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Study on Strength and Durability Properties of Light Weight Aggregate Concrete with Mineral Admixtures and Steel Fibers

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ABSTRACT: In this experimental investigation stands for improving the properties of concrete with respect to strength and durability aspects, especially in this aggressive investigation review states on addition of Cement with mineral admixtures and steel fibers. High performance concrete appears to be a better choice for strong and durable structures. A large amount of by-product or wastes such as silica fume and metakaolin etc. are generated by industries, which causes environmental as well as health problems due to dumping and disposal. Proper introduction of silica fume and metakaolin in concrete improves both the strength and durability characteristics of the concrete. The effects of fibers on workability, density and on various strength properties of high strength concrete M_{60} of grade concrete have been studied. The Steel fibers content varies from (0.5%, 1% and 1.5%) by volume of cement is used in concrete. For this purpose along with a Control Mix, 18 sets were prepared to study the compressive strength, tensile strength and flexural strength. Each set comprises of 9 cubes, 9 cylinders and 9 beams. All specimens are water cured and tested at the age of 7, 14 and 28-days. Super plasticizer is to be used to increase workability. Ductility and bond of concrete is found to increase in steel fibers in the 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% and 50%) by volume, the strength and durability properties of M_{60} grade of concrete was studied.

KEYWORDS: Silica fume, Metakaolin, Compressive Strength, Split tensile Strength, lightweight aggregate; lightweight concrete

I. INTRODUCTION

Lightweight concretes have been used as construction materials since the days of the Roman Empire. The earliest types of lightweight concrete were made by using Grecian and Italian pumice as lightweight aggregates. Developments in lightweight concrete production started in the 20th century. During the World Wars lightweight concrete was employed in the construction of ships and barges. Nowadays, lightweight concretes are commonly used in precast and prestressed components. Specifically speaking, while lightweight concrete compels higher costs compared to normal weight concrete, structures may yet have lower costs as a result of the reductions in dead weight, foundation sizes and costs, and consumed reinforcing bars. Common types of lightweight concretes are composed of lightweight aggregates, from natural sources (such as pumice, diatomite, scoria and tuff) and processed by-product or unprocessed porous materials (such as expanded clay, slag, slate and vermiculite). Pumice is one of the oldest lightweight aggregates used in constructions. During volcanic activation, the outflow of gases from cooling magma produces small hollow voids resulting in the porous structure of pumice. Hitherto, widespread researches have been devoted to the properties of pumice lightweight aggregate concrete and mix proportion effects. These researches indicated that pumice lightweight aggregate concretes can satisfy the requirements of semi lightweight structural concretes. Compressive strengths (28-day) up to 55 MPa were achieved incorporating Turkish pumice aggregates.

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II. LITERATURE REVIEW

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. In this investigation light weight concrete have been used as a construction materials. The earliest types of light weight concrete were made by using Grecian and Italian pumice as a light weight aggregate is used to developments in light weight concrete production started in 20th century. Pumice is one of the oldest lightweight aggregates used in constructions. During volcanic activation, the outflow of gases from cooling magma produces small hollow voids resulting in the porous structure of pumice. Hitherto, widespread researches have been devoted to the properties of pumice lightweight aggregate concrete and mix proportion effects. These researches indicated that pumice lightweight aggregate concretes can satisfy the requirements of semi-lightweight structural concretes. Compressive strengths (28-day) up to 55 Mpa were achieved incorporating Turkish pumice aggregates.

Srivastava V, Kumar R, Agarwal VC, Mehta PK.. Effects of silica fume and metakaolin combination on concrete. *IJCSE* 2012. In this investigation the use of supplementary cementitious materials is fundamental in developing low cost construction materials for use in developing countries. By addition of some pozzolanic materials, the various properties of concrete viz, workability, durability, strength, resistance to cracks and permeability can be improved. Silica fume is a by product resulting from the reduction of high purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or silicon alloys. Silica fume is known to improve both the mechanical characteristics and durability of concrete. The principle physical effect of silica fume in concrete is that of filler, which because of its fineness can fit into space between cement grains in the same way that sand fills the space between particles of coarse aggregates and cement grains fill the space between sand grains. The 28 day compressive strength of concrete generally increases with the Metakaolin content upto its optimum content, at all the Silica fume contents, and thereafter declines. The 7 day compressive strength of concrete generally decreases with the increasing Metakaolin content at all the Silica fume contents. The optimum dose of Silica fume and Metakaolin in combination is found to be 6% and 15% (by weight) respectively at both 7 and 28 day compressive strength. The slump is found to decrease with increase in Metakaolin content at all the Silica fume contents considerably.

