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Study on Performance of Polystyrene Concrete Building Blocks

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ABSTRACT: Traditional burnt bricks, quarry stones, timber, and corrugated iron sheets remain the most commonly used construction materials. The heavy weight of bricks accounts for the great mass of construction and thus causes more vulnerability against earthquake forces. In this study we have tried to reduce the density of masonry material, as well as improve their thermal insulation properties by incorporating Expanded Polystyrene beads in concrete. Polystyrene blocks can be produced by replacing the normal aggregates in concrete or mortar either partially or fully, depending upon the requirements of density and strength levels. The present study covers the use of polystyrene beads to achieve lightweight concrete and hence introducing a light weight building block. The main aim of this study is understanding the mechanical properties of polystyrene blocks and compare the results normal building blocks.

KEYWORDS: Lightweight concrete, polystyrene, non-load bearing bricks, compressive strength

I. INTRODUCTION

The essential characteristic of lightweight concrete is its porosity, which results in low apparent specific gravity. In concrete construction, self-weight represents a very large portion of the load on the structure, and there are considerable advantages in reducing the density of concrete. Furthermore, using lightweight concrete improves construction and handling techniques; larger units are often desirable; obviously transportation and on-site handling would be made more economical. Lightweight concrete reduces the cost of formwork and steel and it also increases productivity. Giving better thermal insulation than ordinary concrete. The practical range of densities of lightweight concrete is between about 300 and 1850 kg/m^3.

Light weight concrete weight is achieved either by:

- The introduction of air as air bubbles of rather coarse size (1-3 mm diameter) in the mortar, this is called “aerated concrete”.
- The introduction of air by using a special agent, this is called “air entrained concrete”.
- The use of lightweight aggregate as a substitute to normal aggregate.

The process of manufacturing lightweight concrete is very costly as complex machinery, chemicals and/or expensive lightweight aggregate are used. This has led to a search for a substitute for expensive lightweight aggregate. The idea of using Polystyrene particle as a substitute of air bubbles (lightweight aggregate) has been introduced, as the density of Polystyrene is nearly negligible (16-27 kg/m^3) when compared to that of concrete aggregates (1700-2000 kg/m^3).

Polystyrene blocks can be produced by replacing the normal aggregates in concrete or mortar either partially or fully, depending upon the requirements of density and strength levels. The present study covers the use of polystyrene beads as lightweight aggregate in building block

II. RELATED WORK

Studies conducted on characteristics of new lightweight concrete consisting of polystyrene sand, cement and water by Zaher Kuhail et al. [7], showed very reliable strengths of up to 200 kg/cm^2 with a low density. He proposed that mix workability was very high at a very low water/cement ratio (down to 0.35).

MakhmudKharun, Alexander P. Svintsov et al. [3] studied about the thermal insulation properties of polystyrene bricks and their study established that the compressive strengths of test samples are in the range of 0.28 MPa to 4.22 MPa in average, and the thermal conductivity – 0.073 to 0.3 W/(m.°C) depending on the average density of polystyrene concrete

Ankur Taya *et al* [1] stated based on his study on different mix proportions for polystyrene concrete that the circular shape of expanded polystyrene beads contributed to the workability of concrete mix and EPS beads that came in direct contact with heated surface shrunk leading to formation of voids in concrete.

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III. METHODOLOGY

Polystyrene concrete cube specimens were casted by incorporating Expanded Polystyrene (EPS) beads by replacing fine aggregates by volume in various mortar mixes. Fine aggregate were replaced by 25%, 50% and 75% with polystyrene beads in mix ratios 1:4, 1:3 and 1:2. Details of specimen casted is given in Table 1

Table 1. Details of Polystyrene concrete cubes casted

Mix Designation	Mix Ratio (Cement: F.A)	% Replacement of F.A with EPS beads
PS 425	1:4	25%
PS 450	1:4	50%
PS 475	1:4	75%
PS 325	1:3	25%
PS 350	1:3	50%
PS 375	1:3	75%
PS 225	1:2	25%
PS 250	1:2	50%
PS 275	1:2	75%

Fig 1: Polystyrene cube specimens

Fig 2. Polystyrene building blocks

Three cubes each were casted for each mixes. Tests on Compression strength were conducted on the cube specimens after 28 days of curing. Based on the results obtained suitable mix proportion was selected for casting bricks. Tests of block density, water absorption and compression test were done on Polystyrene blocks and compared with results of tests done on locally available concrete hollow bricks.

