Experimental Study on Strength Properties of High Strength Fiber Reinforced Light Weight Aggregate Concrete

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Abstract: ***The work deals with an experimental investigation of study on strength properties of high strength fiber rein forced light weight aggregate concrete. The purpose of this research is based on this investigation of hooked steel fibers in structural concrete. In Design of concrete structures, light weight concrete plays a prominent role in reducing the density and to increase the thermal insulation. The use of structural grade light weight aggregate concrete reduces the self weight and helps to construct larger precast units. The work deals with an experimental investigation on strength durability properties of high strength fiber rein forced light weight aggregate concrete. The effects of fibers on workability, density and on various strength properties of high strength concrete (M50) grade concrete have been studied. The fiber content varies from 0.5%, 1%, 1.5% 2% 2.5%and 3% by volume of cement is used in concrete. For this purpose along with a Control Mix, 15 sets were prepared to study the compressive strength, tensile strength and flexural strength. Each set comprises of 6 cubes, 3cylinders and 3 prisms. All specimens are water cued and tested at the age of 7and 28-days. Workability of wet mix is found to be reduced with increase fiber content. Super plasticizer is to be used to increase workability. Ductility and bond of concrete is to found to increase in steel fiber reinforced concrete as observed from the Compressive test, Tensile Strength and Flexural Strength tests were performed in the hardened state. In this study optimum percentage steel fibers arrived at the keeping optimum percentage addition of steel fibers constant and replacing granite aggregate with pumice by 10, 20,30,40,50 % by volume, the strength and durability properties of M_{50} concrete was studied.***

Keywords: hooked end steel fibers, compressive strength, split tensile flexural strength, light weight aggregate (pumice), super plasticizer (Gleninum), Durability and H_2 So_4 .

1. Introduction

Pumice is a natural sponge-like material of volcanic origin composed of molten lava rapidly cooling and trapping millions of tiny air bubbles. In recent years, the existing limited research that has been conducted in this area of structural concrete with compressive strength can be produced with adequate economic benefits using pumice. Pumice and pumice are used to make lightweight construction materials. About three-quarters of pumice and pumice are consumed annually for this purpose. Cement concrete is probably the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be molded to any shape. Fiber reinforced concrete is a composite material made of hydraulic cements, fine and coarse aggregate, and a dispersion of discontinuous, steel fibers. Generally, when used in structural applications, steel fiber reinforced concrete should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration. The production and use of lightweight aggregate concrete has received considerable attention for structural purposes during the last two decades. These studies on the material properties of high strength lightweight concrete (HSLWC) have rapidly advanced material development. In certain applications such as bridge decks and parking garages, the self-weight of structural components represents a large portion of the total load. By reducing the self- weight, considerable savings could be attained, not only in materials but also in construction costs.

2. Literature Review

Rajeswari. S et al [May 2015][1] "Experimental Study of Light Weight Concrete by Partial Replacement of Coarse Aggregate Using Pumice Aggregate". This study is focused to determine the strength parameters of light weight aggregate concrete to find the favorable replacement with the above mentioned replacements. The results are compared with conventional concrete. Compression strength value is compared to normal concrete and replacement of Coarse aggregate by Pumice from different percentages (50%, 60%, 70%). Maximum value of strength is obtained in 60% replacement of Pumice with coarse aggregate. This type of concrete can be utilized in wall panels of non load bearing type for use in precast buildings.

Praveen Kumar Goud .E et al [March 2015][2] "Experimental comparative study on the mechanical properties of hooked end steel, crimped steel and glass fiber reinforced concrete". It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of hooked steel, crimped steel& glass Fiber Reinforced Concrete is its superior resistance to cracking and crack propagation. The comparison of percentage increase of compressive strength for conventional concrete and hooked end steel fiber reinforced concrete at 28 days is 7.3%, conventional concrete and crimped steel fiber reinforced concrete is 6.08%, conventional concrete and glass fiber is 4.34%.

