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Appraisal of the Production and Properties of High Absorption Concrete (Pervious Concrete) in North Cyprus

Kenechi Kurtis Onochie[1*], Ibrahim Khaled[1]

[1]*Department of Civil Engineering, Cyprus International University, 99258 Lefkoşa,via Mersin 10, Turkey, North Cyprus*
*Corresponding E-mail: konochie@ciu.edu.tr

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ABSTRACT. *Pervious concrete or high absorption concrete which derives its name from its permeable nature is a permeable pavement structure with primary function to manage storm water in order to prevent flood while serving as a concrete structure where strength is the most important factor. Fines are systematically removed to create a porous structure which allows water penetrate. In this research, pervious concrete was produced with no fines. The samples contained aggregates with different gradations marked AB (16mm – 19mm), BC (14mm – 19mm), CD (12.5mm – 19mm) and DE (4.75mm – 19mm) with fineness modulus of 3.21 and were tested for compressive strength, density, infiltration rate and porosity. The results show that the optimum mix of pervious concrete was obtained using aggregate gradation DE (4.75mm – 19mm). It was observed that there was good relationship between aggregate gradation, its compressive strength, density, infiltration rate and porosity as shown in the study. The 28-day average compressive strength of this pervious concrete was 16.3MPA. The density obtained for the aggregate gradation DE (4.75mm – 19mm) was 1960kg/m3 with corresponding infiltration rate of 1476.6in/hr and porosity of 20.08%. North Cyprus is a flood prone country and the significance of the study cannot be overemphasized.*

Keywords: Pervious Concrete; Compressive Strength; Infiltration Rate

1. INTRODUCTION

High absorption concrete which is commonly referred to as pervious concrete because of its permeable nature is a permeable pavement structure which manages storm water and also bears loads from pedestrians and sometimes traffic [1]. It can also be described as concrete without fines so as to allow water penetrate through it in order to avoid accumulation and increase flood control [2]. Some other researches have addressed it as a rigid pavement which would allow water to filter through it gradually as a result of its internal structure that is macro porous [3]. The growing need for sustainability makes this types of concrete essentially relevant in construction industry [14]. This type of concrete is commonly utilized in residential areas, parking lot, walkways, and airport fields due to its lower compressive strength compared to conventional concrete pavement. Urbanization has led to the massive construction of buildings and infrastructures hence increasing impermeable areas. This leads to a hydrological imbalance hence increasing surface runoff in event of a storm and most times creating flood. The use of pervious concrete as an alternative to impervious concrete is becoming increasingly popular as a means to contain surface runoff. The materials utilized in the production of pervious concrete are coarse aggregates, cement and little or no fines. Sometimes high performance additives are utilized. Several researchers have suggested different void contents of the high absorption concrete. Nicholas et al suggested a void content range of 10 – 30% [4] while Amush et al used porosities in the range of 15 to 35% but concluded that 20 to 25% is the preferred choice [3]. In determining the porosities, there is need to ensure that the compressive strength is not compromised.

Extensive researches have been conducted on high absorption concrete in different parts of the world especially flood prone areas but none has been conducted in North Cyprus which is prone. This study intends to appraise the production and properties of the high absorption concrete also called pervious concrete in North Cyprus.

1.2 CONCEPT OF PERVIOUS CONCRETE

High absorption concrete is an aggregate system of concrete with a controlled amount of cement paste serving as a binder with little or no sand in the particle size distribution [5]. Alireza et al [6] describes pervious concrete as a zero slump material which contains cement, water, coarse aggregates, little or no fines and sometimes admixtures that allows the infiltration of water through it while recharging the ground water and reducing surface runoff in the event of a storm especially in urban areas prone to flooding due to increased rainfall and less permeability caused by massive constructions using the conventional impervious concrete. Basically the cement paste carefully binds the aggregate particles together but leaving a sizeable amount of interconnected voids which makes it permeable hence the name pervious concrete. During production there is need to ensure that structural performance is not compromised since it is a load bearing structure [7]. Porosity which ranges from 10-35% is a major factor in determining the compressive strength of pervious concrete and the relationship can be established as an increase in the porosity would eventually lead to a decrease in the compressive strength and a further decrease would occur if the aggregates utilized are light weight [8]. The infiltration rate of pervious concrete with aggregate gradation of 19mm – 9.5 mm is observed to be 1700in/hr in which the porosity was between 15 – 35%. This can be explained by the interconnected pore path at the top and bottom due to the physical structure of high strength performance pervious concrete providing a strong correlation between the coefficient of water permeability and porosity. There are some limitations of the use of pervious concrete and one of them is lower compressive strength of 5.6 to 21MPA after 28 days curing when compared to the conventional impervious concrete which gains minimum compressive strength of up to 35MPA after 28 days of curing [8]. Zhong et al shows a clear distinction between the pervious concrete and the impervious concrete in Fig. 1-1 [9].

