Experimental Study on Performance of Triple-Blended Fiber-Reinforced Light Weight Concrete

Sri Mode Pavan[1], Sri B.Sri Datta Subrahmanyam[2]
[1]Dept of CIVIL Engineering
[2]Assistant Professor& HOD, Dept of CIVIL Engineering
[1, 2] KITS-DIVILI

Abstract- *Now a day's light weight aggregate concrete gained more importance than the normal conventional concrete due to its lesser density and high thermal conductivity. fibre reinforced concrete is a composite material used to reduce the brittleness and increases ductility. Increasing utilization of lightweight materials in structural applications is making pumice stone a very popular material. The addition of fibres like polypropylene, polyester and hookes end steel bars are introduced to the light weight aggregate concrete gives better results than light weight concrete. In the present study coarse aggregate is replaced by pumice stone with 5%, 10%, 15%, and 20% along with optimum percentage (5%) of fly ash which is a replacement of cement. The optimum value obtained from these is considered and added with different fibers resulting in hybrid fiber reinforced concrete.*

The test results shows that the density of light weight concrete decreases as increase in the percentage replacement by pumice stone. Compressive strength, split tensile strength and flexural strength results shows that the pumice stone replacement with 5% is the optimum value. Addition of fibres and combination of fibers yielded better results even for small amount of fibers.Trible blending of fibres in light weight concrete yielded better results.

I. INTRODUCTION

Most of the normal weight aggregate of normal concretes is natural stone such as lime stone and granite. With the increasing amount of concrete used, natural environment and resources are excessively exploited. Synthetic light weight aggregate produced from environmental waste like fly ash, is a viable new source of structural aggregate material. The use of light weight concrete permits greater design flexibility and substantial cost savings, reduced dead load, improved cyclic loading, structural response, longer spans, better fire ratings, thinner sections, smaller size structural members, less reinforcing steel and lower foundations costs. Weight of light weight concrete is typically 25% and 35% lighter but its strengths is comparable to normal weight concrete.

The conventional cement concrete is a heavy material having a density of 2500 Kg/m3 and high thermal conductivity. The dead weight of the structure made up of this concrete is large compared to the imposed load to be carried, and a relatively small reduction in dead weight, particularly for members in flexure in high rise buildings, can save money and manpower in construction.

Light Weight Aggregate is a relatively new material. For the same crushing strength, the density of concrete made with such an aggregate can be as much as 35 percent lower than the normal weight concrete. In addition to the reduced dead weight, the lower modulus of elasticity and adequate ductility of light weight concrete may be advantageous in the seismic design of structures. Other inherent advantages of the material are its greater fire resistance, low thermal conductivity, low coefficient of thermal expansion and lower erection and transport costs for prefabricated members.

1.2 OBJECTIVES OF THE STUDY

- To study the mechanical properties of the light weight concrete using pumice stone.
- To study the mechanical properties of the light weight concrete with addition of the admixtures such as fly ash
- To obtain the optimum percentage of the pumice stone.
- To reduce the density of the concrete act as the light weight concrete by using pumice stone.
- To increase the concrete strength by using the admixtures such as fly ash and different fibres.
- Hybridization using 2 fibres and trible bending is carried out.

II. LITERATURE REVIEW

T. Parhizkar, M. Najimi and A.R. Pourkhorshidi (2011) [1] have presented experimental investigation on the properties of volcanic pumice lightweight aggregates concretes. To this end, two groups of lightweight concretes (lightweight coarse with natural fine aggregates concrete, and lightweight coarse and fine aggregates concrete) are built and the physical/mechanical and durability aspects of them are studied. The results of compressive strength, tensile strength and drying shrinkage show that these lightweight concretes meet the requirements of the structural lightweight concrete.

N. Sivalinga Rao, Y.Radha Ratna Kumari, V. Bhaskar Desai, B.L.P. Swami (2013) [2] have studied on Fibre 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 M20 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.

P.C.Taylor [3] presently a professor at Wuhan University of Technology has said that mineral admixtures affect the physical and mechanical properties of High Strength Structural Light Concrete. Addition of Fly Ash enhances the compressive strength and splitting tensile strength of HSSLC when FA was more than 20% in cementitious materials, its 28, 60 and 90 days compressive strength and splitting tensile strengths are less than those of the concrete without FA. Addition of silica fume enhances the compressive strength about 25% and splitting tensile strength also. Incorporating supplementary binders have significant influence on the modulus of elasticity of semi-light weight concrete.

