Cellular Light Weight Concrete Blocks using Different Types of Foaming Agent

M.Wasim Abdullah[1], K.Vijaya prabhu[2], A.Naveen Samuel[3], M.Sathish Kumar[4]

[1,2,3] U.G. Students, Department of Civil Engineering, Velammal College of Engineering and Technology, Madurai, Tamil Nadu, India.
[4]Assistant Professor, Department of Civil Engineering, Velammal College of Engineering and Technology, Madurai, Tamil Nadu, India.

Abstract - *Cellular light weight concrete (CLWC) is not a new one to this world. It has been from roman age. It was made using natural aggregates of volcanic origin such as pumice stone, expanded perlite etc. Light weight concrete is a type of concrete which is made less denser compared to conventional concrete by entrapping air using foaming agent. The usage of cellular light weight concrete blocks in building construction industry plays a vital role in innovative development along with environmental safety. In this paper, experimental study has been made by producing CLWC using fly ash and different foaming agent. The performance of CLWC blocks has been investigated in terms of density, compressive strength and water absorption. In this experimental study, comparison has been made between both protein based and synthetic based foaming agent. In this paper, major aim is to reduce the density of CLWC blocks and also increase the compressive strength compared to burnt clay bricks. According to studies CLWC blocks may change the future development with low cost and high durability property.*

Key Words: **Pumice stone, expanded perlite, entrapping air using foaming agent, compressive strength, water absorption.**

1. INTRODUCTION

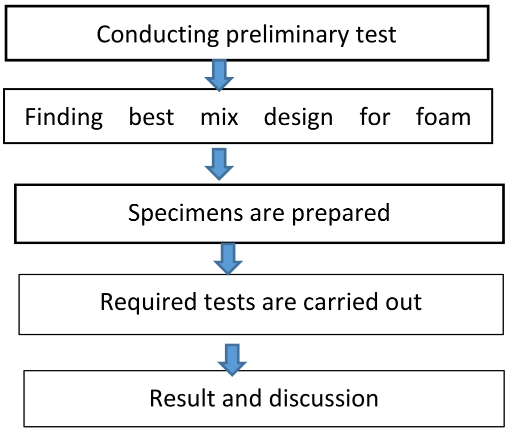
Lightweight concrete is made of lightweight coarse aggregate and sometimes a portion or entire fine aggregates may be replaced with lightweight aggregates instead of normal aggregates. Structural LWC has an in-place density in the range of 90 to 115 lb / ft^3 (1440 to 1840 kg/m^3). Normal weight concrete has density in the range of 140 to 150 lb/ft^3 (2240 to 2400 kg/m^3). For structural applications the concrete compressive strength should be greater than 2500 psi (17.0 MPa). Lightweight aggregates used in structural LWC are typically materials that have been fired in rotary kiln like clay or slate and expanded shale. Also, other products such as air-cooled blast furnace slag can be used. There are other classes of non-structural light weight concrete having lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete. It consists of porous lightweight aggregate of low apparent specific gravity, which is lower than 2.6. This type of concrete can be known as ***lightweight aggregate concrete.*** Large voids are instigated within the concrete or mortar mass. Also, those voids should be clearly different from the extremely fine voids produced by air entrainment. This types of concrete is variously named **as *aerated, cellular, foamed*** or ***gas concrete.*** Omitting the fine aggregate from the mix causes large number of interstitial voids, while normal weight coarse aggregates are used. This concrete may be defined as ***no-fines*** concrete.

Table -1: Based on unit weight

Category	Unit weight of dry aggregate (kg/m^3)	Unit weight of concrete (kg/m^3)	Typical concrete strength (Mpa)
Ultralight weight	<500	300-1100	<7
Light weight	500-800	1100-1600	7-14
Structural light weight	650-1100	1450-1900	17-35
Normal weight	1100-1750	2100-2550	20-40
Heavy weight	>2100	2900-6100	20-40

2. METHODOLOGY

The methodology followed in this project work is shown below. As the result of literature study, there was little easily available information regarding the properties of foamed concrete, particularly regarding mix design procedures. Using that information, the trial and error method were undertaken to obtain the data for mix design formulation. After achieving a complete mix design procedure, trial mixes are made to check with the density achievement at site. Then possible replacements are studied and finalized. For desired density, the trail cubes were casted with required materials.



