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Study on the Effect of Replacing Coarse Aggregate Partially with Polystyrene Beads in Concrete Mix

Deepika K. C.[1], Raghavendra[2]

[1]Assistant professor, Department of Civil Engineering, Bangalore Institute of Technology, Bangalore, Karnataka, India
Email: *civil.deepika[at]gmail.com*

[2]Student, Department of Civil Engineering, Bangalore Institute of Technology, Bangalore, Karnataka, India
Email: *raghavendrah923[at]gmail.com*

Abstract: ***The demand for building materials is rising quickly due to the popularity of contemporary construction techniques. Finding substitute materials is crucial for advancing sustainable development. One such technique is to partially substitute polystyrene beads for coarse particles in concrete. These beads are leftovers from the packaging sector. In this study, traditional concrete blocks and concrete with polystyrene beads substituted are compared. The characteristics of hardened concrete were discovered to be impacted by the addition of polystyrene beads. Concrete of M15 grade was tested with coarse aggregate replacement rates of 10%, 20%, 30%, and 40%. Changes in compressive and flexural strength are evident in the results. Even with a low water-to-cement ratio, the mixes demonstrated high workability, which qualified them for use in construction.***

Keywords: Polystyrene beads, Slump test, Compaction factor test, compressive strength and Flexural Strength

1. Introduction

Rapid urbanization and industrialization are contributing to the rise in municipal solid garbage. Because plastic waste does not decompose naturally, it is a significant issue. Common plastics like polystyrene, typically employed for packaging and storing food items, are frequently discarded untreated because recycling them is more costly than creating new materials. Since this waste is not biodegradable, it causes major environmental problems when it ends up in landfills. It originates from both homes and businesses.

Reduced structural weight, simpler handling during construction, and improved thermal insulation are just a few advantages of using lightweight concrete. The density of lightweight concrete is typically less than 1800 kg/m³. The management of polystyrene waste and its partial substitution for coarse aggregate in concrete are the two main objectives of this study.

Figure 1: Polystyrene beads

2. Literature review

Adeniran Jolaade et.al (2020) Expanded polystyrene (EPS) trash from industry and used consumer goods is used in the present investigation. Since EPS is not biodegradable, it is typically burned or disposed of in landfills, which pollutes the environment. EPS has come into focus in recent times from researchers as a potential partial replacement for fine aggregates in concrete. This study used EPS as an additive while maintaining the same amounts of sand and granite since it differs from regular sand in several ways. After being ground, the mass per unit volume of the EPS was 10.57 kg/m³. Tests were conducted in line with BS 8110-2:1985. The findings demonstrated that EPS has an impact on the attributes of both in both its fresh and solidified states concrete. For instance, in 28 days, 5% EPS concrete achieved 17.07 MPa, making it appropriate for office walls. Using EPS in concrete helps reduce pollution, saves landfill space, and supports sustainable construction.

Amirali Babavalian et al (2020 The combined impact of EPS beads and polypropylene fibers on the splitting tensile capacity and compressive strength under uniaxial loading and confined behavior of concrete is the main topic of this paper. Concrete samples that were cylindrical were subjected to 160 tests in total. According to the test results, using fibers improves strength when there are more EPS beads present. For instance, the strength measured in uniaxial compression rose by 35.5% when 0.5% polypropylene fibers were added. However, the greatest strength gain was observed at just 0.1% fiber content when EPS was added at 5% and 10%, resulting in just 12.1% and 10% improvement. Images of the fracture surface were used to further explain these findings. Additionally, it was observed that the strength loss due to EPS increased by around 10% under confined loading compared to uniaxial loading.

S. Mahmoud et.al (2018 To increase durability and use fewer natural particles, expanded polystyrene (EPS) is incorporated into concrete to substitute a portion of the coarse aggregate. However, EPS is challenging to handle and transport because of its enormous surface area and low bulk density. In this investigation, EPS was granulated and combined with a solid superplasticizer to increase its density.

