Design And Testing Of High Strength Pervious Concrete For High Traffic City Pavements Like Mumbai

[1] Aditya Vishvanath Mhatre, [2]Bhavik Ramesh Bhanushali, [3]Mohammed Rohaan Muslim Shaikh,
[4] Prof. Nikhil Ingale
[1,2,3]Student, [4] Professor,
[1]Department of Civil Engineering,
[1]Rizvi College of Engineering, Bandra, Mumbai, India.

Abstract: The main aim of the project is to improve the strength characteristics of pervious concrete by using special liquid type of water reducing admixture in combination with fibres in pervious concrete mix. The analysis was undertaken by conducting a number of standard concrete tests and comparing the characteristics of the high strength pervious concrete and conventional pervious concrete samples. The tests include compressive strength test, permeability test to determine its properties. Cubes and cylinders are the specimens used for the tests and they are prepared using appropriate mix proportions. The choice of selecting suitable mix proportions of pervious concrete lead to favorable results. In our design and testing we have compared our results with the lowest grade of pavement pervious concrete to check for improvement after addition of admixtures. We used two primary admixtures, one being an organic superplasticizer to decrease the water-cement ratio and other being polypropylene fibres to amass strength in the final product. Proper balance of superplasticizer and fibre content had to be maintained to avoid loss of strength. To develop our conclusions, we followed with basic strength and permeability testing on the cubes.

Keywords— Pervious Concrete, No Fineness concrete, Water drain, Ground water improvement. Crushing strength, Impact value, Ductility, Penetration, stripping value, fibre, superplasticizer

I. Introduction

Pervious concrete is one of the modern marvels which is has the capability of draining water but has low strength characteristics. This study intends to change the later part. Implementation of pervious concrete roads for Indian conditions is very essential for a beneficial town planning with efficient collection system for run-off water. Pervious concrete is a zero-slump, open graded material consisting of cement, coarse aggregate, admixtures and water. Pervious concrete pavement is an effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, pervious concrete is instrumental in recharging groundwater, reducing stormwater runoff. In fact, the use of pervious concrete is considered the best for the management of stormwater runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other stormwater management devices. In doing so, pervious concrete has the ability to lower overall project costs on a first-cost basis.

This paper focuses on increasing comprehensive strength of concrete, but it is observed that there is no specific mix design to be set as standard concrete in any working conditions or in any country. The design has been used in various applications, subjecting it to remodification; Restructuring based on the use of concrete, its functionality, serviceability, etc., although some tests such as permeability, compressive strength have been found to be common in all applications. The addition of different fibres has been found to affect many properties and in many cases the strength of deformed concrete. However more research work needs to be done to investigate how this concrete can be widely used to enhance the strength of the pervious concrete.

Although not a recent know-how (it was first used in 1852), pervious concrete is receiving renewed interest, partly because of flooding that have started to trouble the coastlines around the world due to climate change. The high flow rate of water through a pervious concrete pavement allows rainfall to be captured and to percolate into the ground, recharging groundwater, reducing stormwater runoff, supporting sustainable infrastructure, hence providing a solution for construction that is sensitive to environmental concerns. This ability of pervious concrete offer advantages to the environment, public and building owners by controlling rainwater on-site and addressing stormwater runoff issues. This can be of special interest in urban areas, or where land is very expensive. Depending on local laws and environment, a pervious concrete pavement and its subbase grant enough water storage capacity to ease the pressure on storm drainages. This provides for more efficient land use and is one factor that has led to a renewed interest in pervious concrete. Other applications that take advantage of the high flow rate through pervious concrete include drainage media for hydraulic structures, tennis courts, parking lots, greenhouses, and pervious base layers under heavy-duty pavements. Its high porosity also gives it other useful characteristics: it is thermally insulating (for example, in walls of buildings) and has good acoustical properties (for sound barrier walls).

II. Research Material

2.1 Cement- Ordinary Portland Cement, grade 43 confirming to IS 8112: 1989 is used in our project. Ordinary Portland Cement of 43 Grade of brand name Ultra Tech Company, was used for the testing. Proper care was taken to see that the procurement was made from single batching in air tight containers to prevent it from being affected by atmospheric conditions.

