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Effect of EPS Concrete: Balancing Construction Efficiency and Environmental Sustainability

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ABSTRACT

Expanded polystyrene (EPS) is a material that may be harmful to human health. This is mainly because it releases specific chemicals during its manufacture, usage, and disposal. It is important to remember that the effects on health can change depending on the particular situation, exposure levels, and personal sensibilities. There are initiatives underway to address these environmental issues. Increasing EPS recycling rates, locating substitute materials, and encouraging appropriate disposal techniques are the main goals of several projects. Furthermore, studies into more environmentally friendly EPS substitutes for a variety of applications are still in progress. Creating a circular economy and lowering the total amount of single-use plastics used are two more aspects of larger plans to lessen the environmental impact of materials like EPS. The introduction of EPS cubes into concrete has reduced the adverse effects of EPS materials in the environment. This study substituted EPS, which is generated from industrial waste products, for aggregate. For an experimental study, a good-strength, sustainable concrete mix of grade M30 has been developed. In increments of 25%, five different mix proportions were evaluated for EPS cubes with size variations of 10 mm, 12 mm, and 20 mm. The range of 0 to 100% was studied. The replacement of EPS cubes by volume of course aggregates in the mixture yields the maximum increase in crushing, rupture, and bending strength, according to the mechanical properties of concrete that have been observed. This replacement ratio of 25% was shown to be efficient. The use of EPS materials in concrete is therefore shown to produce large reductions in environmental pollutants in addition to significant cost and energy savings.

INTRODUCTION

Foamed polystyrene (PS), which can be either expanded (EPS) or extruded (XPS), is a lightweight, rigid, insulating thermoplastic widely used across various sectors such as consumer goods, packaging, construction, and marine industries. However, its properties also make it prone to generating waste that easily disperses and fragments in the environment. This review examines the impact of foamed PS in marine environments, including its sources, movement, degradation, contamination, ingestion by marine animals, and the biological effects of the chemical additives it contains. In the ocean, foamed PS is transported by wind and breaks down through photolytic degradation. It can also serve as a platform for organisms while being exposed to high levels of natural and human-made surface-active chemicals in the sea surface microlayer. Near shorelines, fragmentation is increased by the mechanical action of waves and abrasion when the material is beached, with the wind sometimes leading to its temporary burial. Various marine animals, especially those that feed at the surface or inhabit areas where foamed PS accumulates, have been documented ingesting EPS and XPS. This ingestion can cause physical harm, such as gastrointestinal blockages, and expose animals to harmful chemicals, notably flame-retardant hexabromocyclododecane, which is still found in recycled materials. Due to the difficulty in recovering foamed PS once it becomes marine litter, reducing its environmental impact will require eliminating processes that produce foamed waste, improving storage and disposal practices, and developing more sustainable and durable alternatives (Turner 2020). Industries and post-consumer products produce trash made of expanded polystyrene (EPS). They are not biodegradable, but they are typically disposed of by burning or filling a landfill, which pollutes the environment. A very common plastic for packing is polystyrene. In the case of landfilling, it is almost non-biodegradable and takes hundreds of years to break down, while other disposal or treatment techniques have detrimental consequences on the ecosystem. However, this substance is well known for having qualities like strong heat conductivity, sound absorption, and lightweight, which makes it an excellent addition to concrete (Ubi et al. 2022). The material to address contemporary global environmental concerns about sustainability and healthier air quality is to be found for replacement as it should contain less percentage of pentane (Prasittisopin et al. 2022) and a high percentage of styrene for better structural integrity as mentioned in Table 1. Research interest has recently increased due to the potential use of EPS as a partial replacement for fine particles in concrete. (Adeniran & Soyemi 2020). A complete or partial substitute for coarse aggregate is expanded polystyrene beads, which also give better strength results (Moon et al. 2020). The weight of the concrete decreased when EPS grains were added as coarse aggregates (Salahaldeen & Al-Hadithi 2022). EPS has greater resistance to crushing and impact (Borkar & Singi 2020). The main benefits of lightweight EPS concrete are its low heat conductivity, low density, and sound-insulating qualities (Kumar et al. 2021). EPS can enhance thermal insulation and soundproofing, increasing a building's energy efficiency (Shukri et al. 2024). EPS improves workability, increasing building efficiency and utilizing recycled resources to provide acceptable structural strength and environmental sustainability (Hilal et al. 2021). Concrete enhanced with EPS (expanded polystyrene) aggregates offers environmental benefits and can be utilized for various non-load-bearing elements like partition walls, floors, ceilings, bricks, and plaster. By replacing traditional structural members such as columns and beams, this lightweight concrete can significantly reduce the overall dead load of a building (Kaya & Kar 2016). The lightweight material can also be achieved by adding EPS in bead form with a fly ash mixture (Bagde et al. 2022). EPS can be reused as an ingredient in concrete mixtures. Cement production is resource-intensive, consuming substantial energy and raw materials. Moreover, it is responsible for approximately 7% of global CO_2 emissions, a significant contributor to climate change (Raja & Saravanan 2024). Treated recycled expanded polystyrene EPS concrete demonstrates a significant reduction in density, weighing about 30% less than conventional concrete (Mohammed & Hussein 2021). By incorporating EPS concrete in construction, buildings can achieve significant reductions in both structural weight and energy consumption. EPS concrete repurposes recoverable EPS particles, effectively addressing environmental pollution concerns. This material emerges as an economical, environmentally friendly, and energy-efficient option that aligns with green building principles (Pranahita et al. 2022). The recycled expanded polystyrene (EPS) into concrete as a partial replacement for fine aggregate leads to a 15% reduction in carbon dioxide emissions and a 16% decrease in energy consumption during production (Villa et al. 2023). The structural properties of recycled expanded polystyrene (EPS) and a hybrid cement blend show improved crushing strength. This eco-friendly hybrid concrete could be suitable for use as structural lightweight concrete (González-Betancur et al. 2024). The goal is to develop a concrete mixture that balances cost-effectiveness, serviceability, and compliance with lightweight concrete standards. At this 30% EPS beads replacement level, the resulting concrete exhibited density and water absorption characteristics that fell within acceptable ranges (Abah et al. 2018). The incorporation of EPS material reduces environmental pollution and alleviates storage problems associated with EPS waste (Çelikten et al. 2023). The improved EPS concrete formulation could be particularly suitable for non-structural applications in construction and addressing environmental concerns related to waste management (Mun et al. 2021). EPS-bead lightweight concrete is not only resilient and energy-efficient but also stands out as a promising technology that could help meet the growing demands for eco-friendly and high-performance building solutions (Rathore et al. 2024). The EPS-based geomaterial can also be effectively utilized, offering a practical solution for challenging soil conditions where weight reduction is crucial (Menghare et al. 2022). The higher levels of coarse aggregate replacement with EPS had a particularly detrimental impact on crushing strength. Interestingly, replacing fine aggregate with coarse aggregate at certain levels yielded more favorable outcomes, maintaining crushing strength comparable to traditional concrete mixtures (Abdel-Jabe et al. 2023). EPS concrete promotes environmental sustainability through better insulation and durability in residential and commercial structures while increasing construction efficiency by lowering energy consumption and expenses (Azzawi et al. 2023).

