Experimental Study on Previous Concrete with Various Mix Ratios

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***Abstract*— The pervious concrete is designed with cementitious material content just enough to coat the coarse aggregate particles so that a configuration that allows the passage of water at a much higher rate than conventional concrete. The pervious concrete has many advantages that improves city environment, recharges the ground by rain water and could be used as pavement for light vehicles, pedestrian pathways, parking lots, also it reduces the tire pavement interaction noise etc. In this paper, structural property and permeability of pervious concrete made without and with different ratios of fine aggregate and pozzolan. 9.5 mm maximum size of crushed gravel and constant aggregate/cement ratio of 3.6 were used. Mix design void content is tested 20%. The specific gravity of fine aggregate 2.53 and the specific gravity of crushed stone 2.56. Type I Portland cement and water- reducing and retarding concrete admixture were used. Mix design is based on the no slump method from the American Concrete Institute's Committee 211.3R-02, "Standard Practice for Selecting Proportions for No Slump Concrete." This research work was divided into *third*/three sections. The first section is without pozzolan and fine aggregate and second section is with two different ratios of pozzolan third section is without pozzolan and with fine aggregate. Pozzolan is used as a supplementary cementitious material to partially replace Portland cement in pervious concrete mixes up to 20% by weight. Fine aggregate partially replace as a coarse aggregate in pervious concrete mixes up to 10% by weight. *Mix design void content is tested 20%.* This concrete is tested for its properties, such as density, void content, compressive strength and water permeability. The most important property of pervious concrete is its water permeability.**

Keywords— *Pervious Concrete, Pozzolan, Fine Aggregate, Density, Void Content, Compressive Strength, and Permeability*

I. INTRODUCTION[1]

Pervious concrete is a composite material consisting of coarse aggregate, Portland cement and water. *It is different from conventional concrete as the mixture contains no fines in it. The aggregate is usually of a single size and is bonded together by a cement paste.* The result is a concrete with a high percentage of interconnected voids that allow the penetration of water through the material matrix. Normal concrete has a void ratio around 3- 5% and pervious concrete has higher void ratios from 18-40% depending on its application. Pervious concrete differs from normal concrete in several other ways. Pervious concrete has lower compressive strength, higher permeability and a lower density. Its compressive strength could be 65% lower than the normal concrete [1]. Pervious concrete is increasingly being installed to improve stormwater quality and reduce runoff produced by urban settings. During the last few years, pervious concrete has attracted more and more attention in concrete industry due to the increased awareness of environmental protection. The focus of pervious concrete technology is the balance of permeability and mechanical properties as well as durability. Pervious concrete shows in Figure 1. If the mixture is too wet and easy to compact, the voids will be clogged and the permeability will be compromised. If the mixture is too dry and hard for compaction, the pervious concrete pavement will be weak and vulnerable to various types of distress [2].

Figure 1. Pervious Concrete [1]

II. METHOD AND EXPERIMENTAL PROGRAM

A. Material and Mix Proportion

1. Two types of binder materials were used in this study; the first is Type I Portland cement (ASTM C150), and the second is pozzolan

conforming to (ASTM 618) in Figure 2. The specific gravity of Portland cement is 3.08. Fineness of cement is 5.6%.The specific gravity of Popa pozzolan is 2.77. Fineness of Pozzolan is 4.9%.

2. 4.75 mm to 9.5 mm crushed gravel, which is nominal-size, was used as coarse aggregate. The specific gravity of crushed gravel is 2.56 and unit weight is 1482.65 kg/m^3. The absorption of crushed gravel is 0.79%. Abrasion value of crushed gravel is 30.90 %.
3. River sand with specific gravity 2.53 and fineness modulus 2.7 from Hlaing river in Yangon is used as fine aggregate. The unit weight of fine aggregate is 1773.93 kg/m^3.
4. Water- reducing and retarding concrete admixture (ASTM.C-494 type B & D) were used in this study. This admixture colour is brown. The specific gravity of water- reducing and retarding concrete admixture is 1.16-1.18 kg/*l*. The pH value of water- reducing and retarding concrete admixture is 4-6.
5. Potable water was used in this study. The pH value of water is 8.[4]

