International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 5

# Study on Natural Pozzolan as a Partial Replacement for Cement in Pervious Concrete

**Hla Hla Htay, Htet Thu Aung**
Department of Civil Engineering, Yangon Technological University
Republic of the Union of Myanmar, Yangon, Myanmar

**ABSTRACT**
A study on pervious concrete is the balance of permeability and mechanical properties as well as durability. Pervious concrete is important in concrete industry due to the increased awareness of environmental protection. Natural pozzolan is used as a supplementary cementitious material to partially replace of Portland cement in concrete. In this paper mainly focuses on experimental study of different replacement of cement with Popa volcanic natural pozzolan in pervious concrete. This research work is made previous concrete on 10%, 20% by weight replacement of cement with and without pozzolan. 19mm maximum size of crushed gravel was used. 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. This concrete is tested for its properties, such as density, void content, water permeability and the compressive strength with various ages. According to the results, pozzolan replacement of cement increased as the compressive strength and permeability and durability of pervious concrete decreased.

***Keywords:*** *Pervious Concrete, Pozzolan, Void Content, Compressive Strength and Permeability*

## I. INTRODUCTION

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. It has higher void ratios from 18-40% depending on its application. It has lower compressive strength, higher permeability and a lower density. Its compressive strength could be 65% lower than the normal concrete. Pervious concrete is increasingly being installed to improve storm water 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. 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.

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**.**

Pozzolanic material has enough strength and high durability. In Myanmar, natural volcanic pozzolan is obtained from Poppa region in the middle portion of Myanmar has been used in some construction projects such as dams and pavements to get high durability and to reduce construction cost. But the replacement of Popa pozzolan in cement for pervious concrete is not studied in theoretical basis.

The objective of this experimental study is to investigate the optimal replacement of pozzolan in cement to improve the permeability and compressive strength of pervious concrete.

## II. IEXPERIMENTAL PROGRAMME

### A. Material

Type I Ordinary Portland cement, natural volcanic pozzolan from Poppa region, (4.5mm-19mm) size of crushed gravel, water- reducing and retarding concrete admixture and potable water were used in this research. Types I Portland cement, natural volcanic pozzolan from Poppa region and crushed gravel are shown in Figure 1. The details of the chemical compositions of cement and natural volcanic pozzolan are listed in Table 1. The total percent of SiO2, Al2O3 and Fe2O3 in natural pozzolan is greater than 70%. So, it is adequate for ASTM requirement for class N.

The physical properties of cement, pozzolan and crushed gravel are listed in Table 2, 3 and 4. Water-reducing and retarding concrete admixture (ASTM.C-494 type B & D) were used in this study. The specific gravity of this admixture is 1.16-1.18 kg/*l* and the colour is brown. The pH value is 4-6. Potable water was used in this study and the pH value is 8.

(a) Cement

(b) Natural Volcanic Pozzolan

(c) Crushed Gravel (4.75-19 mm)

Figure1. Cement, Natural Volcanic Pozzolan and Crushed Gravel

Table1. Chemical Composition of Cement and Natural Pozzolan

| Cement | | Natural Pozzolan | | |
|---|---|---|---|---|
| Composi-tion | % | Composi-tion | % | Requirements as per ASTM Class N |
| CaO | 67.93 | CaO | 16.22 | SiO2 +Al2O3+ Fe2O3= 70%(min.) |
| SiO2 | 12.80 | SiO2 | 31.64 | |
| Al2O3 | 2.30 | Fe2O3 | 40.59 | |
| Fe2O3 | 8.70 | K2O | 9.49 | |
| K2O | 7.53 | TiO2 | 1.45 | |
| SO3 | 0.23 | SrO | 0.49 | |
| MnO | 0.08 | ZrO2 | 0.06 | |
| Other Total | 0.43 | CuO | 0.06 | |
| Total | 100 | Available alkalies | Nail | Max. 1.5% |
| | | Loss on ignition (%) | 2.26 | Max. 10% |

