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Research paper

Experimental study on polymer fibre included sustainable pervious concrete

A. Jayanthi R. [1]*, B. Deepak M. S. [1], C. Mahendran K. [1], D. Surendar M. [1]

[1]F. A. Lecturer, Department of Civil Engineering, Institute of Technology, Wollega University, Ethiopia
[2]S B. Researcher, Department of Civil Engineering, Government College of Technology, Coimbatore, India
[3]T C. Assistant Engineering Manager, L&T Construction, Heavy Civil Infrastructure, Chennai, India
[4]F D. Assistant Professor Department of Civil Engineering, Easwari Engineering College, Chennai, India
**Corresponding author E-mail: deepakms143@gmail.com*

Abstract

An experimental study on relationship between hardened concrete properties and rate of infiltration of polymer fibre included sustainable pervious concrete has been performed and presented in this paper. In this study, two different coarse aggregate sizes (20mm-10mm and 10mm-4.75mm) and varying percentage of polypropylene fibre included in the concrete mix (0.25%, 0.50%, 0.75%, 1.00%, 1.25%, 1.5%, 1.75% and 2.00%) were considered as parameters. The very little quantity of fine aggregate required in the design mix was replaced by graded bottom ash. A nominal design mix proportion for M30 grade of concrete was assumed as mean target strength. The engineering properties of plain pervious concrete and fibre included pervious concrete were compared with conventional concrete properties. In this study, all the pervious concrete specimens reached above 60% of the target strength. Based on the test results it was found that the using larger size of coarse aggregates in the concrete mix shows increases infiltration capacity but decrease in bond strength properties. Pervious concrete which was made using smaller size aggregates exhibited higher strength but lower infiltration capacity. The optimum fibre content that supports in enhanced strength and appropriate infiltration capacity was 1.5% in the design mix. This study evaluates relationship between the aggregate sizes and properties of fibre included pervious concrete. The results prove that it is possible to produce sustainable pervious concrete with good strength and acceptable infiltration capacity using coarse aggregate of size 20mm-4.75mm along with 1.5% polypropylene fibre addition.

Keywords:*Infiltration Capacity; Pervious Concrete; Polymer Fibre; Target Strength.*

1. Introduction

This project is a one step towards sustainable development. Natural resources are continuously depleted due to increased urbanization and exponential growth of buildings. In normal rigid concrete pavements the storm water does not percolate beneath the surface due to lack of permeability which is disadvantageous because of lot of rain water is wasted. The excess rainwater causes floods and also damages properties; the water stagnant places are contaminated and remain a menace. Pervious concrete pavement is an alternative successive solution for proper drainage management and rain water harvesting. Rain water easily infiltrates through the pores of the pervious concrete to the subsoil. It helps in recharging the underground water table. Pervious concrete is the one which has no or less fine aggregate (FA), cement or binder and coarse aggregate are the main components. The availability of river sand as FA for construction purpose is on a great demand. On one hand the sources have been depleted beyond limit. On the other hand lots of waste products are being produced from industries and dumped in the ecosystem. It is our primary duty to reduce depletion of natural resources and reuse waste products in an efficient manner to achieve sustainable development. In this vision the very little quantity of sand required in pervious concrete has been replaced with bottom ash from industries in this study. Pervious concrete is also used as wall concrete for thermal insulation, surfaces for parking areas, public stalls, gardens and stadiums etc,. Pervious concrete pavements has higher skid resistance, reduced noise in tyre-road interaction, it can also arrest pollutant penetration into the ground. Even though pervious concrete has several advantages, basically the compressive and flexural strength of the concrete is less. In order to understand the strength and hydraulic properties of pervious concrete and to improvise the functionality many research works are being done.

