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Development of Light Weight Geoblocks for Wall Building Units using EPS Beads and Fly Ash

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***Abstract*— In this study Expanded Polystyrene (EPS) beads with fly ash are taken under consideration to manufacture the light weight geo-blocks. It's a novel concept of using EPS beads as an alternative raw material for the production of fly ash blocks which are comparatively lighter in weight. The innovative application of high volume EPS beads in reducing the density of the composite material proved to improve the engineering properties of the geo-material.**

An extensive experimental investigation has been carried out to represent the varied engineering properties of the geo-material consisting of fly ash and EPS beads. There is reduction in unit weight and compressive strength with the addition of EPS beads, however, with the mixing of small percentage of admixture like cement the light weight geo-material can enhance the strength in addition to improve overall properties.

After determining the block properties (water absorption, compressive strength, and unit weights), it was found that light weight geo-material block meets the requirements of the masonry standards used in India. The average bulk unit weight of proposed light weight geo-material block obtained by using Fly ash, sand, cement and EPS beads is 1.25 gm/cc. These Blocks falls under the class 3.5 as per IS 12894:2002 having compressive strength not less than 35 Kgf/Sq.cm and water absorption not more than 20%. The obtained material is lighter than the commercial ones, which facilitates their rapid elaboration, quality control, and transportation.

Keywords—Component; Formatting; Style; Styling; Insert

I. INTRODUCTION

In India Bricks are widely used in building construction as the most common building materials. The heavy weight of bricks accounts for the great mass of construction and thus causes more vulnerability against settlement and earthquake forces. In the present work, it is, therefore, tried to reduce the density of the bricks. Clay bricks are considered one of the most important building materials used to construct walls for buildings. Due to the unsustainable mining of clay soil for clay brick making, cement bricks have been introduced into the industry providing more alternatives. However, the production of cement bricks consumes an enormous amount of cement.

In India Besides, the production of cement is not environmentally friendly. The manufacturing of cement is not only a high energy consuming process, but the production of each ton of cement releases approximately 1 ton of carbon dioxide (CO2) into the environment due to the calcinations of the raw materials and the combustion of fuels. In light of the economic benefits, conservation of natural resources, energy saving and environmental friendliness, the use of alternative materials from waste products has become the main focus of engineers and researchers. This project aims at producing lightweight bricks by using the expandable polystyrene. Polystyrene is chosen due to its lightweight properties, with good energy absorbing characteristic and good thermal insulator.

In comparison with ordinary clay bricks, light weight bricks shows excellent characteristics such as lower density, higher specific strength, better thermal insulation and greater energy absorption which can be obtained by replacing standard aggregate totally or partially by light weight aggregate (LWA). Light weight aggregates are broadly classified into two types: natural (pumice, diatomite, volcanic cinders) and artificial (sintered fly ash, expanded shale etc.). Expanded Polystyrene (EPS) is a type of artificial light weight aggregate with the density of only 10-30 kg/m^3.

II. MAIN AIMS AND OBJECTIVES OF THE PROPOSED WORK

The primary aim of this study was to investigate the feasibility of using a significant portion of fly-ash and EPS beads for beneficial purpose in civil engineering applications that is cost effective and environmentally friendly. The detailed laboratory investigations were planned and carried out for the determination of the best production method and the best mix design. Thus, the main objective of the study undertaken may be summarized as to evaluate various physical parameters of the fly-ash and EPS mixes such as compressive strength, Water absorption, Dry and Wet Bulk unit weights and to select the optimal mixture of EPS among experiments under consideration to manufacture the light weight EPS blocks.

III. MATERIALS

A new alternative light weight building material is prepared by using EPS beads, fly ash, cement, sand and water. The EPS beads used for the preparation of light weight building material were spherical in shape having diameter in the range 2-3 mm. These highly compressible EPS beads had density 0.20kN/m^3. The fly ash was collected in dry state from Koradi Thermal Power Plant, Koradi, Nagpur, India. The percentage of basic chemical compounds present in the fly ash were SiO2 (63.52%), Al2O3 (26.89%), Fe2O3 (5%), CaO (1.23%). According to ASTM C618 the fly ash is classified as Class F. the ordinary Portland cement of 43 grade is used as a binding material. Potable water is used to mix these materials.