Table2. Physical Properties of Cement

| Name of Test | | Results | Specification (ASTM) |
|---|---|---|---|
| Specific Gravity | | 3.08 | 3.1-3.25 |
| ineness | | 5.6 % | |
| Consistency | | 31.8 %. | |
| Setting Time | Initial | 122 min | > 60 min |
| | Final | 236 min | < 600 min |
| Soundness | | 2.5 mm | ≤ 10 mm |
| Compressive Strength Cement Mortar | 3-day | 23.12 MPa | > 12 MPa |
| | 7-day | 31,29 MPa | > 19 MPa |
| | 28-day | 39.18 MPa | - |

Table3. Physical Properties of Natural Pozzolan

| Name of Test | Results | Specification (ASTM) |
|---|---|---|
| Specific Gravity | 2.77 | 3.1-3.25 |
| Fineness | 4.9 % | |

Table4. Physical Properties of Crushed Gravel (4.75-19 mm)

| Name of Test | Result | Specification (ASTM) |
|---|---|---|
| Specific Gravity | 2.56 | 2.4 -2.9 |
| Fineness Modulus | 6.74 | 5.5 - 8 |
| Absorption (%) | 0.79 % | 0.5- 4 |
| Dry Rodded Density of Crushed Gravel(kg/m3) | 1482.65 | 1200-1750 |
| Abrasion (%) | 30.90 % | - |

## III. MIXTURE PROPORTIONS

### A. Mixture Proportion

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. Three different pervious concrete mixes have been prepared in this research: the first mix was made with (0% pozzolan,100% cement), the second mix was made with (10% pozzolan, 90% cement), and the third mix was made with (20% pozzolan, 80% cement). For all three mixes, the water to cement ratio and water to binder materials (cement plus pozzolan) ratio were maintained at 0.27. Coarse aggregate to binder materials ratio at 3.6 and void content at 20% were maintained. The mixture proportions of all mixes are listed in Table 5. In this research, desired slump value is zero.

Table5. Mixture Proportions

| Content | 0 % Pozzo-lan Replace-ment | 10 % Pozzo-lan Replace-ment | 20 % Pozzo-lan Replace-ment |
|---|---|---|---|
| Cement (kg/m³) | 399.72 | 359.748 | 319.78 |
| Pozzolan (kg/m³) | 0 | 39.972 | 79.94 |
| CrushedGravel (kg/m³) | 1439 | 1439 | 1439 |
| Water (kg/m³) | 107.92 | 107.92 | 107.92 |
| Admix: (kg/m³) | 2.00 | 2.00 | 2.00 |
| W/C Ratio | 0.27 | - | - |
| W/(C+ Pozzolan) Ratio | - | 0.27 | 0.27 |
| Aggregate/Cemen t Ratio | 3.6 | 3.6 | 3.6 |
| Void Content (%) | 20 | 20 | 20 |
| Slump (mm) | 0 | 0 | 0 |

### B. Specimens Preparation and Test Methods

Slump test is performed as ASTM 143 procedure, shown in Figure 2. Fresh concrete mixes were produced in a pan-type of concrete mixer. The fresh density of pervious concrete mixes was tested from ASTM C1688.

Figure2. Slump Test

Hardened concrete specimens were tested for compressive strength in accordance with ASTM C39 using 150 mm cube, shown in Figure 3.

(a) Pervious Concrete


(b) Preparation of Samples


(c) Curing in Water


(d) Before Crushing


(e) After Crushing

Figure3. Compressive Strength Test of Pervious Concrete Cube Specimen

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.

$Vr = [1-\{(Mw-Md)/ (\rho w \times \text{vol:})\}] \times 100$ Eqn. (1)

where,
$Vr$ = Void content
$Mw$ = weight under water
$Md$ = oven dry weight
vol: = volume of sample, and
$\rho w$ = density of water

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

$K = (A1l/A2t) \log (h1/h2)$ Eqn. (2)

where,
$l$ = the length of the specimen
A1 = the cross-sectional area of specimen
A2 = cross sectional area of drain pipe

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 ($h1$ to $h2$). 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 permeability of pervious concrete was determined using a procedure described.

