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Research Article

Experimental Study on Partial Replacement of Fine Aggregate by Expanded Polystyrene Beads in Concrete

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ABSTRACT

In the world of construction, concrete is the most crucial component. The construction industry's growing search for environmentally friendly and sustainable materials has prompted research on using some waste materials to partially replace the traditional components of concrete. Expanded Polystyrene (EPS), a non-biodegradable waste product from the packaging sector, is used in our project work. In order to reduce the concrete's self-weight, design must be based on density. Concrete that is lightweight and capable of achieving a dependable, respectable compressive strength can be made by partially or entirely substituting the expanded polystyrene with normal aggregates. Substitution of different eps bead percentages in accordance with desired design elements for various proportions. To determine concrete's mechanical and physical characteristics at ages (7), (14) and (28) days, several tests were performed on fresh and hardened concrete. The findings shows that as the quantity of EPS increases, concrete's strength would decrease as the density is decreased.

1. INTRODUCTION

Due to the increased need for building supplies. Utilizing alternative materials should be crucial for sustainable improvement. For building construction, concrete offers the greatest degree of flexibility[1]. The structure's self-weight is crucial in fundamental structural applications because it discloses the bulk of the load details. Light-weight concrete with a dependable high compressive strength can be made by partially or entirely replacing the section of low weight aggregate with regular particles. The levels of pollutant contamination and the scarcity of construction materials have increased dramatically as a result of Massive construction and industrial growth throughout the world. Light aggregate concrete made of both organic and inorganic elements. It has a lower density, lighter weight, greater thermal insulation performance, and superior sound insulation performance when compared to regular concrete[2]. Both the weight of the structure & the energy consumption of the building might be greatly reduced. It is the perfect material for wall insulation[3].

In today's construction applications, such as offshore projects, big buildings, and long span bridges, lightweight concrete is more in demand. This curiosity is brought about by the maximum load-bearing component size reduction and superiority of light-weight concrete's thermal analysis over that of traditional concrete. By adding foam or air to the paste of cement by partially or totally substituting the fine aggregate, lightweight concrete can be produced. Diatomite, pumice, and volcanic ash are a few examples of natural lightweight aggregates. Artificial lightweight aggregates include perlite, mud, expanded shale and sintered fly ash. Because of the great density of concrete, ordinary concrete has a very high dead load. It is uneconomical to use it as a building element because of its high self-weight. Use of lightweight concrete is required to lessen this dead load. Non-structural elements for example panels for walls, concrete fascia, etc. can use this. As a result, it speeds up construction. The weight of a structure on its foundation is a crucial consideration in design, especially for high-rise buildings and unstable soil. The beams and columns of a framed construction must support the weight of the slabs and walls. The cost will be much lowered if various components (slabs, walls, etc.) are made with lightweight concrete. There are several techniques to make lightweight concrete, including adding gas (or foam) or using lighter aggregates in place of the conventional ones[4-7].

In order to create light-weight concrete EPS are frequently used as aggregates & could be successfully mixed into mortar.[8] Attempt to discuss the use of Expanded Polystyrene as partial Substitution of coarse aggregate in concrete. The results show that decreasing density by compromising strength factors. by substituting cinder as well as light expanded clay aggregates for coarse aggregates, it was possible to compare the effects of light-weighed concrete and ordinary concrete weight on compressive strength and density. Their analysis showed an increase in densities and compressive strength. [9] a study

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project, the impact of incorporating aggregate grains made of expanded polystyrene in concrete was investigated. The coarse aggregates were replaced by 0–40% of polystyrene aggregate granules. The strength of the resulting concrete is reduced as a result of the expanded polystyrene aggregate particles being used as the matrix.
Concrete's self-weight bears a sizable percentage of the load in structural design. The weight of concrete necessitates modifying the structure's foundation in areas with poor soil that has a low bearing capacity. In some circumstances, pile foundations are necessary, and their construction is more expensive. This study looks for a substitute for the traditional concrete used in building that would lighten the structure's weight while maintaining its structural integrity. EPS concrete is a type of inexpensive, eco-friendly, green thermal insulation material that reduces waste generation, saves energy, and is also cost-effective. This material may present new opportunities for green building and building energy conservation. In addition to lowering the dead weight of the structure, lightweight concrete also serves as an insulator of heat. Waste of expanded polystyrene was used as fine aggregates in this project, & the effects on concrete was investigated.

