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Strength and Behaviour of Pervious Concrete with Addition of Nano Silica

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ABSTRACT

This paper reports an experimental investigation into the development of pervious concrete providing the optimal combination of strength and water permeability without using any admixtures. This Nano silica is used as partial replacement to cement to study its behaviour on mechanical properties of pervious concrete. Pervious concrete trial mixes with varying the coarse aggregate and fine aggregate ratio (CA: FA= 100:00, 90:10, 80:20, 70:30) were tested for its mechanical properties such as compressive strength, split tensile strength, water permeability, porosity and density. Trial mix was done on the water/cement ratio of 0.40 and 0.36 with optimum compressive strength along with sufficient permeability is selected as a basic experimental mix for investigating the effect of partial replacement of cement with Nano silica. The highest compressive strength for pervious concrete is observed as 28.20 N/mm2 and water permeability of 0.273 cm/sec is calculated for the experimental mix having 5% replacement of cement with Nano silica

Keywords: - Pervious concrete, Nano silica, Permeability, compressive strength.

I.INTRODUCTION

Pervious concrete is a special high porosity concrete that allows water from precipitation and other source to pass through, thereby reducing the runoff from site and recharging ground water level. Its unique filter action removes pollutants from rain runoffs and allows the suns heat to evaporate volatiles, leaving behind the remaining solids to be consumed by microbial action. This replenishes ground water table and aquifers hence, can also be termed as "Rain Water Harvesting Concrete". This type of concrete has become significantly popular as a sustainable application during recent decades due to its potential contribution in solving environmental issues. Pervious concrete is traditionally used in parking areas, areas with light traffic, pedestrian walkways, play grounds, gardens and areas surrounding swimming pools.

1.1 Pervious Concrete

Pervious concrete also called porous concrete, permeable concrete, no fines concrete and porous pavement. It is made using large aggregate with little or no fine aggregate. The concrete paste then coats the aggregates and allows water to pass through the concrete slab. Pervious concrete consists of cement, coarse aggregate and water with very little to no fine aggregates. The addition of small amount of fine aggregate will increase the strength. Typically, pervious concrete has water to cementitious materials ratio (w/c) of 0.28 to 0.40 with a void content of 15 to 30 percent. In normal concrete, the fine aggregates typically fill in the voids between coarse aggregates. But in pervious concrete fine aggregate is non-existent or present in very small amounts.

1.2 Advantages of pervious concrete.

Pervious concrete is considered a sustainable building alternative for concrete and/or asphalt pavement parking lots because it provides pollution mitigation and storm water management. Pervious concrete acts as a filtration device for storm water and turns the entire parking area, pathway, or other paved surface into a retention treatment basin. Storm water can flow through the pavement to the subgrade underneath, taking with it pollutants that would typically end up in municipal storm water systems. Naturally occurring soil microbes then store and break down the pollutants, preventing aquifer pollution.

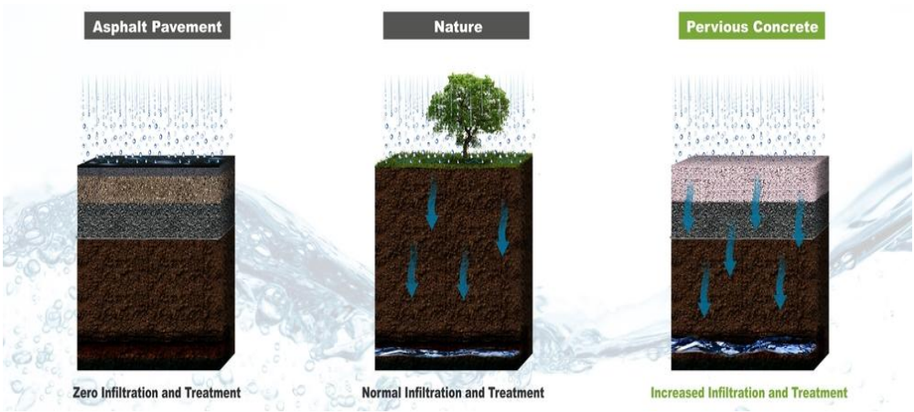


Figure 1.1 Infiltrations through Pervious Concrete.

