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Influence of Foam Densities in Cellular Lightweight Concrete

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Abstract: Foam concrete is a type of aerated light weight concrete. It does not contain any coarse aggregate and it also requires no compaction. This paper explains about the influence of density of foam which leads to variation in strength of the concrete. Foam is produced by using foam generator and mixed with the base mix. The density of foam in the base mix can be controlled by adjusting the revolutions of It the mixer. The main aim of foam is to create the stable air voids in the slurry. This leads to the reduction in weight of the concrete. can also be regarded as the aerated mortar because of absence of coarse aggregate. Here, fly ash is used as a full replacement of fine aggregate. Generally, the foam concrete densities may vary between 400kg/m^3 to 1850kg/m^3. But the densities below 1000kg/m^3 may not produce comparatively sufficient strength. Hence this paper deals with the densities of 1200kg/m^3 and 1500kg/m^3.The focus of this project is to study the physical and mechanical properties of foam concrete with the fly ash as full replacement of fine aggregate. In this paper 4 cubes, 3 cylinders and 1 beam are casted for each density and the results are computed.
Keywords: Foamed concrete, Fly ash, Foam generator, Base mix, Density.

I. INTRODUCTION

Nowadays, builders across the world are paying increasing attention to use eco friendly material as replacement for conventional building materials. since the concrete is a composite construction material. It is mainly composed of cement(usually Portland cement),aggregate(coarse aggregate made of gravel, crushed stone and fine aggregate as sand) water and other chemical agents to get desired properties.

The adverse development in the field of concrete has lead to the development of light weight concrete with good characteristics. There is also a possibility of usage of some other materials for the replacement of cement. This reduces usage of cement and ultimately reduces the emission of co_2 during the manufacturing of cement. The use of fly ash as a replacement of fine aggregate not only decreases the cost of construction but also it is eco friendly in nature.

Foam concrete is a mixture of cement, fine sand(substituted by fly ash),water and predetermined volume of foam. The foam concrete has both fire resistance and thermal insulation properties. The major difference between the foam and conventional concrete is the use of coarse aggregate has been replaced by the air pores inside the concrete. It is called cellular concrete because of its embedded air pores inside the concrete. The foam is generated by diluting the foam in agent with water and aerated to create foam. The cement paste can stick around the foam and hardens. After hardening the foam has sufficient strength to maintain the shape around the voids. Foaming agents may be synthetic or protein based foaming agents. In this project synthetic foaming agent is used.

Protein based foaming agents come from animal proteins such as blood, bones of cows, pigs and other animal carcasses. It is rarely used because it can easily degraded by bacteria and other microbes. Synthetic based foaming agents are purely chemical products and they can give good strength above 1000kg/m^3.

II. OBJECTIVE AND METHODOLOGY

The objective of the study is to

A. To study the influence of density of foamed concrete.

B. To compare the Density and Strength of foamed concrete with Fly ash as a replacement for Sand.

C. To study the Flexural Behaviour of foamed concrete with that of conventional concrete.

D. To work out the cost comparison between Conventional and Foamed concrete.

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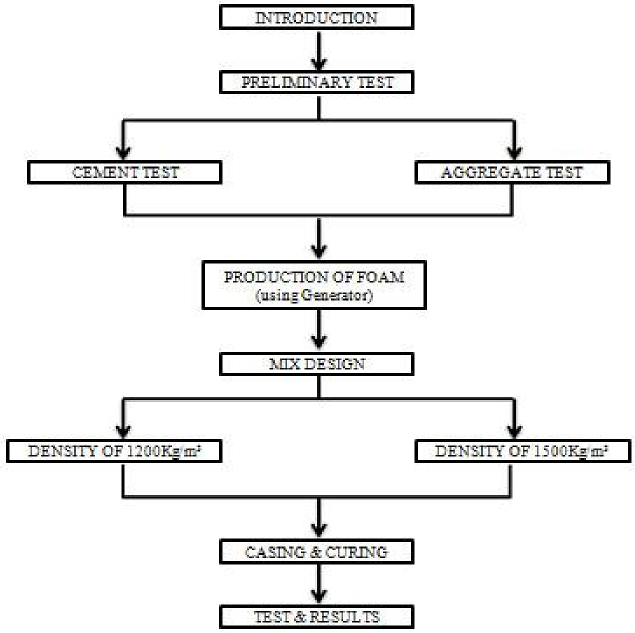

Fig.1 Flowchart for Methodology

III. CONSTITUENT MATERIALS

A. Cement

Ordinary Portland cement of 53 grade conforming to IS:12269-1987 is used. 53 grade cement is used as a binding material to achieve good strength.