IV. EXPERIMENTAL RESULTS

A. Compression Test on Cube specimens

The compressive strength of cubes were tested at 28 days after proper curing. The compressive strength of cube at 28 days with mix ratios 1:4, 1:3 and 1:2 with 25%, 50% and 75% replacement of fine aggregate with polystyrene beads is shown in table 2.

Fig 3. Compression test on polystyrene cubes

Table 2. Test Results of compression test on polystyrene cube specimens

Mix Designation	Mean Weight (kg)	Mean Density (kg/m^3)	Ultimate load (kN)	Compressive strength (N/mm^2)
PS 425	6.183	1832.000	270.00	12.00
PS 450	4.633	1372.740	170.00	7.55
PS 475	2.488	737.185	80.00	3.55
PS 325	6.242	1849.481	340.00	15.11
PS 350	4.605	1364.444	193.33	8.59
PS 375	3.412	1010.963	96.67	4.30
PS 225	6.345	1880.000	433.33	19.26
PS 250	5.143	1523.950	236.67	10.51
PS 275	3.622	1073.185	113.3	5.04

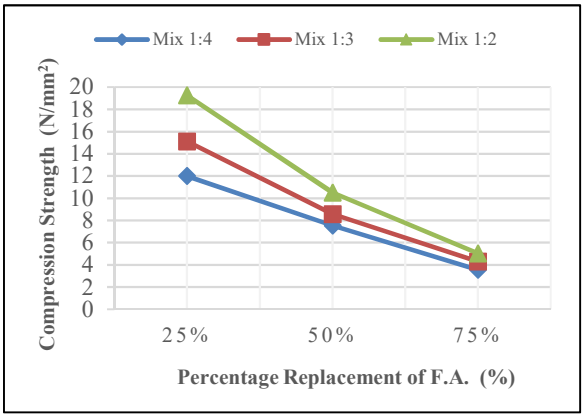


Fig 4. Graph showing test results of compressive strength of various mixes

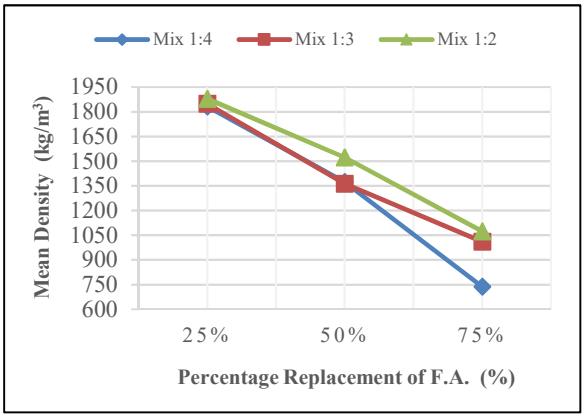


Fig 5. Graph showing mean densities of various mixes

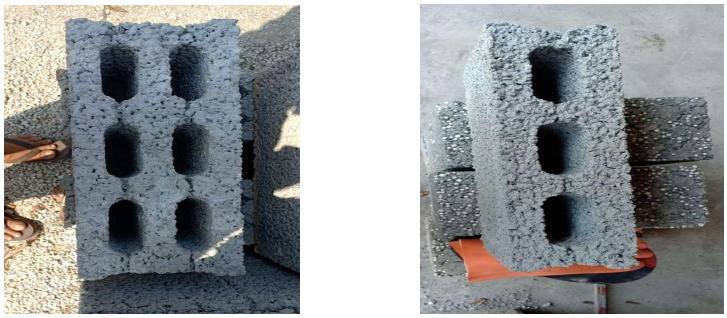
The Compressive strength of 1:4 mix with partial replacement of 25%, 50% and 75% with Polystyrene obtained at 28 days is 12 N/mm^2, 7.55 N/mm^2, and 3.55 N/mm^2. Compressive strength of 1:3 mix with partial replacement of 25%, 50% and 75% with Polystyrene obtained at 28 days is 15.11 N/mm^2, 8.59 N/mm^2, and 4.33 N/mm^2. The Compressive strength of 1:2 mix with partial replacement of 25%, 50% and 75% with Polystyrene obtained at 28 days is 19.26 N/mm^2, 10.51 N/mm^2, and 5.04 N/mm^2. Maximum compressive strength was obtained for mix PS 225 and minimum was obtained for PS 475. From Fig 4 it is evident that the compressive strength of polystyrene concrete is found to be decreasing when more percentage of fine aggregate is replaced by polystyrene beads. Also when the mix become rich in cement content the compressive strength tends to increase.