Cheng et al. (2011) [6] performed experimental investigation on properties of pervious concrete made with recycled aggregates. It was found that concrete mix containing spherical aggregates has higher workability. The use of latex in concrete mix increases the compressive strength and lower permeability properties. The pervious concrete is a sustainable concrete because of its properties. In similar manner, Cosic et al. (2015) [7] in their study concluded that smaller the size of aggregates achieves more flexural strength but decreases the porosity. The efficiency of pervious concrete depends mainly upon the porosity. In the perspective of improving the strength of pervious concrete Huang et al. (2010) [8] in their research made use of latex-polymer and evaluated the properties. Kuo et al. (2013) [13] used washed municipal waste incinerated bottom ash as a substitute for natural aggregate in pervious concrete and studied the interconnected properties. Obla (2007) [15] exposed the advantages of pervious concrete as a sustainable concrete. The infiltration capacity of pervious concrete is essentially suitable for reducing runoff water from site and helps in recharging the ground water. Neithalath et al. (2010) [14] employed a

computational procedure to predict the permeability in three-dimensional reconstruction of pervious concrete.
The strength of the pervious concrete depends on the size and shape of aggregates and the bond strength between cement paste and coarse aggregate (CA). The tensile strength and modulus of rupture can be improved with addition of fibres. The optimum fibre inclusion should be identified so that the hydraulic properties namely porosity and permeability are not affected. Usually, strength of pervious concrete is very less so it is important to improve the strength properties. This research work have been done to establish a relationship between aggregate size, strength characteristics, fibre content and infiltration of pervious concrete for Indian standard materials.

2. Material used

The strength of the concrete primarily depends on its constituting materials and its ratios. Potable water was used for preparation and curing of the specimens. The binders/cement used should produce good cement paste with addition of proper proportion of water. The cement paste should be consistent to bind along with the aggregates for making better quality of pervious concrete. In the present study Ordinary Portland Cement (OPC) 43 Grade confirming to IS 4031-1988 [11] was used for casting all the specimens. The quantity of fine aggregate (FA) used is very less in pervious concrete say 5% of the total FA required to achieve the target strength in the design mix. In this research, industrial waste bottom ash was graded and used as FA. Aggregate ratio and aggregate type has a significant influence on pervious concrete stability. From earlier studies it was found that instead of rounded aggregates, angular dimensional aggregates can perform well in the increase of tensile strength of the pervious concrete, but the workability is slightly reduced, so super plasticiser is used. An appropriate coarse aggregate (CA) grade and size restricted to the composite target strength was selected to cast the specimens. Commercially, available crushed blue granite pieces of nominal size firstly, passing through 20mm sieve and retaining on 10mm sieve and secondly, passing through 10mm sieve and retaining on 4.75mm sieve as recommended in IS: 383-1970 [10] were used in two series of the concrete mix. Polypropylene is one of the commercially available textile polymer fibres. Polypropylene fibres exhibit good resistance to many chemical attacks. It forms binding matrix when exposed to aggressive chemical conditions. The melting point of the fibre is about 165^0C. In normal conditions say 100^0C polypropylene fibres can satisfactorily be used without degradation in its properties. Chemical admixtures can be used in preparation of pervious concrete to meet special engineering design needs. Since pervious concrete sets rapidly generally, retarders or hydration-stabilizing chemical admixtures are employed following the manufacturer's recommendations. Super plasticiser (SP) Conplast-SP430 was used in this study to improve the workability.

i) Properties of materials used

Fundamental tests were conducted on each material and results were compared with the specifications with the Indian design standards to confirm the suitability.

a) OPC 43 grade of cement (IS 4031-1988)

Description	Test Results	Recommended in standards
Consistency	30%	25% - 30%
Initial setting time	35min	Not less than 30 min.
Final setting time	355min	Not more than 600 min
Specific gravity	3.06	2.5 - 3.1
Fineness	6%	Less than 10%

b) Fine Aggregate- Bottom Ash (IS 2386-1963)

Description	Test Results	Recommended in standards
Fineness Modulus	2.70	2.2 - 3.2
Specific Gravity	2.75	2.6 - 2.8
Water absorption	2.5%	Less than 4%
Fineness Modulus	2.70	2.2 - 3.2
Bulk density	1220 kg/m3	

c) Coarse Aggregate 4.75mm to 12.5mm (IS 2386-1963)

Description	Test Results		Recommended in standards
	20mm-10mm	10mm-4.75mm	
Specific Gravity	2.79	2.76	2.6 - 2.85
Water absorption	4.1%	4.3%	Less than 6%
Fineness modulus	7.3	7.0	6.5 - 8
Bulk density	1730 kg/m3	1809 kg/m3	

d) Polypropylene fibre- physical properties (Specified by manufacturer-RECRON-3S)