III. METHODOLOGY

Materials Used And Their Properties

3.1 Materials

The Constituent Materials Used In This Study Are Given Below:

1. Cement
2. Normal Weight Coarse Aggregate
3. Fine Aggregate
4. Fly Ash
5. Polypropylene fibre
6. Polyester fibre
7. Hooked end steel fibre
8. Pumice Stone (Light Weight Coarse Aggregate)

3.2 Material Properties

3.2.1 Cement

The cement used was ordinary Portland cement of 53- grade conforming to IS 12269. The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible.

Table 3.1 Physical Properties Of Portland Cement (53 Grades)

S. No.	Properties/ Characteristics	Test Results	Requirements As Per Is 12269-1987
1	Normal Consistency	33%	---
2	Setting time a) Initial Setting Time b) Final Setting Time	 39 minutes 453 minutes	 Not less than 30 minutes Not more than 600 minutes
3	Specific Gravity	3.09	---
4	Fineness of cement by sieving through sieve No.9 (90 microns) for a period of 15 min.	2.90%	<10%
5	Compressive strength of cement (28 days)	53 MPa	53 MPa

3.2.2 Aggregates

A) Fine Aggregates:

Sand shall be obtained from a reliable supplier and shall comply with IS standards for fine aggregates. It should be clean, hard, strong, and free of organic impurities and deleterious substance. It should inert with respect to other materials used and of suitable type with regard to strength, density, shrinkage and durability of mortar made with it.

Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate, which will have a high density and good workability and which will work into position without segregation and without use of high water content. The fineness of the sand should be such that 100% of it passes standard sieve No.8. The fine aggregate which is the inert material occupying 60 to 75 percent of the volume of mortar must get hard strong nonporous and chemically inert. Fine aggregates conforming to grading zone II with particles greater than 2.36 mm and smaller than 150 mm removed are suitable.

Table3.2: Sieve Analysis (Fine Aggregate)

S. No.	I.S. Sieve No.	Weight retained (gm)	Percentage weight retained	Cumulative percentage retained	Percentage passing
1.	10mm	0	0	0	100
2.	4.75mm	21	2.10	2.10	97.90
3.	2.36mm	65	6.50	8.60	91.40
4.	1.18mm	180	18.00	26.06	73.94
5.	600µ	278	27.80	54.04	45.96
6.	300µ	280	28.00	82.04	17.96
7	150µ	176	17.6	100.00	0
Total :				274.00	

Fineness modulus = 274.0 / 100 = 2.74

Zone = II

B) Normal Weight Coarse Aggregate:

Machine crushed hard granite chips of 64% passing through 20 mm sieve and retained on 10 mm sieve and 36% passing through 10 mm and retained on 10 mm sieve was used a coarse aggregate throughout the work.

C) Light Weight Coarse Aggregate

Pumice Stone

Pumice called pumicite in its powdered or dust form, is a volcanic rock that consists of highly vesicular rough textured volcanic glass, which may or may not contain crystals. It is typically light colored.

Pumice is created when super-heated, highly pressurized rock is violently ejected from a volcano. The unusual foamy configuration of pumice happens because of simultaneous rapid cooling and rapid depressurization. The depressurization creates bubbles by lowering the solubility of gases (including water and CO_2) that are dissolved in the lava, causing the gases to rapidly explosive (like the bubbles of CO_2 that appear when a carbonated drink is opened). The simultaneous cooling and depressurization freezes the bubbles in the matrix.

