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Effects and Optimization of Aggregate Shape, Size, and Paste Volume Ratio of Pervious Concrete Mixtures

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Abstract— *Pervious concrete has been widely used in other countries due to its environmental benefits such as water quality improvement and high permeability. However, due to its high void content, this type of concrete has a significantly lower compressive strength compared to conventional impermeable concrete. In the Philippines, the use of pervious concrete is minimal. To achieve its most effective performance, this paper aims to optimize pervious concrete mixtures in terms of permeability and compressive strength by varying aggregate shape, size, and paste volume (PV) to inter-particle void ratio (IPV). The effect of viscosity modifying admixture (VMA) on the permeability and compressive strength was also quantified. The optimized mix consists of single graded 9.5 mm, angular aggregates with 70.90% PV/IPV. This proportion can produce a compressive strength of 17.95 MPa and a permeability of 1.35 mm/s, applicable for low-traffic pavements such as parking lots. Adding VMA increased the compressive strength by 23.74% and decreased permeability by 35.49%.*

Keywords— pervious concrete, permeable concrete, paste volume, strength, void ratio

I. INTRODUCTION

The Philippines, having an annual rainfall of 965 to 4,064 mm and experiencing a rainy season from June to November [1], is also visited by at least 20 tropical cyclones according to the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). These typhoons cause flooding, which damages homes, infrastructure and even destroys lives. Aside from these damages, the government is also spending billions of pesos on disaster management. Studies showed that previous strong typhoons such as Ondoy, Sendong, and Pablo produced an average of 50 mm/hr, which caused severe flooding in low-lying areas according to PAG-ASA's Color Coded Rainfall Warning System. Since most pavements in the Philippines are made of impermeable concrete, this increases the risk of flooding in areas by preventing the natural infiltration of runoffs to the ground, and thus, a solution must be made to solve this flooding problem.

Pervious concrete, also known as permeable concrete or no-fines concrete, has been widely used in other countries in Europe as well as in the United States and China due to its unique properties compared to conventional concrete, such as its high permeability and porosity that help in recharging groundwater and provide natural infiltration to prevent flood

[2]. Studies also showed that pervious concrete has higher insulation performance, can absorb noise, and improve water quality [3]. The United States Environmental Protection Agency (EPA) has also recognized pervious concrete as a best management practice to reduce first-flush pollutants in stormwater drainage [4]. Since pervious concrete has many voids, its compressive strength is lower than conventional concrete. It is commonly used for low traffic pavements such as parking lots, driveways, and walkways [5]. As of this writing, there is no standard procedure for the preparation of pervious concrete in the Philippines. Mixing and proportioning of pervious concrete is also quite variable. Several factors can affect its compressive strength and permeability, such as w/c ratio, maximum aggregate size (MAS), paste volume to the inter-particle void ratio (PV/IPV), aggregate shape, gradation, admixtures, and other parameters, including construction methods which can either increase or decrease the compressive strength and permeability depending on the combinations of properties and their mix proportions [2]. Several studies are already being conducted in other countries to improve the use of pervious concrete [6], but studies on the applicability of pervious concrete in the Philippines are still minimal. Although this type of concrete can possess several environmental benefits and help alleviate flooding in the Philippines, there is a need to improve its compressive strength to be sufficient for pavement applications. Thus, identifying the parameters that can balance its compressive strength and permeability is crucial to determine an acceptable and usable pervious concrete mixture. This study will promote the benefits of using pervious concrete as an alternative type of concrete for low traffic pavements considering compressive strength and permeability that can help alleviate flooding in the Philippines. Parameters in this study can be used in proportioning and mixing an optimum pervious concrete mixture.

1.1 Objectives

This study aims to obtain a mixture proportion that can be applied for low traffic pavement with acceptable permeability by optimizing three significant parameters. These parameters include the aggregate shape, size, and paste volume to inter-particle void ratio, using locally available materials considering local rainfall conditions. Specifically, this study will:

a) Correlate the aggregate shape, size, and paste volume to inter-particle void ratio with the permeability and compressive strength of pervious concrete;
b) Determine the interactions between the three parameters against permeability, void content, and compressive strength of pervious concrete
c) Determine the effect of Viscosity Modifying Admixture to the compressive strength and permeability of pervious concrete

1.2 Scope and Limitations

This study focuses on proportioning the three significant parameters: Single Sized Aggregate, Paste Volume to Inter-Particle Void Ratio (PV/IPV), and Aggregate Shape to determine its possible effects on the compressive strength and permeability of pervious concrete. For aggregate shape, rounded and angular aggregates are used. For aggregate size, single-sized aggregates of 9.5 and 19 mm are used, and for the Paste Volume to Inter-Particle Void Ratio (PV/IPV), 40%, 50%, and 60% PV/IPV are used. Effects of adding an admixture, specifically Viscosity Modifying Admixture (VMA), to the optimized parameters are also identified. Samples were tested at 14th and 28th days for compressive strength by the Universal

Testing Machine. For permeability, the test is conducted by Falling Head Method. Mix proportions following ASTM and ACI Standards were followed using materials available in the Philippines. Graphical analysis through MS Excel and interaction plots obtained from Two-Level Factorial Design Method was used to analyze the data. Other acceptance requirements such as skid resistance, heat absorption, sound absorption, and pavement design involving the strength of the subgrade and layer thicknesses were not considered and are not part of this study.

