MAHMOUD AL HASSAN

EFFECT OF RECYCLED PWP AS A REPLACEMENT OF COARSE AGGREGATE ON SOME CONCRETE PROPERTIES

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January, 2022

Approval

We certify that we have read the thesis submitted by Mahmoud AL HASAN titled **"Effect of Recycled PWP as a Replacement of Coarse Aggregate on Some Concrete Properties"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Mahmoud AL HASSAN
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Mahmoud AL HASSAN

Abstract

The Effects of Partially Replacing Coarse Aggregates by Plastic Waste Materials on Concrete Properties

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A lot of severe environmental problems are caused every day by the disposal of wastes in a non-environmental way in landfills. For this reason, in order to reduce the environmental impacts and to use more resources in an efficient way, reusing the demolishing waste became an urgent need. For this purpose, a 30 MPa concrete mix was made with the following replacement percentages: 0%, 10%, 15%, and 20% of plastic waste as a partial replacement of the Coarse aggregates. The fresh concrete properties of the four mixes were determined by the slump test (mm) and the air content test (%). With regards to the tests on hardened concrete, the test of compressive strength was carried out at seven, fourteen, and twenty-eight days on cylindrical of diameter equal to 150 mm and height equal to 300mm; in plus to the tests which was done at 28 days for water absorption and the tensile strength tests. In a conclusion, the replacement of coarse aggregate partially by plastic waste materials showed an unclearly effect on the fresh on the concrete mixes properties. While 15% of plastic waste particles gave, at 28 days, higher compressive strength and the moisture content and the tensile strength decreased

Key Words*:* Plastic waste, environment, partial replacement of coarse aggregates, compressive strength, concrete properties.

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List of Abbreviations

CA:	Coarse Aggregate
FA:	Fine Aggregate
FM:	Fineness Modulus
GMI:	Green MED Initiative
PWP:	Plastic Waste Particles
MSW:	Municipal Solid Waste
OPC:	Ordinary Portland Cement
SSD:	Saturated Surface Dry
SCC:	Self-Compacting Concrete
PVC:	Polyvinyl Chloride
σs:	Compressive Strength
σc:	Splitting Tensile Strength
σf:	Flexural Strength
PA:	Plastic aggregate

CHAPTER I

Introduction to Solid Waste Management in Lebanon

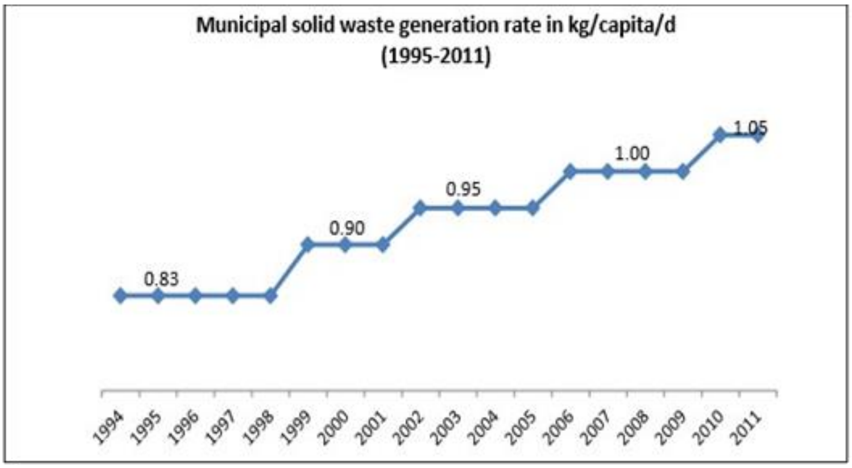
This chapter will discuss waste plastic in Lebanon in general, including an introduction, a problem statement, and the study's objective.

Solid Waste Sector in Lebanon

Lebanon has 5.8 million people and a population density of 560 people/km2, considered as one of the highest densities in the world. The municipal solid waste (MSW) generation has increased significantly from 0.83 kg/capita/day in 1995 to 1.05 kg/capita/day in 2011 and is still increasing; Figure 1 shows an increasing of 26% in the overall Municipal Solid Waste generation rate in Lebanon between 1994 and 2011 (MOE/GEF/UNDP, 2015)..

Figure 1

MSW Generation in Lebanon between 1995 and 2011



Lebanon is suffering every day from specific and deep-rooted problems that are affecting the collection, treatment and disposal of municipal solid waste. Since 1997, the Lebanese waste sector faced an emergency municipal solid waste management plan that ended in July 2015(MOE). The culmination in the current national crisis of trash was mainly caused by the premature closure of the largest sanitary landfill in Lebanon located in Al Naameh in July 2015 (Figure 2).

Figure 2

Naameh Landfill

These problems have led to significant social, economic and environmental difficulties. In Lebanon, the open dumping as shown in Figure 3 and Figure 4, and open burning of municipal waste as shown in Figure 5 is a common and widely accepted practice. Naameh landfill, Zahle landfill, and Tripoli controlled dumpsite, are the three main landfills in Lebanon that deal with only 55% of the total solid waste in Lebanon generated since 1998. The rest is either recycled/composted by some factories and some environmental communities or disposed in an open dumpsite by the local authorities represented by the municipalities or unions of municipalities.

Figure 3

Saida Dumpsite

The lack of a strategy that deals with the problem in a sustainable manner that includes the provision of some basic information such the waste composition and waste quantities in addition to the failure in implementing some relevant laws and regulations that define the needed activities to improve the waste management and waste utilization, and the failure in coordinating the activities of stakeholders have been identified as further key shortcomings in the sector.

Figure 4

MSW Dumped on The Beach of Saida And Burned on The Roads

Regardless all the studies that described the problems affecting the waste sector in Lebanon and addressing some of the specific aspects that could help in solving this problem, like feasibility studies and comprehensive strategies in order to improve the situation step by step; There is a top urgent need for a sustainable solution, that could plan for a way that deal with the problem in a sustainable way, as the current situation is causing environmental, economic and social impacts that are destroying day after day the beautiful nature of large parts of Lebanon.

Excavation in Lebanon

Coarse aggregate production is responsible for different kind of pollution in addition to the high amount of energy needed for the manufacturing process, starting by the extraction from the site and ending by the factory production. In addition, it can transform glorious green areas to barren deserts such in Figure 5.

Figure 5

Green Area Before and After Excavation

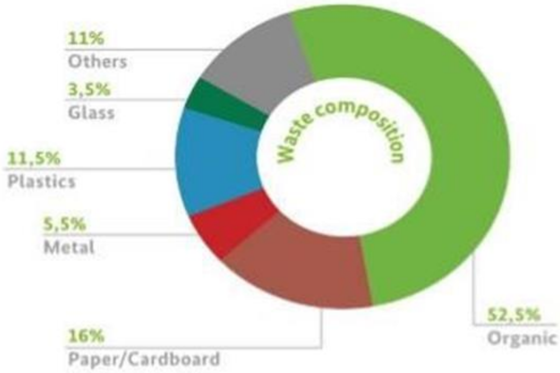
Plastic Waste Generation in Lebanon

Nowadays, the way that most of the countries are using to get rid of their waste is becoming a very serious problem. For this reason, regenerating and reusing some wastes as new resources is becoming an urgent need to reduce the environmental pollution and all the negative impacts that the waste is causing every day.

Simultaneously, millions of tons of plastic waste are being generated annually all over the world and only limited amount is used towards the production of new plastic products. According to GMI, Lebanon produces 2.04 million tons of municipal solid waste per year and plastic represents 11.5 % of this amount (Figure 6). Once the plastic becomes a waste, it is disposed at landfills, which is unsustainable because plastic is an inorganic material that cannot be naturally decomposed; in conclusion, Lebanon disposes more than 234000 tons of plastic waste at landfills that will stay there forever.

Figure 6

Waste Composition in Lebanon (GMI: The Green MED Initiative)



Concrete is becoming one of the most consumed material after the water worldwide, due to the rapid growth of structures. The global concrete industry consumes around 10 billion tons of aggregates, and produces over 1 billion tons of construction and demolition waste annually.

One possible solution is to use plastic waste as a partial replacement of coarse aggregates in new concrete mixtures that helps reducing the toxic gases resulting from quarries and valorizes plastic waste particles instead of being dumped in landfills.

Problem Statement

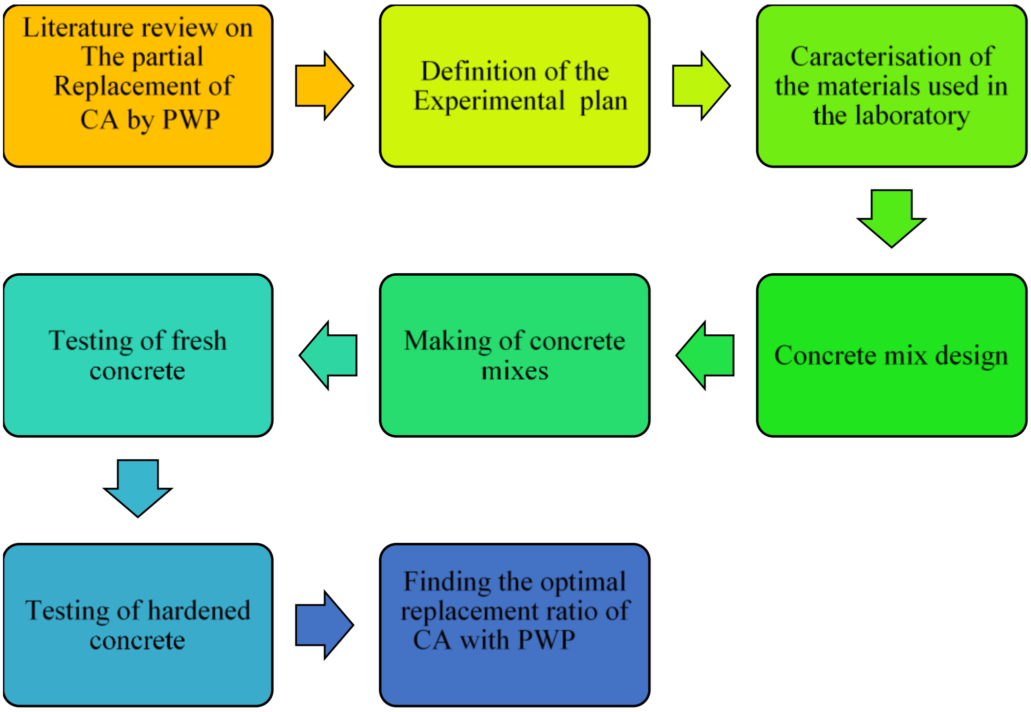
Study of the Feasibility of Partially Replacing Coarse Aggregate with Waste Plastic to Improve Concrete Properties. Many investigations on the qualities of plastic wastes, such as irrigation and agriculture pipes/pumps, have been done. We utilized scrap Polyethylene Terephthalate (PET) bottles as a substitute for coarse materials in this project. Aggregates in concrete are quite costly and have a significant role in the self-weight of concrete components in any concreting project. So we, as engineers, face us problems from the high weight in concrete and by replacing partial coarse aggregates, by plastic, we will be able to reduce the weight of concrete.

Thesis Objective

The main reason of this study is to create a better environment that is free from polluted spaces, and to valorize the waste plastic material, by transforming them into smaller particles size that will be partially replacing the coarse aggregates in the concrete mixes. In order to experimentally verify the effect of the partial replacement of coarse aggregates by plastic particles in concrete, a literature review was first carried out in order to set the experimental plan. A characterization of the materials used in the laboratory in order to adjust the concrete mix design followed. Concrete mixes with different replacement ratios of CA by (PWP) were then made and specimens were prepared. Testing on fresh and hardened concrete were made in order to compare the concrete containing PWP to a reference concrete. The optimal replacement ratio of CA with (PWP) was finally determined. Figure 7 show us the processes.

Figure 7

Methodology of Work



CHAPTER II

Literature Review and Experimental Plan

The past key efforts on the characteristics of concrete have been briefly mentioned and explained in this chapter.