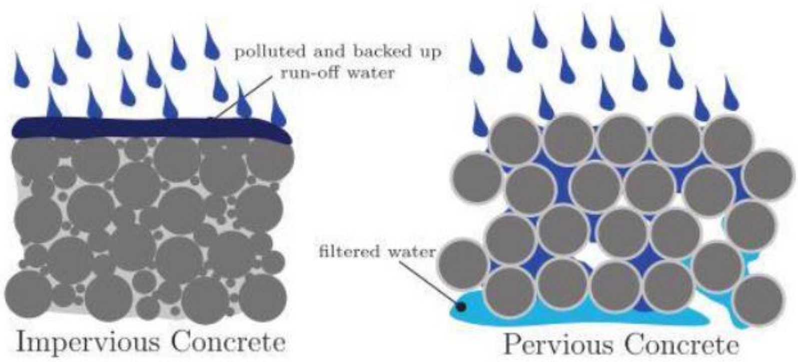

Fig. 1-1: Differences between Impervious and pervious concrete

The most singular characteristic that favors the selection of this special type of concrete is its interconnected porosity usually ranging from 15% to 30% that allows water to flow through at high rates [10]. The lack of fines creates an open void structure which allows water to infiltrate from the surface down through interconnected voids [11]. The open structure of the pervious concrete enables air and water to penetrate into the subsoil through voids existing within the concrete. As a result of the connectivity of the pervious concrete voids, flow pipes are generated which work as a filter and absorb pollutants such as oil or other pollutions in the ground [12]. Pervious concrete mixes typically contain single-sized aggregate with locally optimized levels of cementitious binder and water to provide a structure with at least 15% voids [13].

2.1 EXPERIMENTAL PROGRAM

2.1.1 Introduction

The significance of this research is based on the readily available materials used to produce pervious concrete in North Cyprus, which include Ordinary Portland Cement, Silica fume, clean water, and Coarse Aggregate. The main objective of this experimental program is to locally produce a pervious concrete having a 28-day compressive strength as high as 20 MPa with an average infiltration rate as high as 2500 in/hr. To achieve these mixes, various percentages of silica fume as cement replacement will be examined.

On the other hand, mixes with various gradation of coarse aggregate will be tested. The locally produced mixes of pervious concrete will be tested to measure the compressive strength (7 and 28 days), infiltration rate, porosity, and absorption at 28 days. Analysis of data was done to obtain the optimum pervious concrete mix. The summary of the research is expressed in the experimental program as shown in Fig. 2-1.

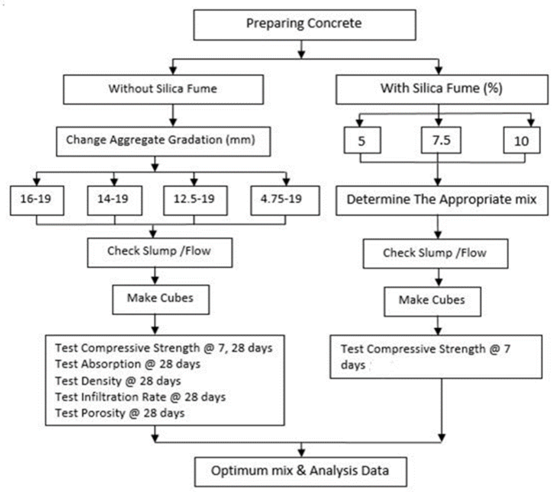

Fig. 2-1: Summary of the Research Experimental Program

2.1.2 Materials used in the Research

The materials utilized in the study are coarse aggregates, water, cement, and silica fume. They are further expressed in detail.

2.1.2.1 Coarse Aggregates

The aggregates gradations utilized in this study were obtained from Tufekci Company, Lefkosa, North Cyprus and the aggregates were stored in an environment mostly without sunlight and largely humid. Tests were done on individual specimen all at once on the same day and under same climatic conditions creating similarity in relation to water content. The sizes, absorption ratio, moisture content and specific gravity were also considered.

The aggregates were classified into four (4) groups based on their size or diameter, namely; coarse aggregates (16mm – 19mm) is (AB) sample, (14mm – 19mm) is (BC) sample, (12.5mm – 19mm) is (CD) sample and (4.75mm – 19mm) is (DE) sample as shown in Fig. 2-2.

