REUSE OF POLYETHYLENE TEREPHTHALATE PLASTIC AND FLY ASH TO ENHANCE THE MECHANICAL PROPERTY OF CONSTRUCTION MATERIAL

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2019

This is to certify that the

Final Year Project Titled

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Has been found satisfactory for requirements of the degree of Bachelors of Engineering

in
ENVIRONMENTAL ENGINEERING

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APPROVAL SHEET

This is to certify that the research work described in thesis is the original work of author and has been carried out under my direct supervision. I have personally gone through all the data/results/materials reported in the manuscript and certify the correctness/authenticity. I further certify that the material included in this thesis is not plagiarized and has not been used in part or full manuscript already submitted or in the process of submission in partial/complete fulfilment of the award of the degree from an institution. I also certify that the thesis has been prepared under my supervision according to the prescribed format and I endorse its evaluation for the award of Bachelor of Engineering in Environmental Engineering degree through the official procedures of the institute.

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ACKNOWLEDGEMENTS

In the name of Allah, the most merciful, the most beneficent, all praise to Him, the lord of the worlds and all prayers and Hazrat Muhammad (S.A.W), his servant and final messenger.

I am, first of all, grateful to Almighty Allah, without Whose willingness and blessings, I would have never achieved what I have ended up ultimately accomplishing.

I would like to show appreciation to my beloved parents and teachers for their unconditional love and support throughout my live and for supporting me in realizing my dreams.

My journey of BSc, especially the thesis year has been a remarkable experience and I cannot be more thankful to all people who were a part of this journey. I find myself at loss of words to express the gratitude to all the people who motivated, encouraged, advised and helped me in successfully completing this journey.

At the outset, I would like to express my appreciation to my supervisor Dr. Yousuf Jamal for his constant mentorship throughout this journey. He remained a source of rare and valuable advice for me during this endeavour for more than a year. He has constantly motivated me to remain focused on achieving the goals. His expertise was integral in helping me demarcate the direction of my research and moving forward with the investigation in depth. His inexorable support immensely helped me during my research and investigation period. My sincerest and heartfelt thanks to him for helping me in becoming hard working, knowledgeable and a better person.

I would also like to express my gratitude to Mr. Noor Haleem, Lab Demonstrator, IESE, NUST for facilitating me and giving me valuable advice in different phases of my project.

I also express my gratitude to Engr. Matiullah Shah and Engr. Atif Mehmood Khan, Structural Lab (NICE, NUST) for their assistance and valuable support.

Dedication

To

My Advisor Dr. Yousuf Jamal

&

My Family and Friends

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ASTM	American Society of Testing and Materials
OPC	Ordinary Portland Cement
PET	Polyethylene Terephthalate
FA	Fly Ash
SEM	Scanning Electron Microscopy
PSA	Particle Size Analysis

CHAPTER 1

INTRODUCTION

1.1 General

1.1.1 Concrete

Concrete is the most widely used construction material in the world due to its versatile characteristics like formlessness, plasticity, hydraulicity, strength and toughness and is relatively cheap. Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. Concrete technology deals with study of properties of concrete and its practical applications. In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements.

Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates. The cement paste coats the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock solid concrete is obtained.

There are different types of binding material used other than cement such as lime for lime concrete and bitumen for asphalt concrete which is used for road construction and fly ash may also be used for bricks.

1.1.2 Fly Ash

Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

Currently fly ash are used in a variety of engineering applications. Fly ash is most commonly used as a pozzolan in PCC applications. Pozzolans are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementious compounds. The unique spherical shape and particle size distribution of fly ash make it a good mineral filler. The consistency and abundance of fly ash in many areas present unique opportunities for use in structural fills and other highway applications.

Fly ash utilization, especially in concrete, has significant environmental benefits including:

1. increasing the life of concrete roads and structures by improving concrete durability

2. net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement
3. reduction in amount of coal combustion products that must be disposed in landfills, and conservation of other natural resources and materials.

Fly ash is typically finer than portland cement and lime. Fly ash consists of silt-sized particles which are generally spherical. These small glass spheres improve the fluidity and workability of fresh concrete. Fineness is one of the important properties contributing to the pozzolanic reactivity of fly ash.

Fly ash consists primarily of oxides of silicon, aluminum iron and calcium. Magnesium, potassium, sodium, titanium, and sulfur are also present to a lesser degree.

1.1.3 Cement

Cement, one of the most important building materials, is a binding agent that sets and hardens to adhere to building units such as stones, bricks, tiles, etc. Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. The raw ingredients are processed in cement manufacturing plants and heated to form a rock-hard substance, which is then ground into a fine powder to be sold. Cement mixed with water causes a chemical reaction and forms a paste that sets and hardens to bind individual structures of building materials.

Cement is an integral part of the urban infrastructure. It is used to make concrete as well as mortar, and to secure the infrastructure by binding the building blocks.

1.1.4 Polyethylene terephthalate Plastic

Polyethylene terephthalate (PET or PETE) is a general-purpose thermoplastic polymer which belongs to the polyester family of polymers. Polyester resins are known for their excellent combination of properties such as mechanical, thermal, chemical resistance as well as dimensional stability. PET is one of the most recycled thermoplastic.

PET Chemical Formula: $(C_{10}H_8O_4)n$

Recycled PET can be converted to fibers, fabrics, sheets for packaging and manufacturing automotive parts. PET is highly flexible, colourless and semi-crystalline resin in its natural state. Depending upon how it is processed, it can be semi-rigid to rigid. It shows good dimensional stability, resistance to impact, moisture, alcohols and solvents. Commercially available PET grades include un-reinforced to glass reinforced, flame retardant and high flow materials for various engineering applications that typically require higher strength and or higher heat resistance.

Pakistan generates about 48.5 million tons of solid waste a year out of which 6% is plastic waste (Pakistan-Waste Management by expert.gov, 2019). 65% of waste that ends up on beaches along Pakistan's coast include water bottles, caps, plastic bags and Packaging. (WWF-Pakistan).

1.2 Problem Statement

The use of recycled plastics in concrete has been explored as a means of improving concrete's mechanical properties while also providing an efficient way to both repurpose waste plastic and partially displace cement for the purpose of reducing carbon emissions. The task remains, however, to develop a cement design that allows for both the addition of plastic and the preservation of high compressive strength. This thesis is aimed to explore the effectiveness of Polyethylene Terephthalate plastic as an additive in cement paste (Portland cement + additives + water) samples for improving the compressive strength. Polyethylene Terephthalate plastic is paired with fly ash, which is commonly used to achieve high strength, with the goal of finding an optimal combination. An internal microstructure analysis is presented in order to provide some insight into the aspects of the materials' chemical compositions that contribute to the observed variation in strength.

1.3 Objectives

In light of components detailed out in the problem statement, the objectives of my thesis are enlisted as follows:

1. To replace Sand in construction material with Fly Ash and Polyethylene terephthalate (PET) Plastic
2. To enhance compressive strength of construction material through incorporation of Fly ash (FA) and PET Plastic

1.4 Thesis Structure

Following this introductory chapter, a literature review is presented in Chapter 2. Chapter 3 describes the experimental research methodology, testing procedures and materials used in casting. Mix design, casting regime and curing has also been discussed in this chapter.