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Fig. 1 *EPS Beads used in geo-material*

IV. EXPERIMENTAL PROGRAM

The experimental program was planned with an objective to understand and investigate the suitability of fly ash-EPS mix as a building material. Laboratory model experiments were carried out for the determination of the best mix design so as to select the optimal mixture of EPS among experiments under consideration to manufacture the light weight EPS blocks.

A. Mix proportion for trial numbers

The mix ratio is defined as the ratio of two materials by weight. There is no consistent mix proportion adopted for all the cases. In all the mixes, the aim was to reach the target unconfined compressive strength after 28 days, after mixing. The work plan comprise of Mix proportions and preparation of specimens with several different combinations of EPS beads, Flyash, Sand and Cement at suitable W.C.(%). However, it is noted that the compressive strength is obviously influenced by the moulding water content. A pilot project work was also conducted before deciding the range of limits of different mix ratios.

TABLE I.

Trial I.	Mix ratio used for the investigation of effect of variation of sand content				
Mix No.	Fly Ash %	Sand %	EPS Beads % (FA + Sand)	Cement % (FA + Sand)	W/C % (FA + Sand)
1	100	0	1	6	35
2	70	30	1	6	35
3	60	40	1	6	35

TABLE II.

Trial II.	Mix ratio used for the investigation of effect of curing period on samples					
Mix No.	Fly Ash %	Sand %	EPS Beads % (FA + Sand)	Cement % (FA + Sand)	W/C % (FA + Sand)	Curing period (days)
1	70	30	0.5	12	35	7
2	70	30	0.5	12	35	14
3	70	30	0.5	12	35	28

B. Specimen Preparation

The fly ash, cement and sand were mixed with the mix ratio of (C / FA+sand) and dry mixing was carried out first to form a uniform mix. For the compound mix potable water was added slowly with mix ratio of (W / FA+sand) and the mixing was carried out by means of hand to form a homogeneous slurry. The EPS beads were then added to this slurry with the mix ratio of (B / FA+sand), and mixing was continued till compound mix of these four material was formed. Finally this compound mix was poured into the cylindrical mould having the internal dimensions of Diameter = 3.8 cm, Height = 7.6 cm. after setting time of one day all the test samples were removed from the mould, covered and kept for curing in the water tank for seven days.

C. Experimental Test

Experimental test for investigation of

- Compressive strength.
- Water absorption.
- Bulk unit weights.
  - When Dry
  - When Soaked

V. DEVELOPMENT OF AN ALTERNATIVE LIGTWEIGHT BUILDING MATERIAL

The above trials tests helps us deciding the determination of the best mix design so as to select the optimal mixture of EPS among experiments under consideration to manufacture the light weight building material. Based on the trial test results the specimens with new mix proportions of EPS beads, Fly ash, Sand and Cement at suitable W.C.(%) are prepared and kept for 14 days and 28 days curing. It is also decided to reduce the water content between 10 and 30 % to obtain better compaction.

The fly ash, cement and sand were mixed with the mix ratio of (C / FA+sand) and dry mixing was carried out first to form a uniform mix. For the compound mix potable water was added slowly with mix ratio of (W / FA+sand) and the mixing was carried out by means of hand to form homogeneous slurry. The EPS beads were then added to this slurry with the mix ratio of (B / FA+sand), and mixing was continued till compound mix of these four material was formed. Finally this compound mix was poured into the specially prepared cuboid shape moulds having internal dimensions of 230 mm x 110 mm x 70 mm. After setting time of one day all the test samples were removed from the mould and kept for curing period of 14 days and 28 days in the water tank after covering with gunny bags.

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TABLE III.

Trial III.	Mix ratios to prepare lightweight geomaterial for wall building units						
Mix No.	*Sample ID*	*FA %*	*Sand %*	*EPS % (FA+Sand)*	*Cement % (FA+Sand)*	*Water % (FA+Sand)*	*Curing Period days*
1	1A	70	30	0.5	12	25	14
	1B	70	30	0.5	12	25	28
2	2A	70	30	0.6	12	25	14
	2B	70	30	0.6	12	25	28
3	3A	70	30	0.5	10	25	14
	3B	70	30	0.5	10	25	28
4	4A	70	30	0.6	10	25	14
	4B	70	30	0.6	10	25	28
5	5A	60	40	0.5	12	20	14
	5B	60	40	0.5	12	20	28
6	6A	60	40	0.6	12	20	14
	6B	60	40	0.6	12	20	28
7	7A	60	40	0.5	10	20	14
	7B	60	40	0.5	10	20	28
8	8A	60	40	0.6	10	20	14
	8B	60	40	0.6	10	20	28

Fig. 2 Test specimen

Fig. 3 Test specimen under compression test

Fig. 4 Test specimen after failure

VI. SUMMARY AND MAJOR FINDING

A. Results Showing the effect of variation of sand content on the density, stress-strain and water absorption on the light weight material

TABLE IV.

