A MIXTURE DESIGN GUIDE TO PRODUCE PERVIOUS CONCRETES BY BASALT AGGREGATES WITH DIFFERENT GRADATIONS AND DETERMINATION OF ENGINEERING CHARACTERISTICS OF PRODUCED CONCRETES

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As a result of rapid urbanization, impermeable surfaces used in* roads, pavements, parks, and gardens cause a rapid increase in the number of urban floods and overflows. As they infiltrate rainwater into the subsurface and decrease the surface water flow, protect the underground water sources, support sustainability, and offer solutions to relieve the environmental concerns, pervious concretes gain importance with each passing day. In this study, to enhance the mechanical characteristics of them without compromising on their permeability characteristics it was aimed to make the optimum mixture design of pervious concretes which are prepared with basalt aggregates. 3 different paste volumes (15%, 20%, 25%) and 3 different aggregate gradations (10-15 mm, 5-10 mm, 10-15 mm (50%) + 5-10 mm (50%)) were used. Density, consistency, void rate, permeability, compressive strength, and splitting tensile strength tests were performed on produced pervious concrete samples. As a conclusion, it was determined that aggregate size has been directly proportional to void rate, while void rate has been inversely proportional to compressive strength in pervious concretes. It was determined that optimum design mixture was the (P25-F100-C0) mixture which was produced with 5-10 mm basalt aggregates that had 25% cement paste volume.

Keywords: *Concrete, Pervious Concrete, Permeability, Basalt*

1. Introduction

Due to rapidly increasing population and developing construction economy, sustainable solutions are required more than ever. By the increase in urbanization, due to impermeable surfaces used in roads, pavements, parks, and gardens, occurrence of urban floods and overflows are inevitable [1]. By the increase in impermeable surfaces, less amount of rainwater can infiltrate into the subsurface and more rainwater causes surface run offs that generate overload for drainage systems [2]. Countries have produced different design concepts and plans to solve this issue. These include: “Low Impact Development” in USA[3], “Water Sensitive Urban Design” in Australia [4], “Rainwater Storage and Infiltration” in Japan [5], “Sustainable Drainage Systems” in Britain [6], and “Sponge City” [7] in China. There is another environmental problem caused by impermeable coatings. As the surface contaminants (such as fuel oil, waste oil, chemical substances etc.) are carried by rainwater drainage systems, concerns on contamination of clean water resources increase day by day [8]. Another problem that is caused by impermeable coatings and concretion in the cities is the urban heat island effect. When the radiation from the sun is absorbed by the open concretes, walls and asphalt in the buildings and streets of the city, heat differences occur within the city. Such heat differences cause summer storms and sudden precipitation [9].

Pervious coatings are perfect alternatives as a solution to sudden precipitations, floods, surface contaminants and urban heat island effect. Studies are concentrated on pervious concretes that provide the transfer and efficient drainage of water due to their porous structure [10]. Pervious concrete, unlike conventional concrete is a concrete type which does not include or hardly include fine aggregates, has 15-35% void rate, and allows water to discharge from these voids. Today, permeable concrete can be applied in parking lots, greenhouse floors, streets and pavements under light and medium traffic load, park and sports facility areas, zoo floors, swimming pool decks, beach and coastal structures [8]. As pervious concrete can drain water from the voids it contains at a high rate, reduces the surface water flow by filtering rainwater underground, protects underground water resources, supports sustainable construction and provides solutions to relieve concerns related with environment, it has been defined as "One of the Best Rainwater Solutions" by Environmental Protection Office of USA and it was suggested to be applied in regions with lower settlement density [11]. Due to its porous structure, it provides considerable amount of sound absorption compared with conventional concrete and thus

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pervious concrete is a very good sound absorption tool [12].

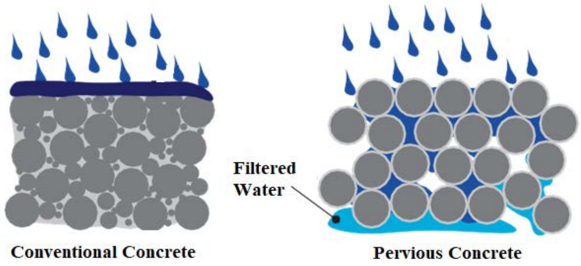


Fig. 1 Comparison of pervious and impervious concretes [13]

Pervious concrete is the best alternative material to remove the surface contaminants. In a study conducted by Haselbach et al. it was reported that pervious concrete was effective in removal of copper and zinc contaminants in rainwater and there was a decrease of contaminants for zinc and copper by 90% and 87%, respectively [14].

Table 1 shows the high retention ratio of contaminant substances by pervious concretes from two separate studies performed in US [11].

Table 1.
Efficiency of porous road coating for retaining contaminants, by mass %

Study Site	**Total Suspended Waste**	**Total Phosphorus**	**Total Nitrogen**	**Chemical Oxygen Demand**	**Metals**
Prince William, VA	82	65	80	-	-
Rockville, MD	95	65	85	82	98-99

To prepare pervious concretes, standard portland cement and pozzolanas can be used such as in conventional concretes [8]. For sustainability, alkaline slag and polymer kinds can also be used instead of cement [15]. Unlike it is for conventional concretes, single type aggregates or aggregates with narrow gradation are used. ACI Committee 522 study group suggests to use only one coarse aggregate size and to select Dmax as 12.5 mm for such a usage [8]. As fine aggregates affect permeability ratio directly, it is recommended to be used with care. Using fine aggregates in 5-7% of the total aggregate weight increases the strength of pervious concretes, however it is known that addition of fine aggregates decrease the permeability of the concrete [16]. Sahdeo et al. has reported that the optimum design to be used for pervious concretes is composed of a mixture of 10 mm and 4.75 mm aggregates [17]. Yu et al. has concluded that aggregates having more than 7 mm of particle size do not enhance the strength characteristics of the pervious concretes [18]. Thus, selection of aggregate gradation in pervious concrete determines the permeability coefficient and strength. These parameters are inversely proportional to each other. Larger aggregates would cause larger voids and that would lead to more permeability and less strength [19].