Chapter 4 includes tests conducted for different samples casted for the afore-mentioned objectives.

Chapter 5 includes conclusions based on findings of this research and future recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Carbon emissions in the cement industry

Cement industry has a very high carbon footprint starting from the extraction of its raw materials to manufacturing and transportation. Each ton of cement produces approximately one ton of CO_2 (Malhotra, 1999). Concrete is the second most widely used material on the planet, after water (Crow, 2008). The cement industry accounts for roughly 5% of global anthropogenic carbon dioxide emissions, making it a critical sector for emission mitigation (Worrell et al., 2001). The production of Portland cement releases carbon dioxide both directly and indirectly (Ali et al., 2011; Tanaka and Stigson, 2009). Direct emissions result from a process known as calcination, which occurs when limestone, the primary component of cement, is heated (Andres et al., 1996). The calcium carbonate in the limestone breaks down into calcium oxide and carbon dioxide (Taylor, 1997). This process accounts for roughly half of all emissions from cement production. To produce cement, limestone and other clay-like materials are heated in a kiln at around 1400 C. Indirect emissions result from the burning of fossil fuels to heat the kiln and account for about 40% of cement production emissions. The electricity used to power additional plant machinery, as well as the final transportation of cement, account for the remaining 10% of total emissions. These emissions make partial replacement of cement with a substitute material an attractive alternative to alleviate the negative environmental impact of cement production.

2.2 Fly Ash Incorporation in Concrete

To cater for this high carbon footprint of cement fly ash can be used as a partial replacement for bonding the components of concrete. The environmental impact of the fly ash cements have a carbon footprint up to 23–55% lower than Portland cement. (Maddalena et al., 2018). The incorporation of Fly ash in cement can offer other benefits as well. The inclusion of HVFA in the mixture reduced the heat of hydration, the degree of hydration, bleeding, segregation, density, but increased workability and setting time (Alaa M.Rashad, 2015). The addition of Fly ash can also significantly increase the strength of construction material. Fly ash has a significant contribution to strength after 3 days due to the significant increase in pozzolanic activity. (Feng et al., 2017)

2.3 Plastic waste and recycling

Constituting a separate environmental issue is the abundance of plastic waste. Plastics have come to play an essential role in our everyday lives. Their favorable properties, including low cost, high strength-to-weight ratio, and low density make them ideal for use in a wide range of products (Gu and Ozbakkaloglu, 2016; Singh et al., 2017). It has been shown that over half of global plastic production is used for one-off disposable consumer products. This contributes heavily to the production of plastic-related waste, most of which is not biodegradable and will not react chemically in natural settings, and therefore it remains in the environment for decades or even centuries. Plastic wastes have become universally accepted as a serious environmental issue. Despite improvements in technology and awareness that have occurred since the recycling of plastic waste began in 1980, the recycling rate of post-consumed plastic wastes is still fairly low (EPA, 2014). A 2012 study showed a plastic recycling rate of only 8.8%, while the remaining 91.2% was simply discarded. The discarded plastic is typically put into a landfill, which is considered the least desirable method of dealing with plastic waste because it demands heavy space consumption and contributes to longterm pollution (EPA, 2014; Gu and Ozbakkaloglu, 2016). In some countries waste plastic is incinerated for energy recovery because of its high calorific value. This method, however, produces toxic ash and releases carbon dioxide and poisonous chemicals into the environment. Recycling, therefore, is seen as the ideal solution for minimizing environmental impact. Among the various approaches to managing recycling are (1) standard mechanical recycling, which aims to recover plastic via mechanical processes (sorting, grinding, cleaning, drying, re-granulating, etc.) and produces recyclates that can be transformed into new plastic products, and (2) recycling in the form of repurposing the waste plastic without fully breaking it down (Al-Salem et al., 2009). Mechanical recycling degrades the quality of the plastic during the service cycle, and often times the plastic that is recycled in the United States is exported, with about two-thirds being shipped to China (Gu and Ozbakkaloglu, 2016). This is due to the fact that the U.S. recycling market is small in comparison to other countries (Yoshida, 2005). The exported plastic is shipped overseas via massive cargo ships, which collectively release billions of tons of CO2 annually, along with considerable amounts of nitrogen and sulfur (Corbett and Fischbeck, 1997). Thus reusing waste plastic in in other industries is considered a more ideal method of disposal

2.4 Plastic as an additive in concrete

The use of a wide range of plastics as additives to concrete, in the form of powder, aggregate and fiber, has been extensively studied by several researchers

(Asokan et al., 2010; Choi et al., 2009; Gesoglu et al., 2017; Kim et al., 2010; Siddique et al., 2008). Recently, researchers have explored waste and recycled plastic's potential as an environmentally friendly construction material by repurposing it as an additive in concrete mix and studying the concrete's resultant behavior (Gu and Ozbakkaloglu, 2016). Specifically, polyethylene terephthalate (PET) has been explored as a lightweight concrete aggregate that could improve various mechanical properties and replace the standard lightweight aggregates that are typically used, which face some problems related to both cost and quality (Choi et al., 2005). A recent study shows that manufactured plastic aggregate can be used at 25% replacement level for natural aggregates while providing a benefit of light weight aggregate concrete subsequently maintaining the required strength and ductility for non-structural applications (Alqahtani et al., 2017). Another work demonstrates that plastic from bottles shredded into small PET particulates was successfully used as sand-substitution aggregates in cementitious concrete composites (Marzouk et al., 2007). Moreover, use of plastic aggregates from foam-extrusion process has led to improved aggregate/binder interface, and reduction in dead-weight of the structure and overall reduction in consumption of natural sand (Coppola et al., 2016). Also, inclusion of plastic as an aggregate can lead to significant reduction in the thermal conductivity subsequently improving the thermal insulation performance of the mortars (Colangelo et al., 2016; Iucolano et al., 2013). Plastic aggregates have five times lower thermal conductivity than silica based aggregated which can be used to control the heat loss from buildings during summer and heat gain in the winter. For detailed review on usage of waste plastic as an aggregate in mortar and concretes the readers are referred to a state of art review article by Saikia and de Brito (2012). PET is a polymer notable for being the constituent of the clear plastic used for soda and water bottle containers. In comparison to Polypropylene (PP) and polyethylene (PE), PET in concrete can improve the concrete's flexural toughness, impact resistance, and workability (Choi et al., 2005; Kim et al., 2010; Pelisser et al., 2012). Moreover, PET is highly sensitive to the alkaline environment in the pore solution of cementious matrix, which can act as a precursor that can contribute to dense forming phases. Various studies have shown mixed results for improvements in tensile strength (Saikia and Brito, 2013). Compressive strength, however, has generally been shown to decrease with the addition of PET. Thus it is apparent that the task remains to produce a PET enhanced concrete capable of demonstrating the aforementioned mechanical improvements without compromising its compressive strength.

CHAPTER 3

MATERIALS AND EXPERIMENTAL METHODOLOGY

3.1 Materials

Following materials were used to develop construction material. The characterization tests of these materials are also shown here. The overall experimental program is also discussed later in the chapter.

