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Experimental Evaluation of Compressive and Flexural Strength of Pervious Concrete by using Polypropylene Fiber

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Abstract **– Pervious concrete had its earliest beginnings in Europe. In the 19th century pervious concrete was utilized in a variety of applications such as load bearing walls, prefabricated panels, and paving. In the United Kingdom in 1852, two houses were constructed using gravel and concrete. In this report, the effects of varying the components of pervious concrete on its compressive strength are investigated. The goal is to achieve a maximum compressive strength without inhibiting the permeability characteristics of the pervious concrete. This will be accomplished through extensive experiments on test cubes, cylinders & beams created for this purpose. Experiments include specific gravity tests, permeability tests, compression tests, split tensile strength & flexural strength. As with any research, the experiments performed are subject to limitations. These limitations are in regards to the type and size of aggregate used and the curing process. Here the polypropylene fiber at 0.2%, 0.4% and 0.6% is used in pervious concrete. It has enhances the bonding between the coarse aggregate and cement paste. The change in the percentage of polypropylene fiber had increment in compressive, flexural and split tensile strength of pervious concrete when compare with similar normal pervious concrete mix.**

Keywords: Pervious concrete, Compressive Strength and Flexural Strength, Polypropylene Fiber.

1. INTRODUCTION:

Pervious concrete is a composite material consisting of coarse aggregate, Portland cement, and water. It is different from conventional concrete in that it contains no fines in the initial mixture, recognizing however, that fines are introduced during the compaction process. The aggregate usually consists of a single size and is bonded together at its points of contact by a paste formed by the cement and water. The result is a concrete with a high percentage of interconnected voids that, when functioning correctly, permit the rapid percolation of water through the concrete. Unlike conventional concrete, which has a void ratio anywhere from 3-5%, pervious concrete can have void ratios from 15-40% depending on its application. Pervious concrete characteristics differ from conventional concrete in several other ways. Compared to conventional concrete, pervious concrete has a lower compressive strength, higher permeability, and a lower unit weight, approximately 70% of conventional concrete.

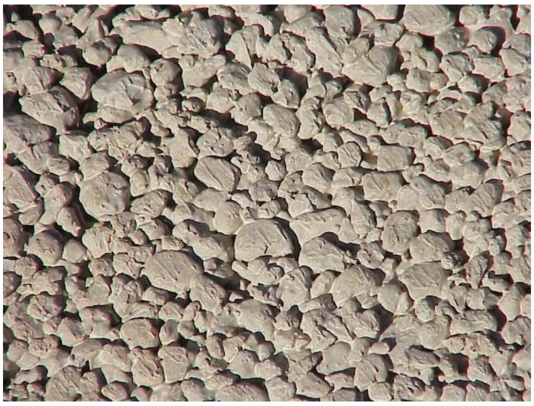

Figure No. 1: Pervious Concrete

1.1. History:

Pervious concrete had its earliest beginnings in Europe. In the 19th century pervious concrete was utilized in a variety of applications such as load bearing walls, prefabricated panels, and paving. In the United Kingdom in 1852, two houses were constructed using gravel and concrete. Cost efficiency seems to have been the primary reason for its earliest usage due to the limited amount of cement used. It was not until 1923 when pervious concrete resurfaced as a viable construction material. This time it was limited to the construction of 2-story homes in areas such as Scotland, Liverpool, London, and Manchester. Use of pervious concrete in Europe increased steadily, especially in the post-World War II era. Since pervious concrete uses less cement than conventional concrete and cement was scarce at the time, it seemed that pervious concrete was the best material for that period. Once again housing construction was its primary use. Pervious concrete continued to gain popularity and its use spread to areas such as Venezuela, West Africa, Australia, Russia, and the Middle East. Since the United States did not suffer the same type of material shortages as Europe after World War II, pervious concrete did not have a significant presence in the United States until the 1970's. Its use began not as a cheaper substitute for conventional concrete, although that was an advantage, but for its permeability characteristics (Ghafoori, 1995). The problem encountered in the United States was that of excessive runoff from newly constructed areas. As more land development took place the amount of impervious area increased. This produced an increase in runoff which in turn led to flooding. This had a negative impact on the environment, causing erosion and a degradation in the quality of water. Pervious concrete began in the states of Florida, Utah, and New Mexico but has rapidly spread throughout the United States to such states as California, Illinois, Oklahoma, and Wisconsin.