(a) Cement (b) Pozzolan

Figure 2. Cement and Pozzolan

A concrete mix design can be proportioned from existing statistical data using the same materials, proportions, and concreting conditions. The one that will be described in this study is based on the no slump method from the American Concrete Institute's Committee 211.3R-02, "Standard Practice for Selecting Proportions for No Slump Concrete." [3]

The mixture proportions used in this study is listed in Table 1. Pervious concrete mixtures require a careful analysis of aggregate properties for a structure which has adequate strength and allowing water to drain through its matrix. Four different pervious concrete mixes have been prepared in this research: Mix 1(0% pozzolan, 0% fine aggregate), Mix 2 (10% pozzolan, 0% fine aggregate), Mix 3 (20% pozzolan, 0% fine aggregate) and Mix 4(0% pozzolan,10% fine aggregate). For all four mixes, the water to binder materials (cement plus pozzolan) ratio was maintained at 0.27 and coarse aggregate to binder materials ratio (cement plus pozzolan) was maintained at 3.6. In this research, desired slump value is zero. This test is performed as ASTM 143 procedure. Testing of slump is shown in Figure 3.

Figure 3. Slump Test of Concrete

Table 1. Mixture Proportions

	Mix 1	Mix 2	Mix 3	Mix 4
Cement (kg/m³)	399.72	359.748	319.78	399.72
Pozzolan (kg/m³)	0	39.972	79.94	0
Fine Agg: (kg/m³)	0	0	0	143.9
Coarse Agg:(kg/m³)	1439	1439	1439	1295.1
Water (kg/m³)	107.92	107.92	107.92	107.92
Admix:(kg/m³)	2.00	2.00	2.00	2.00
W/C	0.27	-	-	0.27
W/Cementitious	-	0.27	0.27	-
A/C	3.6	3.6	3.6	3.6
Slump (mm)	0	0	0	0

The details of the chemical composition of Portland cement and pozzolan are listed in Tables 2 and 3.

Table 2. Chemical Composition of Cement

Analyte	Result	Analyte	Result
CaO	73.927%	ZnO	0.037%
SiO_2	8.900%	ZrO_2	0.033%
Fe_2O_3	8.695%	CuO	0.030%
K_2O	7.534%	MoO_3	0.018%
TiO_2	0.383%	As_2O_3	0.017%
SO_3	0.228%	Ga_2O_3	0.003%
SrO	0.118%	-	-
MnO	0.075%	-	-

Table 3. Chemical Composition of Pozzolan

Analyte	Result
CaO	16.224%
SiO_2	31.639%
Fe_2O_3	40.594%
K_2O	9.485%
TiO_2	1.445%
SrO	0.489%
ZrO_2	0.063%
CuO	0.062%
BaO	0.000%

B. Experimental Program A. Experimental Program

Fresh concrete mixes were produced in a pan-type of concrete mixer. The fresh density of pervious concrete was tested from ASTM C1688 Fresh density test is shown in Figure 4.

Figure 4. Fresh Density Test

Figure 5. Compressive Strength Test

The compressive strength was carried out in accordance with the test procedures given in ASTM C39, and the average compressive strength of results obtained with two identical specimens are reported. The standard compressive strength tests were performed on the cubes (150 mm x 150 mm x 150 mm). The compressive machine for test cubes is hydraulic compression testing machine is shown in Figure 5.

The void content was determined in accordance with ASTM C1754 by taking the difference in weights of an oven dried specimen, and when submerged in water, using Equation 1. Hardened void content is shown in Figure 6.

(a) Place in Oven (110˚C)

(b) Concrete cube

(c) Submersed Wt.

Figure 6. Hardened Void Content Test

The void content was determined in accordance with ASTM C1754 by taking the difference in weights of an oven dried specimen, and when submerged in water, using Equation 1. Hardened void content is shown in Figure 6.

$$V_r = [1 - \{(M_w - M_d)/(\rho_w \times vol:)\}] \times 100 \qquad \text{Eqn. (1)}$$

Where, V_r= Void content

M_w= weight under water

M_d = oven dry weight

vol: = volume of sample, and

ρ_w= density of water

The water permeability was calculated based on Darcy's Law, given below:

$$K = (A_1 l / A_2 t) \log (h_1/h_2) \qquad \text{Eqn. (2)}$$

Where, l is the length of the specimen, A_1 is the cross sectional area of specimen and A_2 is cross sectional area of drain pipe and K is the coefficient of permeability. The valve is then opened, and the time taken (in seconds, t) for the water to fall from the initial head to a final head (h_1 to h_2).