3.1.1 Cement

Best Way Grade 53 cement was used in casting. Total of two bags were utilized in overall casting. Cement was kept in a sealed container to prevent any interaction with the atmosphere. Initially the physical properties of the cement were determined as shown in table 1. Then, Particle Size Analysis (PSA) was performed to determine median size (D_{50}), which came out to be around 5.5 microns as shown in figure 1.

Initial Setting Time	135 mins
Final Setting Time	165 mins
Consistency	7 mm penetration (5-7 mm allowed)
Soundness	
L1 (after 24 hours)	4mm
L2 (after boiling in water for 2 hrs)	8mm
Difference	4mm (10 mm permissible)

Table 1: Cement properties

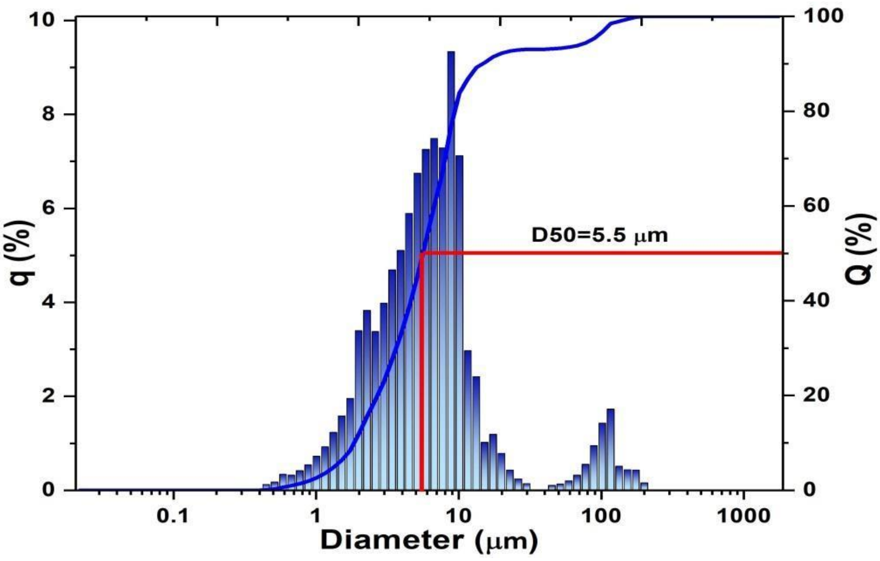

Figure 1: Particle Size Distribution of cement

3.1.2 Fly Ash

Fly ash was procured from Port Qasim coal fired power plant, Karachi and was delievered by the company Tradeworth International. It was slightly fine sized Fly Ash. This was confirmed upon determining fineness modulus as well, which came out to be 2.49 which is within ASTM limits (2.2 to 3.2). Sieve analysis of the Fly Ash in accordance to ASTM C33 was done and the gradation curve was plotted as shown in figure 2. Gradation curve came out to be with the envelope specified by ASTM C33.

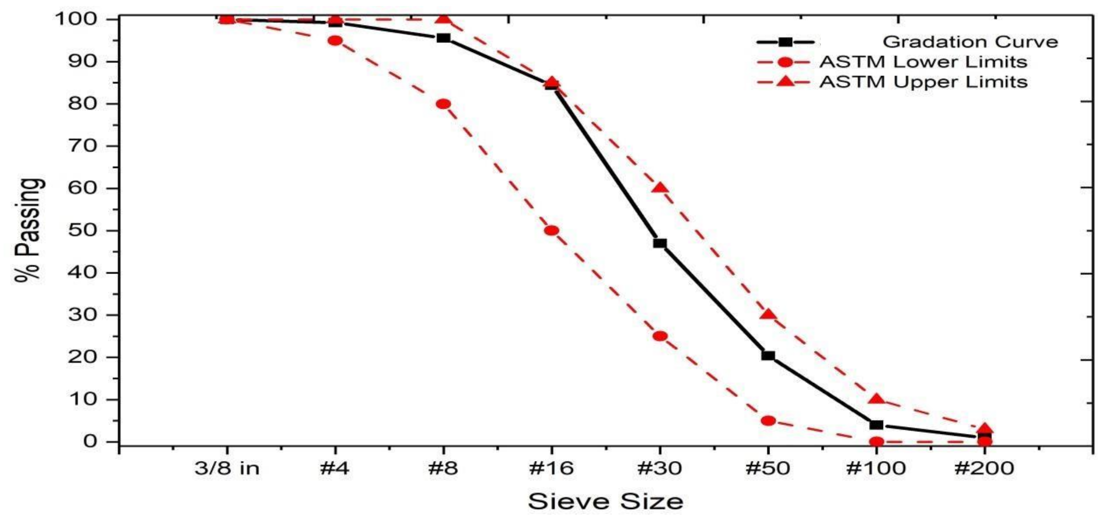

Figure 2: Particle Size Distribution of Fly Ash

3.1.3 Polyethylene Terephthalate Plastic

Mineral water PET bottles of 1.5 were collected from Zainab Hostel, NUST. The bottles were cut into small pieces and heated in muffle furnace in Water and Wastewater Lab IESE at 300C for 20 minutes. The plastic pellets obtained were then crushed into fine particles using a grinder. The small pieces and plastic pellets are shown in figure 3a and 3b respectively.

Figure 3: a) Small cut pieces b) Pellets of PET Plastic

Since PET Plastic is being added in addition to cement, they can effectively serve the purpose of enhancement of mechanical properties and also forming an effective conductive network within cementious matrix by having as fine the particle size as possible. The PET plastic particles procured was supposedly micro-sized. So to investigate the particles size, as well as study the morphology of this raw powder, Particle Size Analysis (PSA) and Scanning Electron Microscopy (SEM) was performed respectively. For PSA, sample was initially sonicated in water for about 60 minutes in order to ensure that PET powder disperses well in water and results are uniform. The results obtained are shown in figure 4. Median size was 5.98 microns. SEM results shown in figure 5 also compliment this finding.

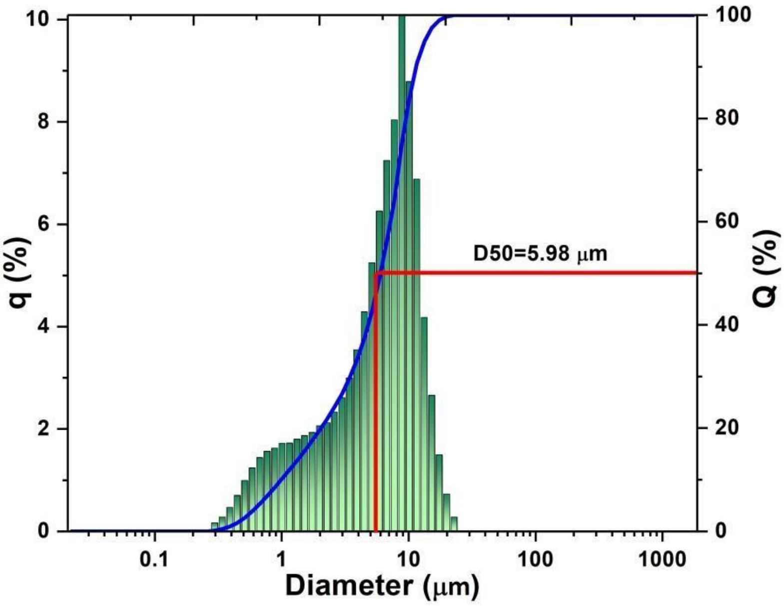

Figure 4: Particle Size Distribution of PET plastic

SEM test also reconfirmed that nano-sized particles are present in PET Plastic.