Introduction

Different authors of the bibliography studied the effects of recycled PWP as a partial replacement of CA on the mechanical properties of concrete. Replacing the polymer with cement binders may produce polymer concrete, but its production is very expensive due to the high cost of conventional resins. Thus, many researchers focused on producing resin from waste PET bottles for use in polymer concrete to lower the price of resin produced according to a natural one. (Rebeiz et al., 1991; Rebes, 1995; Rebes and Fowler, 1996; Abdul Azim, 1996; Tawfiq and Iskander, 2006). Nevertheless, the production of polymer concrete from PET bottles is still very high.

Another way is to convert waste PET bottles into plastic fibers and use them to make reinforced concrete fibers (Silva et al., 2005; Ochi et al., 2007). But the quantity of plastic fiber that can be added to concrete is still very low (0.3% up to 1.5%, then it does not seem an effective way to eliminate the huge amount of PET waste bottles.

The last method that one looks most reasonable is to use PET waste bottles and plastic aggregates in concrete, so it is possible to produce lightweight concrete, eliminate plastic waste PET bottles, reduce the environmental problem, reduce the use of totals Natural, which in turn reduces the distortion of nature due to the spread of total crushers in the mountains.

Plastic use has become largely everywhere around the world lately, this makes huge amounts of existing plastic waste. Plastic waste is currently a real natural hazard to the evolving way of life.

Plastic waste is not buried in landfill because of its extensive and moderate the rate of deterioration. Reusing plastic waste to deliver the latest materials such as aggregate in cement may be among other answers to disposal, due to their financial and natural preferences.

In concrete, various types of plastic waste are used as aggregates, fibres or fillers after mechanical handling. They contain polyethylene terephthalate bottles (PET), polyvinyl chloride, PVC channels, high-density polyethylene (HDPE), thermosetting plastic, blended plastic waste, extended polystyrene, polyurethane foam, polycarbonate, reinforced plastic glass (Akcaoz S, Atais CD and Akcaoglu K. 2010).

Joining plastic aggregates (PA), or plastic fibers (PF) can basically enhance many concrete properties because PA has higher rigidity, greater abrasive behavior, lower thermal connectivity and higher thermal capacity than conventional totals.

Plastic aggregates are mainly very light weight compared to normal aggregate (NA) and along these lines, its fuse brings down the densities of the subsequent concrete (Saikia N & de Brito J., 2010).

This feature can be used to create lightweight concrete. However, the integration of PA into concrete has some negative effects, for example, low workability and poor mechanical behavior (Saikia N & de Brito J., 2010).

Polyethylene Terephthalate Particles' Effects on Concrete Properties

Fresh concrete properties

Several factors impact the workability of PET concrete, including the water-cement ratio (w/c), the percentage level of PET aggregate, and the size of the PET aggregate.

Albano et al. (2009) claimed that increasing the fine aggregate replacement quantity with waste PET bottles reduces the workability of concrete; nevertheless, it was revealed that the higher the w/c ratio, the greater effect this addition has on the workability. Furthermore, he asserted that when PET particle sizes get larger, the detrimental impact on workability will grow. Two distinct w/c ratios (0.5 and 0.6) were employed in this investigation, as well as two different recycled PET replacement levels (10 and 20% by volume) and two different particle sizes (0.26, 1.14 cm) (Albano, 2009).

Choi et al. (2005), on the other hand, reported that the slump test of fresh concrete increased from 10 to 22.3 cm with 75 percent substitution of bottled lightweight aggregate (WPLA), implying a 123 percent increase in workability over the control. This might be due to WPLA's spherical and soft nature, as well as its low absorption rate (Choi, 2005).

Frigione (2010) discovered that when fine aggregate is substituted with waste PET bottles aggregates (WPET) at a rate of 5% by weight, the workability of the concrete is somewhat poorer than normal concrete. (Frigione, 2010)

According to Azhdarpour et al (2016), the results of experimental research showed that adding plastic particles derived from PET bottles to concrete changed its physical qualities. As the PET concentration of the concrete grew, the UPV and density of the concrete decreased (Azhdarpour, 2016).

Concrete's mechanical properties

Choi (2005) used WPET to partially substitute fine particles as lightweight aggregates in concrete with granulated blast furnace slag (GBFS). After 28 days, it was revealed that when using a w/c ratio of 0.73, the c of a specimen containing 25% WPET by volume of the entire mix as sand is reduced by roughly 6% when compared to conventional concrete and by around 9% when compared to concrete with a w/c of 0.45. For w/c of 0.73, the reductions were 19 percent, and for w/c of 0.45, they were 15 percent (Choi, 2005).

It is accounted for in a subsequent publication (Choi et al., 2009) the use of lightweight aggregate produced from waste PET bottles (WPLA) covered with fine particles. WPLA aggregates have a water absorption rate of roughly 0%, which can help to correct the deformities of regular lightweight gravels, which have a high water absorption rate. The flow of WPLA mortar increased significantly as the percentage of plastic aggregate in the mortar rose. Similarly, the mortar σc (compressive strength) tended to decrease as the replacement amount of WPLA increased. After 28 days, the σc (compressive strength) of WPLA concrete specimens was lowered by 5, 15, and 30% compared to conventional lightweight concrete, when the waste PET bottle aggregates percentages in the mixture were 25, 50, and 75%, respectively (Choi, 2009).

Different researchers investigated the performance of two separate mortars, the first built entirely of WPET aggregates and the second made entirely of WPET and fine aggregates (Akcaozog lu et al., 2010). Furthermore, blast-furnace slag was used as a concrete substitute (at half of substitution on weight premise proportion). The WPET/binder ratio and the water/binder (w/b) ratio used in the mixes were 0.45 and 0.50, respectively. The crushed WPET particles used in the mortar combinations ranged in size from 0 to 4 mm. According to the results of the experiment, mortar containing only WPET, mortar including WPET and regular sand, and mortar using slag as a bond substitute may all be termed lightweight concrete based on the strength qualities and unit weight. Finally, the mortar containing WPET aggregates shrank faster than the mortar comprising both WPET aggregate and regular sand.

Albano (2009) investigated the mechanical characteristics of concrete using two different w/c ratios (0.5 and 0.6), two different degrees of recycled PET replacement (10 and 20% by volume of aggregate), and two different plastic sizes (0.26 and 1.14 cm). The results showed that as the volume extent and molecular size of WPET increased, WPET-filled concrete revealed a decrease in σs (Splitting Tensile Strength), σc (compressive strength), modulus of elasticity, and UPV, as well as an increase in water absorption rate. In any event, the fact that the concrete samples were not entirely compacted was accounted for. Similarly, they revealed the formation of pores, which had a significant impact on the quality parameters (Albano, 2009).

Pezzi et al. (2006) used WPET as aggregate in concrete and evaluated the physical and mechanical properties of the mixtures. The integration of WPET with sizes ranging from 15 to 25 mm in amounts up to 10% by volume of an aggregate of entire mix did not result in significant changes in σs (compressive strength) at low w/c ratios (Pezzi, 2006).

When the replacement level reached 50%, the drop in σs (Splitting Tensile Strength) was 32.8 percent. Marzouk et al. (2007) investigated the use of discarded PET bottle aggregates in concrete after they had been separated, washed, and crushed. The substitution level of WPET was determined by the amount of fine aggregate in the whole mixture. The experiment revealed that plastic particles might be used efficiently as fine aggregates in concrete. When the percentage level of WPET inclusion increased from 0 to 50 percent, the σs (Splitting Tensile Strength) of mortar steadily decreased by roughly 16 percent in comparison to regular concrete (Marzouk, 2007).

Ismail and AL-Hashmi (2008) researched in concrete the likelihood of utilizing different wastes of plastic, comprising around 20 % polystyrene and 80 % polyethylene, as sand replacement, with sizes up to 4.75 mm. The outcomes reveal that when the plastic content in concrete increased, the compressive strength tended to decrease at different curing age. When the plastic waste was added by 10 %, the concrete showed the most reduced σc (compressive strength) after 28 days of curing, the loss reached around 30 % compared with the control mix (Ismail, 2008).

Frigione (2010) discovered that when fine aggregate is substituted with waste PET bottle aggregates (WPET) at 5% by weight, the loss of σs(Splitting Tensile Strength) is rather modest in contrast to conventional concrete (-0.02 MPa). This decrease, was larger at higher w/c ratios (Frigione, 2010).

According to Jaivignesh and Sofi (2017), as the percentage of WPET added rose from 10% to 20%, σs (Splitting Tensile Strength) decreased from 10% to 24% when compared to the reference concrete. Similarly, the σf (flexural strength) decrease ranged between 20 and 30 percent (Jaivignesh, 2017).

Sadrmomtazi et al. (2016) reported that in self-compacting concrete when the replacement level of waste PET aggregates was 5% and the proportion of cement substituted with silica fume was 10%, the σf(flexural strength) of the mixture fell by up to 14.7% compared to the reference at 28 days. Furthermore, when WPET concentration is 10% and 30% fly ash is used to substitute cement, this decrease reaches 34.6 percent. As a result, including WPET into the concrete has a significant impact on lowering the f of self-compacting concrete (SCC). Similarly, leftover PET particles in SCC mixtures reduce concrete specimens' splitting tensile strength. Expanding the PET component from 5% to 15% reduces the σs (compressive strength) of concrete samples by about 48.8%. They also said that when the PET concentration grows, the ultrasonic pulse velocity (UPV) rates decrease because WPET raises the porosity rate of the mixes (Sadrmomtazi, 2016).

Azhdarpour et al. (2016) found that when the replacement ratios of fine aggregate by waste PET aggregates in concrete were 5 and 10%, the σs(compressive strength), σc(splitting tensile strength), and σf(flexural strength) of the specimens rose. But, when the replacement level above 10%, all the mechanical parameters of the concrete samples declined. As a result, utilizing polyethylene terephthalate as aggregates improves the mechanical characteristics of concrete if the fine aggregate substitution level with PET particles does not exceed 10% (Azhdarpour, 2016).

Absorption of water

According to Akcaozoglu et al. (2010), mortars containing both WPET and regular sand (Mix3 and Mix4) had lower water absorption than mortars having only WPET (Mix1 and Mix2). Regardless, the porosity ratios of M1 and M2 mixes were lower than those of M3 and M4 mixes (Akçaözoğlu, 2010).

Sadrmomtazi et al. (2016) found that adding WPET enhanced the water absorption rates of all mixes. This is due to the flat surface of PET aggregates and the restriction of cement hydration rate in WPSCC mixtures.

According to Saiki and Brito (2013), adding WPET to concrete samples up to a 10% substitution level improves permeability (Sadrmomtazi, 2016).

Using Plastic Bottle Wastes in Concrete.

T. Ochi a, (2007) employed it in this study to make concrete PET fiber from discarded PET bottles with a 3 percent content. Extrusion apparatus for monofilaments has been used to make the PET bottles fibers with different lengths varies between 30mm to 40mm and a diameter of 0.7mm. In this paper, three water-cement ratios were tested using the bending test (65, 60, 55 percent), and four different substitution levels of recycled PET were used (0%, 0.5%, 1.0%, and 1.5% by volume). When the percentage of plastic fibers increases the bending strength went up. In the compression test, there were 12 test samples, exactly as there were in the bending test. Despite the fact that there is some variety, for all water and cement ratios there is no significant difference in these qualities related with the diverse pet fiber contents. For all examples, the pressure at maximum load will hardly change with various ratios of water, cement and different PET fiber contents (Ochi, 2007).

Doraa Foti (2011), they started by adding low dosage of plastic fibers (2% of the concrete weight). They have two types of fibers a sample of short lamellar fibers (length 32mm) and a "O"Fiber (round shaped plastic) samples (section 20.1mm2). They compared the reinforcement concrete with fiber and without fibers according to bending ability and they divided the specimens into six different groups made up of three different mixtures (1 piece of regular concrete 2 lamellar concrete with short fibers 3 "O"Fibers" Concrete). The bending test is used to test the tensile strength and inflection of the specimens the results showed that there is no difference between the two specimens in terms of tensile strength, they show a big difference between in terms of inflection (Foti, 2011).