II. REVIEW OF RELATED LITERATURE

Pervious concrete as a sustainable urban drainage design has enthralled a lot of designers and developers to apply this technology in their construction projects as it helps them obtain Leadership in Energy and Environmental Design (LEED) Green Building Rating System credits. LEED gauges the environmental performance of a building. Some environmental benefits of using pervious concrete are improved skid resistance, groundwater recharge, tire noise reduction, stormwater management, and temperature reduction [7].

The performance of pervious concrete is usually measured through its compressive strength and permeability. The key to maximizing its use is to balance these two properties. Unlike conventional concrete, pervious concrete has lower compressive strength due to its higher porosity to allow water to flow through it. The compressive strength of pervious concrete has a wide range, usually between 2.8-28 MPa [5], depending on its properties, proportions, and target use. For low-traffic pavements such as parking lots and walkways, the typical compressive strength that must be achieved should be at least 17 MPa [8]. Pervious concrete can also be used as permeable bases, and edge drains help reduce the pumping of subgrade materials and prevent failure in the pavement.

Of the previous studies in the Philippines, the highest compressive strength attained by pervious concrete mixtures only reached 7.76 MPa with a corresponding permeability of 7.9 mm/s [9]. Unfortunately, this compressive strength is not fit for any application; thus, a mixture that maximizes compressive strength is needed. The main focus of pervious concrete is improving its permeability but maintaining a compressive strength that can satisfy its use in construction. The usual range of permeability for pervious concrete can be between 2 to 18 gal./min/ft2 (1.35-12.17 mm/s) with void contents between 15-35% but can be less depending on the aggregate size and density of the mixture [5]. According to Yahia and Kabagire [3], the permeability of pervious concrete with a porosity of 15% (lower bound for pervious concrete) is usually 1 mm/s which is its functional permeability.

Pervious concrete has already been recognized by the U.S. Environmental Protection Agency (EPA) as one of the Best Management Practices (BMP) in controlling first flush pollutants and managing stormwater runoff both on a local and regional basis [7]. Its environmental benefits are well established, and the only disadvantage in using this concrete is its lower strength compared to conventional concrete. This study seeks to optimize the mix of pervious concrete, but there are many factors that should be considered that can affect its mechanical properties. This study focuses on the three chosen parameters and the effect of VMA.

The strength of pervious concrete can be related to the bond strength of the paste and aggregate and void ratio [10]. The ideal scenario is that aggregates are covered with excess paste [11]. A study by Yahia, A, and Kabagire [3] showed that increasing the Paste Volume to Inter-Particle Void Ratio (PV/IPV) can increase the strength and density but decrease porosity and permeability of pervious concrete. Thus, to achieve balanced strength and permeability of pervious concrete, it is recommended to use an optimum range of 30%-60% PV/IPV, but it has only been proved using a w/c ratio of 0.3.

The workability of concrete can depend on the aggregate shape. Smooth and rounded aggregates are more workable due to their smooth surface than angular aggregates with rough surfaces. Although rounded aggregates increase workability, these produce a lesser bond between the paste and aggregate compared to angular aggregates, which have a stronger bond and can increase the strength of the concrete [12]. Colorado Ready Mixed Concrete Association [13] suggested that natural rounded aggregates should be used for mixing pervious concrete. These will help increase the permeability and workability, but common mixes of pervious concrete still use angular. These are more readily available compared to rounded aggregates.

The size and grading of aggregates can affect the void space and paste requirement, thus affecting the strength and permeability of concrete. In mixing pervious concrete, well-graded aggregates should be avoided as these may reduce porosity and permeability [13]. Typical aggregate sizes for pervious concrete are between 9.5- 19mm [10], and a single-sized grading is usually recommended to maximize permeability [3]. Fine aggregates should not be used since these compromise the connection of the voids in pervious concrete, although it slightly increases the compressive strength of concrete [5]. Viscosity Modifying Admixture can stabilize the paste to prevent paste drainage and clogging of pores [14]. It can also increase flowability for easier placement and compaction and increase the compressive strength by enhancing the paste to aggregate bond.

III. MATERIALS AND METHODS

Three parameters were selected to obtain the optimum mix proportion. Rounded and angular aggregates were used for aggregate shape. For aggregate size, single-sized aggregates of 9.5 and 19 mm were used, and for the paste volume to the inter-particle void ratio (PV/IPV), 40%, 50%, and 60% were used. Combinations of these parameters were made per test case, as shown in Table 1.

Table 1. Test Cases for Proportioning Pervious Concrete

Test Cases	Aggregate Shape	Aggregate Size	PV/IPV
1	Rounded	19 mm	40%
2			50%
3			60%
4		9.5 mm	40%
5			50%
6			60%
7	Angular	19 mm	40%
8			50%
9			60%
10		9.5 mm	40%
11			50%
12			60%

Other parameters were fixed, such as w/c ratio to 0.35, and no fine aggregates was used. The 0.35 w/c was used based on the recommendations of previous local study [9]. Crushed aggregates were used for angular shape and natural river stones/pebbles were used for rounded shapes. For the cement, Ordinary Type 1P Portland Cement was used.

