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Behaviour of Light Weight Brick with the Influence of EPS Beads and Silica Fume

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Abstract: The principal reason behind this experimental investigation carried out here is to diminish the dead load of structures with the potential use of light weight bricks. EPS beads and silica fume are light in nature. The investigation work enhanced, with numerous literature study to find out the utilization of Expanded polystyrene(EPS) beads and silica fume in light weight brick can be used in military bases in cold regions due to its low thermal insulating quality. The main objective of this research is to prepare a light weight brick by partial substitution of Cement with silica fume and the replacement of fine aggregate with EPS beads. A total of 70 bricks containing two different sizes of EPS beads say Type A and Type B with different proportions (0%, 7%, 14%, 21%) of each Type were casted in order to check the mechanical properties such as compressive strength, water absorption, efflorescence, workability, and thermal conductivity of the brick. The compressive strength test was carried out at 7, 14 and 28 days of curing. As the percentage of EPS beads in the brick increased the strength of brick decreased while with the increase of EPS beads in the brick the water absorption as well as the thermal conductivity of brick decreased. There were slight presence of Efflorescence in some of the bricks while in most of the brick there were no efflorescence found.

Key Words : EPS beads, Silica fume, Thermal Conductivity, Light weight brick

I. INTRODUCTION

Bricks have always been one of the major necessity of the building construction which can be used for partitions, pavements and other masonry work. Manufacturing of bricks have evolved with time from mud bricks to burnt clay, concrete bricks and to fly ash bricks. In India most of the people rely on ordinary burnt clay bricks for the building construction. These bricks cause certain disadvantages to the nature resulting into air as well as land pollution. For providing strength to ordinary clay bricks these bricks are burnt by using coal as a fuel for combustion which results in huge amount of air pollution. Whereas, large amount of good fertile soils are excavated in need of manufacturing of these bricks which are gathered from agricultural lands. Due to this land pollutions are caused and it affects the loss of good fertile soil . Thus, manufacturing of clay bricks causes a great affect in the erosion of soil and unprocessed emissions [4].

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Expanded polystyrene (EPS) beads are the lightweight closed cellular plastic materials which constitutes of fine spherical shaped particles which are composed of about 98% air and 2% polystyrene [2, 6]. The polystyrene are closely packed round structure and have the ability to repel water [1]. These are good sound and thermal insulating material as well as have admirable tendency to resist load [8]. The main aim of this research is to examine the use of EPS beads with silica fume for the development of a light weight brick. EPS beads are non biodegradable material and have been a threat to the environment as it has a dumping problem [2, 9]. Usually these waste materials are burnt or left in the landfills. The burning of these type of material causes release of hazardous gases which can cause serious health issues. Therefore the best way to utilize these non renewable materials is to consume them for the building construction materials i.e. for the manufacturing of light weight bricks [5, 7].

II. MATERIALS USED

EPS beads used in this investigation was purchased from Balaji thermocol industries from Malanpur, Gwalior. Two types of commercially available EPS beads are used say Type A and Type B. The grading shows that the size of Type A is generally 3-5mm and has a bulk density of $18kg/m^3$ while Type B is generally of 1-2mm size and has a bulk density of $20kg/m^3$. Ordinary Portland cement conforming to 43 grade IS:8112 is preferred for this experimental work. The cement used in this work for all trials is from the same batch of Ultra tech. Stone dust used in this experimental work as a fine aggregate, it was taken from Shrre Ji Stone Crusher. The physical properties of stone dust was carried as per IS 383-1970 and IS 2386-1963. Fly Ash was taken from Amar brick Industries. The specific gravity of this pozzolanic material was carried out as per IS: 1727-1967. The physical properties of the material was tested in the laboratory. Silica fume in this investigation work was taken from Jalyan Trading, Gujarat. The physical properties of the material was tested as per IS: 1727-1967.

III. METHODOLOGY

The purpose of this research was to design a lightweight fly ash brick with the use of Expanded polystyrene(EPS) beads as the replacement of fine aggregate that will help in providing an advantage for reducing the dead weight of structure and to obtain a more economical lightweight brick. In addition cement is being partially replaced by silica fume. For this purpose, two different sizes of EPS beads say TYPE A(bigger) and TYPE B(smaller) of almost same density are taken and are compared with the fly ash brick at 0%, 7%, 14%, and 21% EPS beads content by weight.

