EFFECT OF ACRYLAMIDE GRAFTED POLYETHENE WASTE ON THE PHYSICO-MECHANICAL PROPERTIES OF CONCRETE COMPOSITE

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NIGERIA

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BY

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DEPARTMENT OF TEXTILE SCIENCE AND TECHNOLOGY
FACULTY OF SCIENCE
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NIGERIA

OCTOBER, 2015

DECLARATION

I declare that the work in this Dissertation entitled Effects of Polyethene Grafted with Acrylamide on the Physico-Mechanical Properties of Concrete Compositehas been carried out by me in the Department of Textile Science and Technology. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Idris Alhaji ABUBAKAR _____ _____

Signature **Date**

CERTIFICATION

This Dissertation entitled Effects of Polyethene Grafted with Acrylamide on the Physico-Mechanical Properties of Concrete Composite by Idris Alhaji ABUBAKAR meets the regulations governing the award of Master Degree in Colour Chemistry and Technology of the Ahmadu Bello University,Zaria and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

This research investigates the effect of acrylamide grafted polyethene waste on the physico-mechanical properties of concrete composite. The investigation was first carried out by hydroxylation before chemical grafting of acrylamide onto polyethene, to serve as filler for the production of the composite. Secondly, the grafted polyethene was used to replace the weight of aggregate in the production of Concrete Composites Cubes (CCCs) of standard dimensions (15cm x 15cm x 15cm). The results obtained from Fourier Transform Infrared (FT-IR) spectra shows that the grafting was successful as indicated by the absorption peaks at 1639.55cm^{-1} and 1712.85cm^{-1} due to acrylamide functional group. The FT-IR spectraalso shows the presence of the other functional groups at absorption peaks of 3301.28cm^{-1} and 3621.47cm^{-1} (N – H), 1059.92cm^{-1}, 1368.97cm^{-1}, 1024.24cm^{-1}, 1290.42cm^{-1} and 1368.54cm^{-1} (C – N) functional groups. The compaction factor for the concrete mixes was 0.67 – 0.97 and slump test values of 10mm – 265mm. The CCCs produced show water absorption (3% - 25%), density (1320 – 2280kg/m^3), compressive strength (0.67 – 5.63N/mm^2). The Scanning Electron Microscope (SEM) results for the morphology of the grafted CCCs shows better interaction of aggregates than the ungrafted CCCs and presented fewer voids in the fibre/pore morphology.

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ABBREVIATIONS

ACI	American Concrete Institute
AFM	Atomic Force Microscopy
ASTM	American Society for Testing and Materials
BSI	British Standard Institute
CCCs	Concrete Composite Cubes
CFM	Chemical Force Microscopy
CSH	Hydration Product of Cement
FTIR	Fourier Transform Infrared
HDPE	High Density Polyethene
HPFRCC	High Performance Fibre-Reinforced Cement-based Composites
IR	Infrared
LDPE	Low Density Polyethene
LLDPE	Linear LowDensity Polyethene
NARICT	National Research Institute for Chemical Technology
NILEST	National Institute for Leather Science and Technology
OPC	Ordinary Portland Cement
PAM	Polyacrylamide
PE	Polyethene
PETE	Polyethene Terephthalate
PVC	Polyvinyl Chloride
PP	Polypropylene
PS	Polystyrene
SEM	Scanning Electron Microscopy
SFM	Scanning Force Microscopy
SHCC	Strain-Hardening Fibre Reinforced Cement-based Composites
UHPC	Ultra High Performance Concrete
UHPFRC	Ultra High Performance Fibre Reinforced Composite
w/c	Water Cement ratio

CHAPTER ONE
INTRODUCTION

1.1 Background of the Research

The management of waste has become a major public health and environmental concern in Nigeria and many developing countries. This concern is serious, particularly in our major towns and cities. Landfill sites in general are becoming overcrowded with waste plastics and other polymeric materials such as Polyethylene Terephthalate (PET), High Density Polyethene (HDPE), Polyvinyl Chloride (PVC), Low Density Polyethene (LDPE), Polypropylene (PP), Polystyrene (PS) and other resins. Most of these polymeric wastes are derived from water sachets, water bottles, detergent bottles, cooking oil bottles, milk and juice jugs, plastic pipes, shrink wrap, drinking straws, yoghurt tubes, syrup bottles, Styrofoam cups, peanut, produce bags, wrapping films, food container, "to-go" containers and shopping bags. If the production of waste cannot be prevented, then it is desirable to create an alternative use in another process instead of disposal. Therefore, many developing countries are converting these polymeric wastes into useful products. The use of polymeric and other plastic materials has been investigated for use in concrete in order to improve the properties and reduce cost of the concretes. (Zainab, *et al.*, 2013)

The developments in the last few decades have shown significant research activities and increasing applications of High Performance Fibre-Reinforced Cement-based Composites (HPFRCC). Recently in Japan some research work on some of these materials such as Ultra High Performance Fibre Reinforced Composite (UHPFRC) and Strain-Hardening Fibre Reinforced Cement-based Composites (SHCC) were designed for particular applications varying from high requirement of high strength to

that of high ductility.For example, Ultra High Performance Concrete (UHPC) designed and applied to bridge decks overlays in buildings(Shann, 2012).

Cement and aggregates, which are the most indispensable constituents used in concrete production are also vital materials needed for the construction industry. This has led to a continuous and increasing demand of natural materials used for their production. Meanwhile, waste materials and by-products are being generated in vast quantities causing detrimental effects to the environment. It is therefore imperative to utilize these waste materials and by-products in construction applications. Recently, there have been successful applications of local waste materials as partial replacements for cement or aggregates in manufacturing concrete products in most parts of the world.Among the waste materials, plastic is one of the most common environmental issues in the contemporary world. Disposal of these plastics is considered to be a big challenge due to its non-biodegradable nature. Most of these plastics end up in landfills and give the worst effect when they are burnt. (Ohemeng *et al.*, 2014)

1.2 Workability of Concrete

The behavior of green or fresh concrete from mixing up to compaction depends mainly on the property called “workability of concrete”. Workability of concrete is a term which consistsof the following four partial properties of concrete namely, Mixability, Transportability, Mouldability and Compactibility. In general terms, workability represents the amount of work which is to be done to compact the compact the concrete in a given mould. The desired workability for a particular mix depends upon the type of compaction adopted and the complicated nature of reinforcement used in reinforced concrete. A workable mix should not segregate.

a. Mixability:It is the ability of the mix to produce a homogeneous green concrete from the constituent materials of the batch, under the action of the mixing forces. A less mixable concrete mix requires more time of mixing to produce a homogeneous and uniform mix.

b. Transportability**:** Transportability is the capacity of the concrete mix to keep the homogeneous concrete mix from segregating during a limited time period of transportation of concrete and when forces due to handling operations of limited nature act. Any segregation that is caused during the remaining operations that follows.

c. Mouldability:It is the ability of the fresh concrete mix to fill completely the forms or moulds without losing continuity or homogeneity under the available techniques of placing the concrete at a particular job. This property is complex, since the behavior of concrete is to be considered under dynamic conditions.

d. Compactibility**:** Compactibility is the ability of concrete mix to be compacted into a dense, compact concrete, with minimum voids, under the existing means of compaction at the site. The best mix from the point of view of compatibility should close the voids to an extent of 99% of the original voids present, when the concrete was placed in the moulds.

The concrete workability was determined by compaction factor and slump tests carried out at the concrete laboratory of Civil Engineering Department of Ahmadu Bello University, Zaria.

1.3 Statement of the Problem

In Nigeria today, polyethene is the major constituent of solid waste generated by households which are not fully utilized for reused or recycled. Polyethene littering

leads to untidy environment, blockage of drainages and generation of aerosols when burnt, which leads to ozone layer depletion. Management of polyethene wastes can be linked to creation of jobs, poverty alleviation and community participation. Polyethenewaste can be used as replacement of aggregate(s) in concrete mixes. However, the hydrophobic nature of polyethene wastemakes them hard to be bonded to cement and other aggregates in concrete mixes.

1.4 Aim and Objectives of the Research

The aim of the study is to produce Concrete Composite Cubes using Grafted and Ungrafted waste Polyethene as a replacement of coarse aggregate in the concrete mixes.

The objectives are as follows:

1. Hydroxylation of waste LLDPE and LDPE.
2. Grafting of Acrylamide onto WasteLLDPE and LDPE.
3. Characterization of hydroxylated and grafted waste LLDPE and LDPEusing FT-IR spectroscopy.
4. Production of Concrete Composite Cubes using the grafted and ungraftedPolyethene as a partial replacement of gravel aggregate.
5. Physico-mechanical analysis of the Concrete Composites Cubes using (Density, water absorption, compaction factor test, slump test, compressive strength and scanning electron microscopy.

1.5 Significance of the Study

The research is expected to highlight the effect of grafted and ungrafted waste Low Density Polyethene (LDPE) as a replacement of coarse aggregate in cement concrete with the view to producing cheaper cement concretes to reduce cost in the building

and civil engineering works. The use of waste LDPE in Concrete Composite Cubes (CCCs) will also contribute to providing environmentally friendly solution for waste LDPE disposal problems in Nigeria and the world as a whole. The conversion of waste to wealth will help in the creation of jobs to the unemployed citizens of Nigeria and foreigners. Furthermore, it will attract foreign investment in waste management industry in the country.

1.6 Limitations of the Study

This research is limited to waste Low Density Polyethene (LDPE) from pure water sachets collected around the premises of Ahmadu Bello University, Samaru, Zaria. The raw materials used for the production of the water sachetswere traced to be supplied by AAM plastics Nig. Ltd, Kaduna in form of granules, while the analysis of the Concrete Composite Cubes is limited to physical and mechanical properties.

CHAPTER TWO
LITERATURE REVIEW

Recently, there have been successful applications of local waste materials as a partial replacement for cement or aggregates in manufacturing concrete products in some parts of the world. Numerous researches on application of waste tyres as fine and coarse aggregates are available in the literatures (Eldin and Senouci, 1993; Topcu, 1995; Toutanji, 1996; Khatib and Bayomy, 1999; Ling, 2011; Ohemeng and Valley, 2013), in which they demonstrate the feasibility of using large amounts of waste tyre in concrete products.

Al-Manaseer and Dalal (1997) reported that the bulk density of plastic concrete decreased as the plastic content increased. The density was reduced by about 2.5%, 6%, and 13% when plastic contents of 10%, 30%, and 50% respectively were used. Choi *et al*., (2005) investigated the effect of waste PET bottles aggregate on properties of concrete. The waste plastic could reduce the weight by 2 - 6% of normal weight concrete. Marzouk *et al*., (2007) studied the use of usedPET bottles as sand replacement,noticed that the density was lowered when the PET aggregate exceeded 50% by volume of sand. Suganthy *et al*., (2013) also reported a decreased in weight of concrete as the plastic content was increase. It was also noticed that there was linear relationship between decrease in weight and increase in plastic content.

Mustafa Al Bakri *et al.,* (2011) investigated HDPE waste aggregate on the properties of concrete that HDPE waste plastic has potential application for the production of lightweight concrete, cost savings for raw materials, for minimizing the amount of polymer wastes in landfills anddecoration for attractive landscapedenvironment.

Ohemeng and Valley (2014) demonstrated in a study that there is a great potential for utilization of waste Low Density Polyethene in pavement block mixes which are satisfactory for pedestrian walkways, light traffic and heavy traffic situations.

It has been observed that increase in plastic aggregate content reduces the strengths of plastic concrete Batayneh *et al.,* (2007) mentioned that the incorporation of ground plastic in concrete had effect on its compressive strength. The compressive strength was reduced by about 23%, 35%, 50%, and 71% when fine aggregates of 5%, 10%, 15%, and 20% respectively were substituted with plastics. Naik *et al.,* (1996) investigated the effect of post-consumer waste plastic in concrete as soft filler. The results of the research showed lower compressive strength of the mix made with plastic than the reference mixture without plastic. Choi *et al*., (2005) also noticed a reduction in both compressive strength and splitting tensile strength. The compressive strength was lowered by 33% when compared to that of normal concrete. For the splitting tensile strength, increase in plastic content resulted in its reduction regardless of the water cement ratio used. Marzouk (2007) further reported a reduction of compressive strength in plastic concrete when the sand was replaced by plastic.

Al-Manasser and Dalal (1997) studied the effect of plastic on concrete mixes. It was noticed that the splitting tensile strength decreased as the plastic content was increased. Batayneh *et al*., (2007) also reported that the splitting tensile strength and the flexural strength of concrete mix slumped as the plastic content was increased. The splitting tensile strength was lowered by about 56% when 20% of the aggregate content was replaced by plastic. The flexural strength was also decreased by about 40% when 15% of the aggregate was substituted with plastic.

Ohemeng and Valley (2014) reported in their study of utilization of waste Low Density Polyethene in high strengths concrete pavement blocks production that plastics were put on fire to melt so that the long chains can break apart and allowed to solidify so that they can be grounded into small particle for application in the production of pavement blocks.

Kilda, *et al*., (1992) carried out a study on grafting Acrylamide onto the surface of Polyethene film with the aid of peroxide initiator (tert-butyl peroxyneodecanoate). The grafting has been found to function, but the process require further development to reduce the total grafting time before it can be used commercially.

Po-Yu and Chun-Ku (2011) carried out surface modification of Polyethene grafting with non-ionic polyacrylamide (PAM) to enhance its hydrophillicity. The PAM-graftedpolyethene (PE) was used to interact with cement paste to observe its adherence to CSH (hydration product of cement). The original and PAM-grafted PE was characterized by FT-IR spectroscopy to investigate their functional groups. The hydrophilic property was evaluated by contact angle measurement. The morphology of PE film was studied using Atomic Force Microscopy (AFM). Finally, the interaction of PE film with CSH was observed with Scanning Electron Microscopy (SEM). They reported that the contact angles, IR spectra, and AFM images gave the evidences that PAM was successfully grafted onto the PE surfaces. The hydrophillicity of the PAM-grafted PE was enhanced significantly by this polar polymer. SEM images showed that CSH could adhere to the PAM-grafted PE more tightly than the original PE.

FT-IR spectroscopy was developed in order to overcome the limitationsencountered with dispersive instruments. The main difficulty was the slow scanning process. A methodfor measuring all of the infrared frequencies simultaneously, rather than individually, was needed.A solution was developed which employed a very simple optical device called an interferometer.The interferometer produces a unique type of signal which has all of the infrared frequencies "encoded"into it. The signal can be measured very quickly, usually on the order of one second or so. Thus,the time element per sample is reduced to a matter of few seconds rather than several minutes.Most interferometers employ a beamsplitter which takes the incoming infrared beam anddivides it into two optical beams. One beam reflects off of a flat mirror which is fixed in place. Theother beam reflects off of a flat mirror which is on amechanism which allows this mirror to move a veryshort distance (typically a few millimeters) away fromthe beamsplitter. The two beams reflect off of theirrespective mirrors and are recombined when they meetback at the beamsplitter. Because the path that one beamtravels is a fixed length and the other is constantlychanging as its mirror moves, the signal which exitsthe interferometer is the result of these two beams "interfering" with each other.

The resulting signalis called an interferogram which has the unique property that every data point (a function of themoving mirror position) which makes up the signal has information about every infrared frequencywhich comes from the source.This means that as the interferogram is measured; all frequencies are being measuredsimultaneously. Thus, the use of the interferometer results in extremely fast measurements.Because the analyst requires a frequency spectrum (a plot of the intensity at each individual frequency) in order to make identification, the measured

interferogram signal cannot be interpreted directly. A means of "decoding" the individual frequencies is required. This can be accomplished via a well-known mathematical technique called the Fourier transformation. This transformation is performed by the computer which then presents the user with the desired spectral information for analysis. (Thermo, 2001).

