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A Review on the Effects of Styrofoam Beads in Concrete Block

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Abstract

Expanded polystyrene (EPS) or Styrofoam, a non-biodegradable material, is currently being used as a recyclable material for producing lightweight concrete blocks, which can be used in non-load-bearing walls. Including styrofoam beads in concrete can reduce production costs and reduce carbon footprint. However, the applicability of EPS-incorporated concrete blocks requires the consideration of mechanical properties. Researchers have studied different modes of application of styrofoam in concrete. Tiny beads (diameter of 3mm to 5mm) to a large-sized slice of styrofoam have been used in blocks. Mechanical and physical properties, including compressive strength, unit weight, slump value, and water absorption, have been studied, and relationships with the percentage of beads added to the block have been established. Though the coarse and fine aggregate can be replaced with beads, it requires more investigation. Besides the lack of proper guidelines, different types of applications result in dissimilar observations. Despite disparate results, most of the literature mentions a common trend in compressive strength with the percentage of EPS. Insufficient interaction of EPS with the other constituents in concrete is responsible for lower compressive strength. Furthermore, some studies have been conducted to counteract this tendency using fly ash. This current study overviews EPS concrete blocks' mechanical and physical properties, considering different replacement levels. Furthermore, this study can offer guidance on the forms of EPS beads' application in concrete and help develop a comparison with the existing standard for lightweight masonry units considering mechanical strength.

Keywords: *Styrofoam; EPS beads; Compressive strength; Light-weight; Concrete block.*

1 Introduction

Concrete is a broadly used manmade material (Alexandre et al., 2014). Different experiments have been conducted worldwide to investigate its mechanical properties due to its wide use. Usually, the weight of normal-weight concrete varies around 2200 kg/m^3. Lightweight concrete is an easier approach to reduce the self-weight of construction materials and draw economic benefits. Moreover, the impact on the environment can be minimized to some extent if waste materials with the required quality and potential can be incorporated with concrete and used in places where the high strength of conventional concrete is not needed (Torelli et al., 2020; Fang et al., 2022). Styrofoam or EPS (expanded polystyrene) is extensively used in packaging different products and has a significant percentage of waste contribution. EPS is the only polymeric foam with no cancer-causing agent like formaldehyde (Horvath, 1994). Cook (1972) first introduced concrete having EPS beads as lightweight aggregates. EPS has 98% of air (Sarmiento et al., 2016) in its closed cellular structure; hence, it can easily be used to produce lightweight cement-based material. The density of EPS beads ranges from 12 to 35 kg/m^3 (Assaadet et al., 2018; Lakshmikandhan, 2017; Haghi, 2006). Using different forms of styrofoam as aggregates, lightweight concrete can be cast. Moreover, EPS is considered economical compared to aggregates, and as a replacement will result in the production of green material (Fang et al., 2022). According to ACI (2014), lightweight concrete possesses a density value of 1350 to 1900 kg/m^3 and a compressive strength greater than 17 MPa. This paper reviews the mechanical and physical properties of concrete with Styrofoam. This study can help suggest guidance on applying EPS beads in concrete from the perspective of several research articles.

2 Mix Proportion and Compressive Strength

Most researchers replaced aggregates with EPS beads at different replacement percentages to reduce the weight, enhance insulating properties, and observe the mechanical properties. EPS content replacing from 0%, 25%, 50%, and 75%–100% of aggregate by volume has been explored in different articles. The density of lightweight concrete with EPS varies from 980 kg/m^3 to 2025 kg/m^3 without considerable segregation (Prasittisopin et al., 2022). Table 1 shows different replacement levels of aggregates (both fine and coarse) with EPS content.

Table 1. EPS as a replacement of fine and coarse aggregate at different percentages

Aggregate Type	Replacement Level	Compressive Strength at 28 days (MPa)	Density (kg/m^3)	Reference
Fine	0 – 26%	2.4–9.5	957–2119	Ali et al., 2020
	0 – 60%	1.0–45.6	1110–1280	Ferrandiz-Maz et al., 2014
	0 – 100%	3.8–11.41	1200–2100	Khatib et al., 2019
Coarse	0 – 20%	17.7–19.7	1813–2420	Topacio and Marcos, 2018
	21 – 36%	10.0–21.0	1500–2000	Babu et al., 2006
	40 – 60%	12.0	800–1300	Perry et al., 1991

