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Experimental Study on Mechanical and Physical Properties of Pervious Concrete with Different Admixtures

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Abstract

Pervious concrete pavement is a permeable pavement with a large volume of interconnected voids to satisfy the need for both pavement surface and storm water management. It is made from a mixture of cement, coarse aggregates, and water. However, it contains little or no sand, which results in a porous open-cell structure that water passes through. Enhancement of its physical and mechanical properties is the main objective of this work. Clogging is perceived as a major problem for permeable pavement, so this study is focusing on the clogging phenomena. Eight mixtures of pervious concrete were cast using polypropylene fibers (0.1, 0.15, and 0.2) % by volume of concrete and a waste industrial material (8, 10, 12) % partial replacement of cement as main variables in this research. The specimens were tested at 7, 28, 90 and 120 days. Physical tests included the evaluation of density, water absorption, permeability and clogging. Mechanical tests included the evaluation of compressive strength, splitting tensile strength and flexure strength. The results showed that using polypropylene fiber improved the mechanical properties and water permeability of pervious concrete. The waste industrial material improved the mechanical properties up to 10% replacement of cement. Also increasing the waste industrial material replacement ratio improved the clogging resistance.

Keywords: Pervious Concrete; polypropylene fiber; Industrial waste material; clogging.

1.Introduction

Pervious concrete is a type of concrete with high permeability. It reduces the water runoff from particular site and promotes to ground water recharge. It is also called as "permeable concrete" or "porous concrete" or "no fines" concrete [1,2]. A highly interconnected void content causes high porosity. Pervious concrete has sufficient cementitious paste to coat coarse aggregate particles on preserving the interconnectivity of voids which drains quickly as shown in Figure [1].

Figure [1] Sample of Pervious Concrete [3]

Pervious concrete has been in use for more than (30-50) years, especially in the United States and Japan [4-6]. Several factors should be considered such as the strength of paste, thickness of paste coating the aggregates, and the interface between aggregate and paste. Using smaller coarse aggregates and mineral admixture is suggested as a suitable means to obtain higher strength with pervious concrete. The compressive strength of pervious concrete is related to several factors such as void ratio, unit weight, water-cement ratio, supplementary cementing materials, aggregate size, aggregate to cement ratio and compaction techniques [7,8]. Damage caused by rain water becomes one of the most common failures of highway so pervious concrete is studied as an alternative semi-rigid road base material which can drains out the water entering into the pavement structure to resolve the problem of water damage [9]. Rain water is filtered into ground, which increase and renew ground water table with time. As pavement is air water permeable, the soil underneath is always wet. Pervious concrete pavement can absorb the noise of vehicles, which creates a comfortable environment. In rainy days, the pervious concrete pavement has no plash on the surface and does not bright at night, which insures drivers' safety. Its microstructure has holes that can cumulate heat. It eliminates the phenomenon of hot island in cities. [13, 14] . These advantages make pervious concrete appropriate for a wide range of applications such low-volume pavements, Residential roads, driveways, Parking lots, Low water crossings, Sub base for conventional concrete pavements, Tree grates in sidewalks, Foundations/floors for greenhouses, aquatic amusement centers, Hydraulic structures, and Swimming pool decks [7, 12, 15]. It is an ecofriendly concrete material. Pervious concrete consists of Portland cement, coarse aggregate, little or no fine aggregate, water, and admixtures. These ingredients produce hardened concrete with connected voids [4, 5, 16]. In order to maintain sufficient voids in the material, pervious concrete is usually made up of aggregates sizes in the range of (9.5- 19mm). However, several studies have used coarse aggregates of size (2.36 - 9.5mm) with the main aim to increase the strength properties. The aggregate-to-cement ratio has been varied in the range of 4:1 to as high as 6:1. Typically, the volume of aggregates in pervious concrete is about 50–65% compared to conventional concrete, which is about 60–75% [17]. High range water reducer is introduced in the concrete to improve its strength and workability [18]. The compressive strengths generally fall under the range of 2.8-28 MPa [18, 19]. A small and single-sized aggregate gradation is commonly used to produce pervious concrete, w/c ratio between 0.27 and 0.40 are used normally [20,2]. The permeability in the range of 0.076–3.5 cm/s permeability reduced as the head of water increased [21].The void content of pervious concrete is between 15% and 25% [5]. Pervious concrete has low compressive strength than that of traditional concrete, but it adds benefits like rain water management and low-impact on environment. [22] Cement paste in permeable concrete is very thin layer which binds coarse aggregate. Pervious concrete tends to fail at the binder interface between the aggregate, which results in the low compressive strength [18]. A typical permeable pavement system consists of a top permeable concrete layer placed above a sub-base coarse aggregate layer and subgrade soil [23].pervious concrete is used to reduce local flooding in urban areas. However, it is prone to clogging by particulate matter and requires regular maintenance**.** Several laboratory studies have investigated the effect of sediment type on clogging of permeable concrete. Results are varied due to differences in the clogging material, sample pore structure, exposure conditions and other variables [23]. The highest clogging potential occurred in samples exposed to combined sand and clay so clogging Samples were subjected to water flow containing fine sand and bentonite clay over many cycles to simulate clogging using a falling head permeability cell. The deposition pattern in clogged samples depends on the size of particles relative to pore size [23].Studies have shown that if maintenance has not been applied on time or after a clogging phenomenon, there would be no improvement in the infiltration rate with maintenance because of fully clogging [3, 20].

