a composite material in which the binder consists entirely of a synthetic organic polymer. According to

Bedi *et al.*, (2013) polymer concrete have suitable properties like high compressive strength, fast curing, high specific strength and resistance to chemical attacks. They have therefore found useful applications in thin overlays and floors.

2.1.1.7 Works on Polymer Concrete using Polyethylene and Polyethylene terephthalate

Hinisliogle and Agar (2004) studied the use of waste high density polyethylene as a bitumen modifier in asphalt concrete mix. They concluded that the HDPE modified asphalt concrete results in a considerable increase in the Marshall Stability (strength) value and Marshall Quotient value which is the resistance to deformation. From the work, it was realized that waste HDPE-modified bituminous binders provide better resistance against permanent deformations due to their high stability and high Marshall Quotient and it contributes to recirculation of plastic wastes as well as to protection of the environment.

Yazoghli *et al.*, (2007) in their study of the valorization of post-consumer waste plastic in cementitious concrete composites used PET bottles as partial and complete substitutes for sand in concrete composites. The work showed that substituting sand at a level below 50% by volume with granulated PET, whose upper granular limit equals 5mm, affects neither the compressive strength nor the flexural strength of composites. They concluded that plastic bottles shredded into small PET particles may be successfully used as sand substitution aggregates in cementitious concrete composites which are low cost materials with consistent properties. These would also help in solving some of the solid waste problems.

Zainab and Al Hashmi (2008) studied the use of waste plastic in concrete mixture as aggregate replacement. Their study concluded that reusing waste plastic as a sand substitution aggregate in concrete gives a good approach to reduce the cost of materials and solves some of the solid waste problems posed by plastics.

Gonzalez *et al.*, (2002) studied the rheological techniques used in analyzing polymer- bitumen interactions. The polymers used were HDPE and LDPE blends with ethylene/propylene/ethylidene norbornene. They concluded that above 30°C, the dynamic functions decrease as HDPE / bitumen > HDPE-EPDM / bitumen > LDPE-EPDM / bitumen > EPDM / bitumen > LDPE / bitumen > bitumen.

Perez Lepe *et al.*, (2005) studied the influence of Polymer concentration on the microstructure and rheological properties of HDPE modified bitumen. They concluded that the addition of HDPE to bitumen enhances the mechanical properties of binders, especially in the high temperature region where pavements can be submitted to permanent deformation. The addition of 3% HDPE to bitumen is able to readily modify the structure of the binder, by forming a gel type polymer structure dispersed within the bituminous matrix, providing it with enhanced elastic properties.

A.I. Hadidy and Tan Yi-qiu (2009) studied the effect of polyethylene on life of flexible pavements. They looked at the potential use of LDPE as a modifier for asphalt paving materials. Their results showed that modified binders show higher softening points, which keep the values of ductility at a minimum range of specification and this causes a reduction in percentage loss of weight due to heat and air. Again they stated that the inclusion of LDPE in stone matrix asphalt mixtures can satisfy the performance requirement of high temperature, low temperature and much rain zone.

2.1.1.8 Works on other Polymers and Concrete

Tawfik and Eskander (2006) synthesized polymer concrete by mixing styrenated polyester (SP) and marble wastes as fillers. The unsaturated polyester (UP) used was prepared from the reaction of oligomers obtained from the depolymerization of polyethylene terephthalate (PET) soft drink bottles with maleic anhydride and adipic acid.

Perry *et al.*, (1991) researched on the mix and material behaviour of beaded polystyrene aggregate concrete. They varied the strength and density of the concrete by varying the mix proportions. They found out that the compressive strength varies approximately linearly with the density.

Choi *et al.*, (2009) studied the characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. They reported that for the mortar in which the waste PET lightweight aggregate was used as a fine aggregate, the flow value increased while the compressive strength decreased proportionally.

Mounanga *et al.*, (2008) incorporated polyurethane foam wastes into cementitious mixtures in order to produce lightweight concrete. They found out that the polyurethane foam concrete thermal conductivity and compressive strength obtained were respectively 2 to 7 times and 2 to 17 times lower than those of the reference mixture.

Frigione (2010) investigated how recycled PET bottles can be used as fine aggregates in concrete. The work concluded that the waste unwashed PET concrete display similar workability characteristics, compressive strength and splitting tensile strength slightly lower than the reference concrete and a moderately higher ductility.

Kalu *et al.*, (2015) worked on finding an alternate source of building materials by using laterite. In their work, laterite was reinforced with plastic particulates obtained from plastic wastes, and vulcanized rubber to improve flexural and compressive strength respectively.

They found out that 20% volume fraction of fine grain plastic particulates mixed with matrix (60% laterite + 20% cement) had a better flexural and compressive strength respectively and such could be used as an alternate source of building material in rural areas. By this a very good use is found for plastic waste.

2.2 Aggregate

Construction aggregate is a broad category of coarse particulate used in construction that includes sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates serves as reinforcement to add strength to the overall composite material. Aggregates are used as inert fillers to provide bulk volume as well as stiffness to concrete. (Sivakumar and Gomati, 2012)

2.2.1 Fine Aggregate

Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5mm. According to Fan Cheng *et al.*, (2015) more energy is needed to render concrete into fine aggregate than is required to produce coarse as well as fine aggregate simultaneously.

2.2.2 Coarse Aggregate

Coarse aggregate is gravel which has been crushed, washed and sieved so that the particles vary from 5 up to 50mm in size. There are other characteristics of aggregates that are not present in the originating rock material that are desirable for making concrete. If the coarse aggregates are also well graded, the danger of segregation in concrete is reduced. (Mora, 2000)

2.3 Concrete

Concrete is a composite material composed mainly of water, aggregate and cement. Often additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which

binds the rest of the ingredients together into a durable stone like material with many uses. (Zonghi Li, 2011)

Concrete of different types can be created by varying the proportions of water, the aggregate and cement or by substitution for the cementitious and aggregate phases. The term aggregate consists of large chunks of materials in a concrete mix, generally coarse gravel or crushed rocks like limestone and granite along with finer materials like sand i.e. Silicon oxide or calcium carbonate. The density of normal concrete is of the order of 2200 to 2600. According to Popovics (1969), failure of concrete takes place through progressive internal cracking under various loading conditions. The cracking starts at the interface between the coarse aggregate and mortar under loads which are much less than the ultimate. The strain energy of a concrete specimen under load is transformed to surface energy by the creation and propagation of internal cracks.

2.3.1 Properties of Concrete

Concrete has many properties that make it a popular construction material. The correct proportion of ingredients, placement, and curing are needed in order for these properties to be optimal.

Good-quality concrete has many advantages that add to its popularity. First, it is economical when ingredients are readily available. Concrete's long life and relatively low maintenance requirements increase its economic benefits. Concrete is not as likely to rot, corrode, or decay as other building materials. Concrete has the ability to be molded or cast into almost any desired shape. Building of the molds and casting can occur on the work-site which reduces costs.

Concrete is a non-combustible material which makes it fire-safe and able to withstand high temperatures. It is resistant to wind, water, rodents, and insects. Hence, concrete is often used for storm shelters. (Chamberlain *et al.*, 1995)

Concrete does have some limitations despite its numerous advantages. Concrete has a relatively low tensile strength (compared to other building materials), low ductility, low strength-to-weight ratio, and is susceptible to cracking. Concrete remains the material of choice for many applications regardless of these limitations. (Chamberlain *et al.*, 1995)

When water is added to cement, each of the compounds undergoes hydration and contributes to the final concrete product. Only the calcium silicates contribute to strength. Tricalcium silicate is responsible for most of the early strength (first 7 days). Dicalcium silicate, which reacts more slowly, contributes only to the strength at later times. (Chamberlain *et al.*, 1995)

The equation for the hydration of tricalcium silicate is given by:

Tricalcium silicate + Water \rightarrow Calcium silicate hydrate + Calcium hydroxide + heat



Upon the addition of water, tricalcium silicate rapidly reacts to release calcium ions, hydroxide ions, and a large amount of heat. The pH quickly rises to over 12 because of the release of alkaline hydroxide (OH^-) ions. This initial hydrolysis slows down quickly after it starts resulting in a decrease in heat evolved. (Chamberlain *et al.*, 1995)

The reaction slowly continues producing calcium and hydroxide ions until the system becomes saturated. Once this occurs, the calcium hydroxide starts to crystallize. Simultaneously, calcium silicate hydrate begins to form. Ions precipitate out of solution accelerating the reaction of tricalcium silicate to calcium and hydroxide ions. (Le Chatelier's principle). The evolution of heat is then dramatically increased.

The formation of the calcium hydroxide and calcium silicate hydrate crystals provide "seeds" upon which more calcium silicate hydrate can form. The calcium silicate hydrate crystals grow thicker making it more difficult for water molecules to reach the unhydrated tricalcium silicate.

The speed of the reaction is now controlled by the rate at which water molecules diffuse through the calcium silicate hydrate coating. This coating thickens over time causing the production of calcium silicate hydrate to become slower and slower. (Chamberlain *et al.*, 1995)

2.3.2 Types of concrete

According to the *Concrete Manual* (2003), the types of concrete include

2.3.2.1 Shotcrete

This is usually used to repair surface areas where concrete has deteriorated, but is also used to build up thin layers of concrete to protect steel from corrosion. The mortar is ejected from a nozzle under pressures of 175 to 345kPa.

2.3.2.2 Light weight Concrete

It consists of processed shale, clay and clinker. The production includes a burning process where the material expands and has less density. Due to this expansion, some lightweight aggregate may be very absorptive. Because of the high water absorption of lightweight aggregate, the air content of the mixture is measured using ASTM C173, which is the Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.

2.3.2.3 Pre-Stressed Concrete

Pre-stressed concrete is intentionally placed under stress before any dead or live loads are applied to it. The cement content is about 60 to 89 kg/m³ higher than most concrete.

2.3.2.4 Cellular concrete

It is lightweight Portland cement concrete containing a high percentage of gas cells created mechanically by means of the addition of foaming agents. The materials required for the cellular concrete include a gas forming admixture conforming to ASTM C869, portland cement ASTM C150, pozzolans and potable water free.

2.3.2.5 Self-Consolidating Concrete

This includes such concretes other than cellular concrete that are placed without any mechanical consolidation or are highly super plasticized for enhanced flowability to facilitate non-conventional placement methods.

2.4 Solid waste management in Ghana

According to Boadi and Kuitunene, (2003) municipal solid waste management in Accra, is at present delivered in an unsustainable manner. Due to uncontrolled urbanisation, large quantities of waste are generated daily in Accra, and this exerts much pressure on an over strained solid waste management system. Coupled with weak institutional capacity, and lack of resources, both human and capital, the city authorities face difficulties in ensuring that all the waste generated in the city is collected for disposal. Home collection of waste is limited to high and, some middle income areas while the poor are left to contend with the problem on their own. This leads to indiscriminate disposal of waste in surface drains, canals and streams, creating unsanitary and unsightly environments in many parts of the city. (Benneh *et al.*, 1993)

In Kumasi, Ghana's second largest city, Johan Post reports that in an effort to improve the poor record of the Kumasi's solid waste services, the authorities wish to transfer operations to private producers. This shift will create a completely new set of roles and responsibilities for the various actors involved in solid waste management. Unfortunately, Ghana's history of state-led development has not produced a very receptive environment to this endeavour. The private sector suffers from underdevelopment in general and inexperience in delivering services in particular. The local government is still insufficiently equipped to adequately manage the process. Kumasi's residents are willing to contribute financially to a privatized system but insist on receiving value-for-money. (Post, 1999)

2.5 Composites

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Typical engineered composite materials include:

- Composite building materials such as cements, concrete
- Reinforced plastics such as fiber-reinforced polymer
- Metal Composites
- Ceramic Composites (composite ceramic and metal matrices) (Schaffer, 1993)

Composite materials are generally used for buildings, bridges and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and counter tops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments. (Schaffer, 1993)

Composite fabrication usually involves wetting, mixing or saturating the reinforcement with the matrix, and then causing the matrix to bind together (with heat or a chemical reaction) into a rigid structure. The operation is usually done in an open or closed forming mold, but the order and ways of introducing the ingredients varies considerably. (Schaffer, 1993)

Within a mold, the reinforcing and matrix materials are combined, compacted, and cured (processed) to undergo a melding or blending event. After the melding event, the part shape is essentially set, although it can deform under certain process conditions. For a thermoset polymeric matrix material, the melding event is a curing reaction that is initiated by the application of additional heat or chemical reactivity such as organic peroxide. For a thermoplastic polymeric matrix material, the melding event is solidification from the melted state. (Schaffer, 1993)

The physical properties of composite materials are generally not isotropic (independent of direction of applied force) in nature, but rather are typically anisotropic (different depending on the direction of the applied force or load).

For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel.

In contrast, isotropic materials (for example, aluminium or steel), in standard wrought forms, typically have the same stiffness regardless of the directional orientation of the applied forces and/or moments. (Schaffer, 1993)

2.5.1 Advantages Of Composites

In today's world, there are three main reasons for using composites. One is financial, translating ultimately to profit. This may come through a performance improvement which makes a product more attractive or economic to own, or when a service becomes cheaper to deliver (or more profitable).

The second is legislative, driven by environmental protection factors. The world's most environmentally friendly airliner, the Boeing Dreamliner, uses 32 tons of composites in its construction. Its development was driven in large part by environmental legislation trends and increasing fuel prices. It could not fly without composites.