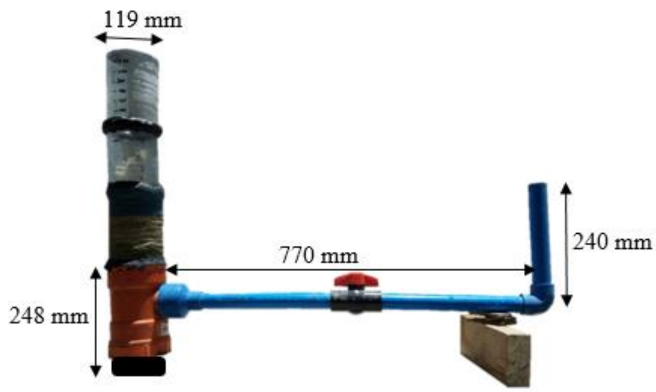
3.1 Material Preparation

Aggregates, cement, and all the necessary equipment were prepared in the laboratory. Rounded and angular aggregates were sieved using ¾" (19 mm) and ⅝" (16 mm) sieves to get single-graded 19 mm, and ⅜" (9.5 mm) and 5/16" (8 mm) sieves were used to get single-graded 9.5 mm aggregates in accordance with ASTM C136 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates" [15]. To determine the required proportions of aggregate, cement, and water, tests for aggregate density and absorption in accordance with ASTM C127 "Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate" [16] were performed. The bulk density and void content of the aggregates were also obtained in accordance with ASTM C29 "Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate" [17].

The amount of aggregate, cement, and water needed in each test case were computed using Appendix 6 of ACI 211.3R-02 "Guide for Selecting Proportions for No-Slump Concrete" [18]. Proportions were calculated for six 4 inch diameter x 8 inch height cylinders with 20% excess for each test case.

3.2 Data Collection

For each test case, 6 samples were obtained (3 samples tested on the 14th day and 3 samples tested on 28th day). The permeability of samples were tested using a falling head permeameter shown in Figure 1a. The set-up is prepared following ACI 522 R-06 "Report on Pervious Concrete" [5].



(a) (b)

Figure 1. (a) Permeability and (b) Compressive Strength Test Set-ups

Testing for compressive strength was made following ASTM C39 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens" [19] using a Universal Testing Machine (UTM) shown in Figure 1b. Rubber was placed on the metal cap before testing to ensure that there will be equal distribution of loads on the sample.

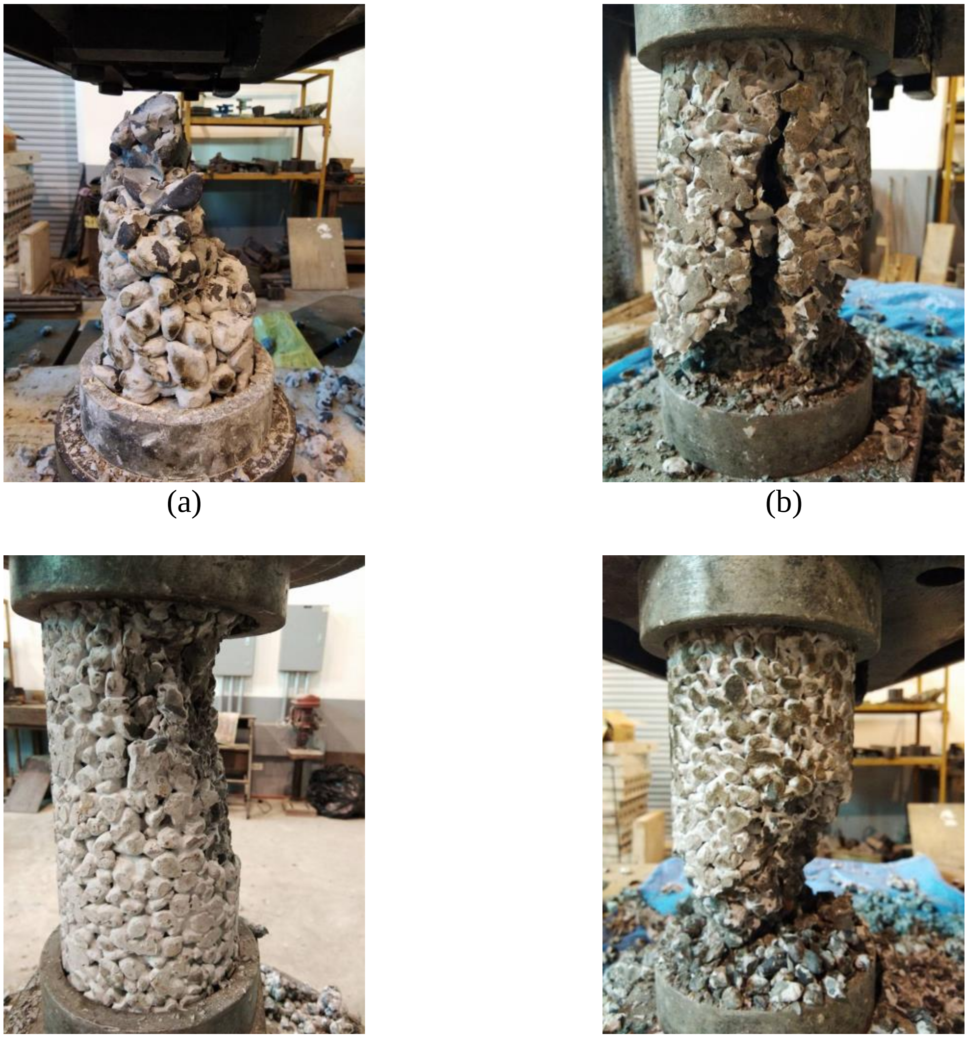
3.3 Analysis and Optimization

After obtaining the compressive strength and permeability test results, these were tabulated and graphed using bar graphs. The optimized mixture for pervious concrete was obtained through these graphs and a two-tail t-test assuming unequal variances as statistical evidence. A two-level factorial design method was used to identify the interaction of each parameter with each other and the magnitude of effects of each parameter on the compressive strength and permeability rate. Manual calculation using MS Excel was performed to produce the numerical values of the effects of each factor and the degree of the effect of the combination of each factor. The data and interaction plots were generated from Minitab 2018.

