The Characteristic of Polyester Concrete with Local Sand of East Borneo as Filter

Asti Lolita Dewi[1,b], Rifqi Aulia Tanjung[1,c], Gusti Umindya Nur Tajalla[1,d], Ade Wahyu Yusariarta Putra Parmita[1,a]

[1] Materials and Metallurgical Engineering Study Program, Kalimantan Institute of Technology, Balikpapan, Indonesia

[a)]Corresponding author: adewahyu27@lecturer.itk.ac.id
[b)]06181013@student.itk.ac.id, [c)]rifqi.aulia@lecturer.itk.ac.id, [d)]gusti.unt@lecturer.itk.ac.id

Abstract. Concrete is a mixture of coarse aggregate and fine aggregate mixed with water and cement as a binder and filler. The disadvantages of traditional concrete are that high water absorption causes low chemical resistance, low modulus of elasticity, low impact strength and a long hardening time to reach its maximum properties, namely 28 days. The solution to these shortcomings that is being developed for construction material applications is by using polymers as polymer concrete. In this research, polyester resin and sand aggregate were used as basic materials. Polyester resin is a type of thermosetting polymer that is widely used in various applications such as automotive parts, composites and construction because of its suitable processing characteristics and affordable price. Meanwhile, the sand used is local Kalimantan sand, where from the XRF and XRD test results, local Kalimantan sand is included in the silica sand type. This research varies the weight fraction of polyester resin used to determine its effect on polymer concrete characteristics such as porosity, water absorption, compressive strength, and macro observations. Variations in the polymer weight fraction used were 20%, 25% and 30%. Compressive strength testing was carried out at the age of 7 days of concrete. The results of the porosity test show that the average porosity of all variations is ± 0.5%. Meanwhile, the average value of water absorption for all fractions is 0.2%. And the highest average value of compressive strength in the 30% polyester resin weight fraction was 66.9 MPa. So it can be concluded that all variations meet SNI standards to become concrete materials.

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INTRODUCTION

Geographically, Indonesia consists of approximately 17,504 islands, and three-quarters of Indonesia's territory is in the sea [1]. Because of Indonesia's vast territory, infrastructure is needed to support the community in its activities, such as bridges and toll roads [2]. There are many construction projects taking place in Indonesia, and they need good-quality materials. The material that is often used and plays an important role in good infrastructure development is concrete [3]. Concrete is the easiest construction material to find and is often used to produce it [4]. Concrete is basically a mixture consisting of coarse aggregate and fine aggregate, then mixed with cement and water to form a fine binder [5]. According to Mulyono [6], the weakness of Portland cement concrete is that it takes a long time, approximately 24 hours, to harden completely and takes 28 days to reach maximum strength. Nowakci [7], in that research, found the disadvantages of traditional concrete are high water absorption, low chemical resistance, low elastic modulus, low impact strength, and long hardening time to achieve maximum properties. So, innovations are needed for concrete manufacturing so that it has faster production times, stronger mechanical properties, and a long-lasting structure. To overcome some of the shortcomings of concrete in general, Albi's research [8] states that there is a new material consisting of aggregate and polymer resin binder, which is being developed for application as a construction material with properties that are superior to cement concrete in general [9].

In the realm of construction, polymers have emerged as versatile materials, finding extensive utility as adhesives and matrices within concrete structures. One notable innovation in this domain is polymer concrete, a relatively recent entrant that has garnered widespread adoption across various sectors. From road infrastructure to bridge construction, underground projects to surface refurbishments, polymer concrete has proven its mettle. Its superiority over traditional cement-based counterparts lies in several key attributes: heightened mechanical resilience, expedited drying and solidification processes, resistance against abrasion and environmental degradation, impermeability to water, and superior sound insulation. These advantages make polymer concrete an attractive choice for modern construction needs [10]. Among the different types of polymers, thermoset polymers are particularly prominent, offering superior strength, thermal endurance, and durability compared to thermoplastic alternatives [11]. In accordance with the Indonesian National Standard (SNI) 7833-2012 [12], concrete is mandated to possess a compressive strength of no less than 17 MPa. Previous investigations into polymer concrete have demonstrated compliance with this standard, showcasing an average compressive strength of 23.043 MPa [13]. This underscores the viability and robustness of polymer concrete as a construction material, meeting and even exceeding regulatory requirements.

