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The Performance of Plastic Bubble Wrap (PBW) as Coarse Aggregate

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Abstract

This research investigates the effects of incorporating plastic bubble wrap (PBW) as a replacement for traditional coarse aggregates in concrete mixtures. The study aims to assess how this unconventional material influences both the compressive strength and density of the resulting concrete. The experimental approach involves varying percentages of PBW substitution for coarse aggregates in concrete mix designs. Compressive strength tests are conducted on standard cubes, while density measurements are taken to evaluate the structural and mass properties of the concrete. Preliminary findings indicate that the inclusion of PBW has a noticeable impact on both compressive strength and density. The results suggest potential benefits in terms of reduced weight and enhanced insulation properties, which may have implications for certain construction applications. This research contributes to the ongoing exploration of alternative materials in concrete production, offering insights into the feasibility and performance of plastic bubble wrap as a substitute for conventional coarse aggregates. The outcomes of this study may have implications for sustainable construction practices and the utilization of recycled materials in the concrete industry. Further analysis and exploration of the long-term durability and structural characteristics of such concrete formulations are recommended for a comprehensive understanding of their practical applicability.

1. Introduction

Plastic waste is a big problem for the environment. It harms ecosystems and human health. The disposal of such waste causes poor soil fertility, emission of toxic gases, poor drainage due to landfill, pollution of groundwater due to leaching of chemicals from these waste products [1]. Researchers are looking for ways to reduce this problem. One promising idea is to use plastic waste in construction materials. Traditional recycling involves sorting, cleaning, and melting plastic to make new products [2]. However, using plastic waste in construction can be even more beneficial. Recycled aggregates are made from construction waste like concrete and bricks. Adding plastic waste to these materials can improve their quality and make them more useful in building projects. Plastics like high-density polyethylene (HDPE) and low-density polyethylene (LDPE) [3] can replace some of the usual materials in concrete, roads, and building foundations. Research shows that plastic waste can make concrete more durable, better insulated, and more flexible while making it lighter. This reduces the need for traditional materials and lowers environmental impact. However, there are challenges. The plastic waste must be sorted, cleaned, and processed correctly to ensure it is safe and effective. We also need to understand how these materials perform over time and their environmental effects. This review will gather current research and progress on using plastic waste in construction. It will look at the technical, environmental, and economic aspects to see how feasible and beneficial this approach is. Online shopping has led to a big increase in the use of bubble wrap and plastic packaging. E-commerce uses more plastic packaging than traditional stores, creating a lot of plastic waste. In 2019, the e-commerce industry used about 1 million tons of plastic for packaging [4]. This study aims to find ways to reduce plastic waste from e-commerce packaging. By exploring sustainable alternatives, it will help promote eco-friendly practices and lessen the environmental impact of packaging materials.

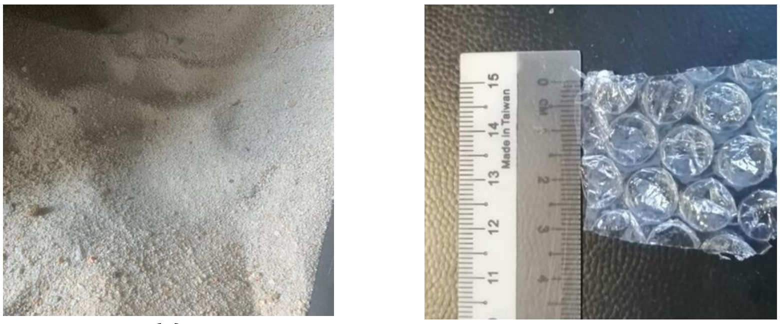
In this study, low-density polyethylene (LDPE), the most widely used material for non-consumer packaging and agricultural applications [5], is used as plastic bubble wrap to replace coarse aggregate in concrete mixes as an additive. There are biodegradable substitutes for bubble wrap, however they are more expensive and limited [6]. The objectives of this research are to observe and investigate the performance of PBW aggregate in concrete, using various percentages. Therefore, substituting normal coarse aggregate for plastic aggregate in concrete will reduce the pressure to produce more concrete at the price of pollution to the environment [7]. Its incorporation into concrete mixtures involves shredding the bubble wrap into small pieces, which act as voids within the concrete matrix, thereby decreasing overall weight without compromising strength. This innovative approach not only addresses environmental concerns by repurposing plastic waste but also offers benefits such as improved thermal insulation and reduced construction material weight. However, challenges related to achieving optimal bonding between the plastic particles and cementitious matrix, as well as potential effects on concrete's long-term durability and performance under various conditions, warrant further investigation. Nonetheless, the exploration of plastic bubble wrap as a coarse aggregate signifies a promising step towards sustainable construction practices and the repurposing of plastic waste in the building industry.