Result of Trial I.					
Mix No.	Bulk unit Wt. gm/cc (Dry)	Bulk unit Wt. gm/cc (Soaked)	Water Absorption %	Stress at failure kg/cm^2	Strain at Failure %
1	0.620	0.885	29	0.687	1.25
2	0.700	0.940	25	0.793	1.5
3	0.720	0.980	25	0.973	1.75

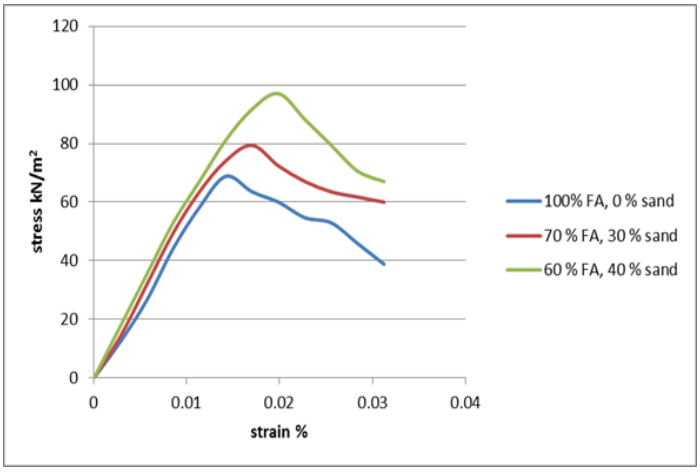

Fig. 5. Compressive stress-strain curves for (B/ FA+sand) ratio 1 %, (C/ FA+sand) ratio 6 % with different sand content after 7 days of curing when (W/ FA+sand) ratio is 35 %

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B. Results Showing the effect of curing period on the density, stress-strain and water absorption on the light weight material.

TABLE V.

Result of Trial II.						
Sample No.	Curing period days	Bulk unit Wt. gm/cc (Dry)	Bulk unit Wt. gm/cm^3 (Soaked)	Water Absorption %	UCS kg/cm^2	% increase in strength
1	7	1.27	1.09	14.5	19.92	----
2	14	1.28	1.10	14	27.51	27%
3	28	1.28	1.10	14	33.86	42%

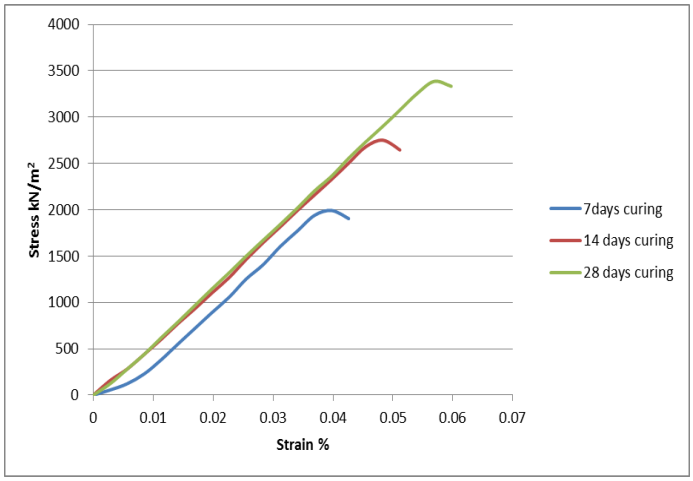

Fig. 6. Compressive stress-strain curves for 7 days, 14 days and 28 days curing at (B/ FA+sand) ratio 0.5 %, (C/ FA+sand) ratio 12 % and FA to sand ratio is 70:30 when (W/ FA+sand) ratio is 35 %

C. Laboratory test results on light weight building blocks

Based on trial test results it was found that the compressive strength of samples of 28 days curing is greater than 30 kg/cm^2 for some of the mix proportions, which is comparable with the compressive strength of the existing fly ash bricks. From the above mix ratios four mix ratios are selected for making the light weight blocks in the laboratory and four specimens of each mix ratio were prepared in cuboid shape moulds having internal dimensions of 230 mm x 110 mm x 70 mm. After setting time of one day all the test samples were removed from the mould, covered with gunny bags and kept for curing period of 28 days in the water tank.