Although it had sluggish beginnings, the use of pervious concrete as a substitute for conventional concrete has grown into a multi-functional tool in the construction industry.

1.2 Uses:

Pervious concrete can be used in the following cases,

- Low-volume traffic pavements
- Sidewalks and pathways
- Parking areas
- Driveways
- Low water crossings
- Tennis courts
- Swimming pool decks
- Noise barriers etc.

1.3 Advantages and Disadvantages:

Pervious concrete is advantageous for a number of reasons. Of top concern is its increased permeability compared with conventional concrete. Pervious concrete shrinks less, has a lower unit weight, and higher thermal insulating values than conventional concrete. Although advantageous in many regards, pervious concrete has limitations that must be considered when planning its use. The bond strength between particles is lower than conventional concrete and therefore provides a lower compressive strength. There is potential for clogging thereby possibly reducing its permeability characteristics. Finally, since the use of pervious concrete in the United States is fairly recent, there is a lack of expert engineers and contractors required for its special installation.

The advantages of pervious concrete can be classified into 3 basic categories:

1. Environmental:

More and more attention is being paid to the impact of the construction industry on our living environment. The Clean Water Act (1977) mandates State counties and Municipalities to adopt steps and procedures to reduce the amount of polluted storm water. Since parking lots are generally impermeable surfaces, they contribute significantly to this issue. The use of pervious concrete is well-suited for this application.

- Reduces the size and sometimes the need for storm water runoffs
- Recharges the ground water level
- Allows for the natural treatment of polluted water by soil filtration
- Does not create heat islands due to its light color
- Reduces risk of flooding and top soil wash away
- Improves the quality of landscaping and reduces the need for watering

2. Safety:

- Reduces tire noise: Due to open interconnected air void structure, pervious concrete has been found to act as an effective acoustic absorbent. The tire noise generated between tire and pavement is lower with pervious concrete as compared to conventional concrete or blacktop.
- Prevents glare: Pervious concrete allows the water to flow freely through the surface which reduces glare, especially at night when the road is wet.
- Reduces hydroplaning and flooding: When pervious concrete is designed correctly all the precipitation should be absorbed by sub-grade or diverted away from pavement by a drainage system (in case of low absorption sub-grade). This results in reduced flooding and a puddle free surface, eliminating hydroplaning.

3. Economics:

Savings and other benefits that come with the usage of pervious concrete are due mostly to the following factors:

- Reduces or eliminates the need for storm sewers or retention ponds
- Increases facilities for parking by reducing water retention areas
- Increases permeable area and may qualify for permeable area credit
- Recognized by Leadership in Energy and Environmental Development (LEED)
- Requires less costly repairs than black top
- Longer service life and lower life cycle cost than asphalt.

1.4 Objectives of the Study:

The objectives of the project are as follows:

- To find the best suitable mix proportions to make a pervious concrete.
- To select the percentage of polypropylene fiber.
- To find out workability of fresh pervious concrete by Slump Cone Test.
- To find out mechanical properties like compressive strength, flexure strength, permeability of pervious concrete.

2. METHODOLOGY AND EXPERIMENTAL EVALUATION:

2.1 Method of placing concrete:

1. Method of Placing- Conventional Hand placing.
2. Member is casted at same time in three layers.

2.2 Method of concreting:

1. We used hand mixing over hard, smooth and watertight surface.
2. Mixing of concrete done uniformly and homogenously by moving concrete up down forward and backward.
3. Sand is totally removed (no fines concrete).

2.3 Method of curing:

Curing of concrete done by covering the concrete surface by plastic up to7 days, and then after immersed in curing tank, in which all concrete cubes, beams and cylinders are placed for different period of curing, like 14days, 21 days and 28 days.