Koneru VS Sukhesh Raja*1, K Venkateswara Rao STRENGTH PROPERTIES OF LIGHTWEIGHT AGGREGATE CONCRETE WITH SILICA FUME AND METAKAOLIN

In this experiment we are going to study the Mechanical Properties of a light weight aggregate concrete M50 using the natural light weight aggregate pumice stone as a replacement to coarse aggregate (10%, 20%, 30%, 40% and 50%) and addition of mineral admixture materials Metakaolin and Silica Fume. For this purpose along with a Control Mix, 18 sets are prepared to study the compressive strength, tensile strength and flexural strength. Each set comprises of 6 cubes, 3 cylinders and 3 prisms. 7 and 28-days Compressive test, Tensile Strength and Flexural Strength tests are to be performed in the hardened state. The test results will be showed on overall strength properties in various trials. Therefore, the strength properties of M50 concrete was studied

VENKATESAN et al., “Strength Characteristics and Durability Characteristics of Silica fume and Metakaolin based Concrete”, *IJIET*, ISSN 2319-1058, [Vol. 5 Issue 1, February 2015]:

This project deals with the properties of concrete, with varying percentage replacement of Silica fume and Metakaolin as a partial replacement for cement. The mix was obtained by replacing (35%, 15%); (40%, 10%) and (45%, 5%) mass of cement by Silica fume and Metakaolin respectively. Finally required specimens were casted to study the behaviors such as compressive strength, tensile strength and durability. Compressive strength and split tensile test were carried out for testing the strength properties is conducted to check the durability properties of concrete. The test results indicated that the two admixtures Silica fume and Metakaolin when used at an optimum combination tend to increase the strength and durability of concrete when compared with conventional concrete.

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Sruthi V(1), Elba Helen George(2) A REVIEW ON SILICA FUME – AN ADDITIVE IN CONCRETE

Silica fume is also known as micro silica and it is a very fine pozzolanic material and composed of amorphous silica produced by electric arc furnaces as a by- product of the production of elemental silicon or ferrosilicon alloys and also consists of spherical particles. The main field of application of silica fume is as pozzolanic material for high performance concrete. Silica fume can also be used in a variety of products such as grouts, and mortars. The range of properties of silica fume generally used in the studies as reported by Amudhavalli N. K and Jeena Mathew [2].

III. EXPERIMENTAL INVESTIGATION

Experimental investigation consists of casting and testing of 18 sets along with control mix. Each set comprises of 9 cubes, 9 cylinders and 9 beams for determining compressive, tensile and flexural strengths respectively. Hooked steel fibers is used to study with The fiber content varies from (0.5%, 1% and 1.5%) by volume of cement is used in concrete. All specimens are water cured and tested at the age of 7 and 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% and 50%) by volume of Pumice stone is used. The different admixtures like steel fiber. Cube section dimension is of 15cmx15cmx15cm, 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.

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

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 Results

S.No	Property	Experimental Value	Requirements As Is Codes
1	Normal consistency	34%	IS 4301-1988(part-4)
2	Specific gravity	3.12	3.15
3	Initial setting time Final setting time	44 min 460 min	30 min 600 min (max) As per 12269
4	Soundness test	7 mm expansion	

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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.

PUMICE STONE (LIGHTWEIGHT AGGREGATE):

Structural light weight concrete has an in-place density (unit weight) on the order 1440 to 1840 kg/m³ compared to normal weight concrete with a density in the range of 2240 to 2500 kg/m³. The pumice aggregate 20 mm size was used. Specific aggregate of pumice used is 0.86.

