A Study on the Mechanical Properties of Light Weight Concrete by Replacing Course Aggregate with (Pumice) and Cement with (Fly Ash)

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***Abstract*— Light weight concrete has become more popular in recent years owing to the tremendous advantages it offers over the conventional concrete. Even Light concrete but at the same time strong enough to be used for the structural purpose. Lightweight concrete has been successfully used since the ancient Roman times and it has gained its popularity due to its lower density and superior thermal insulation properties. Compared with Normal weight concrete, Lightweight concrete can significantly reduce the dead load of structural elements, which makes it especially attractive in multi-storey buildings. The most important characteristic of light weight concrete beside its light weight is its low thermal conductivity. This property improves with decreasing density. The adaptation of certain class of light weight concretes gives an outlet for industrial wastes and dismantled wastes which would otherwise create problems for disposal.**

The conventional mix has been designed for M_{25} grade concrete. Coarse aggregate replaced with Pumice aggregate in volume percentages of 25% and 33.33% further Cement replaced with the Fly ash in weight percentages of 15%, 20%, 25%, 30% for study in the present investigation. The properties like Compressive strength, Split tensile strength, Flexural strength and Youngs' modulus of above combinations were studied and compared with conventional design mix concrete.

It is observed that there is retardation in Compressive strength, Split tensile strength, Flexural strength and Young's' modulus for the light weight aggregate replaced concrete when compared to the concrete made with normal aggregate. For these light weight aggregate concrete mixes when 'cement' was replaced by 'fly ash' it is noticed that there is a marginal improvement in the properties studied. For 25% replaced light weight aggregate when cement was replaced by 15%, 20%,25% and 30%fly ash, the maximum gain in compressive strength of 18.71% at 28 days is observed for 20% replacement of fly ash. Similarly the gain in split tensile strength, flexural strength and Youngs' modulus of 16.66%, 29.51% and 10.15% is observed at 20% replacement of fly ash respectively. For 33.33% replaced light weight aggregate when cement was replaced by 15%,20%,25% and 30% fly ash, the maximum gain in compressive strength of 26.3 % is observed for 20% replacement of fly ash. Similarly the gain in split tensile strength, flexural tensile strength and Youngs' modulus of 19.23%,26% and 3.33% is observed at 20% replacement of fly ash respectively Hence we can infer that 20% replacement of cement by fly ash is optimum proportion among the proportions tested for the properties studied in the present investigation.

Keywords : Fly Ash, Light Weight Aggregate, Punice, Mechanical Properties, Split Tensile Tesh, Compression Test, Felexural Test, YoungsModulus

1. INTRODUCTION

Structural lightweight aggregate concretes are considered as alternatives to concretes made with dense natural aggregate because of the relatively high strength to unit weight ratio that can be achieved. Other reasons for choosing lightweight concrete as a construction material is more attention is being paid to energy conservation and to the usage of waste materials to replace exhaustible natural sources. Lightweight aggregate, due to their cellular structure, can absorb more water than normal weight aggregate. In a 24-hour absorption test, they generally absorb 5 to 20% by mass of dry aggregate, depending on the pore structure of the aggregate. Normally, under conditions of outdoor storage in stockpiles, total moisture content does not exceed two-thirds of that value. This means that lightweight aggregate usually absorb water when placed in a concrete mixture, and the resulting rate of absorption is important in proportioning lightweight concrete. Due to this more absorption of water of light weight aggregate, internal curing will be maintained for a long period. Pumice is a natural sponge-like material of volcanic origin composed from molten lava rapidly cooling and trapping millions of tiny air bubbles. Pumice aggregate are abundant at the outskirts of volcanic mountains, particularly in Mediterranean area, Rocky Mountains in US, and most part of Turkey and Indonesia. The utilization of Light Weight Aggregate Concrete based on natural lightweight aggregate materials such as pumice has been rather limited, partly due to insufficient quantity obtainable in the early years when the material and production know-how is low and partly due to lack of enthusiasm and industrial interests. In recent years, the existing limited research that has been conducted in this area structural concrete with compressive strength up to 25

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MPa can be produced with adequate economic benefits using pumice

