Intensification of Pervious Concrete Strength using Polypropylene Fibre with Varying Aggregate-Cement & Water-Cement Ratio

Shailendra Prasad Tiwari[1] Prof. Rajesh Joshi[2]
[1]M-Tech. Student [2]Head of Department
[1]Department of Civil Engineering
[1]Rajiv Gandhi Proudyogiki Mahavidyalaya, Bhopal, M.P., India

Abstract— Although strength is not the only important requirement from a pervious concrete, but it is equally important as permeability characteristics for structural applications. Previous studies clearly specified that pervious concrete possesses lesser compressive strength than traditional concrete and is only capable of supporting light loadings and low volume traffic. In this dissertation, investigation is made on prior studies on the various properties of pervious concrete, with the main focus on compressive strength of pervious concrete. The several factor that has impeccable impact on compressive strength of concrete are water- cement ratio, aggregate-cement ratio, aggregate size, quantity of admixture and compaction. The results were compared to the results that have been obtained from laboratory experiments conducted on samples of pervious concrete cube prepared. The effectiveness of pervious concrete is due to the voids that reduces the strength considerably. Like for every 5% voids the compressive strength of 1% reduces (as per Klieger, 2003). The aim is to find a balance between water- aggregate and water- cement ratios in order to increase strength and permeability. So the conclusions of this research will be a recommendation as to the water-cement ratio, the aggregate-cement ratio, and aggregate size, quantity of admixture and compaction which is necessary to optimize compressive strength without having any detrimental effects on the permeability of the pervious concrete. Researches indicate that the minimum compressive strengths of acceptable mixtures reached in to 2.8 Mpa- and maximum compressive strength reached to 28 Mpa. As far as permeability is concerned extreme permeable rates were achieved in almost all the concrete mixes designed regardless of the compressive strength.

Key words: Permeability, Pervious Concrete, Water-Cement Ratio, Admixtures

I. Introduction

Pervious concrete is a composite material consisting of binding material, coarse aggregate, admixture and water. It is different from conventional concrete in that it contains no fine aggregate in the mixture. The aggregate usually consists of single size non-graded particles and is bonded together at its points of contact by a paste formed by the cement, admixture and water. This mix when hardens results in a concrete with a high percentage of interconnected voids that, allows the rapid percolation of water. Unlike conventional concrete, which has a void ratio approximately 1-3%, pervious concrete can have void ratio from 15-35%.The characteristics of Pervious concrete differ from conventional concrete in several other ways. If we compare Pervious concrete with conventional concrete, it has a lower compressive strength, higher permeability, and a lower unit weight, approximately 70% of conventional concrete.

A. *Uses of Pervious Concrete*

- The use of Pervious concrete is limited in areas subjected to low traffic volumes and loads.
- Pervious concrete is useful in the construction of parking lots, driveways, sidewalks, residential streets, tennis courts, and swimming pool decks.
- Construction of the pavement for Zoo areas & Sub-base for conventional concrete pavements with the help of pervious concrete.
- Construction of the low-volume pavements residential roads with the help of pervious concrete.
- Sewage treatment plant sludge beds, beach structures and seawalls can be constructed by pervious concrete.
- Bridge embankments & solar energy storage systems can be constructed by pervious concrete.

B. *Advantages of Pervious Concrete*

- Recharging of ground water table
- Sound Absorption
- Skid Resistance
- Storm-water Runoff
- Heat Insulation

II. Literature review

Pervious concrete is a combination of Portland cement, controlled amounts of water, coarse aggregate and little or no sand. The thick cement paste bonds the coarse aggregate together but allows adequate void formation of approximately 15% to 35%.

The rate at which the water flows through pervious concrete is “typically around 480 in./hr (0.34 cm/s which is 5 gal/ft²/min or 200 L/m²/min)” (Tennis et al, 2004).

According to another researcher (V.M. Malhotra) presented in his thesis that to create a pervious concrete structure with optimum permeability and compressive strength, the amount of water, amount of cement, type and size of aggregate, and compaction must all be considered. A number of experiments have been previously conducted throughout the past few decades by a variety of researchers comparing some or all of these elements. The results are presented in a series of tables and graphs. V.M.