Table3.3: Sieve Analysis (Coarse Aggregate)

S No	I.S. Sieve No.	Weight Retained (Gms)	Percentage Weight Retained	Cumulative Percentage Retained	Percentage Passing
1.	40mm	0	0	0	100
2.	20mm	877	35	35	65
3.	10mm	408.5	65	65	35
4.	4.75mm	38	0.76	100.00	0
5.	2.36mm	0	0	100.00	0
6.	1.18mm	0	0	100.00	0
7.	600µ	0	0	100.00	0
8.	300µ	0	0	100.00	0
9.	150µ	0	0	100.00	0
Total :				716.78	

Fineness modulus = 716.78 / 100 = **7.17**

Table 3.4: Physical Properties Of Fine And Coarse Aggregate

S. No.	Properties	Test Results	
		Fine Aggregate	Coarse Aggregate
1.	Specific gravity	2.60	2.73
2.	Bulk Density (Kg/m^3)	1590 kg/m^3	1520 kg/m^3

3.	Fineness Modulus	2.74	7.17

Physical Properties Of Pumice Stone

Pumice is a type of volcanic rock formed when lava with extremely high levels of water and gases is violently ejected from a volcano. As explained by the Mineral Information Institute, when the gases escape, the rock become "frothy." Once the rock hardens, the result is a very light, buoyant material. The main use of pumice is for making lightweight construction materials such as concrete. Small "pumice stones" are commonly used at home or in beauty salons to remove dry skin and calluses from areas such as the feet.

Composition

- Pumice has a chemical composition similar to that of obsidian, or volcanic glass. It has very thin, translucent bubble walls of extrusive igneous rock. Pumice stones as used in beauty salons are generally high in silica and low in iron and magnesium.

Density

- Pumice is very lightweight. This is due to the air bubbles in it, created as gasses departed during the formation process. Pumice stones vary in density, according to the thickness of the solid material between the bubbles. Average porosity is 90 percent, which is extremely high for a rock material.

Buoyancy

- umice stones are so lightweight they will usually float on water for a time, before eventually sinking once becoming waterlogged. Large rafts of pumice have been known to float through oceans for decades after volcanic eruptions.

Abrasivity

- Pumice stones are abrasive, which is why they are good at removing dry skin and calluses from the feet. Pumice is also used as an abrasive in polishes, pencil erasers, cosmetic exfoliants and the production of printed circuit boards.

Color

- Pumice is commonly pale in color, ranging from white, cream, blue or grey, to green-brown or black. Pumice stones found at beauty salons or in pharmacies are generally light gray in color.

Table 3.5 Sieve Analysis of pumice stone
(On a sample 10kg coarse aggregate)

S. No.	Sieve Size	Weight Retained	% Weight Retained	Cumulative % Weight Retained
1	80mm	0	0	0
2	40mm	0	0	0
3	20mm	2.10	21.10	21.10
4	10mm	7.30	73.00	94.10
5	4.75 mm	0.35	3.5	97.60
6	2.36 mm	0.25	2.5	100
7	1.18 mm	0	0	100
8	600 µ	0	0	100
9	300µ	0	0	100
10	150µ	0	0	100
11	Total	10.00kg		712.80

$$\text{Fineness Modulus} = \frac{\text{cumulative \% reatained}}{100}$$

$$= \frac{712.80}{100}$$

= 7.12

Physical Properties:

Specific gravity of pumice stone = 0.68
Bulk density of pumice stone = 650 kg/m^3

Table 3.6: Chemical Properties Of Pumice Stone

S. No	Characteristic	Test Results (%)
1	SiO_2 by mass	60 to 75
2	Al_2O_3 by mass	13 to 17
3	Fe_2O_3 by mass	1 to 3
4	Cao by mass	1 to 2
5	Na_2O-$K_2$0 by mass	7 to 8
6	TiO_2 by mass	Low amount
7	SO_3 by mass	Low amount

Fig.3.1 Pumice Stone

3.2.4 Admixtures

1)
2) **Fly Ash**

Table3.7: Chemical Composition Of The Fly Ash

S. No	Characteristic	Test Results (%)
1	Cao by mass	0.37 to 27.68
2	SiO_2 by mass	27.88 to 59.4
3	Al_2O_3 by mass	5.23 to 33.99
4	Fe_2O_3 by mass	1.21 to 29.63
5	Mgo by mass	0.42 to 8.79
6	SO_3 by mass	0.04 to 4.71
7	Na_2O by mass	0.2 to 6.90
8	K_2O by mass	0.64 to 6.68
9	TiO_2 by mass	0.24 to 1.73
10	Loi by mass	0.21 to 28.37

3) **Polypropylene Fibre:**

Polypropylene fibers (PPF) are polymer fibers type which defines as straight or deformed fragments of extruded, oriented, and cut polymer material.. Primarily, they differ in the length but more importantly in the function that they perform in the concrete. Macrofibers are also called structural fibers because they are able to replace the traditional reinforcement in the form of steel bars and transfer loads acting on the structure. Therefore, the time needed to make steel reinforcement, and thus the investment costs, are saved. Their length is usually between 30 and 50 mm. On the other hand, microfibers are shorter than 30 mm and do not fulfill the load-bearing function. Their main role is to overcome plastic shrinkage and limit the formation of cracks in the concrete. As a result, they increase the durability and prolong the life of the element. Micro PPF can be an alternative to crack control meshes. They can be classified as a monofilament or fibrillated.

