USE OF WASTE POLYETHYLENE FOR PROPERTY IMPROVEMENT OF CONCRETE

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Science in Materials Science

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Declaration

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Abstract

Polyethylene waste products, especially thin polyethylene bag wastes have become a global problem in Environment Pollution Control Management. The primary objective of this project was to manufacture a property improved Polymer-Concrete Composite mix for building construction, using waste polyethylene grocery bags, made out of high-density polyethylene (HDPE). This is proposed as a means of reuse for this polymer product which would give even more benefits.

Research observations, including laboratory test reports indicated that the blending of suitable percentages of polyethylene flakes in to the concrete mixes gives higher workability performance in fresh concrete and it improves the durability characteristic of hardened concrete.

It was verified by controlled laboratory tests that the adding of appropriate proportions of polyethylene cut fragments to grade C30/20 concrete gives very good fresh concrete properties like cohesiveness and workability (flowability) and improved hardened concrete durability properties like higher compressive strength, lower water absorption, low initial surface absorption (ISAT), low water penetration and lower Rapid Chloride Permeability (RCPT).

This research also proposes theoretical explanations for the observations of property changes.

Keywords: concrete, waste polyethylene, environmental pollution, compressive strength, slump, cohesiveness, workability, durability, permeability, penetration, absorption, pore structure.

Table of Contents

List of Abbreviations

PE	Polyethylene
HDPE	High Density Polyethylene
MDPE	Medium Density Polyethylene
LDPE	Low Density Polyethylene
GGBS	Ground Granulate Blast-furnace Slags
WAT	Water Absorption Test
ISAT	Initial Surface Absorption Test
WPT	Water Permeability Test
RCPT	Rapid Chloride Penetration
FTIR	Fourier Transform Infrared Spectroscopy
DTA	Differential Thermal Analysis
TGA	Thermogravimetric Analysis
PCC	Polymer Composite Concrete
FRC	Fibre Reinforced Concrete

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1. INTRODUCTION

Concrete is one of the most frequently used building materials around the world. It can be observed that the usage of concrete in Sri Lanka is increasing annually because of the post war development in construction field in the country [1].

Concrete is a highly versatile building material desirable for many applications. When concrete is in its basic form, it consists of three kinds of basic components.
Those basic components are cement (the binder), aggregates (different sizes from fine aggregates to coarse aggregates) and water. Cement reacts with water to create a hardened structure of silicate compounds that bind all of the ingredient aggregates together into one homogeneous mixer commonly called concrete.
These concrete constituent substances are available naturally in all over the world.

Polyethylene (generally calls as polythene) production is the other major consideration of this project. Polyethylene production is one of the rapidest growing industries around the world and researchers discovered that one trillion of polyethylene bags are being used round the world per year, which is just one example for the massive scale of manufacturing of these polymer products [2].

Figure 1: Polyethylene bags in action

Disposal of polyethylene wastes in environment become a big challenge as polyethylene having high durability characteristics because of polyethylene is non-biodegradable. The nature of the chemical bonds of polyethylene make it very long lasting and make bigger resistance against the natural techniques of degradation. Polyethylene substances have turn out to be very quintessential in each day existence which increases the availability of polyethylene wastes in heaps which either get two merged in to the municipal wastes or thrown over a land areas and water sources.

The common disposal methods of polyethylene wastes are recycling, incineration and land filling. But these methods are having very big harmful influences on the environment. If polyethylene dumped into lands then it pollutes soil and ground water streams and if it is incinerated then it will definitely cause a massive air pollution.

Figure 2: Environmental pollution by Polyethylene wastes

Plastic wastes do adversely effect on the living beings which includes humans and many animals. It is seen that plastic waste (especially polyethylene bags) are major cause of death of many animals, due to suffocation encountered on eating them. Studies show that plastic waste can sustain for centuries because of being a non-biodegradable material [3].

It can be noticed that several studies carried out to explore the possibilities of use of these plastic wastes in construction industry mainly its usage in bituminous carpets in construction of bituminous pavements (carpeted roads) [4].

Accordingly, it has become very important matter to find out an effective, sustainable process to recycle polymer wastes without having any negative effect to the environment.

2. PROJECT OBJECTIVES

The main project objective is to find out a viable reusing solution for waste polyethylene products by incorporating these in concrete mixes. The possibility of mixing polyethylene grocery bag flakes to enhance the properties of C30/20 concrete was investigated in this project**.**

This study also investigates the effect on the workability and durability characteristics of the polymer-concrete composite by subjecting it to controlled standard tests.

3. LITERATURE SURVEY OF THE DIFFERENT TYPES OF POLYETHYLENE GROCERY BAGS

In general, plastic grocery bags are commonly made from polyethylene. Polyethylene is coming under the category of polymer materials. Polyethylene is made out of long chains of ethylene monomers. Ethylene is produced from petroleum gas. Low-Density or High-Density Poly Ethylene are the most common types of polyethylene, which used in plastic shopping bags industry. Generally, colour pigments and other additives are added to give different colours and tinted appearance to the polyethylene. Blown film extrusion is the main manufacturing process of the polyethylene sheets.

Polyethylene shopping bags which commonly used for carrying daily grocery items are made from a range of types of plastic materials. Sometimes those polyethylene bags are referred as single-use bags (disposal), but however, can be reused for some household purposes [5].

From the mid of the year 1980s onwards, polyethylene bags became very popular throughout the developed world. It can be noticed that many types of paper bags and wrappers are increasingly replaced by polyethylene bags and polyethylene wrapping sheets. Also, other materials like glass, metal, stone, timber and other non-plastic materials are remarkably replaced by plastic polymers. Simultaneously, usage of polyethylene bags was exploded, but among the very big environmental pollution issues.

In latest decades, many countries have introduced strict rules for the manufacturing of plastic bags towards the limiting of littering and plastic pollution [6].

Note: It can be noticed that some modern-day grocery bags are made of vegetable-based bioplastics, which can decay organically. These biodegradable plastics are decomposed by the living organisms. It should be noted that the biodegradable polyethylene materials are not recommended to use in this project due to the fact that the biodegradable properties can be affected to the durability parameters of the concrete.

Following major types of Polyethylene can be used in this project:

- High Density Polyethylene (HDPE)
- Medium Density Polyethylene (MDPE)
- Low Density Polyethylene (LDPE)
- Linear Low-Density Polyethylene (LLDPE)

Non-absorbance of water, having properties of electrical insulation and thermal insulation are the very important properties of the above types of polyethylene to use in this project.

3.1 Polyethylene Production

Estimations of government surveys of some countries found that the manufacturing of polyethylene bags in worldwide is between five hundred billion to one trillion bags per year [5].

The United States International Trade Commission pronounced that around one hundred billion polyethylene grocery bags were being used yearly in the United States alone in 2009 [2].

3.2 Manufacturing of Polyethylene Grocery Bags

Polymer grocery bags are usually made from Polyethylene, which made out from long chains of ethylene monomers. Ethylene is produced from petroleum gas. The common types of polyethylene are HDPE and LDPE. Blown film extrusion is the common manufacturing process for the producing of polyethylene bags.

Because of polyethylene grocery bags are so durable, it is good for its intended works but in other hand this high durability is a big problem for the environment. They will not be easily deteriorated and very hazardous for wildlife. Millions of discarded polyethylene shopping bags are accumulated in the environment when improperly disposed of those polyethylene bags, but in the same time polyethylene become very popular commercially because of its low production cost and durable in use.

Due to their durability, polyethylene bags could take hundreds of years to decompose. According to some research findings, polyethylene bags can take between 500 - 1,000 years to decay [7].

Polyethylene bags are one of the most frequent kinds of litter in populated areas. Large accumulations of polyethylene materials can block drainage systems and make contributions to flooding, as example yearly flooding in Manila and devastating flooding happened in Bangladesh in 1988 and 1998 [8].

It was observed that the Polyethylene bags were the extensive element of the floating marine debris around southern Chile, in a study carried out between 2002 and 2005 [9].

Polyethylene bags are generally not friendly with the environment, but many researches from numerous authorities have found and published saying that there are many advantages of polyethylene usage. According to the Recyc-Quebec, a Canadian government agency, they concluded that the conventional polyethylene bags having very big environmental and economic advantages. While comparing with other materials, polyethylene bags are thin and lightweight and its production requires little energy (it reduced the carbon footprint) and raw materials are widely available and cheap [10]. Also, that the government studies from Denmark and the United Kingdom, as well as some researches from Clemson University, got heard to similar conclusions [10].

3.3 Recycling and Reuse

Polyethylene shopping bags are difficult to use in general recycling programs due to the fact that most recycling systems are designed for rigid plastics and not plastic films.

Polyethylene bags are 100% recyclable in the manner of reuse as reusable grocery bags. However, as in hygienic point of view, it is not seemed to be a very good idea. Some large shop chains have banned the reusing of polyethylene shopping bags in their outlets. (Example: IKEA in the U.S. and the U.K and Whole Foods in the USA [11] [12].

Figure 3: Different types of polyethylene covers

4. LITERATURE SURVEY OF POLYETHYLENE

Generally called Polyethylene but in chemistry, it is Polyethylene (IUPAC name-Polyethene)

Can be abbreviate as PE

Chemical formula $(C_2H_4)_n$

Density0.88–0.96 g/cm^3

Melting point115–135 °C

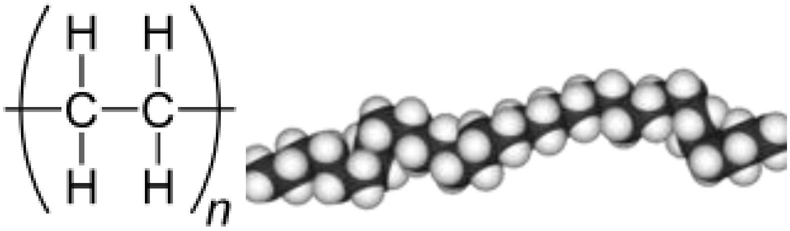


Figure 4: Molecular structure of Polyethylene

Polyethylene is the most common polymer for the manufacturing of grocery bags and wrapping materials. It is recorded in some researches that over one hundred million tonnes of polyethylene resins are produced globally in 2017 and that is the 34% of the whole plastics market. Principal use of polyethylene is in packaging.

Generally, polyethylene having the chemical formula of $\mathbf{(C_2H_4)_n}$. Polyethylene is generally a mixture of ethylene chains with different values of **n**. Polyethylene is a thermoplastic material. However, modified cross-linked polyethylene can be behaved as thermoset plastics.

There are many important properties of polyethylene as follows.

4.1 Properties of Polyethylene Materials

Studying of physical and chemical properties are very important in this project. There are some important properties of Polyethylene can be discussed as follows.

4.1.1 Mechanical properties

Polyethylene is having low strength, low hardness and low rigidity, however has a high ductility and low friction. It is also having a strong creep under persistent force. Polyethylene feels waxy when touched.

4.1.2 Thermal properties

Melting point is the main important thing while looking to the thermal properties.

For the industrial grades of medium and high-density polyethylene generally having the melting point in the range of 120^0C to 180^0C. The melting point for low-density polyethylene is normally coming under the range of 105^0C to 115^0C. Melting points are strongly very with the type of polyethylene.

4.1.3 Chemical properties

Polyethylene is high molecular weight hydrocarbons which consists of carbon and hydrogen molecular structure which is non polar and chemically saturated. Therefore, its chemical behaviour is fairly inert. The structural macromolecules are not covalently bonded. Because of their symmetric molecular structure, they have a tendency to crystallize; commonly polyethylene is partially crystalline. Higher crystallinity will increase density and mechanical and chemical stability.

Polyethylene has very good chemical resistance, therefore it is safe from robust acids or robust bases, and resistant to powerful reducing agents and gentle oxidants. Polyethylene crystalline samples do not dissolve in water at room temperature. Generally, Polyethylene can be dissolved in aromatic hydrocarbons such as toluene or xylene at high temperature, or in chlorinated solvents such as trichloroethane or trichlorobenzene (Except cross-linked polyethylene).

Polyethylene has very little water absorbance and can end up brittle when opened to sunlight.

4.1.4 **Electrical properties of polyethylene**

Polyethylene is a very good electrical insulator. It gives very good electrical resistance. So, this is the principal property to decrease chloride ion permeability of polyethylene mixed Polymer Composite Concrete.

4.1.5 **Optical properties**

PE can vary between clear (transparent), milky-opaque (translucent) or opaque depending on film thickness, pigmentations and the type of polyethylene.

4.1.6 **Thermal Conductivity**

Thermal conductivity means that the characteristic of absorbing and conducting of heat by any material. It creates a temperature gradient though out the material. Unit of the thermal conductivity is $J/s/m^3$.

The average thermal conductivity of polyethylene – 0.4W/m K [13]

Hereby, for the comparative purposes, would like to mention the thermal conductivity of concreate. it depends on its ingredients, means that it depends on the mix design of the concrete (type of concrete).

Different types of concrete having different conductivity as follows:

- Lightweight concrete – 0.1 to 0.3 W/m K
- Medium dense concrete – 0.4 to 0.7 W/m K
- High density concrete – 1.0 to 1.8 W/m K
- Polymer composite concrete – 0.7 to 0.8 W/m K [13, 14]

4.2 Manufacturing Process of Polyethylene (Polyethylene)

Polyethylene produces by the polymerization of Ethane Monomers

4.2.1 Monomer of Polyethylene

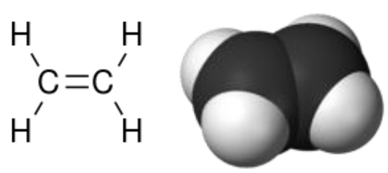


Figure 5: Molecular structure of Ethylene (Ethane)

The monomer of the polyethylene is ethylene (ethene is the IUPAC), a gaseous hydrocarbon which is the chemical formula of C_2H_4.

Ethylene is usually produced from petroleum crude oil and further generated through ethanol dehydration.

4.2.2 Polymerization

Ethylene can be polymerized by using catalysts. The reaction is exothermic. The most persistent technology is the coordination polymerization, which metallic chlorides or metallic oxides are used. Titanium (III) chloride is the most frequent catalysts, (Ziegler–Natta catalysts). Phillips catalyst is another popular one which depositing chromium (VI) oxide on silica. Further to above, polyethylene can be produced through radical polymerization.

4.3 Classification

Polyethylene can be classified by means of their density and molecular branching.

Properties of polyethylene depend on various types of features like the nature of branching, the features of crystal structure and the different molecular weights.

By considering those properties, there are four main types of polyethylene can be found as follows:

- High Density Polyethylene (HDPE)
- Medium Density Polyethylene (MDPE)
- Linear Low-Density Polyethylene (LLDPE)
- Low Density Polyethylene (LDPE)

4.3.1 High-density polyethylene (HDPE)

HDPE can be defined as the polyethylene in the range of density is equal or greater than 0.941 g/cm^3. HDPE has a lower amount of branching. Well packed linear molecules give strong intermolecular forces than in the polymers which is having heavily branched molecules. HDPE production can be done by using Ziegler–Natta catalysts or metallocene catalysts or Chromium / Silica catalysts. Formation of branching can be controlled by controlling of the reaction conditions and the selecting of catalysts. Above catalysts promote the formation of free radicals at the ends of the growing polyethylene molecular chain. This promotes new ethylene monomers to add to the ends of the molecular chain which is causing of the growth of a linear chain instead of side branches.

Compare with other types of polyethylene, HDPE has higher strength. It is mainly used in packaging such as various types of ready-made drink packets and bottles, disposable water bottles, butter tubs, rubbish containers etc. water pipes and fittings and many types of toys are another popular product. Further to above, HDPE can be used for manufacturing of various kinds of polyethylene sheets and grocery bags. Some researchers found that the global HDPE consumption reached a volume of greater than 30 million tons in 2017 [2].

4.3.2 **Medium-density polyethylene (MDPE)**

MDPE's density is coming in the value between 0.926 g/cm^3 – 0.940 g/cm^3.

MDPE can be produced by Ziegler–Natta catalysts, Chromium / Silica catalyst. or metallocene catalysts. MDPE is having very good shock and impact resistance properties. MDPE's tearing resistance is higher than HDPE. MDPE is majorly use to the manufacturing of pipes and fittings, sacks, wrapping films and grocery bags.

4.3.3 **Linear low-density polyethylene (LLDPE)**

LLDPE's density is coming in-between 0.915 g/cm^3–0.925 g/cm^3. LLDPE is a drastically linear polymer. It is having substantial numbers of short branches, made with the co-polymerization of ethylene with short-chain alpha-olefins (1-butene, 1-hexene, and 1-octene can be given as some examples).

LLDPE bears greater tensile strength than LDPE, and having puncture resistance and impact resistance than LDPE. Compared with LDPE, low thickness (gauge) films can be blown.

4.3.4 **Low-density polyethylene (LDPE)**

Density varies from 0.910 g/cm^3–0.940 g/cm3 for LDPE. It has a high degree of short and long chain molecular branching; Therefore, the chains do not compact into the crystal structure nicely. Accordingly, intermolecular forces are weak as the instantaneous-dipole induced-dipole attraction is less. This gives lower tensile strength but increases the ductility. LDPE can be manufactured with free-radical polymerization.

Some common properties of these polymers are as follows,

1. Those above all types of polymers are having zero water absorption.
2. All are electrical and thermal insulators.
3. While those polymers having longer molecular chains, surely, they can increase the tensile strength of the materials when composite together to form a composite material.
4. Capillary tubes, micro and macro pores and pore pathways can be closed when add polyethylene particles in to the concrete matrix.
5. Above all types of polymers are highly inert (non-corrodible) materials.
6. Long-lasting in aggressive environments by resisting to chemical attacks and biodegradations.

Accordingly, resistant to the water permeability & absorption, the electrical and thermal insulation and non-corrodible (inert) properties are the main important parameters for this project. So, density variations do not give any major effect on the final product durability properties. Accordingly, it can be used any kind of grocery bag cut pieces for this project.

As the next step, would like to do some literature study about Fiber Reinforced Concrete (FRC), because it can be noticed that the usage of fibers with cementitious and aggregate ingredients having some similarities with this project production of Polymer Composite Concrete (PCC), even though it is not exactly similar with each other. Therefore, it's important to study about fiber reinforced concrete as in upcoming pages of this thesis.

5. LITERATURE SURVEY OF FIBRE REINFORCED CONCRETE

Figure 6: Various types of concrete additives

Fiber Reinforced Concrete is a composite material which consists of cement, Aggregate and uniformly dispersed fibrous materials.
Concrete reinforced fibers can be defined as small thread like pieces of reinforcing material having certain good characteristics properties to make concrete more durable, workable and increasing its strength. Concrete fibers can be circular or flat. Fiber can be technically described by aspect ratio parameter. Aspect ratio is the ratio of its length to its diameter. Aspect ratio of the concrete fibers can be seen that ranging from 30 to 150.

There are different types of fibers like steel fibers, glass fibers, synthetic plastic polymer fibers and natural fibers (coconut fibers, banana leaf fibers etc.)
Type of the fiber material, its geometries, distribution, orientation and densities can give different durability and workability characteristics to the concrete.

Fiber reinforced concrete, mainly used as lightweight concrete in past decades, but nowadays with the new technology of modern advanced concrete mix designs it can cater to any kind of robust constructions like concrete slabs, beams, pillars (columns), box foundations and file foundations.

5.1 Effect of fibers in concrete

Adding of fibers are normally used in concrete to control plastic shrinkage and drying shrinkage cracks. Fibers can lower the permeability of concrete and consequently reduce bleeding of water. Further fibers can give greater impact and abrasion resistance. But overdosage of fibers can reduce the compressive strength of the concrete [15]. So, fibers have to be very carefully blended with concrete by doing appropriate researches.

If the modulus of elasticity of the fiber material is greater than the matrix (concrete binder and aggregates), then they increase the tensile strength of the concrete and helping to carry the structural loads (tensile loads). Accordingly, the fiber materials which are having higher modulus of elasticity can provide high strength and high stiffens to the concrete (steel fibers, glass fibers and carbon fibers are some of examples). For the stress transfer there should be a very good interfacial bonds in-between matrix and the fibers.

Some disadvantages of fibers are using of higher percentage can decrease the concrete strength and too long fibers can create fiber balls which can create workability problems.

5.2 Special characteristics of Fiber Reinforced Concrete

1. Increasing of Tensile Strength
2. Reduces the porosity
3. Increases the concrete durability
4. Improving creep resistance
5. Thermal stresses can be reduced, hence it can reduce thermal cracks
6. Fibers can act as crack arrester and consequently fibers can significantly improve the static and dynamic properties of concrete

5.3 Mixing of fibers in to the concrete mix

Concrete batch mixing should be carryout very carefully to avoid balling of fibers and segregations. It should be uniformly mixed to get homogeneous mixture. Mixing volume and aspect ratio shall be preciously controlled.