Malhotra discussed pervious concrete as it relates to applications and properties. He provided details on such properties as proportions of materials, unit weight, compatibility, and curing in an attempt to maximize permeability in the pervious concrete. Malhotra also conducted multiple experiments on various test cylinders in an attempt to find a correlation between compressive strength and any of the material’s properties. We found that the compressive strength of pervious concrete was decreased with the increase of aggregates proportion in mix and if we increase the amount of water in mix, it also results in reduction of the compressive strength of pervious concrete. He also concluded that even the optimum ratios still would not provide compressive strengths comparable to conventional concrete. Malhotra went on to investigate the effects of compaction on compressive strengths. Malhotra presents a correlation between compressive strength and unit weight he shows that compressive strength increases with increase in density, when different aggregate cement ratios along with various aggregate gradings are employed. Malhotra also experimented on different types of aggregates and their effect on compressive strength the relationship between aggregate type and compressive strengths, he shows that Rounded Quartzite Gravel provides higher compressive strength as compare to Crushed Limestone and Crushed Granite (Malhotra, V.M., 1976).

The EPA Storm Water Phase II Final Rule has regulations to manage the quantity of pollutants entering bodies of water (Tennis et al, 2004). Contaminants may include oils, grains, grease, sediment, anti-freeze, fertilizers, and pesticides. The partially filtered water is able to percolate into the soil and be further filtered by the soil structure, and in turn recharge the ground water table and readily water the surrounding plants. With pervious concrete, the need for management systems to control excess water flow is minimized. Along with these environmental benefits are safety concerns that are eliminated such as pooling, spraying and hydroplaning (Tennis et al, 2004). Pervious concrete now has the potential of being certified for construction projects by the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System, because of its environmental benefits along with the capability of lowering the heat island effect (Tennis et al, 2004). Urban areas tend to enclose large numbers of impervious pavements which add to the level of heat. The concentrated heat wave can be reduced by the open structure of pervious concrete that allows air to flow through it. Additionally, the roots of plants and trees adjacent to these pavements not only experience watering but also aeration (Tennis et al, 2004).

Economic concerns and regulations have rekindled an interest in pervious concrete. Regulations such as storm water impact fees are increasing the cost of developing real estate because of the size and cost of required drainage systems (Tennis et al, 2004). The labor, construction, and maintenance cost of implementing storm water management systems, such as retention ponds, pumps, swales, and storm sewers can be substantially reduced or even eliminated with the proper construction of pervious concrete pavements. Land developers who have installed these pavements have been rewarded with more available building area. Another economical benefit of pervious concrete presents itself to local concrete companies. Because of the low slump property of pervious concrete, the delivery time is relatively short and would create issues for contractors and owners, but for companies that operate close to the construction site, they would have the advantage over their competitors who are further away. Finally, pervious concrete has a lower maintenance cost over its life- cycle due to its durability and strength in comparison to asphalt pavements (Tennis et al, 2004).

The surface of pervious concrete possesses a peculiar texture, because its mix is comprised of gravel or crushed stone and little or no fines. The coarse aggregate texture of the pervious pavement surface improves skid resistance by removing excess precipitation during rainy days and causes snow to melt faster (Schaefer et al, 2006).

The surface of pervious concrete pavements experiences some raveling which only last during the early weeks after placement (Tennis et al, 2004). Proper compaction and curing methods greatly reduce this defect. The possibility of drying shrinkage of the hardened concrete is lower than conventional concrete since there is less water in the fresh mix (Offenberg, 2005). Because cracking is not as prevalent in pervious concrete pavements, control joints are spaced further apart (i.e., around 20 feet from each other) (Tennis et al, 2004).

