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Comparative Study on Strength and Permeability of Pervious Concrete by Using Nylon and Polypropylene Fiber

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Abstract- 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 fine sin 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.

Keywords- **Pervious concrete, Permeability, nylon and polypropylene fiber**.

1. Introduction

Pervious concrete is a special type of concrete with high porosity. It can used for concrete flatwork applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing ground water recharge. The concrete paste then coats the aggregates and allows water to pass through the concrete slab. Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses. It is an important application for sustainable construction and is one of many low 0impact development techniques used by builders to protect water quality.

The pervious concrete system and its corresponding strength are as important as its permeability characteristics. The strength of the system not only relies on the compressive strength of the pervious concrete but also on the strength of the soil beneath it for support. Pervious concrete consists of cement, coarse aggregate and water with little to no fine aggregates. Water to cement ratio of 0.28 to 0.40 with a void content of 15 to 25%. The correct quantity of water in the concrete is critical. A low water to cement ratio will increase the strength of the concrete, but too little water may cause surface failure. As this concrete is sensitive to water content, the mixture should be field checked. Entrained air may be measured by a Rapid Air system, where the concrete is stained black and sections are analyzed under a microscope. A pervious concrete mixture contains little or no sand (fines), creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Typically, between 15% and 25% voids are achieved in the hardened concrete, and flow rates for water through pervious concrete are typically around 480 in./hr (0.34 cm/s, which is 5 gal/ft²/ min or 200 L/m²/min), although they can be much higher.

2. Uses

Practical for many applications, pervious concrete is limited by its lack of durability under heavy loads. This lack of resiliency restricts the use of pervious concrete to specific functions. Pervious concrete is limited to use in areas subjected to low traffic volumes and loads. Although once used as load bearing walls in homes, pervious concrete is now utilized primarily in parking lots but does have limited applications in areas such as greenhouses, driveways, sidewalks, residential streets, tennis courts (limited to Europe), and swimming pool decks.

3. Pervious Concrete Technology

Also known as no-fines or low fines concrete, pervious concrete is a mix of Portland cement, coarse aggregate, water and admixtures. Because there is little or no sand in the mix, the pore structure contains many voids that allow water and air to pass through.

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4. Pervious Concrete Advantage

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. Due to the absence of fine aggregate, pervious concrete has high porosity, Since the pervious concrete pavement is permeable, water can be captured and flow through the pavement during rainfall. In the mean time, free air is stored in the pavement and allows the communication between the subsurface and the air. These properties offer many advantages for pervious concrete.

New federally mandated storm water management regulations are in effect making pervious concrete systems a viable solution. While the EPA recognizes pervious concrete as a Best Management Practice (BMP), building owners are realizing better land utilization and LEED credits with pervious concrete parking lots. Pervious concrete applications can be used as an alternative to complex drainage systems and water retention areas in reducing storm water runoff.

5. Workability Assessments for Pervious Concrete

5. 1. Workability

Even though few researches have reported slump values for pervious concrete, the standard slump is not suitable for pervious concrete to asses its workability because of light weight nature of pervious concrete. It has been established that workability for pervious concrete should be assessed by forming ball with the hand to establish the mouldability of pervious concrete. Mouldability of pervious concrete is quite sensitive to the water content; hence the amount of water should be strictly controlled.

(A) Too little water (B) proper amount of water (C) too much water

5.2 Durability

Durability of concrete is substantially affected by the material permeability. Since pervious concrete facilitates mobility of moisture, one would expect this to affect durability. The durability problems should not be analogous to traditional concrete since the permeability of pervious concrete is not same as traditional concrete; that is, traditional flow-through permeability is not a measure of durability for pervious concrete.

5.3 Compressive Strength

Though pervious concrete can be used for various applications, its primary drawback is low compressive strength. Since the paste layer between aggregates is thin, it cannot provide sufficient compressive strength compared with traditional concrete. Thus, the usage of pervious concrete was limited in high volume pavements. Instead, pervious concrete was applied in parking lots, which do not require high compressive strength.To broaden the application of pervious concrete through increased compressive strength, several factors should be considered such as the strength of paste, thickness of paste coating the aggregates, and the interface between aggregate and paste. Using smaller coarse aggregate and mineral admixture is suggested as a suitable means to obtain higher strength with pervious concrete (Schaefer et al., 2006). To be specific, the compressive strength of pervious concrete is related to several factors such as void ratio, unit weight, water-cement ratio, supplementary cementing materials, aggregate size, and aggregate to cement ratio.