Besides the limestone aggregate used in conventional concretes, basalt aggregates can also be used in concretes. Basalt is a hard, dense, volcanic rock which can be found in many places of the world. For long years, it has been used in architectural applications and in making granolithic floor. Crushed basalt stone has taken place in concrete production in time [20]. It has been used generally in highway and airport coatings. Basalt aggregate provides high abrasion resistance and UV resistance. Specific weight of basalt aggregate is greater and its abrasion loss and water absorption is less than that of conventional limestone aggregate [21].

Preparation of pervious concretes include the same processes as preparation of conventional concretes. However, mixture ratios include less error margin than conventional concretes. To obtain the required results, strict controls on blending of all components should be applied [11]. Besides mixture gradation, another important parameter which contributes to concrete coating properties is the type and amount of compression which affect the porosity [22]. Rodding technique which is used in conventional concretes is not recommended for pervious concretes [23]. Pervious concretes with low slump value need to be compressed by rolling. The aim of compressing is to settle down the aggregate and to strength the bond between the aggregates [24]. The main principle in pervious concrete production is to provide an equilibrium between void, strength, cement paste content and processability[8].

There have not been any national or international standards available for pervious concrete designs, yet. As there are no standards available, the investigators generally determine the pervious concrete mixtures by making premixture designs with local materials. In this study, with an acceptation similar to the relationship of void rate and paste volume suggested by American Concrete Institute (ACI) Committee 522, 9 different mixtures with 3 different gradations and 3 different paste volumes have been prepared with basalt aggregates. Mechanical and physical characteristics of pervious concrete samples prepared with the void rate-paste volume acceptation of ACI Committee 522 was investigated under laboratory conditions. It is aimed to enhance the mechanical characteristics of pervious concretes prepared with basalt aggregates without compromising on their permeability characteristics by using the optimum mixture design with the help of all obtained numerical and statistical data, and by this way it is desired to provide contribution to the literature.

2. MATERIALS AND METHOD

2.1. Materials

Aggregate: 5-10 mm and 10-15 mm basalt aggregates were used in the study.

Table 2

Chemical and mechanical characteristics of cement used in the study

	Characteristics	CEM I 52,5 R White Portland Cement
Chemical Characteristics (%)	SiO_2	21.6
	Al_2O_3	4.05
	Fe_2O_3	0.26
	CaO	65.7
	MgO	1.30
	SO_3	3.30
	Loss on Ignition	3.20
	Na_2O	0.30
	K_2O	0.35
	Chloride	0.01
	Free CaO	1.60
Physical Characteristics	Specific Weight (g/cm^3)	3.06
	Specific Surface (cm^2/g)	4600
	28 days of Compressive Strength (MPa)	60

Cement: In experimental studies, ÇİMSA Super White CEM I 52,5 R White Portland cement was used. Chemical and technical characteristics provided by the manufacturer company are given in Table 2**Hata! Başvuru kaynağı bulunamadı.**.

Chemical Additive: Superplasticizer additive which was about 1.3% of the cement weight was used in the mixtures prepared in the concept of this study. Technical characteristics of the additive provided by the manufacturer are given in Table 3.

Table 3

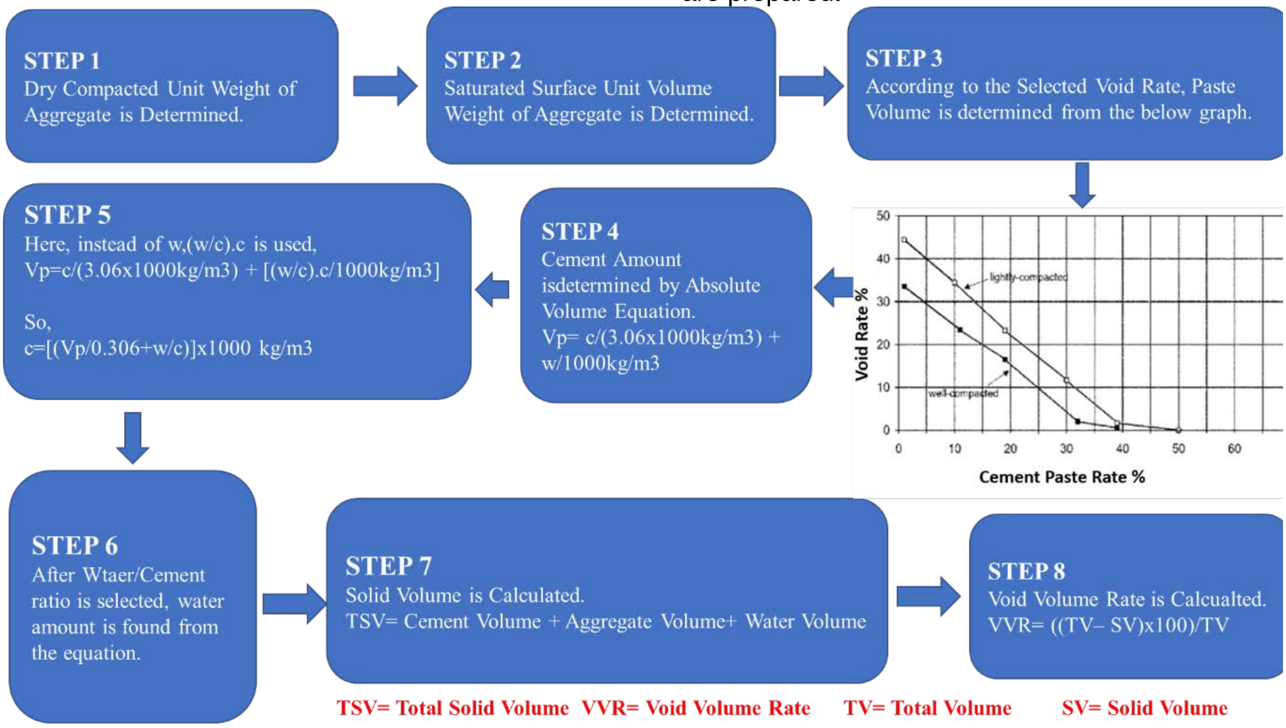
Technical Characteristics of Superplasticizer

