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Reinforcing Pervious Concrete Using Carbon Fiber

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Abstract

Pervious concrete has gained interest due to its ability to allow water to flow through it which recharges the ground water table and thus minimizes the surface runoff. Pervious Concrete has various exclusive features, thus making it a construction material which is environment friendly. It helps the pollutants of any type tobe drained into the subsurface through its porous structure& then be treatedby the micro-organisms present in the soil, rather than runoff &thereby polluting the water bodies.Low mechanical properties and durability are the properties affecting the structural strength of pervious concrete, using restrictedly as a pavement material only. The aim of this study was to determine the physical and mechanical properties of reinforced pervious concrete in comparison to the different volume fractions. In this study chopped carbon fiber strands of 12mm size was incorporated into a mixture of pervious concrete in 2 volume fractions. In order to study the effects of volume fractions, 2 mix designs were proceeded with.After the test results it was observed that the reinforced pervious concrete possess more strength than theordinary pervious concrete. The flexural strength of Pervious Concretereinforced with Cured Carbon Fiber Composite Material (CCFCM) was found to be 30 to 35% higher than the conventional pervious concrete.The study of reinforcing pervious concrete using carbon fiber has turned

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out to be beneficial due to its promising results of improving the various properties without affecting the permeability much.

Keywords: *Carbon fiber, CCFCM, Environment friendly, Pervious Concrete, Surface runoff.*

Introduction

Huge progress in technologies and material development has played a key role in recent years. Pervious concrete is one such development which allows water to flow through the concrete thereby increasing the groundwater. This innovative material is sometimes also called as no fines concrete[1,2]. Popularity of pervious concrete has been increasing in the last few years, though it was in use since 1960s as a pavement material. Pervious concrete is being used since then for various types of lanes, walkways, sidewalks & at the places of low volume roadways as the strength of pervious concrete was less than the conventional concrete, restricting its usage [3]. Pervious concrete proves to be advantageous as a pavement material in various aspects. Pervious concrete pavement plays an important role in reducing the runoff volume and as well as reducing the excess storm water in areas of heavy storm. It also recharges the ground water table from the excess retained storm water. Storm sewers can be eliminated by using the pervious concrete, thereby reducing the cost of construction [4]. These all things makes the pervious concrete a boon for saving the rainwater rather than runoff. Pervious concrete on the other hand also helps to reduce the traffic noise& heat island effect.[3,5]. USA EPA (United States Environmental Protection Agency) has accepted pervious concrete as Best Management Practice for storm water runoff due to its unique & advantageous features.However pervious concrete in India is in the stage of research & development. Many initiatives are taken in-order to increase the strength properties of the concrete. Since the concrete is porous, there is need of enhancing the mechanical properties so that it can be used effectively anywhere when the problems of high storm exist commonly & could be placed consistently in the variety of environment conditions. There are many types of improvements that are recently been made with the objective of increasing its strength by reinforcing it with various additives. Various studies focus on upgrading its mechanical properties which includes reinforcing the pervious concrete using various types of fibers. The basic objective of these studies been done is to increase the compressive strength, tensile strength and flexural strength of pervious concrete. Thus various improvements are introduces to make its usage more effective [6-8].

In this recent years, the roads of India face a lot of problems like water logging, runoff water etc. The use of pervious concrete as a pavement material in such area will be helpful as it will allow the rainwater to pass through it, thus recharging the ground water and reducing the surface runoff. It is one of the solutions for storm-water management [9].Pervious concrete has similar ingredients as that of conventional concrete but here, the fine aggregates are eliminated. Thus it is also called as no fines concrete. Also these concrete has low w/c ratio. Elimination of fine aggregate & proper gradation of course aggregate gives good interconnected system and also provides voids for the flow of water.

Due to the lack of fine aggregate, the coarse aggregates grains in PC are bounded solely by a thin layer of cement paste, resulting in lower mechanical properties of PC comparing to conventional PCC thus, in order to increase this strength; concrete is reinforced with carbon fiber [10].The study aims to improve the strength of pervious concrete without affecting permeability &encouraging higher traffic volume [11].