2. BACKGROUND

Building energy consumption has rapidly expanded and now makes up 37% of all yearly primary energy consumption in India due to the social economy's rapid growth. The need to cut back on building energy use is critical. The problem of environmental pollution can be efficiently eliminated by using EPS concrete, which consumes a significant number of recoverable EPS particles. The researchers found that the strength and reduction after conducting the various tests by raising the proportion of EPS using examples like 40%, 45%, 50% in concrete, the strength has been decreased, but the weight reduction has been achieved to make the light weight concrete blocks[10].
[11] The experiment's conclusions from concrete's durability and workability testing, which included flexural, split tensile, and compressive strength tests by using polystyrene in place of coarse particles are included in their work. In this study, expanded polystyrene with coarse aggregate in various ratios of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, and 25% is tested using M50 and M60 grade materials. The findings achieved were contrasted with those of traditional concrete. Workability and compressive strength improves as polystyrene beads content rises. By addition of more EPS to mixtures of concrete, lowers the material's flexural and tensile strength. Concrete's strength diminishes as the w/c ratio rises, yet its lower unit weight satisfies the requirements for light concrete even while concrete's strength is decreased as the amount of EPS raises.
[12] In order to reduce the concrete's self-weight in this project from 2000 kg/m3 to 990 kg/m3, using a 0.40 water cement ratio, a density factor must be used in the development of the concrete. The majority of the load information is revealed by the structural self-weight, making it essential. Lightweight concrete with a dependable high compressive strength can be created by partially replacing conventional aggregates with EPS beads (less weight aggregate). Depending on the intended design elements, different percentages of EPS beads are exchanged for varying quantities. In order to assess the material's physical and mechanical characteristics at 7 and 28 days of age, several experiments were performed on freshly mixed and cured concrete.
[13] In an experimental study, EPS beads were used in concrete mixtures to partially substitute coarse aggregate. The best results are obtained by substituting EPS beads for aggregate in regular proportionate concrete mixing. Investigated are the results of replacing coarse aggregate in concrete with 0, 5, 10, and 15% waste EPS Beads. According to the study's findings, concrete is strong up to 5% replacement and weakens at 15%.
[14] study that would replace natural aggregates in cement concrete by volumes ranging from 0% to 60% in multiples of 15% of expanded polystyrene (EPS) beads with a size of 10 mm. The unit weigh or dry density, workability, split tensile strength and compressive strength, of concrete with and without the addition of EPS (Expanded Polystyrene) were compared. Additionally, these characteristics were noted and compared to regular concrete using EPS of M20 grade. Expanded Polystyrene (EPS) bead % increases the fresh concrete's workability while decreasing the hardening qualities including split tensile & compressive strength and unit weight. Beads made of expanded polystyrene added to concrete make it meet the requirements for lightweight concrete.
[15] inquiry of the characteristics of lightweight concrete using Expanded Polystyrene (EPS) beads, including compressive and tensile strengths. Its characteristics are contrasted with those of regular concrete. Studies have shown that the strength and density of the concrete reduces noticeably in compared to ordinary concrete when the percentage of polystyrene is increased and workability is increased with an increase in EPS content in concrete mixtures.

3. MATERIALS

3.1 Cement

A binder, also known as a chemical that sets, hardens, and attaches to different substances for holding them together, is a cement. In most cases, cement is used to bond sand and gravel, not on its own. OPC 53 grade, which meets with IS: 8112-1989 was utilized.

TABLE I. PHYSICAL CHARACTERISTICS OF CEMENT

Property	Value
Fines of cement	7.5
Specific gravity	3.15
Initial setting	30min
Final setting	60 min
Average consistency	35%

3.2 Fine Aggregate

Natural sand or other crushed stone particles make up fine aggregates. Using a 4.75mm IS sieve, fine aggregate made from locally available sand is employed in accordance with IS 383 - 1970 requirements. To remove debris and excessively large particles, the river sand is cleaned and screened.

TABLE II. CHARACTERISTICS OF SAND

Property	Value
Modulus of fineness	4.44
Sp. gravity	2.8
Water absorption %	0.46
Unbound bulk density	2490 kg/m³
Bulk density after compacting	2790 kg/m³

3.3 Coarse Aggregate

More so than with hardened concrete, the texture and shape of the aggregate influences the qualities of new concrete. When rounded and smooth aggregate is utilized in place of elongated, rough, or angular aggregate, concrete is easier to work with.

TABLE III. PHYSICAL CHARACTERISTICS OF COARSE AGGREGATE

Property	Value
Modulus of fineness	7.950
Specific gravity	2.69
Water absorption %	1.343
Unbound bulk density	1275 kg/m³
Bulk density after compacting	1620 kg/m³

3.4 Water

One essential component of concrete is water, which aids in the chemical reaction between cement and water. Strength of concrete is primarily influenced by the hydrated cement gel's binding properties. To get the necessary consistency for appropriate workability, water is added. Fresh, potable water must be utilized for the concrete mixing process; drainage and ocean water is inappropriate to use due to the reaction of sulfate.