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. 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%

IV. RESULTS AND ANALYSIS

Results for various percentages of mineral admixtures

Table 3: compressive strength results

Mix	Compressive strength(N/mm ²)		
	7 days	14 days	28 days
M ₀	43.26	66.86	69.33
M ₁	45.25	67.01	71.88
M ₂	47.01	67.37	73.31
M ₃	49.90	67.58	73.91
M ₄	50.70	68.37	75.57
M₅	51.84	70.67	77.85
M ₆	45.89	67.34	72.64
M ₇	43.09	64.09	69.34

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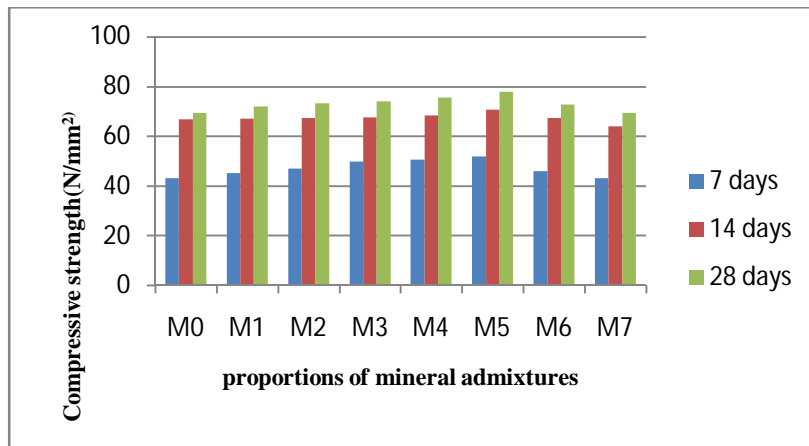


Fig. 1. Overall results of compressive strength

SPLIT TENSILE TEST RESULTS

When silica fume percentage increases from 0% to 20%, the normal consistency is increases about 40%. Increase in split tensile strength beyond 10% silica fume replacement was almost unsatisfactory. I this study M60 grade concrete and it was found that maximum split tensile strength of 6.07 N/mm² was obtained for 1.5% replacement of silica fume and 1% of metakaolin with 1% of steel fibers.

Table 4: Split tensile strength results

Mix	Split tensile strength(Mpa)		
	7 days	14 days	28 days
M0	1.18	3.17	4.73
M1	1.51	3.47	4.96
M2	1.74	3.76	5.28
M3	1.89	3.97	5.41
M4	2.01	4.13	5.84
M5	2.48	5.10	6.07
M6	2.31	4.81	5.37
M7	2.46	3.72	4.96

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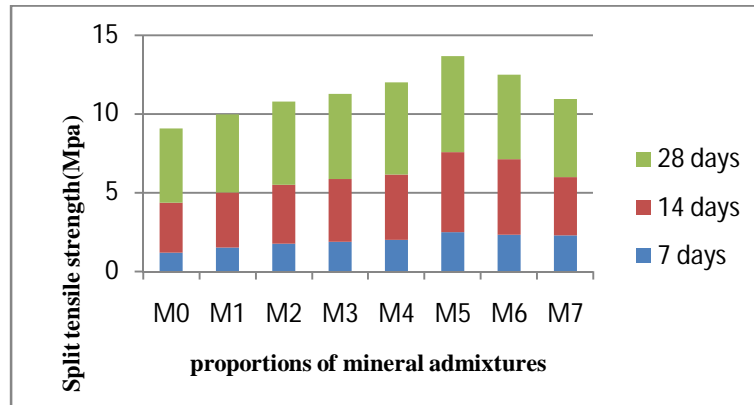


Fig.2. Split tensile testing of cylinder

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/m² 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.