5.4 Unit Weight (Density)

Due to high porosity pervious concrete is light weight concrete. The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. In-place densities on the order of 1600 kg/m³ to 2000 kg/m³ are common, which is in the upper range of lightweight concretes.

5.5 Void Ratio

The data in Figure includes various coarse aggregates such as river gravel, pea gravel, and limestone. This graph shows a general relationship between void ratio and seven-day compressive strength. Seven day compressive strength of pervious concrete declines linearly as void ratio increases. For pervious concrete, the void ratio refers explicitly to the entrapped macro porosity and does not include entrained air, gel or capillary porosity.

6. Benefits of Fiber Reinforced Concrete

1. Controlled Plastic Shrinkage.
2. Minimized Crack Growth.
3. Reduced Permeability.
4. Improved Surface Durability.
5. Uniform Reinforcement in All Directions.

Most of the applications, the function of the fibres does not consist into increasing the strength (although an increase of tensile strength is a consequence) but just to control and delay both widening cracks and the behaviour of the concrete after the crack of the matrix.

6.1. Types of Fibres

6.1.1 Glass Fibre

Glass fibre is available in continuous or chopped lengths. Fibre lengths of up to 35-mm are used in spray applications and 25-mm lengths are used in premix applications.

Fig. 4 Steel fibres

6.1.2. Natural Fibres

Natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology.

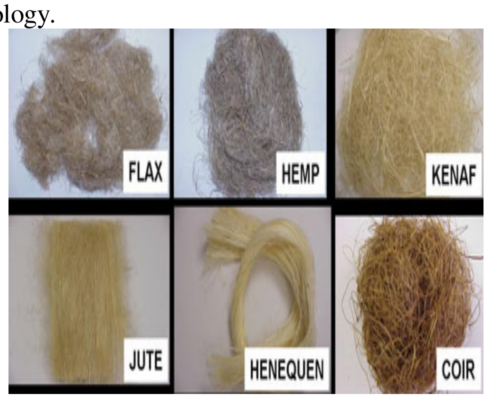

Fig. 5 Natural fibres

6.1.3. Synthetic Fibres

Synthetic fibres are man-made fibres resulting from research and development in the petrochemical and textile industries. There are two different physical fibre. Fibre types that have been tried in cement concrete matrices include: acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene.

Fig. 6 Synthetic Fibres

6.1.4. Behaviour of Nylon Fibre

Nylon has light weight and high strength.

Strength: Nylon has good tenacity and the strength is not lost with age. Nylon has a high strength to weight ratio. Nylon has excellent abrasion resistance.

Elasticity: Nylon has good elasticity. Nylon like other fibers has its own limit of elasticity.

- Excellent abrasion resistance
- Durability: its high tenacity fiber.
- High elongation.

Fig.7 Nylon Fibre

6.1.5. Behaviour of Polypropylene Fibre

Polypropylene is smooth, light weight and high strength. A synthetic fibre formed from a polypropylene melt.

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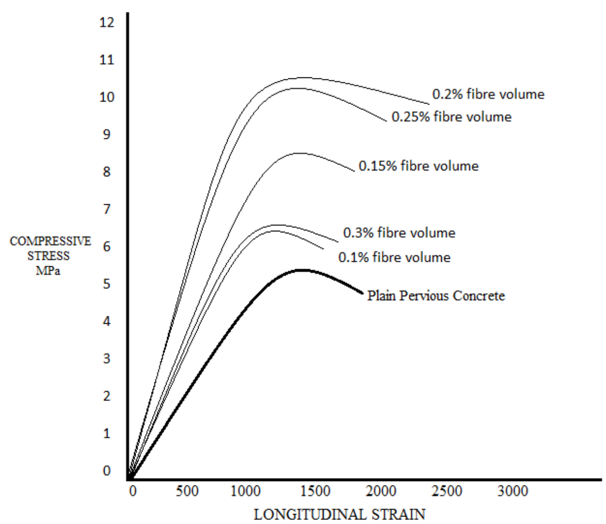
Fig. 8 Polypropylene Fibre

Polypropylene fibres have been reported to reduce unrestrained plastic and drying shrinkage of concrete at fibre contents of 0.1 to 0.3% by volume. The polypropylene fibres are made with 100% purity provided as a filament fibre for secondary reinforcement of concrete.