The cast test specimens were demoulded after 24 hours and stored in water at 20˚C until the age of testing. The water permeability of pervious concrete was determined using a procedure described [4]. Water permeability test is shown in Figure 7.

Figure 7. Water Permeability Test

The absorption was determined in accordance with IS 2386. The absorption test is shown in Figure 8. The (150mm x150mm x150mm) Cubes after casting will be immersed in water for 28 days curing. These specimens will then oven dried for 24 hours at the temperature 110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W_1) of the block. After that the specimen will be kept in hot water at 85°C for 3.5 hours. Then this weight will noted as the wet weight (W_2) of the block. After crushing that specimen will noted as the wet weight (W_3) of the block. The percentage Water Absorption (W_A) is calculated as follows.

% Water Absorption $W_A=[(W_3 - W_1)/W_1]x100$ Eqn. (3)

Where, W_1 = Oven dry weight of the cubes in grams
W_2 = after 3.5 hour wet weights of cubes in grams
W_3 = after crushing weights in grams

(a) Place in Oven (110˚C)

(b) Place in hot water (85˚C) (c) After Crushing

Figure 8. Absorption Test of Pervious Concrete

III. RESULTS AND DISCUSSION

Figure 9 for Mix1, Figure 10 for Mix 2, Figure 11 for Mix 3 and Figure 12 for Mix 4 show comparison of specified cube compressive $f'_{c,cube}$ and three consecutive compressive strength $f'_{cr,cube}$.

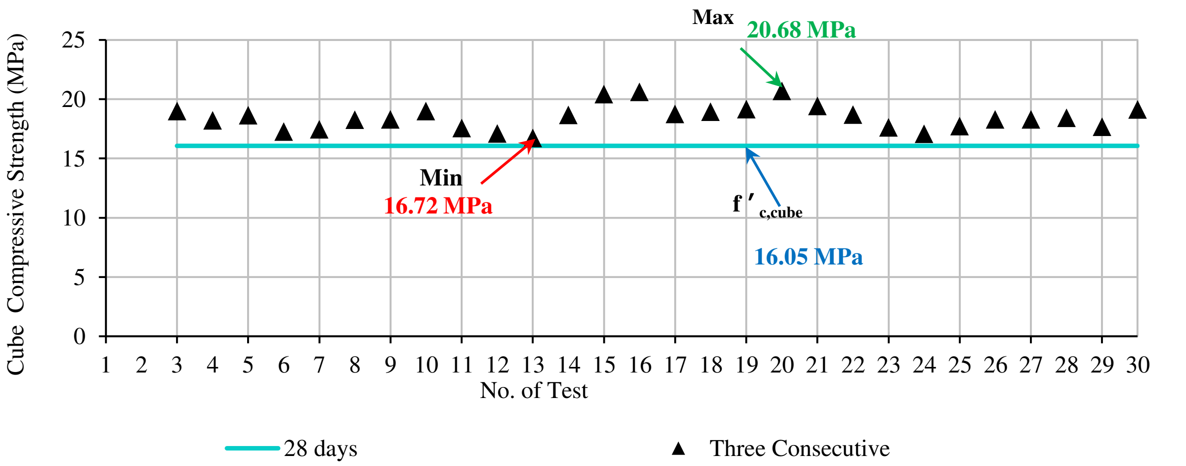

Figure 9. Comparison of 28 days Specified Cube Strength $f'_{c,cube}$ and Three Consecutive Test Result $f'_{cr,cube}$ for 0% Pozzolan