EPS Waste

EPS (Expanded Polystyrene Foam) waste management in India shows that the country faces significant challenges in managing plastic waste, especially EPS, a common form of non-biodegradable plastic used in packaging. EPS waste shown in Fig. 1 is like other types of plastic and contributes to India's massive plastic pollution problem. India generates around 9 million metric tons of plastic waste every year, much of which is not properly treated or disposed of. EPS waste is particularly problematic as its lightweight structure makes it difficult to collect and recycle. Though India has put in place frameworks for plastic waste management, such as the Plastic Waste Management Rules and Extended Producer Responsibility (EPR), recycling rates remain low. Only about 12.3% of plastic waste in the country is recycled, while the remaining 20% is incinerated. Despite efforts to improve waste management infrastructure, production of single-use plastics, including EPS, continues to increase. India, along with other developing countries with limited recycling capacity, is one of the countries hardest hit by plastic waste mismanagement, accounting for over 52% of global plastic mismanagement. This trend is expected to worsen unless additional steps are taken to improve recycling and reduce single-use plastics such as EPS. India's Ministry of Environment 2024 report highlights major challenges in waste management, including the growing expanded polystyrene (EPS) waste problem. EPS is a common plastic used in packaging and insulation, but its low recyclability and high volume contribute to India's plastic waste crisis. The Centre for Science and Environment (CSE) stresses that while the plastic ban targets single-use plastics, more comprehensive measures are needed to combat EPS and other forms of plastic waste. India's entire plastic waste management system is in trouble, with over 79% of the plastic produced worldwide ending up as waste. The 2024 report highlights the lack of proper infrastructure for EPS recycling, especially in urban areas where waste segregation is still limited. The Energy and Resources Institute (TERI) and CSE advocate for increased regulation of plastic manufacturers and improved recycling systems as key solutions to manage this growing problem. Regarding volume, EPS waste is a danger to the environment. This is because it tends to accumulate on discharge and navigation channels, which increases waste management issues. Decisions such as the extension of the manufacturer (EPR) and the extension treatment initiative are part of the agenda to reduce plastic waste in this format.

Fig. 1: EPS waste.

MATERIALS AND METHODS

When expanded polystyrene (EPS) is used in concrete specimens, it often serves as a lightweight aggregate or filler. EPS cubes shown in Fig. 2 are incorporated into the concrete matrix to reduce the overall density of the specimen while maintaining adequate strength. This modification is commonly used in lightweight concrete applications where weight reduction is critical, such as in non-load-bearing walls or thermal insulation layers. The inclusion of EPS in concrete can also enhance its better thermal conductivity

Table 1: Chemical properties of EPS.

Properties	Value
Chemical Formula	$(C_8H_8)n$
Molecular Weight	104.15 $g.moL^{-1}$ (per styrene unit)
Styrene Content	> 95%
Pentane Content (blowing agent)	< 2%

Table 2: Physical properties of EPS.

Properties	Value
Density	20 $kg.m^{3-}$
Thermal Conductivity	0.036 W/(m·K)
Crushing Strength (10% deformation)	80 kPa
Bending Strength	170 kPa
Tensile Strength	150 kPa
Water Absorption (by volume)	0.5-3%
Coefficient of Linear Thermal Expansion	5-7 × 10[illegible]/K
Maximum Service Temperature	75-80°C
Glass Transition Temperature	~100°C
Specific Heat Capacity	1.3 kJ/(kg·K)
Sound Transmission Class (STC)	25 dB
Oxygen Index	24-26%
Vapor Diffusion Resistance Factor (μ)	75

properties as shown in Table 2, making it a popular choice for energy-efficient building designs. Concrete specimens are typically composed of a mixture of binder-cement whose physical properties are given in Table 3, M sand in Table 4, partial replacement of 10 mm aggregate specified in Table 5, water, and admixture-like superplasticizers. The cement acts as the binder, holding the aggregates together as the mixture hardens.

