Mechanical Behavior of Composite Wall Panel using Cellular Light Weight Concrete

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Abstract - – *The use of light weight wall panel become one of the absolute choice to fulfill the need of rapid and temporary shelter for building safety. People require innovative energy efficient building material for strong and rapid construction at affordable cost. The use of light weight become the alternatively to conventional construction using brick work. The use of panel provides a sustainable and environment friendly construction. This paper describes the overview of wall panel, method of construction and its properties. The experimental studied carried out to understand the flexural behavior of cellular concrete wall panel under four point bending test. The test on concrete consists of compressive strength of concrete, water absorption test, dry shrinkage test.*

***Key Words*... self compacting concrete, light weight panel, four point flexural tests.**

1. INTRODUCTION

This Cellular light weight concrete is produced by the mixing of cement, fly ash, water and foaming agent. Light weight concrete has its advantages of high strength / weight ratio, good compressive strength. Density of this concrete is considerably low (600 kg/m^3 to 1800 kg/m^3) as compared to normal concrete (2200 kg/m^3 to 2600 kg/m^3). Foamed concrete is self compacting concrete requires no compaction. Light weight concrete is popular in construction industry because of rapid casting and easy construction and handling. Cellular light weight concrete is produced by mixing of cement, fly ash, water, foaming agent and air voids where foam is mixed into the mortar or concrete. The entrapment of air to create air voids has been normally obtained by introducing protein–based or synthetic-based foaming agent. Generally the voids created by the mechanical or chemical reaction of the components. Light weight concrete has air voids between 10% and 60% air voids. Light weight concrete has its advantages of high strength / weight ratio, good compressive strength, low coefficient of thermal expansion. Density of this concrete is considerably low (600 kg/m^3 to 1800 kg/m^3) as compared to normal concrete (2200 kg/m^3 to 2600 kg/m^3). Foamed concrete is self compacting concrete requires no compaction. The light weight concrete is very popular in the construction industry because of its good properties such as easy moulding, light in weight, cheap and easy to manufacturing.

1.2 Composite Wall Panel

The greater part of cellular concrete production has been in the form of building blocks, wall panel, because of their lightness in weight can be very much larger in size than the building bricks, effect economics both in handling and in construction. The other advantage is from environmental point of view due to utilization of waste materials like bottom ash. The composite wall panel has been widely used for building structure of different exemplary structure due to their admirable thermal and structural efficiency such as residential building, commercial building, ware houses, temporary shades and also used for making sound proof it also has flat smooth & flat surface. These wall panel also used in tall structure buildings, the cellular panel gives an insulated outer shell to high rise building mostly bearing the vertical sustained gravity loads of components, horizontal wind load and earthquake action.

2. Material properties

2.1 Cement: Cement is used as a binding element in both concrete and mortar. It is made most commonly of limestone, clay, shells, silica sand and other materials. These materials are crushed and then combined with other ingredients (including iron ore), and then heated to about 2,700 Fahrenheit. In the project OPC Ordinary Portland cement (OPC) (53 Grade) confirming to IS CODE (12269) was used.

2.2 Fly ash: Fly ash also known as "Pulverized Fuel Ash" of class C which was used in the project is brought from Pithampur has produced from burning of bituminous coal, having pozzolanic properties and also as some self-cementing properties. It is partially replaced with cement. (IS 3812 – 2003 part 1).

2.3 Steel Mesh: A wire mesh is made up of uniformly crossed wires in regular patterns to form a barrier or screen. The patterns can be large or small, square or polygonal depending upon the purpose or application of the end product.

2.3 Super plasticizer: Super plasticizers are concrete mixer and water-based adhesive, are ready to use for clear silicate liquid, formulated with chemically reactive raw materials to harden and dustproof concrete. This waterborne solution, when properly applied, offers substantial improvement in abrasion and chemical resistance and will significantly improve the durability, it prevent the steel, any mesh from corrosion of the concrete surface when compared to untreated concrete. The chemical adhesive is poured with a definite ratio and penetrates into the concrete material, a chemical reaction takes place, producing that fills in the pores of the concrete. This should be added in proportion of (50:500) i.e. in 50 kg cement the chemical ratio should be 500 ml. These also decrease the w/c ratio to increase the strength of the concrete

2.4 Foaming agent: The foaming agent shall be such a chemical composition that capable of producing stable foam cells in concrete, which can endure the physical and chemical forces to be imposed during mixing, pumping and setting of concrete. A chemical which facilities the process of forming foam and enables it the ability to support its integrity by getting the strength to each and every single bubbles of foam is known as foaming agent.

