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Developing High Strength Pervious Concrete Mixtures with Local Materials

Anthony Torres[1*], Federico Aguayo[1], Cristian Gaedicke[2], Parker Nerby[1], Mario Cavazos[1], Collin Nerby[1]

[1]Texas State University, San Marcos, TX, USA
[2]California State University-East Bay, Hayward, CA, USA
Email: *anthony.torres@txstate.edu

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Abstract

This study focuses on developing pervious concrete mixtures that have higher compressive strengths than conventional pervious concrete. This study also focuses on producing high strength pervious concrete that is also made with locally available materials. The study focused on four aspects of pervious concrete to produce high compressive strengths. These parameters were the effect of the coarse aggregate (type and size), the compaction of the test specimens, the effect of the w/c along with superplasticizers, and lastly the effect of silica fume. This study was completed parametrically in order to isolate each variable in order to see its individual affect. Once an optimum performance was obtained from one variable the best performing mixture was used for the next variable testing. This method allowed for the highest performing mixture to be obtained from each of the investigated variables. The results showed that high strength pervious concrete made with local aggregates, without polymers, and without fibers can be produced in the range of 15.44 MPa - 21.63 MPa. A porosity range 19.1% - 32.9% with a percolation rate range of 5.8 mm/s - 1.9 mm/s was also achieved, with a porosity of 19.4% and percolation rate of 2.6 mm/s for the highest performing mixture.

Keywords

Pervious Concrete, High Strength, Compressive Strength, Local Materials, Sustainable

1. Introduction and Background

Pervious concrete is a type of concrete that is made to allow a high rate of water to pass through itself. Conventional concretes have a very low permeability, in which water simply runs-off of its surface. Pervious concrete, therefore, is a specialty type of concrete with high permeability that has minimal run-off and allows for superior stormwater management and groundwater recharge. Pervious concrete is typically produced with coarse aggregate (rounded or angular) of similar size, cement, water, and little to no fine aggregate [1]-[11]. Pervious concrete typically has a void content of 15% - 30%, which creates a permeability of 2 mm/s - 7 mm/s [1]-[11]. Average compressive strengths range from 5 MPa - 10 MPa [1] [2] [3]. According to researchers, it is difficult to produce pervious concrete mixtures in excess of 12 MPa without the use of polymers [12] [13] [14]. Even without the use of polymers, compressive strengths in the 10 MPa range often require specialty aggregate to achieve such strengths. These high strengths also typically have very low permeability. In general, the most important performance criterion of pervious concrete is its ability to allow water to pass through the hardened pavement. However, by eliminating the fine aggregate to help create these mixtures, strength is sacrificed. The porosity (void content) of the mixtures is the critical design parameter such that a higher porosity produces higher performing percolation of water through the system. However, higher porosity also produces lower compressive strengths, which leads to insufficient structural capacity. Therefore, there is a difficult balance between its primary ability of percolation versus compressive strength. This research focuses on developing higher strength pervious concrete mixtures, without the aid of polymers, while also using readily available aggregates from the local area. Completing this investigation will allow researchers and industry designers to know what is required to produce higher strength pervious mixtures at a more economical cost, without sacrificing the percolation rate. This study was completed in San Marcos, TX.

Zhong, R., & Wille, K (2015) [12] were able to achieve pervious concrete mixtures exceeding 50 MPa, and a hydraulic conductivity in excess of 2 mm/s [12]. They completed their research by first focusing on an ultra high strength binder system, which included cement, silica fume, silica powder, water and a high range water reducing admixture (HRWRA). This became the binder system for the pervious concrete that had a tailored aggregate-to-binder ratio (A/B). The authors argue that a high strength binder using silica fume and silica powder increases the interfacial transition zone (ITZ). The authors then describe the importance of balancing the A/B, such that two high of an A/B results in higher strength, but lower porosity. Whereas, a low A/B leads to low strength but higher porosity. Therefore, creating a higher strength ITZ between the aggregate and the binder, while simultaneously balancing the A/B, is the best method for creating a high strength pervious concrete mixture.

Emiko *et al.* (2013) [13] completed a study in which they achieved compressive strengths of 13.9 MPa to 25 MPa [13]. The authors focused their designs by first proportioning the A/B then finally by proportioning the water-to-cement ratio (w/c). Emiko *et al.* (2013) [13] used Type 1 cement, crushed granite aggregates in the size range of 19 - 1.18 mm, HRWRA, hooked steel fibers, and polymers. The results show that the including steel fibers and polymers produce the highest performing compressive strength specimens. The authors also stated that a w/c of 0.20 is too low and leads to a very dry mix and low compressive strength. Increasing the steel fiber content from 1% to 2% did not significantly change the compressive strengths. However, the mixtures containing 2% polymer additive showed significantly higher compressive strengths.

