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Experimental Investigation Pervious Concrete by using GGBS, Microslica and Artificial Fibers

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Abstract: Pervious concrete is a light-weight concrete which is prepared by eliminating the fine aggregate from conventional concrete, also known as 'no fine concrete' or 'porous concrete'. It is a combination of graded coarse aggregates, cement materials and water. Now-a-days we are very much interested in sustainable and eco-friendly way of constructions. It is an important application for sustainable construction.

It is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses. The experimental investigation will be carried out to study the properties of concrete with artificial fibers (Polypropylene fiber & Steel fiber) to increase the strength of the concrete with replacement of cement by different percentage of GGBS & micro silica problems will be discussed in this project.

Keywords: M40 grade, GGBS & micro silica, Pervious, Polypropylene fiber, Steel fiber, etc.

I. INTRODUCTION

Pervious concrete (also called porous concrete, permeable concrete, and no fines concrete and porous pavement) is a special type of concrete with a high porosity 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 groundwater recharge. Pervious concrete is made using large aggregates with little to no fine aggregates.

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 impact development techniques used by builders to protect water quality.

Pervious concrete was first used in the 1800s in Europe as pavement surfacing and load bearing walls. Cost efficiency was the main motive due to a decreased amount of cement. It became popular again in the 1920s for two storey homes in Scotland and England. It became increasingly viable in Europe after WWII due to the scarcity of cement. It did not become as popular in the US until the 1970s. In India it became popular in 2000

II. MATERIALS USED

1) 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. The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength.
2) Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.
3) Polypropylene (PP) is a thermoplastic. It is a linear structure based on the monomer C_nH_{2n}. It is manufactured from propylene gas in presence of a catalyst such as titanium chloride. Beside PP is a by-product of oil refining processes. Polypropylene chips can be converted to fibre/filament by traditional melt spinning, though the operating parameters need to be adjusted depending on the final products. Spun bonded and melt blown processes are also very important fiber producing techniques.
4) Steel fibre is a metal reinforcement. A certain amount of steel fibre in concrete can cause qualitative changes in concrete's physical property, greatly increasing resistance to cracking, impact, fatigue, and bending, tenacity, durability, and other properties


A. Silica fume


B. Polypropylene fibre


C. Steel fibres

III. MATERIAL TESTING

A. Tests For Cement

Specific Gravity Of Cement

Initially the empty dry density bottle was weighed and taken as M1. Then the bottle is filled with some amount of cement and it was weighed as M2. Then the density bottle was filled with kerosene up to the top and it was weighed as M3. Then the density bottle was dried and filled up to the top with kerosene and weighed as M4.

Specific gravity of cement, G = (M2 – M1) / [(M2 –M1) – (M3 –M4)]

M1 = Mass of empty density bottle
M2 = Mass of density bottle with cement
M3 = Mass of the density bottle with cement and kerosene
M4 = Mass of the density bottle completely filled with kerosene
The specific gravity of cement is generally around 3.15(IS: 4031-PART 11-1988)

B. Tests For Coarse Aggregate

1) *Specific Gravity Of Coarse Aggregate:* The specific gravity of aggregates ranges from about 2.5 to 3.0 (IS 2386 – 1963 part I - IV)
2) *Sieve Analysis Of Coarse Aggregate:* The permissible values of fineness modulus of coarse aggregate 6.50 to 8.00 (IS 12269 – 1987 (225)
3) *Aggregate Crushing Test:* The value is not exceed in 45% Refer (IS: 2386 – Part 4)
4) *Aggregate Impact Test:* The value is not exceed in 45% Refer (IS: 283-1970)

C. Tests for GGBS

Specific Gravity Of Ggbs

D. Tests For Silica Fume

Specific Gravity Of Microsilica

IV. MIX DESIGN

Mix design for M40 grade concrete by Indian Standard Institute recommended method of concrete mix design as per design code IS 456: 2000