Pumice is a natural aggregate of abundant resource around the world and it is environmentally friendly. However, pumice is far from being fully utilized in lightweight concrete at the time being. Concrete structures are generally designed to take advantage of its compressive strength. The primary structural property of concrete that a concrete designer is generally concerned is the compressive strength of concrete at a specific age. Pumice is the only rock that floats on water, although it eventually becomes waterlogged and sink. Since pumice is a volcanic rock, and retains its useful properties only when it is young and unaltered, pumice deposits are found in areas with young volcanic fields. Worldwide, over 50 countries produce pumice products. The largest producer is Italy, which dominates pozzolana production. Other major pumice producers are Greece, Chile, Spain, Turkey, and the United States. Pumice and pumicite are used to make lightweight construction materials. About three-quarters of pumice and pumicite is consumed annually for this purpose.

2. OBJECTIVES

The specific objectives of the present investigations are as listed below.

- To conduct the feasibility study of producing light weight aggregate pumice concrete with fly ash admixture.
- To investigate the mechanical properties of pumice aggregate concrete, such as, compressive strength, tensile strength, flexural strength and modulus of elasticity.
- To investigate the flexural behavior of pumice Light Weight Aggregate Concrete beam.
- To study the effect of various replacements (25% and 33.33%) of natural aggregate by light weight aggregate(pumice) and replacement of cement by an admixture (fly ash) in different percentages, (15%, 20%, 25%,and 30%) on 3,7, 28,90,180 days compressive strength,
- To study the effect of various replacements (25% and 33.33%) of natural aggregate by light weight aggregate(pumice) and replacement of cement by an admixture (fly ash) in different percentages, (20%) on 3,7, 28,days split tensile strength
- To study the effect of various replacements (25% and 33.33%) of natural aggregate by light weight aggregate(pumice) and replacement of cement by an admixture (fly ash) in percentages, (20%,) on 3,7, 28, days flexural strength (fs) and modulus of elasticity (E).

3. MATERIALS AND METHODS

To start with mix design has been conducted for M_{25} concrete making use of ISI method of mix design using normal constituents of concrete. In the course of investigation, normal granite aggregate has been replaced by, 25%, and 33.33%, of light weight aggregate namely pumice. In the present investigation the normal cement has been replaced by admixture (fly ash) in equal proportions in four percentages i.e., 15%, 20%, 25%, 30%. For the study of various properties, different specimens have been cast and tested. Here a constant water cement ratio of 0.50 has been with the workability throughout the investigation. The experimental part of the investigation has been planned in the following three stages.

Main constituents of the concrete viz., fine aggregate, coarse aggregate (granite), cement, water, light weight aggregate (pumice) and fly as have been procured from various places. Fine aggregate has been procured from LocalRiver. Coarse aggregate (20mm) has been procured from (machine crushed)., local drinking water is used for mixing and curing. Pumice which is a nenatural light weight aggregate produced by the release of gases during solidification of lava, has been procured from Turkey. The fly ash is procured from RTTP

3.1 CEMENT

Locally available Bharathi Ordinary Portland Cement (OPC) of 53 grade of Cement Brand conforming to ISI standards has been procured and various tests have been carried out according IS 8112-1989 from them it is found that,

Table 3.1: The Chemical Composition of Cement

S.NO	Oxide	Cement
1	SiO_2	20.65
2	Al_2O_3	5.6
3	Fe_2O_3	4.13
4	CaO	61.87
5	MgO	2.6
6	SO_3	2.79
7	K_2O	0.83
8	Na_2O	0.14
9	Loi	1.43

3.2 FINE AGGREGATE

The locally available natural river sand is procured and is found to be conformed to grading zone-II of Table of IS 383-1970. Various tests have been carried out as per the procedure given in IS 383(1970) from them it is found that.

- Specific Gravity of fine aggregate is 2.66
- Fully compacted density of fine aggregate is 1670 kg/m3

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- Partially compacted density of fine aggregate is 1500 kg/m3
- Fineness Modulus of Fine Aggregate is 3.2

Table 3.2: Sieve Analysis of Fine Aggregate

S No	IS Sieve No	Weight Retained (in grams)	Cumulative weight Retained (in grams)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing
1	4.75	20	20	2	98
2	2.36	20	40	4	96
3	1.18	180	220	22	78
4	0.6	305	525	52.5	47.5
5	0.3	395	920	92	8
6	0.15	70	990	99	1
7	0.075	10	1000	100	0
8	Pan	0	1000	100	0

3.3 COARSE AGGREGATE (GRANITE)

Machine Crushed granite aggregate confirming to IS 383-1970 consisting 20 mm maximum size of aggregate has been obtained from the local quarry. It has been tested for Physical and Mechanical Properties such as Specific Gravity, Sieve Analysis,

Density values and the results are as follows.