Bhutta *et al.* (2012) [14] also completed a study on evaluating the properties of high performance porous concrete, which required no special vibration or curing. Their mixtures used three sizes of coarse aggregates with an appropriate amount of high water-reducing and thickening (cohesive) agents. This cohesive agent is presumable a polymer admixture. The three aggregate sizes were No. 5 (12 - 20 mm), No. 6 (5 - 13 mm), and No. 7 (2.5 - 5 mm). The authors simply state that it is a crushed coarse aggregate, and nothing about the specific type. The results show that including a water reducing admixture and a cohesive agent helps to improve the workability and strength of pervious concrete. They also state that the cohesive agent decreases the total void ration and permeability but significantly increases the strength. The authors also demonstrate that aggregate size did not seem to affect the performance of the pervious concrete. The strengths achieved by these authors ranged from 30 Mpa to 15 Mpa at 28-day compressive strengths.

These studies show that it is possible to improve the strength of pervious concrete. The authors suggest the key to improving the strength of pervious concrete is to focus on the A/B, w/c, and to improve the bonding strength between the aggregates. It is also observed that these studies made use of higher strength aggregates, fibers, and in particularly a polymer agent. These modifications will help improve the performance of pervious concrete, but will however increase the price of the material. The purpose of this study is to take the lessons learned from these previous authors, but to develop high strength pervious concrete mixtures without drastically driving the price of the mixture up. Therefore, the mixtures will be developed with local aggregates, without fibers, and without the use of a polymer agent. This methodology will help local producers produce pervious concrete with what is already available and at a more feasible cost.

2. Procedures and Materials

This study was completed parametrically, in that the variables were minimized and one variable was tested at a time. The highest performing mixture from one set of testing was then used in the next set of testing, in which an entirely different variable was tested. These parameters tested were the effect of the coarse aggregate (type and size), the compaction of the test specimens, the effect of the w/c along with superplasticizers, and lastly the effect of silica fume, in that order. The first parameter tested was the aggregate. Two sizes and two types were used in order to determine the effect of aggregate size and type (angular versus rounded). The two sizes were 9.54-mm and 6.35-mm. The two types were limestone (angular), and pea gravel (rounded), which were both obtained from local quarries in Hays County, Texas. The two sizes and types were chosen to reflect what is typical of pervious concrete mixtures [1]-[11]. The specific gravity, water absorption, voids, and unit weight of each aggregate size is shown in **Table 1**, all of which were obtained following the procedures and equations of ASTM C29 [15], and ASTM C127 [16] respectively.

Following constituent characterization, mixture proportions were developed using the two aggregates. All mixtures were made with these two aggregates and Type I/II cement, that was obtained locally. Since this study was completed parametrically, multiple sets of mixture proportions were developed. The initial mixture proportions, which investigate the aggregate type and compaction can be seen in **Table 2**.

The mixtures were then mixed in a standard drum mixer, compacted, and cured at minimum of 98% relative humidity. According to multiple references [1] [2] [3] [4] [5], which includes the American Concrete Institute (ACI) 522 Specifications on Pervious Concrete [1], there is no specific requirement for

Table 1. Physical properties of aggregates.

Property	Unit	Limestone (9.54 m)	Limestone (6.35 mm)	Pea Gravel (9.54 mm)	Pea Gravel (6.35 mm)
Unit Weight	kg/m^3 (lb/ft^3)	1442 (90.0)	1458 (91.0)	1505 (94.0)	1586 (99.0)
Water absorption	%	2.32	3.54	2.05	2.25
Bulk Specific Gravity$_{ssd}$[a]	-	2.56	2.58	2.59	2.62
Bulk Specific Gravity$_{od}$[b]	-	2.52	2.52	2.57	2.60
Voids	%	29.35	30.15	32.54	33.80

[a]ssd, saturated surface dry condition; [b]od, oven dried condition.

Table 2. Initial mixture proportions.