A. Stipulations of Proportioning

- Grade designation = M40
- Type of cement and grade of cement = PPC
- Maximum nominal size of aggregate = 20 mm
- Minimum cement content = 360 kg/m3
- Workability in term of slump = 50 mm (slump)
- Exposure Condition = mild (for reinforced concrete)
- Type of aggregate = Crushed angular
- Maximum cement content = 450 kg/m3
- Water cement ratio = 0.45

B. Test Data of Material

- Specific gravity of cement = 3.16
- Specific gravity of fine aggregate = 2.69
- Specific gravity of coarse aggregate = 2.73

C. Target Strength

- f' ck = fck + 1.65 s
  = 40 + 1.65 x 5
  = 48.25 N/mm2
- f' ck = Target mean compressive strength at 28 days
- fck = Characteristic compressive strength at 28 days
- s = Standard deviation.

D. Water Cement Ratio

- Maximum water cement ratio = 0.40

E. Water Content

- Maximum 20mm aggregate = 185 kg (25 to 50mm slump)
- For every 50mm Slump = 185 Litres
- As superplasticizer is used, the water content can be reduced up 20 percent and above.
- Based on trials with superplasticizer water content reduction of 29 percent has been achieved. Hence, the arrived water content = 185 * 0.71 =131.35 liters .

F. Calculation of Cement Content

- Water cement ratio = 0.4
- Cement content =131.35/0.40 = 328.375 kg/m3> 450 kg/m3
- Cement content = 328.38 kg/m3
- From Table 5 of IS 456, minimum cement content for “mild " exposure
- Condition = 300 kg/m3 < 328.38 kg/m3.

G. Aggregate Proportion between Coarse and Fine Aggregate

ACI (211.1 -1991) , Volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone-I) for water cement ratio 0.50 = 0.60 .

Present water cement radio = 0.40

Therefore difference is 0.5 - 0.40 = 0.10

The proportion of volume of coarse aggregate is increased by 0.02 (At the rate of -/+ 0.01 for + 0.05 change in W/C ratio)

= 0.60+0.02 = 0.62

Therefore volume of coarse aggregate = 0.62.

Volume of Fine aggregate = 1 - 0.62 = 0.38

H. Mix Calculation & Proportion

Table 5.1 Mix Design for M40 grade concrete

WATER	CEMENT	FA	CA
131.35	328.38	143.67	1908.72
0.40	1	0.44	5.81

Table 5.2 Mix Design for M40 grade concrete (MIX A1)

CEMENT (50%)	GGBS (50%)	MICRO SILICA (10%)	NCA	SAND (7% of CA)	Polypropylene fibre (1%)
242.77	242.77	24.28	1410	98.70	20.19

Table 5.3 Mix Design for M40 grade concrete (MIX A2)

CEMENT (50%)	GGBS (50%)	MICRO SILICA (10%)	NCA	SAND (7% of CA)	Steel fibre (1%)
242.77	242.77	24.28	1410	98.70	20.19

Table 5.4 Mix Design for M40 grade concrete (MIX B1)

CEMENT (40%)	GGBS (60%)	MICRO SILICA (10%)	NCA	SAND (7% of CA)	Polypropylene fibre (1%)
194.21	291.32	19.421	1566	109.62	21.81

Table 5.5 Mix Design for M40 grade concrete (MIX B2)

CEMENT (40%)	GGBS (60%)	MICRO SILICA (10%)	NCA	SAND (7% of CA)	Steel fibre (1%)
194.21	291.32	19.421	1566	109.62	21.81

V. EXPERIMENTAL RESULT

A. *Compressive Strenght Of Cube*

The experimental program was designed to study the mechanical properties of concrete with partial replacement of coarse aggregate by steel slag for M40 grade of concrete. The compressive strength of the cubes after replacing the Cement by 50-60% of GGBS and micro silica and artificial fibres is studied after 7,14 and 28days For the test specimens, 53 grade Portland Pozzolana cement natural river sand and coarse aggregate, steel slag from steel plants are being utilized. The maximum size of the coarse aggregate was limited to 20mm. sieve analysis conforming to IS 383 – 1970 the concrete mix design was proposed to achieve the compressive strength of 40Mpa after 7days and 28days curing, in case of cubes. The concrete cubes (150mmX150mmX150mm). Each layer was compacted with 25 blows using 16mm dia rod.