Mix Design and Specifications

W/C ratio: The water-cement ratio is crucial for controlling the strength and durability of the concrete. According to IS 10262:2019, a lower W/C ratio results in higher strength, and 0.4 is used for M-30 grade concrete.

Table 3: Physical properties of cement.

Characteristics	Experimental Data
Stiffening time	36 min
Hardening time	530 min
Density ratio	3.15
Consistency	30.5%
Soundness	1.4 mm
Maximum crushing stress (MPa)	15.0 at three days
	23.5 at seven days
	31.5 at twenty-eight days

Table 4: Physical properties of M sand.

Physical Properties	Experimental Data
Grading index	2.80
Density	1720 kg.m^{-3}
Impact value	15%
Density ratio	2.70

Table 5: Physical properties of 10 mm aggregate.

Physical Properties	Experimental Data
Grading index	7.00
Density	1550 kg.m^{-3}
Density ratio	2.80

Fig. 2: EPS cubes.

Cement content: This amount complies with IS 456:2000, which stipulates a minimum cement content based on environmental exposure conditions. For M-30 grade concrete, 330 kg.m^{-3} is a typical value.

Fine aggregate and Coarse aggregate: These M sand (675 kg.m^{3-}) and aggregate (1110 kg.m^{3-}) are calculated based on the mix design procedure outlined in IS 10262:2019. The exact quantities may vary slightly depending on the specific gravity and grade of the aggregates used.

Water: The water content (150 kg.m^{3-}) is calculated to achieve the desired workability with the specified W/C ratio. This aligns with IS 10262:2019.

Mineral admixture: Mineral admixture fly ash can replace a portion of the cement to improve durability and workability. According to IS 456:2000 and IS 10262:2019, up to 20% replacement is typical for this grade of concrete.

Superplasticizer: Superplasticizers are used to enhance the workability of the concrete mix without increasing the water content, which is essential for maintaining a low W/C ratio. According to IS 10262:2019, a typical dosage is around 0.5% by weight of cementitious content. A sulfonated Naphthalene Formaldehyde (SNF) - based Superplasticizer is used.

Fig. 3: Mixture for specimen casting.

Table 6. Mix design.

Ratio of ingredients	
Target crushing strength [Mpa]	30
Water/Cement ratio	0.4
Cement content [kg.m^{-3}]	330
M sand [kg.m^{-3}]	675
10 mm aggregate [kg.m^{-3}]	1110
Water content [kg.m^{-3}]	150
Supplementary Cementitious material [kg.m^{-3}]	20%
Dosage of superplasticizer used to improve workability [kg.m^{-3}]	0.5%

Fig. 4: Cube and cylinder specimens.

Testing of Specimens

Casting of specimens: As per IS 516:1959, concrete specimens should be cast in clean, water-tight molds made of non-absorbent material. Fill the molds in three layers after proper mixing as shown in Fig. 3, compacting each layer with a tamping rod. After filling, level the top surface and mark the specimens for identification. The mixed proportions of specimens are referred to in Table 6. For cubes, use 15 cm x 15 cm x 15 cm molds; for cylinders, use molds with a diameter of 15 cm and height of 30 cm as shown in Fig. 4 and for beams, use 15 cm x 15 cm x 70 cm molds.

Initial curing: According to IS 516:1959, cover the specimens with wet burlap or similar material immediately after casting to prevent evaporation. Keep them in a place free from vibration for 24 ± 2 h at a temperature of 27 ± 2°C. For specimens in cold weather, maintain the temperature between 22°C and 32°C.

Demolding: As specified in IS 516:1959, remove the specimens from the molds after 24 ± 2 h of casting. If the specimens are too weak to be handled after 24 h, leave them in the molds for up to 72 h. Handle the specimens carefully to avoid damage or distortion.

Curing: Following IS 516:1959 guidelines, immediately after demolding, store the specimens in clean, fresh water at a temperature of 27 ± 2°C until the time of testing. Change the water in the curing tank periodically to maintain cleanliness. For specimens that will be tested at 28 days or later, you may transfer them to a moist room with 90% or more relative humidity after the initial 7 days of water curing.

Preparation for testing: As per IS 516:1959, remove the specimens from water storage at least 2 h before testing. For cubes and cylinders, wipe the surface water and grit from the specimens. For beams, keep them wet until testing. Measure and record the dimensions of the specimens accurately.

Testing procedure: Follow IS 516:1959 for the testing procedures. For cubes and cylinders, place the specimen centrally on the lower plate of the testing machine. Apply the load without shock and increase it continuously at a rate of approximately 140 $kg.sq^{-1}$ $cm.min^{-1}$ until the specimen

Fig. 5: Testing of cube specimen.

Fig. 6: Testing of cylinder specimen.

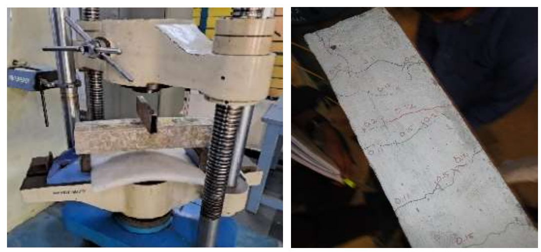

Fig. 7: Testing of beam specimen.

fails. For beams, use the two-point loading method, applying the load at one-third points of the span.

