International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-6, April 2020

Assessment of Physical and Mechanical Behaviour of Foam Concrete using Bottom Ash and Fly Ash

Amritha.C.V, Padmanaban.I, Dharsana S., Balamurali.K

Abstract: Foam concrete is a kind of air inflated lightweight concrete, which doesn't contain coarse aggregate and can be regarded as an air inflated mortar. Foam concrete is made by adding foam into the cement slurry, the main use of foam in the cement mortar is to create air voids which act as a ball bearings inside the concrete mix. Foam is prepared by using foam generator or it can be made by sonication process of hydrogen peroxide. In this research work foam is formed by the sonication process of hydrogen peroxide separately then the foaming agent is diluted with water and air inflated to create the foam. Bottom ash from thermal power plant is collected and added in different proportions in the concrete mix to study the mechanical behaviour of the foam concrete. Mechanical properties such as compressive strength, split-tensile strength, flexural strength and thermal conductivity tests are carried out under controlled environment. The targeted design densities of all the specimens were expected to be 1600 kg/m^3. The binder to filler ratio used in this study is 1:1, with the sand being completely replaced with bottom ash and Fly ash.

Keywords: Foam concrete, consistency, thermal conductivity, sound absorption

I. INTRODUCTION

Increase in construction activities increases the use of binding and filler materials, binder and filler plays a major role in the concrete mix because binder holds all the necessary ingredients which are required for the strength property of the elements [1]. Cement is one of the mainly used binder in the modern world and the aggregates are made by quarrying of hard rocks on the earth's surface. Concrete mix made by conventional materials have high density and large weight, to reduce the dead weight and maintain the same density is a challenging work [2]–[4]. Light weight element can be done by reducing the high specific area materials such as conventional coarse aggregate and maintain a moderate density to withstand the concrete under durability actions [5].

Revised Manuscript Received on April 30, 2020.
***** Correspondence Author
Amritha C.V, Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, India. Email: 18tpcv002@skct.edu.in
Padmanaban.I, , Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, India.
Dharsana S., Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, India. Email: dharshana.s@skct.edu.in
Balamurali.K*, Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, India. Email: 18tpcv006@skct.edu.in

This type of issue can be overcome by Foam concrete which maintain the same density and reduced dead weight of the elements by neglecting the use of coarse aggregate in the concrete mix [6]. Foam concrete is made by injecting air bubbles inside the concrete mix during pre-hardening stage of the mix. Foam used in the concrete has the tendency to absorb the humidity during pre-hardening stage of the concrete mix till it exposes to the external atmospheric action [7]. Foam concrete mix consists of cement, fine aggregate, water and special foam. Foam is created with the help of foam generator separately, then it is mixed in the fresh state of the concrete mix the entrained air creates voids in the form of ball bearings inside the concrete [8]. Due to zero coarse aggregate content and increase in air voids the mix possess high flow ability and maintain the slurry as a light weight medium. The density of light weight concrete should lies between 800 kg/m^3 to 1800 kg/m^3, because of its density it possesses high sound and thermal insulation property [9].

II. EXPERIMENTAL PROGRAM

Three sets of concrete specimens are made to study the behavior of foam concrete, first set consists of foam concrete with density 1200kg/m^3, second set consists of foam concrete with density 1400kg/m^3, and the third set consists of foam concrete with density 1600kg/m^3. To create different sets of concrete, bottom ash is used as a replacement of filler at different ratios.

A. Materials

As per Indian standard IS 269, ordinary Portland cement is used in all the mix proportions the physical characteristics of cement are determined under controlled environment as per code. Specific gravity, Consistency, Fineness of cement are 3.15, 30% and 0.5%. The chemical composition of the cement are shown in table 1. Filler used in this study is Bottom ash obtained from the thermal power plant. The specific gravity of bottom ash is 2.43 and the fineness of bottom ash is obtained from the particle size distribution. The fineness of bottom ash is less than 1.18mm from the semi-log graph as shown in figure 1. The chemical composition of bottom ash is shown in table 2.