Compressive strength = (Maximum load on failure)/(Area of the load faces)

Fig 1.1 Compressive strength test of cube

B. Split Tensile Strength On Concrete

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consist of applying a compressive line load along the opposite generators of concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. The magnitude of this tensile stress σsp is given by the formula $\sigma sp = 2p/\pi dl$

Where p is the applied load, d and l are the diameter and the length of the specimen respectively. Due to the tensile stress, the specimen fails by splitting vertically into two halves; this test is also called the split test. The test has been standardized for concrete specimens with diameter larger than four times the maximum size of the coarse aggregate or 150mm whichever is greater. The length of the specimens shall not be less than the diameter and not more than twice the diameter. For the routine testing, the specimens shall be cylinders 150mm diameter and 300mm in length. The apparatus used are Cylinder mould, compression testing machine.


Fig 1.2 Split Tensile Strength of Concrete

C. Flexural Strength Of Concrete

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the ‘pull’ applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure the flexural strength property of concrete. The value of the modulus of rupture (extreme fibre stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central point loading and third point loading. In the central point loading, maximum fibre stress will come below the point of loading where the bending moment is maximum. In the symmetrical two point loading, the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of modulus of rupture than the centre point loading.

Flexural strength, $F = Pl/bh2$

Where, P= load in Newton shown in dial gauge

l= length of rectangular prism in mm i.e. 700 mm

b= breadth of rectangular prism i.e. 150 mm

h= height of rectangular prism i.e. 150 mm

Fig 1.3 Flexural Strength of Concrete

D. Infiltration Test

Infiltration rate per single ring infiltrometer was determined in accordance with ASTM C1701. The apparatus, shown in Figure 6.5.1, consists of a ring 12” (30.0 cm) in diameter, which is to be sealed to the PCP surface with plumber’s putty. The location was pre-wetted by pouring 0.12 ft3 (3.6 litres) of water into the ring and keeping water levels between 0.4” and 0.6” (1.0 cm and 1.5 cm) above the surface of the pavement. Locations taking more than 30 seconds to infiltrate the pre-wetting water were tested for infiltration rate using 0.12 ft3 (3.6 litres) of water, other locations required 0.63 ft3 (18 litres) of water for testing. Water was poured into the ring and kept between 0.4” and 0.6” (1.0 cm and 1.5 cm) above the surface of the pavement. Time was recorded from when water made contact with the pavement surface to the time when water was no longer visible. Determine infiltration rate by dividing the volume of water by the area tested and the time required for infiltration.

I (mm/hr) = K*M/(D2*T)
K= Infiltration constant (4583666000 for SI units)
M= Mass of infiltrated water (18 kg)
D= Diameter of the ring (300 mm)
T= Time taken by the infiltrated water
I = 4583666000*18/(3002*69*3600)= 3.68 mm/s

E. Density Test

To conduct the ASTM C 1688 test, typically the bucket which has a volume of 0.25 cubic feet. A sample is collected from various locations in the batch. The container is filled with pervious concrete in two equal lifts and each lift is compacted by 20 blows with a Standard Proctor Hammer. The pervious concrete is then struck off flush and the bucket is weighed both with the pervious inside and empty. The concrete's weight is divided by the volume and the result is the density