B. Water

Potable water is used. Care should be taken because the presence of organic matter in the water can seriously affect the quality of foam. High water content do not affect the porosity of the foamed concrete but they promote segregation. Hence the adequate amount of water is added.

C. Fly ash

Fly ash is a by product obtained while burning of pulverized coal. It is used as a replacement of fine aggregate because it can give good strength and due to its finer particles than sand it promotes uniform distribution of voids. ASTM broadly classifies fly ash into two types. Class F- it contains 7% lime and it is obtained by harder bituminous coal and old anthracite. Class C- it contains more than 20% lime and it is obtained by burning of younger lignite and sub bituminous coal.

D. Foaming Agent

Foaming agent is broadly classified into synthetic and protein based foaming agents. Synthetic based foaming agents are globally used due to its easier production and availability. Foam is produced by using foam generator after diluting it with water. The concentration of foaming agent with that of water is 1:30 is used.

IV. FOAM CONCRETE PRODUCTION

Foam concrete is produced either by
Pre-foaming method
Mixed foaming method
In Pre-foaming method, base mix(cement slurry + fly ash + water) and foaming agent is separately produced and blended together in the mixture to produce foam concrete. It is further sub divided into wet foam and dry foam. If the foaming agent is introduced through fine mesh then its called as Wet foam. If the foaming agent is introduced through generator then its called as Dry foam.
In mixed foaming method, surface active agent (foam) is mixed with cement slurry and then blended together in the mixture. The

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cellular structure is formed after hardening.

Here Synthetic-based foaming agent is used which is purely a chemical product. Sodium Lauryl Sulphate is used as the synthetic agent which is stable at concrete densities above 1000Kg/m^3 and gives good strength. These are mainly surfactants that allows finer bubbles to spread evenly on the surface.

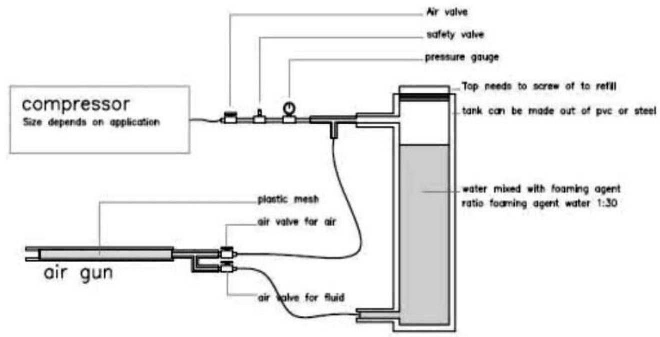

Fig.2 Production method of Foam

A. Compressor

It generates pressure for the foam generator to work.

B. Air valve

The pressure that goes to the system can be adjusted with the air valve.

C. Pressure guage

It will make sure for maintaining the work at same pressure to get same foam every time.

D. Air gun

At the air gun, the water is pushed through the fine mesh by the air pressure and forms a stable foam.

V. PRELIMINARY TEST

Table.1 Basic Test for Materials

CEMENT TEST				
S. NO.	TEST NAME	CODE BOOK	RESULT	RANGE
1.	Specific gravity	IS 4031 (Part 2) 1988	3.14	3.12-3.19
2.	Fineness test	IS 4031 (Part1) 1988	7.3%	< 10%
3.	Standard consistency test	IS4031 (Part4) 1988	30%	26%-30%
4.	Initial setting time	IS 4031 (Part5) 1988	40mins	>30mins
FINE AGGREGATE TEST				
5.	Specific gravity	IS2386 (Part3) 1963	2.68	2.65-2.68
6.	Particle size determination	IS 2386 (Part1) 1963	2.642	2.6-2.7

VI. MIX DESIGN

Definite methods are not available for proportioning of Foamed Concrete and so the site trials were undertaken. The results were computed from the site trials and used as Mix Design. Here 4 cubes, 3 cylinders and a beam is casted for respective densities.