3. MATERIAL USED AND PROPERTIES

Material property is its physical property that does not shows the amount of the material. To make an engineering product fit for particular usage it is important to know the mechanical property of the material. The strength and ability of a material to be molded in suitable shape is affected by the mechanical properties of a material.

3.1. Material used

1) Cement
2) Fly ash
3) Water
4) Foaming agent
   a) Protein based(Animal protein)
   b) Synthetic based(SLES+NAOH)

3.2. Properties of material used

3.2.1. Cement

Portland cement is used more compared to other cements, such as pozzolana. For early setting and optimum mechanical properties, high-grade (early strength) cement is recommended. The slower, hardening and better the final better quality of concrete. Where economical, fly ash may be added to the mix to replace some of the cement. Fly ash decrease the hardening time. In this experiment 53 grade Ordinary Portland cement and Fine Fly ash has been used.

3.2.2. Fly ash

Fly ash is a by-product material produced in the combustion process of coal used in power stations. It is a fine grey coloured powder that have spherical glassy particle. As fly ash contains pozzolanic materials components when react with lime to form cementatious materials. Thus Fly ash is majorly used in concrete, mines, landfills and dams.

Fly ash used for this project is class-F fly ash obtained from the industrial are of Nungambakkam in Chennai.
Specific Gravity= 2.1 to 3.0
Density = 540 to 860 kg/m^3.

3.2.3. Water

Potable water available near the site passing through IS 456 standards is used for mixing and curing. The suitable water for light weight concrete is drinking water.

Limits

- Content of organic solids not higher than 0.02%
- Content of organic solids not higher than 0.30%
- Content of sulphates not lower than 0.05%
- Content of sulphate alkali chlorides not higher than 10%

3.2.4. Foaming agent

a) Protein based (animal protein)

It used to form light weight concrete and other concrete materials. Foam does not change the reaction on concrete but it serves as a layer which is air trapped and forms no fumes or toxic. To make foam it requires comparatively more amount of energy. It is manufactured with raw material in presence of $Ca(OH)_2$ and a small portion of $NaHSO_3$. For improving the stability of foaming agent it is altered with the addition of various kinds of gel and surfactants.

Table -2: Properties of animal protein.

Particulars	Properties
Type	Animal protein(protein based)
Appearance	Blackish brown
Specific gravity	2.6 – 3.31
pH value	3.5 – 8.0
Foaming agent dilution	Dilution ratio 1:25

b) Synthetic based (SLES + NaOH)

CLWC has very good advantage which helps to structure the cellular lightweight applications. Using right type of foaming agent makes a major changes in product such as the mechanical properties of concrete and it resistance etc. Surface tension of liquid is reduced by using synthetic foaming agent and commonly used all over the world to make blocks, bricks, CLW concrete etc where the low density is needed and it requires less energy for production as compared to other foaming agents. It is highly advisable to use in the constructional fields where requirement of light weight concrete is increasing day by day. Prepared by 2% of SLES *(sodium lauryl ether sulfate)* and 6% of NaOH *(sodium hydroxide)* concentrated in 1 litre of water and keep in room temperature for about one day.

Table -3: Properties of SLES+NaOH

Particulars	Properties
Type	SLES+NaOH (Synthetic based) 2% + 6% in one litre of water
Appearance	Crystalline white
Specific gravity	1.03-1.04
pH value	7.0 – 9.0
Foaming agent dilution	Dilution ratio 1:20

4. MIX DESIGN

The process of selecting suitable ingredients of concrete as per IS code was termed as concrete mix design. The various materials used will be elaborated in detail including the type of foaming agent and mix ratio of foaming agent with water to produce stable foam.