IV. EXPERIMENTAL RESULTS

Table4.1 Compressive strength with optimum percentage of fly ash

S no	Mix designation	7 days (MPa)	28 days (MPa)	56 days (MPa)
1	M40 Control mix	35.46	48.26	49.42
2	M40 5% P + 5%FA	33.96	47.50	48.88
3	M40 10%P+ 5%FA	32.86	46.44	48.12

4	M40 15%P + 5%FA	31.88	45.70	47.00
5	M40 20%P + 5%FA	30.66	45.20	46.32

Table: 4.2Tensile strength with optimum percentage of fly ash

S no	Mix designation	7 days (MPa)	28 days (MPa)	56 days (MPa)
1	M40 Control mix	2.955	6.03	6.44
2	M40 5% P + 5%FA	2.83	5.70	6.29
3	M40 10%P+ 5%FA	2.738	5.57	6.18
4	M40 15%P + 5%FA	2.656	5.52	6.07
5	M40 20%P + 5%FA	2.555	5.45	5.99

Table: 4.3 Flexural strength with optimum percentage of fly ash

S no	Mix designation	7 days (MPa)	28 days (MPa)	56 days (MPa)
1	M40 Control mix	4.2	7.45	7.67
2	M40 5% P + 5%FA	4.08	7.23	7.40
3	M40 10%P+ 5%FA	4.033	7.02	7.27
4	M40 15%P + 5%FA	3.91	6.92	7.15
5	M40 20%P + 5%FA	3.87	6.85	6.97

4.3 Graphs

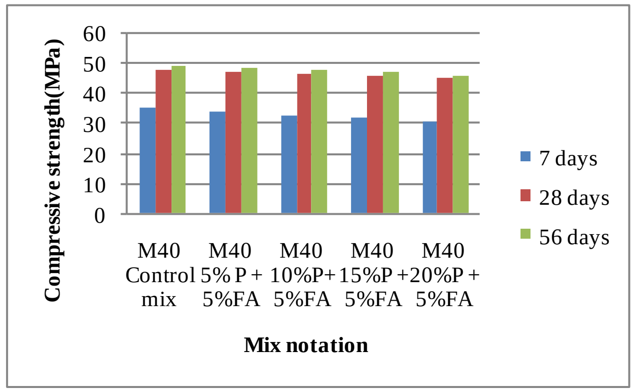


Fig 4.1 Graph representing compressive strength in MPa for 7, 28, 56 days with different mixes

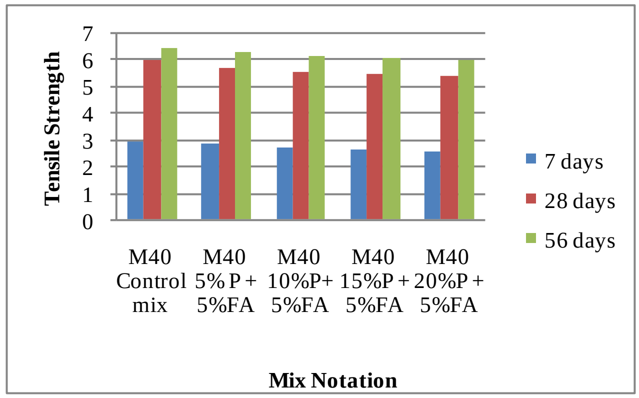


Fig 4.2 Graph representing tensile strength in MPa for 7, 28, 56 days with different mixes