Workable concrete is the one which exhibits very little internal friction between particle and particle or which overcomes the frictional resistance offered by the formwork surface or reinforcement contained in the concrete, with just the amount of compacting efforts forthcoming. The factors helping concrete to have more lubricating effect to reduce internal friction for helping easy compaction are given below:

a) **Water content:**Water content in a given volume of concrete, will have significant influences on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. At the work site, supervisors who are not well versed with the practice of making good concrete resort to adding more water for increasing workability. This practice is often resorted to because this is one of the easiest corrective measures that can be taken at the site. It should be noted that from the desirability point of view, increase of water content is the last recourse to be taken for improving the workability even in the case of uncontrolled concrete. For controlled concrete one cannot arbitrarily increase the water content. In case all other steps to improve workability fail, only as last recourse the addition of more water can be considered. More water can be added, provided a

correspondingly higher quantity of cement is also added to keep the water/cement ratio constant, so that the strength remains the same.

b) **Mix proportions:**Aggregate/cement ratio is an important factor influencing workability. The higher the aggregate/cement ratio, the leaner is the concrete. In lean concrete, less quantity of paste is available for providing lubrication, per unit surface area of aggregate and hence the mobility of aggregate is restrained. On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make themix cohesive and fatty to give better workability.

c) **Size of aggregate:**The bigger the size of the aggregate, the less the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction. For a given quantity of water and paste, bigger size of aggregates will give higher workability. The above ofcourse will be true within certain limits.

d) **Shape of aggregates:**The shape of the aggregate influences the workability in good measure. Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates. Contribution to better workability to rounded aggregate will come from the fact that for the given volume or weight it will have less surface area and less voids than angular or flaky aggregate. Not only that, being round in shape, the frictional resistance is also greatly reduced. This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand and aggregate. The importance of shape of the aggregate will be of great significance in the case of present day high strength and high performance concrete when we use very low w/c in the order of about 0.25. In years to come natural sand will be exhausted or costly. One has to go for manufactured sand. Shape of crushed sand as available

today is unsuitable but the modern crushers are designed to yield well shapedand well graded aggregates.

e) **Surface texture:**The influence of surface texture on workability is again due to the fact that the total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume. It can be inferred that rough textured aggregate will show poor workability and smooth or glassy textured aggregate will give better workability. A reduction of inter particle frictionalresistance offered by smooth aggregates also contributes to higher workability.

f) **Grading of aggregates:**This is one of the factors which will have maximum influence on workability. A well graded aggregate is the one which has least amount of voids in a given volume. Other factors being constant, when the total voids are less, excess paste is available to give better lubricating effect. With excess amount of paste, the mixture becomes cohesive and fatty which prevents segregation of particles. Aggregate particles will slide past each other with the least amount of compacting efforts. The better the grading, the less is the void content and higher the workability. The above is true for thegiven amount of paste volume.

g) **Use of admixtures:**Of all the factors mentioned above, the most important factor which affects the workability is the use of admixtures. It is to be noted that initial slump of concrete mix or what is called slump of reference mix should be about 2–3 cm to enhance the slump many fold at a minimum dose. Without initial slump of 2-3cm, the workability can be increased to higher level but it requires higher dosage – hence uneconomical. The American Concrete Institute (ACI, 2000) describes workability as “that property of freshly mixed concrete or mortar that

determines the ease with which it can be mixed, placed, consolidated, and finished to a homogenous condition." The Japanese Association of Concrete Engineers defines workability as "that property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, and compacted due to its consistency, the homogeneity with which it can be made into concrete, and the degree with which it can resist separation of materials" (Neville, 1981) and (Ferraris,1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Linear Low Density Polyethene (LLDPE) was purchased from 3-Star Plastics Limited, Kaduna, Nigeria.Waste low density polyethene (LDPE), Ordinary Portland Cement (OPC) Dangote, Sand, Gravel, Water. Acrylamide (AAm) monomer, Potassium Persulfate ($K_2S_2O_8$), Ceric Ammonium Nitrate [$(NH_4)_2Ce(NO_3)_6$] and Nitric Acid (HNO_3), were purchased from Zayo-Sigma Aldrich, Padeborn – Elsen, Germany. Acetone was purchased fromRomptech Scientific Supplies Co. Ltd. Zaria, Nigeria.Nitrogengas was purchased from BOC Gas Nigeria Ltd.

One litre four necked reaction flask, three litre reaction flasks, four necks ace reaction flask heads, glass beakers, measuring cylinders, test tubes, spatula, glass rod, syringe, funnel, corks, utility clamp, ring stand, safety goggles, assorted rubber stoppers, gas cylinder, clamp stands, boss weights scissors, razor blades, cello-tape, electronic balance, mouth mask, hand gloves, safety boot, 2JB thermostatic water bath, electric stirrer, thermometers, rubber tubes, condenser, Avery weighing balance, chilling system, film crushing machine (Changda), casting moulds (15cm x 15cm x 15cm), British Standard Test Sieve (0.475cm), shovel, scoop, trowel, compacting rod, hand float, measuring ruler, iron pan, slump apparatus, stapula, tamping rod, iron buckets, water curing vessel, Denison crushing machine, compacting factor apparatus, Fourier Transform Infrared (FT-IR) – 84005 Spectrophotometer, Scanning Electron Microscope (SEM).

3.2 Methods

3.2.1 Preparation of waste Low Density Polyethene

The waste Polyethene was sourced from pure water sachets, within Ahmadu Bello University, Samaru, Zaria premises.They were opened and dried outside to remove water trapped in the sachets.The waste Polyethene was crushed in the film crushing machine into stripes. Three (3) different samples were obtained using three (3) different beaterroller settings.The beater roller settings were adjusted using a feeler gauge(s).

Sample No. 1 5mm feeler gauge setting

Sample No. 2 10mm feeler gauge setting

Sample No. 3 15 mm feeler gauges setting

After crushing the stripes were washed in acetone to remove all impurities and adsorbed additives on the surfacesof the waste Polyethene. They were dried at room temperature. The control linear low density polyethene chips were also washed in acetone in order to remove any surface impurity. They were dried at room temperature.

3.2.2 Hydroxylation of Waste Low Density Polyetheneand LinearLow Density Polyethene

Surface modifications of polyethene were carried out to improve its adhesion. The particulates samples and the chips were functionalized by thermal decomposition in potassium persulfate to create grafting sitesIn a 3 litre and four (4) necks reaction flask the waste LDPE and LLDPE were hydroxylatedseparately with a 10% w/v of $K_2S_2O_8$ aqueous solution. The reaction flasks were de-aerated by bubbling N_2 gas slowly and continuously into the solution(s). The reaction(s) were allowed to proceed

at 80°C for 3 hours and was vigorously stirred at an interval of 30 minutes with the mechanical stirrer at 100rpm, 200rpm, and 300rpm at intervals. At the end of the reaction(s), the sample(s) were removed and washed several times with hot water and dried at room temperature and stored(See Appendix $AI_{3.1}$ and $AI_{3.2}$).

3.2.3 Grafting of the Hydroxylated Samples

The Ceric (IV) ion technique was used to initiate the grafting on the hydroxylated sites using Ceric Ammonium Nitrate [$(NH_4)_2Ce\ (NO_3)_6$] by chemical force.In a 3 litre, 4 necks reaction flask, the hydroxylated samples of the waste LDPE and LLDPE were grafted separately. The solutions consisting of $3x10^{-3}$ mol/L Ceric Ammonium Nitrate and 7% w/v of AAm in 0.05 mol/L HNO_3. Nitrogen gas was continuously and slowly bubbled through the reaction medium in order to remove oxygen gas throughout the reaction. The temperature of the reaction was kept at 50^0C using a water bathequipped with a thermometer. The grafting was allowed to proceed for five (5) hours. The reaction was stopped, the sample(s) were washed thoroughly with hot water and soaked overnight in order to remove the residual monomer and homopolymers that may have been on the surface(s) of the sample(s). The sample(s) were dried at room temperature and weighed (See Appendix $AI_{3.3}$ and$AI_{3.4}$)

.

3.3 Characterization of Hydroxylated and Grafted Samples by FT-IR Spectroscopy

The infrared spectrum represents a finger print and functional groups of a sample with absorption peaks which correspond to the frequencies of vibration between bonds of the atoms making up the material. Because each different material is a unique combination of atom, no two compounds produce the exact same infrared spectrum. Therefore, infrared spectroscopy is used for positive identification of every different

material. The size of the peaks in the spectrum is a direct indication of the amount of material present. In this study, the FT-IR analysis of the hydroxylated and the grafted samples were carried out with FT-IR – 84005 Fourier Transform Infrared Spectrophotometer at National Research Institute for Chemical Technology (NARICT), Zaria.

3.4 Preparation ofComponents CompositeCubes

3.4.1 Cement, Sand and Gravel

The analysis of the Ordinary Portland Cement 3X – 42.5R grade was carried to determine the chemical composition of the cement at the concrete laboratory (see table 3.1). British Standard Sieve size 0.47mm was used to Sieve the sand aggregate while about 10mm size of gravel was used in the mix.

Table 3.1: Chemical Composition of Ordinary Portland cement – Dangote

Chemical Composition	Content %
Calcium Oxide (CaO)	64.53 $\pm$ 0.02
Silicon Dioxide (SiO_2)	20.64 $\pm$ 0.14
Aluminium Oxide (Al_2O_3)	5.40 $\pm$ 0.04
Iron Oxide (Fe_2O_3)	3.99 $\pm$ 0.01
Magnesium Oxide (MgO)	2.35 $\pm$ 0.01
Sulphur Oxide (SO_3)	1.77 $\pm$ 0.04
Phosphouros Oxide (P_2O_3)	0.52 $\pm$ 0.01
Potassium Oxide (K_2O)	0.26 $\pm$ 0.01
Free Calcium Oxide (CaO)	2.33 $\pm$ 0.04
Loss on Ignition	5.80

3.4.2 Prepared Moulds

Moulds of 15cmx15cmx 15cm were fabricated at the Department of Mechanical Engineering workshops of Ahmadu Bello University, Zaria. The moulds were of standard laboratory dimensions as shown in plate 3.1.



Plate 3.1: 15cm x 15cm x 15cm prepared moulds

3.5 Production of Concrete Composite Cubes (CCCs)

3.5.1 Concrete Mix Design

The mix proportion of 1:2:4 (cement: sand: coarse aggregates) and 1:2 water: cement ratio was used for the control sample. While for the grafted samples to replace the gravel coarse aggregate by 2.5%, and theungrafted sample 2.5%, 5%, 7.5% and 10%, were used.

3.5.1.1 Calculation of Weight of Control Sample

Volume = 0.15m x 0.15m x 0.15m = $0.000375m^3$

Add 10% for shrinkage + waste

Density of Concrete = $2400Kg/m^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$2400Kg/m^3 = \frac{\text{Mass}}{0.0037125m^3}$$

Mass = 2400Kg x 0.0037125

= **8.91Kg**

Mass of concrete 8.91Kg

:. Mass of concrete for 6 Nos. = 8.91Kg x 6 = **53.46Kg**

i.	Cement	=	1/7.5 x 53.46	=	7.128Kg
ii.	Sand	=	2/7.5 x 53.46	=	14.256Kg
iii.	Gravel	=	4/7.5 x 53.46	=	28.512Kg
iv.	Water	=	0.5/7.5 x 53.46	=	3.564Kg
			Total	=	**53.46Kg**

3.5.1.2 Calculation of Partial Replacements of Coarse Aggregate (gravel)

a) *2.5%* = 2.5/100 x 28.512Kg = 0.7128Kg

2.5% replacement = 28.512 – 0.7128 = 27.7992of Gravel

b) *5%* = 5/100 x 28.512Kg = 1.4256Kg

28.512kg – 1.4256Kg = 27.0864 of Gravel

c) *7.5%* = 7.5/100 x 28.512Kg = 2.1384Kg

28.512kg – 2.1384Kg = 26.373Kg of Gravel

d) *10%* = 10/100 x 28.512Kg = 2.8512Kg

28.512kg – 2.8512Kg = 25.6608Kg of Gravel

The control Concrete Composite Cubesis denoted as **A** while the grafted concrete composite is denoted as **B**and the rest of the batches with ungrafted waste polyethene with 2.5%, 5%, 7% and 10% were denoted **C, D, E** and **F** respectively.

3.5.1.3 MixProportion of Concrete Composite Cubes

Tables 3.2 show a summary of the mix proportion of the constituent materials used in the production of the various CCCs, while Appendix II, tables 1.1 to 1.14 displays the calculated mix proportion(s) of the aggregates.

Table 3.2: Summary of Mix Proportions of Materials used for various CCCs

S/N	Batch	Cement	Sand	Gravel	Water	Waste Polyethene Kg		Waste Polyethene %	
						Grafted	Ungrafted	Grafted	Ungrafted
1	A	7.128	14.256	28.512	3.564	---	---	---	---
2	B	7.128	14.256	4.6332	3.564	0.118		2.5%	
3	C	7.128	14.256	4.6332	3.564	---	0.118	---	2.5%
4	D	7.128	14.256	4.5144	3.564	---	0.2376	---	5%
5	E	7.128	14.256	4.3955	3.564	---	0.3564	---	7.5%
6	F	7.128	14.256	4.2768	3.564	---	0.4752	---	10%

3.5.1.4 Mixing and Compaction of Concrete Composite Cubes

Mixing operations were made in the concrete laboratory in the Civil Engineering Department of Ahmadu Bello University, Zaria. Weighing of cement, sand, water and grafted and ungrafted polyethene were carried out using Avery weighing equipment. The mixing was done manually using a shovel to aid mixing the aggregates and pouring water at intervals.Mixing continued until a homogenous mixture was obtained.The workability test was carried out on the homogeneous mixes before casting of the Concrete Composites Cubes. The homogenous mixes were cast into the moulds. Thirty-six (36) CCCs were cast i.e. six (6) cubes for control, six (6) cubes for 2.5% (grafted Waste LDPE), six (6) cubes each for Waste LDPE (2.5%, 5%, 7.5% and 10%)denoted as A, B, C, D, E, and F respectively.The concrete mix was poured in three layers in the moulds. Each layer was compacted by using a tapping rod until the concrete is leveled off smoothly to the top of the moulds.

3.5.1.5 Workability of Concrete

3.5.1.6 Compaction Factor Test

The compaction factor test was in accordance with British Standard BS 1881-103, 1993. Plate 3.2 shows the apparatus used for the test. The apparatus consists of a rapid frame support, two conical hopper vertically aligned above each other and mounted above the cylinder as shown in plate 3.2. The top hopper is slightly larger than the bottom, while the cylinder is smaller in volume than both hoppers. To perform the test, the top hopper was filled with concrete but not compacted. The door on the bottom of the top hopper was opened and the concrete was allowed to drop into the lower hopper. Once all the concrete has fallen from the top hopper, the door on the lower hopper was opened to allow the concrete to fall to the bottom cylinder. A

tamping rod can be used to force especially cohesive concrete through the hoppers. The excess concrete is carefully struck off the top of the cylinder and the mass of the concrete in the cylinder was recorded. This mass was compared to the mass of fully compacted concrete in the same cylinder achieved with hand float. The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of fully compacted concrete (see Appendix $AI_{3.6}$). The compacting factor formula is stated below:

$$\text{Compacting Factor} = \frac{M_p}{M_f} \quad \text{-----} \quad (3.1)$$

Where:

M_p is the mass of the partially compacted concrete (in grams)

M_f is the mass of the fully compacted concrete (in grams)

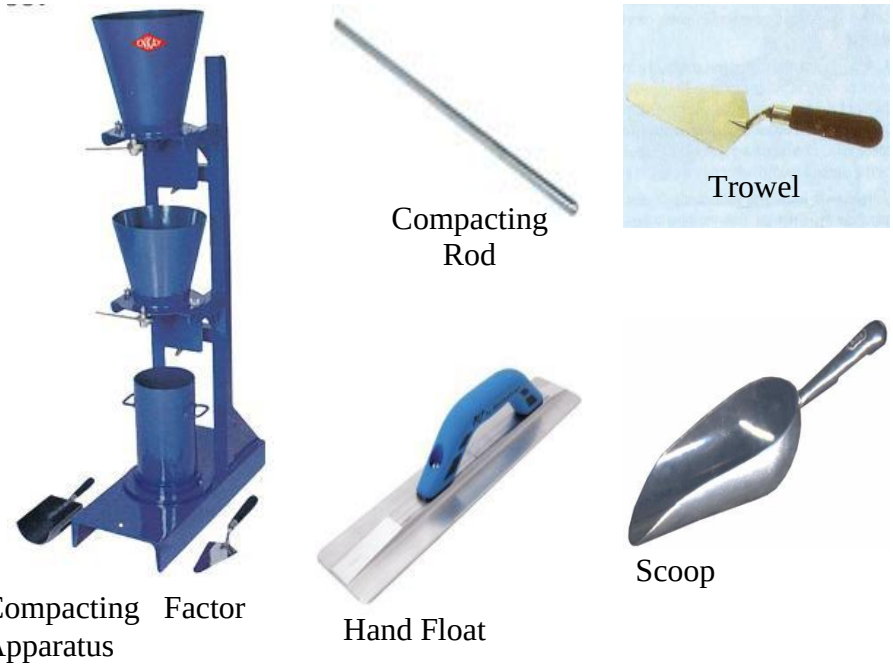


Plate 3.2: Compacting Factor Test Apparatus

The standard test apparatus described above is appropriate for maximum aggregate size of up to 20mm. A larger apparatus is available for concretes with maximum aggregate sizes of up to 40mm. The compaction factor test gives more information about compatibility. The test is a dynamic test and thus is more appropriate than other static tests on compatibility for highly thixotropic concrete mixtures. In a dynamic test energy is impacted into the concrete by compacting with the compacting rod. However, in static tests, do not add such energy and often rely on the concrete mixes to flow under its own weight. Hence, for this study in respect of Concrete Composites mixes the dynamic test was used.

3.5.1.7Slump Test

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including in ASTM C143 in the United States and EN 12350-2 in Europe**.**

The apparatus consists of a mould in the shape of a frustum of a cone with a base diameter of 20cm, a top diameter of 10cm, and a height of 30cm. The mold was filled with concrete inthree layers of equal volume. Each layer was compacted with 25 strokes of a tamping rod. Theslump cone mold was lifted vertically upward and the change in height of the concrete is measured.Four types of slumps are commonly encountered; (True, Zero, Collapse and Shear).The only type of slumppermissible under ASTM C143 is frequently referred to as the “true” slump, where the concreteremains intact and retains a symmetric shape. A zero slump and a collapsed slump are bothoutside the range of workability that can be measured with the slump

test. Specifically, ASTMC143 advises caution in interpreting test results less than 1.25cm and greater than 22.5cm. Ifpart of the concrete shears from the mass, the test must be repeated with a different sample ofconcrete. A concrete that exhibits a shear slump in a second test is not sufficiently cohesive andshould be rejected.