2. Experimental Work

Enhancing mechanical properties was very important to overcome low compressive strength of pervious concrete. Crushed limestone with one size was used to insure porous section. Materials used in the experimental work, mixture proportions, manufacturing and curing of the test specimens are detailed afterwards. Also, the types of specimens used and test parameters.

2.1 Materials

2.1.1 Coarse Aggregate

One size of crushed limestone (4.75-9.5mm) was used as a coarse aggregate (well graded according to ASTM C-33). The max. nominal size of aggregate is 9.5. Weight of coarse aggregate: cement weight equal 4:1.

2.1.2 Fine Aggregate

Natural siliceous sand was used. It has physical and mechanical properties that agree with Egyptian Standard Specification (E.S.S1109/2008). It is clean and nearly free from impurities with a specific gravity 2.56 t/m^3 and a fineness modulus of 2.38. Sand used is (4.75 mm) maximum nominal size. The proportion of sand used was10% replacement of coarse aggregate weight. Physical and mechanical properties of coarse and fine aggregate are shown in Table (1).

Table [1] Physical and Mechanical Properties of Coarse and Fine Aggregate.

Description	Coarse	Fine
Volume weight (t/mm^3)	1.55	1.64
Specific gravity (t/m^3)	2.5	2.56
Absorption %	2.0	0.78
Void ratio %	36.6	33.8
Fineness	6.08	3.6

2.1.3 Cement

Ordinary Portland cement, type (CEMI 42.5 N) was used. Its chemical and physical characteristics satisfied the Egyptian Standard Specification (E.S.S.4756-1/2013). Cement content is 400 kg/m^3.

2.1.4 Water

Tape water was used. Water to cement ratio was 0.28.

2.1.5 Admixture

The use of chemical admixtures like superplasticizers is a promising technique to improve the flowability and the bond between the aggregates and the cement paste. While mineral admixture like fiber reinforcement is an effective method to enhance the mechanical behavior of pervious concrete through bridging action over the cracks [8].

2.1.5.1Chemical admixtures

2.1.5.1.1 Super Plasticizer (Viscocrete 3425)

High performance superplasticizer Concrete Admixture is used as a highly effective water reducing agent from Sika Company according to (ASTM-C-494). Percentage of addition was 0.2 % of cement. It gives proper workability as shown in table (2).

