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Research Article

Development and Evaluation of Lightweight and Floating Concrete Using Pumice Stones and EPS Beads: A Comparative Study

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Abstract **–** The advancement in employing Light Weight Concrete (LWC) for structural and non-structural purposes have enhanced in the recent decades. However, there are reservations when it comes to comparing material cost with load bearing capacity. This study deals with the development of lightweight concrete using inexpensive lightweight aggregate namely as Pumice Stones and EPS Beads. Lightweight aggregate plays a crucial role in construction by reducing the dead weight of the structures, improving thermal insulation and durability in harsh conditions by using light weight components. In this study, EPS beads are utilized to lessen the density of concrete and increase buoyancy, enabling it to float, though lowering its compressive strength while simultaneously recording its effect on strength and density. This analysis will help practitioners gain deeper understanding to improve their mix design to suit specific purposes.

Keywords – Lightweight concrete, Pumice stones, EPS beads, Light weight aggregate, strength

I. Introduction

Light weight concrete has gained widespread use due its particular advantage of reducing dead load and providing thermal insulation. However, achieving a balance ratio between density reduction and mechanical strength still proves to be challenge. This research aims to use EPS beads and pumice stones in place of light weight aggregate in order to investigate the trade-off between density reduction and strength.

II. Literature Review

Creating an enhanced mix design to achieve lightweight and floating concrete has been widely studied throughout the decades; however, the challenge that is encountered is balancing density and sufficient strength. Reference [1] used pumice stones as coarse aggregate, which significantly reduced the weight and density of concrete. A foaming agent was used for air entraining, and crushed pumice sand was used as fine aggregate. Results show that floating concrete can be made using the above materials, achieving substantial strength, which can be used for non-structural purposes as well as for heat and sound insulation. However, the study does not demonstrate the performance of concrete when exposed to harsh environmental conditions.

The sound and heat insulation properties were further analyzed by [2], who used Thermocol (EPS) and soap solution to create floating concrete, emphasizing its thermal and sound insulation properties. The study produced significant results; however, the focus of the study was shifted from bonding between the matrix and mechanical properties.

The study of [3] proposes that replacing part of conventional aggregate with EPS significantly reduces the density; however, the strength is greatly impacted. This is the critical problem in the production of lightweight concrete. The same is stressed upon by [4], who further explored the use of EPS beads in combination with fly ash and silica fume. Their results also suggested that using these materials in the conventional mix did not meet strength requirements for load-bearing structures. The findings of our study are further highlighted by [5], where the properties of lightweight concrete are discussed, emphasizing the importance of aggregate selection in achieving desired density and strength. Thus, using pumice and EPS beads will lower density; however, it would decrease the compressive strength as well. Reference [6] discusses the microstructure of lightweight concrete and how the bonding between cement and lightweight aggregates like EPS beads can be weak, leading to reduced strength. This is particularly relevant to our findings, where the weak bond between cement and EPS beads resulted in lower compressive strength. Reference [7] found that the use of high-strength lightweight aggregates can improve the mechanical properties of lightweight concrete. However, they also noted that the cost and availability of such aggregates can be a limiting factor, which is why materials like pumice and EPS beads are often preferred. Reference [8] examined the effect of different aggregates on the properties of lightweight concrete. They found that pumice stones, due to their porous nature, provide good thermal insulation but can also lead to higher water absorption, which can affect the durability of the concrete. This is an important consideration for our study, as we used pumice stones as a primary aggregate. Reference [9] explored the use of volcanic pumice in lightweight concrete. The study found that pumice-based concrete has excellent thermal insulation properties but noted that the compressive strength is generally lower than that of conventional concrete. This aligns with our findings, where the use of pumice stones resulted in a significant reduction in density but also a decrease in compressive strength. Reference [10] investigated the use of recycled materials in lightweight concrete, highlighting the potential of using industrial by-products to enhance sustainability while maintaining structural performance. Similarly, Reference [11] explored the role of nanotechnology in improving the bonding between cement and lightweight aggregates, offering a promising avenue for future research in lightweight concrete development. Reference [12] emphasized the importance of sustainability in construction materials, particularly the use of recycled aggregates in concrete, which can contribute to reducing environmental impact. Reference [13] further advanced this concept by exploring the use of nanotechnology to develop ultra-lightweight concrete, demonstrating that nanomaterials can enhance the mechanical properties and durability of lightweight concrete.

