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Development of light-weight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder

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ABSTRACT :

Lightweight concrete is an innovative construction material known for its reduced density and enhanced thermal insulation properties, making it a sustainable alternative to conventional concrete. This experimental investigation aims to evaluate the properties of lightweight concrete produced by incorporating varying proportions of recycled-expanded polystyrene (R-EPS) beads and waste aluminium powder, with the goal of developing a new sustainable building material.

The primary objective of this study is to assess the strength properties of lightweight concrete by replacing sand with R-EPS beads in different percentages (0%, 10%, 20%, 30%, 40%, 50%, 60%, and 70% by volume) and replacing cement with waste aluminium powder in varying amounts (0%, 0.5%, 1%, 1.5%, and 2% by weight). The experimental investigation focuses on determining key strength properties, including compressive strength, tensile strength, flexural strength, and shear strength, and comparing them across the different mix proportions.

The findings indicate that optimal compressive, tensile, flexural, and shear strengths are achieved at a 10% replacement level of sand with R-EPS beads and at 1% replacement level of cement with waste aluminium powder. Beyond these thresholds, the strength properties begin to decline. The study demonstrates the viability of incorporating these waste materials into concrete production, offering a promising pathway towards more sustainable building practices.

Keywords: Light-weight concrete, Recycled-expanded polystyrene (EPS) beads, Waste aluminium powder, Mechanical strength, Sustainable construction materials.

INTRODUCTION :

Lightweight Concrete (LWC) is a type of concrete characterized by its reduced density compared to conventional concrete, achieved by incorporating lightweight aggregates such as expanded polystyrene beads, pumice, or perlite. LWC offers significant benefits, including lower dead load, enhanced thermal insulation, and improved fire resistance, making it ideal for high-rise buildings, bridges, and structures where weight reduction is crucial. Additionally, LWC's improved workability and ease of handling contribute to faster construction processes and reduced labour costs.

LWC not only reduces the carbon footprint associated with cement production but also promotes resource efficiency. The lighter weight of LWC structures can lead to smaller foundation requirements, further reducing material use and overall environmental impact.

The construction industry is exploring lightweight concrete as a sustainable solution to reduce structural load and improve energy efficiency in buildings. Traditional concrete is heavy, posing challenges in handling and transportation. Lightweight aggregates like expanded polystyrene (EPS) beads and waste aluminium powder offer promising alternatives. Recycling EPS, a byproduct of the packaging industry, into concrete reduces density and improves thermal insulation. Waste aluminum powder, when added to concrete, creates a porous structure, enhancing insulation properties while reducing density. Both materials contribute to eco-friendly construction, but careful optimization is needed to maintain strength and durability.

Overall, LWC aligns with the principles of sustainable construction by offering a durable, efficient, and environmentally friendly alternative to traditional concrete, contributing to the development of green buildings and sustainable infrastructure.

OBJECTIVE OF THE STUDY

The primary objective of this experimental investigation is to evaluate the properties of light weight concrete produced by incorporating varying proportions of recycled- expanded polystyrene beads and waste aluminium powder. and develop it as a new sustainable building material:

To achieve the above objective the strength properties of light weight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder in different percentages are found and compared. The strength properties such as compressive strength, tensile, flexural and shear are found.

The sand is replaced by R-EPS beads in different percentages such as 0 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 % and 70 % by volume. Also, cement is replaced by waste aluminium powder in different percentages such as 0 %, 0.5 %, 1 %, 1.5 % and 2 % by weight.

MATERIALS AND METHODOLOGY

3.1 Materials

- **Cement:** For this study, the cement used is OPC-43 grade from Birla Company which has a specific gravity of 3.12
- **Fine aggregate:** In the experiment, Single-washed M sand with permitted limits of 2.2 to 3.2 and 2.65 to 2.67 in terms of specific gravity and fineness modulus was employed.
- **Recycled - expanded polystyrene beads:** EPS boards and waste materials were collected from different sources and crushed into smaller particles for mixing in concrete.
- **Waste aluminium powder:** Waste aluminium powder is a fine powder made from Aluminium. It is procured from AEQUS Pvt. Ltd, Belagavi. Waste aluminium powder is the by-product of the manufacturing process.
- **Superplasticizer:** In this study, the super-plasticizer used is from Fosroc Company-with trade name Conplast SP 430-DIS. Conplast SP 430 DIS is a chloride-free, superplasticizer admixture based on selected sulfonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water.