The third reason is, simply, because there is no alternative - the Apollo mission could not have gotten to the moon without composites used in the suits the astronauts wore. All the technological advantages fall under one of these three categories - economic, legal or 'no alternative'. (Johnson, *About Money*, 2015)

Again, the advantages of using composite materials according to Mazumdar (2002) include the following:

1. The ability of single composite components to replace several metallic components
2. The ability of composite structures to provide in service monitoring of fatigue damage in aircraft structures and resin flow in resin transfer molding. This monitoring is done with the aid of embedded sensors in the composite.
3. Composites have a high specific stiffness or stiffness- to- density ratio
4. The specific strength or strength to density ratio of composite materials are also high. This property enables airplanes and automobiles to move faster with better fuel efficiency.
5. The fatigue strength of composite materials is also very high
6. Composite materials also offer high corrosion resistance.
7. Composite materials offer increased amounts of design flexibility
8. Complex parts and special contours which are sometimes not possible with metals can be fabricated using composite materials.
9. Composite materials offer greater feasibility for employing design for manufacturing (DFM) and design for assembly (DFA) techniques. These techniques help minimize the number of parts in a product and thus reduce the assembly and joining time.
10. Composites offer good impact properties.

11. Noise, vibration and harshness (NVH) characteristics are better for composite materials than metals. These characteristics are used in a variety of applications from the leading edge of an airplane to golf clubs.
12. The cost of tooling required for composites processing is much lower than that for metals processing because of lower pressure and temperature requirements. This offers greater flexibility for design changes in a product.

2.5.2 Disadvantages Of Composites

Mazumdar (2002) enumerates the drawbacks of composites as follows:

1. High material cost for composite materials when compared to steel and aluminium.
2. Lack of high volume production methods which limit the widespread use of composite materials.
3. Classical ways of designing products with metals depend on the use of machinery and metal handbooks, and design and data handbooks. Large design databases are available for metals. Designing parts with composites lack such books because of the lack of a database.
4. The temperature resistance of composite parts depends on the temperature resistance of the matrix materials. A large proportion of composites use polymer based matrices and as such their temperature resistance is limited by the properties of the plastic.
5. Composites absorb moisture which affects the properties and dimensional stability of the composites.

2.6 Compressive Test

According to Mecmesin, 2013 compressive tests are used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behaviour under a compressive load.

Compressive tests can be used to assess the strength of components, characterize the compressive properties of materials like polyethylene terephthalate and assess the performance of products. (Mecmesin, 2013)

Compression testing provides data on the integrity and safety of materials, components and products helping manufacturers ensure that their finished products are fit for purpose and manufactured to the highest quality.

Certain materials when subjected to a compressive force show a physical manifestation of Hooke's law which states:

$E = \text{Stress (s)} / \text{Strain (e)}$ where E is the Young's Modulus for compression. (Mecmesin, 2013)

A material's ability to return to its original shape after deformation has occurred is referred to as its elasticity. Vulcanized rubber being an elastic material will revert back to its original shape after considerable compressive force has been applied. (Mecmesin, 2013)

At a certain force or stress threshold, permanent or plastic deformation occurs and is shown on graphs as the point where linear behaviour stops. The threshold is known as the proportional limit and the force at which the material begins exhibiting this behaviour is called the yield point or yield strength. (Mecmesin, 2013)

2.7 Compressive Strength of Concrete

The compressive strength of concrete is the most common performance measure used by engineers in designing buildings and other structures. It is measured by breaking cylindrical concrete specimens in a compression testing machine. (NRMCA, 2003)

The compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of pound-force per square inch (psi) in the United States and megapascals (MPa) in S.I. units. (NRMCA, 2003)

Concrete compressive strength requirements can vary from 17 MPa or 2500 psi for residential concrete to 28 MPa or 4000 psi and higher in commercial structures. (NRMCA, 2003)

Concrete has relatively high compressive strength but significantly lower tensile strength and as such is reinforced by materials that are strong in tension like steel. The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develop. (NRMCA, 2003)

2.8 Sodium carbonate and concrete

Sodium carbonate (soda ash) is used as a builder in detergent powders and tablets for water softening in the washing process. It is also used in laundry additives, machine dish washing products, surface cleaners, toilet cleaners and other household cleaning products. The product sodium carbonate is available for consumers and solutions of sodium carbonate in water have been used in the past for soaking of clothes, dishwashing, floor washing, degreasing operations and for personal care.

Again, sodium carbonate can also be used in glass manufacture, manufacture of detergents, treatment of brine, water hardness removal, pH adjustment in water or wastewater, flue gas desulphurization, coal treatment and ion exchange regeneration. (TATA, 2012)

After use of the household cleaning products, the water containing the sodium carbonate will be disposed via the drain. It will therefore be necessary to check the effect of the sodium carbonate on the composite since the chemical is mostly used and can be found in the environment.

2.9 Sulphuric acid and concrete

Acids attack concrete by dissolving both hydrated and unhydrated cement compounds as well as calcareous aggregate. Siliceous aggregates are resistant to most acids and other chemicals and are sometimes specified to improve the chemical resistance of concrete, especially with the use of chemically-resistant cement. (Kerkhoff, 2007)

The source of sulphate attack on concrete may either be due to external or internal sources. External sources are natural occurring sulphates in the environment or those that are the product of industrial processes or various human activities e.g. fertilizers often release sulphates into the soil and groundwater.

10 % sulphuric acid has a rapid disintegration effect on concrete. In the same way, 10 % and 37 % sulphuric acid also has a rapid disintegration on concrete and steel. (Kerkhoff, 2007)

2.10 Water and concrete

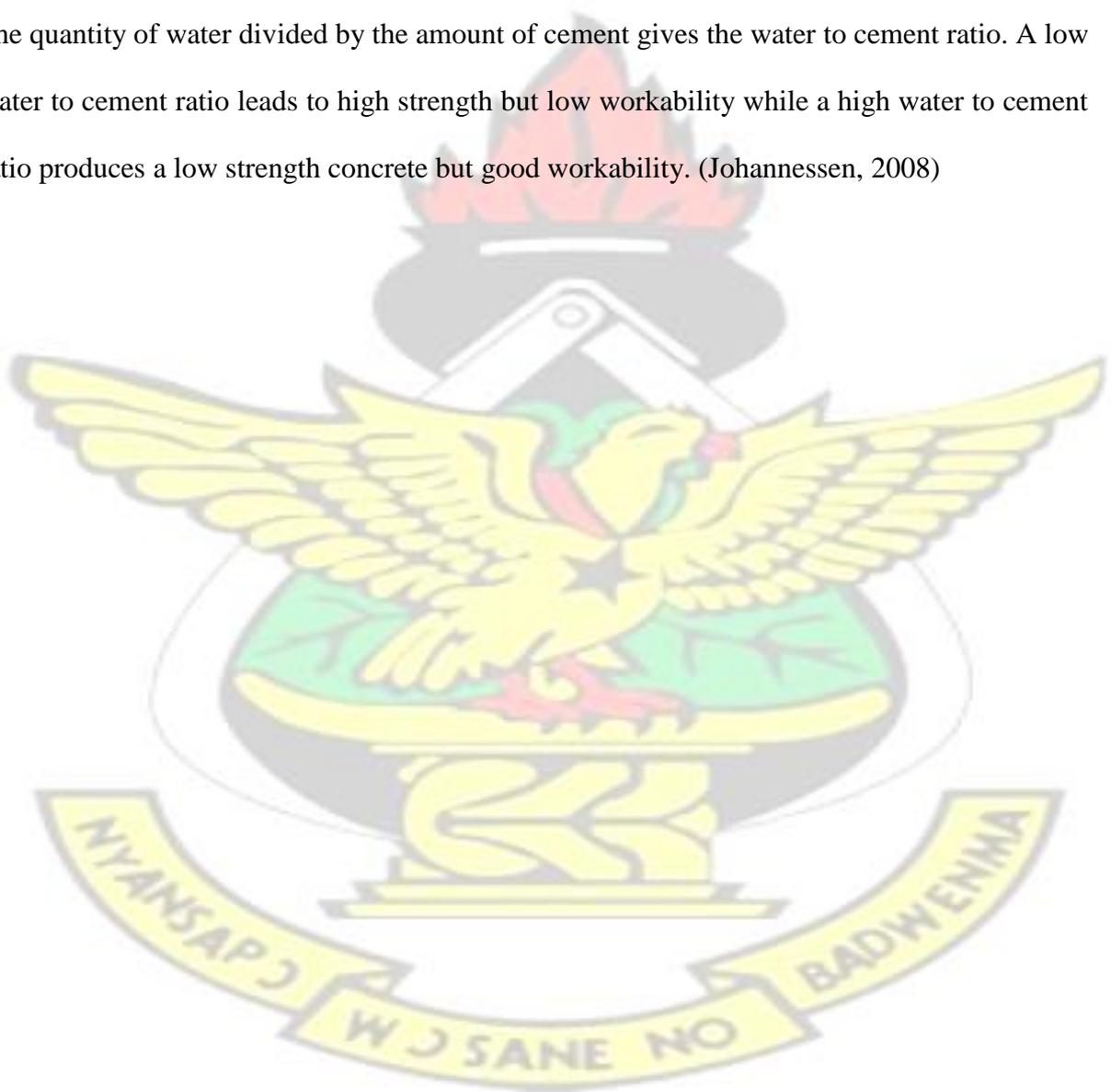
Concrete is not damaged by water. Concrete submerged in water absorbs very small amounts of water over long periods of time and the concrete is not damaged. In flood damaged areas, concrete buildings are often salvageable. (MPA, 2009)

Concrete contributes to moisture problems in buildings if it is enclosed in a system that traps moisture between the concrete and other building materials. For instance, a vinyl wall covering in hot and humid climates will act as a vapour retarder and moisture can get trapped between the concrete and the wall covering. (MPA, 2009)

Good quality water is required for the mixing of concrete. Drinking water is the best for mixing concrete. Salt water should not be used for mixing concrete. (Johannessen, 2008)

The strength of concrete increases when less water is used during the preparation of the mix. Although the hydration process consumes a certain amount of water, wet concrete actually contains more water than required for the hydration reactions. The excess water is added to provide the wet mix with sufficient workability. Concrete needs to be workable so that it can be moulded into the desired shapes and consolidated to the required density. (Johannessen, 2008)

The quantity of water divided by the amount of cement gives the water to cement ratio. A low water to cement ratio leads to high strength but low workability while a high water to cement ratio produces a low strength concrete but good workability. (Johannessen, 2008)



CHAPTER 3

3.0 METHODOLOGY

3.1 Materials

3.1.1. Polymeric material

Low linear density polyethylene films which are popularly called “polyethylene” were collected and stored over a period of a month. The brand of polyethylene was “Special Ice” and “Deep” mineral water. This low linear density polyethylene films contains 60 % HDPE and 40 % LDPE. They were dried in the sun to remove the water and odour. The low linear density polymer films were then shredded using both a shredder and a scissors.



Fig 3.1 Low linear density polyethylene films popularly called “water sachet”

3.1.2. Coarse Aggregate (stones)

The coarse aggregate was obtained from the Civil Engineering Department of the Kwame Nkrumah University of Science and Technology. The maximum size of the coarse aggregate was 19 mm. This was determined through sieve analysis.

3.1.3 Fine Aggregate (sand)

The fine aggregate which is the sand was obtained from the Civil Engineering Department of the Kwame Nkrumah University of Science and Technology. The maximum size of the sand is 3.35 mm. This was determined through sieve analysis.

3.1.4. Tetraoxosulphate (VI) acid

An Analar Reagent acid of sulphuric acid with the following properties was used

Relative density (g/cm^3)	1.85
Percentage by mass	98%
Molarity	18.4 M

3.1.5. Anhydrous Sodium Carbonate

An anhydrous sodium carbonate from PS Park Scientific Limited with the following properties was used.

Molecular weight	105.99
Min	99.5%

3.1.6. Water

Potable water was used to do the soaking of the concrete in 7 days and 28 days. The water is suitable for drinking and free from impurities.

3.2 Equipment

Some of the equipment used in the work includes the following

- i. Shredder for cutting the low linear density films into smaller sizes
- ii. Scissor for manual cutting the low linear density films into smaller sizes
- iii. Electronic balance for weighing the mass of the coarse aggregates, fine aggregate and the polymeric material. The balance is also used to measure the mass of the molded composite.
- iv. Aluminium cooking pot which was used to melt the low linear density polyethylene films into a melt.
- v. A wooden stirring rod and a steel stirring rod was used to ensure that the melted low linear density polyethylene, the coarse aggregates and the fine aggregates was stirred whilst on fire to ensure a homogenous mixture as possible
- vi. 100 mm x 100 mm x 100 mm metal mould block was used to cast the composite
- vii. Trowel was used to take the composite from the aluminium pot into the metal mold
- viii. Tamping rod was used to tamp the sides of the moulds during casting
- ix. Mixing bowl was used to soak the composite blocks in sulphuric acid and sodium carbonate
- x. Bruker Infra-red spectrophotometer to do FTIR analyses on the composites, the polymeric materials and the aggregates
- xi. Hydraulic compressive strength testing machine
- xii. Avery Impact testing machine
- xiii. Mortar and pestle
- xiv. Diamond cutter
- xv. Samsung Galaxy Young Smartphone

3.3 Preparation of the low linear density polyethylene film

3.3.1 Batching by weight

The low linear density polyethylene films were sundried in the open. The polyethylene films were shredded to smaller pieces. For making mixes containing the low linear density polyethylene films, batching by weight was done. The amount of the linear density polyethylene in the mix containing the coarse aggregate, fine aggregate and polymeric material were 9 %, 12.5 %, 14 %, 25 % and 28.5 % by weight. The various mixes of the composite are shown in Appendix A of the Miscellaneous tables.

3.3.2 Processing (Mixing, Casting and Curing)

Melt blending technique was employed for preparing the composites. Different weights of the shredded polyethylene shown in fig. 3.3 were weighed using an analytical balance and heated in an aluminium pot as shown in fig. 3.2. At fluid condition of the melted polyethylene, the sand was added first to the melted polymer. This is shown in fig. 3.8 and then the granite was slowly added. The mixture was continuously stirred at a temperature of about 120 °C. The mix ratios generally used was 1:1:2 for polyethylene, sand and granite respectively. Melting of the polyethylene was carried out for 1 hour to produce homogenous mixtures before the sand and granite were added. The low linear density polyethylene composite was then transferred to the metal molds, labeled and stored for further testing after 7 days and 28 days.

