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EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF LIGHT WEIGHT AGGREGATE CONCRETE

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Abstract: In this study, an attempt has been made to study the Mechanical Properties of a structural grade light weight concrete M25 using the light weight aggregate pumice stone as a partial replacement to coarse aggregate and mineral admixture materials like Fly Ash and Silica Fume. For this purpose along with a Control Mix, 12 sets were prepared to study the compressive strength, tensile strength and flexural strength. Each set comprises of 4 cubes, 2 cylinders and 2 prisms. Slump test were carried out for each mix in the fresh state. 28-days Compressive Strength, Tensile Strength and Flexural Strength tests were performed in the hardened state. 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 32.8% at 28 days is observed for 20% replacement of fly ash. Similarly the gain in split tensile strength, flexural strength and Young's modulus of Elasticity are 20%, 11.3% and 41.9% is observed at 20% replacement of fly ash respectively.
Keywords: Concrete, Mechanical Properties, Light weight aggregate, Pumice stone, Compressive strength.

I. INTRODUCTION

Light weight concrete has become more used in recent years owning to the tremendous advantages it offers over the conventional concrete. Lightweight concrete can be defined as a type of concrete which includes an Expanding agent in it that increases the volume of the mixture while reducing the dead weight. It is lighter than the conventional concrete with a dry density of 300 kg/m3 up to 1840 kg/m3. The main specialties of lightweight concrete are its low density and low thermal conductivity. Lightweight concrete (LWC), with its reduced weight and improved durability, enables longer spans, fewer piers, and longevity for bridge structures. The use of structural grade light weight concrete reduces the self weight and helps to construct larger precast units An experimental study has been conducted on concrete with partial replacement of conventional coarse aggregate by another light weight aggregate. Experimental work has been done by replacing the coarse aggregate with Pumice stone. Low specific gravity of cinder in compression with natural aggregates resulted in the concrete made with cinder to be lighter than normal concrete. The main function for usage cinder material is to minimize the cost and it is reduced to disposal of waste material and it helps in reduction of dead load. The M20 grade concrete mix is designed using IS method. We make concrete by replacing coarse aggregate with cinder of different percentages like 10%, 20%, and 30% with curing of 7, 14, 21 and 28 days. Among all the percentages the better compressive strength obtained percentage is selected. Today, light weight aggregates are produced in a very wide range of densities varying from 50 kg/m3 from expanded perlite to 1000kg/m3 for clinkers. It is possible to make light weight aggregate concrete of 80Mpa compressive strength. The lightweight aggregate concrete can be divided into two types according to its application. One is partially compacted lightweight aggregate concrete and the other is the structural lightweight aggregate concrete. The partially compacted lightweight aggregate concrete is mainly used for two purposes that are for precast concrete blocks or panels and cast in-situ roofs and walls. The main requirement for this type of concrete is that it should have adequate strength and a low density to obtain the best thermal insulation and a low drying shrinkage to avoid cracking The production of lightweight aggregate concrete has been expanding, and now includes all types – from no fines concrete of low density, mainly for block production, to structural concrete with densities from 1000 to 2000 kg/m3 and compressive strength up to 80MPa.

1.1 ADVANTAGES OF LIGHT WEIGHT AGGREGATE CONCRETE

a) Purity of aggregate: Because it is man-made
b) Lower dead load
c) Better physical properties: lower modulus, lower coefficient of thermal expansion, easier drilling
d) Improved durability: This is because of the reduced likelihood of shrinkage and early thermal cracking, lower permeability and etc.
e) Environmental problems: The benefit can be significant of industrial waste products are used to manufacture LWA.
f) Offshore Platforms construction: additional buoyancy, better cracking behaviour, lower permeability, improved freeze-thaw resistance, savings on transport, etc.
e) Demolition

1.2 DISADVANTAGES OF LIGHT WEIGHT AGGREGATE CONCRETE

a) Reduced resistance to locally concentrated loads
b) More brittle
d) Special measures for pumping concrete.

1.3 OBJECTIVES OF PROJECT

The main objects of concrete mix design are:
1. To achieve the stipulated minimum strength and durability
2. To make the concrete in the most economical manner

Design of concrete mix requires complete knowledge of the various properties of the constituent materials, the implication in case of change on these conditions at the site, the impact of properties of plastic concrete on the hardened concrete and complicated inter-relationship between the variables.