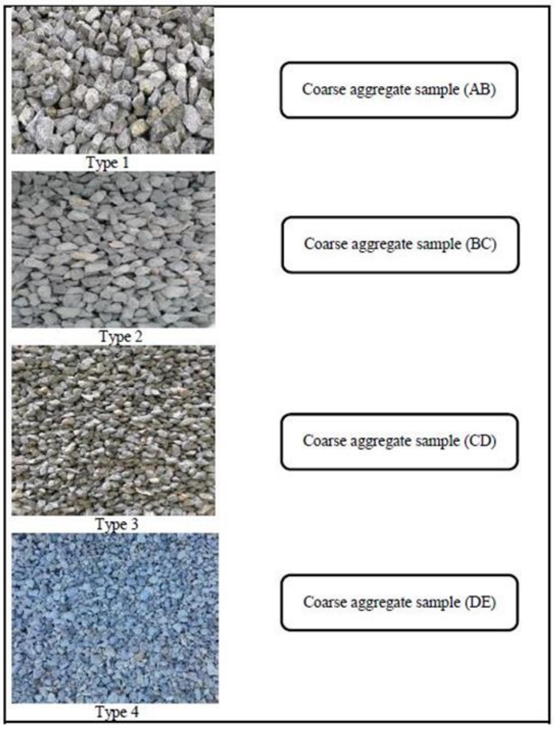

Fig 2-2: Gradation of aggregates used

2.1.2.2 Cement

PC 42.5 type of cement used for the research was obtained from Bogaz Industry Company, Iskele, in North Cyprus and was stored at Cyprus International University laboratory, and kept moisture free. Tables 2-1 shows the physical properties of the cement and Table 2-2 shows the chemical compositions of the cement.

Table 2-1: Physical properties of cement

Features			Analysis Results	Procedure	Default Values	
					Min	Max
Physical	Specific Surface Blaine (cm^2/g)		3600	EN 196-6		
	Specific Gravity (g/cm^3)		2.98			
	45 Micron (%)		4.62			
	90 Micron Sieve (%)		0.14			
	Setting Time (min)		175	EN 196-3		
	W/C Ratio (%)		28.5		60	
	Expansion Le Chatelier (mm)		0.0			10
Compressive strength (Mp_a)		2 days	21.90	EN 196-1	10	
		7 days	36.70			
		28 days	51.04		42.5	62.5
C_3A in the cement (%)		4.08	Calculation			

Table 2-2: Chemical compositions of the cement.

Features		Analysis Results	Method	Default Values	
				Minimum	Maximum
Chemical	Loss on Ignition (%)	2.42	EN 196-2		
	SiO_2 (%)	19.86			
	CaO (%)	62.74			
	Fe_2O_3 **(%)**	4.00			
	AI_2O_3 (%)	5.32			
	SO_3 (%)	3.08			3.50
	MgO (%)	2.04			
	Insoluble Residue (%)	0.16			
	CaO free (%)	1.00			
	CI (%)	0.00	EN 196-21		0.1

2.1.2.3 Micro silica (Silica Fume)

Silica fume—very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a byproduct of the production of elemental silicon or ferrosilicon alloys (also known as condensed silica fume and micro silica). It is an extremely fine powder (100times finer than cement) with non-crystalline particles. They are usually used to produce high strength concrete. The physical and chemical properties of silica fume are illustrated in Table 2-3.

Table 2-3: Physical and Chemical Properties of Silica Fume

Parameter	Analysis Results
View	Dust
Chlorine (%)	< 0.1
SiO_2 (%)	> 85
CaO (%)	< 1
SO_3 (%)	< 2
0.045 Particle Size Greater (%)	< 40
Activity Index (%)	> 95
Specific Gravity (Kg/m^3)	2300

2.2 MIX DESIGN

To obtained mix design that was effective, clear objectives were set including the desired strength. The main objective of the study is to produce high absorptive concrete (previous concrete) using locally available material in Northern Cyprus and targeting C20 mix.

C20 concrete mix was used as bench mark in adherence to the standard mixture used in North Cyprus to analyze different concrete mixes. Different ratio of the mixture was shown to help ascertain the amounts of materials used to obtain an optimum mix design proportion of pervious concrete including the permeability and strength that will be used in the trial test so as to obtain an optimal replacement ratio.

The aggregate to cement ratio of the control was 3:1, the control C20 concrete mix is named Mix 1, Mix 2 and Mix 3, etc. The mix proportions covers cement, coarse aggregates, water and the quantity of concrete admixtures, whether it's going to be based on the setting time, durability, workability, and required strength. The main concern was not the aggregates ratios and neither was it a problem rather the differentiation standards which are becoming complex and the proportions of the mixes were prepared such that the standards were followed.