VII. GUIDELINES FOR THE MANUFACTURING OF THE PROPOSED LIGHT WEIGHT GEOMATERIAL WALL BUILDING BLOCKS

For actual manufacturing of the proposed light weight geomaterial building blocks the mix ratios of the raw material by weight are converted into the mix ratio of raw material by volume. The mass unit weights of all the raw materials are worked out in the laboratory by dividing weight upon volume of the materials. The details of which are given below.

TABLE VI.

Mass unit weights of the raw material in gm/cc		
Sr.No.	Material	Mass unit weight gm/cc
1	Fly Ash	1.05
2	EPS Beads	0.01
3	Sand	1.70
4	Cement	1.25

TABLE VII.

Results of the laboratory test on light weight building blocks												
Mix No.	S. ID	FA %	Sand %	Cement % (FA + Sand)	EPS % (FA + Sand)	Water % (FA + Sand)	Curing Period	Avg Comp. Strength Kg/cm^2 (Soaked)	Avg Comp. Strength Kg/cm^2 (Dry)	Avg Water Absorp %	Avg Bulk Density Dry Gm/Cc	Avg Bulk Density Soaked Gm/Cc
1	A1	70	30	12	0.5	25	14	32.2		17.75	1.157	1.35
	A2	70	30	12	0.5	25	28		35.98	18.4	1.152	1.35
2	B1	60	40	12	0.5	20	14	38.31		15.02	1.18	1.36
	B2	60	40	12	0.5	20	28		42.46	14.85	1.18	1.36
3	C1	60	40	12	0.6	25	14	27.23		13.55	1.13	1.29
	C2	60	40	12	0.6	25	28		31.98	14.6	1.1	1.24
4	D1	60	40	10	0.5	20	14	23.1		17.6	1.15	1.36
	D2	60	40	10	0.5	20	28		27.5	18.76	1.158	1.37

Based on the compressive strength, among all the mixes light weight geo-material prepared with mix No.2 is recommended for making light weight wall building units showing best results. These blocks exhibit the average compressive strength of 42.46 kg/cm^2, water absorption 14.85 % and dry density 1.18 gm/cc. The compressive strength of the proposed light weight geomaterial building block is comparable with the presently available burnt clay bricks and percent water absorption of the proposed geomaterial is below the permissible limit. These blocks falls under the class 3.5 Bricks as per IS 12894:2002 having compressive strength in the range 35 Kgf/cm^2 to 50 Kgf/cm^2 and permissible water absorption not more than 20%.

VIII. CONCLUSIONS

- It was found that in all the mixes the stress-strain curve is linear upto the failure loading condition.
- The variation between densities of the lightweight building material to B/ (FA+sand) ratio is found to be linear.
- There is no significant change in the unit weight were observed when W/ (FA+Sand) ratio is decreased from 35 % to 20% for all C/ (FA+sand) ratios. This

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indicates that the unit weight of the light weight building material is mainly depending upon the percentage of EPS beads to be added with respect to the fly ash.

- The compressive strength of the light weight material is found to be increase with increase in the percent of sand for all the mix ratios. The compressive strength of the light weight material increased from 35.27 kg/cm^2 to 40.56 kg/cm^2 on increasing the sand percent from 30 % to 40 %.
- Duration of curing period has a considerable effect on the compressive strength of the light weight building material. For all the mix ratios the compressive strength increases linearly with the variation between 7 days compressive strength and 28 days compressive strength.
- The compressive stress strain curves having same nature and pattern for both 14day and 28 days curing period. All the specimens were failed at a strain range near about 0.6 % to 0.8 %. The specimens were failed at lesser strain values for higher values of B/ (FA+Sand) ratios.

IX. SUGGESTIONS ON FUTURE TESTING AND APPLICATIONS

The data, results, and interpretations contained herein expand the existing knowledge of Fly ash and EPS beads and provide a foundation for their potential use in construction industry for making light weight building blocks. Based on the knowledge and experiences gained throughout this research program a more detailed discussion of potential applications and additional work on the fire resistant properties, thermal insulation properties, dimensional stability and durability needed to support the use of EPS beads for its applications in the construction industry.

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