IV. RESULTS AND DISCUSSION

4.1 Failure Patterns of Pervious Concrete

During the compressive strength test, the aggregates splutter as it approaches the maximum compressive strength. Different behavioral patterns on the failure of pervious concrete were also observed, and recorded as shown in Figure 2. Most of the samples exhibited a shear failure (Type 4) based on ASTM C39/C39M [19]. The following prevalent failure pattern is the columnar cracking (Type 3) which leaves elongated concrete parts. The difference in exhibited patterns may be due to the method of compacting the aggregate samples because manual compaction was used; thus, stress distribution from testing could be variable.



(a) (b) (c) (d)

Figure 2. Typical Failure Patterns of Pervious Concrete: (a) Shear Failure, (b) Columnar Cracking, (c) Side Fracture on one side, (d) Side Fracture on bottom forming a cone

4.2 Effects of Aggregate Shape, Size and PV/IPV to Void Content, Permeability, and Compressive Strength

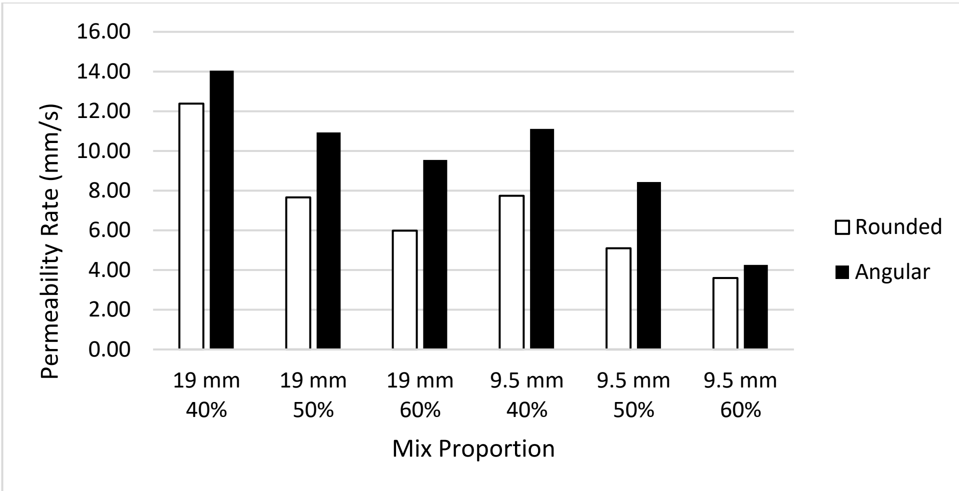
The void content obtained from this study ranged from 17.29% to 28.70% for the 28th-day testing. The results obtained ranged from 3.60 mm/s to 14.04 mm/s on the 28th day for the permeability rate. Results showed that all samples have values within the expected characteristics of pervious concrete based on void content (18-35%) and permeability at least 1.35 mm/s based on ACI 522 R-06 “Report on Pervious Concrete” [5] as shown in Table 2 below.

Table 2. Average Void Content, Permeability Rate, and Compressive Strength of 28th Day Samples

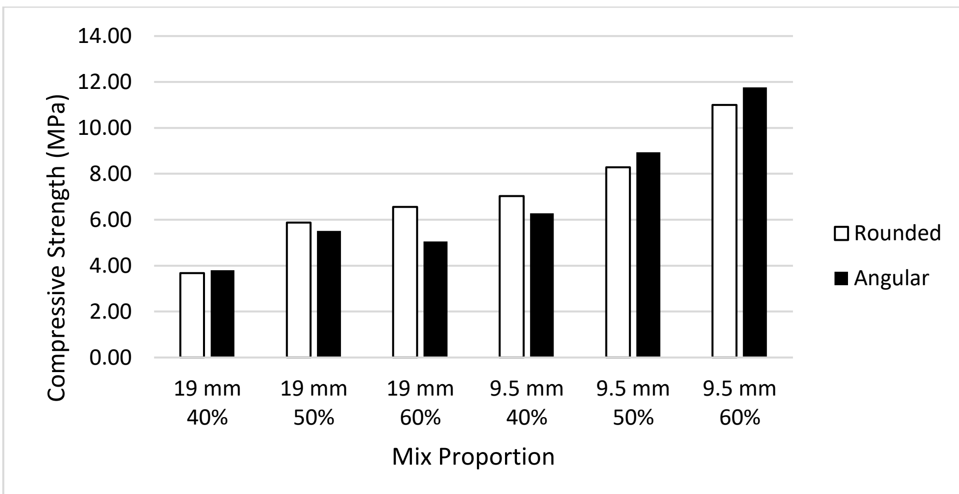
Test Cases	Aggregate Shape	Aggregate Size (mm)	PV/IPV (%)	Ave. Void Content (%)	Ave. Permeability Rate (mm/s)	Ave. Compressive Strength (MPa)
1	Rounded	19	40	23.55	12.38	3.68
2			50	20.83	7.66	5.88
3			60	18.61	5.98	6.56
4		9.5	40	22.03	7.74	7.03
5			50	18.76	5.10	8.29
6			60	17.29	3.60	11.00
7	Angular	19	40	28.70	14.04	3.81
8			50	25.97	10.93	5.52
9			60	25.80	9.55	5.05
10		9.5	40	26.79	11.11	6.28
11			50	23.80	8.44	8.95
12			60	19.77	4.25	11.77

4.2.1 Effects of Aggregate Shape

Angular aggregates produced higher void content compared to rounded aggregates. Single-sized angular aggregates have rougher surfaces and almost equal sizes, which resists concrete compaction, leaving a higher amount of voids. For the effect of aggregate shape on permeability, 28th day testing results showed that angular aggregates have higher permeability rates as shown in Figure 3a. Angular aggregates have a higher surface area, requiring a higher amount of paste coating, thus leaving a smaller amount of excess paste to fill the voids between the aggregates. Since voids are less filled in angular aggregates than rounded aggregates, these larger interconnected voids allow easier infiltration of water through the pervious concrete, resulting in higher permeability rates.