Table- I: Chemical composition of cement

Main oxides	Percentage
CaO	58.2
SiO_2	18.2
Al_2O_3	6.6
Fe_2O3	2
Na_2O	0.3

K_2O	0.5
MgO	4.8
SO_3	2.5
Loss of ignition	1.1

Table- II: Chemical composition of Bottom Ash

Oxide	Bottom ash
Cao	1.8
SiO_2	48.2
Al_2O_3	23.1
Fe_2O_3	18.7
MgO	0.5
TiO_2	1.9
P_2O_5	0.3
SO_3	0.26
Na_2O	0.33
K_2O	2.5
Loss of ignition	0.75

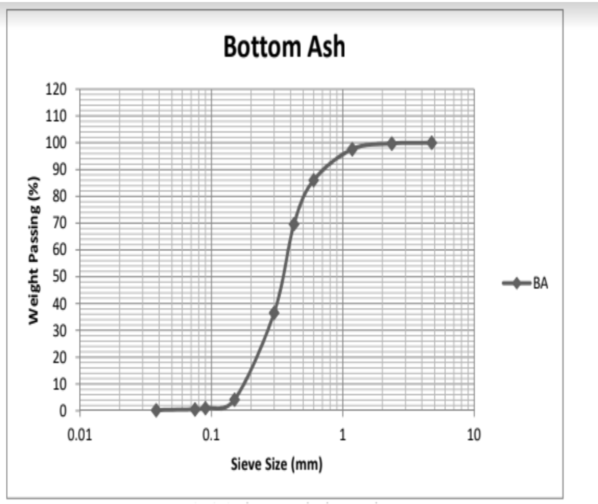

Fig. 1. sieve analysis of Bottom Ash

B. Mixing and Specimen Preparation

All the mixes in this study are made as per the Indian standard specification, cement and filler material bottom ash of different proportions are mixed at dry state. Mixing of binder –filler mix and water are done till the mix completely get consistent. At the same time foam is created by means of sonication process, sonication is the process of creating turbulence in hydrogen peroxide, the blades spin at a rate of 100 rpm to 200rpm. The process is repeated until the foam is created. Required amount of prepared foam is added to the cement slurry and mixed completely till the foam get spreader throughout the mix.

III. MIX PROPORTIONS

The targeted density of the concrete mix as 'ρ' kg/m^3, is given by the following equation

$$\rho = b + f + w + fc \qquad (1)$$

where, ρ is the density of foam concrete in kg/m^3, b is the binder content in kg/m^3, f is the filler content in kg/m^3, w is the water content in l/m^3, fc is the foam content required for the preparation of foam concrete.

The above equation can be rewritten as

$$\rho = s + w \qquad (2)$$

where, s is denoted as solid content expressing in terms of kg/m^3 it is the combination of total volume of binder and filler required for the mix preparation as shown in equation (3), this is done because the foam used for the mix was negligibly smaller when compared to other mix ingredients.

$$s = b + f \qquad (3)$$

IV. HARDENED PROPERTIES

A. Compressive Strength

Compressive strength test is performed after 28 days of curing as per IS 2250, the specimen size adopted for this test is 50mm x 50mm x 50mm. The specimen is air dried for 24 hrs. After the curing period of 28 days before the test is performed. Specimen is placed at the compression testing machine as shown in figure 2, load is applied gradually until the specimen is fractured. Maximum load carrying capacity of the specimen is noted and the compressive strength result is obtained from the following equation, $\sigma = P/A$, where P is the maximum load that the specimen has observed in N and A is the cross-sectional area of the specimen in mm^2, σ is the compressive strength in N/mm^2.

Fig. 2. Foam concrete specimen befor testing

Mixes with cement: filler ratio of 1:1 was adopted and design target densities of 1200 kg/m3, 1400 kg/m3 & 1600 kg/m3 were selected for each mix. Due to the filler size water-solids ratio (w/s) was taken instead of water-cement ratio. The w/s ratio changes for each mix and the volume of foam is directly proportional to the w/s ratio.