II. METHODS AND MATERIALS

The experimental investigation consists of casting and testing of 9sets along with control mix. Each set comprises of 4 cubes, 2 cylinders and 2 prisms for determining compressive, tensile and flexural strengths respectively. Pumice stone is used in the study with different percentages as a partial replacement to natural weight coarse aggregate along with the varying percentages of the different admixtures like Silica Fume and Fly Ash. 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.

2.1 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. Silica Fume
6. Pumice Stone (Light Weight Coarse Aggregate)

2.2 COARSE AGGREGATES:

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/m3
- Partially compacted density of coarse aggregate is 1466kg/m3
- Fineness Modulus of Coarse Aggregate 9.09

Table 2.1: Sieve Analysis of Coarse Aggregate

S.NO	IS Sieve No	Weight retained (gm)	Cumulative weight retained (gm)	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

2.3 FINE AGGREGATES:

Sand shall be obtained from a reliable supplier and shall comply with ASTM standard C 33 for Fine aggregates. It should be clean, hard, strong and free of organic impurities and deleterious substances. It should be 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 density and good workability and which will work into position without segregation and without use of high water content. The fineness of sand should be such that 100% of its passes through sieve no 8. 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
- Partially compacted density of fine aggregate is 1500 kg/m3
- Fineness Modulus of Fine Aggregate is 3.2

Table 2.2: Sieve Analysis of Fine Aggregate

S.NO	IS Sieve No	Weight retained (gm)	Cumulative weight retained (gm)	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.	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

2.4 FLY ASH:

Fly Ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. Fly Ash is the most commonly and widely used pozzolanic material all over the world. Fly ash was first used in large scale in the construction Hungry Hose Dam in America in the approximate amount of 30% by weight of cement. In India, it was used in Rihand Dam construction replacing cement upto 15%.

Figure 2.1 Fly Ash

2.5 SILICA FUME:

Silica fume is a by product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor. Silicon metal and alloys are produced in electric furnaces as shown in this photo. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume, rather than being land filled. Perhaps the most important use of this material is as a mineral admixture in concrete. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Silica-fume concrete does not just happen.

Figure 2.2 Silica Fume

2.6 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. 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 ex solve (like the bubbles of CO_2that appear when a carbonated drink is opened). The simultaneous cooling and depressurization freezes the bubbles in the matrix. Eruptions under water are rapidly cooled and the large volume of pumice created can be a shipping hazard for cargo ships. 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/m3
- Loose density of Light weight coarse aggregate is 140kg/m3

Figure 2.3 Light weight Aggregate (Pumice)

Table 2.3: Sieve Analysis of (Pumice) Aggregate

S.NO	IS Sieve No	Weight retained (gm)	Cumulative weight retained (gm)	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

2.7 MIX DESIGN

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. Mix design for each set having different combinations are carried out by using IS: 10262 – 2009 method .The mix design for a concrete of M25 grade are shown in table 2.4

Table 2.4 Mix design of M25

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 M25 grade with replacement of cement by fly ash 20% shown in table 2.5.

Table 2.5 Mix design of M25 after replacement of cement.

Water	Cement	F.A	C.A
191.58	383.16	533.3	1164
0.5	1	1.391	3.03

III. TEST RESULTS AND DISCUSSIONS

3.1 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 and are shown in Table 3.1.

Table 3.1: 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	20	24	34	39.5	40.6
1.	0% Fly Ash 25 % LWA	15.288	16.28	23.2	24.98	25.9
2.	15% Fly Ash 25 % LWA	16.5	17.88	28.2	30.43	31.23
3.	20% Fly Ash 25 % LWA	17.78	19.07	30.5	33.45	34.55
4.	25% Fly Ash 25 % LWA	16.7	18	28.5	30.99	31.798
5.	30% Fly Ash 25 % LWA	16.2	17.5	28.2	30.16	31.05