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Table.2 Mix Design for Cube

Site Trial no.	Density (Kg/m^3)	Cement (Kg)	Fly Ash (Kg)	Water (Lit)	Foam (g)	Foam (Lit)
1	1200	8	16	9.6	26	1.1
2	1500	8	18	10	16	0.6

Table.3 Mix Design for Cylinder

Site Trial no.	Density (Kg/m^3)	Cement (Kg)	Fly Ash (Kg)	Water (Lit)	Foam (g)	Foam (Lit)
1	1200	4	8.8	4.8	13	0.6
2	1500	4	8	5.1	8	0.3

Table.4 Mix Design for Beam

Site Trial no.	Density (Kg/m^3)	Cement (Kg)	Fly Ash (Kg)	Water (Lit)	Foam (g)	Foam (Lit)
1	1200	3.5	7	4.2	11	0.5
2	1500	3.5	7.7	4.5	7	0.3

VII. CASTING OF SPECIMEN

The important steps to be carried out in casting are as follows.

Step 1 - To determine the volume of a cement as per mix design.

Step 2 - To determine the volume per cubic meter.

Step 3 - This step comprises of mixing the base mix (cement, Flyash & water) components in the mixer.

Step 4 - The concentrated preformed foam is added to the mixer and blended well.

Step 5 - The required density of foamed concrete in the wet mix is calculated.

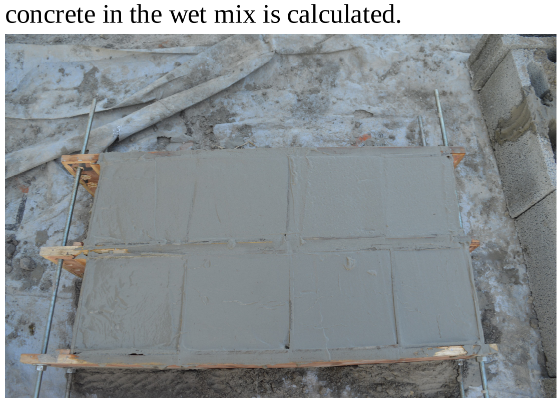

Fig.3 Casting of Specimen

They can be directly poured to the moulds because of high flowability. It can flow freely due to the thixotropic nature (shear thinning property) of foam bubbles. The curing should be done as per IS456 – 2000. The demoulding should be done after 24hours of casting. After demoulding, the specimen is kept under shade for 2 to 3 weeks. This prevents the initial shrinkage of foamed

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concrete.

VIII. EXPERIMENTAL PROCEDURE

The test procedure includes,

A. Physical properties

1) Dry density
2) Water absorption
3) Specific strength
4) Fire Resistance

B. Mechanical properties

1) Compressive strength
2) Split tensile strength
3) Flexural strength
4) Stress Strain relationship

a) Dry Density: As per ASTM C 642-97 the cured samples must be free from cracks, fissures and shattered edges. The specimen should be cured for 28 days in water. The dry density of sample is calculated as

$$\text{Dry Density } (\rho) = \frac{\text{Dry Mass of the Specimen}}{\text{Volume of the specimen}}$$

b) Water Absorption: The water absorption is determined for the cured specimens. The samples are immersed in water not less than 24 hours and saturated mass is recorded. These are then dried in oven at temperature of 100ºC to 115ºC and dried mass is recorded.

Fig.4 Water Absorption Test

$$\text{Percentage of Water Absorption} = \frac{B - A}{A} \times 100\ \%$$

Where,

A-Mass of oven dried sample

B- Mass of saturated sample

c) Specific Strength: The specific strength is the measure of yield strength of the material. It is the ratio of material strength to its density. It can be done with help of tensile testing machine. Higher Strength - Density ratio results in good mechanical and durability characteristics which in turn reduces the load on the structure.

$$\text{Specific strength} = \frac{\text{Material Strength}}{\text{Density}}\ \text{(N-m/Kg)}$$

d) Fire Resistance: This test is done on sample cubes under elevated temperature of about 800ºC for nearly 8 hours and allowed to

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reach its ambient temperature. After that, Compressive Strength were obtained by performing Compression test on that samples. The performance of specimen on both normal and high temperature were compared.