Fig 1.4 Infiltration Test

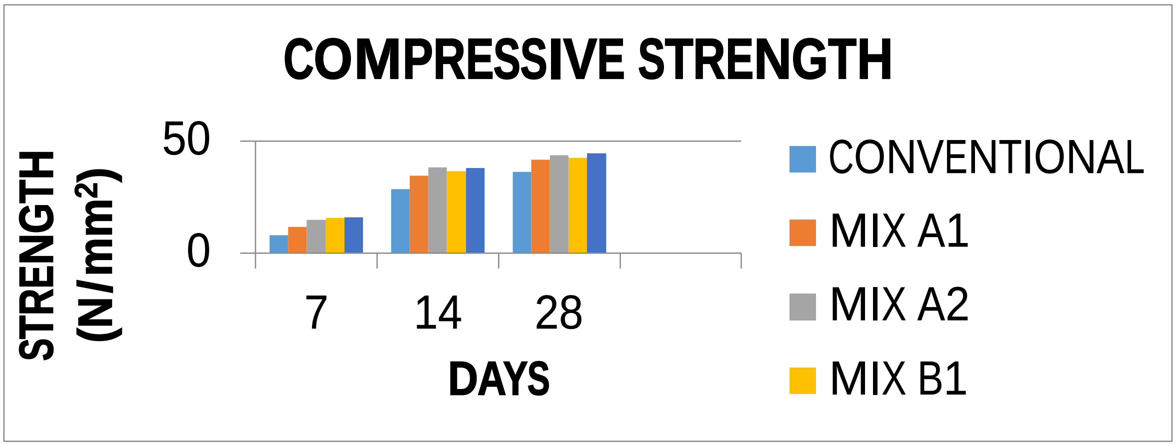
Fig 1.5 Density Test

VI. RESULT AND DISCUSSION

A. Compressive Strength Test Result

Table 7.1 Compressive Strength Test Result

CONCRETE	SAMPLE	DAY 7	Average Strength	DAY 14	Average Strength	DAY 28	Average Strength
CONVENTIONAL	1	7.44	7.82	26.54	28.56	38.67	36.22
	2	7.81		28.91		32.54	
	3	8.20		30.25		37.45	
MIX A1	1	10.23	11.75	35.21	34.62	39.81	41.86
	2	12.66		34.87		42.66	
	3	12.38		33.79		43.12	
MIX A2	1	13.26	14.89	38.69	38.25	42.78	43.9
	2	15.80		36.52		45.65	
	3	15.61		39.54		43.27	
MIX B1	1	16.61	15.56	36.52	36.62	41.5	42.54
	2	15.42		35.54		44.2	
	3	14.66		37.82		41.9	
MIX B2	1	14.78	15.84	36.54	37.9	44.12	44.72
	2	16.85		37.78		43.98	
	3	16.9		39.19		46.25	



B. Flexural Strength Test Result

Table 7.2 Flexural Strength Test Result

CONCRETE	SAMPLE	DAY 7	Average Strength	DAY 14	Average Strength	DAY 28	Average Strength
CONVENTIONAL	1	3.21	3.28	3.65	3.66	5.78	6.37
	2	3.67		3.84		6.36	
	3	2.96		3.49		6.98	
MIX A1	1	3.69	4.05	5.18	5.45	7.15	7.86
	2	4.12		5.37		8.75	
	3	4.33		5.82		7.69	
MIX A2	1	4.52	4.41	5.42	6.023	8.25	8.49
	2	4.65		6.08		8.67	
	3	4.05		6.57		8.56	
MIX B1	1	4.85	4.48	4.65	5.59	7.65	7.81
	2	4.38		6.15		7.45	
	3	4.21		5.98		8.33	
MIX B2	1	4.84	4.59	6.82	6.93	8.85	8.51
	2	4.16		6.54		8.26	
	3	4.78		7.45		8.41	