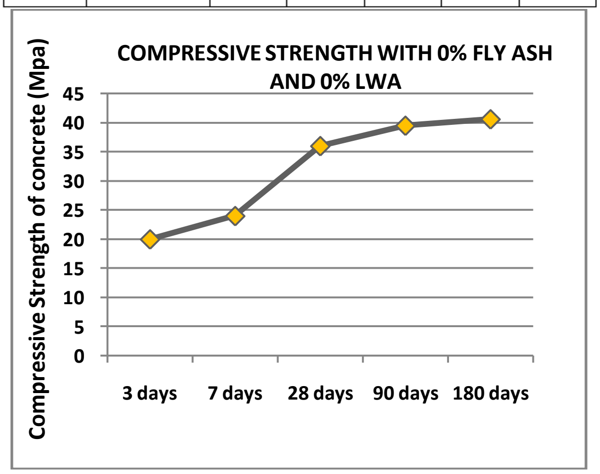

Figure 3.1 Compressive strength with 0% fly ash and 0% LWA

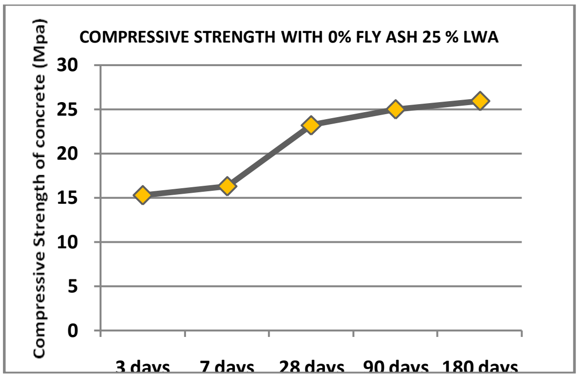

Figure 3.2 Compressive strength with 0% fly ash and 25% LWA

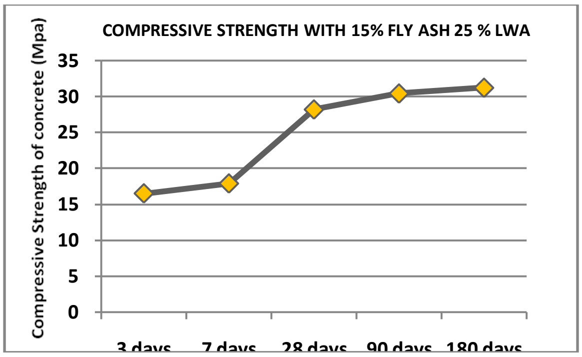

Figure 3.3 Compressive strength with 15% fly ash and 25% LWA

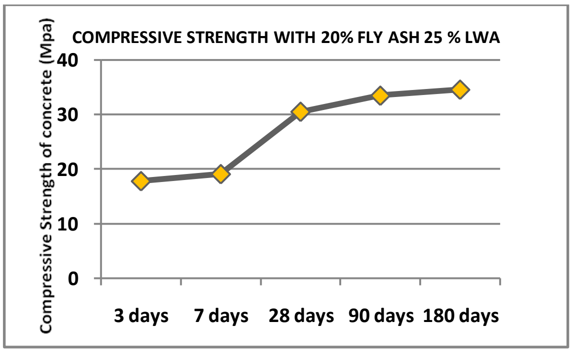

Figure 3.4 Compressive strength with 20% fly ash and 25% LWA

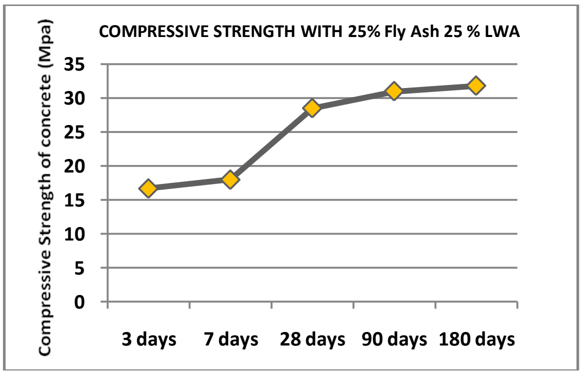

Figure 3.5 Compressive strength with 25% fly ash and 25% LWA

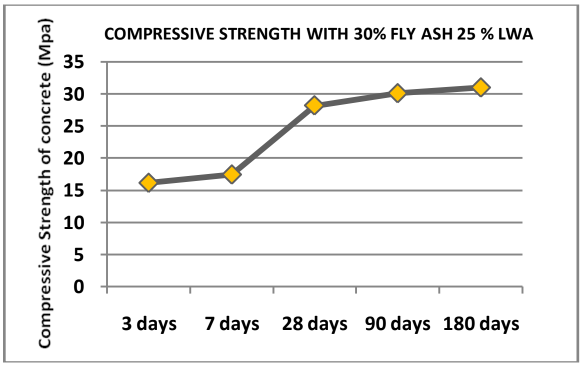

Figure 3.6 Compressive strength with 30% fly ash and 25% LWA