Table 5: Flexural strength results

Mix	Flexural strength(Mpa)		
	7 days	14 days	28 days
M0	1.54	4.40	6.29
M1	1.98	4.14	6.41
M2	2.01	4.43	6.53
M3	2.24	4.80	6.66
M4	2.58	5.16	7.57
M5	2.96	5.69	7.68
M6	3.27	5.30	6.48
M7	3.19	5.07	5.73

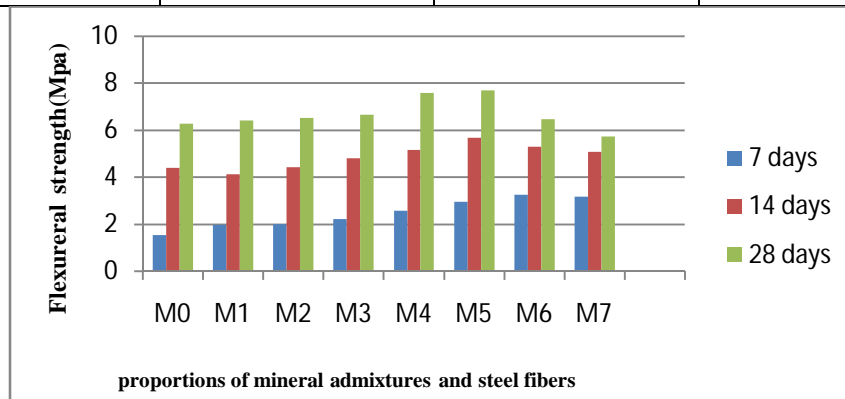


Fig.3. Lightweight aggregate replacement to optimized conventional M₆₀ mix

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Table 6: compressive strength results of replacing pumice stone

M ₅	% replacement of pumice	Compressive strength(N/mm ²)		
		7days	14 days	28 days
S.F-1.5% M.K-1.0% & steel fibers 1%	0%	48.84	70.67	77.85
	10%	49.27	71.95	78.08
	20%	50.34	72.30	78.19
	30%	36.91	49.78	69.45
	40%	32.12	42.70	53.35
	50%	30.17	35.40	49.40

COPRESSIVE STRENGTH TEST RESULTS WITH PUMICE AND STEEL FIBERS

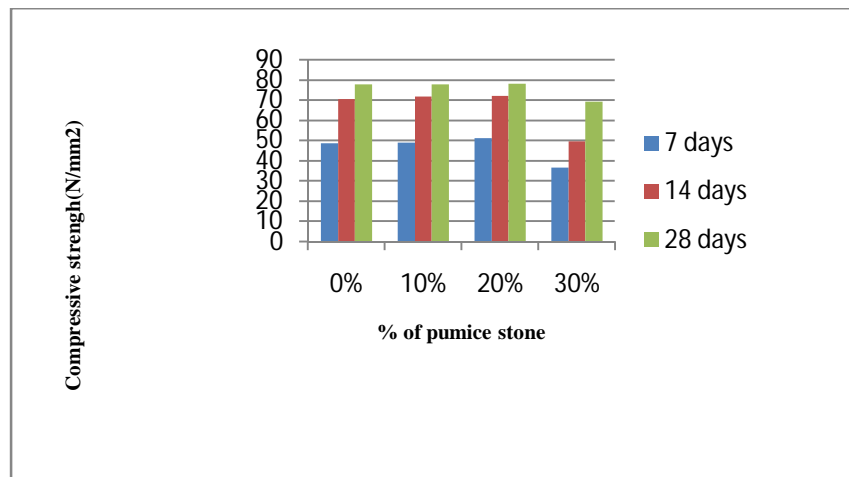


Fig. 4. Graph Showing Various Percentages of Pumice Stone

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The Behaviour of Cylinders Casted with Pumice Stone and Steel Fibers

Table 7: split tensile strength of pumice stone

M5	% replce of pumice	Tensile strength(Mpa)		
		7 days	14 days	28 days
S.F-1.5% M.K-1 % Steel fibers- 1%		2.76	5.88	6.84
	0	2.34	4.66	6.95
	10	2.51	4.32	7.25
	20	1.68	3.68	5.89
	30	1.30	3.24	4.10
	40	1.18	2.48	3.78
	50			