Fig.5 Fire Resistance Test

a) Compressive Strength test:The sample cubes are eventually dried for 2 hours prior to the test. This test is performed with the help of Compression Testing Machine. An Axial load with pre-determined rate of loading is applied to the face of cube. The maximum load carried by the specimen is noted and test is terminated until the failure is attained.

Fig.6 Compressive Strength Test

The Compressive Strength of specimen is determined by

$$f_c = \frac{P}{A_c} \quad (N/mm^2)$$

where,

P - Peak load carried by specimen, N

A_c - Cross sectional area, mm^2

b) Split tensile test: The Split Tensile test is done as per the method recommended by ASTM C496. The cylinders of 150mm diameter and 300mm length are casted and cured as per the above mentioned standards. After 28 days of curing, the cylinders are air dried before the test is performed. Supplementary bearing plate is placed on the either side of the cylindrical surface to distribute the load along the length of the cylinder. The test is terminated until the specimen fails.

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Fig.7 Split Tensile Test

The splitting tensile strength of the specimen is calculated as

$$f_t = \frac{2P}{\pi d l} \quad (\text{N/mm}^2)$$

where,

f_t - Splitting tensile strength, N/mm² P - Peak load carried by specimen, N d - diameter of specimen, mm l - length of specimen, mm

c) Flexural Strength test: The Flexural test is performed in accordance with ASTM C293 (2002). The standard dimension of 150mm x 150mm x 600mm beam is used as a test specimen. The prisms were placed on either side of the specimen at an offset of 100mm from the edge. The center-point loading is applied using the testing machine at a constant rate of 0.1mm/min until the beam attains its ultimate strength observed by cracks.

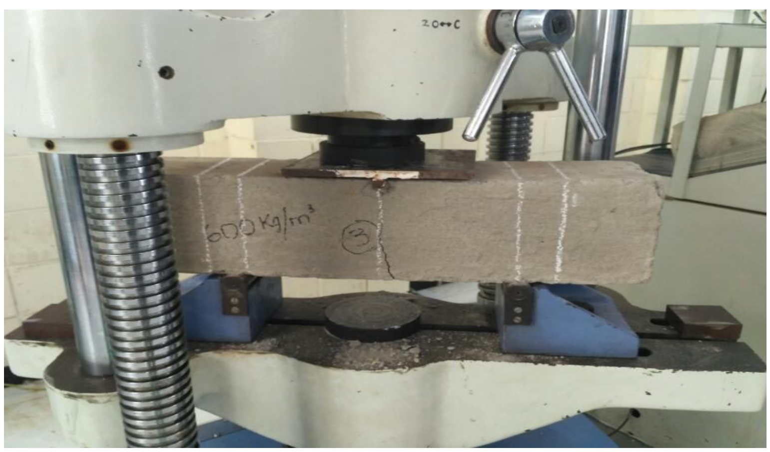

Fig.8 Flexure test setup

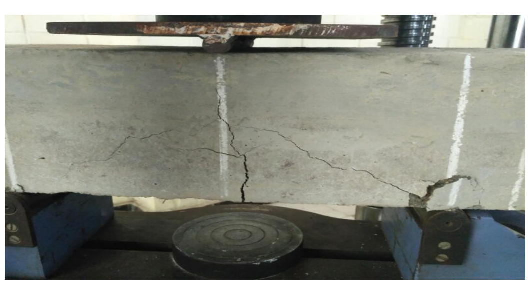

Fig.9 Flexural cracks

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d) *Stress strain relationship:* The Stress strain relationship is the direct function of Modulus of Elasticity or Young's Modulus. The cylindrical specimen is tested to determine the stress strain curve from load – deflection result. The test is terminated until the specimen fails to accept the load.