Table- III: Compressive Strength Result

Density	1200	1400	1600
Days	kg/m^3	kg/m^3	kg/m^3
7	1 Mpa	2 Mpa	8 Mpa
14	4 Mpa	6 Mpa	20 Mpa
28	10 Mpa	12 Mpa	28 Mpa

B. Split Tensile Strength

Split Tensile strength is carried out for the specimen of size 150mm in diameter and 300mm in height, the specimen is placed in the compression testing machine in a horizontal manner and the load is applied gradually till the specimen fails, the breaking load is noted.

Fig. 3. Split Tensile test on Foam concrete specimen

Table- IV: Chemical composition of Bottom Ash

Density	1200 Kg/m^3	1400 Kg/m^3	1600 Kg/m^3
28th day	1.1 Mpa	1.2 Mpa	1.6 Mpa

C. Flexural Strength Test

Flexural strength test was carried on the foam concrete specimen with the dimension of 700mm length, 100mm breadth and 100mm depth. Figure 4. Shows the placing of specimen in Universal testing machine. Two – point loading system is adopted for the specimen and the load is applied gradually till the specimen fails. The following formula is used to determine the flexural strength of the foam concrete.

$$\delta = 3PL/b \qquad (4)$$

Where;
δ = Flexural strength, N/mm^2
P = Maximum applied load indicated by the testing machine
L = Span length, mm
B = Breadth of the specimen

Fig. 4. Flexural Strength test on Foam concrete specimen

Table- V: Flexural strength test result

Density / Days	1200 kg/m^3	1400 kg/m^3	1600 kg/m^3
28th day	1.17 Mpa	1.24 Mpa	1.41 Mpa

D. Thermal Conductivity

Thermal conductivity of foam concrete is done by placing a sample of size 700mm x 700mm x 10mm between the hot and cold plate, a heated wire is inserted between the specimen and cold plate to measure the values of T5 and T6 which shows the temperature of cold plate.
The temperature of the hot plate increases gradually at a rate of 2^{o}c per minute till the temperature of hot plate becomes constant. Thermal conductivity of foam concrete can be calculated using Equation 5.

$$K = QL/2A(T_h - Tc) \text{ W/mK} \qquad (5)$$

Vi =outer heater input (volts)

I= Amplitude

L= Thickness

A= Area

T_h =Hot plate temperature (T1+T2+T3+T4)

T_c=Cold Plate Temperature (T5+T6)

Q=V_iI(W)

K= Conductivity

Fig. 5. Thermal conductivity test

Table- VI: Thermal conductivity Test result

Time	V	I	L	A	T1	T2	T3	T4	T5	T6	Th	Tc	K
20 mins	70	1.07	0.02	0.08325	45	48					24	0	0.374875
40 mins	70	1.071	0.02	0.08325	46	49	64	64	25	25	56.5	25	0.285886
50 mins	70	1.071	0.02	0.08325	47	50	65	66	25	25	58	25	0.272891
70 mins	70	1.072	0.02	0.08325	48	52	67	67	25	25	59.5	25	0.26127
80 mins	70	1.082	0.02	0.08325	52	57	72	72	26	25	64.5	25	0.230327
90 mins	70	1.082	0.02	0.08325	68	72	86	84	31	27	78	27	0.17839
100 mins	70	1.083	0.02	0.08325	71	75	88	86	33	28	80.5	28	0.173453
110 mins	70	1.083	0.02	0.08325	50	54	69	69	26	25	61.5	25	0.249488
120 mins	70	1.085	0.02	0.08325	52	57	71	71	28	26	64	26	0.240082
130 mins	70	1.085	0.02	0.08325	60	65	72	72	30	29	68.5	29	0.230965
140 mins	70	1.085	0.02	0.08325	62	70	80	80	31	28	75	28	0.194109
150 mins	70	1.085	0.02	0.08325	66	78	84	89	33	28	83.5	28	0.164381
160 mins	70	1.083	0.02	0.08325	71	78	86	91	35	28	84.5	28	0.161174
170 mins	70	1.091	0.02	0.08325	75	79	88	90	36	29	84.5	29	0.16529
180 mins	70	1.091	0.02	0.08325	76	79	90	90	36	29	84.5	29	0.16529
190 mins	70	1.09	0.02	0.08325	77	80	92	90	36	29	85	29	0.163664
200 mins	70	1.09	0.02	0.08325	78	81	92	92	37	29	86.5	29	0.159394
210 mins	70	1.092	0.02	0.08325	79	82	92	92	37	29	87	29	0.15831
220 mins	70	1.097	0.02	0.08325	79	83	93	93	37	29	88	29	0.156339
230 mins	70	1.093	0.02	0.08325	79	83	93	94	38	29	88.5	29	0.15446
240 mins	70	1.09	0.02	0.08325	79	84	93	94	38	29	89	29	0.152753
250 mins	70	1.086	0.02	0.08325	79	84	93	94	38	29	89	29	0.152192