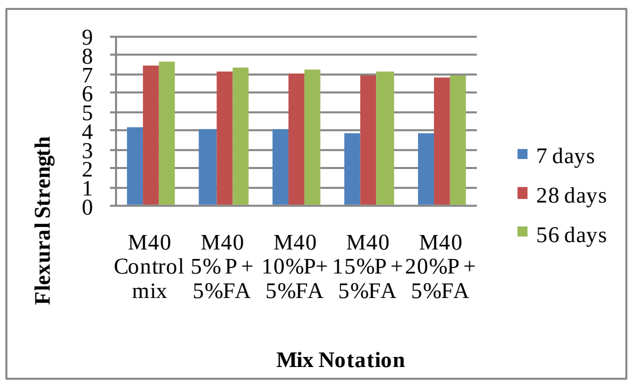


Fig 4.3 Graph representing flexural strength in MPa for 7, 28, 56 days with different mixes

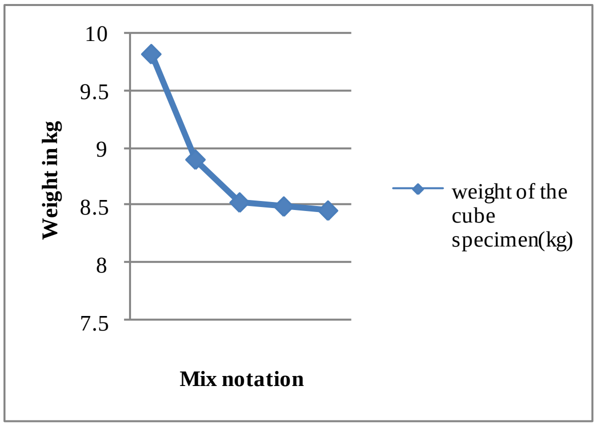
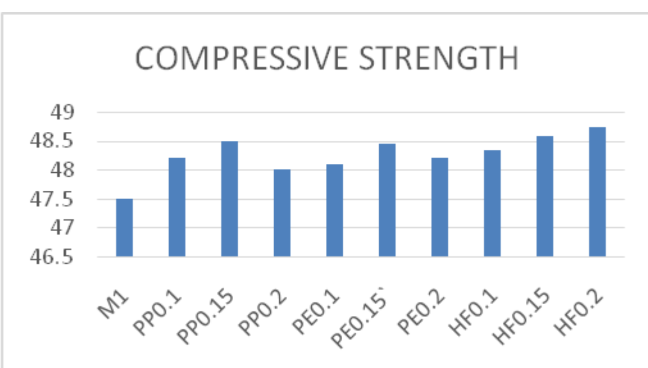


Fig 4.4 Weight of the Specimen with Different Replacements

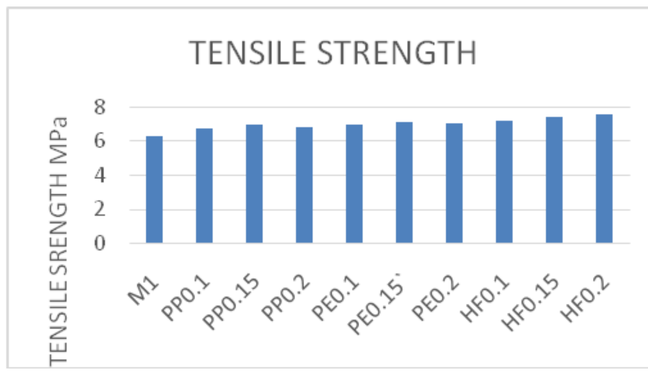
The optimum mix is chosen as 5% replacement of coarse aggregate with Pumice stone as our objective is light weight concrete without compromising the strength view. After casting there observed some micro cracks in the cubes. Hybridization is better concept in restricting the microcracks. Non-metallic fibres and metallic fibreis used in this work. However the concept of hybridization improves the properties .In this work 3 fibres, namely polypropylene, polyester and hooked-end steel fibres were used for hybridization.

MIX ID	COMPRESSIVE STRENGTH	% INCREASE
M1	47.50	-
PP0.1	48.21	1.5
PP0.15	48.49	2.1
PP0.2	48.02	1.1
PE0.1	48.11	1.3
PE0.15`	48.45	2.0
PE0.2	48.22	1.5
HF0.1	48.35	1.8
HF0.15	48.59	2.3
HF0.2	48.73	2.6



Mechanical properties and their percentage increase in strength of non-metallic Fibres . From the table it can be observed that the strength effectiveness of fiber addition in compression is less and mostly insignificant for all the mixes. An increase of 2.1% for Polypropylene fibre is observed for PP 0.15 mix compared to that of optimum mix derived i.e M1 and 2.0 % for Polyester PE 0.15 and 2.6% for hybrid combination of 0.2 % (75%PP+25%PE) HF 0.2.The percentage increase is not such significant however tested further for split tensile and flexural strengths.