Table 2.1Physical properties of OPC 43 Grade cement

Sr. No	Characteristics	Required Value
1.	Fineness (by Blaine's apparatus)	Not less than 225 m^2/Kg
2.	Soundness	
	a) Le Chatelier method	Not more than 10 mm

	b) Autoclave test	Not more than 0.8%
3.	Setting time	
	a) Initial setting time in minutes	Not less than 30
	b) Final setting time in minutes	Not less than 600
4.	Compressive strength	
	a) 72 +/- 1 hour (3 days)	Not less than 27 MPA
	b) 168 +/- 2 hours (7 days)	Not less than 37 MPA
	c) 672 +/- 4 hours (28 days)	Min -43 MPA, Max -58 MPA

2.2 Aggregates- Locally available crushed stone coarse aggregates of nominal size 10mm and 20mm were used for the trial. Crushed aggregates of less than 20mm size were used. The aggregate exclusively passing through 20mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements like gradation, fineness modulus, specific gravity and bulk density with respect to IS: 2386-1963. The individual aggregates were mixed to induce the required combined grading. The particular gravity and water absorption of the mixture are given in table. Following table shows the physical properties of coarse aggregates.

Table 2.2 Properties of type of aggregates considered for design mix.

Size	Specific Gravity	Water Absorption %	Flakiness Index %	Elongation Index %	Crushing Value	Impact Value
10 mm.	2.92	1.10	9.48	14.28	11.76	5.76
20 mm.	2.92	1.01	8.21	10.49	12.34	5.40

2.3 Superplasticizer - In our project we have used polycarboxylate-based superplasticizer which are also known as high range water reducers are synthetic water-soluble organic compounds that reduce the amount of water required to achieve certain stability of concrete, reduce water-cement ratio, decrease water content and increase slump. The use of superplasticizers reduces quantity of mixing water required to produce a concrete mix of consistency by 25 to 30%. Superplasticizer's dosage is usually 0.5-3% of the volume of cement.

2.4 Polypropylene Fibres- Polypropylene fibres are used to avoid fissures appearing in the concrete caused by humidity, so reducing cracks. Moreover, compressive and flexural strength can be increased. increase in compressive strength by more than 30%, and tensile strength by almost 35%, using 0.9 kg/m3 of polypropylene fibres in the mixture.

2.5 Water- For casting and curing water used is free from organic matter and portable water is used as per clause no. 5.4 of IS 456-2000. pH value ranges between 6 to 9.

III. MIX DESIGN

3.1 Mix proportion of M30 grade Pervious Concrete for 10mm Coarse Aggregate:

i. Type of cement: OPC 43(Ordinary Portland Cement) grade 43, confirming to IS 8112:1989.
ii. Specific gravity of cement: 3.15
iii. Maximum nominal size of aggregate: 20mm
iv. Specific gravity of aggregates: 2.92
v. Water absorption of coarse aggregate: 1.10
vi. Type of aggregate: Crushed angular aggregate
vii. Free moisture of coarse aggregate: Nil
viii. Exposure condition: Severe

Step 1: Determining the Target Strength for Mix-Proportioning
f'ck = fck + 1.65 x S
= 30 + 1.65 x 5 = 38.25 N/mm2(s=5, as per the table 1 from IS 456)

Step 2: Water-Cement Ratio
Maximum water-cement ratio = 0.45 (as per table.5 of IS 456)
Adopt Water-Cement ratio = 0.4

Step 3: Selection of Water Content
Maximum water content for 10 mm aggregate = 208 Kg/m3 (for 25 to 50 slump)
Here, we are using the superplasticizer as an admixture, so we can reduce water content by 23%.
Water content = 208-(23/100)× 208 kg/m3
∴ Water content = 160.14 kg/m3

Step 4: Calculation of Cement Content
Water-Cement Ratio = 0.4
Water content from Step 3 i.e. 160.14 litres
Cement Content = Water content / "w-c ratio" = (160.14/0.40) = 400.35 kgs
From Table 5 of IS 456,
Minimum cement Content for moderate exposure condition = 360 kg/m3

400.35 kg/m3 > 360 kg/m3, hence, OK.

Step 5: Proportion of Volume of Coarse Aggregate and Fine Aggregate Content
As we are calculating mix-proportions for pervious concrete i.e., no fines concrete. We will take the proportion of volume of fine aggregate=0 and coarse aggregates=1.

