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ENHANCEMENT OF CONCRETE INSULATION AND STRENGTH USING POLYSTYRENE AND GLASS FIBER

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ABTRACT

Concrete is the most widely used building material globally due to its durability, cost-effectiveness, and strength. However, in regions like Oman, where high temperatures prevail for most of the year, concrete's insulation properties are inadequate, leading to increased air conditioning costs in large malls and public buildings. Improving the insulation properties of concrete can significantly reduce the operational and maintenance costs of these buildings. This research investigates the enhancement of concrete's insulation properties while maintaining its strength by incorporating varying percentages of polystyrene and glass fiber. The study reveals that replacing 25% of fine aggregates with polystyrene and adding 2.5% glass fiber significantly improves the insulating properties of concrete. Comprehensive tests, including compressive strength and thermal conductivity tests, were conducted to determine the optimal material percentages. The findings indicate that the modified concrete not only meets the required strength standards but also offers superior thermal insulation, making it a viable solution for reducing energy consumption in buildings.

KEYWORDS: *Compressive strength of concrete, thermal conductivity, polystyrene, glass fiber, concrete insulation.*

1.INTRODUCTION

In the present construction industry, there is a continuous demand for innovative materials that can enhance the performance and efficiency of buildings. A lot of research work is carried out all over the world to identify and use these advanced building materials. Among these, Expanded Polystyrene (EPS) and glass fiber have emerged as promising additives to concrete, offering distinct benefits in terms of thermal insulation and soundproofing.

Expanded Polystyrene (EPS) has been identified for efficiency to significantly reduce the thermal conductivity of concrete. This reduction in thermal transfer helps maintain cooler interior temperatures, especially during the intense heat of summer months. Consequently, buildings incorporating EPS-modified concrete experience reduced reliance on cooling systems, leading to notable savings in maintenance costs. Additionally, the inclusion of EPS slightly enhances the compressive strength of concrete, ensuring structural integrity is maintained.

Glass fiber on the other hand, contributes to the acoustic properties of concrete, effectively reducing sound transmission and creating soundproof environments. This attribute is particularly valuable in urban settings where noise pollution is a concern.

This research focuses on determining the optimal proportions of EPS and glass fiber in concrete mixtures, aiming to develop a building material that not only improves thermal and acoustic performance but also remains economically viable. By exploring the synergistic effects of these materials, the study seeks to provide a sustainable solution for the construction industry, enhancing both the comfort and cost-efficiency of residential and commercial buildings.

2. MATERIALS AND CONCRETE MIX DESIGN

The materials utilized in the preparation of the concrete specimens include:

- **Cement:** Ordinary Portland Cement (OPC) conforming to the British Code BS 8500 specifications.
- **Aggregates:** Clean and well-graded coarse and fine aggregates complying with BS EN 12620:2013 standards.
- **Water:** Potable water free from impurities and contaminants.
- **Expanded Polystyrene (EPS):** Expanded Polystyrene is a light weight and rigid thermoplastic foam material used in walls, beams and roofs of a building. Commercially available EPS beads or boards with uniform particle size and density is as shown in the figure 1 below. It has been found from the research work that the thermal conductivity of Polystyrene granular concrete can be as low as 0.338 W/m-K and thermal conductivity of concrete decreases with the increase in amount of polystyrene particles in the concrete.

Figure 1 Expanded Polystyrene Foam Blocks

- **Glass Fiber:** Glass fiber is a material consisting of numerous extremely fine fibers of glass extensively used in FRP tanks and vessels. Alkali-resistant glass fibers in the form of chopped strands or fibers conforming to BS specifications is as shown in the figure 2 below.

Figure 2 Glass Fiber

It has been found from the studies that the glass fibers have improved the compressive strength of concrete and durability but have decreased the flow ability.

3. METHODOLOGY:

In the present research work FOUR types of concrete mixes were selected. They are

1. Mix 1: Conventional concrete that contains coarse and fine aggregates, ordinary Portland cement (OPC), and water. No EPS or glass fibers were added.
2. Mix 2: Contains the same materials as the previous Mix 1 but 25% of fine aggregate is replaced with EPS and 2% of glass fiber is added.
3. Mix 3: Contains the same materials as the Mix 1 but 50% of fine aggregate is replaced with EPS.
4. Mix D: Contains the same materials as the Mix 1 but 25% of fine aggregate is replaced with EPS.

For the above samples the following test shown in figure 3 were conducted.

