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# Experimental Study on Mechanical Properties of Light Weight Concrete with Mineral Admixtures and Steel Fiber as Partial Replacement

K. Chiranjeevi<sup>1</sup>, K. Siva Kiran<sup>2</sup>

P.G. Student, Department of Civil Engineering, Kallam Haranadhreddy of Technology, AP, India<sup>1</sup>

Assistant Professor, Department of Civil Engineering, Kallam Haranadhreddy of Technology, AP, India<sup>2</sup>

**ABSTRACT:** Light weight aggregates concrete can be defined as expansion in the volume of concrete mixture by adding some admixtures which improves strength and quality of the concrete. It is lighter in weight compared to ordinary concrete. The light aggregate concrete is very special about its less density and its thermal conductivity. It is used in the construction of larger precast units. In this experiment we are going to study the Mechanical Properties of a light weight aggregate concrete M60 using the natural light weight aggregate pumice stone as a replacing material to coarse aggregate (0%, 10%, 20%, 30%, 40% and 50%) and addition of mineral admixture materials Silica fume, Metakaolin and steel fibers. 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 9 cubes, 9 cylinders and 9 Beams. 7, 14 and 28 days Compressive test, Tensile Strength and Flexural Strength tests are to be performed in the hardened state. The test results are shown on overall strength properties in various trials. Therefore, the strength properties of M60 concrete were studied.

**KEYWORDS:** Silica Fume, Metakaolin, Light Weight Aggregate, Pumice Stone, Mechanical Properties, Master Cement, Steel fibers.

## I. INTRODUCTION

Light weight concrete is used as a building material from olden days. Grecian and Italian pumice are used as a light weight aggregates to create the earliest forms of light weight concrete. Developments in the manufacture of light weight concrete started in the 20<sup>th</sup> century. The conventional cement concrete is a heavy material having a density of 2696 Kg/m<sup>3</sup>. The dead weight is high, particularly for members in flexure. ex. in high rise buildings, can save money and manpower in construction.

Light weight composite is a new material. Density of light weight concrete is 35% less than normal conventional concrete with the same crushing capacity. It is a preferable material in seismic design structures with lower elasticity unit and ductility and reduced dead weight.

## LIGHT WEIGHT AGGREGATES

Categories of light weight concrete are given below:

- (i) Light aggregates like Clay, shale & slate, vermiculite etc., need further processing to use.
- ii) Industrial by-products such as hematite and sintered pulverized fuel ash (fly ash) expanded blast furnace slag, etc.
- (iii) Some of the examples of light weight aggregate are naturally occurred pumice, foamed lava, volcanic tuff and porous limestone.



## LIGHT WEIGHT CONCRETE

The light weight concrete contains less unit weight compared to normal concrete i.e. 1440-1840 kg/m<sup>3</sup>. The density of normal concrete is in between 2240- 2500kg/m<sup>3</sup>. The concrete density need to be greater than 17.0 Mpa for good structural applications. The concrete mixture is made of a thin, coarse aggregate. In some situations, a component or the whole fine aggregate may be a light weight material. Commonly expanded shale, clay or slate, pumice materials fired in a rotary kiln is used to create a porous structure with light weight. We can use materials like air-cooled blast furnace slag, hematite, etc., In the cement paste matrix, for example within cellular concrete, there are other classes of non-structural lightweight concrete with lower density made from other aggregate materials and higher air voids. Typically these are used for the properties of the insulation.

The major advantage of light weight concrete is to reduce the dead weight concrete structure. By reducing deadweight structure size of the column, footings and other load bearing components will be reduced. The mixture was designed to get same strength as normal concrete with less weight. Light weight concrete in structural elements has a more effective strength-to-weight ratio. In most cases, it was very costly and that was compensated with reduction of size of structural elements, less reinforced steel and lower concrete density. For houses it is preferable with a higher fire-rate and structural light weight concrete. The porosity of the light weight aggregate provides a source of moisture for the concrete's inner curing, ensuring constant improvement of concrete durability and strength. This does not prevent physical healing. For steel and concrete frame towers, parking structures, tilt- up walls, top slabs and composite slabs on metal surface, structural light weight concrete was used for bridge decks, piers, columns, slabs and wall components. With a combination of fine and coarse light weight aggregate or coarse light weight aggregate and regular fine weight aggregate, light weight concrete can be made.

Full replacement of the normal weight fine aggregate with a light weight aggregate would reduce the concrete density by about 160Kg / m<sup>3</sup>. Designers understand that, usually in an oven-dry environment, structural light weight concrete will not work. Therefore, structural design is generally based on a density of equilibrium (sometimes referred to as air-dry density) the state in which some moisture is retained within the light weight concrete.