Materials

A. Cement

Cement-Ordinary Portland cement (OPC) of 53 Grade confirming to IS 12269:2013 was used as a binder to produce pervious concrete with good durability and strength.

Specific gravity of cement: 3.15

B. Aggregates

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In pervious concrete, various sizes of coarse aggregates ranging from 4.75 mm to 20 mm are used without fine sand and withaddition of admixtures. Pervious concrete needs proper gradation of the aggregates with proper selection of size & shape of aggregate. Coarse Aggregates which are angular in shape are advantageous to concrete as flaky & elongated type of aggregate lead to blockage problems underneath [12].Angular aggregates are used since they are generally preferable for pavement construction as they have more surface area which results in proper bonding with the cement paste.

10% of aggregates ranging from 4.75mm to 10 mm are used.

90% of aggregates ranging from 10mm to 20 mm are used.

Specific gravity of coarse aggregate: 2.8

C. Water

Water is the essential component in concrete making. The water content & w/c ratio possess a crucial role in the performance of the pervious concrete mixes.Thus, water used in concrete should be fit for drinking.

Water-cement ratio adopted for the mix 1 & mix 2 was 0.34 & 0.37 respectively.

D. Admixture

In pervious concrete, at least one type of admixture is been used as they plays a vital role to improve the properties of the concrete. Since the water content & w/c ratio required is less medium to high range water reducers are most commonly been used in pervious concrete.Polycarboxylate based super plasticizer- PermaPlast PC- 100 has been used. Up to 30% reduction of water content has been achieved using PC-100.

Specific Gravity of Admixture: 1.145

E. Carbon Fiber

The unique part of our project is reinforcing the pervious concrete using the carbon fiber. This carbon fiber can be obtained excessively from the aerospace industry. The scrap material which is lately obtained from this industry can be reused because of its valuable properties. Carbon fiber is strong and light weight polymer used in many applications, includingspacecraft, wind turbines, automotive,etc. Carbon is much stronger than steel and is more durable/corrosion free. It has very high tensile strength and low thermal expansion and can withstand up to 900 degree centigrade. In this project raw carbon fiber strands chopped in 12 mm sized are been used into the pervious concrete mixture to potentially improve various properties of pervious concrete.

Specific Gravity of Carbon Fiber: 1.8

Table 1. Properties of carbon fiber

Dia. (μm)	Length (mm)	Tensile Strength (MPa)	Elastic Modulus (GPa)	Aspect Ratio (l/d)
6.97	12	4810	225	1720

Experimental Design

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We designed an experiment to examine the effects of carbon fiber of different volume fractions on the properties of concrete.Thus, in this study carbon fiber of same size fraction in two different mixtures containing two volume fractions was incorporated, followed by volume fraction in percentage as 1.33 & 0.5 for mix 1 & mix 2 respectively. Water-cement ratio for the mix 1 & mix 2 was 0.34 & 0.37 respectively. The carbon fiber was dispersed over the cement and aggregates and the dry mix was prepared. Admixture was diluted with water and then mixed with dry mix. Three types of specimen were casted for this experiment, each of two of:small cylindrical specimen,beams and cubes were casted for Cantabro test, flexural test and compressive test respectively. Slump cone test was performed to check the workability of freshly made concrete.

Figure 1: Test Specimens

Curing procedure: Due to the porous structure of pervious concrete, easily drying of the concrete can lead to loss of moisture necessarily needed for hydration of cement. Thus Plastic sheets were used to cover the exposed sides of concrete totally until demoulding to prevent the loss of moisture from top surface of concrete. After demoulding cubes were cured in water tank.

Result and Discussion

A. Porosity

Upon demoulding the specimens at 7-day age, porosity and dry density were determined. The volume of the specimens was determined based on the average dimensions, diameter and height for cylinders using a caliper. Dry mass of the specimens was noted. The submerged mass was recorded after submerging the specimen in water for 30 minutes. The difference in the mass of dry & wet specimen helped to evaluate the volume of solids[3].