2. Materials and Methods

2.1 Materials

In this study Ordinary Portland Cement (OPC) grade 43 was used as the raw material source for this experiment. It has an extremely high specific gravity of 3.12. OPC is appropriate for a variety of applications and hardens at a medium rate. Regarding structural applications, BS 12:1971 provides the broadest backing for this one. OPC settings typically require a minimum of 30minutes and a maximum of 600 minutes. OPC concrete cubes have minimum compressive strengths of 13 N/mm2 for three days and 29 N/mm2 for 28days, as per BS 4550. The study's concrete mixing material, as seen in Figure 1. The nominal dimensions of the coarse aggregates utilized in this study are 20 mm, their specific gravity is 2.47 mm, and their water absorption is 0.5 percent, respectively. Sand's specific gravity of 2.63 and its 1% water absorption rate make it an excellent choice for fine aggregate. The five millimeter-sized fine aggregate used in the concrete was made from natural sand that had been filtered to minimize its size. PBW aggregate was extracted from raw plastic bubble wrap. For this study, the plastic bubble wrap aggregate used did not go through any treatment due to several factors. The lack of facilities such as machines to burn and cut bubble wrap into solid coarse aggregate fragments. The additional material was used in different percentages (1%, 3% and 5%) at length at average 20mm – 30mm.

(a) (b)



(c) **(d)**

Fig. 1 *(a) Ordinary Portland Cement; (b) Coarse Aggregate, (c) Sand, (d) Shredded Plastic Bubble Wrap*

2.2 Method

This chapter outlines a systematic approach using various experimental methods to compare plastic bubble wrap (PBW) aggregates with conventional aggregates, conducted at the Concrete Technology Laboratory (FTK). The study aims to provide data on the structural, environmental, and economic impacts of using PBW as a coarse aggregate. Key factors considered include the size, shape, and proportion of PBW in the material, the effects of different binding agents, and manufacturing processes on performance. By evaluating the practical applications and limitations of using PBW in construction, this research aims to offer valuable insights that could lead to more sustainable construction practices and reduce the environmental impact of traditional aggregates. The proposed mix's workability according to tests for compressive strength and slump conducted at the Concrete Technology Laboratory. After being cured for twenty-eight days, the ready-to-use concrete cubes for sample preparation were subjected to conventional testing procedures, including density and compressive strength measurements. The methodical process flow chart is displayed in Figure 2.