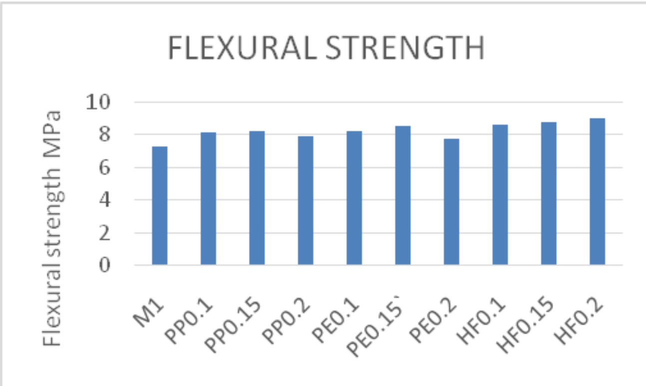
MIX ID	TENSILE STRENGTH	% INCREASE
M1	6.29	-
PP0.1	6.70	6.5
PP0.15	6.93	10.2
PP0.2	6.80	8.1
PE0.1	6.95	10.6
PE0.15`	7.11	13.1
PE0.2	7.0	11.2
HF0.1	7.20	14.5
HF0.15	7.39	17.6
HF0.2	7.55	20.1



From the results it is observed that the increase in tensile strength is significant with addition of fibres as much as 10.2% for PP 0.15 mix and 13.1 % for PE0.15 and Hybrid mix HF0.2(i.e 75%PE+25%PP) as 20.1% compared to that of optimum mix derived from previous work. The HF0.2 mix have atensile strength of 20.1% i.e 7.55MPa. It can be shown that the hybridization of fibres into the concrete shown better results compared to addition of Mono-fibres into the concrete . This takes close to our objective in arriving at Light weight hybrid reinforced concrete.It can be concluded that hybridization yielded better results.

MIX ID	FLEXURAL STRENGTH	% INCREASE
M1	7.23	-
PP0.1	8.11	12.3
PP0.15	8.21	**13.6**
PP0.2	7.90	9.3

PE0.1	8.19	13.3
PE0.15`	8.48	**17.3**
PE0.2	7.70	6.61
HF0.1	8.61	19.1
HF0.15	8.75	21.1
HF0.2	8.98	**24.3**



It is observed that there is significant increase in hybridization of fibres HF 0.2 compared to mono fibres. A maximum increase of strength of 24.3% in flexural strength is observed in a combination of 25%PP and 75% PE For hybrid mix of HF0.2 (0.2% FIBRE). From the results it can be concluded that the hybridization of non metallicfibres into the concrete has shown better results at same fibre dosage.

HFRC with combination of PP and PE improved concrete properties at low -stress levels only, and at high stress levels, these may not be promising in controlling the growth of macro-cracks because of the shorter length and lower modulus of these fibres. To increase the properties at high stress levels, long and high modulus steel fibres were introduced.

Mechanical properties of metallic and non-metallic HFRC

MIX ID	Total fibre dosage (%)	Fibre dosage(%)	
		Metallic	Non-metallic (75%-25%)
		steel (25mm)	PO(12mm) PP(6mm)
HS1	1	1	-
THF1		0.95	0.05
THF2		0.9	0.10
THF3		0.85	0.15
THF4		0.8	0.20

MIX ID	Compressive strength	% Increase	Tensile strength	% Increase	Flexural strength	% Increase
M1	47.50	-	6.29	-	7.23	-
HS1	50.20	5.7	7.45	18.5	8.78	21.5
THF1	50.30	5.9	8.46	34.6	9.98	38.1
THF2	51.25	7.9	8.64	37.4	10.35	43.2
THF3	51.87	9.2	8.78	39.6	10.55	46
THF4	48.73	2.6	8.08	28.5	8.82	22.1

From the above results it is clearly seen that triple blended of fibres have comparatively a little increase in compressive strength where as in tensile and flexural strength view triple blended fibre THF3 yielded better results compared to other mixes. There is an increase of 39.6% in tension and 46% increase in flexural.