The absorption was determined in accordance with IS 2386. The 150mm 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 ($W1$) of the block. After that the specimen will be kept in hot water at 85°C for 3.5 hours. Then this weight will be noted as the wet weight ($W2$) of the block. After crushing that specimen will noted as the wet weight ($W3$) of the block. The percentage Water Absorption ($WA$) is calculated as follows.

$WA = [(W3 - W1)/W1] \times 100$ Eqn. (3)
where,
$WA$ = % Water Absorption
$W1$ = Oven dry weight of the cubes in grams.
$W2$ = after 3.5 hour wet weights of cubes in grams
$W3$ = after crushing weights in grams

## IV. RESULTS AND DISCUSSION

### A. Fresh Density Test Results

Total 9 cubes (3 cubes for each mix) were tested for three mixes with cement replacement by 0%,10% and 20% natural pozzolan. According to results, the fresh density decreased marginally when 0% to 20% pozzolan replacement in cement. Because specific gravity of pozzolan is less than specific gravity of cement. The results listed in Table 6 and are shown in Figure 4.

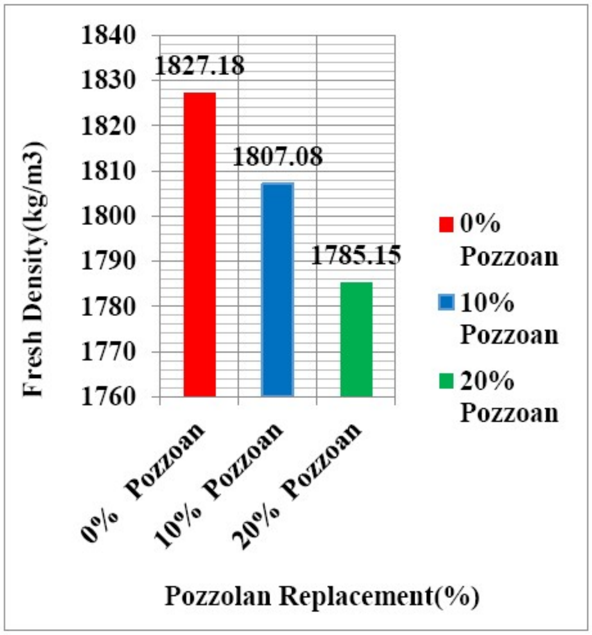


Figure4. Comparison of Fresh Density with Pozzolan Replacement 0% to 20%

### B. Compressive strength Test Results

The mean compressive strength results obtained with two identical specimens are reported for one number of test. In this study 30 number of tests at specified age for one mix. Total 360 cubes (60 cubes for specified age and one mix) are cast to allow the mean compressive strength $fcr,cube'$to be monitored at 7-day, 28- day respectively. These results are listed in Table 6 and shown in Figure 5.

According to experimental results, the mean compressive strength $fcr,cube'$ at 7-day and 28-day increased significantly when the cement is partially replaced with pozzolan 0% to 10%. In 20% pozzolan replacement significantly decreased. So, 10% of pozzolan replacement is optimized value for highest strength of pervious concrete than without pozzolan in concrete.