Polyester resin, a quintessential thermoset polymer, plays a pivotal role in composite and construction applications due to its favorable processing characteristics and cost-effectiveness [14]. Polymer concrete formulations incorporating polyester resin exhibit commendable chemical resistance and structural integrity, making them suitable for a myriad of applications including fillers, piping materials, staircases, and fabrication components. The efficacy of polymer concrete hinges upon the composition and proportions of aggregates, as well as achieving a harmonious balance between aggregate constituents and resin content [15].

Furthermore, the utilization of locally sourced Kalimantan sand in this study as a constituent in polymer concrete blends aims to optimize mechanical and physical properties. This necessitates further investigations to delineate the ramifications of varying polyester volume fractions on the nuanced attributes of polymer concrete. By leveraging Kalimantan sand as a filler, the research endeavors to ascertain the optimal polyester resin volume fraction required to attain the desired mechanical and physical properties in polymer concrete formulations. This pursuit underscores a commitment to enhancing construction materials through empirical inquiry and innovation, catering to the evolving demands of contemporary infrastructure development and ensuring sustainability in construction practices.

METHODOLOGY

In this study, the characterization of polymer concrete is investigated through macroscopic observations, mechanical property analysis, water absorption, and porosity considering variations in the weight fraction of polyester resin. The study is divided into two main phases, namely the manufacturing process of polymer concrete samples and sample testing. The first phase involves the preparation of local Kalimantan sand by drying and sieving, as well as analysis using X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) techniques, and specific gravity measurement to identify the composition and physical characteristics of the sand. Subsequently, the composition of materials and resin is weighed according to the prescribed procedure before being homogeneously mixed in a single container. The mixture is then cast using a cylindrical mold with standard diameter and height, with lubrication applied to the mold for easy sample release after being allowed to stand for 24 hours at room temperature. After a 7-

day curing period at room temperature, the samples are macroscopically observed, and tests are conducted on compressive strength, porosity, and water absorption.

TABLE 1. Polymer Concrete Composition

No	%wt Polyester Resin	%wt Kalimantan Local Sand	Hardener
1	20%	80%	2%
2	25%	75%	2%
3	30%	70%	2%

RESULTS AND DISCUSSION

X-Ray Fluorescence Analysis

The results of XRF testing in Table 2 indicate that local sand from Kalimantan contains ten elements, with the highest mass percentage being silica (Si) at 96.8064%, followed by iron (Fe), aluminum (Al), and titanium (Ti). This finding is consistent with a previous study by Silvia [13], which also found that natural sand has the highest silica (Si) content at 81.7%, followed by iron (Fe) at 2.49%, calcium (Ca) at 14.8%, and several other elements with percentages of less than 1%, which can be considered impurities. Therefore, it can be concluded that this natural sand is silica sand due to the dominance of the Si element percentage in the XRF testing results.

TABLE 2. XRF test result

Element	Concentration	Unit	Line	Intensity	Judgment
Al	0.7450	wt%	Kα	58.87	---
K	0.0000	wt%	Kα	0.00	---
Si	96.8064	wt%	Kα	22055.77	---
Fe	1.0316	wt%	Kα	11289.10	---
Ti	0.7185	wt%	Kα	3505.02	---
S	0.2728	wt%	Kα	129.13	---
Ca	0.2269	wt%	Kα	517.98	---
Ni	0.1219	wt%	Kα	1557.03	---
V	0.0480	wt%	Kα	306.89	---
Cu	0.0289	wt%	Kα	387.21	---

X-Ray Diffraction Analysis

The XRD testing results of the local sand are depicted in Figure 1, showing similar findings to Hakim's study [16], where the peak intensity is highest at $2\theta = 26.59211°$. Additionally, Silvia's research [13] confirms this similarity, indicating that both the XRD curves of natural sand and local sand from Kalimantan exhibit the highest peak characteristic of quartz (SiO2) at $2\theta = 26.59°$. This alignment is further supported by XRF testing, which highlights the dominance of silicon (Si) in local Kalimantan sand, affirming its classification as silica sand.