The fibers should be added to the mixer before adding water to the mixture. After the properly mixing fiber particles with aggregates and cement, then water can be added.

5.4 Different types of fibers used in FRC

Some common types of concrete fibers can be identified as follows:

- Steel
- Polypropylene
- Glass fibers
- Asbestos fibers
- Carbon fibers
- Natural organic fibers

This project findings observed that Polypropylene fiber reinforced concrete having some similar characteristics with this project invention of Polymer Composite Concrete which we used polyethylene grocery bag particles instead of polypropylene fibers in the concrete mix.

Figure 7: Various types of fibers which used in Oriental Ready mix, Oman

Above types of fibre reinforced concretes are manufactured in the production factory of Ms. Oriental Ready-mix in Sultanate of Oman as a daily practice. As per the above practical knowledge of using above various sizes of polypropylene fibers, it can be recommended that use of polyethylene cut pieces up to the maximum size of 10mm X 5mm of length and width, and the thickness of the particles does not have any significant effect while it is coming under the ordinary usage of grocery/ shopping bags.

6. LITERATURE SURVAY OF CONCRETE STRENGTH, WORKABILITY AND DURABILITY

6.1 Durability of Concrete

Durability of concrete is a very important factor in the construction industry. Durability of concrete can be defined as the ability to withstand by resisting to the aggressive weathering actions while maintaining the desired engineering properties. Apparently more durable concrete structures have a longer lifespan.

There are many factors which can be affected to the concrete durability. Water Penetration (permeability), Water Absorption, Chloride Ion Permeability are some of major parameter for the durability of concrete structures. Water and chloride ion permeability can create the corrosion of embedded steel rebars of the concrete structures. Corrosion of embedded steel reinforcement bars is one of the major causes for structural failures.

Corrosions will be resulted with spalling and delamination of concrete structure and reduced its load bearing capacity.

Insufficient cover to reinforcement, higher permeability of concrete, concrete cracks, carbonation, aggressive environmental conditions are the some of the major factors for embedded steel re-bars corrosion.

Figure 8: Reinforcement steel bar corrosion because of the high permeability of concrete

Generally, the Durability is inversely proportional to the Permeability

According to the above relationship between the durability and the permeability, it can be indirectly measured the durability of any concrete structure by conducting permeability tests for the relevant concrete material.

6.1.1 Capillary rise, Permeability and Absorption of Hardened Concrete

Capillaries are very tiny holes and tube-like structures which exist in concrete. Water rises into these holes, which is called capillary porosity. The height of rise depends on the continuation of this pores. Because of capillary rise, it is preferable to give generally 75mm to 100 mm width of cover to the reinforcement from the substructure or from the surrounding environment, cover width depending on the deleterious materials in the soil, ground water and surrounding air atmosphere. Pore blocking agents can reduce this process effectively. Accordingly, in this project, that the main objective was to add polyethylene grocery bags cut pieces as additive for the concrete mix to reduce capillary rise.

Figure 9: Demonstration of the capillary rice of hardened concrete

Ingress of water is the leading cause of early deterioration of concrete in many construction sites around the world. Therefore, to have a durable structure that the passage of water through concrete must be reduced.

Figure 10: Water absorption by concrete

As previously discussed, the permeability is the penetration of water, fluids, chemical ions, air, different types of gases in to the microstructure (pore structure) of concrete. High permeability can cause decaying of concrete structure by allowing chemical attacks. Low permeability concrete has the resistance to the penetration of water, chloride ions, sulphate ions, alkali ions, and other harmful substances.

Mainly, the volume and size of the interconnected capillary pores are the main considerable characteristics of the pore structure. The hydration reaction of cement produces the hardened part of the matrix together with micro pore systems. The pore network of structural concrete matrix provides passage for the transport of above-mentioned substances into concrete.

Recently, it has been recognized that the Sorptivity **(**an index of moisture transport into unsaturated specimens) as an important index of concrete durability. In this sorptivity process, that the driving force for water ingress into concrete is the capillary suction within the pore spaces of concrete.

Many researchers found that the sorptivity coefficient is essential to predict the service life of concrete and the idea will help to the manufacturing of durable concrete [16].

Use of GGBS or silica fume (Microsilica) etc. can reduce the water absorption and permeability by blocking the pore structure with their fine particles. But those types of additive will increase the production cost of the concrete.

In this project that the main objective was to control water absorption / permeability by adding polyethylene grocery bag cut pieces to the mix. When dispersing polyethylene cut pieces throughout the concrete matrix it disturbs the continuation of capillary tubes and the mosaic formation of pore structure. Blocking capillary tubes and pore structure by using polyethylene particle is the main technical point of this project. This enhance the durability of the concrete and concrete testing have been carried out to make sure that the adding of polyethylene does not give any negative impact on the strength and fresh concrete and hardened concrete properties and also to find any effect from high ambient temperature (By keeping sample in 105 ^{0}C for three days -72 hrs.).

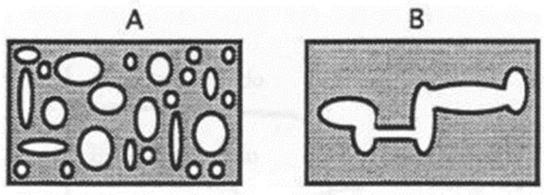


Figure 11: Pore structure and the pore interconnections in concrete

Researches shows that the concrete permeability depends on the pressure gradient, capillary pore size and pore interconnections.

Similarly, absorption depends on moisture gradient, capillary pore size and pore interconnections, and diffusion depends on concentration gradient, capillary pore size and pore interconnections [20].

This project was conducted by keeping above concept as the baseline of the project. One of the main project objectives of this project was to disturb (block) the pore structure with polyethylene particles to reduce the pore size and pore interconnections to reduce the permeability, absorption and diffusion of the concrete.

For the study of the concrete properties (Fresh concrete and hardened concrete properties) and durability parameters there are nine types of concrete laboratory tests were carried out for the concrete which manufactured by adding polyethylene particles in this project as follows explains.

Concrete Laboratory Tests

For this project, nine types of concrete laboratory tests were carried out in Ms. Oriental Ready mix Company LLC, Oman, as follows.

6.2 Fresh Concrete Testing

Fresh concrete testing should be carried out to find out the workability (flowability) and the cohesiveness of the fresh concrete mix before it gets hardened.

There are three types of tests were done in this project as follows,

1. Fresh concrete temperature
2. Slump test
3. Air content test

6.2.1 Fresh Concrete Temperature

Calibrated thermometer was used to check the temperature for each trail production of polymer composite fresh concrete and recorded. (Please refer to the Table 03 for the results)

6.2.2 Slump Test

British standard BS EN 12350-2: Testing of fresh Concrete- Slump Test, is the most common standard to find out slump height of the fresh concrete. Slump height indirectly assess the consistency and workability of fresh concrete.
It also gives some practical idea about the water content of the mix.
(Please refer to the Table 03 for the slump test result)

Figure 12: Measuring of Slump Height

6.2.3 Air Content & Density of Fresh Concrete

Air content can be measured by using a pressure meter by filling the meter container with fresh concrete. Generally, follow the British standards of BS EN 12350-7 for Air Content Test & BS EN 12350-6 for finding of Density of fresh concrete.

Air content is very important factor in concrete technology. The amount of air will have the impact on concrete strength, durability and workability. Also, important factor while producing porous (sponge) concrete which can resistance to thawing and freezing deterioration (Airport runaway construction). Fresh concrete density is important factor while designing bearing capacity of formworks, falls work and the existing columns and beams, also important in light weight concrete production.

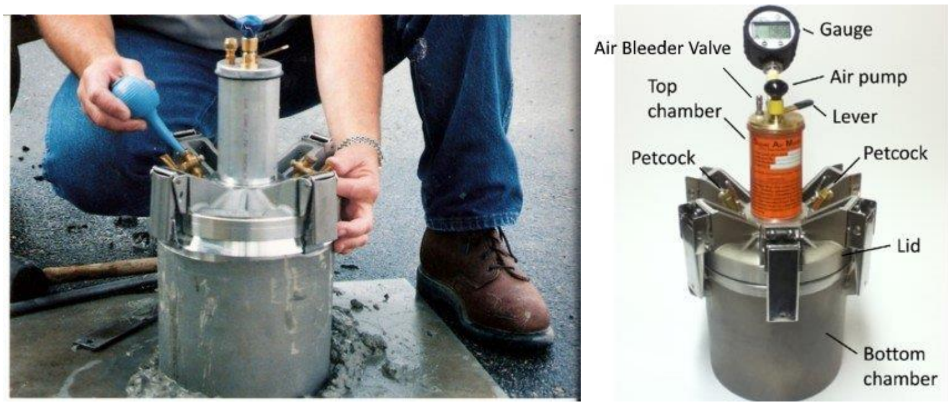


Figure 13: Measuring of Air Content & Density

6.3 Hardened Concrete Testing

There are five types of hardened concrete tests (those are specially called Durability Tests) were carried out in Ms. Oriental Readymix, Oman as follow explained.

1. Water Absorption Test
2. Initial Surface Absorption Test
3. Depth of Water Penetration Under Pressure Test
4. Rapid Chloride Permeability Test
5. Concrete Cube Crushing Strength Test

6.3.1 Water Absorption Test

Figure 14: Shows the experimental setup of the water absorption test

For the water absorption test, BS 1881-122: 2011 – Testing Concrete – Method for Determination of Water Absorption, testing procedure was followed. This test is one of the popular methods of determining of the water-tightness of concrete.
In this test results, the lower the absorption, the better the results.

International standard references for the water absorption of concrete [15]

Extremely non permeable concrete – 4% to 5% by mass
Very good concrete – 5% to 6% by mass
General commercial concrete – 6% to 7% by mass
Normal ordinary concrete – 7% to 10%. by mass

Above test were carried out for all the five trail mixes test cube samples and those test results can be found in Table 02.

6.3.2 Initial surface absorption Test

The initial surface absorption test (ISAT) is covered by the British Standard of BS 1881-208. In this test, it can be found out the nature of capillary absorption of concrete.

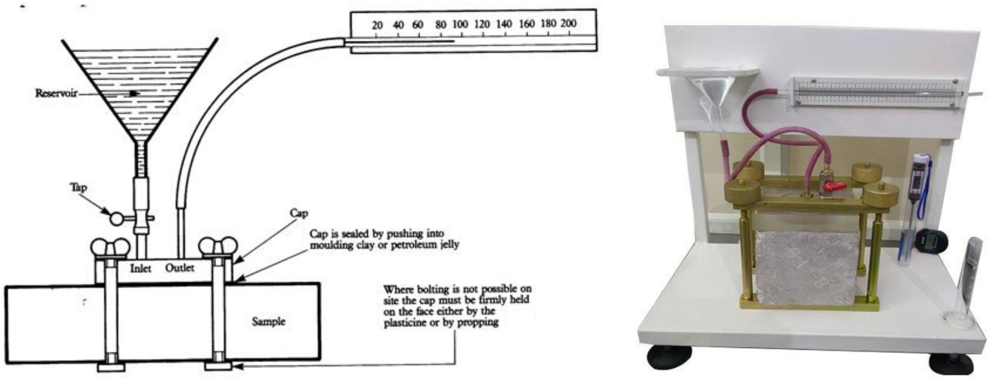


Figure 15: Shows the experimental setup of the initial surface absorption test

Above test were carried out for all the five trail mixes test cube samples and those test results can be found in Table 02 (ISAT unit is ml/mm^2/sec).

6.3.3 Depth of water penetration under pressure (5 bar) Test

This test is usually conducted for assessing of the durability of highly impermeable high-performance concrete.

The hydrostatic pressure of 5 bar (0.5Mpa) is applied to one surface of the concrete cube specimen (150 x 150x 150 mm concrete cubes) for a standard specified time and then split the specimen perpendicular to the injected face and measuring the depth of penetration in millimeters (mm).

The testing procedure is covered by BS EN 12390–8:2000: Part 8: Testing of hardened concrete for water penetration.

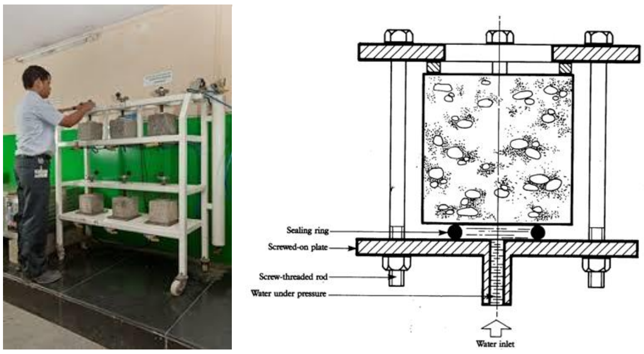


Figure 16: Shows the experimental setup of the water penetration test

Above test was carried out for all the five trail mixes test cube samples and those test results can be found in Table 02.

6.3.4 Rapid Chloride Permeability Test

The Rapid Chloride-ion Permeability Test (RCPT) can be conducted to find out the resistance to the penetration of chloride ions in to the concrete microstructure.

The test method is covered by ASTM C1202, Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration.

The theory behind the test method is that, it is measuring the amount of electrical current passed through cylindrical specimens for six-hour duration. After the completion of the specified time, the total charge passed will be measured and results will be compared with the specified standard requirements.

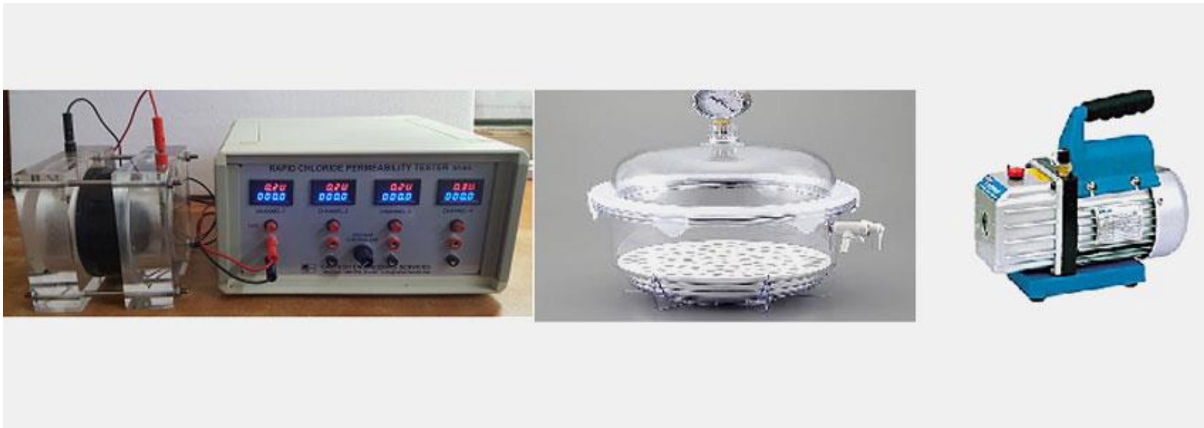


Figure 17: Shows the rapid chloride permeability test setup

Table 01: Standard Rating of Chloride Permeability of Concrete [12].

High Permeability: > 4000 Coulombs

Moderate Permeability: 2000 to 4000 Coulombs

Low Permeability: 1000 to 2000 Coulombs

Very Low Permeability: 100 to 1000 Coulombs

Negligible Permeability: < 100 Coulombs

Above test were carried out for all the five trail mixes test cube samples and those test results can be found in Table 02.

6.3.5 Compressive strength of concrete cubes test

The testing method to finding out of Compressive Strength of concrete cubes covered by the British standard BS EN 12390: Part 3:2002.

Many factors can be affected on the compressive strength of concrete such as type and amount of cement (binder), water content in the mix (water / cement ratio), cement strength, quality of aggregate materials, and adequate quality control during production and casting (pouring) of concrete etc.

Test for compressive strength can be carried out either on concrete test cubes or cylinders.
The formula of compressive strength is as follows:

Compressive Strength = Load / Cross-sectional Area (N/mm^2)

Size of 15cm x 15cm x 15cm molds are commonly used to make standard test cubes.

Figure 18: Steel cube molds

Test cubes cast by pouring and compacting of fresh concrete in these standard molds as per the standardize procedure. These cube specimens shall be tested upon the completion of its water curing age of 7 days and 28 days by crushing in compression testing machine as per the above standard procedure. The test result values can be directly obtained from the crushing machine.

Above test were carried out for all the five trail mixes test cube samples and the test results can be found in Table 02.

Figure 19: Concrete test cubes

Figure 20: Shows the experimental setup of the cube crushing strength test

Table 02: Standard compressive strengths for different grades of concrete [17]

Grade Concrete	**Minimum compressive strength N/mm^2 at 7 days**	**Specified characteristic compressive strength (N/mm^2 at 28 days**
C15	10	15
C20	13.5	20
C25	17	25
C30	20	30
C35	23.5	35
C40	27	40
C45	30	45

Note: This project was done by manufacturing of strength class of C30 concrete, by adding of different weights of polyethylene grocery bag flakes and carried out tests for the fresh concrete just after the production, and durability tests were conducted for the test cubes at the age of 28 days.

6.4 Polyethylene Identification and Classification Tests

There were two types of analysing tests were carried out as identification and classification tests for Polyethylene grocery bag cut pieces as follows:

6.4.1 Fourier Transform Infrared Spectroscopy (FTIR) Test

Fourier Transform Infrared Spectroscopy (FTIR) technique is used to obtain an absorption or emission of infrared (IR) spectrum of materials. This technique can be used to identify unknown materials of solid, liquid or gas by comparing with known FTIR spectra.

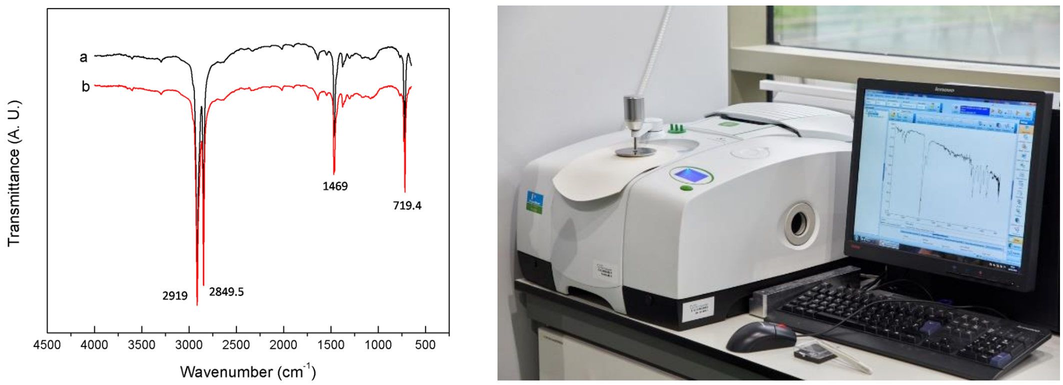


Figure 21: FTIR Apparatus

6.4.2 Differential Thermal Analysis (DTA) and Thermo gravimetric Analysis (TGA) Test

DTA and TGA tests are coming under the thermo analytic techniques which can be successfully used for identifying unknown substances by finding its melting point and weight loss. It can be used with ceramics, metals, polymer materials etc.

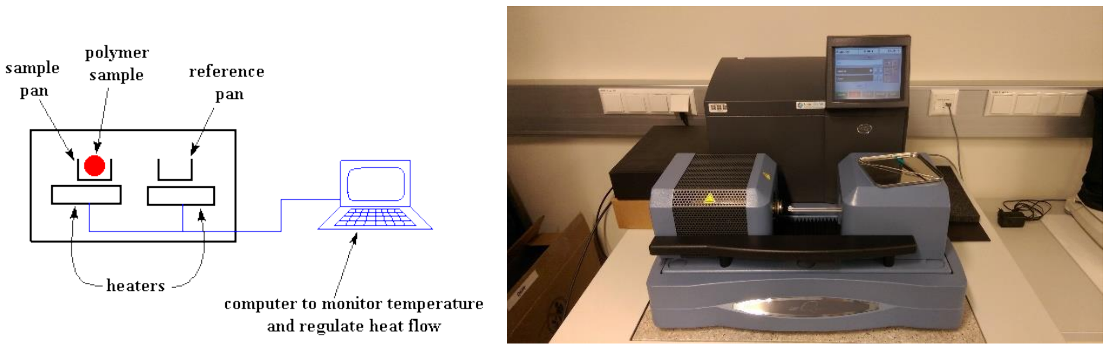


Figure 22: DTA and TGA Apparatus

Note: Above tests No: 6.4.1 and 6.4.2 were conducted to find out the properties of polyethylene wastes which were used in this project (Please refer to the attached reports at Appendix 2)

7. METHODOLOGY AND EXPERIMENTAL PROCEDURE (LABORATORY TRIAL MIXING AND TESTINGS)

7.1 Main Steps of the Project Methodology and Testing Procedure

1. Waste polyethylene particles were identified by conducting of FTIR, DTA and TGA laboratory tests.
2. Concrete mix designs have been carried out theoretically in the design paper by preparing of control mix which is without adding polyethylene particles and another four numbers of mixes by mixing of 5 kg, 10 kg, 15 kg and 20 kg of polyethylene flakes by volumetric replacement of the river sand from the control mix river sand weight proportion.
3. All the ingredients were weighted as per design sheet proportions.
4. Mixing was carried out for the above weighted concrete ingredients in a motorized concrete mixture for an adequate mixing time (mixing cycle).
5. Fresh concrete tests were conducted. (Fresh concrete temperature, slump tests, air content and, fresh concrete density).
6. Concrete test cubes were made, properly labelled and covering with polyethylene sheets.
7. After 24 hours, all cubes were de-molded and placed in laboratory curing tank.
8. After the completion of 28 days, durability tests were conducted.
   (Five types of tests: Water Absorption, Water Penetration, ISAT, RCPT, Cube Crushing)
9. Test results were reported.
10. Analysing of test reports were conducted.