Herki (2017) made a composite aggregate where 80% waste shredded polystyrene of different sizes was used with 10% natural additives and 10% Portland cement. Fine aggregate was replaced with 0%, 30%, 60%, and 100% of the composite aggregate by volume. Patel et al. (2017) conducted a similar study where 0%, 20%, 40%, 80%, and 100% aggregates were replaced with Styrofoam by weight. 150 mm cube sample was prepared. Tayal et al. (2004) conducted research where 15 cm cubes were prepared. Coarse aggregate was replaced with EPS beads and binder: FA: CA was maintained as 1.87: 2.34: 3.45. Styrofoam food containers were used in another study (Ismail et al., 2021). Here both the coarse and fine aggregates were replaced. A water-cement ratio of 0.5 and 150mm cubes are used. Cement: CA: FA ratio used here is 38:114:57. At different replacement percentages, 28 days of compressive strength observed from the experiments is depicted in Figure 1.

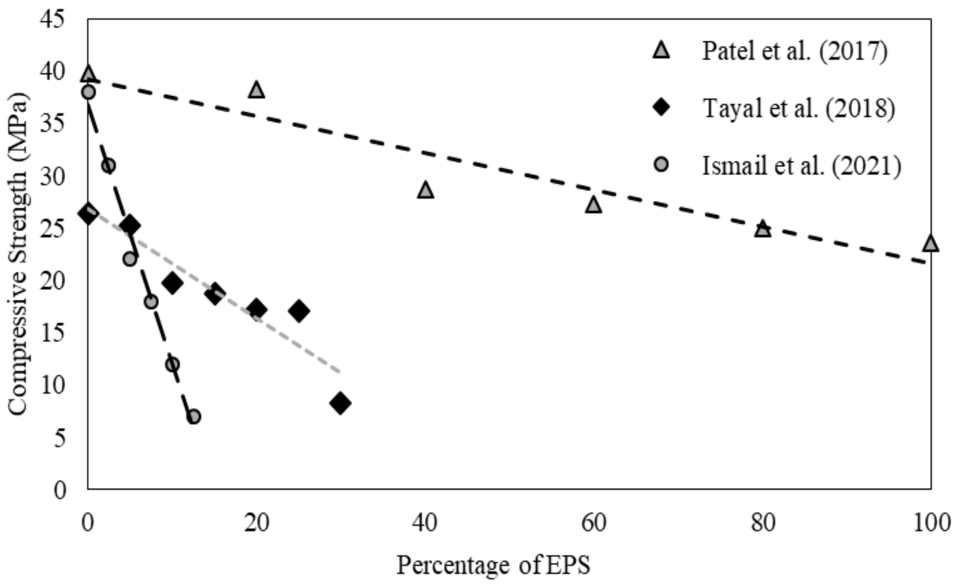

Figure 1. Effect of different percentages of EPS on the compressive strength of the concrete block

3 Water Absorption

Water absorption of Styrofoam-incorporated concrete specimens increases with the increase of Styrofoam content (Herki & Khatib, 2013; Ismail et al., 2021; Herki, 2017; Wibowo, 2021; Solikin & Ikhsan, 2018; Solikin et al., 2019). Styrofoam itself is a nonabsorbent material (Herki, 2017), yet this occurs due to its failure to make a strong bond with the surrounding material in the matrix and results in cavities (Herki, 2017; Wibowo, 2021). Hence, the total void distributed in Styrofoam-embedded concrete and water absorption increases (Ismail et al., 2021; Solikin & Ikhsan, 2018). Depending on the water-cement ratio, type of aggregate replaced, percentage of replacement, pretreatment applied of Styrofoam, and the number of days of curing, water absorption varied within a long range of 1.5 to 42.8%, summarized in Table 1.

Table 1: Water absorption capacity and percentage of EPS

References	Types of aggregate replaced	w/c ratio	Percentage of Replacement	Range of Percentage of Water Absorption
Herki and Khatib, 2013	CA and FA	0.6	30	10.5~32
			60	
			100	
Ismail et al., 2021	CA and FA	0.5	2.5	1.5~3.8
			5	
			7.5	
			10	
			12.5	
Herki, 2017	Natural Aggregate (Lime)	0.6	30	9.7~42.8
			60	
			100	
		0.8	30	
			60	
			100	
		1	30	
			60	
			100	
Wibowo, 2021	CA and FA	0.23	20	3.17~5.26
			40	
			60	
			80	
Solikin and Ikhsan, 2018	CA and FA	0.38	30	-
			40	
			50	
Solikin et al., 2019	CA and FA	0.5	60	7.53~10.88
			70	
			80	