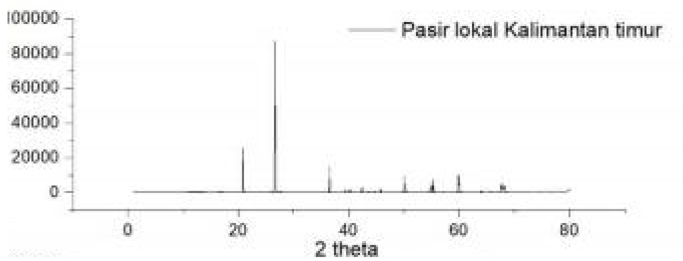

FIGURE 1. XRD Test Results for Local Kalimantan Sand

Macro Observations

Macroscopic observations were conducted to visually examine the polymer concrete specimens using a digital microscope. The average pore sizes obtained from a 20% resin weight fraction were 0.36 mm, while those obtained from a 25% resin weight fraction were 0.37 mm. Increasing the resin content to 30% resulted in the absence of large pores, but some small pores were observed, as shown in Figure 4. These pores were assumed to be due to sand grains detached because the grain size ranged from 0.297 mm to 0.147 mm, rather than trapped air. All images (2, 3, and 4) exhibit white areas representing polyester resin and gray areas representing aggregates. However, black areas with irregular or round edges indicate the presence of pores [17].

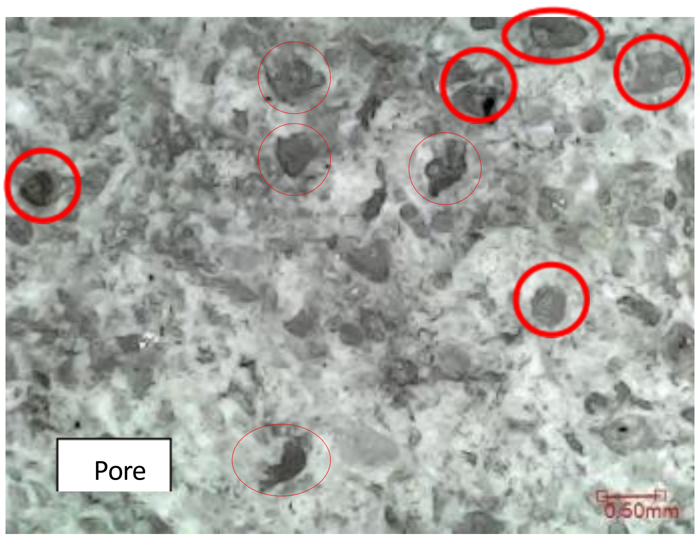

FIGURE 2. Results of macro observations of polymer concrete specimens with a weight fraction of 20% at 100X magnification

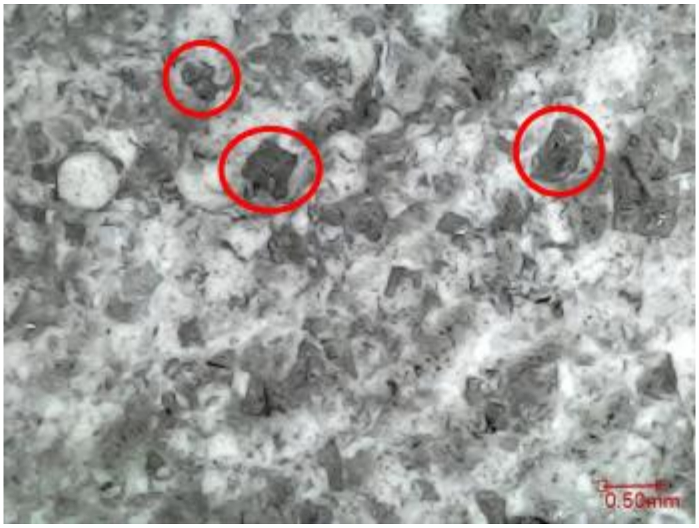

FIGURE 3. Results of macro observations of polymer concrete specimens with a weight fraction of 25% at 100X magnification