Mixture Identification	w/c	Type I Cement (kg/m^3)	Water (kg/m^3)	Coarse Aggregate (kg/m^3)	Notes
Unc-LS-9.54 mm	0.33	350	115.5	1465	Uncompacted
Unc-LS-6.35 mm	0.33	311	102.7	1532	Uncompacted
Unc-PG-9.54 mm	0.33	355	117.2	1450	Uncompacted
Unc-PG-6.35 mm	0.33	320	105.6	1525	Uncompacted
2L5R-LS-9.54 mm	0.33	350	115.5	1465	2 Lifts 5 Rods
2L5R-LS-6.35 mm	0.33	311	102.7	1532	2 Lifts 5 Rods
2L5R-PG-9.54 mm	0.33	355	117.2	1450	2 Lifts 5 Rods
2L5R-PG-6.35 mm	0.33	320	105.6	1525	2 Lifts 5 Rods
3L10PH-LS-9.54 mm	0.33	350	115.5	1465	3 Lifts 10 Proctor Hammer
3L10PH-LS-6.35 mm	0.33	311	102.7	1532	3 Lifts 10 Proctor Hammer
3L10PH-PG-9.54 mm	0.33	355	117.2	1450	3 Lifts 10 Proctor Hammer
3L10PH-PG-6.35 mm	0.33	320	105.6	1525	3 Lifts 10 Proctor Hammer

LS = Limestone; PG = Pea Gravel; L = Lift; R = Rod; PH = Proctor Hammer.

compaction of laboratory prepared pervious concrete cylinders. The general understanding is that low compaction yields higher porosity and lower compressive strengths, whereas higher compaction yields lower porosity with higher compressive strengths. Low and high compaction of the cylinders refers to the method of compaction and the energy used within each method. To minimize variables, this study focuses on three compaction methods that would yield three broad categories of compaction; no compaction, medium compaction, and high compaction. To achieve this, the no compaction method was accomplished by simply placing the concrete in the cylinder mold in one lift and screeding the top surface smooth with the top of the cylinder mold. The medium compaction was accomplished by placing the concrete in the cylinder mold in two separate lifts and compacting with a 9.52-mm steel rod five times per lift. The high compaction method was accomplished by placing the concrete in the cylinder mold in three lifts and compacted with 10 times per lift with a 2.5-kg standard proctor hammer having a height of fall of 300-mm, that distributes the concrete with a 100-mm head. The concrete specimens were cast and compacted in plastic cylinder molds of 200-mm lengths by 100-mm diameter molds.

3. Results

3.1. Effect of Aggregate and Compaction

The initial mixture designs developed in **Table 2** were then tested for compressive strength performance. The compressive strength tests were performed in accordance with ASTM C39-15a [17]. The specimens were capped on the ends using a sulfur compound to provide plane surfaces and ensure an even distribution of the compressive force, which was completed in accordance to ASTM C617-15 [18]. The compressive force was applied in accordance to ASTM C39-15a [17] until the specimen displayed a well-defined fracture pattern. The compressive strength of the specimens was determined at the age of 28-day and three samples were tested and averaged per data point. The average compressive strength results for the initial mixture proportions can be seen in **Figure 1**.

As seen in **Figure 1**, the 28-day compression strengths revealed the effect of the aggregate type, size, and corresponding compaction. As expected, the low compaction method (uncompacted) yielded the lowest compressive strengths and the highest compaction method (3L10PH) produced the highest compressive strengths. Investigating the effect of the aggregate type, limestone (angular) versus pea gravel (rounded), it appears that the pea gravel outperformed the limestone aggregate. This result is consistent with the literature [1] [2] [3] [4] [5], as the limestone aggregate is generally a weaker aggregate and the rounder aggregate allows for a more consistent paste thickness and bridging between aggregates [11]. As articulated by Torres *et al.* [11] the paste thickness and the bridging thickness between each aggregate have a large impact on the mechanical performance of pervious concrete. The compaction energy directly effects the bridging thickness between aggregates. Therefore, since the paste amount was

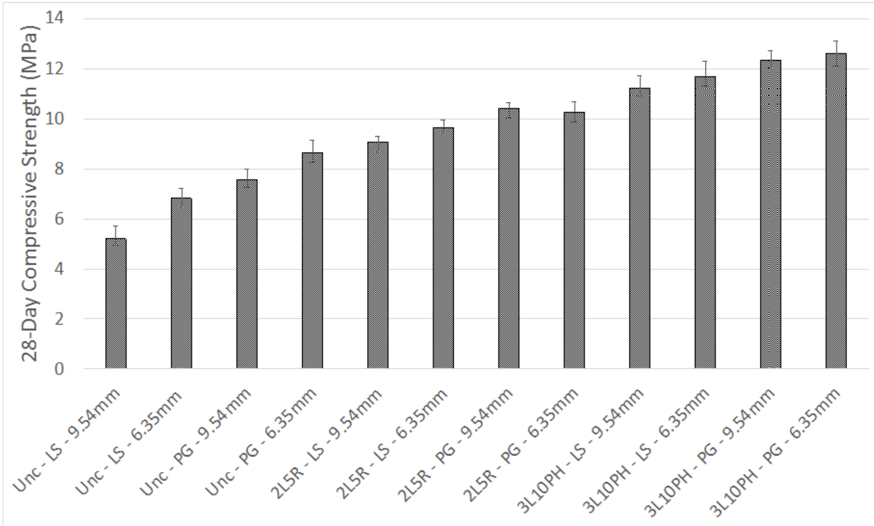

Figure 1. Initial mixture proportions average 28-day compression strength.