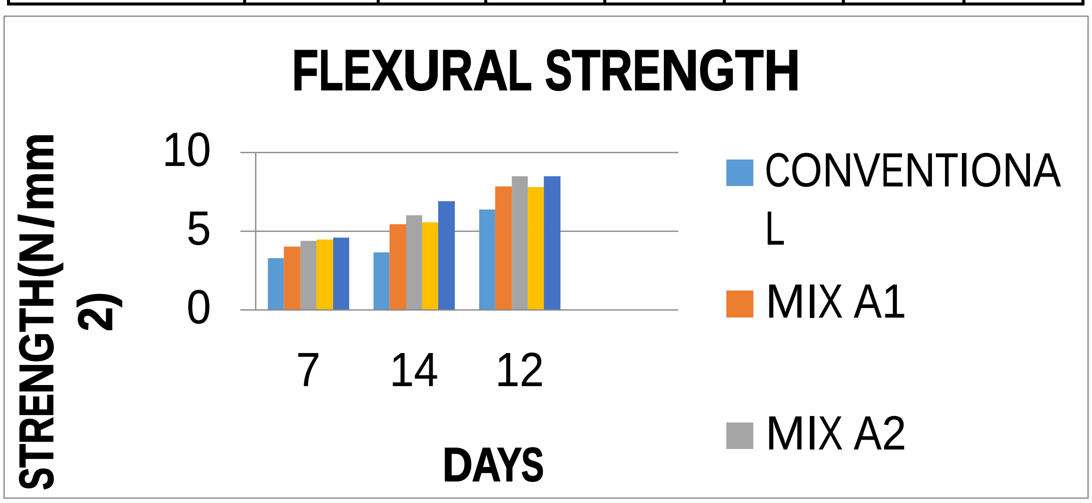


Fig 7.2 Graph for Flexural Strength Test

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C. *Split Tensile Strength Test Results*

Table 7.3 Split Tensile Strength Test Results

CONCRETE	SAMPLE	DAY 7	Average Strength	DAY 14	Average Strength	DAY 28	Average Strength
Conventional	1	1.25	1.36	2.58	2.58	3.45	3.12
	2	1.36		2.69		2.98	
	3	1.47		2.47		2.94	
MIX A1	1	1.56	1.66	2.93	2.96	3.08	3.47
	2	1.69		2.81		3.71	
	3	1.72		3.13		3.62	
MIX A2	1	1.82	1.68	3.33	3.41	3.97	4.36
	2	1.65		3.64		4.89	
	3	1.58		3.25		4.25	
MIX B1	1	1.68	1.713	3.33	3.46	4.1	3.99
	2	1.72		3.42		3.98	
	3	1.74		3.64		3.87	
MIX B2	1	1.75	1.78	3.51	3.62	4.54	4.37
	2	1.79		3.44		4.21	
	3	1.80		3.91		4.32	