FIGURE 4. Results of macro observations of polymer concrete specimens with a weight fraction of 30% at 100 X magnification

Porosity Analysis

Porosity can be defined as the ratio of pore volume to the total volume of the composite. The aim of this test is to determine the percentage of concrete pores relative to the total concrete volume. The data above are derived from calculations involving the mass of dry specimens, the mass of specimens weighed after being submerged for 24 hours, and the specimen volume. From Figure 5, the average porosity values were obtained: for a resin weight fraction of 20%, the average porosity percentage was 0.59%; for polymer concrete with a resin weight fraction of 25%, the average porosity percentage was 0.57%; and for polymer concrete with a resin weight fraction of 30%, the average porosity percentage was 0.52%. According to Tarigan [18], the porosity value for a resin weight fraction of 20% indicates a lack of molecular bonding in the polymer concrete, resulting in the formation of numerous pores. Additionally, the addition of resin leads to a reduction in porosity because the resin fills the pores and seals micro-defects in the polymer concrete [19].

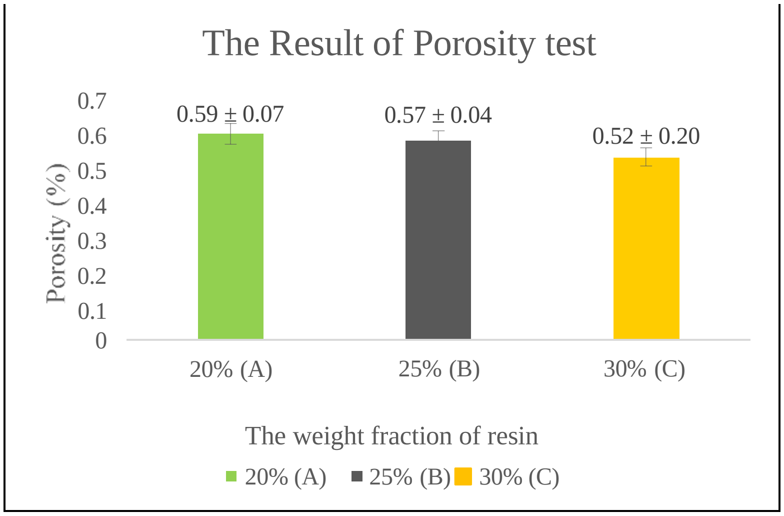

FIGURE 5. Graph of the relationship between porosity percentage and variations in weight fraction of polyester resin

Water Absorption Analysis

The data above are derived from calculations involving the mass of dry specimens and the mass of specimens weighed after being submerged for 24 hours. From Figure 6, the average values of water absorption testing are shown. For a resin weight fraction of 20%, the average water absorption percentage was 0.27%; for polymer concrete with a resin weight fraction of 25%, the average water absorption percentage was 0.24%; and for polymer concrete with a resin weight fraction of 30%, the average water absorption percentage was 0.19%.

Water absorption in concrete decreases as the polymer content increases, attributed to the pore-blocking effect of polymer particles [19]. Additionally, polymers are water-resistant materials, so polymer particles distributed within the concrete pores hinder water from penetrating through the concrete particles. With the addition of a resin weight fraction of 30%, the minimum water absorption value obtained was 0.19%, as the resin acts as a binder, reducing the pores in the polymer concrete. A lower water absorption percentage indicates higher quality polymer concrete [20].