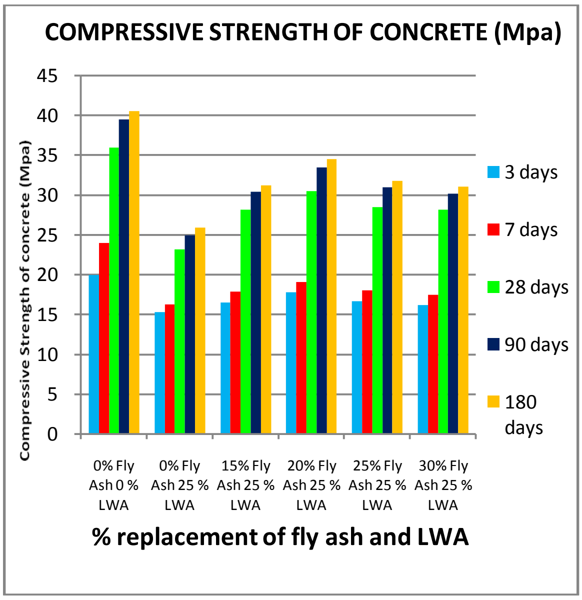

Figure 3.7 Compressive strength concrete

Figures 3.1 to figure 3.6 shows the graphs individually for different percentage replacements of fly ash and LWA and figure 3.7 shows the combined graph of replacement of fly ash and LWA.

3.2 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 and are shown in Table 3.2

Table 3.2: Split Tensile Strength of Concrete Cylinder

S.NO	% replacement of fly ash	Split tensile strength (Mpa)		
		3 days	7 days	28 days
1	0% LWA 0 % Fly Ash	2.6	1.9	2.2
2	25% LWA 0% Fly Ash	1.9	2.1	2.3
3	25% LWA, 20% Fly Ash	2.2	2.3	2.8