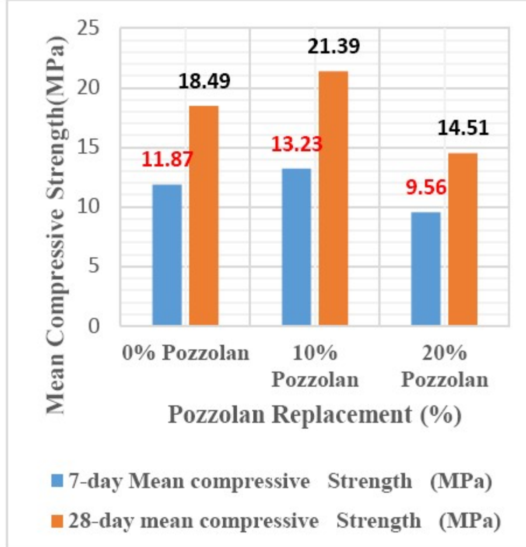


Figure 5. Comparison of Mean Compressive Sterngth $fcr,cube'$ with Pozzolan Replacement 0% to 20%

### C. Void Content, Permeability and Absorption Test Results

Total 27 cubes (3 cubes for one mix with one pozzolan replacement) are tested with all mixes for void content, permeability and absorption. All of these results were marginally reduced when the pozzolan replacement were increased. Because of void content with pozzolan less than without pozzolan, the absorption and permeability content with pozzolan are less than concrete without pozzolan. The results of void content, permeability and absorption for all mixes are listed in Table 6 and shown in Figure 6, 7 and 8.

### D. Durability Test Results

For durability of pervious concrete, total 45 cubes (15 cubes for each mix) for all mixes are cast to allow the mean compressive strength $fcr,cube'$to be monitored at 7-day, 28-day, 56-day, 90-day and 180-day respectively. These results are listed in Table 7 and shown in Figure 9. According to experimental results, the mean compressive strength increased significantly when the cement is partially replaced with pozzolan 0% to 10%. In 20% pozzolan significantly decreased. And then, the mean compressive strength develops with age for all mixes of pervious concrete. After 28-day, the mean compressive strength develops slowly.