(a)



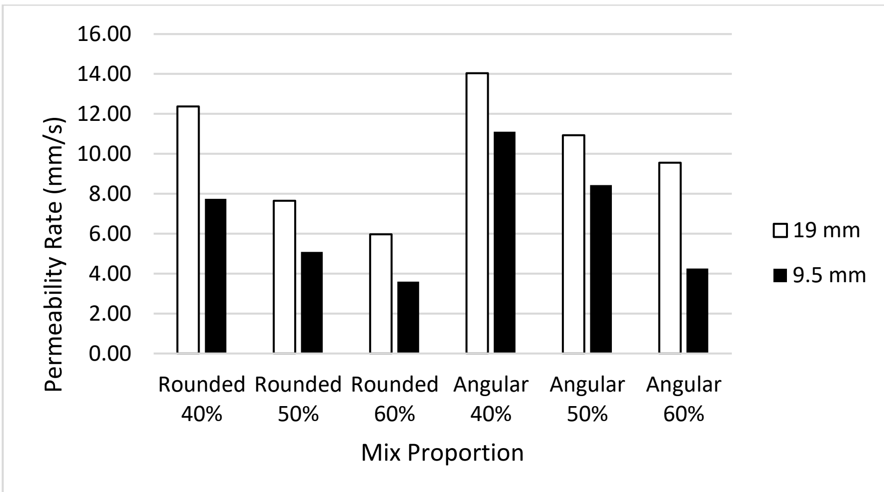
(b)

Figure 3. Effect of Varying Aggregate Shape to the (a) Permeability and (b) Compressive Strength of 28th Day Pervious Concrete Samples

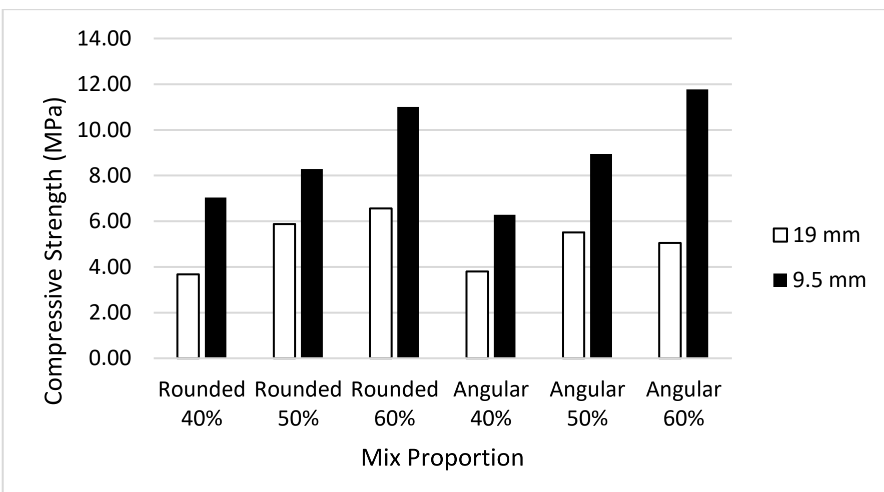
Visually, it is noticeable that there is only a small difference in the compressive strength values for both shapes, as shown in Figure 3b. Rougher surfaces and higher surface area of angular aggregates also prevent the paste from draining down to the bottom of the concrete sample. The more significant friction between angular aggregates also resists compression aside from the paste bond between aggregates, thus producing higher compressive strength.

4.2.2 Effects of Aggregate Size

For the effect of aggregate size on the void content of the sample, the samples with 19 mm aggregate size have higher void content than 9.5 mm aggregate size as shown in Figure 4a. If single-graded aggregates are used, these produce higher void content compared to well-graded aggregates since well-graded aggregates contain varying sizes that easily fill up the available spaces between aggregates, thus producing a higher packing density and a lower percentage of voids. If large sizes of single-sized aggregates are used, void content increases, but in return, properties such as compressive strength is compromised. The 14th day and 28th day test results showed that the 19 mm aggregates produced a higher permeability rate than the 9.5 mm aggregates. The 9.5 mm aggregates, which are smaller in size and had smaller void content, prevented water from easily passing through the voids, thus decreasing permeability. Still, all samples are above the minimum accepted permeability of pervious concrete, which is 1.35 mm/s. As shown in Figure 4b, the 9.5 mm aggregates produced higher compressive strength compared to the 19 mm aggregates.