Table (2) Typical Properties of Viscocrete 3425

Properties	Value
Appearance	Clear liquid
Density	1.08 kg/It (ASTM C-494)
Solid content	40% by weight
Chloride content	Zero

2.1.5.1.2 Adicrete B2

Accelerator and Plasticiser concrete Admixture is used for improving workability and increasing strength of concrete from chemicals for Modern Building (CMB) according to (E.S.S 1899-1). Addition of Adicrete was 2% of cement weight.

2.1.5.1.3 Waste Industrial Material

A waste material from the plastic industry. It is a local material. It is mixed with dry materials of concrete. Proportions used in this research were 8%, 10%, 12% as a replacement of cement by weight It was used without any additional preparations

2.1.5.2 Mineral admixtures

2.1.5.2.1 Polypropylene Fiber

polypropylene fiber with 12mm length and 3mm thickness was used. Density of the fiber was 0.9 kg/m^3. The proportion was used in this research were 0.1%, 0.15%, 0.2% of volume of concrete as shown in Table (3)

Table (3) Physical and Mechanical Properties of Polypropylene Fibers

Absorption	Nil
Specific Gravity	0.90
Electrical Conductivity	Low
Thermal Conductivity	Low
E-Modulus	3.5 GPa
Melt Point	162°C (324°F)
Ignition Point	593°C (1100°F)

2.2 Preparation of Specimens

Eight different concrete mixtures were prepared as shown in Figure (2).

(A)

(B)

Figure (2) Concrete Mixtures

2.3 Mix Proportion

Eight different concrete mixtures were prepared with proportions as shown in Table 4. M1 is a control mix containing Viscocrete admixture. M2, M3, M4 are mixes with industrial waste material 8, 10, 12% as a replacement of cement by weight, M5, M6, M7 are mixed with fiber 0.1, 0.15, .0.2 % of concrete mix volume. Each pervious concrete mixture contained the water cement ratio of 0.28, visocrete 0.2 % of cement by weight. Cement content was 400 kg/m^3. Aggregate / cement ratio as 4:1. Fine aggregate was replaced by coarse aggregate 10% by weight. M8 is a mix replaced by Adicrete-B2 2% of cement weight.

12 cubes 15 x15 x 15 cm were cast of each mix to evaluate compressive strength at 7, 28, 90, 120 days. 6 cylinders 10 cm diameter x 20 cm height were cast of each mix to measure splitting strength, permeability and clogging at 28 days. 3 prisms 10 x 10 x 50 cm were cast of each mix to measure flexure strength at 28 days. The molds were cleaned and oiled. Bolts are tightened to prevent any leakage of mortar. All mixes were machine mixed. All of the ingredients of Pervious Concrete like cement, coarse aggregate and fine aggregate were first weighed as per mix design proportion. Coarse, fine aggregate and cement of Pervious Concrete were first mixed in dry condition. After the homogeneous dry mix was obtained, water was added into the mix with admixture. After the mixing of concrete, each mould was filled in three layers and hand compacted. The top surface of concrete was levelled and any excessive concrete was removed. The specimens were left for 24 hours to achieve its hardening, then all samples were curing in water.

Table (4) Experimental Mix Proportion

mix	Water/cement proportion (w/c)	Cement (kglm^3)	Water (kg/m^3)	viscocrete (kg/m^3)	Adicrete B2(kg/m^3)	Sand (kg/m^3)	Crushed limestone (kg/m^3)	Waste material Kg/m^3	Fiber Kg/m^3
M1				0.8	_			_	_
M2				0.8	_			32	_
M3				0.8	_			40	_
M4	0.28	400	112	0.8	_	160	1440	48	_
M5				o.8	_			_	0.9
M6				0.8	_			_	1.35
M7				0.8	_			_	1.8
M8				_	8			_	_

3. Properties of Pervious Concrete

3.1 Workability Test

Even though few researches have reported slump values for pervious concrete, the standard slump is not suitable for pervious concrete to assess its workability because of light weight nature of pervious concrete. It has been established that workability for pervious concrete should be assessed by forming ball with the hand to establish the mouldability of pervious concrete as shown in Figure (3). Mouldability of pervious concrete is quite sensitive to the water content; hence the amount of water should be strictly controlled. [7]