Description	Specifications
Length and Diameter	L= 12mm and D=0.04mm
Aspect ratio	300
Density	0.91 gm/cm3
Melting Point	1600C - 1700C
Tensile Strength	550 – 700MPa
Elongation	21%
Length	12mm

e) Super Plasticizer CONPLAST- SP430

Description	Specifications
Appearance	Brown liquid
Specific gravity	1.20 at 30°C
Air entrainment (%)	Less than 2
pH value	7 to 8

3. Design mix- m30-illustration

In this study the target mix design was calculated as recommended by Indian Standard specifications IS: 10262-2009. [12]

i) Data:

Specific Gravity of Cement: 3.06
Specific Gravity of FA: 2.75
Specific Gravity of CA: 2.79
Maximum Size of CA: 20mm
Fineness Modulus of FA: 2.7
Quality Control: Good
Exposure Condition: Mild exposure

ii) Mix Design Procedure – M30

Step – 1: Determination of Target Mean Strength
F'ck = fck + 1.65 S
Where, fck = Characteristic Cube Compressive Strength required at 28 days = 30MPa;
Standard deviation, S= 5; tolerance limit= 1.65
f'ck = 30 + 1.65 x 5
f'ck = 38.25 MPa
Step – 2: Selection of Water Cement Ratio:
The maximum water cement ratio for M30 grade of concrete under mild exposure condition as per design code is 0.45. Water cement ratio of 0.40 was selected for the mix design. Since SP is added the workability is increased, moreover addition of fibre increases the flow ability.
Step – 3: Selection of Water content:
Maximum water content
per metre cube of concrete = 186 litres
SP is used, so the water content can be reduced by 20% and above. Here water content is reduced by 25%.
The water content = 186 x 0.75 = 140 litres
Total water content = 140 litres
Step – 4: Calculation of Cement Content:
Water cement ratio = 0.40: Cement = 140 /0.40 = 350kg
From Table 3, IS 456, minimum cement content for mild exposure condition is 300 kg/m^3
Here 350kg is taken therefore better bonding can be achieved.
Step – 5: Proportion of Volume of Coarse Aggregate and Fine Aggregate Content:

According to Table 3, IS 10262:2009, Volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone III) for water cement ratio is 0.5 = 0.64.
In the present case water cement ratio is 0.40. Therefore, volume of coarse aggregate required to be increased to decrease the fine aggregate content. As the water cement is lower by 0.10 the proportion of volume of coarse aggregate is increased by 0.02.
The Volume of Coarse aggregate for the water cement ratio of 0.40 = 0.66
The Volume of fine aggregate content = (1 – 0.66) = 0.34
Step – 6: Mix Calculation:
The mix calculation per unit volume of concrete shall be as follows:
Volume of Concrete (a) = 1 m^3
Volume of Cement (b) = (Mass/Specific gravity) x (1/1000)
= (350/3.06) x (1/1000) = 0.114 m^3
Volume of water (c) = (Mass / Specific gravity) x (1/1000)
= (140 /1) x (1/1000) = 0.140 m^3
Volume of all in aggregate (d) = [a – (b+c)] = 1 – (0.114+ 0.140) 25=0.749m^3
Mass of Coarse Aggregate (e) = (d) x Volume of CA x specific gravity of CA x 1000
= 0.749 x 0.66 x 2.79 x 1000= 1380 kg
Mass of Fine Aggregate (f) = d x Volume of FA x Specific Gravity of FA x 1000
= 0.749 x 0.34 x 2.75 x 1000 = 680 kg
Therefore total quantity of fine and coarse aggregate= 1380 + 680 = 2060 kg
For pervious concrete only 5% of sand is considered= (0.05 x 2060) = 103 kg.
Hence the final mix proportion per m^3 of pervious concrete is

Water	Cement	Fine aggregate (FA)	Coarse Aggregate (CA)
140kg	350kg	103kg	1957kg

Total weight per cubic metre per m^3 of pervious concrete is= 2250kg
Mix ratio of pervious concrete is
Water: Cement: FA: CA => 0.4: 1: 0.34: 5.59
RECRON-3S polypropylene microfilament polymer fibre is added additionally to the design mix by proportion of total weight of materials used for preparing the concrete 12.75kg, 25.50kg, 38.25kg and 51.00kg for 0.5%, 1.0%, 1.5% and 2.0% of fibre inclusions, respectively.