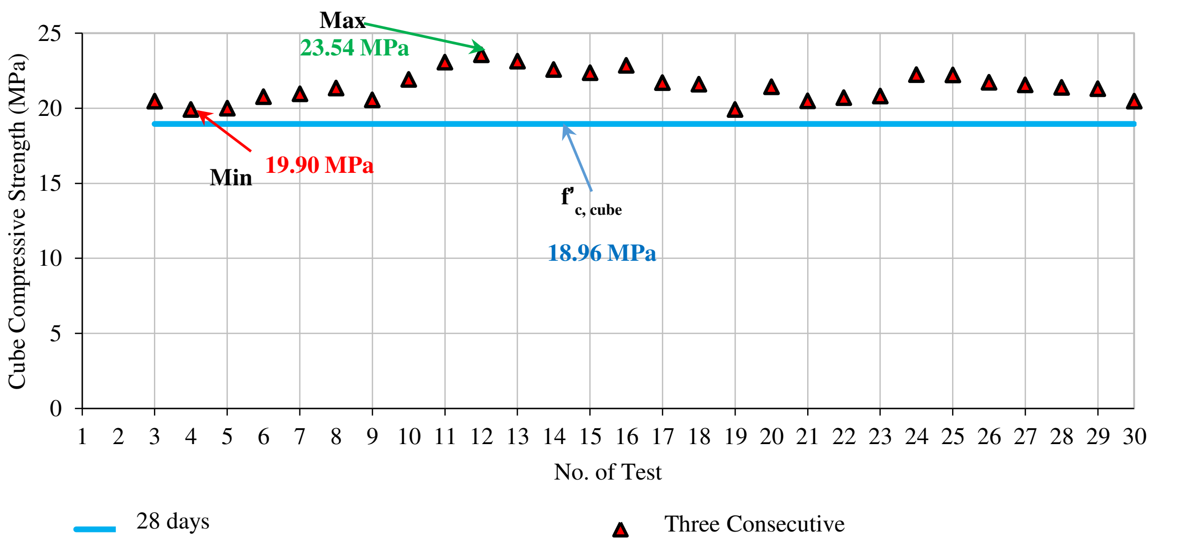

Figure 10. Comparison of 28 days Specified Cube Strength $f'_{c,cube}$ and Three Consecutive Test Result $f'_{cr,cube}$ for 10% Pozzolan

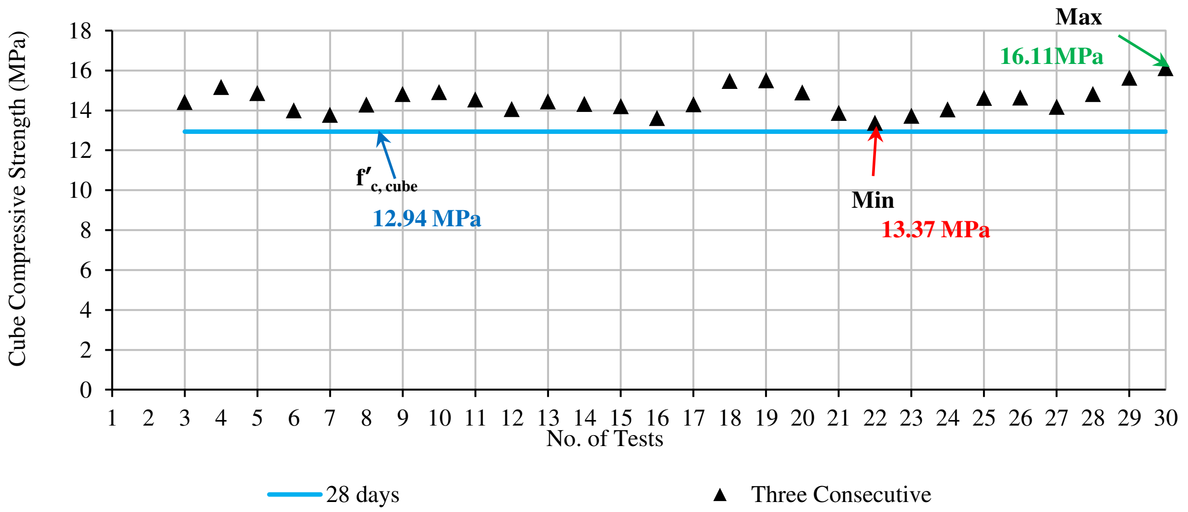

Figure 11. Comparison of 28 days Specified Cube Strength $f'_{c,cube}$ and Three Consecutive Test Result $f'_{cr,cube}$ for 20% Pozzolan