V. CONCLUSION

The Density of Foam Concrete is varied by adding foam content in the range of 15%, 25% and 35%, it shows that 15% foam volume has the density of 1600 kg/m^3, 25% foam volume has the density of 1400 kg/m^3, and 35% foam volume has the density of 1200 kg /m3.

It shows that strength is directly proportional to density of sample, table 3. Shows that compressive strength of concrete increase when the density of concrete increases and also strength of foam concrete after 28 days of curing shows 28 Mpa in the mix ratio of 1:1.

Thermal conductivity of conventional concrete is 1.5 W/m K at 2400 kg/m^3, whereas thermal conductivity of foam concrete is 0.167 W/m K at 1600 kg/m^3, 0.198 W/m K at 1400 kg/m^3, 0.211 W/m K at 1200 kg/m^3, it is observed that the heat conductivity of the concrete specimen is inversely proportional to the density of the concrete.

Increase in foam volume results in decrease in concrete density, foam volume of 15% with bottom ash has an effective strength of 28Mpa. Thereby concluding that volume of foam less than 15% has increase in density and Targeted strength

ACKNOWLEDGMENT

The Authors are thankful to Dr. V. Sreevidya Associate Professor and Project Co-coordinator for her support throughout the project work

REFERENCES

1. Jingwen Zhang, Ningshan Jiang, Hui Li and Chengyou Wu, "Study on Mix proportion design of cement Foam concrete", IOP Conference Series: Material Science and Engineering, vol. 439, pp. 1-5, September 2018.
2. Sung-Sil Cho, Jin-Man Kim, and Ic-Pyo Hong, "Electromagnetic Shielding Characteristics of Eco-Friendly Concrete wall", International journal of Antennas and Propagation, vol. 2017, pp. 1-8, April 2017.
3. Xin Wang, Jian Huang, Shaobin Dai and Qi jiang,"Investigation of Silica Fumes as foam cell stabilizer for foamed concrete", Construction and Building Materials, vol. 237, pp. 1-12, February 2020.
4. Osman Hulusi Oren, Aliakabar Gholampour, Osman Gencel and Togay Ozbakkaloglu, "Physical and mechanical properties of Foam concrete containing granulated blast furnace slag as fine aggregate", Construction and Building Materials, vol. 238, pp. 1-12, February 2020.
5. Xiaoyun Yang, Ling Zhao, M. Aminul Haque, Bing Chen, Zeng Ren, Xinde Cao, Zhemin She," Sustainable conversion of contaminated dredged river sediment into eco-friendly foamed concrete", Journal of Cleaner Production, pp. 1-40, February 2020
6. Essam Eltayeb, Xing Ma, Yan Zhuge, Osama Youssf, Julie E. Mills," Influence of rubber particles on the properties of foam concrete", Journal of Building Engineering, pp. 1-35, February 2020.
7. Juan He, Qie Gao, Xuefeng Song, Xiaolin Bu and Junhong He, "Effect of foaming agent on physical and mechanical properties of alkali-activated slag foamed concrete", Construction and Building Materials, vol. 236, pp. 280-287, August 2019.
8. Pengwei Li, Huijun Wu, Yanchen Liu, Jianming Yang, Zhaosong Fang and Borong Lin, "Preparation and Optimization of ultra-light and thermal insulative aerogel foam concrete", Construction and Building Materials, vol. 205, pp. 529-542, April 2019.
9. M.A. Othuman Mydin, N. Mohd Zamzani and A.N Abdul Ghani,"Experimental data on compressive and flexural strength of coir fibre reinforced foam concrete at elevated temperature", Data in brief, vol. 25, pp. 529-542, july 2019.

