DYNAMES
Dynamics in Engineering Systems: Innovations and Applications
DYNAMES 1(2): 89-94
ISSN 3048-2666

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Effect of immersion in ordinary water (PH7) with time variation on the bending strength of composite water gates

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Received Date: May, 22 2024 Revised Date: July 25, 2024 Accepted Date: August 31, 2024

ABSTRACT

Background: Glass fiber reinforced polymer (GFRP) composites have a disadvantage in terms of bending strength. The use of unsaturated polyester (UP) can enhance the strength of GFRP. However, good mixing is required to ensure proper bonding between the UP and fiberglass as the filler. This study aims to investigate the effect of UP and mixing conditions on the bending strength properties of GFRP/UP composites. UP polymer, glass fibers, and methyl ethyl ketone peroxide (MEKP) (1wt%) and cobalt were used as the matrix, reinforcement, and compatibilizer, respectively, to fabricate the composite. **Methods:** MEKP (1wt%) and cobalt were mixed using a manual method. **Finding:** UP-glass fiber-MEKP (1wt%) and cobalt composites were made using the hand lay-up process. The hand lay-up technique is a common method for combining resin and fiber. Its main advantage is that it can be used to produce large and complex samples. **Conclusion:** The results of the study concluded that composites with UP-glass fiber-MEKP (1wt%) and cobalt did not perform well in withstanding bending strength. Significant changes in sample strength were observed with different mechanisms over periods of 360, 720, and 1080 hours. **Novelty/Originality of this article:** This study found that, although the addition of UP, glass fiber, MEKP, and cobalt offers potential for improving composite strength, the resulting material is not strong enough to withstand bending forces in practical applications.

KEYWORDS: bending; composite; immersion; plain water; sluice gate.

1. Introduction

Global warming and fluctuations in sea level significantly disrupt human life in coastal areas where the land elevation is categorized as flood-prone (Shalsabilla et al., 2022). Tidal fluctuations can occur during both day and night, and are also influenced by full moon phases, a phenomenon commonly referred to as tidal flooding or "rob" (Dewi, 2010). These disturbances become more severe in densely populated urban areas. The resulting losses include economic damage, reduced comfort, diminished urban aesthetics, and negative impacts on environmental health. Therefore, it is necessary to install flow barriers or water gates to regulate the inflow and outflow of water. These gates are expected to minimize, or even eliminate, the impacts of rising average water levels by controlling water flow (Hidayah & Prihantoko, 2016).

Manual operation of water gates demands significant labor costs and a high degree of worker discipline (Mahendra & Sukardi, 2021). Since fluctuations in sea level may not occur at consistent times, there is a need for automatic water gates (Fitriansyah et al., 2021).

Cara Pengutipan:
Hartati, R.Y. & Nuraliyah, A. (2024). Effect of immersion in ordinary water (PH7) with time variation on the bending strength of composite water gates. *Dynamics in Engineering Systems: Innovations and Applications*, 1(2), 89-94. https://doi.org/10.61511/dynames.v1i2.996.

However, when automated gates rely on mechanical systems, there is a risk of theft, which can render the gates nonfunctional. This highlights the urgency of developing naturally operated automatic water gates that utilize the difference in water surface height (Bahri & Yuniarti, 2016). During high tide, the gate will close automatically to prevent seawater from entering drainage channels that lead into urban areas. Conversely, during low tide, the gate will open to allow drainage water from the city to flow back into the sea.

The automatic composite water gate is one of the flagship products of the Gate Capture System (STP), functioning automatically without a motor by utilizing the difference in water surface levels. The water gate system comprises four main components: the frame, shaft, gate, and float. The frame, made of cement and sand, serves as a base for the shaft and separates the river/sea from the drainage system. The shaft, made of POM plastic, supports the gate and float and also acts as a connector that facilitates the gate's opening and closing movements.

A water gate is a thermoset composite that functions as a barrier to regulate water flow. Similar to the water gate, the float is also a thermoset composite that serves to control the rotation of the shaft. Fiberglass-reinforced polymer composites have undergone significant development worldwide since the 1940s. Glass fiber-reinforced polymer (GFRP) is widely used in various fields, including aerospace, automotive, and construction. The automatic composite water gate is made from plastic materials, specifically unsaturated polyester (UP) combined with fiberglass as the filler. In terms of cost, UP is more economical compared to other thermoset polymers. Additionally, UP has a relatively low density among thermosets, which significantly affects the composite manufacturing process.