N. Sivalinga Rao et al [May-2013][3] Fiber Reinforced Light Weight Aggregate (Natural Pumice Stone) Concrete. In their study, the mix design was M20 and the test results are as follows: More than the target means strength of M 20 concrete is achieved with 20 percent replacement of natural coarse aggregate by pumice aggregate and with 1.5 percent of fibber. Also with 40% pumice and with 0.5% of fibbers average target mean strength of M 20 concrete is achieved. The compressive strength of pumice concrete is seen to increase with the fiber content and reaches an optimum value at 1.5% of fiber content and afterwards it gets decreased for various contents of pumice.

3. Experimental Investigation:

Experimental investigation consists of casting and testing of 7 sets along with control mix. Each set comprises of 6 cubes, 3 cylinders and 3 prisms for determining compressive, tensile and flexural strengths respectively. hooked steel fibers is used to study with The fiber content varies from 0.5%, 1%, 1.5% 2% 2.5%and 3% by volume of cement is used in concrete. All specimens are water cued and tested at the age of 7and 28-days. Workability of wet mix is found to be reduced with increase fiber content. Super plasticizer is to be used to increase workability. Ductility and bond of concrete is to found to increase in steel fiber reinforced concrete. In this study optimum percentage steel fibers arrived at the keeping optimum percentage addition of steel fibers constant and replacing granite aggregate with pumice by 10%, 20%, 30%, 40%, 50 % by volume of Pumice stone is used. The different admixtures like steel fiber. Cube section dimension is of15cmx15cmx15cm, cylinder section dimension is 15cmx30cm and prism dimension is 50cmx10cmx10cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and prisms are moved to the curing tank carefully.

3.1 Materials

The constituent materials used in these studies are given below:
1) Cement
2) Fine aggregate
3) Normal weight of coarse aggregate
4) Pumice stone(light weight coarse aggregate)
5) Glenium B233 (chemical admixture)
6) Hook-end steel fibers

3.1.1 Cement

The cement used was Ordinary Portland cement (OPC) of 53-grade conforming to IS 12269 is used in experimental work.

Table 1: cement test result

S. no	*properties*	*value observed in investigation*	*Value as per IS: 1489-1991*
1	Consistency (%)	32	-
2	specific Gravity	3.12	-
3	Fineness (%)	0.5	Min 0.1
4	Initial setting time(min)	42min	Min 30 minutes
5	Final Setting time(min)	450min	Max 600 minutes

3.1.2 Aggregate

It should be passed through IS Sieve. As fine aggregate (F.A) natural sand from river is used conforming to IS383-1970.Which comes under zone II. As a course aggregate hard granite chips passing 20mm down where used conforming to IS383-1970. Various tests such as specific gravity water absorption and sieve analysis have been conducted on (F.A) and (C.A) to know the good quality and grading.

3.1.3 Pumice Stone (Light Weight Aggregate)

Light weight aggregate can be classified into two categories namely natural light weight aggregate and artificial light weight aggregates. Natural light weight aggregate include Pumice, diatomite, scoria, volcanic cinders, sawdust and rice husk. Artificial lightweight aggregate include artificial cinders, coke breeze, foamed slag, bloated clay, expanded shale and slate, sintered fly ash and exfoliated vermiculate. Pumice stone is a lightweight aggregate of low specific gravity and low density. Pumice is a colour less or light gray colored coarse aggregate, which floats on water. It is a natural raw material. It also possesses excellent mechanical strength and acts as an excellent insulating material. Pumice is also fire resistant with a high melting point and has low specific gravity. It could also be employed in high sound regions as a good sound proofing material due to its excellent sound proofing properties

Pumice stone

3.1.4 GLENIUM B233 (Chemical Admixture)

GLENIUM B233 is an admixture of new generation based on modified polycarboxylic ether. The addition of this superplasticizer to dry aggregate or cement is not recommended and forced action for 60 seconds in mixers is recommended after addition of GLENIUM B233. This is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. At the start of mixing process the electrostatic dispersion occurs but the presence of lateral chains, linked to the polymer backbone, generate a seric hindrance which stabilizes the cement particle to separate and disperse

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The physical properties of GLENIUM B233 obtained from BASF construction chemicals are shown below in the table.