1 The benefits of pervious concrete are not limited to its infiltration capacities.
2 It removes pollutants from water,
3 Decreasing flooding possibilities, especially in urban areas and reducing puddles on the road
4 Reduce noise, improve skid resistance, and
5 Help mitigate the heat island effect
6 It returns rain water to the ground, recharging ground water and aquifers
7 The runoff from paved areas is reduced, which reduces the need for separate storm water retention
8 Supporting vegetation growth
9 Effective management of storm water runoff, which may reduce the need for curbs and the number and sizes of storm sewers.

1.3 Disadvantages of pervious concrete.

1 Low compressive strength due to high porosity so limited use in heavy traffic areas.
2 Specialized construction practice.
3 Sensitivity to water content and control in fresh concrete.
4 Lack of standard test methods.
5 High maintenance requirement.


Figure 1.2 Pervious Concrete used in Parking lot and Garden.

II. TESTING OF MATERIAL

2.1 Cement

Ordinary Portland cement was used for the project work. The cement was tested as per IS codal provisions. Following are the observations

Table 2.1 Summary of test results of Cement.

SL no	Properties	Result obtained	Standard values as per Indian Standards	Codal Provision
1	Standard Consistency	33%	-	IS 269:1989 Clause No. 11.3 IS4031(Part4):1988 Clause No. 5.1
2	Initial setting time	38 min	Not be less than 30min	IS 269:1989 Clause No.5.2 and 6.3
3	Final setting time	360 min	Not be greater than 600min	IS 269:1989 Clause No. 5.3 and 6.3
4	Soundness	3mm	<10	IS 269:1989 Clause No. 6.2.1 IS4031(Part3):1988
5	Specific Gravity	3.15	-	
6	Fineness	1.40	<10	IS 269:1989 Clause No. 6.1 IS4031(Part2):1988

2.2 Fine Aggregates

Natural fine aggregates which were locally available were used in the project work. Following are the result obtained after testing of fine aggregates

Table 2.2 Summary on Physical Properties of fine aggregates.

Sl no	Properties	Result obtained
1	Type	Natural
2	Specific gravity	2.63
3	Bulkage	6%
4	Fineness modulus	3.1
5	Surface texture	Smooth
6	Particle shape	Rounded
7	Grading zone	Zone-II

2.3 Coarse Aggregates

Natural coarse aggregates which were locally available were used in the project work. Following are the result obtained after testing of coarse aggregates.

Table 2.3 Summary on Physical Properties of Coarse Aggregates

Sl no	Properties	Result obtained
1	Type	Natural
2	Specific gravity	2.72
3	Maximum size	10mm
4	Fineness modulus	7.24
5	Surface texture	Rough
6	Particle shape	Angular
7	Impact value	5.5%

2.4 Nano Silica

Nano Silica was provided by Astra chemicals, the physical and chemical properties of Nano silica are as follows.

Table 2.4 Physical and Chemical Properties Nano silica.

SL no	Properties	Value	Units
1	Appearances	White crystalline powder	-
2	Surface area	202	m^2/g
3	P_H value	4.12	wt.%
4	Particle size (nm)	17	nm
5	Tamped density	44g/L	g/L
6	Specific gravity	2.2-2.4	wt.%
7	$Si0_2$ (%)	99.8	wt.%
8	Carbon content (%)	0.06	wt.%
9	Chloride content (%)	0.009	wt.%
10	AL_2O_3 (%)	0.005	wt.%
11	Fe_2O_3 (%)	0.001	wt.%
12	TiO_2	0.004	wt.%