Calculations and reporting: Calculate the strength as per IS 516:1959. A minimum of 3 specimens for each test age is required to account for variability, typically 7 days, 14 days, and 28 days.

- **Crushing strength test** (Cube): as per IS 516, 150mm cubes are cured for 28 days and loaded at a rate of 13.7$MPa.min^{-1}$ is applied as shown in Fig. 5. The crushing strength is calculated as f_c = maximum load/ cross-sectional area.
- **Rupture strength test** (Cylinder): as per IS 5816, A cylinder of 150mm diameter x 300mm height is cast and cured for 28 days, and load at a rate of 1.2 to 2.4 $Mpa.min^{-1}$ is applied as shown in Fig. 6. The rupture strength is calculated using the formula $f_t = 2P/(\pi LD)$, where P = failure load, L = length, and D = diameter.
- **Bending strength test** (Beam): as per IS 516. A beam size of 100mm x 100mm x 500mm was fabricated, and curing for 28 days was done. The load at a rate of 400 $kg.min^{-1}$ is applied as shown in Fig. 7. The bending

strength is calculated using the formula bending strength $f_b = PL/bd^2$, where P = failure load, L = span, b = breadth, and d = cross-sectional depth.

Acceptance Criteria: Refer to IS 456:2000 for concrete strength acceptance criteria. The concrete satisfies the energy requirements if the average strength of the set of test results is equal to or higher than the required strength and no single test result, except for 3 MPa, is less than the nominal strength.

Material Blending

The specimen mixes represent various combinations of Ordinary Portland Cement (OPC), Manufactured sand (M sand), and Expanded Polystyrene (EPS) cubes of different sizes (10 mm, 12 mm, and 20 mm) with varying aggregate. These mixes are designed to explore the potential of lightweight concrete by replacing traditional 10 mm aggregates with EPS cubes, a material known for its lightweight and insulation properties. The percentages of aggregates and EPS cubes are systematically varied, ranging from 25% to 100% as mentioned in Table 7 to assess their impact on the mechanical properties of concrete, such as strength, density, and thermal insulation. Such studies are crucial in civil engineering for developing materials that are both structurally efficient and offer energy-saving benefits, particularly in applications where less self-weight is essential, like in multi-story buildings or thermal insulation applications.

RESULTS AND DISCUSSION

Crushing Strength Test Results

The data presented in Table 8. outlines the crushing strength performance of various Expanded Polystyrene Concrete (EPSC) mixes with different EPS contents over a curing period of seven, fourteen, and twenty - eight days. The study shows a general trend where increasing the EPS content in the concrete mix results in a decrease in crushing strength when compared to the conventional mix. Specifically, mixes with 10%, 12%, and 20% EPS content show a reduction in strength at 28 days as EPS content increases, with the most significant drop observed at 100% EPS replacement as illustrated in Fig. 8. While some mixes (e.g., EPSC (10) 25 and EPSC (20) 25) exhibit a slight increase in crushing strength, the overall trend indicates that higher EPS content leads to a gradual decrease in crushing strength, demonstrating the trade-off between reducing the density of concrete and maintaining its structural integrity. The 28-day crushing strength test results with statistical analysis for the different concrete specimens are summarized in Table 9. below. The data exhibits variability through the use of 95% confidence intervals (CI), mean strength, and estimated standard deviations. Certain specimens, such as EPSC (10)25, demonstrate high strength and minimal variability, whereas other specimens, such as EPSC (20)100, show more variability with wider confidence intervals and lower strength. Comments emphasize relative results reliability and trends like strength retention or reduction.

Rupture Strength Test Results

The average rupture strengths of various mixes with expanded polystyrene (EPS) aggregates at different curing ages (7, 14, and 28 days) are presented in Table 10. The mixes are labeled with different percentages (25%, 50%, 75%, 100%) and EPS bead sizes (10mm, 12mm, 20mm). The results show that % of EPS replacement increases, and the rupture strength generally decreases as illustrated in Fig. 9.

Table 7: Material Blending.

Specimen Label	Material Blending	Water in mix [kg.m^{-3}]	Cement in mix [kg.m^{-3}]	Workability [mm]
EPSC(10)25	OPC + 100 % M sand + 75 % 10 mm aggregate + 25 % EPS cubes 10 mm	157.5	350	97
EPSC(10)50	OPC + 100 % M sand + 50 % 10 mm aggregate + 50 % EPS cubes 10 mm	157.5	342	89
EPSC(10)75	OPC + 100 % M sand + 25 % 10 mm aggregate + 75 % EPS cubes 10 mm	157.5	337	84
EPSC(10)100	OPC + 100 % M sand + 100% EPS cubes 10 mm	157.5	323	79
EPSC(12)25	OPC + 100 % M sand + 75 % 10 mm aggregate + 25 % EPS cubes 12 mm	157.5	342	92
EPSC(12)50	OPC + 100 % M sand + 50 % 10 mm aggregate + 50 % EPS cubes 12 mm	157.5	331	81
EPSC(12)75	OPC + 100 % M sand + 25 % 10 mm aggregate + 75 % EPS cubes 12 mm	157.5	322	77
EPSC(12)100	OPC + 100 % M sand + 100% EPS cubes 12 mm	157.5	312	70
EPSC(20)25	OPC + 100 % M sand + 75 % 10 mm aggregate + 25 % EPS cubes 20 mm	157.5	338	88
EPSC(20)50	OPC + 100 % M sand + 50 % 10 mm aggregate + 50 % EPS cubes 20 mm	157.5	328	73
EPSC(20)75	OPC + 100 % M sand + 25 % 10 mm aggregate + 75 % EPS cubes 20 mm	157.5	315	69
EPSC(20)100	OPC + 100 % M sand + 100% EPS cubes 20 mm	157.5	306	65

The maturity strength values are compared to a conventional mix, with some mixes showing improvement (e.g., EPSC (10) 25 with a 14.19% increase) while others exhibit reduced strength (e.g., EPSC (20) 100 with a 14.52% decrease). The data suggests that smaller EPS bead sizes (10 mm) and lower replacement percentages tend to perform better in terms of rupture strength, while larger bead sizes (20 mm) and higher replacement percentages result in more significant strength reductions compared to the conventional mix.

