International Journal of Research in Vocational Studies (IJRVOCAS)
Vol. 5, No. 4, January 2026, pp. 69~74
Print ISSN 2777-0168| Online ISSN 2777-0141| DOI prefix: 10.53893
https://journal.gpp.or.id/index.php/ijrvocas/index

The Use of Expanded Polystyrene (EPS) Waste on the Compressive Strength of Concrete Using Fiber Reinforced Polymer (FRP)

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To cite this article:
Rasendriya, S., Effendi, R., Setiawan, R., & Purnama, I. A. (2026). The Use of Expanded Polystyrene (EPS) Waste on the Compressive Strength of Concrete Using Fiber Reinforced Polymer (FRP). *International Journal of Research in Vocational Studies (IJRVOCAS), 5(4), 69–74. https://doi.org/10.53893/ijrvocas.v5i4.263.*

Received: 10 19, 2025; **Revised**: 11 24, 2025; **Accepted**: 12 18, 2025; **Published**: 01 30, 2026

Abstract: The increase in restaurants and online food ordering can increase waste or waste made from Expanded Polystyrene (EPS). Expanded Polystyrene (EPS) can be used as an additive to concrete because it has properties that are difficult to decompose naturally. Along with the development of the times, many innovations have sprung up in the world of construction to increase the strength of structures. The reinforcement of concrete is done by providing alternative materials that are quite popular, namely Fiber Reinforced Polymer (FRP). This study was conducted to determine the physical properties, mechanical properties of concrete, and the percentage of the use of the most optimum additives that will be applied to the foundation structure using additional materials in the form of Expanded Polystyrene (EPS) with variations of 0%, 1%, 1.5%, 2%, and 2.5% and a layer of Fiber Reinforced Polymer (FRP) as much as 1 layer which will be tested compressively, by looking at the effect of two types of water for curing, namely peat water and normal water with a planned concrete quality of 21.7 MPa using a cylindrical concrete mold 15 cm in diameter and 30 cm high. Concrete compressive strength tests were conducted at 7 days and 28 days of concrete age. Based on the test results, there is an increase in the highest water absorption of concrete, namely in the 28-day normal water immersion variation of 2% EPS + FRP by 4.05% The addition of Expanded Polystyrene (EPS) and Fiber Reinforced Polymer (FRP) in concrete can increase the highest concrete compressive strength, namely in the 7-day NORMAL water immersion variation 1.5% EPS + FRP by 27.54 MPa. While the highest concrete strength value in peat water immersion for 7 days of normal variation is 27.10 MPa.

Keywords: Expanded Polystyrene (EPS), Fiber Reinforced Polymer (FRP), Concrete, Peat Water

1. Introduction

The increase in restaurants and online food orders will certainly have various impacts, one of which is pollution caused by waste or garbage, both organic and inorganic. According to the 2024 National Waste Management Information System of Pontianak City, West Kalimantan Province, there is a daily waste accumulation of 411.96 tons and an annual accumulation of 150366.28 tons. The above conditions encourage efforts to make better use of waste or garbage by utilizing waste or garbage in the form of beverage containers and food wrappers made from Expanded Polystyrene (EPS) as an additive in concrete because Expanded Polystyrene has properties that make it difficult to decompose naturally.

As time goes by, many innovations have emerged in the world of construction to increase the durability of structures so that they can withstand loads in accordance with their design. The method used to address structural failure issues is to repair the structure [1]. Therefore, infrastructure needs to be considered in order to prioritize the strength and safety of buildings so that they are safe and comfortable to use, especially in the city of Pontianak.

While waste poses some environmental threats, some waste offers potential as lightweight aggregates. Furthermore, modern concrete often requires external reinforcement such as the use of FRP. Structural elements are reinforced to prevent building failure or damage. Concrete reinforcement is carried out by applying a popular alternative material, Fiber Reinforced Polymer (FRP), to the exterior of the concrete using waterproof paint. Fiber Reinforced Polymer (FRP) is used as an alternative material because it has several advantages, namely it is corrosion resistant, lightweight, and quick and easy to apply.

The water used in the concrete treatment and mixing process is generally normal water. However, not all areas have access to normal water. There are several areas in Pontianak, such as Sungai Raya Dalam, that do not have full access to normal water, so sometimes the local community uses ditch water or peat water for concrete work. Peat water is groundwater that is commonly found in swamps, lowlands, and tidal areas. Peat water is characterized by its reddish-brown color, low pH level between 3 and 5, and organic content. The differences in characteristics between peat water and normal water affect the strength of concrete structures.