Protein based foaming agent used in the project work. Protein based foaming agent requires comparatively more energy to make foam. The used of protein based foam agent was diluted with 1:40 ratio which has density of 40-80 mg/m^3. It is suitable for concrete densities of 600kg/m^3 to 1800 kg/m^3.

3. Material Test

3.1 Consistency test: The consistency test is to find out the water content required to produce a cement paste of standard consistency. It is used to determine the % of water required for preparing cement paste for test. A penetration device used to determine the setting characteristics of hydraulic cement consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

3.2 Density test: The density of both fresh and hardened concrete involved for numerous reasons including its effect on durability, strength and resistance to permeability. Density is the amount of mass a substance has per unit of volume. The density is the fundamental physical characteristic of the material. Density is defined by mass of a Unit volume of a material substance, expressed as kilograms per cubic meter

3.2 Foam density: Measurements of foam density should be taken because density can vary according to the volume of the surfactant solution in the containment vessel and also with the time of storage. The density of foam is mainly depending on the proportion of water and foaming agent. The density of foam lies between 40-80 kg/m^3. The foam ratio taken for the work was 1:40 and the density 70kg/m^3 achieved. The density of foam is determined by pouring of 1 litre of vessel with foam and calculates the weight, after removing foam again calculate the weight of vessel. The difference between empty and poured vessel shows the foam density

3.3 Foam concrete density: The properties of foamed concrete are critically dependent upon the quality of the foam. The foam concrete density is determined by making slurry of light weight concrete. Then density is checked by filling slurry in 1 liter measuring jar. Then the weight of the measuring jar is determined, the given result shows the density of the concrete. The average block density was not varying more than ± 50 or ± 5 percent of the density (IS 2185 part 4): 2008.

3.4 Mortar flow test: The investigation of properties of self-compacting concrete comprises of mortar flow test on the different density of cellular light weight concrete. The mortar flow test investigates the workability of concrete focusing on the homogeneity of self- compacting concrete. In the test a slum cone is filled with foam concrete. After 30 sec the slum is removing from conventional cone and the concrete get deformed. If the measurement of the two diameters differs by more than (50 mm), then test and density get changes.The deformed concrete is measured with tape.

4. Mix design

The ingredients shall be mixed in mixer rotator drum. There are no guidance for design of cellular light weight concrete because the hardened of light weight concrete depend on saturation level and pores Amran et al., [2015]. Different sample mix proportion is used with different w/c ratio or with different density; however trial and error method may be worked out with the given set of site material. The foamed concrete is self compacted concrete, so that no additional inner or outer vibration is necessary for the compaction.

4.1 Sample preparation: The sample that used in the project is concrete cube and wall panel. The concrete cube was use to check the compressive strength wall panel to be test with flexural test. The size of wall panel used in the dimension of (500x300x80mm) but the thickness of wall panel varies of (40,60 and 80mm). Every concrete mix will have 9 sample of cube. The wall panel also has 9 samples for each density and thickness. Since the concrete has high workability the slurry didn't required compaction.

Table 1: Proportion for trail method

Required density (kg/m^3)	Required Compressive Strength at 28-day (N/mm^2)	W/C ratio	Mortar ratio (cement & fly ash)	Foam (1:40) (kg/m^3)	Fly ash (kg)	OPC 53 grade (kg)	Water (kg)
800	2.5	0.45	1:1	70	285	285	130
1000	3.5	0.45	1:1	70	365	365	165
1200	6.5	0.45	1:1	70	445	445	200
1400	12	0.45	1:1	70	545	545	245
1600	14.5	0.45	1:1	70	605	605	275

5. Testing procedure

In order to study the behavior of lightweight concrete, normal concrete testing was done to determine the material and structural properties of each type of lightweight concrete and how will these properties differ according to a different type of mixture and its proportion. Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics. For new light weight concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures

5.1 Compressive strength: The compressive test is done on different cube. The strength of cube is different for differ density. Compressive strength of lightweight concrete is determined on the 7, 14 and 28 days for each sample. There were three samples for each test and the results would be taken as the average of these three. The cubes were taken out from the water tank and place it for dry of minimum 1 day. The cube is placed at centre of the testing machine for test. An axial compressive load with a specified rate of loading is applied to the cube until failure. Water cement ratio is 1:0.45 to see the effect of variable of foamed concrete ratio Arvind et al. [2008].

5.2 Flexural test: Flexural strength of wall panel is one measure of the tensile strength, compression test and shear and so the flexural properties of the specimen are the result of combine's effect of all stress as well as the geometry of the specimen and the rate of the load applied. The most common purpose of the flexural test is to measure flexural strength and flexural modulus. The flexural strength is expressed as modulus of rupture in Mpa and is determined by the four point loading (IS 516-1959).

