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Mechanical Properties of Pervious Concrete with Partial Replacement of Cementatious Materials and Addition with Fibers

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ABSTRACT

Concrete is a combination of different materials due to its versatility, durability, sustainability, and economy it is used as a construction material. As the concrete is prepared by using vast amount of natural resources and which in turn produces significant quantity of construction and demolition waste (CDW). The impervious nature of the conventional pavement systems has resulted in increased storm water runoff quantity that has stemmed in a large volume of first flush containing unacceptable level of pollutants, and unwarranted flash floods. Moreover, the treatment of first flush requires large detention basins and purification plants before it is discharged into the natural water bodies. In addition, problems such as decreased groundwater recharge, hydroplaning surfaces, and non-skid resistant wearing courses is virtuous of the impervious pavement systems.

The main objective of this investigation is to study the tensile strength and compressive of pervious concrete. The mix design considered for this study is M30 and PC30. The fine aggregate is replaced with coarse aggregate by different ratios like 0%, 5%, 10%,15%.by adding different pozzolanic matrals like fly ash , GGBS , silica fume with glass fibers.

With reference of normal concrete pervious concrete decreases its strength. And by adding pozzolanic materials strength lightly increases. When compared to standard pervious concrete mix.

1. INTRODUCTION

Sustainable Concrete

Sustainable concrete is a concrete capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage. With the wave of sustainability also impacting the construction industry, scientist and engineers throughout the world are looking for sustainable and reusable construction materials. One such material is pervious concrete (PC). Pervious concrete is composited of cement, coarse aggregates, pozzolanic materials and fibers and small ratio of fine aggregates.Pervious concrete pavements (PCP) are permeable pavement structures, simultaneously serving storm water management and bearing pedestrian/traffic loads, depending on the application. In this pavement system, a 150– 300 mm pervious concrete (PC) layer with a high air void content is placed on a highly voided stone bed as the base layer, to allow for a rapid infiltration of runoff through the pavement system rather than allowing it to pond or run on the surface. For sidewalks, reduced icing and therefore pedestrian slipping, and for parking lots/bike trails and light traffic streets, reduced hydroplaning and wet weather accidents are among the additional expected outcomes of using PCP. PC's prominent characteristic is the high content of hardened air void, typically ranging between 15 and 25 percent of the total volume. Porosity is an essential property of PC, impacting its hydraulic, mechanical and durability characteristics, and is highly dependent on the mixture design parameters and the method of compaction. PC mixture design is based on limiting the coarse aggregate grade to single-sized or grade 9.5–19 mm, and either completely removing or using a minimal amount of fine aggregate for added strength.

Necessary to add fibers with pervious concrete

By adding the glass fibers to concrete, it is possible to improve the tensile strength of the concrete. Reinforcing glass fibers can improve the durability of the concrete matrix by increasing the ductility and absorbing energy when subjected to impact loads and external vibrations. When mixing the glass fibers into the concrete mixture, the fibers will form clusters and the uniform distribution cannot be achieved. Clusters of fibers often trap considerable amount of air, which has an adverse effect on the mechanical properties of the fiber-reinforced concrete. Therefore researchers have adopted several chemical treatment processes to increase its surface energy.

Pozzolanic materials

Pozzolanas are materials containing reactive silica which in themselves possess little or no cementitious value but which combines with lime in finely divided form in the presence of water to produce cementing compounds. Some of the pozzolanic materials that are used in this study is

Fly Ash

Fly ash is finely divided ash resulting from the burning of pulverized coal or lignite in boilers. The fly ash obtained from lignite is considered superior because of its higher lime content. Fly ash is a waste product and today, it is available in all parts of India.

GGBS

To produce GGBS, this granulated blast furnace slag is dried and ground to a fineness similar to that of Portland cement. Civil and Marine operates five slag grinding plants, located across England and Wales. Each is a sophisticated production facility, capable of processing up to half a million tonnes a year, to accurately controlled fineness. GGBS is normally used in combination with Portland cement. The GGBS and cement are added into the concrete mixer as separate constituents. Where appropriate, the ratio of GGBS to cement can be varied according to the technical requirements for any particular application. The British Standard for Concrete (BS8500) uses the following notations for specifying the percentage of GGBS as a percentage of the total cementitious content.

Silica fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable

Fibers

The concept of using fibres as reinforcement is not new. In ancient times horsehair was used in mortar and straw in mudbricks. In 1900s asbestos fibres were used in concrete. But asbestos was discouraged due to detection of health risk. In 1963 Romualdi and Botson published their classic paper on FRC. After that new material like steel, glass and synthetic fibres replaced asbestos in concrete. Research is still in progress on this technology. FRC is considered one of the greatest advancement in the construction engineering.