IX. EXPERIMENTAL RESULTS AND DISCUSSION

A. Dry Density

The dry density of foamed concrete depends on the volume of the foam incorporated in it. Hence, the dry density for 1200kg/m^3 and 1500kg/m^3 is 1085kg/m^{3}and 1360 kg/m^3 respectively. According to ASTM C 567, for an structural light weight concrete the air density should not exceed 1840 kg/m^3. The obtained results is in accordance with the standards.

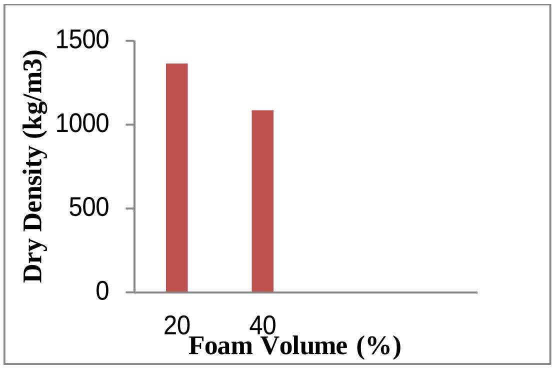

Fig.10 Dry Density of Foamed Concrete

B. Water Absorption

According to ASTM C 140, the average water absorption for the overall samples should not exceed 5% and for unit samples it should not be greater than 7%. The water absorption values for 1200 kg/m^3 and 1500 kg/m^{3}are 8.41% and 5.97%.

It is also found that higher the concrete densities, lower will be the water absorption and vice versa. Hence the concrete density of 1500 kg/m^3 is in accordance with the standards.

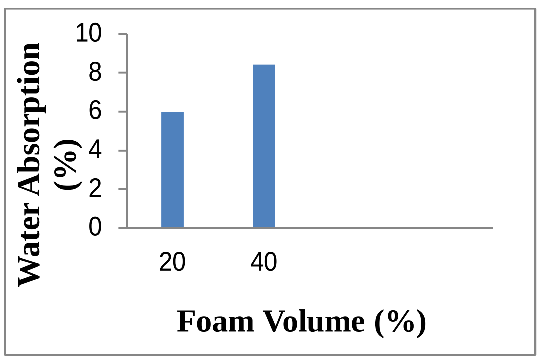

Fig.11 Water Absorption of foamed concrete

C. Specific Strength

The specific strength of concrete increases with the age and density of concrete. For 1200kg/m^3 and 1500kg/m^3 densities the specific strength was found to be 4.34 Nm/Kg and 7.083 Nm/Kg. Only the foamed concrete cube of 1500kg/m^3 produce satisfactory results.

Table.5 Test Result of Specific Strength

S. No	Density(Kg/m^3)	Specific Strength (Nm/Kg)		
	Age	14th day	21st day	28th day
1.	1200	1708.33	2583.3	4354.16
2.	1500	2800	3950	7083.33

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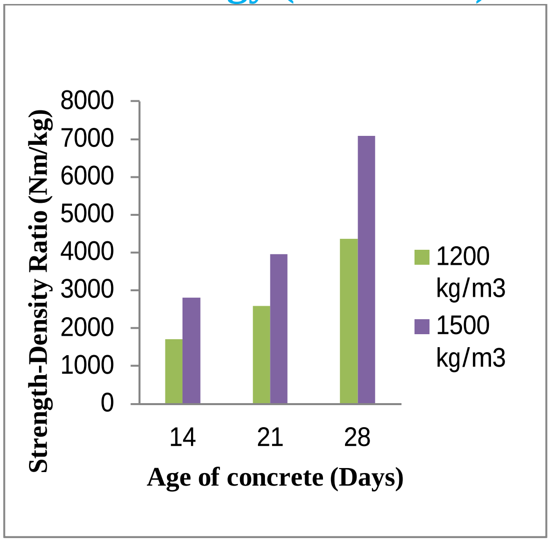

Fig.12 Relationship Between specific strength and age of concrete

D. Fire Resistance

According to the international Building code (IBC-2000) section 703, the fire resistance of the building is the ability of the components to perform structural functions or to withstand fire over a certain period of time. Here, the foamed concrete performs well in structural functions and withstand fire for a longer period of time because of its porous nature.