Bending Strength Test Results

The bending strength is measured at 7, 14, and 28 days, with the 28-day strength compared to a conventional mix. Table 11. presents data on the average bending strength of various concrete mixes incorporating EPS as a partial substitute for aggregates. Generally, the results prove that % of EPS and its beads size increase, which tends to decrease the bending strength of the concrete. The mix EPSC (10) 25, with 25% replacement using 10 mm EPS beads, shows the highest improvement in bending strength (15% increase) compared to the conventional mix at 28 days. Conversely, EPSC (20) 100, with 100% replacement using 20mm EPS beads, exhibits the most significant decrease in bending strength (-28.57%) at 28 days as illustrated in Fig. 10. This data suggests that while EPS can be incorporated into concrete mixes, careful consideration must be given to the replacement percentage and bead size to maintain adequate bending strength for structural applications.

Table 8: Crushing strength test results.

Specimen Label	Crushing strength of three specimens at each test age [Mpa] (9 samples totally under each specimen label)			% variation in crushing strength compared with the conventional mix at 28 days.
	Early age strength (7^{th} Day)	Midterm strength (14^{th} Day)	Maturity strength (28^{th} Day)	
EPSC(10)25	24.11	31.20	35.45	12.54 (31.5)
EPSC(10)50	22.84	26.81	33.10	5.08
EPSC(10)75	21.11	25.02	30.15	-4.29
EPSC(10)100	18.64	24.75	29.12	-7.56
EPSC(12)25	22.65	28.47	32.35	2.70
EPSC(12)50	21.53	27.46	31.20	-0.95
EPSC(12)75	19.55	25.09	29.18	-7.37
EPSC(12)100	19.11	24.02	27.30	-13.33
EPSC(20)25	21.79	28.62	31.52	3.24
EPSC(20)50	19.77	27.07	30.42	-3.43
EPSC(20)75	18.43	24.95	28.35	-10.00
EPSC(20)100	17.79	23.54	26.16	-16.95

Table 9: Statistical analysis of Crushing strength test results.

Specimen	Mean [Mpa]	Standard Deviation [Mpa]	95% CI Lower [Mpa]	95% CI Upper [MPa]	Remarks
EPSC(10)25	35.45	3.55	26.64	44.26	High strength, narrow CI
EPSC(10)50	33.10	3.31	24.88	41.32	Slight reduction in strength
EPSC(10)75	30.15	3.02	22.66	37.64	Moderate reduction, wide CI
EPSC(10)100	29.12	2.91	21.89	36.35	Noticeable reduction in strength
EPSC(12)25	32.35	3.23	24.31	40.39	Good strength retention
EPSC(12)50	31.20	3.12	23.45	38.95	Stable strength
EPSC(12)75	29.18	2.92	21.93	36.43	Moderate strength reduction
EPSC(12)100	27.30	2.73	20.52	34.08	Lower strength, wide variation
EPSC(20)25	31.52	3.15	23.69	39.35	Good strength, narrow CI
EPSC(20)50	30.42	3.04	22.86	37.98	Stable performance
EPSC(20)75	28.35	2.84	21.31	35.39	Reduced strength, wide CI
EPSC(20)100	26.16	2.62	19.66	32.66	Lowest strength, wide variation

Table 10: Rupture strength results.

Specimen Label	Rupture strength of three specimens at each test age [Mpa] (9 samples totally under each specimen label)			% variation in Rupture strength compared with the conventional mix at 28 days.
	Early age strength (7th Day)	Midterm strength (14th Day)	Maturity strength (28th Day)	
EPSC(10)25	2.40	3.15	3.54	14.19 (3.10)
EPSC(10)50	2.30	2.65	3.34	7.74
EPSC(10)75	2.15	2.55	3.01	-2.90
EPSC(10)100	1.86	2.50	2.95	-4.84
EPSC(12)25	2.23	2.81	3.25	4.84
EPSC(12)50	2.15	2.73	3.11	0.32
EPSC(12)75	1.95	2.52	2.85	-8.06
EPSC(12)100	1.91	2.40	2.70	-12.90
EPSC(20)25	2.18	2.87	3.15	1.61
EPSC(20)50	1.98	2.70	3.00	-3.23
EPSC(20)75	1.85	2.49	2.88	-7.10
EPSC(20)100	1.75	2.36	2.65	-14.52