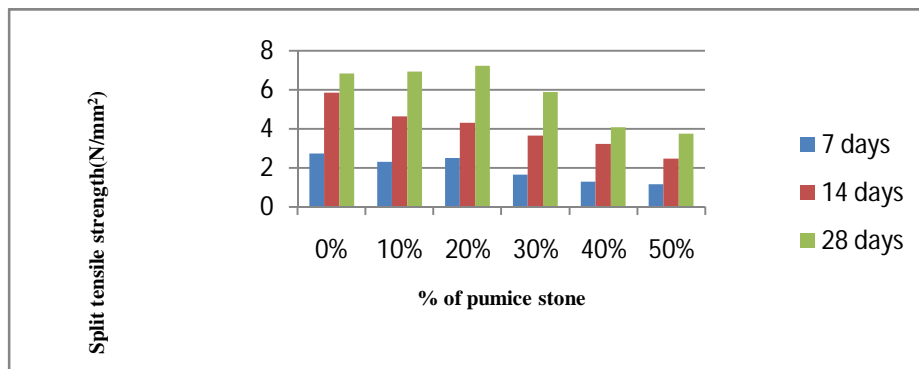


Fig. 5. Graph showing tensile strength for various percentages

The behaviour of prisms casted with different % of pumice stone and steel fibers

Table 8: flexural strength of pumice stone

M5	% replacement of pumice	Flexural strength(Mpa)		
		7 days	14 days	28 days
S.F-1.5% M.K-1% And steel fibers-1%		2.33	5.83	7.88
	0	2.56	5.98	7.91
	10	2.81	6.18	8.21
	20	1.86	3.61	5.36
	30	1.42	2.96	4.28
	40	1.16	2.42	3.25
	50			

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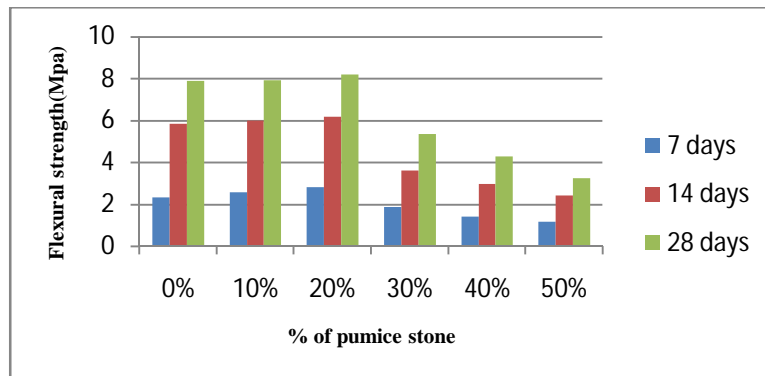


Fig. 6. Graph showing flexural strength of pumice & fibers

Density of pumice concrete M₆₀ mix

Table 9: Density values of concrete

M ₅	% replace of pumice stone	Density of concrete(Kg/m ³)
S.F-1.5% M.K-1% Steel fibers-1%	0	2696.30
	10	2577.78
	20	2459.25
	30	2307.40
	40	2216.30
	50	2097.77

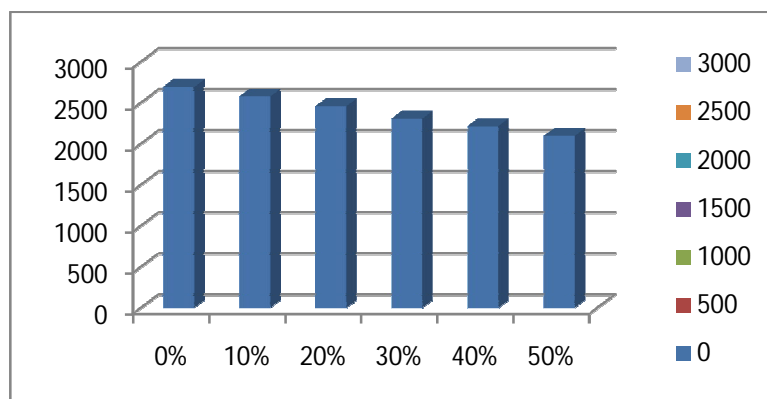


Fig. 7. Density of Light Weight Aggregate Concrete at Different Replacement Levels

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Durability studies of lightweight aggregate concrete:

The concentrations of acids in water are 2% HCL and 2% H₂SO₄. Durability studies of compressive strength of lightweight aggregate concrete is effected with chemicals as follows