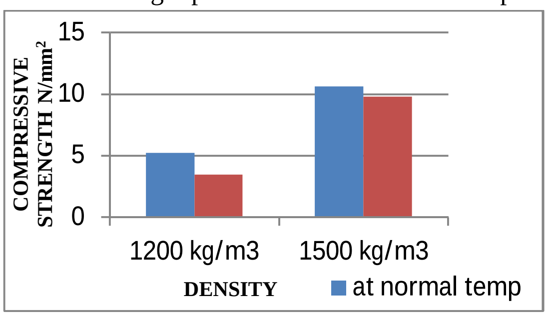

Fig.13 Fire Resistance of Foamed Concrete

E. Compressive Strength test

The main aim of this test is to identify the performance of foamed concrete in terms of its density. It is noted that strength increases with age and density. Hence, the density is proportional to the compressive strength of the foamed concrete and varies exponentially. Compressive strength can also be greatly influenced by the size and distribution of voids. The compressive strength values are tabulated below.

Table.6 Test Result of Compressive Strength

S.No	Density (Kg/m^3)	Compressive Strength (N/mm^2)		
	Age	14^{th} day	21^{st} day	28^{th} day
1.	1200	2.05	3.1	5.22
2.	1500	4.2	5.92	10.62

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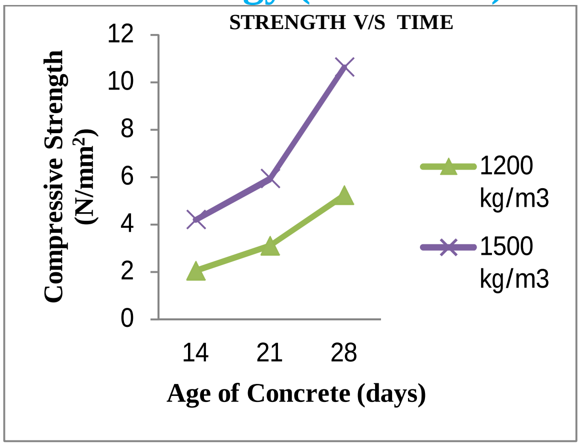

Fig.14 Increase in Strength With Increase In Age and Density

The required minimal structural strength for light weight concrete is 17N/mm^2.
Eventhough it has low compressive strength, obtained result satisfies the minimal required strength of light weight concrete as per IS 2185 (Part 4): 2004.

F. Split tensile test

The tensile strength of the concrete depends on the volume of foam incorporated. The density varies inversely to the volume of foam. Usually split tensile strength will be greater than the direct tensile strength and lower than the flexural shrinkage. The split tensile values are tabulated below.

Table.7 Test Result of Split Tensile Strength

S.No	Density (Kg/m^3)	Split Tensile Strength (N/mm^2)		
	Age	14th day	21st day	28th day
1.	1200	1.06	1.53	1.77
2.	1500	1.43	1.82	2.01

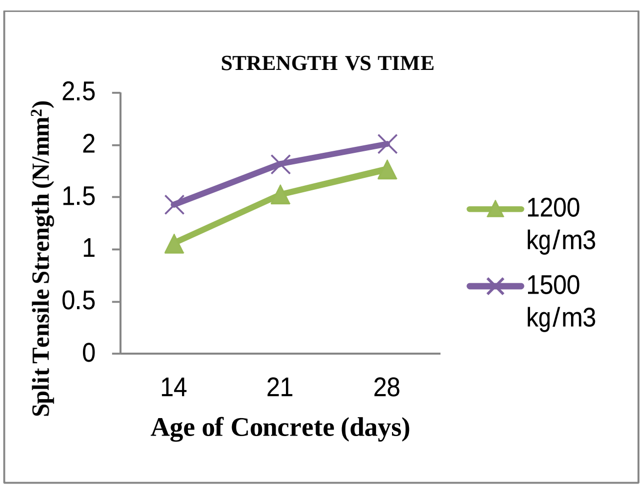

Fig.15 Split Tensile Strength of Concrete

From the above graph it is found that split tensile strength is greater for concrete having high density. According to ASTM C-330, the minimal split tensile strength for structural light weight concrete is 2.0N/mm^2. The concrete with the density of 1500N/mm^2 only

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satisfies the minimal requirements yet it cannot be used for structural purposes because of low tensile strength.