AUTHORS PROFILE

Amritha C V Currently doing master's program in the civil engineering department at Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India. Completed higher secondary in the year of 2013, and joined as under graduate student in the department of civil engineering at Malabar institute of technology, Kerala. And completed under graduate degree in the year of 2017. B.tech project –Analysis and Design of indoor stadium. ME project –phase 1 assessment of physical and mechanical behavior of foam concrete using fly ash and bottom ash as filler material under the guidance of respected Head of Department, department of civil engineering, sri Krishna College of technology, Dr. I. Padmanaban, and Assistant Professor Ms. Dharshana. Attended and Presented paper on the title of titled "flexural strength studies on concrete using synthetic polymer as shear reinforcement" in the 3rd national conference on current & emerging process technologies in kongu engineering college, Perundurai, Erode, Tamil Nadu. Patents:1.Methods of constructing concrete filed polymer tube section,2.Saw bricks.

Padmanaban.I, Currently working as Professor and Head of Civil Engineering Department at Sri Krishna College of Technology from October 2015 to till date ¬ Professor and Head of Civil Engineering Department at Jansons Institute of Technology from December 2010 to October 2015(5 years) ¬ Worked as Senior Lecturer in Civil Engineering Department at V.L.B Janakiammal College of Engineering and Technology(from July 2007 to December 2010, (3years) ¬ Worked as Lecturer in Civil Engineering Department at Kumaraguru College of Technology, Coimbatore (from May 2006 to June 2007 for a period of 1 year) ¬ Teaching Research Associate in Govt. Engg. College, Salem from April 2002 to April 2006 (acquired teaching and research experience for a period of 4 years) ¬ Experience in Developing High Volume Fly ash Concrete Mix Design of High Performance Characteristics ¬ Testing and consultancy experience in Soil Engineering and concrete mix design ¬ Introduced First of its kind Experiential Learning in Civil Curriculum starting from first year ¬ MOU collaboration with 12 of established construction Industries ¬ Projects evaluated by Industrial Experts. CONTRIBUTION TO THE DEPARTMENT ¬ Convener for the International conference on Frontline areas of Civil Engineering. 5-6 Jan 2018 at Sri Krishna college of Technology sponsored by AICTE ¬ Convener for the Industrial Aspects of Cold Formed Steel Structures ", April 6, 2017. sponsored by CSIR ¬ Motivated our Civil Engineering faculty to obtain research funding under DST SERB, DRDO,MOES,CSIR, ICMR to a tune of 35 lak ¬ Co-ordinatior for Faculty Development Programme on "CE2302 Structural Analysis –I" from 11th to 17 June 2013 at Jansons Institute of Technology ¬ Convener for the National conference NCONET'14 for Civil Engineering Department at Jansons Institute of Technology ¬ Convener for the National conference NCONET'13 for Civil Engineering Department at Jansons Institute of Technology.

Dharsana S., completed her under graduation in civil engineering from Ahalia School of engineering and technology affiliated to University of Calicut and pursued master's degree in Structural and Construction engineering from Amrita Vishwa Vidyapeetham, Coimbatore. Worked in few projects entitled 'Seismic Vulnerability Assessment of city regions based on Building Typology' 'Effective Utilization of Lime Sludge in manufacturing soil blocks'. Highly passionate in teaching, started career as assistant professor at Sri Krishna College of Technology since 2019 June. Academic experience in structural domain which include, Design of Concrete structures, Design of Steel Concrete Composite Structures. Area of research include sustainable materials and vulnerability assessment of buildings.