4.1. Mix design calculation

Since there is no standard mix design for light weight concrete. Required mix design is calculated by trial and error method. By referring many literature we know that density is the major factor for light weight concrete preparation. As the density of the concrete decreases the compressive strength of the light weight concrete is also decreases. This is because of the increase in voids which is the reason for decrease in density of the concrete.
After trial and error method we came to an end with a mix proportion using our own formula.

Volume of cube = 0.150 x 0.150 x 0.150
= 0.003375 m^3
Weight of concrete = volume x density required
= 0.003375 m^3 x 1000 kg/m^3
= 3.375 kg
Assume wastage 20% weight of concrete
Total weight of concrete/cube = 4.05 kg

4.2. Mix ratio per cube

Cement : fly ash = 1:1
Weight of cement = 4.05/2 = 2.025 kg
Weight of fly ash = 4.05/2 = 2.025 kg
Water cement ratio = 0.50
Water in litres = 1 litre
Dosage of Foaming agent = 2 seconds (approximately 4 litre capacity)

4.3. Mix procedure

Mixing process is completely different from conventional concrete because mix design done here is by trial and error method.

a) Sieving and mixing

The manufacture of cellular light weight concrete is follows two steps.

1) Preparation of cement slurry with fly ash using required amount of water.
2) Adding foam to the slurry from the foam generator.

Firstly, the fly ash is sieved to the required amount and thoroughly mixed with calculated amount of cement. Add water to the mix until it attains slurry consistency. Secondly,
foaming agent is diluted in water with above mentioned dilution ratio. The diluted foaming agent is sent into foam generator. Foam generator suck in the solution and compressor blown the air out. Compressed air expands the foam solution into the stable foam. Then the foam is mixed with prepared cement slurry using paint blender. The foam creates small voids in it and thus cellular light weight concrete is prepared.

Fig -1: Sieving fly ash

Fig -2: Preparing cement slurry

b) Casting of moulds

To avoid sticking, Make sure that the moulds are greased before pouring the foamed concrete in to it. After mixing the foamed concrete the concrete should be placed in the mould as soon as possible. Because it cause the stable foam to break. Before breaking down of foam the foamed concrete is placed in the greased moulds. Here no compaction has to be done it breaks the stable foam. Gently tamp the outer side of the mould to make the foam concrete cover the edges of concrete. Cut the excess concrete from the top of the mould.

The specimens were kept for 24 hours to set. Demoulding is done after 24 hours using required tools.

Fig -3: Casting of moulds

Fig -4: Demoulding of cube

c) Curing

Curing of cellular light weight concrete block is done using two methods one is water curing and another is steam curing but here we using water curing (moist curing). After the blocks were demoulded it is placed in water at 27±2 ˚C for 7, 14 and 28 days. Then the compressive strength test, dry density test and water absorption test are done.

5. RESULT AND DISCUSSION

In this chapter, discussion will be focused on the performance of different type of foaming agent on light weight concrete. All the tests method adopted were done according to IS standards as well as ASTM procedures. The results presented in this chapter are regarding the various preliminary tests done to various materials used as well as the compressive strength test for different types of foaming agent.

a) Dry density test

In this project the target density is 1300 kg/m^3, the density of the specimen depends upon the amount of foam is added to concrete. If the amount of foam content is increased in the mix results in decrease in dry density. Result of dry density is given in table -4.

Table -4: Result for dry density test

Foaming agent type	No of cube	Weight (kg)	Density (kg/m^3)
Animal protein	Sample 1	4.530	1342.22
	Sample 2	4.550	1348.15
	Sample 3	4.670	1383.70
SLES+ NaOH	Sample 1	4.700	1392.59
	Sample 2	4.384	1298.96
	Sample 3	4.590	1360

b) Water absorption test

Result of water absorption is shown in the table - 5. Water absorption due to animal protein is comparatively higher than SLES + NaOH.