7.2 Raw Materials

Details of used raw material ingredients are as follows,

7.2.1 Polyethylene cut pieces (Polyethylene grocery bags – waste polyethylene)

The waste material used in this study was polyethylene grocery bag flakes (Figure 23). It is shredded in to tiny cut pieces using scissors.

Figure 23: Sample of waste polyethylene used.

For the production of polythene cut particles there are polythene cut and shredded machines are commonly available now in the market. Water cleaning system is inbuilt with these machines.

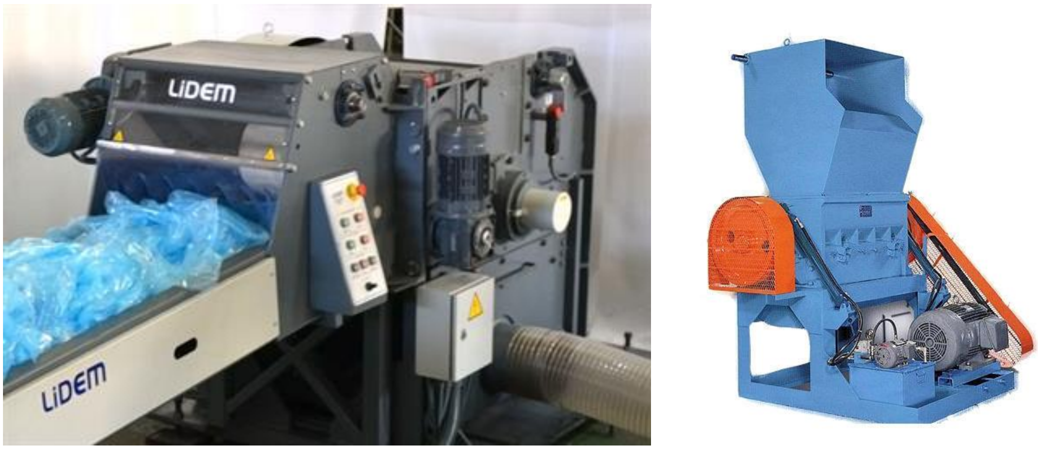


Figure 24: Polyethylene cut and shredded machines.

When it is going to use of municipality wastes then the polyethylene should be separated from the other deteriorated garbage. Separated polyethylene wastes have to be wash cleaned and dry, then should be cut into small particles. Also, polyethylene should be separated from other types of hard plastic wastes like plastic bottles and some polystyrene (Rigi foam), some hard-plastic bags which generally called as fertilizer bags made out of polypropylene.

However, these types of screening, washing and cutting will have some added cost on the final production, but when compare with the adding of additives like Microsilica to get the same durability will have several times of cost increments than the adding of polyethylene flakes, so the project finding is reducing the unit price of the durable concrete, accordingly it is good in economically.

Further study conducted towards how to identify the common properties and types of waste polyethylene particles as follows.

Conducting of FTIR, DTA and TGA testing

FTIR tests conducted at the Thermal Laboratory of faculty of Engineering of University of Moratuwa.

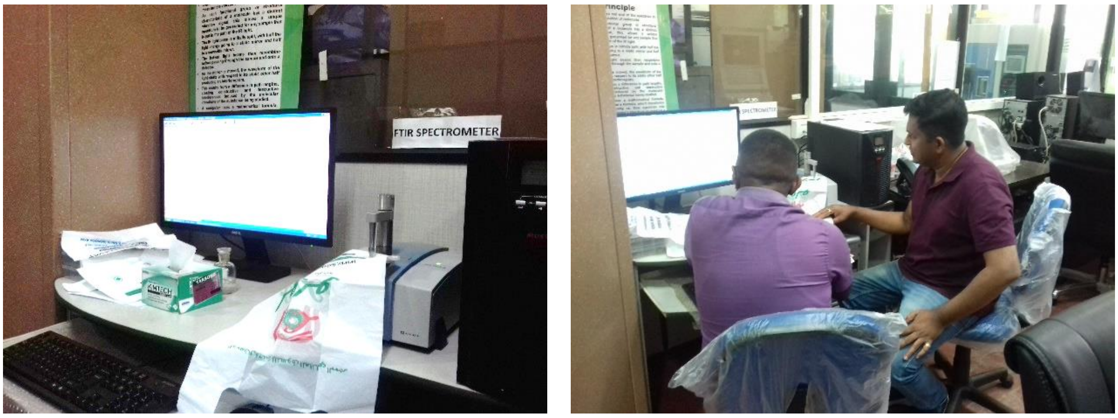


Figure 25: Conducting of FTIR.

DTA and TGA tests were conducted at the Thermal Laboratory.

Figure 26: Conducting of DTA and TGA.

7.2.2 Cement

Ordinary Portland Cement (OPC), which is complying with the British standard of BS EN 197-1-CEM 42.5 N (factory test report is attached in Appendix - 2) was used for this project.

7.2.3 Coarse aggregate

The coarse aggregates of 20mm and 10mm which available in local quarries were used for this project. The specific gravity of coarse aggregate is 2.7.

7.2.4 Fine aggregate

5mm crushed sand from local quarries and natural river sands were used as fine aggregates.

7.2.5 Water

Potable water was used for mixing and curing. A water cement ratio (w/c) of 0.41was adopted for concrete mixes.

7.2.6 Superplasticizer

In this project, superplasticizer used was GIC SP 672 (Gulf International Chemicals LLC) and used the dosage of 1.5% of the weight of cement content of the mix for the purpose of enhancing of the workability of concrete.

7.3 Mix Designs

Mix designs were done as per the DOE-Unite Kingdom method. We made one general deign for grade C30/20 (Strength class is 30 N/mm^2 and maximum aggregate size of 20mm) as the control mix and made another four mix designs by adding polyethylene flakes by volumetric replacing of fine aggregate (river sand) to facilitate the adding of above different weights of polyethylene cut pieces. (Please refer to the attached mix designs in Appendix -01).

7.3.1 General details of the mix designs (designed by weight per one cubic meter):

Cement Content: 350 kg
Water/Cement ratio: 0.41
Chemical Admixture (Superplasticizer GIC 672) 1.5% of cement content = 5.25 kg

Control mix design made without polyethylene added and other four designs were made by volumetric replacing of river sand by adding of the weights of 5kg, 10kg, 15kg and 20kg polyethylene grocery bag cut pieces per one cubic meter of fresh concrete.

7.4 Experimental procedure of conducting of laboratory trial mixes

practical experimental works started by weighing of designed proportions by using of the calibrated weighing scales. (Calibration reports are attached in Appendix - 3).

After that the mixing of above weighted ingredients were done by using 1000 watts electrical laboratory trial mixer machine. All the five mixes of fresh concrete were manufactured at the same date and carried out the above explained fresh concrete tests and reported. Set of concrete cubes were made, 12 cubes per one trial mix.

12 X 5 = 60 concrete cubes were made as per the standard procedure of BS 1881: Part 101

Cube molds were covered with polyethylene sheets and kept for 24 hours and the next day de-molded and put in the curing tank.

Cube crushing strength tests carried out After 28 days (3 numbers of cubes for each mix designs) separately. Other durability tests were carried out for above mention tests and all the test results were reported. (Please refer to the Appendix - 02 for fresh concrete and harden concrete test results).

8. TEST RESULTS

It was observed that while increasing the mixing percentage of polyethylene particles in the mixes that the cohesiveness and workability increased up to some percentage and in higher percentage these characteristics were decreased.

Temperature was stable at all the times. Test cubes were made and tested at the age of 28 days to find the compressive strength and other remaining cubes are used to use in durability hardened concrete tests after the completing of 28 days curing in the laboratory curing water tank (at the water temperature of 25^0C – following the British Standards)

Note: All the testing procedures followed as per the British (BSI) and American Standards (ASTM)

8.1 Tabulated Test Results

Table 03: Comparative summary of the test results

(Original Test Reports are attached in Appendix – 01 & Appendix – 02)

Type of tests	**Polyethylene added % by the weight of sand replacing**				
Fresh Concrete Tests	Control Mix (without adding of Polyethylene)	5 kg/m^3	10 kg/m^3	15 kg/m^3	20 kg/m^3
1.Temperature (^{0}C)	22	21	21	22	22
2. Slump Height after half hours (mm)	154	165	171	148	130
3. Density (kg/m^3)	2519	2485	2473	2458	2421
4.Air content (%)	1.2	1.4	1.5	1.7	3.1
Hardened Concrete Tests					
1.Cube crushing strength (N/mm^2)	37	39	40	40	32

2.Cube crushing strength after keeping 72 hours in 105^0C electric oven (N/mm^2)	38	40	41	39	31
3.Water absorption (%)	1.7	1.2	0.9	0.5	0.4
4.Initial Surface absorption (mm)	0.07	0.04	0.03	0.03	0.03
5.Water penetration (mm)	16	12	7	3	3
6.Rapid Chloride Penetration (Coulomb)	3175	2934	2252	2202	1989

8.2 Graphical relationship of test results.

<u>TEMPERATURE (℃)</u>

Table 04: Relationship of the Temperature (℃) vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (℃)	22	22	21	22	22
sample 2 (^{0}C)	21	21	22	22	21
sample 3 (℃)	22	21	21	21	22
SD (˚C)	0.577	0.577	0.577	0.577	0.577
AVG (℃)	21.67	21.33	21.33	21.67	21.67

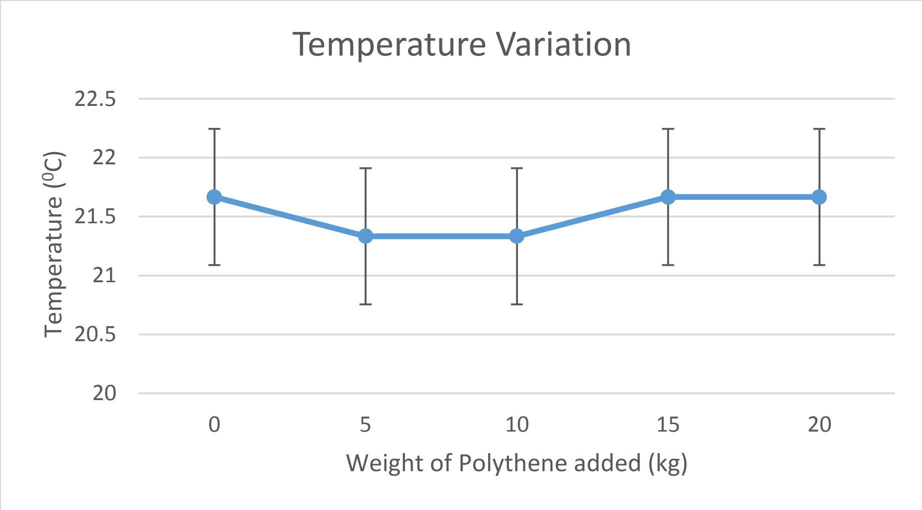


Chart 01: Relationship of the Temperature (℃) vs. Weight of Polyethylene added

SLUMP HEIGHT (mm)

Table 05: Relationship of the Slump Height vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (mm)	157	167	170	145	133
sample 2 (mm)	150	165	172	152	130
sample 3mm (mm)	155	164	172	147	127
SD (mm)	3.605	1.527	1.155	3.605	3.000
AVG (mm)	154.00	165.33	171.33	148.00	130.00

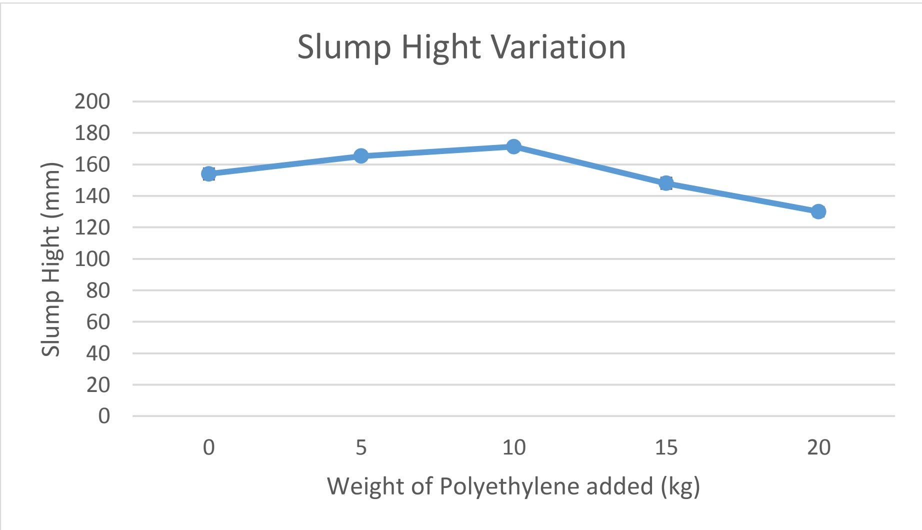


Chart 02: Relationship of the Slump Height vs. Weight of Polyethylene added

DENSITY

Table 06: Relationship of the Fresh Concrete Density vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (kg/m^3)	2522	2487	2475	2454	2418
sample 2 (kg/m^3)	2517	2488	2471	2457	2422
sample 3 (kg/m^3)	2519	2481	2474	2458	2425
SD (kg/m^3)	2.516	3.785	2.082	2.082	3.512
AVG (kg/m^3)	2519.3	2485.3	2473.3	2456.3	2421.7

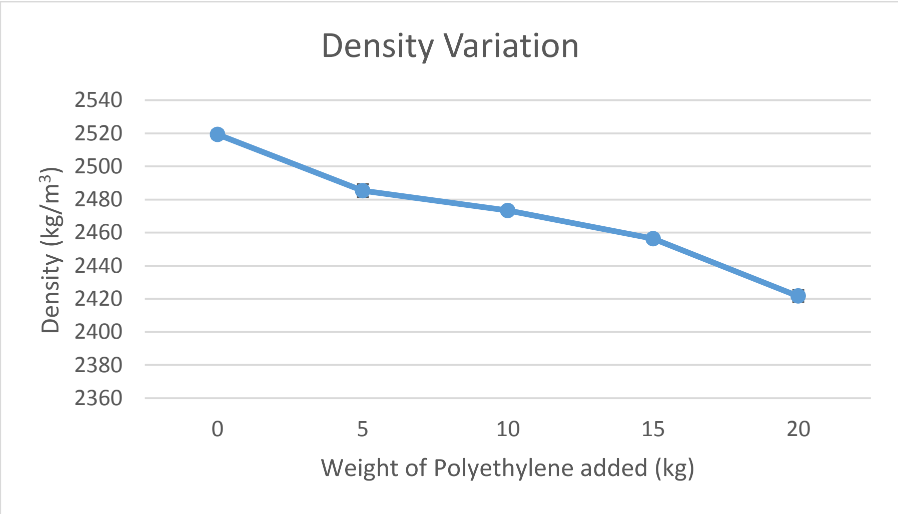


Chart 03: Relationship of the Fresh Concrete Density vs. Weight of Polyethylene added

AIR CONTENT

Table 07: Relationship of the Air Content vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (%)	1.2	1.4	1.5	1.7	3.2
sample 2 (%)	1.2	1.3	1.4	1.8	2.8
sample 3 (%)	1.1	1.4	1.5	1.7	2.9
SD (%)	0.0577	0.0577	0.0577	0.0577	0.208
AVG (%)	1.1667	1.3667	1.467	1.7333	2.9667

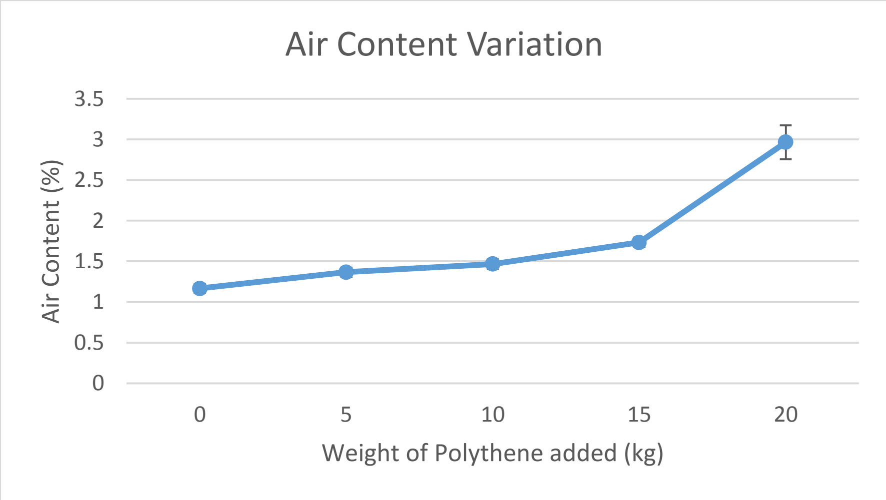


Chart 04: Relationship of the Air Content vs. Weight of Polyethylene added

HARDENED CONCRETE TESTS

CUBE CRUSHING STRENGH (N/mm^2)

Table 08: Relationship of the Cube Crushing Strength vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (N/mm^2)	37	39	41	40	32
sample 2 (N/mm^2)	39	40	40	39	33
sample 3 (N/mm^2)	36	37	39	41	32
SD (N/mm^2)	1.527	1.527	1.000	1.000	0.577
AVG (N/mm^2)	37.33	38.67	40.00	40.00	32.33

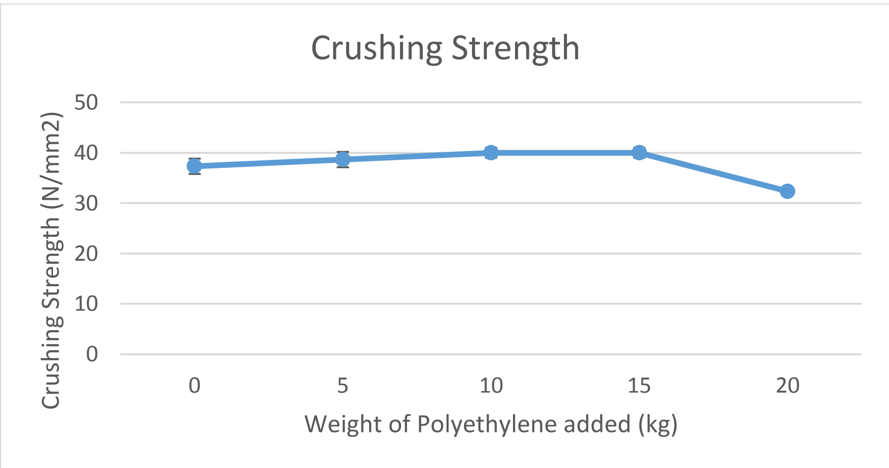


Chart 05: Relationship of the Cube Crushing Strength vs. Weight of Polyethylene added

CUBE CRUSHING STREENGTH AFTER KEEPING 72 HOURS IN 105°C ELECTRIC OVEN (N/mm^2)

Table 9: Relationship of the Crushing Strength (oven dried) vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (N/mm^2)	39	41	41	40	30
sample 2 (N/mm^2)	39	41	40	38	32
sample 3 (N/mm^2)	37	40	41	39	31
SD (N/mm^2)	1.155	0.577	0.577	1.000	1.000
AVG (N/mm^2)	38.33	40.67	40.67	39.00	31.00