Step 6: Estimation of Concrete Mix Calculations
The mix calculations per unit volume of concrete shall be as follows:
a) Volume of concrete = 1 m3
b) Volume of cement = (Mass of cement / Specific gravity of cement) x (1/1000) = (400.35/3.15) x (1/1000) = 0.127 m3
c) Volume of water = (Mass of water / Specific gravity of water) x (1/1000) = (160.16/1) x (1/1000) = 0.16016 m3
d) Total Volume of Aggregates = 1- (b+c) =1- (0.127+0.16016) = 0.713 m3

Note:
∴ Total Volume of Aggregates = (0.713-0.2) m3 =0.512 m3
1. Mass of coarse aggregates = Total volume of aggregates X Volume of Coarse Aggregate X Specific Gravity of Coarse Aggregate X
1000 = 0.512 X 1 × 2.92 X 1000 = 1495.04 kg/m3
2. Mass of fine aggregates = Total volume of aggregates X Volume of Fine Aggregate X Specific Gravity of Coarse Aggregate X 1000 = 0.512 X 0 = 0 kg/m3

Step 7: Concrete Mix Proportions
Cement = 400.35 kg/m3
Water = 160.16 kg/m3
Water-cement ratio = 0.40
Coarse aggregate = 1495.04 kg/m3
∴ Mix Proportions = Cement: Coarse Aggregate = 1:3.73
For Mix 1 we have made concrete equivalent to volume of 9 standard cubes of (150 × 150 × 150) mm.
Hence, total proportion required for casting Mix 1 are as follows:
Volume of 1 cube = 3.375 × 10-3 m3
Volume of 9 cube = 0.030375 m3
Cement = 0.030375 × 400.35=12.16 kg
Coarse aggregate = 0.030375 × 1495.04 = 45.41 kg
Water = 0.030375 × 160.15 = 4.86 kg
Coarse aggregate = 1495.04 kg/m3

Step 8: Moisture Correction:
Moisture Content = 1.01 %
Corrected Value of Coarse Aggregate = 45.41 + 0.4541 = 45.8641kg
Corrected Value of Water Content = 4.86 – 0.4541 = 4.4059 kg

Table 3.1 Quantity of materials required for testing.

Cement	Coarse Aggregate	Water
12.16 kg	45.86 kg	4.40 kg

IV. TESTING

4.1 Compression Test

The capacity of material or structure to resist or withstand under compression is the Compressive strength of a material. The ability of the material to resist failure in the form cracks and fissure determines the compressive strength of a material. In this test, the push force applied on the both faces of concrete specimen and the maximum compression that concrete bears without failure is noted. The load, which causes the failure of a standard specimen of size 150mm×150 mm divided by the area of cross section in uniaxial compression under a given rate of loading is called the compressive strength of concrete. The test can be conducted on compression testing machine or UTM.

4.2 Permeability Test

The permeability of cement mortar or concrete is of particular importance in structures intended to retain water or that come into contact with water. In addition to functional considerations, permeability is also closely related to the durability of concrete, especially its resistance, against progressive deterioration due to exposure to severe climates and leaching due to prolonged water filtration, particularly when it contains aggressive gases or minerals in solution. The determination of the permeability characteristics of mortar and concrete, therefore, acquires considerable importance. The test consists of subjecting the mortar or concrete sample of known dimensions, contained in a specially designed cell, to a known hydrostatic pressure from one side, measuring the amount of water that seeps through it during a given time interval and calculating the coefficient of permeability. The test allows you to measure both the water that enters the sample and that which comes out.

V. Results and Discussions

5.1 Compressive strength Test Results

We tested the cubes for compressive strength after curing the cubes for 7, 14 and 28 days.

Cubes were tested in following order,

i. Pervious Concrete without any admixtures.

ii. Pervious Concrete with Superplasticizer (0.15%)

iii. Pervious Concrete with Superplasticizer (0.15%) and Polypropylene Fibres (0.2%)

The following are the results,

Table 5.1 ,5.2, 5.3 Shows the compression test results for plain pervious concrete for 7 ,14 and 28 days respectively. Average Stress for 7 days is 13.7 MPa, 14 days is 15.18 MPa and 28 days is 18.29 MPa.