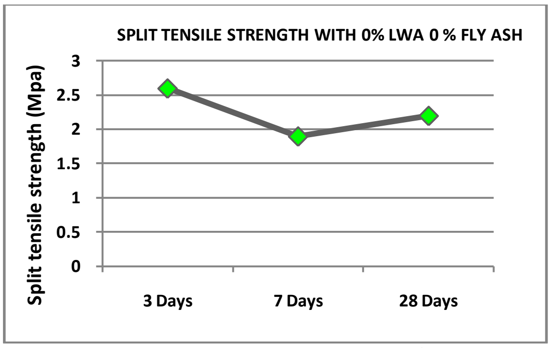

Figure 3.8 Split tensile strength with 0% fly ash and 0% LWA

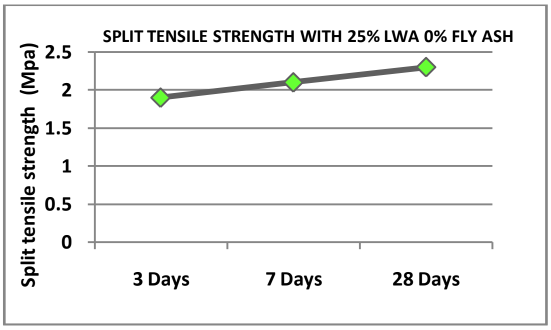

Figure 3.9 Split tensile strength with 25% fly ash and 0% LWA

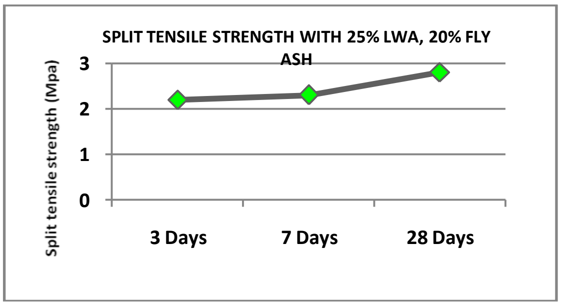

Figure 3.10 Split tensile strength with 25% fly ash and 20% LWA

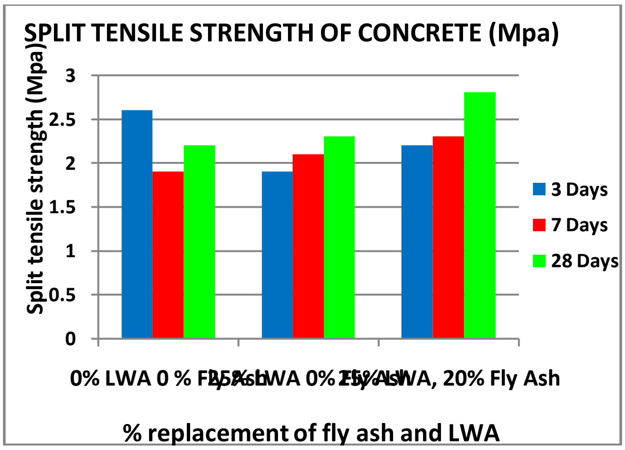

Figure 3.11 Split tensile strength of concrete

Figures 4.8 to figure 4.10 shows the graphs individually for different percentage replacements of fly ash and LWA and figure 4.11 shows the combined graph of replacement of fly ash and LWA.

3.3 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 and the results are shown in table 3.3 and table 3.4.

Table 3.3: Modulus of Elasticity of Concrete

S. NO	% replacement of fly ash	Modulus of Elasticity (Mpa)		
		3 days	7 days	28 days
1	0% LWA 0 % Fly Ash	2.5X10^{4}	2.6X10^{4}	2.85X10^{4}
2	25% LWA 0% Fly Ash	2.35X10^{4}	2.45X10^{4}	2.58X10^{4}
3	25% LWA, 20% Fly Ash	2.6X10^{4}	3.45X10^{4}	3.663X10^{4}