III. MIX PROPORTION

The concrete mix is designed as per as IS 10262 -2009 and IS 456-2000, for different water to cement ratios

Pervious concrete mix designs (W/C = 0.45)					
Pervious ratio (CA:FA)	**Cement (Kg/m^3)**	**Coarse aggregate (Kg/m^3)**	**Fine aggregate (Kg/m^3)**	**Nano silica (Kg/m^3)**	**Ratio (C:CA:FA)**
100:0	362	1956	0	19.08	1:5.4:0
90:10	362	1760	196	19.08	1:4.86:0.54
80:20	362	1563	391.27	19.08	1:4.32:1.08
70:30	362	1369	586.9	19.08	1:3.78:1.62

Table 1 Showing Pervious Concrete mix proportion for 0.40(w/c)

Pervious concrete mix designs (W/C = 0.363)					
Pervious ratio (CA:FA)	**Cement (Kg/m^3)**	**Coarse aggregate (Kg/m^3)**	**Fine aggregate (Kg/m^3)**	**Nano silica (Kg/m^3)**	**Ratio (C:CA:FA)**
100:0	395	1918	0	20.8	1:4.85:0
90:10	395	1726	191.8	20.8	1:4.36:0.48
80:20	395	1534	383.6	20.8	1:3.88:0.97
70:30	395	1342	575.4	20.8	1:3.39:1.45

Table 2 Showing Pervious Concrete mix proportion for 0.363(w/c)

3.2 Preparation of Pervious Concrete Specimen

1. The weighed materials of cement, fine aggregate, coarse aggregates, Nano silica and super plasticizer were then placed on a large mixing tray which is clean and free from impurities.
2. The ingredients were then mixed to obtain a uniform mix after which the required water was poured and mixed well for 5 minutes.
3. The concrete mix is then placed into the concrete cube mould (150 mm x 150 mm x 150mm) in three successive layer with 25 blows each layer, with the help of a tamping rod, the top surface is then smoothened.

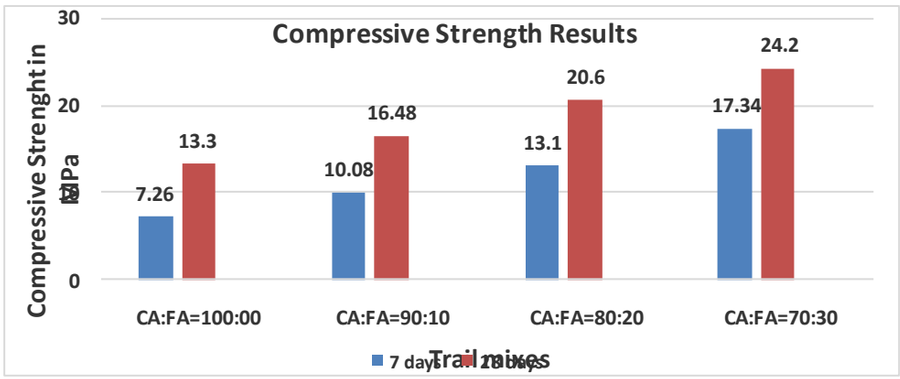
4. The concrete mould is then placed in a safe location for 24 hours, after which the mould is opened and the mortar cube is placed in a curing tank for a specified period of time.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

4.1 Experimental results of Compressive strength for M20 grade Pervious concrete

Ratio of CA : FA	Compressive strength MPa (W/C=0.40)	
	7days	28days
100:00	7.26	13.3
90:10	10.08	16.48
80:20	13.1	20.60
70:30	17.34	24.2