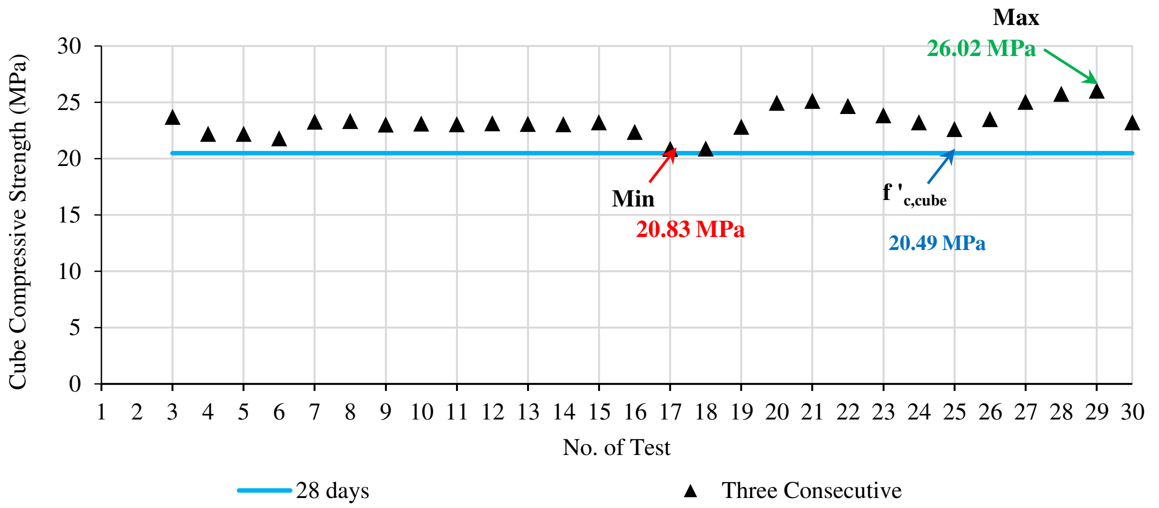

Figure 12. Comparison of 28 days Specified Cube Strength $f'_{c,cube}$ and Three Consecutive Test Result $f'_{cr,cube}$ for 10% Fine Aggregate

Table 4 shows comparison of pervious concrete (Mix 1: 0% pozzolan, 0% fine aggregate), (Mix 2: 10% pozzolan, 0% fine aggregate), (Mix 3: 20% pozzolan, 0% fine aggregate) and (Mix 4: 0% pozzolan, 10% fine aggregate) test results. For mean compressive strength $f'_{cr,cube}$, total 120 cubes (60 cubes for each mix) are cast to allow the compressive strength to be monitored at 28 days. Figure 13 shows durability of pervious concrete test results. For compressive strength, total 60 cubes (15 cubes for each mix) are cast to allow the mean compressive strength $f'_{cr,cube}$ to be monitored at 7 days, 28 days, 56 days, 90 days and 180 days respectively.

Table 4.Comparison of Pervious Concrete (With or Without Pozzolan) and (With or Without Fine Aggregate)

Mix No.	Density (kg/m^3)	Void Content (%)	Permeability (mm/s)	Absorption (%)	Mean Compressive Strength (MPa)
Mix 1	1827.18	23.9	12.49	0.93	18.49
Mix2	1807.08	22.02	10.12	0.89	21.39
Mix 3	1785.15	20.59	8.84	0.85	14.51
Mix 4	1845.01	20.02	6.23	1.02	23.21