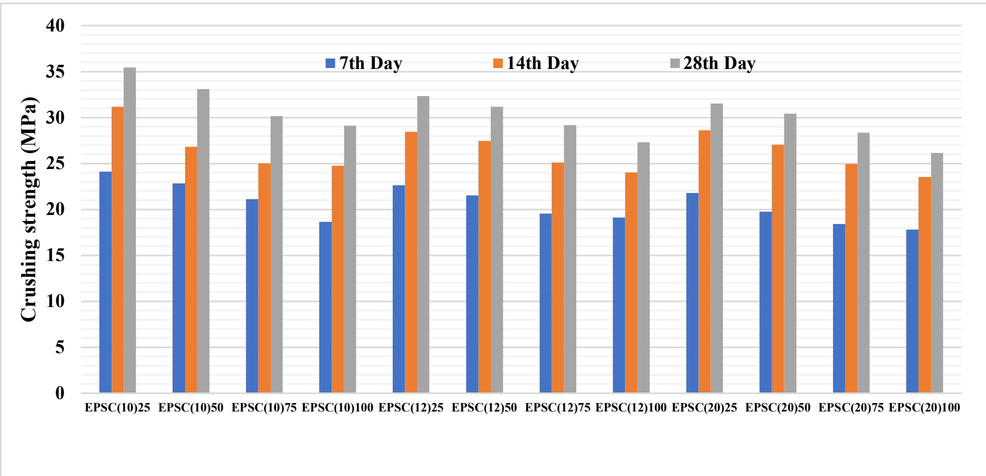

Fig. 8: Crushing strength test results.

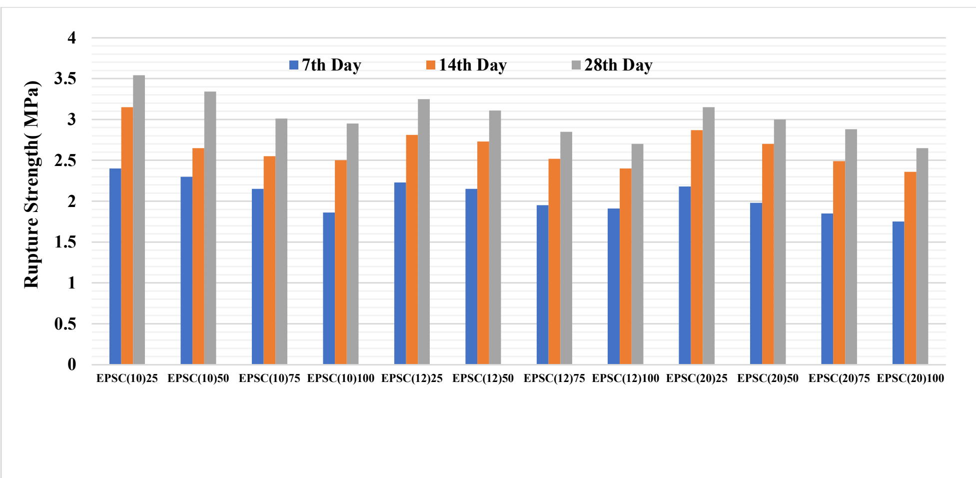

Fig. 9: Rupture strength test results.

Table 11: Bending strength test results.

Specimen Label	Bending strength of three specimens at each test age [Mpa] (9 samples totally under each specimen label)			% variation in bending strength compared with the conventional mix at 28 days.
	Early age strength (7^{th} Day)	Midterm strength (14^{th} Day)	Maturity strength (28^{th} Day)	
EPSC(10)25	3.28	4.25	4.83	15.00 (4.2)
EPSC(10)50	3.05	3.58	4.42	5.24
EPSC(10)75	2.91	3.44	4.15	-1.19
EPSC(10)100	2.55	3.38	3.98	-5.24
EPSC(12)25	3	3.77	4.52	7.62
EPSC(12)50	2.86	3.64	4.14	-1.43
EPSC(12)75	2.63	3.37	3.92	-6.67
EPSC(12)100	2.66	3.34	3.8	-9.52
EPSC(20)25	2.7	3.8	4.3	2.38
EPSC(20)50	2.28	3.12	3.50	-16.67
EPSC(20)75	2.08	2.82	3.20	-23.81
EPSC(20)100	2.04	2.70	3.00	-28.57

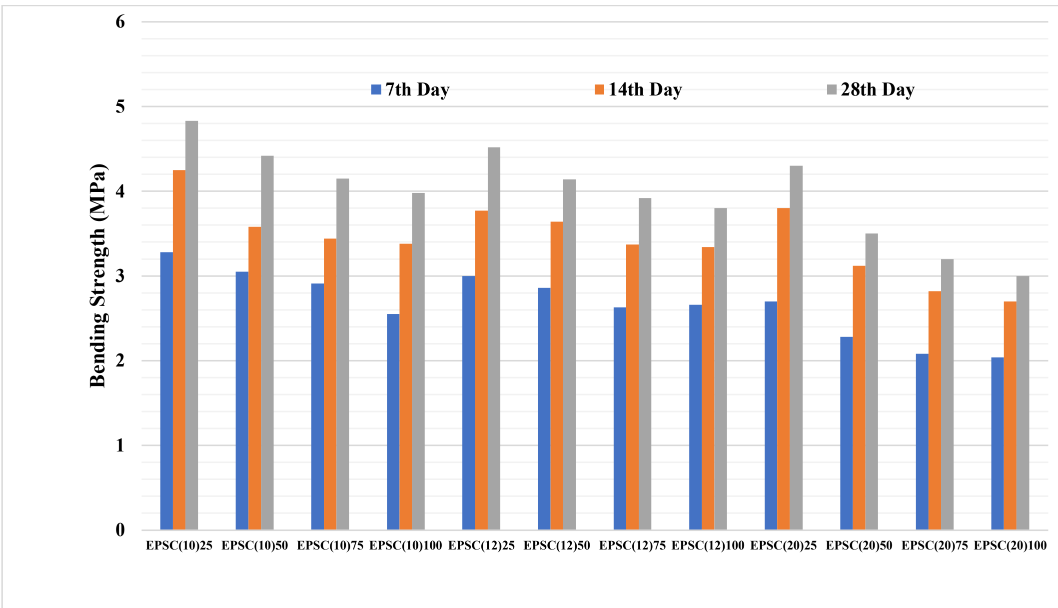

Fig. 10: Bending strength test results.