III. METHODOLOGY

The materials used for the preparation of lightweight concrete samples are cement, sand, pumice stone, water and EPS (Expanded Polystyrene beads). Their properties are discussed below.

A. *Cement:*

Ordinary Portland cement (OPC) was used.

Table 1. Property of Ordinary Portland cement

Property	Value
Bulk Density	1440 kg/m³
Initial setting time	30 min
Final setting time	262 min

B. *Aggregates*

Pumice stone was used which is light weight aggregate in nature. The properties of Pumice are given below:

Table 2. Property of Pumice stone

Property	Value
Bulk Density	750 kg/m³
Water Absorption	0.56

C. Sand:

Normal limestone sand is used which is also used in Pakistan construction industry. The bulk density of sand is 1520 kg/m

D. EPS Beads:

It is a white foam plastic material produced from solid beads of polystyrene. It is used for packaging and construction. It is a closed-cell, rigid foam material. It has low thermal conductivity and low moisture absorption.

E. Water:

Water is the key ingredient used for moistening the cement and create binding of all materials.

IV. Results

The key findings are as follows: We have cast samples of cube to find the compressive strength. The results of the study are summarized in Tables 3 to 7, which provide the density and compressive strength of the concrete samples after 7 days of curing. The key findings are as follows: The size of cube is given below:

Cube size: 0.1m x 0.1m x 0.1m

Curing time: 7 days

Sample Ratio: 1: 1.5: 3

Table 3. Properties of Normal Mix

Property	Value
Density(kg/m³)	2400
Compressive strength at 7days (MPa)	13.5

Table 4. Properties of Sample 1

Property	Value
Design Density(kg/m³)	850
Cement(g)	288
Sand(g)	456
Pumice stone(g)	300
EPS beads	1/3 volume of pumice
Wastage	10% of volume
Water(g)	100.8
w/c	0.35
Density(kg/m³)	851
Compressive strength at 7days (MPa)	1.892
Loading rate (MPa/sec)	0.1

Table 5. Properties of Sample 2

Property	Value
Design Density (kg/m³)	900
Cement(g)	261.8
Sand(g)	414.5
Pumice stone(g)	327.3
EPS beads	1/5 volume of pumice
Wastage	10%
Water(g)	93.8
w/c	0.35
Density(kg/m³)	1256
Compressive strength at 7days (MPa)	3.272
Loading rate (MPa/sec)	0.1

Table 6. Properties of Sample 3

Property	Value
Design density(kg/m³)	850
Cement(g)	288
Sand(g)	456
Pumice stone(g)	450
Wastage	10%
Water(g)	100.8
w/c	0.35
Density(kg/m³)	1190
Compressive strength at 7days (MPa)	4.254
Loading rate (MPa/sec)	0.1