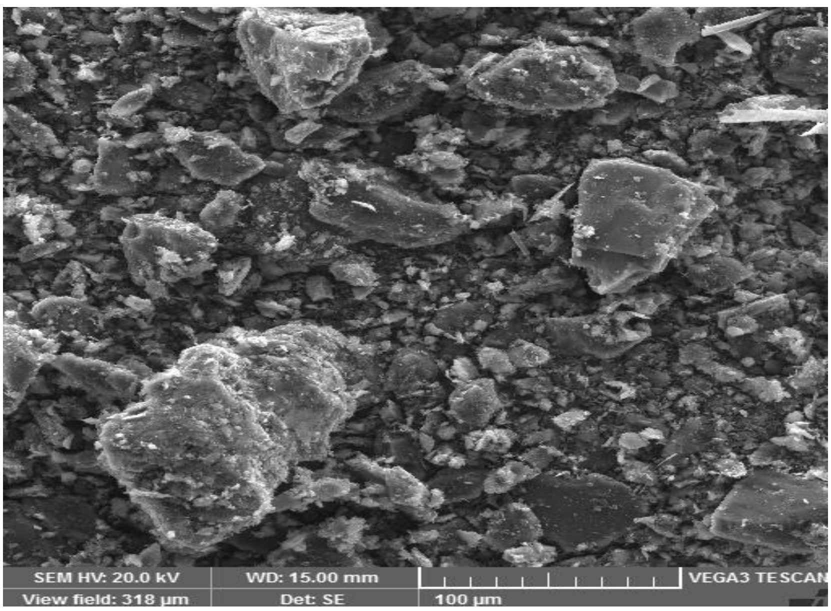

Figure 5: SEM images of PET Plastic at 100 microns

3.1.4 Water

Water available in Structural lab, NICE was tested from IESE. Sample was found to be in accordance to WHO's (World Health Organization) guidelines and standards for portable use. Properties are shown in table 2.

Sr. No.	Parameter	Results	WHO Standard	Pakistan Standards
1	pH	6.9	6.5-8.5	6.5-8.5
2	Turbidity	0.7	<5	<5
3	TDS	460	<500	<1000
4	Chlorides	78	<250	<250
5	Hardness	330	<500	<500

Table 2: Water properties

3.2 Experimental Methodology

3.2.1 Water Demand

The samples were weighed using weighing balance with water also weighed in the same way. The samples of cement, fly ash, plastic were dry mixed manually in a plastic box. The water is poured in the steel cup and cement (fly ash, plastic) was poured and let absorb for 30 seconds. Then it is put in Hobart Mixer and mixed at slow rotation for 30 seconds. Then for 15 seconds it is stopped and edges are cleaned to remove any material on it and then mixed at high rotation for 1 min. the mixture is then taken out. Make a ball out of it and toss it 6 times with a distance of 6 inch between both hands. The ball is then poured in a mould, the mould is inverted on a plastic plate. The extra material is removed with help of spatula and penetration is checked. The value should be plus/minus 10

In order to perform different types of tests on construction material, cubes of 2in x 2in x 2in were casted.

3.2.1 Mix Design

The complete mix design for the concrete samples is shown in Table 3. Included are three different cement binders: Type I Ordinary Portland Cement (OPC), OPC with fly ash (OPC+FA) and OPC with Fly Ash and PET Plastic (OPC+FA+PET). Each individual combination was triplicated so that an average compressive strength with an uncertainty could ultimately be determined. For each of the non-control samples, the plastic made up 1%, 1.5% and 2% of the dry mass. For samples containing both the plastic additive and one of the mineral additives as the binder, the plastic only displaced the cement dry mass; the mineral additive consistently made up 15% of the total dry mass. No super plasticizer was used in casting. The composition of different composites are shown in table 3.

Notation	Binder	Total Dry Mass (g)	PET Plastic Powder (g)	Cement (g)	Fly Ash (g)
OPC	OPC	1400	0	1400	0
OPC+FA	OPC+FA	1400	0	1190	210
OPC+FA+1%PET	OPC+FA	1400	14	1176	210
OPC+FA+1.5%PET	OPC+FA	1400	21	1169	210
OPC+FA+2%PET	OPC+FA	1400	28	1162	210

Table 3: Mix design

3.2.3 Mixing Regime

Hobart mixer of NICE Structural Lab was used to mix all materials together to get a homogenous mix. The mixing regime along with the casting steps are shown in table 4.

Step 1	Weigh required amounts of OPC, FA and PET powder
Step 2	Dry mix the weighed amounts in a plastic box
Step 3	Pour mix cement, fly ash and PET plastic powder in Hobart Mixer along with water for 30 seconds.
Step 4	After 30 seconds, Slow mix in Hobart Mixer for 30 seconds
Step 5	Stop for 15 seconds and scratch the edges of mixer to remove the material from the edges
Step 6	Fast wet mix for 90 seconds
Step 7	Cast the samples in moulds with the help of shaking table

Table 4: Execution steps of casting

3.2.4 Curing

Samples were demolded 20-24 hours after casting. Samples were cured in curing tank, at room temperature, for a standard 28 days for most of the tests. For compressive strength analysis, different curing periods were deployed which will be discussed in Chapter 4.

CHAPTER 4

EXPERIMENTAL TESTS AND RESULTS

4.1 Water Demand

Water demand was found out by Vicat apparatus as discussed in the Experimental Methodology in Chapter 3. The results obtained are shown in table 5.

Composite	Water to Cement ratio (W/C)
OPC	26.5 %
OPC+FA	25 %
OPC+FA+PET	25 %

Table 5: Water Demand

The W/C Ratio decreases as OPC was replaced by FA because FA itself acts as a plasticizer. The W/C remains the same when PET was added because plastic is inert and does not react with water. The results are shown in figure 6.