Some examples or famous structures built by FRC system

1. Roman colosseum was built in 80 AD, used horse-hair as secondary reinforcement.
2. Tipu Sultan's palace at Srirangpattnam has been built with Sheep's wool.
3. A Pueblo house built in 1540 with straw reinforcement adobe brick is believed to be the oldest house in the USA.
4. Use of horsehair in plaster has many historical references.

DIFFERENT TYPES OF FIBRES

1. SFRC - Steel Fiber Reinforced Concrete
2. GFRC - Glass Fiber Reinforced Concrete
3. SNFRC - Synthetic Fiber Reinforced Concrete
4. NFRC - Natural Fiber Reinforced Concrete

2. REVIEW OF LITERATURE

Anush et al. [1] In the last few years, the use of pervious concrete as a pavement material in low-volume road applications has gained importance due to its positive environmental aspects. This paper reviews the developments and state-of-the-art pertinent to pervious concrete research and practices. The investigations on mechanical-hydrological-durability properties of pervious concrete performed in various studies have been reviewed. The storm water purification efficiency of pervious concrete has been documented. The field investigations of few test sections and in-service pervious concrete pavements have been discussed. A review has been made on rehabilitation techniques to increase the hydraulic efficiency of pervious concrete pavements. A note has been mentioned on the life cycle cost analysis of pervious concrete. Due to an increased use of pervious concrete in the pavement industry due to its multitudinous benefits, there exists an expansive scope for further research to understand the material better, which will make it a promising sustainable roadway material in future.

B. Radha Kiranmaye et al. [2] Conventional Portland cement Concrete is commonly used for pavement construction. The impervious nature of the concrete pavements contributes to the increased water runoff into the drainage system, over-burdening the infrastructure and causing excessive flooding in built-up areas. Pervious concrete is a special type of concrete with a high porosity used for concrete pavement 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 glass fiber can be the effective material to improve the properties of the pervious concrete. It will explore the use of glass fiber which is environmentally detrimental. The presence of glass fiber with cement content strengthens the concrete in greater extent. In this paper, glass fiber is used as partial replacement of cement in volume fraction of 1.5%. Pervious concrete with little or no fine aggregate in various proportions is used. The study evaluates the effect of fine aggregate in varying fraction of 0%, 10% and 20% with coarse aggregate. The tests to be carried out to analyze the properties of pervious concrete are void ratio, compressive strength, flexural strength, split tensile strength and permeability test with varying fraction of fine aggregate.

B.V.R.Murthy, G.Rajeswari [3] Pervious Concrete Is A Concrete Containing Little Or No Fine Aggregate Provides Direct Drainage Of Rainwater, Helps To Recharge Groundwater In Pavement Applications. The Objective Of This Work Is To Improve Compressive Strength At Which The Strength Achieves Better Permeability. The Design Mix Is Prepared For M25 Consisting Of 53 Grade Cement, Two Different Sizes Of Coarse Aggregate Which Are Passing Through 25mm I.S Sieve Size And Retained On 16mm I.S Sieve Size As S1 And Aggregates Passing Through 10 Mm And Retained On 6mm Named As S2 Were Taken For This Work River Sand And Robo Sand Were Selected As Fine Aggregate And W/C Ratio Maintained As 0.35 In All The Cases. The Design Mix Is Developed With Constant Percentage Of Coarse Aggregate And Altering The Proportions Of Coarse Aggregate With Simultaneous Addition Of Percentages Of River Sand And Robo Sand In The Concrete. From The Experimental Results It Is Found That The Compressive Strength And Permeability Is Satisfactory At Adding Of 5% Robo Sand As A Fine Aggregate And Combination Of 80% S1 And 20% S2 As Coarse Aggregate In The Pervious Concrete.

Dang Hanh Nguyen et al. [4] As a new material type for pavement, pervious concrete should be designed to maintain both porosity and the structural strength. The actual mix proportions for pervious concrete depend on the application, the mechanical properties required and the materials used. Actually, the mix proportions of pervious concrete were determined for locally available materials based frequently on trial batching and experience. Another analytical method should be developed to facilitate the concrete producers. Based on the assumption that the cement paste only plays a role of coating, it does not fulfill the void among the grains of gravel; this paper focuses on one modified method for the design of the pervious concrete. The volume cement paste is divided by the surface area of the aggregates to determine the thickness of the excess paste. A scaling factor has been defined to evenly distribute the cement paste toward the size of gravel. Moreover, a binder drainage test is proposed to determine the critical w/c ratio towards to prevent the flow of cement paste to the lower layers of concrete under the action of vibration or compaction. The pervious concrete has been formulated according to this method to validate it. The mechanical and hydraulic tests are performed to characterize the pervious concrete. The obtained pervious concrete presents a large sufficient permeability (1 mm s_1) for draining rainwater and good mechanical resistance (Rc = 28.6 MPa) with regard to typical pervious concrete applications such as parking lots, walkways and low-traffic roadways. In addition, the mechanical strength of pervious concrete in this research is found higher than that generally reported by other authors. The results indicate that the theoretical mix design method is a successful theory for an optimizing composition of pervious concrete.