The quality and performance of pervious concrete depends on the quality of the sub-grade, and the constructor's ability to correctly proportion, mix, place, finish and cure the mixture (Crouch et al, 2003). A vibrating screed is used to maximize the density and strength and a steel pipe roller is used for compaction. The pavement is immediately sealed with plastic sheeting which remains on the pavement for at least a week and the cured pervious concrete has the appearance of Rice Krispies treats (Tennis et al, 2004). The gradations of pervious concrete mixes can be adjusted to meet the desired performance requirements for a given application whether for pedestrians, vehicles, or sound absorption. The unique abilities of pervious concrete offer solutions to environmental issues, public agencies, and building owners, which allow for diverse applications in which it can be used successfully. Some of the applications for pervious concrete involve residential roads and driveways, sidewalks, parking lots, low water crossings, sub-base for conventional concrete pavements, patios, artificial reefs, slope stabilization, hydraulic structures, well linings, noise barriers and many other applications exist (Tennis et al, 2004).

Fresh pervious concrete is characterized as having a very low slump of about ¾ inches; therefore, it cannot be pumped. Generally, the coated aggregates maintain a molded shape since the mix is quite sticky. With regards to achieving some level of quality control and quality assurance, unit weight measurements are the best means of doing so. A unit weight range of 100 to 125 lb/ft3 is typical with a tolerance of ± 5% or 5 lb/ft3. The mixing and placement time for pervious concrete is usually one hour, but it can be increased to one and one-half hours when retarders or hydration stabilizers are added (Tennis et al, 2004). Modifications to the mixing process of allowing the aggregate to rotate for 1 minute with 5% of the total cement has increased the 7-day strength of the specimens tested (Schaefer et al, 2006).

III. OBJECTIVE OF STUDY

- To investigate the mechanical and physical properties of the materials that is to be used for research.
- To prepare pervious concrete mixes with varying aggregate cement ratio and water cement ratio.
- Establish an experimental procedure to determine water permeability of pervious Concrete.

- To adulterate pervious concrete mixes with polypropylene fibres to enhance its strength and again the water permeability will be checked.
- The purpose of this dissertation is to provide tools to evaluate and improve the durability and strength of pervious concrete with sufficient permeability such that it may be more secretly engaged in town roadways, driveways, and parking lots.

IV. MATERIAL

- Cement (PPC)
- Coarse Aggregate (10 mm i.e. 100% passing through 12.5 mm and 100% retained on 10 mm sieve)
- Admixture – Superplasticizer, to reduce water requirements and enhance strength
- Polypropylene Fibres (6mm to 12 mm length)
- Water

V. OBSERVATION

S.No.	Water Cement Ratio	Aggregate Cement Ratio	Quantity of admixture (ml/kg of cement)	Weight of concrete (kg)	Density (kg/m3)
1	0.38	5	5	4.288	1905
2	0.36	5	10	4.280	1902
3	0.34	5	15	4.254	1890
4	0.38	4.5	5	4.236	1882
5	0.36	4.5	10	4.231	1880
6	0.34	4.5	15	4.220	1875
7	0.38	4	5	4.168	1852
8	0.36	4	10	4.159	1848
9	0.34	4	15	4.150	1844

Table 1: Density of Fresh Pervious Concrete

Sample No.	W/C Ratio	A/C Ratio	Load taken by sample after 7 days (kg)	Load taken by sample after 28 days (kg)	Compressive Strength after 7 days (kg/cm2)	Compressive Strength after 28 days (kg/cm2)
I II III	0.38	5	8000 8000 9000	14000 13000 14000	35.56 35.56 40.00	62.22 57.78 62.22
I II III	0.36	5	10000 9000 9000	15000 14000 15000	44.44 40.00 40.00	66.67 62.22 66.67
I II III	0.34	5	11000 10000 11000	17000 16000 16000	48.89 44.44 48.89	75.56 71.11 71.11
I II III	0.38	4.5	11000 12000 12000	18000 17000 17000	48.89 53.33 53.33	80.00 75.56 75.56
I II III	0.36	4.5	12000 12000 13000	18000 19000 19000	53.33 53.33 57.78	80.00 84.44 80.00
I II III	0.34	4.5	12000 13000 13000	18000 20000 19000	53.33 57.78 57.78	80.00 88.88 84.44
I II III	0.38	4	14000 13000 13000	20000 21000 21000	62.22 53.33 53.33	88.88 93.33 93.33
I II III	0.36	4	14000 14000 13000	23000 21000 22000	62.22 62.22 53.33	102.22 93.33 97.78
I II III	0.34	4	14000 15000 14000	23000 22000 23000	62.22 66.67 62.22	102.22 97.78 102.22