Table 2: Properties of GLENIUM B233

Properties	*Limits*
Colour	Light brown liquid
Relative density	1.09±0.01
p^H	>6
Chloride ion content	<0.2%

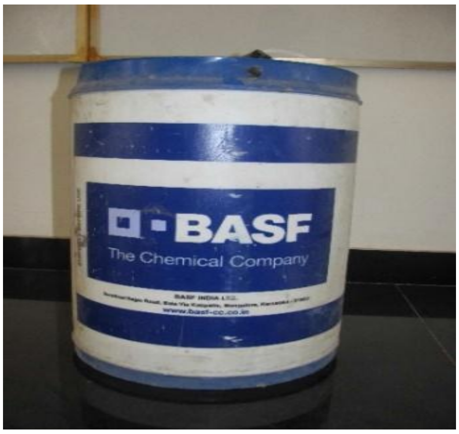

Figure 1: GLENIUM B233

3.1.5 Steel Fibers

The steel fiber can entirely replace traditional steel fiber reinforced concrete. This is most common in industrial flooring but also in some other pre casting applications. Typically, these are corroborated with laboratory testing to confirm performance requirements are met. Care should be taken to ensure that local design code requirements are also met which may impose minimum quantities of steel reinforcement within the concrete. There are increasing numbers of tunneling projects using precast lining segments reinforced only with steel fibers. the advantage of steel fiber are Improved structural strength, reduced steel reinforcement requirements, Improved ductility, Reduced crack widths and control of crack widths thus improving durability, Improved impact & abrasion resistance, Improved freeze-thaw resistance of steel fibers.

Table 3: Properties of hooked-end steel fibres

S. no	*Properties*	*Description*
1	Cross Section	Hook end steel fibers
2	Diameter	0.75mm
3	Length	60mm
4	Density	7900 Kg/mm^2
5	Young's Modulus	$2.1*10^5$ N/mm^2
6	Resistance to Alkalis	Good
7	Resistance to Acids	Poor
8	Heat resistivity	Good
9	Tensile strength	500-2000 N/mm2
10	Aspect ratio	80

Figure 1: Hooked end steel fibers

3.2 Process of Manufacture of Concrete

1) **Batching:** The measurement of materials for making concrete is known as Batching.
2) **Weigh Batching:** Weigh is the correct method of measuring the material. Use of weight system is batching, facilitates accuracy, flexibility and simplicity
3) **Measurement of water:** When weigh batching is adopted, the measurement of water must be done accurately. Addition of water by graduated bucket in terms of litters will not be accurate enough for the reason of spillage of water etc.

3.2.1 Preparation of Concrete Cubes:

Metal moulds, preferably steel or cast iron, strong enough to prevent distortion is required. They are made in such a manner as to facility the removal of the moulded. Specimen without damage and are so maintained that, when it is assembled, the dimensions and internal faces are required to be accurate within the following limits.

Compacting: The testing cube specimens are made as soon as possible after mixing and in such a manner to produced full compaction of the concrete with neither segregation nor excessive bleeding

Curing: The test specimens are stored in a place free from vibration in moist air of at least 90% relative humidity and at a temperature of 27^0 C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds.

Testing:

(i) Compressive Strength: The test was conducted For compressive test, cube specimens of dimension 150 x150x150 use for concrete cubes were cast. The specimens were demoulded, after 24hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. After 28 days curing, cubical specimens are placed on compression testing machine having a maximum capacity of 2000 KN and a constant rate of loading of 40 kg/m2 per minute is applied on test specimen. Ultimate load at which the cubical specimen fails is noted down from dial gauge reading. This ultimate load divided by the area of specimen gives the compressive strength of each cube.

Figure 2: Compression testing of cube

(ii) Tensile Strength: The test was conducted as per IS 5816:1999. For tensile strength test, cylindrical specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were remolded after 24hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. After 28 days curing, cylinder specimens are placed on tensile testing machine having a maximum capacity of 2000 KN and a constant rate of loading of 40 kg/m^2 per minute is applied on the test specimen by placing two steel plates below and above the cylinder in the horizontal direction Ultimate load at which the cylindrical specimen fails is noted down from dial gauge reading.