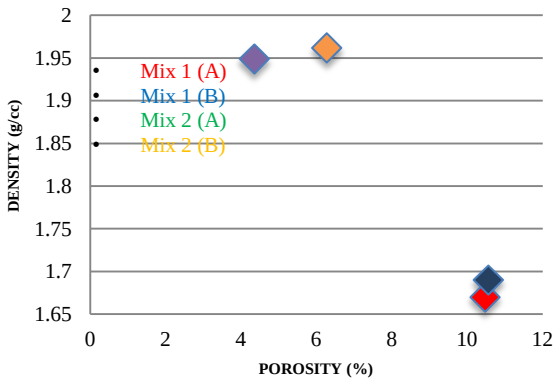

Figure 2: Graph of Porosity vs Density.

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Porosity can be calculated as:

$$Porosity = ((Mw- Md) / Md) x 100$$

Where, Mw = mass of submerged specimen in g and Md= mass of dry specimen.

- The average porosity for 1st mix was found to be 10.53%.
- The average porosity for 2nd mix was found to be 5.32 %.

B. Compressive Strength

Figure 3: Compressive Strength Test

A cube specimen of 150mm size is used for determining the compressive strength of pervious concrete. The cubes were cured for 7, 21 & 28 days. The test was performed on compression testing machine. The compressive strength of the concrete cubes was tested after 28 days of curing. The use of 150mmcubes have been made as per IS: 516-1959 & IS 456-2000[13].

- The average compressive strength for 1stmix was found to be 3.78MPa.
- The average compressive strength for 2ndmix was found to be 10.25MPa.

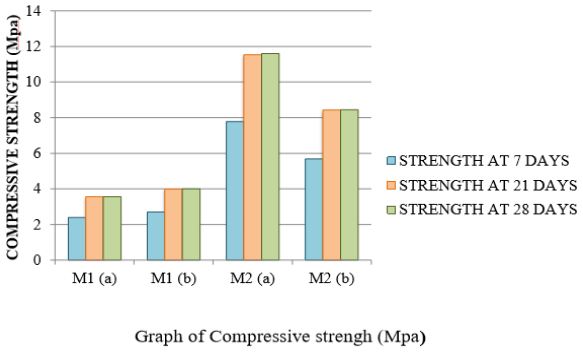

Figure 4: Graph of Compressive Strength.

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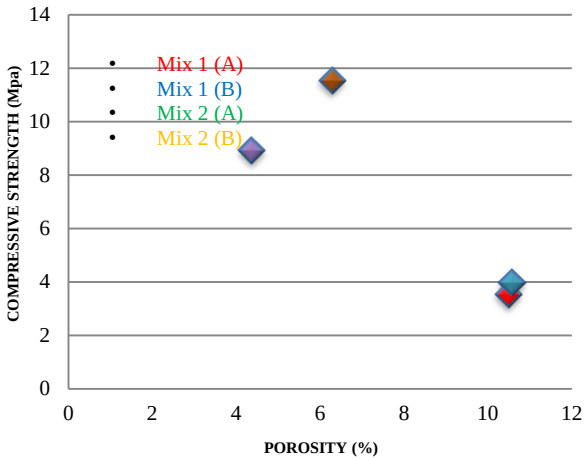

Figure 5: Graph of Porosity vs Compressive Strength

C. Flexural strength

Direct shearing stresses occur when the concrete is exposed to compressive, tensile & bending stresses. Highway pavements are the examples of the same which are subjected to flexure. Thus to evaluate the strength of concrete for pavements, bending tests needs to be done. Flexural strength is performed on 100x100x500mm beam specimens. The maximum tensile stress at rupture is known as Modulus rupture. Flexural strength sometimes is also represented as "Modulus rupture" [1].

Flexural strength was calculated as

Flexural strength= 3FL/ (2WD^2)

Figure 6 : Flexural Strength Test

- The average flexural strength for 1st mixwas found to be3.19MPa.
- The average flexural strength for 2nd mix was found to be4.88MPa.