Basic guidelines for mix designs for strength of pervious concrete were taken from Cyprus International University's Civil Engineering laboratory. Various mix design ratio of pervious concrete examined in this experimental program using various aggregate gradation are shown in Table 2-4. Table 2-5 shows the mix design ratio using silica fume and (CD) aggregate gradation type used to check the effect of using silica fume in various percentage on the compressive strength of pervious concrete.

It was ensured that the Trial mix volume for each was not less than 1m3 and the equation used to determine the density is shown in equation (1).

$$Density = {}^{Mass\ (kg)}\!\big/_{Volume\ (m^3)} \qquad (1)$$

The ratio of the free w/c utilized in the control mix was taken as 0.3. Rate of absorption was considered for all materials. The expected minimum compressive strength by the control concrete at 28 days is 20MPa, hence equation (2) is used for the calculations.

$$Total\ water = Free\ water\ + Absorbed\ water \qquad (2)$$

Table 2-4: Mix Design ratio without Silica Fume

Materials	Mix Design

	Mix 1	Mix 2	Mix 3
Cement (kg/m^3)	400	400	450
(AB) Aggregates (kg/m^3)	1457.5	1480	1410
Water (kg/m^3)	126	126	141
Aggregate / Cement ratio	3.64	3.70	3.13
Water / Cement ratio	0.3	0.3	0.3
Materials	Mix Design		
	Mix 1	Mix 2	Mix 3
Cement (kg/m^3)	400	400	450
(BC) Aggregates (kg/m^3)	1468.5	1500	1410
Water (kg/m^3)	129	129	143.5
Aggregate / Cement ratio	3.67	3.75	3.13
Water / Cement ratio	0.3	0.3	0.3
Materials	Mix Design		
	Mix 1	Mix 2	Mix 3
Cement (kg/m^3)	400	400	450
(CD) Aggregates (kg/m^3)	1450	1480	1410
Water (kg/m^3)	126	126	141
Aggregate / Cement ratio	3.63	3.70	3.13
Water / Cement ratio	0.3	0.3	0.3
Materials	Mix Design		
	Mix 4	Mix 5	Mix 6
Cement (kg/m^3)	450	450	450
(CD) Aggregates (kg/m^3)	1410	1423	1410
Water (kg/m^3)	127	132	141
Aggregate / Cement ratio	3.13	3.16	3.13
Water / Cement ratio	0.27	0.28	0.3
Materials	Mix Design		
	Mix 1	Mix 2	Mix 3
Cement (kg/m^3)	400	400	450
(DE) Aggregates (kg/m^3)	1551.24	1600	1410
Water (kg/m^3)	129	129.6	143.5
Aggregate / Cement ratio	3.88	4.00	3.13
Water / Cement ratio	0.3	0.3	0.3

Table 2-5: Mix design ratio using Silica Fume

Materials	Mix Design		
	Mix A	Mix B	Mix C
Cement (kg/m^3)	427.5	416.25	405
(CD) Aggregates (kg/m^3)	1410	1410	1410
Water (kg/m^3)	141	141	141
Water ratio %	0.3	0.3	0.3
Silica Fume (kg/m^3)	22.5	33.75	45
Silica Fume %	5	7.5	10

Equation (2) shows the water absorbed by the dry coarse aggregate while equation (3) shows the water required during mixing to hydrate the cement. The Total water is the addition of the water absorbed by the coarse aggregate and Free water by the cement.

$$Free\ water = Amount\ of\ binder * Ratio\ of\ water\ binder \quad (3)$$

2.3 COMPRESSİVE STRENGTH TEST

This test is performed using standard cube sizes of 150mm x 150mm x 150mm. Plastic molds were prepared and lubricated to prevent concrete from sticking to the mold after preparation in this study. The concrete was placed inside the cube in three stages and in each stage the external sides of the concrete mold were adjusted by the trowel to avoid having large gaps and then left to set at room temperature. After 48 hours, the cubes were removed from the molds gradually so as to avoid crushing the edges of the molds.

The concrete samples were taken from the cubes, and placed in the water tank for 7 and 28 days. Afterwards they were removed from the curing tank and thoroughly wiped clean with a dry cloth, and left to dry for 60minutes. The cube is first weighed and then placed in a compressive machine which is electronically controlled in such a way that good tolerance is allowed (Fig 2-3). Minimum of 2 cubes are crushed per given sample.