## II. RELATED WORK

**Geoffrey, et al., "Properties of Pumice Light weight Aggregate" IJSTE, ISSN 2222-1719 (Paper) ISSN 2222-2863 (Online)[Vol 2, No.10, 2012].** The properties of volcanic pumice light weight aggregates obtained from long not in Mai Mahiu area in Kenya were experimentally investigated and this study presents the experimental results of the investigation. Three lightweight aggregate sample properties are investigated and compared with the conventional normal aggregate. The experimental investigation was conducted for the physical and mechanical properties. Pumice aggregates may have the similar physical properties of concrete aggregates and it is used as a light weight aggregate which can satisfy the requirements of light weight concrete with less weight. Further the produced concrete was used to construct domestic houses, where high strengths are not necessary with less weight. The pumice aggregates available in this country have a potential to produce commercially low light weight concrete.

**Srivastava V, Kumar R, Agarwal VC, Mehta PK... Effects of silica fume and metakaolin combination on concrete. IJCSE 2012.** The use of additional cementitious materials is important in developing low-cost construction materials for use in developing countries in this investigation. The different properties of concrete viz, workability, durability, endurance, crack resistance and permeability can be improved by adding some pozzolanic materials. Silica fume is a by- product resulting from the reduction in the processing of silicon metal or silicon alloys of high purity quartz with coal or coke and wood chips in an electric arc furnace. Mechanical characteristics and strength of concrete are considered to enhance silica fume. The main physical effect of silica fume in concrete is that of filler, which due to its fineness will fit into space between cement grains in the same way as sand fills the space between particles of coarse aggregates and cement grains fills the space between sand grains.

**M.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 plan deals with the properties of concrete as a partial substitute for cement, with varying percentage substitution of Silica fume and Metakaolin. The mix was obtained by replacing (35%, 15%); (40%, 10%) and (45%, 5%) the mass of cement with Silica fume and Metakaolin respectively. Casting eventually allowed samples to test behaviors such as compressive strength, tensile strength, and durability. For checking the force properties, compressive strength and break tensile testing are carried out to verify the toughness properties of concrete. The test results showed that, when used in an ideal combination, the two admixtures Silica fume and Metakaolin tend to increase concrete strength and durability compared to conventional concrete.



### III. METHODOLOGY

#### EXPERIMENTAL INVESTIGATION

The experimental study consists of casting and testing 18 sets together with the control combination. Each set includes 9 cubes, 9 cylinders and 9 beams to assess compressive, tensile and flexural strengths. In the analysis, Pumice stone is used with different percentages as a partial replacing material of natural coarse aggregate along with the different percentages of different mineral admixtures those are Silica Fume and Metakaolin using the super plasticizer master glemium as well.

Cube section dimension is of 15cm x 15cm x 15cm, cylinder section dimension is 15cm x 30cm and prism dimension is 50cm x 10cm x 10cm. When inserting the cement, the molds are coated with a lubricant. The molds were removed after a day of casting. The tubes, cylinders and prisms were moved carefully into the healing tank.

#### 1) CEMENT

The cement used was a 53-grade Ultra-tech gold (ordinary Portland cement) product locally available in compliance with IS 12269. The cement should be fresh and of uniform consistency. The concrete is expected to be clean and consistent. It should not be used when there is evidence of lumps or any foreign matter in the material. The cement should be processed for as short a time as possible under dry conditions. Cement is the main ingredient in concrete processing. Through altering the quality of cement, the properties of concrete will be greatly affected. The cement used in this project is 53 grades Ordinary Portland Cement which confirms IS 12269 –1987.

Cement can be defined as a bonding material which contains cohesive & adhesive properties which makes it capable to unite with different construction materials in forming a compacted material. Portland cement is one of the most widely used cements.

In 1824, "Joseph Aspdin" gave the name Portland cement because of its resemblance in color and consistency when it becomes as hard as Portland stone. Portland Stone in Portland, Dorset, is light gray calcareous.

#### COMPOSITION OF OPC:

The main chemical components used in ordinary Portland cement are given below:

- |            |          |
|------------|----------|
| 1. Calcium | 2.Silica |
| 3. Alumina | 4.Iron   |

Calcium is usually valid from limestone and chalk while silica, alumina and iron will come from sand, clays & iron ores. Other raw materials may include that are shale, and industrial by products.