Lutfur Akand, Mijia Yang, Xinnan Wang [5] Fiber reinforcement delays the crack generation and enhances the strength of the host matrix. However, the bonding mechanism between fiber and concrete matrix is controversial in literature and needs better explanation. Due to surface smoothness and inert chemical nature of commercially available fibers, several mechanical and chemical treatment techniques have been studied by researchers to increase the fiber-matrix bonding properties. The use of fibers in pervious concrete is even more challenging due to high porosity and insufficient fiber-matrix bonding interface. This study discusses the effect of chemical treatment on short polypropylene fibers and its uses in pervious concrete as reinforcement. The change in fiber surface due to the treatment is determined through fiber wettability test and Atomic Force Microscopy (AFM). Changes on the tensile strength of fibers by the treatment methods are also tabulated. Single fiber pullout tests are conducted to study the effect of the treatment type on fiber-cement interface properties. Treated fibers are then put into pervious concrete matrix for compressive and flexural strength tests. Chemical treatments are found to improve the surface roughness and cement matrix interface properties, as well as to enhance the overall strength of the fiber reinforced pervious concrete.

Lei Lang et al. [6] The new pervious concrete (PC) were prepared using magnesium phosphate cement (MPC) as binding and waste steel slag as coarse aggregate. A series of laboratory experiments were carried out to study the influence of aggregate size and molding method on the compressive strength, flexural strength, porosity and water permeability coefficient of magnesium phosphate cement steel slag pervious concrete (MSPC). Experimental results showed that the influence of aggregate size on compressive strength is different when different molding methods were adopted. Through comparative analysis, the MSPC with medium particle size formed by vibration molding had the highest compressive strength, and the maximum can reach 41.5 MPa. Based on the excellent bonding strength of MPC, the MSPC has better flexural strength than traditional PC, and the maximum 28-day flexural strength can reach 8.0 MPa. The porosity increases with the increase of aggregate size, and which is in the range of 23.8–26.5% for all the MSPC mixtures. Similarly, the water permeability coefficient of MSPC increases as the increase of aggregate size, and with the range from 5.85 to 7.10 mm/s. The 28-day bend-press ratio of MSPC is close to 1/5. Unlike the traditional PC, the mechanical strength of MSPC increased first and then decreased with the porosity, while regardless of aggregate size and molding method, the water permeability coefficient increased linearly with the porosity. The test results indicate that the MSPC made of steel slag aggregates and MPC is a very promising eco-friendly PC.

Lutfur Akand et al. [7] Fiber reinforcement delays the crack generation and enhances the strength of the host matrix. However, the bonding mechanism between fiber and concrete matrix is controversial in literature and needs better explanation. Due to surface smoothness and inert chemical nature of commercially available fibers, several mechanical and chemical treatment techniques have been studied by researchers to increase the fiber-matrix bonding properties. The use of fibers in pervious concrete is even more challenging due to high porosity and insufficient fiber-matrix bonding interface. This study discusses the effect of chemical treatment on short polypropylene fibers and its uses in pervious concrete as reinforcement. The change in fiber surface due to the treatment is determined through fiber wettability test and Atomic Force Microscopy (AFM). Changes on the tensile strength of fibers by the treatment methods are also tabulated. Single fiber pullout tests are conducted to study the effect of the treatment type on fiber-cement interface properties. Treated fibers are then put into pervious concrete matrix for compressive and flexural strength tests. Chemical treatments are found to improve the surface roughness and cement matrix interface properties, as well as to enhance the overall strength of the fiber reinforced pervious concrete.