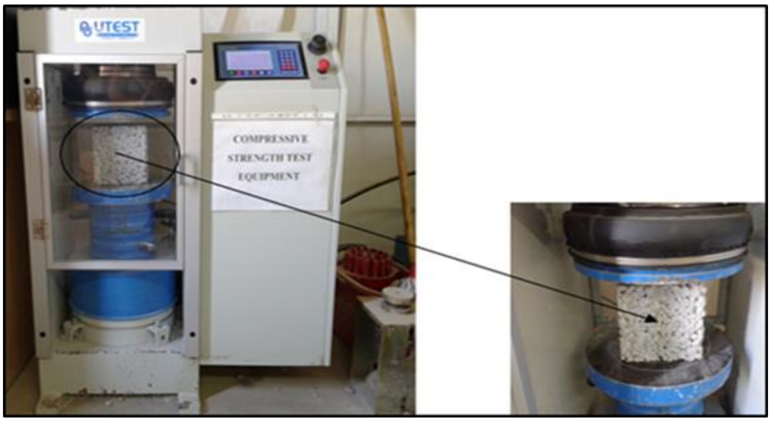

Fig 2-3: The compressive strength testing machine and the concrete cube

The failure load of each cube is recorded and the strength calculated. The compression resistance of concrete was tested in the following days: 7 days and 28 days.

2.4 WATER ABSORPTİON TEST FOR CONCRETE CUBES

Cube specimens of size 150mm × 150mm × 150mm are put in oven at 105ºC for 72 hours, after which the weight of the oven dry specimens are taken. The samples are then soaked in water then removed and weighed after 30 minutes and the saturated weight is recorded. The water absorption is calculated using equation 4.

$$Water\ absorption\ for\ cubes\ \% = {(Wa - Wo)}/{Wo} * 100 \qquad (4)$$

Where:

Wo = Oven dry weight (g)
Wa = Saturated weight (g)

2.5 TEST METHOD FOR INFİLTRATİON RATE

To measure the infiltration rate of the concrete mix, mold of 60cm x 60cm x 15cm was prepared. Lubricate the molds for easy removal. When the molds were prepared, the concrete was placed inside in three stages and in each stage the external sides of the concrete mold were adjusted by the trowel to avoid having large gaps and then left to set at room temperature. After 24 hours they are placed in the water tank for 28 days to be cured. The infiltration rate test is done for each concrete mixture according to ASTM 1701C which is the standard test method for measuring the infiltration rate of pervious concrete. The Infiltration rate of concrete was tested for 28 days. It is measured using equation 5.

$$I = \frac{K * M}{(D)^2 * T} \qquad (5)$$

I = Infiltration rate, mm/hr (in/hr).
K = Constant factor is 126,870 in (inch – bound) units.
M = Mass of infiltrated water, kg (lb).
D = Inside diameter of infiltration ring, mm (in).
T = Time required for measured amount of water to infiltrate the concrete (s).

3.1 RESULTS AND DISCUSSIONS

The section presents the analysis of the results of all the tests performed on the materials utilized and the concrete samples with all mixes obtained incorporating content for pervious concrete mixes.

3.1.1 Water Absorption and Specific Gravity of Coarse Aggregates

The water absorption for coarse aggregates were calculated to obtain the total water necessary for each mix design. The specific gravity (SG) and water absorption were calculated and recorded in Tables 3-1, 3-2, 3-3 and 3-4 respectively.

Table 3-1: Specific Gravity & Absorption Capacity of Coarse Aggregate for (AB) group

Wt. of S.S.D aggregates in Air B (gm)	Wt. of S.S.D aggregates in Water C (gm)	Wt. of O.D aggregates in Air A(gm)	
500	311.5	498	
Tests	Formula	Calculation	Results
S.G	A/(A-C)	498/(498-311.5)	2.67
S.S.G	B/(B-C)	500/(500-311.5)	2.65
Bulk Specific gravity (Oven Dry Basis)	A/(B-C)	498/(500-311.5)	2.64
Absorption Capacity %	(B-A)/A*100	(500-498)/498*100	0.40%

Table 3-2: Specific Gravity & Absorption Capacity of Coarse Aggregate for (BC) group

Wt. of S.S.D aggregates in Air B (gm)	Wt. of S.S.D aggregates in Water C (gm)	Wt. of O.D aggregates in Air A (gm)	
500	313	497	
Tests	Formula	Calculation	Results
S.G	A/(A-C)	497/(497-313)	2.70
S.S.G	B/(B-C)	500/(500-313)	2.67
Bulk Specific gravity (Oven Dry Basis)	A/(B-C)	497/(500-313)	2.65
Absorption Capacity %	(B-A)/A*100	(500-497)/497*100	0.60%

Table 3-3: Specific Gravity & Absorption Capacity of Coarse Aggregate for (CD) group

Wt. of S.S.D aggregates in Air B (gm)	Wt. of S.S.D aggregates in Water C (gm)	Wt. of O.D aggregates in Air A (gm)	
500	310	498	
Tests	Formula	Calculation	Results
S.G	A/(A-C)	498/(498-310)	2.65
S.S.G	B/(B-C)	500/(500-310)	2.63
Bulk Specific gravity (Oven Dry Basis)	A/(B-C)	498/(500-310)	2.62
Absorption Capacity %	(B-A)/A*100	(500-498)/498*100	0.40%

Table 3-4: Specific Gravity & Absorption Capacity of Coarse Aggregate for (DE) group.

