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Study on Pervious Concrete by Partial Replacement of Cement with Fly Ash , GGBS, Silica Fume and Adding Glass 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.

Keywords:- fly ash, GGBS, Cement, silica fume, compressive strength.

INTRODUCTION

Concrete has historically been and remains the building material of choice because it is readily available, versatile, and cost-effective and can be made durable. With the new millennium progressing, the construction industry faces challenges not only in terms of the material strength but also in leading the production towards a sustainable development. The cement-concrete industry is one of the largest consumers of natural resources. World demand for cement is projected to rise to 5.2 billion metric tonnes in 2019. For every one ton of cement clinker produced, one ton CO_2 is generated causing serious environmental concerns. More than 56% of the CO_2 emissions are caused by the thermal decomposition of calcium carbonate into calcium oxide and during the sintering process of portland clinker. With this amount of the gas pollutant production, the cement industry accounts for second largest producer at global level. Besides consuming considerable amount of resources to an extent of exploitation, it also requires energy consuming industrial process making it the most expensive component of concrete.

The materials that are byproducts from other processes or natural materials which may or may not be further processed and being used in place of conventional OPC are referred to as Supplementary cementing materials (SCMs). The SCMs or pozzolanas are siliceous or siliceous and aluminous materials which in itself possess little or no cementitious value but will, in finely divided form and in the presence of moisture chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. These are the materials that, when used in conjunction with portland cement contributes to the properties of hardened concrete through hydraulic or pozzolanic activity or both. Examples of supplementary cementing materials include ground granulated blast furnace slag, fly ash, silica fume, metakaolin, glass powder, rice husk ash, limestone powder, calcined clay etc. Mineral admixtures have a beneficial influence on many properties of fresh and hardened concrete, either through purely physical effects associated with the presence of very fine particles or through physio-chemical effects associated with pozzolanic and cementatious reactions.

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.

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.

LutfurAkand, 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.

EXPERIMENTAL WORK

TESTS ON CEMENT

The cement used is ordinary Portland cement (OPC 53) confirming to IS: 12269-1987. The KCP OPC 53 grade is used in experimental work. The physical properties of the cement are tested in accordance with IS: 4031-1988.

S.No	Description of test	Test result	Permissible limits
1.	Specific Gravity	3.09	3.15
2.	Fineness	7.8%	Should not exceed 10% residue on 90 micron sieve(max)
3.	Standard consistency	33%	Minimum 23 % till obtaining viscous paste
4.	Initial Setting time	30 min	Should not be less than 30 minutes
5.	Final setting time	275 min	Maximum 600 minutes

TESTS ON FINE AGGREGATE

Fine aggregate should pass through I.S. sieve 4.75 mm. Standard coarse sand is to be from river origin. According to IS 383-1970, fine aggregate used in this present study confirms to zone – II classification.

S. No	Property	Test Results	Standard Limits	IS Standard Testing Code
1	S Specific gravity (Fine aggregate) Zone II Sand	2.5019	> 2.5	IS 2386-1963] Part III
2	Fineness modulus of Fine aggregates	2.58	2.6-3.2 (Coarse Sand)	IS 2386-1963 Part III
3	Bulk Densityin Fineaggregates	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 ofFineaggregates - Natural riversand 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

S.No	Property	Test Results	Permissible Limit	IS Standard Testing Code
1	Specific gravity	For 20mm-2.80 For 10mm-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	El Elongation 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

Mix Proportions:

Grade designation	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

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/m^3

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

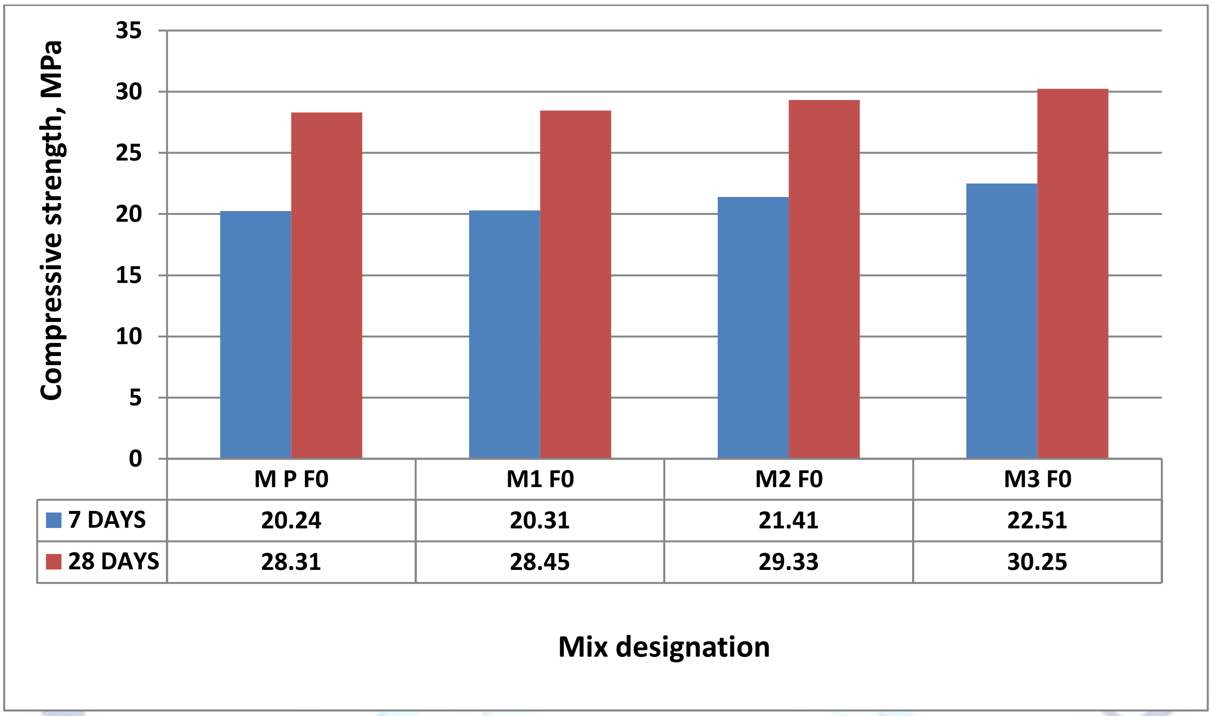
Table 5.4 PC 30 mix with and with pozzolanic materials.

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	%

RESULTS AND DISCUSSIONS

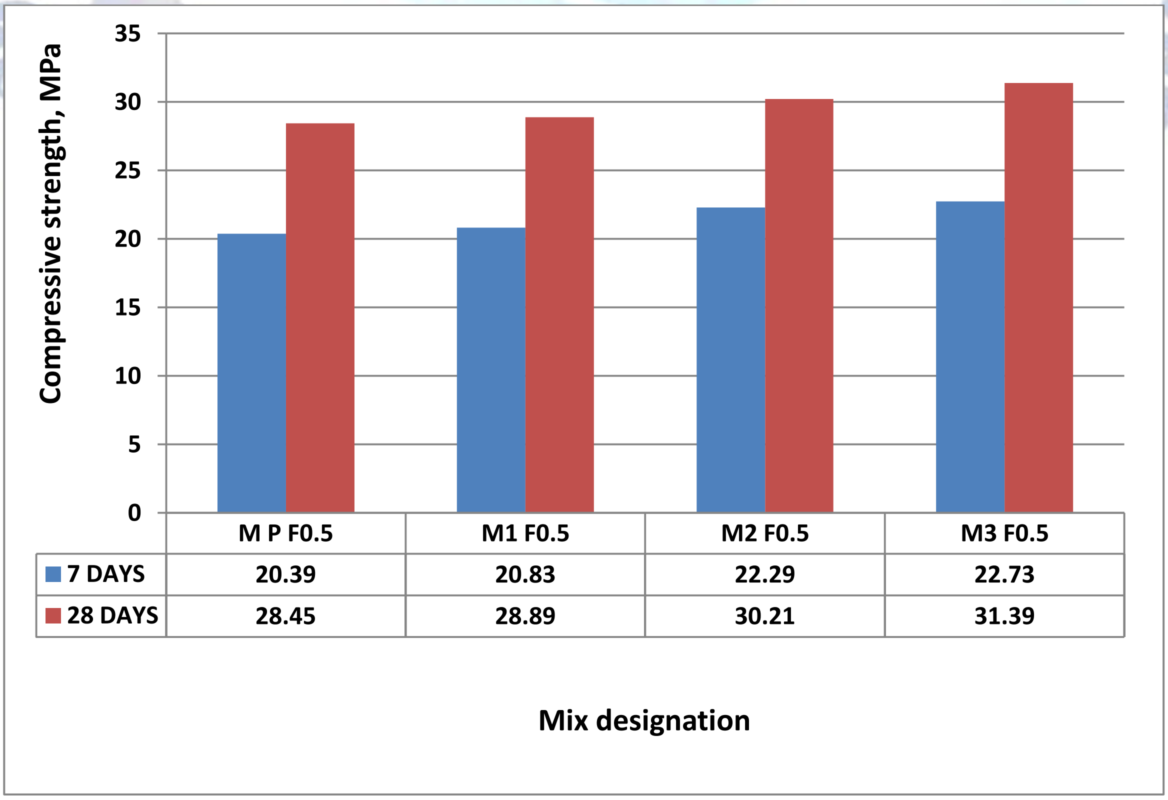
a) Compressive strength of PC 30 with & without Pozzolanic materials for 7 & 28 days. (Pozzolanic materials such as GGBS and silica fume and fly ash)