A total of 7 mixes and for each mix 10 samples were prepared with constant binder content i.e., cement, silica fume, water and fly ash. Further these 7 mixes are divided into different groups according to the percentage of EPS beads and type of EPS beads used. Keeping the percentage of silica fume (2%), cement(8%), fly ash(50%) constant, the remaining 40% of fine aggregate i.e., stone dust was replaced by EPS beads at 7%, 14%, and 21% by weight in both TYPE A(bigger) and TYPE B(smaller) EPS beads. A nominal mix was prepared with 0% EPS beads having 40% stone dust. All the mechanical properties of both the sizes of EPS beads were compared with this nominal mix which has been termed as FLB (fly ash brick). The water cement ratio was kept constant i.e., 0.40. The mechanical properties of these bricks were conducted such as workability, water absorption, compressive strength, efflorescence test, thermal conductivity tests were carried out. The materials used in the manufacturing of these bricks were hand mixed with masonry trowel until a homogeneous mix was achieved. These bricks were casted in two layers and was hand compacted by the means of tamping rod, in each layer the mix were tamped 25 times to make sure there wasn't any voids left in the brick. A proper care was taken to remove the bricks from the mould.

A. Mix Proportions

The mix proportions of the brick for two different sizes of EPS beads were taken same as to compare their mechanical properties such as workability, water absorption, efflorescence, compressive strength. Firstly three specimens of type A(bigger) EPS beads were prepared, tagged as 7EPS01, 14EPS01, 21EPS01(here 7,14,21 are the percentage of EPS contents and 01 shows type A EPS beads). A total of 10 samples were prepared of each specimens.

Table 1 : Mix proportions of brick with different EPS beads

Specimens	Sample with EPS	Fly Ash	Cement	Silica fume	Stone dust + EPS beads
FLB	0%	50%	8%	2%	40% stone dust + 0% EPS
7EPS01	7%	50%	8%	2%	33% stone dust + 7% EPS
14EPS01	14%	50%	8%	2%	26% stone dust + 14% EPS
21EPS01	21%	50%	8%	2%	19% stone dust + 21% EPS
7EPS02	7%	50%	8%	2%	33% stone dust + 7% EPS
14EPS02	14%	50%	8%	2%	26% stone dust + 14% EPS
21EPS02	21%	50%	8%	2%	19% stone dust + 21% EPS

Similarly, three specimens of type B(smaller) EPS beads were prepared, tagged as 7EPS02, 14EPS02, 21EPS02(here 7,14,21 shows the percentage of EPS content and 02 shows type B EPS beads). A total of 10 samples were prepared for each specimen. Finally, a specimen containing 0% EPS beads was prepared, tagged as FLB which shows Fly ash brick with 0% EPS beads content. A total of 10 samples were prepared for this specimen as well.

IV. RESULTS AND DISCUSSION

B. Workability Test

The workability of the fresh mixture was calculated with the help of slump test as per IS 1199-1959. The slump for normal fly ash brick ranged from 35-60mm while that of EPS bricks ranged from 50-110mm. The slump tests of mix design containing Type B EPS beads gave good results as compared to the mix designs having Type A EPS beads. The Slump for Type A EPS beads ranged from 70-110mm while the slump for Type B EPS beads ranged from 50-80mm.

C. Compressive Strength Test

The compressive strength of bricks were tested in laboratory after 7, 14, and 28 days of curing in water. This property was investigated by testing the standard size (190x90x90) mm bricks under the compressive testing machine(CTM) as per IS 3495-1992 part I. The bricks were placed between two iron sheets of 3mm thickness and carefully centred between the plates of the testing machine. The loads on the brick was applied axially at a uniform rate of 14N/mm^2 until the brick was cracked and stop to take more load as there is no increase in the reading of testing machine and stops at the failure of the brick. The final load at which the brick crack is noted as the maximum load or ultimate load.

$$C.S = \frac{Ultimate\ load}{Area} x\ 1000\ N/mm2$$

The experimental investigation shows that the compressive strength of the bricks having Type A EPS beads were relatively less than that of bricks having Type B EPS beads. The maximum compressive strength of brick having Type A EPS beads were at 7 % EPS content in the brick which was achieved at 28 day curing is 8.65N/mm^2 while the maximum compressive strength of brick having Type B EPS beads were at 7 % EPS content in the brick which is also achieved at 28 day curing is 9.90N/mm^2

Table 2 : Compressive Strength results of brick with two different types of EPS beads

Specimens	Compressive strength in N/mm^2		
	7 day	14 day	28 day
FLB	7.63	9.86	11.22
7EPS01	4.33	6.63	8.65
14EPS01	2.83	4.77	7.25
21EPS01	2.44	3.32	5.38
7EPS02	5.91	7.28	9.90
14EPS02	5.23	6.79	9.07
21EPS02	3.35	6.10	8.35

A graphical representation of these compressive strength on the basis of their curing age to depict more precisely the strength pattern of these bricks with Type A EPS beads have been shown in the figure below.