4. Preparation of concrete

Concrete mix was prepared for every 50kg (1 bag) of cement for each time of batching. Therefore, the mix proportion for every batch is,
Water= 20kg; Cement= 50kg; FA= 14.71kg; and CA=279.57kg. And so the fibre inclusions are 1.82kg, 3.64kg, 5.46kg and 7.28kg for 0.5%, 1.0%, 1.5% and 2.0% of fibre inclusions in each batch, respectively.
All the specimens were prepared and tested according to the American standards ASTM-C192 [2] specifications. In this study, a total of 198 specimens were tested that includes 60 cubes, 60 cylinders, 60 prisms and 18 slabs.
Pan mixture was used to prepare the concrete mix in batches. Normal compaction using tamping rods on each layer of casting was adopted. Water curing for 28 days was done. Proper measures were taken every time for batching and preparing the concrete mix.

ENGINEERING PROPERTIES

i) Fresh Concrete Properties

The pervious concrete mixture exhibit characteristic open matrix that was very stiff when compared with nominal concrete. Tests to obtain fresh concrete properties, such as flow-ability, passing ability and segregation resistance are not test are not having an important effect for pervious concrete. Usually pervious concrete lacks higher strength, the limited strength of largely depends on voids ratio. The unit weights of pervious concrete mixtures are approximately 70% of nominal concrete mixtures.

ii) Hardened Concrete Properties

a) Cube Compressive test:

Characteristic cube compressive strength is an essential factor for deciding the quality of the concrete. The cube compressive strength test was carried out according to ASTM-C39 [3] using 3000kN capacity AIMIL compression testing machine. Loading was applied at a rate of 0.5kN/s. Cube specimens measuring 150 mm x 150 mm x 150 mm were prepared for each mix. The compressive strength was accounted based on average of 3 specimens in each set of tests performed at the age of 3 days, 7days and 28days.
Calculation of compressive strength = P/A (N/mm^2); where, P= Load applied (N) and A = Cross sectional area of the cube (mm^2)

b) Split tensile test:

Split tensile tests were performed on cylindrical specimens (150mm diameter and 300mm in height) in order determine the tensile strength of the specimen. The load was applied by compression perpendicular to its length. The tests were performed at age of 3days, 7days and 28 days using 3000kN capacity AIMIL compression testing machine. The tests were conducted as per the guidelines of ASTM-C496 [4]. The split tensile strength was accounted based on the average of three cylinders specimens tested per set.
Split tensile strength = $2P/\pi LD$ (N/mm^2)
Where, P- Load on Cylinder in N; L- Length and D- Diameter of Cylinder in mm

c) Flexural test:

Flexural tests were conducted unreinforced concrete beam 100mm x 100mm x 500mm to resist failure under 3-point bending. The flexural strength is expressed as Modulus of Rupture. The tests were performed at age of 3days, 7days and 28 days using 1000kN capacity Hi-tech universal testing machine. Testing was performed according the specifications of ASTM-C496/C78 [5].
Flexural strength = $3Pa/bd^2$ (N/mm^2)
Where, a= the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen; b= width of specimen (mm); d= failure point depth (mm); l= span (mm); P= Load (N).

