



## Effect of Partial Replacement of Fine Aggregates by EPS Beads on Ultrasonic Pulse Velocity (UPV) and Compressive Strength of M25 Concrete

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**Abstract:** This study examines the effect of partially replacing fine aggregates with Expanded Polystyrene (EPS) beads on the Ultrasonic Pulse Velocity (UPV) and compressive strength of M25 grade concrete. EPS beads, which are lightweight and non-absorbent, were used as a sustainable alternative at replacement levels of 0%, 10%, 20%, 30%, and 40% by volume. Concrete specimens were tested after 7, 21, and 28 days of curing period. The results showed that as EPS content increased, compressive strength and UPV values decreased due to lower density and bonding. However, moderate EPS content improved workability and energy absorption, making it suitable for non-structural components.

**Keywords - Lightweight concrete, Sustainable construction, Density reduction, Acoustic property.**

### I. INTRODUCTION

The development of EPS mix lightweight concrete originated from the growing need for construction materials that are light in weight and energy-efficient. Traditional concrete is strong and long-lasting, but it is very heavy and adding large dead load to structures. To solve this problem, researchers and engineers began searching for alternative materials that could reduce the weight without affecting important properties. One effective solution was the use of Expanded Polystyrene (EPS) beads, which is a type of thermoplastic polymer known for its very low density, closed-cell structure, and thermal insulation properties. It is a waste product from the plastic industry.

The use of EPS in concrete became popular in the late of 20<sup>th</sup> century, especially for eco-friendly and sustainable construction. Because EPS is lightweight which helps to produce concrete with densities lower than conventional concrete. Today, it is commonly used in non-load-bearing walls, roof panels, floating structures, and insulation layers. It also provides good thermal insulation, sound absorption, and resistance to moisture.

### Various types of lightweight concrete by adding impurities as follows:

#### a) Lightweight aggregate concrete-

This type of concrete is made by replacing normal aggregates with lightweight materials like pumice, expanded clay, shale etc. These aggregates contain air voids or porous in nature, which significantly decrease the density of concrete. Industrial by-products such as sintered fly ash or expanded slag are also used as lightweight aggregates.

#### b) Aerated or Cellular concrete-

In this type, impurities such as aluminum powder, hydrogen peroxide, or foam-producing agents are added to the mix. Aerated concrete has excellent thermal insulation and sound absorption properties, making it suitable for partition walls and non-load-bearing structures.

#### c) No-Fines Concrete-

This type is produced by removing fine aggregates (sand) completely and using only coarse aggregates bound together with cement paste. The voids between the aggregates make the concrete lighter and provide better drainage.

#### d) Polymer and EPS concrete-

Expanded Polystyrene (EPS) beads or plastic waste can be introduced as aggregates replacements. These materials reduce the density and enhance the concrete's insulation properties while using recyclable waste.

#### e) Sawdust and Other Organic Concrete-

Impurities like sawdust, rice husk, or coconut shell can partially replace aggregates. These organic materials make the mix lighter and eco-friendly, though they may slightly reduce the compressive strength.

## II. LITERATURE REVIEW

Raja and Saravanan (2024) found that replacing cement with montmorillonite calcinated powder and coarse aggregates with EPS increases the workability of concrete. They tested replacement levels of coarse aggregates at 0%, 5%, 10%, 15%, 20%, and 25% using EPS beads. As the replacement level increased, the weight of concrete reduced significantly. The maximum reduction was observed at 25% of EPS replacement of coarse aggregate and 0% montmorillonite powder, where the weight was 8.81% lower than normal concrete.

Kartheeswaran and Bharathi (June 2024) observed that adding silica fume improves the strength of both normal concrete and EPS-based concrete. They used small replacement levels of 0%, 2%, and 3%. At 2% EPS replacement of fine aggregate, the strength was close to conventional concrete. However, at 3% replacement, compressive strength decreased compared to the conventional concrete. They also studied water absorption and sorptivity at 10% replacement in M30 grade concrete.

