Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 7; July-September, 2018, pp. 518-522

http://www.krishisanskriti.org/Publication.html

Effect of Material Proportions on the Strength of Pervious Concrete

Shubham S. Jain[1], Ashfaque Ansari[2] and M.M. Mahajan[3]

[1,2,3]*VNIT, Nagpur*
E-mail: [1]jainshubham689@gmail.com, [2]a_ashfaq@rediffmail.com, [3]mukundmmahajan@gmail.com

Abstract—*The major objective of this study is to determine the influence of various components of pervious concrete on its strength. Normal or conventional concrete is made by mixing cement, coarse aggregates and fine aggregates with water, while in the case of pervious concrete, only coarse aggregates, cement and water are used. The absence of fine aggregates in the mixture increases the amount of air voids in the concrete, resulting in high porosity and high permeability in pervious concrete. Many research work has been carried out to study the behavior of pervious concrete, but till date no standard relationship is developed between its different parameters and strength. Pervious concrete samples of single sized aggregates were casted in the laboratory using a specific mix design procedure. A constant water/cement ratio was maintained in the preparation of the above samples. Influence of various components on the strength of pervious concrete were studied. This study helped in deducing a proper relation between the different parameters used in the preparation of pervious concrete. The mix design procedure, used in this study, could also be further improvised to develop a standard methodology to develop pervious concrete.*

1. INTRODUCTION

In the modern era of urbanization, the climatic conditions are changing drastically. This results in the increase of floods and temperature in the region, causing an impact to the environment as well as to the social life of human beings. As pervious concrete is an eco-friendly material, its demand in the construction industry has increased. Pervious concrete is a special type of concrete which composes of gap graded aggregates, cement and water. The aggregates, covered by a thin layer of cement paste, are assembled by cement paste layers partially being in contact, thus incorporating a high amount of air voids. This makes its physical properties different from conventional concrete. The pore structure of pervious concrete determines all its major properties, like permeability and compressive strength. This pore structure includes the characteristic pore sizes, degree of connectivity in the pore system and the porosity. The features of these pore structure depend on the water-cement ratio, cement paste content, aggregate sizes and degree of compaction. The increased permeability in the pervious concrete may be used to reduce the flooding risk, recharge groundwater, reduce storm-water runoff, prevent glare and skidding during rainy season and reduce noise when in contact with vehicle tyres. As compared to conventional or normal concrete, pervious concrete has lesser shrinkage, lower unit weight and higher thermal insulating values. Therefore, it is currently being used in various applications that require permeability, noise absorption or thermal insulation. In this paper, an experimental study is carried out to derive relations of different parameters of pervious concrete with its compressive strength.

Various mix design methods have been proposed bydifferent researchers to develop pervious concrete in laboratory to obtain desired strength. Many experiments are conducted to obtain permeable concrete with enhanced structural strength. The results of an experimental investigation[6] showed the effects of mix designs on the compressive strengths and permeability of permeable concrete. In another experimentation [2], 18 pervious concrete mixers were prepared and tested for hardened density, compressive strength, permeability and porosity. Based on the results, a methodology was developed that could be used to obtain targeted properties of pervious concrete through a series of regression equations. A methodology was proposed by [1] for mix proportioning based on the ratio of paste volume and interparticle voids. This method indicated that an increase in the paste volume would result in a reduction of permeability but increase in its strength properties. [8, 13] studied the effect of mix proportion on strength and permeability of pervious concrete for use in pavement. The study by[5] analyses the impact strength of different types of porous concretes in correlation with their mixture compositions and production techniques. In [3], the author describes the development of a mathematical model to characterize the relationship between the strength and porosity for porous concrete using empirical results and theoretical derivatives.

Pervious concrete is mainly used due to its property of permeability. Increasing permeability of concrete will result in the reduction of its strength. So, a proper balance has to be maintained between the permeability and the strength of pervious concrete. For this purpose, there is a need to determine the effect of various mix design parameters on the strength of pervious concrete.