(A) (B) (C)

(A) Too Little Water
(B) Proper Amount of Water
(C) Too much Water

Figure (3) Types of Pervious Concrete Fresh Properties According to Water Content. [7]

3.2 Physical Tests
3.2.1 Density Test
Density is the ratio of dry weight to total volume. Density was set at 28 days of curing of three 15×15×15 cm concrete cubes of every mix. The sample was dried in the laboratory oven at 110°C for 24 hour and then weighed after cooling.

3.2.2 Water Absorption Test
Absorption (A) is the ability of concrete to pull water into voids. Water absorption test was conducted at 28 days of curing of three 15×15×15 cm concrete cubes of every mix. The samples were dried in the laboratory oven and then were been weighed.

A = (weight with water–dry weight)/dry weight (2)

3.2.3 Permeability Test
It is the property indicating the flow of water through the pore space. A falling-head apparatus was installed to measure the permeability, Fig (4). Permeability measurements are based on Darcy’s Law and the assumption of laminar flow within the pervious concrete. The permeability coefficient k is given by:

$$k = [(A_1 L / A_2 t) \ln (h_1/h_2)] \quad (3)$$

where:

k = The coefficient of water permeability

h_1 , h_2= initial and final water head (mm)

L = length of specimen (mm)

A_1 = cross-sectional area of tube (mm^2)

A_2 = cross-sectional area of specimen (mm^2)

t = time (s)

Three cylindrical samples 10 cm diameter and 20 cm height were used for permeability test at 28 days. Specimens were isolated using silicon and tapes around sides to ensure that the water only vertically infiltrated through the samples. The sealed samples were placed at the bottom of the standpipe at an initial head of water above the sample. The time was started till the water level reached initial head of water and end at a final head of water using a stop watch. This process was repeated three times for each specimen and the average values are reported.

Figure (4) Permeability Test (Simple Falling Head Apparatus) [1]

3.2.4 Clogging Test

Clogging potential is defined as the number of cycles required to reduce porosity (or permeability) to half the initial value [23]. Samples exposed to water flow containing fine sand and clay over many cycles to simulate clogging as shown in figure (5). Falling head permeability apparatus used for clogging test as shown in Figure (4). Fifty grams of clogging materials was used to mix them into a 1kg bucket of water. clogging liquid was poured into the sample in the clogging apparatus then exposed to maintenance every two cycle of clogging. Combination of sweeping, Pressure Washing and Vacuuming were used. Sample placed in the falling head permeability test to determine the reduction in permeability.

Figure (5) Clogging Sample

3.3 Mechanical Tests
3.3.1 Compressive Strength Test
Three cubes of 15 cm x 15 cm x 15 cm for each mix were tested to determine the Compressive Strength at 7, 28, 90, 120 days. as shown in Figure (6).

Figure (6) Compressive Strength Test

3.3.2 Splitting Tensile Strength Test
Three cylindrical with 10 cm diameter and 20 cm height were used for test for each mix.

The splitting tensile strength test of concrete cylinder was carried out according to ECP1658/1988. as shown in Figure (7).

Fig (7) Split Tensile Testing of Pervious Concrete

3.3.3 Flexure strength test

Three prism 10 x 10 x 50 cm were used for test for each mix**.** Flexure strength of concrete prism was determined based on ASTM C39-86. as shown in Figure (8).

Fig (8) Flexure Strength Test

4. Test Results and Analysis

4.1 workability

Forming a ball with hand to establish the mouldability of pervious concrete for every mix, and ensure that the mix was homogenous and proper amount of water was used as shown in Figure (9).

Figure (9) A ball of Mix

4.2 Physical properties

As shown in Table 5.