G. Flexural Strength test

Table.8 Test Result of Flexure Strength\

S.No	Density (Kg/m^3)	Flexural Strength (N/mm^2)
1.	1200	7.53
2.	1500	9.41

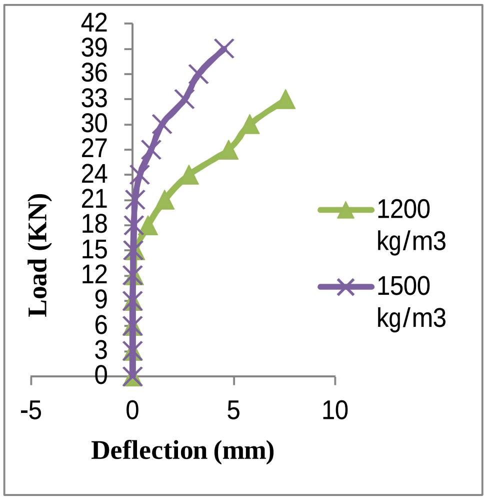

Fig.16 Flexural Strength of Foamed concrete

The flexural strength of foamed concrete is not satisfactory. Hence, it can be used for non structural purposes such as partition wall, sunshades and replacement of brick as it reduces the self weight of the building.

H. Stress strain relationship

The stress-strain values are plotted as below. It is found that concrete density of 1200kg/m^3 deflect more when compared to 1500kg/m^3. It is due to the volume of foam used in the respective densities. Hence it is concluded that , increase in foam volume decreases the strength of the concrete.

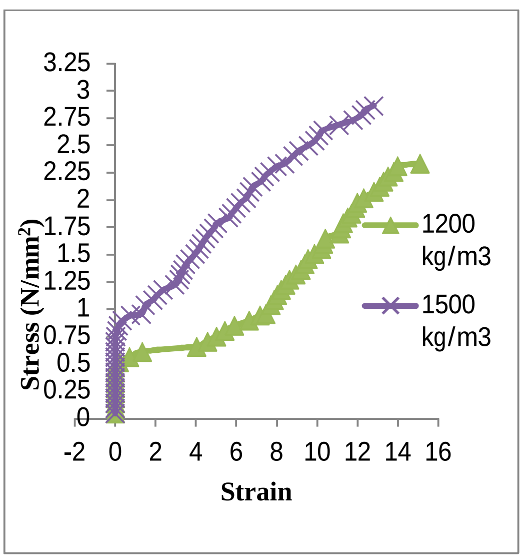

Fig.17 Stress-Strain Relationship of Foamed Concrete

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X. CONCLUSIONS

A. The maximum compressive is obtained for the density of 1500 kg/m^3 and can be used for structural purposes. Hence, it is concluded that the increase in density increases the compressive strength.

B. Split tensile strength and flexure strength of foamed concrete is low. The lowest strength is due to the presence of voids and the absence of coarse aggregates.

C. The results of water absorption shows highest value of 8.41% for 1200 kg/m^3. It is due to the lowest density of foamed concrete.

D. The specific strength of the concrete increases with age and density of cube.

E. The fire resistance of foamed concrete is satisfactory and posses good fire resisting properties.

F. The addition of fly ash increases the strength of the foamed concrete.

G. The density of concrete is varies inversely to the volume of foam added.

H. Due to less weight, there is a reduction in dead loads thereby decrease in the shape of members are considered.

XI. RECOMMENDATIONS

A. The density range of about 1200 – 1600kg/m^3 are used in the form of bricks, blocks. Since compressive strength is less than 17N/mm^2, it performs less under structural purposes.