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



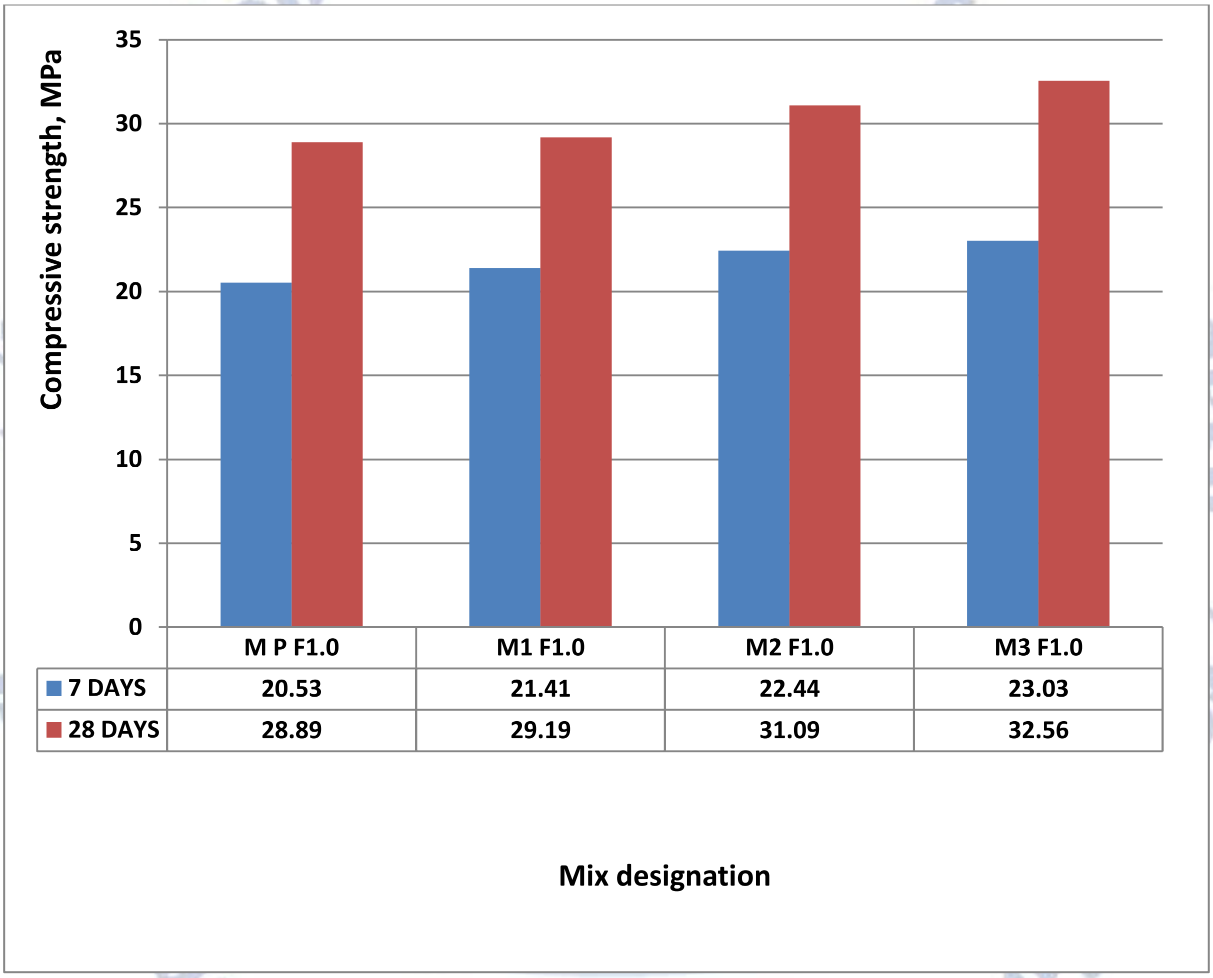
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