2. MATERIALS

2.1 Cement

In this study, ordinary Portland cement, available in the local market, confirming to ISI standard of 53 Grade 'Ultra Tech' was used. The cement was tested for various properties as per IS 4031-1988 and was found to be confirming to various specifications of IS 12669-1987. Specific gravity is 3.15 and fineness is 2800 cm^2/gm. The cement was stored in dry place to prevent it from atmospheric moisture.

2.2 Aggregates

No fine aggregates were used in this investigation. The coarse aggregates used were clean, hard and dry and were obtained from basalt rock. Single sized aggregates of size 20mm were used as shown in Figure 1.

2.3 Water

Locally available potable water is used. The water was free from chemicals, oil or any other form of impurities.

Figure 1: Aggregates of size 20mm

Figure 2: Concrete Mixer

3. METHODOLOGY

A detailed study regarding the guidelines of concrete mix proportioning is done using the code IS 10262:2009. Calculations have been made for the mix design for different concrete grades, namely M20, M25 and M30, using the standard mix design procedure as specified in the above IS code. The standard mix design ratios for cement, coarse aggregates, fine aggregates and water is calculated. The calculated ratio of cement and total aggregates (coarse aggregates and sand combined) is given in Table 1**.**

Table 1: Ratio of Cement and Aggregates (by mass)

Grade of Concrete	Cement	Total Aggregates
M20	1	4.71
M25	1	4.16
M30	1	3.6

Experimental work for pervious concrete was carried out according to the calculated ratios of cement and aggregates. Water, cement and coarse aggregates were mixedusing a concrete mixer as shown in Figure 2. Coarse aggregates of size 20mm were used, while water-cement ratio of 0.29 was maintained. A proper mix was prepared, which was then poured into cylindrical moulds of diameter 15cm and height 30cm. The mix was poured in 3 layers in the cylindrical mould. After each layer, vibrations were given to the mould. After completely filling the moulds, the top surface of the sample was smoothened using a trowel. These samples were kept in the moulds for 24 hours to gain initial strength. The samples were then removed from the moulds and immersed in a water pond for proper curing for 28 days.

Figure 3: Testing of the sample (Just before load is applied)

Figure 4: Testing of the sample (Just after failure)

4. TESTING

After 28 days of proper curing, the samples were removed from the water pond. After draining out all the pore water, the samples were weighed and tested for their compressive strengths. The testing results of each of these samples are given in Table 2.

4.1 Density

The samples were weighed on a weighing machine and the volume was calculated using the dimensions of the cylindrical mould. The ratio of mass to volume gives the density of each sample.

4.2 Porosity

The calculation of actual density has been discussed above. The theoretical density can be calculated by measuring the masses and volumes of each of the materials, namely cement, water and aggregates, used in the preparation of pervious concrete. The actual and theoretical densities help to calculate the void content in the sample. Thus, the porosity can be calculated using the equation:

$$Porosity = \frac{Volume\ of\ voids}{Total\ Volume} * 100$$

4.3 Compressive Strength

All the 9 samples were tested for their compressive strengths. Figure 3 and Figure 4 shows the cylindrical sample being tested by compression testing machine. Flat thin plates were placed above and below the sample so that the loading is applied uniformly throughout the sample. The first crack or rupture in the sample gives the compressive strength of the sample. Table 2 gives the values of the applied load and the corresponding strengths of the samples.

Table 2: Test results of various samples

Grade of Concrete	Sample	Mass (kg)	Density (kg/m3)	Load (kN)	Strength (MPa)	Porosity (%)
M20	M1	9.017	1701	190.8	10.32	22
M20	M2	9.182	1732	208.1	11.28	21
M20	M3	9.044	1706	197.4	10.56	21
M25	M4	9.646	1820	245	13.26	20.5
M25	M5	9.789	1847	268.2	14.20	19.6
M25	M6	9.655	1822	252.9	13.86	20
M30	M7	10.211	1927	311.1	16.81	19
M30	M8	10.488	1979	329.8	17.14	18.9
M30	M9	10.103	1906	308.9	16.42	19.2

5. RESULTS AND DISCUSSION

5.1 Density

Density is a very important characteristic of concrete. Table 2 shows the calculated values of density for all the 9 samples. It can be seen that as the density increases, the strength value also increases, while the porosity decreases. This phenomenon can also be observed from the plot shown in Figure 5 and Figure 6.