Fig 5.1 Flexural Test on UTM

5.3 Water absorption: Water absorption is an important factor due to the porous structure of the cellular lightweight concrete. These properties are particularly important in concrete, as well as being important for durability. The absorption capacity is determined by calculating the weight of surface-dry sample after it has been soaked for 24 hr and again finding the weight after the sample has been dried in an oven; the difference in weight, expressed as a

percentage of the dry sample weight, is the absorption capacity.

Absorption percentage calculated by-

{F= (D1+D2)/2}

Where, A = Wet mass of block in kg.

B = Dry mass of block in kg.

5.4 Drying shrinkage test: The difference between the length of specimen which has been immersed in water and then subsequently dried to constant length, all under specified conditions expressed as a percentage of the dry length of the specimen. Drying shrinkage shall be a maximum of 0.05% for the load bearing class of panel and a maximum of 0.08% for the non-load bearing class.

6. RESULTS AND DISCUSSIONS

Firstly the compressive strength was tested to check the strength of trial and error mix design. After getting the best proportion result different density of cube were tested to check the desire strength. Similarly flexural strength test on load bearing wall panel were done on wall panel. Following are the result obtained,

6.1 Compressive strength:

DENSITY (kg/m^3)	Ratio		Compressive strength at 7 Days(N/mm^2)	Average Compressive strength at 7 Days(N/mm^2)
	Cement	Fly Ash		
800	1	1	1.631	1.591
			1.292	
			1.851	
	1	2	0.534	0.506
			0.414	
			0.571	
	2	1	0.814	1.122
			1.310	
			1.244	

Table 6.1.1 Compressive strength of 800 kg/m^3 for 7 Days

DENSITY (kg/m^3)	Ratio		Compressive strength at 14 Days(N/mm^2)	Average Compressive strength at 14 Days(N/mm^2)
	Cement	Fly Ash		
800	1	1	1.908	2.128
			2.226	
			2.251	
	1	2	1.30	1.246
			1.147	
			1.292	
	2	1	2.351	2.16
			2.108	
			2.139	

Table 6.1.2 Compressive strength of 800 kg/m^3 for 14 Days

DENSITY (kg/m^3)	Ratio		Compressive strength at 28 Days(N/mm^2)	Average Compressive strength at 28 Days(N/mm^2)
	Cement	Fly Ash		
800	1	1	2.457	2.530
			2.548	
			2.586	
	1	2	1.504	1.720
			1.726	
			1.931	
	2	1	2.241	2.247
			2.151	
			2.351	

Table 6.1.3 Compressive strength of 800 kg/m^3 for 28 days

Figure 6.1 Compressive strength of different ratio

Age	1st Cube	2nd cube	3rd cube	Average Compressive strength (N/mm^2)
7 Days	4.449	3.929	4.327	4.235
14 Days	6.317	6.182	5.802	6.100
28 Days	6.641	6.585	6.527	6.524

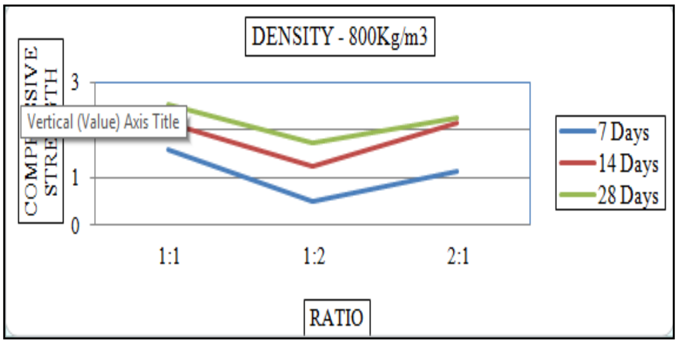
Table 6.1.4 Compressive strength of 1200 kg/m^3

Age	1st Cube	2nd cube	3rd cube	Average Compressive strength (N/mm^2)
7 Days	7.249	8.681	6.487	7.472`
14 Days	11.106	11.289	11.267	11.220
28 Days	14.027	14.317	14.257	14.200

Table 6.1.5 Compressive strength of 1400 kg/m^3

Age	1st Cube	2nd cube	3rd cube	Average Compressive strength (N/mm^2)
7 Days	12.817	13.310	13.027	13.051
14 Days	15.013	14.627	14.960	14.867
28 Days	17.641	173441	17.723	17.603

Table 6.1.6 Compressive strength of 1600 kg/m^3



Discussion on compressive test

1).The water cement ratio has been set to get the most suitable and economic mixture. In the preparation of foam concrete, the foaming agent and thickness of the slurry should match. If the w/c ratio decreases from 0.45 during the mixing process, it can be seen that the slurry consistency decreases. If the w/c ratio increase from 0.45 the slurry get thin and do not succeed for further process also the gas rush out of the surface of the sample and leave cracks, which decreases the strength of the sample

2). Based on the compressive strength test lightweight concrete according to the percentage of cement & fly ash in each mixture. It is seen that that the mixture with ratio (1:1) is higher than the compressive strength (1:2) and (2:1). The comparison between these different mixtures .So, the compressive strength of ratio (1:1) will be accomplish with the right proportion of foamed concrete.