Milena Rangelov et al. [8] Pervious concrete pavements are gaining popularity for stormwater management. Therefore, there is an impending need for the development of quality control and acceptance specifications. In this study, the necessary initial steps are taken towards this goal. The procedures to conduct fresh and hardened density/porosity (u) and 28-day compressive strength (f 0 c) were evaluated. The proper methodology for casting specimens in the field was identified by examining the agreement between the fresh (D) and hardened density (q). The effect of cylindrical size, and curing methods as combinations of air and moist curing during the four-week period on f 0 c was studied. Both cylinder sizes demonstrated comparable values of hardened porosity (u = 16 percent) and hardened density (D = 2.11 kg/m3), as well as strong linear u–D correlations (R2 range 0.60–0.90). The values of D agree well with those of the fresh density (two percent or less difference), which confirmed the suitability of the implemented casting and compaction procedure. Small cylinders presented higher 28-day f 0 c than large cylinders by 7.7 to 19 percent, depending on the curing category. The two-week air followed by two-week moist curing (2A2 M) method yielded the highest 28-day f 0 c for both specimen sizes, however, longer periods of moist curing did not result in higher strengths. Cylinders from 1A3M, which were exposed to the longest moist curing, demonstrate the lowest f 0 c. Thermo gravimetric analysis (TGA) confirmed the trends seen in 28-day f 0 c and proved (that) longer moist curing resulted in the loss of C–S–H and Ca(OH)2. 2017Chinese Society of Pavement Engineering.

Critical Review:

From all the above literature reviews we need to compare the results of pervious concrete with and without pozzolanic materials as addition of fibers with cement, fly ash, GGBS and silica fume with different fine aggregate ratio.

- Further studies can also be done like flexure strength & split tensile strength with fibers.
- we need to compare Acid attack for pervious concrete.
- Durability tests like sulphate attack, corrosion, permeability, chloride penetration test also need to be done for PC
- Elevated temperatures for PC for different replacements.

3. PRELIMINARY INVESTIGATION

Cement

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel crushed stone to make a concrete. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials, clay predominates and in calcareous materials calcium carbonate predominates. Ordinary Portland cement of grade – 53 (KCP cement) conforming to Indian standards (IS: 12269-1987) has been used in the present study.

The chemical and physical properties of the Cement were tested as per the IS: 4031-1985 & IS: 4031-1988 respectively. OPC 53 Grade cement is required to conform to BIS specification IS: 12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/cm2.

Physical Properties of ordinary Portland cement.

S.NO	Characteristics	Values obtained	Values as per Is Code
1	Specific gravity of Cement	3.136	3.15
2	Fineness of cement	7.2%	10% residue on 90 micron sieve
3	Standard consistency	33%	Minimum 23% as per present code
4	Initial setting time	35	Not less than 30 minutes
5	Final setting time	330	Not greater than 600 minutes
6	Compressive strength of cement (MPa) 3 days 7 days 28 days	 28.4 36.9 54.2	 23 37 53

Brand of cement – OPC 53 grade (KCP)

Result – The properties of the cement tested lie within the Indian standard limits and are considered to be of standard quality.

Fine aggregate:

The material which passes through 4.75 mm sieve is termed as fine aggregate. Usually natural sand is used as affine aggregate at places where natural sand is not available crushed stone is used as affine aggregate. The sand used for the experimental works is locally procured and According to IS 383-1970. It is conformed to grading zone II.

Physical Properties of Fine aggregates

S. No	Property	Test Results	Standard Limits	IS Standard Testing Code
1	ecific gravity (Fine aggregate) Zone II Sand	2.5019	> 2.5	1963] Part III
2	Fineness modulus of Fine aggregates	**2.58**	2.6-3.2 (Coarse Sand)	-1963 Part III
3	Bulk Density in fine aggregates	**1.49**	1.5 ~ 1.7	IS 2386-1963 Part III
4	Water absorption	**0.47**	(0.5- 1) %	IS 2386-1963 Part III

Type of Fine aggregates -
Natural river sand

Result – The properties of the fine aggregates tested lie within the Indian standard limits and are considered to be suitable for production of concrete since the properties come under ZONE II category

Natural Coarse aggregates

Aggregate which retained on 4.75 mm sieve and the broken stone is generally used as a Coarse aggregates. The nature of work decides the maximum size of the coarse aggregates. Locally available coarse aggregates having the maximum size 20 mm and minimum size 10 mm was used in the present work.

Several laboratory testing will be carried out and compared to the standard requirements as per IS: 2386-1963 has grouped the test methods for aggregates into different parts.

Physical Properties of natural coarse aggregates

S.No	Property	Test Results	Permissible Limit	IS Standard Testing Code
1	Specific gravity	For 20 mm-2.80 For 10 mm-2.68	2.5 to 3.0	IS 2383-1986
2	Water Absorption	For 20 mm-0.3 For 10 mm-0.60	Not more than 0.6 %	IS 2383-1986
3	Bulk density **(kg/m ^{3})**	1738	1520 to 1680 kg/m^3	IS 2383-1986
4	Flakiness Index %	11.3%	Not more than 15 %	IS 2383-1963 Part 1
5	ngation Index	18.9%	Not more than 15 %	IS 2383-1963 Part 1
6	Aggregate Impact Value	28.6%	Not more than 30%	IS 2383-1963 Part 1
7	Aggregate Crushing Value	26.459%	Not more than 30%	IS 2383-1963 Part 1
8	Fineness modulus	6.27	-	IS 2383-1963 Part 1

Pozzolanic materials

Pozzolans are materials containing a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. Pozzolanic materials like fly ash and silica fume and their properties are discussed below.