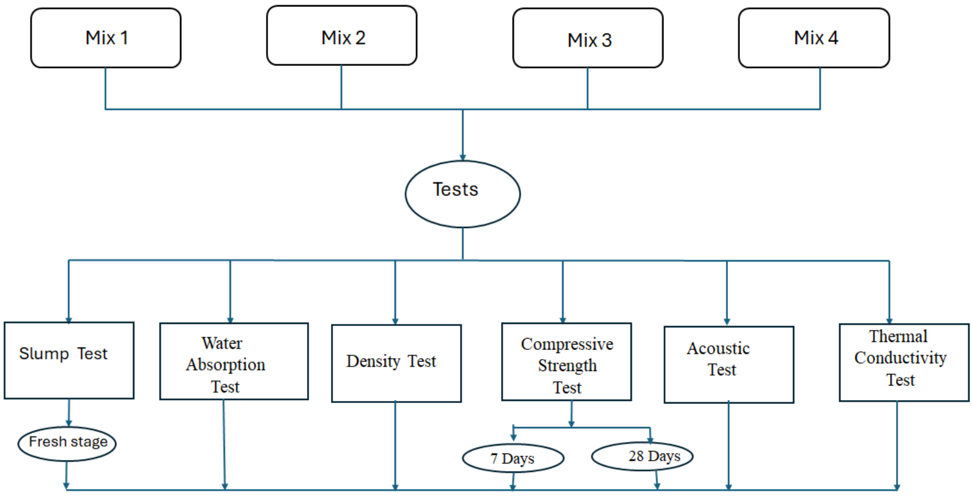

Figure 3 Tests conducted on concrete mixes

4. CONCRETE MIXING AND PREPARATION OF SPECIMENS.

For attaining the required ingredients of concrete, the amount of cement, aggregates, water, EPS and glass fiber were decided on preparatory testing and theoretical calculations. Water-cement ratio was carefully chosen to provide sufficient hydration of cement and preserving the workability and strength of concrete. Various percentage of EPS and glass fibers were added to study the mechanical, thermal and acoustic properties of concrete. Control concrete was prepared without adding any EPS or glass fiber.

4.1 Mixing procedure:

1. The required quantities of cement, aggregates, EPS, glass fibers and water was scaled out.
2. Dry components were mixed thoroughly for at least 3 minutes.
3. Water was gradually added with constant mixing. It was mixed until a homogeneous mix was prepared.
4. Molds of standard measurements planned for test specimens were cleaned and lubricated. The freshly prepared concrete was carefully poured into the molds and were compacted using a mechanical vibrator. The molds were of dimension 100 mm x 100mm.
5. After casting, the molds were left undisturbed for about 24 hours at room temperature. After that the molds were cured at a controlled atmosphere at a temperature of 20 ± 2° C.

5. TESTING PROCEDURE

The slump test was carried out on the fresh concrete. Water absorption test, compressive strength test, thermal conductivity test and sound insulation or acoustic test were conducted on the hardened concrete. The cured molds were allowed for surface drying for about 24 hours and the tests were conducted.

5.1 Slump Test:

The slump tests were carried out for the freshly prepared concrete confirming to the B S Standards. The slump tests were carried out to know the consistency of concrete and the workability of concrete. The slump test also identifies the defects in concrete if any, the slump tests were carried out as shown in the figure 4 below.

Figure 4 Slump tests

5.2 Water Absorption Test:

The concrete molds were surface dried and the initial weight is recorded. After immersing it for a specified time in water the molds are again weighed. The increase in weight of the molds is calculated and the increase in weight expressed as a percentage of original weight is recorded as water absorption of concrete. The water absorption test was carried out after 28 days of cuing.

5.3 Density Test:

The density test was carried out as per BS specifications. The ratio of mass of quantity of compacted fresh concrete to its volume is the density of concrete and is expressed in kg/m^3. Each specimen cube is weighed separately and the density of concrete is calculated.

5.4 Compressive Test:

The compression tests were carried out after 7 days and 28 days of curing. The cured cubes were removed out of curing tank and surface dried and the tested in a compression testing machine. The cubes are gradually loaded as per BS standards at the rate of 140 Kg/cm^2 per minute. The cubes are steadily loaded till failure as shown in the figure 5 below and the maximum compressive load on the cube is recorded. The ratio of maximum compressive load to the cross sectional area of concrete gives the compressive strength of concrete.