As a result of the findings of prior experiments, we decided to make new samples with a varying and developing fiber content. The "O" fiber has a diameter of 6 cm and a breadth of roughly 5 mm, according to the study. The short lamellar fibers, on the other hand, have a width of 5 mm and a length of 35 mm. Three samples of commonly encountered concrete were found to be devoid of fibers. Three samples with a dosage of "O" fiber equal to 0.75 percent of the sample's maximal weight. Four samples containing a dosage of 0.50 percent "O" fibers and four samples containing a dose of 0.50 percent short lamellar fibers were generated. It has been shown in the tensile strength test a big different between normal concrete and concrete with different values of plastic.

The results of compression testing show that fibre samples have lower resistance than those found simply in concrete.

José Luis Ruiz-Herrero et al (2015), in this study it has been used two different plastic (polyethylene and PVC residues coming out of sheath protective electrical cables) with five different percentages (0%, 2.5%,5%,10%,20%). Density, porosity, water absorption, and carbonization behaviour were all investigated. The development of mechanical characteristics over time (compression and flexural). As a results density decreased when the percentages of plastic increased. In additional, there is a positive correlation between porosity and plastic quantities. Also, between carbonation depth and plastic quantity there is positive correlation. But about compression strength and flexural strength when increasing the amount of plastic, we noticed a significant decrease especially in samples with more than 10% plastic.

Ms K.Ramadevi, Ms. R. Manju (2012), in this paper it has been different percentages of PET bottle fiber (1%, 2%, 4% and 6%) and compared with normal concrete. It has been taken 3 types of specimens (cubes, cylinder and prism), after seven days and 28 days, 18 specimens were shed and tested. Compression, tensile splitting, and flexural strength tests were performed. The compressive strength increased significantly until 2% of the fine aggregate was replaced by PET bottle fibers, after which the compressive strength steadily decreased. It is seen that the split tensile strength of the cylinder improves until 2% of the fine aggregate is replaced by PET bottle fibers, and then decreases significantly as the fine aggregate replacement increases. The flexural strength of the samples steadily improves as fine aggregate is replaced with PET bottle fibres, as the proportion of replacement increases, nonetheless, it's possible decrease with respect to a more replacement rate because it is somewhat the same for 4% and 6%. Finally, the publisher recommended to use a concrete with plastic percentage not more than 2% (Manoj, 2016).

Marzouk et al. (2007) studied the use of PET bottles as a coordination for natural aggregate in concrete, and ended up successfully replacing the exact natural fine aggregate with shredded PET plastic bottles in concrete successfully. (Marzouk, 2007)

More recently, self-compacting concrete (SCC) has been investigated. It is a very workable and cohesive concrete that does not need to vibrate after casting, due to its ability to consolidate by your weight.

Using Glass in Concrete

There are also many other studies that take another topic into consideration to save the environment; the results of the most important studies that are related to the topic of using glass and recycled aggregates in concrete as a partial replacement of cement and Coarse aggregates respectively are the following:

Hongjian Du and Kiang Hwee Tan (2014) turned trash bear bottles – soda lime glass into 75 m diameter powder in their study on waste glass powder as cement replacement in concrete. Their goal was to research the pozzolanic response of GP for up to 60% cement replacement and its impact on the microstructure of cement paste, which had never been studied before. The compressive strength and resistance to chloride and water penetration of concrete with the same cement replacement levels as the paste were tested. In this study, the design compressive strength was 48 MPa, with four percentages of glass powder replacing cement in the concrete mixes. Partial Replacement of Cement by Glass Waste Powder: 15, 30, 45 percent, and 60% by weight of cement. Moreover, instead of replacing the cement, an extra 15% of glass powder was added to the control mix. Because of the dilution of cement in the mix, the rate and total heat produced during hydration decreased with increasing glass powder concentration. At 28 days, 30 percent cement replacement with glass powder resulted in the maximum compressive strength (49 MPa), whereas at 91 days, the compressive strength was 55 MPa.

Manoj Kumar et al. (2016), have demonstrated that the use of the glass waste powder can be used in mixture as partial replacement of the cement material for normal concrete with (10%, 20%, and 30%) can increase at 28 days within 20% of the compressive and flexural tensile strengths. The workability test showed an increase in slump with the increase of the percentage of replacement (Manoj, 2016).

Roz-Ud-Din Nassar et. al. (2011), came up with a conclusion that the usage of waste glass that is pulverized into micro-scale particle size, as a partial replacement of cement develops the concrete characteristics: the resistance of moisture absorption, and destructive transportation. Consequently, 20 % replacement of cement by glass waste powder improved various features of concrete such as resistance to abrasion, long-term strength and resilience properties (Roz, 2011).

Shao et al. (2000) established that concrete that has 30% glass powder smaller than 38 μm did not show higher compressive strength up until 90 days after curing; the strength activity index was 91, 84, 96, and 108 % at 7, 28, and 90 days, correspondingly (Shao, 2000).

As seen in the preceding literature, there are a lot of materials than can substitute the components of concrete; the plastic waste is one of these materials that could be a possible solution to decrease the usage of Coarse Aggregates without affecting the compressive strength the strength at a certain concentration; therefore, using PWP as a partial replacement of the CA in concrete mixes is possible when plastic is crushed into smaller particles.

Definition of the Experimental Plan

Lebanon In this study, a concrete mix having compressive strength of 30 MPa was made with different replacement ratios of coarse aggregates by plastic waste particles, following the 10 steps of concrete mix design (Absolute Volume Method).

The different percentages of coarse aggregates replacement by the plastic waste particles are the following: 0%, 10%, 15%, and 20%. This resulted in four concrete mixes that were prepared and tested in the laboratory. The tests on fresh concrete included the slump test, and the air content test.

The compressive strength test on hardened concrete for the different concrete mixes was performed at 7, 14 and 28 days (3 specimens were tested at each age); therefore 9 specimens were tested for the compressive strength, and one extra specimen will be tested for the indirect tensile strength test. In total 40 cylinders of 150 mm diameter and 300 mm height were made for each concrete mix. In addition, the water absorption test was made to evaluate the effect of the plastic waste material as partially replacement of coarse aggregates on the porosity of concrete. Data analysis of this study aims to find out the optimum replacement ratio of coarse aggregates by the plastic waste material.

Disadvantages of using plastic

Throughout my research, I discovered that the disadvantages of using plastic in concrete are numerous, and most of the articles I read mentioned the same downsides. The main disadvantages of using plastics in concrete are as follows:

- Because plastics have poor bonding properties, the strength of concrete, such as compressive, tensile, and flexural strength, is reduced.
- Because of its low melting point, it cannot be used in furnaces because it melts when it comes into contact with high-temperature heat.

CHAPTER III

Material Characterizations

This chapter (experimental process and materials) explains in detail the steps used in all of the tests and techniques carried out in accordance with international standards

Overview

The used materials include ordinary Portland cement (OPC), water, sand (FA), and coarse aggregates (CA), in addition to the plastic waste particles (PWP) as a partial replacement of coarse aggregates.

Cement

The used Portland cement is manufactured by Holcim (Liban) S.A.L.; the fabrication is based on the Lebanese specification LIBNOR (NL 53:1999) for the cement PA-L, 42.5.The specific gravity of the ordinary cement is 3.15 and its density is 1551 kg/m3. The Chemical Analysis of cement is presented in Table 1 and its physical properties are presented in Table 2 accordingly.

Table 1.

Chemical Analysis of Cement

Component	**%**	
Fire Loss	9.66	
SiO_2	16.32	
Al_2O_3	3.8	
Fe_2O_3	2.8	
CaO	61.14	
MgO	1.333	
SO_3	2.9	3.50 Maximum
K_2O	0.24	
Na_2O	0.2	
TiO_2	0.41	
Mn_2O_3	0.041	
P2O5	0.25	
Cl	0	0.10 Maximum
Total	99.1	

Table 2.

Physical Properties of Cement

Blaine (cm^2/g)	5372		3000 Minimum
Expansion (mm) The Chatelier	0.1		10 Maximum
Initial setting Time (minutes) (Vicat)	145		75 Minimum
Compression Resistance (N/mm^2)	2 Days	18.6	
	7 Days	33.3	
	28 Days	49.1	Min 46 - Max 50

Plastic Waste Particles

The plastic waste was first of all collected from Hasan Al Baba factory for plastic production, located at Al-Mina North Lebanon, the plastic was shredded into particles of less than 4.75 mm diameter. The needed amount of the PWP for the four mixes was about 10 kg, including the cylinders and the fresh concrete testing. All the plastic that is used in this research was a mixed colored plastic coming from bottles from different usage. The density of the used PWP was 1300 kg/m^3.

Fine Aggregates

Grading

The needs of ASTM C 33 or AASHTO M 6/M 43 allow a fairly wide-ranging in the fine-aggregate range, on the other hand, other facilities have restrictions on their specifications. The most desired fine-aggregate grading relies on several factors such as the nature of work, the maximum size of coarse aggregates, and the richness of the mixture. To obtain the required workability in a leaner mixture, use small-size coarse aggregates and a range strategy that aims for the highest possible percentage of aggregates passing each sieve is recommended. Generally, when the water-cement ratio doesn't change and the ratio of fine-to-coarse aggregates is selected appropriately, a wide spectrum in grading is acceptable with no effect on the strength.

In contrast, economical wise the finest concrete mixture is achieved by regulating the concrete mixture to work out with the gradation of the local aggregates. The ASTM C 33 (AASHTO M 6) limits with respect to sieve size and the available fine-aggregate grading are presented in Table 3 and Table 4 respectively.

Table 3.

Fine-Aggregate Grading Limits (ASTM C 33/AASHTO M 6)

Percent Passing by Mass		
Sieve Opening (mm)	**Upper limit**	**lower limit**
4.75	100 %	95 %
2.36	100 %	80 %
1.18	85 %	50 %
0.6	60 %	25 %
0.3	30 %	5 %
0.15	10 %	0 %

Table 4.

Available Fine-Aggregate Grading Results

Percent Passing by Mass	
Sieve opening (mm)	**Available FA**
4.75	100
2.36	95.1
1.18	85.8
0.6	62.5
0.3	6.1
0.15	1.8

Figure 8.

Grading Curves of the Used FA and the Limits Specified in ASTM C 33

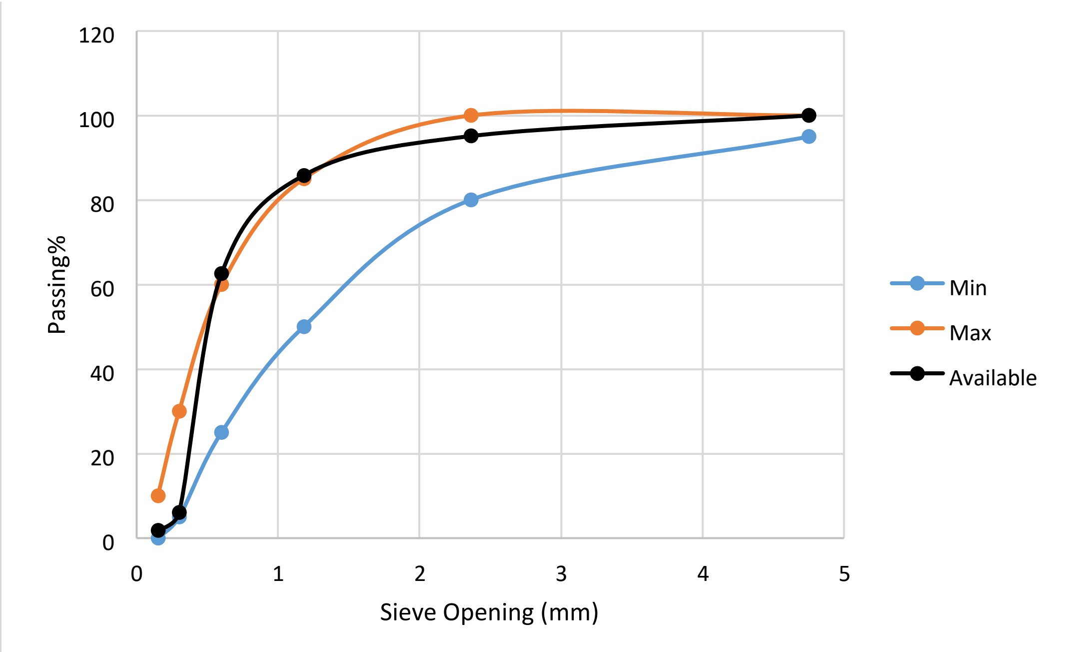


Figure 8 represents the grading and the grading limits that are expressed as the percentage of material passing each sieve of the fine aggregates. As mentioned before, a wide range in grading can be used without a measurable effect on strength when the water-cement ratio is not changed and the ratio of fine-to-coarse aggregate is precisely selected; that's why, there is no problem if we use the available fine aggregate even if its graph did not fit between the limits.