(a)

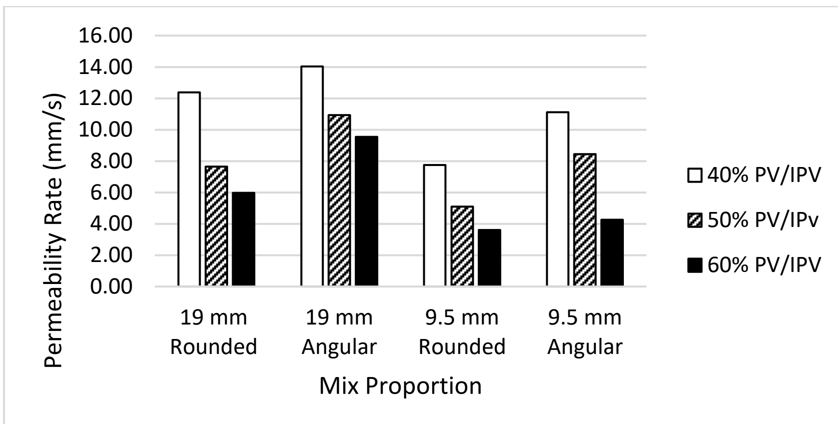


(b)

Figure 4. Effect of Varying Aggregate Size to the (a) Permeability and (b) Compressive Strength of 28th Day Pervious Concrete Samples

4.2.3 Effects of PV/IPV

For the effect of PV/IPV on the void content of the sample, it was observed that as the PV/IPV increases, the void content decreases as shown in Figure 5a. Higher PV/IPV produces larger amounts of paste, which fills up the voids, thus decreasing the void content in the pervious concrete, while a lower PV/IPV produces lesser paste, which increases the void content of pervious concrete. Permeability results of varying PV/IPV produced the same trend that is similar to the effect on the void content wherein as the PV/IPV increases, the permeability of the samples decreases. To increase permeability, lesser percentage of PV/IPV is needed. It should be noted though that even if 60% PV/IPV produced lower permeability rates, it is still above the minimum range of permeability of pervious concrete, which is 1.35 mm/s according to ACI 522R-06 [5]. With this, further increasing the PV/IPV may be possible given that it is still within the acceptable permeability. Increasing PV/IPV, increases the compressive strength of the pervious concrete as shown in Figure 5b. This increase in compressive strength as PV/IPV increases may be due to larger amounts of paste filling up the voids, increasing the paste to aggregate bond necessary to increase the compressive strength.



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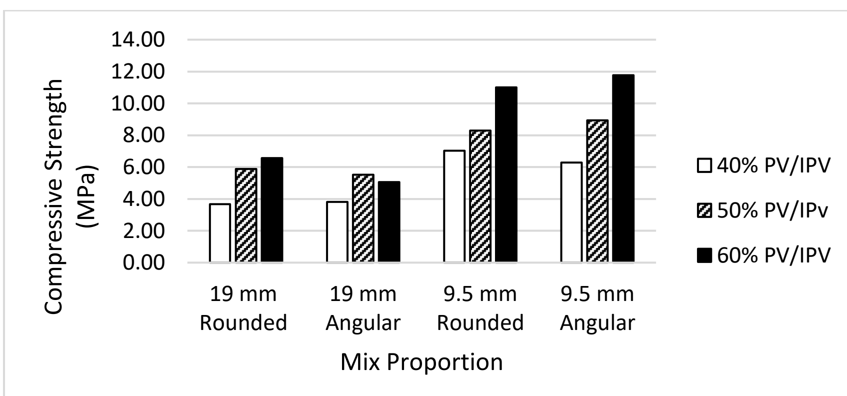

(b)

Figure 5. Effect of Varying PV/IPV to the (a) Permeability and (b) Compressive Strength of 28th Day Pervious Concrete Samples

4.3 Interaction and Main Effects of Aggregate Shape, Size and PV/IPV

Two-level factorial design method was used to determine the main effects of each factor on the void content, compressive strength, and permeability rate of pervious concrete and the interaction between the three factors against the response variables. For the factors and their combination with void content as the response variable, no factor or combination of factors exceeded the statistically significant value of 6.098. This means that all the factors and their combinations do not significantly affect void content at a 95% confidence level. For the effects of the factor and its combination to permeability rate, PV/IPV has the highest effect among the factors and possible factor combinations on permeability rate and has exceeded the statistical line of the significance of 4.122, leading to the conclusion that PV/IPV significantly affects the permeability rate with a confidence level of 95%. In addition, aggregate size and PV/IPV significantly affect compressive strength using a 95% confidence level by surpassing the statistical line of significance valued at 1.969. It was also found out that any interactions between the three parameters do not significantly affect the void content, permeability rate, and compressive strength significantly.

4.4 Optimization of Pervious Concrete Mixture

As previously mentioned, aggregate shape, size, and PV/IPV have no significant interaction with each other and thus can be optimized individually. To compare the levels of each parameter, two tail t-test assuming unequal variances were employed with a 95% confidence level. A p-value less than 0.05 will result to levels of parameters being significantly different.

4.4.1 Optimizing Aggregate Shape

It was found that the compressive strength of concrete with rounded aggregates is 2.52% higher compared to angular aggregates. Using a t-test with a confidence interval of 95%, the p-value of 0.8424 (>0.05) was calculated. This shows that rounded aggregates and angular aggregates have no significant difference in terms of compressive strength. However, the permeability rate of angular aggregates is 27.23% higher compared to rounded aggregates. With a p-value of 0.016 (<0.05), it can be inferred that there is a significant difference between the permeability rate of rounded aggregates and angular aggregates using a 95% confidence interval. The goal of the pervious concrete mixture optimization in this study is to create a mixture that will produce the greatest compressive strength while achieving an acceptable permeability and void content that fits the definition of pervious concrete. Since angular aggregates can provide the same compressive strength as the rounded aggregate with the advantage of having higher permeability, angular aggregates can be chosen as a better aggregate shape for pervious concrete.