3.2 Methodology

To achieve the objective the strength properties of light weight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder in different percentages are found and compared. The strength properties, such as compressive strength, tensile strength, flexural strength, and shear strength, are found.

The sand is replaced by R-EPS beads in different percentages such as 0 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 % and 70 % by volume. Also, cement is replaced by waste aluminium powder in different percentages such as 0 %, 0.5 %, 1 %, 1.5 % and 2 % by weight.

To evaluate the strength properties of lightweight concrete produced using recycled-expanded polystyrene (R-EPS) beads and waste aluminium powder, a comprehensive methodology is employed. Initially, materials such as Ordinary Portland Cement (OPC), R-EPS beads, waste aluminium powder, fine aggregates, coarse aggregates, and potable water are selected and prepared. The cement is tested for quality through assessments of fineness, consistency, and setting times, while the R-EPS beads are cleaned, dried. Waste aluminium powder, which partially replaces the cement, is finely ground.

The mix design is developed based on following standards like IS 10262: 2019 or ACI 211.1. Concrete mixes are prepared by varying the percentage of R-EPS beads (0%, 10%, 20%, 30%, 40%, 50%, 60%, and 70%) as a sand replacement by volume, and waste aluminium powder (0%, 0.5%, 1%, 1.5%, and 2%) as a cement replacement by weight. The materials are accurately weighed and dry mixed to ensure uniform distribution. The waste aluminium powder is added to the dry mix, followed by the gradual addition of water until a homogeneous mixture is achieved.

Test specimens are then cast in standard moulds for compressive, tensile, flexural, and shear strength testing. The fresh concrete is poured into moulds in layers, compacted to eliminate air voids, and allowed to set for 24 hours. After demoulding, the specimens are cured in water at 27°C ± 2°C for 28 days period. The strength properties are tested using a compression testing machine (CTM) for compressive strength, a split tensile strength method for tensile strength, a third-point loading method for flexural strength, and appropriate methods for shear strength testing. The data from these tests are compiled to analyze the effects of varying R-EPS bead and aluminium powder content on strength properties.

EXPERIMENTAL RESULTS AND DISCUSSIONS

1.1. Compressive strength test results of lightweight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder.

Table 1 Results of compressive strength

Percentage of R-EPS beads	Compressive strength (MPa) of light weight concrete when cement is replaced by waste aluminium powder in diffrenet percentages				
	0% replacement	0.5% replacement	1% replacement	1.5% replacement	2% replacement
0% (Reference mix)	25.78	26.44	27.19	26.07	24.96
10%	29.78	30.44	31.41	30.15	28.89
20%	22.67	23.41	24.07	22.67	21.26
30%	18.59	19.41	20.07	18.81	17.56
40%	14.59	15.39	16.13	14.73	13.32
50%	10.67	11.33	12.00	10.74	9.48
60%	8.00	8.67	9.48	8.22	6.96
70%	7.26	7.93	8.73	7.32	5.91

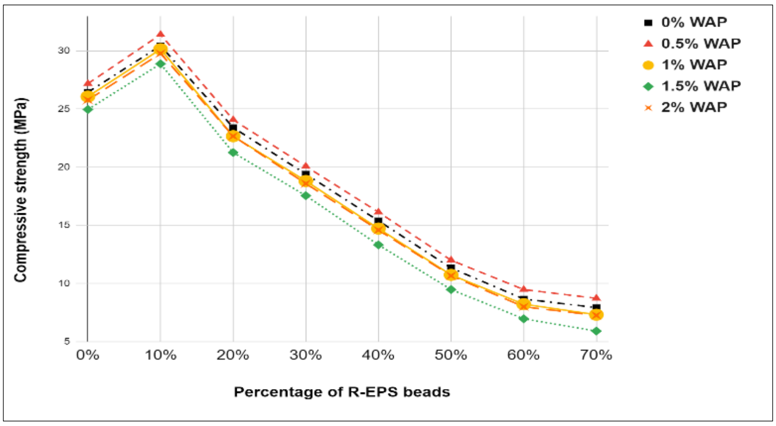


Fig 1 Variation of compressive strength.