not increased, but the compaction energy was increased, the compressive strength increased proportionally. The last variable investigated in the initial set of mixture proportions is the effect of the aggregate size. It can be seen that the smaller aggregates consistently outperformed the larger aggregates. This result is as expected, as smaller aggregates produce a higher surface area, which in turn allows for more cement paste coating and bridging between aggregates, which allows for higher compressive strengths to be obtained [11]. Based off these results it can be seen that the highest performing mixture is the 3L10PH-PG-6.35 mm samples, which is the three lift, ten blows from the proctor hammer, 6.35 mm pea gravel samples. This mixture produced an average 28-day compressive strength of 12.61 MPa. Shortly behind that mixture was the 3L10PH-PG-9.54 mm, which produced a 28-day compressive strength of 12.33. A statistical analysis (student t-test) shows that these two values are not statistically significant between each other. Although this is true, only one mixture was selected to move forward to the next variable tested. This was done due to time and material limitations. Therefore, the highest obtained average 28-day compressive strength mixture was chosen, which was the 3L10PH-PG-6.35 mm.

In addition to the compressive strength testing, the modulus of elasticity was also obtained at an age of 28-days. The modulus of elasticity was determined for this study as it is an important parameter in structural design. The modulus of elasticity was calculated at 40% of the maximum stress in accordance to ASTM C469-14 [19] and the initial mixture results are shown in **Figure 2**. As with the compressive strength testing, three samples were tested and averaged per data point.

The results from the modulus of elasticity testing of the initial mixtures, shows similar results to that of the compressive strength testing. The uncompacted samples yielded the lowest modulus, the medium compaction (2L5R) produced the second highest, and the high compaction (3L10PH) produced the overall

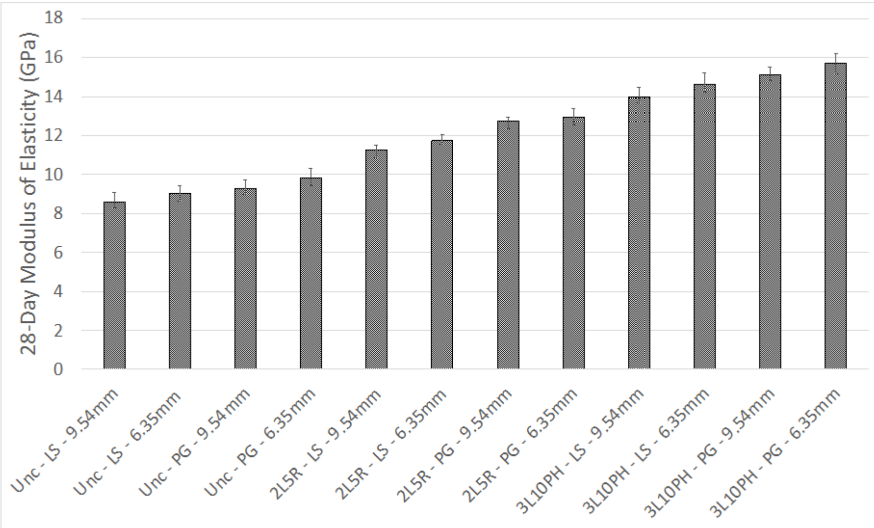

Figure 2. Initial mixture proportions average 28-day modulus of elasticity.

highest modulus of elasticity. This result is predictable as the 28-day compressive strength is typically proportional to the elastic modulus. These results are also consistent with the literature. Of note, is that the highest performing mixture was still the 3L10PH-PG-6.35 mm sample. From this mixture, the next set of variables was investigated.

3.2. Effect of W/C and Superplasticizer

Based off of the results of the aggregate and compaction testing, a new set of mixture proportions were developed, in which only the w/c was changed. The initial mixture already tested (3L10PH-PG-6.35 mm) had a w/c of 0.33, as did all of the mixtures in the initial mixture proportions. A w/c of 0.33 is a common w/c ratio for pervious concrete mixtures, which is why it served as a starting point for this study [1] [2] [3] [4] [5]. The next set of mixtures, only focus on reducing the w/c down to 0.20 in 0.20 increments. The w/c mixture proportions can be seen in **Table 3**.