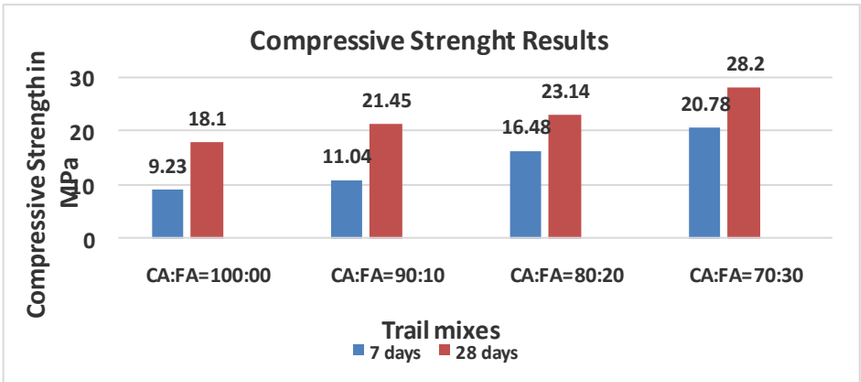
Table 4.1 showing Compressive strength results for Compressive strength of M20 grade Pervious Concrete.



Graph 4.1 showing Compressive strength results for M20 grade Pervious Concrete with (W/C = 0.40)

Ratio of CA : FA	Compressive strength MPa (W/C=0.36)	
	7days	28days
100:00	9.23	18.1
90:10	11.04	21.45
80:20	16.48	23.14
70:30	20.78	28.20

Table 4.2 showing Compressive strength results for Compressive strength of M20 grade Pervious Concrete



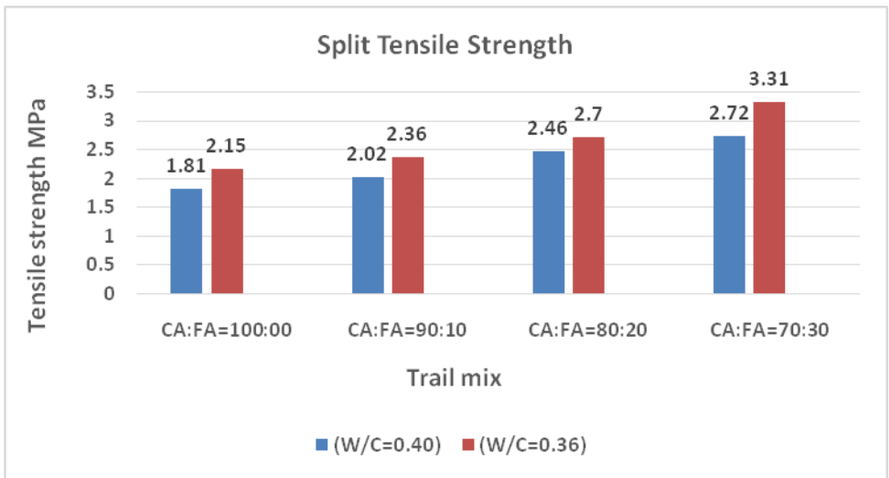
Graph 4.2 showing Compressive strength results for M20 grade Pervious Concrete with (W/C = 0.36)

4.2 Experimental results of Split Tensile strength for M20 grade Pervious concrete

	Split tensile strength MPa

Ratio of CA : FA	(W/C=0.40)	(W/C=0.36)
100:00	1.81	2.15
90:10	2.02	2.36
80:20	2.46	2.7
70:30	2.72	3.31

Table 4.3 Showing Split tensile strength results for Split tensile strength of M20 grade Pervious Concrete for 28days curing.