Technical Characteristics	Superplasticizer:
Chemical Content	Naphthalene Sulphanate Based
Appearance	Brown Liquid
Density	1.18 kg/l
pH Value	7.5
Chlorine Content	< 0.1%
Alkaline Content	< 6%
Freezing Point	- 6 ℃

2.2. Method

2.2.1. pervious concrete mixture design

When literature is reviewed it is observed that mixture designs are prepared by making test mixtures with local materials in pervious concrete sample production. By taking reference of the relationship between void rate and paste volume as suggested by ACI Committee 522 [8], steps given in Figure 2 are used and pervious concrete mixtures are prepared.



STEP 1
Dry Compacted Unit Weight of Aggregate is Determined.

STEP 2
Saturated Surface Unit Volume Weight of Aggregate is Determined.

STEP 3
According to the Selected Void Rate, Paste Volume is determined from the below graph.

STEP 4
Cement Amount isdetermined by Absolute Volume Equation.
Vp= c/(3.06x1000kg/m3) + w/1000kg/m3

STEP 5
Here, instead of w,(w/c).c is used,
Vp=c/(3.06x1000kg/m3) + [(w/c).c/1000kg/m3]

So,
c=[(Vp/0.306+w/c)]x1000 kg/m3

STEP 6
After Wtaer/Cement ratio is selected, water amount is found from the equation.

STEP 7
Solid Volume is Calculated.
TSV= Cement Volume + Aggregate Volume+ Water Volume

STEP 8
Void Volume Rate is Calcualted.
VVR= ((TV– SV)x100)/TV

TSV= Total Solid Volume VVR= Void Volume Rate TV= Total Volume SV= Solid Volume

Fig. 2 Mixture Design Guide

Table 4

Pervious concrete mixture ratios (for 1m^3)

Mixture No	5-10mm Aggregate (kg)	10-15mm Aggregate (kg)	Volume of Paste (%)	Cement (kg)	Water (kg)	Water/ Cement	Additive (kg)
P15-F0-C100	0	1561	15	243.90	73.17	0.3	3.17
	788.50	788.50	15	243.90	73.17	0.3	3.17
P15-F100-C0	1525	0	15	243.90	73.17	0.3	3.17
P20-F0-C100	0	1561	20	325.20	97.56	0.3	4.23
P20-F50-C50	788.50	788.50	20	325.20	97.56	0.3	4.23
P20-F100-C0	1525	0	20	325.20	97.56	0.3	4.23
P25-F0-C100	0	1561	25	406.50	121.95	0.3	5.28
P25-F50-C50	788.50	788.50	25	406.50	121.95	0.3	5.28
P25-F100-C0	1525	0	25	406.50	121.95	0.3	5.28

Table 5

Tests performed on basalt aggregate and produced pervious concrete samples

	Test Description	Standard Used
Basalt Aggregate Tests	Saturated Surface Particle Density Water absorption	TS EN 1097-6 [25]
	Loose and Compacted Unit Volume Weight	TS EN 1097-3 [26]
	Resistance to Fragmentation	Los Angeles Method, TS EN 1097-2 [27]
Fresh Concrete Tests	Density	TS EN 12350-6 [28]
	Consistency	(Snowball Method)
Hardened Concrete Tests	Density/Void Rate	ASTM C1754/C1754M-12 [29]
	Water absorption	ASTM C 642 [30]
	Compressive Strength	TS EN 12390-3 [31]
	Splitting Tensile Stength	TS EN 12390-6 [32]
	Permeability	ASTM C1781/C1781M-21 [33]

Where;

c = Cement amount
Vp = Volume of Paste
w/c = Water/Cement ratio
3.06 = Specific weight of cement that is used

3 different paste volumes (15%, 20%, 25%) and 3 different aggregate gradations were used by using the above scheme while w/c ratio was kept as constant (3) and totally 9 different pervious concrete mixtures were prepared. Values of prepared mixtures are given in Table 4.

The definition of codes given to pervious concrete samples are described in Fig. 3

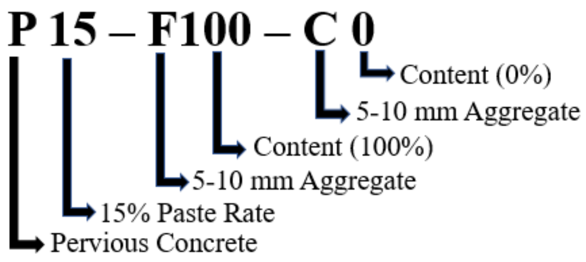


Fig. 3 Definition of codes

2.2.2. Sample Preparation

The mixtures were prepared under laboratory conditions at 20±2 ºC ambient temperature and 60±5 % relative humidity.