Table 5.1: 7 Days Compression Test For Plain Pervious Concrete

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.100	280	12.44	
2	8.150	320	14.22	13.7 MPa
3	8.260	325	14.44	

Table 5.2: 14 Days Compression Test For Plain Pervious Concrete

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.115	350	15.55	
2	8.120	345	15.33	15.18 MPa
3	8.230	330	14.66	

Table 5.3: 28 Days Compression Test For Plain Pervious Concrete

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.060	400	17.77	
2	8.150	420	18.66	18.29 MPa
3	8.250	415	18.44	

Table 5.4 ,5.5, 5.6 Shows the compression test results for pervious concrete with Superplasticizer for 7 ,14 and 28 days respectively. Average Stress for 7 days is 15.30 MPa, 14 days is 16.44 MPa and 28 days is 20 MPa

Table 5.4: 7 Days Compression Test Using Superplasticizer In Concrete (0.15%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.120	340	15.11	
2	8.160	349	15.51	15.30 MPa
3	8.200	344	15.29	

Table 5.5: 14 Days Compression Test Using Superplasticizer In Concrete (0.15%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.210	372	16.53	
2	8.190	368	16.35	16.44 MPa
3	8.160	370	16.44	

Table 5.6: 28 Days Compression Test Using Superplasticizer In Concrete (0.15%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.230	468	20.8	
2	8.210	429	19.06	20 MPa
3	8.215	449	19.95	

After studying the previous papers, we noticed that the optimum usage of polypropylene fibres was 0.2 % of total volume of concrete mix since if the amount was increased or decreased there was a significant drop of compressive strength. The optimum usage of superplasticizer is 0.15% of total volume of concrete mix since if the amount was increased or decreased there was a significant drop of compressive strength.

Table 5.7: 7 Days Compression Test Using Superplasticizer (0.15%) & Polypropylene Fibre In Concrete (0.2%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.160	390	17.33	
2	8.200	399	17.73	17.52 MPa
3	8.220	394	17.51	

Table 5.8: 14 Days Compression Test Using Superplasticizer (0.15%) & Polypropylene Fibre In Concrete (0.2%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.260	472	20.97	
2	8.145	468	20.8	20.87 MPa
3	8.135	470	20.89	

Table 5.9: 28 Days Compression Test Using Superplasticizer (0.15%) & Polypropylene Fibre In Concrete (0.2%)

Cube	Weight (In Kg)	Load (In KN)	Stress (In MPa)	Average Stress
1	8.145	590	26.22	
2	8.150	610	27.11	26.66 MPa
3	8.210	600	26.66	

5.2 Permeability Test Results

Here, the cylinders were cured for 28 days.

Table 5.10: Water Retained in ml when 1000 ml passed

Sr. No	Mix Type	Quantity Passes (In ml)	Quantity Retained (In ml)
1	Plain Pervious Concrete	1000	860
2	Plain Pervious Concrete & Superplasticizers 0.15%	1000	930
3	Plain Pervious Concrete, Superplasticizers 0.15%, Polypropylene Fibre 0.2%	1000	970

5.3 Graphical representation of overall results

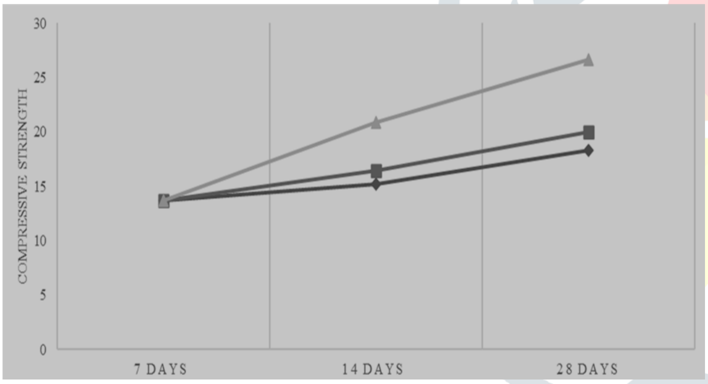

Figure 5.1: Comparison between plain pervious concrete & superplasticizer (0.15%) & superplasticizer (0.15%) with polypropylene fibre in concrete (0.2%)