2.4 Material and grade of concrete mix:

Grade of concrete: - M20

Following are the materials used in concrete mix:-

- Cement: - OPC 53 grade
- Course Aggregate: - 12.5mm sized crushed angular aggregate.
- Fine aggregate :- Nil
- Polypropylene fibers- 33micron (6 denier), 12mm length
- Admixture- Super Plasticizer: Ask O Max (Accelerator)
- Water :- Normal potable water

2.5 Material used with properties:

2.5.1 Cement:

53 grades Ordinary Portland cement was used throughout the experimental work. Cement was tested in the laboratory and results are shown below.

2.5.1.1 Fineness of cement:

Table No 1: Observation for fineness of the cement

Sr. No.	Mass of cement (gms)	Mass of residue (gms)	Residue (%)
01	100	99	1
02	100	98	2
03	100	99	1

Limiting value is 10% hence ok

2.5.1.2 Standard consistency of the cement paste:

Reference- IS 5513: 1976 Specification for Vicats apparatus

Table No.2: Observation for standard consistency of the cement paste

Sr. No.	Description	Remark
01	Grade of cement	53
02	Temperature at test	28
03	Gauging in time	3 to 5min

Table No.3: Observation for standard consistency of the cement paste

Sr. No.	Mass of cement (gms)	Mass of water added in (ml)	Penetration measured from the bottom (mm)
01	400	29x4=116	20
02	400	30x4=120	17
03	400	31x4=124	10
04	400	32x4=128	6

Percentage of water required to produce a paste of standard consistency = 128ml

Standard consistency (pn) of cement paste = (qty. of water / wt. Of cement) x 100

Standard consistency (pn) of cement paste = (128 / 400) x 100 = 32 %

2.5.1.3 Initial and final setting time of the cement:

References: - IS8112: 1989 Specifications for 53 grade ordinary Portland cement

Table No.4: Initial and final setting time of the cement

Sr. No.	Description	Value
01	Quantity of the cement	400 gms
02	Standard consistency of cement paste	32%
03	Qty. of the water	108 ml
04	Time at which gauging is started	9.30 am
05	Initial setting time	120min
06	Final setting time	275min

2.5.1.4 Specific gravity of the coarse aggregate by Pycnometer Bottle method:

Table No. 5: Observation table for the specific gravity of the aggregate

Observation	Sample (gms)
Mass of empty container	457
Mass of container + coarse aggregate	924
Mass of water + container (W1)	1226
Mass of container + CA +water (W2)	1525
Mass of CA(W3)	467
Mass of equal volume of water as the aggregate W4=(W1+W3)-W2	168
Specific gravity= w3/w4	2.78

2.5.1.5 Aggregate crushing value test:

Table No. 6: Observation table for aggregate crushing value

Sr. No	Observation	Sample 1	Sample 2	Sample 3
01	Wt. Of the sample	3000 gms	3000 gms	3000 gms
02	Wt. of the sample passing through the 2.36 is sieve	617.5 gms	610 gms	613.5 gms

Aggregate crushing value for:

Sample 1 = 20.6 %

Sample 2 = 20.3%

Sample 3= 20.45%

Average aggregate crushing value = 20.45%

As crushing value is less than 30% value used for the wearing and non-wearing surfaces.

2.5.1.6 Aggregate impact value:

Table No.7: Observation table for the aggregate impact value

Sr. No.	Observation	Sample 1	Sample 2	Sample 3
01	Wt. of the sample	400 gms	400 gms	400 gms
02	Wt. of sample passing through 2.36 mm is sieve after impact	36 gms	42 gms	38.5 gms

Impact value for:
Sample 1 = 9 %
Sample 2 = 10.6 %
Sample 3 = 9.62 %
Average aggregate Impact value = 9.70 %
As Average aggregate Impact value less than 10% the sample exceptionally strong.