Fineness Modulus

According to ASTM C 125, the fineness modulus of aggregates, whether coarse or fine, is calculated as follows: Divide the total by 100 after adding the growing percent by mass retained on each of the indicated series of sieves. It should be noted that dissimilar aggregate ranges may have the same FM. The Fineness Modulus is used in concrete mixtures to approximate the proportions of fine and coarse aggregates. Table 5 shows the fine aggregate fineness modulus. Friction and abrasion will degrade the fine aggregates which will reduce the FM and increase the quantity of materials smaller than the 75 µm (No. 200: Pan) sieve.

Table 5.

Determination of Fineness Modulus of Fine Aggregates

Sieve opening (mm)	**Mass Retained (g)**	**% Retained**	**Cumulative % Retained**
4.75	0	0	0
2.36	62.8	4.8	4.8
1.18	75.5	5.8	10.7
0.6	256.7	19.9	30.6
0.3	728.5	56.5	87.1
0.15	129.5	10	97.18
Pan	36.4	2.8	100
Total	1289.4		Sum = 327 FM = 327 ÷ 100 = 3.27

Figure 9.

Fine Aggregates of Diameter Less Than 4.75 mm

Specific Gravity and Absorption

Specific gravity according to (ASTM C 128) is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. The specific gravity of water at a temperature of 23°C (73.4 °F) is 1.0. For example, an aggregate that has specific gravity equal to 2.0 would be two times as heavy as water with the equal volume. To calculate solid volume, the specific gravity is used. (solid volume doesn't change and is a constant parameter in mixture designs)

Absorption leads to an increase in mass as a result of the water absorbed in the pores of the material. The amount of water that will be absorbed by an aggregate is vital in the mix design constraints in addition to the quality control of the produced material. To determine the specific gravity and the water absorption of the fine aggregates, the following weights should be recorded:

A: Oven dry weight (Figure 11)

B: the weight of a Pycnometer filled with water in relation to its adjusted capacity (Figure 10)

C: Pycnometer weight and SSD sample loaded to its preset capacity

S: SSD sample weight (Figure 10)

- Bulk specific gravity (dry) = A / (B+S-C)
- Bulk specific gravity (SSD) = S/(B+S-C)
- Apparent specific gravity = A/ (B+A-C)
- Absorption = (S-A)/A×100

Figure 10.

Pycnometer Filled with Water and the FA at the SSD state

Figure 11.

Fine Aggregates (Dry Sample)

In order to avoid the adjustment of the required quantity of water at each time before mixing the ingredients of each concrete mix, the fine aggregates have been dried in the oven till constant mass. Table 6 represents the physical properties of fine aggregates that will be used in the preparation of each concrete mix

Table 6.

Physical Properties of Fine Aggregates

Bulk specific gravity (Dry)	2.55
Bulk specific gravity (SSD)	2.58
Apparent specific gravity (Dry)	2.62
Absorption (%)	1.1 %
Moisture Content (%)	0%
Fineness Modulus	3.27

Coarse Aggregates

Grading:

ASTM C 33 (AASHTO M 80) coarse aggregate grading requests allow for a variable range of grading and size variability. The maximum size of aggregate that can be used is determined by a variety of factors. For example, the shape and size of the concrete member, as well as the distribution of buttress steel. Aggregate size is related to the strength of concrete thus it may vary slightly for equal water-cement ratio. For instance, concrete mixtures, with a less maximum-size concrete might have greater compressive strength (specifically true for high-strength concrete) noting that mixtures have same water cement ratio.

The ASTM C 33 upper and lower limits of coarse aggregates considering the sieve size are presented in Table 7 and the coarse aggregate grading results are shown in Table 8.

Table 7.

Coarse-Aggregate Grading Limits (ASTM C 33))

Percent Passing by Mass		
Sieve Opening (mm)	**Upper limit**	**lower limit**
25	100%	100%
19	100%	100%
12.5	100%	90%
9.5	70%	40%
4.75	15%	0%
2.36	5%	0%

Table 8.

Available Coarse-Aggregate Grading

Percent Passing by Mass	
Sieve Opening (mm)	**Available CA**
25	100
19	98.2
12.5	96.4
9.5	65.5
4.75	3.79
2.36	2.4

Figure 12.

Grading Curves of the CA Used and the Limits Specified in ASTM C 33

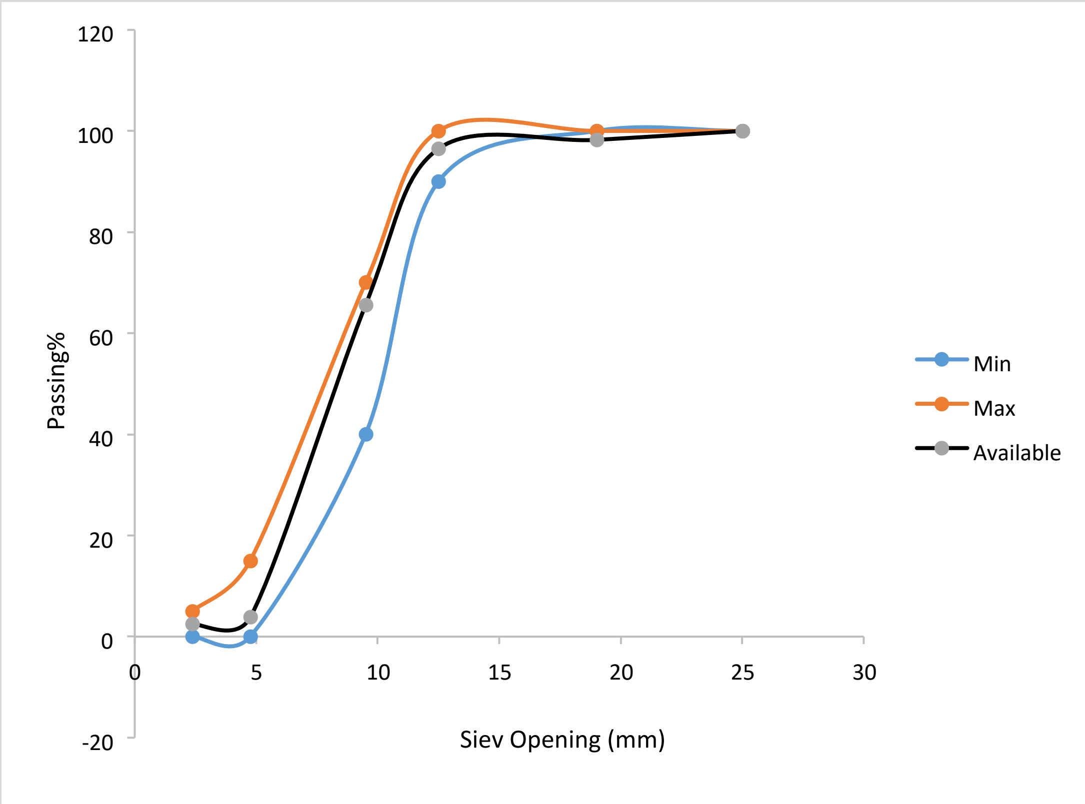


Figure 12 shows that the grading of the available coarse aggregate is not 100% within the range determined by the lower and upper limits but is still acceptable.

Specific Gravity and Absorption

The aggregate's relative density (specific gravity) is represented as the ratio of its mass to the mass of an equal absolute volume of water. It is used in certain calculations for control and mixture proportioning; for instance, it's used in the absolute volume technique of mix design as a whole by finding the volume occupied by the aggregate. It is not used in determining the quality of the use aggregate, however some porous aggregates that demonstrate accelerated freeze-thaw deterioration have low specific gravities. The relative densities of most aggregates ranges between 2.39 and 2.89 with particle (mass) densities of 1500 and 2900 kg per m^3 respectively.

The relative densities of coarse and fine aggregates are assessed using ASTM C 127 (AASHTO T 85) and ASTM C 128 test techniques (AASHTO T 84). An aggregate's relative density can be calculated on an oven dry or a saturated surface dry

(SSD) basis. The relative densities (oven dry and saturated surface-dry) are used in calculations in proportion of concrete mixes.

To determine the specific gravity and the water absorption of the coarse aggregates, the following weights should be recorded:

B: SSD sample Weight in air (Figure 13)

A: oven dry weight of the sample

C: SSD sample weight in water (Figure 14)

Now the specific gravity and absorption for the aggregate can be computed as follows:

- Bulk specific gravity (dry) = A/(B-C)
- Bulk specific gravity (SSD) = B/(B-C)
- Apparent specific gravity = A/(A-C)
- Absorption = ((B-A))/A× 100

Figure 13.

Coarse Aggregates (SSD Sample)

Figure 14.

Weight of the SSD sample in water

In order to avoid the adjustment of the required quantity of water at each time before mixing the ingredients of each concrete mix, coarse aggregates have been dried until a constant mass.

Table 9 represents the physical properties of coarse aggregates that will be used in the preparation of each concrete mix.

Table 9.

Physical Properties of Coarse Aggregates

Bulk specific gravity (Dry)	2.60
Bulk specific gravity (SSD)	2.63
Apparent specific gravity (Dry)	2.67
Absorption	0.9 %
Moisture Content	0 %
Density	1635 Kg/m³

Concrete Mix Design (30 MPa)

The Conditions and Specifications

•The Concrete is required for slabs, columns and footings that should have low permeability when exposed to water.

•30 MP of compressive is required for 28 days.

•I noticed that there was no air entry.

•Slump test limits are (25 mm-75 mm).

•Moderate sulfate exposure.

•19 mm should be the maximum size of the aggregate.

•I couldn't observe any statistical data regarding previous mixes.

- Cement: PA-L 42.5 with respect to LIBNOR (NL 53:1999) with a relative density of 3.15
- Coarse aggregates: 19-mm nominal maximum-size gravel with an oven dry relative density of 2.60, absorption of 0.9 % (moisture content at SSD condition) and oven dry rodded bulk density (unit weight) of 1635 kg/m^3. The sample of laboratory for trial batches is dried until it reaches a moisture content of 0 %.
- Fine aggregates: Natural sand with an oven dry relative density of 2.55 and an absorption of 1.1 %. The laboratory sample for trial batching is dried until it reaches a moisture content of 0%. The fineness modulus is 3.27.

Computation of the required quantities of each concrete ingredient is determined using the absolute volume method that follows 10 steps described below.

Step 1 - Required Compressive Strength. Concerning the exposure condition, the required design strength of 30 MPa is more than the 28 MPa needed in Table 10 and for sulfate exposure in Table 11; so the minimum design compressive strength is 30 MPa.

Table 10.

Maximum Required Water-Cementitious Material Ratios and Minimum Design Strengths for Different Exposure Conditions.

Exposure condition	For concrete, the maximum water-cementitious material ratio by mass	Minimum design compressive strength, MPa (psi)
Deicing chemicals or aggressive substances are used to protect concrete from freezing and thawing.	Select water-cementitious material ratio on basis of strength, workability, and finishing needs	Strength should be chosen depending on structural needs.
When exposed to water, concrete is designed to have low permeability.	0.5	28 (4000)
Deicers or concrete subjected to freezing and thawing in a damp environment	0.44	31 (4500)
To prevent reinforced concrete against chloride corrosion induced by deicing salts, saltwater, brackish water, seawater, nor spray from all these sources.	0.4	35 (5000)

Table 11.

Requirements for Concrete Exposed to Sulfates in Soil or Water

Sulfate exposure	Water-soluble sulfate (SO*) in soil, percent by mass*	Sulfate (SO4) in water, ppm*	Type of cement **	Max water-cementitious materials mass ratio	Minimum compressive strength required for design.MPa(psi)
negligible trace	Less 010	Less 150	There is no specific type required.	--	--
Moderate^	0.1 to 0 2	150 to 1500	II, MS, IP(MS), IS(MS). P(MS). I(PMXMS), I(SM)(MS)	050	28 (4000)
Severe	0.20 to 2 00	1500 to10,000	V, HS	045	31 (4500)
Very severe	Over 2.00	Over 10,000	V, HS	040	35 (5000)

Table 12.