Table (5) shows density, Absorption % and permeability before clogging

Mix No	density gm/cm^2	Absorption %	permeability (k) mm/sec
M1	2.1	3.6	7.8
M2	2.1	3.5	8.0
M3	2.14	3.3	5.39
M4	2.17	3.0	3.7
M5	2.16	3.62	10.5
M6	2.1	4.56	11.1
M7	1.9	5.52	12.9
M8	2.3	2.7	1.81

4.2.1 Density

The density of pervious concrete depends on the properties and proportions of the materials used as shown in figure (10). Polypropylene fiber mixes give law density than mixes without fibers. Density increases when proportion of fiber decreases. Density decreases with increasing waste material proportion. Density increases with using Adicrete-B2. Adicrete-B2 has the highest density as shown in figure (10).

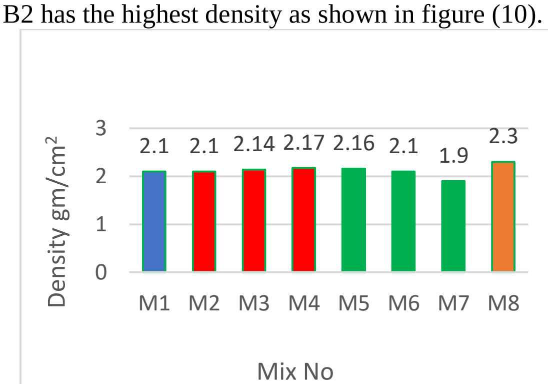

Figure (10) Density of all Mixes

4.2.2Water Absorption

Each result was average of three test specimens. It is shown that adding fibers to the concrete has direct effect on water absorption. The water absorption of all specimens increases by adding polypropylene fibers. It may be concluded that increase in water absorption is due to entrapment of air during the mixing and thereby generating voids in concrete. Adding waste material makes a glassy surface coating to pervious concrete, this decreases water absorption of concrete. Increasing waste material proportion decreases water absorption. Adding Adicrete reduce water absorption as in figure (11).

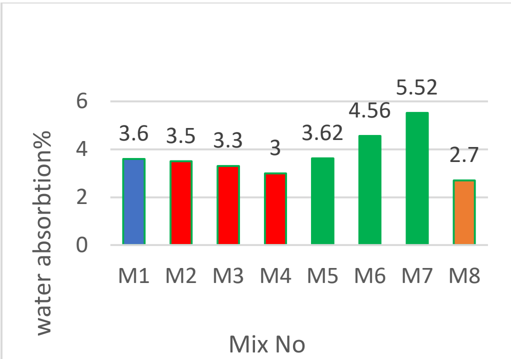

Figure (11) Water Absorption of all Mixes of Pervious Concrete

4.2.3 Permeability

The permeability is the most important parameter used in hydrological design of pervious concrete. Permeability is inversely proportional to time that sedimentation material infiltrate through samples. It was shown in Figure (12) that permeability decreases with increasing waste industrial material and also it decreases by using Adicrete B2, in the other hand permeability increases with increasing fiber. The permeability of M7 greater than permeability of control mix (M1) by 165%.

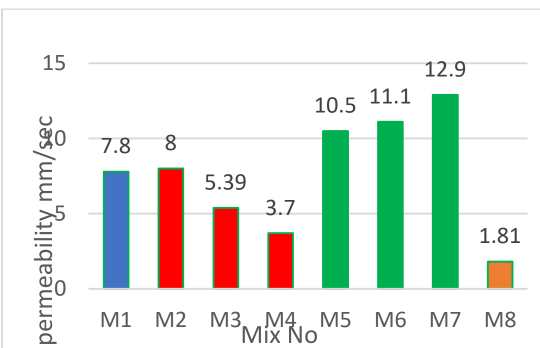

Figure (12) Permeability of all Mixes of Pervious Concrete

4.2.4 Clogging

After clogging a thin layer of sand and clay were performed on the top surface of samples which prevent water to flow into the sample. Significant permeability reductions were observed in all samples, when simultaneously exposed to sand and clay. This is because clay adhered to surface of sand particles and this caused increased clogging.