#### 2) FINE AGGREGATES

Sand is purchased from a reputable source and complies with IS code for fine aggregates: 2386-1986(part3). It should be clean, hard, powerful, and free from organic impurities and harmful substance. It should be inert in relation to other materials used and of an appropriate type in relation to the strength, size, shrinkage and durability of the mortar made with it.

The grading of the sand is to be such that a mortar of defined proportions is developed with a uniform distribution of the aggregate, which will have a high density and good workability and work in position without segregation and without the usage of more water content. Fineness of sand should be 100% of it passes through the generic sieve No.8.

The fine aggregate is the inert substance which occupies 60 to 75 percent of the mortar weight, must be hard-pressed and chemically inert. Fine aggregates with particle size should not greater than 2.36 mm and less than 150 mm are appropriate for grading zone II.

#### 3) COARSE AGGREGATE

Machine crushed 65% hard granite chips through a sieve of 20 mm and retained on a sieve of 12 mm and a sieve of 33% through 12 mm and retained on a sieve of 10 mm.



#### 4) LIGHT WEIGHT COARSE AGGREGATE

##### 3.2.4 .1 PUMICE STONE

Pumice stone is a textural material formed from rapidly cooling viscous molten rock by trapping gas bubbles which results in a foamy whipped glass. The word pumice is derived from Latin word pumice, that meaning foam. It is even formed in deep underground sand when the magma erupts from the volcano by forming the gases which leaves a frothy structure. The transformed magma is the amorphous rock

i.e. pumice. Pumice is found in various textures such as pyroclastic flows, accumulated drifts, and piles at the river banks by the action of wind. The pure pumice is obtained in a floating mass or near the shore as it saturates by sinking and near the water bodies by the action of wind.

Pumice is an amorphous plentiful rock that is found all over the country where not all pumice is ideal for refining and use in industry. In ancient days many innovative techniques are adopted in concrete mixtures with pumice by Greeks and Romans. The majority of the ancient structures were built with the pumice stone. It is not a localized product by its varying characteristics. The market demand of pumice is high because of its Mohr scale hardness, purity level, whiteness and the ability of the company that mine sand refines. There is an increasing demand of pumice stone particularly for water filtration, chemical spill containment, manufacturing of cement, horticulture and in pet industry.

#### WATER

The water used in the mixing should be clean and free from any natural and unhealthy substances that will result in degradation of the mortar's properties. It is not appropriate to use salt water. Drinking and distilled water are ideal for both mixing water and concrete curing. For concrete processing, drinkable water can be used. It is possible to use drinking water to make concrete. The effect of water containing more than 2000 ppm of dissolved salts on concrete should be tested.

- Chloride ions not more than 1000ppm
- Sulphate ions not more than 3000ppm
- Bicarbonate ions not more than 400ppm

Water quality is an important factor because the unfavorable pollutants in it can affect strength of concrete and cause steel reinforcement corrosion. Water used in concrete mixture should be clean and free of harmful substances like oil, acid, alkali, salt, sugar, silt, and organic matter. The water used to drink is best suited for building purposes in order to gain more energy. Therefore, in this research, potable tap water was used to combine and heal.

Water cement ratio =0.25

#### METAKAOLIN:

Metakaolin (MK), which is available from the mid- 1990s, is one of the newly developed additional cementing materials (SCM) in compliance with ASTM C618, Class-N Pozzolanic specifications. Metakaolin differs from other additional cement- based products, such as fly ash, silica smoke and slag, in that it is not a by-product of an industrial process; it is processed for a specific purpose under carefully controlled conditions. This allows the optimization in the process of production of Metakaolin, ensuring the production of a reliable pozzolanic material. Metakaolin is formed at temperatures of 650-900 ° C by heating kaolin, one of the most abundant natural clay minerals. In the term, the Meta prefix is used to denote change. The prefix's scientific use is used for a combination form denoting a series' least hydrated. The transition that is taking place in the case of metakaolin is dehydroxylation, caused by heat application over a defined period of time. This heat treatment, or calcinations, breaks down the kaolin structure. Bound hydroxyl ions are extracted and the resulting disorder between layers of alumina and silica results in a highly reactive, amorphous product with pozzolanic and latent hydraulic reactivity that is ideal for use in cementing. The first recorded use of MK was mixed into the concrete used in the Jupia Dam in Brazil in 1962.