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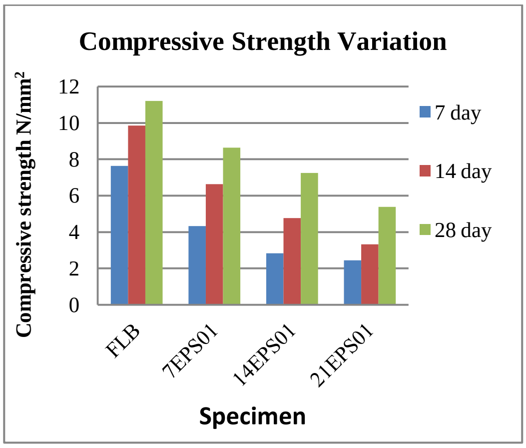

Figure 1 : Graph showing Compressive Strength of Type A EPS beads

A graphical representation of these compressive strength on the basis of their curing age to depict more precisely the strength pattern of these bricks with Type B EPS beads have been shown in the figure below.

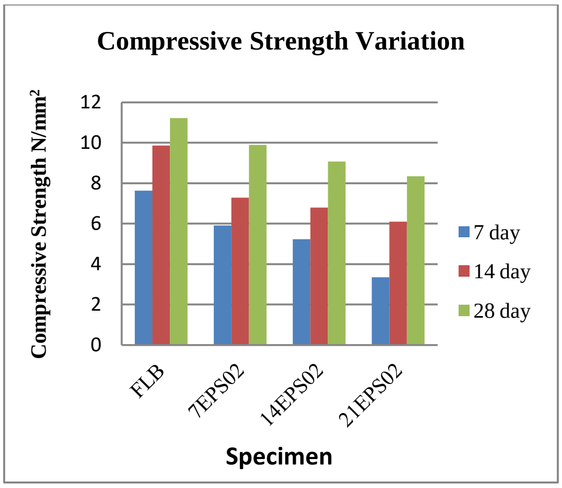

Figure 2 : Graph showing Compressive Strength of Type B EPS beads

D. Water Absorption Test

Water absorption test of a brick is conducted to understand how much amount of water is absorbed by the brick. This test is carried out according to IS : 3495-1992 part II. In this test first a dry brick is taken and the weight of this brick is taken as W_1 then this brick is immersed in the water for 24hours and then taken out from water and weighed, this weight is taken as W_2 . The water absorption of a brick should not be more than 20%. The water absorbed by the brick is then calculated according to the given formula below.

$$\text{water absorption} = \frac{W2-W1}{W1} \times 100$$

The water absorption results of brick containing two different Types of EPS beads are shown in the table below:

Table 3 : Average water absorption of brick with different types of EPS beads

Specimen designation	Sample	Initial Weight(W_1) (gram)	Final Weight(W_2) (gram)	Water Absorption %	Average Water Absorption %
FLB	I	2628.5	3056	16.26	16.39
	II	2619	3052	16.53	
7EPS01	I	2170.5	2492	14.81	14.56
	II	2247.5	2569.5	14.32	
14EPS01	I	2051	2323	13.26	13.28
	II	2089.5	2367.5	13.30	
21EPS01	I	1837	2070.5	12.71	12.73
	II	1791.5	2020	12.75	
7EPS02	I	2312	2669	15.44	15.35
	II	2308	2660.5	15.27	
14EPS02	I	2088.5	2394	14.62	14.61
	II	2118	2427.5	14.61	
21EPS02	I	1925	2186.5	13.58	13.40
	II	1934	2190	13.30	

The figure below shows the graphical representation of the decrease of water absorption with the increase in EPS content of Type A in the brick.

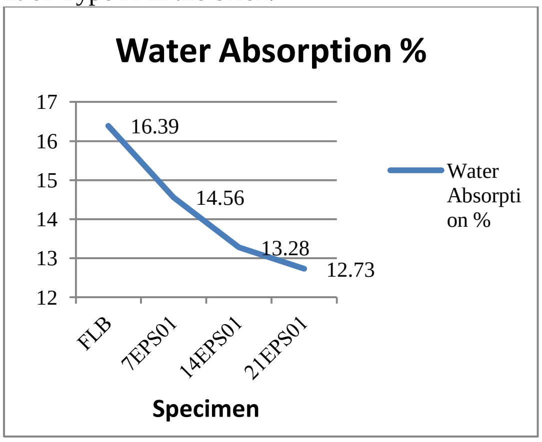

Figure 3 : Graph showing water absorption of Type A EPS beads

The figure below shows the graphical representation of the decrease of water absorption with the increase in EPS content of Type B in the brick.