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



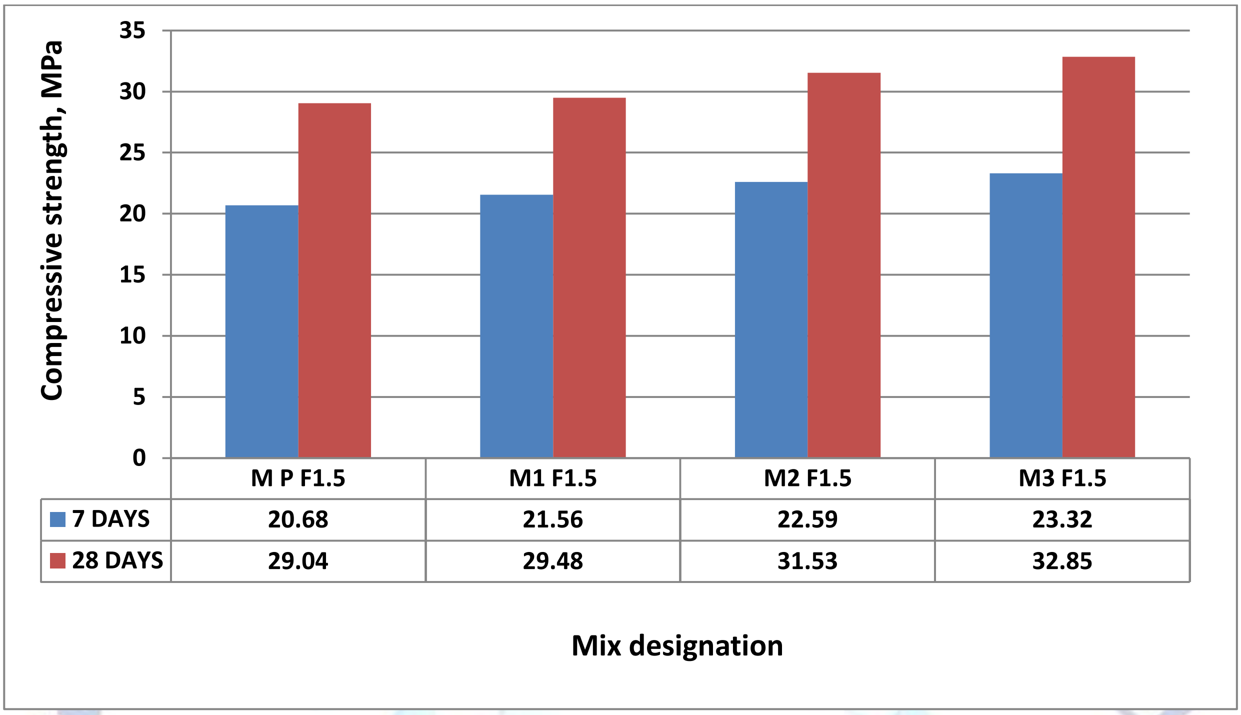
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