Discussions &Conclusions

1. By using 5% pumice stone as a partial replacement to the natural coarse aggregates the compressive strength is promising.
2. The density of concrete is found to decrease with increase in percentage replacement of natural aggregate by pumice aggregate.
3. The compressive strength of concrete is found to decrease with increase in- pumice content.
4. The light weight aggregate is no way inferior to natural coarse aggregate and it can be used for construction purpose.
5. When the fibre added to the optimum percentage of pumice stone, the slump value obtained is very less.
6. The compressive strength decreased 6.28% for 56 days strength when 20% pumice stone is added
7. The tensile strength decreased 6.98% for 56 days strength when 20% pumice stone is added.
8. The flexural strength decreased 9.12% for 56 days strength when 20% pumice stone is added.
9. Optimum mix M1 choosen to be Puice stone replacement as 5%.
10. It is observed for PP 0.15 mix compared to that of optimum mix derived i.e M1 and 2.0 % for Polyester PE 0.15 and 2.6% for hybrid 10 An increase of 2.1% for Polypropylene fibre combination of 0.2 % (75%PP+25%PE) HF 0.2.The percentage increase is not such significant .
11. HFRC with combination of PP and PE improved concrete properties at low -stress levels only, and at high stress levels, these may not be promising in controlling the growth of macro-cracks because of the shorter length and lower modulus of these fibres. To increase the properties at high stress levels, long and high modulus steel fibres were introduced.

12. HFRC developed by blending PP and PO fbers exhibited better strength and toughness properties than their monocounterparts and control mix.
13. Triple- blended hybrid fiber- reinforced concrete mix THF3 yielded better results compared to other mixes. There is an increase of 39.6% in tension and 46% increase in flexural.

The concept of triple blended gave better results with the concept of hybridization achieved superior performance in strength and also in stress strain behaviour.

REFERENCES

[1] T. Parhizkar, M. Najimi and A.R. Pourkhorshidi, “(Application of pumice aggregate in structural lightweight concrete”, asian journal of civil engineering (building and housing) VOL. 13, NO. 1 (2012) PAGES 43-54.

[2] N. Sivalinga Rao, Y.Radha Ratna Kumari, V. Bhaskar Desai, B.L.P. Swami, “Fibre Reinforced Light Weight Aggregate (Natural Pumice Stone) Concrete”, International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013 ISSN 2229-5518.

[3] Banthia, N. and Trottier, J., ‘Concrete reinforced deformed steel fibbers, part 1: Bond-slip mechanisms’, ACI Material Journal 91 (5) (1994) 435-446.

[4] Compione, G.,Mindess, S. and Zingone, G., ‘compressive stress-strain behavior of normal and high- strength Carbone- fiber concrete reinforced with steel spirals’. ACI Materials Journal 96 (1) (1999) 27-34.

[5] Balaguru, P.; and Ramakrishnan, V.’ ’Properties of lightweight fiber reinforced concrete’, Fiber Reinforced concrete- Properties and applications, SP105, American Concrete Institute, Detroit, Michigan, 1987.pp. 305-322.

[6] Holm, Thomas A.," Lightweight concrete and aggregate", Standard Technical Publication STP 169c, pp. 522-532, 1995.

[7] Short, A., and Kinniburagh, W., "Lightweight concrete", Applied Science Publishers, Third Edition, London, pp. 78-81, 1978.

[8] Bron: pumice, , pp.4, 2004.9BS.882, "Specification for aggregates from natural sours fo. r concrete", British Standards Institution, 8pp, 1992.

[9] ASTM C330-78, "Standard specification for lightweight aggregate for structural concrete", Annual Book of ASTM Standards, Vol. 02-04, pp. 190-192, 1989.

[10] AL-Khalaf, M.N., and Yousif, H.A., "Use of rice husk ash in concrete", the international Journal of cement Composites and lightweight concrete, Vol.6, No.4, Nov, pp. 241-248,.1984.

[11] ASTM C311-87a, "Standard test method for sampling and testing fly ash or natural pozzolans for use as a mineral admixture in Portland cement.