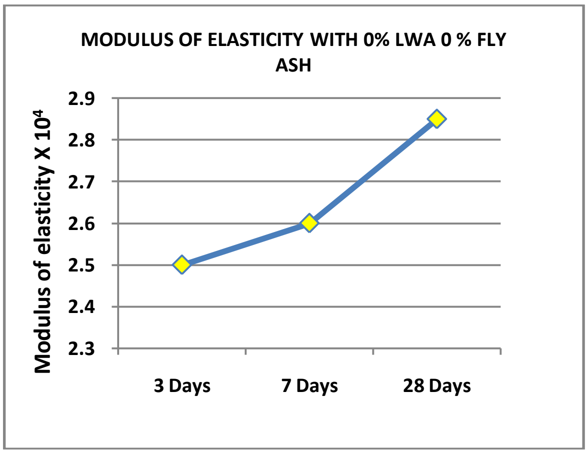

Figure 3.12 Modulus of elasticity with 0% fly ash and 0% LWA

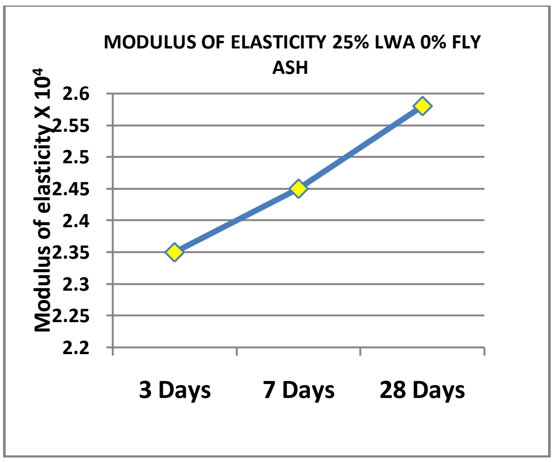

Figure 3.13 Modulus of elasticity with 25% fly ash and 0% LWA

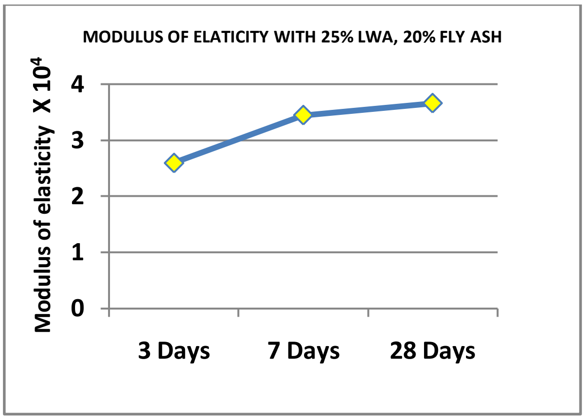

Figure 3.14 Modulus of elasticity with 25% fly ash and 20% LWA

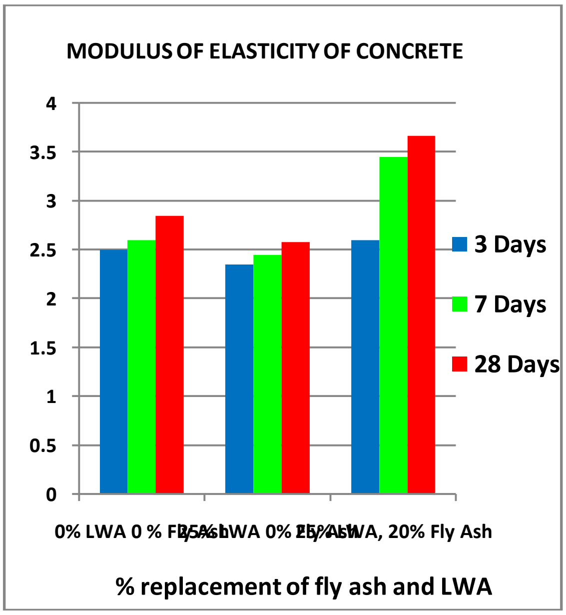

Figure 3.15 Modulus of elasticity

Figures 3.12 to figure 3.14 shows the graphs individually for different percentage replacements of fly ash and LWA and figure 3.15 shows the combined graph of replacement of fly ash and LWA.

Table 4.4: Flexural Strength of Concrete

S.NO	% replacement of fly ash	Flexural Strength (Mpa)		
		3 days	7 days	28 days
1	0% LWA 0 % Fly Ash	2.69	2.82	3.72
2	25% LWA 0% Fly Ash	2.43	2.6	2.93
3	25% LWA, 20% Fly Ash	2.53	2.7	3.26