Table 2: Compressive Strength of Pervious Concrete

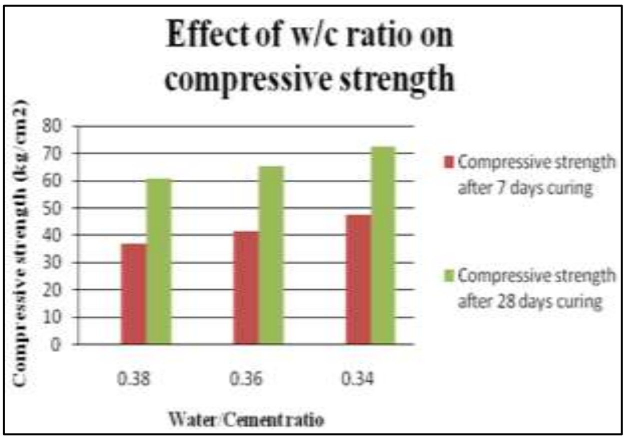

Figure.1. Compressive strength v/s water cement ratio at A/C = 5

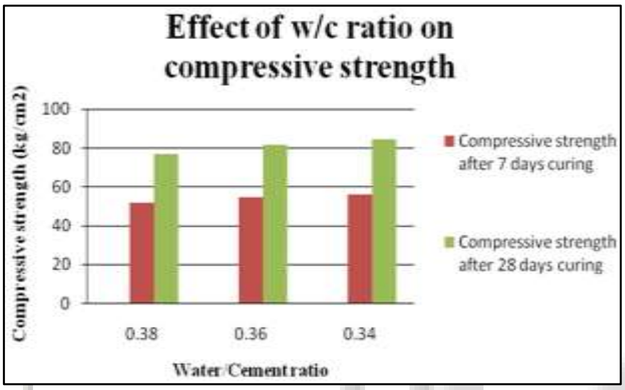

Fig. 2: Compressive Strength v/s Water Cement Ratio at A/C = 4.5

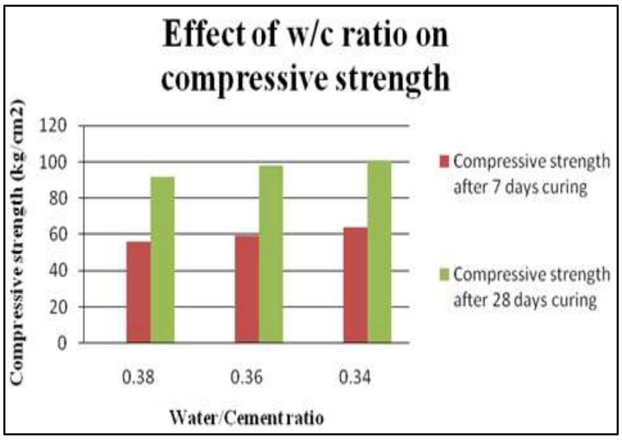

Fig. 3: Compressive Strength v/s Water Cement Ratio at A/C = 4

S.No.	A/C Ratio	Msd(kg)	Mbm (kg)	Mod (kg)	Porosity (%)
1	5 5 5	7.018 7.012 7.010	6.987 6.979 6.976	6.925 6.912 6.910	33.33 33.00 34.00
2	4.5 4.5 4.5	6.995 6.988 6.980	6.967 6.962 6.954	6.897 6.895 6.886	28.57 27.95 27.66
3	4 4 4	6.970 6.964 6.958	6.945 6.940 6.932	6.858 6.852 6.832	22.32 21.43 20.63