The impact of these EPS granules on the durability and strength of concrete was examined in this study. The findings demonstrated that the concrete's strength and surface electrical resistivity were enhanced by both slurry and granulated EPS. Additionally, permeability was decreased in comparison to regular concrete without EPS, indicating improved performance all around.

3. Objective

1) This study aims to evaluate the strength characteristics of concrete when EPS beads are used in different amounts as a replacement for natural coarse aggregates.
2) To find out how using different percentages of EPS beads, by weight of coarse aggregate, affects the fresh concrete properties.
3) To find out how using different percentages of EPS beads, by weight of coarse aggregate, affects the hardened concrete properties.
4) To check the concrete's ability to withstand compression with and without EPS at various grades and proportions.
5) To check the flexural capacity of concrete incorporating and excluding EPS at various grades and proportions.
6) To make a comparison between the properties of concrete incorporating EPS and concrete without EPS.

4. Material

1) **Cement**: OPC 53 grade cement served as a binding agent in this mix. The relative density of the tests revealed the cement to be 3.12.
2) **Fine Aggregate**: Crushed sand was employed as fine aggregate material. It passed through the 4.75 mm sieve and was retained on the 60-micron sieve. Sand exhibited a specific gravity of 2.58 as well as its ability to absorb water was 1%.
3) **Coarse Aggregate**: The coarse aggregate's maximum grain size used was 20 mm. It had a relative density of 2.68 and 2% water absorption.
4) **Polystyrene Beads**: Part of the coarse aggregate was replaced using EPS beads in different proportions such as ranging from 10% to 40% in steps of 10% for preparing the concrete specimens.
5) **Admixture**: A superplasticizer was incorporated into the mix, with a relative density of 1.1.
6) **Water**: Mixing was done using potable water. It met the IS 456:2000 standards. The water-cement ratio used in this mix was 0.5.

5. Testing Program

5.1 Slump test

Generally speaking, it was observed that adding polystyrene beads enhanced the flowability of the concrete mix. The cement-based material became easier to mix and place as the ratio of coarse aggregate used replaced by polystyrene increased. This indicates that the mix became more workable the more polystyrene was used in place of coarse aggregates. The main factor contributing to this rise in workability is that polystyrene's smooth texture and light weight lessen friction between the mixture's constituent particles. Especially at higher replacement levels like 30% or 40%, its round shape and low density help the concrete flow better and make handling easier. When simple concrete placing is required without the use of excessive water or additional admixtures, this feature may be useful.

Table 1: Slump value for different percentage of polystyrene beads

Concrete Mix	Slump Value
10% replacement	60
20% replacement	64
30% replacement	67
40% replacement	68

5.2 Compaction factor test

A different method used to evaluate how workable fresh concrete is is the compaction factor test. Compared to the slump test, it provides more accurate findings, particularly for blends with low or medium workability. It is evident from the test findings that the more polystyrene beads added to the concrete, the better its workability. This is due to polystyrene's smoothness and light weight, which facilitates the free movement of concrete particles during mixing and placement. Higher levels of polystyrene replacement of coarse aggregate were associated with higher compaction factor values, indicating that the mix became easier to compact. This test is helpful in understanding how well concrete can be placed in areas with dense reinforcement or narrow formwork without much effort or vibration.

Table 2: Compaction factor test for different percentage of polystyrene beads

Concrete Mix	Slump Value
10% replacement	0.876
20% replacement	0.899
30% replacement	0.902
40% replacement	0.910

5.3 Compressive strength Test

The experiment was executed using 150 x 150 x 150 mm concrete blocks. At intervals of 7, 14, and 28 days of curing, the concrete cubes were withdrawn from the curing tank. The surface water was removed and then let run off. A 200-ton Compression Testing Machine (CTM) was then used to test the cubes. The cube was positioned at a right angle to the way it was cast during testing. The specimen was correctly aligned in a way that its axis coincided positioned to match the midpoint of the spherically mounted plates of the CTM. Until the cube collapsed, the force exerted was increased gradually and steadily without any abrupt shocks, increasing at a steady at a pace of 3.5 N/mm² per minute. The concluding compressive strength value for each batch was established through the mean value of the values of three cube specimens. By dividing the greatest load by the cube's cross-sectional area, the structural strength recorded was the structural strength recorded was determined. The strength under compression for each of the various mixtures was thus determined.