Required Average compressive strength used without known data

Specified compressive strength, MPa	Average compressive strength is required. A'rr MPa
fewer than 21	*f* +7.0
21 to 35	+3.5
Over 35	t.10/c +5.0

Step 2 - Water-to-Cement Ratio. The suggested water to cementitious material ratio for f'cr of 38.5 MPa can be calculated by interpolation from Table 13: $\frac{(40-38.5)\,(0.47-0.42)}{(40-35)} + 0.42 = 0.435$

Table 13.

Water-to-Cementitious-Material-Ratio Relationship

Compressive strength at 2S days. MPa	By mass, the water-cementitious material ratio	
	Non-air-entrained concrete	Air-entrained concrete
45	**0.33**	**0.30**
40	**0.42**	**0.34**
35	**0.47**	**0.39**
30	**0.54**	**0.45**
25	**0.61**	**052**
20	**0.66**	**0.60**
15	**0.79**	**0.70**

Another suggested water to cement ratio is 0.5, that is determined from Table 10 and 3.11 respectively that is based on the exposure condition and sulfate exposure; while the least water-cement ratio controls, the mix should be planned for W/C = 0.435.

Step 3 - Air Content. Based on Table 14, a recommendation of a recommended air content of 2 % for a 19-mm maximum size of aggregate. The mixture is therefore designed for 2 % air for batch proportions. The air content in the trial batch must be in between ±0.5 percent points of the maximal allowed air content.

Step 4 – Slump. The slump is indicated at a range from 25 mm to 75 mm. Take 75 mm plus or minus 20 mm for proportional targets.

Step 5 - Water Content. Referring to Table 14, water content should be about 205 kg/m^3

The water content is determined based on:

- 75-mm slump,

- non-air-entrained concrete prepared with 19mm nominal maximum-size aggregate

Table 14.

Approximate Requirements for Mixing Water and Target Air Content for Different Slumps and Nominal

Slump, mm	Water, kilos per cubic meter of concrete, using the aggregate sizes indicated*							
	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm"	75 mm"	150 mm*'
	Non-air-entrained concrete							
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	02
	Air-entrained concrete							
25 to 60	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	—
Recommended average total air content, percent, for level of exposure:?								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Severe exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

Step 6 - Cement Content. The cement content is determined by the maximum water content and the water-cement ratio. Hence, divide the 205 kg per m³ of water with a water cement ratio of 0.435 needs a cement content of 471 kg per m³; the obtained value is more than 320 kg per m³ mandatory for resistance of frost in Table 15. Since the higher cement content governs, the mix must be designed for 471 kg of cement per 1 m³ of concrete.

Table 15.

Minimal Requirements of Cementing Materials for Concrete Utilized

The aggregate's nominal maximum size, mm fin.)	**Materials for cementing,** IqW **(lb/yd')**r
37.5 (114)	280 (470)
(1)	310 (520)
19 (%)	320 (540)
12.5 C14)	350 (590)
9.5 (K)	350 (610)

Step 7 - Coarse-Aggregate Content. From Table 16, estimate the amount of 19-mm nominal maximum-size coarse aggregate. When using sand that has a fineness modulus of 3.27, the bulk volume of coarse aggregate suggested is 0.573 (using interpolation). The bulk density of coarse aggregate is 1635 kg/m3; then for a cubic meter of concrete, the oven dry mass of coarse aggregate can be calculated as the following:

Oven dry mass = $bulk\ density \times bulk\ volume = 1635\ x\ 0.573 = 937\ kg.$

Table 16.
Bulk Volume of Coarse Aggregate per Unit Volume of Concrete

Nominal maximum of aggregate.		**Dry-redded coarse aggregate bulk volume per unit Concrete volume for various different fineness moduli of fine aggregate**			
mm	(in.)	**2.40**	**2.60**	**2.80**	**3.00**
9.5	(*)	0.50	0.48	0.46	0.44
12.5	33	0.59	0.57	0.55	0.53
19	W	0.66	0.64	0.62	0.60
25	(1}	0.71	0.69	0.67	0.65
37.5	(1HJ	0.75	0.73	0.71	0.69
50	(2)	0.79	0.76	0.74	0.72
75	<3>	0.82	0,80	0.78	0.76
150	(6}	0.87	0.85	0.83	0.81

Step 8 - Admixture Content. No admixtures were used.

Step 9 - Fine-Aggregate Content. Till this step, all the ingredients' amounts are known except of the fine aggregates. To calculate the volume of fine aggregates, the absolute volume method is used by subtracting the absolute volumes of the identified ingredients from 1 cubic meter. To calculate the absolute volumes of the water, cement, admixtures and coarse aggregate divide each mass's known mass ingredient by the product of the relative density of each ingredient and the density of water.

The following are the volume calculations:

- Water = 205/1000 = 0.205 m^3
- Cement = 471 /3150 = 0.15 m^3
- Air = 2/100 = 0.020 m^3
- Coarse aggregate = 937/2630= 0.356 m^3

The total volume of known ingredients = 0.73 m^3

Absolute volume of fine aggregate = 1 – 0.73 = 0.27 m^3

Weight of dry fine aggregate = 0.27 x 2.58 x 1000 = 694 kg

Step 10 - Moisture correction. Corrections are required to take into consideration the moisture found in the aggregate and on the surface of the aggregate. On site, aggregates have some quantifiable amount of moisture. Hence, the dry batch weights of the aggregates should be expand to take for the moisture that is present on the surface of each particle, between the particles, and absorbed moisture in the aggregates. Consequently, the amount of mixing water added to the batch should be decreased by the amount of free moisture of the aggregates. In this thesis the coarse aggregate and the fine aggregate were dried until they reached a constant weight, therefore, the moisture content of the coarse aggregate and fine-aggregate is 0%. Based on moisture content of the aggregate indicated, the trial batch aggregate proportions remain the same.

Required Mixing water =

$$\text{mass of water} - \text{dry mass of fine aggregate}\left(\frac{\text{moisture content} - \text{absorption}}{100}\right) - \text{dry mass of coarse aggregate}\left(\frac{\text{moisture content} - \text{absorption}}{100}\right)$$

Mixing water required $=205 - 697\,\frac{(0-1.1)}{100} - 937\,\frac{(0-0.9)}{100}$=221 kg for 1 m^3 of concrete.

The volume of each mix, consists the volume of 10 cylinders (0.053 m3).

Table 17 shows the required mass of each concrete ingredient to prepare 0.053 m^3 of mix 1 (0% of replacement of the CA by Shredded Plastic Waste).

Table 17.

Mix Proportions of the Controlled Mix (30MPa)

Material	Mass (kg)
Cement	25
Shredded Plastic	0
FA	36.7
CA	49.7
Water	11.7

When replacing the CA by PWP waste powder, the only mass that will be changed is the mass of coarse aggregates, whereas all the other masses will remain the same. Table 18 shows the mix proportions for 10%, 15% and 20% s of coarse aggregates by the shredded plastic waste particles.

Table 18.

Mix proportions of 10%, 15%, 20% and 25% Replacement of

Replacement Level %		**Cement Kg**	**Plastic Waste Particles Kg**	**Fine Aggregate Kg**	**Coarse Aggregate Kg**	**Water Kg**
Mix 2	10%	25	3.9	36.8	44.7	11.7
Mix 3	15%	25	5.9	36.8	42.2	11.7
Mix 4	20%	25	7.9	36.8	39.7	11.7

Preparation of Concrete Mixes

Concrete should be mixed well till it reaches a homogeneous appearance, where all of the ingredients are evenly dispersed. Mixer can't not be overloaded and must be functional at the labelled capacity and speed capacity specified by the industrial unit. If concrete was mixed properly, Samples collected from different parts of a batch should have roughly identical density, air content, slump, and coarse-aggregate content. Figure 15 shows the concrete mix after adding water in the concrete mixer. Whereas, Figure 16 represents the concrete cylinders at fresh state.

Figure 15.

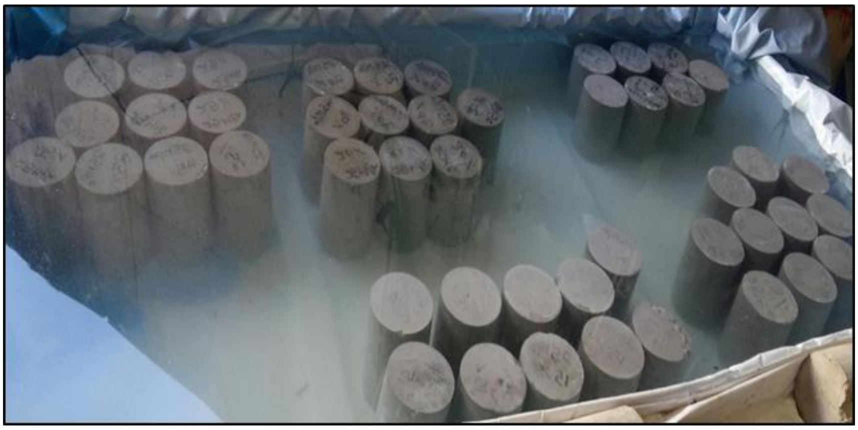
Concrete ingredients with water in the mixer

Figure 16.

Cylinders Filled With Concrete at Fresh State

Figure 17:

Cylinders cured in the water tank



CHAPTER IV

Characterization of Concrete with Partial Replacement of Ca by Pwp

The conclusions drawn from the experiments and analyses are presented in this chapter.

Overview

Testing of fresh and hardened concrete is required to monitor the construction process as well as ensure that desirable concrete properties are achieved. Quality control and acceptance testing are necessary parts of the construction process to confirm that the proprieties are obtained. Making judgments about mix adjustments based on the test findings, which give essential feedback; therefore, it is necessary to check the fresh and hardened concrete properties of the concrete mixes in order to find out, how PWP with different percentages of replacement affects the concrete mixes.

Routine standard tests for fresh concrete include air content test, slump test, flow test, and compacting factor test. The most common tests of hardened concrete are measuring the compressive strength, indirect tensile strength test and/or flexural strength test. Other tests of hardened concrete that could be considered include methods to assess volume change, durability in freeze-thaw environments, absorption/permeability, and microstructural characterization. In this thesis, the tests on fresh and hardened concrete that were evaluated are the following: slump test and air content test, compressive strength test, indirect tensile strength test and water absorption test.

Fresh Concrete Tests

Slump Test

We implied the slump test, ASTM C 143 (AASHTO T 119), which is a well-known method for determining the consistency of concrete. A slump cone (a metal conical mold 300 mm high with a 200-mm diameter base and a 100-mm diameter top) and a steel bar with a 16 mm diameter and a 600 mm tall with a hemispherical shaped tip form the test apparatus. Three layers of roughly equal volume must be filled into the damped slump cone. And positioned upright on a level, non-absorbent hard surface. Filling the cone should go as follows:

1-Depth 70 mm for the first layer

2-Depth of 160 mm for the second layer

3-Overfilled for the third layer.

25 times, each layer is rodded. (Figure 18).

After rodding the cone, the final layer is removed vertically, the cone is slowly raised 30mm in 5 (plus and minus 2 seconds) (Figure 19). As the concrete get stabilized to a new height, invert the empty slump cone and gently placing it beside the settled concrete. The settled concrete is slumped, measured to the nearest 5 mm; the original center of the subsided concrete to calculate from the top of the slump cone (mold) to the displaced by using value considering the bigger slump value aw expressive of more fluid concrete see (Figure 20).

Figure 18.

Slump Cone Filled to its Third Layer

Figure 19.

Slump Cone while Removed

Figure 20.

Slump Measurement

Table 19 and Figure 21 represent the variation of the slump value with the variation of the percentage of replacement of the coarse aggregates by the plastic waste particles for the concrete mix of 30 MPa designed concrete grade.

Table 19.

Slump Values for Different Percentages of Replacement (30 MPa).