Table 10. Compressive strength of lightweight aggregate concrete is effected with chemicals

s.no	% of pumice stone	% of weight loss	Compressive strength(N/mm ²)	
			28 days	90 days(2% H ₂ so ₄)
1	0	4.85	78.85	74.39
2	10	3.51	74.35	71.25
3	20	4.52	71.28	68.25
4	30	5.7	64.35	51.53
5	40	6.61	54.45	47.97
6	50	7.74	51.35	43.76

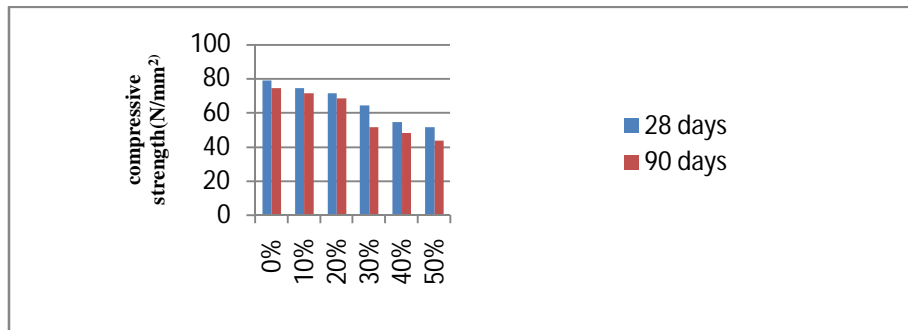


Fig. 8. Compressive strength of lightweight aggregate concrete with steel fibers

Durability test in presence of HCL solution

Table 11. Compressive strength of Light Weight aggregate concrete with HCL Solution

S.no	% of pumice stone	% of weight loss	Compressive strength(N/mm ²)	
			28 days strength	90 days(2% HCL)
1	0	2.65	78.85	71.39
2	10	3.92	74.35	67.25
3	20	4.70	71.28	61.25
4	30	5.24	64.35	49.53
5	40	6.61	54.45	43.97
6	50	7.64	51.35	39.76

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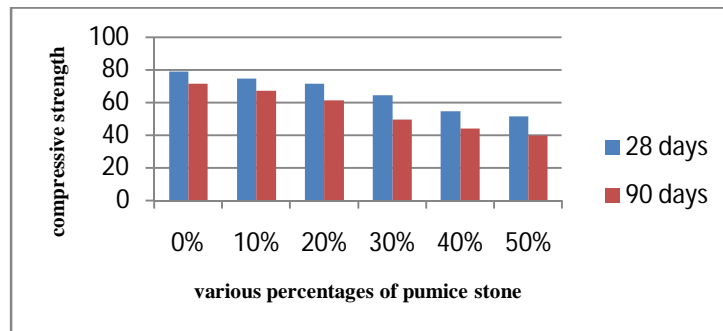


Fig. 9. Durability test in presence of HCL solution

V.CONCLUSIONS

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn:

- Addition of 2.0% Silica Fume and 1.5% Metakaolin and steel fibers 1% to M_{60} Conventional concrete mix, there is an increase in compressive strength up to 21.3% over conventional concrete.
- Up to 20% replacement of coarse aggregate with light weight aggregate, the optimized conventional concrete has good compressive strength and strength results are promising up to 30% replacement.
- Split Tensile Strength increases by 16.5% with addition of 2.0% Silica Fume and 1.5% Metakaolin and steel fibers 1% to M_{60} Conventional concrete.
- Up to 20% replacement of coarse aggregate with light weight aggregate, the optimized conventional concrete has good Split Tensile Strength and strength results are promising up to 30% replacement.
- Flexural strength increases by 25% with addition of 2.0% Silica Fume and 1.5% Metakaolin and 1% steel fibers to M_{60} Conventional concrete.
- Up to 20% replacement of coarse aggregate with light weight aggregate, the optimized conventional concrete has good Flexural Strength and strength results are promising upto 30% replacement.
- Though it is not a light weight concrete the density of concrete is reduced by 18.69% for promising strength results.

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