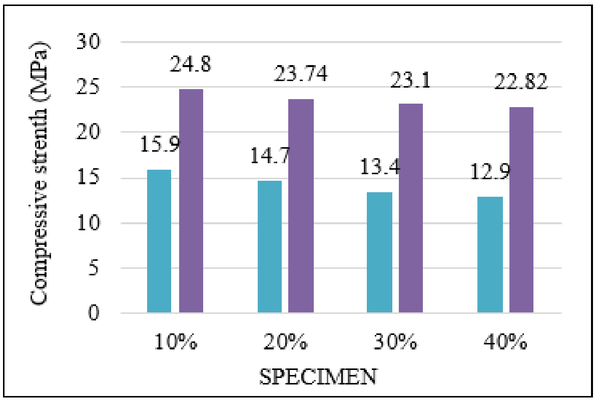

Figure 2: Compression strength of 7 days and 28 days curing

5.4 Flexural strength test

The outcomes of assessment of flexural strength in concrete specimens created with varying mix amounts and cured for varying lengths of time. To examine how the strength changes over time, after curing periods of 7, 14, and 28 days, the flexural strength test was administered. For buildings like beams and slabs, the test assesses the effectiveness of the concrete can withstand bending stresses. The table below contains a compilation of test results corresponding to each mix and curing age. Additionally, a graph is provided to illustrate how each mix's flexural strength varies as the number of curing days increases. Test of flexural strength. It is evident from the results that flexural strength rises with curing age for all blends, and the graph makes this effect very evident. The findings also demonstrate how the bending strength of concrete at various curing stages is impacted by the addition of polystyrene beads.

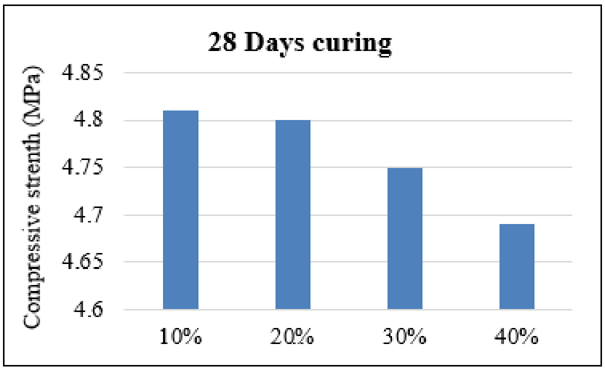

Figure 3: Flexural strength of 28 days Curing

6. Conclusions

1) Increase in the EPS beads content in concrete mixes reduces the compressive and tensile strength of concrete.
2) All the EPS concrete without any special bonding agent show good workability and could easily be compacted and finished.
3) Workability increases with increase in EPS beads content
4) The replacement by using EPS has shown a positive application as an alternate material in building non structural members, and it also serves as a solution for EPS disposal

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Author Profile

Deepika K. C., BE (Civil) and M.Tech (Structural Engineering), specializing in Structural Design and Concrete Technology. Teaching interests include Structural Engineering, RCC Design, Concrete Technology, and Surveying. Actively involved in research and guiding students in the areas of Structural Engineering and Concrete Innovations. she is member of Association of Consulting Civil Engineers.

Raghavendra. received B.E. in civil engineering from Dr.AIT, Bengaluru (2023) and Persuing M.tech. degrees in structural Engineering from BIT, Bengaluru. (2025).