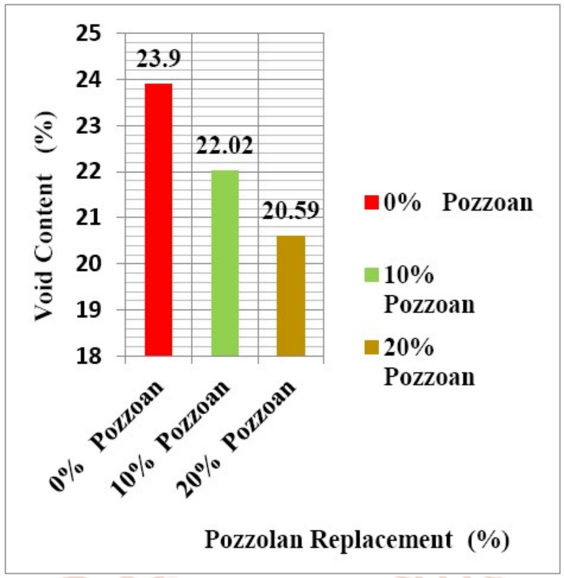


Figure6. Comparison of Void Content with Pozzolan Replacement 0% to 20%

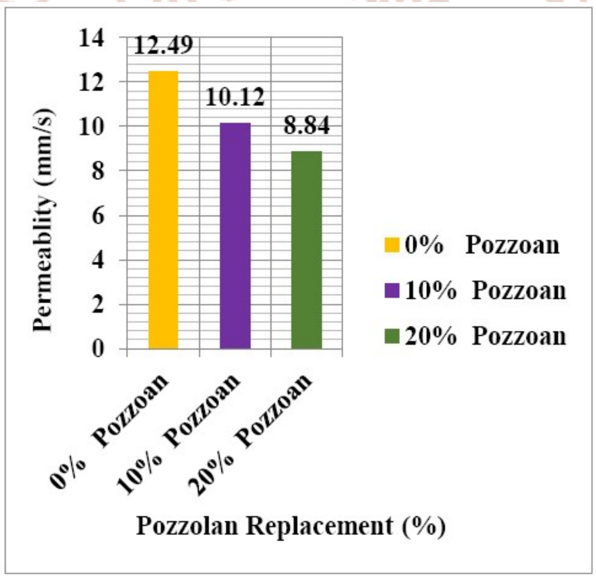


Figure7. Comparison of Permeability with Pozzolan Replacement 0% to20%

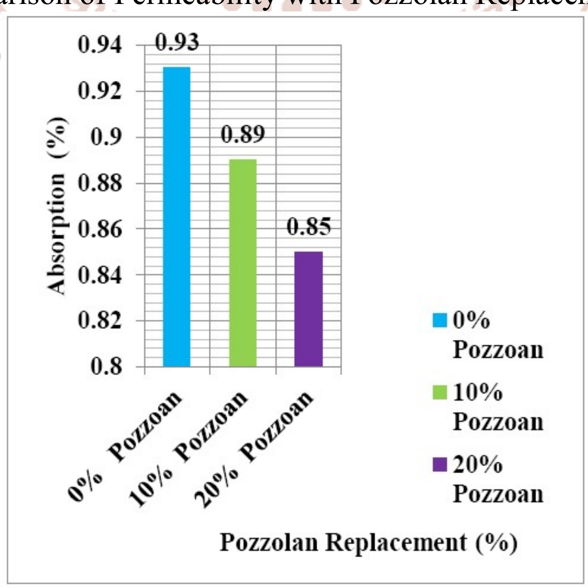


Figure8. Comparison of Absorption with Pozzolan Replacement 0% to 20%

Table6. Comparison of Test Results of Pervious Concrete with Pozzolan Replacement 0% to 20%

| Pozzolan Replacement (%) | Fresh Density (kg/mm3) | 7-day avg. compressive Strength $fc,cube'$(MPa) | 28-day avg. compressive Strength $fc,cube'$(MPa) | Void Content (%) | Permeability (%) | Absorption (%) |
|---|---|---|---|---|---|---|
| 0% Pozzolan | 1827.18 | 11.87 | 18.49 | 23.9 | 12.49 | 0.93 |
| 10% Pozzolan | 1807.08 | 13.23 | 21.39 | 22.02 | 10.12 | 0.89 |
| 20% Pozzolan | 1785.15 | 9.56 | 14.51 | 20.59 | 8.84 | 0.85 |

Table7. Comparison of Mean Compressive Sterngth $fcr,cube'$ for Durability with Pozzolan Replacement 0% to 20%

| Pozzolan Replacement (%) | 7-day Mean compressive Strength $fcr,cube'$(MPa) | 28-day Mean compressive Strength $fcr,cube'$(MPa) | 56-day Mean compressive Strength $fcr,cube'$(MPa) | 90-day Mean compressive Strength $fcr,cube'$(MPa) | 180-day Mean compressive Strength $fcr,cube'$(MPa |
|---|---|---|---|---|---|
| 0% Pozzolan | 11.8 | 18.42 | 19 | 19.42 | 19.44 |
| 10% Pozzolan | 13.18 | 21.02 | 22.14 | 22.37 | 22.35 |
| 20% Pozzolan | 9.46 | 14.32 | 14.36 | 14.33 | 14.29 |