Table 1: Properties of Fibre Included Sustainable Pervious Concrete

Specimen-id (M30)	Polypropylene Fibre Content	Compressive strength (N/mm^2)			Tensile strength (N/mm^2)			Flexural strength (N/mm^2)			Voids Ratio, e	Porosity, η (%)	Infiltration Capacity (inches/hr)
		3 days	7days	28days	3 days	7days	28days	3 days	7days	28days			
Series 1- Maximum CA size 20mm (A=>20mm-10mm)													
PA1	0.00	10.44	13.21	16.58	1.08	1.37	1.81	1.89	2.42	3.18	0.29	28.12	732.50
PFA2	0.25	10.78	13.88	17.01	1.10	1.41	1.85	1.99	2.63	3.29	0.28	27.42	718.42
PFA3	0.50	11.01	14.43	17.75	1.17	1.54	1.94	2.05	2.72	3.41	0.28	26.99	655.40
PFA4	0.75	11.55	14.70	17.95	1.20	1.59	1.97	2.12	2.77	3.45	0.27	26.55	644.10
PFA5	1.00	11.78	14.91	18.09	1.25	1.60	1.98	2.20	2.81	3.48	0.27	26.04	612.42
PFA6	1.25	12.15	15.30	18.55	1.29	1.64	2.06	2.27	2.92	3.61	0.27	25.72	583.71
PFA7	1.50	12.66	16.08	19.78	1.34	1.73	2.17	2.37	3.04	3.81	0.27	25.56	566.02
PFA8	1.75	12.47	15.91	19.62	1.38	1.75	2.18	2.41	3.10	3.88	0.26	25.13	557.58
PFA9	2.00	11.63	15.75	18.87	1.43	1.79	2.22	2.52	3.15	3.91	0.26	24.94	541.41

NA		21.22	25.61	36.28	2.23	2.74	3.83	3.31	3.86	4.93	0.02	1.98	
Series 2- Maximum CA size 10mm (B=>10mm-4.75mm)													
PB1	0.00	11.07	14.00	17.57	1.14	1.46	1.92	2.01	2.56	3.37	0.27	25.78	667.10
PFB2	0.25	11.44	14.63	17.89	1.20	1.51	1.97	2.05	2.52	3.42	0.25	24.10	633.18
PFB3	0.50	11.67	15.30	18.82	1.24	1.64	2.05	2.18	2.88	3.62	0.24	23.46	612.42
PFB4	0.75	11.99	15.64	19.01	1.30	1.66	2.08	2.25	2.90	3.64	0.24	23.11	583.71
PFB5	1.00	12.49	15.80	19.18	1.33	1.69	2.10	2.33	2.98	3.69	0.24	22.89	566.02
PFB6	1.25	12.88	16.66	19.45	1.40	1.72	2.18	2.41	3.08	3.83	0.24	22.65	549.38
PFB7	1.50	13.42	17.04	20.97	1.43	1.83	2.30	2.51	3.22	4.04	0.23	21.92	526.16
PFB8	1.75	13.27	17.00	20.90	1.47	1.84	2.31	2.58	3.22	4.07	0.22	21.45	511.75
PFB9	2.00	12.33	16.90	20.89	1.51	1.89	2.34	2.67	3.23	4.08	0.21	20.18	498.10
NB		22.49	27.15	38.46	2.36	2.90	4.06	3.51	4.10	5.22	0.02	1.84	
Optimum Mix- Maximum CA size 20mm (AB=>20mm-4.75mm)													
PFAB3	1.50	13.44	18.16	21.62	1.44	2.01	2.39	2.24	2.82	3.67	0.23	22.45	547.01

iii) Infiltration test

Infiltration tests were conducted to calculate the rate of flow of water through the pervious concrete per hour. The tests were performed on slab specimens that were casted in each set after the concrete being cured for 28days. The specimen was a rectangular slab of size 450mm x 450mm x 50mm. The specimens were prepared, cured and tested according to ASTM-C1701 [1] standard.

The infiltration rate is calculated as, $I = KM/D^2T$ (inches per hour)

Where, M= Water Mass (5 gallon); D= Infiltration Ring Diameter (12 inches); T= Time to Infiltrate (s); K = 126870 (constant)

5. Results and discussions

In this study, the raw materials were selected based on Indian standards and the experimental procedure were followed according to American standards and procedures specified for pervious concrete. Different aggregate sizes and different proportions of fibre inclusions were considered in the tests. The corresponding results obtained were tabulated in Table 1 and Figure 1-4.

i) Compressive strength:

The 28 days compressive strength of for fibre included pervious concrete was ranging between 16N/mm^2-20N/mm^2 in the specimens prepared using aggregate size between 20mm and 10mm; For specimens prepared using aggregate size between 10mm-4.75mm the 28 days compressive strength was obtained between 17N/mm^2-21N/mm^2. The average increase in compressive strength was about 5% increase in the compressive strength when the coarse aggregate size was small. In both the series the optimum inclusion of polypropylene fibre in the pervious concrete mix was around 1.5%. From the test results for every increase of 0.25% inclusion in concrete specimen contributes to 2-3% increase in compressive strength up to an optimum limit of 1.5%. 60% of the target strength was achieved in the pervious concrete specimens. The nominal concrete specimen with the same materials with fine aggregate as bottom ash achieved the target strength. Only 5% of the required fine aggregate proportion was used to prepare all the pervious concrete specimens.

It was observed that increasing the size of aggregates reduces the compressive strength. This critical factor is decided by the bonding strength between aggregates and cement paste which is termed as the interfacial transition zone. The cement paste should be evenly distributed to achieve strength. This bonding is good when the aggregate size is smaller. However the voids ratio decreases while using smaller size aggregates so the porosity is affected/ reduced. Fig. 1 shows the bar chart regarding the 28 days compressive strength results of pervious concrete mixes for various proportions of fibre inclusions (1-9) and different coarse aggregate sizes (A and B).

ii) Tensile strength:

The results obtained from the split tensile strength tests shows that the average tensile strength was one in tenth of the compressive strength. As expected the fibre inclusion in the design concrete mix showed good improvement in the tensile strength of pervious concrete. For every increase of 0.25% of fibre in pervious concrete mix increased the tensile strength of concrete by 5-7%. Considering the factor of varying aggregate sizes smaller the size of aggregates the higher was the tensile strength of pervious concrete. For instance in Series-1 the 28 days split tensile strength of set- PFA7 specimens was 2.37N/mm^2 whereas, for set-PFB7 specimens in Series-2 it was 2.50N/mm^2 which is 6% increase in the tensile strength. Fig. 2 shows the bar chart regarding the split tensile strength results of pervious concrete mixes for various proportions of fibre inclusions and different coarse aggregate sizes.

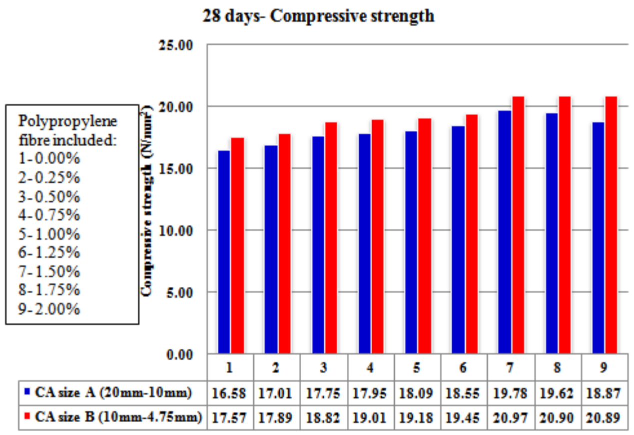


Fig. 1: Compressive Strength Of Fibre Included Pervious Concrete.

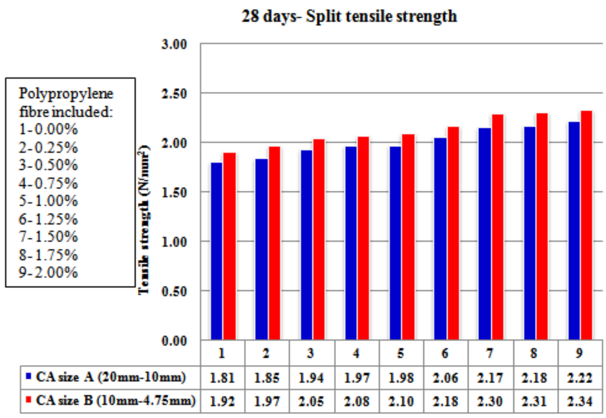


Fig. 2: Tensile Strength of Fibre Included Pervious Concrete.