Fly ash:

Fly ash, also known as "pulverised fuel ash" in the United Kingdom, is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. Fly ash is a fine grained material consisting mostly of spherical, glassy particles. It is a by-product of the combustion of pulverized coal in thermal power plant. The use of fly ash in concrete is to achieve more benefits like improving workability, durability and reduction of heat of hydration. As a part of the composite concrete mass, fly ash acts both as a fine aggregate and as a cementitious component. It influences the rheological properties of the fresh concrete and the strength, finish, porosity and durability of the hardened concrete mass. There are two general classes in fly ash:

- Class C, normally produced from lignite or subbituminous coal and
- Class F, normally produced from bituminous coals.

Fly ash from the combustion of subbituminous coal contains more calcium and less iron than the fly ash from the bituminous coal. Fly ash used in experimental work was obtained from simhadri thermal power plant, NTPC, Visakhapatnam.

Silica fume:

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolanic.

Concrete containing silica fume can have very high strength and can be very durable.Properties of silica fume as per IS codes

S.NO	Description of test	IS code
1	Specific gravity	IS 15388-2003
2	Fineness	IS 15388-2003

Silica fume, also known as micro silica which is a non-crystalline material of silicon dioxide, silica. It is the by-product of silicon and ferrosilicon alloy production and contains of spherical particles with an average particle diameter of 150nm. Silica fume is an ultrafine powder and improves bonding with in the concrete. Silica fume reduces the permeability, increases the durability and increases the compressive and flexural strength. Silica fume used in experimental work was obtained from local industries of Visakhapatnam.

GGBS:

Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

CONCRETE MIX DESIGN

Mix design is a process of selecting suitable ingredients and determining their relative proportions with the objective of producing concrete of having certain minimum workability, strength and durability as economically as possible.

S.NO	Description of test	IS code
1	Concrete mix-proportioning	IS 10262-2009

Mix Proportion = Cement: Fine Aggregate: Coarse Aggregate: water 330: 725: 1242: 0.45

Mix Proportions:

Mix Design is done for M30 grade of concrete as per code specifications IS 10262-2009. Several trail mixes were carried out and cubes casted for the above grades of concrete to attain the required target strength before the final design mixes are fixed by considering the optimum cement content and water- cement ratio as per BIS Standards.

Grade esignati on	Cement (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (kg/m^3)	W/c ratio	Target strength	Compressive strength (MPa)	
							7 days	28 days
M30	330	725	1242	148.5	0.45	38	26.3	38.27

4. EXPERIMENTAL INVESTIGATION

Trail mix design of PC 30

The selection of water cement ratio plays an important role during the production of Pervious Concrete (PC). Three trail batches were conducted using mix proportions mentioned. First trail and second trail containing PC30 with w/c ratios 0.45 and 0.40, have failed to achieve 7 days compressive strength. The third trail was conducted with same mix proportions but with lowered w/c ratios in PC. i.e. 0.38 we have achieved the strength.

Mix designation	Cement (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	W/C Ratio	Slump (mm)	Compressive strength(MPa) for 28 days
M30	330	725	1242	**0.45**	**61**	**38.27**
	330	725	1242	**0.40**	**57**	**37.42**
	330	725	1242	**0.38**	**49**	**34.50**
	330	725	1242	**0.50**	**52**	**35.00**

Grade designation	Cement (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	W/c ratio	Target strength	Compressive strength (MPa)	
						7 days	28 days
M30	330	725	1242	0.45	38	26.3	38.27

Details of final mix proportions in PC:

Proper mix design proportion were fixed after several trail mixes mentioned in table and the finalized mixes of pervious concrete made up of 0%,5%,10%,15% of fine aggregates were mentioned in table

Percentage Quantities of materials required for different replacement of Fine aggregate Pervious concrete and using pozzolanic materials of PC30 grade:

MIX DESIGNATION		M S	M P	M 1	M 2	M 3	UNITS
CEMENT		100	100	85	80	75	%
FLY ASH		0	0	5	10	10	%
GGBS		0	0	5	5	10	%
SILICA FUME		0	0	5	5	5	%
FINE AGGREGATE		100	0	5	10	15	%
COARSE AGGREGATE	**20 mm**	70	70	65	60	55	%
	10 mm	30	30	30	30	30	%
WATER		100	100	100	100	100	%
SP		100	100	100	100	100	%