Concrete attains its maximum curing strength at 28 days. The composite material's compressive strength at 7 days and 28 days will give an idea on how comparable the material's compressive strength is to concrete.

Before casting, the metal molds were cleaned and the bolts tightened. The molds were filled with the composite in three layers and tapping was done twenty five times with the tamping rod. The specimens were allowed to remain in the metal moulds for 24 hours. After 24 hours

the composite specimens were remove from the moulds then kept till the day of testing as seen in fig. 3.9.



Fig 3.2 Aluminium pot used to melt the low linear density polyethylene



Fig 3.3 Shredded polyethylene (LDPE/HDPE)



Fig 3.4 Polyethylene being melted in aluminium pot



Fig 3.5 Melted polyethylene



Fig. 3.6 Melted polyethylene on fire



Fig. 3.7 Adding fine aggregate to melted LLDPE



Fig. 3.8 Adding coarse aggregate to mixture of fine aggregate and melted LLDPE



Fig. 3.9 Composite block of low linear density polyethylene, fine aggregate and coarse aggregate in metal mold

3.3.3 Fabrication of the composite block

3.52 kg of shredded low linear density polyethylene films was weighed on an electronic balance and poured in an aluminium pot. A fire was lit from a pile of wood and sticks. The aluminium pot was placed on the fire and heated till the low linear density polyethylene films form a melt.

After the melt is formed, 3.52 kg of sand was weighed on an electronic balance. The sand was then poured into the low linear density polyethylene melt. The mixture is manually stirred with a wooden stirrer till a homogenous mixture of the sand and LLDPE melt is formed.

With the aluminium pot still on the fire, 7.05 kg of granite is weighed on an electronic balance and poured in the LLDPE-sand mixture. The mixture is manually stirred with a wooden stirrer till the granite mixes with the heated mixture.

The aluminium pot is covered and the LLDPE-sand-granite composite mixture is allowed to heat for 5 minutes.

With the aluminium pot on fire, a trowel is then used to take the composite into moulds. The aluminium pot must always be on fire whilst the composite is being taken into the moulds to prevent premature hardening of the composite upon removal from the fire. With a tamping rod, the composite is tamped till the mixture fills the mould completely.

The composite is allowed to cool for 24 hours and the composite product is removed from the mould. After 7 days and 28 days, tests are carried out on the composite block.

3.4 Tests conducted

3.4.1. Aggregates Test

3.4.1.1. FTIR Analyses on polymeric material, fine aggregate and coarse aggregate

FTIR analysis was conducted on the low linear density polyethylene film after it has been cut into a size of 1mm using a scissors.

Again, the sand and stone was ground into powder using a mortar and pestle. The FTIR analyses were conducted on the coarse aggregate and fine aggregate to determine their initial chemical composition.

In order to determine if a chemical change occurred during the melting of the polymer and the various aggregates forming the composite, Fourier transform infrared spectroscopy (FTIR) spectra were measured for the composites after the composite had been formed.



Fig. 3.10 FTIR Bruker Spectrophotometer

3.4.1.2 Particle Size Distribution

It is done to determine the gradation of the coarse aggregate and the fine aggregate.

0.260 g of the fine aggregate was weighed and then placed on the first sieve of the arranged series of sieves of the Malest Auto sieve shaker and the machine turned on. The sieve shaker shakes the fine aggregates with some of the aggregates passing through some sieves and others retained in others. After 10 minutes the sieve shaker automatically stops and coarse aggregates retained in the respective sieves are weighed for the masses retained. The same process is repeated with 0.649 kg of the coarse aggregates respectively.



Fig. 3.11 Malest Auto sieve shaker

3.4.2 Compressive test

The average of three compressive strength values for each curing day was used for the analysis. The compressive testing machine used is an ELA model with a capacity of 1 500kN. The composite material was placed on the compressive testing machine and the compressive strength taken after the material had failed.



Fig. 3.12 Compressive testing of the composite block

3.4.3 Effect of water, sulphuric acid and sodium carbonate on composite

After the composite had been molded, it is fully immersed in water, sodium carbonate and sulphuric acid. The compressive strength of the cubes was measured after 7 days and 28 days of the cubes having been immersed in these solutions. The weights after 7 days and 28 days will also be measured.

3.4.3.1 Effect of water on composites

After the concrete had been moulded, it was placed in water for 7 days and 28 days. Compressive tests were carried out on the blocks to check the effect of water after 7 days and 28 days

3.4.3.2 Effect of acid on composites

500 mL of 0.5 M solution of H_2SO_4 was taken and dissolved in 7.5 L of water.

Concentration of concentrated acid=0.5 M

Volume of concentrated sulphuric acid taken=500 mL

Volume of water taken =7.5 L

From the dilution formula, $C_1V_1=C_2V_2$ where C_1 is concentration of the concentrated acid; V_1 is the volume of the concentrated acid; C_2 is the concentration of the diluted acid and V_2 is the volume of the diluted acid

$$0.5\text{M} \times 500 \text{ mL} = C_2 \times 7500 \text{ mL}$$

$$C_2 = (0.5\text{M} \times 500\text{mL}) / 7500 \text{ mL}$$

$$C_2 = 0.0333\text{M}$$

The concentration of the diluted sulphuric acid which is 0.0333 M was prepared and the composites was fully immersed in the sulphuric acid solution for 7 days and 28 days.

Compressive tests were carried out after 7 days and 28 days.

3.4.3.3 Effect of base on composites

100 mL of 0.5 M solution of Na_2CO_3 was taken and dissolved in 6.0 L of water.

Concentration of concentrated base =0.5 M

Volume of concentrated sulphuric acid taken =100 mL

Volume of water taken =6.0 L

From the dilution formula, $C_1V_1=C_2V_2$ where C_1 is concentration of the concentrated base; V_1 is the volume of the concentrated base; C_2 is the concentration of the diluted base and V_2 is the volume of the diluted base $0.5 \text{ M} \times 100 \text{ mL} = C_2 \times 6000 \text{ mL}$

$$C_2 = (0.5\text{M} \times 100 \text{ mL})/6000 \text{ mL}$$

$$C_2 = 0.0083\text{M}$$

The concentration of the diluted sodium trioxocarbonate (IV) which is 0.0083 M was prepared and the composite blocks were placed in the base solution for 28 days. Compressive tests were carried out after 7 days and 28 days.

3.4.4 FTIR analyses of low linear density polyethylene composite

FTIR analyses was done on the low linear density polyethylene composite to determine if a chemical change had occurred after the formation of the polymeric composites. A piece of the polymeric composite was ground in a mortar and pestle into fine powder. A piece of the ground powdery polymeric composite was then placed in the sample holder of the Bruker Spectrophotometer and FTIR analyses carried out.

3.4.5 Impact test

There are two types of impact tests. They are the izod test and the charpy test.

The impact test measures the impact energy of the material. An Avery Impact testing machine was used to do a charpy test on the low linear density polyethylene composite. The capacity of the machine is 120FT.LB. The difference in the two lies in the fact that the material is placed in a vertical position in the grip of the impact testing machine for the izod test, while for a charpy test, the material is placed in a horizontal position in the grip. The impact test is used to evaluate the overall hardness of the material.

An Avery impact testing machine was used to perform a charpy test on the concrete blocks measuring 50 mm x 50 mm after the 100 mm x 100 mm cubes had been sliced to the desired dimensions with a diamond cutter.

The formula $PE = m \times g \times h$ is used for the calculation where

PE is the Potential Energy; m is the mass; g is the acceleration due to gravity and h is the height.

On the Avery impact testing machine, the mass and height have been predetermined to be 30 kg.

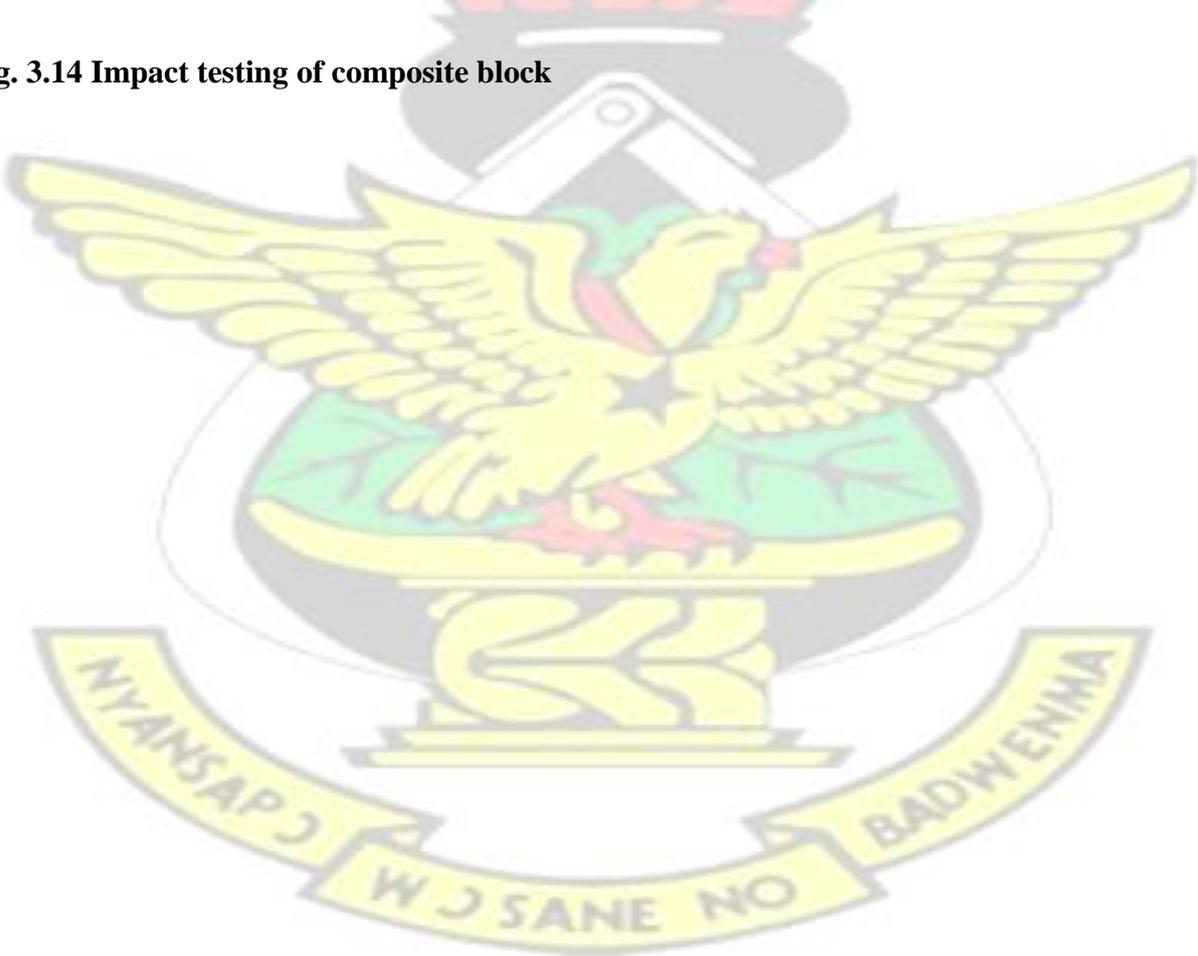
Using the mix ratio of 1:1:2 for the low linear density polyethylene, sand and granite respectively, 100 mm x 100 mm concrete blocks were moulded as previously done.



Fig. 3.13 Composite block in impact tester



Fig. 3.14 Impact testing of composite block



CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 MECHANICAL PROPERTIES

4.1.1. Compressive strength

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. From the test conducted it can be seen that as the percentage of polyethylene increases, the compressive strength of the block increases. However, there is a fall in compressive strength when the percentage of the polyethylene is increased from 25% to 28.5% for both 7 days and 28 days as shown in fig. 4.1 and fig. 4.2 respectively. This fall in compressive strength could be due to the increase in plastic loading.

Raghatate (2012) reports that as the plastic content in a concrete block is increased, the compressive strength decreases.

Again Ohemeng *et al.*, (2014), reports that as the percentage of plastic content is increased, the compressive strength of a concrete block decreased.