4.4.2 Optimizing Aggregate Size

Using t-test, it was found that 9.5 mm single graded aggregates produced 42.81% higher compressive strength compared to 19 mm aggregates. Using a 95% confidence interval and with a p-value of 1.25x10-6 or an almost zero value, it was shown that the two aggregate sizes are significantly different with 9.5 mm aggregates dominating in terms of compressive strength. In terms of permeability, 19 mm single graded aggregate produced 33.53% higher permeability rates compared to 9.5 mm aggregates. The t-test results yielded a p-value of 0.0015 (<0.05), thus it can be concluded that there is a significant difference between 9.5 mm and 19 mm aggregates in terms of permeability with a 95% confidence interval. Nevertheless, both aggregate sizes satisfied the minimum permeability requirement of 1.35 m/s as stated in the previous discussion. Using the results of laboratory tests and statistical analyses, it can be inferred that using 9.5 mm single-graded aggregate is more beneficial to pervious concrete mixture since it provided the highest compressive strength value while still achieving an acceptable permeability rate.

4.4.3 Optimizing PV/IPV

After it has been statistically shown that 9.5 mm single graded, angular aggregates will produce the highest compressive strength with an acceptable permeability, an additional test case using a 70% PV/IPV shown in Table 3 was batched in order to improve and further justify the accuracy of the regression model used in the optimization of PV/IPV.

Table 3. Summary of Results of Single-Graded 9.5 mm Angular Aggregates

PV/IPV (%)	Ave. Void Content (%)	Ave. Permeability Rate (mm/s)	Ave. Compressive Strength (MPa)
40	26.79	11.11	6.28
50	23.80	8.44	8.95
60	19.77	4.25	11.77
70	16.19	1.89	17.51

Figure 6 shows the relationship of permeability rate and PV/IPV using a scatter plot. A linear model was fitted on the points, and it resulted in an R-squared value of 96.92%. To maximize the properties of pervious concrete, the lowest acceptable permeability for pervious concrete, which is 1.35 mm/s, was used to obtain the optimized PV/IPV, which was 70.90%.

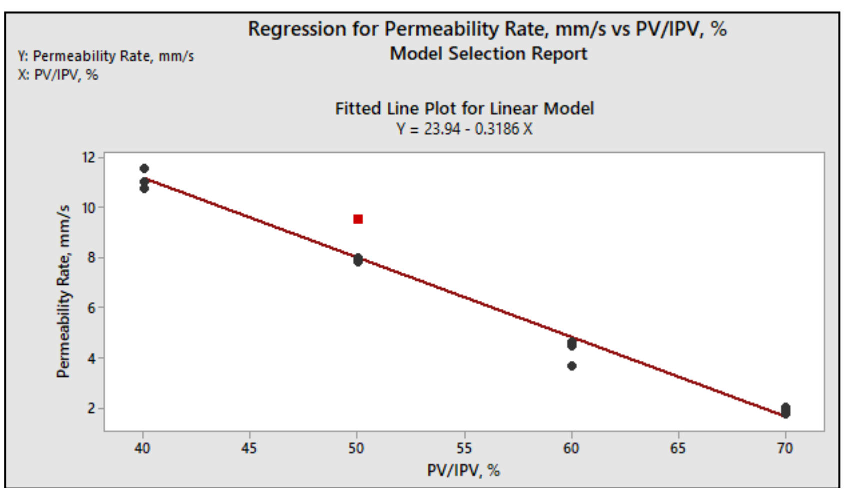

Figure 6. Regression for Permeability Rate: Linear Model Graph

On the scatter plot of compressive strength and PV/IPV, a quadratic model was fitted with an R-squared value of 92.34%. Using the optimized PV/IPV, which is 70.90%, leads to a theoretical compressive strength value of 17.94 MPa. The theoretical void content corresponding to the mixture with a PV/IPV of 70.90% resulted in a value of 15.95%, satisfying the void content range of 15-35% for pervious concrete stated in ACI 522R-06 [5].

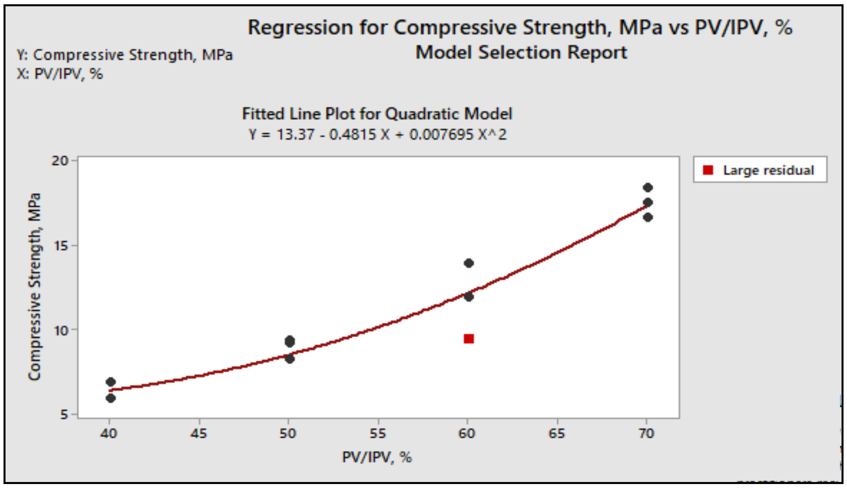

Figure 7. Regression for Compressive Strength: Quadratic Model

In Figure 8, a three-axes plot of permeability rate, compressive strength, and PV/IPV based on the experimental results are shown with their respective trendlines. This plot can be useful to determine a PV/IPV if a specific compressive strength or permeability rate is desired. The optimized mix proportion can already be used for low-traffic pavements such as parking lots and walkways, permeable bases, shoulders and edge drains that require at least 17 MPa.