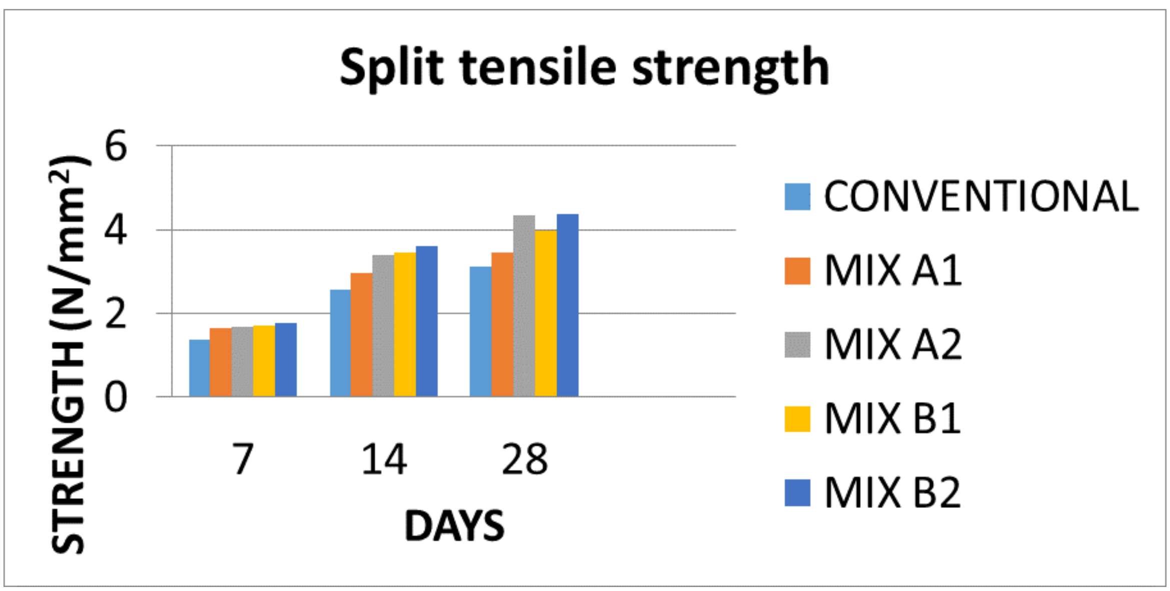

Fig 7.3 Graph for Split Tensile Strength

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D. Infiltration Test Result

Table 7.4 Infiltration Test Result

CONCRETE	SAMPLE	TIME (S)	INFILTERATION RATE (mm/s)	AVERAGE
Conventional	1	49	5.19	5.33
	2	43	5.92	
	3	52	4.89	
MIX A1	1	63	4.04	4.15
	2	54	4.72	
	3	69	3.67	
MIX A2	1	52	4.89	5.16
	2	49	5.2	
	3	47	5.41	
MIX B1	1	61	4.17	3.91
	2	63	4.04	
	3	72	3.53	
MIX B2	1	58	4.39	4.89
	2	49	5.2	
	3	55	5.09	