Based on the background mentioned above, the author chose the title "The Use of Expanded Polystyrene (EPS) Waste on the Compressive Strength of Concrete Using Fiber Reinforced Polymer (FRP)" for his final project. This study aims to determine the physical and mechanical properties of concrete applied to foundation structures using Expanded Polystyrene (EPS) and Fiber Reinforced Polymer (FRP) layers as additives, which will be tested for compressive strength, by observing the effect of two types of water for curing, namely peat water and normal water, and determining the most optimal percentage of Expanded Polystyrene (EPS) and Fiber Reinforced Polymer (FRP) usage.

This research is expected to provide benefits, namely, to develop environmentally friendly building materials science and technology, particularly in concrete, to reduce Expanded Polystyrene (EPS) waste, and to determine the effect of Fiber Reinforced Polymer (FRP) layers on concrete using Expanded Polystyrene (EPS) additives.

2. Literature Review

2.1. Concrete

Concrete is produced from a mixture of Portland cement or other hydraulic cement, coarse aggregate (gravel), fine aggregate (sand), and water, with or without admixtures. The mixture hardens over a period due to a chemical reaction between the cement and water [2]. Concrete is the dominant construction material used in structural buildings. The advantages of concrete are its resistance to compressive loads, weather changes, high temperatures, and ease of forming and maintenance.

2.2. Expanded Polystyrene (EPS)

Expanded Polystyrene (EPS) or Styrofoam is a material that is often used in everyday life. Expanded Polystyrene is commonly used as containers for food, beverages, electronic equipment protection, and other purposes. Expanded Polystyrene consists of air-filled beads and has low density [3]. EPS has a specific gravity of approximately 13-16 kg/m^3 [4]. EPS is known as a material that is lightweight, resistant to moisture, and capable of maintaining dimensional stability and heat insulation [5]. EPS is used in the construction industry for insulation for roofs, walls, floor coverings, and architectural elements in buildings. However, EPS also has a negative impact on the surrounding environment because it is a type of waste that is difficult to decompose naturally. Therefore, measures are needed to reduce pollution from Expanded Polystyrene (EPS) waste by reprocessing EPS waste, such as mixing EPS waste as an additive in concrete. The advantages of Expanded Polystyrene are that it can be used for a long time, does not absorb water, and is resistant to corrosion.

Figure 2. Expanded Polytyrene

2.3. Fiber Reinforced Polymer (FRP)

Fiber Reinforced Polymer is a material formed from a combination of synthetic fibers such as glass, aramid, and carbon, which are bound together by a matrix such as epoxy. Fiber Reinforced Polymer is used in the construction industry for structural repair and reinforcement, creating new constructions using FRP entirely or concrete composites, and can increase the compressive strength of concrete [6]. FRP is used to repair and reinforce various structures, including beams, columns, slabs, and bridges. The advantages of using FRP as a structural reinforcement material are that the FRP installation method is easy and does not interfere with other structural elements, FRP installation does not take long, and FRP material is thinner and lighter than steel reinforcement.

Figure 3. Fiber Reinforced Polymer

2.4. Waterproof Paint

Waterproof paint is a type of paint designed to prevent water from seeping through walls, floors, and other surfaces. Waterproof paint is typically used in environments that are prone to water exposure. In addition to being waterproof, this paint can also maintain a comfortable temperature indoors. The advantages of using waterproof paint include its resistance to water damage, prevention of mold and mildew growth, and maintenance of room temperature. In this study, waterproof paint was used as an adhesive for Fiber Reinforced Polymer (FRP) materials on cylindrical concrete.

3. Methodology

3.1. Materials and Equipment

In this study, the method used is an experimental method. This study will examine the behavior of concrete using Expanded Polystyrene (EPS) mixed materials and Fiber Reinforced Polymer (FRP) additives soaked in peat water and normal water. The test specimens used are cylindrical in shape with a diameter of 15 cm and a height of 30 cm, which are molded using a cylindrical mold. The test specimens will then undergo physical testing and concrete compressive strength testing after 7 and 28 days of soaking. The testing will be conducted directly at the Civil Engineering Laboratory of the Pontianak State Polytechnic, West Kalimantan.