Prepared mixtures were poured into plastic molds of 10x10x10 cm size. Pouring was performed in 2 stages by compressing with a plastic mallet. A total of 90 cubic samples, which included 10 samples for each mixture batch, were poured. Mixtures were kept in a mold for 24 hours and then removed from the mold and kept in water cure for 28 days. Images of produced samples are given in Figure 4.

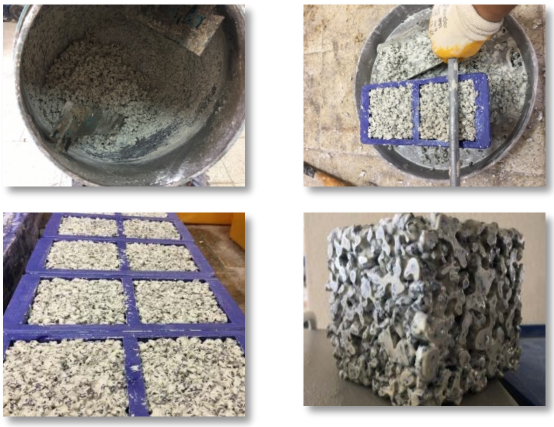


Fig. 4 Images of pervious concrete samples

2.2.3. Test Procedure

Tests performed on basalt aggregate and produced pervious concrete samples are given in Table 5.

Fresh Concrete Density Test

Densities of prepared fresh concrete samples were measured according to TS EN 12350-6 standard.

Consistency Test

As consistency of pervious concretes cannot be measured like consistency of conventional concretes, Tennis et al. have suggested snowball method for processing and accurate water proportioning of pervious concretes. In this application if aggregates adhere to cement paste and do not crumble when fresh concrete has been taken into hand and formed in a ball shape, this is accepted as the optimum consistency. Snowball method applied on mixtures is shown in Fig 5.

Fig 5. As a result of the pervious concrete consistency test, the mixtures that stayed in snowball form

Density, Void Content and Water Absorption Test for Hardened Pervious Concretes

On hardened concrete samples, density, and void rate (porosity) tests were applied according to ASTM C1754/C1754M-12 standard, and water absorption test was applied according to ASTM C642 standard.

For determination of void rate, the following formula is used:

$$Void\ Rate = \left[1 - \left(\frac{A-B}{p_w .D^2.L}\right)\right] x100 \qquad (1)$$

where;
A : Oven dry mass of sample (kg)
B : Mass of sample in water (kg)
ρ_w : Water Density (kg/m^3)
D : Width of Sample (m)
L : Height of sample (m)

Compressive Strength Test

For each mixture type, 3 of the produced pervious concrete samples were subjected to 7 days of compressive strength test according to TS 12390-3 standard and 3 of them were subjected to 28 days of compressive strength test.

Splitting Tensile Strength Test

Splitting tensile strength test was applied on pervious concrete samples in accordance with TS EN 12390-6 standard.

Permeability Test

With an assembly modified in accordance with the principles specified in ASTM C1781/C1781M standard, permeability coefficients were calculated for cubic samples prepared. The surrounding of 10x10x10 cm cubic samples have been covered by a polyethylene-based cover to prevent water leak. The system was made up of transparent plexiglass material which has 102x102 mm cross sectional size and 700 mmm height that will completely contain the sample inside. Fig 6 shows that concrete sample was placed in the lower part of sample apparatus which had a square prism shape. 10 cm above the sample was marked as h2 level, while 20 cm above the sample was marked as h1 level. After the system was filled with 4.0 l water, the time (t) required for the decrease of water level from h1 to h2 was measured by a chronometer and recorded. For each sample this procedure was repeated for 3 times and by taking the arithmetic mean value for the results, the permeability constant was calculated.

Fig 6. Permeability Test

By using the data from the tests and Darcy's law, permeability coefficient was calculated by using equation (2);

$$k = \frac{a \cdot L}{A \cdot t} \cdot \log\left(\frac{h_1}{h_2}\right) \qquad (2)$$

where;
K : Permeability coefficient (cm/sec)
a : Area of water reservoir (cm^2)
L : Height of sample (cm)
A : Cross section area that the water flows from the sample (cm^2)
t : Time needed for the flow of specified volume of water (sec)
h_1 : Initial depth of water in the reservoir (cm)
h_2 : Final depth of water in the reservoir (cm)

3. FINDINGS AND DISCUSSION

Results of tests performed on Basalt Aggregates are given in Table 6**Table 6**.

Basalt aggregates used within the concept of the study has been evaluated as aggregates with normal density according to TS 706 EN 12620 standard. When resistance to fragmentation test

Table 6

Physical characteristics of basalt aggregates used in the study

Tests	**5-10 mm Basalt Aggregate**	**10-15 mm Basalt Aggregate**	**5-10 (50%) and 10-15mm (50%) Mixed Basalt aggregate**
Saturated Surface Particle Density (TS EN 1097-6 Encl-B)	2.63	2.62	-
Water absorption (%)	0.823	0.98	
Loose Unit Volume Weight (TS 3529) g/dm^3	1364.65	1380.30	1414.99
Compacted Unit Volume Weight (TS 3529) g/dm^3	1525.44	1561.04	1576.99
Resistance to Fragmentation (Los Angeles Method, TS EN 1097-2)	20.06	18.16	-

Table 7

Consistency Test Results

Volume of Cement Paste	**Aggregate Gradation:**	**Mixture No**	**Result of Snowball Method**
15%	10-15 mm	P15-F0-C100	-
	5-10mm (50%) +10-15mm (50%)	P15-F50-C50	-
	5-10 mm	P15-F100-C0	-
20%	10-15 mm	P20-F0-C100	-
	5-10mm (50%) +10-15mm (50%)	P20-F50-C50	Positive
	5-10 mm	P20-F100-C0	Positive
25%	10-15 mm	P25-F0-C100	Positive
	5-10mm (50%) +10-15mm (50%)	P25-F50-C50	Positive
	5-10 mm	P25-F100-C0	Positive

results were reviewed it was determined that the aggregates were in LA20 category as per their abrasion resistance.