Quantities of materials required for different replacement of Fine aggregate Pervious concrete and using pozzolanic materials of PC30 grade:

MIX DESIGNATION		M S	M P	M 1	M 2	M 3	UNITS
CEMENT		330	330	280.50	264.00	247.50	kg/m³
FLY ASH		0	0	16.50	33.00	49.50	kg/m³
GGBS		0	0	16.50	16.50	33.00	kg/m³
SILICA FUME		0	0	16.50	16.50	16.50	kg/m³
FINE AGGREGATE		725	0	43.47	86.94	130.41	kg/m³
COARSE AGGREGATE	20 mm	869.40	869.40	825.93	784.46	738.99	kg/m³
	10 mm	372.60	372.60	372.60	372.60	372.60	kg/m³
WATER		148.50	148.50	148.50	148.50	148.50	kg/m³
SP		9.90	9.90	9.90	9.90	9.90	kg/m³

Compressive strength of hardened Pervious Concrete (PC30):

Minimum of three specimens were selected for conducting compressive strengths at 7 days. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected.

S.No	Description of test	IS code
1	Compression Testing Method	IS 516 [1959]

Split tensile strength:

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete member that may crack.

S.NO	Description of test	IS code
1	split tensile strength	IS 5816

PC 30 mix with and with pozzolanic materials.

MIX DESIGNATION		M S	M P	M 1	M 2	M 3	UNITS
CEMENT		100	100	85	80	75	%
FLY ASH		0	0	5	10	10	%
GGBS		0	0	5	5	10	%
SILICA FUME		0	0	5	5	5	%
FINE AGGREGATE		100	0	5	10	15	%
COARSE AGGREGATE	20 mm	70	70	65	60	55	%
	10 mm	30	30	30	30	30	%
WATER		100	100	100	100	100	%
SP		100	100	100	100	100	%

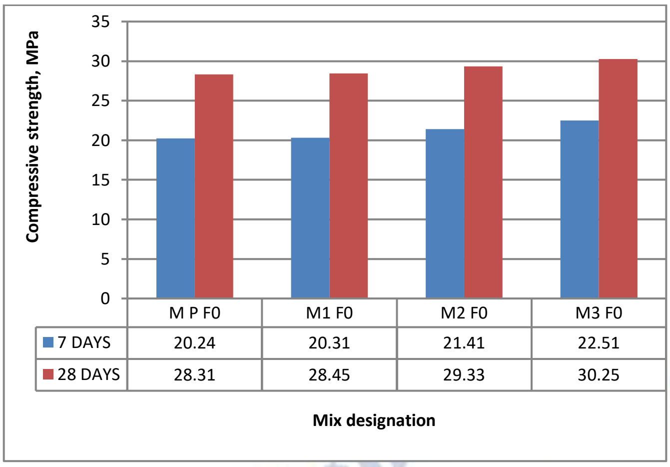
No of specimens casted for testing for PC

Type of PC mix	Mix designation	No of cubes at days		No of cylinders at days	
		7	28	7	28
PC 30	M S	3	3	3	3
	M P	3	3	3	3
	M P F 0.5	3	3	3	3
	M P F 1.0	3	3	3	3
	M P F 1.5	3	3	3	3
	M 1	3	3	3	3
	M 1 F 0.5	3	3	3	3
	M 1 F 1.0	3	3	3	3
	M 1 F 1.5	3	3	3	3
	M 2	3	3	3	3
	M 2 F 0.5	3	3	3	3
	M 2 F 1.0	3	3	3	3
	M 2 F 1.5	3	3	3	3
	M 3	3	3	3	3
	M 3 F 0.5	3	3	3	3
	M 3 F 1.0	3	3	3	3
	M3 F 1.5	3	3	3	3
Total		51	51	51	51

5. RESULTS AND DISCUSSION

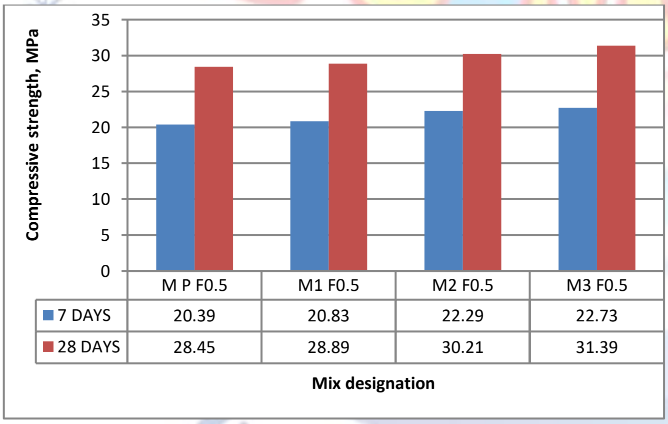
Compressive strength of PC 30 with & without Pozzolanic materials for 7 & 28 days. (Pozzolanic materials such as GGBS and silica fume and fly ash)