The mean density of specimens casted in 1:4 mix with partial replacement of 25%, 50% and 75% with Polystyrene was found to be 1832 kg/m^3, 1372.74 kg/m^3 and 737.185 kg/m^3. The mean density of specimens casted in 1:3 mix with partial replacement of 25%, 50% and 75% with Polystyrene was found to be 1849.48 kg/m^3, 1364.44 kg/m^3 and 1010.96 kg/m^3. The mean density of specimens casted in 1:2 mix with partial replacement of 25%, 50% and 75% with Polystyrene was found to be 1880 kg/m^3, 1523.95 kg/m^3 and 1073.185 kg/m^3. From Fig 5, the densities are found to be decreasing with increase in percentage replacement of fine aggregates with polystyrene beads. This is due to the reduced weight of polystyrene beads. The range of density for lightweight concrete is 300-1850 kg/m^3. The densities of various specimens obtained by replacing fine aggregate by polystyrene is within the range of lightweight concrete except PS 225. There was large decrease in the density in leaner mix ratio due to lesser cement content.

As per IS 2185:2005 (part 1) the minimum average compressive strength is 3.5 N/mm^2 for the brick with density greater than 1500kg/m^3. If the density is in between 1500 to 1100 kg/m^3 it should have an average compressive strength of 3.5 to 5 N/mm^2. All the specimens in the study are satisfying the recommendations as per Indian standard code. Based on the experimental results obtained, polystyrene concrete may be used for the manufacturing of bricks.

Even though every mix is satisfying the recommendations as per IS 2185:2005 (part 1) for building blocks, PS 350 (1:3 50% replaced) and PS 450 (1:4 50% replaced) are found to have lesser density with better compressive strength, These

mixes have been chosen for the further study the properties of Polystyrene building blocks .Polystyrene blocks were casted with mix PS 350 and PS 450. For a comparative study 4 inch and 6 inch hollow concrete blocks were obtained from local industry.



(a) (b)

Fig 6. Locally available concrete hollow bricks. (a) 6 inch block. (b) 4 inch block

B. Block Density of the Bricks.

Polystyrene concrete blocks were casted with mix PS 350 and PS 450. The block densities was checked as per IS 2185 (part 1): 2005. The density obtained for concrete hollow blocks and polystyrene concrete blocks is given in table 4.4

Table 3. Block densities of hollow concrete and polystyrene blocks

Specimen	Mean volume (cm^3)	Mean weight (kg)	Density (kg/m^3)
4” Hollow concrete block	8593.43	16.208	1886.091
6” Hollow concrete block	12971.02	22.267	1716.673
PS 350 Block	9261.98	12.396	1338.447
PS 450 block	10439.84	15.268	1462.506