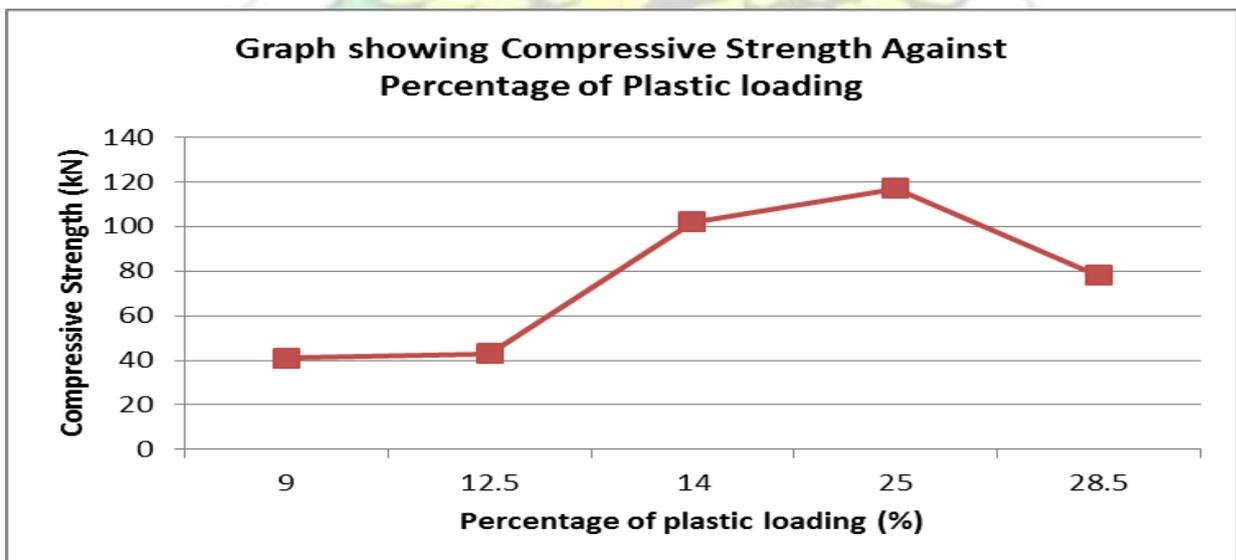


Fig.4.1 Graph of Compressive Strength against Percentage of Polyethylene after 7 days

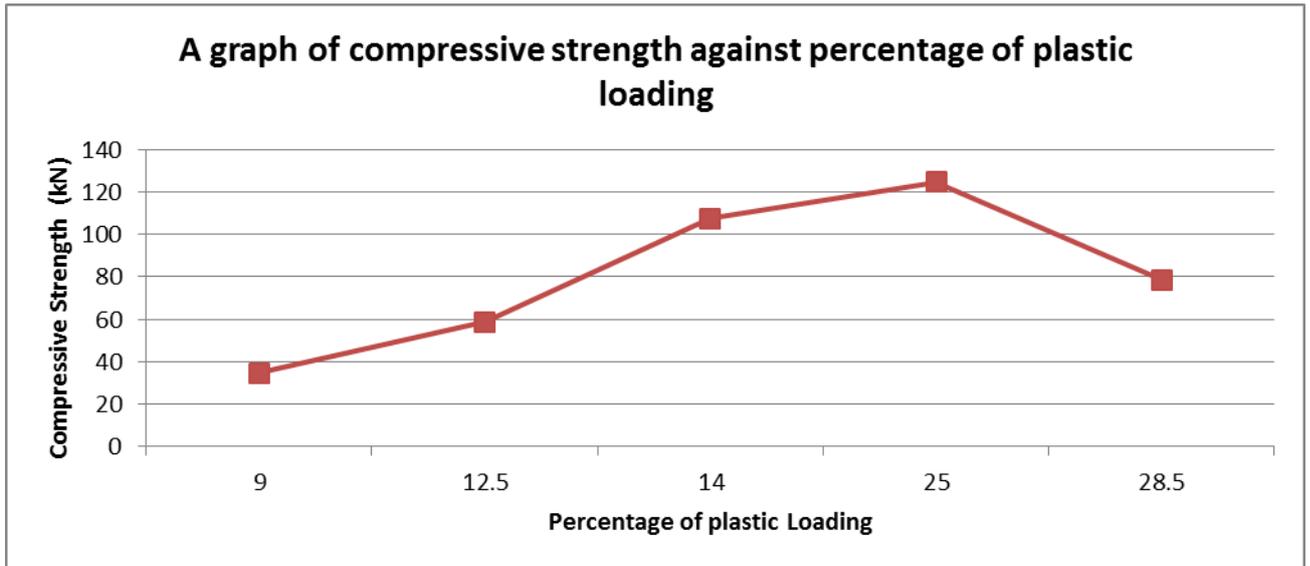


Fig 4.2 Graph of Compressive Strength against Percentage of Polyethylene after 28 days

Table 4.1 Percentage of LLDPE and compressive strength for 7 days

7 DAYS	PERCENTAGE OF LLDPE	COMPRESSIVE STRENGTH
	9	41
	12.5	43
	14	102
	25	117.3
	28.5	78

Table 4.2 Percentage of LLDPE and compressive strength for 28 days

28 DAYS	PERCENTAGE OF LLDPE	COMPRESSIVE STRENGTH
	9	34.6
	12.5	58.6
	14	107.3
	25	124.6
	28.5	78.6



25% LLDPE BLOCK

9% LLDPE BLOCK

Fig 4.3 Composite blocks after compressive strength testing after 7 days



25% LLDPE BLOCK

9% LLDPE BLOCK

Fig. 4.4 Composite blocks after compressive strength testing after 28 days

The 9 % LLDPE composite block for 7 days and 28 days is seen to fail easily and cracks when compressed because the polymer loading is lower. However, the 25 % LLDPE composite block for 7 days and 28 days is seen to withstand the load and does not show signs of cracking and compression even after failure have occurred This can be attributed to the increase in the percentage of polymer load.

As the percentage of polymer load increases, there is better binding and adhesion between the polymer and the aggregates.

4.1.2 The Effect Of Aging On The Compressive Strength Of The Composite

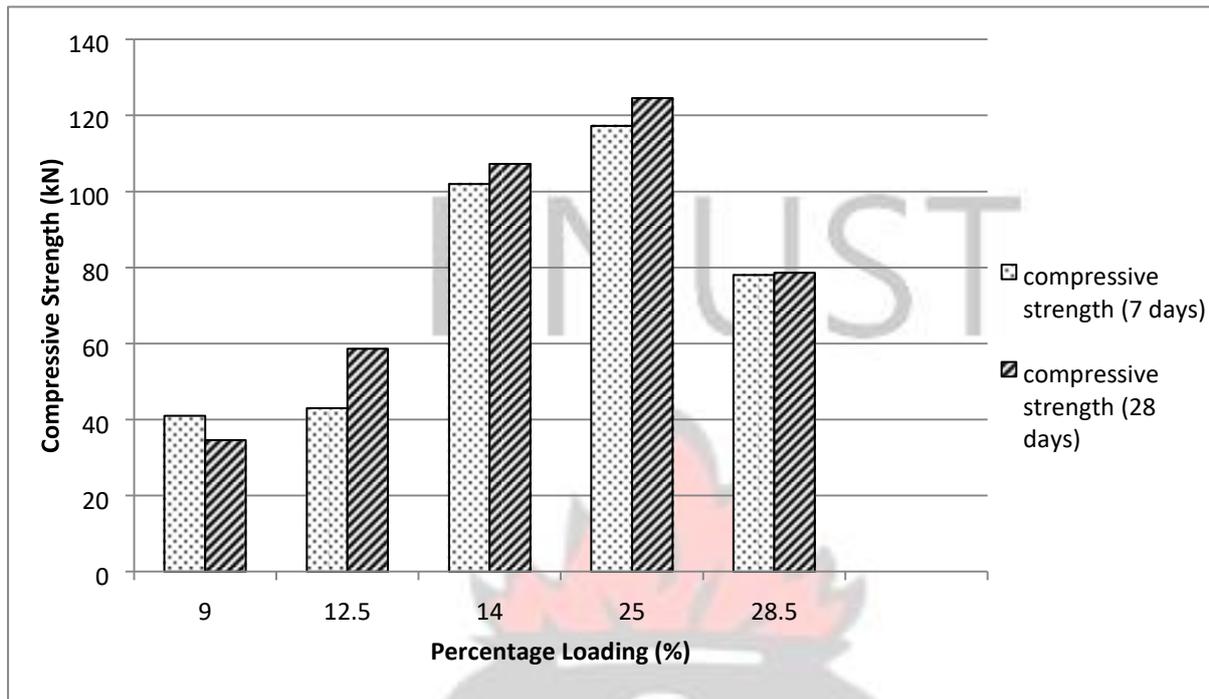


Fig. 4.5 Bar chart showing combined compressive strength for 7 days and 28 days From the graph above it can be seen that the compressive strength of the composite increases as the days increase from 7 days to 28 days.

Table 4.3 Comparing the effect of aging and polymer loading on the Compressive Strength of the Composite

	Compressive strength after 7 days (kN)	Compressive strength after 28 days (kN)	Change in Compressive Strength due to aging
9 % polymer loading	41	34	-7
25 % polymer loading	117	125	8
Change in compressive Strength due to polymer loading	76	91	

Comparing the change in compressive strength, the change in polymer loading is higher than the change in compressive strength as a due to aging.

From table 4.3, it is clearly shown that polymer loading dependence is significantly stronger than the aging dependence.

The increase in compressive strength is due to the increase in polymer loading which results in the increase in compressive strength due to the better adhesion of the LLDPE binder and the aggregates.

4.2 Results for Impact Testing

Impact testing measures the energy required to break a specimen by dynamically applying a load.

The results of the impact test on the low linear density polyethylene composite block of polymer loading at 14%, 25% and 28.5% are 72.59 J/mm², 80.44 J/mm² and 68.67 J/mm² respectively and are shown in table 4.4.

Table 4.4 Table showing results of impact strength of composite blocks

PERCENTAGE LOADING	IMPACT STRENGTH, J/mm²
9.0	0.0
12.5	0.0
14.0	72.59
25.0	80.44
28.5	68.67

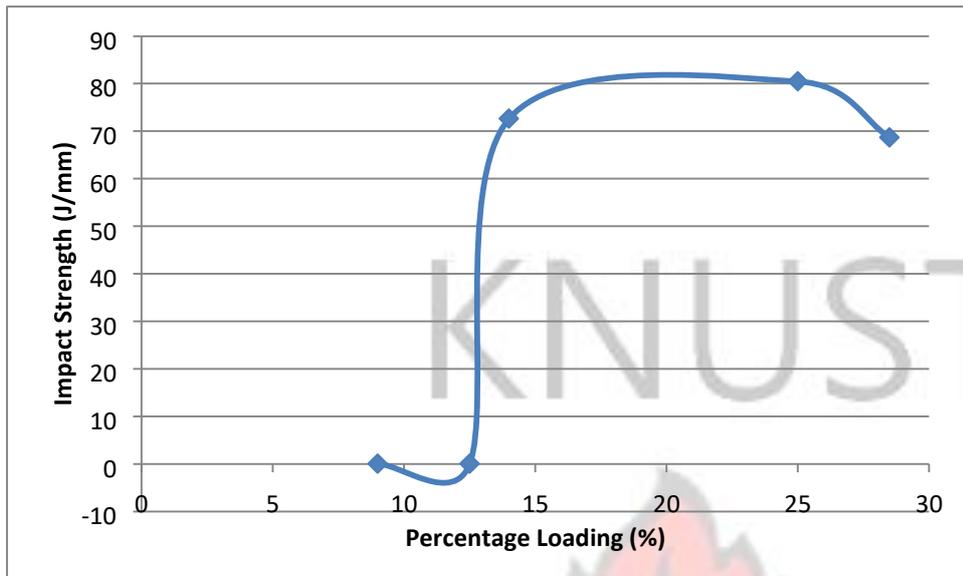


Figure 4.6 Graph showing impact strength and percentage of plastic loading

The impact strength of the composite block increases from 15% to 25% and drops at 28.5% and this is shown in fig. 4.6. The impact strength for 9 % and 12.5 % percentage loading could not be read by the scale on the impact tester and as a result could not be determined as a result of the lower adhesion between the LLDPE binder and the aggregates.

The formula $PE = m \times g \times h$ (1)

Impact Strength (I.S) = K x Reading on scale (2)

is used for the calculation of the impact strength where

P.E is the Potential Energy; m is the mass; g is the acceleration due to gravity, K is a constant which is 9.8 m/s^2 and h is the height.

Therefore the reading on the scale when the pendulum is raised and swung is multiplied by the acceleration due to gravity which is 9.81 m/s^2 .