Consistency test results of produced concretes are given in Table 7.

Table 7 shows that in batches with 15% cement volume and in P20-F0-C100 batch with 20% cement volume, aggregates did not adhere to each other with cement paste as a result of the snowball test. But, in other batches it was observed that the concrete mixture did not change its shape after it was formed as a snowball and aggregates did not separate from each other. Tennis et al. reported in their study that snowball method can be applied with determination of correct water/cement ratio [11]. But, within the concept of the study, some of the mixtures with constant water/cement ratio did not stay in snowball form, and this can be explained with insufficient cement paste that surrounds the aggregates. In pervious concrete mixtures that do not have sufficient amount of cement paste, it is considered that the bond between the aggregates would be poor, and this would cause losses in physical characteristics of the pervious concrete.

Results of fresh concrete density test performed on the samples are given in Fig. 7.

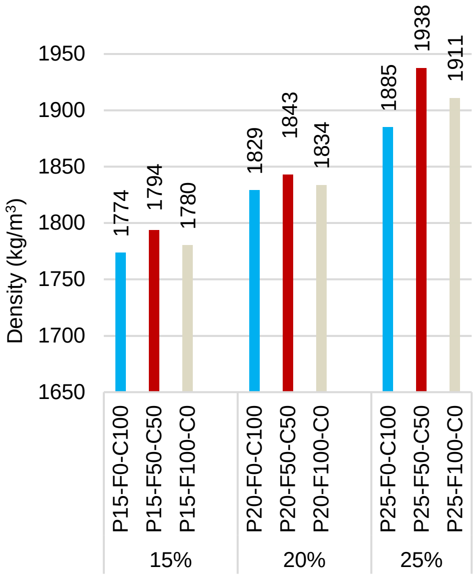


Fig. 7 Fresh Concrete Density Test Results

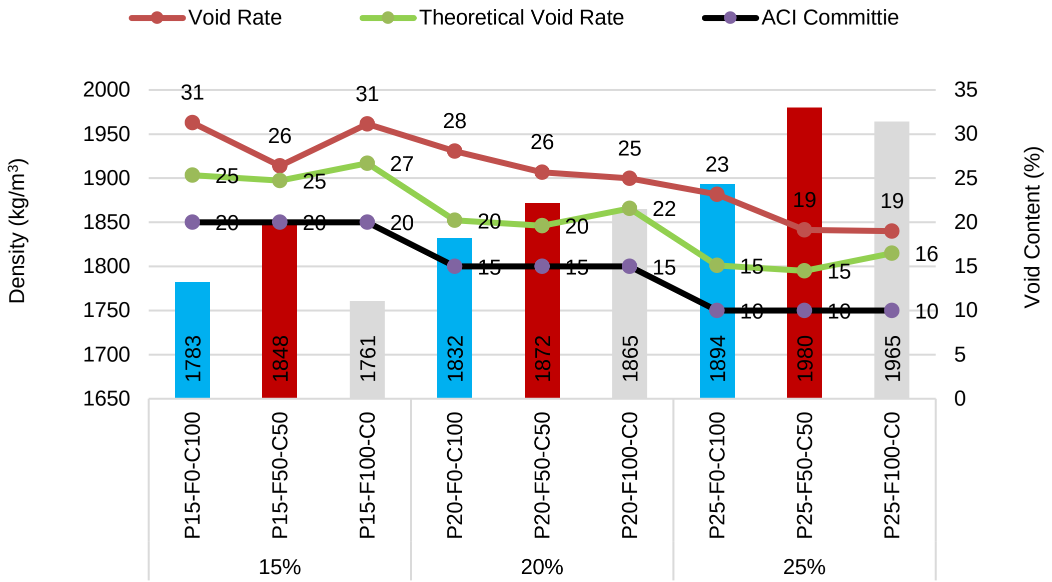


Fig. 8 Density and Void Rate Values of Pervious Concrete Samples

Fig. 7 shows that the density of pervious concrete samples increases with increasing cement paste volume. When pervious concrete samples prepared with coarse aggregates (10-15mm) were examined it was observed that the density of pervious concrete sample with 25% paste volume was 3.05% greater than that of the pervious concrete sample with 20% paste volume, and 6.27% greater than that of the pervious concrete sample with 15% paste volume. When samples of mixtures composed of coarse and fine aggregates (10-15mm + 5-10mm) were examined it was observed that the density of pervious concrete sample with 25% paste volume was 5.12% greater than that of the pervious concrete sample with 20% paste volume, and 8.02% greater than that of the pervious concrete sample with 15% paste volume. When pervious concrete samples prepared with fine aggregates (5-10 mm) were examined, it was observed that the density of pervious concrete sample with 25% paste volume was 4.2% greater than that of the pervious concrete sample with 20% paste volume, and 7.34% greater than that of the pervious concrete sample with 15% paste volume.

Void Rate and Density

Fig. 8 shows the results of the density and void rate tests applied on hardened pervious concrete samples, theoretically calculated void rates, and void rates according to the guideline recommended by ACI Committee 522, comparatively.