Gamal et al. (2023) studied the effect of replacing 50%, 55%, and 60% of coarse aggregates with recycled EPS beads. At this level, the mix became non-cohesive and showed shear slump. As EPS content increased, thermal conductivity decreased linearly. Compacted samples had values around 0.77 W/mk (about 37% to 26.5% of control mix), while un-compacted samples ranged from 0.45 to 0.31 W/mk (about 21.7% to 15%).

Kumar et al. (July 2022) investigated that increasing Styrofoam content made the concrete more ductile, improving energy absorption compared to normal concrete. Flexural strength also increased especially at 15% replacement. They tested replacement levels of 0%, 40%, 45%, and 50%. All mixes met slump flow requirements with proper use of superplasticizer.

Solikin and Ikhsan (2018) studied Styrofoam as a partial replacement for fine aggregate at 0%, 30%, 40%, and 50%. They found that higher Styrofoam content increased water absorption and reduced compressive and flexural strength. However, it significantly reduced weight, meeting lightweight concrete criteria. They suggested 50% replacement as optimal due to minimum weight and acceptance properties.

Vandiyar, Babu and Nagarajan (2016) replaced coarse aggregates with EPS at levels of 0% to 50% and also replaced 30% cement with fly ash. They observed that increasing EPS reduced concrete density. At 10% replacement, there was a slight reduction in strength, while at 50%, the concrete achieved lightweight properties. The density decreased by 3.5% to 23.5% as EPS content increased from 10% to 50%.

## III. SCOPE AND OBJECTIVES OF THE STUDY

### III.I Problem Statement:

Conventional concrete is heavy and dense, which makes it less suitable for lightweight structural applications and increases the overall dead load of buildings. To solve this problem, Expanded Polystyrene (EPS) beads can be used as a partial replacement for fine aggregates. However, their impact on the mechanical properties and durability of concrete is not completely understood yet. Therefore, it is important to study how different proportions of EPS affect the Ultrasonic Pulse Velocity (UPV) and compressive strength of M25 grade concrete. This will help in achieving the best possible performance while also improving sustainability.

### III.II. Scope of the Study:

The growing need for sustainable and lightweight construction materials has encouraged the use of alternative aggregates to reduce concrete weight without affecting its strength. Traditional concrete is strong but heavy, which increases dead load and construction cost. Expanded Polystyrene (EPS) beads are lightweight and recyclable, making them a good option to replace fine aggregates. However, their effect on properties like UPV and compressive strength in M25 concrete is not fully clear. This study focuses on finding the right amount of EPS replacement to achieve lower weight while maintaining strength and durability.

### III.III. Objectives:

1. To study the Ultrasonic Pulse Velocity (UPV) test results and analyze the quality, uniformity, and strength of EPS concrete in comparison to conventional concrete.
2. To find the optimum percentage of replacing fine aggregates with EPS beads so that a proper balance between workability, strength, and overall structural performance can be achieved.
3. To examine how the replacement affects quantity of fine aggregates used in concrete.

## IV. MATERIALS AND METHODS

**Cement:** Ordinary Portland Cement (OPC) of 53 Grade having specific gravity 3.15. The cement is fresh, free from lumps, and stored in dry conditions.

**Coarse Aggregate:** The aggregates generally available from local source having size range between 10 mm to 20 mm. The aggregates are clean, hard, and free from dust.

**Fine Aggregates:** Natural river sand which passing through a 4.75 mm IS sieve. It is clean, well graded.

**EPS Beads:** EPS beads are lightweight polystyrene spheres. They are white, spherical and uniform size.

**Table No. 1 Properties of EPS beads**

| Property             | Average Value     |
|----------------------|-------------------|
| Density              | 13 Kg/cubic meter |
| Compressive Strength | 0.09 Mpa          |
| Flexural Strength    | 0.21 Mpa          |
| Water Absorption     | 4% by Volume      |

Water: Clean potable water, free from impurities, oils, and organic substances. It is used for both mixing and curing.