Fig. 4.7 Fractured Surface of the composite block after impact testing

SURFACE MORPHOLOGY OF COMPOSITE BLOCK

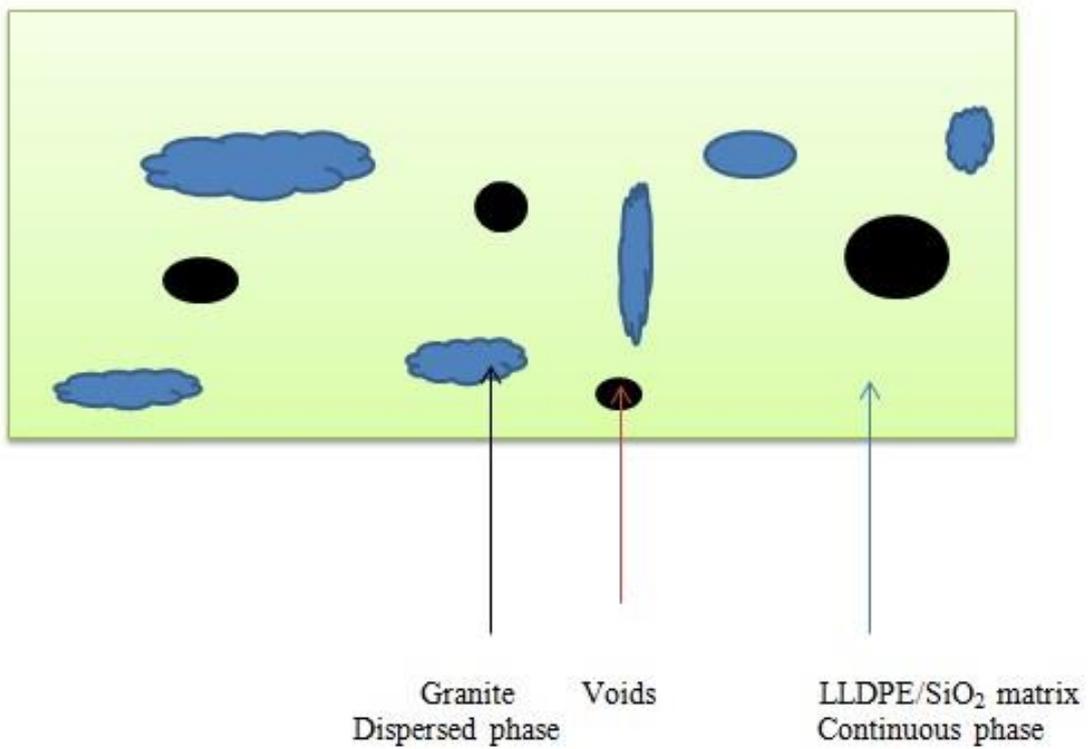
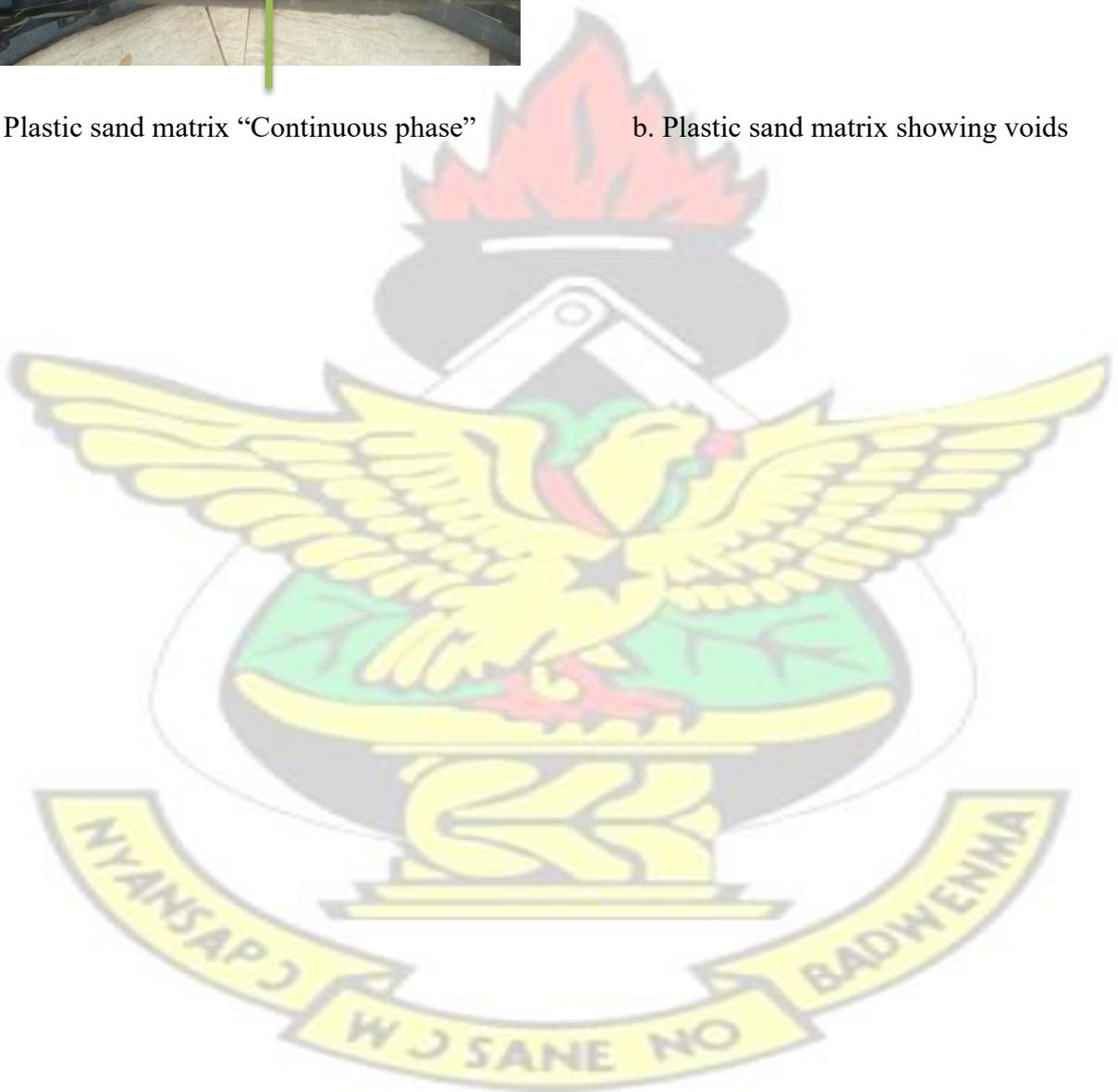


Fig 4.8 Diagrammatic representation showing the compositional structure of the composite



a. Plastic sand matrix “Continuous phase”

b. Plastic sand matrix showing voids



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Fig 4.9 Surface of the composite block



Granite or stone dispersed phase



LLDPE/SiO₂ matrix continuous phase

Fig. 4.10 Surface morphology of the composite block after molding

It can be seen in fig. 4.9 that the composite material has a continuous phase comprising of the plastic and sand matrix. There are some voids in the continuous phase shown in fig. 4.9 b. Found within the continuous phase are the granite found dispersed in the continuous phase shown in fig. 4.10.

4.3 Chemical Properties

4.3.1 Results for FTIR

The FTIR test was carried out to detect the functional groups present in the polymer composite. This information will help ascertain whether there is the formation of any possible new bonds via the modification process. Still, the equivalent concentrations prepared for all the different proportions of plastics, will assist in identifying the intensity changes in the peaks of the spectrum.

4.3.1.1 FTIR Spectra For LLDPE

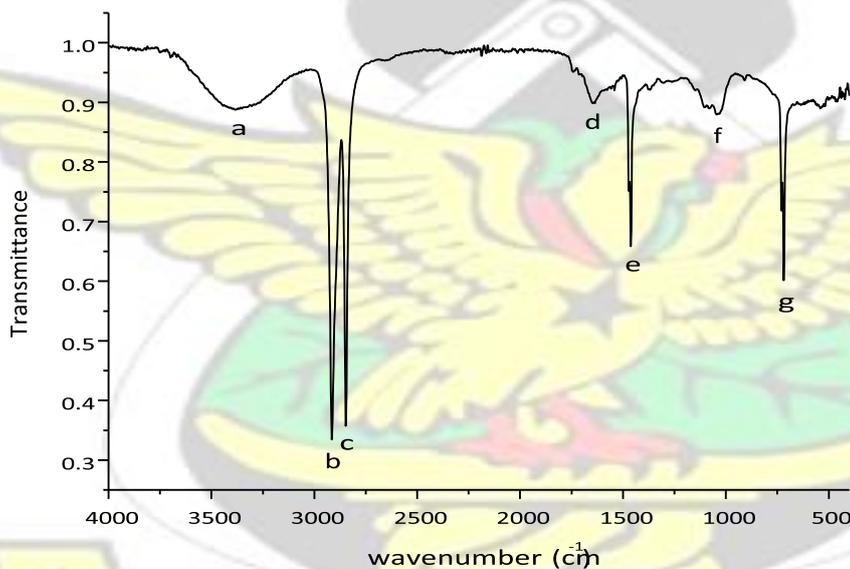


Fig 4.11 FTIR Spectrum of low linear density polyethylene

The figure of the Infra-Red spectroscopic analysis of the shredded low linear density polyethylene is shown in figure 4.10. The peak at 3400 cm^{-1} shows the O-H stretching peak. The strongest peak, with a transmittance of 100 can be observed to occur within the $2850\text{--}2800\text{ cm}^{-1}$ IR frequency range. This range is typical of sp^3 symmetrical and CH_2 stretching peak of the C-H bond. The peak at 1800 cm^{-1} shows a C=O stretch. The 1500 cm^{-1} wavenumber

corresponds to the C-C deformations in aliphatic. The 1000 cm^{-1} wavenumber corresponds to the C-O stretch whilst the 700 cm^{-1} corresponds to the CH_2 rocking vibrations. The spectrum confirms that the material is composed mainly of aliphatic CH bonds confirming that the material is a polyethylene material.

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4.3.1.2 FTIR Spectra for Fine Aggregate

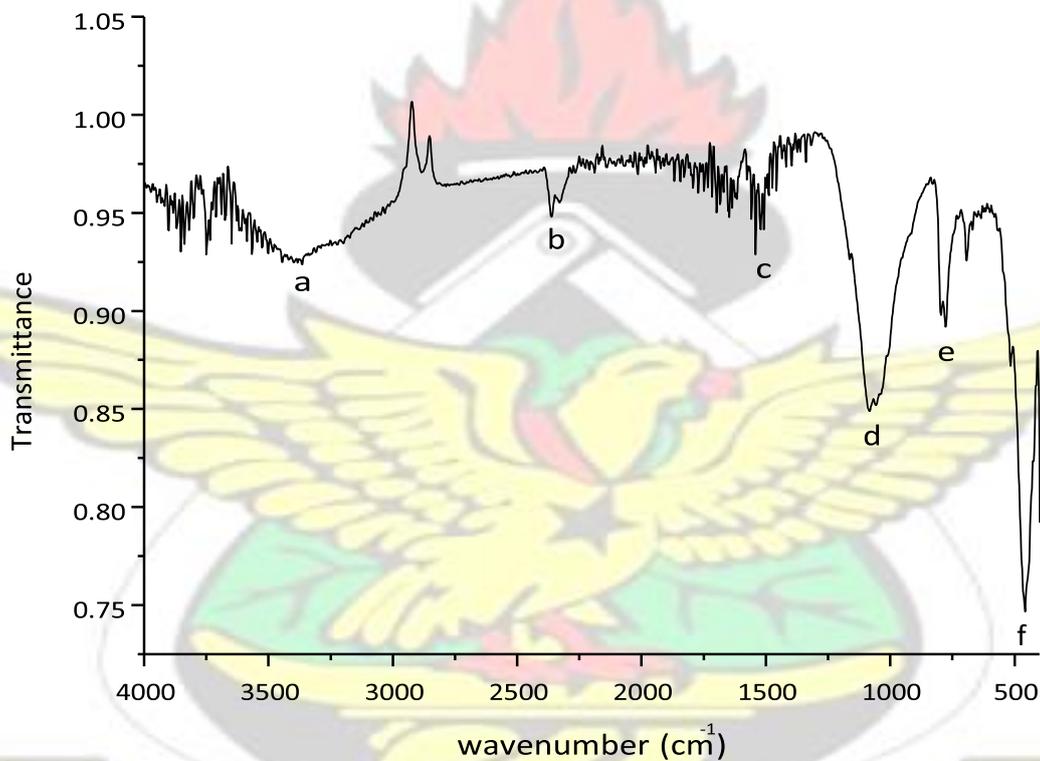


Fig. 4.12 FTIR Spectrum of sand

The figure of the Infra-Red spectroscopic analysis of the fine aggregate is show in figure 4.11. The fine aggregate was ground into a powdery form in a mortar and pestle. A piece of the ground fine aggregate was then placed in the sample holder of the Bruker spectrophotometer and FTIR analyses carried out. The wavenumbers for the major peaks in the sand can be seen at 500cm^{-1} , 750cm^{-1} , 1050cm^{-1} , 2300cm^{-1} and $3000\text{-}3500\text{cm}^{-1}$.

The wavenumber of 500cm^{-1} corresponds to the Si-O rocking bond. The wavenumber of 750cm^{-1} corresponds to the Si-Si stretching bond in the sand. The wave number of 1050cm^{-1} corresponds to the Si-Si stretching bond. The wave number of 2300 cm^{-1} corresponds to the SiO-H bond. (Karakassides *et al.*, 1999) The chemical composition of sand is mostly categorized by the most popular bonding agents like silica, calcium, clay and iron oxide.

Looking at the various spectra of the sand characterized using the FTIR it confirms that the sand used in the work is mostly made of silicon (IV) oxide.