Figure 5 Compression test on cubes

5.4 Thermal Conductivity Test:

Thermal conductivity of a material is a measure of how well or poorly it conducts heat. The heat flow meter was used to determine the thermal conductivity of concrete molds. The rate of heat flow through the concrete cubes gives their thermal conductivity. An aluminum block as of same size of concrete cube, a thin metal plate, timer, a Styrofoam box and a thermometer were used to record the thermal conductivity of various specimens. The test was conducted in the following steps:

1. Place the EPS concrete block on one side of the metal plate. Make sure that the full face of the concrete block is in contact with the metal plate for effective heat conduction.
2. Place an ice cube between the other face of the concrete block and metal plate. Make sure that the ice cube and metal plate are in complete contact.
3. To reduce the heat loss, insulate the entire setup from the surroundings.
4. The EPS concrete cube and metal plate must be in direct contact with no any other material in between.
5. As soon as you place the ice cube, set the timer and record the time required ($T_{\text{concrete block}}$) to melt the ice completely.
6. Repeat the experiment with aluminum block instead of the EPS concrete block and note down the time required ($T_{\text{Aluminum block}}$) to melt the ice completely.

Assuming that the thickness and the contact area of the concrete block and aluminum block were same, and the ratio of thermal conductivity of the concrete block and aluminum block is proportional, the ratio of thermal conductivity of concrete cube and aluminum block is calculated as

$$R = \frac{\text{Theramal conductivity of concrete block}}{\text{Thermal conductivity of the aluminum block}} = \frac{\text{Tconcrete block}}{\text{Taluminum block}}$$

The experiment is repeated for the various concrete mix blocks and the value of R is recorded for each case.

5.5 Sound Insulation or Acoustic Test:

A shoe box was used to create a controlled environment where the test takes place. A concrete block was placed inside the sound box to test its sound insulation properties. A hole is made in the shoe box and a sound box is placed which create a sound wave at 125 Hz inside the sound box. Another hole is made and a sound meter is placed to measure the ability of concrete block to deflect the sound waves. Sound levels are recorded both with and without the concrete block to compare the differences. The acoustic test was conducted on the concrete block reinforced with EPS and glass fiber. The test setup is as shown in the figure 6 below

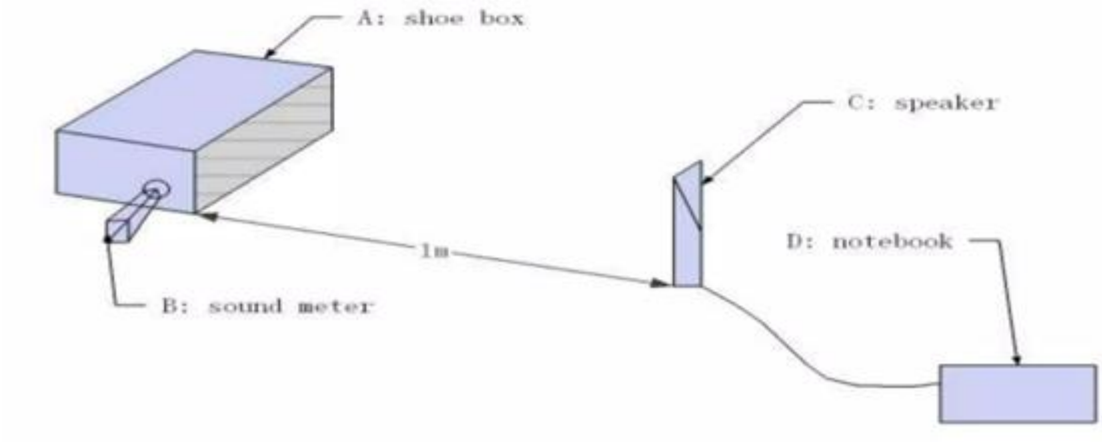

Figure 6 Acoustic Testing Set up

6. Test Results

Concrete mix design was done as per the BS standards and about SIX cubes were casted for each type of Mix and total 24 cubes were casted and tested. The slump test was carried out on fresh concrete before casting the cubes and the results are tabulated in table 1 below.

Table 1 Slump Test Results

Type of mix	Slump value in mm	Classification
Mix 1 (conventional concrete)	40	Low as per BS standards
Mix 2 (25% EPS and 2% glass fiber	10	Classified as very low as per BS standards
Mix 3 (50% EPS)	100	Classified as very high as per BS standards
Mix 4 (25% EPS)	30	Classified as low as per BS standards

The 7 day and 28 day compression tests and density tests were carried out on the cubes of different mixes and the test results recorded are shown in table 2

Table 2 Compression test and density test results

S.NO	Percentage of replacement	7 days Strength (N/mm2)	Average	Density of cube after 7 days (kg/m3)	28 days Strength (N/mm2)	Average	The density of the cube after 28 days (kg/m3)
Mix 1	0%	22.712	21.658	2308.9	32.521	31.196	2588.4
		20.732		2312.7	31.244		2569.1
		21.532		2338.4	29.825		2476.9
Mix 2	25% + Fiber Glass	18.052	18.768	2205.6	26.783	27.810	2301.2
		19.666		2243.6	27.452		2332.9
		18.587		2207.8	26.221		2334.7
Mix 3	25%	19.581	18.504	2218.4	25.923	26.075	2370.1
		18.635		2209.3	26.543		2375.5
		17.297		2262.2	25.651		2347.2
Mix 4	50%	14.123	15.831	1691.3	22.231	24.083	2004.5
		15.584		1763.6	24.453		2074.3
		17.785		1848.5	25.563		2034.4

The water absorption test results are tabulated and are shown in the table 3 below.