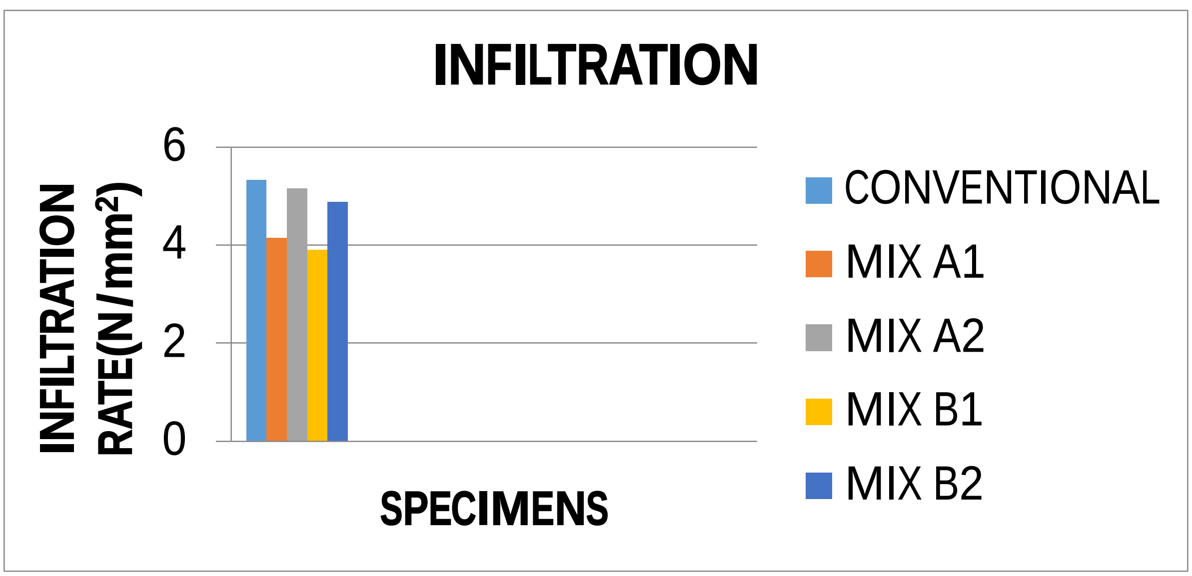

Fig 7.4 Graph for Infiltration Rate

E. *Density Test Result*

Table 7.5 Density Test

CONCRETE	SAMPLE	MASS (kg)	DENSITY (kg/m^3)	AVERAGE
Conventional	1	10.6	1429.96	1549.42
	2	10.17	1432.39	
	3	12.68	1785.91	
MIX A1	1	13.44	1892.95	1743.18
	2	12.54	1766.19	
	3	11.15	1570.42	
MIX A2	1	11.62	1636.61	1771.83
	2	12.58	1771.83	
	3	13.54	1907.04	
MIX B1	1	14.85	2091.55	1995.77
	2	14.12	1988.73	
	3	13.54	1907.04	
MIX B2	1	14.25	2007.04	2184
	2	16.54	2329.57	
	3	15.73	2215.49	

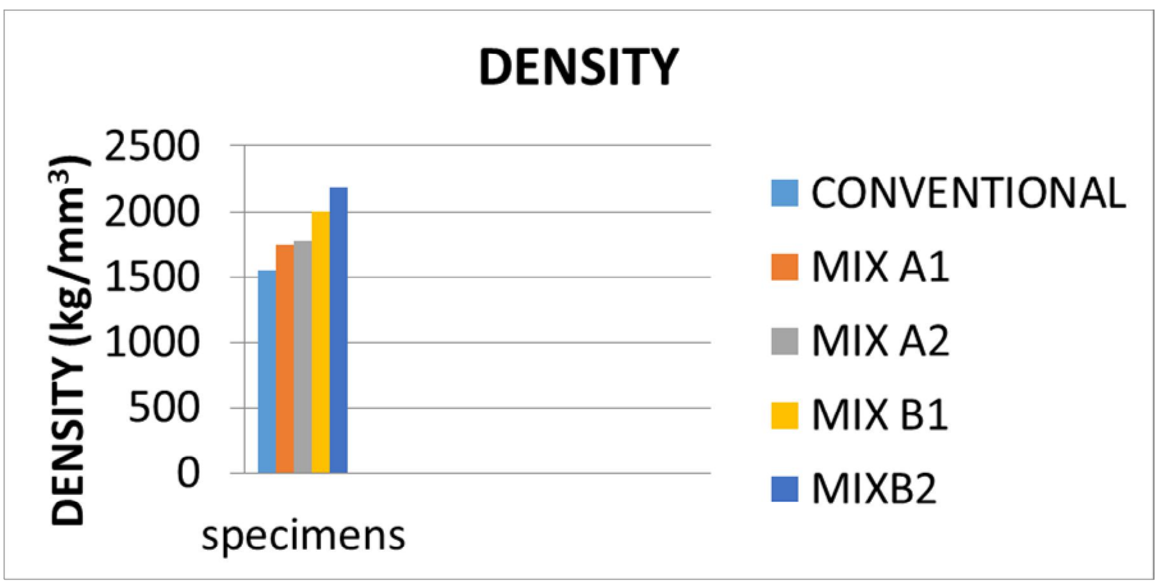

Fig 7.5 Density of mixes

VII. CONCLUSIONS

In our project we have investigated the strength of concrete with artificial fibers like polypropylene fibers and steel fibers and replacement of cement by GGBS and micro silica

1) Density of concrete is more as percentage of fiber increases.
2) Compressive strength, flexural strength, split tensile strength increase
3) Linearly with increased percentage of GGBS.

4) Compressive strength, flexural strength, split tensile strength of mix.
5) Containing steel fiber is greater than the mix containing polypropylene Fiber.
6) Compressive strength increased by 23%, flexural strength increased by 34% and split tensile strength increased by 40%.
7) Infiltration rate and workability decreased due to the incorporation of fibers.