#### SILICA FUME

Silica Fume is the by-product of silicon metal or silicon alloys from Ferro. It is a very reactive pozzolon because of its chemical and physical properties. Concrete with the composition silica fumes was more strong and durable. Silica fume is available from concrete admixture suppliers and it was added simply while mixing concrete. Special attention on the part of the concrete contractor is needed to place finish and cure Silica Fume concrete. As shown in this image, silicon metal and alloys are developed in electric furnaces. Quartz, coal, and wood chips are the raw materials. The smoke



arising from the operation of the furnace is collected and sold as silica fume instead of being filled with soil. It is used in concrete because of presence of silicon dioxide (SiO<sub>2</sub>) amorphous (non-crystalline) to increase its strength. Size of this particle is very small i.e., 1/100<sup>th</sup> of cement particle.

Concrete from silica-fume doesn't just happen. To order to achieve desirable concrete properties, a specifier must make as conscious decision to include it in concrete. Assistance can be received from major suppliers of admixture to identify silica-fume concrete for high strength or improved durability. Wet and dry types of silica fume are available to use in concrete mix. It is usually added in a concrete plant, as shown in the picture, during concrete production. In both central- mix and dry- batch plants, silica fume-concrete was successfully produced. Assistance in all aspects of the handling of silica fumes is readily available and is used to produce consistent, high quality concrete.

**MASTER GLENIUM**

The Master Glenium SKY B233 product offering from BASF comprises new generation high-range water-reducing admixtures that are specially formulated for concrete applications where slump retention, high/early strengths and durability are required. Concrete mixtures containing these premier products can be optimized for delivery in remote locations and for use in hot and cold climates.

**STEEL FIBERS**

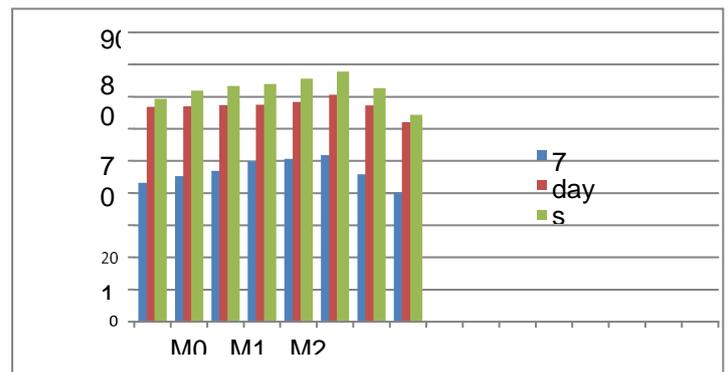
The steel fiber will completely replace the conventional reinforced concrete made from steel fiber. This is most popular in industrial flooring, but also in other applications of pre-casting. These are usually confirmed by laboratory tests to verify the performance requirements. The advantage of steel fibers is increased structural strength, decreased requirements for steel reinforcement and strengthened toughness, ductility and abrasion resistance.

**IV. EXPERIMENTAL RESULTS**

**Mineral admixtures addition to conventional m<sub>60</sub> mix**

**COMPRESSIVE STRENGTH:** Compressive strength is obtained by applying crushing load on the cube surface and it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x150mm x150 mm cubes. The test results are presented here for the Compressive strength of 7 days, 14 days and 28 days of testing.

Mix design	Compressive strength (N/mm <sup>2</sup> )		
	7 days	14Days	28 days
M0	42.12	66.81	70.1
M1	43.26	66.92	70.92
M2	45.25	68.01	71.01
M3	46.01	68.14	72.27
M4	47.01	68.97	73.97
M5	50.98	71.03	77.93
M6	45.89	64.34	75.13
M7	43.02	61.17	5.37