As can be seen in **Table 3**, six additional mixtures were developed with incrementally smaller w/c. It can also be seen that at a w/c of 0.26 and lower, a polycarboxylate superplasticizer was needed, in a small amount. The average 28-day compressive strength results from the w/c mixture proportions can be seen in **Figure 3**.

As seen in **Figure 2** the effect of the w/c ratio in pervious concrete affects the concrete differently than conventional concrete. Conventional concrete, traditionally improves in strength with a lower w/c; however, this is not the case with pervious concrete. As described in ref [1] too high of a w/c results in the paste flowing from the concrete and filling the voids. Too low of a w/c results in reduced adhesion between the aggregates [1]. Therefore, the results of this parameter testing (**Figure 2**) show consistent results with the literature. The results show an increase in compressive strength up to a w/c of 0.28, but a steady

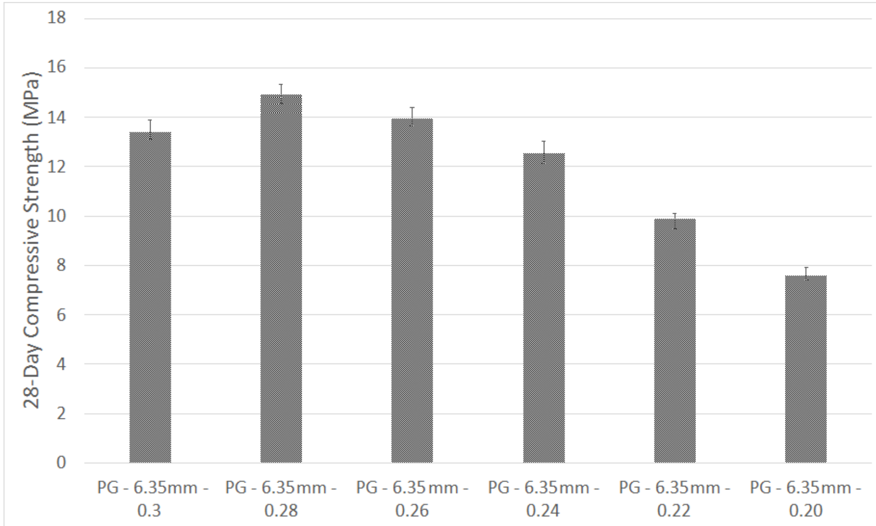

Figure 3. W/C mixture proportions average 28-day compression strength.

Table 3. W/C mixture proportions.

Mixture Identification	w/c	Type I Cement (kg/m³)	Water (kg/m³)	Coarse Aggregate (kg/m³)	Superplasticizer (L/m³)
PG-6.35 mm-0.3	0.30	320	105.6	1525	-
PG-6.35 mm-0.28	0.28	320	89.60	1525	-
PG-6.35 mm-0.26	0.26	320	83.20	1525	0.5
PG-6.35 mm-0.24	0.24	320	76.80	1525	0.5
PG-6.35 mm-0.22	0.22	320	70.40	1525	0.75
PG-6.35 mm-0.20	0.20	320	64.00	1525	0.75

decrease thereafter, with a w/c of 0.20 producing the lowest compressive strength. Recall that all of these mixtures are based on the 310PH-PG-6.35 mm mixture from the initial mixture proportions, therefore, all of the mixtures in the w/c testing have a 3L10PH, (high) compaction. Comparing the last data point from **Figure 1** (3L10PH-PG-6.35 mm), which had a 0.33 w/c to the first data point in **Figure 2**, which was the same mixture, but with a 0.30 w/c, shows an increase in average 28-day compressive strength. The average 28-day compressive strength increased from 12.61 MPa to 13.40 MPa. A statistical test was performed on all of these values, and a statistical significance was measured across all data points.

The 28-day elastic modulus was also investigated for this set of tests and the results can be seen in **Figure 4**.

The results shown in **Figure 4** demonstrate a consistent trend with that of the 28-day compressive strength results discussed in **Figure 3**. Such that the highest performing mixture was the PG-6.355 mm-0.28. Therefore, the fact that too low of a w/c starts to negatively impact pervious concrete, and within the variables investigated studied, that is less that a w/c of 0.28. In addition to that trend, it