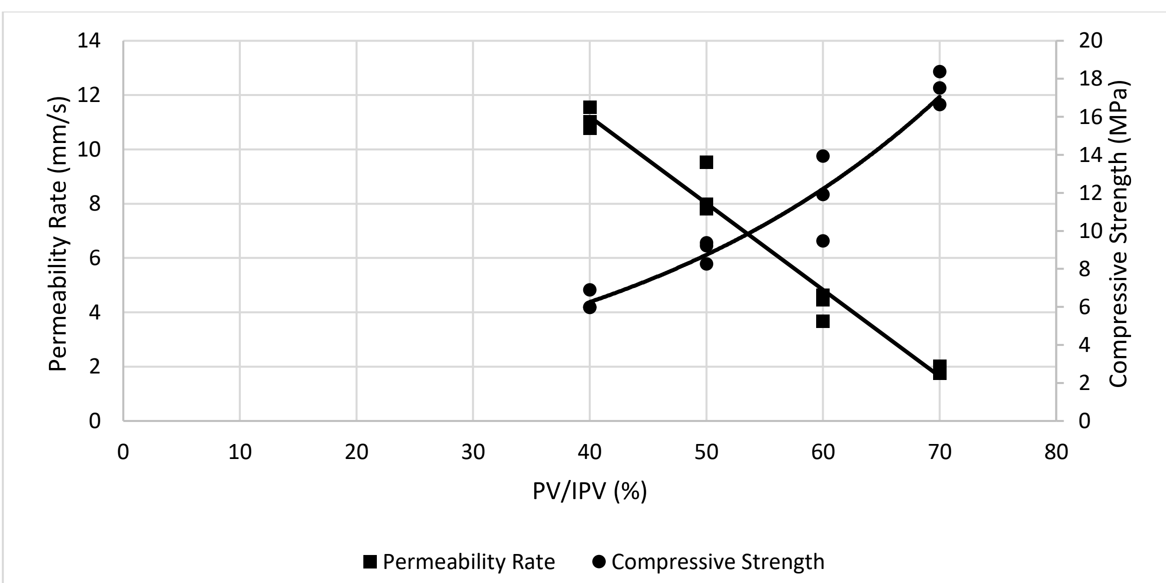

Figure 8. Three-axis Graph Showing the Relationship of PV/IPV, Permeability Rate and Compressive Strength

4.5 Effect of Viscosity Modifying Admixtures

Six 4" x 8" cylinder samples composed of single graded 9.5 mm, angular aggregates with 60% PV/IPV were made wherein three samples were mixed with admixture, and the other three samples were mixed without admixture. Since this part of the experiment is only concerned with the effect of admixture on the pervious concrete's mechanical properties, only 1% VMA by weight of cementitious component was used. The permeability and compressive strength of the concrete samples with and without VMA were tested on the 28th day. The samples with VMA had 2.69% higher void content compared to samples without VMA. However, the permeability rate decreased by 35.49% when VMA was added. On the other hand, the compressive strength of concrete samples with VMA contributed an increase of 23.74% compared to those without admixture. T-test was not used to statistically verify the significant difference between the two test cases since at least 20 samples are needed for the t-test conclusion to be valid.

Table 4. Comparison of Mechanical Properties with and without VMA

Test Case	Admixture	Ave. Void Content (%)	Ave. Permeability Rate (mm/s)	Ave. Compressive Strength (MPa)
1	Without VMA	20.80	4.17	10.15
2	With VMA	21.36	2.69	12.56
% Difference		2.69%	35.49%	23.74%

V. CONCLUSION

Overall, this study was able to produce a pervious concrete which can be used for low traffic pavement applications such as parking lots and walkways. This concrete had 17.94 MPa compressive strength with an acceptable permeability of 1.35 mm/s obtained from single-graded 9.5 mm, angular aggregates with 70.90% PV/IPV. It was also verified that as void content of pervious concrete increases, permeability increases but compressive strength decreases and at 95% level of confidence, there are no significant interactions between each parameters.

For the effect of admixture, adding VMA to the samples resulted to a 2.69% higher void content, 35.49% decreased permeability rate and 23.74% increase on compressive strength. The permeability and void content both satisfies the usual properties of a pervious concrete thus, it can be concluded that through the addition of VMA, there is a possibility that compressive strength can be increased in the use of pervious concrete.

VI. RECOMMENDATIONS

Since this study has already optimized pervious concrete mixture that can already be used for low-traffic pavements, it is recommended to study its feasibility for replacing the current pavement system in the Philippines. A market viability and life cycle analysis study of the pervious concrete will also help in promoting its use in the Philippines. A pervious pavement design including the design of drainages may also help in realizing the savings in using pervious concrete.

This paper has shown the importance of accounting PV/IPV, aggregate shape and aggregate size to the parameters but the costs to make the required proportions can be minimized. Thus it is recommended to further study other set of parameters that can affect pervious concrete. With the start-up study of viscosity modifying admixture in this paper, it is also recommended that other dosages of VMA should be tested to maximize the increase in strength of pervious concrete. Other types and combinations of admixture such as superplasticizers and set-retarding admixtures should also be studied which can improve the quality of pervious concrete.

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