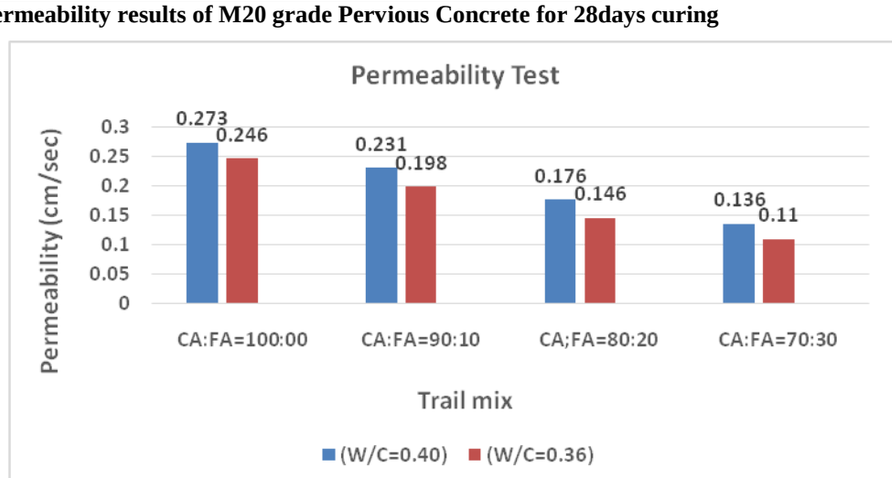


Graph 4.3 showing Split tensile strength results of M20 grade pervious concrete under 28days curing.

4.3 Experimental results of Permeability test for M20 grade Pervious concrete

Ratio of CA : FA	Permeability cm/sec	
	(W/C=0.40)	(W/C=0.36)
100:00	0.273	0.246
90:10	0.231	0.198
80:20	0.176	0.146
70:30	0.136	0.11

Table 4.4 showing Permeability results of M20 grade Pervious Concrete for 28days curing



Graph 4.4 showing Permeability test results of M20 grade Pervious Concrete under 28days curing.

Figure 4.1 Compressive Strength, Split Tensile and Permeability Testing of Pervious Concrete specimen

4.4 Summary of results

1 Varying amount of replacement of fine aggregate like 30%, 20%, 10% and 0 % has been considered for manufacturing the Porous Concrete.

2 Compressive strength for 30 % replacement FA is having more of 28.20N/mm2 compared to 20, 10, 0 % having 23.14, 21.45 and 18.1N/mm2 respectively for water cement ratio of 0.36

3 Compressive strength for 30 % replacement FA is having more of 24.2N/mm2 compared to 20, 10, 0 % having, 20.60, 16.48 and 13.3N/mm2 respectively for water cement ratio of 0.40

4 Compressive strength of pervious concrete for W/C ratio 0.36 is more than 0.40.

5 Split tensile strength is more for 30% replacement i.e. 3.31 N/mm2 and for 20%, 10% and 0% has 2.7, 2.36 and 2.15N/mm^2 for w/c ratio of 0.36.

6 Split tensile strength is more for 30% replacement i.e. 2.72 N/mm2 and for 20%, 10% and 0% has 2.46, 2.02 and 1.81N/mm^2 for w/c ratio of 0.40.

7 Split tensile strength of pervious concrete for W/C ratio 0.36 is more than 0.40.

8 Permeability of W/C ratio 0.40 for 28 days has more permeability with FA replacement of 0% and 10% is 0.273 and 0.231 cm/sec respectively.

9 Permeability of W/C ratio 0.36 for 28 days has more permeability with FA replacement of 0% and 10% is 0.246 and 0.198 cm/sec respectively.

10 . Permeability of pervious concrete for W/C ratio 0.40 is more than 0.36.

V. CONCLUSION

1 Compressive strength of pervious concrete increases and water permeability decreases with the increase of fine aggregate in pervious concrete.

2 Pervious concrete with maximum compressive strength can be obtained by using 10mm size aggregate along with use of fine aggregate in small quantity.

3 Addition of Nano silica as partial replacement to cement improves the compressive strength and splitting tensile strength of pervious concrete.

4 Water permeability is most important characteristic of pervious concrete therefore fine aggregate used in pervious concrete is varied.

5 Permeability was not much varied due to variation in paste density. Permeability is moreover related to method of compaction and size of aggregates used.

6 Pervious concrete can be applied for various engineering applications in India such for Green Building culture, Jogging tracks, low traffic density roads, pavement sidewalks.

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