1.2. Tensile strength test results of lightweight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder.

Table 2 Results of tensile strength

Percentage of R-EPS beads	Tensile strength (MPa) of light weight concrete when cement is replaced by waste aluminium powder in diffrenet percentages				
	0% replacement	0.5% replacement	1% replacement	1.5% replacement	2% replacement
0% (Reference mix)	3.77	3.99	4.22	3.87	3.51
10%	3.92	4.13	4.44	4.03	3.63
20%	2.55	2.62	3.07	2.90	2.74
30%	2.34	2.59	2.81	2.41	2.01
40%	2.01	2.26	2.50	2.05	1.60
50%	1.84	2.05	2.26	1.86	1.46
60%	1.63	1.84	2.10	1.70	1.30
70%	1.46	1.67	1.93	1.48	1.03

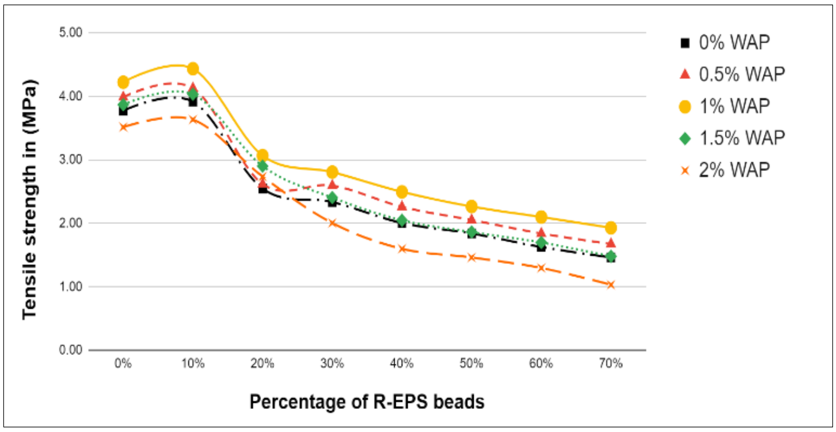


Fig 2 Variation of tensile strength.

1.3. Flexural strength test results of lightweight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder.

Table 3 Results of flexural strength

Percentage of R-EPS beads	Flexural strength (MPa) of light weight concrete when cement is replaced by waste aluminium powder in diffrenet percentages				
	0% replacement	0.5% replacement	1% replacement	1.5% replacement	2% replacement
0% (Reference mix)	2.53	3.60	5.00	4.07	3.25
10%	2.68	3.74	5.24	4.17	3.37
20%	2.51	3.15	4.55	3.52	2.85
30%	2.31	3.00	4.44	3.27	2.51
40%	1.63	2.60	4.08	3.12	2.35
50%	1.37	2.36	3.99	2.95	1.88
60%	1.13	2.19	3.79	2.86	1.66
70%	1.03	2.09	3.32	2.52	1.43