4.3.1.3 FTIR Spectra for Coarse Aggregate

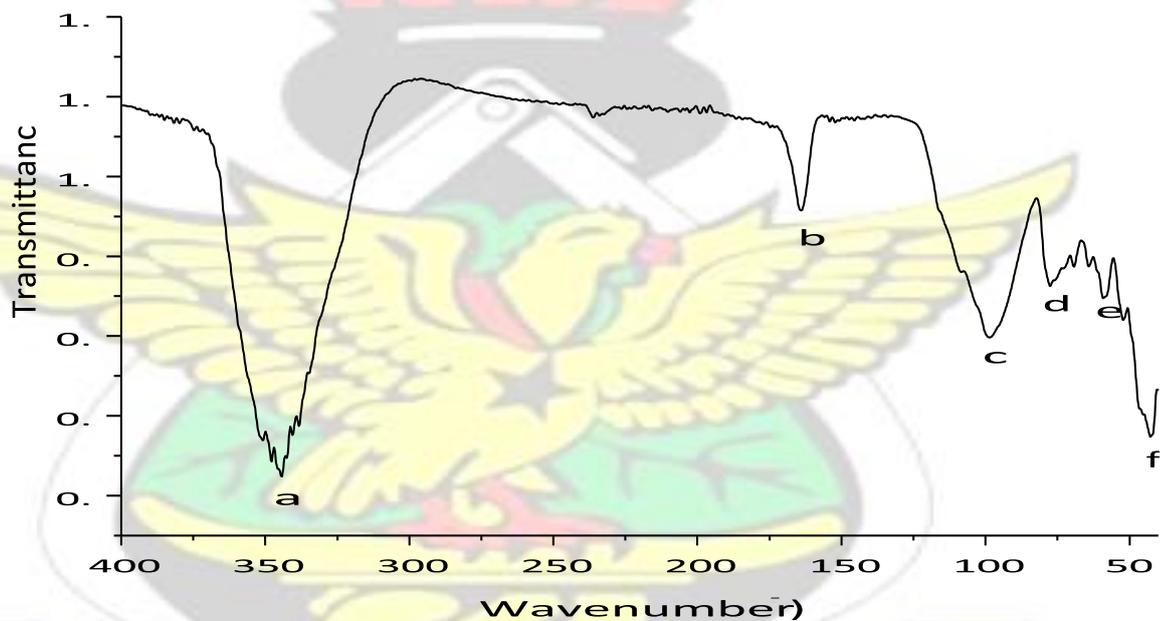


Fig. 4.13 FTIR spectrum of the coarse aggregate

FTIR spectrum of coarse aggregate

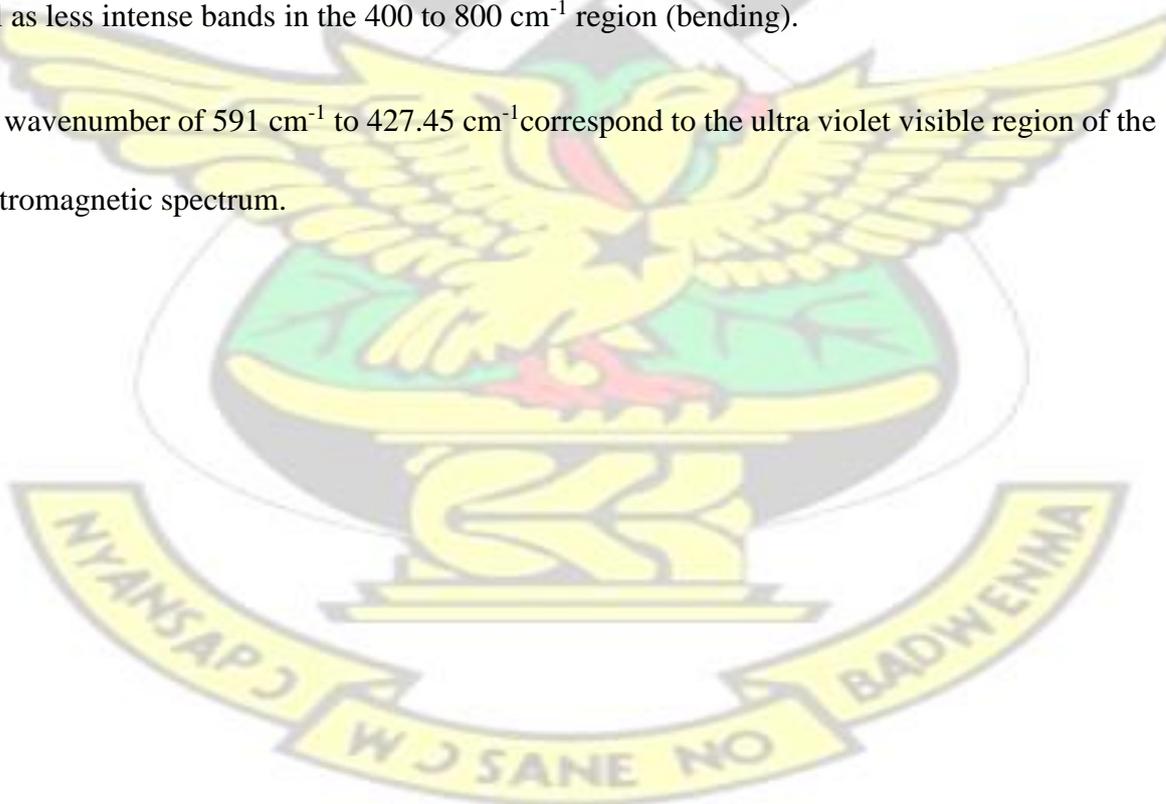
The figure of the Infra-Red spectroscopic analysis of the coarse aggregate is show in figure 4.12. The coarse aggregate was ground into fine powder in a mortar and pestle. A piece of the ground coarse aggregate was then taken and placed in the sample holder of the Bruker Spectrophotometer and the FTIR analyses carried out. From the FTIR spectrum above for the

granite, it is seen that the major peaks appear at the following wave numbers: 3443.06 cm^{-1} , 1640.28 cm^{-1} , 958.79 cm^{-1} , 775.56 cm^{-1} , 591.00 cm^{-1} , 522.02 cm^{-1} and 427.45 cm^{-1} .

The wavenumber of 3443.06 cm^{-1} corresponds to a strong –OH functional group. The wavenumber of 1640.28 cm^{-1} also corresponds to the –OH bending modes. The various bands in the region 3000 - 3800 cm^{-1} are all due to OH stretching and in the region 1600 - 1700 cm^{-1} are due to OH bending modes of water or hydroxyls. (Rajesh *et al.*, 2013)

The wavenumbers of 958.79 cm^{-1} and 775.56 cm^{-1} correspond to the less intense Si-O functional group and is due to O-Si-(Al)-O bending vibration in the samples. The Si-O bonds are the strongest bonds in the silicate structure and can be readily recognized in the infrared spectra of such minerals by very strong bands in the region 900 to 1100 cm^{-1} (stretching) as well as less intense bands in the 400 to 800 cm^{-1} region (bending).

The wavenumber of 591 cm^{-1} to 427.45 cm^{-1} correspond to the ultra violet visible region of the electromagnetic spectrum.



4.3.1.4 FTIR spectra for composite

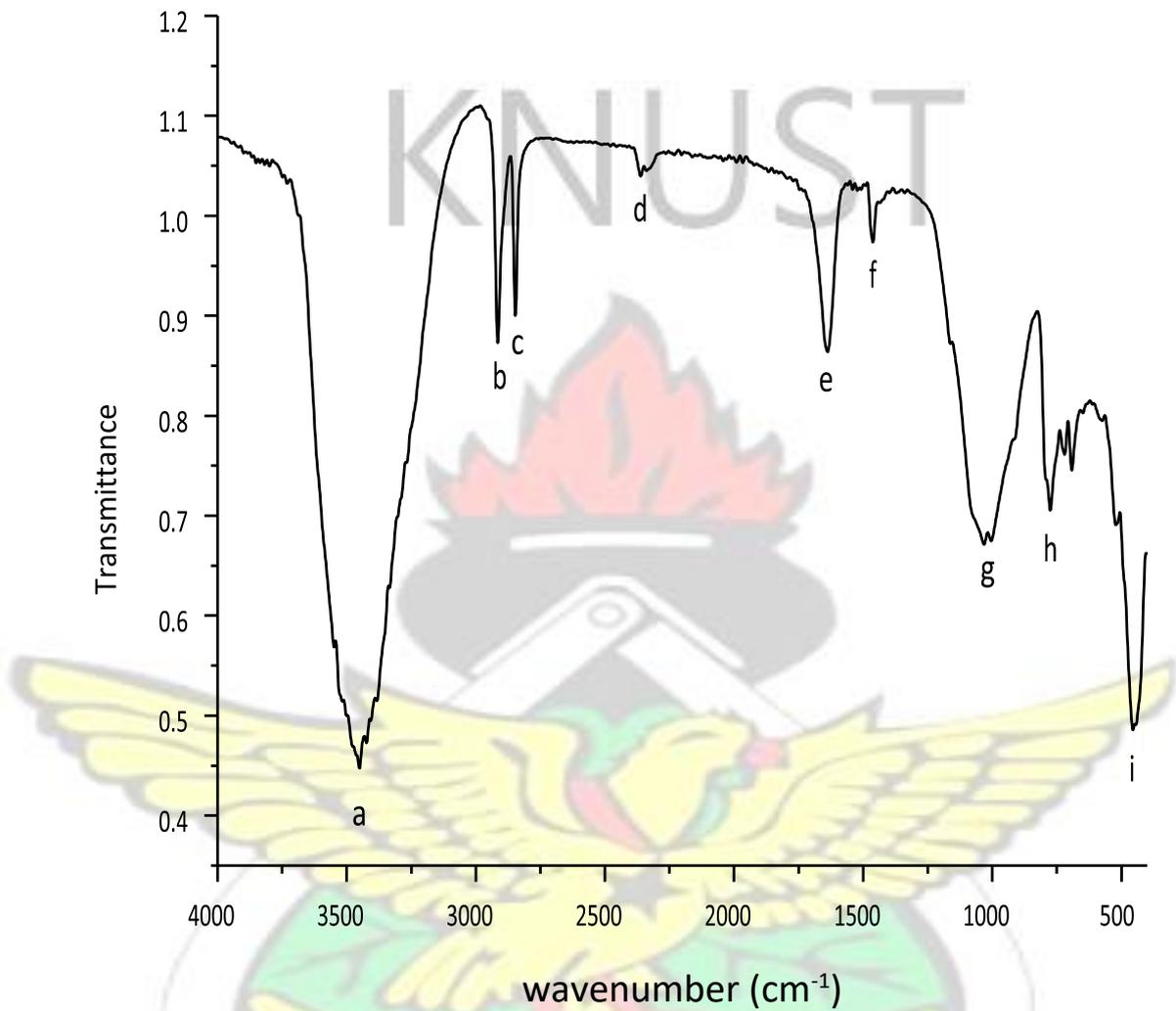


Fig. 4.14 FTIR spectrum of the composite

The major peaks of the composite material occur at the wavenumbers of 3450.67 cm^{-1} , 2915.00 cm^{-1} , 2847.10 cm^{-1} , 2361.25 cm^{-1} , 1637.66 cm^{-1} , 1462.61 cm^{-1} , 1032.18 cm^{-1} , 775.57 cm^{-1} , 720.01 cm^{-1} , 692.32 cm^{-1} , 521.81 cm^{-1} and 455.74 cm^{-1}

The peak which shows at 3450.67cm^{-1} is the peak for the strong $-\text{OH}$ functional group. In the starting material of the coarse aggregate, the wavenumber displayed as the strong $-\text{OH}$ functional group in the granite was at 3443.06cm^{-1}

The peaks of wavenumber displayed as 2915.00cm^{-1} and 2847.10cm^{-1} in the FTIR spectra of the composite could be attributed to the presence of the organic carbon which is displayed as 2800.00cm^{-1} and 2850.00cm^{-1} in the LLDPE composite. The peak which is displayed as a wave number of 2361.25cm^{-1} is the peak which is displayed as 2300.00cm^{-1} in the FTIR spectra of the fine aggregate. That is the peak displayed for the SiO-H bond displayed. Thus the fine aggregate has its peak displayed in the composite material.

The wave number of 1637.66cm^{-1} which is seen in the composite material can be attributed to the $-\text{OH}$ bending mode in the coarse aggregate which is displayed as 1640.28cm^{-1} .

The wave number of 1462.61cm^{-1} can be attributed to the peak for the carbon to carbon double bond which is displayed as 1500.00cm^{-1} in the LLDPE material. The wave number is reduced as a result of the thermal decomposition of the polyethylene material as it is heated.

The wave number of 1032.18cm^{-1} in the FTIR spectra of the composite is as a result of the Si-O stretching bond found in the fine aggregate and which is displayed as 1050cm^{-1} .

The wave number of 775.57cm^{-1} in the composite material corresponds to the less intense SiO bonds. In the coarse aggregate it is initially displayed as 775.56cm^{-1} .

The wave number of 720.01cm^{-1} in the composite material could correspond to the $-\text{CH}_2$ rocking vibration which is displayed in the LLDPE as 700cm^{-1} .

It should be noted that the variations in values of OH stretching and bending wave numbers are attributed to the varying strengths of hydrogen bonding between OH and water molecules and some oxygen in the structure. (Rajesh et al; 2013)

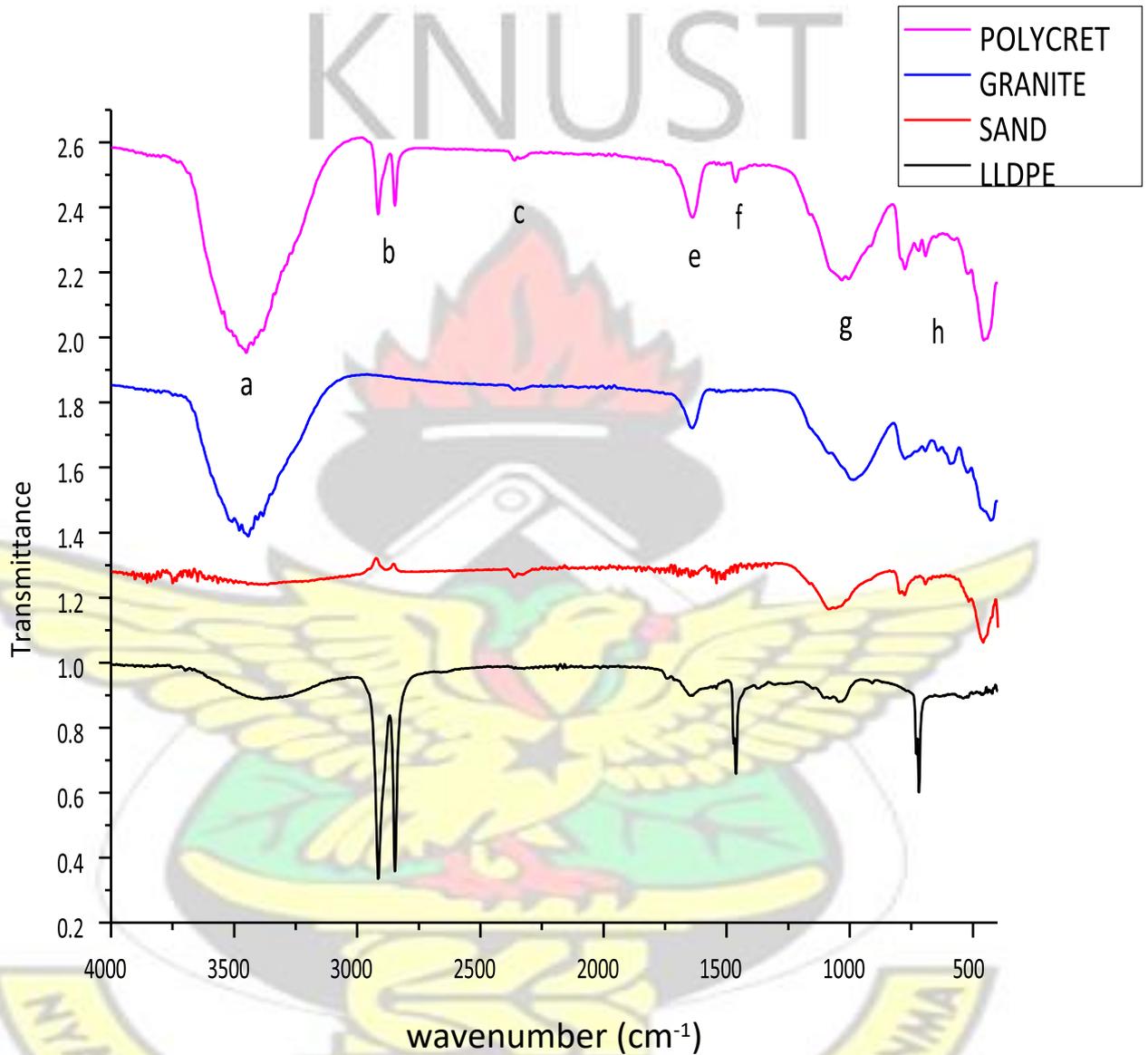


Fig. 4.15 Stacked FTIR spectra of the composite, LLDPE and aggregates

In the figure 4.14 above, the various FTIR of the LLDPE, fine aggregate, coarse aggregate and the composite material are stacked together to determine the various types of reactions formed. The various peaks are labeled a, b, c, e, f, g and h for the composite material.