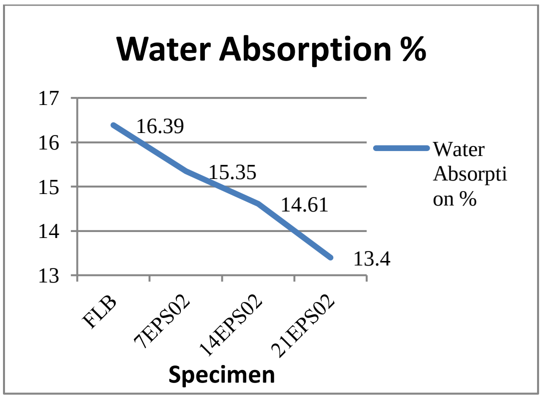

Figure 4 : Graph showing water absorption of Type B EPS beads

E. Efflorescence Test

The efflorescence of a brick can be tested as per IS: 3495 part III 1992. The results show that there was not any pattern of efflorescence present in the bricks. Most of the bricks had Nil efflorescence while some of the bricks had a slight presence of efflorescence. It was difficult to judge which mix proportion had maximum efflorescence as all the results were almost similar. The bricks with Type A EPS beads having 7% EPS content had almost negligible efflorescence in all its samples. Similarly, the bricks with Type B EPS beads having 14% EPS content had zero efflorescence in all its samples. The maximum efflorescence was found in type B EPS beads having 21% EPS content i.e., in the sample of three bricks, two had efflorescence less than 10 % while one had zero efflorescence.

F. Thermal Conductivity Test

Thermal conductivity of two types of brick comprising of different size of EPS beads say Type A(bigger) and Type B(smaller) of almost same density were tested with different proportions of EPS beads at 7%, 14%, and 21% . This test is carried out on the basis of steady state condition according to the code IS 3346: 1980. In this experimental investigation testing bricks were drilled on two ends of the brick in order to measure the temperature of the brick using thermocouple. One end of the brick was attached to a heater coil, thermocouples were placed at both the ends and the whole brick except one side was insulated with a highly insulating material called glass wool to abstain the loss of heat from other directions and to grant the flow of heat to move in one direction. The heater coil is assembled with an electric circuit through ammeter, voltmeter, dimmer stat(voltage regulator). This whole experimental investigation was done in a closed room to avoid the delay in information of steady state condition. When the power button is switched on the voltage and current is adjusted with the help of dimmer stat. The temperature at heater coil raises and the temperature at the outer end of the brick also raises after a period of time. After the steady state condition is achieved the temperature at the heater coil is noted as T_1(Hot) and temperature at the outer end of the brick is noted as T_2(Cold). The parameters of the current and voltage passed is noted with the help of ammeter and voltmeter as *i* and *v* [5]. The thermal conductivity of the brick sample is calculated using the formula below.

$$\text{Thermal conductivity } (K) = \frac{V \times i \times l}{A(T1-T2)} \text{ W/m- }^{o}\text{C}$$

Where, k = Thermal conductivity
v = voltage
i = current
l = length of the material
A = cross section area of material
T_1 = Temperature at hot coil
T_2 = Temperature at cold coil

The table below shows the results of sample of brick having two different Types of EPS beads. It is quite clear from the result that as the content of EPS beads increases the thermal conductivity of the brick decreases.

Table 4 : Thermal Conductivity test results of bricks having two different Types of EPS beads.