Table 7. Buoyancy of samples

Sample NO.	Floating
1	No
2	Yes
3	No
4	No

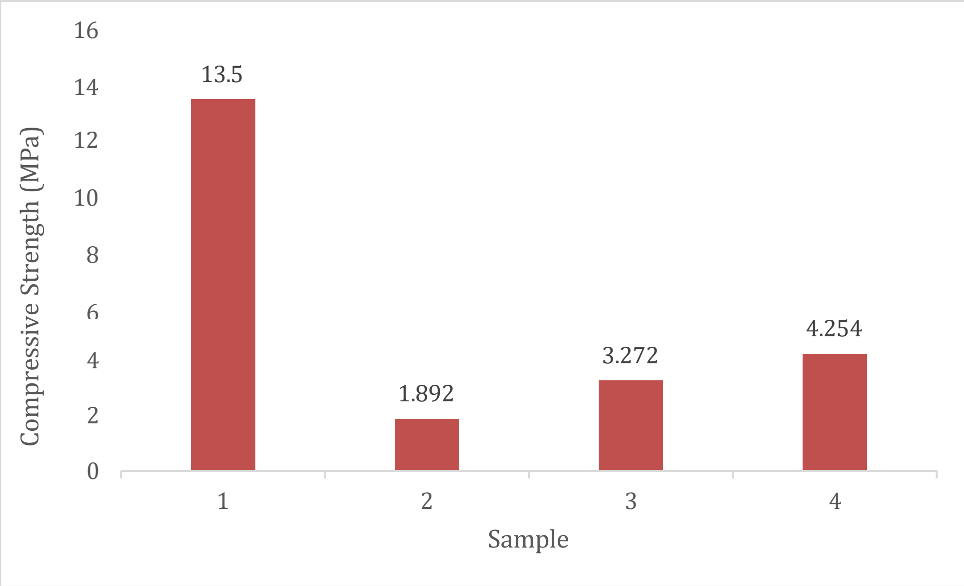

Fig 1. Comparison of compressive strength of samples

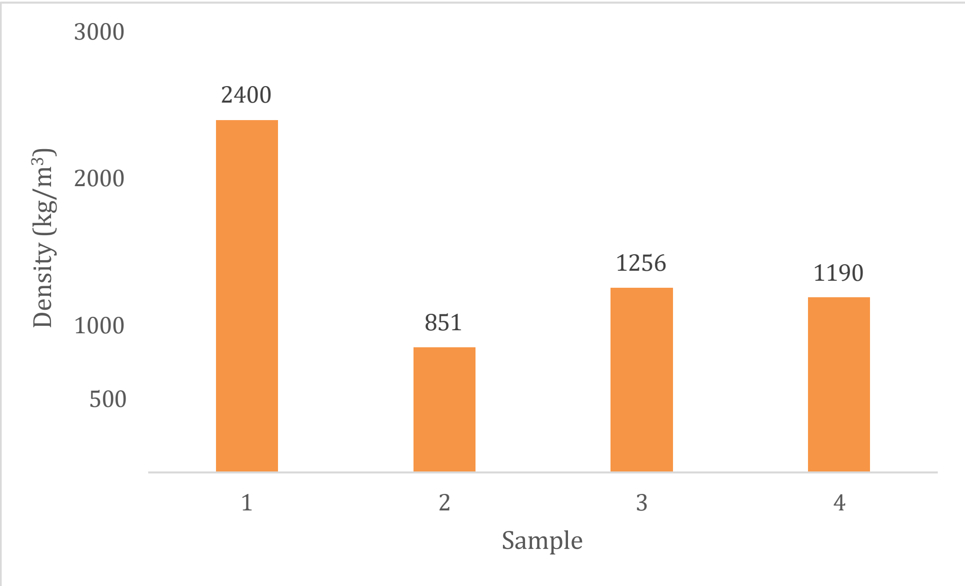

Fig 2. Comparison of density of samples

V. Discussion

The results demonstrate that using EPS beands and pumice stone as aggregate significantly impact strength while reducing density. The properties of sample 2 (851kg/m3) suggest that it can be classified as floating concrete thus be used for bouyant structures such oil and gas platforms or insulation panels. However, the trade-off between density reduction and compressive strength is evident, as Sample 2 exhibited a much lower compressive strength (1.892 MPa) compared to conventional concrete (13.5 MPa). This aligns with previous findings such as those by Khaloo and Dehestani [10] and Mehta and Monteiro [8] which suggests that use of lightweight aggregate compromises the load bearing capacity of the concrete due to weaker bonding between the cement matrix and the aggregates.

In sample 3 the EPS beads were taken by 1/5 volume of pumice stone and the result obtained are density (1256kg/m3) and compressive strength of (3.272 Mpa). The increase in the bonding and strength are a consequence of reducing the amount of EPS beads.

Similarly, in sample 4 completely omitting the use of EPS beads and using only pumice stone showed enhanced compressive strength (4.254 Mpa) and achieved a density of 1190 kg/m3. The mix showed improved bonding within the matrix and hence the improved strength. Our study comprehensively demonstrated that the use of EPS beads proposes challenges such as decreased bonding in the matrix which leads to cracks and voids in the sample as well. Along with impacting the strength of the concrete the proportion of EPS beads also influences the density of the mix. In accordance with prior findings our research confirms that using EPS beads and pumice achieved light weight and floating concrete however structural capacity still remains a limiting factor.

VI. CONCLUSION

This study successfully developed lightweight and floating concrete using pumice stones and EPS beads, achieving significant density reduction while maintaining acceptable compressive strength. The results showed that Sample 2, with a density of 851 kg/m³, could float, but its compressive strength was low (1.892 MPa). Samples 3 and 4, with reduced EPS bead content, achieved higher compressive strengths (3.272 MPa and 4.254 MPa) while remaining lightweight. The findings highlight the trade-off between density reduction and strength, indicating that lightweight concrete is suitable for non-load-bearing applications. Future research should focus on optimizing the mix design and exploring supplementary materials to enhance strength and durability.

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