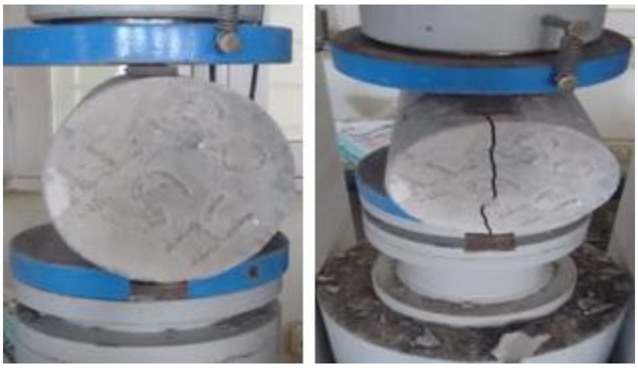

Figure 3: Split tensile testing of cylinder

(iii) Flexural Strength: the steel mould of size 500x100x100 is well tighten and oiled thoroughly . They were allowed for curing in a tank After 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m^2 per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading.

Figure 4: Flexural testing of beam

4. Test Results and Discussions

4.1 Compressive Strength Test Result

Tests were conducted on compressive strength after 7 and 28 days of curing. The results of compressive strength for 0% to 3% of steel fiber are given in.

Table 4: Test result for Compressive strength by using steel fibers

% of steel fibers	*Compressive strength*		*Percentage increase*	
	7days	28days	7days	28days
Conventional	42.05	62.02	0.00	0.00
0.5%	46.10	64.08	9.63	3.32
1.0%	52.70	71.30	25.32	14.96
1.5%	49.34	69.30	17.33	11.73
2.0%	48.08	66.19	14.34	06.72
2.5%	48.18	65.61	14.57	05.78
3.0%	49.00	67.13	16.52	08.23

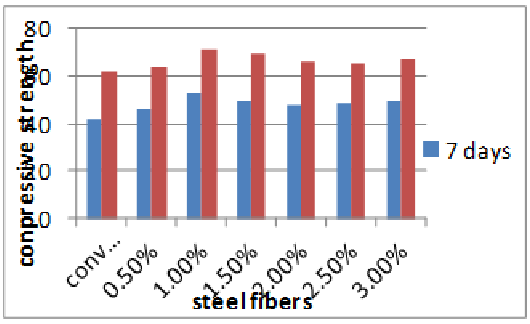

Figure 5: Comparison of compressive strength using different fibers

Table 5: Compressive strength Test Results for various proportions light weight coarse aggregate (Pumice) and with H.S F

	Percentage replacement of pumice stone	*Compressive strength*		*Percentage increase*	
		7 days	28 days	7 days	28 days
1% of steel fibers	conventional	48.62	71.30	0.00	0.00
	10%pumice	42.40	60.46	12.13	15.20
	20%pumice	38.83	55.05	20.13	22.79
	30%pumice	33.56	46.32	30.97	35.05
	40%pumice	29.24	38.50	39.07	46.00
	50%pumice	26.09	27.21	46.33	61.83

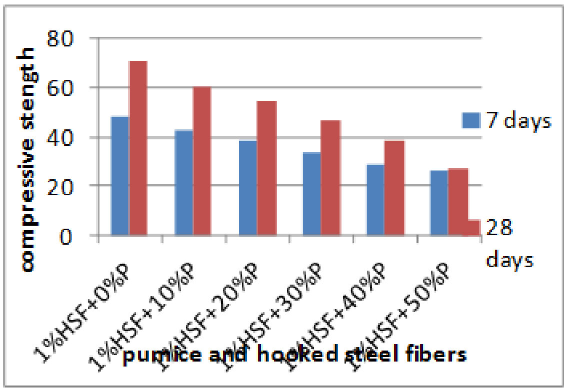

Figure 6 Graph: Compressive strengths for various proportions of pumice stone with steel fibers

4.2 Split Tensile Strength Test Results

Tests were conducted on Splitting Tensile Strength 28days of curing. The results of Splitting Tensile Strength for 0.5 to 3% volume of steel fibers are given in

Table 6: Test result for split tensile strength various percentage of steel fibers

