World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(RESEARCH ARTICLE)

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Characteristics of Environmentally Friendly Concrete Made from Tailings with the Addition of Sika Grout 215 New

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World Journal of Advanced Engineering Technology and Sciences, 2025, 17(02), 431-437

Publication history: Received 06 October 2025; revised on 20 November 2025; accepted on 22 November 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.17.2.1504

Abstract

With the rapid development of the construction sector, demand for construction materials is also rising, while natural material reserves are declining. To anticipate this, it is crucial to find alternative materials for concrete production, such as waste materials. The increase in mining and ore processing activities generates tailings waste, which can become an environmental burden if not properly managed.

The purpose of this study was to examine the characteristics of concrete using tailings waste as a sand substitute, with the addition of Sika Grout 215 as an additive. The tailings substitution for sand was 0%, 10%, 15%, and 20%.

The results showed that Sika Grout 215 New did not significantly increase the concrete's compressive strength. The use of tailings in the mixture affected the concrete's characteristics: the higher the tailings percentage, the longer the initial and final setting times. The compressive strength increased to an optimum of 26.31 MPa at 15% tailings substitution. The density increased, and the absorption rate decreased.

The results demonstrate the potential of tailings waste as an environmentally friendly, sustainable construction material.

Keywords: Concrete; Environmentally Friendly; Sustainable; Sika Grout; Tailings

1. Introduction

Tailings waste from the mining industry is one of the main challenges facing environmental conservation efforts today. Poorly managed tailings can pollute soil and water resources and negatively impact the health of surrounding communities. Tailings often contain hazardous materials that can pollute the environment if not handled properly [1]. Therefore, utilizing tailings as an alternative material in the manufacture of environmentally friendly concrete has the potential to be an effective solution that can reduce waste accumulation while conserving the use of increasingly depleting natural resources. The use of tailings in construction not only reduces environmental impacts but can also reduce material costs, thus providing economic benefits to the construction industry [2].

Research [3] reports that the use of tailings as aggregate in concrete can reduce environmental impacts and increase sustainability in the construction industry. This study found that tailings can partially replace conventional aggregates without compromising concrete quality. Other studies [4, 5] indicate that the use of tailings in concrete mixes can improve corrosion resistance, a major problem in construction. This indicates that concrete containing tailings performs well in freeze-thaw resistance tests.

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Several studies have also shown that using industrial waste in concrete production can reduce the carbon footprint. It has been reported that by utilizing waste, the construction industry can contribute to reducing greenhouse gas emissions [6, 7, 8, 9, 10].

Currently, the use of additives such as Sika Grout 215 New in concrete mixes can improve the mechanical properties of concrete, such as compressive strength and durability, thereby meeting performance standards in building construction [11]. Research [12] reports the importance of using additives in improving the performance of concrete containing waste.

Sika Grout 215 New can increase the strength and durability of concrete, making it an ideal choice for structural applications [13]. This additive has also been reported to improve interparticle bonding, thus contributing to increased compressive strength. The use of additives in concrete mixes can improve overall performance, including durability and water absorption [14]. Based on previous research, the focus of this study is to explore the characteristics of tailings-based concrete and Sika Grout 215 New, where tailings can be used as a substitute for fine aggregate to produce environmentally friendly concrete.

2. Materials and methods

The tailings used in this study were taken from the tailings impoundment owned by PT. Meares Soputan Mining (MSM) in East Likupang, North Sulawesi Province, Indonesia (Figure 1). Sika Grout 215 New is a ready-to-use grouting cement containing silica fume and composed of more than 95% SiO_2. It has excellent flowability, resistance to shrinkage, and relatively high compressive strength. Sika Grout 215 New can be classified as a hydraulic cement because it hardens when water is added. The fine aggregate was sourced from the Klabat quarry, while the coarse aggregate was from the Tateli quarry.

Figure 1 Tailings Waste Location

The research method used laboratory experiments. The physical characteristics of the sand and gravel were tested, as presented in Table 1. The test results showed that the sand from the Klabat quarry had a relatively coarse gradation based on gradation analysis and met construction material specifications. The characteristics of the gravel from the Tateli quarry demonstrated good aggregate strength, as evidenced by the abrasion test results of 19.10%, and met concrete specifications. Initial and final setting time tests were then conducted using a Vicat tester, referring to SNI 03-6827 2002 [15].

The next stage was concrete mix design (Table 2) referring to SNI 03-2834-2000 [16], with a target compressive strength of 25 MPa, a water-cement ratio of 0.54, and a slump of 8-12 cm. Five variations of the mixture were made, namely Normal Concrete (BN) and 4 variations of the mixture using Sika Grout 215 New with a composition of 10% Sika: 90% cement, which was then added with tailings as a sand substitution material of 0%, 10%, 15% and 20% with the mixture code respectively BST 0, BST 10, BST 15, and BST 20. The mixing process used a concrete mixer machine to obtain a homogeneous mixture. Followed by a concrete slump test to measure the level of workability of the concrete mixture by referring to SNI 4810-2013 [17]. The test specimen was made using a cylindrical mold with a diameter of 10 cm, a height of 20 cm, followed by concrete compaction using a vibrator. The concrete curing process was carried out by soaking it in a water bath until the test ages were 7 and 28 days for the compressive strength and absorption test of concrete [18]. Each test used 3 test specimens, and then the average value was taken.