2.5.1.8: Fineness modulus of the coarse aggregate

Total mass = 5000 gms

Table No.7: Sieve Analysis

IS sieve (mm)	Mass retained	Cumulative mass retained	Cumulative mass retained (%)	Cumulative mass passing (%)
80	Nil	Nil	Nil	100
63	Nil	Nil	Nil	100
40	Nil	Nil	Nil	100
20	Nil	Nil	Nil	100
16	Nil	Nil	Nil	100
12.5	3897.5	3897.5	77.95	22.05
10	45.5	3943	78.86	21.14
4.75	1035	4978	99.56	0.44
2.36	3	4981	99.62	0.38
Pan	19	5000	100	-

Fineness modulus = 455.89/100 = 4.56

Table No. 9: Properties of the coarse aggregate

Sr. No	Test	Result
01	Specific gravity	2.78
02	Crushing value	20.45
03	Impact value	9.70
04	Fineness modulus	4.56

2.6 Mix design:

Mix design for M20 grade concrete
Reference – IS 10262: 1982 and IS 10262:2009 & various papers of mix design of pervious concrete.

2.6.1 Design Stipulations:

- Characteristics compressive strength = 20N/mm^2
- Max. Size of coarse aggregate = 12.5mm
- Degree of quality control = Good
- Type of exposure = Moderate
- Min. Cement content = 320kg/m^3 (IS- 456)
- Max. W/c ratio = 0.6

Table No. 10: Summary of Concrete Mix Design

1	Characteristic Compressive Strength	20 N/mm^2
2	Degree of quality control	Good
3	W/C ratio	0.32
4	Type of cement	OPC
5	Nominal size of coarse aggregate	12.5mm
6	Specific gravity of cement, S_c	3.15
7	Specific gravity of coarse aggregate, S_{ca}	2.78
8	Water content per m^3 of concrete	151.87 Kg/m^3
9	Cement content for W/C = 0.32	474.61 Kg/m^3
10	Total coarse aggregate per m^3 of concrete, C_a	1964.07Kg/m^3
11	Mix proportion	1 : 4.14

Mix proportion = 1 : 4.14 with w/c 0.32

2.7 Investigation program:

During the investigation, we have casted cubes, beams & cylinders of concrete with polypropylene added to the weight of cement to check the compressive, flexural and split tensile strength of concrete and permeability of concrete. The varying percentages of polypropylene fibers were used as 0.2%, 0.4%, and 0.6% to the weight of cement.

As we have to check properties of pervious concrete when polypropylene fibers are added to the weight of cement, two types of concrete were used in this experiment.

- Normal pervious concrete
- Fiber reinforced pervious concrete

Table No. 11: Details of Castings

Sr. No.	Members	Description	Number of Cast			Total
			For 7th day test	For 14th Day Test	For 28th Day Test	
1	Cubes	Normal Pervious Concrete	3	3	3	9
2		0.2% PP Fiber	3	3	3	9
3		0.4% PP Fiber	3	3	3	9
4		0.6% PP Fiber	3	3	3	9
		Total No. of Cast	12	12	12	36
5	Cylinders	Normal Pervious Concrete	0	0	3	3
6		0.2% PP Fiber	0	0	3	3
7		0.4% PP Fiber	0	0	3	3
8		0.6% PP Fiber	0	0	3	3
		Total No. of Cast	0	0	12	12

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9		Normal Pervious Concrete	0	0	3	3
10	Beams	0.2% PP Fiber	0	0	3	3
11		0.4% PP Fiber	0	0	3	3
12		0.6% PP Fiber	0	0	3	3
		Total No. of Cast	0	0	12	12

2.8 Casting procedure:

Mix the concrete ingredients thoroughly as per the mix design. Concrete ingredients are filled in to the mould in three layers and each layer is compacted by tamping rod not less than 25 blows or by using surface vibrator. Then level the top surface and smoothen it with the trowel.

The test specimens are stored in a moist air for 24 hours and after this period the specimen are removed from the mould and marked. Then cubes kept in the clear plastic bags until 7 days and then placed in curing tank for curing.

Minimum three specimens should be tested at each selected age. If strength of any specimen varies more than 15 percent of average strength results of such specimen should be rejected. Average of three specimens gives the compressive strength of concrete.