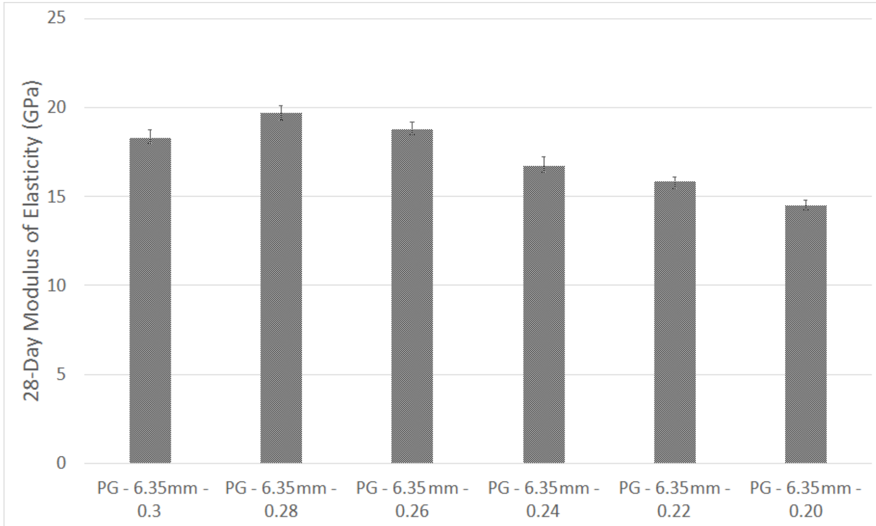

Figure 4. W/C mixture proportions average 28-day elastic modulus.

can be noticed that the modulus of elasticity values obtained are consistent with the literate [1] [2] [3] [4], but on the higher end of values. Following the w/c testing, the last parameter was then tested.

3.3. Effect of Silica Fume

Lastly, the effect of including silica fume in the mixtures was explored. Silica fume is known as a Supplementary Cementitious Material (SCM), in which it facilitates the strength grain of cement, therefore creating stronger adhesion between aggregates. Similar to previous testing, the highest performing mixture from the proceeding testing, became the baseline mixture for the next set of testing. In this case the highest performing mixture from the w/c mixture testing was the PG-6.35 mm-0.28 mixtures. Therefore, that mixture design was used and 10% - 30% silica fume replacement of cement was incorporated in 5% increments. The mixture proportions for the silica fume testing can be seen in **Table 4**.

As can be seen in **Table 4**, five additional mixtures were developed that incorporate silica fume replacement of cement at five different percentages. Recall that these mixtures still carry over a 3L10PH compaction and a w/c of 0.28, however, now that silica fume is included, it is referred to as a water-to-cementitious ratio (w/cm). As reported by the literature [1]-[11], producing a higher strength binder system helps in producing higher strength pervious concrete, therefore, including silica fume into the binder system should improve the strength. The results for the silica fume testing can be seen in **Figure 5**.

The results of the effect of the silica fume inclusion show an increase in average 28-day compressive strength with an increase in silica fume percentage. This result is expected, as the adhesion between aggregates is ultimately increased with the inclusion of silica fume. The highest performing mixture was the PG-6.35 mm-30% SF, which produced an average 28-day compressive

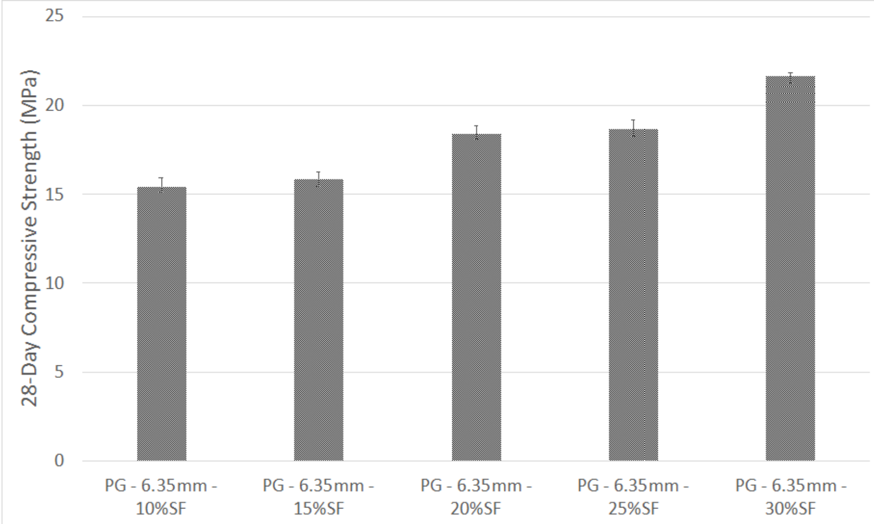

Figure 5. Silica fume mixture proportions average 28-day compression strength.

Table 4. Silica fume mixture proportions.