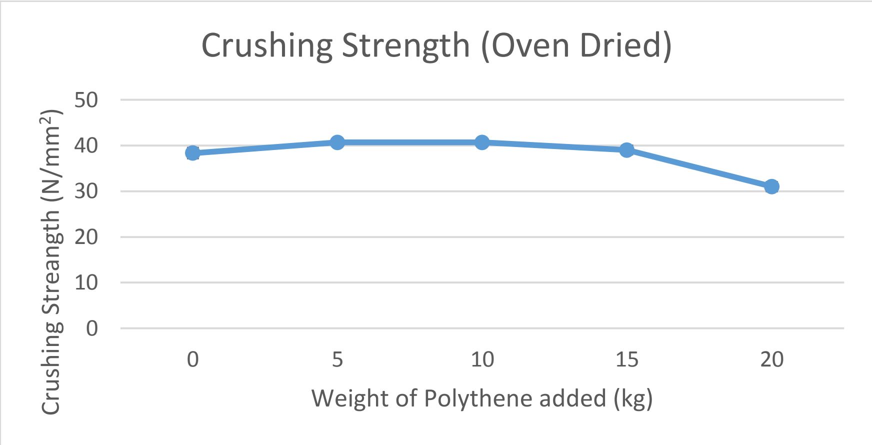


Chart 06: Relationship of the Crushing Strength (oven dried) vs. Weight of Polyethylene added

WATER ABSORPTION

Table 10: Relationship of the Water Absorption vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (%)	1.6	1.2	1	0.4	0.3
sample 2 (%)	1.8	1.1	0.8	0.6	0.5
sample 3 (%)	1.7	1.3	0.9	0.5	0.4
SD (%)	0.1	0.1	0.1	0.1	0.1
AVG (%)	1.7	1.2	0.9	0.5	0.4

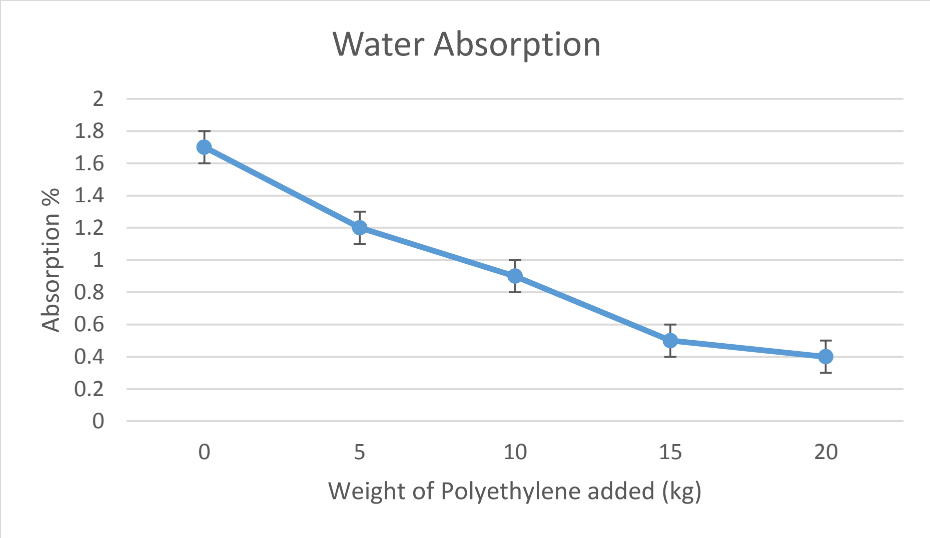


Chart 07: Relationship of the Water Absorption vs. Weight of Polyethylene added

INITIAL SURFACE ABSORPTION (ISAT)

Table 11: Relationship of the Initial Surface Absorption vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (%)	1.6	1.2	1	0.4	0.3
sample 2 (%)	1.8	1.1	0.8	0.6	0.5
sample 3 (%)	1.7	1.3	0.9	0.5	0.4
SD (%)	0.1	0.1	0.1	0.1	0.1
AVG (%)	1.7	1.2	0.9	0.5	0.4

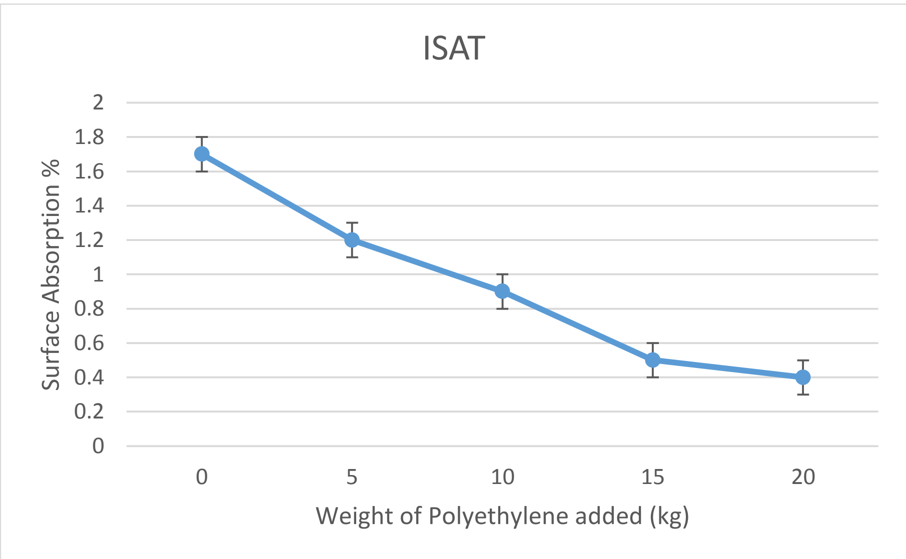


Chart 08: Relationship of the Initial Surface Absorption vs. Weight of Polyethylene added

WATER PENETRATION

Table 12: Relationship of the Water Penetration vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (mm)	15	11	6	4	3
sample 2 (mm)	17	13	7	3	4
sample 3 (mm)	16	12	8	3	3
SD (mm)	1	1	1	0.577	0.577
AVG (mm)	16.00	12.00	7.00	3.33	3.33

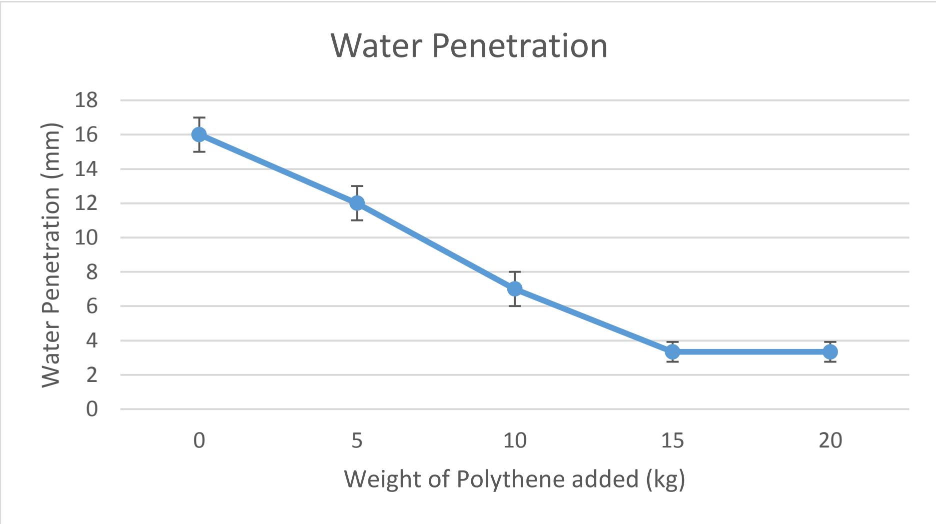


Chart 09: Relationship of the Water Penetration vs. Weight of Polyethylene added

RAPID CHLORIDE PERMEABILITY TEST (RCPT)

Table 13: Relationship of the Rapid Chloride Permeability vs. Weight of Polyethylene added

Weight of polyethylene added (kg)	**0**	**5**	**10**	**15**	**20**
sample 1 (Coulombs)	3172	2935	2241	2198	1976
sample 2 (Coulombs)	3179	2923	2268	2211	1996
sample 3 (Coulombs)	3174	2944	2247	2197	1995
SD (Coulombs)	3.605	10.535	14.177	7.810	11.269
AVG (Coulombs)	3175	2934	2252	2202	1989

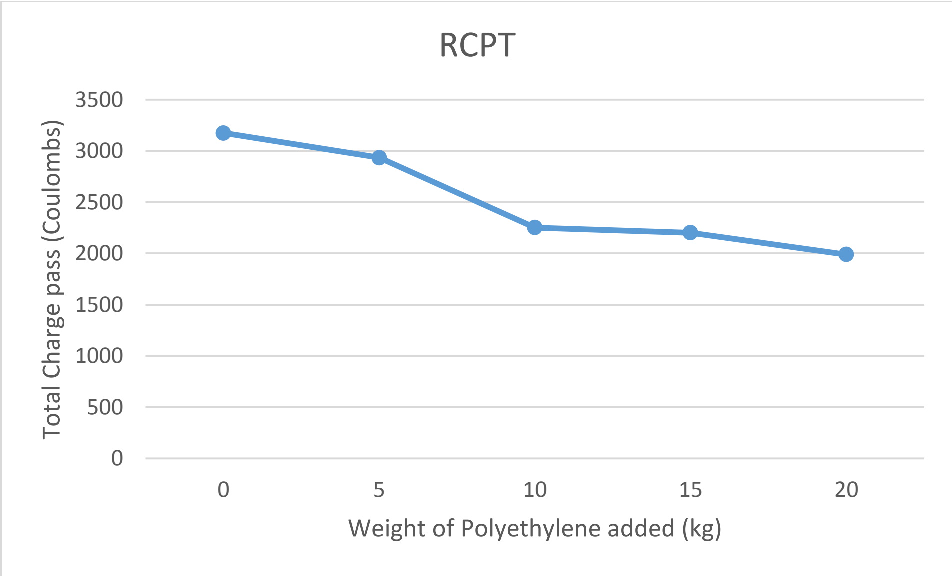
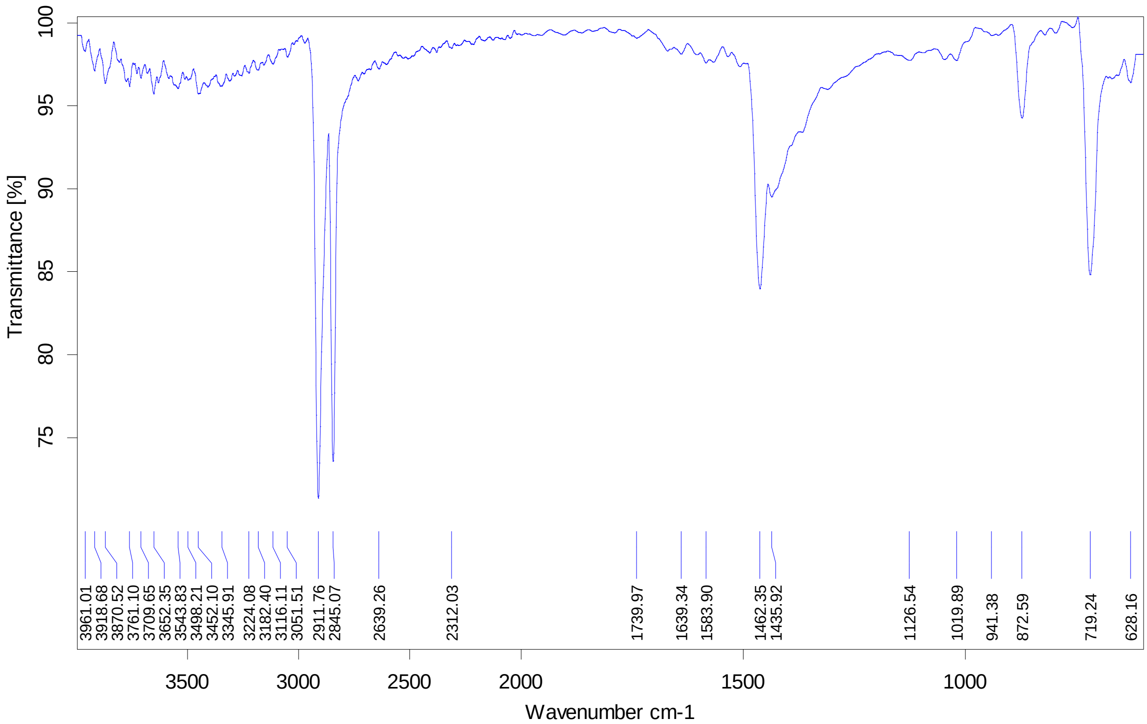
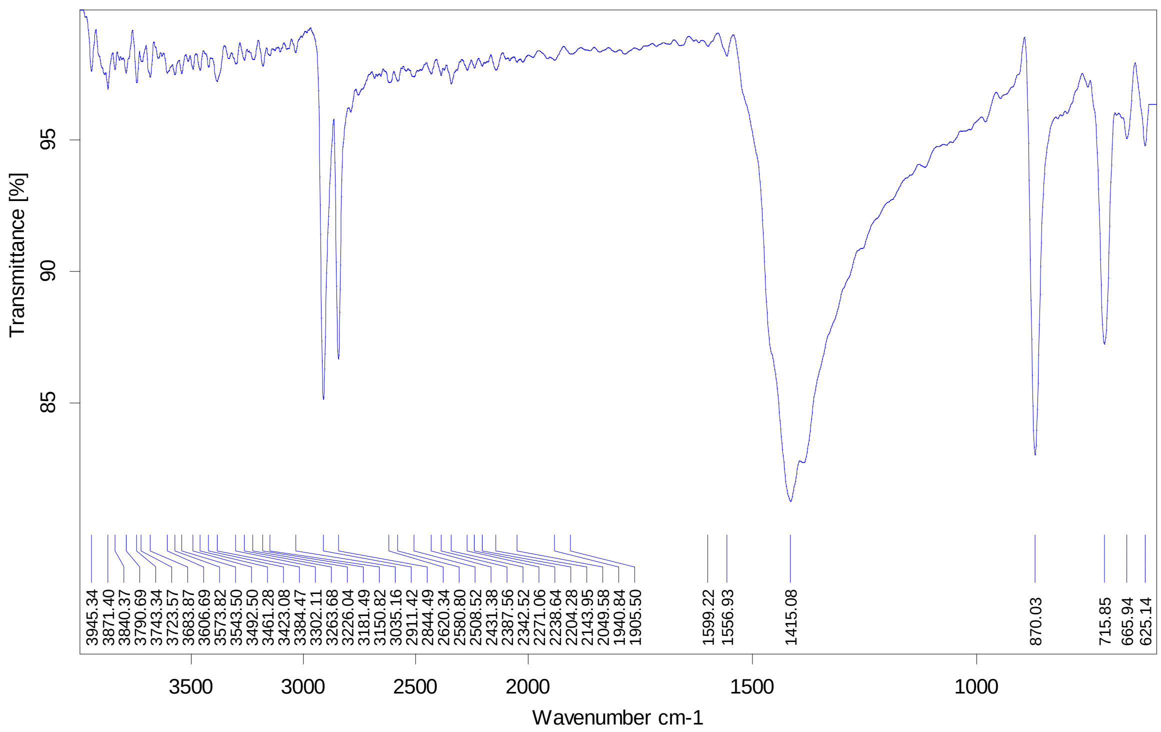


Chart 10: Relationship of the Rapid Chloride Permeability vs. Weight of Polyethylene added

<u>FTIR ANALISIS REPORT</u>

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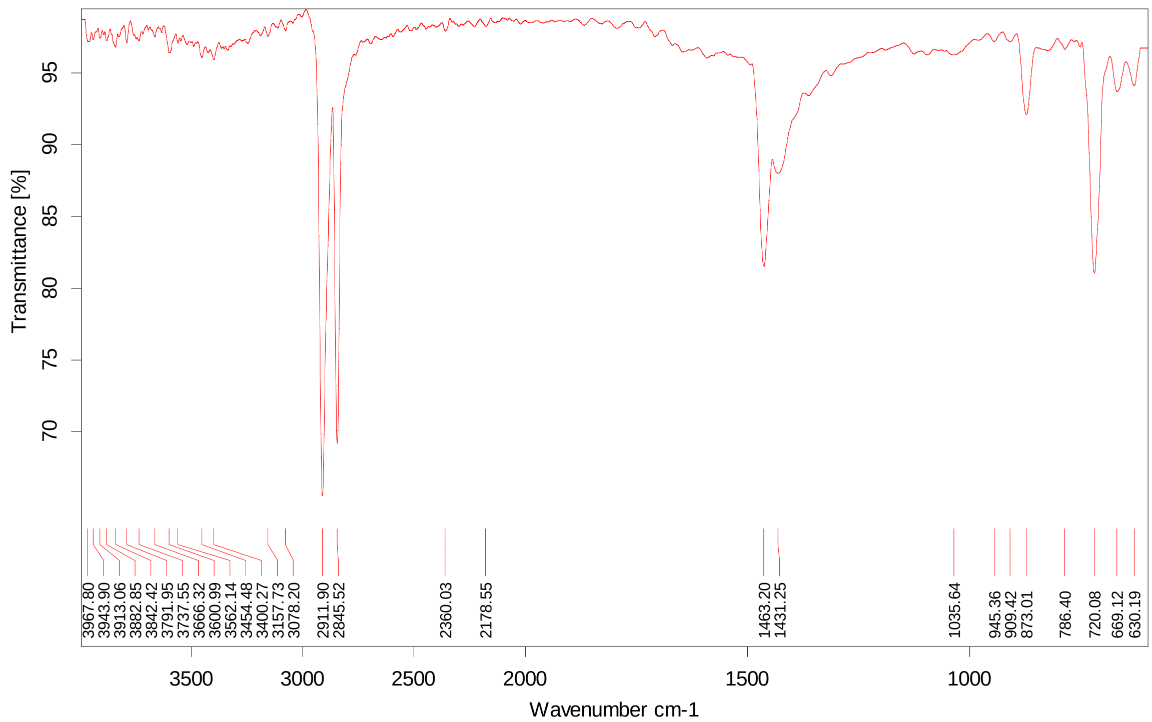
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90
85
80
75
70
3967.80
3943.90
3913.06
3882.85
3842.42
3791.95
3737.55
3666.32
3600.99
3562.14
3454.48
3400.27
3157.73
3078.20
2911.90
2845.52
2360.03
2178.55
1463.20
1431.25
1035.64
945.36
909.42
873.01
786.40
720.08
669.12
630.19
3500
3000
2500
2000
1500
1000
Wavenumber cm-1

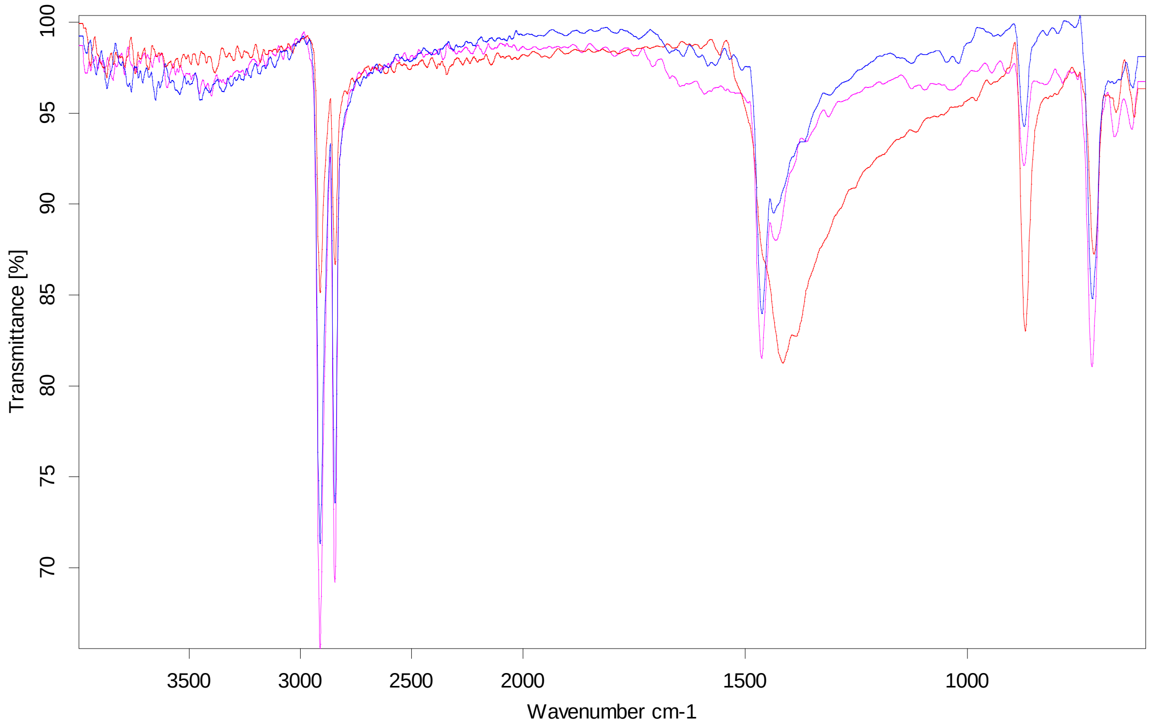


Chart No: 11 to 14: FTIR Analysis Reports for different three polyethylene grocery bag samples

Note: Terms of “BLUE”, “GREEN” and “WHITE” were used as sample identification because of the appearance colour of the polyethylene samples.