**Preparation of specimens-** Concrete specimens were prepared for all mixes with 0%, 10%, 20%, 30%, and 40% EPS replacement by volume under controlled conditions. Dry materials (cement, sand and aggregates) were first mixed for two minutes. EPS beads were added at the final stage to ensure uniform distribution. The fresh mix was tested for workability using slump test. Concrete was poured into oiled moulds in three layers and compacted on a vibrating table. After 24 hours, specimens were removed from moulds and cured in water for 7, 21 and 28 days for testing purpose. Total 45 cubes were casted, each replacement level containing 9 cubes. The specimen casting process has done with batch-wise. The material data provided below for casting of four specimens.

**Table No. 2 Material required for casting of specimens**

| EPS replacement levels (%) | Sand volume (cubic meter) | Sand weight (Kg.) | EPS volume (cubic meter) | EPS weight (gm.) |
|----------------------------|---------------------------|-------------------|--------------------------|------------------|
| 0%                         | 0.0037125                 | 5.94              | 00                       | 00               |
| 10%                        | 0.00334125                | 5.35              | 0.00037125               | 4.8              |
| 20%                        | 0.00297                   | 4.75              | 0.0007425                | 9.7              |
| 30%                        | 0.00259875                | 4.16              | 0.00111375               | 14.5             |
| 40%                        | 0.0022275                 | 3.56              | 0.001485                 | 19.3             |

Other materials (cement- 5.35 Kg, coarse aggregates- 11.14 Kg, and water- 2.4 Liter.) keep as it is for all mixes.

#### Tests conducted-

**Slump Cone Test:** This test is conducted on fresh concrete. It is used to determine workability of concrete.

**UPV Test:** To determine the quality and uniformity of concrete and detect internal flaws and cracks by measuring the velocity of an ultrasonic pulse through the concrete cube. It is non-destructive test conducting after 28 days curing period.

**Figure No. 1 UPV testing of specimen**

**Compressive Strength Test:** The compressive strength test on a concrete cube is conducted to determine the load carrying capacity of hardened concrete under compression. It was conducting after 7, 21, and 28 days of curing period.



Figure No. 2 Compressive strength testing of specimen

## V. RESULTS AND DISCUSSION

The experimental results showed that the slump value increases as we replacing the amount of EPS beads in increasing order. The slump value varies from 96mm to collapse slump from 0% to 40% of EPS. The replacement of fine aggregates with Expanded Polystyrene (EPS) beads had a clear effect on both Ultrasonic Pulse Velocity (UPV) and compressive strength of M25 concrete. At 10% replacement, the compressive strength dropped slightly compared to normal mix, but the concrete still had good bonding and could carry loads properly. However, after 20% replacement, the strength reduced more noticeable because EPS is lightweight and porous, which lowers the density and weakens the bond between cement and aggregates.

Table No. 3 -Compressive Strength results

| % of EPS Replacement | Compressive Strength (N/mm <sup>2</sup> ) |                         |                         |
|----------------------|---|-------------------------|-------------------------|
|                      | 7 Days                                    | 21 Days                 | 28 Days                 |
| 0%                   | 18.70 N/mm <sup>2</sup>                   | 24.10 N/mm <sup>2</sup> | 28.42N/mm <sup>2</sup>  |
| 10%                  | 18.23 N/mm <sup>2</sup>                   | 23.90 N/mm <sup>2</sup> | 27.23 N/mm <sup>2</sup> |
| 20%                  | 14.82 N/mm <sup>2</sup>                   | 20.42 N/mm <sup>2</sup> | 25.61 N/mm <sup>2</sup> |
| 30%                  | 14.63 N/mm <sup>2</sup>                   | 17.80 N/mm <sup>2</sup> | 22.47 N/mm <sup>2</sup> |
| 40%                  | 12.75 N/mm <sup>2</sup>                   | 15.94 N/mm <sup>2</sup> | 19.21 N/mm <sup>2</sup> |



Figure No. 3 Compressive Strength at different stage

UPV values also decreased as the EPS percentage increased, indicating less uniform concrete and more internal voids. Up to 20% replacement, the concrete quality was still considered good, but beyond that, it shifted to medium quality. The relationship between UPV and compressive strength showed that both properties were affected by adding EPS beads.