Wt. of S.S.D aggregates in Air B (gm)	Wt. of S.S.D aggregates in Water C (gm)	Wt. of O.D aggregates in Air A (gm)

500	321	497	
Tests	Formula	Calculation	Results
S.G	A/(A-C)	497/(497-321)	2.82
S.S.G	B/(B-C)	500/(500-321)	2.79
Bulk Specific gravity (Oven Dry Basis)	A/(B-C)	497/(500-321)	2.77
Absorption Capacity %	(B-A)/A*100	(500-497)/497*100	0.60%

S.G = Apparent surface dry specific gravity
S.S.G = Saturated surface dry specific gravity
O.D = Oven Weight of aggregates (gm)
A = Weight of Oven Dry aggregates in Air (gm)
B = Weight of S.S.D aggregates in Air (gm)
C = Weight of S.S.D aggregates submerged in the water (gm)

3.1.2 Concrete Test Results

3.1.2.1 Effect of Coarse Aggregate Gradation on Compressive Strength of Pervious Concrete

The control samples 7 day compressive strength are shown in Chart 3-1 and Chart 3-2 for pervious concrete without silica fume and with silica fume respectively. The 28 day compressive strength of pervious concrete without silica fume is shown in Chart 3-3.

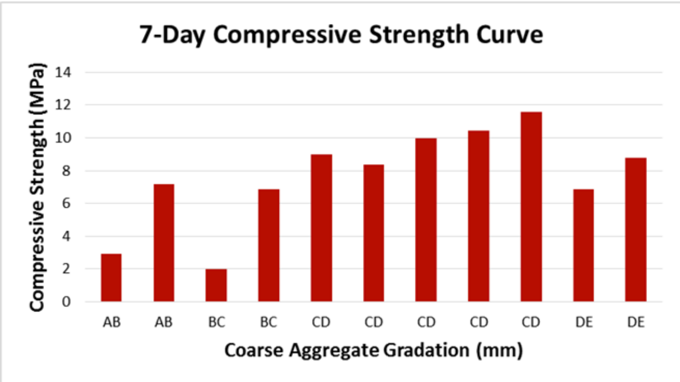

Chart 3-1: 7-Day Compressive Strength for each Pervious Concrete Mixes (AB, BC, CD, DE) without silica fume

The sample containing Ordinary Portland Cement with CD (12.5mm -19mm) aggregate gradation had an average compressive strength of 11.6MPA while the sample containing 7.5% Silica fume had an average compressive strength of 9.71MPA as shown in Chart 3-2.

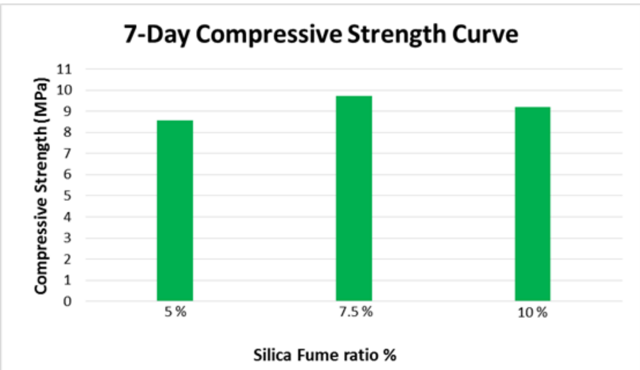

Chart 3-2: 7-Day Compressive Strength for Pervious Concrete Mix (CD) with silica fume

The increase of coarse aggregates size showed decrease in compressive strength due to increase in void ratio. The 28-day compressive strength was 16.3 MPa for group (DE) concrete mix and it was the highest, which represents an increase in compressive strength compared to the each mixes as shown in Chart 3-3. There were increases with increase in small aggregate size, due to decrease in void ratio.