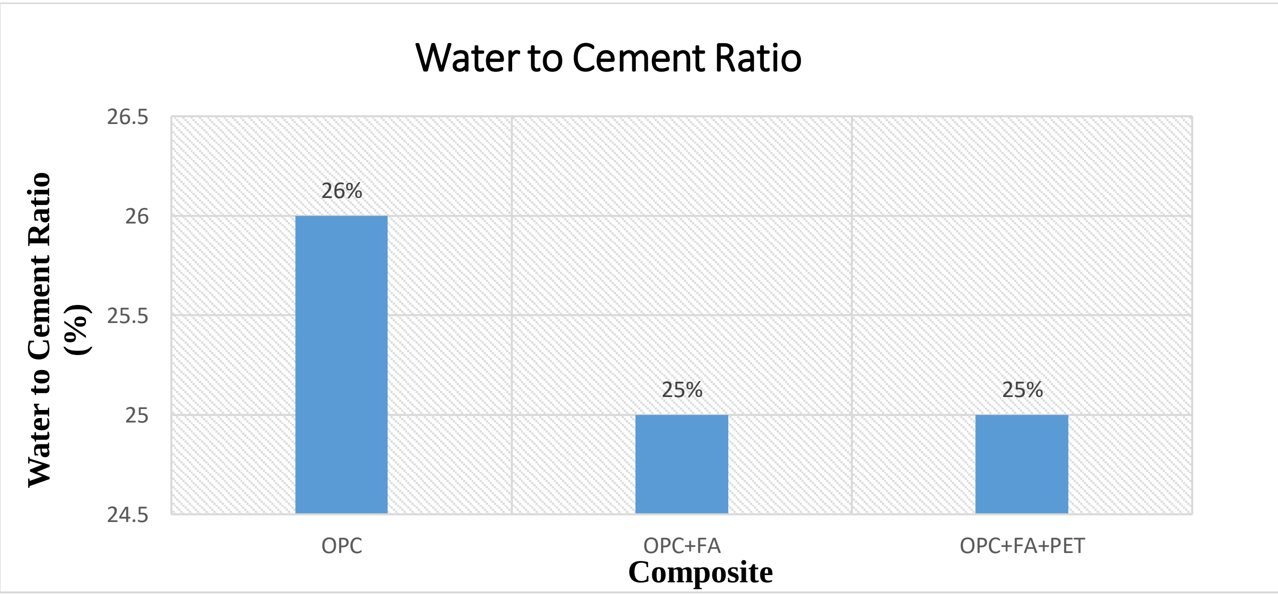

Figure 6: W/C Ratio

4.2 Compressive Strength

Compression test was performed at a stress rate of 0.25 MPa/sec as per ASTM C 109.

Specimens were tested at 3,7,14 and 28 days of curing.

4.2.1 OPC

The results of compressive strength of OPC are shown in table 6.

Curing Days	Compressive Strength (N/mm^2)
3	39.83
14	46.3
21	50.2
28	57.8

Table 6: Compressive Strength of OPC

The increase in compressive strength is due to increase in pozzolanic activity with the increase in number of curing days. The graphical representation is shown in figure 7.

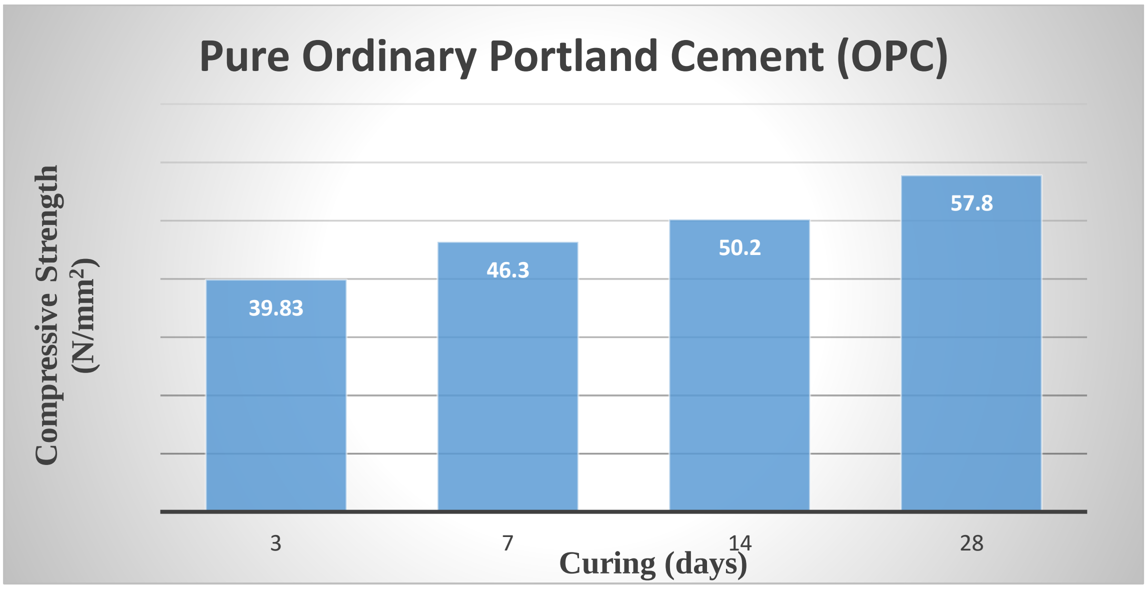

Figure 7: Compressive Strength of OPC

4.2.2 OPC+FA

The results of compressive strength of OPC are shown in table 7.

Curing Days	Compressive Strength (N/mm^2)
3	47.85
14	53.6
21	59.36
28	61.9

Table 7: Compressive Strength of OPC+FA

The increase in compressive strength is due to increase in binding strength of OPC and FA with the increase in number of curing days. The graphical representation is shown in figure 8.