Table 3 Water Absorption Test Results

S.no	Wet weight (kg)	Dry weight (kg)	Water absorption (%)	Average absorption
Mix 1 (0%)	2.376	2.28	3.9	3.7
	2.450	2.369	3.4	
	2.468	2.376	3.8	
Mix 2 (25% + fiberglass)	2.301.2	2.2056	4.5	4.8
	2.332.9	2.2436	4.0	
	2.334.7	2.2078	5.9	
Mix 3 (25%)	2.3701	2.2184	7.2	6.13
	2.3755	2.2093	7.7	
	2.3472	2.2622	3.5	
Mix 4 (50%)	2.0045	1.6913	18.34	13.38
	2.0743	1.7636	13.6	
	2.0344	1.8485	8.2	

The thermal conductivity test results are tabulated as shown in table 4 below.

Table 4 Thermal Conductivity Test Results

S. No	R (ratio of Thermal Conductivities)
Mix 1 (0% EPS)	1.427
Mix 2 (25% EPS + fiberglass)	0.334
Mix 3 (25% EPS)	0.212
Mix 4 (50% EPS)	0.169

The acoustic insulation test results are as shown in table 5 below

Table 5 Acoustic Insulation Test Results

S. No	Acoustic ability/ sound deflection (dB)
Mix 1 (0% EPS)	48
Mix 2 (25% EPS + fiberglass)	54
Mix 3 (25% EPS)	59
Mix 4 (50% EPS)	68

7. DISCUSSION ON TEST RESULTS AND CONCLUSIONS

Based on the test results the following conclusions were drawn.

1. The addition of Expanded Polystyrene (EPS) and glass fiber can enhance the thermal insulation 4.27 times when compared to the conventional concrete.
2. The addition of Expanded Polystyrene (EPS) and glass fiber can enhance the sound deflection by 12.5% when compared to the conventional concrete.
3. The addition of EPS and glass fiber to the concrete cubes leads to an increase in water absorption, which is undesirable.
4. Incorporating EPS and glass fiber into the concrete results in a slight reduction in the 7-day and 28-day cube compressive strength values.
5. The inclusion of less dense materials such as EPS and glass fiber results in a slight reduction in the overall density of the concrete.

In conclusion, concrete containing 25% EPS and 2% glass fiber demonstrates outstanding thermal and acoustic insulation properties, making it highly recommended for use in construction projects. This combination effectively enhances the material's performance, providing better insulation and soundproofing compared to conventional concrete.

8. REFERENCES:

1. Prasittisopin, L., Termkhajornkit, P., & Kim, Y. H. (2022). *Review of concrete with expanded polystyrene (EPS)*: *Performance and environmental aspects*. Journal of Cleaner Production, 366, 132919.
2. Adeala, A. J., & Soyemi, O. B. (2020). *Structural use of expanded polystyrene concrete.* International Journal of Innovative Science and Research Technology, 5(6), 1131-1138.
3. Qureshi, L. A., & Ahmed, A. (2013). *An investigation on strength properties of glass fiber reinforced concrete*. Int. J. Eng. Res. Technol, 2, 2567-2572.
4. Ramli Sulong, N. H., Mustapa, S. A. S., & Abdul Rashid, M. K. (2019). *Application of expanded polystyrene (EPS) in buildings and constructions*: A review. Journal of Applied Polymer Science, 136(20), 47529
5. American Society for Testing and Materials. (n.d.). ASTM *Standards for Concrete Testing.* Retrieved from https://www.astm.org/Standards/concrete-testing-standards.html
6. American Concrete Institute. (2016). *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete* (ACI 211.1-91). Farmington Hills, MI: Author.
7. Neville, A. M., & Brooks, J. J. (2010). *Concrete Technology (2nd ed.).* Pearson Education Limited.
8. Mindess, S., Young, J. F., & Darwin, D. (2003). *Concrete (2nd ed.).* Prentice Hall.

9. Bentur, A., & Mindess, S. (2007). *Fibre Reinforced Cementitious Composites (2nd ed.).* Taylor & Francis.
10. Standard, B. (1986). *Structural use of concrete. BS8110*.

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