Several studies have demonstrated that UP can be effectively used as a matrix in GFRP composites, yielding favorable mechanical properties. UP plastic is chosen due to the frequent exposure of water gates to aquatic environments, making corrosion resistance a critical factor to ensure long service life. Fiberglass is one of the most commonly used fibers, valued for its affordability and availability. It provides adequate strength to serve as a water barrier, as evidenced by its widespread use in ship hulls. Glass fiber composites have proven to enhance mechanical properties compared to natural fibers such as kenaf, jute, coir, hemp, and flax. However, GFRP is known to have poor fire resistance. Previous studies have shown that fiberglass-reinforced polymers exhibit low fire-retardant properties.

The outer layer of the water gate and float is coated with gel coat, which serves to provide a smooth finish and enhance the external appearance of the gate. Gel coat also offers corrosion and chemical resistance. Typically, gel coats are pigmented to improve the aesthetic value of the water gate, even though the outermost layer will eventually be painted.

UP and fiberglass are fabricated using the hand lay-up method, one of the most common techniques for combining resin and fibers. The primary advantage of this method is its suitability for producing large and complex samples. An additional benefit is the use of simple equipment, making it relatively inexpensive compared to other methods. Generally, water gates are manufactured as flat sheets with a specific thickness. Achieving a smooth surface is not difficult, as glass can be used as a base or mold. The size of the glass/mold is adjusted according to the desired dimensions of the water gate.

The automatic composite water gate developed by STP has been successfully implemented in the Pekalongan area and functions properly. However, despite its effective performance, STP currently lacks data on the physical, mechanical (bending strength due to water flow pressure), and chemical (immersion resistance) characteristics of the water gate and its float. Therefore, characterization of the water gate and float is necessary as a basis for initial specifications and usage prediction.

UP is a thermoset polymer that is widely used due to its affordability, ease of processing, and balanced mechanical, electrical, and chemical properties. Since the 1930s, UP has been employed in various applications such as water storage tanks, swimming pools, boat components, and more. Glass fiber is produced from several minerals—including Al_2O_3, CaO, MgO, B_2O_3, and silica—that are melted at approximately 1250 °C. The main advantages of glass fiber are its low cost, high tensile strength, resistance to chemical reactions, and excellent insulating properties. There are three types of glass fiber: continuous rovings (UD), woven roving (WR), and chopped strand mat (CSM), which are differentiated by the orientation of their fibers.

The catalyst methyl ethyl ketone peroxide (MEKP) is a clear liquid with a strong odor that serves as an indispensable auxiliary for resin. It accelerates the curing process of the fiberglass mixture; however, an excessive amount can prolong the drying time and generate excessive heat, potentially even causing the release of smoke, whereas too little accelerates the drying process excessively. Gel coat is a pigmented material available in various colors, used to create molded surfaces that are subsequently sanded and filled to remedy uneven or porous textures, thereby ensuring that the resulting fiberglass surfaces are smooth and level for further processing.

Cobalt is a blue, ink-like chemical liquid with an unpleasant odor, used as an additive in the resin (UP) and as a catalyst to aid in the curing process of fiberglass, thereby enhancing adhesion. However, excessive use of cobalt can result in brittle fiberglass. The hand lay-up (HLU) process is a manual method of fiber lamination and is one of the earliest techniques used in composite fabrication. Frequently, a plastic mold reinforced with fibers is employed. HLU is a simple, open fabrication method that is particularly well-suited for producing large components in low volumes. Finally, mirror wax is a paste used as a release agent on fiberglass products, applied prior to composite fabrication for sluice gates or floats.