CONCLUSION

The experimental study led to the following conclusions:

1. The expanded polystyrene concrete (EPSC) usage shows promise in reducing the environmental impact of traditional concrete while maintaining acceptable strength levels. Notably, EPSC (10) 25 and EPSC (10) 50 mixes achieved crushing strengths at 28 days, which were 12.54% and 5.08% higher than the conventional mix, respectively. This suggests that incorporating up to 50% EPSC with a 10 mm particle size can enhance strength while potentially reducing the overall concrete volume needed. Even at higher EPSC percentages and larger particle sizes, the strength reductions were generally moderate, with many mixes still achieving over 30 MPa at 28 days. This indicates that EPSC can be a viable partial replacement for traditional aggregates, which could lead to reduced natural resource extraction and lower carbon emissions associated with aggregate production. The ability to use recycled polystyrene in EPSC further contributes to waste reduction and circular economy principles. Overall, these results demonstrate

that EPSC mixes can offer a balance between structural performance and environmental benefits, potentially leading to more sustainable construction practices.

2. A notable environmental advantage can be observed in the use of expanded polystyrene concrete (EPSC) mixes. The results show that certain EPSC mixes, particularly EPSC (10) 25 and EPSC (10) 50, exhibit improved rupture strength compared to the conventional mix at 28 days, with increases of 14.19% and 7.74%, respectively. This suggests that incorporating expanded polystyrene, a waste material, into concrete can potentially enhance its performance while simultaneously addressing environmental concerns. By utilizing expanded polystyrene in concrete production, we can reduce the amount of this non-biodegradable material ending up in landfills or polluting ecosystems. Additionally, the use of EPSC could potentially decrease the demand for traditional concrete materials, thereby reducing the environmental impact associated with their extraction and production. While some mixes show decreased strength, the overall trend indicates that with proper mix design, EPSC can offer a viable eco-friendly alternative in certain construction applications, contributing to waste reduction and resource conservation efforts.
3. The incorporation of expanded polystyrene concrete (EPSC) in various percentages shows promising results for sustainable construction practices. Notably, EPSC (10) 25 and EPSC (10) 50 mixes demonstrate improved bending strength compared to the conventional mix at 28 days, with increases of 15% and 5.24%, respectively. This suggests that the partial replacement of traditional concrete with recycled expanded polystyrene can maintain or even enhance structural performance while potentially reducing the carbon footprint associated with cement production. The use of expanded polystyrene, a common waste material, in concrete mixes addresses the issue of plastic pollution by repurposing a material that would otherwise contribute to environmental degradation. Additionally, the lighter weight of EPSC mixes could lead to reduced transportation emissions and lower energy requirements in construction, further contributing to climate change mitigation efforts. While some mixes show decreased strength at higher replacement levels, the overall trend indicates that optimized EPSC formulations could play a significant role in developing more environmentally friendly construction materials, thereby supporting pollution reduction strategies and promoting a circular economy approach in the building sector.
4. The results of this study support and broaden existing theories on material efficiency and waste utilization in concrete production, which advances environmental engineering and sustainable construction. By showing that expanded polystyrene concrete (EPSC) may largely replace coarse aggregates without significantly compromising structural performance, EPS is challenging the conventional dependence on natural aggregates in civil engineering. Improvements in crushing and bending strengths are demonstrated by the results, especially for EPSC (10) 25 and EPSC (10) 50. This suggests that adding lightweight waste materials like EPS to concrete can preserve or even improve its mechanical qualities. Challenging traditional theories that emphasize using high-density aggregates for strength creates opportunities for creative material uses that put sustainability first without affecting loading-carrying capability. These findings, which take expanded polystyrene from landfills and repurpose it in concrete, are consistent with.

The circular economy and waste valorization concepts from the standpoint of environmental engineering. Modern sustainable engineering techniques that address plastic waste management minimize carbon emissions from aggregate extraction and manufacture, and lessen resource depletion are all in line with this. As part of the continuous transition to low-carbon, resource-efficient building technologies, the study shows that incorporating EPS into concrete is a feasible strategy to lessen the environmental impact of building materials. To establish EPSC as a competitive alternative in environmentally friendly building methods, this study expands on current frameworks by showing that optimum mix designs can strike a compromise between sustainability and structural integrity.

FUTURE STUDIES

The following crucial areas should be investigated in further research on this project since they might also be seen as its limitations with regard to the wider economic and environmental effects of employing EPS concrete in large-scale projects:

- Durability Testing
- Structural Behavior
- Mix Design Optimization
- Life-Cycle Assessment
- Scalability and Sourcing

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REFERENCES

Abah, J.C., Ndububa, E.E. and Ikpe, E.O., 2018. An evaluation of the water absorption and density properties of expanded polystyrene sanded concrete. *Open Journal of Civil Engineering*, 8(4), DOI: 10.4236/ojce.2018.84037.

Abdel-Jabe, M., Shatarat, N.K. and El-Nimri, R., 2023. Influence of using expanded polystyrene beads on the density and crushing strength of hardened concrete. *Civil Engineering and Architecture*, 1, pp.45–53.