Brick Detail	EPS Utilization %	Size of Brick Sample(cm)	Current Passed (i)	Voltage Passed (v)	Temp at coil (T_1)	Temp at coil (T_2)	Thermal conductivity (k)
FLB	0%	19X9X9	0.4	30	72.7	41.1	1.05
7EPS01	7%	19X9X9	0.4	30	71.6	35.7	0.92
14EPS01	14%	19X9X9	0.4	30	73.7	34.2	0.84
21EPS01	21%	19X9X9	0.4	30	72.9	30.1	0.77
7EPS02	7%	19X9X9	0.4	30	70.3	35.6	0.96
14EPS02	14%	19X9X9	0.4	30	71.7	32.5	0.85
21EPS02	21%	19X9X9	0.4	30	73.5	31.4	0.79

The bricks should have low thermal conductivity in order to use them in harsh climatic conditions. The results from the above table show that the thermal conductivity of brick having Type A EPS beads is comparatively lower than Type B EPS beads when the percentage of EPS content in both of them were similar. The best thermal conductivity of brick containing Type A EPS beads was achieved at 21 % EPS content i.e., 0.77 W/m- ^{o}C. The best thermal conductivity of brick containing Type B EPS beads brick was achieved at 21 % EPS content i.e., 0.79 W/m- ^{o}C. The maximum thermal conductivity achieved was that of Fly Ash brick being 1.05 W/m- ^{o}C

Figure 5 : Showing Thermal conductivity set up

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G. Cost Analysis

Cost of each brick having different mix proportions were calculated and are shown in the table below.

Table 5 : Cost of brick having two different EPS beads

Specimens	Cost of one brick(Rupees)
FLB	3.03
7EPS01	3.53
14EPS01	4.04
21EPS01	4.54
7EPS02	3.76
14EPS02	4.50
21EPS02	5.24

Cost Comparison of Type A EPS beads brick with Fly ash brick

The cost of each brick with different mixtures of Type A EPS beads was calculated and it was observed that as the percentage of EPS beads increased by 7% in the brick the cost of brick also increased by approx 0.50 rupees. The table below shows the unit cost of each compositions of brick. The cost increase of brick is best depicted in the flow chart given below. It can be noted that as the percentage of EPS beads increased while decreasing the percentage of stone dust in the brick there is a substantial increase in the cost of the brick.

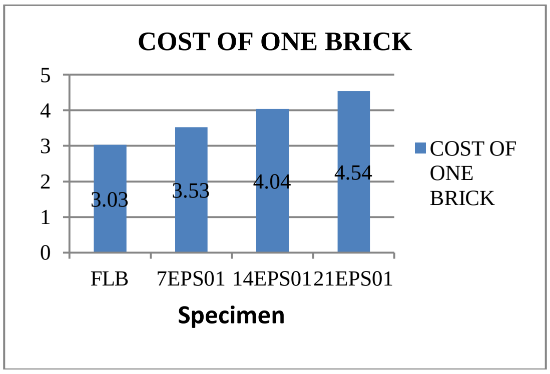

Figure 6 : Flow chart showing brick cost having Type A EPS beads

Cost comparison of Type B EPS beads with Fly ash bricks

The cost of each brick with different mixtures of Type B EPS beads was calculated and it was observed that as the percentage of EPS beads increased by 7% in the brick the cost of brick also increased by approx 0.74 rupees. The cost increase of brick is best depicted in the flow chart given below. It can be noted that as the percentage of EPS beads increased while decreasing the percentage of stone dust in the brick there is a substantial increase in the cost of the brick.

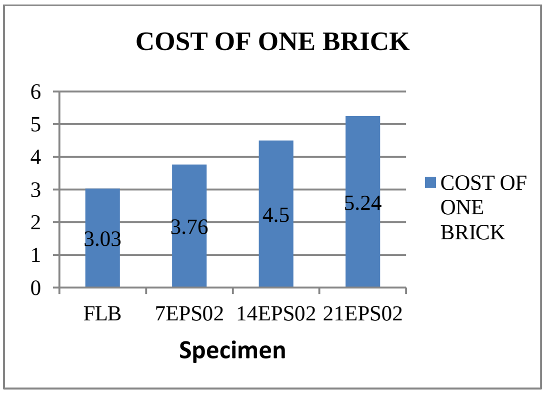

Figure 7 : Flow chart showing brick cost having Type B EPS beads

V. CONCLUSION

EPS bricks give good workability and is easy to cast and handle. The bricks having Type B EPS beads were comparatively easier to handle, compact and mix because of its closely packed intermolecular arrangements while brick having Type A EPS beads were loosely packed and were very light which caused minor segregation.

It was noted that the compressive strength of Type B EPS beads brick was comparatively better than Type A EPS beads. It was because the density of Type B EPS beads were greater than Type A EPS beads. The strength of the brick was highly dependent on the size, density, and the intermolecular arrangements of the EPS beads.

EPS beads have the ability to repel water. The water absorption of brick having Type A EPS beads were comparatively better because the size of Type A was greater and it occupied more space in the brick than Type B EPS beads.