Mixture Identification	w/cm	Type I Cement (kg/m³)	Silica Fume (kg/m³)	Water (kg/m³)	Coarse Aggregate (kg/m³)
PG-6.35 mm-10% SF	0.28	288	32	89.6	1525
PG-6.35 mm-15% SF	0.28	272	48	89.6	1525
PG-6.35 mm-20% SF	0.28	256	64	89.6	1525
PG-6.35 mm-25% SF	0.28	240	80	89.6	1525
PG-6.35 mm-30% SF	0.28	224	96	89.6	1525

strength of 21.63 MPa. The lowest performing mixture, was the one with the lowest amount of silica fume at 10% inclusion. However, this mixture still produced an average 28-day compressive strength of 15.44 MPa, which is an improvement from the baseline mixture that did not include any silica fume. Therefore, it can be seen that silica fume helps improve the compressive strength of pervious concrete, even at small dosages. A statistical analysis was performed on these results and no statistical difference was observed between 10% and 15%, 20% and 25% mixtures, but a statistical difference was obtained between, the 10%, 20%, and 30% mixtures. This result demonstrates that a 10% increment results in statistically significant results, when including silica fume in these mixtures.

The modulus of elasticity was also investigated on the silica fume mixtures and can be seen in Figure 6.

As seen in Figure 6, the elastic modulus is consistent with the compressive strength test for the silica fume additions. The highest performing mixture, is still the PG-6.35 mm-30% SF and there is still an upward trend of improved modulus with an increase of silica fume. Comparing these results with the literature demonstrate higher modulus of elasticity than conventional pervious

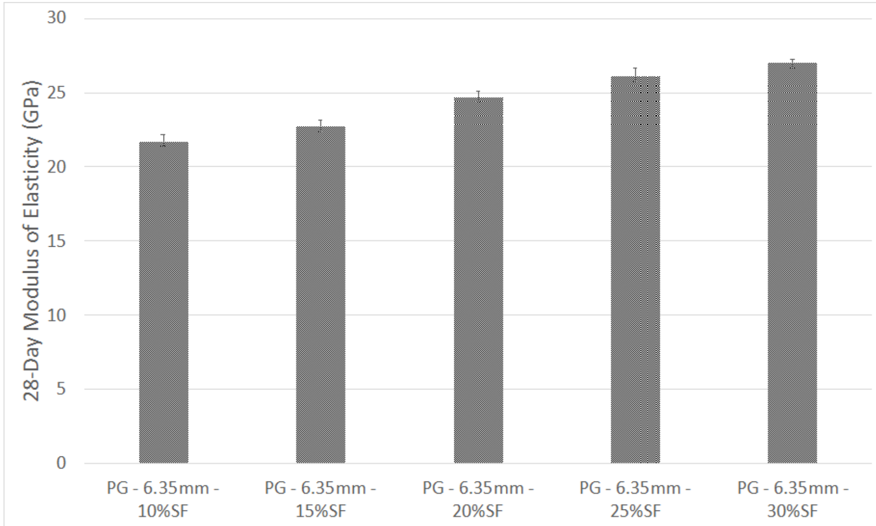

Figure 6. Silica fume mixture proportions average 28-day modulus of elasticity.

concrete, but in the range of high performance pervious concrete studies [12] [13].

3.4. Porosity and Percolation Rate of Mixtures

The most important parameter of these mixtures is the porosity and the percolation rate. As these mixtures are primarily designed to allow water to pass through the hardened concrete system. Therefore, it is critical to also discuss how all parameters investigated affected the porosity and percolation rate. As described in the literature, porosity and percolation rate are related, in that higher porosity results in a higher percolation rate. However, a higher porosity results in lower compressive strengths. Therefore, there is a difficult balance between percolation performance and strength. All mixtures in this study were also tested to obtain their hardened cylinder porosity and percolation rate using ASTM Standard C1754 [20] and reference [2] respectively. A falling head permeameter and the corresponding equations developed in reference [2] were used to determine the percolation rate. The results can be seen in **Table 5** and a relationship between porosity and compressive strength can be seen in **Figure 7**.

As seen in **Table 5**, all porosities and percolation rates are within the acceptable range of pervious concrete [1]-[11]. The range for all mixtures spanned 19.1% - 32.9% for the porosity and 1.9 mm/s - 5.8 mm/s for the percolation rate. Notice that the major changes occurred within the initial mixtures, in which the compaction amount was investigated. After the highest performing compaction method (3L10PH) was obtained, that method was used throughout the remaining mixtures. Due to this fact the porosity and percolation of the next two sets of mixtures did not change much. Notice in **Figure 7** that as the porosity decreases the 28-day compressive strength increases, however at approximately 20% porosity, the 28-day compressive strength increases while maintaining the same porosity. The average porosity for these remaining mixtures was 19.4% and