To determine the consistency of concrete composite mix, the slump test was used. Unsupported fresh concrete flows to the sides and a banking in height takes place. This vertical settlement is known as slump. In this test, fresh concrete composite mix was filled into the mould and the settlement or slump measured when the supporting mould was removed.The slump test was carried out in accordance with British Standard BSI 1881-102, 2003. The change in height between fully compacted and partially compacted is measured in mm.

3.6 Curing of Concrete Composites Cubes

Water curing was used to cure the produced Concrete Composites Cubes. Water curing promotes hydration, elimination of shrinkage and absorption of the heat of hydration. The prepared CCCs casted were left in the mould for 24 hours before curing started. They were cured at room temperature, totally immersed inside water for seven (7) days and twenty-eight 28 days (See plate 3.3).



Plate 3.3: Curing of CCCs Totally Immersed in Water for 7 and 28 Days Curing

3.7 Dryingof the Concrete Composites Cubes

The drying of the CCCs was carried in an open atmosphere under direct sunlight on top of a clean surface as shown in Plates 3.4 and Appendix AI: Plates 3.7 to 3.9.



Plate 3.4: Drying of Control and 2.5% Waste LDPE Specimens

3.8Physical Characterization

3.8.1 Density Test

Density is the mass of a quantity of compacted fresh concrete divided by its volume, expressed in kilograms per cubic meter. The density of the Concrete Composites Cubes (CCCs) was carried out in conformity with British Standard BS 1818-129:2003.

3.8.1.1 Calculation of Density

The density, D (kg/m3) was calculated from the formula:

$$D = \frac{m}{V} \quad \text{----} \quad (3.2)$$

Where:

m is the mass of the concrete composite sample in the container (in kg).

V is the volume (capacity) of the container (in m^3).

3.8.1.2 Calculation of Volume of Concrete Composite per Batch

The volume of concrete composite cube per batch (V_b) required was calculated (in m^3) from the formula:

$$V_b = \frac{m_c + m_s + m_a + m_w}{D} \quad \text{----} \quad (3.3)$$

Where:

m_a is the mass per batch of gravel/LDPE used in kg.

m_c is the mass per batch of cement (in kg).

m_s is the mass per batch of sand used (in kg).

m_w is the mass of mixing water added to batch (in kg).

D is the density of fully compacted fresh concrete (in kg/m^3)

3.8.1.3 Calculation of Cement Content

The cement content, C, (in kg/m^3) of Concrete Composite required was calculated from the formula:

$$C = \frac{m_c}{V_b} \quad \text{or} \quad C = \frac{Dm_c}{m_c + m_s + m_a + m_w} \quad \text{----} \quad (3.4)$$

Where:

m_a is the mass per batch of gravel/LDPE used in kg.

m_c is the mass per batch of cement (in kg).

m_s is the mass per batch of sand used (in kg).

m_w is the mass of mixing water added to batch (in kg).

D is the density of fully compacted fresh concrete (in kg/m^3)

3.9 Scanning Electron Microscopy (SEM)

Generally, there are two types of electron microscopes, transmissionelectron microscope (TEM) and scanning electron microscope (SEM). SEM was used to study the Concrete Composites Cubes (CCCs). SEM images the sample surface by scanning itwith electron beams in a raster scan pattern. The electrons interact with the sample atoms producing signals that containinformation about the sample's surface topography, composition and other properties such as electrical conductivity.SEM looks at the surface (or the near-surface).Signals produced by an SEM result from interactions of the electron beam with atoms at or near the surface of thesample, include secondary electrons, back-scattered electrons (BSE), characteristic X-rays, light(cathodoluminescence), specimen current and transmitted electrons. By detection of secondary electron, SEM canproduce vivid images of a sample surface (secondary electron image, or SEI), with superior resolution about 1 to 5nm. The SEM analysis was carried out at Chemical Engineering Department, Ahmadu Bello University, Zaria. Using SEM Microscope Model Phenom World Prox.

3.10 The Sample Analysis Process

The normal FT-IR instrumental process is as follows:

1. **The Source:**Infrared energy is emitted from a glowing black-body source. This beam passes through an aperture which controls the amount of energy presented to the sample (and, ultimately, to the detector).
2. **The Interferometer:**The beam enters the interferometer where the “spectral encoding” takes place. The resulting interferogram signal then exits the interferometer.
3. **The Sample:**The beam enters the sample compartment where it is transmitted through or reflected off of the surface of the sample, depending on the type of

analysis being accomplished. This is where specific frequencies of energy, which are uniquely characteristic of the sample, are absorbed.

4. **The Detector:**The beam finally passes to the detector for final measurement. The detectors used are specially designed to measure the special interferogram signal.

5. **The Computer:**The measured signal is digitized and sent to the computer where the Fourier transformation takes place. The final infrared spectrum is then presented to the user for interpretation and any further manipulation. (Thermo, 2001).

3.11 Compressive Strength

The compressive strength test was performed in accordance with British Standard BS 6717 – Part 1 (1986) which is in conformity with BSEN 12390 – 3 & 4:2000. The tests were carried out in the concrete laboratory of Civil Engineering Department, Ahmadu Bello University, Zaria, using Denison Machine(See Plate 3.5, 3.6 and 3.7).



Plate 3.5: Denison Machine

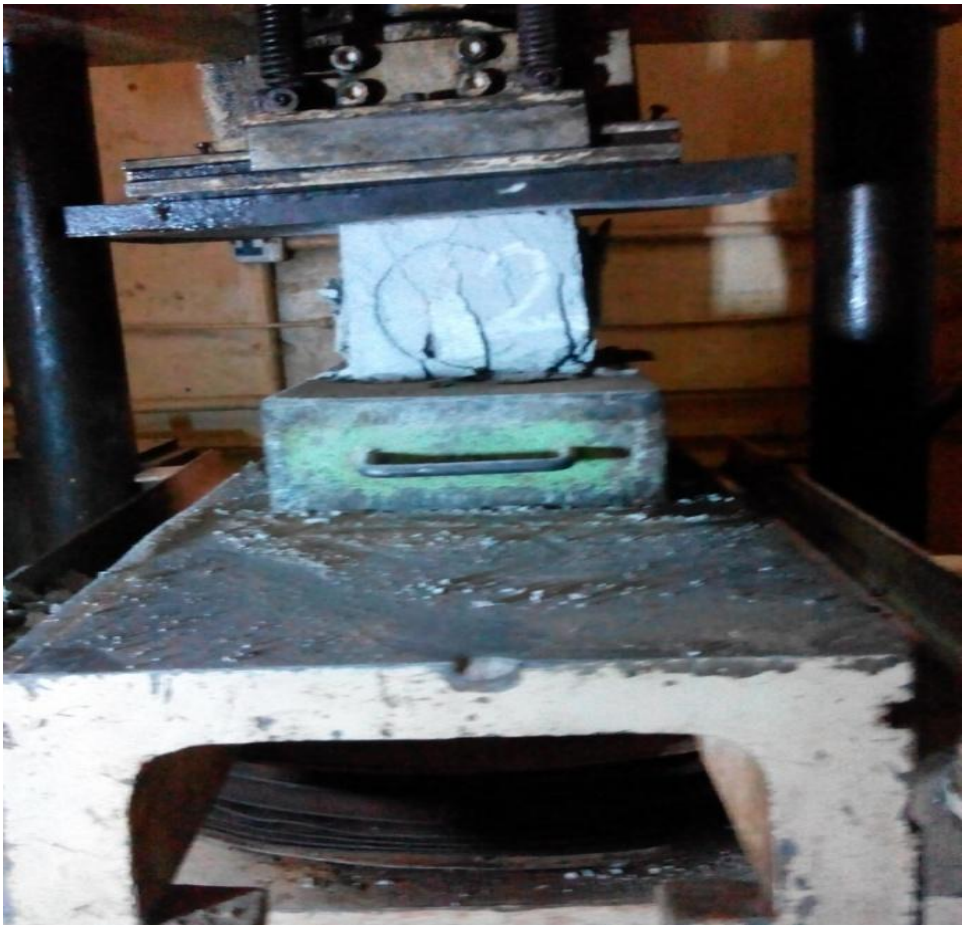


Plate 3.6: Crushing of Cube in Progress using Denison Machine



Plate 3.7: Crushed Cube using Denison Machine

CHAPTER FOUR

RESULTS

4.1 FT-IR of the Hydroxylated and Grafted LLDPE and LDPE

Table 4.1: FT-IR of the Hydroxylated LLDPE

S/No	Absorption Peak (cm^{-1})	Functional Group
1.	3373.61	-OH
2.	3630.15	-OH

Table 4.2: FT-IR of the Hydroxylated LDPE Spectrum

S/No	Absorption Peak (cm^{-1})	Functional Group
1.	3375.54	-OH
2.	3629.19	-OH

Table 4.3: FT-IR of Acrylamide Grafted onto LLDPE

S/No	Absorption Peak (cm^{-1})	Functional Group
1.	1639.55	C – O
2.	3310.28	N – H
3.	1059.92	C – N
4.	1356.97	C – N

Table 4.4: FT-IR of Acrylamide Grafted onto Waste LDPE

S/No	Absorption Peak (cm^{-1})	Functional Group
1.	1712.82	C – O
2.	3621.47	N – H
3.	1024.24	C – N
4.	1290.42	C – N
5.	1368.54	C – N

4.2 Compaction Factor and Slump Test Results

Table 4.5: Compaction Factor Test Results

Batch	Waste LDPE (%)	Compaction Factor
A	0	0.89
B	2.5	0.83
C	2.5	0.85
C	2.5	0.92
C	2.5	0.88
Average		**0.88**
D	5	0.96
D	5	0.98
D	5	0.97
Average		**0.97**
E	7.5	0.70
E	7.5	0.71
E	7.5	0.72
Average		**0.71**
F	10	0.60
F	10	0.59
F	10	0.50
Average		**0.56**

Table 4.6: Slump TestResults

Batch	Waste LDPE (%)	Slump (mm)
A	0	10
B	2.5	20
C	2.5	30
C	2.5	30
C	2.5	35
Average		**32**
D	5	185
D	5	186
D	5	176
Average		**182**
E	7.5	255
E	7.5	253
E	7.5	256
Average		**255**
F	10	270
F	10	260
F	10	265
Average		**265**

4.3 Density Profile of Waste LDPE

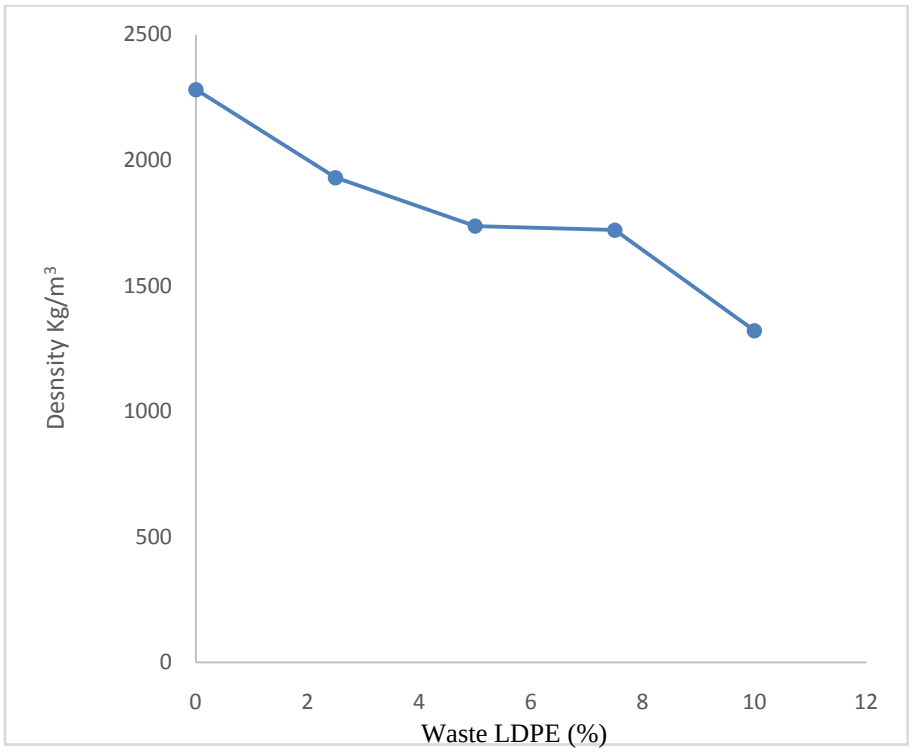


Fig 4.1: Relationship between Densityand Waste LDPE (%) gravel aggregate replacement

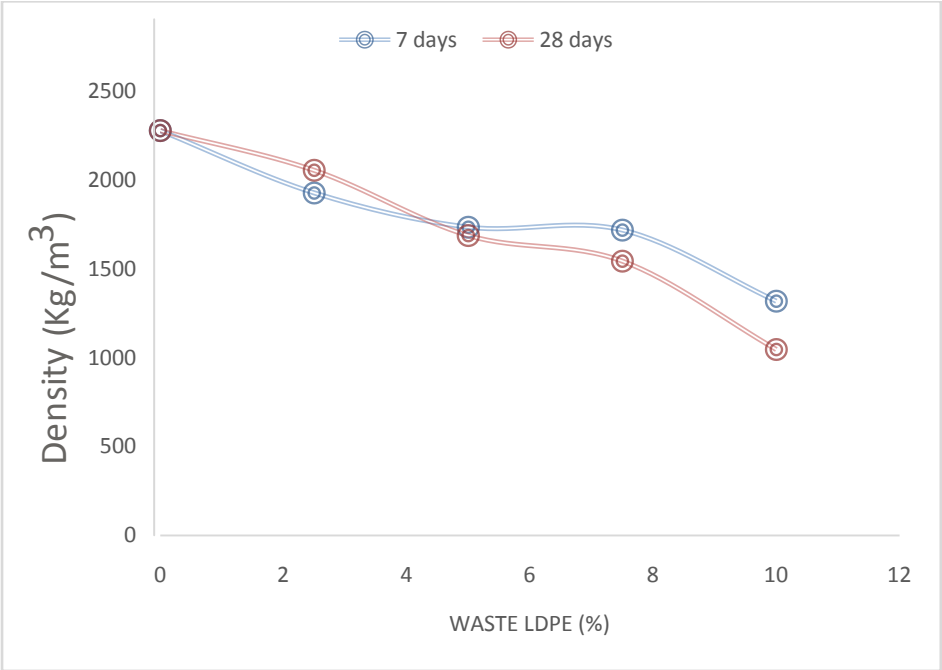


Figure 4.2:Relationship between Density and Waste (%) LDPE gravel aggregate replacement for 7 and 28 day curing

4.4 Results of Water AbsorptionTest

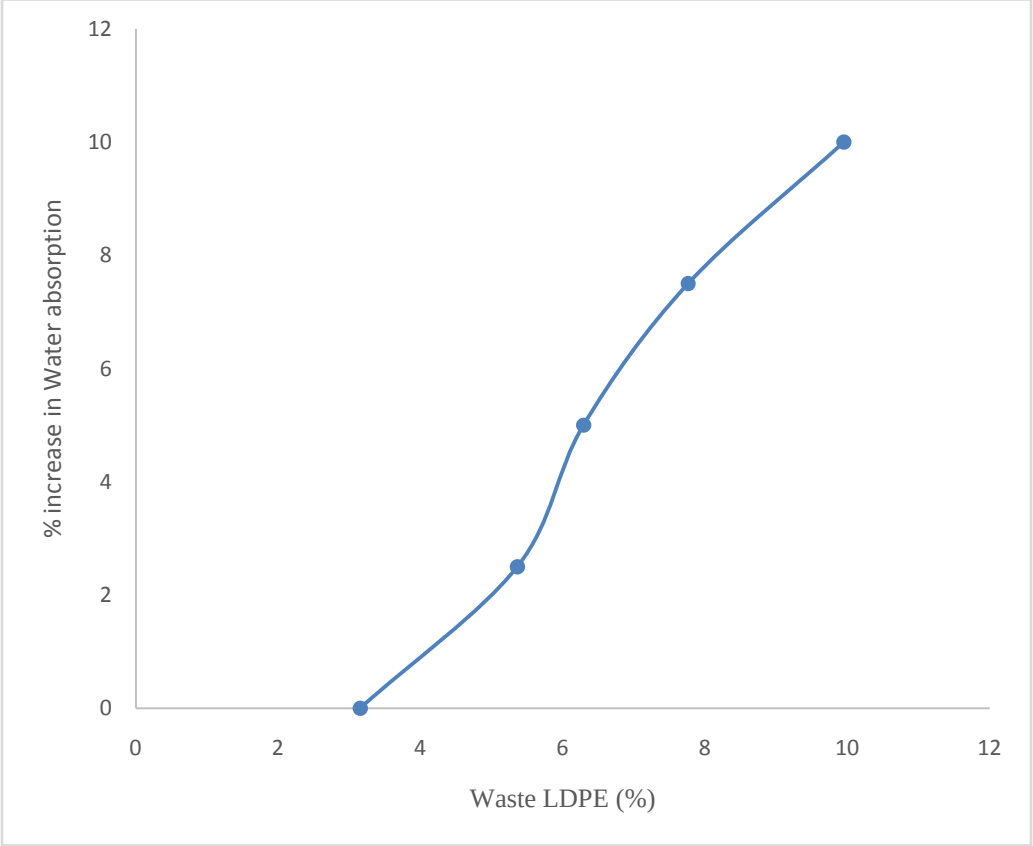


Fig 4.3:Days Curing Relationship between Water Absorption and Waste LDPE (%) gravel aggregate replacement