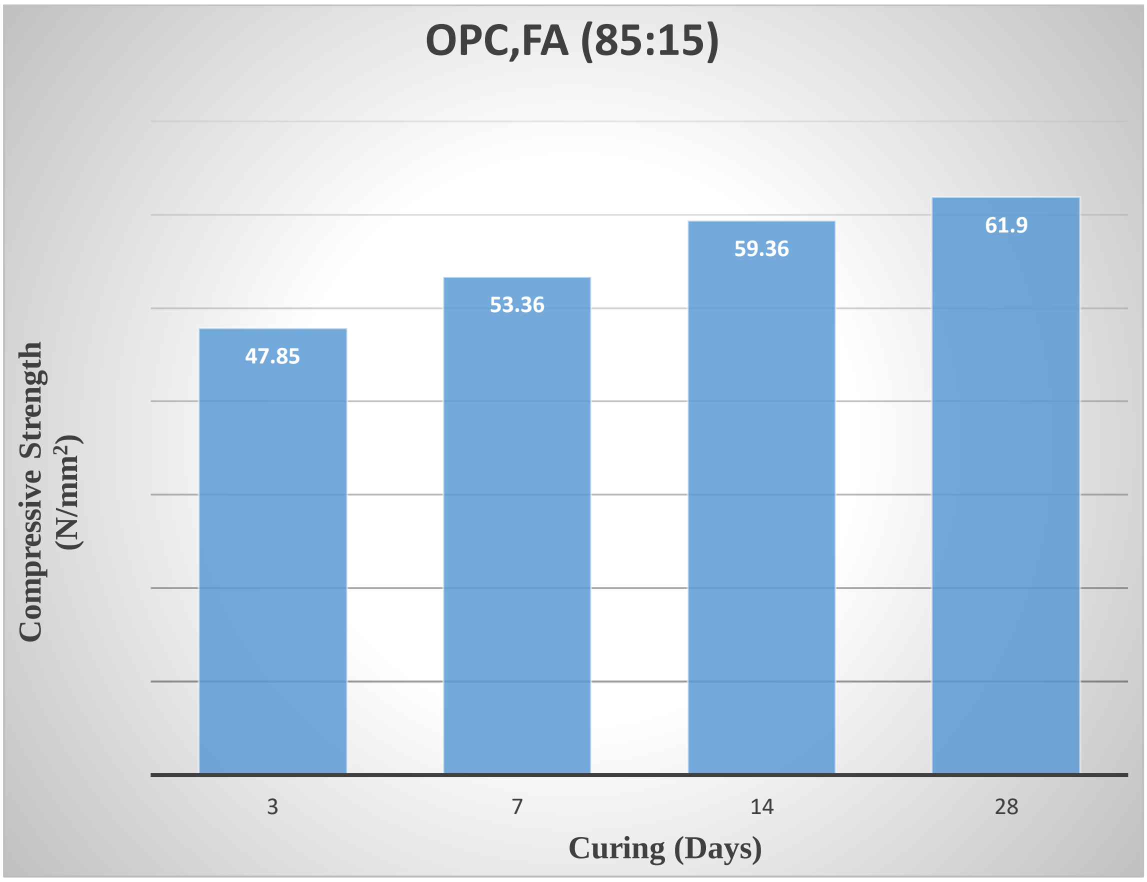

Figure 8: Compressive Strength of OPC+FA

4.2.3 OPC+FA+1%PET

The results of compressive strength of OPC are shown in table 8.

Curing Days	Compressive Strength (N/mm^2)
3	33.4
14	48.3
21	59.7
28	62.1

Table 8: Compressive Strength of OPC+FA+1%PET

The increase in compressive strength is due to increase in binding strength of OPC, FA and PET with the increase in number of curing days. The graphical representation is shown in figure 9.

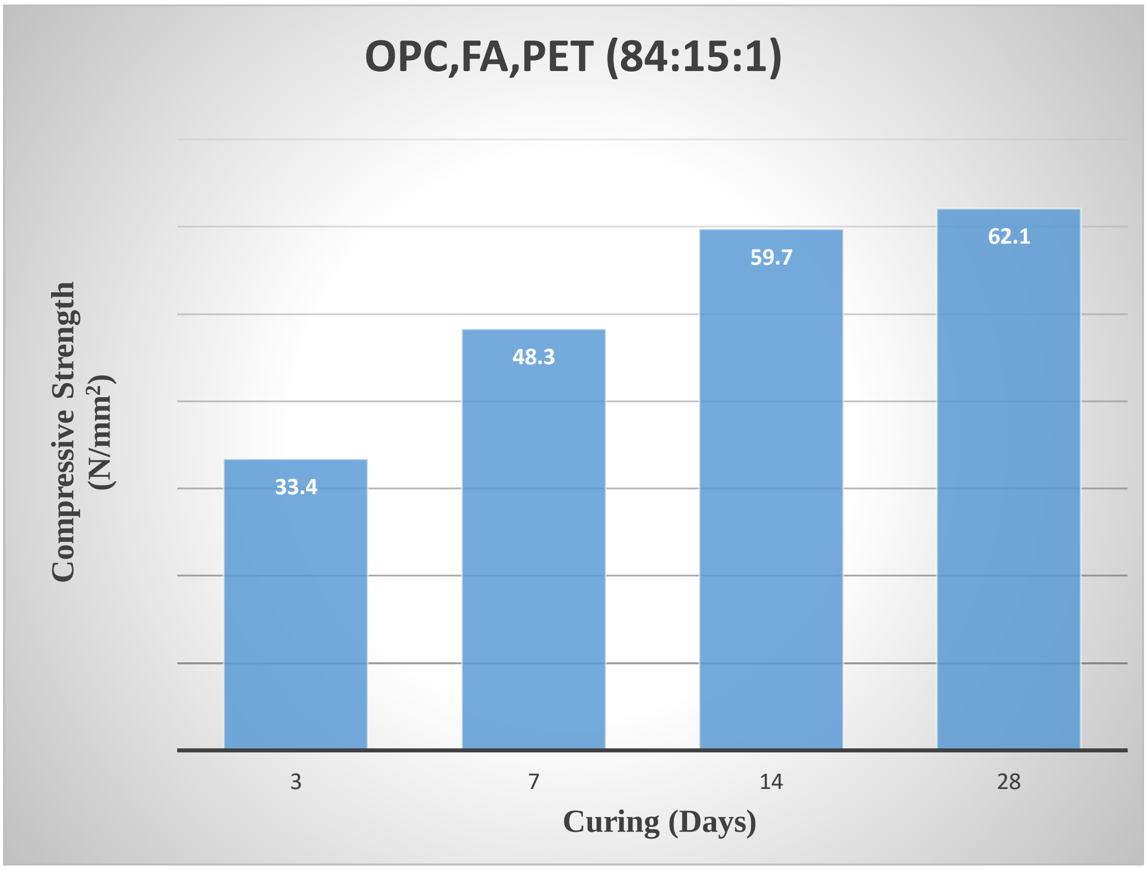

Figure 9: Compressive Strength of OPC+FA+1%PET

4.2.4 OPC+FA+1.5%PET

The results of compressive strength of OPC are shown in table 9.

Curing Days	Compressive Strength (N/mm^2)
3	36.8
14	52.03
21	63.43
28	64.4

Table 9: Compressive Strength of OPC+FA+1.5%PET

The increase in compressive strength is due to increase in binding strength of OPC, FA and PET with the increase in number of curing days. The strengths obtained are higher than the previous composite. The graphical representation is shown in figure 10.