B. It can also be used as a thermal insulation over a roof slab because of its good thermal properties.

C. It posses greater fire resistance than the conventional brick blocks.

D. It can also be used as a back fill in retaining walls.

E. Used as a soil stabilizer in the hilly areas.

F. In tunnel works, it is used as a grouting material.

G. It can resist fire up to 5 hours, if a wall of 13cm thickness and 1300 kg/m^3 of density provided.

H. Used as a filling material in hollow spaces.

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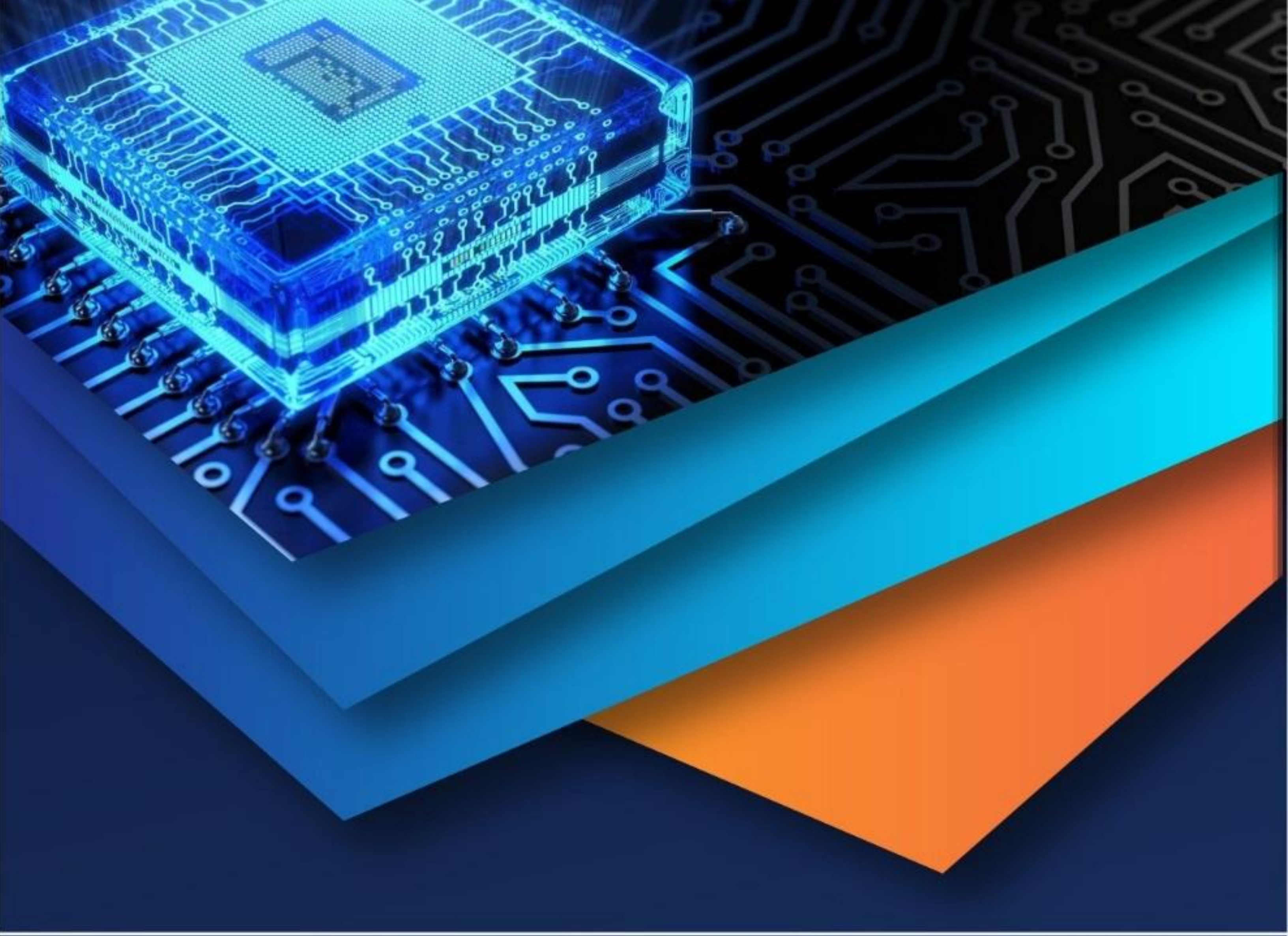

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