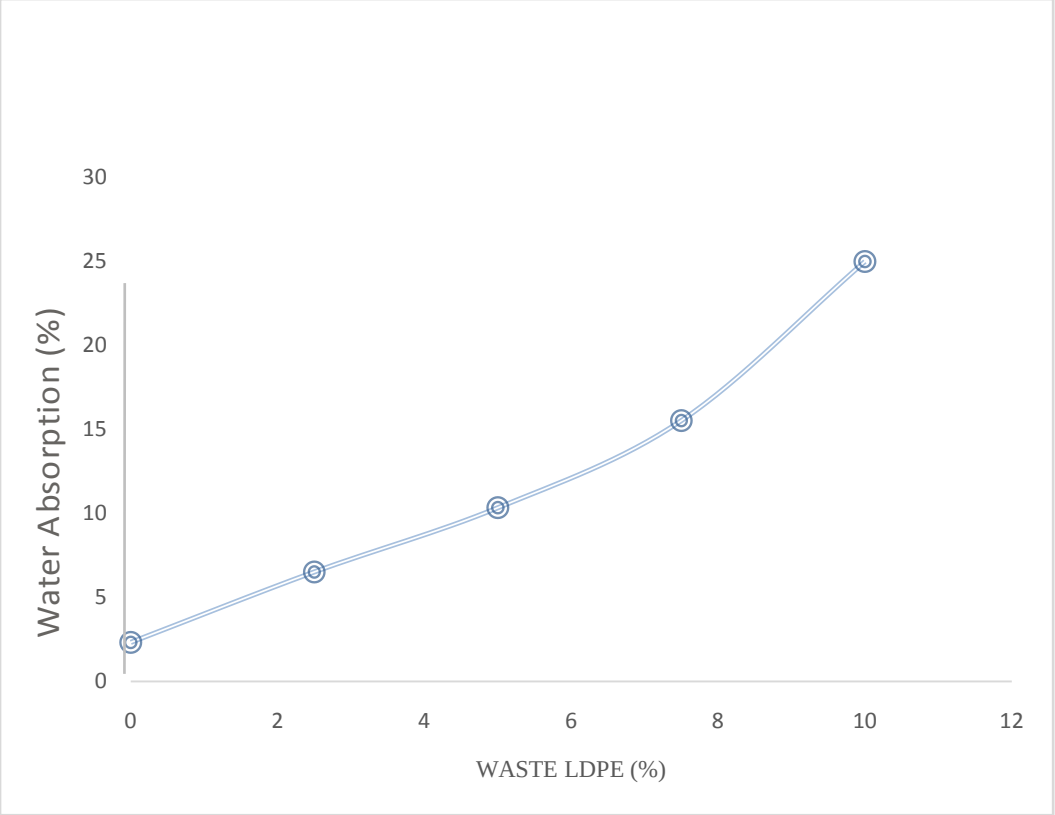


Fig 4.4: 28 Days Curing Relationship between Water Absorption and Waste (%) gravel aggregate replacement

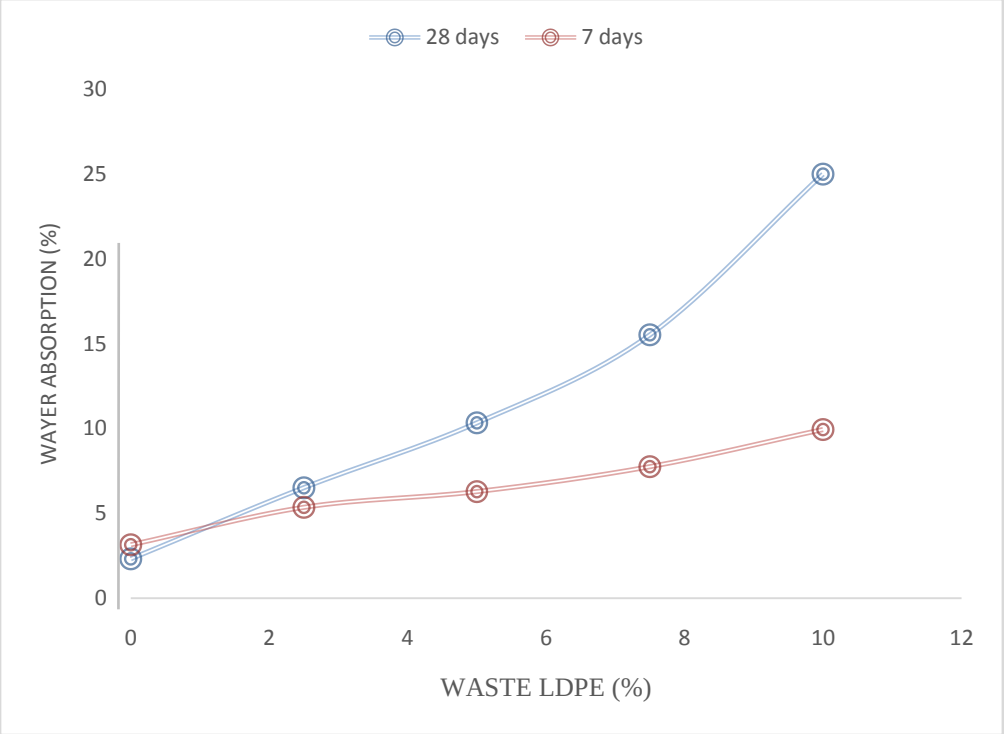


Figure 4.5: Comparison of Water Absorption and WasteLDPE(%) gravel aggregate replacement for 7and 28 days curing

4.5 Compressive Strengths Results

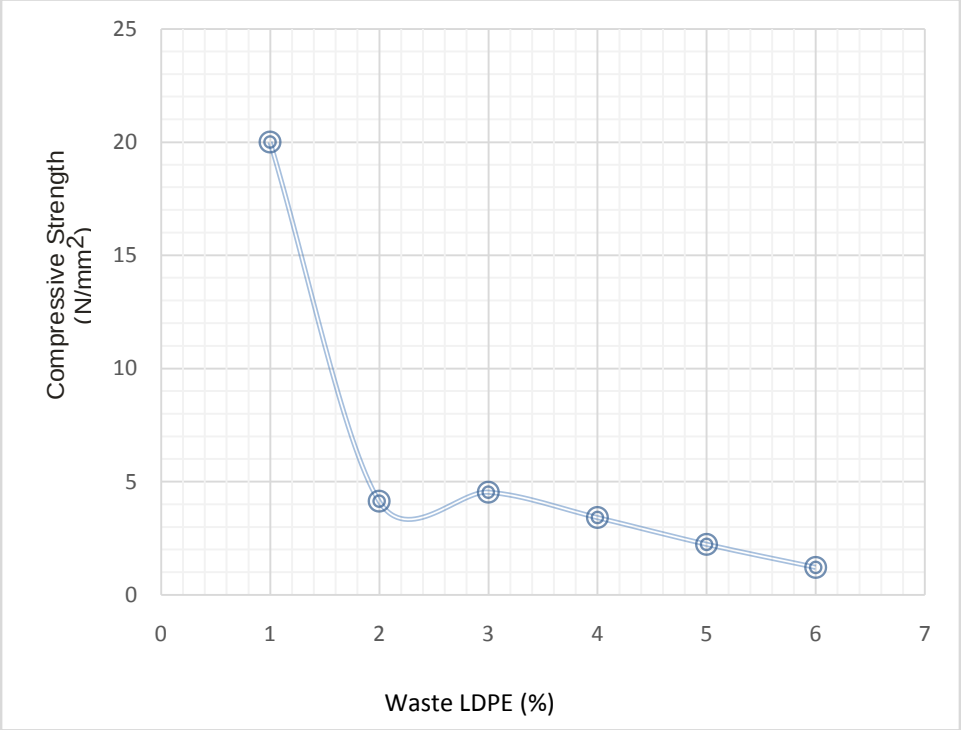


Figure4.6: 7 Days Curing Compressive Strength and Waste LDPE (%) gravel aggregate replacement

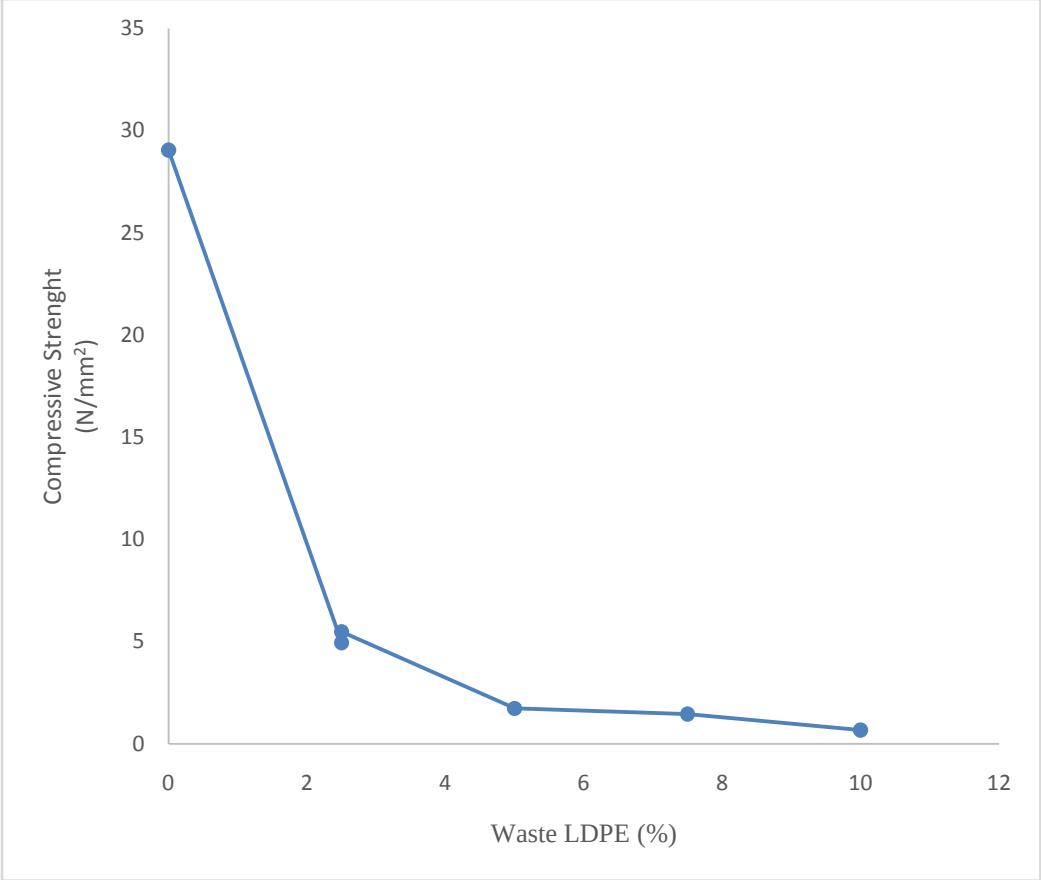


Figure 4.7: 28 Days Compressive Strength andWaste LDPE (%) gravel aggregate replacement

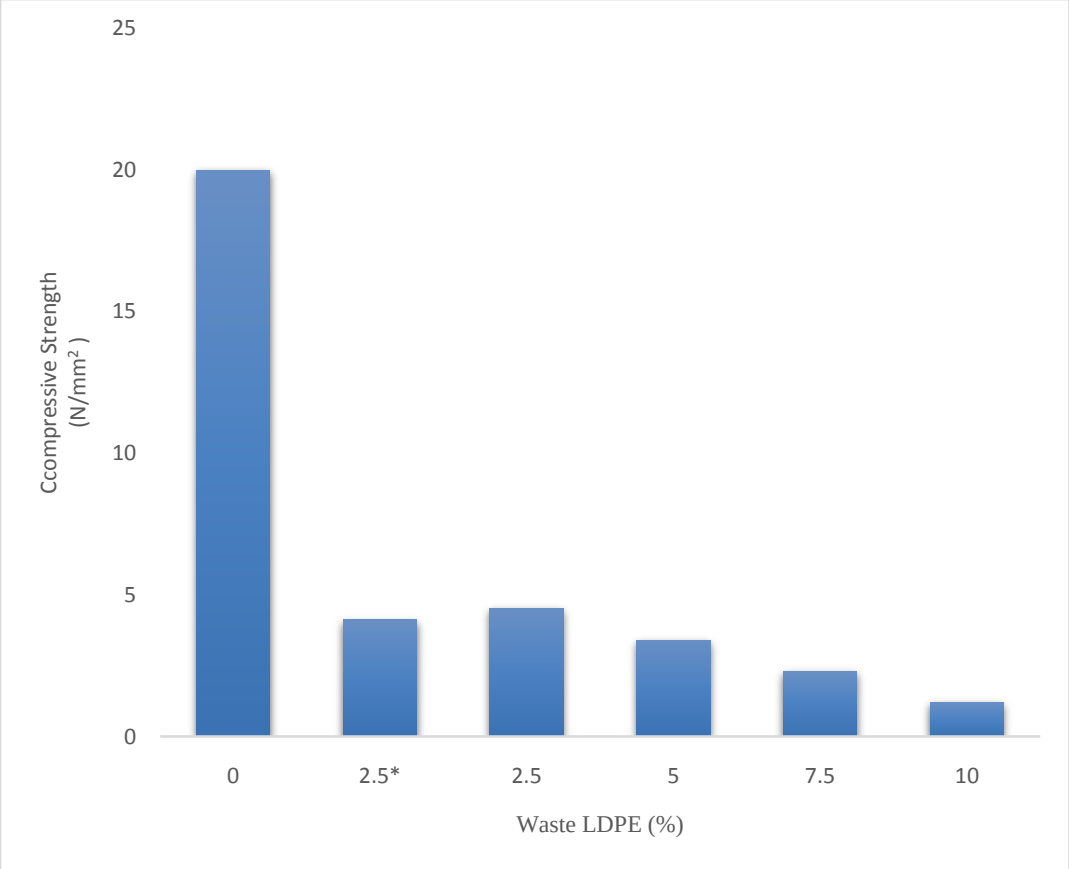


Figure4.8: 7 Days Compressive Strength andWaste LDPE (%)gravel aggregate replacement

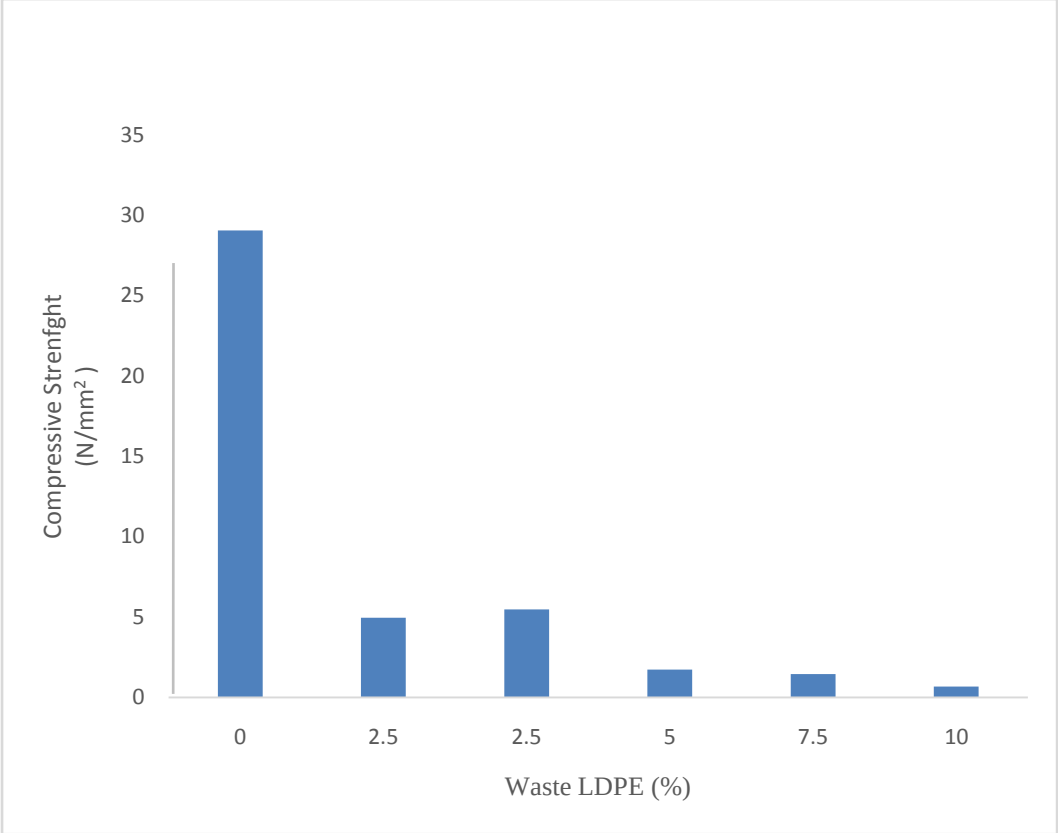


Figure4.9: 28 Days Compressive Strength andWaste LDPE (%)gravel aggregate replacement