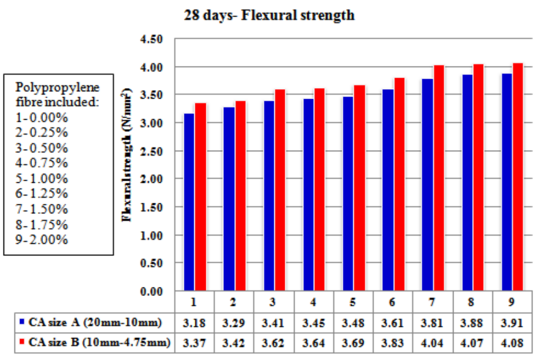


Fig. 3: Flexural Strength of Fibre Included Pervious Concrete.

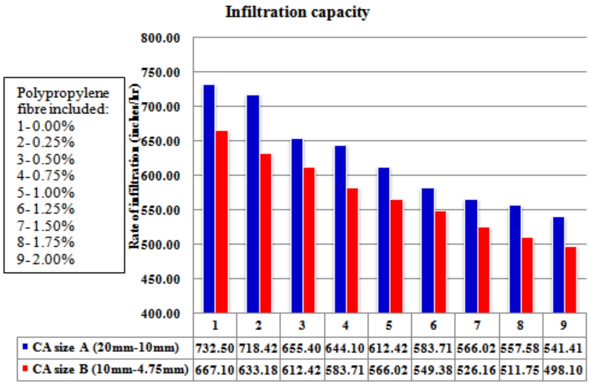
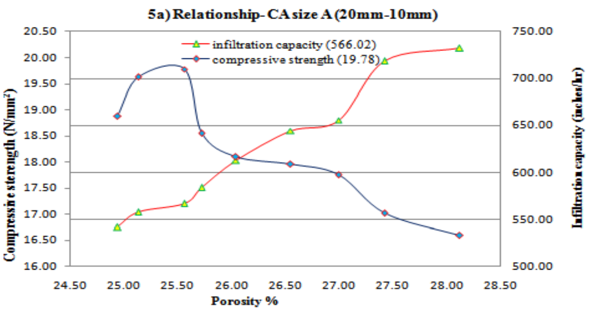


Fig. 4: Infiltration Capacity of Fibre Included Pervious Concrete.



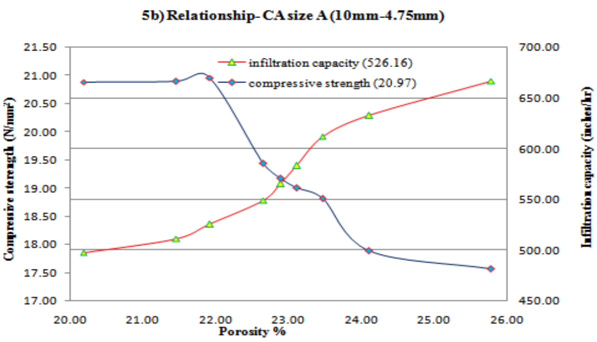


Fig. 5: Relationship between Compressive Strength, Porosity and Infiltration Capacity.

iii) Flexural strength;

The result obtained from 3-point bending tests indicates that in increase in fibre content in the design mix improved the modulus of rupture in the concrete. For every increase of 0.25% of fibre in pervious concrete mix increased the flexural strength of concrete by 6-8%.With respect to aggregate size there was more flexural strength in specimens made up of small size aggregates.For example in Series-1 the 28 days flexural strength of set- PFA7 specimens was 3.04N/mm^2 whereas, for set-PFB7 specimens in Series-2 it was 3.22N/mm^2 which is 6% increase in the flexural strength. Fig. 3 shows the bar chart regarding the flexural strength (modulus of rupture) results of pervious concrete mixes in the present study.

iv) Porosity:

The larger is the size of coarse aggregate then voids ratio and porosity of the concrete increases. In this study, Series-1 (i.e. 20mm-10mm-CA size) specimens had more porosity ranging from 25% to 29% than specimens in Series-2 (i.e. 10mm-4.5mm-CA size) having reduced porosity ranging from 20% to 25%. For every 0.25% increase in fibre content in concrete decreases the porosity of the pervious concrete by 2%. As expected the fibre material fills the voids of the concrete.