3.5 Expanded Polystrene Beads

EPS is a thin, fully recyclable material. These are made up of tiny, round particles and are light in weight. Since using lightweight concrete, there are several advantages to consider. These include reduced loads during construction, decreased structural self-weight and improved thermal resistance. The current study was undertaken with two main objectives in mind: replacing polystyrene trash with conventional aggregate and transferring waste from an environmental perspective.

TABLE IV. CHARACTERISTICS OF EPS

Property	Value
Water absorption	4.2%
Density	12.5 kg/m³
flexural strength	0.3 Mpa
Compressive strength	0.1 Mpa

TABLE V. MIX DESIGN

Materials	Quantity
Water	160 litre
Cement	360.21 kg
Coarse aggregate	1306.39 kg
Fine aggregate	583.52 kg

4. EXPERIMENTAL PROCEDURE

4.1 Slump Test

An evaluation of the uniformity or workability of a concrete mix that has been created construction site or in a lab as the project is being completed is the goal of a concrete slump test. Concrete slump tests are done at each batch to make sure that the performance of the concrete remains uniform during the process of building. A concrete's slump value, which also indicates the proportion of water to cement, is frequently used to measure concrete's workability. The characteristics of the materials, admixtures, dosage, mixing process and among other things, may influence slump value of concrete. At 1.5% and 3%, EPS' ability to replace fine aggregate was put to the test.

TABLE VI. SLUMP CONE TEST ON CONCRETE

Percentage Replacement	Value (mm)
0%	115
1.5%	95
3%	82

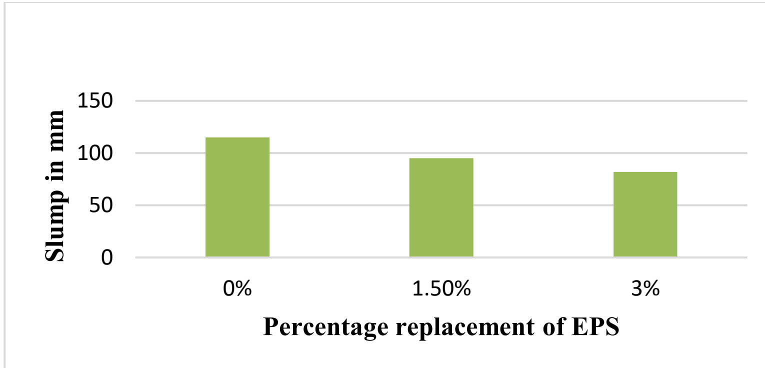

Fig.1. Slump value on concrete

4.2 Compressive Strength Test

Compressive strength refers to a material or structure's capacity to sustain or resist compression. Compressive strength is the ability of a material to tolerate failures takes the manner of fissure and crack.

$$Compressive\ Strength = Load / Area$$

Fig.2. Compressive test

TABLE VII. STRENGTH IN COMPRESSION

Grade of concrete	Percentage of Replacement	Compressive strength in N/mm^2		
		Day 7	Day 14	Day 28
M30	0%	20.1	25.1	28.3
	1.5%	23.5	29.6	31.2
	3%	22.3	28.4	29.9

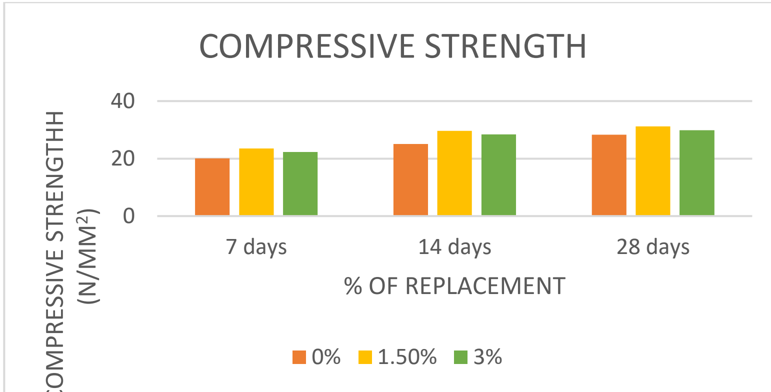

Fig.3. Compressive strength on concrete

4.3 Flexural Strength Test

The 750mmx 150mmx 150 mm beam specimens were used for testing. After seven days of curing, specimens were allowed to dry outdoors before being put through a test for flexural strength with a components for flexural testing. Till rupture, place the load at a pace which continuously raises the level of stress. Within the middle third of the span length, the tension surface is where the fracture is located. The formula (R) was used to calculate the flexural strength.