S.No	Mix designation	Compressive Strength (n/mm2)	
		7 DAYS	28 DAYS
1	M P F0	20.24	28.31
2	M1 F0	20.31	28.45
3	M2 F0	21.41	29.33
4	M3 F0	22.51	30.25



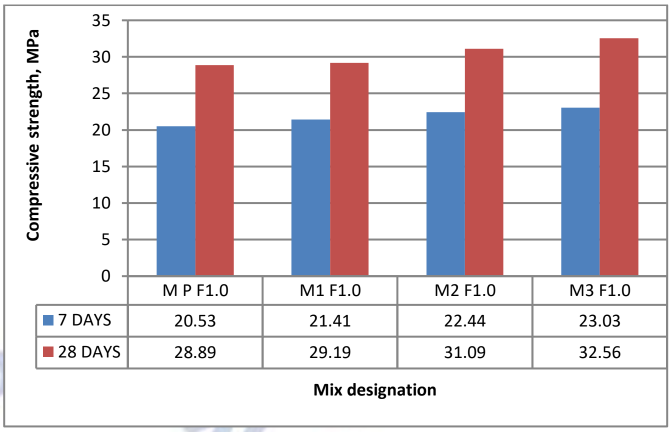
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

S.No	Mix designation	Compressive Strength (n/mm2)	
		7 DAYS	28 DAYS
1	M P F0.5	20.39	28.45
2	M1 F0.5	20.83	28.89
3	M2 F0.5	22.29	30.21
4	M3 F0.5	22.73	31.39



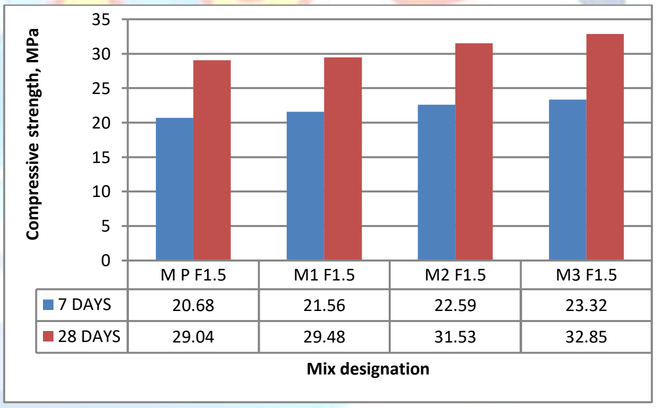
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

S.No	Mix designation	Compressive Strength (n/mm2)	
		7 DAYS	28 DAYS
1	M P F1.0	20.53	28.89
2	M1 F1.0	21.41	29.19
3	M2 F1.0	22.44	31.09
4	M3 F1.0	23.03	32.56



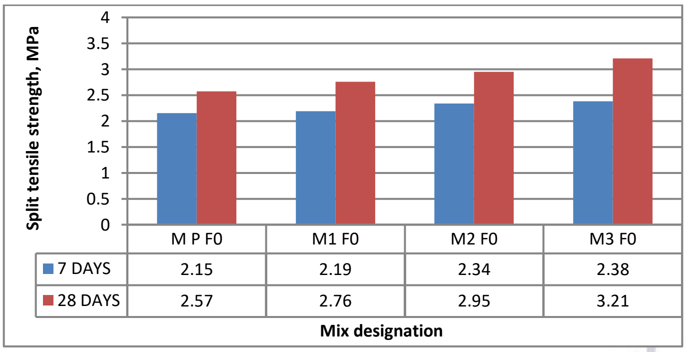
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

S.No	Mix designation	Compressive Strength (n/mm2)	
		7 DAYS	28 DAYS
1	M P F1.5	20.68	29.04
2	M1 F1.5	21.56	29.48
3	M2 F1.5	22.59	31.53
4	M3 F1.5	23.32	32.85



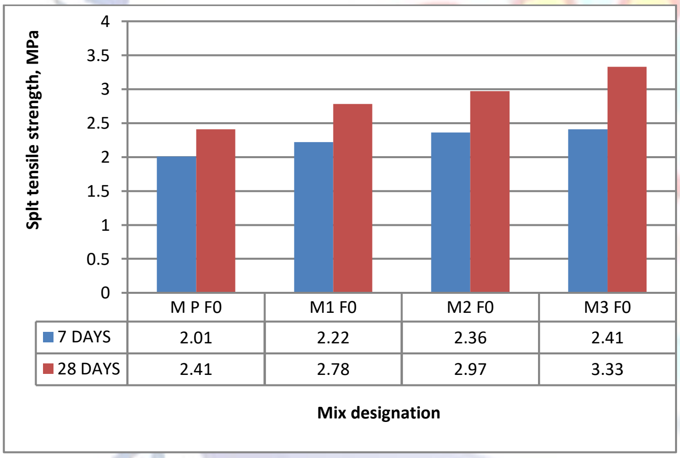
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