Figure No. 2: Cast Cubes

2.9 Test:

2.9.1 Compressive strength of pervious concrete:

Compressive strength of a concrete is a measure of its ability to resist static load, which tends to crush it. Most common test on hardened concrete is compressive strength test' It is because the test is easy to perform. Furthermore, many desirable characteristic of concrete are qualitatively related to its strength and the importance of the compressive strength of concrete in structural design. The test is carried out on the cube specimen. Cast iron moulds are used to cast the cubes having leak proof metal base plate. The joints between the sections of the mould are thinly coated with the mould oil to prevent adhesion of concrete to the mould surface.

Figure No. 3: Compressive Strength Test

2.9.2 Flexural strength of pervious concrete:

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 150 x 150-mm concrete beams with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading). Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design.

Figure No. 4: Flexural Strength Test

2.9.3 Permeability test of pervious concrete by constant head method:

Permeability of pervious concrete can be calculated by using following equation

$$k = VL/Aht$$

Where, K = Coefficient of permeability

V = Collected volume of water

L = Length of pervious concrete column

A = Area of the pervious concrete column

h = Head difference

t = Time required to get V volume

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3. RESULTS AND DISCUSSIONS:

3.1 Workability of Pervious Concrete:

There are no fine aggregates in pervious concrete. Pervious concrete is also called as zero slump concrete since it has zero slump.

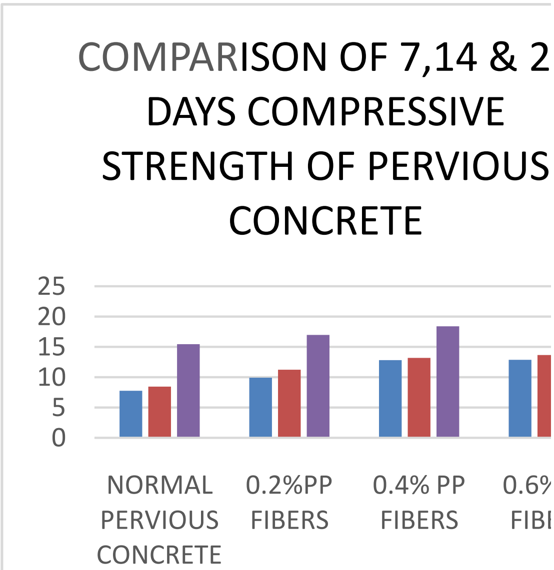
PP Fiber Percentage	Slump(mm)
Normal Pervious Concrete	00
0.2% PP Fibers	00
0.4% PP Fibers	00
0.6% PP Fibers	00

3.2 Compressive strength:

It was observed that there was increase in compressive strength with increase in percentage of polypropylene fibers. The result of compressive strength test is shown below.

Table No.12: Results of compressive strength

Batch	7 Days	14 Days	28 Days	% Increase
Normal Pervious Concrete	7.77	8.44	13.43	-
0.2%PP fibers	9.93	11.23	14.56	8.41
0.4% PP fibers	12.84	13.20	17.42	29.70
0.6% PP fibers	12.89	13.67	18.95	41.10



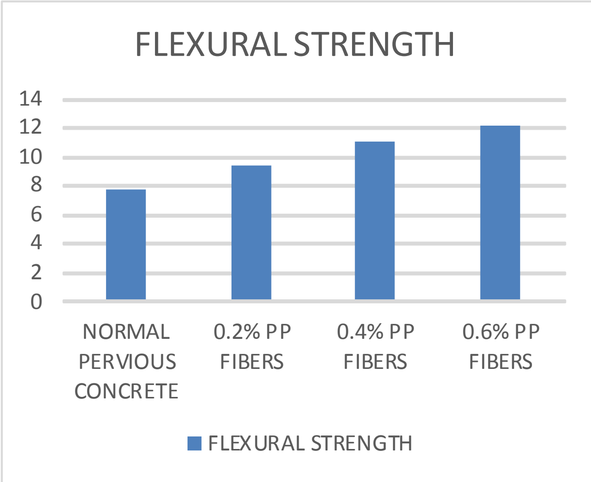
Graph No.1: Comparison of 7, 14 & 28 Days Compressive Strength of Pervious Concrete