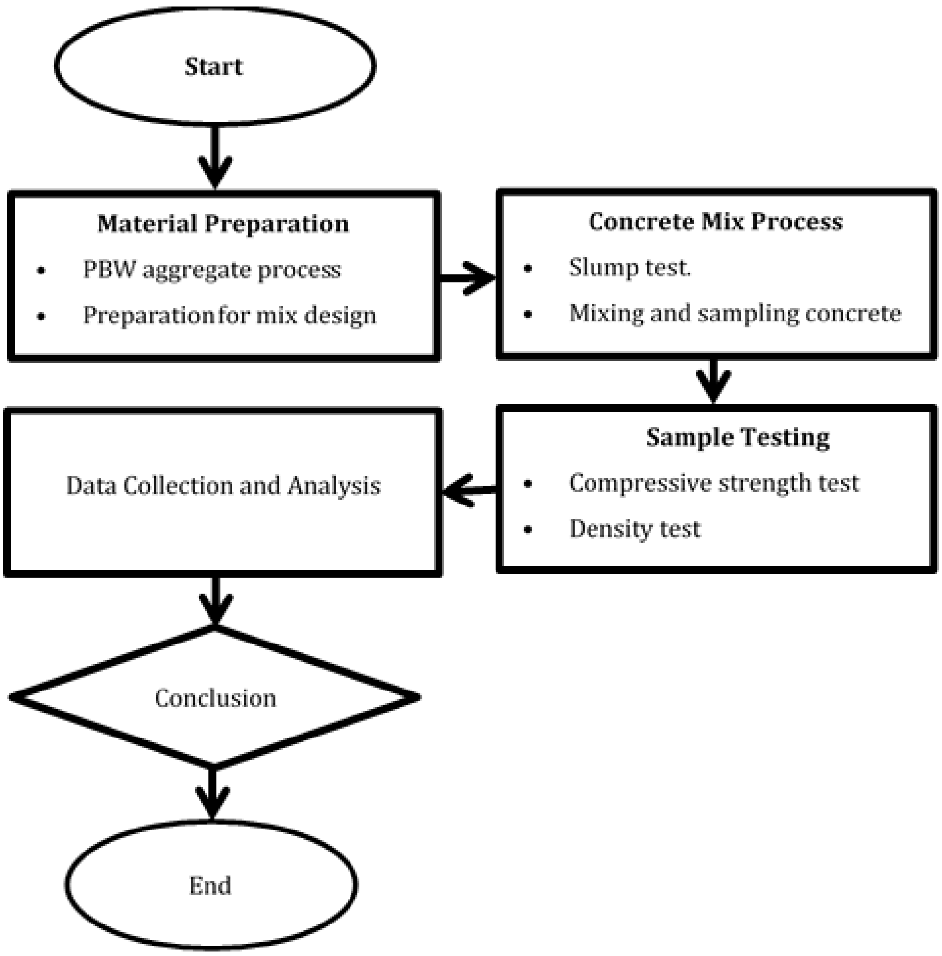


Fig. 2 The procedure flow chart for the methodology

2.1.1 Concrete Mix Design

A cube mold measuring 100 mm by 100 mm by 100 mm is used to create cube-shaped concrete; gather all the ingredients required to create three cubes of concrete for every percent.

Table 1 Concrete Mix Design

No	Percentage of PBW replacement (%)	w/c	Cement (kg)	Water (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	PBW aggregate made from Bubble wrap (kg)
1	0	0.5	0.96	0.48	1.74	4.25	0
2	1	0.5	0.96	0.48	1.74	4.207	0.043
3	3	0.5	0.96	0.48	1.74	4.122	0.128
4	5	0.5	0.96	0.48	1.74	4.037	0.213

Table 1 displays the mass of water, cement, fine and coarse aggregate. Table 1 also shows PBW aggregate used in concrete in place of coarse aggregate.

3. Results and Discussion

3.1 Slump Test

Table 2 lists the result of fresh concrete mixes. The reference mix's expected slump and water to cement ratio (w/c) are both 0.5. The concrete mixture's workability did not significantly change. The mixes became more harder as the proportion of natural aggregates was reduced. This is because, in comparison to conventional aggregates, PBW aggregates have a lower absorption rate and more free water.

Table 2 Result of Slump Test

Percentage of PBW replacement (%)	w/c
0	0.5
1	0.5
3	0.5
5	0.5

The slump value for sample concrete was 113mm, which indicates great workability, according to Table 2. The fresh concrete slump value increased as the proportions of PBW aggregates increased. The slump value upon the replacement of 1% PBW aggregates was measured to be 60mm, indicating a medium degree of workability. The slump values decreased to 23 mm and 2 mm, respectively, after 3% and 5% substitution of PBW aggregates extremely poor workability. As the quantity of PBW aggregates rises, the slump value falls. This is due to the fact that PBW aggregates will alter the water cement ratio and do not absorb more water than regular coarse aggregates. As a result, the concrete's workability will somewhat decrease.

3.2 Density

Since PBW aggregates are lighter than conventional coarse aggregates, the density of the concrete dropped. This can lead to a less dense concrete mixture overall. Table 3 shows the density value decreased when more PBW aggregates were used.

Table 2 Result of Density Test

Percentage of PBW replacement (%)	Weight (kg)	Density (kg/m^3)	Average Density (kg/m^3)
	2.15	2150	
0	2.20	2200	2190
	2.22	2220	
	1,95	1950	
1	1.93	1930	1920
	1.88	1880	
	1.60	1600	
3	1.66	1660	1633
	1.64	1640	
	1.45	1450	
5	1.50	1500	1480
	1.49	1490	

As replacement aggregate was added, the density of the concrete mixtures steadily dropped. The average density of the concrete cubes in the sample was 2190 kg/m^3. The average density of the concrete cubes at 1% substitution of PBW aggregate is 1920 kg/m^3. The average density of concrete cubes decreased to 1633 kg/m^3 and 1480 kg/m^3 when the substitution of PBW aggregates reached 3 and 5 percent. Since the replacement mix has a density of no more than 1850 kg/m3, it qualifies as lightweight concrete.

3.3 Compressive Strength

When compared to sample concrete mixes using conventional aggregates like crushed stone or gravel, the use of plastic bubble wrap as coarse aggregate may result in a decrease in compressive strength. The flexible substance may not make as strong of a link with the surrounding concrete matrix as regular aggregates do. Reduced compressive strength can be attributed to this poorer interfacial binding. Table 3 shows the result of compressive strength test on concrete containing PBW aggregates at 28 days.

Table 2 Result of Compressive Strength Test

Percentage of PBW replacement (%)	Load (kN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
	384.9	38.49	39.67
0	403.3	40.33	
	400.2	40.02	
	79.4	7.94	7.73
1	87.7	8.77	
	65.0	6.50	
	32.5	3.25	3.20
3	28.1	2.81	
	35.6	3.56	
	10.2	1.02	
5	12.9	1.29	1.15
	11.5	1.15	

The concrete sample had a total compressive strength rating of 39.67 MPa, according to the test results. The compressive strength of concrete has changed significantly when PBW aggregates are added. The compressive strength value of concrete decreases with each percentage increase of PBW aggregates. The poor connection between the cement and PBW aggregates is what caused this to occur. Cement paste usually cannot bond well with plastics. There may be weak spots in the concrete as a result of the plastic particles' weak attachment to the cement matrix, which lowers the concrete's overall strength.