Table -5: Result for water absorption test

Foaming agent type	No of cube	Wet weight in kg (a)	Dry weight in kg (b)	Water absorption in %
Animal protein	Sample 1	4.670	4.530	3.09
	Sample 2	4.710	4.550	3.52
	Sample 3	4.800	4.670	2.78
Average				***3.13***
SLES + NaOH	Sample 1	4.810	4.700	2.34
	Sample 2	4.500	4.384	2.64
	Sample 3	4.710	4.590	2.61
Average				***2.53***

c) Compressive strength test

Result of compressive strength test is shown in table-6 and also in chart -1. As increase in voids in foam concrete predominantly decrease the compressive strength of the cube. Compared to animal protein, SLES+NaOH shows the good result in compressive strength.

Fig -5: Failure pattern of cube

Table -6: Result for compressive strength test

S.No	Days	Compressive strength in N/mm²	
		Animal protein	SLES+NaOH
1	7 days	4.311	4.533
2		4.342	4.423
3		4.412	4.452
Average		***4.355***	***4.469***
4	14 days	6.67	7.04
5		6.80	6.98
6		6.71	7.01
Average		***6.726***	***7.01***
7	28 days	8.33	8.76
8		8.21	8.82
9		8.25	8.65
Average		***8.263***	***8.743***

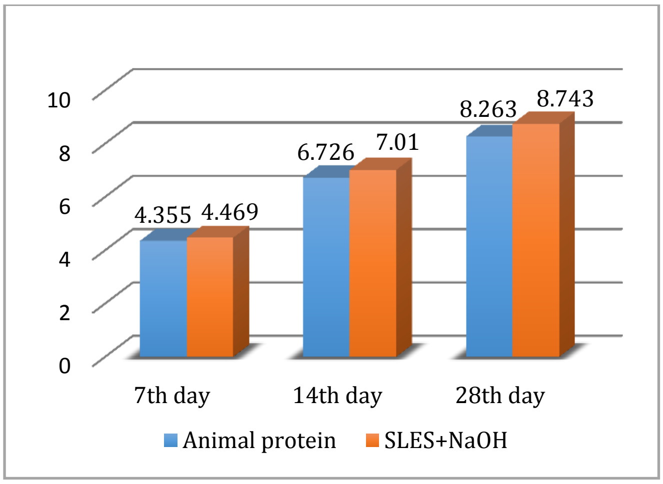


Chart -1: Graph shows difference between the compressive strength of two foaming agent

d) Comparison

On comparing CLWC blocks with burnt clay bricks. Density of CLWC blocks is very much reduced compared to burnt clay bricks. Similarly in water absorption CLWC blocks absorbs less amount of water. Compressive strength is much more higher than burnt clay bricks shown in table -7.

Table -7: Comparing CLWC blocks with burnt clay bricks

Mechanical properties	Specimen with SLES+NaOH	Specimen with Animal protein	Burnt clay bricks
Dry density (kg/m³)	1300-1400	1340-1380	2400
Water absorption (%)	2.53	3.13	12-20
Compressive strength (N/mm²)	8.743	8.263	3.5

6. CONCLUSION

If the density of the CLWC blocks increases thus results in increase in compressive strength of the concrete. If the water – cement ratio increases leads to decrease in strength of the concrete.

- It can be concluded that the cellular light weight concrete blocks has a desirable compressive strength more than burnt clay bricks as the amount of void increases the compressive strength decreases.
- Density of CLWC blocks is less compared to other building materials.
- On comparing the types of foaming agent there is not much difference in compressive strength and also other properties in CLWC blocks.
- CLWC blocks is economical and also it is advantageous in terms of general construction properties as well as eco-friendliness. Hence it is green construction material.

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BIOGRAPHIES

M.Wasim Abdullah,
Final year,
Department of Civil Engineering,
Velammal College of Engineering and Technology, Madurai, Tamil Nadu.

K.Vijaya prabhu,
Final year,
Department of Civil Engineering,
Velammal College of Engineering and Technology, Madurai, Tamil Nadu.

A.Naveen Samuel,
Final year,
Department of Civil Engineering,
Velammal College of Engineering and Technology, Madurai, Tamil Nadu.

M.Sathish Kumar M.E.,
Assistant Professor, Department of Civil Engineering, Velammal College of Engineering and Technology, Madurai, Tamil Nadu.