Table No. 4-UPV Test results

| % of EPS Replacement | UPV Value (Km/Sec) |
|----------------------|--------------------|
| 0%                   | 3.98               |
| 10%                  | 3.94               |
| 20%                  | 3.72               |
| 30%                  | 3.46               |
| 40%                  | 3.35               |

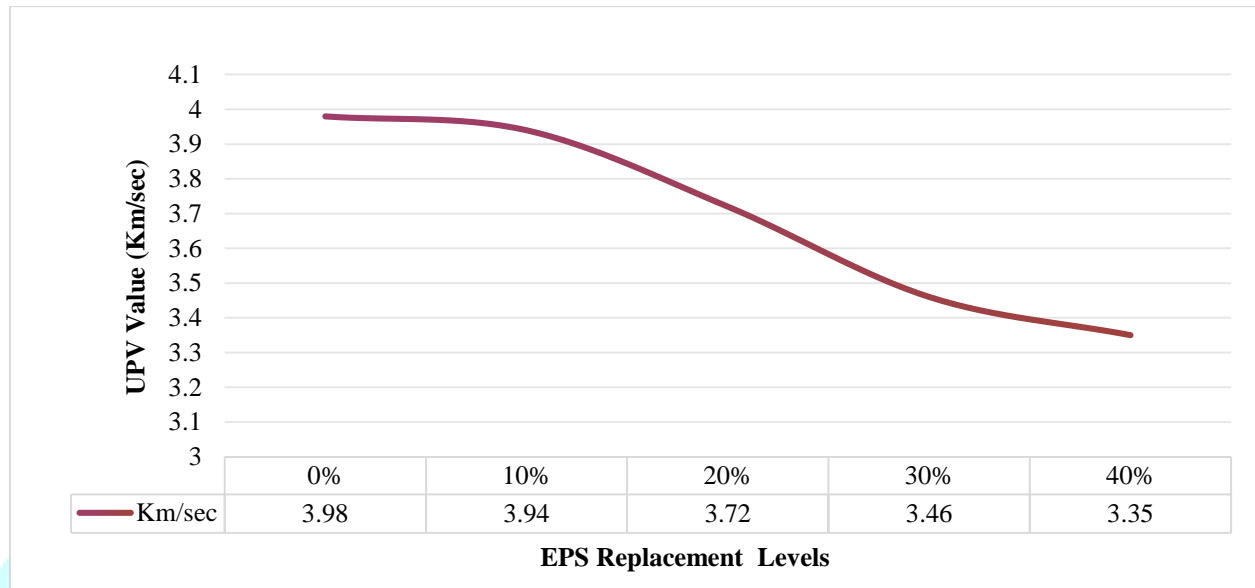


Figure No. 4 UPV Value at different stage

## VI. CONCLUSION

The study on the effect of partially replacing fine aggregates with EPS beads on Ultrasonic Pulse Velocity (UPV) and compressive strength of M25 concrete shows that using Expanded Polystyrene (EPS) beads has a noticeable impact on the strength and durability of concrete. EPS beads increases the workability of fresh concrete. As the percentage of EPS increases, both compressive strength and UPV values decrease because EPS is lightweight and porous, which reduces density and weakens the bonding within the concrete. However, up to 20% replacement, the concrete still maintains acceptable strength and UPV values. Using a moderate amount of EPS (20%-30%) can help produce lightweight concrete with acceptable strength and durability. EPS concrete helps to reduce dead load, and provides sustainable option by reusing waste materials without greatly affecting performance.

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