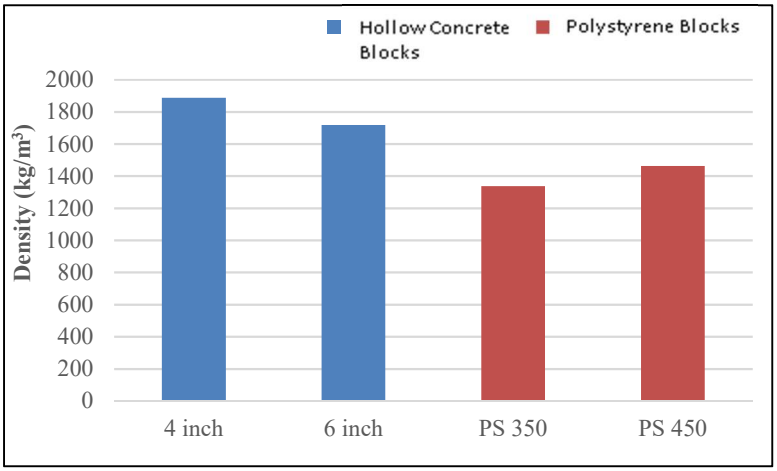


Fig 7. Graph showing mean density of Hollow concrete blocks and Polystyrene blocks

From Fig 7, it can be seen that, density have decreased by incorporating Polystyrene beads. Density of Hollow brick was found to be 1886.091 kg/m^3 and 1716.673 kg/m^3 respectively for 4 inch and 6inch blocks. Meanwhile the density of polystyrene blocks PS 350 and PS 450 are 1338.447 kg/m3and 1462.506 kg/m3 respectively. This shows that, addition of Polystyrene beads has reduced the brick density more than 25%.

For Brick 450 it was found that the brick density was decreased upto 20% from normal brick. Thus it is evident that, EPS has significantly reduced the brick density due to its low density. Similar finding was found by Mulla & Shelake *et al.* [4], where replacement of Polystyrene in the concrete mix had reduced the brick density about 29% to 40% from

the conventional brick. Meanwhile, according to research by Ankur Tayal *et al* [1], 30% of EPS has reduced the concrete density up to 37% from normal concrete.

C. Water Absorption Test on bricks

Water absorption was checked as per IS 2185 (part 1): 2005. The percentage of water absorption obtained for concrete hollow blocks and polystyrene concrete blocks is given in table 4.

Table 4 Percentage of water absorption for hollow concrete and polystyrene blocks

Specimen	Avg. water absorption (%)
4" Hollow concrete block	8.011
6" Hollow concrete block	8.239
PS 350 Block	6.738
PS 450 block	5.913

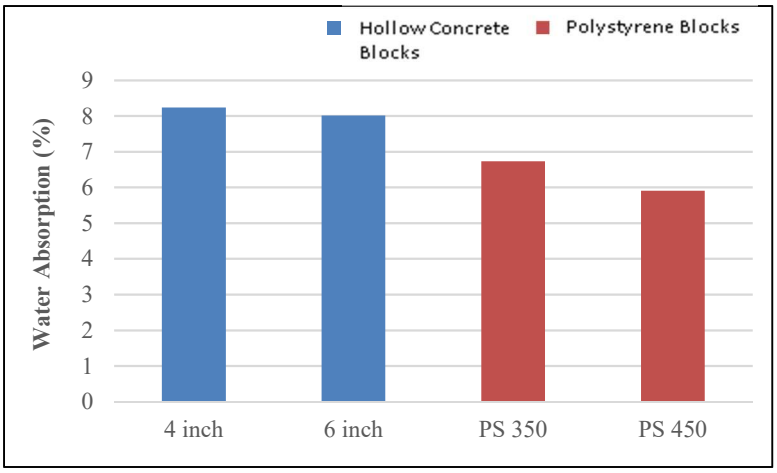


Fig 8. Graph showing Average Water absorption Percentage of Hollow concrete blocks and Polystyrene blocks

Fig 8 shows the percentage of water absorption for each types of brick. Water absorption of hollow brick is found to be 8.011% and 8.239% for 4 inch and 6 inch hollow bricks respectively. Polystyrene PS 350 shows a water absorbing percentage of 6.378% and PS 450 had lower percentage of 5.913% water absorption. Based on the results, it can be seen that, water absorption have decreased by incorporating Polystyrene beads. The same observation was found by Babu *et al* [6]. In their study on the effect of moisture migration of concrete containing Polystyrene. They had found that, concrete containing Polystyrene show lower water absorption comparing to normal concrete. Thus it can be observed that, the reduction of percentage of water absorption with the increment of Polystyrene was due to non-absorbent characteristic of Polystyrene.