7. Compressive Strength

Polypropylene has a high strength to weight ratio. It has excellent abrasion resistance. Fibres do little to enhance the static compressive strength of concrete, with increases in strength ranging from essentially nil to perhaps 25%. When pervious concrete in addition to the polypropylene fibres, the fibres have little effect on compressive strength. However, the fibres do substantially increase the post cracking ductility, or energy absorption of the material.

This is shown graphically in the compressive stress-strain curves of PPLICP in figure



Graph 3 compressive strength of pervious concrete, nylon fibre and polypropylene fibre

8. Objective

1. To strengthen the pervious concrete using polypropylene fibre as a admixture.
2. To recharge the water table of soil beneath the construction.
3. To increase life of structure.

9. Methodology

We will prepare several cubes for testing the compressive strength.

9.1 Batching

Batching is the process of measuring and combining the ingredients of concrete. Careful procedure was adopted in the batching, mixing and casting operations.

Fig. 9 Casting

For compressive strength with water cement ratio 0.36% and different percentage of admixtures by volume of concrete.

Dosage of fibres and their calculations:

1. Calculation for volume of cube

Volume of one cube= (0.15x0.15x0.15) m3
= 0.003375 m3

Weight of one cube = 0.003375x2362 = 7.972 kg

2. Calculation of volume of concrete for M20 grade

a. Volume of cement for one meter cube = 1/(1+4)
= 0.2 m3

Weight of cement per meter cube= 0.2 x 1200
= 240 kg

b. Volume of aggregate for one meter cube = 0.2 x 4

=0.8 m3

Weight of aggregate per meter cube = 0.8 x 1450

= 1160 kg

c. Water cement ratio =0.36

Weight of water = 258.16 x (1/0.36)

= 717.11 kg

d. Density of concrete = (weight of (cement +sand +aggregate +water)) per meter cube

= (240+1160+717.11)

= 2117.11 kg/m3

e. Weight of concrete for one cube

= 2117.11 x 0.003375 = 7.145 kg

3. Weight of Polypropylene fibre

a. 0.1% of Polypropylene fibre

= 7.145 × 0.1 = 71.45gm

b. 0.15% of Polypropylene fibre

= 7.145 × 0.15 = 107.1 gm

c. 0.2% of Polypropylene fibre

= 7.145 × 0.2 = 143.1 gm

d. 0.25% of Polypropylene fibre

= 7.145 × 0.25 = 178.6 gm

e. 0.3% of Polypropylene fibre

= 7.145 × 0.3 = 214 gm

9.2 Curing

The specimens were allowed to remain in iron mould for 24 hours under ambient condition. After that, these were remolded with care so that no edges were broken and were placed in curing tank at the ambient temperature for curing. The ambient temperature for curing was 27± 2◦ C.

Fig. 10 Curing

10. Testing Of Specimen

10.1 Details of Slump Test

Fill the cone with concrete in three layer and taper 25 blows evenly in each layer with 5/8 inch diameter and 24 inch long hemisphere steel rod. Remove the excess concrete from top of the cone, using tapering rod, clean overflow from base of cone.

Fig. 11 Slump Cone Test

10.2 Compressive Test

The specimen after a fixed curing period of 7 days, 14days and 28 days were tested for compressive strength on 2000 KN compressive testing machine (UTM).

Fig. 12 Compressive Strength Machine (UTM)

10.3 Permeability Test

The property of the concrete which permits water (fluids) to percolate through its continuously connected voids is called its permeability.

a. Case7

We check the permeability of plain pervious concrete cube. 1000 ml water which is passed through the voids of the plain pervious concrete cube and the water is retained to another pan that stored water measures it is 860 ml.

Fig. 13 Permeability testing of plain pervious concrete cube

b. Case

The permeability of 0.1% fibre mixed pervious concrete cube. 1000 ml water which is passed through the voids of the fibre mixed pervious concrete cube and the water is retained to another pan that stored water measures it is 880 ml.
The permeability of 0.15% fibre mixed pervious concrete cube, it is 900 ml. The permeability of 0.2% fibre mixed pervious concrete cube. 1000 ml water which is passed through the voids of the fibre mixed pervious concrete cube and the water is retained to another pan that stored water measures it is 920 ml.The permeability of 0.25% fibre mixed pervious concrete cube, it is 940 ml.The permeability of 0.3% fibre mixed pervious concrete cube, it is 960 ml.