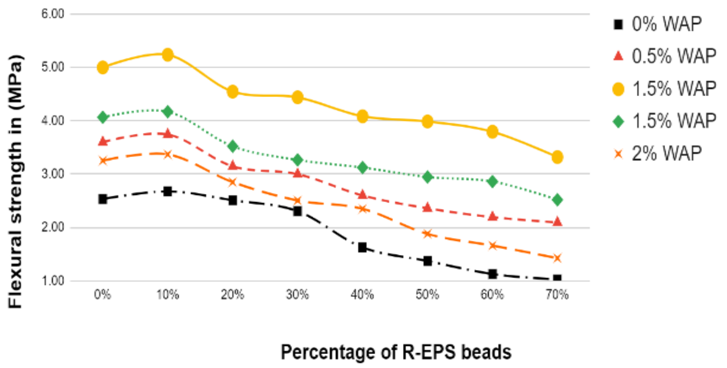


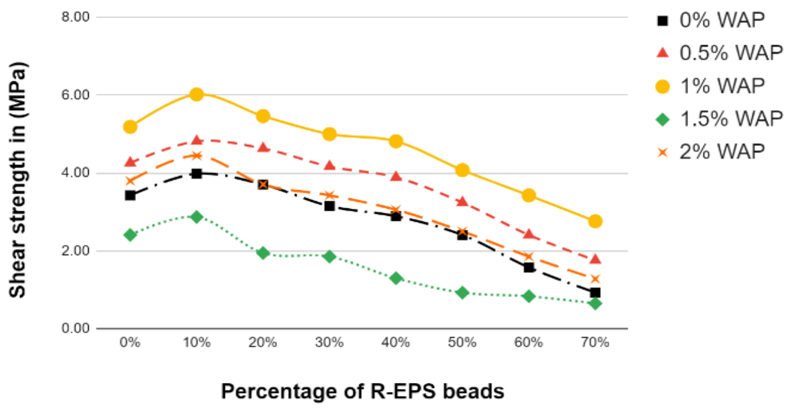
Fig 3 Variation of flexural strength.

1.4. Shear strength test results of lightweight concrete produced by using recycled-expanded polystyrene beads and waste aluminium powder.

Table 4 Results of shear strength

Percentage of R-EPS beads	Shear strength (MPa) of light weight concrete when cement is replaced by waste aluminium powder in diffrenet percentages				
	0% replacement	0.5% replacement	1% replacement	1.5% replacement	2% replacement
0% (Reference mix)	3.43	4.26	5.19	3.80	2.41
10%	3.98	4.81	6.02	4.44	2.87
20%	3.70	4.63	5.46	3.70	1.94
30%	3.15	4.17	5.00	3.43	1.85
40%	2.89	3.89	4.81	3.06	1.30
50%	2.41	3.24	4.07	2.50	0.93
60%	1.57	2.41	3.43	1.85	0.83
70%	0.93	1.76	2.76	1.28	0.65

Fig 4 Variation of shear strength.



5. OBSERVATIONS AND DISCUSSIONS

The following observations are made with the experimental results on light-weight concrete produced by using recycled expanded polystyrene beads and waste aluminium powder.

1. It is observed from table 1 that the compressive strength of light-weight concrete produced by replacing sand by using recycled expanded polystyrene beads reaches a higher value at 10% replacement, After 10% the comprehensive strength starts decreasing. This is true for all the percentage replacement of cement by waste aluminium powder in different percentages such as 0%, 0.5%, 1%, 1.5% and 2%.

   This may be due to the fact that the 10% replacement of sand by recycled expanded polystyrene beads, may result in good bonding with recycled expanded polystyrene beads. A higher replacement level may result in poor bonding between the cement matrix and recycled expanded polystyrene beads.

   Thus it may be concluded that the compressive strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.

2. It is observed from table 1 that the compressive strength of light-weight concrete produced goes on increasing as the percentage replacement of cement by waste aluminium powder increases and it reaches a peak value at 1% replacement level. After 1% replacement compressive strength starts decreasing. this is true for all the percentage of replacement of sand by recycled expanded polystyrene beads

   This may be due to the fact that 1% replacement of cement by waste aluminium powder may produce homogeneous concrete mass and a uniform microstructure which results in higher compression strength.

   Thus it may be concluded that the compressive strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder, Thereafter compressive strength decreases.

3. It is observed from table 2 that the tensile strength of light-weight concrete produced by replacing sand by using recycled expanded polystyrene beads reaches a higher value at 10% replacement, After 10% the tensile strength starts decreasing. This is true for all the percentage replacement of cement by waste aluminium powder in different percentages such as 0%, 0.5%, 1%, 1.5% and 2%.