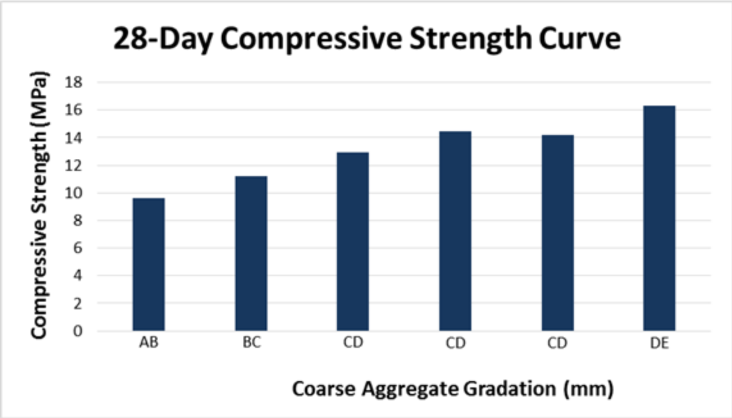

Chart 3-3: 28-Day Compressive Strength for each Pervious Concrete Mixes (AB, BC, CD, DE) without silica fume

3.1.2.2 Effect of Coarse Aggregate Gradation on Absorption of Pervious Concrete Mixes

The effect of coarse aggregate gradation on absorption of pervious concrete mixes is shown in Chart 3-4 for each group. Group DE had a water absorption of 1.3% showing higher water absorption characteristics. This makes it more susceptible to freeze-thaw compared to other groups of aggregate gradation.

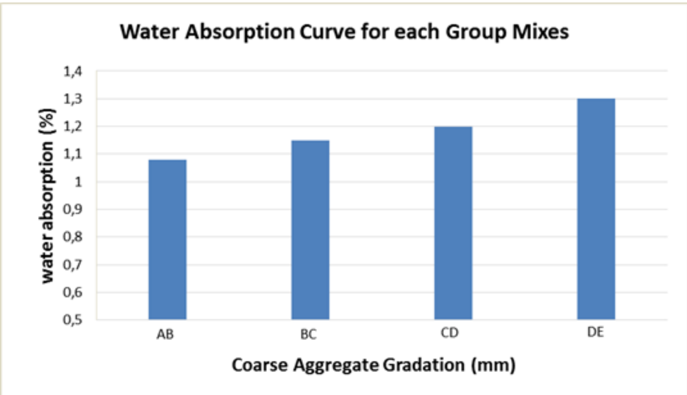

Chart 3-4: Water absorption ratio for each of Pervious Concrete Mixes

3.1.2.3 Effect of Coarse Aggregate Gradation on Density of Pervious Concrete Mixes

The density of pervious concrete reduces with increase in void ratio due to the increase of coarse aggregate size. Density of pervious concrete mixes in fresh and hardened states is shown in Chart 3-5 respectively.

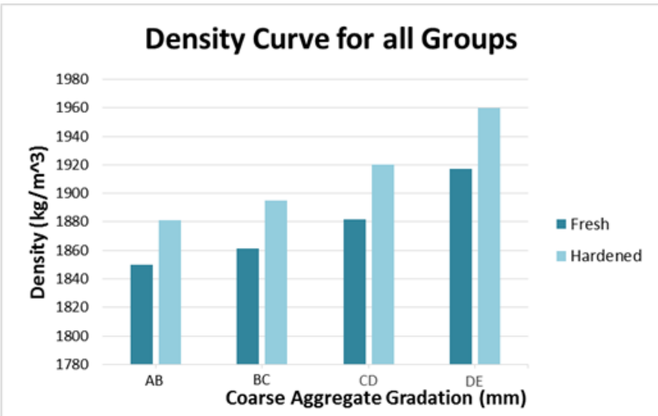

Chart 3-5: Weight density for fresh and hardened pervious concrete

3.1.2.4 Infiltration Rate Test Results

The result of infiltration rate tests for pervious concrete mixes are shown in Chart 3-6. It can be seen that the decrease in the aggregate size resulted in the decrease in the infiltration rate due to the decrease in the void ratio.

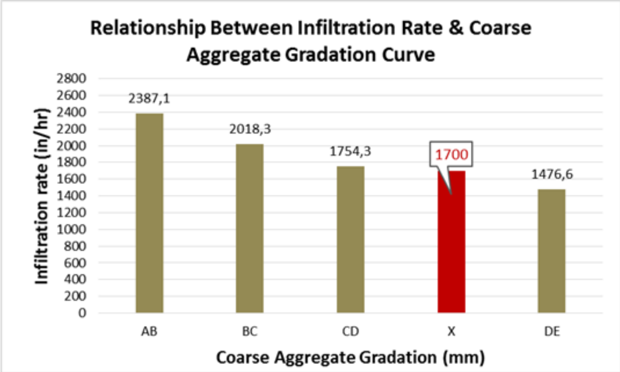

Chart 3-6: Relationship between Infiltration rate and coarse aggregate gradation Curve

The Comparison between infiltration rate values for (AB, BC, CD and DE) groups in experimental program and value for (X) group in literature review is to clearly show the effect of coarse aggregate gradation on infiltration rate as shown below in Chart 3-6. The Infiltration Rate measurement appeared to increase with an increase in size of aggregates used in pervious concrete mixes. The results obtained from the tests is shown in Chart 3-7.