Sand and clay particles are larger than pores and retained on the top surface forming a deposition layer. Finer sand particles tend to be trapped within the permeable concrete away from the surface. Very fine clay particles pass through the sample. Table (7) shows the measured permeability coefficients after two and four cycles of clogging

Table (7): Permeability after two and four cycles of clogging

mixes	Permeability(k) mm/sec 2 cycles of clogging	Permeability (k) mm/sec 4 cycle of clogging
M1	6.3	3.2
M2	7.0	4.3
M3	5.0	3.1
M4	3.2	2.4
M5	8.7	5.0
M6	9.3	5.6
M7	11.1	6.5
M8	0.98	0.6

Figure (13) show that all mixes have drop in results of permeability after clogging except mixes with industrial material which have smooth decrease in permeability, it may be because of its inner glassy surface voids that prevent clogging material from sticking.

It was found that five cycles of clogging to achieve fully clogging and difficult to infiltrate water from samples. The changes in permeability of specimens subjected to sand and clay cleaned by the combination of sweeping, vacuuming and pressurized washing. showed improvement in specimens permeability. Permeability after maintenance is low than permeability before clogging. When number of cycles of clogging increase, permeability decrease. Maintenance of pervious concrete should be achieved before complete clogging. All used admixtures improved clogging resistance in different percentages.

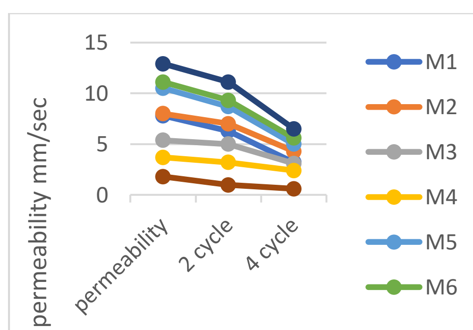

Figure (13) Permeability Before Clogging and Permeability After Two and Four Cycles of Clogging

Significant permeability reductions were observed in all samples exposed to sand and clay. Clogging occurred due to sand and clay particles retained on the top surface of samples. Complete clogging occurred after 5 cycles. Pervious concrete must be exposed to maintenance before fully clogging.

4.3 Mechanical Properties

Development of the compressive strength of the concrete mixes are shown in Table (6).

Table (6) Mechanical Properties of Concrete Mixes (MP)

Mix no	Compressive strength				flexure strength	split tensile strength
	7day	28 day	90 day	120 day	28 day	28 day
M1	13.0	16.7	17.7	18.3	3.9	2.5
M2	13.0	19.0	21.5	22.5	3.8	2.8
M3	16.7	22.3	26.6	27.7	4.8	3.5
M4	12.5	14.2	17.5	17.7	3.0	2.0
M5	17.33	23.8	24.6	25.3	4.8	4.3
M6	19.0	26.5	28.3	28.5	5.7	5.2
M7	21.6	28.1	30.0	31.3	7.2	6.0
M8	21.0	27.6	29.0	30.0	6.3	5.2

4.3.1 Compressive Strength

Compressive strength increases with increasing Polypropylene fiber. Compressive strength increases with increasing of waste industrial material till 10% as a replacement of cement. Compressive strength decreases when the proportion of waste industrial material increases than 10% as a replacement of cement. Also, using Adicrete-B2 increases compressive strength compered to viscocrete admixture. As shown in Figure (14)

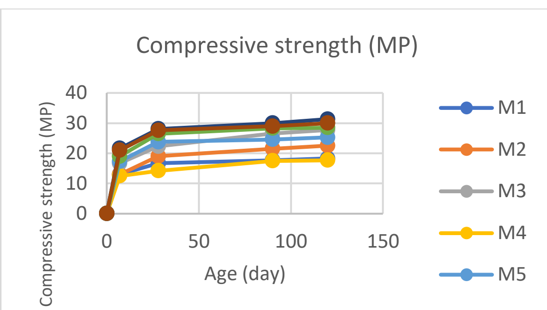

Figure (14) Compression Strength of all Mixes

The performance of polypropylene fibers in the concrete mixture can be attributed to generation a good cohesion with other aggregates which enhances mechanical properties so an increase in the fiber content has direct effect on compressive strength. Increase in waste industrial material increases compression strength till 10% waste industrial material as replacement of cement. Adding waste industrial material decreases compression strength.