4.6 Scanning Electron Microscope Model (Phenom World – Prox)

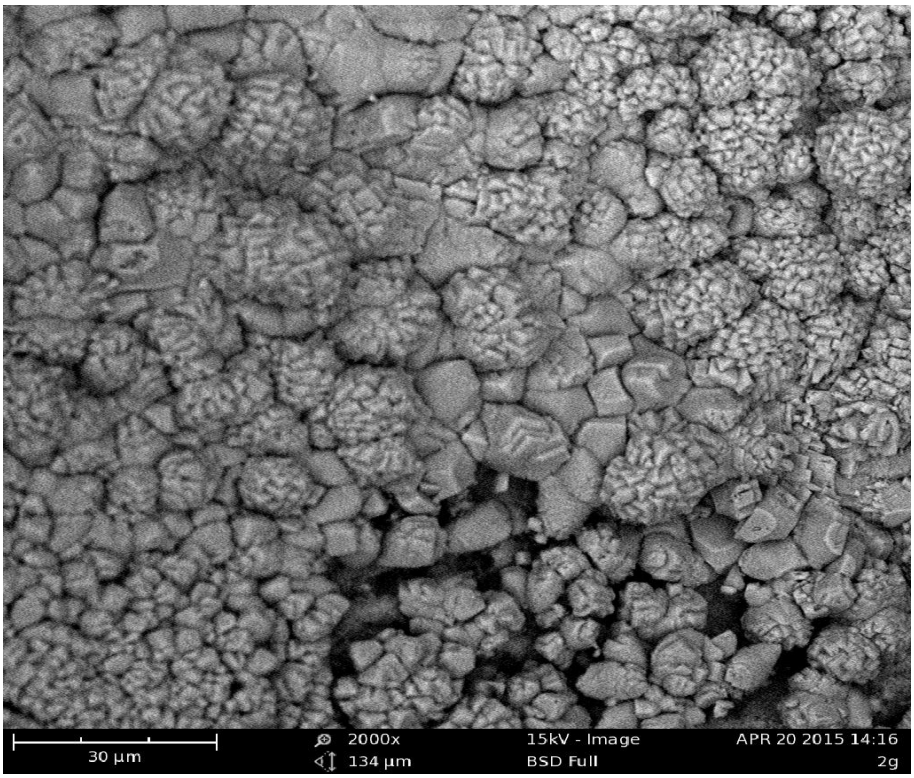


Plate 4.1 (a): Scanning Electron Micrograph of Grafted Waste LDPE Concrete Composite

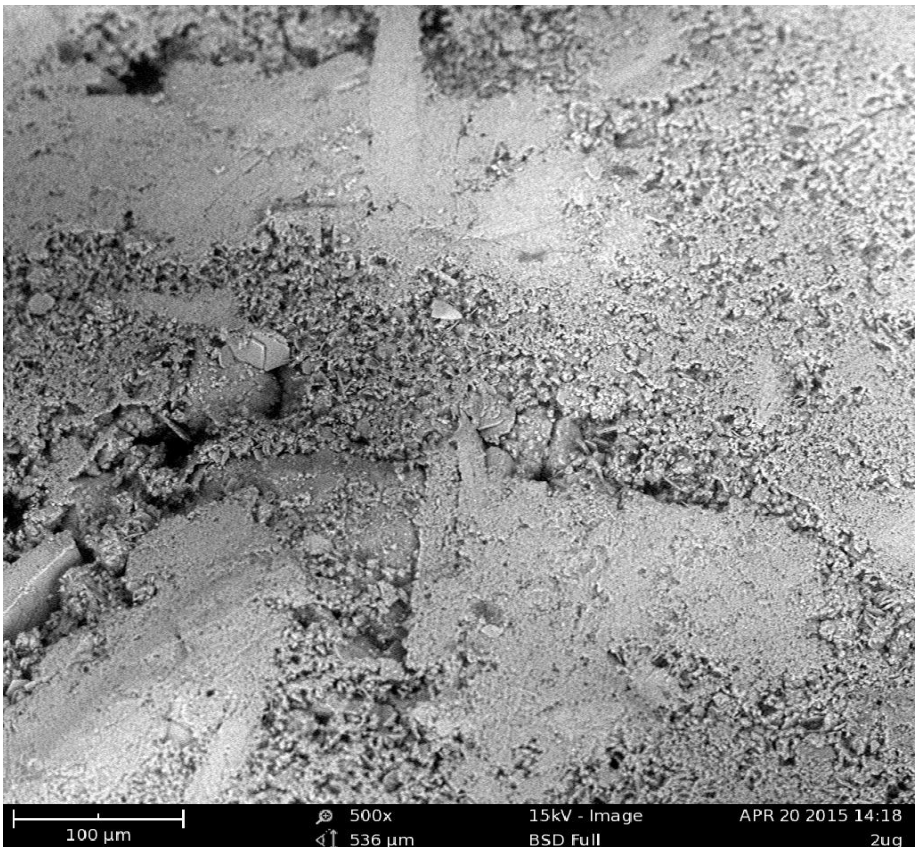


Plate 4.1 (b): Scanning Electron Micrograph of Ungrafted Waste LDPE Concrete Composite

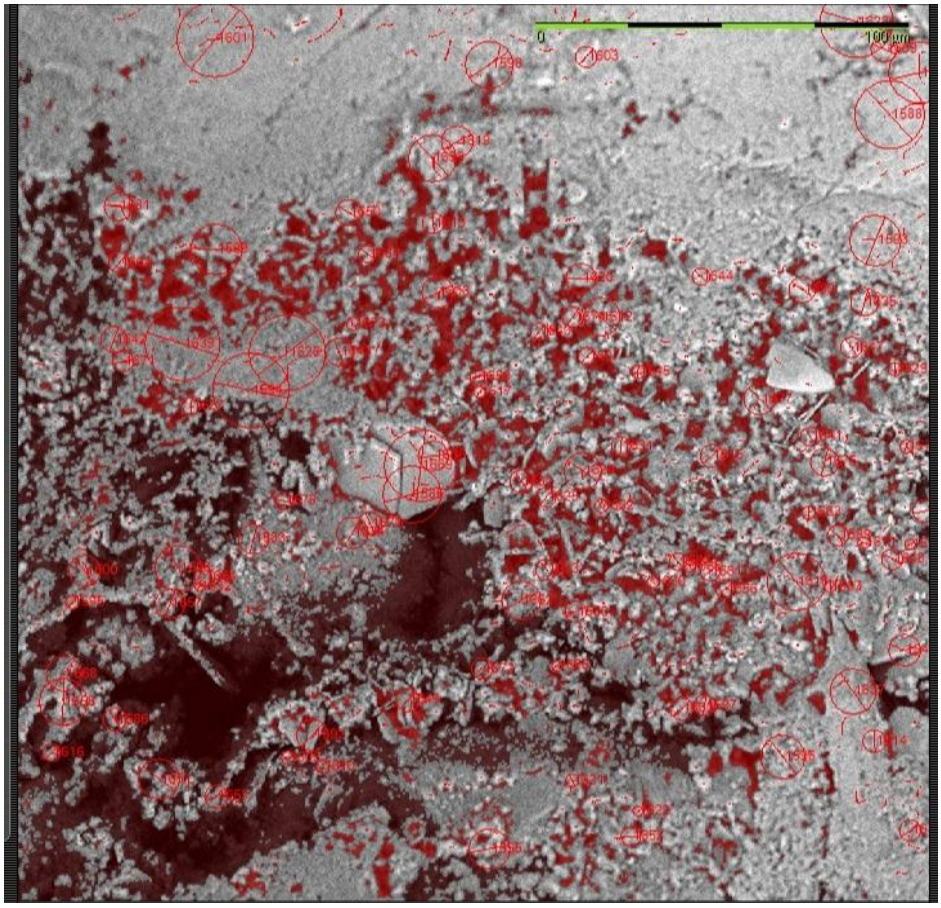


Plate 4.2 (a): Fibre/Pore Ungrafted Waste LDPE (Diameter)

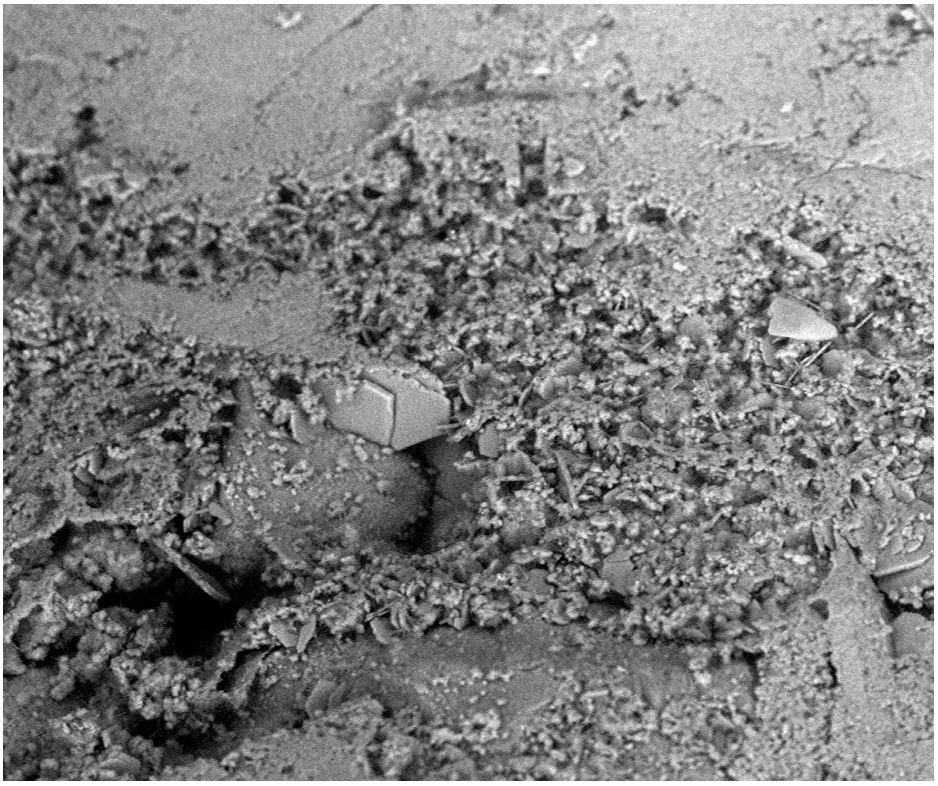


Plate 4.2 (b): Fibre/Pore Ungrafted Waste LDPE

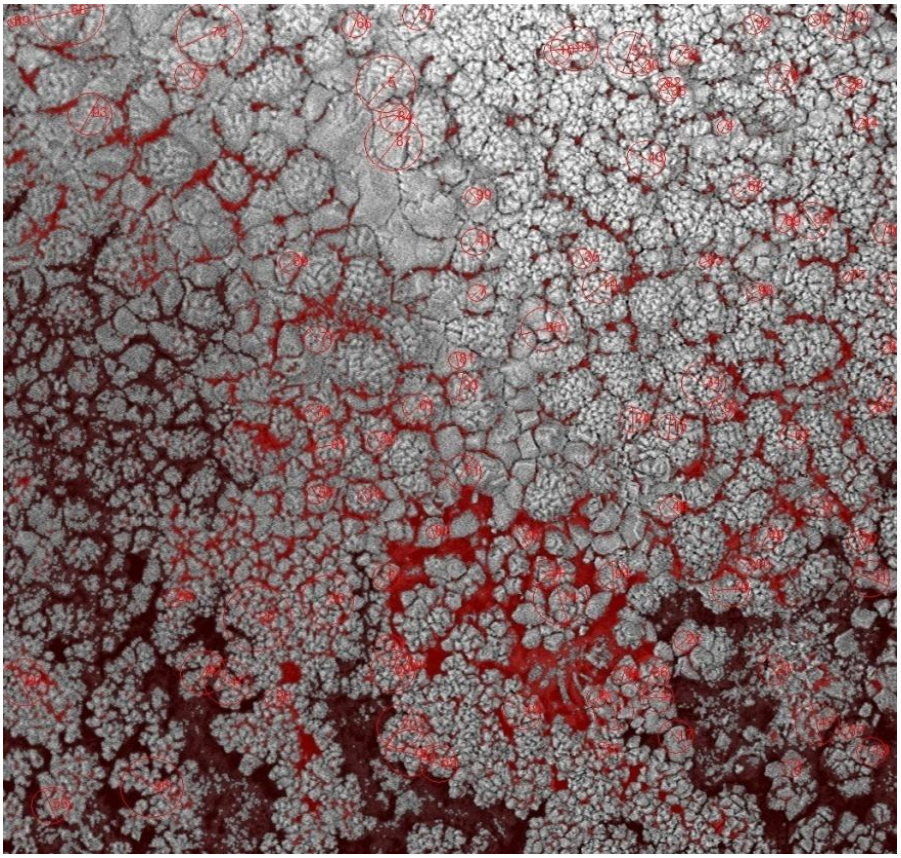


Plate 4.3 (a): Fibre/Pore Grafted Waste LDPEConcrete Composites (Diameter)

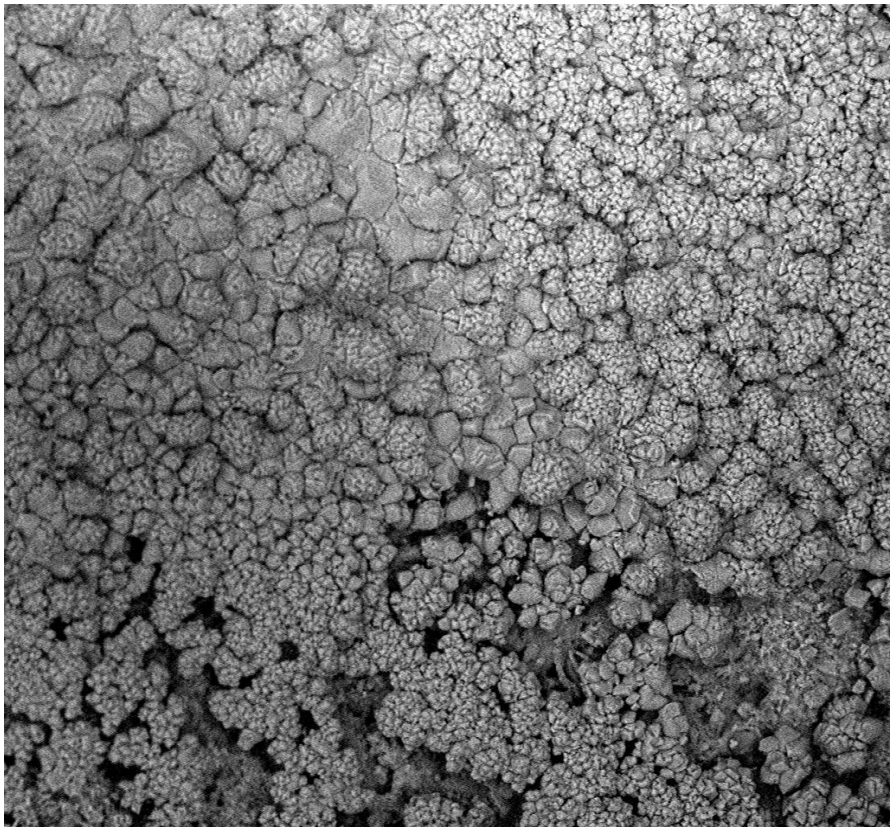


Plate 4.3 (b): Fibre/Pore Grafted Waste LDPE Concrete Composites

CHAPTER FIVE

DISCUSSION

5.1 FT-IR of the Hydroxylated and Grafted

The FT - IRspectra of the hydroxylated linear low density polyethene and wastelow density polyethene are presented in Appendix IV. Table 4.1 and 4.2. The figures show that the LLDPE was hydroxylated with –OH group. The absorption peaks are within the range of –OH functional group. The absorption occurred at 3373.61$cm^{-1}$and 3630.15cm^{-1} for the LLDPE. while Table 4.2 shows that the absorption of –OH group for the waste LDPE occurred at 3375.54cm^{-1} and 3629.19cm^{-1}, the absorption peaks are also within the range of the absorption peaks of the –OH functional group. The FT-IR for the grafted LLDPE is presented in Table 4.3. The IR spectrum shows an absorption frequency at 1639.55cm^{-1}due to Acrylamide carbonyl functional group, i.e. AAm – grafting LLDPE while Table 4.4 shows the IR spectra of the grafted waste LDPE absorption occurred at 1712.85cm^{-1}(Acrylamide Carbonyl functional group) i.e. AAm – Grafting waste LDPE. Similarly, the IR spectra of the copolymer adsorption peak of 3301.28cm^{-1} in Table 4.3 for LLDPE and 3621.47cm^{-1} in Table 4.4 indicates the presence of N – H functional group, while 1059.92cm^{-1} and 1356.97cm^{-1} in Table 4.3 indicates the presence of –C–N– Functional group for the grafted LLDPE while Table 4.4 indicates presence of –C–N– for the waste LDPE at 1024.24cm^{-1}, 1290.42cm^{-1} and 1368.54cm^{-1}respectively. Hence, AAm has been grafted successfully onto LLDPE and waste LDPE. A similar pattern was also observed by (Termnak *et al.* 2008), detailed study of chemical morphology in grafting Acrylamide to Polyethene using Scanning Force Microscopy (SFM) and Chemical Force Morphology (CFM) which investigated the growth of grafted Polyacrylamide (PAM) chains onto Polyethene (PE) – film.Also FT-IR analysis of the hydroxylated samples for waste

LDPE and LLDPE as shown in Table 4.1 and 4.2 indicates that the absorption peaks corresponds to the frequencies of vibration between bonds of atoms of –OH functional group; (3200 – 3700cm^{-1}). However, the IR absorption frequency varies within the same sample. Hence, the finding of the study supports that; hydroxylation process is not uniform. Hydroxylation in solution commonly yielded a non-uniform surface as also reported by Termnak *et al*. (2008).