For A, it can be seen that the peak formed at the composite material at A is an enhanced peak comprising of the FTIR spectra of the coarse aggregate and LLDPE. The peak at a is enhanced with the same wave number of 3500cm^{-1} of the granite and a slight contribution coming from the LLDPE. This tells us that there was a reaction of the LLDPE and the coarse aggregate which resulted in the peak of the composite at that point showing as a.

For the peak labeled b, it is clearly seen that the peak at b corresponds to the peak showing for the LLDPE. The LLDPE composite has a peak showing at a wave number of between 2800 and 2850 cm. The same peak but with a shorter transmittance is seen at the same point or position in the composite material. This also confirms the fact that the LLDPE material has reacted and is part of the composite material.

The peak at c is coming from the fine aggregate and the coarse aggregate material. The fine aggregate and coarse aggregate also make a contribution as far as the reaction of the composite material is concerned. The peak at c in the composite comes from the peak being displayed in the sand and the granite.

The peak at e in the composite material comes from the coarse aggregate alone.

The peak at f in the composite material comes from the fine aggregate alone.

The peak at g in the composite material is an enhanced peak coming from the peaks displayed in the coarse aggregate, LLDPE and in the fine aggregate.

The peak at h in the composite material is contributed by both the coarse aggregate and the fine aggregate.

The peaks in the starting materials that are the fine aggregate, LLDPE and coarse aggregate that are not seen in the composite material are as follows:

Two peaks in the LLDPE don't appear in the composite. They are at wavenumbers 1500 and 750 cm^{-1} . The carbon - carbon double bond which appears at the wavenumber of 1500 disappears in the composite. Again the $-\text{CH}_2$ bond which has a wavenumber of 700 cm^{-1} appears in a less intense form in the peaks displayed by the composite material.

For the sand, comparing the peak of the sand with the composite material, it is seen that one major peak does not appear in the sand. This peak is the kaolinite material found in the sand.

The peak which doesn't appear has a wavenumber range from 3000 cm^{-1} – 3500 cm^{-1} .

From the spectra it can be seen that the coarse aggregate appears widely in the composite material with the fine aggregate and the LLDPE also having their peaks appearing in the composite block. For a composite material to be classified as such it should have all the materials that were used in the startup or initial stages appearing in the final material and it can be seen that all the materials including the LLDPE, coarse aggregate and fine aggregate reacted to give the composite material.

4.3.2 Effect Of Sodium Carbonate, Sulphuric Acid And Water On 25% Plastic Loading

The mix ratio which gave the best results for the composite, which is 3.52 kg of low linear density polyethylene, 3.52 kg of sand and 7.05 kg of granite was used to prepare the composite cubes which were soaked in water, sodium carbonate and sulphuric acid. The reason this particular mix ratio was used is because, this mix ratio used in preparing the composite cubes gave the best results with a compressive strength of 117kN at 7 days and 124.6kN at 28 days for a plastic loading of 25%.

4.3.2.1 Composite block in water

After 7 days and 28 days, the mass of water absorbed by the composite was 2.27kg and 2.437kg respectively. The control cube had a mass of 1.99kg and 2.020kg after 7 days and 28 days respectively.

The compressive strength of the composite blocks after 7 days was 60.66kN and 56.66kN after 28 days. The compressive strength of the blocks reduced 4kN during the period. The reduction in the compressive strength could be as a result of the voids that were found in the composite as a result of the imperfect stirring when the aggregates were added to the melted low linear density polyethylene. The composite material absorbed water which reduced the compressive strength of the composite material.

4.3.2.2 Composite blocks in sulphuric acid

Again, the composite blocks were soaked or immersed in sulphuric acid. After 7 days and 28 days, the mass of the block was 2.1575 kg. The weight of the composite cubes after 28 days was 2.2195 kg.

The compressive strength of the cube after being immersed in the sulphuric acid for 7 days was 84 kN whilst the compressive strength of the cubes after being immersed in the acid for 28 days was 88 kN. The acid did not have any deteriorating effect on the composite block.

4.3.2.3 Composite blocks in sodium carbonate

For the base, the weight of the blocks after 7 days was 2.199 kg whilst the weight of the block after 28 days was 2.3045 kg.

The compressive strengths measured after being immersed in the sodium carbonate for 7 days was 46 kN and 49 kN for 28 days.

4.3.3. Effect Of The Reagents On The Composite Block

The effect of sodium carbonate on the composite was not much. After 7 days, the compressive strength recorded was 46kN. After 28 days, the compressive strength was 49kN. This shows that the sodium carbonate did not have any much effect on the compressive strength of the composite block. This is confirmed by Kerkoff (2007) who states that sodium carbonate has no effect on concrete. The sodium carbonate also did not have any effect on the composite material.

When the composite block was immersed in the dilute sulphuric acid, it was seen that the weight of the cube after 7 days was 2.1575kg. The compressive strength of the cube after being immersed in the sulphuric acid after 7 days was 84kN.

After the 28 days period, it was found out that the weight of the cube after 28 days increased to 2.2195kg. The compressive strength after the 28 days period was also found out to be 88kN.

There was a slight increase in the weight and compressive strength of the composite block when it was immersed in the sulphuric acid. The acid did not have any deteriorating effect on the composite material.

For the low linear density polyethylene composite, the mass of the water when it was immersed in water after 7 days is 2.27kg. After 28 days, the mass of the water was 2.437kg.

For the compressive strength of the composite, the block had a compressive strength of 60.66kN for 7 days and 56.66kN for 28 days. The compressive strength reduced as the days increased. This could be due to the voids found in the composite and it shows that the water absorption of the composite block is high. The voids in the composite block can be attributed to the inability of the mixture to be uniformly mixed.

4.3.4 Effect Of Compressive Testing Machine On The Dimensions Of The Composite

For the composite blocks molded, it was observed after compressive testing had been done on the block to test for its compressive strength, there was virtually no change in the length, breadth and width of the composite block.

The initial dimensions of the blocks which were moulded were 100mm x 100mm x 100mm for the length, breadth and thickness respectively.

After the compressive test had been done on the block, the length, breadth and thickness were measured again to check if there had been a significant reduction in the dimensions of the cube after compression on the block.

It was seen that there was no significant reduction in the dimensions of the block. This may be attributed to the effective nature of the LLDPE as a binder in binding the aggregates together thus resulting in no significant reduction in dimensions after testing.

4.3.5 Cost Analysis Of Normal Concrete And The Composite

The materials used in making concrete in Ghana include cement, fine aggregate which is the sand, coarse aggregate which is the granite or stones and finally water. Normally, on the site the workers pick a bag of cement a quantity of sand is measured in head pan or wheelbarrow and stone and water added till it becomes concrete of the right texture.

In Ghana quite recently, the cost of cement has been rising due to the power crises faced by many industries which has caused manufacturing companies to spend much more money on fuel to power their production plant and other equipment.

A bag of cement in Ghana costs GH¢33. A trip of sand costs about GH¢200 and a trip of granite or stones from the quarry costs GH¢600. In addition to these costs, the builder will have to buy

water for mixing the concrete at GH¢40 per drum. The total costs for these combined items amounts to GH¢873.

The weight for the sand is 2700 kg, 3800 kg for the stones, 50 kg for the cement and 120 kg for the barrel of water. This gives a combined weight of 6670 kg for a normal concrete.

For this composite material, the items needed are the stones, the sand and the low linear density polyethylene film as raw materials. Again a source of heat which will be used for melting the low linear density film will also be needed. A bundle of sticks for creating the fire can be obtained at a cost of GH¢15 at weight of 300kg. The low linear density polyethylene film costs GH¢10 at a weight of 20kg. As stated earlier, the sand cost GH¢200 at a weight of 2700kg and the stones cost GH¢600 at a weight of 3800kg. The total cost for producing the composite is GH¢825 at a total weight of 6800kg. The unit cost for the normal concrete is GH¢0.1308 whilst the unit cost for the composite block is GH¢0.1213. The unit cost of the composite is cheaper than the normal concrete.

Table 4.5 Table showing the cost analysis of normal concrete and the composite

MATERIAL	COST (GH¢)	QUANTITY(kg)	UNIT COST(GH¢)
NORMAL CONCRETE	873	6670	0.1308
COMPOSITE BLOCK	825	6800	0.1213
SAVINGS MADE			0.0095

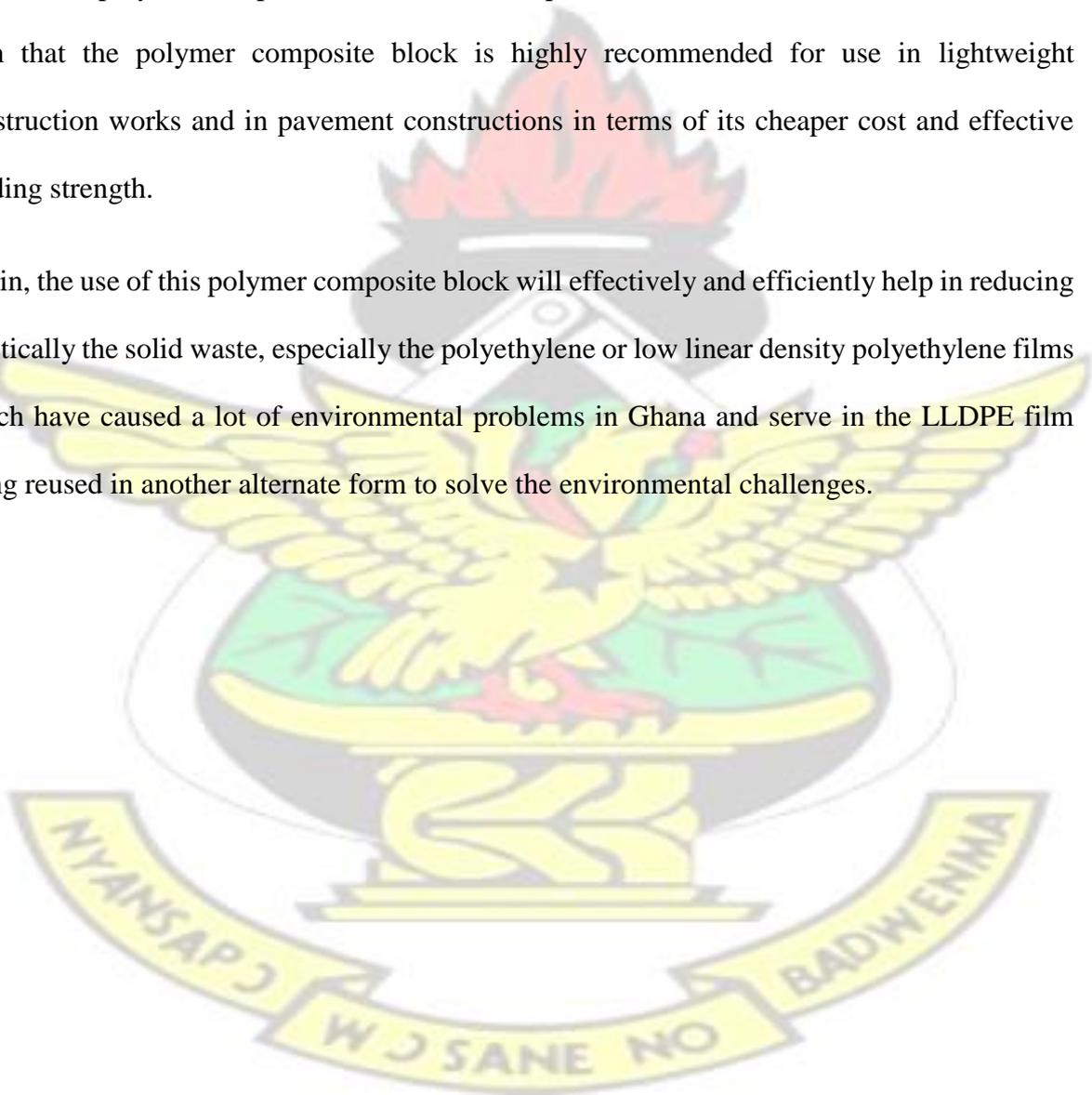
Comparing the essential property of compressive strength of the 2 blocks, the normal concrete block has a compressive strength of 146kN and 194.6kN for 7 days and 28 days respectively.

The polymer composite block has a compressive strength of 117.3kN and 124.6kN for 7 days and 28 days respectively.

The difference in compressive strength for the normal concrete block and the composite block is 70kN for 28 days and 28.7kN for 7 days.

In terms of the slight differences in compressive strength when the 2 are compared and the fact that the polymer composite block is also cheaper than the normal concrete block, it can be seen that the polymer composite block is highly recommended for use in lightweight construction works and in pavement constructions in terms of its cheaper cost and effective binding strength.