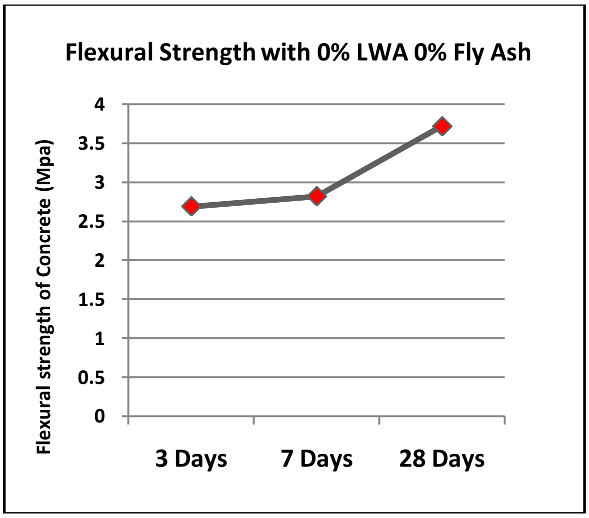

Figure 3.16 Modulus of elasticity with 0% fly ash and 0% LWA

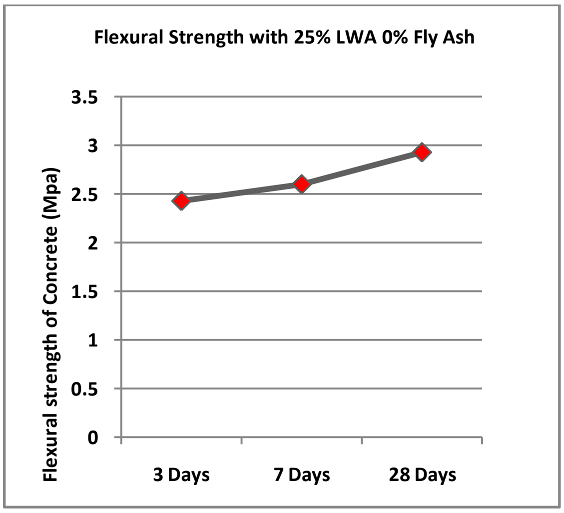

Figure 3.17 Modulus of elasticity with 25% fly ash and 0% LWA

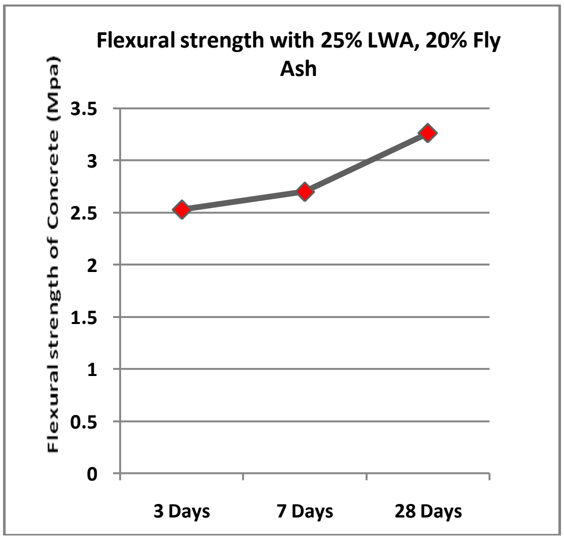

Figure 3.18 Modulus of elasticity with 25% fly ash and 20% LWA

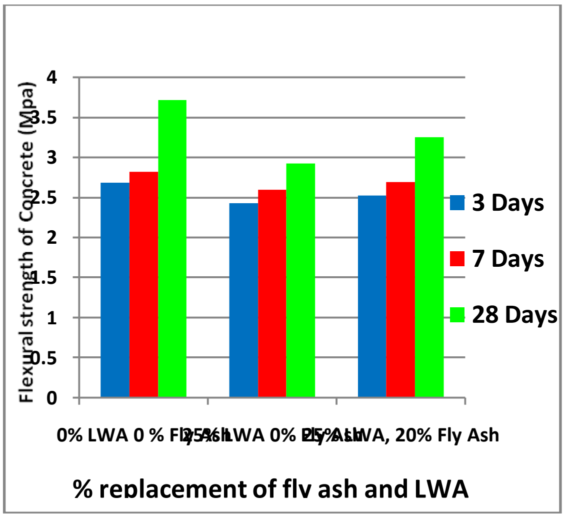

Figure 3.19 flexural strength of concrete

Figures 3.16 to figure 3.18 shows the graphs individually for different percentage replacements of fly ash and LWA and figure 3.19 shows the combined graph of replacement of fly ash and LWA.

IV. 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% LWA replacement in coarse aggregate. The conclusions are summarised below:

- Compressive strength tends to decrease with use of LWA. At 28 days normal concrete attained a compressive strength of 34 MPa, but with increased LWA and Fly ash content compressive strength reduces and at 20% Fly ash and 25% LWA, compressive strength reaches its peak value of 30.5 MPa.
- The split tensile strength at 28 days for 0% replacement of cement by fly ash and 25% light weight aggregate replacement in normal coarse aggregate it is observed as 2.25 MPa
- Further split tensile strength at 28 days for 20% replacement of cement by fly ash and 25% light weight aggregate replacement in normal aggregate it is observed as 2.7 MPa
- The Flexural strength at 28 days for 0% replacement of cement by fly ash and 25% light weight aggregate replacement in normal coarse aggregate it is observed as 2.92 MPa.
- Further The Flexural strength at 28 days for 20% replacement of cement by fly ash and 25% light weight aggregate replacement in normal aggregate it is observed as 3.25MPa
- The young's modules at 28 days for 0% replacement of cement by fly ash and 25% light weight aggregate replacement in normal coarse aggregate it is observed as 2.58X104MPa
- Further the young's modules at 28 days for 20%

replacement of cement by fly ash and 25% light weight aggregate replacement in normal aggregate it is observed as 3.663X104 MPa.

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