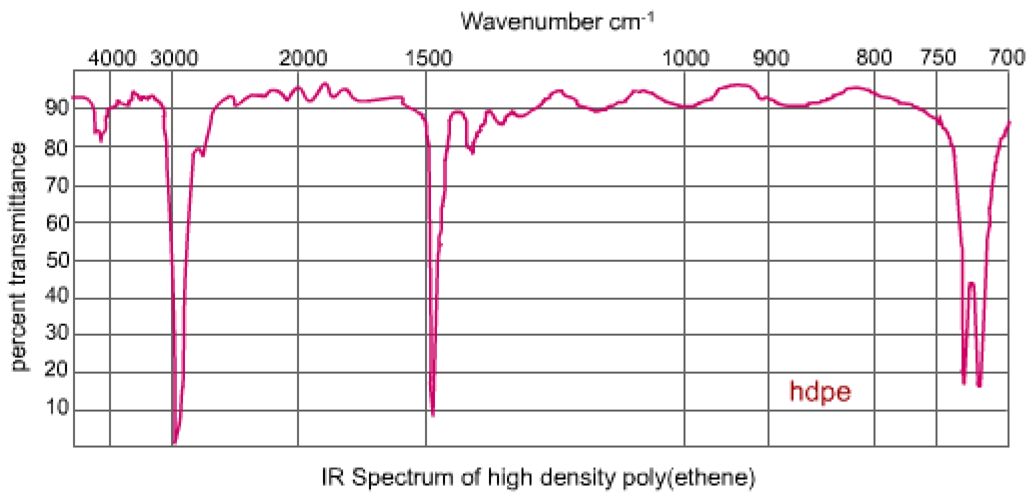
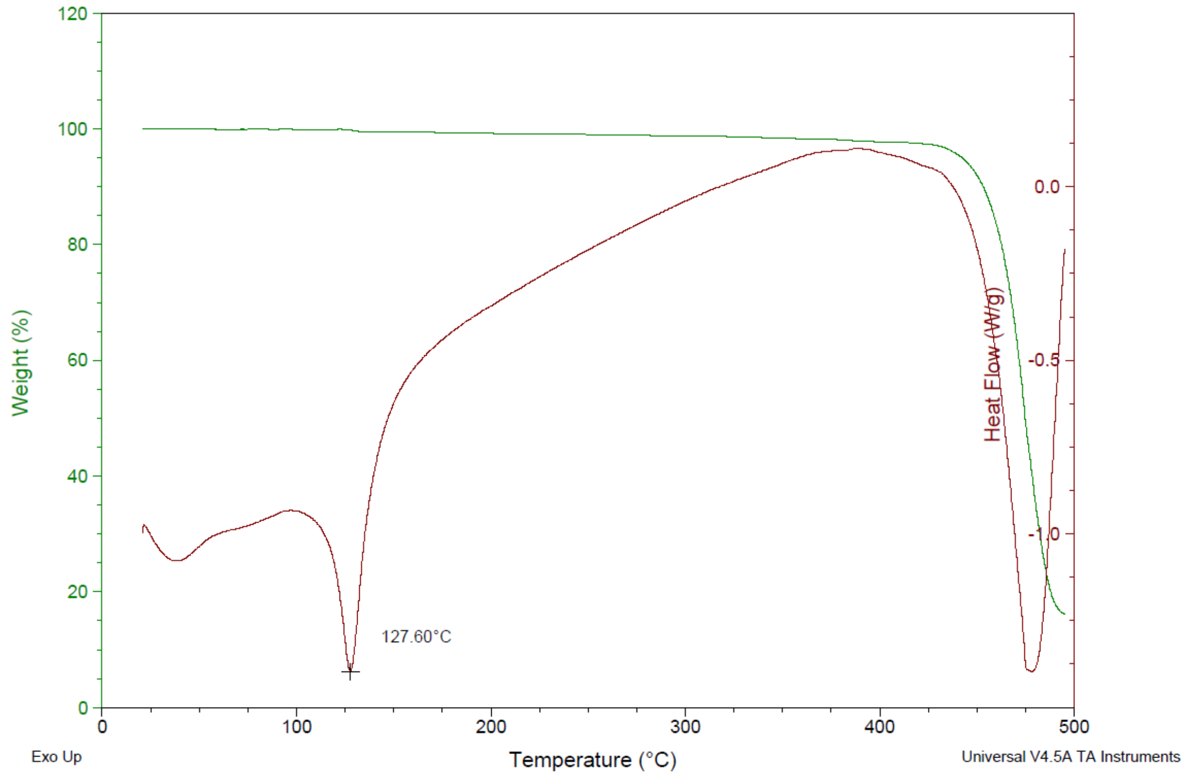
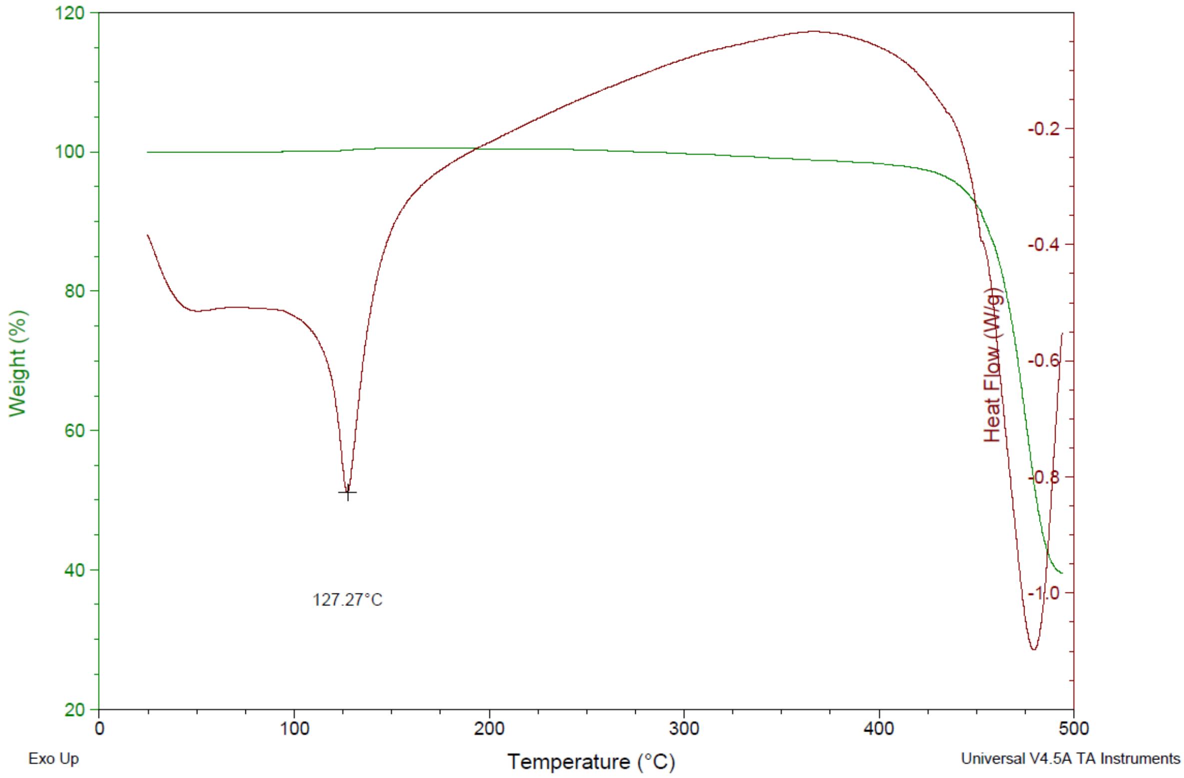


Chart No: 15 Reference FTIR Analysis Reports for HDPE sample

When compared with above experimental Chart No: 14 with the reference Chart No: 15[2], it can be confirmed that the all three samples are coming under the category of HDPE.

DTA & TGA ANALISIS REPORT





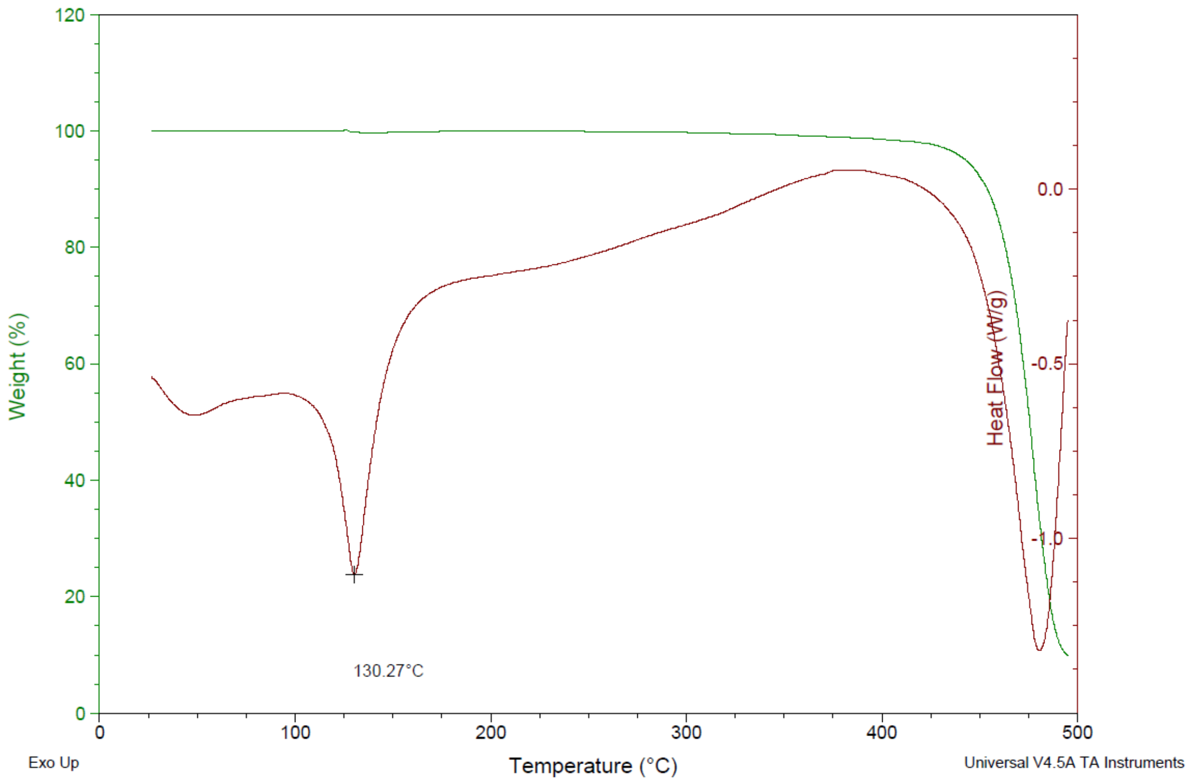


Chart No: 16 to 18: DTA & TGA Analysis Report

Above TDA & TGA reports proven that the Melting points for the above three random polyethylene grocery bag samples are lying on the values of 127.6^{0}C, 127.27^{0}C, 130.27^{0}C, which proves these samples are coming under the category of HDPE (Table No:14) [19]

(Ref: http://www.matweb.com/reference/deflection-temperature.aspx)

Table 14: Typical Melting Points of Polymers

Polymer Type	**Melting Points (^{0}C)**
Polyethylene (HDPE)	**130**
Polyethylene Terephthalate (PET)	**250**
Polypropylene	**160**
Acetal Copolymer	**200**
Acrylic	**130**

9. DISCUSSIONS BY THE SCIENTIFIC ANALYSIS OF THE TEST RESULTS

1. Temperature

It was observed that the temperature was not changed throughout the trial mix process, because these series of trail mixes were carried out inside the Ms. Oriental Testing Laboratory where temperature was controlled by air condition system. It was indirectly proven that there were no any reaction in-between polyethylene and other ingredients of the concrete.

(Table No: 03 and Appendix – 02)

2. Slump Tests

It was observed that the slump height was increased till 10 kg of polyethylene adding and afterward started reducing with the increments of polyethylene particle dosage comparing with control mix and but till 15kg it was almost similar to the control mix and started more deflection after passing the dosage of 20kg.

The reason for this graphical relation is that when adding till 10 kg of polyethylene cut pieces that the adding volume has been compensated with the reduction of river sand and it was approximately 15% river sand volume reduction from the control mix sand volume. So that 15% of polyethylene particle is not absorbing the water from the mix. This will not give any variations of water/cement ratio of the mix, because design calculation already considered this polyethylene proportion as absorption was zero. Accordingly, free water content is same like as control mix but these non-absorbent, non-wettable polyethylene particles give some friction reduced surfaces to slip aggregates from each other inside the mix. This will enhance the workability without increasing water/ cement ratio, which is better in terms of workability and durability of the concrete. Further, because of these lesser friction surfaces enhance the pumping efficiency for pumpable concrete without increasing the water content. This is a very good solution to increase the workability/pumpability of the concrete mix without increasing water/cement ratio.

But, more dosage (more than 20kg) polyethylene cut pieces can be clustered together and can make polyethylene balls which disturb to free movements of the aggregate which obviously reduce the workability of the mix. Accordingly, the mix end up with low slump heights.

Graphical chart of the results shows that using of 12kg will be the best percentage to manage the best slump and obviously the best workability.

(Table No: 03 and Appendix – 02)

3. **Fresh concrete Density**

It was observed that the density of fresh concrete was decreasing with the increments in dose of polyethylene particles comparing with control mix. Until 15kg, the density was almost similar to the control mix and started to decrease after passing the dosage of 20kg.

Results found that using of up to 15kg of polyethylene does not have any significant reduction in fresh concrete density. The reason is that the polyethylene is not lightweight material like Polystyrene. So, there is not much density reduction up to 15kg. Normally Rigi foam balls are using to manufacturing of low-density light weight concrete.

(Table No: 03 and Appendix – 02)

4. **Air Content**

Observations found that the air content of the fresh concrete was increasing with the percentage increments of the polyethylene adding. Observed that the air content was increased until 15kg are less than 2% and when added 20kg polyethylene then it was given the values of more than 2% which exceeding mostly common project standard specification requirements.

Polyethylene is not foaming agent, that's why the air content does not have much variation by comparing with conventional mix, but when increase to higher content of polyethylene cut pieces then air bubbles can be trapped in between cluster particles of polyethylene. That is the reason why the air content increases with higher dosage of polyethylene.

Accordingly results proven that up to 15kg of Polyethylene addition was not given any problem with air content of fresh concrete.

(Table No: 03 and Appendix – 02)

5. Cube crushing strength

Concrete test cube crushing was done in the Oriental Laboratory by using compressive strength testing machine – (Duly calibrated with third-party calibration body and tests were done as per the BS 1881: Part 116: 1983).

Results found that up to 10kg polyethylene additions were increasing the cube crushing strength and 15kg mixed cube strength was almost same as of 10kg mixed strength and when it was increased up to 20kg, then there was some little drop in the strength (Please refer to the test results of above Table No.03)

Testing cubes (3 numbers of cubes from each trial mix) were kept in laboratory electric oven (105^0C electric oven) for 72 hours and tested to find out the temperature effect on the polyethylene mixed cubes. Results found that there were no any considerable strength drops by the effect of high temperature

(Please refer to the laboratory test results in Table No: 03 and Appendix – 02)

Scientific explanation of above behaviour is that the strength of concrete depending mainly on following parameters:

1. Cement content of the mix
2. Water/Cement ratio of the mix
3. Maximum size and the proportion of the coarse aggregate used in the mix
4. Aggregate/Cement ratio
5. Type of aggregates (lightweight aggregate, heavy weight aggregate etc.)
6. Some special kind of additives (GGBS, Microsilica, Fly ash etc.)
7. Content of air entrained in the mix.

There were no any changes in the above parameters in this polyethylene added concrete. Therefore, obviously there were not having any chance to the reducing of the strength compared with the control mix until adding of 15kg of polyethylene.

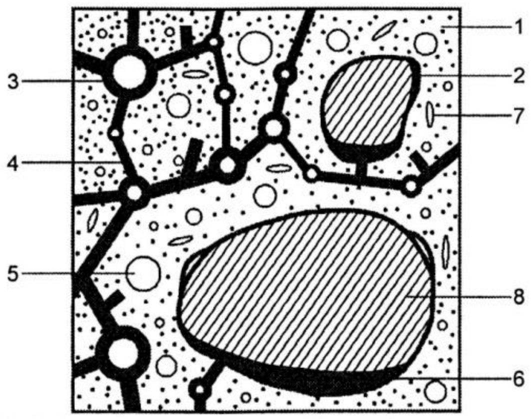
In the higher dosage (20kg) of the polyethylene found that little drop in the compressive strength of the concrete, this can be because of increasing of the air content in the mix

6. Water Absorption

It was observed in the laboratory reports that the water absorption was decreasing while polyethylene adding proportion was increasing. Accordingly, it can be observed that the water absorption is inversely proportional to the percentage of adding polyethylene particles in the concrete mix. Obviously, it is increasing the durability of concrete.

Scientific evaluation of this project confirms that reduction of absorption because of the blocking of capillary tube pathways and pore pathways, inside the hardened concrete, by the added polyethylene particles.

(Please refer to the laboratory results in Table No: 03 and Appendix – 02).



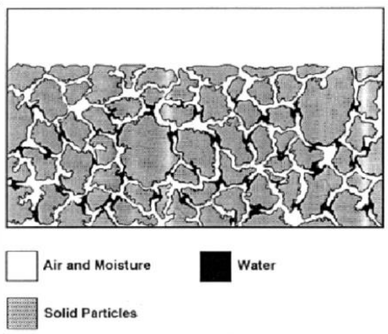


Figure 27: The scheme of porous structure of cement concrete , 1-gel pores, 2-pores in the contact zone between aggregate grains and cement paste, 3-air opened pores, 4- capillary pores in cement paste, 5-closed off pores, 6-sedimentary pores, 7-microcracks, 8-aggregate grain (Sliwinski 2002)

7. **Initial Surface Absorption**

It was observed in the laboratory reports that the initial surface absorption was decreasing while the polyethylene adding proportion was increasing. Accordingly, it can be observed that the initial surface absorption is inversely proportional to the percentage of adding polyethylene particles in the concrete mix. Obviously, it is increasing the durability of concrete. Scientific reason for the reduction of absorption because of the blocking of capillary tube pathways and pore pathways by the added polyethylene particles.

(Table No: 03 and Appendix – 02).

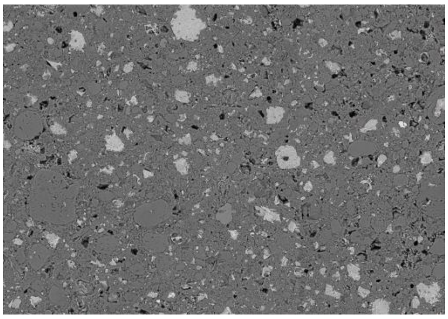


Figure 28: An Electron Microscope Image of the Porous Hydrated Cement Matrix with Water-Cement Ratio of 0.55

8. **Water Penetration**

Figure 29: Porosity of concrete

It was observed in the laboratory reports that the water penetration was decreasing while adding proportion was increasing. Accordingly, it can be observed that the water penetration is inversely proportional to the percentage of adding polyethylene particles in the concrete mix. Obviously, it is increasing the durability of concrete.

Project analysis found that the reason of the reduction of absorption because of the blocking of capillary tube pathways and pore pathways by the added polyethylene particles.
(Table No: 03 and Appendix – 02).

9. Rapid Chloride Permeability

Laboratory test results found that the amount of coulomb passing was decreasing upon the increment of adding polyethylene particle percentage in the concrete mix. In the conventional mix it should be added around 8% of Microsilica to get concrete less than 1000 coulomb which obviously production cost increase 10% of the initial cost.

This Project proved that the adding of 10kg of waste polyethylene particles in the mix can achieve the same low coulomb pass without Microsilica.
(Table No: 03 and Appendix – 02).

Accordingly, it can be noted that the rapid chloride permeability is inversely proportional to the percentage of adding polyethylene particles in the concrete mix. Obviously, it is increasing the durability of concrete.

Reason for above lowering of the chloride ions penetration is because when adding of waste polyethylene particles create some kind of blockage for the ion exchange pathways because of the polyethylene's characteristic of electrical insulation.