6.2 Flexural Strength

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm2)
7 days	0.417	0.482	0.441	0.446
14 days	0.502	0.527	0.516	0.515
28 days	0.582	0.579	0.588	0.566

Table 6.2.1 Flexural strength of wall panel with Steel mesh of density 1200 kg/m^3

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm2)
7 days	0.204	0.207	0.216	0.209
14 days	0.228	0.247	0.241	0.238
28 days	0.259	0.266	0.262	0262

Table 6.2.2 Flexural strength of wall panel without Steel mesh of density 1200 kg/m^3

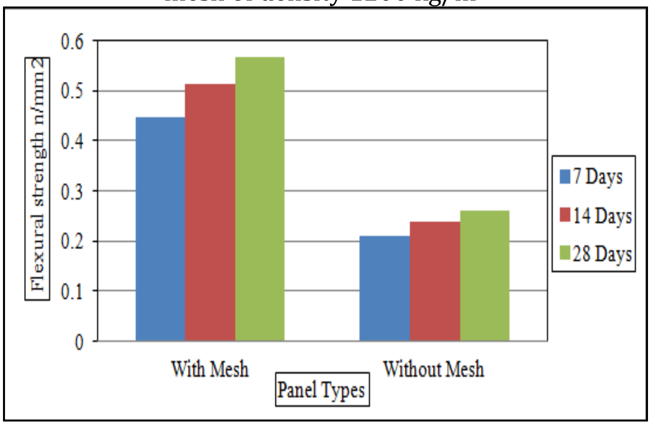


Figure 4.1 Flexural strength of wall panel with steel mesh

Age	1st Panel	2nd Panel	3rd Panel	Average flexural strength (N/mm2)
7 days	0.479	0.443	0.481`	0.467
14 days	0.516	0.553	0.537	0.535
28 days	0.613	0.604	0.641	0.619

Table 6.2.3 show the flexural strength of density 1200kg/m^3 and thickness of Panel is 60mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm2)
7 days	0.484	0.543	0.527	0.518
14 days	0.643	0.652	0.659	0.651
28 days	0.662	0.653	0.680	0.665

Table 6.2.4 show the flexural strength of density 1200kg/m^3 and thickness of Panel is 80mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm2
7 days	0.493	0.511	0.530	0.511
14 days	0.616	0.640	0.634	0.63
28 days	0.710	0.683	0.717	0.703

Table 6.2.5 Show the flexural strength of density 1400kg/m^3 and thickness of Panel is 400mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm^2)
7 days	0.647	0.582	0.672	0.633
14 days	0.641	0.662	0.667	0.656
28 days	0.738	0.723	0.731	0.730

Table 6.2.6 show the flexural strength of density 1400kg/m³ and thickness of Panel is 60mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm^2)
7 days	0.703	0.681	0.711	0.698
14 days	0.758	0.766	0.762	0.762
28 days	0.834	0.827	0.830	0.830

Table 6.2.7 show the flexural strength of density 1400kg/m³ and thickness of Panel is 80mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm^2)
7 days	0.652	0.649	0.642	0.647
14 days	0.680	0.710	0.691	0.691
28 days	0.721	0.738	0.733	0.730

Table 6.2.8 show the flexural strength of density 1600kg/m³ and thickness of Panel is 40mm.

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm^2)
7 days	0.621	0.637	0.639	0.632
14 days	0.801	0.780	0.787	0.789
28 days	0.831	0.822	0.838	0.830

Table 6.2.8 show the flexural strength of density 1600kg/m³ and thickness of Panel is 60mm

Age	1st Panel	2nd Panel	3rd Panel	Average Flexural strength (N/mm^2)
7 days	0.681	0.677	0.673	0.677
14 days	0.832	0.800	0.853	0.828
28 days	0.919	0.949	0.922	0.93

Table 6.2.8 show the flexural strength of density 1600kg/m³ and thickness of Panel is 80mm

Discussion on flexural test

The flexural strength of light weight wall panel is made of mixture (1:1) cement and fly ash for foam ratio (1:40) is used. The panel of density 1200kg/m³ of size (500x300x80 mm) along with different thickness of (80, 60 and 40 mm). The strength with steel mesh show higher flexural strength of 0.566N/mm² for 28 days and without steel mesh the flexural strength downs of 0.262 N/mm² for 28 days can be seen in Figure 4.8. The steel mesh shows the better strength for load bearing wall panel. The four point bending test is done, first cracks occur in bottom at the load of 41.5kN.