Using Adicrete B2 increases compression strength with compered to viscocrete as shown in figure (14).

Compressive strength increases with using waste industrial material till 10% replacement of cement then decreasing by using proportion 12% as a replacement of cement. Adding Adicrete-B2 to pervious concrete gives good results of compressive strength of pervious concrete.

At 28 days, Waste material addition by 8,10 % as a replacement of cement increases compression strength by 113.8%, 133.5 % of control mix compression strength respectively. Waste material addition by 12% decrease compression strength by 15% of control mix. Polypropylene addition by 0.1, 0.15, 0.2 % by volume of concrete increases compression strength 142.5%, 158.7%, 168.3% of control mix compression strength respectively. Adding Adicrete B2 increases compression strength by 165.3% of control mix compression strength.

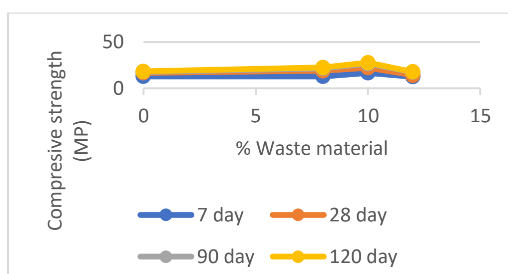

Figure (15) Compressive Strength of Different Proportion of Industrial Waste Material with Compere to Control Mix

Waste material increases compression strength for all ages. The best proportion was 10 % waste material. 12% waste material gives low compressive strength with compered to 8% waste material and control mix as shown in figure (15).

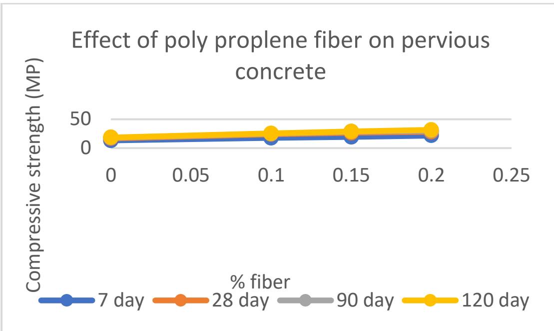

Figure (16) Compressive Strength of Different Proportion of Polypropylene Fiber with Compere to Control Mix

Compressive strength increases by increasing fiber for all ages. All proportions give best results with compered to control mix.

4.3.2 Split Strength and Flexure Strength

From results Split strength increases with using waste industrial material till 10 % replacement of cement then decreasing. Split strength increasing with increasing polypropylene fiber.Split strength increasing with using Adicrete-B2.At 28 days, Waste material addition by 8,10 % as a replacement of cement increases Split Strength by 112%, 140 % of control mix Split Strength respectively. Waste material addition by 12% decrease compression strength by 20% of control mix. Polypropylene addition by 0.1, 0.15, 0.2 % by volume of concrete increases Split Strength by 172%, 208%, 240% of control mix compression strength respectively. Adding Adicrete B2 increases Split Strength by 208% of control mix Split Strength.

Flexure strength increases with using waste industrial material till 10 % replacement of cement then decreasing. Flexure strength increasing with increasing polypropylene fiber. Flexure strength increasing with using Adicrete B2.At 28 days, Waste material addition by 8,10 % as a replacement of cement increases flexure strength by 97.4%, 123 % of control mix flexure Strength respectively. Waste material addition by 12% decrease flexure strength by 23.1% of control mix. Polypropylene addition by 0.1, 0.15, 0.2 % by volume of concrete increases Flexure strength by 123%, 146.15%, 184.6% of control mix flexure strength respectively. Adding Adicrete B2 increases flexure strength by 161.5% of control mix flexure strength.