5.2Compaction Factor and Slump Test

The results obtained for compaction factor as depicted in table 4.5 shows the degreeof workability is very low in respect of the 2.5% gravel aggregate replacement for the grafted/ungrafted waste LDPE results of slump (20 – 32mm) and compaction factor (0.83 – 0.88). The standard values of workability, slump and compaction factor ranges were interpreted and described in British Road Note 4 (Wilby, 1991) in table 5.1 as a very low degree of workability. Hence, the Concrete Composite mix of 2.5% are workable and the best mix from the point of view of compatibility when compared with 5%, 7.5% and 10% of compaction factor, 0.97, 0.71 and 0.56 as well as slump results of 182mm, 255mm and 265 respectively, which are outside the range of workability of British Standard Institution. Also slump test results as presented in Table 4.6 indicates that the 2.5% of the grafted and ungrafted are within the acceptable range. However, the ASTM 143 for concrete mix that exhibits collapse or shear slump results as presented by 5%, 7.5% and 10% in this investigation, which does not show sufficient cohesiveness. Therefore, they should be rejected. The only type of slump permissible under ASTM 143 is the “True Slump” which the 2.5% waste LDPE presented when the Concrete Composite mix remains intact and retains a symmetric shape.

Table 5.1: Standard values of workability, slump, and compaction factor of concrete with 20mm or 40mm maximum size of aggregate

British Road Note 4 (Wilby, 1991)

Degree of Workability	Slump mm	Compaction factor		Applications
		Small Apparatus	Large Apparatus	
Very Low	0–25	0.78	0.80	Vibrated concrete in roads or other large sections.
Low	25–50	0.85	0.87	Mass concrete foundation without vibration. Simple reinforced sections with vibration.
Medium	50–100	0.92	0.935	Normal reinforced work without vibration and heavily reinforced sections with vibration.
High	100–180	0.95	0.96	Sections with congested reinforcement. Not normally suitable for vibration.

5.3 Densities

Figure 4.1 depicted the relationship between density and the % of Waste LDPE in CCC's which shows that as the percentage waste increases the density decrease.While figure 4.2 indicated the relationship between 7 and 28 days curing densities results,that as the percentage waste increases the densities decreases.Al-Manaseer and Dalal (1997) reported that the bulk density of plastic concrete decreased as the plastic content increased. The density was reduced by about 2.5%, 6%, and 13% when plastic contents of 10%, 30%, and 50% respectively were used. The reason for the decrease in density is as a result of the partial replacement of the gravel aggregate with Waste LDPE which has lower weight when compared with gravel. Density is directly

proportional to increase in weight and inversely proportional to volume. The volume used for this study (15mm x 15mm x 15mm)was constant.

5.4 Water Absorption

Figures 4.3 and 4.4presents the comparison of Water Absorption versus WasteLDPE for 7 Days and 28 Days curing which shows an increase in water absorptionas thepercentage LDPE waste increases. The polar group(s) in AAm monomer grafted onto the Waste LDPE are responsible for the higher water absorption because of the increase in hydrophilicity on the AAm and LDE co-polymer, while the higher moisture absorption in respect of the ungrafted waste LDPE can be attributed to large voids as seen from the SEM of the ungrafted waste LDPE CCCs see plate 4.1(b).

5.5Compressive Strength

Figures 4.5 and 4.6 indicated the relationship between 7 and 28 Days Curing Compressive Strength and Waste LDPE.The compressive strength decreased from control specimen 20N/mm^2 to grafted specimen 4.13N/mm^2 to ungrafted specimens 4.5N/mm^2 to 3.41N/mm^2 to 2.23N/mm^2 to 1.21N/mm^2 at 0%, 2.5%, 2.5%, 5%, 7.5%, 10% of waste Polyethene respectively. This indicates that after 7 days of curing the compressive strength decreased with increased of waste polyethene content as replacements of gravel. The findings are supported by Batayneh *et al.* (2007) where a reduction of compressive strength with increase in plastic contents was experienced.However, the increase in compressive strength reaches its optimum level at 5.48N/mm^2 with 2.5% Waste LDPE content as replacement of gravel aggregate, at this level any increase in % Waste LDPE results in a rapid decrease of compressive strength after 28 days cured. The results show low compressive strength from

3.41N/mm^2, 2.23N/mm^2 and 1.21N/mm^2 for 7 days curing and 1.73N/mm^2, 1.45N/mm^2 and 0.67N/mm^2 for 28 days respectively.

Figure 4.7and 4.8 shows the bar chartsrelationship between the control sample, waste LDPE grafted and ungrafted LDPE with their corresponding compressive strengths. From the figures the control sample 0% shows an increase from 20-29.04N/mm^2, grafted 2.5% sample 4.13-4.49N/mm^{2}and the ungrafted 2.5% sample 4.53-5.48N/mm^{2}respectively. However, there was decrease in compressive strength as the percentage waste LDPE increases from 5% above. The reasons of this rapid decrease of the compressive strength indicate that an optimum level for partial replacement of gravel has been reached at 2.5% Waste LDPE for this effect it was similar findings to Po – Yu and Chun-Ku (ICCE, 2011).

5.6Scanning Electron Microscopy

The plate 4.1(a) depicted the morphology of grafted waste LDPE (CCCs) image which shows bright spots of AAm–grafted LDPE. The modules are very close in sizes, a pattern generally observed in surface grafting. While plate 4.1 (b) depicted the morphologyof the ungrafted waste LDPE (CCCs) shows smooth surface with voidswithin the interface.A similar pattern was also observed by Termnak *et al.* (2008), detailed study of chemical morphology in grafting Acrylamide to Polyethene using Scanning Force Microscopy (SFM), Chemical Force Morphology (CFM) to study the growth of grafted Polyacrylamide (PAM) chains onto Polyethene (PE) – film.

Plates 4.2(a) and (b) shows the Fibre/Pore (Diameter) of the ungrafted Waste LDPE (CCCs). While Plates 4.3(a) and (b) shows theFibre/Pore (Diameter) of the Grafted Waste LDPE (CCCs) as compared respectively.The grafted LDPE SEM image portrays closer relationship at the interface than the ungrafted images. Therefore, thehydrophilicity of grafted LDPE plays a significant role in the compactness of the composite and lower water absorption.A similar pattern was also observed by Termnak *et al.* (2008).

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The FT-IR analysis gave evidence that grafting was successful. The resultant copolymer shows higher water absorption for the grafted waste LDPE CCCs than the control sample as a result of the improved hydrophilicity due to the presence of amide group from the AAm – monomer. The SEM image gave large voids for the ungrafted waste LDPE CCCs which indicate higher water absorption by the ungrafted waste LDPE CCCs than the grafted and the control CCCs. The resultsobtained from this research clearly demonstrated that there is a great potential for the use of waste low density polyethene in the production of Concrete Composites mixes.These findings indicate the degree of workability being very low with respect of the 2.5% gravel aggregate replacement for the grafted/ungrafted waste LDPE, while the slump test of (20 – 32mm) and compaction factor (0.83 – 0.88)are within the range of British Standard Institution. Also Composite Mix of 2.5% are workable and produce the best mix with respect to compatibility when compared with 5%, 7.5% and 10% results of compaction factor, 0.97, 0.71 and 0.56 as well as slump results of 182mm, 255mm and 265 respectively, which are outside the range of workability of British Standard Institution.The ASTM 143 also advise a concrete mix that exhibits collapse or shear slump results as presented by 5%, 7.5% and 10% in this research study that they are not sufficiently cohesive. (ASTM, 2000) Therefore, they should be rejected. The only type of slump permissible under ASTM 143 is the “True Slump” which the 2.5% waste LDPE present where the Concrete Composite mix remains intact and retains a symmetric shape. Also, the findings indicate 2.5% grafted/ungrafted waste LDPE as a

replacement of coarse aggregate has the highest compressive strength when compared with 5%, 7.5% and 10%.Furthermore, both physical and mechanical properties of CCCs were affected when Waste LDPE grafted/ungrafted were used as a replacement of gravel aggregate. Decreases in density, compressive strength were observed when part of the gravel was substituted with waste LDPE grafted/ungrafted. However, the water absorption of the CCCs increased as the percentage waste PE increased, while the strength of CCCs decreases as the amount of waste LDPE increases. The compressive strength of 4.53N/mm^{2}obtained from 2.5% waste LDPE was within the acceptable range of American Concrete Institute Part 1, 1994,in applications such as low traffic pedestrian walkways e.g. gardens, irrigated farmlands and areas where the soil is always moist as a result of the high water absorption observed when the waste LDPE is used as a replacement of the gravel aggregate in the CCCs.Therefore, for a cheaper and safe waste management, suitable plants waste/animal waste should be thought with the view towards replacement of chemical modification to impact hydrophilic properties to the Waste LDPE in order to adhere well to cement and other aggregates in the Cement Concrete Composite(s). The amount of waste LDPE in Nigeria and the world in general has created a big challenge for their disposal. Also the use of wastes Polyethene in concrete Composite Cubes will help to address and mitigate their environmental effects and can aid the reduction of cost for specialized applications.

6.2 Conclusion

It was observed that;

The values of compaction factor; 0.83 – 0.88 and the values of slump; 20 – 35mm are within the range of British Standard, BS 1881-103, 1993 and BS 1881-102, 1983 for the 2.5% grafted/ungrafted waste LDPE respectively, hence,they are suitable for lightweight concrete applications.

After 7 and 28 days curing, the maximum compressive strength was attained when 2.5% Waste LDPE was used as partial replacement of gravel aggregate.

The grafted 2.5% Waste LDPE CCCs shows a lower compressive strength than the ungrafted Waste LDPE. Hence, grafting was uneconomical.

The density of CCCs decreases with increase in the content of Waste LDPE.

The SEM results also indicate improved interactions of the aggregates in the CCCs for the grafted waste LDPE.

There is a significant increase in water absorption with increase of Waste LDPE content. The voids are responsible for higher water absorption in the CCCs for the ungrafted waste LDPE as presented in the SEM results

Therefore, the CCCs would contribute to the disposal of Waste LDPE and can be use in lightweight concrete applications for pedestrians walkways in gardens and irrigated farmland.

6.3 Recommendations

Based on the results obtained in this research work, the following recommendations are presented.

Ungrafted waste LDPE (2.5%) has higher strength than the grafted LDPE (2.5%), hence, it is more suitable for applications in lightweight concrete.

Ungrafted waste (2.5%) can also be used for low strength concrete filling parameters.

Plant(s) and animal(s) waste(s) should be investigated to impact hydrophilic properties on LDPE in order to reduce cost of grafting.

Waste LDPE as a replacement of cement and sand aggregates studies should be carried out with the view to obtain a high compressive strength in the resultant Concrete Composite Cubes.

More mechanical properties tests such as, flexural strength and splitting strength are needed to understand whether it is a feasible method to use Waste LDPE as a concrete constituents for Building and Civil Engineering works.

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APPENDIX AI

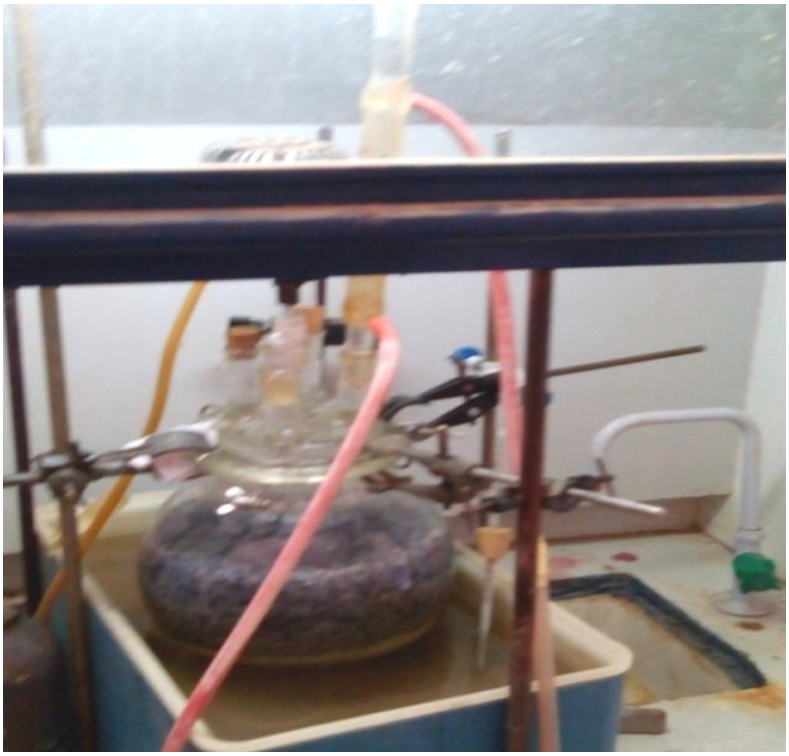


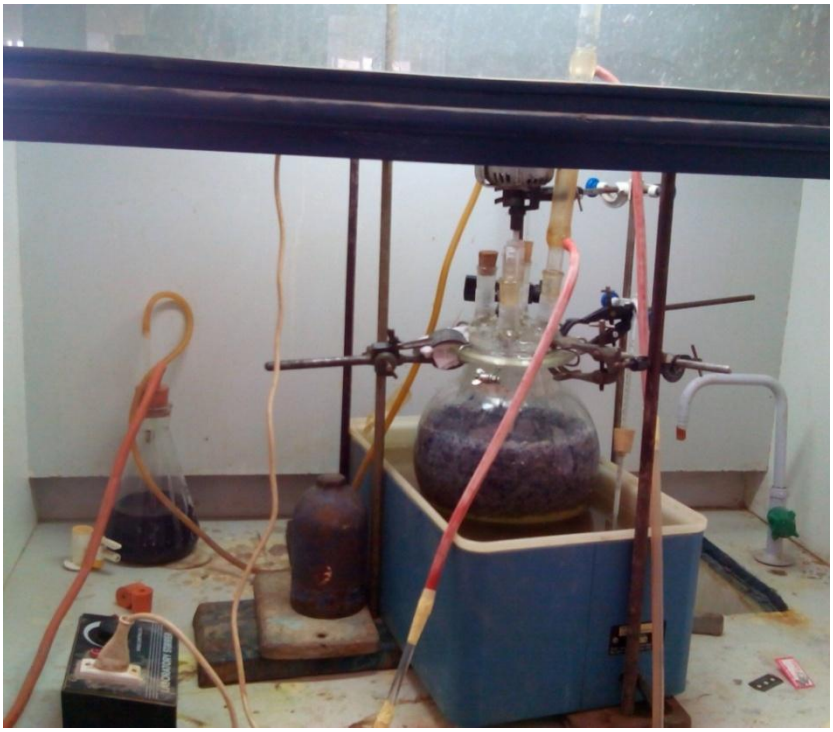
Plate $AI_{3.1}$: Hydroxylation of Waste LDPE



Plate $AI_{3.2}$: Hydroxylation of LLDPE



Plate $AI_{3.3}$: Grafting of LLDPE



Plate$AI_{3.4}$: Grafting of Waste LDPE



Plate $AI_{3.5}$: Mixture of Cement, Sand, Gravel and Waste LDPE



Plate $AI_{3.6}$: Compaction Factor Apparatus showing compacted concrete



Plate $AI_{3.7}$: Drying of CCCs of 5% Waste LDPE Specimens



Plate $AI_{3.8}$: Drying CCCs of 7.5% Waste LDPE Specimens



Plate $AI_{3.9}$: Drying CCCs of 10% Waste LDPE Specimens



Plate $AI_{3.10}$: Film Crushing Machine



Plate $AI_{3.11}$: Crushing Beater Roller

APPENDIX AII

Table $AII_{1.1}$: Mix Proportions of Control Sample

	Constituents of CCCs weight in kilograms			
Batch	**Cement**	**Sand**	**Gravel**	**Water**
A1	1.188	7.128	4.752	0.594
A2	1.188	7.128	4.752	0.594
A3	1.188	7.128	4.752	0.594
A4	1.188	7.128	4.752	0.594
A5	1.188	7.128	4.752	0.594
A6	1.188	7.128	4.752	0.594