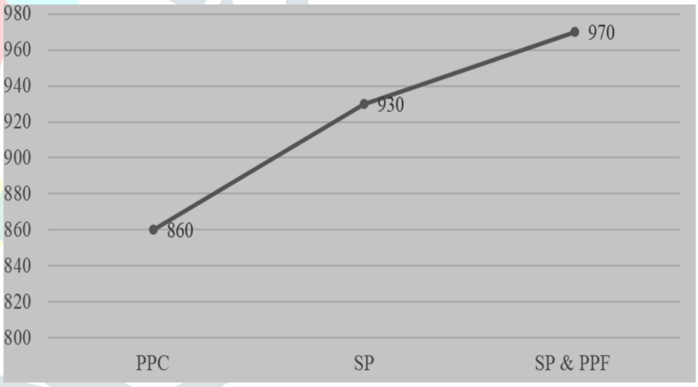

Figure 5.2: Water Retained in ml when 1000 ml

VI. Conclusions

i. Increase in Percentage of Compressive Strength when superplasticizer (0.15%) is added in Plain Pervious Concrete is 9.5% after 28 days.

ii. Increase in Percentage of Compressive strength when superplasticizer (0.15%) & Polypropylene fibre (0.2%) is added in Plain Pervious Concrete is 35% after 28 days.

iii. Increase in Percentage of Permeability Index when superplasticizer (0.15%) is added in Plain Pervious Concrete is 12.79% after 28 days.

After testing the specimens, we can conclude that the usage of polypropylene fibre and superplasticizer did increase the strength of concrete by a significant amount and it can be used for pavement in district roads where there is a problem of water logging. The permeability of polypropylene fibre and superplasticizer mixed pervious concrete is increased as compared to the plain pervious concrete.

REFERENCES

1. Laboratory Investigation Of Compacted No-Fines Concrete For Paving Materials By Nader Ghafoori, Member, ASCE, and Shivaji Dutta,2 Student Member, ASCE (1995)
2. Tennis, Paul, D.; Leming, Michael, L.; and Akers, David, J., *Pervious Concrete Pavements,*
3. Laboratory evaluation of permeability and strength of polymer-modified pervious concrete Baoshan Huang *, Hao Wu, Xiang Shu, Edwin G. Burdette (2009)
4. Pervious Concrete – An Overview Karthik H. Obla (2010)
5. Kryeziu, Driton R.; Qafleshi, Mevlan; and Kadiu, Fisnik, "Pervious Concrete-New Solution for Sustainable Urban Street Construction Case: Prishtina and Tirana" (2013).
6. Experimental Analysis on High Strength Pervious Concrete CH. Hari Sai Priyanka (2017)
7. Influence of Limestone Dust on the Strengths of Pervious Concrete by using Recycled Aggregates Muslekh Hussain Barbhuiya, M Raju, K Vamshi, V Ranjith, S Rahul. (2018)
8. Mr.G.N.Chavanpatil. and Mr. S.S. Chokakkar (2018) Selection of Additives and Fibers for Improving the Mechanical and Safety Properties of Porous Concrete Pavements through Multi-Criteria Decision-Making Analysis Eduardo-Javier Elizondo-Martínez, Valerio-Carlos Andrés-Valeri, Jorge Rodríguez-Hernández and Cesare Sangiorgi (2020)
9. An Experimental Study on Pervious Concrete, 1Mukund Chougale, 2Saahil Dehankar, 3Atharva Karmore, 4Rohit Jadhav, 5Prathamesh Daingade 1Assistant Professor, 2,3,4,5Student Department of Civil Engineering D. Y. Patil College of Engineering, Pune, India 2020
10. Study on Compressive Strength of Pervious Concrete for Utilisation as Pavement, Debamalya Dey Student, Dept of Civil (Structural) Engineering, Dayananda Sagar College of Engineering, Bangalore, Karnataka, INDIA 2017
11. Pervious Concrete: New Era for Rural Road Pavement, Darshan S. Shah 1, Prof. Jayeshkumar Pitroda2, Prof.J.J. Bhavsar Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Anand, Gujarat –India 2013
12. Enhancing The Strength Of Pervious Concrete Using Polypropylene Fibre, Fuel Vinayak Kharbikar1, Sudhanshu Pathak2 Construction Management, D.Y. Patil College of Engineering, Akurdi, Pune,India 2017