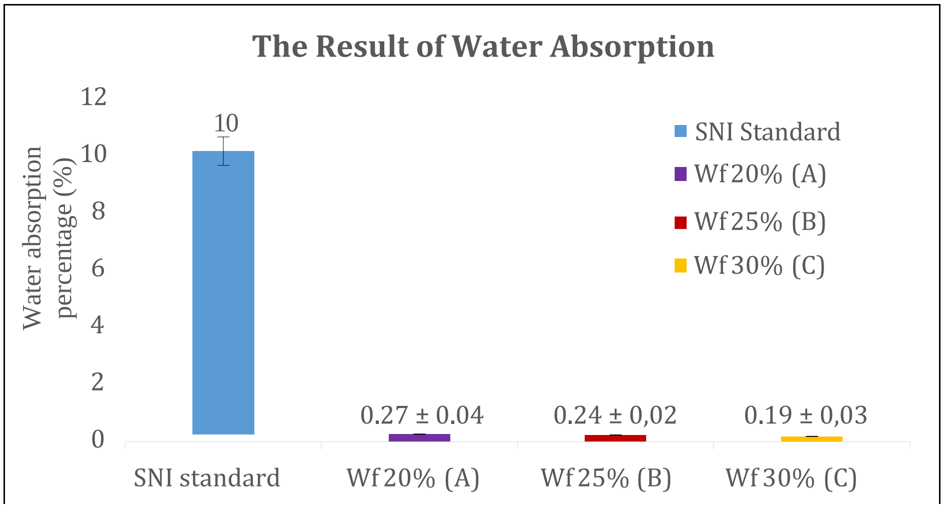

FIGURE 6. Graph of the relationship between the percentage of water absorption and variations in the weight fraction of polyester resin

Compressive Strength Analysis

The purpose of this test is to determine the concrete's ability to withstand compressive forces per unit area of concrete surface. The test was conducted on cylindrical polymer concrete samples with polyester resin weight fractions of 20%, 25%, and 30% at a testing age of 7 days. From Figure 7, the average values of compressive strength testing are shown. For ordinary cement concrete, the average compressive strength value obtained was 18.45 MPa. However, for polymer concrete with a 20% resin weight fraction, the average compressive strength value was 56.96 MPa; for polymer concrete with a 25% resin weight fraction, it was 60.76 MPa, and for polymer concrete with a 30% resin weight fraction, it was 66.9 MPa. The increase in resin percentage enhances the bonding between resin and aggregate, as polyester resin acts as a binder to bind aggregates and fill the interparticle voids, thus reducing the pores in the concrete [21]. This is supported by macroscopic observations, porosity testing, and water absorption testing, where an increase in resin content results in resin covering the pores or voids of the polymer concrete specimens, leading to stronger bonding between sand particles and resin, thus increasing the compressive strength. The lowest strength value was obtained with a 20% resin weight fraction, as a reduction in resin weight fraction can cause an increase in pores in the polymer concrete [19].

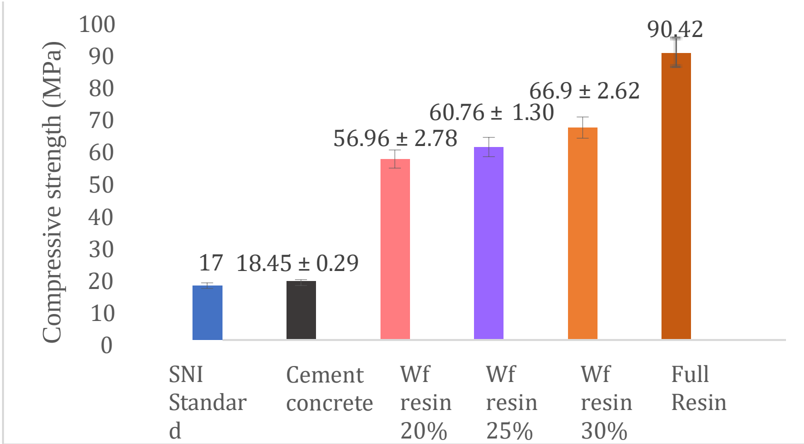

FIGURE 7. Graph of the relationship between compressive strength and variations in the weight fraction of polyester resin in polymer concrete

CONCLUSION

The conclusion drawn from this research is the successful production of polymer concrete, as evidenced by the testing results surpassing the average SNI standards for all variations of polymer concrete. The most optimal material is found in polymer concrete with a 30% polyester resin weight fraction, exhibiting the lowest porosity value at 0.52%, the lowest water absorption value at 0.19%, and the highest compressive strength at 66.9 MPa. Macroscopic testing of specimens with a 30% resin content reveals that polyester resin uniformly coats the aggregate, consisting of sand, resulting in the nearly imperceptible presence of pores.

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