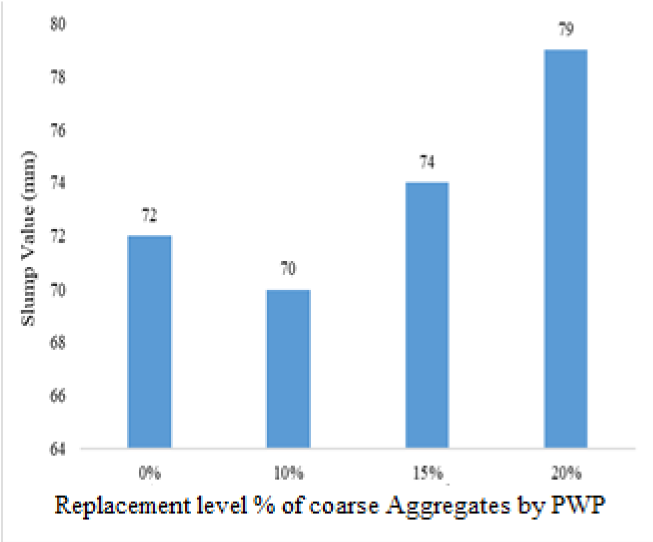
% of Replacement	**Slump Value (mm)**
0%	72
10%	70
15%	74
20%	79

As shown, the control mix did not exceed the slump height set in the design of this concrete mix; 72 mm is still below the maximum slump value indicated in the mix design (75 mm).

We can notice that the addition of the plastic waste particles as partial replacement of the coarse aggregates had increased the value of the slump, which made the concrete mix at each percentage of replacement more fluid. This can be justified by the decrease of the percentage of coarse aggregates that are supposed to absorb the water, what the plastic cannot do as it is an unabsorbent material.

Figure 21.

Slump Test Results



Air Content Test

The air voids provide empty spaces within the concrete that act as reservoirs for the freezing water, relieving pressure and preventing damage to the concrete. Too many methods can be used to measure air content of freshly mixed. Concrete such as:

1-ASTM standards include the pressure method (C 231) (AASHTO T 152).

2-The volumetric method (C 173) (AASHTO T 196).

3-The gravimetric method (C 138) (AASHTO T 121).

The pressure method which relates pressure to volume, is based on Boyle’s law. Calibration for commercial air meters is required to read air content directly when a predetermined pressure is applied. The air, within the concrete sample including the air in the pores of aggregates compressed by applying pressure. This method is not appropriate for determining the air content of concrete made with some lightweight aggregates or other very porous materials. To obtain the correct air content, deduct the aggregate correction factors that recover for air trapped in normal-weight aggregates from the pressure meter gauge reading. Calibrated instruments should be used for various elevations above sea level if this instrument will be used in locations with significant elevation differences.

Few meters are not affected by changes in elevation, make use of a known air volume's pressure change. Widely, pressure meters are used as the specific gravities and mix proportions of the concrete ingredients need not be known. Also, conducting test in less time than is needed for other methods. In measuring bowl, the concrete is placed in three layers that have equal volume.

Using the tamping rod, 25 strokes, distributed over the cross section each layer of concrete is unified. Following rodding of each layer, the bowl sides are tapped smartly 10to 15 times with the hammer to shut voids caused by the tamping rod in addition to emitting any big bubbles of air that could have been confined. Then over its depth, the bottom layer is rodded, but the rod shall not unwillingly hit the bottom of the measure. In the process of rodding the second and final layers, only enough force to permit the rod to penetrate the surface of the preceding layer about one in should be used. After the concrete consolidation, the upper surface is stroke off by moving the strike-off bar in sliding through the top flange or edge of the measuring bowl with a cutting motion till the bowl is of full level. On consolidation completion, the bowl should not have an excess or deficit amount of concrete.

The flanges or rims of the bowl are then cleaned as well as the cover assembly in order when the cover is compressed in place a pressure-tight seal will be obtained. The device is then assembled then water is added over the concrete by a tube till it rises to about the midway marked in the standpipe, then the air content is read at the gauge (Figure 22).

Figure 22.

Air Content test

Table 20 and Figure 23 represent the variation of the Air Content with the variation of the percentage of replacement of the coarse aggregates by the plastic waste particles for the designed 30 MPa concrete mix.

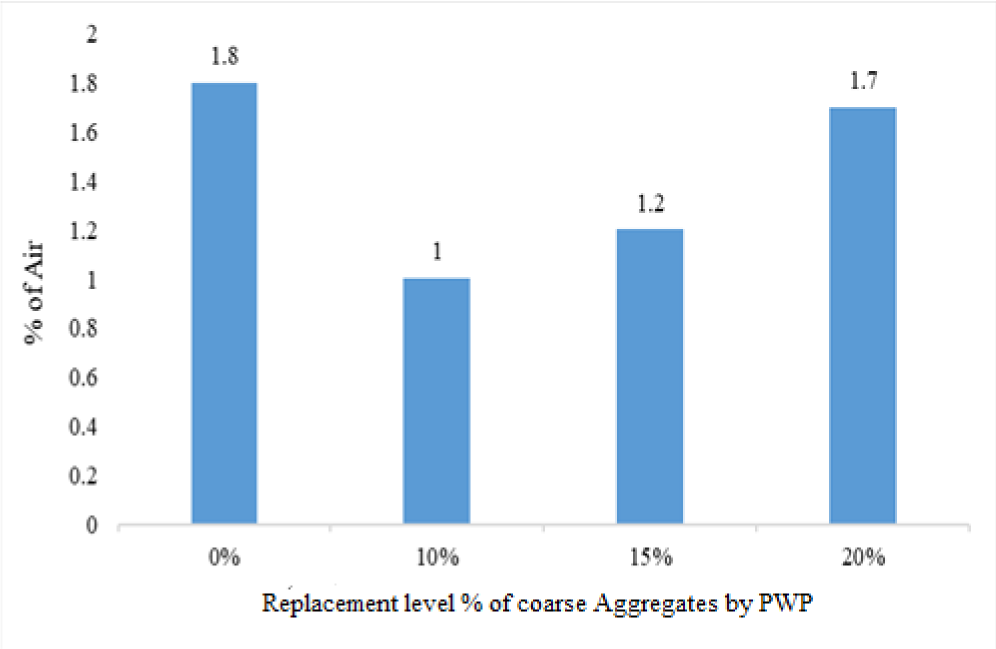
Table 20.

Air Content for Different Percentages of Replacement (30 MPa)

% of Replacement	**Air Content %**
0%	1.8
10%	1
15%	1.9
20%	1.7

Figure 23.

Air Content Test Results



The results show no clear effect of the Plastic Waste Particles on the air content in fresh concrete. The results obtained are close and within the calculated air content for non-air entrained concrete specified in the concrete mix design that was 2%.

Hardened Concrete Tests

Strength testing is an integral part of the mixture design process and construction monitoring for concrete. According to ASTM C 39 (AASHTO T 22) the test of specimen should be done for compressive strength and ASTM C 496 (AASHTO T 198) for splitting Tensile strength.

Compressive Strength Test

The compressive strength test is a test process that apply a compressive axial load to precast cylinders or cores at a rate that are at a recommended range till failure happens. The compressive strength of the specimen is compute by dividing the maximum load reached in the test by the specimen's cross-sectional.

Figure 24 shows the different types of fractures of cylinders while testing their compressive strength. Whereas Figure 25, represents one of the different types of fracture of the tested cylinders in the laboratory.

Figure 24.

Sketches of Types of Fracture

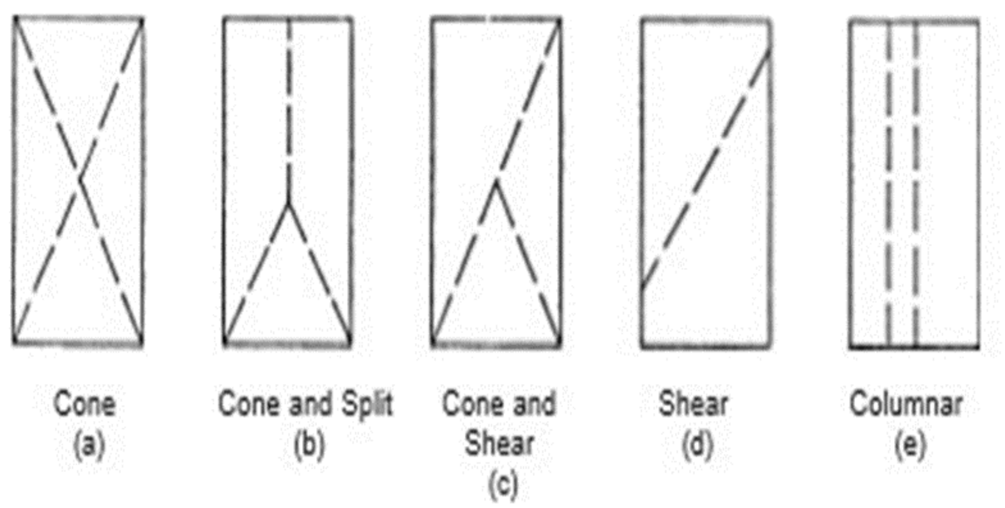


Figure 25.

Columnar Fracture (Result of the compressive strength)

The compressive strength of the original mix design and the four different percentages of replacement of coarse aggregates by PWP at 7 Days (for a target compressive strength 30 MPa at 28 days) are shown in Table 21 and Figure 26 below.

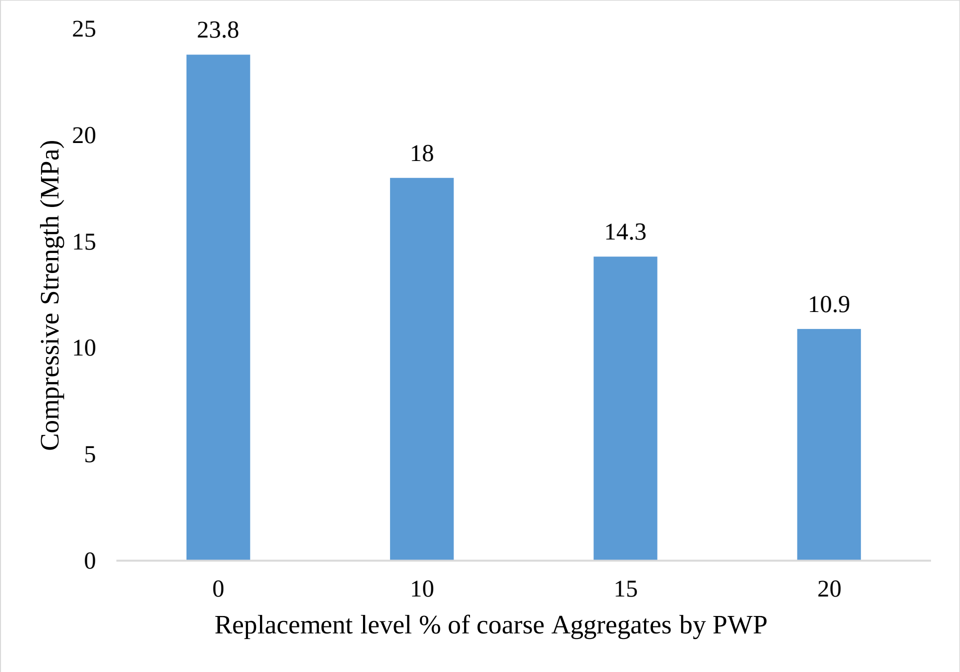
Table 21.

Compressive Strength Test Results at 7 Days

% of Replacement	**f'c (MPa)**
0	23.8
10	18
15	14.3
20	10.9

Figure 26.

Evolution of Compressive Strength at 7 Days



The results point out that the compressive strength decreases when increasing the percentage of replacement of coarse aggregates by PWP; the highest compressive strength at this age (18 MPa) appeared for 10% PWP as a partial replacement of the CA.

Table 22 and Figure 27 represent the developing compressive strength with different percentages of coarse aggregates by PWP at 14 days (for a target compressive strength of 30 MPa at 28 days).