Studies on capillary water absorption (CWA) show similar trends to water absorption, and the reason behind this is also similar (Herki & Khatib, 2013; Herki, 2017). Water absorption by capillary action occurs faster within the first 30 minutes than at later stages. In addition, the later study established a relation between CWA and water cement (w/c) ratio and CWA and days curing. For constant w/c ratio, final CWA for specimens with curing periods of 1 day, 7 days, and 28 days do not show much variation. However, after a curing period of 360 days, the CWA of the specimens decreases significantly, which implies larger curing time tends to retard CWA action. On the other hand, for a constant curing period, CWA tends to increase with the increment of the w/c ratio, which implies a proportional relation between CWA and w/c ratio at a constant curing period (Herki, 2017).

4 Dry Density

In all the experiments conducted by Wang et al., 2019, Patel et al., 2017, Tayal et al., 2018 and Ismail et al., 2021, it has been established that the density of the concrete block decreases as the percentage of EPS is stepped up in the specimen. The effect of different percentages of Styrofoam beads on the density of concrete specimens is shown in Figure 2.

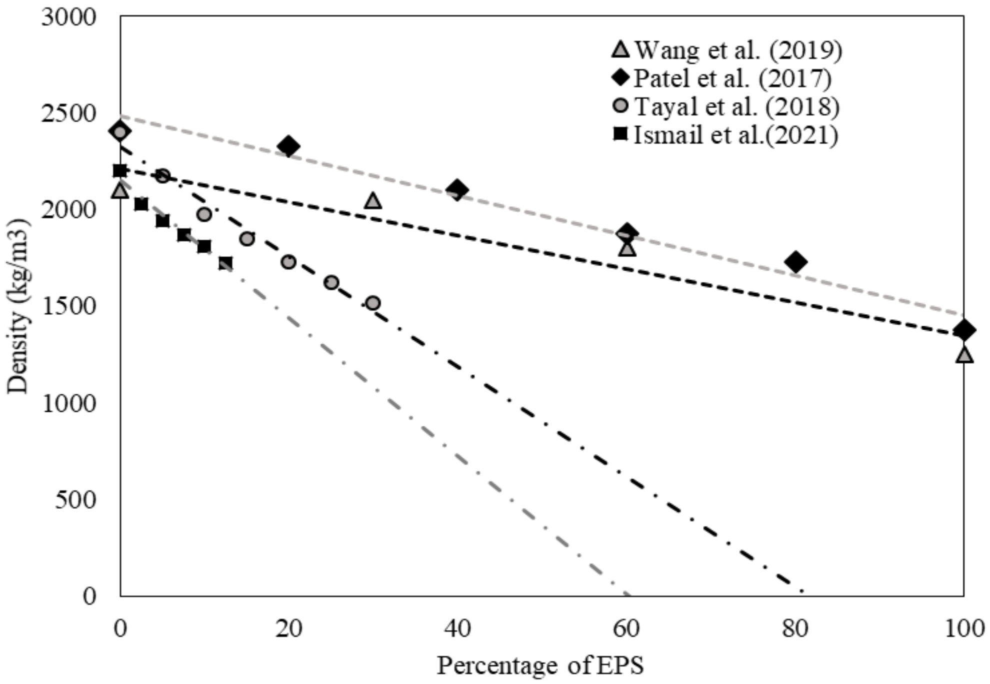

Figure 2: Relationship between Density and percentage of EPS in concrete block

5 Conclusion

The current review of Styrofoam-incorporated concrete blocks discusses some physical and mechanical properties and trends in their variation concerning changes in styrofoam percentage. The highlights of the publications discussed are as follows:

- Water absorption increases with the increment of styrofoam doses in the concrete block due to the bonding mechanism and consequent void percentage in the matrix.
- Styrofoam is a lighter material, and hence the dry density of produced concrete blocks decreases with the addition of it.
- The compressive strength of styrofoam concrete blocks decreases drastically with the increment of styrofoam percentage depending on the w/c ratio and types of aggregate.

Styrofoam concrete blocks enable utilizing Styrofoam-containing waste by offering lighter-weight structures with reasonable strength. Development of standards for styrofoam incorporation is required to bring the utilization up front. Moreover, research on the improvement of mechanical properties of such a mix can help provide an efficient way to use Styrofoam as a construction material. To decelerate the adverse effect of waste styrofoam as a non-biodegradable polymer on nature, it is advisable to use it in construction industries in this era of sustainability.

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