4.4 Compressive Strength of Polystyrene Blocks

Test on compressive strength conforming to IS 2185:2005 (part 1) was done normal hollow concrete blocks and polystyrene blocks. The test results is provided in Table 5.

Table 5. Results of compression test on Polystyrene blocks

Specimen	Mean compressive strength (N/mm^2)
PS 450 Block	2.025
PS 350 Block	4.438
4" Hollow concrete block	1.807
6" Hollow concrete block	1.973

Fig 9 Compression Test on Polystyrene block

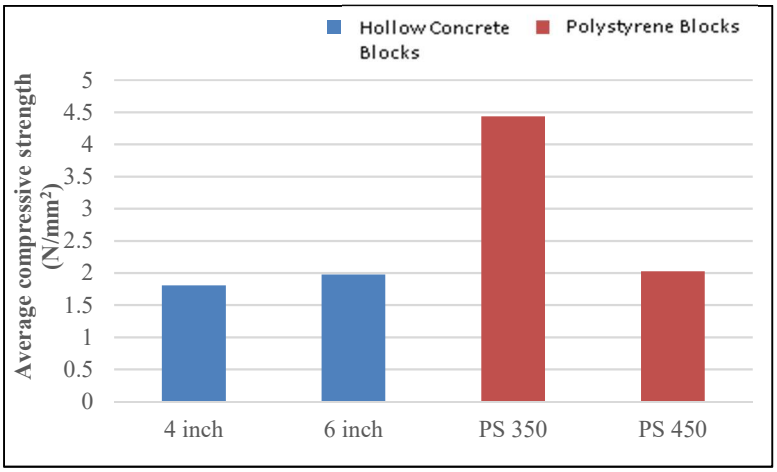


Fig 10 Graph showing average compressive strength of Hollow concrete blocks and Polystyrene blocks

As per IS 2185:2005 (part 1) the minimum average compressive strength required for building blocks is 3.5 N/mm^2. But sample collected from the nearest Hollow Brick Industry gave an average compressive strength of 1.807 N/mm^2 for 4 inch brick and 1.973 N/mm^2 for 6 inch brick. These hollow concrete brick are being used to make non load bearing partition wall in framed buildings and construction of boundary walls. Whereas average compressive strength for polystyrene blocks PS 450 is found to be 2.025 N/mm^2 and PS 350 is found to be 4.438 N/mm^2.The result indicate that the polystyrene blocks can be used as a substitute for the locally available hollow concrete bricks and can yield better results.

V. CONCLUSION

Due to the increased demand and less availability of conventionally used building blocks, there is an urgent need for an innovative builder material with lesser cost. Also these conventional building blocks are much heavier and tend to increase the dead load, leading to heavier structural elements. These heavier elements have poor resistance to earthquake load. This study aimed to arrive at an innovative building material by incorporating polystyrene beads into cement mortar by partially replacing the fine aggregates, thus arriving at a light weight concrete.

Experimental studies were conducted on different percentages (25%, 50% and 75%) of partial replacement in different mix ratios (1:2, 1:3 and 1:4). The results has shown that 50% partial replacement in mix ratios 1:3 and 1:4 are yielding good results with economic value. Thus building blocks were constructed using these proportions and tested for its compressive strength, water absorption and block density. The polystyrene blocks have performed well in the experimental analysis comparing to locally available concrete hollow bricks.

The studies have shown, polystyrene blocks can be used as a substitute material over conventional masonry material for constructing non load bearing walls. The polystyrene building blocks do not have very much strength for load bearing

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walls. The low weight and better thermal conductivity property of this material gives advantages over other materials. The density and water absorption of the material of polystyrene block is found to be lower than the conventional hollow bricks. The reduction in weight is due to low density property of the Polystyrene and the low water absorption is due to the non-absorptive nature of polystyrene. The weight of the sample is reduced by increase in Polystyrene content and water absorption also founded in same manner. The compressive strength of the polystyrene bricks is founded nearly double comparing to conventional hollow brick in local market. Which indicate higher load bearing capacity of a single unit.

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