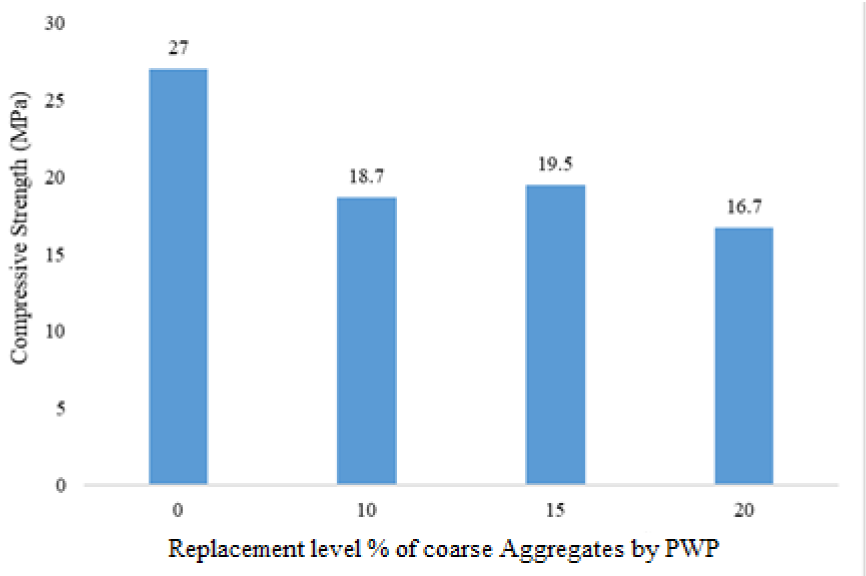
Table 22.

Compressive Strength Test Results at 14 Days

Replacement level %	**f'$_c$ (MPa)**
0	27
10	18.7
15	19.5
20	16.7

Figure 27.

Evolution of Compressive Strength at 14 Days



The results show a reduction in the compressive strength with the increase of the percentage of plastic waste particles, as the case of the age of 14 days; the highest compressive strength at this age (19.5 MPa) was achieved with 15 % of coarse aggregates as a replacement by PWP.

Table 23 and Figure 28 represent the variance of the compressive strength with the variation of the percentages of replacement of the coarse aggregates by Plastic Waste Particles at 28 days (for a target compressive strength of 30 MPa at 28 days).

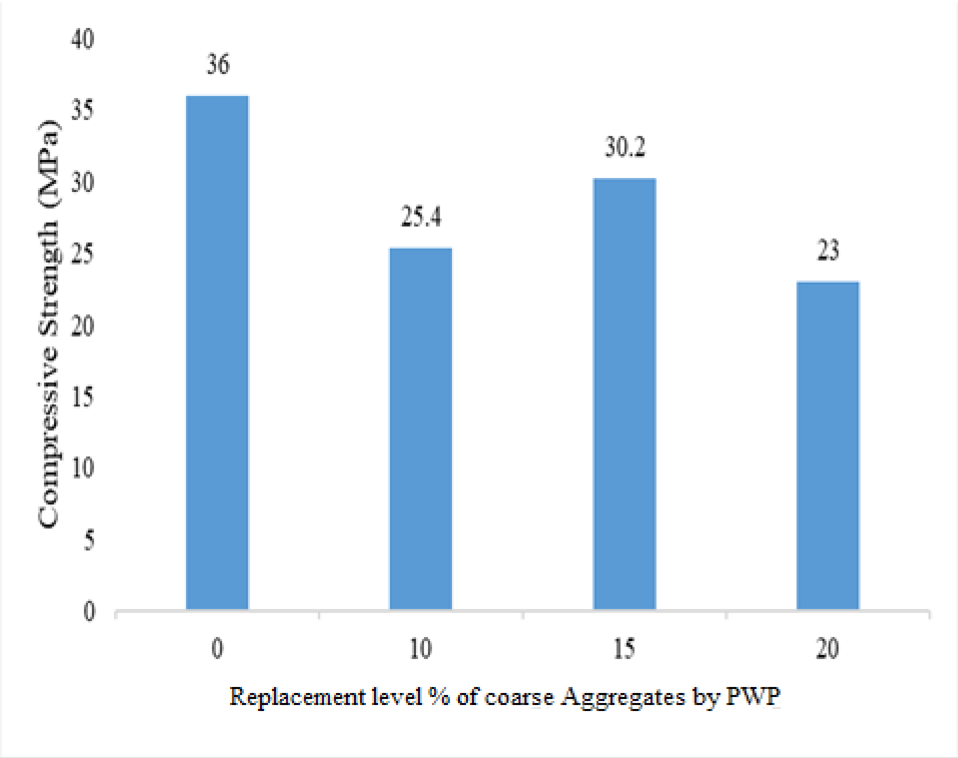
Table 23.

Compressive Strength Test Results after 28 Days

Replacement level %	**f'_c (MPa)**
0	36
10	25.4
15	30.2
20	23

Figure 28.

Evolution of Compressive Strength at 28 Days



At this age the compressive strength show also a decreasing when increasing the percentage of replacement of coarse aggregates by PWP. The highest compressive strength at this age (30.2 MPa) appeared at 15% replacement of coarse aggregates by PWP. When the substitution of plastic waste particles from the large size coarse aggregate was done, the strength automatically decreased because the coarse aggregate is the main pressure point, which means that when any failure happens it starts with the coarse aggregate deficiency then continues to the concrete.

As result, the compressive strength of concrete with varying contents of PWP, at different ages, shows a decrease when increasing the percentage of replacement. The following conclusion may be formed based on the newly gathered data:

At 28 days, the designed compressive strength (30 MPa) was observed for concrete with 15% PWP. However, concrete with 10% and 15% PWP had higher compressive strengths at early ages (18 MPa and 19.5 MPa at 7 days and 14 days respectively) but this increase was not observed in later age strength for both percentages of replacement. Therefore, for a concrete mix with a designed compressive strength of 30 MPa, 15% replacement of coarse aggregates by PWP represent the optimal replacement that does not affect the compressive strength of the mix design at the age of 28 days.

The compressive strengths with the addition of PWP in 30 MPa concrete mix at different ages are given in Figure 181; Compared to that of the control mix, the results were lower. (0% of PWP replacement). The results are arranged to be compared when obtained at 7, 14, and 28 days age, but maximum compressive strength of 30.2 MPa achieved the goal and exceeded the designed compressive strength (30 MPa) at 28 days age with 15% replacement of coarse aggregates by PWP.

Figure 29 represents the development of the compressive strength of 30 MPa concrete mix for 0%, 10%, 15% and 20% of PWP as a partial substitute for cement at 7, 14 and 28 days.

Figure 29.

Evolution of the Compressive Strength of 30 MPa Concrete Mix for 7, 14 and 28 Days at Different percentages of CA by PWP

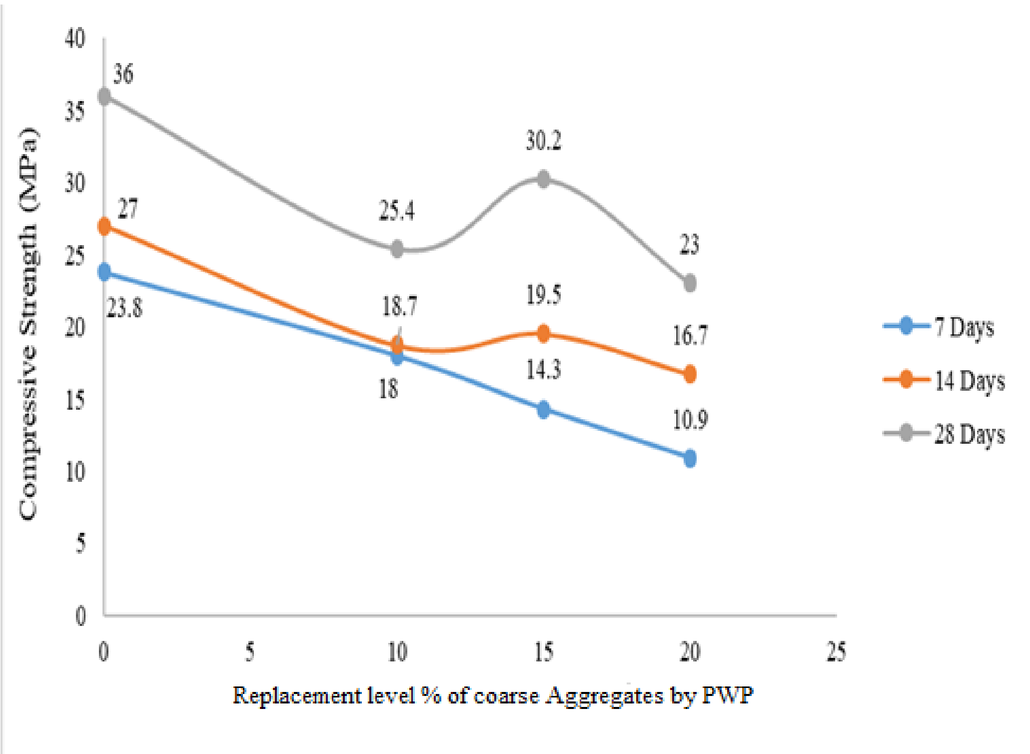
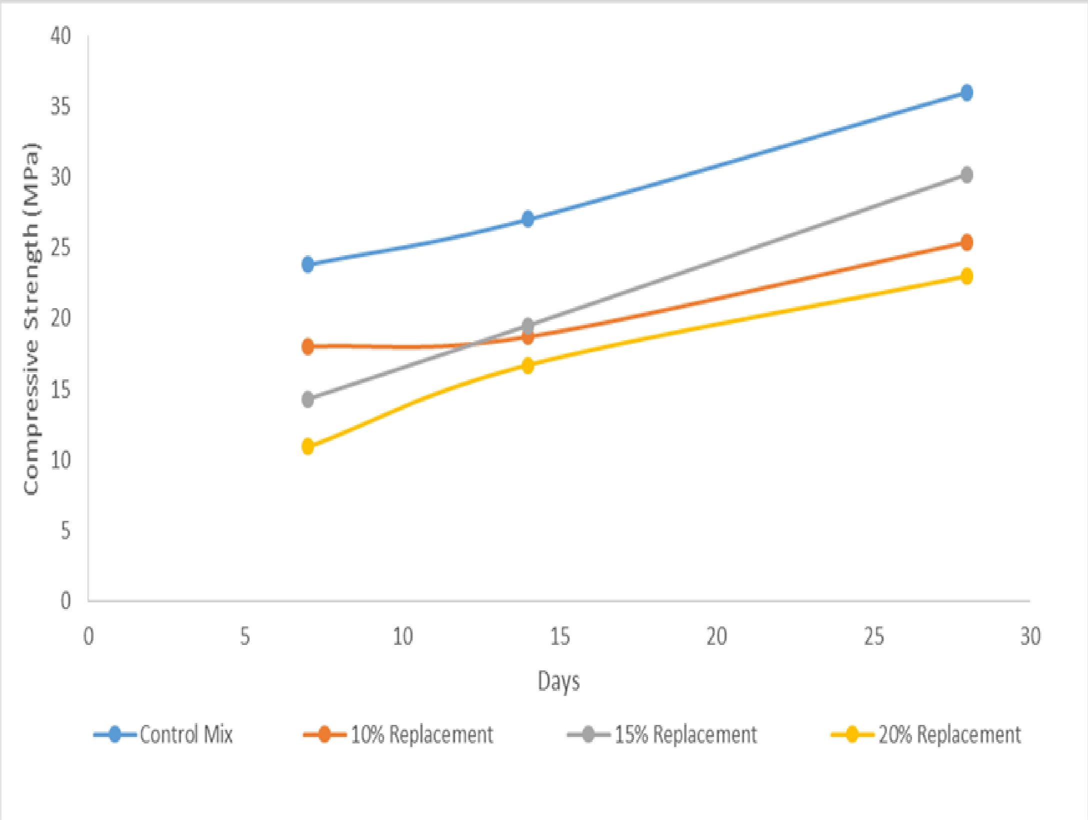


Figure 30.

Evolution of the Compressive Strength for 0%, 10%, 15% and 20% of PWP as Replacement of CA at 7, 14 and 28 Days



Splitting Tensile Strength Test

This test method is a process that applies a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is recommended range till failure happens. This loading produces tensile stresses on the plane where the load is applied and relatively high compressive stresses in the area directly around the applied load. Rather than compressive failure, tensile failure happens due to the state triaxle compression on the areas of the applied load. The specimen's maximum load is divided by suitable geometrical aspects to find the splitting tensile strength.