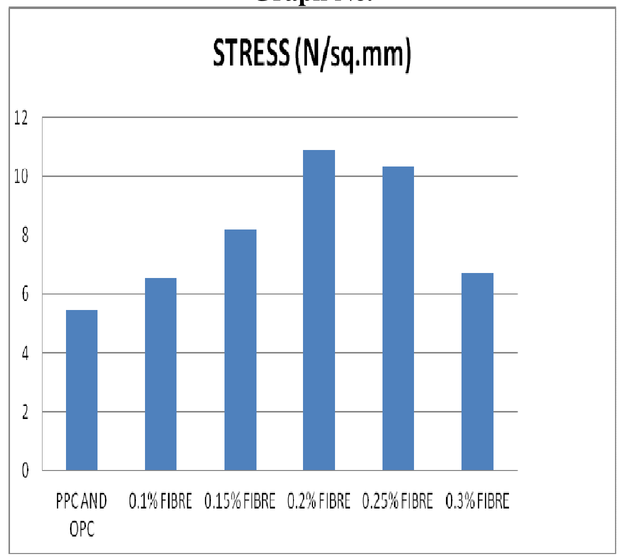
Fig. 14 Permeability testing of fibre mixed pervious concrete cubes

11. Results

11.1 Results for pervious concrete in compressive test

11.2 Bar Chart

Bar Chart Increase in Stress with Increase in Percentage of Polypropylene Fibre
Graph No.



Bar Chart for PPC and OPC
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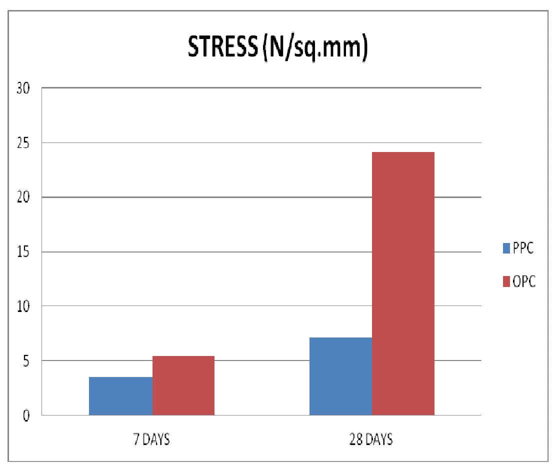

Bar Chart for Plain Cement Pervious Concrete with 0.1% of Nylon and Polypropylene Fibre
Graph No.

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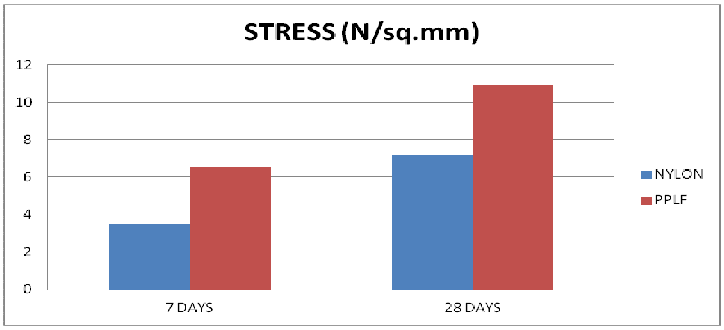
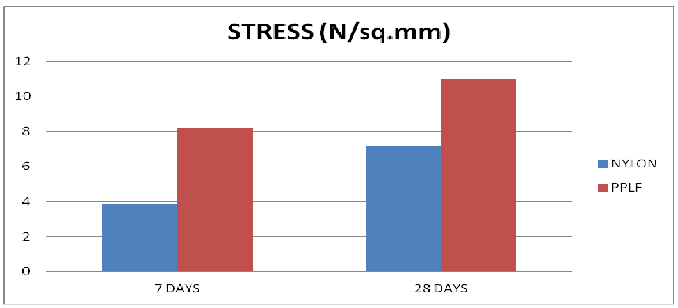
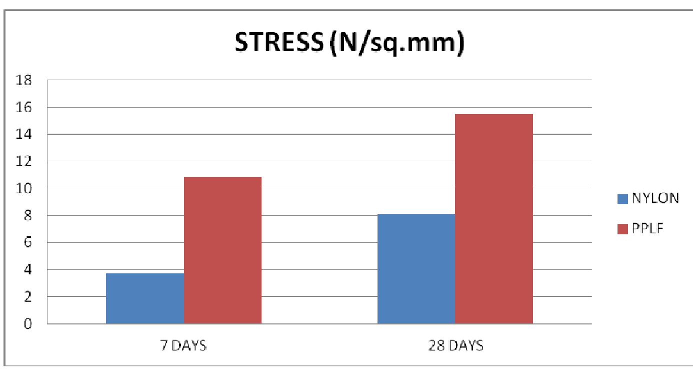