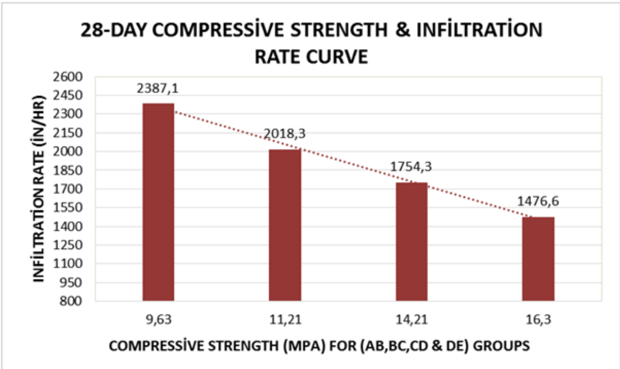

Chart 3-7: Relationship between 28-Day Compressive Strength and Infiltration Rate Curve for (AB, BC, CD, and DE) Pervious Concrete Group

3.1.2.5 The Effect of Porosity on 28-day Compressive Strength and Infiltration Rate

The effect of porosity of pervious concrete mixes on 28-day compressive strength can be seen in Chart 3-8 It is clear that the hardened concrete compressive strength decrease with increase of porosity due to increase of aggregate size.

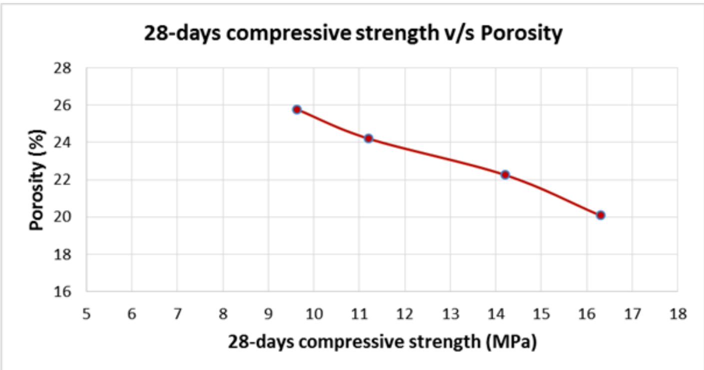

Chart 3-8: Relationship between porosity and 28-days compressive strength

4. CONCLUSION AND RECOMMENDATION

The production of pervious or high absorption concrete tries to balance compressive strength with infiltration rate. In this research, different aggregate gradation sizes were used to obtain an optimum gradation of aggregates. The 7 day compressive strength were tested for samples containing silica fume at proportions of 5, 7.5 and 10%

and it was observed that there was an increase in the compressive strength up to 9.71MPA at 7.5% silica fume before it begins to decrease as the percentage of silica fume used increases as seen at 10%. This value was however proven to be unreliable when compared to the 7 day average compressive strength obtained without the use of silica fume for same aggregate gradation which was 11.6MPA. The 28day average compressive strength of samples containing aggregate gradation DE (4.75mm – 19mm) was 16.3MPA which was highest compared to the other aggregate gradation sizes due to the presence of smaller aggregate sizes in the mix but this affected the infiltration rate which was observed to be 1476.6in/hr which is consistent with the observed infiltration rate for aggregate gradation of 19mm – 9.5mm at 1700in/hr in the literature. Also, aggregate gradation of CD (19mm – 12.5mm) was observed to be 1754in/hr which is more than DE due to the bigger aggregate sizes present. A relationship was established between the average compressive strength and the infiltration rate such that an increase in the earlier leads to a decrease in the earlier. Due to higher compressive strength of pervious concrete containing aggregate gradation of DE, it resulted in the least infiltration rate when compared to other samples containing other aggregate gradation. It was also observed to have a higher density of 1960kg/m^3 due to smaller aggregate sizes contained in the gradation which led to decrease in the voids when compared to other gradations tested. This also affected the porosity which was observed to be the lowest at 20.08% when compared to other samples tested. Most researches have obtained porosity within the range of 15 – 25%. This shows there is a relationship between aggregate gradation, its compressive strength, density, infiltration rate and porosity which are all important factors in the production of pervious or high absorption concrete.

Further studies are recommended in the following area:
Ways to enhance the workability of pervious concrete for easier placing and the effect of introducing some little amounts of fine aggregates on both compressive strength and infiltration rate of pervious concrete.

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