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



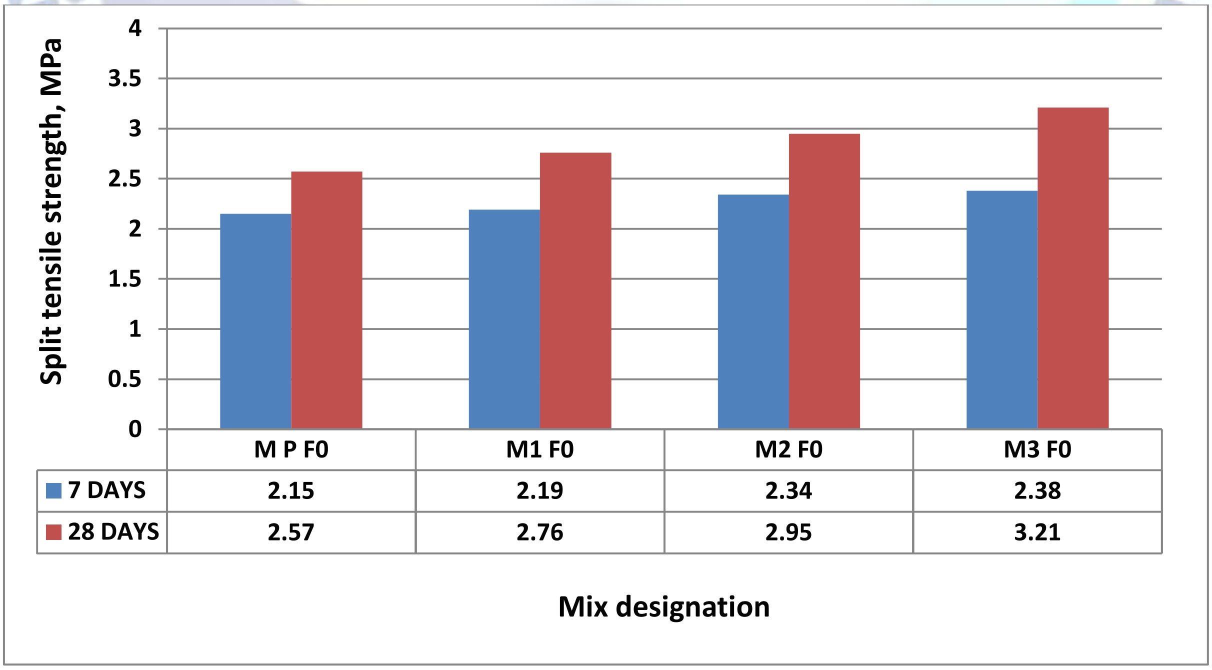
COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL AND DIFFERENT PERCENATGE OF FINE AGGREGATE AND ADDITION WITH GLASS FIBERS