5.2 Porosity

Percentage porosity for the various specimen of pervious concrete has been stated in Table 2. The corresponding values of strength and density are plotted in Figure 6 and Figure 7.

5.3 Compressive Strength

The obtained values of compressive strength corresponding to the applied load is shown in Table 2. Percentage porosity and density of the pervious concrete samples corresponding to obtained compressive strength can also be seen in Figure 5 and Figure 7.

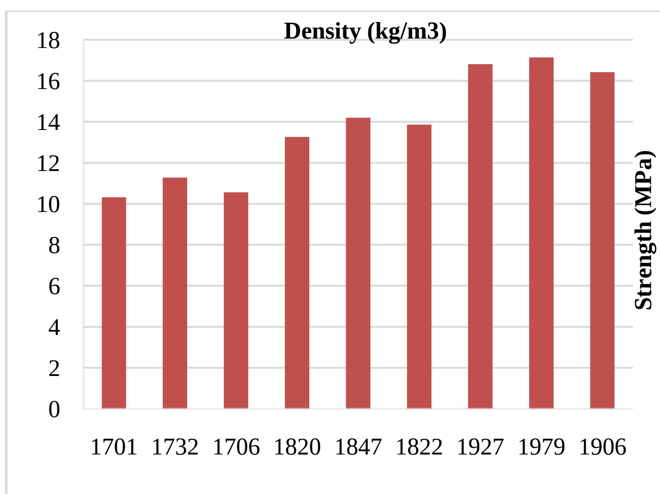

Figure 5: Density vs Strength plot

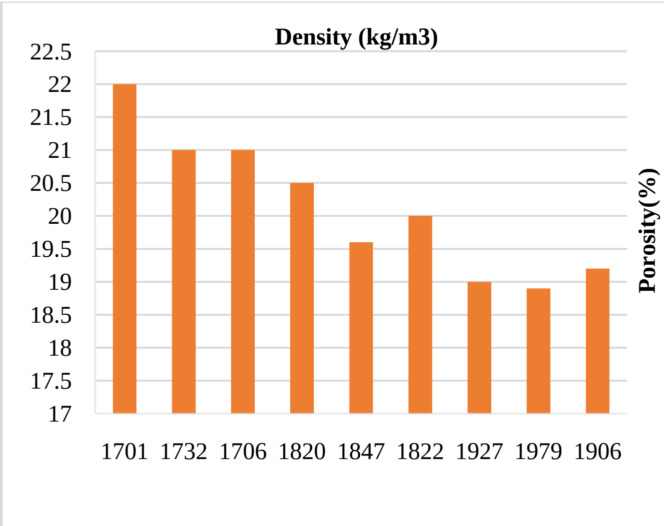

Figure 6. Density vs Porosity plot

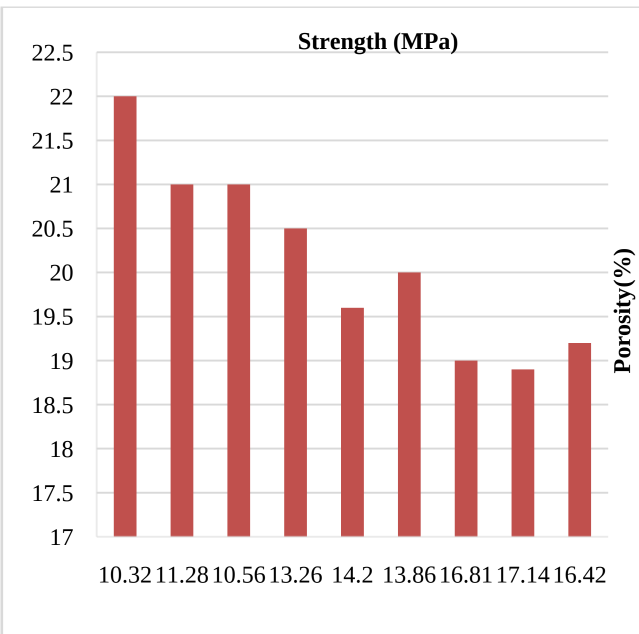

Figure 7: Strength vs Porosity plot

5.4 Discussion

In this experimental study, pervious concrete samples of single sized aggregates were prepared (M1 to M9). Three samples each of M20, M25 and M30 were tested for their compressive strengths. The measured strength values are shown in Table 2. The corresponding values of density and porosity are also shown in the above table (Table 2). As shown in the tables and the plots, there exist some relation among the different parameters of pervious concrete, namely compressive strength, density and porosity. It is observed that, irrespective of the grade of concrete, a sample with higher density will have higher value of compressive strength and lesser porosity.