6.3 Dry shrinkage

Density (kg/m^3)	Dimension	Fresh de-moulded Panel (Dimension)	Dry Panel(Dimension)	Shrinkage on Panel
1200	Panel (P1)	500mmx300mmx80mm	500mmx300mmx80mm	No shrinkage
	Panel (P2)	500mmx300mmx60mm	500mmx300mmx60mm	No shrinkage
	Panel (P3)	500mmx300mmx40mm	500mmx300mmx40mm	No shrinkage

Table 6.3.1 drying shrinkage test of 1200 kg/m³

Density (kg/m³)	Dimension	Fresh de-moulded Panel (Dimension)	Dry Panel(Dimension)	Shrinkage on Panel
1400	Panel (P1)	500mmx300mmx80mm	500mmx300mmx80mm	No shrinkage
	Panel (P2)	500mmx300mmx60mm	500mmx300mmx60mm	No shrinkage
	Panel (P3)	500mmx300mmx40mm	500mmx300mmx40mm	No shrinkage

Table 6.3.2 drying shrinkage test of 1200 kg/m³

Discussion on dry shrinkage test

Drying shrinkage also important factor for light weight concrete. In the experimental program, it is observed that the no changes occur in the dimensions of the light weight panels. The drying shrinkage value is zero for all density panels. That means the chances of crack in the panels in less and the panel is more durable.

6.4 Water absorption test

Density kg/m³	Dimension	% of water absorbed
1200	500mmx300mmx40mm	9.07
	500mmx300mmx60mm	8.58
	500mmx300mmx80mm	8.33

Table-6.4.1 Water absorption test of 1200kg/m³

Density	Dimension	% of water absorbed
1400	500mmx300mmx40mm	8.20
	500mmx300mmx60mm	7.53
	500mmx300mmx80mm	7.47

Table -6.4.2 Water absorption test of 1400kg/m³

Density kg/m³	Dimension	% of water absorbed
1200	500mmx300mmx40mm	9.07
	500mmx300mmx60mm	8.58
	500mmx300mmx80mm	8.33

6.4.3 Water absorption test of 1600kg/m³

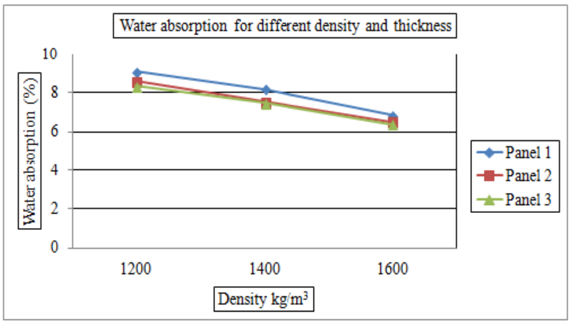


Fig. 6.4.1 Water absorption test

Discussion on water absorption test

Water absorption is an important factor due to the porous structure of the lightweight concrete. The water absorption test is done using the samples prepared at the age of 28 days using the method has been describing in methodology. There are three samples for each density test. Figure 4.17 shows different water absorption for different density of concrete. It can be seen that, water absorption increased when the density of light weight concrete is decreased. This is because the higher percentage of foam ratio applied in each mixture. Besides that, the foam agent (1:40) and water ratio (1:45) will also affect the water absorption ratio. The high water absorption of the concrete will also affect the density and strength of the light weight concrete.

7. CONCLUSIONS

The initial findings have shown that the lightweight concrete has a desirable strength to alternative construction material for the industrialized building system. For a desired density the increase in fly ash decrease the strength and replacing the cement with high fly ash quantity also decrease the compressive strength but partially replacing with fly ash with cement decrease the pores sizes and increase the compressive strength the cellular light weight wall also used in construction with advantage of thermal comfort. The interiors remain cooler in summer and warmer in winters and create aesthetically pleasing wall surface and cost of plastering and painting also may be avoided. Production process of foam concrete is even simpler than producing any other ordinary concrete. We also save labor and time in the construction as pre- cast wall only skilled labor is required

ACKNOWLEDGEMENT

The authors can acknowledge any person/authorities in this section. This is not mandatory.

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