4. Conclusion

This study tested the strength characteristics of concrete prepared with increasing proportions of plastic bubble wrap (PBW) aggregates in place of coarse aggregate using various concrete testing methods. The mix designs tested included a control mix and mixes with 1%, 3%, and 5% PBW replacement by volume. Three tests were carried out: compressive strength, density, and slump, with the compressive strength test conducted at 28 days.

The research concluded that the shape and texture of PBW aggregates can disrupt the flowability of concrete. The angular plastic particles interlock, increasing internal friction within the mix and lowering the slump value. Additionally, PBW aggregates increase air entrainment within the concrete mix due to their shape and surface properties, leading to a lower density. Finally, cement paste and plastics typically fail to bond effectively. Unlike traditional aggregates with rough surfaces that form a strong bond with the cement matrix, the smooth, non-absorbent surfaces of plastic particles result in poor bonding and create weak spots in the concrete.

5. Recommendation

The use of plastic bubble wrap (PBW) aggregates in concrete represents an encouraging approach to environmentally friendly building, addressing resource conservation and waste management issues. However, this investigation has highlighted several significant problems with the current application of PBW aggregates, such as poor bonding with the cement matrix, reduced workability, and increased air content. To improve the material qualities for wider application in construction, targeted suggestions have been developed with the goal of enhancing the performance and usability of PBW aggregate concrete.

One suggestion is to optimize aggregate preparation to improve PBW aggregates. The lack of facilities like crusher machines makes it challenging for researchers to prepare better materials. Adjusting the shape of PBW aggregates is also vital for better bonding with cement. Methods such as granulation or controlled shredding can produce more rounded particles, enhancing flowability and reducing internal friction. Additionally, promoting recycling centers to develop processes for creating plastic and other recycled aggregates can help meet the demand from the structural engineering industry [8].

References

[1] Utilization of Waste Plastic and Waste Glass Together as Fine and Coarse Aggregate in Concrete. (2020). Eurasian Journal of Science and Engineering, 6(2). https://doi.org/10.23918/eajse.v6i2p1

[2] Costello, L., & Kramer, K. (n.d.). Extruded recycled plastic as a partial coarse aggregate in concrete. Retrieved June 3, 2024, from https://krex.k-state.edu/server/api/core/bitstreams/75932cad-1c13-4f00-87b8-54b89d5f9292/content.

[3] Noriya, P., Dwivedi, P., & Scholar, P. (2021). Experimental Investigation of Concrete Utilizing Plastic Waste HDPE and LDPE as a Replacement of Aggregate in Concrete A Review. International Journal of Scientific Research in Civil Engineering © 2021 | IJSRCE |, 5, 2456–6667. https://ijsrce.com/paper/IJSRCE21558.pdf

[4] Hub, Iisd. S. K. (n.d.). Guest Article: Addressing Plastic Packaging Waste in E-commerce Retail | SDG Knowledge Hub | IISD. https://sdg.iisd.org/commentary/guest-articles/addressing-plastic-packaging-waste-in-e-commerce-retail/

[5] ELECTRONIC PEER-REVIEWED JOURNAL ON ALL TOPICS OF INDUSTRIAL AND MUNICIPAL ECOLOGY RECENZOVANÝ ČASOPIS PRO VÝSLEDKY VÝZKUMU A VÝVOJE Z OBLASTI PRŮMYSLOVÉ A KOMUNÁLNÍ EKOLOGIE YEAR 2018 No. 4 Pages 407 -571. (n.d.). Retrieved June 7, 2024, from https://www.wasteforum.cz/cisla/WF_4_2018.pdf#page=87.

[6] View of Evaluating Bubble Wrap and Proposing Post-consumer Textile Waste as Alternative Material: A review. (2024). Ijibs.utm.my. https://ijibs.utm.my/index.php/ijibs/article/view/124/100.

[7] Md. Jahidul Islam. (2022). Comparative Study of Concrete with Polypropylene and Polyethylene Terephthalate Waste Plastic as Partial Replacement of Coarse Aggregate. Advances in Civil Engineering, 2022, 1–13. https://doi.org/10.1155/2022/4928065

[8] Costello, L., & Kramer, K. (n.d.). Extruded recycled plastic as a partial coarse aggregate in concrete. https://krex.k-state.edu/server/api/core/bitstreams/75932cad-1c13-4f00-87b8-54b89d5f9292/content