   This may be due to the fact that the 10% replacement of sand by recycled expanded polystyrene beads, may result in good bonding with recycled expanded polystyrene beads. A higher replacement level may result in poor bonding between the cement matrix and recycled expanded polystyrene beads.

   Thus it may be concluded that the tensile strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.

4. It is observed from table 2 that the tensile strength of light-weight concrete produced goes on increasing as the percentage replacement of cement by waste aluminium powder increases and it reaches peak value at 1% replacement level. After 1% replacement tensile strength starts decreasing. This is true for all the percentage replacement of sand by recycled expanded polystyrene beads

   This may be due to the fact that 1% replacement of cement by waste aluminium powder may produce homogeneous concrete mass and a uniform microstructure which results in higher tensile strength.

   Thus it may be concluded that the tensile strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder, Thereafter tensile strength decreases.

5. It is observed from table 3 that the flexural strength of light-weight concrete produced by replacing sand by using recycled expanded polystyrene beads reaches a higher value at 10% replacement. After 10% the flexural strength starts decreasing. This is true for all the percentage replacement of cement by waste aluminium powder in different percentages such as 0%, 0.5%, 1%, 1.5% and 2%.

   This may be due to the fact that the 10% replacement of sand by recycled expanded polystyrene beads, may result in good bonding with recycled expanded polystyrene beads. A higher replacement level may result in poor bonding between the cement matrix and recycled expanded polystyrene beads.

   Thus it may be concluded that the flexural strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.

6. It is observed from table 3 that the flexural strength of light-weight concrete produced goes on increasing as the percentage replacement of cement by waste aluminium powder increases and it reaches peak value at 1% replacement level. After 1% replacement flexural strength starts decreasing. This is true for all the percentage replacement of sand by recycled expanded polystyrene beads

   This may be due to the fact that 1% replacement of cement by waste aluminium powder may produce homogeneous concrete mass and a uniform microstructure which results in higher flexural strength.

   Thus it may be concluded that the flexural strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder, Thereafter flexural strength decreases.

7. It is observed from table 4 that the shear strength of light-weight concrete produced by replacing sand by using recycled expanded polystyrene beads reaches a higher value at 10% replacement. After 10% the shear strength starts decreasing. This is true for all the percentage replacement of cement by waste aluminium powder in different percentages such as 0%, 0.5%, 1%, 1.5% and 2%.

   This may be due to the fact that the 10% replacement of sand by recycled expanded polystyrene beads, may result in good bonding with recycled expanded polystyrene beads. A higher replacement level may result in poor bonding between the cement matrix and recycled expanded polystyrene beads.

   Thus it may be concluded that the shear strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.

8. It is observed from table 4 that the shear strength of light-weight concrete produced goes on increasing as the percentage replacement of cement by waste aluminium powder increases and it reaches peak value at 1% replacement level. After 1% replacement shear strength starts decreasing. This is true for all the percentage replacement of sand by recycled expanded polystyrene beads

   This may be due to the fact that 1% replacement of cement by waste aluminium powder may produce homogeneous concrete mass and a uniform microstructure which results in higher shear strength.

Thus it may be concluded that the shear strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder, Thereafter shear strength decreases.

6. CONCLUSIONS

The following conclusions are drawn based on the experimentation conducted on the properties of light-weight concrete produced by using recycled expanded polystyrene beads and waste aluminium powder.

- The compressive strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.
- The compressive strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder. Thereafter compressive strength decreases.
- The tensile strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.
- The tensile strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder. Thereafter tensile strength decreases.
- The flexural strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.
- The flexural strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder. Thereafter flexural strength decreases.
- The shear strength of light-weight concrete produced by replacing sand with recycled expanded polystyrene beads reaches the peak value at 10% replacement level.
- The shear strength of light-weight concrete goes on increasing up to 1% replacement of cement by waste aluminium powder. Thereafter shear strength decreases.

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