3.2. Data Types and Sources

This study requires several data as a basis to support the research. The data listed are primary and secondary data. Primary data is data obtained directly by researchers. Some of the primary data tested and observed in this study was the pH test of peat water. The peat water sampling location was on Jalan Parit Haji Muksin II. Secondary data is data obtained from various parties and other sources. Secondary data obtained in this study includes Indonesian National Standards (SNI), journals related to the research conducted, and previous studies.

3.3. Research Variables

The variables used in this study are as follows

Table 1. Test Object Variable

Amount Added Expanded Polystyrene (EPS)	*Number of Fiber Reinforced Polymer (FRP) Layers*	*7 (Days) Curing*		*28 (Days) Curing*	
		Peat Water	*Normal Water*	*Peat Water*	*Normal Water*
0 %	*0 layer*	*3*	*3*	*3*	*3*
1 %	*1 layer*	*3*	*3*	*3*	*3*
1,5 %	*1 layer*	*3*	*3*	*3*	*3*
2 %	*1 layer*	*3*	*3*	*3*	*3*
2,5 %	*1 layer*	*3*	*3*	*3*	*3*

4. Result and Discussion

4.1. Peat Water Test Results Data

The pH test of the peat water was 3.51, which meets the requirements for peat water. The peat water was collected from Jalan Parit Haji Muksin II, and will be used for soaking as part of the curing process for concrete test specimens.

Figure 4. Peat Water Test Results Data

4.2. Aggregate Test Results Data

4.2.1 Testing the Moisture Content of Coarse Aggregates

The results obtained from testing the moisture content of coarse aggregate were 1.08%, which meets the moisture content standard required by [7], which ranges from 0.5-4%. In conclusion, the coarse aggregate sample can be used in concrete mixtures.

4.2.2 Testing the Moisture Content of Fine Aggregates

The results obtained from testing the moisture content of fine aggregate were 3.21% and met the moisture content standards required by [7], which range from 0.5-4%. In conclusion, the coarse aggregate sample can be used in concrete mixtures.

4.2.3 Specific Gravity and Absorption Testing of Coarse Aggregate

The results obtained from testing the specific gravity of coarse aggregate in the SSD (Saturated Surface Dry) condition were 2.64 grams/cm^3 and this specific gravity value meets the specific gravity specification standard of 2.4–2.8 grams/cm^3. The absorption of coarse aggregate obtained was 0.23% and meets the specification standard of below 3%.

4.2.4 Specific Gravity and Absorption Testing of Fine Aggregate

The results obtained from testing the specific gravity of fine aggregate in the SSD (Saturated Surface Dry) condition were 2.65 grams/cm^3, and this specific gravity value meets the specific gravity specification standard of 2.4–2.8 grams/cm^3. The absorption of coarse aggregate was 0.88% and met the specification standard of a maximum of 3%.

4.2.5 Testing of the Bulk Density of Coarse Aggregate

The results of the coarse aggregate bulk dens:ity test showed an average of 1.42 grams/cm^3. The coarse aggregate bulk density determined according to [8] must reach 1,4 to 1,9 grams/cm^3.

4.2.6 Fine Aggregate Bulk Density Test

The results of the fine aggregate bulk density test showed an average of 1.63 grams/cm^3. The fine aggregate bulk density determined according to [8] must reach 1.4 to 1.9 g/cm^3.

4.2.7 Coarse Aggregate Sieve Analysis Test

The Fineness Modulus (Gravel) value is 4.81. From the test data, the coarse aggregate sieve analysis is distributed into a graph to determine the gravel gradation limit and meet the maximum size of 40 mm.

4.2.8 Abrasion and Wear Testing of Coarse Aggregate

The results of the coarse aggregate abrasion and wear test yielded a wear value of 19.70%, which meets the abrasion specification requirement of < 40%.

4.3 Concrete Mix Design

Concrete mix design using [9] Procedures for Calculating Unit Prices for Concrete Work for Building and Housing Construction with a quality of f'c 21.7 MPa. The number of materials required for 12 cylinder test specimens in one mixing process is as follows

Table 2. Concrete Mix Design

No	Variation	Cement (kg)	Sand (kg)	Gravel (kg)	Water (liter)	*EPS* (grams)	FRP (layer)	No Drop (grams)
1	Normal	26,858	48,401	72,671	15,038	-	-	-
2	1%	26,858	48,401	72,671	15,038	268,583	12	3394,286
3	1,5%	26,858	48,401	72,671	15,038	402,875	12	3394,286
4	2%	26,858	48,401	72,671	15,038	537,166	12	3394,286
5	2,5%	26,858	48,401	72,671	15,038	671,458	12	3394,286

4.4 Concrete Slump Testing

From the Slump Test results, an average value of 101 mm was obtained and can be used as a fresh concrete mix.