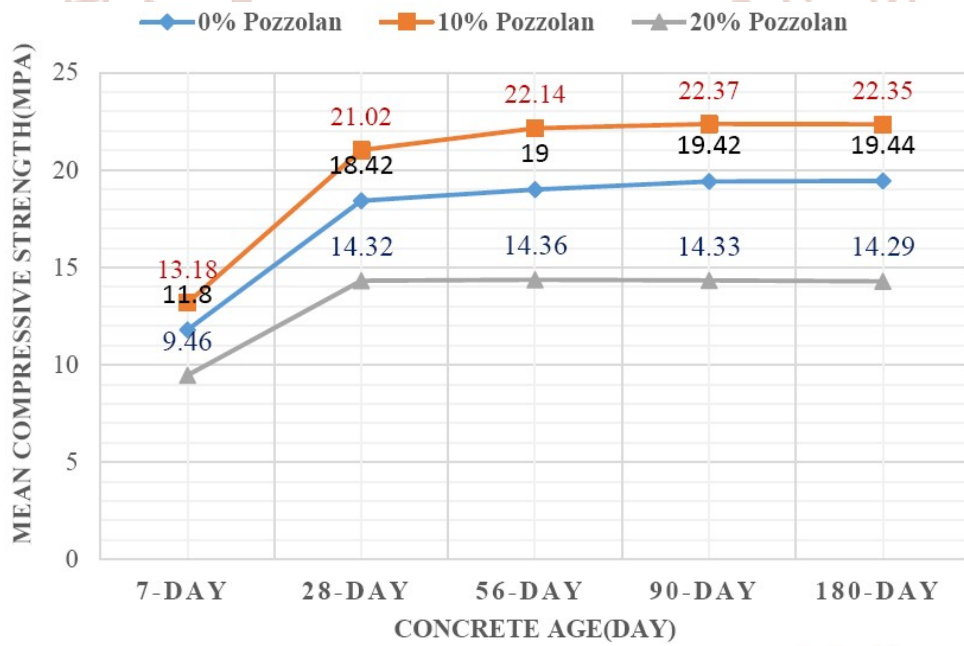


Figure9. Comparison of Mean Compressive Sterngth $fcr,cube'$ for Durability with Pozzolan Replacement 0% to 20%

## V. CONCLUSION

Due to voids in pervious concrete, it is difficult to obtain high strength by using the common material and proportion of mixture. Based on the results of this study, it can be concluded that:

1. The fresh density decreased marginally when cement replacement by pozzolan increased till 20% than without pozzolan. Because specific gravity of natural pozzolan is less than specific gravity of cement.
2. The void content of pervious concrete decreased marginally when cement replacement by 0% to 20% pozzolan. So, the absorption and permeability decreased marginally when natural pozzolan replacement increased. From these results the permeability with 10% pozzolan

replacement is optimized value for pervious concrete with pozzolan.

3. The mean compressive strength developed at 7-day and 28-day when the cement replacement by pozzolan increased till 10% than without pozzolan. So, 10% of pozzolan replacement is optimized value for highest strength of pervious concrete than concrete without pozzolan.
4. Durability of pervious concrete, the mean compressive strength develops with age for all mixes of pervious concrete. After 28day, the mean compressive strength develops slowly.
5. The properties of pervious concrete are the balance of permeability and mechanical properties as well as durability. So, in this research it can be concluded that 10% pozzolan replacement is the optimized result for pervious concrete with partially pozzolanic material replacement.

Pervious concrete has high water permeability due the presence of interconnected air voids. So, pervious concrete should be used in flooded area such as pavement edge drains, low water crossings area, path ways and shoulder. 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.

## VI. ACKNOWLEDGEMENTS

The author is deeply grateful thanks to her student Htet Thu Aung for his support and effort to writing this paper.

## VII. REFERENCES

1. Kosmatka, Steven H. and Wilson, Michelle L. 2011. Design and Control of Concrete Mixtures, 15th ed, Portland Cement Association, Skokie, Illinois, USA.
2. Md.Iftekar Alam. 2014. "Laboratory Investigation of No Fine Concrete". Proceedings of the 2nd International Conference on Civil Engineering for Sustainable Development'
3. S. Deepa shri, N. Mohanraj and C. Krishnaraj. 2016. "An Experimental Study on the Durability Characteristics of Pervious Concrete". ARPN Journal of Engineering and Applied Sciences, vol. 11, No. 9
4. American Concrete Institute (ACI). 2000. Use of Raw or Processed Natural Pozzolans in Concrete (ACI 232.1R-00), American Concrete Institute Committee, U.S.A.
5. American Concrete Institute (ACI). 2002. Guide for Selecting Proportions for No-Slump Concrete (ACI 211.3R-02), American Concrete Institute Committee, U.S.A.