10. FTIR, DTA and TGA Analysis

These tests were conducted for the waste polyethylene particles to identify the thermal properties of the used polyethylene grocery bag particles and those test reports were proven that all the different particles are coming under the category of HDPE. (Please refer to the attached test report sand reference comparison in above section 8.2: Graphical relationship of test results, and the attached test reports in Appendix 2)

10. CONCLUTIONS AND RECOMMENDATIONS

In order to achieve the objective of implementing a successful reuse method for the polyethylene bag material, it was necessary to determine the suitability of this material for the purpose of incorporating into the selected concrete grade of C30/20. As per the tests conducted on the trial mixes, following conclusions can be achieved:

- Upon the addition of waste polyethylene, best workability based on slump was achieved between 10-15kg/m^3 of polymer addition.
- Best compressive strength after 28 days curing was observed in the sample with 15kg/m^3 polymer addition, which produced a strength of 35Nmm^{-2}.
- It was also noted that there was no significant effect on 28 days compression strength due to exposure to the temperatures up to 110°C for the concrete mixes which made by blending with polyethylene. (Chart No: 05 and Chart No: 06)
- Tests results found that the water absorption reduced to 0.5% when the dosage of polyethylene added was at 15kg/m^3. (Chart No: 11)
- Initial Surface Absorption Test results confirmed that the adding of polyethylene will decrease the absorption of polymer composite concrete than conventional concrete. Accordingly, the durability of waste polyethylene particle added concrete would be greater than the normal concrete without polyethylene particles. (Please refer to the Chart No: 12)
- Water penetration with 5 bar test results showed that the water penetration decreased by 79 % when increasing of the polyethylene quantity was at 15kg/m^3. This test also shows that the adding of polyethylene increases the durability of concrete. (Please refer to the Chart No: 13)

- Rapid Chloride ion Penetration Test (RCPT) showed that chloride ion penetration was reduced up to 30% at 15kgm^{-3} polymer content. (Please refer to the Chart No: 14)

As per the observations, it can be concluded that the adding of waste polyethylene grocery bag flakes by the weight up to 15kg per one cubic meter of ready-mix concrete is a very good solution for the recycling of polythene bag wastes which can improve the quality properties of concrete. This will be an environmentally friendly Green Product which will give a very effective solution for managing the waste polyethylene products while producing of the property improved higher durable concrete for the construction market.

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12. APPENDIX – 01 – CONCRETE MIX DESIGNS

TRIAL MIX REPORT

EN 206-1, EN 12350-2,6,7, EN 12390-2, 3, 7, 8, EN 1097-5,6, BS 1881-122, 208, ASTM C403/C 403M, ASTM 1202

Lab: Rusayl Plant:

Batching Plant : Oriental ready-mix Plant Date : 17.01.2019
Lab. Ref. : TRIAL : 102
Client Ref. : Polymer Composite Concrete Weather: Windy [ ] Normal [X]
Mix No. : Control Mix
Type of Concrete : Normal [x] SCC [ ] HPC [ ]
Description of Mix : Cement
Grade : C 30/20 OPC
W/B ratio : (Binder = Cement + Mineral Additives) W/C ratio : 0.41
Total binder : 350 (kg) Batch : 0.025 (Litres)

MIX PROPORTIONS

Materials – Details	Materials – Source	Mass (kg/m³)	Density	Vol. (L/m³)	Abs. EN 1097-6 (%)	Moisture Content EN 1097-5 (%)	Abs. Correct. (kg)	Final Quantity (kg/m³)	Batch Weight (kg/m³)	Remarks (addition, time of addition)
Cement	OPC	350	3.15	111.1					8.75	
GGBS		0	2.8	0.0					0.00	
FA			2.3	0.0					0.00	
PE Fiber		0	0.9	0.0					0.00	
Micro Silica			2.2	0.0					0.00	
Water		145	1.00	145.0				161.6	4.041	
20 mm		660	2.86	230.8	0.5	0.00	3.300	656.7	16.42	
10 mm		380	2.85	133.3	0.6	0.00	2.280	377.7	9.44	
Crushed Sand		620	2.78	223.0	1.2	0.00	7.440	612.6	15.31	
River sand		360	2.72	132.4	1.0	0.00	3.600	356.4	8.91	
Admixture-1	SP 679	5.25	1.2	4.38					0.131	
Admixture-2		0.00	1.2	0.0					0.000	
Admixture-3		0							0.00	
Others				20.0					0.00	
	Total:	2520		1000		0.00	16.62		63.01	

FRESH PROPERTIES

Density (EN 12350-6)	:	2519.4	(kg/m³)
Air Content (if required) (EN 12350-7)	:	1.2	%
Target Initial Slump	:		(mm)
Required Slump on Site	:		(mm)
Initial Time of Setting (ASTM C 403)	:		(hr:min)
Final Time of Setting (ASTM C 403)	:		(hr:min)

Time (min)	INITIAL	30	60	90	120
Slump (mm) (EN 12350-2)	180	160	154	149	145
Temperature(Degee celcius)	21	22	22	22	22
Slump flow (mm)					
V- funnel (s)					
J-ring + Cone (mm)					

Note: Form of slump = True or Shear or Collapsed

HARDENED CONCRETE

Age (D)	Load	N/mm²	Density (EN 12390-7)
28	826	37	2557.0
28	872	39	2563.0
28	812	36	2551.1
	Average	37	

DURABILITY TEST

Water Absorption (BS 1881-122), %	
ISAT (BS 1881-208), ml/m².sec	
RCP (ASTM C 1202), coulumbs	
Water Penetration (EN 12390-8), mm	

Mix satisfactory: Yes [ ] No [ ]

Remarks:

Conducted by: Laboratory Technician Witness by: Consultant/Conctractor **Approved by:** QC Manager

QUALITY CHECKED 17 JAN 2019 ORIMIX LABORATORY

TRIAL MIX REPORT

EN 206-1, EN 12350-2,6,7, EN 12390-2, 3, 7, 8, EN 1097-5,6, BS 1881-122, 208, ASTM C403/C 403M, ASTM 1202

Lab: Rusayl **Plant:**

Batching Plant	: Oriental ready-mix Plant	**Date :**	17.01.2019
Lab. Ref.	: TRIAL : 103		
Client Ref.	: Polymer Composite Concrete	**Weather:**	Windy [ ] Normal [X]
Mix No.	: Polythene 5 kg		
Type of Concrete	: Normal [x] SCC [ ] HPC [ ]		
Description of Mix	: Cement		
Grade	: C 30/20 OPC		
W/B ratio	: (Binder = Cement + Mineral Additives)	**W/C ratio**	: 0.41
Total binder	: 350 (kg)	**Batch**	: 0.025 (Litres)

MIX PROPORTIONS

Materials		Mass	Density	Vol.	Abs. EN 1097-6	Moisture Content EN 1097-5	Abs. Correct.	Final Quantity	Batch Weight	Remarks
Details	Source	(kg/m^3)		(L/m^3)	(%)	(%)	(kg)	(kg/m^3)	(kg/m^3)	(addition, time of addition)
Cement	OPC	350	3.15	111.1					8.75	
GGBS		0	2.8	0.0					0.00	
FA			2.3	0.0					0.00	
Polythene		5	0.9	5.6					0.13	
Micro Silica			2.2	0.0					0.00	
Water		145	1.00	145.0				161.5	4.037	
20 mm		660	2.86	230.8	0.5	0.00	3.300	656.7	16.42	
10 mm		380	2.85	133.3	0.6	0.00	2.280	377.7	9.44	
Crushed Sand		620	2.78	223.0	1.2	0.00	7.440	612.6	15.31	
River sand		346	2.72	127.2	1.0	0.00	3.460	342.5	8.56	
Admixture-1	SP 679	5.25	1.2	4.38					0.131	
Admixture-2		0.00	1.2	0.0					0.000	
Admixture-3		0							0.00	
Others				20.0					0.00	
	Total:	2511		1000		0.00	16.48		62.78	

FRESH PROPERTIES

Density (EN 12350-6)	:	2485.3	(kg/m^3)
Air Content (if required) (EN 12350-7)	:	1.4	%
Target Initial Slump	:		(mm)
Required Slump on Site	:		(mm)
Initial Time of Setting (ASTM C 403)	:		(hr:min)
Final Time of Setting (ASTM C 403)	:		(hr:min)

HARDENED CONCRETE

Age (D)	Load	N/mm²	Density (EN 12390-7)
28	869	39	2542.2
28	895	40	2548.1
28	839	37	2554.1
	Average	39	

Time (min)	INITIAL	30	60	90	120
Slump (mm) (EN 12350-2)	185	170	165	160	142
Temperature(Degee celcius)	20	20	21	21	21
Slump flow (mm)					
V- funnel (s)					
J-ring + Cone (mm)					

Note: Form of slump = True or Shear or Collapsed

DURABILITY TEST

Water Absorption (BS 1881-122), %	
ISAT (BS 1881-208), ml/m^2.sec	
RCP (ASTM C 1202), coulumbs	
Water Penetration (EN 12390-8), mm	

Mix satisfactory: Yes [ ] No [ ]

Remarks:

Conducted by: Laboratory Technician

Witness by: Consultant/Conctractor

QUALITY CHECKED 17 JAN 2019 ORIMIX LABORATORY

Approved by: QC Manager

TRIAL MIX REPORT

EN 206-1, EN 12350-2,6,7, EN 12390-2, 3, 7, 8, EN 1097-5,6, BS 1881-122, 208, ASTM C403/C 403M, ASTM 1202

Lab: Rusayl Plant:

Batching Plant : Oriental ready-mix Plant Date : 17.01.2019

Lab. Ref. : TRIAL : 104

Client Ref. : Polymer Composite Concrete Weather: Windy [ ] Normal [X]

Mix No. : Polythene 10 kg

Type of Concrete : Normal [x] SCC [ ] HPC [ ]

Description of Mix : Cement

Grade : C 30/20 OPC

W/B ratio : (Binder = Cement + Mineral Additives) W/C ratio : 0.41

Total binder : 350 (kg) Batch : 0.025 (Litres)

MIX PROPORTIONS

Materials		Mass	Density	Vol.	Abs. EN 1097-6	Moisture Content EN 1097-5	Abs. Correct.	Final Quantity	Batch Weight	Remarks
Details	Source	(kg/m³)		(L/m³)	(%)	(%)	(kg)	(kg/m³)	(kg/m³)	(addition, time of addition)
Cement	OPC	350	3.15	111.1					8.75	
GGBS		0	2.8	0.0					0.00	
FA			2.3	0.0					0.00	
Polythene		10	0.9	11.1					0.25	
Micro Silica			2.2	0.0					0.00	
Water		145	1.00	145.0				161.3	4.033	
20 mm		660	2.86	230.8	0.5	0.00	3.300	656.7	16.42	
10 mm		380	2.85	133.3	0.6	0.00	2.280	377.7	9.44	
Crushed Sand		620	2.78	223.0	1.2	0.00	7.440	612.6	15.31	
River sand		329	2.72	121.0	1.0	0.00	3.290	325.7	8.14	
Admixture-1	SP 679	5.25	1.2	4.38					0.131	
Admixture-2		0.00	1.2	0.0					0.000	
Admixture-3		0							0.00	
Others				20.0					0.00	
	Total:	2499		1000		0.00	16.31		62.48	

FRESH PROPERTIES

Density (EN 12350-6)	:	2473.1	(kg/m³)
Air Content (if required) (EN 12350-7)	:	1.5	%
Target Initial Slump	:		(mm)
Required Slump on Site	:		(mm)
Initial Time of Setting (ASTM C 403)	:		(hr:min)
Final Time of Setting (ASTM C 403)	:		(hr:min)

HARDENED CONCRETE

Age (D)	Load	N/mm²	Density (EN 12390-7)
28	912	41	2497.8
28	895	40	2485.9
28	873	39	2491.9
	Average	40	

Time (min)	INITIAL	30	60	90	120
Slump (mm) (EN 12350-2)	190	175	171	165	158
Temperature(Degee celcius)	20	21	21	21	22
Slump flow (mm)					
V- funnel (s)					
J-ring + Cone (mm)					

Note: Form of slump = True or Shear or Collapsed

DURABILITY TEST

Water Absorption (BS 1881-122), %	
ISAT (BS 1881-208), ml/m².sec	
RCP (ASTM C 1202), coulumbs	
Water Penetration (EN 12390-8), mm	

Mix satisfactory: Yes [ ] No [ ]

Remarks:

Conducted by: Laboratory Technician

Witness by: Consultant/Conctractor

Approved by: QC Manager

QUALITY CHECKED 17 JAN 2019 ORIMIX LABORATORY

TRIAL MIX REPORT

EN 206-1, EN 12350-2,6,7, EN 12390-2, 3, 7, 8, EN 1097-5,6, BS 1881-122, 208, ASTM C403/C 403M, ASTM 1202

Lab: Rusayl   Plant:

Batching Plant : Oriental ready-mix Plant   Date : 17.01.2019
Lab. Ref. : TRIAL : 105
Client Ref. : Polymer Composite Concrete   Weather: Windy [ ] Normal [X]
Mix No. : Polythene 15 kg
Type of Concrete : Normal [x] SCC [ ] HPC [ ]
Description of Mix : Cement
Grade : C 30/20 OPC
W/B ratio : (Binder = Cement + Mineral Additives)   W/C ratio : 0.41
Total binder : 350 (kg)   Batch : 0.025 (Litres)

MIX PROPORTIONS

Materials – Details	Source	Mass (kg/m³)	Density	Vol. (L/m³)	Abs. EN 1097-6 (%)	Moisture Content EN 1097-5 (%)	Abs. Correct. (kg)	Final Quantity (kg/m³)	Batch Weight (kg/m³)	Remarks (addition, time of addition)
Cement	OPC	350	3.15	111.1					8.75	
GGBS		0	2.8	0.0					0.00	
FA			2.3	0.0					0.00	
Polythene		15	0.9	16.7					0.38	
Micro Silica			2.2	0.0					0.00	
Water		145	1.00	145.0				161.2	4.029	
20 mm		660	2.86	230.8	0.5	0.00	3.300	656.7	16.42	
10 mm		380	2.85	133.3	0.6	0.00	2.280	377.7	9.44	
Crushed Sand		620	2.78	223.0	1.2	0.00	7.440	612.6	15.31	
River sand		315	2.72	115.8	1.0	0.00	3.150	311.9	7.80	
Admixture-1	SP 679	5.25	1.2	4.38					0.131	
Admixture-2		0.00	1.2	0.0					0.000	
Admixture-3		0							0.00	
Others				20.0					0.00	
	Total:	2490		1000		0.00	16.17		62.26	

FRESH PROPERTIES

Density (EN 12350-6)	2456.5	(kg/m³)
Air Content (if required) (EN 12350-7)	1.7	%
Target Initial Slump		(mm)
Required Slump on Site		(mm)
Initial Time of Setting (ASTM C 403)		(hr:min)
Final Time of Setting (ASTM C 403)		(hr:min)

HARDENED CONCRETE

Age (D)	Load	N/mm²	Density (EN 12390-7)
28	892	40	2477.0
28	882	39	2483.0
28	932	41	2465.2
	Average	40	

Time (min)	INITIAL	30	60	90	120
Slump (mm) (EN 12350-2)	190	150	148	143	140
Temperature(Degee celcius)	20	22	22	22	23
Slump flow (mm)					
V- funnel (s)					
J-ring + Cone (mm)					

Note: Form of slump = True or Shear or Collapsed

DURABILITY TEST

Water Absorption (BS 1881-122), %	
ISAT (BS 1881-208), ml/m².sec	
RCP (ASTM C 1202), coulumbs	
Water Penetration (EN 12390-8), mm	

Mix satisfactory: Yes [ ] No [ ]

Remarks:

Conducted by: Laboratory Technician   Witness by: Consultant/Conctractor   **Approved by:** QC Manager

QUALITY CHECKED 17 JAN 2019 ORIMIX LABORATORY

TRIAL MIX REPORT

EN 206-1, EN 12350-2,6,7, EN 12390-2, 3, 7, 8, EN 1097-5,6, BS 1881-122, 208, ASTM C403/C 403M, ASTM 1202

Lab: Rusayl Plant:

Batching Plant : Oriental ready-mix Plant Date : 17.01.2019

Lab. Ref. : TRIAL : 106

Client Ref. : Polymer Composite Concrete Weather: Windy [ ] Normal [X]

Mix No. : Polythene 20 kg

Type of Concrete : Normal [x] SCC [ ] HPC [ ]

Description of Mix : Cement

Grade : C 30/20 OPC

W/B ratio : (Binder = Cement + Mineral Additives) W/C ratio : 0.41

Total binder : 350 (kg) Batch : 0.025 (Litres)

MIX PROPORTIONS

Materials		Mass	Density	Vol.	Abs. EN 1097-6	Moisture Content EN 1097-5	Abs. Correct.	Final Quantity	Batch Weight	Remarks
Details	Source	(kg/m³)		(L/m³)	(%)	(%)	(kg)	(kg/m³)	(kg/m³)	(addition, time of addition)
Cement	OPC	350	3.15	111.1					8.75	
GGBS		0	2.8	0.0					0.00	
FA			2.3	0.0					0.00	
Polythene		20	0.9	22.2					0.50	
Micro Silica			2.2	0.0					0.00	
Water		145	1.00	145.0				161.0	4.026	
20 mm		660	2.86	230.8	0.5	0.00	3.300	656.7	16.42	
10 mm		380	2.85	133.3	0.6	0.00	2.280	377.7	9.44	
Crushed Sand		620	2.78	223.0	1.2	0.00	7.440	612.6	15.31	
River sand		300	2.72	110.3	1.0	0.00	3.000	297.0	7.43	
Admixture-1	SP 679	5.25	1.2	4.38					0.131	
Admixture-2		0.00	1.2	0.0					0.000	
Admixture-3		0							0.00	
Others				20.0					0.00	
	Total:	2480		1000		0.00	16.02		62.01	

FRESH PROPERTIES

Density (EN 12350-6)	:	2421.6	(kg/m³)
Air Content (if required) (EN 12350-7)	:	3.1	%
Target Initial Slump	:		(mm)
Required Slump on Site	:		(mm)
Initial Time of Setting (ASTM C 403)	:		(hr:min)
Final Time of Setting (ASTM C 403)	:		(hr:min)

HARDENED CONCRETE

Age (D)	Load	N/mm²	Density (EN 12390-7)
28	726	32	2456.3
28	746	33	2450.4
28	716	32	2459.3
	Average	32	

Time (min)	INITIAL	30	60	90	120
Slump (mm) (EN 12350-2)	190	150	130	122	120
Temperature(Degee celcius)	20	22	22	23	23
Slump flow (mm)					
V- funnel (s)					
J-ring + Cone (mm)					

Note: Form of slump = True or Shear or Collapsed

DURABILITY TEST

Water Absorption (BS 1881-122), %	
ISAT (BS 1881-208), ml/m².sec	
RCP (ASTM C 1202), coulumbs	
Water Penetration (EN 12390-8), mm	

Mix satisfactory: Yes [ ] No [ ]

Remarks:

Conducted by: Laboratory Technician

Witness by: Consultant/Conctractor

Approved by: QC Manager

QUALITY CHECKED 17 JAN 2019 ORIMIX LABORATORY

13. APPENDIX – 02 – LABORATORY TEST REPORTS FOR THE EXPERIMENTAL WORKS OF THE PROJECT

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ORIENTAL
Group of Companies

ORIENTAL READYMIX LLC
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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0102/28

Mix : CONTROL MIX **Testing Date: 14.02.2019**

Project : POLYMER COMPOSITE CONCRETE

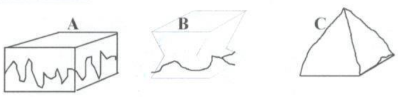
Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

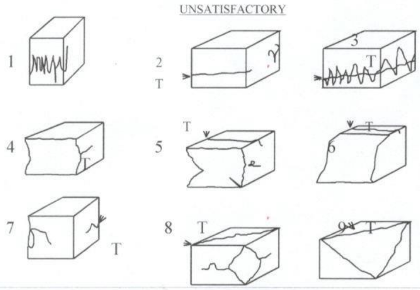
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m^3)	Load at Failure (kN)	Compressive Strength (N/mm^2)	Mode of Failure
1	102	17.01.2019	28	150	150	150	8.63	2557.0	826	37	A
2	102	17.01.2019	28	150	150	150	8.65	2563.0	872	39	A
3	102	17.01.2019	28	150	150	150	8.61	2551.1	812	36	A
								AVERAGE		37	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS

Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by

Laboratory Technician

QUALITY CHECKED
14 FEB 2019
ORIMIX LABORATORY

Checked by

QC MANAGER

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0103/28

Mix : POLYTHENE 5KG **Testing Date:** 14.02.2019

Project : POLYMER COMPOSITE CONCRETE

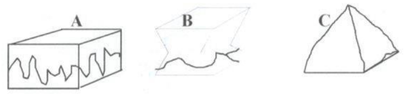
Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