It can be seen from Figure 5 that for higher value of density, the strength value is also high. Also,as the density increases, the percentage of air voids in the sample decreases. This shows that the permeability for lesser dense concrete will be greater.

6. CONCLUSIONS

This paper gives the results of an experimental investigation conducted on 9 pervious concrete samples, namely M1 to M9. From the obtained results, the following conclusions were drawn:

- The relationship between compressive strength, density and porosity does not differ with the grades of concrete.
- Density of concrete is directly proportional to its compressive strength.
- As the density increases, the volume of voids in the concrete reduces. Density is inversely proportional to porosity.
- Similarly, compressive strength and porosity are also inversely proportional to each other.
- Lesser value of cement to aggregate ratio gives higher compressive strength for pervious concrete.
- The amount of cement, aggregate and water in the composition determines the compressive strength of pervious concrete.

REFERENCES

[1] Yahia, A., and D. Kabagire. (2014). “New approach to proportion pervious concrete.” Constr. Build. Mater. 62: 38–46.

[2] Chandrappa, A. K., Biligiri, K. P. (2018). “Methodology to Develop Pervious Concrete Mixtures for Target Properties Emphasizing the Selection of Mixture Variables*”, J. Transp. Eng., Part B: Pavements*, 2018, 144(3): 04018031.

[3] Lian, C., Zhuge, Y., Beecham, S. (2011). “The relationship between porosity and strength for Pervious concrete”, *Construction and Building Materials 25* (2011) 4294–4298.

[4] Sonebi, M., Bassuoni, M., Yahia, A. (2016). “Pervious Concrete: Mix Design, Properties and Applications”, *RILEM Technical Letters* (2016) 1: 109 – 115.

[5] Ozbek, A. S. A., Weerheijm, J., Schlangen, E., Breugel, K. (2013). “Dynamic behavior of pervious concretes under drop weight impact testing”, *Cement & Concrete Composites 39* (2013) 1–11.

[6] Lian, C., Zhuge, Y. (2010). “Optimum mix design of enhanced permeable concrete – An experimental investigation”, *Construction and Building Materials 24* (2010) 2664–2671.

[7] Chandrappa, A. K., Biligiri, K. P. (2016). “Pervious concrete as a sustainable pavement material – Research findings and future prospects: A state-of-the-art review”, *Construction and Building Materials 111* (2016) 262–274.

[8] Lim, E., Twan, K.H., Fwa, T.F. (2013). “Effect of mix proportion on strength and permeability of pervious concrete for use in pavement”, *Proceedings of the Eastern Asia Society for Transportation Studies*, vol. 9, 2013.

[9] Ghafoori, N., Dutta, S. “Laboratory investigation of compacted no-fines concrete for paving materials”, *J. Mater. Civ. Eng.* 7 (3) (1995) 183–191 (American Society of Civil Engineering).

[10] Yang, J., Jiang, G. “Experimental study on properties of pervious concrete pavement materials”, *Cem. Concr. Res.* 33 (2002) 381–386 (Elsevier).

[11] Li, H., Kayhanian, M., Harvey, J.T (2013). “Comparative field permeability measurement of permeable pavements using ASTM C1701 and NCAT permeameter methods”, *J. Environ. Manage.* 118 (2013) 144–152 (Elsevier).

[12] Montes, F., Valavala, S., Haselbach, L.M. (2005). “A new test method for porosity measurements of portland cement pervious concrete”, *J. ASTM Int.* 2 (1) (2005) 1–13.

[13] McCain, G.N., Dewoolkar, M.M. (2009). “Strength and permeability characteristics of porous concrete pavements”, *Transp. Res. Board* (2009) 1–13.