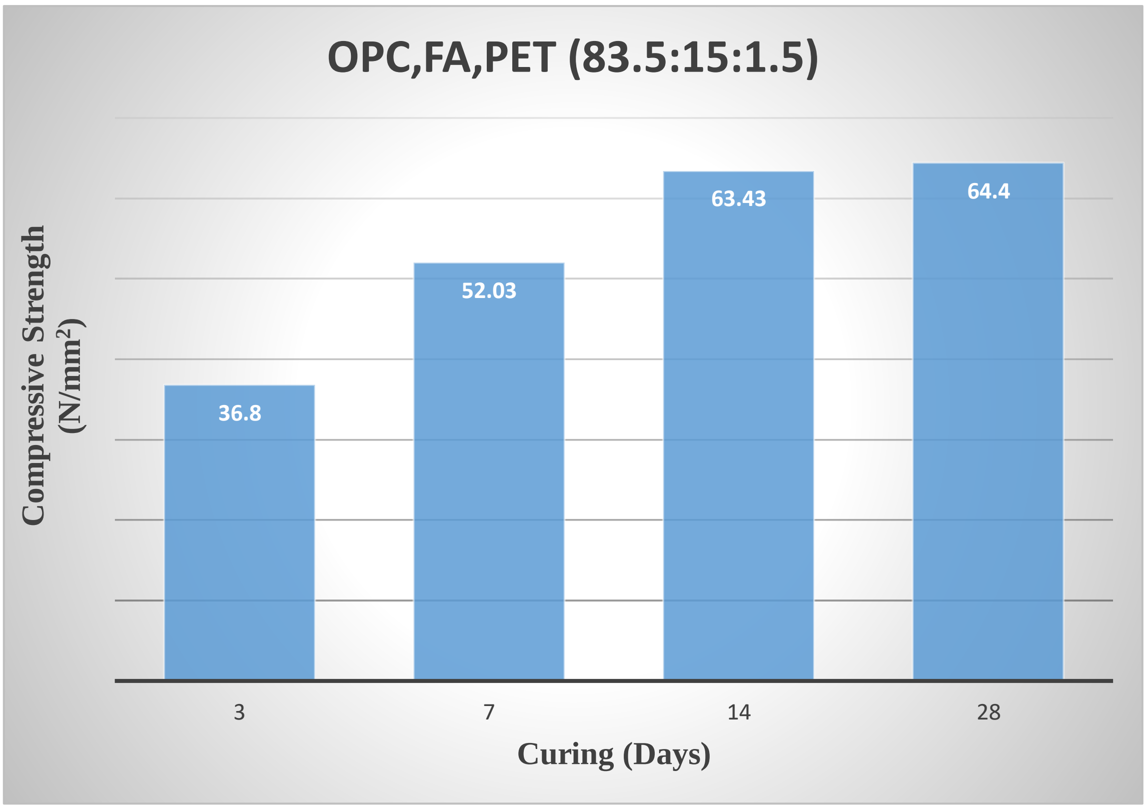

Figure 10: Compressive Strength of OPC+FA+1.5%PET

4.2.5 OPC+FA+2%PET

The results of compressive strength of OPC are shown in table 10.

Curing Days	Compressive Strength (N/mm^2)
3	38.3
14	52.3
21	62.8
28	63.6

Table 10: Compressive Strength of OPC+FA+2%PET

The increase in compressive strength is due to increase in binding strength of OPC, FA and PET with the increase in number of curing days. The strengths obtained are lower than the previous composite because of the brittleness with increasing PET percentage. The graphical representation is shown in figure 11.

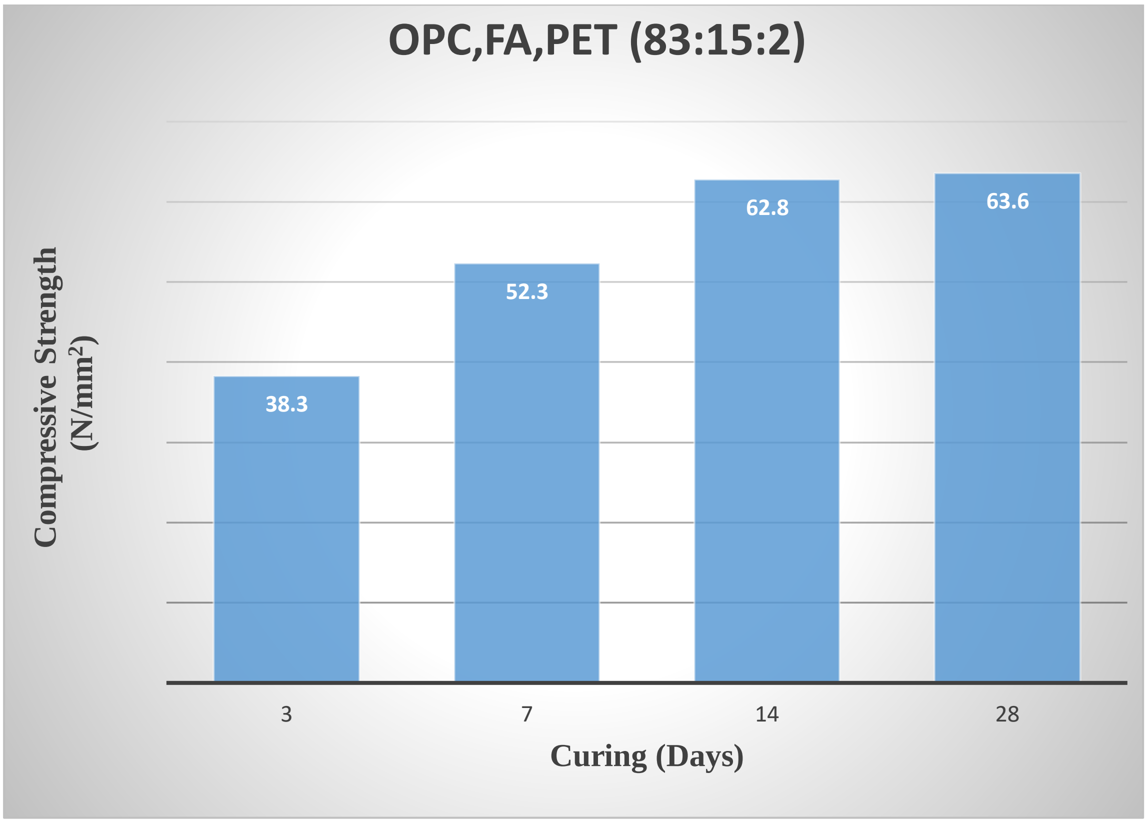

Figure 11: Compressive Strength of OPC+FA+2%PET

4.2.6 Comparison

The composite shown with 1.5% PET (Yellow line) showed the highest compressive strength, followed by the one with 2% PET (Blue line). The comparison with other composites are also shown in figure 12.