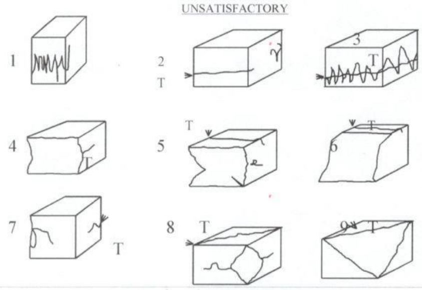
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	103	17.01.2019	28	150	150	150	8.58	2542.2	869	39	A
2	103	17.01.2019	28	150	150	150	8.60	2548.1	895	40	A
3	103	17.01.2019	28	150	150	150	8.62	2554.1	839	37	A
								AVERAGE		39	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by
Laboratory Technician

QUALITY CHECKED
14 FEB 2019
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Checked by
QC MANAGER

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : **ORML--0104/28**

Mix : **POLYTHENE 10KG** **Testing Date: 14.02.2019**

Project : **POLYMER COMPOSITE CONCRETE**

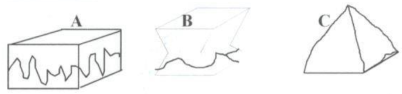
Design Strength : **C 30/20** N/mm² **OPC** **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

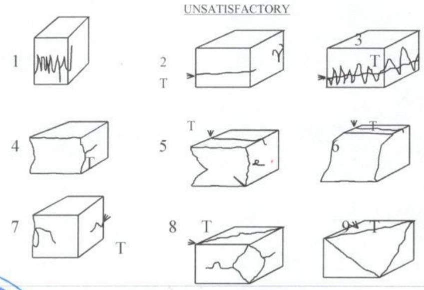
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	104	17.01.2019	28	150	150	150	8.43	2497.8	912	41	A
2	104	17.01.2019	28	150	150	150	8.39	2485.9	895	40	A
3	104	17.01.2019	28	150	150	150	8.41	2491.9	873	39	A
								AVERAGE		40	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by
Laboratory Technician

QUALITY CHECKED
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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0105/28

Mix : POLYTHENE 15KG **Testing Date:** 14.02.2019

Project : POLYMER COMPOSITE CONCRETE

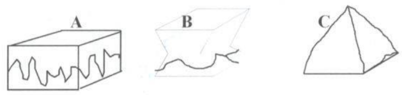
Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

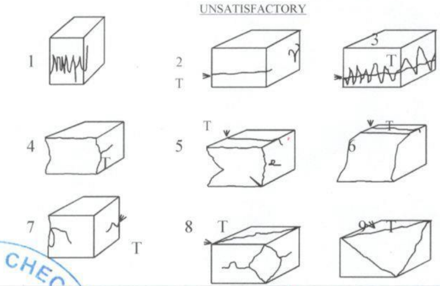
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm)			Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
				Height	Length	Width					
1	105	17.01.2019	28	150	150	150	8.36	2477.0	892	40	A
2	105	17.01.2019	28	150	150	150	8.38	2483.0	882	39	A
3	105	17.01.2019	28	150	150	150	8.32	2465.2	932	41	A
								AVERAGE		40	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by
Laboratory Technician

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14 FEB 2019
ORIMIX LABORATORY

Checked by
QC MANAGER

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0106/28

Mix : POLYTHENE 20KG **Testing Date:** 14.02.2019

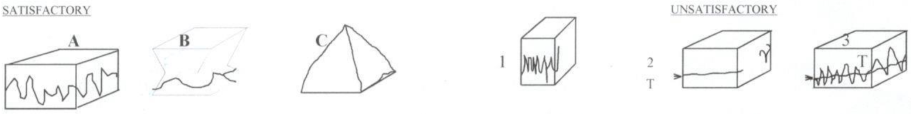
Project : POLYMER COMPOSITE CONCRETE

Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

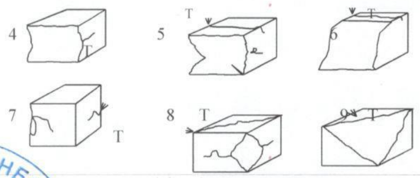
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm)			Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
				Height	Length	Width					
1	106	17.01.2019	28	150	150	150	8.29	2456.3	726	32	A
2	106	17.01.2019	28	150	150	150	8.27	2450.4	746	33	A
3	106	17.01.2019	28	150	150	150	8.30	2459.3	716	32	A
								AVERAGE		32	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983



REMARKS

Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.



Note: A indicates tensile cracking

Tested by

Laboratory Technician

QUALITY CHECKED
14 FEB 2019
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QC MANAGER

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : **ORML--0102/28**

Mix : **CONTROL MIX** **Testing Date: 14.02.2019**

: **KEEPING 72 HOURS IN 105°C ELECTRIC OVEN**

Project : **POLYMER COMPOSITE CONCRETE**

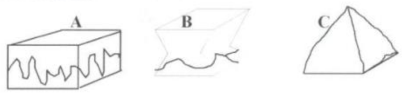
Design Strength : **C 30/20** N/mm² **OPC** **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

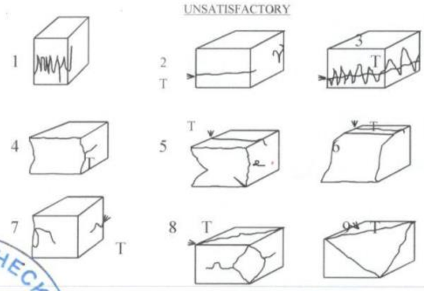
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm)			Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
				Height	Length	Width					
1	102	17.01.2019	28	150	150	150	8.60	2548.1	867	39	A
2	102	17.01.2019	28	150	150	150	8.63	2557.0	881	39	A
3	102	17.01.2019	28	150	150	150	8.61	2551.1	834	37	A
								AVERAGE		**38**	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by
Laboratory Technician

QUALITY CHECKED ★ 14 FEB 2019 ★ ORIMIX LABORATORY

Checked by
QC MANAGER

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0103/28

Mix : POLYTHENE 5KG **Testing Date: 14.02.2019**

: KEEPING 72 HOURS IN 105°C ELECTRIC OVEN

Project : POLYMER COMPOSITE CONCRETE

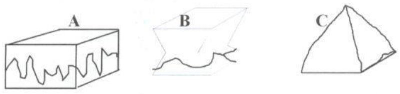
Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist □

Method of Compaction : Vibration □ Manual ■

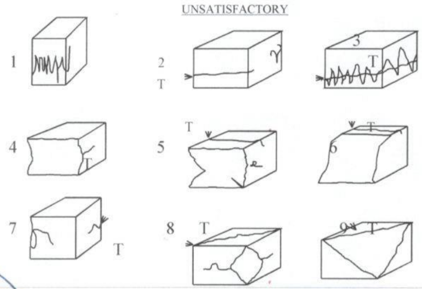
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	103	17.01.2019	28	150	150	150	8.52	2524.4	921	41	A
2	103	17.01.2019	28	150	150	150	8.50	2518.5	912	41	A
3	103	17.01.2019	28	150	150	150	8.54	2530.4	897	40	A
								AVERAGE		40	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by

Laboratory Technician

QUALITY CHECKED
14 FEB 2019
ORIMIX LABORATORY

Checked by

QC MANAGER

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P.O BOX 666, PC 111, Muscat, Sultanate of Oman

CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : **ORML--0104/28**

Mix : **POLYTHENE 10KG** **Testing Date: 14.02.2019**

: **KEEPING 72 HOURS IN 105°C ELECTRIC OVEN**

Project : **POLYMER COMPOSITE CONCRETE**

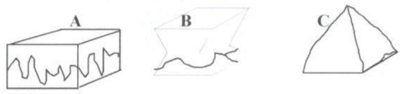
Design Strength : **C 30/20** N/mm² **OPC** **Condition of Cube at Testing** : Saturated ■ Moist □

Method of Compaction : Vibration □ Manual ■

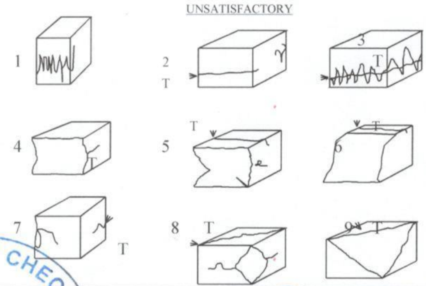
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	104	17.01.2019	28	150	150	150	8.40	2488.9	932	41	A
2	104	17.01.2019	28	150	150	150	8.37	2480.0	892	40	A
3	104	17.01.2019	28	150	150	150	8.38	2483.0	915	41	A
								AVERAGE		41	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

Tested by
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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : ORML--0105/28

Mix : POLYTHENE 15KG **Testing Date: 14.02.2019**

: KEEPING 72 HOURS IN 105°C ELECTRIC OVEN

Project : POLYMER COMPOSITE CONCRETE

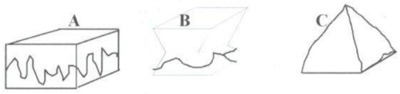
Design Strength : C 30/20 N/mm² OPC **Condition of Cube at Testing** : Saturated ■ Moist ☐

Method of Compaction : Vibration ☐ Manual ■

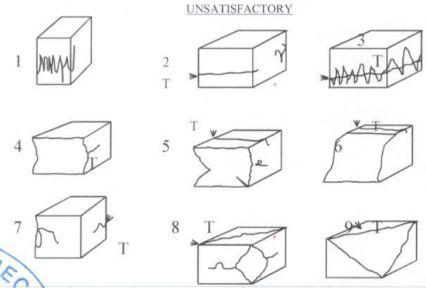
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	105	17.01.2019	28	150	150	150	8.33	2468.1	895	40	A
2	105	17.01.2019	28	150	150	150	8.35	2474.1	864	38	A
3	105	17.01.2019	28	150	150	150	8.31	2462.2	872	39	A
								AVERAGE		39	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS

Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

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CONCRETE CUBE CRUSHING REPORT

Test Method: BSEN 12390: Part 3:2002
Specimen Type: 150 x 150 x 150 mm Cube

Report No. : **ORML--0106/28**

Mix : **POLYTHENE 20KG** **Testing Date: 14.02.2019**

: **KEEPING 72 HOURS IN 105°C ELECTRIC OVEN**

Project : **POLYMER COMPOSITE CONCRETE**

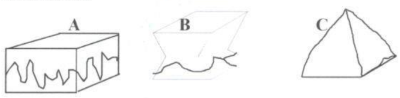
Design Strength : **C 30/20** N/mm² **OPC** **Condition of Cube at Testing** : Saturated ■ Moist □

Method of Compaction : Vibration □ Manual ■

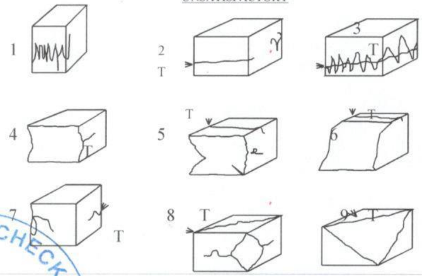
Lab Ref. No.	Sample Identity Mark	Date Cast	Age (Days)	Dimensions (mm) Height	Length	Width	Weight (kg)	Density (kg/m³)	Load at Failure (kN)	Compressive Strength (N/mm²)	Mode of Failure
1	106	17.01.2019	28	150	150	150	8.25	2444.4	685	30	A
2	106	17.01.2019	28	150	150	150	8.23	2438.5	722	32	A
3	106	17.01.2019	28	150	150	150	8.28	2453.3	705	31	A
								AVERAGE		31	

MODES OF FAILURE AS PER BS 1881 : Part 116 : 1983

SATISFACTORY



UNSATISFACTORY



REMARKS
Density measurement were carried out in accordance with BS 1881 : Part 114:1983 in the as received condition for Moist specimens & in the saturated condition for Laboratory cured specimens.

Note: A indicates tensile cracking

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WATER ABSORPTION TEST

Report No.	: ORML-031	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0102
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Control Mix

RESULTS

Specimen ID		1	2	3
Nominal Dimension (mm)	H	150	150	150
	D	74	74	74
Density of Specimen(kg/m³) (as received)		2561	2543	2575
Measured Absorption (%)		1.6	1.8	1.7
Average (%)		1.7		

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 122 : 1983 Cls 4.1
Test Method	: BS 1881 : Part 122 : 1983 Cls 5
Test Method Variation	: None
Tested By	: M. Rao Dunna

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Laboratory Technician	Laboratory Manager

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WATER ABSORPTION TEST

Report No.	: ORML-033	**Report Date :**	: 14.02.2019
Project Name	: Polymer Composite Concrete	**Sample NO**	: Lab Trial 0104
Sampled By	: Orimix Lab	**Date of Casting**	: 17.01.2019
Sample Description	: Test Cubes	**Date of Test**	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	**Age at Test**	: 28 days
Curing Condition	: Curing Water Tank	**Mix**	: Polythene 10kg

RESULTS

Specimen ID		1	2	3
Nominal Dimension (mm)	H	150	150	150
	D	74	74	74
Density of Specimen(kg/m³) (as received)		2582	2544	2537
Measured Absorption (%)		1.0	0.8	0.9
Average (%)			0.9	

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 122 : 1983 Cls 4.1
Test Method	: BS 1881 : Part 122 : 1983 Cls 5
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by	Checked by
Laboratory Technician	Laboratory Manager

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WATER ABSORPTION TEST

Report No.	: ORML-032	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0103
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 5kg

RESULTS

Specimen ID		1	2	3
Nominal Dimension (mm)	H	150	150	150
	D	74	74	74
Density of Specimen(kg/m³) (as received)		2548	2566	2540
Measured Absorption (%)		1.2	1.1	1.3
Average (%)			1.2	

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 122 : 1983 Cls 4.1
Test Method	: BS 1881 : Part 122 : 1983 Cls 5
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by

Laboratory Technician

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WATER ABSORPTION TEST

Report No.	: ORML-034	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0105
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 15kg

RESULTS

Specimen ID		1	2	3
Nominal Dimension (mm)	H	150	150	150
	D	74	74	74
Density of Specimen(kg/m³) (as received)		2552	2573	2564
Measured Absorption (%)		0.4	0.6	0.5
Average (%)			0.5	

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 122 : 1983 Cls 4.1
Test Method	: BS 1881 : Part 122 : 1983 Cls 5
Test Method Variation	: None
Tested By	: M. Rao Dunna

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Laboratory Technician		Laboratory Manager

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WATER ABSORPTION TEST

Report No.	: ORML-035	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0106
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 20kg

RESULTS

Specimen ID		1	2	3
Nominal Dimension (mm)	H	150	150	150
	D	74	74	74
Density of Specimen(kg/m³) (as received)		2539	2582	2576
Measured Absorption (%)		0.3	0.5	0.4
Average (%)		0.4		

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 122 : 1983 Cls 4.1
Test Method	: BS 1881 : Part 122 : 1983 Cls 5
Test Method Variation	: None
Tested By	: M. Rao Dunna

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Laboratory Technician	Laboratory Manager

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INITIAL SURFACE ABSORPTION TEST

Report No.	: ORML- 036	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0102
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Control Mix
Orientation of Test Surface	: Horizontal	Diameter of CAP (mm) :	84.6

Temperature of Concrte Surface (°C) : 21

Area of Water Concrete of CAP (mm²) : 5618

Lenghth of Capillary Tube (mm) : 600

Description of the Concrete Surface under Test : Cast Surface Having Smooth Finish Without Cracks, Honeycombs & Voids

RESULTS

Specimen Identity	1	2	3
Water absorption(ml/m².sec) corrected to equivalent 20°C value	0.08	0.07	0.06
Average (%)		0.07	

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 208 : 1996 Cls 8.1.3
Test Method	: BS 1881 : Part 208 : 1996 Cls 8.5 & 8.6
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by	Checked by
Laboratory Technician	Laboratory Manager

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INITIAL SURFACE ABSORPTION TEST

Report No.	: ORML- 037	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0103
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 5kg
Orientation of Test Surface	: Horizontal	Diameter of CAP (mm) :	84.6

Temperature of Concrte Surface (°C) : 21

Area of Water Concrete of CAP (mm²) : 5618

Lenghth of Capillary Tube (mm) : 600

Description of the Concrete Surface under Test : Cast Surface Having Smooth Finish Without Cracks, Honeycombs & Voids

RESULTS

Specimen Identity	1	2	3
Water absorption(ml/m².sec) corrected to equivalent 20°C value	0.03	0.05	0.04
Average (%)		0.04	

Sampling Method	: BS 1881 : Part 101 : 1983
Test Specimen preperation	: BS 1881 : Part 208 : 1996 Cls 8.1.3
Test Method	: BS 1881 : Part 208 : 1996 Cls 8.5 & 8.6
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by		Checked by
Laboratory Technician	QUALITY CHECKED 14 FEB 2019 ORIMIX LABORATORY	Laboratory Manager

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INITIAL SURFACE ABSORPTION TEST

Report No.	: ORML- 038	Report Date :	:	14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	:	Lab Trial 0104
Sampled By	: Orimix Lab	Date of Casting	:	17.01.2019
Sample Description	: Test Cubes	Date of Test	:	14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	:	28 days
Curing Condition	: Curing Water Tank	Mix	:	Polythene 10kg
Orientation of Test Surface	: Horizontal	Diameter of CAP (mm) :		84.6

Temperature of Concrte Surface (°C) : 21

Area of Water Concrete of CAP (mm²) : 5618

Lenghth of Capillary Tube (mm) : 600

Description of the Concrete Surface under Test : Cast Surface Having Smooth Finish Without Cracks, Honeycombs & Voids

RESULTS

Specimen Identity	1	2	3
Water absorption(ml/m².sec) corrected to equivalent 20°C value	0.03	0.04	0.02
Average (%)		0.03	

Sampling Method	:	BS 1881 : Part 101 : 1983
Test Specimen preperation	:	BS 1881 : Part 208 : 1996 Cls 8.1.3
Test Method	:	BS 1881 : Part 208 : 1996 Cls 8.5 & 8.6
Test Method Variation	:	None
Tested By	:	M. Rao Dunna

Tested by		Checked by
Laboratory Technician	QUALITY CHECKED 14 FEB 2019 ORIMIX LABORATORY	Laboratory Manager

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INITIAL SURFACE ABSORPTION TEST

Report No.	: ORML- 039	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0105
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 15kg
Orientation of Test Surface	: Horizontal	Diameter of CAP (mm) :	84.6

Temperature of Concrte Surface (°C) : 21

Area of Water Concrete of CAP (mm²) : 5618

Lenghth of Capillary Tube (mm) : 600

Description of the Concrete Surface under Test : Cast Surface Having Smooth Finish Without Cracks, Honeycombs & Voids

RESULTS

Specimen Identity	1	2	3
Water absorption(ml/m².sec) corrected to equivalent 20°C value	0.03	0.04	0.03
Average (%)	0.03		

Sampling Method	:	BS 1881 : Part 101 : 1983
Test Specimen preperation	:	BS 1881 : Part 208 : 1996 Cls 8.1.3
Test Method	:	BS 1881 : Part 208 : 1996 Cls 8.5 & 8.6
Test Method Variation	:	None
Tested By	:	M. Rao Dunna

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INITIAL SURFACE ABSORPTION TEST

Report No. : ORML- 040
Report Date : : 14.02.2019
Project Name : Polymer Composite Concrete
Sample NO : Lab Trial 0106
Sampled By : Orimix Lab
Date of Casting : 17.01.2019
Sample Description : Test Cubes
Date of Test : 14.02.2019
Class of Concrete : C 30/20 - OPC
Age at Test : 28 days
Curing Condition : Curing Water Tank
Mix : Polythene 20kg
Orientation of Test Surface : Horizontal
Diameter of CAP (mm) : 84.6
Temperature of Concrte Surface (°C) : 21
Area of Water Concrete of CAP (mm^2) : 5618
Lenghth of Capillary Tube (mm) : 600
Description of the Concrete Surface under Test : Cast Surface Having Smooth Finish Without Cracks, Honeycombs & Voids

RESULTS

Specimen Identity	1	2	3
Water absorption(ml/m².sec) corrected to equivalent 20°C value	0.04	0.02	0.03
Average (%)		0.03	

Sampling Method : BS 1881 : Part 101 : 1983
Test Specimen preperation : BS 1881 : Part 208 : 1996 Cls 8.1.3
Test Method : BS 1881 : Part 208 : 1996 Cls 8.5 & 8.6
Test Method Variation : None
Tested By : M. Rao Dunna

Tested by		Checked by
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WATER PENETRATION WITH PRESSURE TEST

Report No.	: ORML- 041	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0102
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Control Mix