4.5 Fresh Concrete Specific Gravity Test

The results of testing the weight of normal variable fresh concrete showed an average of 2.55 kg/dm^3. Test results for the weight of fresh concrete with 1% EPS + FRP, with an average of 2.55 kg/dm^3. Test results for the weight of fresh concrete with 1.5% EPS + FRP, with an average of 2. 53kg/dm^3. Test results for the weight of fresh concrete with 2% EPS + FRP, with an average of 2.51 kg/dm^3. Test results for the weight of fresh concrete with 2.5% EPS + FRP, with an average of 2.53 kg/dm^3.

4.6 Concrete Absorption Test

4.6.1 Concrete Absorption Test in Normal Water (7 Days)

The highest result was obtained in the 1% EPS + FRP variation, which was 2.10%, and the lowest result was obtained in the normal variation, which was 1.31%.

4.6.2 Concrete Absorption Test in Peat Water (7 Days)

The highest result was obtained in the 1% EPS + FRP variation, which was 3.76%, and the lowest result was obtained in the normal variation, which was 0.77%.

4.6.3 Concrete Absorption Test in Normal Water (28 Days)

The highest result was obtained in the 2% EPS + FRP variation, which was 4.05%, and the lowest result was obtained in the normal variation, which was 1.57%.

4.6.4 Concrete Absorption Test in Peat Water (28 Days)

The highest result was obtained in the 2.5% EPS + FRP variation, which was 3.27%, and the lowest result was obtained in the normal variation, which was 1.04%.

4.7 Concrete Compressive Strength Testing

4.7.1 Concrete Compressive Strength Test at 7 Days of Age with Normal Water

Based on the results of the 7-day concrete compressive strength test using normal water, it can be concluded that the highest concrete compressive strength was found in the 1.5% EPS + FRP variation with an average value of 27.54 MPa, while the lowest value was found in the 1% EPS + FRP variation with an average value of 20.48 MPa. Several factors that cause high concrete compressive strength are the mixture composition factor, workmanship factor, and aggregate properties factor.

4.7.2 Concrete Compressive Strength Test at 28 Days of Age with Normal Water

It can be concluded from the results of the 28-day concrete compressive strength test using normal water that the highest concrete compressive strength value was found in the normal variation with an average value of 26.46 MPa, while the lowest value was found in the 1% EPS + FRP variation with an average value of 20,61 MPa. Several factors contribute to high concrete compressive strength, including mix composition, construction process, and aggregate properties.

From the explanation of the 7- and 28-day compressive strength of normal water, below is a graph of the normal compressive strength of water.

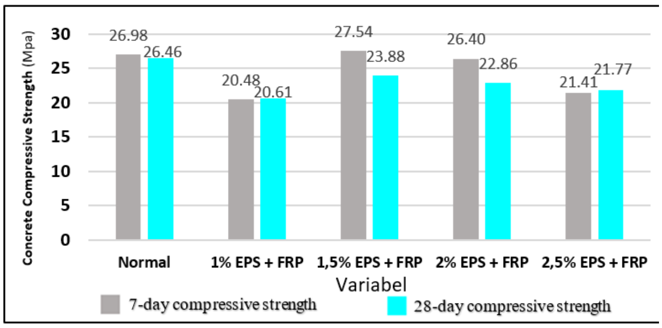

Figure 5. 7-Day And 28-Day Concrete Compressive Strength Test Chart for Normal Water

The compressive strength value above was obtained from the results of compressive strength testing using a concrete compressive strength testing machine.

4.7.3 Concrete Compressive Strength Test at 7 Days of Age with Peat Water

The highest compressive strength in the normal variation, with an average value of 27.10 MPa, while the lowest value is found in the 1% EPS + FRP variation with an average value of 21.25 MPa.

4.7.4 Concrete Compressive Strength Test at 28 Days of Age with Peat Water

The highest compressive strength of concrete was found in the normal variation with an average value of 23.99 MPa, while the lowest value was found in the 2,5% EPS + FRP variation with an average value of 17.77 MPa.