Again, the use of this polymer composite block will effectively and efficiently help in reducing drastically the solid waste, especially the polyethylene or low linear density polyethylene films which have caused a lot of environmental problems in Ghana and serve in the LLDPE film being reused in another alternate form to solve the environmental challenges.



CHAPTER FIVE

5.0 CONCLUSION

The following can be concluded:

- The waste LLDPE plastics are suitable to replace cement as a binder in the formulation of pavement blocks.
- There was an increase in the compressive strength of the concrete with increase in the percentage of the waste low linear density polyethylene content in the composite from 9% weight to 25% weight of polymer loading
- The compressive strength of all the composite samples increases with increasing curing days. However the polymer loading dependence is significantly stronger than the aging dependence.
- The impact strength as prepared on the low linear density polyethylene composite block with polymer loading 14%, 25% and 28.5% are 68.67J, 80.442J and 68.67J respectively. The impact strength increases marginally as the percentage of the LLDPE increases.
- The compressive strength for the normal concrete is higher than the compressive strength of composite samples containing waste low linear density polyethylene.
- Sodium carbonate virtually had no effect on the compressive strength of the composite.
- H_2SO_4 had no deteriorating effect on the concrete
- The composite can be used for pavements and light construction works
- This composite block can be a means of solving the sanitation problem in Ghana because large volumes of the low linear density films or polyethylene are melted and applied in this composite materials, the amount of polyethylene films in the

environment which have caused environmental problems in Ghana would be suitably managed.

- The low linear density polyethylene film is a very good binder of the aggregates. During the compressive tests, it was seen that the failure of the composite blocks was not so pronounced. It could be seen that the block looked very solid in spite of the fact that failure had occurred. This shows that the polyethylene film when melted is a very good binding material for the aggregates.
- The composite block may find useful application in waterlogged areas or areas prone to flooding.
- The unit cost of the composite is less or cheaper than the unit cost for the normal concrete.

5.1 RECOMMENDATIONS

From this work and its findings the following recommendations will be suggested for future work

- The concrete mixers used in mixing concrete to give it a uniform mix should be considered in the future. The manual stirring using the rod could not ensure a uniform mixture of the composites as was required.
- Electrical properties, flexural strength and slump test of LLDPE waste plastic composites can be evaluated to further understand the behavior of the composite
- The thermal properties of the composite should be investigated and worked on in future work
- The stability of the composite block to ultra violet exposure should also be investigated.

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APPENDIX

Miscellaneous tables

Compressive test for various mix ratios of LLDPE and aggregates

Weight and Compressive strength of block after 7 days	Weight and Compressive strength of block after 28 days	Polyethylene kg	Sand kg	Granite kg	Cement kg
2.314kg; 94kN	2.116kg; 110kN	1.7644651	3.5289302	7.0578604	
2.097kg; 110kN	2.074kg; 100kN				
	2.075kg; 112kN				

2.349kg; 40kN	2.382kg; 56kN	1.7644651	3.5289302	7.0578604	1.7644651
2.410kg; 46kN	2.452kg; 66kN				
	2.413kg; 54kN				
2.281kg; 56kN	2.276kg; 40kN	1.05867906	3.5289302	7.0578604	
2.254kg; 46kN	2.384kg; 40kN				
	1.659kg; 100*80; 24kN				
1.839kg; 74kN	1.891kg; 74kN	3.5289302	1.7644651	7.0578604	
2.161kg; 82kN	1.987kg; 90kN				
	2.059kg; 72kN				

7 days	28 days	Polyethylene kg	Sand kg	Granite kg	Cement kg
2.056kg; 114kN	2.227kg; 132kN	3.5289302	3.5289302	7.0578604	normal
1.926kg; 120kN	1.935kg; 124kN				
1.988kg; 118kN	1.900kg; 118kN				
2.459kg; 64kN	2.461kg; 68kN	3.5289302	3.5289302	7.0578604	water
2.107kg; 58kN	2.360kg; 54kN				
2.244kg; 60kN	2.491kg; 48kN				

1.869kg; 80kN	2.234kg; 78kN	3.5289302	3.5289302	7.0578604	Sulphuric acid
2.446kg; 88kN	2.205kg; 98kN				
2.199kg; 46kN	2.238kg; 46kN	3.5289302	3.5289302	7.0578604	Sodium carbonate
	2.371kg; 52kN				
2.247kg; 164kN	2.231 kg; 152kN	3.5289302	3.5289302	7.0578604	Normal Concrete
2.272kg; 130kN	2.254kg; 224kN				
2.312kg; 144kN	2.198kg; 208kN				

APPENDIX A

CALCULATIONS FOR PERCENTAGE OF POLYETHYLENE FOR 7 DAYS

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 1.7644651 = 12.3512557$$

$$\text{Percentage of polyethylene} = (1.7644651/12.3512557)*100$$

$$=0.14285714*100$$

$$=14.285714\%$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$1.7644651 + 3.5289302 + 7.0578604 + 1.7644651 = 14.1157208$$

$$\begin{aligned} \text{Percentage of polyethylene} &= (1.7644651/14.1157208)*100 \\ &= 0.125*100 \\ &= 12.5\% \end{aligned}$$

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TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 1.05867906 = 11.64546966$$

$$\begin{aligned} \text{Percentage of polyethylene} &= (1.05867906/11.64546966)*100 \\ &= 0.09090909*100 \\ &= 9.0909\% \end{aligned}$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$3.5289302 + 1.7644651 + 7.0578604 = 12.3512557$$

$$\begin{aligned} \text{Percentage of polyethylene} &= (3.5289302/12.3512557)*100 \\ &= 0.28571428*100 \\ &= 28.571428\% \end{aligned}$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 3.5289302 = 14.1157208$$

$$\text{Percentage of polyethylene} = (3.5289302/14.1157208)*100$$

$$= 0.25 * 100$$

$$= 25\%$$

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APPENDIX B

CALCULATIONS OF PERCENTAGE OF POLYETHYLENE FOR 28 DAYS

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 1.7644651 = 12.3512557$$

$$\text{Percentage of polyethylene} = (1.7644651/12.3512557) * 100$$

$$= 0.14285714 * 100$$

$$= 14.285714\%$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$1.7644651 + 3.5289302 + 7.0578604 + 1.7644651 = 14.1157208$$

$$\text{Percentage of polyethylene} = (1.7644651/14.1157208) * 100$$

$$= 0.125*100$$

$$=12.5\%$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 1.05867906 = 11.64546966$$

Percentage of polyethylene =

$$(1.05867906/11.64546966)*100$$

$$= 0.09090909*100$$

$$=9.0909\%$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$3.5289302 + 1.7644651 + 7.0578604 = 12.3512557$$

Percentage of polyethylene = $(3.5289302/12.3512557)*100$

$$=0.28571428*100$$

$$=28.571428\%$$

TOTAL WEIGHT OF THE POLYMER CONCRETE MIXTURE

$$7.0578604 + 3.5289302 + 3.5289302 = 14.1157208$$

Percentage of polyethylene = $(3.5289302/14.1157208)*100$

$$= 0.25*100$$

$$=25\%$$

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APPENDIX C

RESULTS FOR PARTICLE SIZE DISTRIBUTION FOR AGGREGATES

SIEVE ANALYSIS FOR FINE AGGREGATE

SIEVE SIZE	MASS OF SAND g	% RETAINED	% PASS
3.35MM	3.29	1.26	98.74
2.00MM	8.59	3.30	95.44
1.00MM	64.21	24.67	70.76
600MIC	63.80	24.51	46.25
425MIC	34.65	13.31	32.94
300MIC	25.08	9.64	23.30
150MIC	32.67	12.55	10.75
75MIC	16.58	6.37	4.37

APPENDIX D

SIEVE ANALYSIS FOR COARSE AGGREGATE

SIEVE SIZE MM	MASS OF STONE kg	% RETAINED	% PASS
19.000	0.222	34.206	67.794
13.200	0.389	59.938	7.855
9.500	0.036	5.547	2.308
6.700	0.001	0.154	2.154

APPENDIX E

RESULTS FOR PARTICLE SIZE DISTRIBUTION FOR AGGREGATES

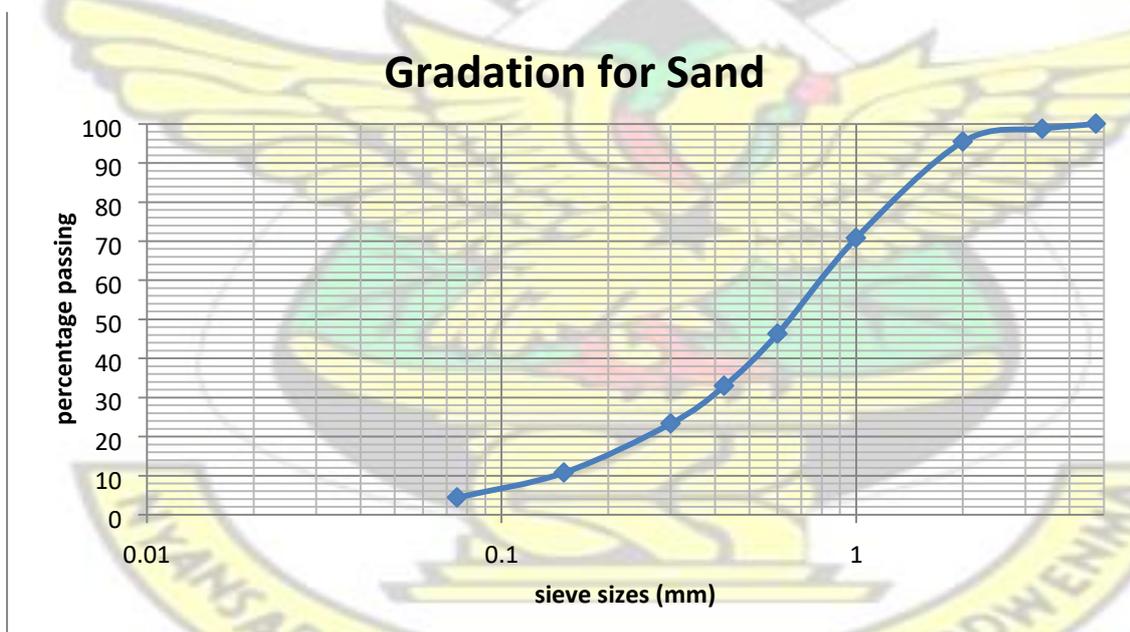


Fig. 4.5 Graph showing sieve analysis of fine aggregates

GRAPH OF PERCENTAGE PASS AGAINST SIEVE SIZE FOR GRAVEL

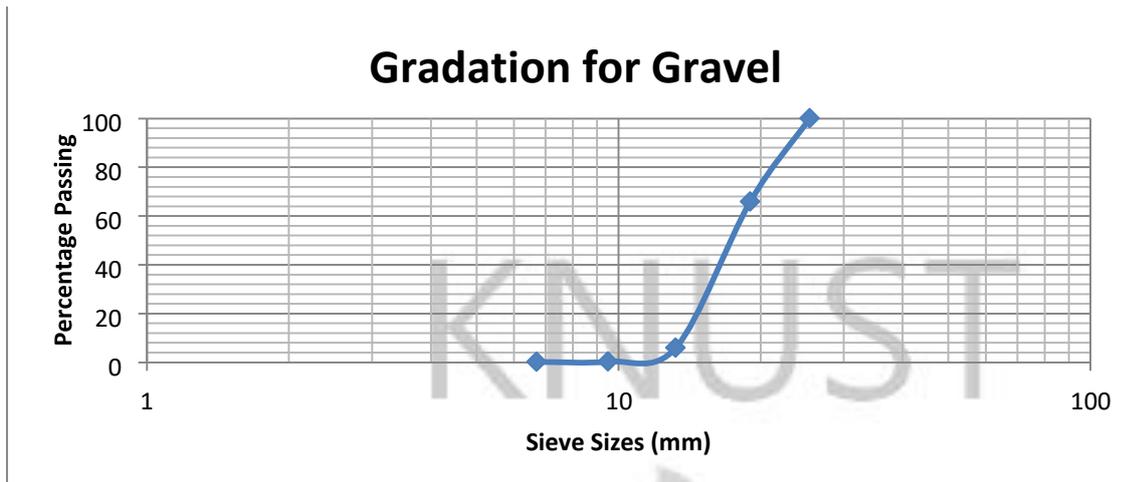


Fig. 4.6 Graph showing sieve analysis for coarse aggregates

APPENDIX F

CALCULATIONS OF COMPRESSIVE MODULUS

Compressive Modulus = Compressive Stress/Compressive Strain

Compressive Stress = Force / Cross Sectional Area

Compressive Strain = Extension/ Original Length

Force = 1500kN

Cross Sectional Area of Composite block = 100mm*100mm

=10 000mm²

PERCENTAGE LOADING	EXTENSION (mm)	ORIGINAL LENGTH (mm)	COMPRESSIVE STRESS kN/m ²	COMPRESSIVE MODULUS
9.0	4	100	1.50*10 ⁵	3.75*10 ⁶
12.5	2	100	1.50*10 ⁵	7.50*10 ⁶

14.0	1	100	1.50×10^5	1.50×10^7
25.0	1	100	1.50×10^5	1.50×10^7
28.5	1	100	1.50×10^5	1.50×10^7

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PERCENTAGE LOADING	COMPRESSIVE MODULUS, mPa	COMPRESSIVE STRENGTH, kN	COMPRESSIVE STRESS kN/m²
9.0	3.75×10^6	34.6	1.50×10^5
12.5	7.50×10^6	58.6	1.50×10^5
14.0	1.50×10^7	107.3	1.50×10^5
25.0	150×10^7	124.6	1.50×10^5
28.5	150×10^7	78.6	1.50×10^5