RESULTS

Specimen ID	1	2	3
Specimns Dimension (mm)	150x150x150	150x150x150	150x150x150
Maximum Depth of Penetration (mm)	15	17	16
Mean water Penetration Value (mm)		16	

Sampling Method	: BS 1881 : Part 101 : 83 AMD 6728:91
Test Specimen preperation	: DIN 1048 : 1991/EN 12390-8:2000
Test Method	: DIN 1048 : 1991/EN 12390-8:2000
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by		Checked by
Laboratory Technician	QUALITY CHECKED ★ 14 FEB 2019 ★ ORIMIX LABORATORY	Laboratory Manager

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WATER PENETRATION WITH PRESSURE TEST

Report No.	: ORML- 042	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0103
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 5kg

RESULTS

Specimen ID	1	2	3
Specimns Dimension (mm)	150x150x150	150x150x150	150x150x150
Maximum Depth of Penetration (mm)	11	13	12
Mean water Penetration Value (mm)		12	

Sampling Method	: BS 1881 : Part 101 : 83 AMD 6728:91
Test Specimen preperation	: DIN 1048 : 1991/EN 12390-8:2000
Test Method	: DIN 1048 : 1991/EN 12390-8:2000
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by	Checked by
Laboratory Technician	Laboratory Manager

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WATER PENETRATION WITH PRESSURE TEST

Report No.	: ORML- 043	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0104
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 10kg

RESULTS

Specimen ID	1	2	3
Specimns Dimension (mm)	150x150x150	150x150x150	150x150x150
Maximum Depth of Penetration (mm)	6	7	8
Mean water Penetration Value (mm)		7	

Sampling Method	: BS 1881 : Part 101 : 83 AMD 6728:91
Test Specimen preperation	: DIN 1048 : 1991/EN 12390-8:2000
Test Method	: DIN 1048 : 1991/EN 12390-8:2000
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by Laboratory Technician	QUALITY CHECKED ★ 14 FEB 2019 ★ ORIMIX LABORATORY	Checked by Laboratory Manager

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WATER PENETRATION WITH PRESSURE TEST

Report No.	: ORML- 044	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0105
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 15kg

RESULTS

Specimen ID	1	2	3
Specimns Dimension (mm)	150x150x150	150x150x150	150x150x150
Maximum Depth of Penetration (mm)	4	3	3
Mean water Penetration Value (mm)	3		

Sampling Method	: BS 1881 : Part 101 : 83 AMD 6728:91
Test Specimen preperation	: DIN 1048 : 1991/EN 12390-8:2000
Test Method	: DIN 1048 : 1991/EN 12390-8:2000
Test Method Variation	: None
Tested By	: M. Rao Dunna

Tested by	Checked by
Laboratory Technician	Laboratory Manager

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WATER PENETRATION WITH PRESSURE TEST

Report No.	: ORML- 045	Report Date :	: 14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO	: Lab Trial 0106
Sampled By	: Orimix Lab	Date of Casting	: 17.01.2019
Sample Description	: Test Cubes	Date of Test	: 14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test	: 28 days
Curing Condition	: Curing Water Tank	Mix	: Polythene 20kg

RESULTS

Specimen ID	1	2	3
Specimns Dimension (mm)	150x150x150	150x150x150	150x150x150
Maximum Depth of Penetration (mm)	3	4	3
Mean water Penetration Value (mm)		3	

Sampling Method	:	BS 1881 : Part 101 : 83 AMD 6728:91
Test Specimen preperation	:	DIN 1048 : 1991/EN 12390-8:2000
Test Method	:	DIN 1048 : 1991/EN 12390-8:2000
Test Method Variation	:	None
Tested By	:	M. Rao Dunna

Tested by
Laboratory Technician

QUALITY CHECKED ★ 14 FEB 2019 ★ ORIMIX LABORATORY

Checked by
Laboratory Manager

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ORIENTAL READYMIX LLC

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RAPID CHLORIDE ION PENETRATION TEST

Report No.	: ORML- 046	Report Date :	14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO :	Lab Trial 0102
Sampled By	: Orimix Lab	Date of Cast :	17.01.2019
Sample Description	: Test Cubes	Date of Test :	14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test :	28 days
Curing Condition	: Curing Water Tank	Mix :	Control Mix

RESULTS

Specimen ID	1	2	3
Total Charge Passed in six hours (Coulombs)	3172	3179	3174
chloride Permeabillty Based on Charge passed (table 1 ASTM c 1202:1997)	LOW	LOW	LOW
Average	3175		

Sampling Method	: BS 1881 : Part 101 : 1983 (AMD 6278 : 1991)
Initiaal sample Preparation	: ASTM C 1202 : 97 CL 8
Test Specimen preperation	: ASTM C 1202 : 97 CL 9
Test Method	: ASTM C 1202 : 97 CL 10
Test Method Variation	: None
Tested By	: M. Rao Dunna

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RAPID CHLORIDE ION PENETRATION TEST

Report No.	: ORML- 047	Report Date :	14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO :	Lab Trial 0103
Sampled By	: Orimix Lab	Date of Cast :	17.01.2019
Sample Description	: Test Cubes	Date of Test :	14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test :	28 days
Curing Condition	: Curing Water Tank	Mix :	Polythene 5kg

RESULTS

Specimen ID	1	2	3
Total Charge Passed in six hours (Coulombs)	2935	2923	2944
chloride Permeabillty Based on Charge passed (table 1 ASTM c 1202:1997)	LOW	LOW	LOW
Average	2934		

Sampling Method	: BS 1881 : Part 101 : 1983 (AMD 6278 : 1991)
Initiaal sample Preparation	: ASTM C 1202 : 97 CL 8
Test Specimen preperation	: ASTM C 1202 : 97 CL 9
Test Method	: ASTM C 1202 : 97 CL 10
Test Method Variation	: None
Tested By	: M. Rao Dunna

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RAPID CHLORIDE ION PENETRATION TEST

Report No.	: ORML- 048	Report Date :	14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO :	Lab Trial 0104
Sampled By	: Orimix Lab	Date of Cast :	17.01.2019
Sample Description	: Test Cubes	Date of Test :	14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test :	28 days
Curing Condition	: Curing Water Tank	Mix :	Polythene 10kg

RESULTS

Specimen ID	1	2	3
Total Charge Passed in six hours (Coulombs)	2241	2268	2247
chloride Permeabillty Based on Charge passed (table 1 ASTM c 1202:1997)	LOW	LOW	LOW
Average	2252		

Sampling Method	: BS 1881 : Part 101 : 1983 (AMD 6278 : 1991)
Initiaal sample Preparation	: ASTM C 1202 : 97 CL 8
Test Specimen preperation	: ASTM C 1202 : 97 CL 9
Test Method	: ASTM C 1202 : 97 CL 10
Test Method Variation	: None
Tested By	: M. Rao Dunna

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RAPID CHLORIDE ION PENETRATION TEST

Report No.	: ORML- 049	Report Date :	14.02.2019
Project Name	: Polymer Composite Concrete	Sample NO :	Lab Trial 0105
Sampled By	: Orimix Lab	Date of Cast :	17.01.2019
Sample Description	: Test Cubes	Date of Test :	14.02.2019
Class of Concrete	: C 30/20 - OPC	Age at Test :	28 days
Curing Condition	: Curing Water Tank	Mix :	Polythene 15kg

RESULTS

Specimen ID	1	2	3
Total Charge Passed in six hours (Coulombs)	2198	2211	2197
chloride Permeabillty Based on Charge passed (table 1 ASTM c 1202:1997)	LOW	LOW	LOW
Average	2202		

Sampling Method	: BS 1881 : Part 101 : 1983 (AMD 6278 : 1991)
Initiaal sample Preparation	: ASTM C 1202 : 97 CL 8
Test Specimen preperation	: ASTM C 1202 : 97 CL 9
Test Method	: ASTM C 1202 : 97 CL 10
Test Method Variation	: None
Tested By	: M. Rao Dunna

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RAPID CHLORIDE ION PENETRATION TEST

Report No.	: **ORML- 050**	**Report Date :**	**14.02.2019**
Project Name	: **Polymer Composite Concrete**	**Sample NO :**	**Lab Trial 0106**
Sampled By	: **Orimix Lab**	**Date of Cast :**	**17.01.2019**
Sample Description	: **Test Cubes**	**Date of Test :**	**14.02.2019**
Class of Concrete	: **C 30/20 - OPC**	**Age at Test :**	**28 days**
Curing Condition	: **Curing Water Tank**	**Mix :**	**Polythene 20kg**

RESULTS

Specimen ID	1	2	3
Total Charge Passed in six hours (Coulombs)	1976	1996	1995
chloride Permeabillty Based on Charge passed (table 1 ASTM c 1202:1997)	LOW	LOW	LOW
Average	1989		

Sampling Method	:	**BS 1881 : Part 101 : 1983 (AMD 6278 : 1991)**
Initiaal sample Preparation	:	**ASTM C 1202 : 97 CL 8**
Test Specimen preperation	:	**ASTM C 1202 : 97 CL 9**
Test Method	:	**ASTM C 1202 : 97 CL 10**
Test Method Variation	:	**None**
Tested By	:	**M. Rao Dunna**

Tested by

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14. APPENDIX – 03 – CALIBRATION CERTIFICATES FOR LABORATORY EQUIPMENTS

Global Space Tracks

GLOBAL SPACE TRACKS

CR No: 1104031, P.O. Box: 1853 P.C: 114, Jibroo, Sultanate of Oman
Tel: 24587616, GSM: +968 96543801, E-mail-: info@gstcalibration.com

CERTIFICATE OF CALIBRATION

WEIGHING INSTRUMENTS

Date of Issue: 24 April 2019 **Certificate No: 3725001**

CERTIFICATE DETAILS			
Date Received	: 22 April 2019	Date of Calibration	: 22 April 2019
Job No	: 190042205	Recommended Due Date	: 21 April 2020
CUSTOMER DETAILS			
NAME	: Oriental Readymix LLC		
ADDRESS	: P.O Box : 666,P.O : 111,Muscat,Sultanate of Oman		
INSTRUMENT DETAILS			
INSTRUMENT	: Weighing Scale	SERIAL NO	: 0608016081
MANUFACTURER	: Citizen	MODEL NO	: CFH-3H
RANGE	: 0 to 30 kg	INSTRUMENT ID	: NA
CALIBRATION DETAILS			
CALIBRATION PROCEDURE		: (OIML) NO.R 111-1: 2004(E).	
LOCATION		: One Site: Oriental Readymix LLC	
ENVIRONMENTAL CONDITION			
TEMPERATURE	: (20 ±2) ° C	HUMIDITY	: (45 to 60) %
MASTER INSTRUMENT DETAILS			
INSTRUMENT	: F1 & M1 Weights		
SERIAL NO	: GST000114	CERTIFICATE NO	: W/18/11
TRACEABILITY	: Dubai Central Laboratory Department(DCLD)		

CALIBRATION DATA SHEET-1

Load applied (kg)	UUT Indication (kg)				Error in Reading ±(kg)	*MPE allowed ± (Kg)
	Test-I	Test-II	Test-III	Average		
20g	0.020	0.020	0.020	0.020	0.000	0.002
100g	0.100	0.100	0.100	0.100	0.000	0.002
500g	0.500	0.500	0.500	0.500	0.000	0.004
2.0	2.000	2.000	2.000	2.000	0.000	0.006
5.0	5.000	5.000	5.000	5.000	0.000	0.006
10.0	10.000	10.000	10.000	10.000	0.000	0.010
20.0	19.998	19.998	19.998	19.998	0.002	0.015
30.0	29.995	29.995	29.995	29.995	0.005	0.020

Remarks: The above instrument meets its accuracy as per the manufacturer's specifications. This Certificate may not be reproduced other than in full, without the written approval from the issuing laboratory.

Calibrated By: **Approved By:**

Calibration Engineer **Ajo Jose(Technical Manager)**

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CERTIFICATE OF CALIBRATION

WEIGHING INSTRUMENTS

Date of Issue: 24 April 2019 **Certificate No: 3725001**

CERTIFICATE DETAILS			
Date Received	: 22 April 2019	**Date of Calibration**	: 22 April 2019
Job No	: 190042205	**Recommended Due Date**	: 21 April 2020
CUSTOMER DETAILS			
NAME	**: Oriental Readymix LLC**		
ADDRESS	: P.O Box : 666,P.O : 111,Muscat,Sultanate of Oman		
INSTRUMENT DETAILS			
INSTRUMENT	**: Weighing Scale**	**SERIAL NO**	**: 0608016081**
MANUFACTURER	: Citizen	**MODEL NO**	: CFH-3H
RANGE	: 0 to 30 kg	**INSTRUMENT ID**	: NA
CALIBRATION DETAILS			
CALIBRATION PROCEDURE		: (OIML) NO.R 111-1: 2004(E).	
LOCATION		: One Site: Oriental Readymix LLC	
ENVIRONMENTAL CONDITION			
TEMPERATURE	: (20 ±2) ° C	**HUMIDITY**	: (45 to 60) %
MASTER INSTRUMENT DETAILS			
INSTRUMENT	: F1 & M1 Weights		
SERIAL NO	: GST000114	**CERTIFICATE NO**	: W/18/11
TRACEABILITY	: Dubai Central Laboratory Department(DCLD)		

CALIBRATION DATA SHEET-1						
Load applied (kg)	**UUT Indication (kg)**				**Error in Reading ±(kg)**	***MPE allowed ± (Kg)**
	Test-I	**Test-II**	**Test-III**	**Average**		
20g	0.020	0.020	0.020	0.020	0.000	0.002
100g	0.100	0.100	0.100	0.100	0.000	0.002
500g	0.500	0.500	0.500	0.500	0.000	0.004
2.0	2.000	2.000	2.000	2.000	0.000	0.006
5.0	5.000	5.000	5.000	5.000	0.000	0.006
10.0	10.000	10.000	10.000	10.000	0.000	0.010
20.0	19.998	19.998	19.998	19.998	0.002	0.015
30.0	29.995	29.995	29.995	29.995	0.005	0.020

Remarks: The above instrument meets its accuracy as per the manufacturer's specifications. This Certificate may not be reproduced other than in full, without the written approval from the issuing laboratory.

Calibrated By: **Approved By:**

Calibration Engineer **Ajo Jose(Technical Manager)**

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CERTIFICATE OF CALIBRATION

TEMPERATURE INSTRUMENTS

Date of Issue: 24 April 2019 **Certificate No:3725034**

CERTIFICATE DETAILS			
Date Received	: 22 April 2019	**Date of Calibration**	: 22 April 2019
Job No	: 190042204	**Recommended Due Date**	: 21 April 2020
CUSTOMER DETAILS			
NAME	**: Oriental Readymix LLC**		
ADDRESS	: P.O Box : 666,P.O : 111,Muscat,Sultanate of Oman		
INSTRUMENT DETAILS			
INSTRUMENT	**: Digital Thermometer**	**SERIAL NO**	**: 130103268**
MANUFACTURER	: Center	**MODEL NO**	: 300
TYPE	: K	**INSTRUMENT ID**	: NA
RANGE	: -200 to 1370°C		
CALIBRATION DETAILS			
CALIBRATION PROCEDURE		: OIML NO.R 35-2, EURAMET cg-8 Version 2.1 (10/2011).	
LOCATION		: At site (Oriental Readymix LLC)	
ENVIRONMENTAL CONDITION			
TEMPERATURE	: (20 ±2) ° C	**HUMIDITY**	: (45 to 60) %
MASTER INSTRUMENT DETAILS			
INSTRUMENT	: Document Process Calibrator Fluke 754		
SERIAL NO	: 2615501	**CERTIFICATE NO**	: E/18/02
TRACEABILITY	: UKAS		

Standards used for the calibration are traceable to UKAS

CALIBRATION DATA SHEET			
UUT Reading (°C)	**Measured Reading (°C)**	**Error in Reading ±(°C)**	**Acceptable Error (°C)**
-50.0	49.6	0.4	±1°C of F.S.D
-10.0	9.7	0.3	
0.0	0.1	0.1	
20.0	20.2	0.2	
50.0	50.2	0.2	
100.0	100.3	0.3	
500.0	500	0.0	
1000	999	1.0	

Remarks: The above instrument meets its accuracy as per the manufacturer's specifications. This Certificate may not be reproduced other than in full, without the written approval from the issuing laboratory.

Calibrated by : **Approved By:**

Calibration Engineer **Ajo Jose (Technical Manager)**

***** END OF CERTIFICATE *****

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CERTIFICATE OF CALIBRATION

WEIGHING INSTRUMENTS

Date of Issue: 24 April 2019 **Certificate No: 3725002**

CERTIFICATE DETAILS			
Date Received	: 22 April 2019	**Date of Calibration**	: 22 April 2019
Job No	: 190042206	**Recommended Due Date**	: 21 April 2020
CUSTOMER DETAILS			
NAME	**: Oriental Readymix LLC**		
ADDRESS	: P.O Box : 666,P.O : 111,Muscat,Sultanate of Oman		
INSTRUMENT DETAILS			
INSTRUMENT	**: Weighing Scale**	**SERIAL NO**	**: 72703**
MANUFACTURER	: GSC	**MODEL NO**	: NA
RANGE	: 0 to 100 kg	**INSTRUMENT ID**	: NA
CALIBRATION DETAILS			
CALIBRATION PROCEDURE		: (OIML) NO.R 111-1: 2004(E).	
LOCATION		: One Site: Oriental Readymix LLC	
ENVIRONMENTAL CONDITION			
TEMPERATURE	: (20 ±2) ° C	**HUMIDITY**	: (45 to 60) %
MASTER INSTRUMENT DETAILS			
INSTRUMENT	: F1 & M1 Weights		
SERIAL NO	: GST000114	**CERTIFICATE NO**	: W/18/11
TRACEABILITY	: Dubai Central Laboratory Department(DCLD)		

CALIBRATION DATA SHEET-1

Load applied (Kg)	UUT Indication (Kg)				Error in Reading ±(Kg)	*MPE allowed ± (Kg)
	Test-I	Test-II	Test-III	Average		
0.0	0.00	0.00	0.00	0.00	0.00	0.000
5.0	5.00	5.00	5.00	5.00	0.00	0.010
10.0	10.00	10.00	10.00	10.00	0.00	0.020
25.0	24.99	24.99	24.99	24.99	0.01	0.050
50.0	49.98	49.98	49.98	49.98	0.02	0.050
75.0	74.96	74.96	74.96	74.96	0.04	0.100
100.0	99.95	99.95	99.95	99.95	0.05	0.100

Remarks: The above instrument meets its accuracy as per the manufacturer's specifications. This Certificate may not be reproduced other than in full, without the written approval from the issuing laboratory.

Calibrated By: **Approved By:**

Calibration Engineer **Ajo Jose(Technical Manager)**

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CERTIFICATE OF CALIBRATION

MEASURING INSTRUMENTS

Date of Issue: 24 April 2019 **Certificate No: 3725037**

CERTIFICATE DETAILS			
Date Received	: 22 April 2019	**Date of Calibration**	: 22 April 2019
Job No	: 190042201	**Recommended Due Date**	: 21 April 2020
CUSTOMER DETAILS			
NAME	**: Oriental Readymix LLC**		
ADDRESS	: P.O Box : 666,P.O : 111,Muscat,Sultanate of Oman		
INSTRUMENT DETAILS			
INSTRUMENT	**: Air Entrainment Meter**	**SERIAL NO**	**: 800-444-1508**
MANUFACTURER	: GILSON	**MODEL NO**	: NA
RANGE	: 0 to 15 Psi	**INSTRUMENT ID**	: NA
CALIBRATION DETAILS			
CALIBRATION PROCEDURE		: As per Manufacturers Specifications	
LOCATION		: At site (Oriental Readymix LLC)	
ENVIRONMENTAL CONDITION			
TEMPERATURE	: (20 ±2) ° C	**HUMIDITY**	: (45 to 60) %
MASTER INSTRUMENT DETAILS			
INSTRUMENT	: Digital Pressure Calibrator		
SERIAL NO	: 2654141	**CERTIFICATE NO**	: CC160179800

Standards used for the calibration are traceable to national or International standards

CALIBRATION DATA SHEET

Pressure in Psi

Applied Pressure (Psi)	Measured Value(Psi)	Error ±(Psi)	Acceptable Error
00.00	00.00	0.00	±0.05 % of Range
05.00	05.03	0.03	
10.00	10.05	0.05	
15.00	15.07	0.07	

Remarks: The above instrument meets its accuracy as per the manufacturer's specifications. This Certificate may not be reproduced other than in full, without the written approval from the issuing laboratory.

Calibrated by : **Approved By:**

Calibration Engineer **Ajo Jose (Technical Manager)**

******END OF CERTIFICATE******

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