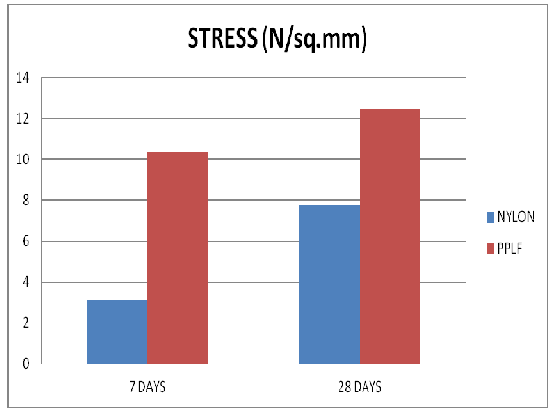
Bar Chart for Plain Cement Pervious Concrete with 0.15% of Nylon and Polypropylene Fibre Graph No.



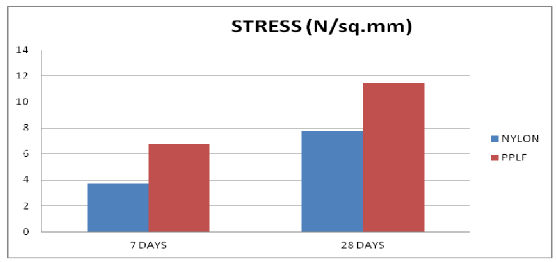
Bar Chart for Plain Cement Pervious Concrete with 0.2% of Nylon and Polypropylene Fibre Graph No.



Bar Chart for Plain Cement Pervious Concrete with 0.25% of Nylon and Polypropylene Fibre Graph No.



Bar Chart for Plain Cement Pervious Concrete with 0.3% of Nylon and Polypropylene Fibre Graph No.



12 .Conclusions

12.1 Compressive Test (Cube) Of M20

The test carried out at 7 days, 14 days and 28 days, the comparison is made between the plain pervious concrete , pervious concrete with nylon fibre and polypropylene fibre .

a. The compressive strength of nylon fibre and polypropylene fibre mixed with pervious concrete is increased as comparison to the plain pervious concrete.
b. When we used the nylon fibre and polypropylene fibre in pervious concrete in various proportion 0.1 %, 0.15%, 0.2% ,0.25% and 0.3% of volume of concrete the result obtained by the compressive strength of nylon fibre and polypropylene fibre up-to 0.2 % of used result get increased.

12.2 Permeability test of M20

Plain Pervious Concrete

1000 ml water which is passed through the voids of the plain pervious concrete cube and the water is retained to another pan that stored water measures it is 860 ml.

Nylon Fibre Mixed Pervious Concrete

1000 ml water which is passed through the voids of the polypropylene fibre mixed pervious concrete cube and the water is retained to another pan that stored water measures it is 910 ml.

a. The permeability of nylon fibre mixed pervious concrete is increased as comparison to the plain pervious concrete.
b. The 0.25% and 0.3% polypropylene fibre mixed pervious concrete is compressive strength is less but the permeability is more than 0.2% nylon fibre mixed pervious concrete.
c. The strength of pervious concrete is increased when fibre used in 0.2% more than of its used the strength decreased. So we conclude that the ratio of fibre used as less than 0.2%.
d.

Polypropylene Fibre Mixed Pervious Concrete

1000 ml water which is passed through the voids of the polypropylene fibre mixed pervious concrete cube and the water is retained to another pan that stored water measures it is 970 ml.

e. The permeability of polypropylene fibre mixed pervious concrete is increased as comparison to the plain pervious concrete.
f. The 0.25% and 0.3% polypropylene fibre mixed pervious concrete is compressive strength is less but the permeability is more than 0.2% polypropylene fibre mixed pervious concrete.
g. The strength of pervious concrete is increased when fibre used in 0.2% more than of its used the strength decreased. So we conclude that the ratio of fibre used as less than 0.2%.

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