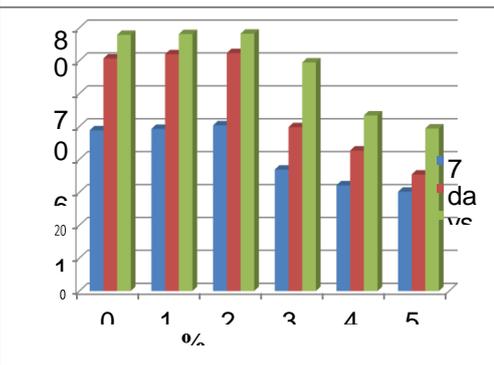


Compressive strength graph

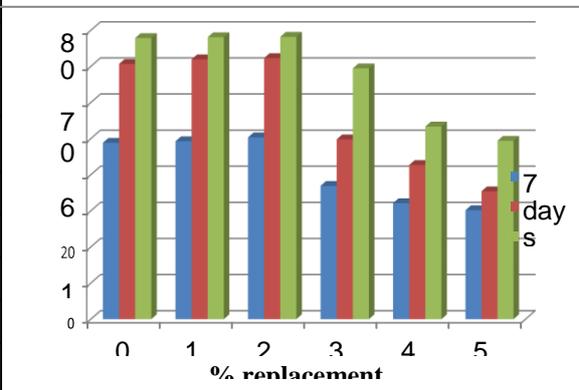


Mix design	Split Tensile Strength (Mpa)			Flexural Strength ( Mpa)		
	7 days	14 days	28 days	7 days	14 days	28 days
M0	1.19	3.01	3.92	1.42	3.99	6.19
M1	1.42	3.17	4.16	1.87	3.17	5.83
M2	1.57	3.58	4.81	1.93	4.48	6.13
M3	1.63	3.66	4.89	2.14	4.93	6.82
M4	1.79	3.99	5.17	2.67	4.80	6.89
M5	2.32	5.19	6.59	2.69	5.69	7.12
M6	2.26	4.92	5.97	3.14	5.12	7.41
M7	2.37	2.67	5.21	3.27	5.09	6.14

M5	% replacement with pumice stone	Compressive Strength		
		7 days	14 days	28 days
M.K-1.0% S.F-1.5% and steel fibers1%	0%	48.73	70.27	76.16
	10%	48.94	71.95	78.08
	20%	49.21	72.03	78.19
	30%	49.50	48.18	69.45
	40%	50.94	46.13	53.35
	50%	36.91	35.40	49.40

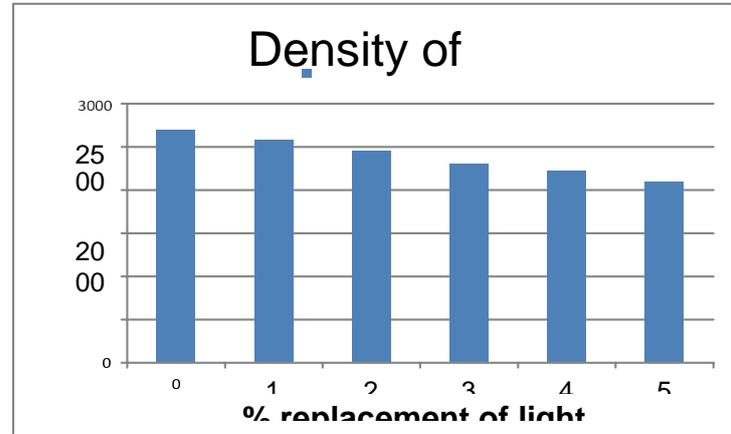


M5	% replacing with pumice stone	Tensile Strength (mpa)		
		7 days	14days	28 days
M.K-1.0% S.F-1.5% and Steel fibers 1%	0%	2.81	5.90	6.81
	10%	2.45	4.81	6.90
	20%	2.53	4.36	7.29
	30%	1.50	3.54	5.50
	40%	1.30	3.02	4.40
	50%	1.08	2.69	3.05





M5	% replacement with pumice stone	Flexural Strength (Mpa)		
		7 days	14 days	28 days
M.K-1.5% S.F-2.0% and steel fibers1%	0%	2.03	5.05	7.88
	10%	2.06	5.98	7.91
	20%	2.51	6.66	8.21
	30%	1.87	3.71	5.36
	40%	1.14	2.85	4.28
	50%	1.93	2.42	3.25



DENSITY OF PUMICE CONCRETE M60MIX

M5	% Replacement with pumice stone	Density of concrete (kg/m <sup>3</sup> )
M.K-1.0% S.F-1.5%	0	2696.70
	10	2577.68
	20	2459.45
	30	2307.90
	40	2216.33
	50	2097.71



Fig 7.1: Mixing of concrete mix





## V. CONCLUSION

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

- Addition of 1.5% Silica Fume and 1.0% Metakaolin and steel fibers 1% to M60 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 1.5% Silica Fume and 1.0% Metakaolin and steel fibers 1% to M60 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 1.5% Silica Fume and 1.0% Metakaolin and 1% steel fibers to M60 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 up to 30% replacement.
- Though it is not a light weight concrete the density of concrete is reduced by 18.69% for promising strength results.
- Light weight aggregate replacement to the granite coarse aggregate is good up to 10% for conventional concrete mix and 20% for optimized conventional concrete mix.
- Lightweight aggregate replacement to the granite coarse aggregate is promising up to 20% for conventional concrete mix and 30% for optimized conventional concrete mix.
- Durability test results shows there is reduction in strength by 14.04% when coarse aggregate is replaced with pumice stone.
- Durability test results show a difference of 2.46% when compared to H<sub>2</sub>SO<sub>4</sub> and HCL solutions.

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