Mix designation of concrete	*% of steel fibers*	*Split tensile strength at 28 days(N/mm^2)*	*Percentage increase in strength*
1	0.0%	4.77	0.00
2	0.5%	5.47	14.67
3	1.0%	6.32	32.49
4	1.5%	5.40	13.20
5	2.0%	5.47	14.67
6	2.5%	5.42	13.62
7	3.0%	6.06	27.04

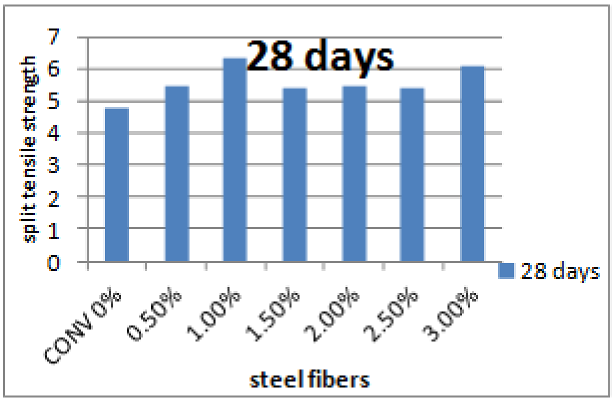

Figure 7: Comparison of split tensile strength using different fibers

Table 7: Split tensile strength Test Results for various proportions light weight coarse aggregate (Pumice) and with H.S.F

	Partial replacement of pumice	*Split tensile test*	*Percentage increase*
		28 days	28 days
1% of steel fibers	conventional	6.078	0.00
	10%pumice	4.831	20.51
	20%pumice	4.184	31.16
	30%pumice	3.703	39.07
	40%pumice	2.677	55.95
	50%pumice	2.452	59.65

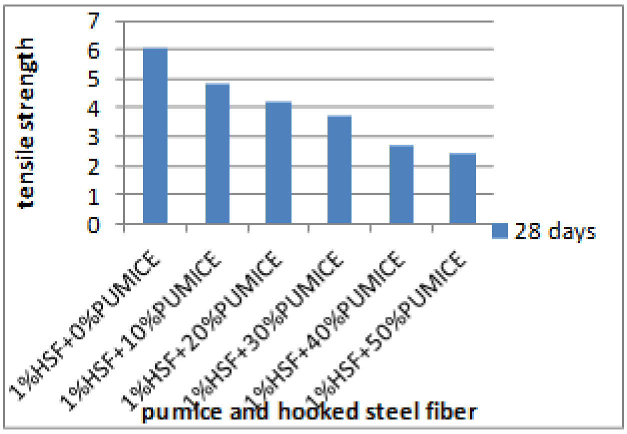

Figure 8 Graph: Compressive strengths for various proportions of pumice stone with steel fibers

4.3 Flexural Strength Test Results

Tests were conducted on flexural Strength 28 days of curing. The results of flexural Tensile Strength for 0.5 to 3% volume of steel fibers are given in

Table 8: Test result for flexural strength various percentage of steel fibers

Mix designation of concrete	*% of steel fibers*	*Flexural strength at 28 days(N/mm^2)*	*Percentage increase in strength*
1	0.0%	5.56	0.00
2	0.5%	6.08	9.35
3	1.0%	7.01	26.07
4	1.5%	6.27	12.76
5	2.0%	6.25	14.41
6	2.5%	6.36	14.38
7	3.0%	6.69	20.32

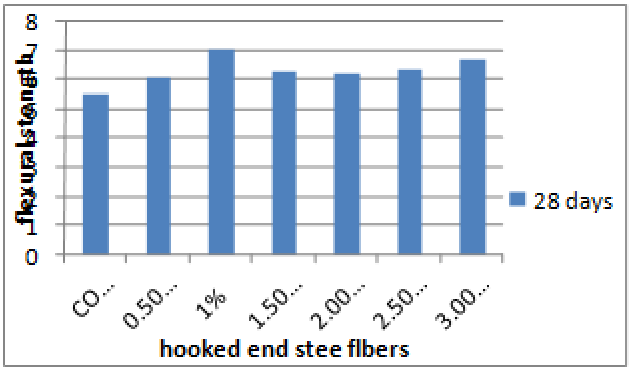

Figure 9: Comparison of flexural strength using different fibers

Table 9: Flexural strength Test Results for various proportions light weight coarse aggregate (Pumice) and with H.S.F