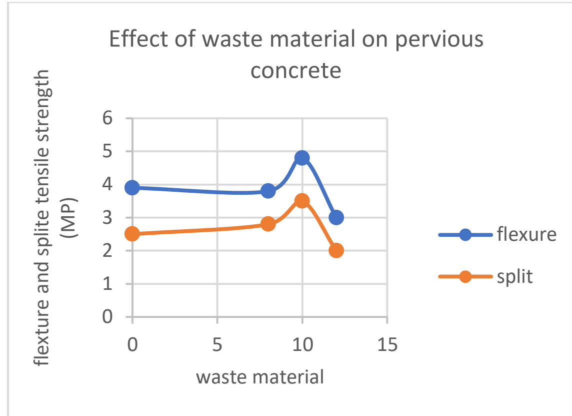

Figure (17) Flexure and Split tensile Strength of Different Waste Material Mixes with Compere to Control Mix at 28 Days

Flexure and split tensile strength increase with increase in waste material till 10% then they decrease by increases in waste material as shown in figure (17). 10% waste material as a replacement of cement gives the optimum result for flexure and split tensile strength for this scheme. 12% waste material as a replacement of cement decreased flexure and split tensile strength. Flexure and split tensile strength increase with increase in polypropylene fiber as shown in figure (18).

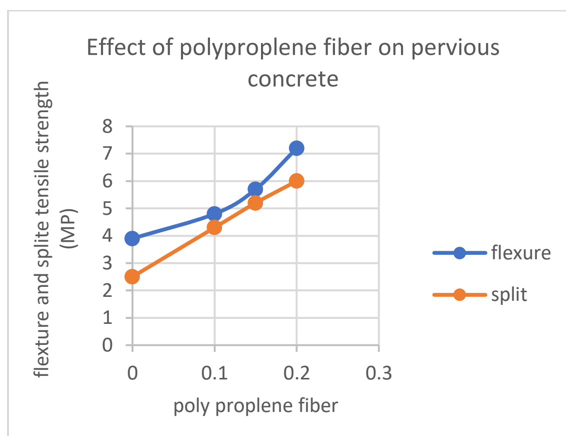

Figure (18) Flexure and Split tensile strength of Different Proportion of Polypropylene Fiber with Compere to Control Mix

8. Conclutions

Based on the obtained test results , the following conclusions can be drawn:

1- 0.2 fiber by volume of concrete and using Adicrete B2 gives the highest compressive strength of pervious concrete.

2- Increasing waste industrial material with proportion 10,12 % as a replacement of cement by weight increases density 1.9, 3.3 % respectively, and decreases absorption with proportion 8.3, 16.67% respectively

3- Increasing polypropylene fiber with proportion 0.1, 0.2 % by volume of concrete decreases density 2.86, 9.52 % respectively and increases absorption with proportion 0.55, 53.33% respectively.

4- Adicrete-B2 gives the best results for clogging resistance.

5- Increasing waste industrial material improves clogging resistance due to its glassy surface, and comes in the second stage.

6- Increasing polypropylene fiber decreases clogging resistance.

8- Increasing polypropylene fiber with proportion 0.1, 0.15, 0.2 increases strength of compressive strength by 42.51, 58.68, 68.3% respectively at 28 days.

9- Increasing polypropylene fiber increases water permeability of pervious concrete.

10- Using Adicrete-B2 increase compressive strength by 65.26% but decrease water permeability of pervious concrete.

11- Compressive strength increases with increasing of waste industrial material till 10% as a replacement of cement then it decreases.

12- splitting-tensile strength of pervious concrete equal 15-20 % of compressive strength and flexural strength equal 20-25 % of compressive strength as same as traditional concrete.

13- five cycles of clogging is needed to achieve fully clogging and difficult to infiltrate water from samples.

14- Maintenance of pervious concrete should be achieved before complete clogging.

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