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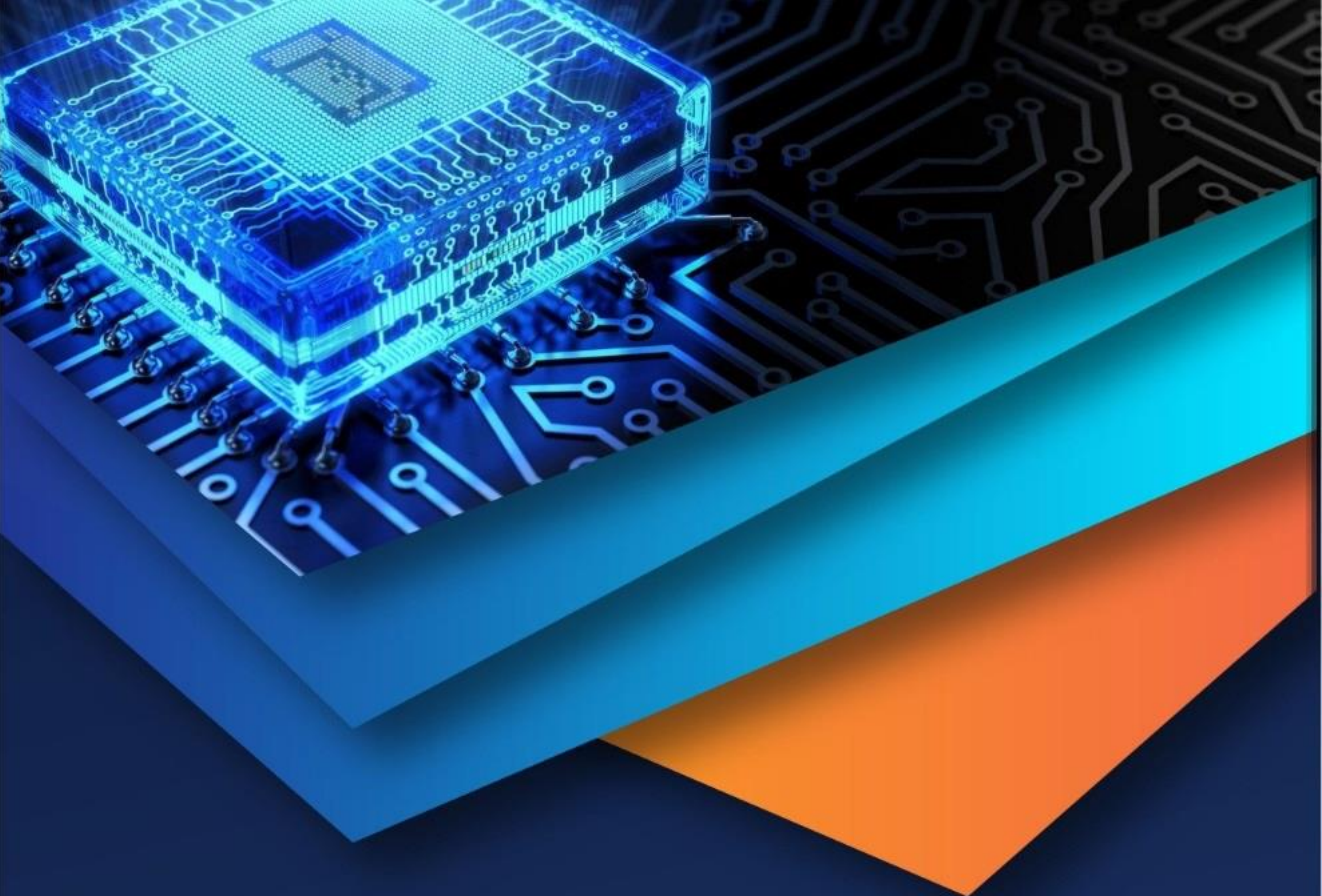

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