- Specific Gravity coarse aggregate is 2.61
- Fully compacted density of coarse aggregate is 1690kg/m^3
- Partially compacted density of coarse aggregate is 1466kg/m^3
- Fineness Modulus of Coarse Aggregate 9.09

Table 3.3: Sieve Analysis of Coarse Aggregate

S. No	IS Sieve No	Weight Retained (in grams)	Cumulative weight Retained (in grams)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing
1	25	0	0	0	100
2	20	1660	1660	33.2	66.8
3	16	2080	3740	74.8	26.2
4	12.5	1035	4775	95.5	4.5
5	10	145	4920	98.4	1.6
6	6.3	40	4960	99.2	0.8
7	4.75	40	5000	100	0
8	Pan	0	5000	100	0

3.4 LIGHT WEIGHT AGGREGATE (PUMICE)

Pumice is a natural aggregate of abundant resource around the world and it is environmentally friendly. However, pumice is far from being fully utilized in lightweight concrete at the time being. Concrete structures are generally designed to take advantage of its compressive strength. Light weight aggregate (pumice) is procured from Turkey. The size of light weight aggregate is 20mm. Some of its properties are as follows

- Specific Gravity coarse aggregate is 1.14.
- Specific Gravity LWA -25%-2.1
- Specific Gravity LWA- is 33.33%- 2.3
- Fully compacted density of Lightweight coarse aggregate is 85kg/m^3
- Loose density of Light weight coarse aggregate is 140kg/m^3

Fig: 3.1 Light weight Aggregate (Pumice)

Table 3.4: Sieve Analysis of (Pumice) Aggregate

S.No	IS Sieve No	Weight Retained	Cumulative weight Retained (in grams)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing
1	25	0	0	0	100
2	20	1440	1760	88	12
3	16	285	1945	97.25	2.75
4	12.5	175	2000	100	0
5	10	0	0	100	0
6	6.3	0	0	100	0
7	4.75	0	0	100	0
8	Pan	0	0	100	0

3.5 FLY ASH

The Fly ash was obtained from the Af sin-Elbistan Thermal Power Plant in Turkey. It contained High amounts of calcium and sulfate (Erdogan, 1997; Tokyay and Erdogdu, 1998). The fly ash was class, C, since it was obtained from lignite coal (ASTM C618, 1991). The total fly ash reserves are about million a year.

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Fig: 3.2 Fly ash

Table 3.5: The Chemical Composition of Fly Ash

S.No	0xide	Fly Ash
1	SiO2	18.95
2	Al2O3	7.53
3	Fe2O3	3.85
4	CaO	51.29
5	MgO	1.58
6	SO3	12.06
7	K2O	1.51
8	Na2O	0.32
9	Loi	1.94

4. DETAILS OF TESTS CONDUCTED

1. Cube Compressive Strength of concrete,
2. Split Tensile Strength of concrete,
3. Flexural Strength of concrete,

4.1 MIX DESIGN PROCEDURE

The mix design for a concrete of M25 grade

Water	Cement	F. A	C.A
191.58	383.16	561.95.	1195
0.5	1	1.426	3.119

The mix design for a concrete of m 25 grade with replacement of cement by fly ash 20%.

water	Cement	F. A	C.A
191.58	383.1	533.3	1164
0.5	1	1.391	3.03

4.2 CUBE COMPRESSIVE STRENGTH OF CONCRETE

For each percentage of fly ash, 3 cube specimens have been cast. In all 165 cubes of size 150 mm x 150 mm x 150 mm have been cast

The cube compressive strength of concrete at different days for the different replacements of fly ash with the cement and with 25% light weight aggregate replaced in coarse aggregate