$$R = Pl / bd^2$$

TABLE VIII. FLEXURAL STRENGTH

Grade of concrete	Percentage of Replacement	Flexural strength in N/mm²		
		Day 7	Day 14	Day 28
M30	0%	3.5	4.3	5.8
	1.5%	4.1	5.1	6.1
	3%	4.03	4.9	5.9

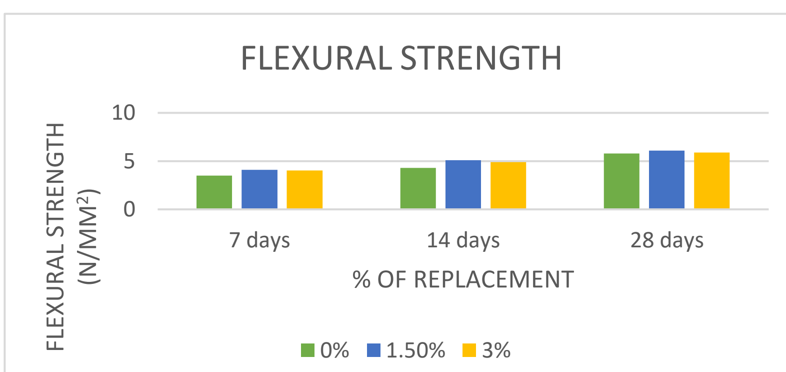

Fig.4. Flexural strength on concrete

4.4 Water Absorption Test

One of the most important qualities of high-quality concrete is the lack of permeability, particularly in concrete which is impervious to freeze and thaw. Concrete with a low rate of permeability are more resistant to thaw and freeze as well as resists infiltration of water. Water can penetrate pores in a cement mix and even into the aggregate. Concrete's permeability affects how quickly a liquid moves through it. The amount of liquid employed while mixing and the initial hardening phase causes a pore networks in concrete, which influences the permeability of that concrete.

TABLE IX. ABSORPTION OF WATER

Trial mix	Dry weight in grams (W1)	Wet weight in grams (W2)	Water absorption %
CC	7.98	8.19	2.63
M1	7.10	7.23	1.83
M2	7.05	7.29	3.4
M3	7.18	7.38	2.78

5. CONCLUSION

Polystyrene can be used to produce lightweight concrete by decreasing its density and dead weight. However, increasing the substitution of polystyrene significantly decreases its strength compared to conventional concrete. EPS concrete can be created using less water and cement than necessary, and its compaction factor is lower than the standard mix. As EPS concrete becomes more workable, its strength diminishes. The ideal replacement percentage for EPS is 1.5%, as it produces better compressive and flexural strength but reduces workability. The maximum strength achieved at 28 days with 1.5% EPS replacement is 31.2 N/mm2. EPS-based concrete also has superior water absorption compared to traditional concrete, making it a promising alternative for construction.

Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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References

[1] A.J. Adeala and O.B. Soyemi, "Structural Use of Expanded Polystyrene Concrete," International Journal of Innovative Science and Research Technology, vol. 5, no. 6, pp. 1131-1138, 2020.
[2] K. Kohling, "The manufacture of light weight concrete using pre-expanded styropore particles as aggregates," Betorstein – Zeitung, vol. 26, pp. 208-212, 1960.
[3] T. Mandlik, S. Sarthak Sood, et al., "Lightweight Concrete Using EPS," ISSN (Online): 2319-7064, 2013.
[4] G. Maura, "Light weight concrete made with expanded substituted polystyrene," IL Cement (Rome), vol. 75, part 1, pp. 21-29, 1978.
[5] Momtazi et al., "Durability of Lightweight Concrete Containing EPS in Salty Exposure Conditions," 2010.
[6] G.M. Parton and M.E. Shendy-EL-Barbary, "Poly styrene–bead concrete properties and mix design," Journal Of Cement Composite And Light weight Concrete, vol. 4, no. 3, pp. 153-161, 1982.
[7] P. Tamut et al., "Partial replacement of coarse aggregate by expanded polystyrene Beads in concrete," vol. 3, no. 2, 2014.
[8] M.P. Jayanth and S.M. Sowmya, "Experimental Study on Replacement of Coarse Aggregate by EPS Beads in Concrete to achieve Lightweight Concrete," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 7, pp. 610-616, 2018.

[9] E.M. Mbadike and N.N. Osadebe, "Technical note: Effect of Incorporating Expanded Polystyrene aggregate Granules in Concrete Matrix," Nigerian Journal of Technology (Nijotech), vol. 31, no. 3, pp. 401-404, November 2012.