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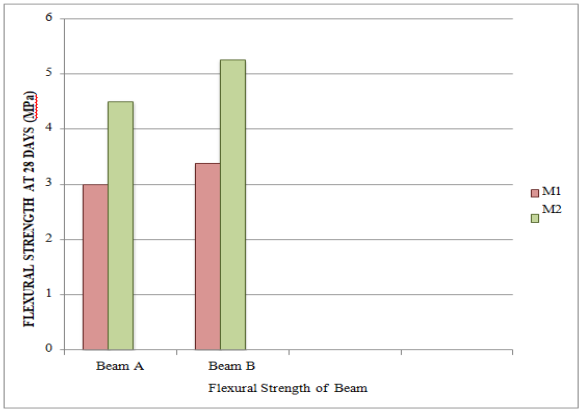

Figure 7: Graph of Flexural Strength.

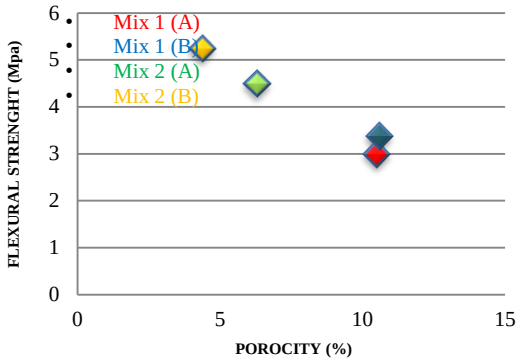

Figure 8: Graph of Porosity vs Flexural Strength.

D. Cantabro Test (for abrasion test)

The abrasion test is already performed on a coarse aggregate mix with a large amount of air voids to drain water. A porous asphalt mixture contains void content about 15%, which is very much similar to Portland Cement Pervious Concrete (PCPC).Thus considering the above similarity, the test was conducted on PCPC to determine its abrasion resistance.

Figure 9: Cantabro Test Sample.

For the abrasion test on pervious concrete, the steel ball charges are not used when the test is performed in the Los Angeles abrasion machine. The weightloss during the test was used to computethe abrasion resistance ofPCPC [14].

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- The average mass loss for 1st mix was found to be81.6%.
- The average mass loss for 2nd mix was found to be50%.

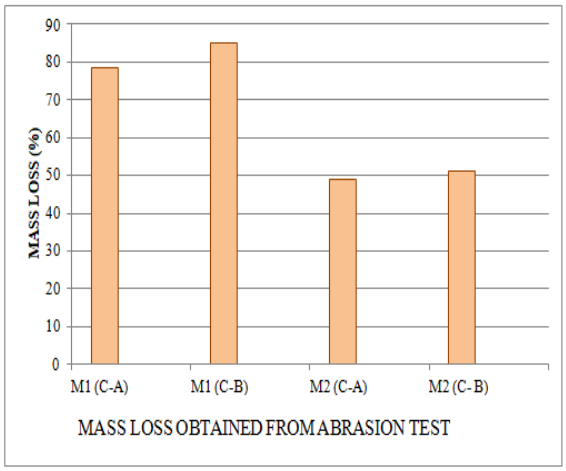

Figure 10: Cantabro Abrasion Test.

Conclusion

Based on the experimental investigation on pervious concrete following conclusions have been drawn. The study was designed and executed in order to investigate the strength and feasibility of mixing pervious concrete (PC) with carbon fiber .The results obtained from mix 2 were found to be comparatively better than mix 1. Thus considering the conclusions based on mix 2.
Main conclusions are summarized below:

- With using 0.37 w/c ratio and cement to aggregate ratio as1:4.5 the strength of reinforced pervious concrete was found to be considerably higher.
- The porosity of pervious concrete was obtained between 10-20% as compared with conventional concrete's 3%-5%.
- The Flexural strength of reinforced pervious concrete was found to be 4.88MPa which is much higher than the conventional pervious concrete.
- The Compressive strength of reinforced pervious concrete was found to 10.25MPa which was also higher than normal pervious concrete.
- The density of pervious concrete was about 1950kg/m3 which were25% lower than that of conventional concrete.

The strength of pervious concrete was significantly improved due to the usage of the carbon fiber as a reinforcing material. The porosity of the Pervious concrete was also consistently or nearly maintained. These study indicates that the addition of CCFCM has proved to be beneficial & promising to improve the overall properties of pervious concrete. Thus, more research on optimum volume and size fraction of CCFCM can be studied effectively due to its promising results.

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