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



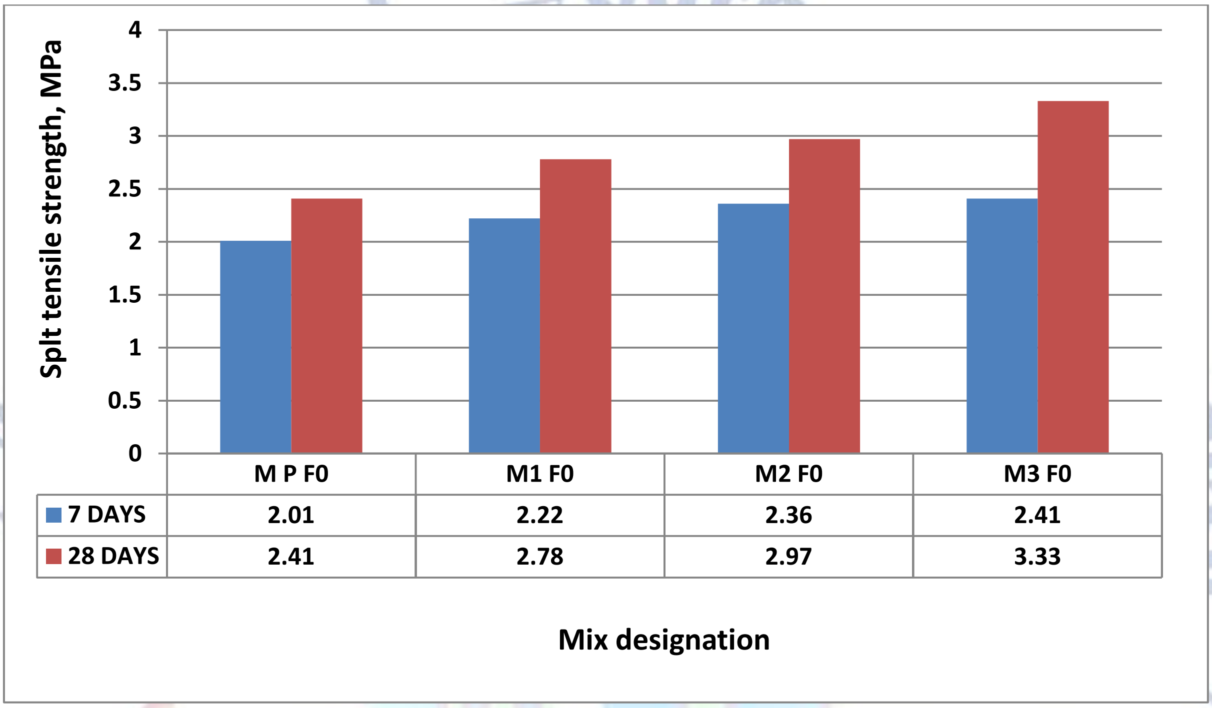
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

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



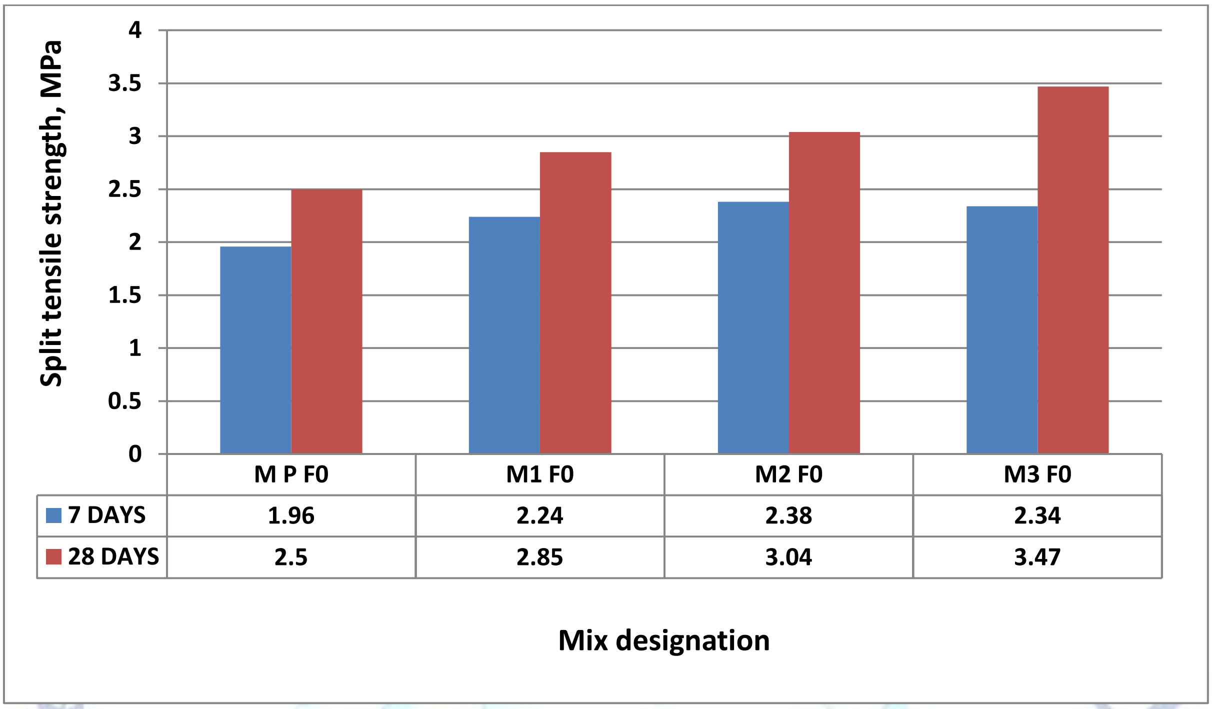
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