Fig. 8 shows that when cement paste volume has increased, the density has increased and void rate has decreased, as expected. In pervious concrete samples prepared by coarse (10-15 mm) and fine (5-10 mm) aggregates, it was observed that fine particles got in between coarse particles and decreased the void amount. As aggregate particle size increases, the void rate in pervious concrete mixture increases. Theoretically calculated void rates and experimentally obtained void rates have shown similar characteristics, however experimentally obtained void rates have been higher due to the effects of compressing and settling parameters. According to the test results, void rates for pervious concrete samples were greater than the theoretically calculated void rate values by 23.6%, 6.7%, 16.7%, 38.9%, 31.0%, 15.7%, 53.3%, 32.1%, 15.3%, respectively. Void rates obtained in our mixture design had higher values according to the void rates specified in the acceptance of paste volume-void rate of ACI Committee 522. In ACI Committee 522's void rate-paste volume suggestion, there are no parameters about the aggregate particle size. But, according to the test results, due to particle size variations, different void rate values were obtained with the same cement volume. When density values were reviewed, it was observed that the minimum value (1761.0 kg/m^3) was obtained by P15-F100-C0 mixture, while the maximum value (1980.0 kg/m^3) was obtained by P25-F50-C50 mixture.

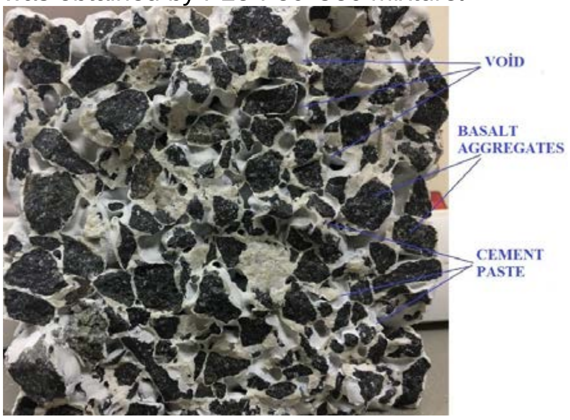


Fig. 9 Cross-sectional image of pervious concrete sample

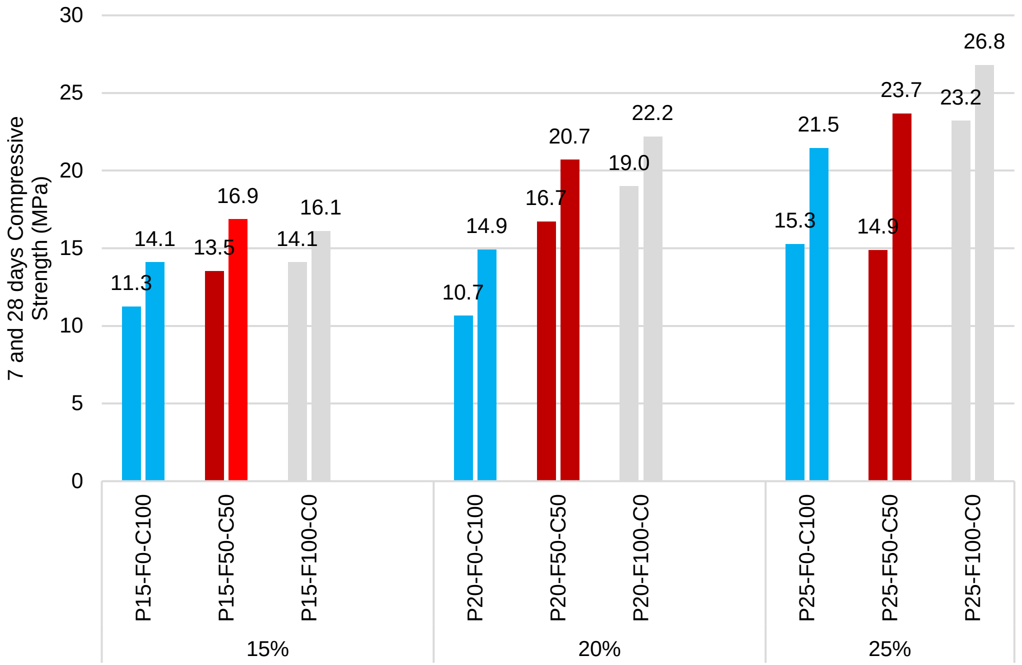


Fig. 10 Compressive Strength Test Results

Compressive Strength

7 days and 28 days of compressive strength test result obtained for pervious concrete samples prepared in the concept of this study are given in Fig. 10.

As shown in Fig. 10, among the pervious concrete samples that have 9 different design mixtures within the concept of the study, the maximum compressive strength was obtained with (28th Day: 26.81MPa) P25-F100-C0 coded pervious concrete sample, while the minimum compressive strength (28th Day: 14.10 MPa) was obtained with P15-F0-C100 coded pervious concrete sample. Compressive strength value increases with increasing cement paste volume. When the results were reviewed according to aggregates, P15-F50-C50 coded mixture from mixtures of 15% paste volume was found to be the mixture with the greatest compressive strength in 28 days (16.87 MPa). P20-F100-C0 coded mixture from mixtures of 20% paste volume was found to be the mixture with the greatest compressive strength in 28 days (22.20 MPa). P25-F100-C0 coded mixture from mixtures of 25% paste volume was found to be the mixture with the greatest compressive strength in 28 days (26.81). Yu et al. has reported that aggregate size over 7 mm used in pervious concretes has no positive effect in compressive strength [18]. As can be seen from the test results, it is observed that as the aggregate size increases, the compressive strength decreases. Depending on this, compressive strength increases with the increase in cement paste volume. This would decrease the permeability by decreasing the voids in pervious concrete.