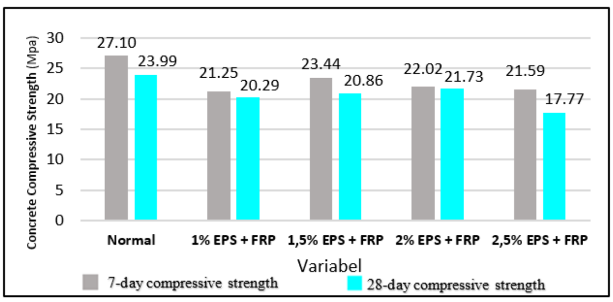

Figure 5. 7-Day And 28-Day Concrete Compressive Strength Test Chart for Peat Water

The compressive strength values above are obtained from compressive strength tests using a concrete compressive strength testing machine. The concrete compressive strength test was carried out after the concrete had reached the specified curing age of 7 and 28 days.

5. Conclusion

5.1. Conclusion

The following are some conclusions drawn from the research results:

Physical Properties (Water Absorption) of Expanded Polystyrene (EPS) additives and Fiber Reinforced Polymer (FRP) adhesion in normal water and peat water immersion. The highest value obtained for 7-day-old normal water in the 1% EPS + FRP variation was 2.10%, while for 28-day-old normal water in the 2% EPS + FRP variation, it was 4.05%. Meanwhile, the highest value for 7-day-old peat water immersion in the 1% EPS + FRP variation was 3.76%, and for 28-day-old peat water immersion in the 2.5% EPS + FRP variation, it was 3.27%. The high-water absorption value is caused by imperfect compaction and the inherent properties of Expanded Polystyrene (EPS), which contains air, thus forming pores in the concrete.

The highest compressive strength of concrete in normal water was at 7 days of immersion in the 1.5% EPS + FRP variation, which was 27.54 MPa, and the lowest compressive strength of concrete in normal water was at 7 days of immersion in the 1% EPS + FRP variation, which was 20.48 MPa. Meanwhile, the highest concrete compressive strength in peat water was at 7 days of age in the normal variation, which was 27.10 MPa, and the lowest concrete compressive strength in peat water was at 28 days of age in the 2.5% EPS + FRP variation, which was 17.77 MPa. The high concrete compressive strength is due to the good design and workmanship, namely the casting process, compaction process, and proper maintenance.

The percentage of Expanded Polystyrene (EPS) and Fiber Reinforced Polymer (FRP) addition that produces the optimum compressive strength value is in the 7-day PDAM water immersion with a variation of 1,5% EPS + FRP, with an average compressive strength value of 27.54 MPa. while in a 7-day peat water immersion with a variation of 1.5% EPS + FRP, the average compressive strength was 23.44 MPa. The most optimal water absorption value was found in a 7-day PDAM water immersion with a normal variation of 1.31%, while in a 7-day peat water immersion with a normal variation, it was 0.77%.

5.2. Suggestions

Based on the research results, there are several suggestions for further development and research:

- To obtain a low water absorption value, optimal compaction must be carried out thoroughly to remove air pockets trapped in the concrete mixture.
- Before making test specimens, the aggregate must be washed thoroughly to remove any dust or mud, to ensure optimal consistency of the concrete mixture.
- For further research when melting Expanded Polystyrene (EPS), the mixture is stirred until a homogeneous mixture resembling the consistency of glue is formed, with the aim of ensuring that the remaining gasoline has evaporated completely and minimizing the amount of gasoline mixed into the concrete mixture.
- Further research should seek other alternative materials for melting Expanded Polystyrene (EPS) that do not reduce the quality of the concrete.
- When attaching Fiber Reinforced Polymer (FRP) using

no-drop wall paint, it should be measured using a measuring cup to ensure a balanced proportion.

- Further research should seek alternative materials that can be applied to Fiber Reinforced Polymer (FRP) on concrete surfaces.

Acknowledgements

The author would like to express his deepest gratitude to several parties who have provided support in the form of advice, input, and motivation, enabling the author to complete this final project smoothly. Therefore, the author would like to express his sincere gratitude to Pontianak State Polytechnic, the Civil Engineering Laboratory of Pontianak State Polytechnic, and his supervisors, Mr. Randy Setiawan and Mr. Ikhwan Arief Purnama.

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