There were no such pattern of Efflorescence present in the brick. In most of the brick samples the efflorescence observed was nil or either slight while the maximum efflorescence observed was in Type B EPS beads having 21 % EPS content.

For better results high density, greater size and closely packed intermolecular arrangements would provide better mechanical properties.

There wasn't much difference in the thermal conductivity results between Type A and Type B EPS based bricks. Thermal conductivity of Type A EPS beads brick were comparatively better than Type B EPS beads brick due to its size. The best thermal conductivity of brick containing Type A EPS beads was achieved at 21 % EPS content i.e., 0.77 W/m- ^{o}C. The best thermal conductivity of brick containing Type B EPS beads brick was achieved at 21 % EPS content i.e., 0.79 W/m- ^{o}C.

Cost of brick increased with the increase of EPS content in the brick. The cost of Type A EPS beads brick was comparatively lower than Type B EPS beads brick. The cost of Type A EPS beads brick rise by 0.50 rupees as the content of EPS beads increased. At 7% the cost of brick was 3.53 rupees while at 21 % the cost of brick was 4.54 rupees. The cost of Type B EPS beads brick rise by 0.74 rupees as the content of EPS beads increased. At 7 % the cost of brick was 3.76 rupees while at 21 % the cost of brick was 5.24 rupees.

REFERENCES

1. Jayanth M .P & Sowmya S.M. (2018) Experimental study on replacement of coarse aggregate by EPS beads in concrete to achieve lightweight concrete, International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 05 Issue: 07 | July-2018
2. Tarun Jain & Prof. Archana Tiwari. (2017) Light Weight Bricks Using Waste EPS Beads. International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN: 2321-9653, Volume 5 Issue VI, IC Value: 45.98
3. Magdy A. Abd-ElAziz, Ahmed Serag Faried & Mahmoud M. A. Kamel (2017) . Influence of Silica Fume Incorporation on the Fresh, Thermal and Mechanical Properties of Expanded Polystyrene (EPS) Foamed Concrete. American Journal of Civil Engineering, ISSN: 2330-8729 (Print); ISSN: 2330-8737 (Online), Vol. 5, No. 3, 2017, pp. 188-195. doi: 10.11648/j.ajce.20170503.19
4. N. Thirugnanasambantham et. and al. (2017) Effect Of Silica Fume On Fly Ash Bricks, International Journal of Science and Engineering Research (IJ0SER), 3221 5687, (P) 3221 568X, Vol. 5 Issue 3 March -2017
5. Saride Lakshmi Ganesh & Sambangi Arunchaitanya (2016). An Experimental Study on Hardened and Thermal Properties of Fly ash Bricks Using Polystyrene Beads as Partial Replacement of Sand. International Journal of Innovative Research in Science, Engineering and Technology, ISSN(Online): 2319-875 , ISSN (Print): 2347-6710, Vol. 5, Issue 6
6. Aman Mulla & Amol Shelake (2016) Lightweight Expanded Polystyrene Beads Concrete, International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue National Conference “VishwaCon'16”
7. Bengin A Herki et. & al.(2016) Engineering Properties of Sustainable Lightweight Concrete Using Waste Polystyrene, International Journal of Engineering and Innovative Technology (IJEIT), ISSN: 2277-3754, Volume 5, Issue 12, June 2016
8. P.L Chowdary. (2015) Strength Properties of Expanded Polystyrene Beads, Concrete, Journal of Environmental Science, Computer Science and Engineering & Technology, E-ISSN: 2278–179X, JECET; June 2015- August 2015; Sec. A; Vol.4.No.3, 734-742.
9. Thomas Tamut et. & al. (2014) Partial replacement of coarse aggregates by Expanded Polystyrene beads in concrete, International Journal of Research in Engineering and Technology (IJRET), eISSN: 2319-1163 | pISSN: 2321-7308, Volume: 03 Issue: 02 | Feb-2014
10. Abdulkadir kan & Ramazan Demirboga, (2009) A novel material for lightweight concrete production, Cement & Concrete Composites 31 (2009) 489–495.
11. Sohrab Veiseh & Ali A. Yousefi (2003). The Use of Polystyrene in Lightweight Brick Production. Iranian Polymer Journal / Volume 12 Number 4 (2003)
12. K. Ganesh babu, D. Saradhi Babu (2002) Behaviour of lightweight expanded polystyrene concrete containing silica fume, Cement and Concrete Research 33 (2003) 755–762
13. IS 3495 (Part 1 to 4) : 1992 Determination of Compressive strength, Determination of Water absorption test, Determination of Efflorescence, Determination of warp

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