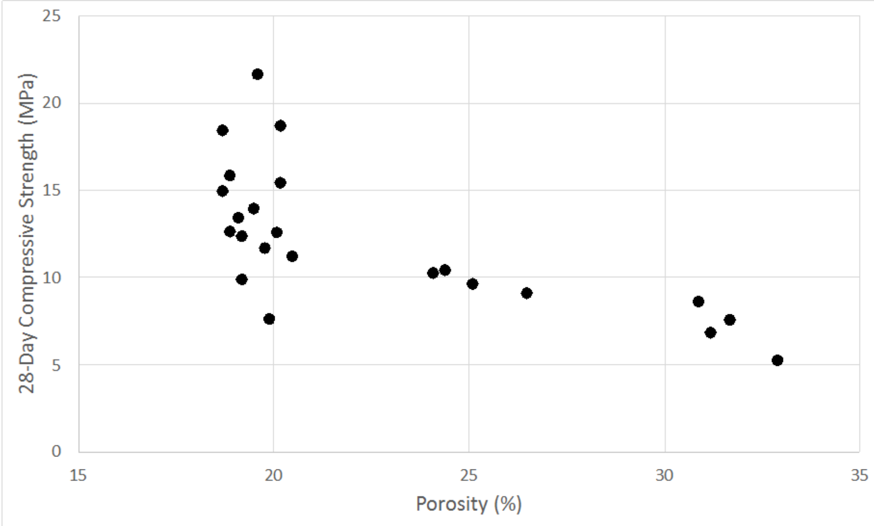

Figure 7. Relationship of 28-day compressive strength and porosity for all samples.

Table 5. Porosity and percolation rate of all mixtures.

Mixture Identification	Porosity (%)	Percolation Rate (mm/s)
Unc-LS-9.54 mm	32.9	5.8
Unc-LS-6.35 mm	31.2	4.9
Unc-PG-9.54 mm	31.7	5.5
Unc-PG-6.35 mm	30.9	5.2
2L5R-LS-9.54 mm	26.5	4.1
2L5R-LS-6.35 mm	25.1	3.9
2L5R-PG-9.54 mm	24.4	4.0
2L5R-PG-6.35 mm	24.1	3.7
3L10PH-LS-9.54 mm	20.5	3.2
3L10PH-LS-6.35 mm	19.8	3.9
3L10PH-PG-9.54 mm	19.2	3.5
3L10PH-PG-6.35 mm	18.9	2.2
PG-6.35 mm-0.3	19.1	2.9
PG-6.35 mm-0.28	18.7	2.4
PG-6.35 mm-0.26	19.5	2.2
PG-6.35 mm-0.24	20.1	3.9
PG-6.35 mm-0.22	19.2	3.0
PG-6.35 mm-0.20	19.9	2.1
PG-6.35 mm-10% SF	20.2	1.9
PG-6.35 mm-15% SF	18.9	2.8
PG-6.35 mm-20% SF	18.7	2.1
PG-6.35 mm-25% SF	20.2	2.9
PG-6.35 mm-30% SF	19.6	3.2

percolation rate of 2.6 mm/s. This percolation rate, is an ideal percolation rate for pervious concrete [1]-[11] and is excellent for a mixture that also obtained a 28-day compressive strength higher than 20 MPa and did not contain expensive polymers and steel fibers.

4. Conclusion

This study developed high strength pervious concrete by parametrically investigating multiple variables, in order to ascertain the best mixture. These mixtures were produced only using locally available materials and without expensive additions, such as polymer agents and steel fibers, which are typical of high strength pervious mixtures. Therefore, economical and producible high strength pervious concrete mixtures were developed. The results show that smaller, rounded, aggregate produced higher compressive strengths. Additionally, the higher the compaction energy, the higher the compressive strength, which is consistent with literature. Secondly, lower w/c did not produce higher strengths in these mixtures. It was found that within the mixture proportions and materials investigated in this study, a 0.28 w/c resulted in the highest average 28-day compressive strength. Lastly, the final parameter tested resulted in a 30% inclusion of silica fume as the highest performing mixture as a higher binder system produces higher compressive strength performance. In this study a range of 28-day compressive strengths was obtained that ranged from 5.23 MPa - 21.63 MPa. The high strength pervious concrete mixtures produced a 28-day compressive strength range of 15.44 MPa - 21.63 MPa. A porosity of range 19.1% - 32.9% with a percolation rate range of 5.8 mm/s - 1.9 mm/s was also achieved, with a porosity of 19.4% and percolation rate of 2.6 mm/s for the highest performing mixture. This porosity and percolation rate is an excellent result for a high strength pervious concrete mixture.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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