Table 4.1: Compressive Strength of Concrete Cube

S. No	% replacement of fly ash	Compressive strength (Mpa)				
		3 days	7 days	28 days	90 days	180 days
	0%NA	19.5	23	35	38.5	39.6
1	0% Fly Ash 25%LwA	14.288	15.28	22.2	23.98	24.9
2	15% Fly Ash 25% LwA	15.5	16.88	27.2	29.43	30.23
3	20% Fly Ash 25% LwA	16.78	18.07	29.5	32.45	33.55
4	25% Fly Ash 25% LwA	15.7	17	27.5	29.99	30.798
5	30 Fly Ash 25% LWA	15.2	16.5	27.2	29.16	30.05

4.3 SPLIT TENSILE STRENGTH

For each percentage of fly ash, 3 cylindrical specimens have been cast. In all 54 cylinders of size 150 mm diameter and 300 mm height, have been cast.

In this present investigation based on the Compressive strength results obtained for 25% light weight aggregate with different proportions as of fly ash replacement in cement. It is noticed that the maximum compressive strength is obtained for 20% fly ash replacement in cement. Hence the split tensile proposing is studied for the combination of 25% light weight aggregate, replacement in coarse aggregate and 20% replacement of fly ash in cement

Table 4.2: Split Tensile Strength of Concrete Cylinder

S. No	Age in Days	Split Tensile Strength (MPa)		
		0% LWA 0 % Fly Ash	25% LWA 0% Fly Ash	25% LWA, 20% Fly Ash
1	3	2.5	1.8	2.1
2	7	2.7	2	2.2
3	28	3.6	2.25	2.7

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4.4 MODULUS OF ELASTICITY &FLEXURAL STRENGTH

For each percentage of fly ash, 3 beam specimens have been cast. In all 108 beams of size 700 mm x 150 mm x 150 mm, have been cast.

Table 4.3: Modulus of Elasticity of Concrete

S. No	Age in days	Modulus of Elasticity (MPa)		
		0% Lwa & 0% Fly Ash	25% LWA & 0% Fly Ash	25% Lwa & 20% Fly Ash
1	3	$2.5X\ 10^4$	$2.35X10^4$	$2.6X10^4$
2	7	$2.6X10^4$	$2.45X10^4$	$3.45X10^4$
3	28	$2.85X10^4$	$2.58X10^4$	$3.663X10^4$

Table 4.4: Flexural Strength of Concrete

S. No	Age in Days	Flexural Strength(Mpa)		
		0% Lwa & 0 %Fly Ash	25% Lwa & 0% Fly Ash	25%Lwa 20% Fly ash
1	3	2.68	2.42	2.52
2	7	2.81	2.5	2.6
3	28	3.71	2.92	3.25

CONCLUSIONS

- The results obtained with 25% light weight aggregate replacement in normal aggregate were studied with fly ash replacement in cement by 0%, 15% 20%, 25% and 30%. At 20% replacement of cement by fly ash the maximum compressive strength is observed for 25% and 33.33% LWA replacement in coarse aggregate.
- The split tensile strength at 28 days for 0% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal coarse aggregate it is observed as 2.10 MPa
- Further split tensile strength at 28 days for 20% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal aggregate it is observed as 2.6 MPa
- The Flexural strength at 28 days for 0% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal coarse aggregate it is observed as 2.9 MPa.
- Further The Flexural strength at 28 days for 20% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal aggregate it is observed as 3.0MPa
- The young's modules at 28 days for 0% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal coarse aggregate it is observed as $2.54X10^4$MPa
- Further the young's modules at 28 days for 20% replacement of cement by fly ash and 33.33% light weight aggregate replacement in normal aggregate it is observed as $3.52X10^4$ MPa

SCOPE FOR FURTHER STUDY

- The similarly studies can be carried for different replacement of light weight aggregate.
- The similarly studied can be carried for different design mixes.
- An investigation can be made on pre-wetting of the light weight natural pumice aggregate for different mixes.
- Studies on fibrous (metallic, nonmetallic and natural) light weight aggregate (Pumice) concretes can be evaluated.
- The studies on SSC with light weight aggregate (pumice) can be evaluated)
- Behavior of the pumice aggregate concrete mixes with different mineral admixtures can be made.
- Durability studies can be carried out by exposing to chloride sulphate and acidic environments.
- Elevated temperature studies, freezing, thawing and chloride permeability tests on this particular type of concrete can be studied.
- Studies on Rice husk and GGBS with light weight aggregate (pumice concrete can be evaluated)

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