S.No	Mix designation	Split tensile Strength (Mpa)	
		7 DAYS	28 DAYS
1	M P F0	2.15	2.57
2	M1 F0	2.19	2.76
3	M2 F0	2.34	2.95
4	M3 F0	2.38	3.21



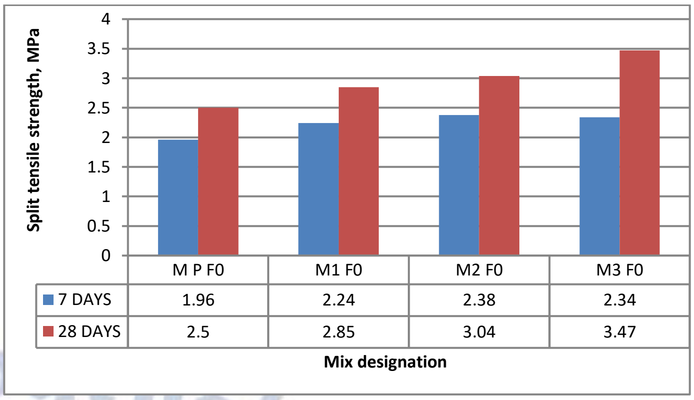
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

S.No	Mix designation	Split tensile Strength (Mpa)	
		7 DAYS	28 DAYS
1	M P F0.5	2.01	2.41
2	M1 F0.5	2.22	2.78
3	M2 F0.5	2.36	2.97
4	M3 F0.5	2.41	3.33



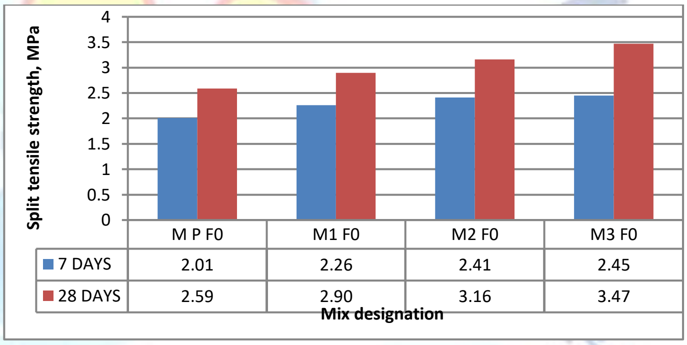
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

S.No	Mix designation	Split tensile Strength (Mpa)	
		7 DAYS	28 DAYS
1	M P F1.0	1.96	2.50
2	M1 F1.0	2.24	2.85
3	M2 F1.0	2.38	3.04
4	M3 F1.0	2.34	3.47



SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

S.No	Mix designation	Split tensile Strength (Mpa)	
		7 DAYS	28 DAYS
1	M P F1.5	2.01	2.59
2	M1 F1.5	2.26	2.90
3	M2 F1.5	2.41	3.16
4	M3 F1.5	2.45	3.47



6.SUMMARY AND CONCLUSIONS

The results from a wide experimental campaign carried out for evaluating the most important physical and mechanical properties like split tensile, compressive strength of PC30 with and without pozzolanic materials for different replacement of fine aggregates with coarse aggregates. The main test variables of concrete have been produced by replacing (0%, 5%, 10% and 15%) given amounts of fine aggregates with coarse aggregate concrete and by adding fly ash and Silica fume and GGBS in partial replacement of Cement.

The following Conclusions can be summarized by analyzing tests performed on PC specimens:

- A significant reduction of workability.
- A progressive addition in both split tensile and compressive strength by increasing the percentage of fine aggregates and pozzolanic materials in mix.

- The inclusion of fine aggregate content in the specimen increases the density and increase the pozzolanic materials addition.
- The addition of fly ash and silica fume and GGBS in the mixtures enhances the split tensile strength and compressive strength performance of the concrete,
- The addition of Fly ash and silica fume and GGBS in the mixtures improve strength.
- The split tensile strength and compressive strength increases even after adding pozzolanic materials. Due to increase of fine aggregate content.
- For all replacement levels of PC with other mixes goes on decreasing in strength when compared with parent grade of M30.
- Compressive and split tensile strength slightly increased by adding glass fibers to the all mixes.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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