3.3 Flexural strength:

It was observed that there was increase in Flexural strength with increase in percentage of polypropylene fibers. The result of Flexural strength test is shown below Table no. 5.4 Results of split tensile strength

Table No. 13: Results for Flexural Strength of Pervious Concrete

Batch	28 Days	% Increase
0% fibers	7.77	-
0.2% fibers	9.38	17.16
0.4% fibers	11.02	29.50
0.6% fibers	12.10	35.78



Graph No. 2: 28 Days Flexural Strength of Pervious Concrete

3.4 Permeability test of pervious concrete by constant head method:

It was observed that there was decrease in permeability with increase in percentage of polypropylene fibers. The result of permeability test is shown below.

Table No. 14: Discharge for Permeability Test of Pervious Concrete

Discharge (Q)			
Specimen	10 Sec	20 Sec	30 Sec
Normal Pervious Concrete	380	750	1150
0.2% Pp Fibers	370	730	1135
0.4% Pp Fibers	350	710	1120
0.5% Pp Fibers	320	700	1110

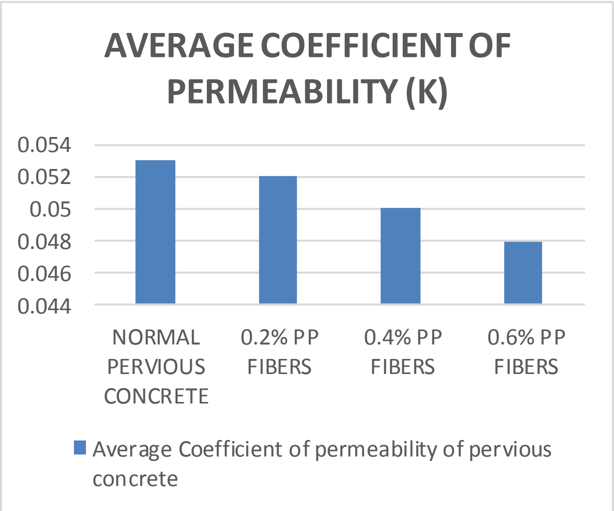
Table No. 15: Coefficient of Permeability of Pervious Concrete

Coefficient of Permeability (K)			
Specimen	10 Sec	20 Sec	30 Sec
Normal Pervious Concrete	0.053	0.053	0.054
0.2% Pp Fibers	0.052	0.051	0.053
0.4% Pp Fibers	0.049	0.050	0.053
0.5% Pp Fibers	0.045	0.049	0.052

Sample calculations:
k = VL/Aht
Where, K = Coefficient of permeability
V = Collected volume of water
L = Length of pervious concrete column = 15 cm
A = Area of the pervious concrete column = 88.331 cm2
h = Head difference = 120 cm
t = Time required to get V volume
k = VL/Aht
= 380*15/(88.331*120*10)
= 0.053 cm/sec

Table No. 16: Average Coefficient of Permeability of Pervious Concrete

Specimen	Average Coefficient Of Permeability (K)
Normal Pervious Concrete	0.053
0.2% Pp Fibers	0.052
0.4% Pp Fibers	0.050
0.5% Pp Fibers	0.048



Graph No. 3: Average Coefficient of Permeability of Pervious Concrete

4. CONCLUSION:

This study represents the effect of use of polypropylene fiber in pervious concrete on compressive, flexural, split tensile strength& permeability of pervious concrete. From the results obtained during investigation and based on literatures review following conclusions can be drawn:

- The use of polypropylene fiber in pervious concrete enhances the bonding between the coarse aggregate and cement paste.
- Higher content of polypropylene fiber in pervious concrete decreases workability of concrete.
- Using polypropylene fiber in pervious concrete at 0.2, 0.4 and 0.5% ,It was observed that, there was increment in compressive , flexural and split tensile strength of pervious concrete when compare with similar normal pervious concrete mix.
- Using polypropylene fiber in pervious concrete at 0.2, 0.4 and 0.5%, it was observed that, the coefficient of permeability decreases with increase in % PP fiber.

- Scope for further study:

The following works can be conducted in future:-

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