v) Infiltration Capacity:

Infiltration capacity test values for all the design mixes are tabulated in Table 4. The rate of infiltration ranges from 541.41inches/hour to 732.50inches/hour for ‘A’ Series-1 of larger size type coarse aggregates. The rate of infiltration ranges from 498.10inches/hour to 667.10inches/hour for ‘B’ Series-2 of smaller size type coarse aggregates. The infiltration capacity mainly depends mainly upon the size of voids or pores. From the results it is clear that smaller the size of aggregates used lesser is the flow of water through the pervious concrete. And also the fibre content in the concrete mix has an important role in reduction of infiltration capacity, for every 0.25% inclusion of propylene fibre reduces the infiltration of water by 6%-7%. From the results obtained, although the fibre inclusion affects the infiltration ability the values exceed the minimum requirement of 480inches/hour according to ASTM-C1701 standards. The rate of infiltration results comparison of both coarse aggregate grading sizes for the different mixes of pervious concrete mixes are illustrated in form of bar chart in Fig. 4.

vi) Relationship between the strength properties:

The relationship between compressive strength, porosity and infiltration capacity for different aggregate sizes (Series 1 and 2) of various fibre included pervious concrete are as shown in Fig. 5.

From test results it was evident that there is good co relationship between the compressive, tensile, and flexural strength. The strength properties are enhanced by improving the fibre content. The strength properties decrease with increase in size of aggregate. The porosity has a direct relationship with the infiltration capacity. The higher the porosity then faster is the flow of water through the concrete. The size of aggregate increases (10mm-20mm) the voids in the pervious concrete increases which directly increases the porosity. The smaller size aggregates (10mm-4.75mm) fills the voids. The addition of fibre also fills the voids. In Series-1 PFA7 was found to be the good mix proportion. In Series-2 PFB7 was found to be the good mix proportion. In both the mixes 1.5% inclusion of polypropylene fibre showed improved strength characteristics. All the mixes showed satisfactory infiltration capacities.

Nominal concrete mixes were prepared for both the size of aggregates which comfortably achieved the target strength. Combining all the sizes of coarse aggregates (20mm-4.75mm) and for 1.5% fibre inclusion pervious concrete mix PFAB was prepared and the specimens were casted and tested. It was found that coarse aggregate size ranging from 20mm to 4.75mm with 1.5% fibre addition satisfies all the strength and infiltration requirements shown in Table 1. Such that, Compressive strength= 21.62N/mm^2 (72% strength of the target M30 grade normal concrete); Tensile strength= 2.39N/mm^2; Flexural strength= 3.67 N/mm^2; Porosity= 22.45% and Rate of infiltration= 547.01inches/hr;

6. Conclusions

A total of 21 batches of specimens were tested. This project successfully demonstrates the investigation on physical strength properties, rate of infiltration and behaviour of polymer fibre included pervious concrete. The very little use of bottom ash in the mix as a replacement of sand performed well. Based on the study the following conclusions were arrived.

- It was found that the inclusion of fibre enhances the compressive, tensile and flexural strength of the concrete. The optimum percentage of Polypropylene fibre content in concrete mix is 1.5% addition to the total weight of the concrete mixture for both grades of coarse aggregate sizes, A and B (20mm-10mm and 10mm-4.75mm) of M30 grade of pervious concrete, respectively.
- It was found that the use of larger size of aggregates (20mm-10mm) in pervious concrete exhibits lower strength and higher infiltration capacity. The use of small size aggregates (10mm-4.75mm) increases strength but decreases the infiltration capacity.
- Based on the infiltration test results, it is found that as the percentage of fibre content increases there is decrease in the rate of flow of water. However, the rate of infiltration was within the satisfactory range. Thus fibre included pervious concrete can be used effectively in storm water management applications.
- It is concluded that for the pervious concrete to have sufficient hardened concrete strength (72% of M30 grade of

normal concrete) and infiltration capacity aggregate size ranging from 20mm-4.75mm can be used with inclusion of 1.5% polymer content. The polymer content increases the tensile strength and modulus of rupture of the concrete.

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