Void Rate-Compressive Strength Relation

Effect of void rate of pervious concrete samples on compressive strength is given in

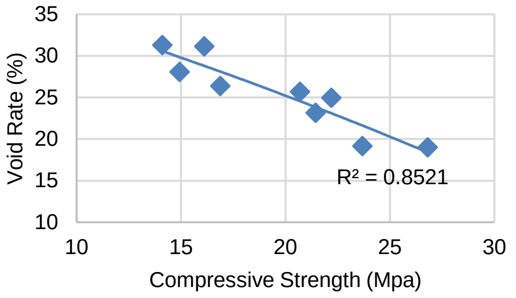


Fig. 11.

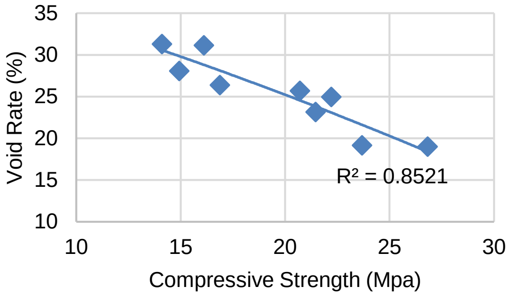


Fig. 11 Void rate- compressive strength relation

Although voids in pervious concretes form the characteristic structure of the concrete, as the void amount increases the compressive strength decreases. While fine materials were not used in the mixtures, it was observed that by increasing the cement paste amount, void rate has decreased quickly, and compressive strength has increased.

Permeability

Fig. 12 shows the permeability values of pervious concrete samples prepared in the concept of this study.

Fig. 12 shows that paste volume and aggregate gradation affects the water discharge amount of the pervious concretes. As mixtures of coarse aggregates would form larger voids, they would have higher permeability. Also, as the cement paste amount increases, the void rate and permeability will decrease. P15-F0-C100 coded mixture has the maximum permeability coefficient, while P25-F100-C0 coded mixture has the minimum permeability coefficient.

Permeability value depends on a number of factors such as porosity, pore size distribution, pore roughness, narrowing of pore space, connectivity of internal pore channels etc. [34]. Permeability test results are compatible with literature and directives of ACI Committee 522.

Figure 13 shows that in all mixtures compressive strength decreases and permeability increases as the void rate increases. It was observed that produced concrete samples had compressive strength values between 14.10 MPa-26.81 MPa, permeability values between 0.49 cm/sec – 1.24 cm/sec and void rates between %19-%31.3.

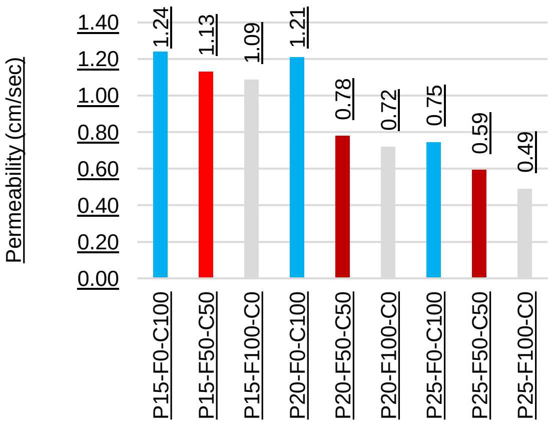


Fig. 12 Permeability Results

The information from the literature confirms the relationship between these parameters. When all results are reviewed with reference values given by ACI Committee 522 (compressive strength 2.8-28 MPa, permeability 0.14-1.22 cm/sec, void rate 15-35%), it is concluded that the prepared mixtures are consistent with literature.

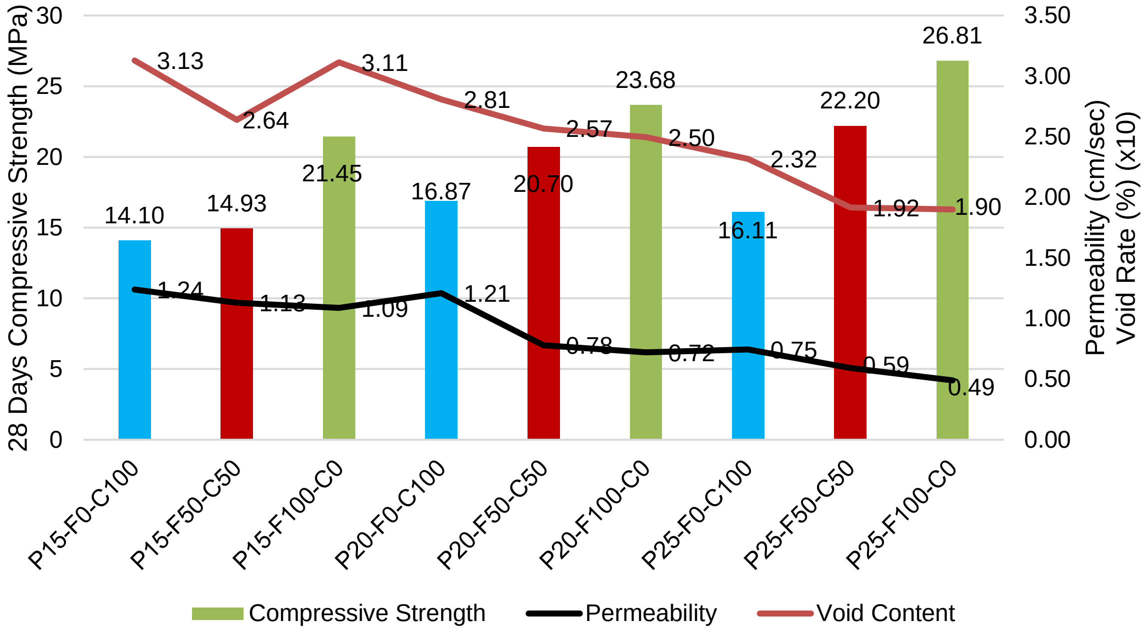


Figure 13. Compressive Strength – Permeability -Void Rate Relationship

Splitting Tensile Strength

Results of splitting tensile strength test performed on samples are given in Fig. 14.