Table $AII_{1.2}$: Mix Proportions of Grafted Waste Polyethene (2.5%)/size 5mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Ungrafted PE**	**Water**
B1	1.188	7.128	4.6332	0.1188	0.594
B2	1.188	7.128	4.6332	0.1188	0.594
B3	1.188	7.128	4.6332	0.1188	0.594
B4	1.188	7.128	4.6332	0.1188	0.594
B5	1.188	7.128	4.6332	0.1188	0.594
B6	1.188	7.128	4.6332	0.1188	0.594

Table $AII_{1.3}$: Mix Proportions of Waste Polyethene (2.5%)/size 5mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Grafted PE**	**Water**
C1.1	1.188	7.128	4.6332	0.1188	0.594
C2.1	1.188	7.128	4.6332	0.1188	0.594
C3.1	1.188	7.128	4.6332	0.1188	0.594
C4.1	1.188	7.128	4.6332	0.1188	0.594
C5.1	1.188	7.128	4.6332	0.1188	0.594
C6.1	1.188	7.128	4.6332	0.1188	0.594

Table AII$_{1.4}$: Mix Proportions of Waste Polyethene (2.5%)/size 10mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Ungrafted PE**	**Water**
C1.2	1.188	7.128	4.6332	0.1188	0.594
C2.2	1.188	7.128	4.6332	0.1188	0.594
C3.2	1.188	7.128	4.6332	0.1188	0.594
C4.2	1.188	7.128	4.6332	0.1188	0.594
C5.2	1.188	7.128	4.6332	0.1188	0.594
C6.2	1.188	7.128	4.6332	0.1188	0.594

Table AII$_{1.5}$: Mix Proportions of Waste Polyethene (2.5%)/size 15mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Waste PE**	**Water**
C1.3	1.188	7.128	4.6332	0.1188	0.594
C2.3	1.188	7.128	4.6332	0.1188	0.594
C3.3	1.188	7.128	4.6332	0.1188	0.594
C4.3	1.188	7.128	4.6332	0.1188	0.594
C5.3	1.188	7.128	4.6332	0.1188	0.594
C6.3	1.188	7.128	4.6332	0.1188	0.594

Table AII$_{1.6}$: Mix Proportions of Waste Polyethene (5%)/size 5mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
D1.1	1.188	7.128	4.5144	0.2376	0.594
D2.1	1.188	7.128	4.5144	0.2376	0.594
D3.1	1.188	7.128	4.5144	0.2376	0.594
D4.1	1.188	7.128	4.5144	0.2376	0.594
D5.1	1.188	7.128	4.5144	0.2376	0.594
D6.1	1.188	7.128	4.5144	0.2376	0.594

Table AII$_{1.7}$: Mix Proportions of Waste Polyethene (5%)/size 10mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
D1.2	1.188	7.128	4.5144	0.2376	0.594
D2.2	1.188	7.128	4.5144	0.2376	0.594
D3.2	1.188	7.128	4.5144	0.2376	0.594
D4.2	1.188	7.128	4.5144	0.2376	0.594
D5.2	1.188	7.128	4.5144	0.2376	0.594
D6.2	1.188	7.128	4.5144	0.2376	0.594

Table AII$_{1.8}$: Mix Proportions of Waste Polyethene (5%)/size 15mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
D1.3	1.188	7.128	5.5144	0.2376	0.594
D2.3	1.188	7.128	5.5144	0.2376	0.594
D3.3	1.188	7.128	5.5144	0.2376	0.594
D4.3	1.188	7.128	5.5144	0.2376	0.594
D5.3	1.188	7.128	5.5144	0.2376	0.594
D6.3	1.188	7.128	5.5144	0.2376	0.594

Table AII$_{1.9}$: Mix Proportions of Waste Polyethene (7.5%)/size 5mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
E1.1	1.188	7.128	4.3955	0.3564	0.594
E2.1	1.188	7.128	4.3955	0.3564	0.594
E3.1	1.188	7.128	4.3955	0.3564	0.594
E4.1	1.188	7.128	4.3955	0.3564	0.594
E5.1	1.188	7.128	4.3955	0.3564	0.594
E6.1	1.188	7.128	4.3955	0.3564	0.594

Table AII$_{1.10}$: Mix Proportions of Waste Polyethene (7.5%)/size 10mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
E1.2	1.188	7.128	4.3955	0.3564	0.594
E2.2	1.188	7.128	4.3955	0.3564	0.594
E3.2	1.188	7.128	4.3955	0.3564	0.594
E4.2	1.188	7.128	4.3955	0.3564	0.594
E5.2	1.188	7.128	4.3955	0.3564	0.594
E6.3	1.188	7.128	4.3955	0.3564	0.594

Table AII$_{1.11}$: Mix Proportions of Waste Polyethene (7.5%)/size 15mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Coarse Aggregate**	**Waste PE**	**Water**
E1.3	1.188	7.128	4.3955	0.3564	0.594
E2.3	1.188	7.128	4.3955	0.3564	0.594
E3.3	1.188	7.128	4.3955	0.3564	0.594
E4.3	1.188	7.128	4.3955	0.3564	0.594
E5.3	1.188	7.128	4.3955	0.3564	0.594
E6.3	1.188	7.128	4.3955	0.3564	0.594

Table AII$_{1.12}$: Mix Proportions of Grafted Waste Polyethene (10%)/size 5mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Waste PE**	**Water**
F1.1	1.188	7.128	4.2768	0.4752	0.594
F2.1	1.188	7.128	4.2768	0.4752	0.594
F3.1	1.188	7.128	4.2768	0.4752	0.594
F4.1	1.188	7.128	4.2768	0.4752	0.594
F5.1	1.188	7.128	4.2768	0.4752	0.594
F6.1	1.188	7.128	4.2768	0.4752	0.594

Table AII$_{1.13}$: Mix Proportions of Waste Polyethene (10%)/size 10mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Waste PE**	**Water**
F1.2	1.188	7.128	4.2768	0.4752	0.594
F2.2	1.188	7.128	4.2768	0.4752	0.594
F3.2	1.188	7.128	4.2768	0.4752	0.594
F4.2	1.188	7.128	4.2768	0.4752	0.594
F5.2	1.188	7.128	4.2768	0.4752	0.594
F6.2	1.188	7.128	4.2768	0.4752	0.594

Table AII$_{1.14}$: Mix Proportions of Waste Polyethene (10%)/size 15mm

	Constituents of CCCs weight in kilograms				
Batch	**Cement**	**Sand**	**Gravel**	**Waste PE**	**Water**
F1.3	1.188	7.128	4.2768	0.4752	0.594
F2.3	1.188	7.128	4.2768	0.4752	0.594
F3.3	1.188	7.128	4.2768	0.4752	0.594
F4.3	1.188	7.128	4.2768	0.4752	0.594
F5.3	1.188	7.128	4.2768	0.4752	0.594
F6.3	1.188	7.128	4.2768	0.4752	0.594

APPENDIX III

Table 4.3: 7 Days Curing Density Results

Batch No	Waste LDPE (%)	Density (kg/m^3)
A_1	0	2280.05
A_2	0	2280.01
A_3	0	2280.04
Average	**0**	**2280.00**
B_1	2.5	1890.16
B_2	2.5	1890.04
B_3	2.5	1890.50
Average	**2.5**	**1890.00**
C_1	2.5	2056.07
C_2	2.5	2056.01
C_3	2.5	2056.03
Average	**2.5**	**2056.00**
D_1	5	1690.01
D_2	5	1696.96
D_3	5	1680.05
Average	**5**	**1689.00**
E_1	7.5	1581.66
E_2	7.5	1533.33
E_3	7.5	1522.33
Average	**7.5**	**1545.00**
F_1	10	1050.51
F_2	10	1020.01
F_3	10	1070.77
Average	**10**	**1047.00**

Table 4.4: 28 Days Curing Density

Batch No	Waste LDPE (%)	Density (kg/m^3)
A_4	0	2316.04
A_5	0	2316.07
A_6	0	2316.09
Average	**0**	**2316.00**
B_4	2.5	1993.05
B_5	2.5	1993.01
B_6	2.5	1939.09
Average	**2.5**	**1993.00**
C_4	2.5	2011.07
C_5	2.5	2011.01
C_6	2.5	2011.31
Average	**2.5**	**2011.00**
D_4	5	1753.03
D_5	5	1730.02
D_6	5	1739.04
Average	**5**	**1737.00**
E_4	7.5	1718.50
E_5	7.5	1719.60
E_6	7.5	1720.49
Average	**7.5**	**1720.00**
F_4	10	1310.43
F_5	10	1320.26
F_6	10	1330.41
Average	**10**	**1320.00**

Table 4.5: 7 Days Curing Water Absorption (%)

Batch No	Waste LDPE (%)	Water Absorption (%)
A_1	0	
A_2	0	
A_3	0	
Average	**0**	**3.15**
B_1	2.5	
B_2	2.5	
B_3	2.5	
Average	**2.5**	**4.13**
C_1	2.5	
C_2	2.5	
C_3	2.5	
Average	**2.5**	**5.37**
D_1	5	
D_2	5	
D_3	5	
Average	**5**	**6.29**
E_1	7.5	
E_2	7.5	
E_3	7.5	
Average	**7.5**	**7.76**
F_1	10	
F_2	10	
F_3	10	
Average	**10**	**9.95**

Table 4.6: 28 Days Curing Water Absorption (%)

Batch No	Waste LDPE (%)	Water Absorption (%)
A_4	0	3.03
A_5	0	3.23
A_6	0	3.45
Average	**0**	**3.23**
B_4	2.5	4.45
B_5	2.5	4.48
B_6	2.5	4.46
Average	**2.5**	**4.46**
C_4	2.5	6.48
C_5	2.5	6.77
C_6	2.5	6.43
Average	**2.5**	**6.60**
D_4	5	10.32
D_5	5	10.38
D_6	5	10.36
Average	**5**	**10.34**
E_4	7.5	15.53
E_5	7.5	15.56
E_6	7.5	19.50
Average	**7.5**	**15.53**
F_4	10	25.01
F_5	10	25.04
F_6	10	25.00
Average	**10**	**25.00**

Table 4.7: 7 Days Compressive Strength Test Results for Control Specimen

Batch	Failure Load (kN)	Compressive Strength N/mm^2
A1	440	19.55
A2	460	20.44
A3	450	20.00
Average	**450**	**20**

Table 4.8: 28 Days Compressive Strength Test Results for Control Specimen

Batch	Failure Load (kN)	Compressive Strength N/mm^2
A4	620	27.56
A5	680	30.22
A6	660	29.33
Average	**653.33**	**29.04**

Table 4.9: 7 Days Curing Compressive Strength Results for Grafted LDPE 2.5%

Batch	Failure Load (kN)	Compressive StrengthN/mm^2
B1	89	3.955
B2	90	4.00
B3	88	3.9
Average	**89**	**3.96**

Table 4.10: 28 Days Compressive Strength Results for Grafted LDPE 2.5%

Batch	Failure Load (kN)	Compressive Strength N/mm^2
B3	95	4.22
B4	96	4.27
B5	92	4.08
Average	**94.33**	**4.19**

Table 4.11: 7 Days Calculation of Compressive Strength for Ungrafted Waste LDPE (2.5%) size 5mm – 15mm

Batch	Failure Load (kN)	Compressive Strength (N/mm^2)
C1	100	4.44
C2	100	4.44
C3	94	4.18
Average	**98**	**4.35**

Table 4.12: 28 Days Compressive Strength for Ungrafted LDPE (2.5%) size 5mm – 15mm.

Batch	Failure Load (kN)	Compressive StrengthN/mm^2
C3	110	4.89
C4	140	6.22
C5	130	5.78
Average	**126.66**	**5.63**

Table 4.11: 7 Days Curing – Compressive Strength Vs Percentage Waste LDPE

% WASTE P.E	0	2.5	5	7.5	10
COMP.ST (N/mm^2)	20.0	4.53	3.41	2.23	1.21

Table 4.12: 28 Days Curing–Compressive Strength Vs Percentage waste LDPE

% WASTE P.E	0	2.5	5	7.5	10
COMP.ST (N/mm^2)	29.04	5.48	1.73	1.45	0.67

Table 4.13: 7 Days Curing – Relationship between % Waste LDPE and Water absorption

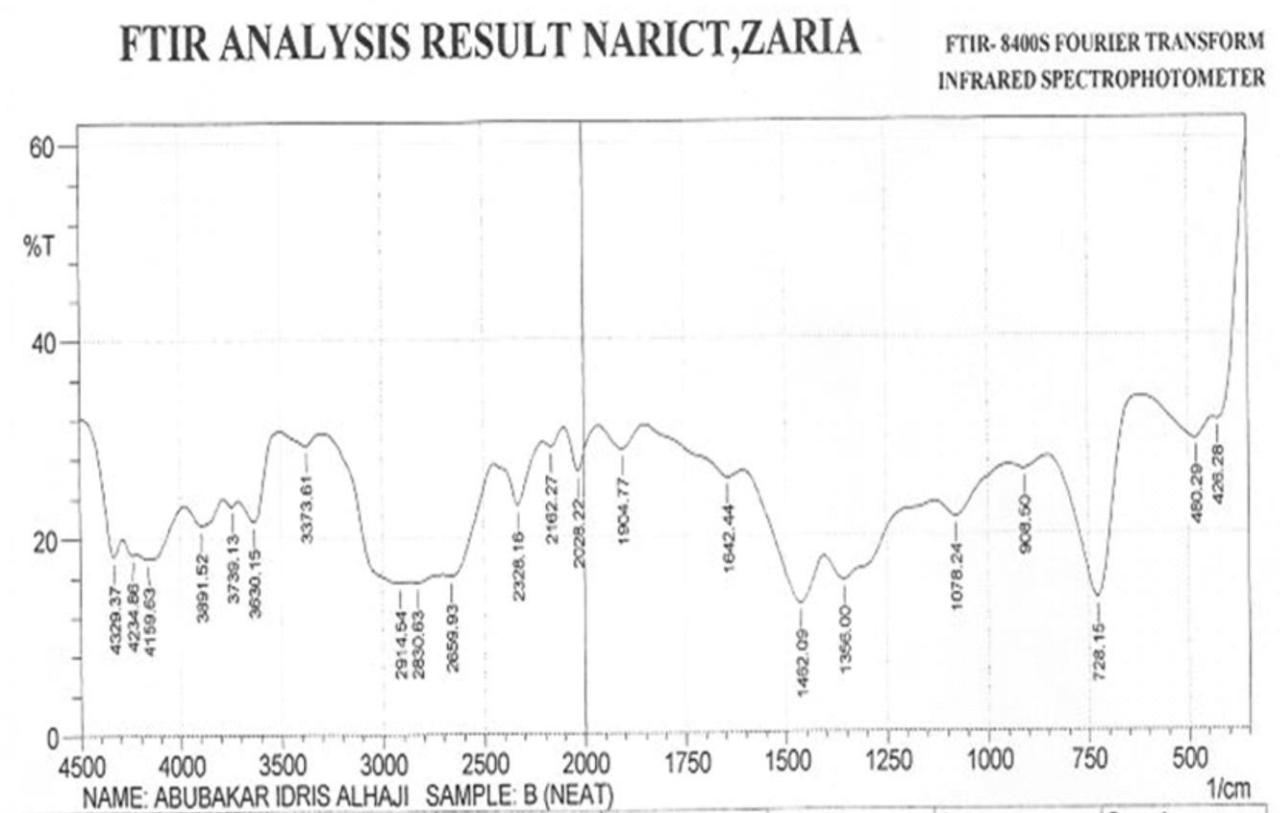
Water Absorption (%)	3.15	5.37	6.29	7.76	9.95
Waste P.E (%)	0	2.5	5	7.5	10

Table 4.14: 28 Days Curing –Relationship between % Waste LDPE and Water Absorption