2. Methods

The methodology of this research was conducted at the Polymer Technology Center-Agency for the Assessment and Application of Technology (STP - BPPT), Serpong. The sample was a UP composite, reinforced with fiberglass coated with gel coat. Furthermore, a series of tests were carried out, namely a bend test with ASTM D790 standards, water absorption without treatment and with treatment (0, 350 hours, 720 hours, and 1080 hours). The treatment imposed was a regular water resistance test (PH 7). The tools in this study were a ladle, scissors, pipettes, brushes, rollers, gloves, masks, digital scales, calipers to measure the thickness and width of the sample, buckets for soaking in regular water and salt water (0, 360, 720, and 1080 hours). The bend test tool is with ASTM D790 standards. Meanwhile, the materials are UP (Yukalac150 HRN-EX), glass fiber with chopped starnd mat (CSM) type, MEKP (1wt%), cobalt, gel coat, fiberglass, mirror glaze (maximum mold release wax) plasticizer platinum. The research procedure is as follows. First, make a formula with a variable amount of UP, MEKP (1wt%) and cobalt ratio stirred evenly until the color changes. Second, the UP-glass fiber sample is fabricated using the HLU method followed by a drying method at room temperature. The UP-glass fiber sample is used as a reference sample for the composite water gate. Furthermore, the composite sample of the water gate and buoy is cut according to the test standard using a hand grinder. The testing procedure consists of two. The first is soaking in ordinary water (PH 7). This is done in several steps: (1) prepare the sample to be tested; (2) cut the sample 15 x 2 cm; (3) record the weight of the sample when in water and in air. Input into the calculation density formula into the software The next test is carried out with a bend test (ASTM D790). This test includes several methods: (1) prepare the sample to be tested; (2) measure a 15 x 2 cm sample that has been soaked in plain water (PH 7); (3) input into the software; (4) clamp the sample on the tensile machine.

3. Result and Discusion

In all five samples, a comparison was made based on the results of the water absorption test and the bending test (ASTM D790). The results of water absorption and density tests were compared using mass measurements in water and in air, with a composition of UP-MEKP (1 wt%) + cobalt, to observe the effects on the UP-glass fiber composite. The findings indicate that the composite sluice gate possesses sufficient strength against water pressure and is suitable for use in drainage channels or urban water systems.

Table 1. The result of the increase in the percentage of weight of ordinary water immersion

	Average percentage weight gain
360 Ab	0.32
720 Ab	0.33
1080 Ab	0.45

Table 1 present the results of the water absorption test under neutral water immersion. After 360 hours of immersion, the composite sluice gate samples showed an average weight increase of 0.32%, attributed to water absorption from the external environment into the composite material. At 720 hours, water absorption increased by 0.01% from the previous stage, resulting in a total weight increase of 0.33%. After 1080 hours, the sample absorbed an additional 0.12%, leading to a total weight increase of 0.45%. These results indicate that during the immersion periods of 360, 720, and 1080 hours, water consistently penetrated the composite sluice gate samples, resulting in a significant increase in sample weight.

Furthermore, Table 2 present the results of the bending test. The bending strength of the composite sluice gate sample after immersion in neutral water for 360 hours was 187.226 MPa, with no visible water absorption into the sample. After 720 hours, the bending strength decreased to 172.646 MPa, with water absorption recorded at 0.01%, resulting in a slight increase in sample weight. However, this water absorption led to a reduction in strength.

Table 2. Results of the percentage increase in weight of the bending test

	Pressure Mpa
360 hours	187.226
720 hours	172.646
1080 hours	158.745

The presence of water weakened the composite sluice gate's ability to withstand pressure. Finally, after 1080 hours, the sample's strength further declined to 158.745 MPa, with water absorption reaching 0.12%, which significantly affected the material's mechanical properties. The absorbed water negatively influenced the pressure resistance of the composite sluice gate sample.

4. Conclusion

Based on the results of immersion in neutral water (pH 7) for 360, 720, and 1080 hours on the bending strength of composite sluice gates, the following conclusions can be drawn. First, unsaturated polyester (UP) and fiberglass were processed using the Hand Lay-Up (HLU) method, a common technique for combining resin and fibers. Second, the composite sluice gate sample experienced a weight increase of 0.12% over 1080 hours, which led to a decrease in pressure resistance, measured at 158.745 MPa. Third, this study can serve as a reference for designing automatic sluice gates used to control water flow to drainage systems in urban areas.

Two recommendations are proposed from this research. First, careful attention should be paid when inputting measurements into the bending test apparatus, as it can affect the accuracy of the strength data. Second, additional testing variables should be included to obtain more accurate comparisons and to enhance the flexibility of materials used in the construction of various types of sluice gate components.

Acknowledgement

The authors have equally contributed to the conception, writing, and revision of this article, ensuring its accuracy and integrity.

Author Contribution

The authors solely contributed to the conception, writing, and revision of this article.

Funding
This research does not use external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The authors declare no conflict of interest.

Open Access

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