Table 3: Test Observation for Porosity

Sample No.	W/C Ratio	A/C Ratio	Quantity of admixture (ml/kg of cement)	Quantity of water (ml)	Time (Seconds)
I II III	0.38	5	5	1450	33 34 32
I II III	0.36	5	10	1450	33 34 36
I II III	0.34	5	15	1450	33 32 34
I II III	0.38	4.5	5	1450	36 34 38
I II III	0.36	4.5	10	1450	35 34 36
I II III	0.34	4.5	15	1450	35 36 34
I II III	0.38	4	5	1450	38 37 39
I II III	0.36	4	10	1450	37 36 36
I II III	0.34	4	15	1450	38 37 38

Table 4: Hydraulic Conductivity of Pervious Concrete Mixes

S. No.	Water Cement Ratio	Aggregate Cement Ratio	Time (Sec)	Permeability (mm/sec)
1	0.38	5	33	25.45
2	0.36	5	34	24.70
3	0.34	5	33	25.45
4	0.38	4.5	36	23.33
5	0.36	4.5	35	24.00
6	0.34	4.5	35	24.00
7	0.38	4	38	22.11
8	0.36	4	36	23.33
9	0.34	4	38	22.11

Table 5: Results of Hydraulic Conductivity of Pervious Concrete Mixes

VI. CONCLUSION

1) We can improve the compressive strength of pervious concrete around 9%-15 % with use of superplasticizer.
2) The porosity of pervious concrete was between 20%-34% as compare with conventional concrete's 3%-5%.
3) The compressive strength of pervious concrete was around 100 kg/cm2.
4) The permeability of pervious concrete was 22.11 mm/sec- 25.45 mm/sec.
5) The density of pervious concrete was 1844 kg/m3 -1905 kg/m3 which was 20%-25% lower than that of conventional concrete.
6) The hydraulic conductivity decreased as the decrement takes place in the percentage of aggregate in mix.

ACKNOWLEDGEMENT

The author are Grateful to the Department of Civil Engineering, Rajiv Gandhi Prodhyogiki Mahavidhyalaya, Bhopal, M.P., India for extending the facilities and support during study, and also very thankful to the project guide Prof. Rajesh Joshi (HOD) for their guidance and support.

REFERENCES

[1] ACI, Pervious concrete ACI 522R-06, 2006: 25.
[2] ASTM C1602 / C1602M - 12 Standard Specifications for Mixing Water Used inthe Production of Hydraulic Cement Concrete.
[3] ASTM C1688, Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete.
[4] Cube Moulds- (As per IS: 516:1959)
[5] Descornet, G. (2000). "Low-noise road surface techniques and materials," Proceedings of Inter Noise 2000, Nice, France, pp. 6.
[6] EPA, U.S., Storm water technology fact sheet porous pavement. In Storm Water Technology Fact Sheet, EPA, Editor. United States Environmental Protection Agency: Washington, D.C, 1999.
[7] Ghafoori, N. and S. Dutta, Laboratory investigation of compacted no-fines concrete for paving materials. Journal of Materials in Civil Engineering, 1995:7(3): p. 183-191.
[8] Haselbach, L.M., S. Valavala, and F. Montes, Permeability predictions for sandclogged38. Scholz, M. and P. Grabowiecki, Review of permeable pavement systems. Building and Environment, 2007: 42(11): p. 3830-3836.
[9] Haselbach, L.M. and R.M. Freeman, Vertical porosity distributions in pervious concrete pavement. ACI Materials Journal, 2006: 103(6): p. 7.
[10] Matsuo, Y., K. Morino, and E. Iwatsuki, A study of porous concrete using electric arc furnace oxidizing slag aggregate, in Research report of Aichi Institute of Technology, 2005: p. 8.
[11] Malhotra, V.M., No-Fines Concrete – Its Properties and Applications, ACI Journal, November 1976, Vol. 73, Issue 11, pp 628-644.
[12] Mindess, S., Young, J. F., and Darwin, D. (2004). “Aggregates and Response of Concrete to Stress” Concrete, 2nd Ed., Pearson Education, Inc. Upper Saddle River, NJ., Chap. 7, 121, and Chap. 13, 318.
[13] Naik, R. T. and Kraus, N. R., Development and demonstration of high-carbon CCPs and FGD by-products impermeable roadway base construction, in Centre for By-Products Utilization, 2002: p. 95.