Water Absorption (%)	3.23	4.46	6.60	15.53	25.00
Waste P.E (%)	0	2.5	5	7.5	10

APPENDIX IV

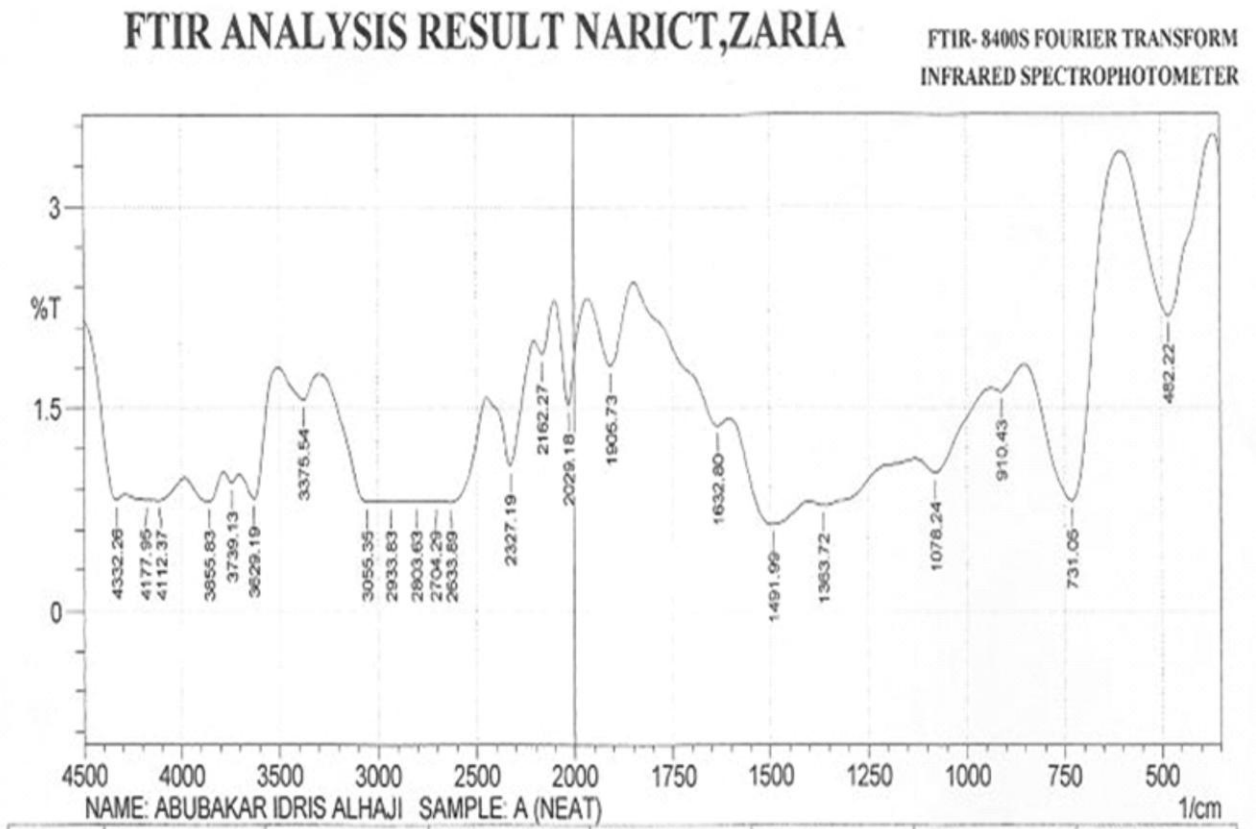
AIV$_{1.1}$



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	426.28	31.369	3.814	437.86	349.13	35.492	3.49
2	480.29	29.466	2.576	611.45	438.82	86.909	2.904
3	728.15	13.554	17.285	848.71	612.42	150.267	29.083
4	908.5	26.505	0.795	946.12	849.67	54.817	0.575
5	1078.24	21.816	2.519	1128.39	947.08	111.877	3.083
6	1356	15.468	3.254	1403.26	1129.36	196.521	8.286
7	1462.09	13.105	7.196	1603.86	1404.22	147.649	15.253
8	1642.44	25.885	1.373	1847.87	1604.83	133.202	1.801
9	1904.77	28.825	2.419	1963.6	1848.83	59.987	2.001
10	2028.22	26.596	4.511	2096.69	1964.56	71.203	4.19
11	2162.27	29.107	1.011	2202.78	2097.66	55.305	0.768
12	2328.16	23.262	5.185	2446.78	2203.75	140.753	8.102
13	2659.93	16.122	2.01	2702.36	2447.75	178.003	6.55
14	2830.63	15.495	0.216	2867.28	2703.33	131.134	0.383
15	2914.54	15.47	1.701	3295.49	2868.24	291.554	13.588
16	3373.61	29.274	1.359	3495.13	3296.46	103.94	1.929
17	3630.15	21.717	4.626	3705.38	3498.99	123.065	6.547
18	3739.13	23.28	0.638	3781.57	3706.34	47.168	0.454
19	3891.52	21.364	2.305	3975.42	3782.53	125.526	4.971
20	4159.63	17.956	1.603	4212.67	3976.39	166.56	5.413
21	4234.86	18.371	0.519	4286.94	4213.64	53.08	0.523
22	4329.37	18.191	4.165	4500.08	4287.9	127.742	4.481

Fig 4.1: FT-IR Spectrum of Hydroxylated LLDPE

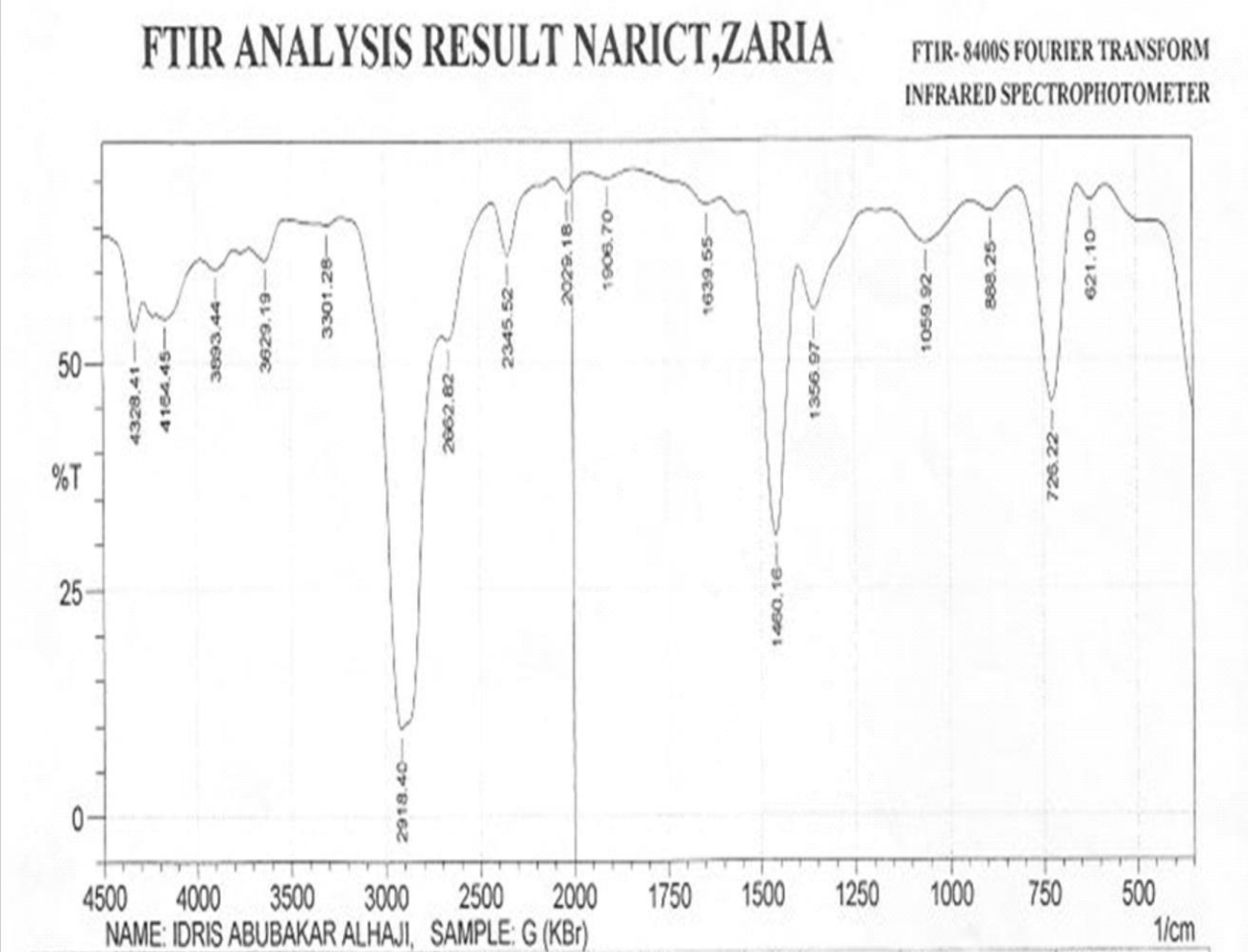
AIV$_{1.2}$



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	482.22	2.182	1.293	602.77	365.52	368.641	22.45
2	731.05	0.818	1.775	850.64	603.74	444.364	49.065
3	910.43	1.622	0.077	935.51	851.6	148.528	0.799
4	1078.24	1.026	0.239	1129.36	936.47	365.798	6.278
5	1363.72	0.783	0.07	1400.37	1130.32	548.738	4.637
6	1491.99	0.642	0.446	1601.93	1401.33	417.55	22.588
7	1632.8	1.372	0.178	1846.9	1602.9	424.493	2.668
8	1905.73	1.818	0.559	1964.56	1847.87	196.089	6.552
9	2029.18	1.526	0.785	2097.66	1965.53	227.059	10.854
10	2162.27	1.899	0.218	2202.78	2098.62	176.091	2.354
11	2327.19	1.078	0.708	2445.82	2203.75	444.747	21.122
12	2633.89	0.811	0.168	2685	2446.78	476.654	13.578
13	2704.29	0.814	0.001	2747.69	2685.97	128.936	0.015
14	2803.63	0.813	0.005	2868.24	2748.65	249.78	0.143
15	2933.83	0.816	0	2936.72	2869.21	140.938	0.009
16	3055.35	0.814	0.182	3294.53	2999.41	570.155	6.721
17	3375.54	1.558	0.217	3499.95	3295.49	363.584	5.855
18	3629.19	0.837	0.459	3700.56	3500.92	385.351	13.473
19	3739.13	0.954	0.068	3781.57	3701.52	160.536	1.208
20	3855.83	0.813	0.203	3981.21	3782.53	407.142	10.608
21	4112.37	0.82	0.041	4148.06	3982.17	341.185	2.139
22	4177.95	0.823	0.012	4286.94	4149.02	286.571	0.679
23	4332.26	0.826	0.311	4500.08	4287.9	401.882	8.752

Fig 4.2: FT-IR Spectrum of Hydroxylated Waste LDPE

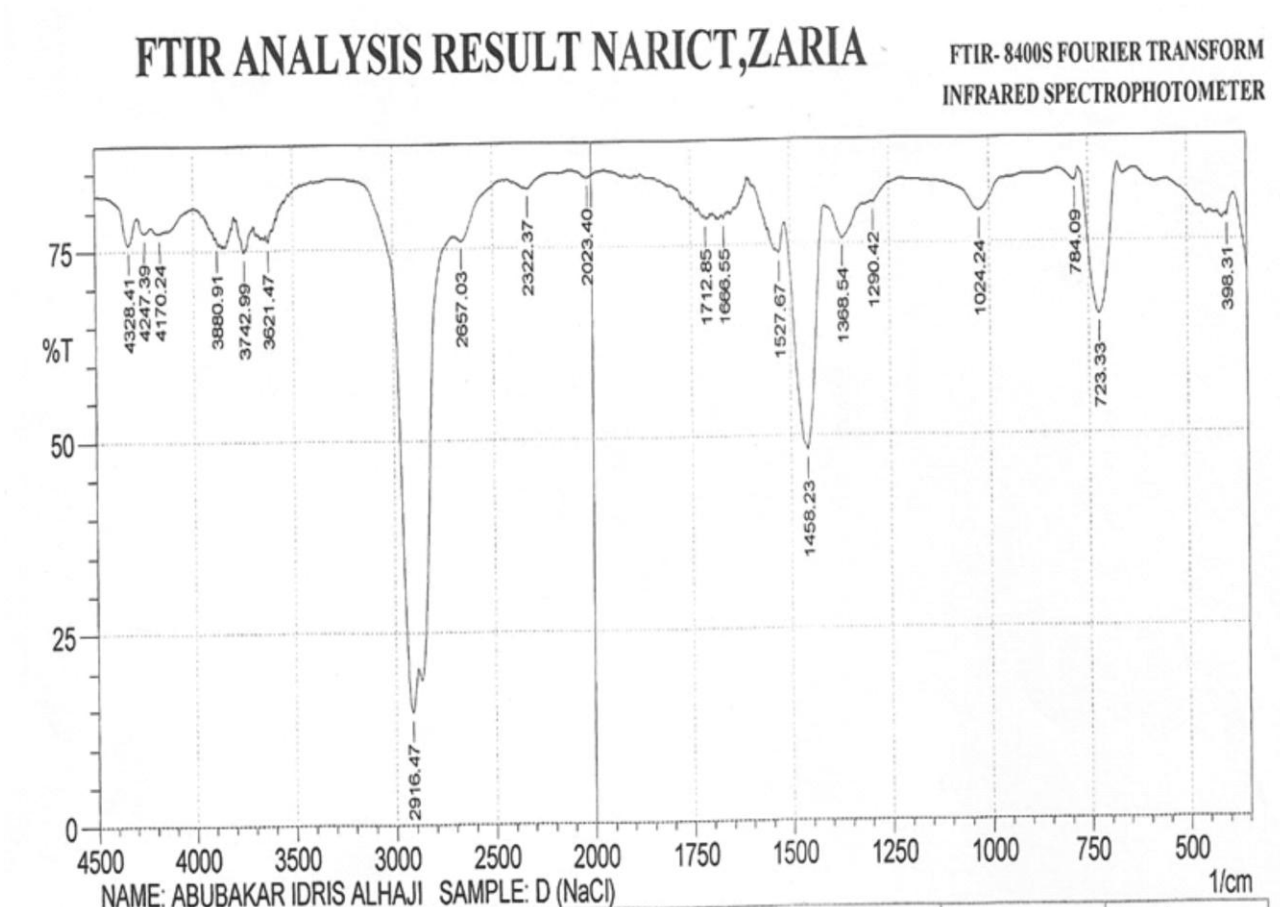
AIV$_{1.3}$



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	621.1	67.605	1.478	655.82	579.63	12.595	0.356
2	726.22	45.365	23.601	815.92	655.82	37.415	11.563
3	888.25	66.407	1.572	939.36	816.88	21.025	0.58
4	1059.92	63.015	3.872	1157.33	939.36	40.757	2.755
5	1356.97	55.61	6.052	1396.51	1209.41	40.154	3.038
6	1460.16	30.686	32.311	1541.18	1396.51	46.67	17.911
7	1639.55	67.267	1.104	1837.26	1604.83	36.873	0.159
8	1906.7	70.227	0.758	1958.78	1837.26	18.351	0.282
9	2029.18	68.687	1.842	2093.8	1958.78	21.193	0.729
10	2345.52	61.73	6.412	2428.46	2181.56	44.186	3.547
11	2662.82	52.353	2.327	2697.54	2428.46	59.009	-1.303
12	2918.4	9.74	48.564	3225.09	2697.54	241.972	121.77
13	3301.28	65.102	0.465	3350.46	3225.09	23.11	0.185
14	3629.19	61.341	2.645	3711.17	3523.1	37.815	1.578
15	3893.44	60.38	1.566	3972.53	3793.14	38.325	1.085
16	4164.45	54.877	1.589	4208.82	3972.53	56.663	1.336
17	4328.41	53.475	4.94	4490.43	4279.22	47.493	1.027

Fig 4.3: FT-IR Spectrum of Acrylamide Grafted onto LLDPE

AIV$_{1.4}$



	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	398.31	77.882	0.685	400.24	380.95	1.906	-0.014
2	723.33	65.462	19.259	775.41	674.14	13.173	5.875
3	784.09	82.839	1.515	825.56	775.41	3.899	0.186
4	1024.24	79.109	4.228	1132.25	906.57	19.497	1.649
5	1290.42	80.249	0.246	1293.31	1220.02	6.272	-0.121
6	1368.54	75.612	4.161	1402.3	1316.46	9.378	0.976
7	1458.23	47.973	30.962	1513.21	1410.98	21.351	10.8
8	1527.67	73.843	1.872	1537.32	1513.21	2.987	0.119
9	1666.55	78.469	0.429	1671.37	1663.66	0.804	0.01
10	1712.85	78.462	0.224	1716.7	1709.95	0.706	0.004
11	2023.4	83.985	0.047	2035.93	2019.54	1.239	0.004
12	2322.37	82.623	1.297	2391.81	2198.92	15.026	0.498
13	2657.03	75.964	1.746	2696.57	2443.89	24.177	-0.172
14	2916.47	14.663	11.964	3169.15	2889.46	76.134	6.978
15	3621.47	76.053	0.633	3624.37	3609.9	1.667	0.026
16	3742.99	74.775	0.961	3757.46	3735.28	2.744	0.089
17	3880.91	76.146	0.108	3885.73	3879.94	0.677	0.002
18	4170.24	77.276	0.604	4210.75	4135.52	8.321	0.16
19	4247.39	77.361	1.348	4284.04	4210.75	7.935	0.314
20	4328.41	75.805	4.12	4483.68	4284.04	19.458	0.868

Fig 4.4: FT-IR Spectrum of Acrylamide Grafted onto Waste LDPE