From Fig. 14, it can be seen that the strength values increase as the volume of cement paste increases. P25-F100-C0 coded mixture had the maximum tensile strength (3.38 MPa), while P15-F0-C100 coded mixture had the minimum tensile strength (1.74 MPa).

Fig. 15 gives the relationship between compressive strength, splitting tensile strength and void rate of pervious concrete samples.

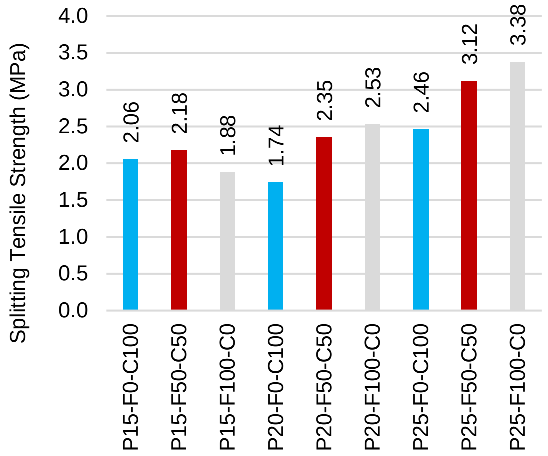


Fig. 14 Splitting Tensile Strength values

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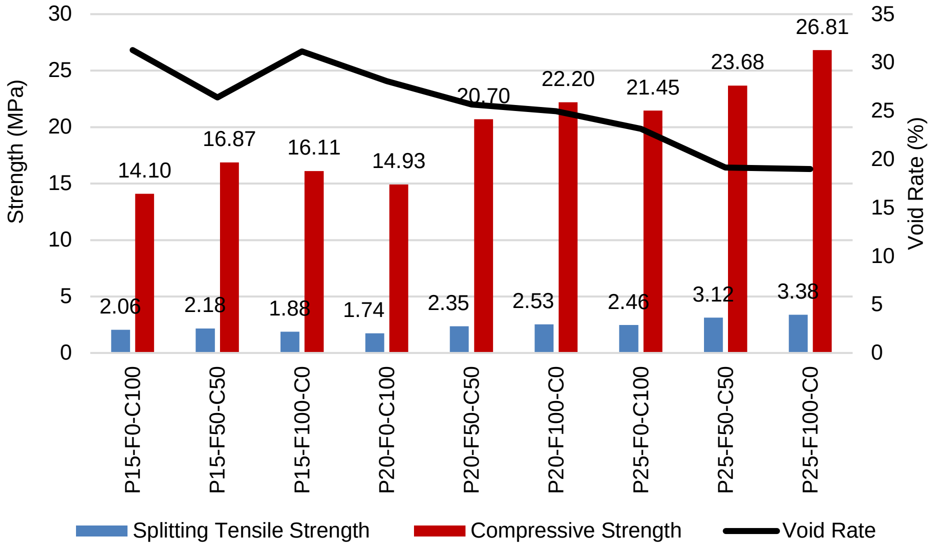

Fig. 15 Relationship of Void Rate with Compressive Strength and Tensile Strength

Fig. 15 shows that as it is for the compressive strength values, the tensile strength values of pervious concretes depend on the void rate. As void rate decreases, it is observed that the compressive strength and tensile strength of pervious concrete increases.

4. CONCLUSION AND RECOMMENDATIONS

Conclusions

The results of this study investigating the production of pervious concrete using basalt aggregate are given below.

As there are no national or international standards available for pervious concretes, new guides for determining mixture ratios are required. With the mixture design guide prepared in this study, pervious concrete mixture designs can be made. It is believed that this information would provide contribution to literature.

In pervious concrete design, as cement paste volume increased, 28 days of compressive strength value increased, but permeability value decreased. Concrete samples with 25% paste volume had greater compressive strength values than batches produced with other paste volumes. When studies of recent years are reviewed it is seen that these data are consistent with each other.

Pervious concrete samples produced with 5-10 mm basalt aggregates had less void rate and more compressive strength than the pervious concrete samples produced with 10-15 mm basalt aggregates. As the void rate between the coarse aggregates were higher, an increase in permeability values were observed. It is determined that in pervious concretes aggregate size is directly proportional to void rate, while void rate is inversely proportional to compressive strength.

Mixtures with 5-10 mm aggregate and 25% cement paste volume had the maximum compressive and tensile strength besides the minimum permeability. However, it is considered that they can be used in required areas such as pavements, roads, parking lots etc. where their permeability value is consistent with the literature.

As it was aimed in this study to enhance the mechanical characteristics of pervious concretes by using basalt aggregates without compromising on their permeability value, it was determined that the optimum design mixture was P25-F100-C0 coded mixture which had 25% cement paste volume.

Recommendations

In the pervious concrete sample production step, it was observed that compressing parameters have played a significant role and this has directly affected the void rate. While some applications have been seen in literature by vibration and rodding techniques, it is not considered to be effective if these methods were used for pervious concretes. Thus, it is recommended to perform more studies on compressing methods.

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