	Percentage replacement of pumice stone	*flexural strength*	*Percentage increase*
		28 days	*28 days*
1% of steel fibers	conventional	7.010	0.00
	10%pumice	6.580	6.13
	20%pumice	5.510	21.24
	30%pumice	5.170	34.95
	40%pumice	4.563	41.95
	50%pumice	4.136	41.08

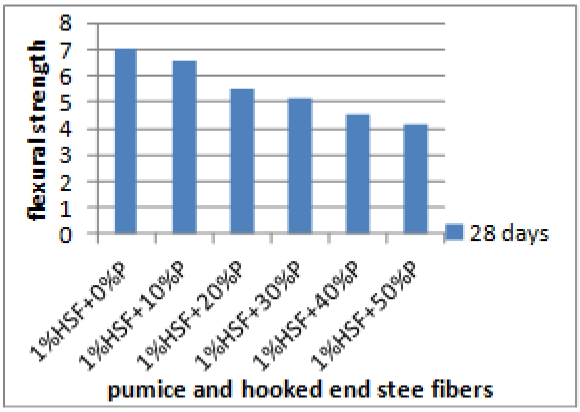

Figure 10 Graph: Compressive strengths for various proportions of pumice stone with steel fibers

5. Durability Test Results

To study durability characteristics, the specimens are subjected to 5% solution of sulfuric acid (H_2SO_4) for 28 days. In this investigation, the concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 28days of curing. 5% of H_2SO_4 solution is taken weight of water was added to water in which the concrete cubes were stored. The p^H was maintained throughout the period of 28 days. After 28 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water. The Percentage loss in Weight and strength for M_{50} Grade.

Figure 11: Curing of Cubes in H_2SO_4

Table 10: percentage of compressive strength loss and weights of 28 days

Mix designation of concrete	*Percentage replacement of pumice stone*	*% loss in cube weight for 28 days acid curing*	*% loss in compressive strength for 28 days acid curing*
1	Conventional	1.68	15
2	10% pumice	1.04	13
3	20% pumice	1.40	22
4	30% pumice	2.21	29
5	40% pumice	2.52	33
6	50% pumice	2.86	36

6. Conclusion

Following conclusions may be drawn based on the observations based on experimental investigation.

1) Addition of 1% steel fibres result in higher compressive strength and use of more than 1% steel fibres will bring down the compressive strength.
2) Therefore the maximum percent increase of compressive observed at 1% of steel fibres of the comparison of percent increase compressive for conventional concrete high strength fibre reinforced concrete at 7 days and 28 days is 25.32% and 14.96%.
3) The comparison of % increase of split tensile strength and flexural strength for conventional concrete of high strength fibre reinforced concrete at 28 days 32.49% and 26.07%.
4) Based on the compressive strength, tensile strength and flexural strength results it can be concluded. that the optimum percentage of steel fibre to be added in the concrete mix is 1% by volume fraction.
5) The density of concrete is found to decrease with the increase in percentage replacement of natural aggregate by pumice aggregate.
6) The compressive strength of concrete is found to decrease with the increase in pumice content. It is found to decrease from 71.30 to 27.21 M Pa as the pumice content is increased from 0 to 50 percent.
7) The impact values are optimum at 1% of fibre content for each percentage of pumice content considered in this investigation. The test value is achieved at the combination of 20% pumice content with 1% of steel fibre content.
8) For 20% partial replacement of pumice stone gives strength value and beyond 20% the compressive strength result and density of cube are decreased. By using 20% of light weight aggregate as a partial replacement to Natural Coarse Aggregates the compressive strength is promising.
9) Acid resistance of pumice concrete is nearly equal to conventional concrete, and it could be used as replacement to conventional concrete. Pumice concrete can be used in place where acid rain is more prevalent.
10) Compressive strength decreased with increase in pumice content is subjected to acid curing compare to normal curing.

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