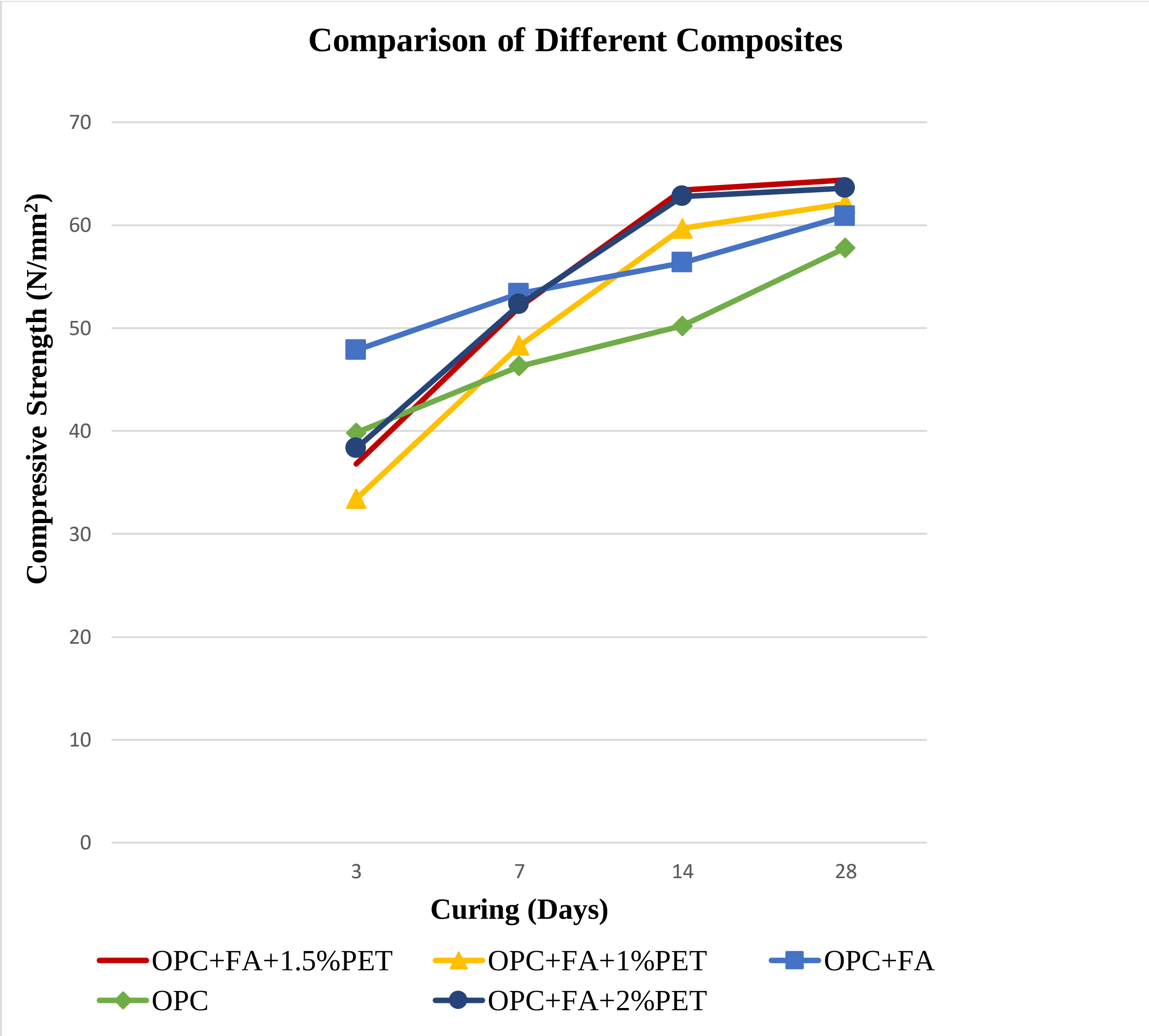

Figure 12: Comparison of Compressive Strengths

4.3 SEM Analysis of OPC+FA+PET Composite

To study the surface structure of the composite with highest strength, Scanning Electron Microscopy was performed. The SEM anaylsis showed how PET particles adhered to the needle like FA particles bonded with the cement. The red circles show the fine PET plastic particles in figure 13.

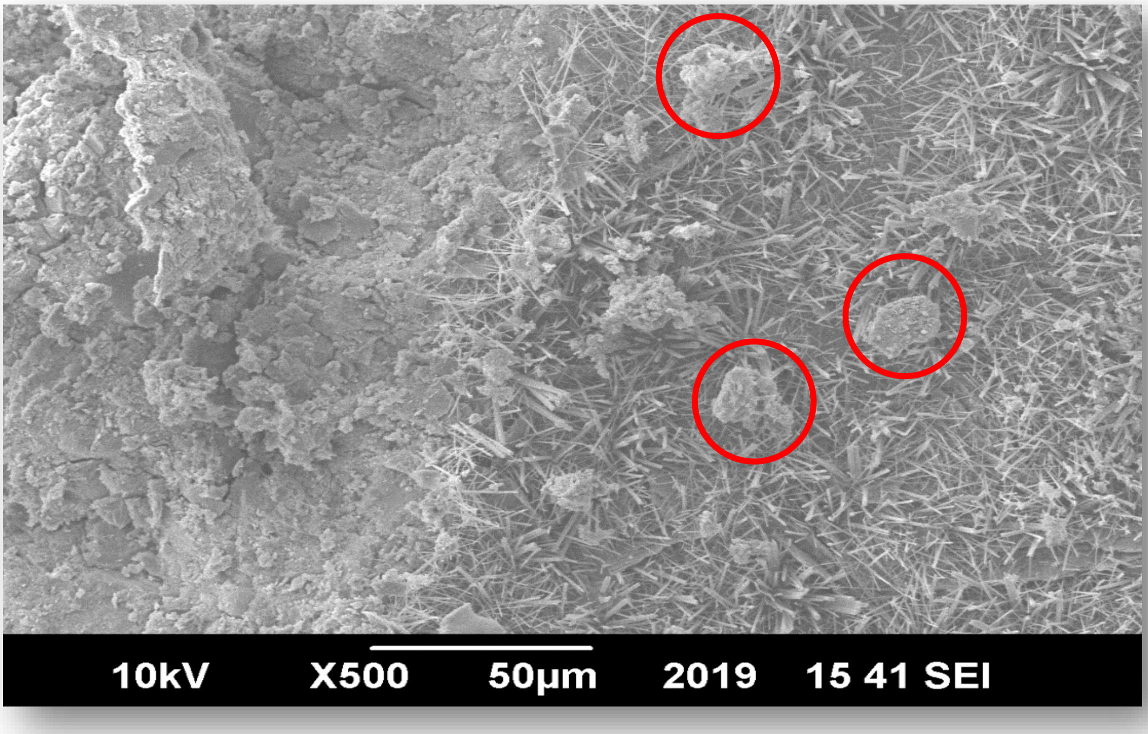

Figure 13: SEM Analysis of OPC+FA+PET at 50 microns

CHAPTER 5

5.1 CONCLUSIONS

The following conclusions are deduced from this research

1- The composite of Cement and Fly ash demanded less water than cement alone as fly ash acts as a plasticizer.

2- The percentage remained the same when plastic was incorporated because the water doesn't react with plastic.

3- 100% Ordinary Portland Cement showed increase in compressive strength with increase in the number of curing days

4- Composite of 85% Ordinary Portland Cement and 15% Fly ash also showed the trend of increasing compressive strength with the increase in the number of days. The strengths obtained are higher than those of 100% Ordinary Portland Cement

5- A composite with the same percentage of Fly ash and replacing 1% of Ordinary Portland Cement with PET Plastic showed an increasing trend in compressive strengths.

6- A composite of 15% Fly ash, 83.5% Ordinary Portland Cement and 1.5% PET showed the highest strength among all the composites.

7- A mixture of 83% plastic 15% fly ash and 2% PET plastic by weight followed an increasing trend in compressive strength at 3 and 7 days after which it gained minimal strength as compared to the composite with 1.5% PET.

8- The compressive strength of composite with 83% plastic 15% fly ash and 2% PET plastic by weight showed less strength at 14 and 21 days as compared to the composite with 1.5% PET plastic.

5.2 RECOMMENDATIONS

The following recommendations are proposed to broaden the scope of this research

1- Analyse effects of water with different properties on the compressive strength of construction material

2- Analyse effects on different grades of PET plastics on the compressive strength of construction material.

3- Study the economic viability of construction material infused with plastic for industrial use.

4- Research the flexural and tensile strength of the afore-formed construction material.

5- Analyse the impact of increasing percentage of Fly ash on the construction material.

6- Study the impact of different particle sizes of PET plastic on the compressive strength of construction material.

7- Study the curing of construction material at different temperatures.

8- Analyse the compressive strength of construction material by replacing Fly Ash with sand.

9- Analyse water content effects on the curing days of construction material.

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