Adeniran, J.A. and Soyemi, O.B., 2020. Structural use of expanded polystyrene concrete. *International Journal of Innovative Science and Research Technology*, 5(6), pp.1131–1138.

Azzawi, R., 2023. Green construction and sustainability using modified expanded polystyrene (EPS) insulation. *9th International Engineering Conference on Sustainable Technology and Development (IEC)*, pp.102–109. https://doi.org/10.1109/iec57380.2023.10438799

Bagde, R., Gajbhiye, R. and Nagdevte, P., 2022. Experimental studies on expanded polystyrene beads (fly ash geometrical). *International Journal of Innovative Research in Technology*, 8(12), pp.1557–1561.

Borkar, Y. and Singi, M., 2020. EPS-based light weight concrete design with enhancement of strength. *International Journal of Civil and Structural Engineering Research*, 7(2), pp.44–54.

Çelikten, S., İsa, İ., Özcan, Z.A., Durak, U., İlkentapar, S., Karahan, O. and Atiş, C.D., 2023. Recycling waste expanded polystyrene as aggregate in the production of lightweight screed mortar. *Journal of Construction*, 22(3), DOI: https://doi.org/10.7764/RDLC.22.3.581.

González-Betancur, D., Hoyos-Montilla, A.A. and Tobón, J.I., 2024. Sustainable hybrid lightweight aggregate concrete using recycled expanded polystyrene. *Materials*, 17(10), Article 2368. https://doi.org/10.3390/ma17102368.

Hilal, N., Hamah, N., Rabar, S. and Faraj, H., 2021. Development of eco-efficient lightweight self-compacting concrete with high volume of recycled EPS waste materials. *Environmental Science and Pollution Research*, 28(36), pp.50028–50051. https://doi.org/10.1007/S11356-021-14213-W

Kaya, A. and Kar, F., 2016. Properties of concrete containing waste expanded polystyrene and natural resin. *Construction and Building Materials*, 155, pp.572–578.

Kumar, C.V., Arun, E. and Bhaskar, B., 2021. Lightweight concrete using EPS (expanded polystyrene) beads. *International Journal of Research Publication and Reviews*, 2(8), pp.1591–1598.

Menghare, D., Welekar, V., Shende, R., Bagde, S., Gajbhiye, R. and Nagdevte, P., 2022. Experimental studies on expanded polystyrene beads (fly ash geometrical). *International Journal of Innovative Research in Technology*, 8(12), pp.1557–1561.

Mohammed, H.J. and Hussein, Y.G., 2021. Concrete properties using treated recycled EPS. *IOP Conference Series: Earth and Environmental Science*, 17, p.128. DOI: 10.1088/1755-1315/877/1/012028.

Moon, A.S., Lingait, P.B., Meshram, S.B., Maske, M.S., Mohinkar, K.G. and Chimurkar, K.S., 2020. Investigation of EPS concrete. *International Research Journal of Engineering and Technology*, 7(6), pp.6269–6272.

Mun, C.Z., Kwong, K.Z., Lee, F.W. and Lim, J.H., 2021. Mechanical, sound and thermal properties of recycled expanded polystyrene concrete reinforced with 0.5% to 5.5% kenaf fibre. *European Journal of Environmental and Civil Engineering*, 26(14), pp.7345–7358.

Pranahita, D.L., Kumar, P., Shwetank, Banu, S., 2022. Experimental study on partial replacement of coarse aggregate by EPS (expanded polystyrene) beads in concrete blocks. *International Journal of Research Publication and Reviews*, 3(7), pp.477–485.

Prasittisopin, L., Termkhajornkit, P. and Kim, Y.H., 2022. Review of concrete with expanded polystyrene (EPS): Performance and environmental aspects. *Journal of Cleaner Production*, 13, p.291. DOI: 10.1016/j.jclepro.2022.132919.

Raja, R.P.S.S. and Saravanan, J., 2024. Evaluation of lightweight concrete using expanded polystyrene aggregate with montmorillonite calcined powder. *SSRG International Journal of Civil Engineering*, 11(6), pp.50–59.

Rathore, A., Hingve, A., Singh, H., Munde, R., Yadav, R. and Prajapati, S., 2024. Lightweight concrete using expanded polystyrene beads. *International Journal of Innovative Research and Creative Technology*, 10(2), pp.1–17.

Salahaldeen, A.S. and Al-Hadithi, A.I., 2022. The effect of adding expanded polystyrene beads (EPS) on the hardened properties of concrete. *Engineering, Technology & Applied Science Research*, 12(6), pp.9692–9696.

Shukri, Z., Umar, K. and others, 2024. Enhancing the use of expanded polystyrene (EPS) for lightweight concrete wall panels. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 47(2), pp.160–170. https://doi.org/10.37934/araset.47.2.160170

Turner, A., 2020. Foamed polystyrene in the marine environment: Sources, additives, transport, behavior, and impacts. *Environmental Science and Technology*, 54(17), pp.10411–10420.

Ubi, S.E., Ewa, D.E., Bessong, A.R. and Nyah, E.D., 2022. Effects of incorporating expanded polystyrene in concrete construction. *Journal of Building Construction and Planning Research*, 10(3), p.421. DOI: 10.4236/jbcpr.2022.103004.

Villa, D.M., Patino, J.S., Mogrovejo, D.E. and Bernal, J.G., 2023. Influence of recycled expanded polystyrene for sustainable structural concrete. *Structural Journal*, 120(3), pp.87–89.