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



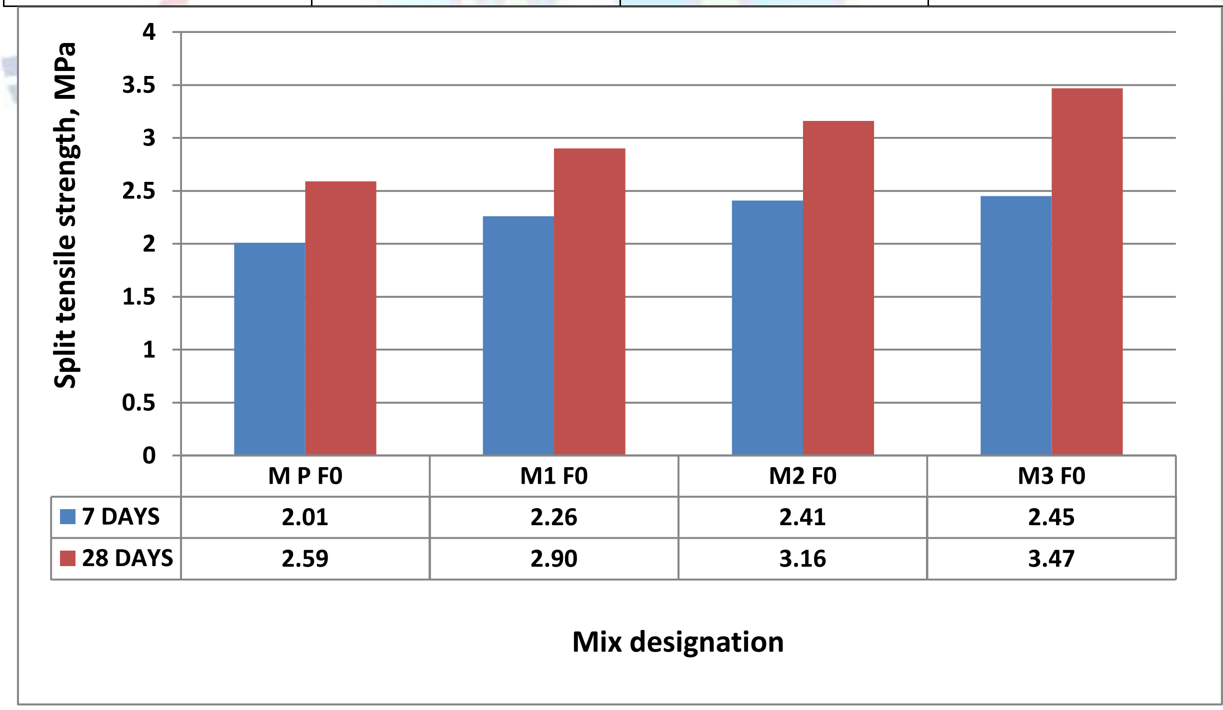
SPLIT TENSILE STRENGTH STRENGTH OF PERVIOUS CONCRETE; VARIOUS PECETAGE REPLACEMENTS OF CEMENT WITH OTHER CEMENTATIOUS MATERIAL.

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



CONCLUSIONS

- 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 ofM30.

Compressive and split tensile strength slightly increased by adding glass fibers to the all mixes

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