Generally, splitting tensile strength is more than direct tensile strength and smaller than the flexural strength (modulus of rupture). In the design of structural lightweight concrete, splitting tensile strength is used. The splitting tensile strength is beneficial in evaluating the shear resistance and determining the reinforcement length

Figure 31.

Cylinder positioned for the Indirect tensile strength test

Figure 31 shows a cylinder placed into the machine while testing its tensile strength.

Table 24 and Figure 32 show the variation of the tensile strength with the variation of the percentage of replacement of the CA by PWP for the 30 MPa concrete mix.

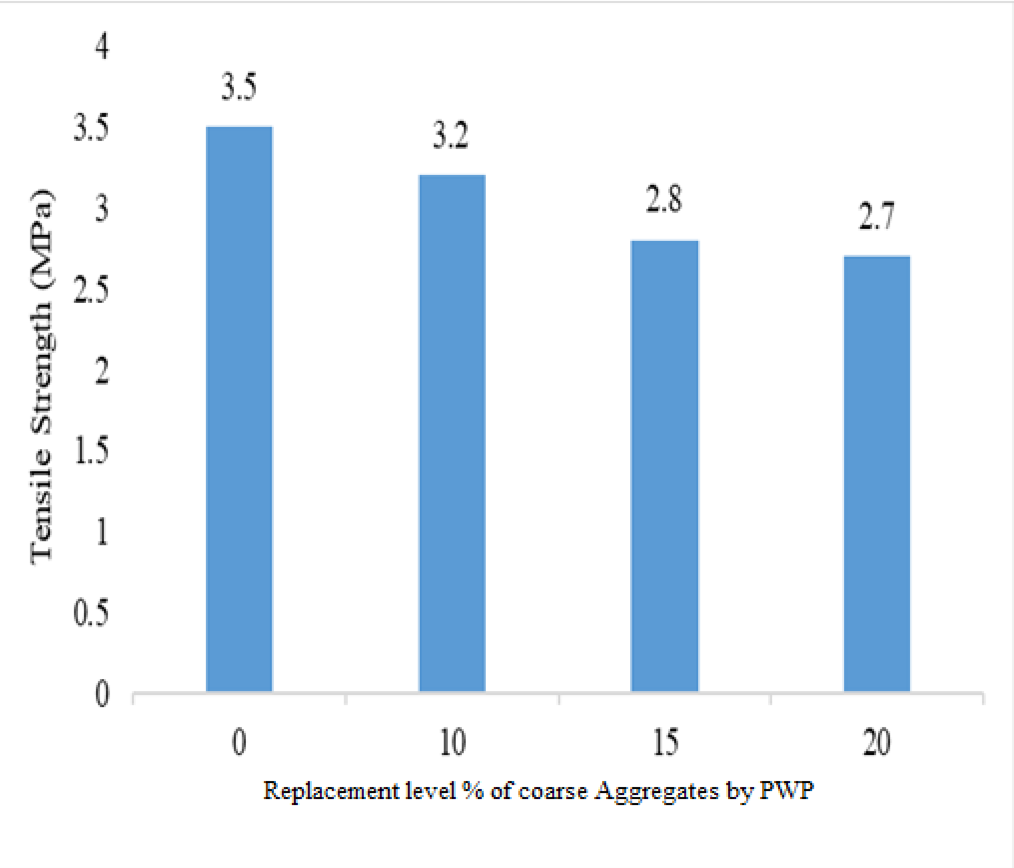
Table 24.

Results of Tensile Strength Test at 28 Days (30 MPa)

% of Replacement	f'c (MPa)
0	3.0
10	2.8
15	2.5
20	2.4

Figure 32.

Evolution of the Tensile Strength at 28 Days



When PWP percentage increases, the tensile strength decreases proportionally. The results show that the tensile strength decreased by 0.3 MPa compared to the control mix with 10% replacement of coarse aggregates by PWP; whereas, it decreases more and more below the tensile strength of the control mix (3.5 MPa) for 15% replacement of coarse aggregates by PWP that showed the highest values at the age of 28 days, compressive strength was measured. Similarly, for 20% and 25%, the tensile strength decreases and goes below the tensile strength of the control mix as the case of the other percentages.

The results show a clear effect of the plastic waste particles on the tensile strength test for 30 MPa concrete mix, where we notice that the results obtained show a decrease in the tensile strength when the percentage of PWP replacing the coarse aggregates increases.

Water Absorption Test

One of the most significant qualities of high-quality concrete, particularly one that is resistant to freezing and thawing, is its low permeability. A low permeability concrete resists water entry and is less vulnerable to chilling and thawing. Water seeps into the pores of the cement mix and even the aggregates.

The test process is drying a specimen to a constant weight, weighing it, immersing it in water for a certain length of time, and weighing it again. The increase in weight as a percentage of the initial weight is referred to as absorption. (In %).

The test samples' average absorption must not be above 5%, with no one unit exceeding 7%.

Oven-Dry Mass. First of all, the mass of the portions was determined; for not less than 24 hours, the mass portions are dried in an oven at a temperature between 100°C and 110°C. Once each specimen are removed from the oven, let the specimen cool in dry air to a temperature of 20 to 25°C; then, we determined the mass.

Designate the final oven-dry mass by A.

Saturated Mass After Immersion. After final drying, cooling, and determination of mass, for not less than 48 hours, immerse the specimen in water at around water temperature 21°C. After taking two successive readings of the mass values at an interval of 24 hours, the mass of surface-dried indicate an increase in mass of less than 0.5 % of the greater value. Then determine the surface-dried mass of the specimen by removing the moisture by a towel. Label B as the final surface-dry mass after immersion.

Absorption after immersion = [(B – A) / A] * 100.

Table 25 represents the water absorption calculation for the 30 MPa Concrete mix at different percentages of Plastic waste particles.

Table 25.

Calculation of Water Absorption of the 30 MPa Concrete at 28 days.

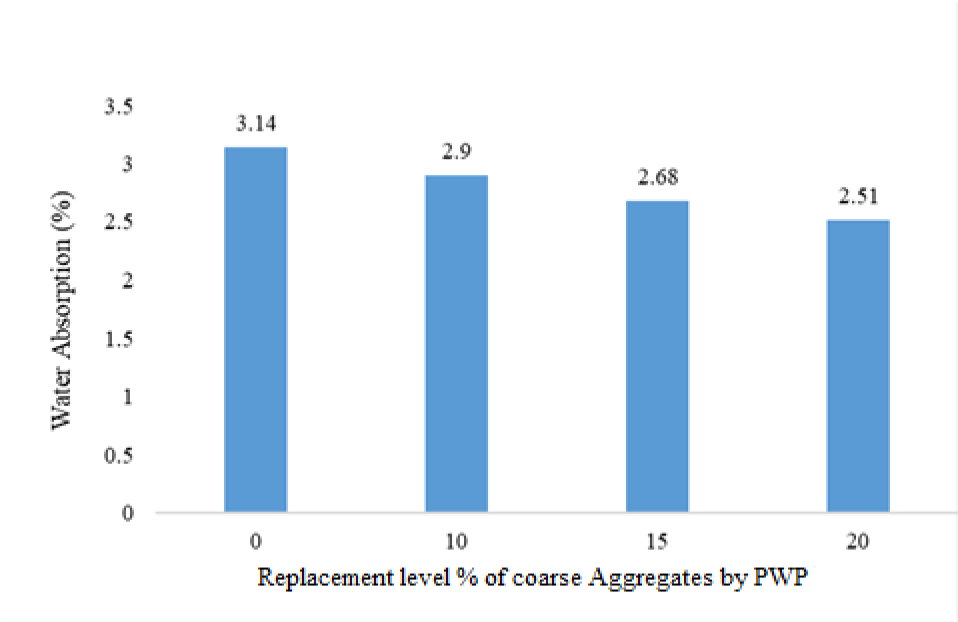
30 MPa					
specimen		Dry Mass (Kg)	Wet Mass (Kg)	Water Absorption (%)	Average (%)
0%	A	3.5	3.61	3.14	3.14
	B	3.51	3.62	3.13	
10%	A	5.49	5.65	2.91	2.90
	B	5.88	6.05	2.89	
15%	A	6.03	6.2	2.82	2.68
	B	5.51	5.65	2.54	
20%	A	5.37	5.5	2.42	2.51
	B	3.46	3.55	2.60	

Figure 33 shows the effect of PWP on the water absorption of concrete specimens when added on concrete as partial replacement of the coarse aggregates.

For concrete mix of 30 MPa, the water absorption decreases when the percentage of plastic waste particles increases; 20% of PWP gave the lowest water absorption (2.51%). This indicate that the replacement of coarse aggregates by PWP is a main factor that should be taken into consideration when such concrete mix is exposed to freeze and thaw cycles, as it is an important factor that could be taken into consideration if we want to reduce the damages in concrete caused by the freeze and thaw cycles in cold areas.

Figure 33.

Evolution of Water Absorption With different Replacement Ratios at 28 days



CHAPTER V

General Conclusions and Recommendations

Several conclusions from this research work are drawn in this chapter, based on the findings of the preceding chapter

In closing

The goal of this research was to reduce the effects of plastic waste particles (PWP) as a partial replacing of coarse aggregates in different concrete mixes. Therefore, to achieve a similar reaction to that of concrete, plastic was shredded, and particles were reduced to less than 10 mm. Then, concrete mixes were prepared and tested for fresh and hardened properties.

The results of the slump test show no clear effect of the partial replacement of coarse aggregate with plastics aggregate; the slump values are adjacent and are within the target values (25 mm to 75 mm). Where PWP at twenty percent demonstrated the towering level of a slump (79 mm), which is proven to be beneficial for boosting workability when mixing plastic waste particles with coarse aggregates, but it’s not effective significantly for the compressive strength. On the opposite hand, PWP at 15% gave a slump of 74 mm which does not exceed the limit specified in the mix design calculations.

Also, the findings of the air content test demonstrate that there is no discernible effect of the plastic waste particles on the air content in fresh concrete for all the percentages of replacement; the results obtained are close and within the measured content air for non-air entrained concrete and at the same time close to the percentage of air in the control mix. Where the measuring of the air contents showed that not only the control mix (0% replacement) had the highest air content (1.8%), but also the concrete mixed with 15% Plastic waste particles had the highest air content (1.9%) for 30 MPa concrete mix. This will lead us to a clear conclusion that states that the plastic waste particles have no effects on the fresh concrete properties at 15% of the total mass of the coarse aggregates needed for the concrete mix of 30MPa.

The compressive strength of developed concretes at different ages were found to be less than normal concrete for the 30 MPa concrete mix. However, at 28 days, the concrete mix with 15% Plastic waste is used to substitute coarse aggregates. Particles

(PWP) exceeds the design compressive strength (30 MPa) by 0.6%, and gave 30.2 MPa.

Concerning the tensile strength of concrete, 15% substitution of coarse aggregates by plastic waste particles in the concrete mix of 30 MPa had decreased the tensile strength of the control mix from 3.5 MPa to 2.8 MPa.

In terms of durability, the concrete mix's water absorption of 30 MPa with 15% GWP has decreased by 0.46 MPa compared with the control mix. Further, construction in cold areas are lift up for such concrete use.

Future Recommendations

To standardize plastic waste particles as a partial replacement of coarse aggregates materials in new concrete mixes, hence the need to undertake more microscopic and hydration investigations for the qualitative and quantitative analysis of hydration and pore fillers based on the physical characteristics and chemical compositions of plastic waste.

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ETHICS LETTER

TO GRADUATE SCHOOL OF APPLIED SCIENCES

REFERENCE: MAHMOUD ALHASAN (20183087)

I would like to inform you that the above candidate is one of our postgraduate students in the Civil Engineering department he is taking a thesis under my supervision and the thesis entailed: **EFFECT OF RECYCLED PWP AS A REPLACEMENT OF COARSE AGGREGATE ON SOME CONCRETE PROPERTIES**. The data used in his study was our data obtained from experimental work conducted by a student in Lebanon.

Please do not hesitate to contact me if you have any further queries or questions.

Thank you very much indeed.

Best Regards,

Assoc. Prof. Dr. Shaban Ismael Albrka Ali

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