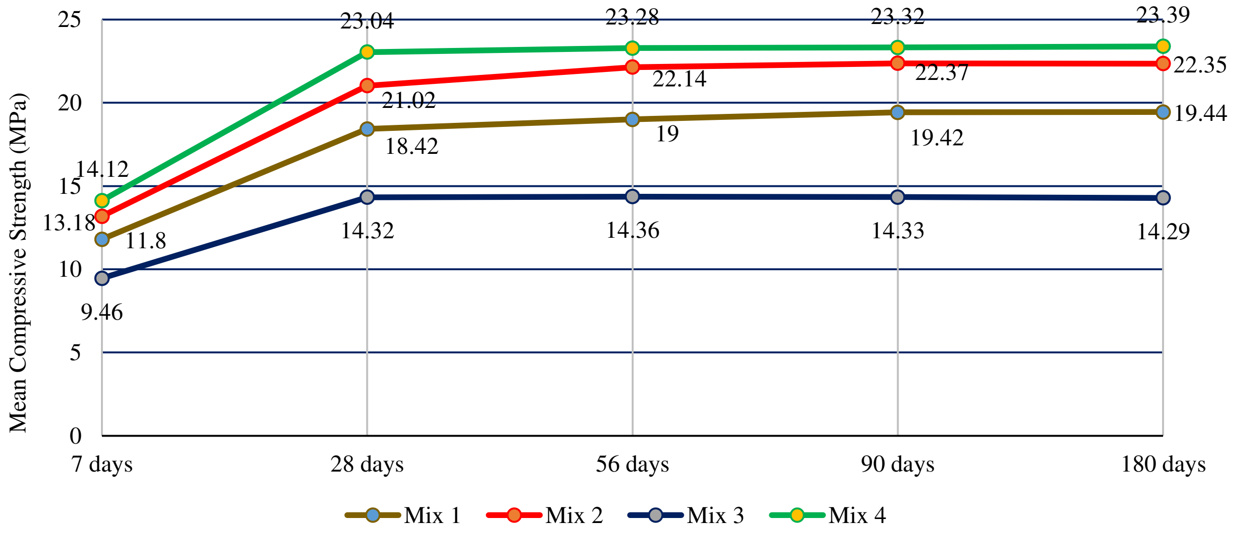

Figure13. Durability Test Results of Pervious Concrete

The density of pervious concrete without fine aggregate decreased marginally when the cement is partially replaced with pozzolan. The density values were 1827.18, 1807.08 and 1785.15 kg/m3 when 0 %, 10 % and 20 % of cement was replaced with pozzolan, respectively. The density of pervious concrete without pozzolan was marginally increased by adding fine aggregate. The density of pervious concrete without pozzolan and with 10 % fine aggregate was 1845.01 kg/m3. The void content and water permeability of pervious concrete were marginally reduced when the fine aggregate content and pozzolan content were increased. The compressive strength of pervious concrete without fine aggregate increased marginally when the cement is partially replaced with pozzolan 10% but 20% pozzolan marginally decreased. The compressive strength values were 18.49, 21.39 and 14.51 MPa when 0%, 10 % and 20 % of cement was replaced with pozzolan, respectively. The compressive strength of pervious concrete was influenced when increasing the fine aggregate content. The compressive strength value was 23.21 MPa. Pervious concrete without pozzolan and fine aggregate is the best performed in water permeability. Pervious concrete with 10 % fine aggregate will improve compressive strength but at the same time permeability will be reduced. Durability of pervious concrete, the compressive strengths develop with age for all four mixes of pervious concrete. After 28days, strength develops slowly.

IV.CONCLUSION

Due to voids in pervious concrete, it is difficult to obtain high-strength by using the common material and proportion of mixture. Replacement of 10% pozzolan in cement will improve the compressive strength and workability but at the same time permeability will be reduced. It can be seen that replacement of pozzolan in cement should not be more than 10%. The pervious concrete made without fine aggregate and pozzolan performed best in water permeability and workability. The compressive strength of pervious concrete without pozzolan will significantly increase with the addition of fine aggregate but at the same time permeability and workability will be reduced. The partial replacement of the fine aggregate content in coarse aggregate should not be more than 10%. More than that will reduce the permeability also which are the major properties of pervious concrete. Replacement of 10% fine aggregate in coarse aggregate should not be used rainfalls area. Pervious concrete has high water permeability due the presence of interconnected air voids. So, pervious concrete should be used Yangon flooded area such as pavement edge drains, low water crossings area, path ways and shoulder. It can be concluded that pervious concrete with good characteristics can be produced by partially replacing cement with pozzolanic material. This leads to multiple advantages such as improving pervious concrete, reducing production cost and also decreasing the carbon dioxide emission due to the reduction in amount of cement.

V. REFERENCES

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