Table 1 Sand and Gravel Characteristics

NO.	Type of Test	Quarry		
		Klabat	Tateli (20-30 mm)	Tateli (10-20 mm)
1	Los Angeles Abrasion (%)	-	19.1	
2	Bulk Specific Gravity/Ov	2.163	2.516	2.510
	SSD Specific Gravity	2.326	2.576	2.581
	App. Specific Gravity	2.584	2.677	2.702
3	Absorption (%)	7.53	2.401	2.826
4	Unit Weight (kg/dm3)	1.342	1.284	1.305
5	Silt Content (%)	1.667	0.882	0.915
6	Organic Content	NO. 1	-	-
7	Sieve analysis (Gradation)	Zone 2	-	-

Table 2 Concrete Mix Design Quality 25 MPa

No..	Material	Unit	Mix Variation				
			BN	BST 0	BST 10	BST 15	BST 20
1	PCC Cement	kg	379.63	341.67	341.67	341.67	341.67
2	Sika Grouth 215 New	kg	0	37.96	37.96	37.96	37.96
3	Sand	kg	658.15	658.15	592.33	559.43	526.52
4	Tailings	kg	0	0	65.81	98.72	131.63
5	Gravel 10-20	kg	394.89	394.89	394.89	394.89	394.89
6	Gravel 20-30	kg	592.33	592.33	592.33	592.33	592.33
7	Water	kg	205.00	205.00	205.00	205.00	205.00

3. Results and Discussion

3.1. Setting Time

Setting time tests on Sika Grout 215 New paste mixtures with tailings of 0%, 10%, 15%, and 20% are shown in Figure 2. The test results show that the initial setting times for BST 0, BST 10, BST 15, and BST 20 mixtures were 96 minutes, 98 minutes, 124 minutes, and 140 minutes, respectively, while the final setting times were 165 minutes, 195 minutes, 210 minutes, and 225 minutes, respectively. The higher the tailing percentage, the longer the initial and final setting times. A longer initial setting time is required in concrete work to complete the casting, compaction, and finishing stages.

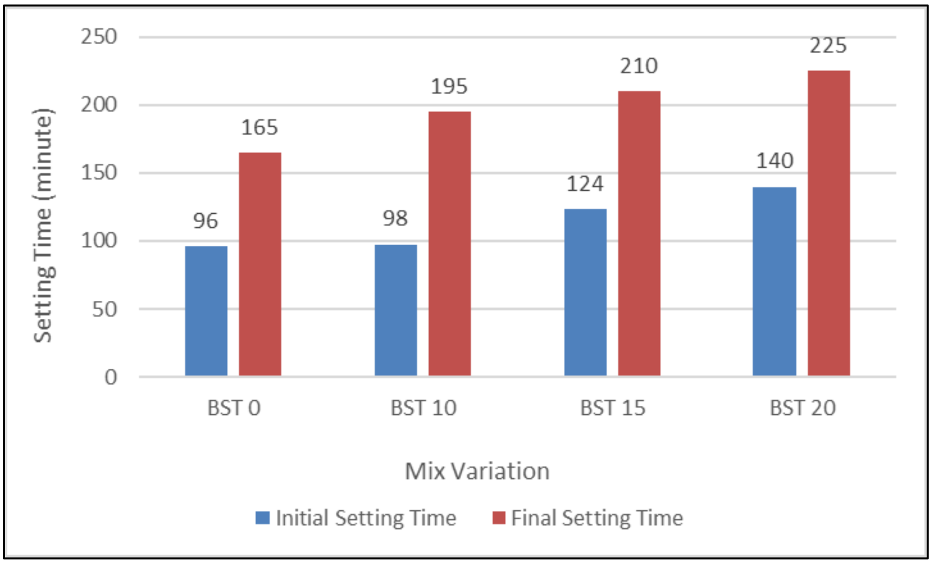

Figure 2 Setting Time

3.2. Compressive Strength

The compressive strength of concrete in five mix variations is shown in Figure 3. The 7-day compressive strength values for BN, BST 0, BST 10, BST 15, and BST 20 were 21.03 MPa, 22.06 MPa, 15.89 MPa, 19.87 MPa, and 14.53 MPa, respectively. The use of 10% Sika Grout 215 New in the BS mix compared to BN showed an increase in compressive strength, although not significant. After the addition of 10%, 15%, and 20% tailings, the 7-day compressive strength decreased compared to BN and BS. These results align with the setting time test shown in Figure 2, which shows that the addition of tailings delays the initial and final setting times, which also contributes to the slower increase in compressive strength at younger concrete ages. At the age of 28 days, the compressive strength values of BN, BST 0, BST 10, BST 15, and BST 20 were respectively 25.01 MPa, 25.07 MPa, 24.71 MPa, 26.31 MPa, and 23.08 MPa. In mixtures that use tailings, the compressive strength increases with the addition of 10% and 15% tailings and then decreases with the addition of 20% tailings. This is probably because the greater the percentage of tailings added, the greater the total surface area of the tailings that must be covered by cement paste to provide a strong bond [19], whereas in the mix design, the amount of cement used is constant for all mix variations. The high compressive strength is partly due to the strength of the bond between the aggregate and cement which covers all surfaces of the aggregate [20]. Figure 3 shows that the compressive strength values of variations BN, BST 0, and BST 15 reach the design compressive strength of 25 MPa, while BST 10 and BST 20 do not. If we look at the results of the setting time test in Figure 2 and compare it with the concrete compressive strength value in Figure 3, it is possible that the unachieved design compressive strength is related to the slow hydration process which affects the hardening of the concrete and the strength of the concrete. From these results, it is still necessary to conduct tests to determine the compressive strength of the concrete at the ages of 60 and 90 days. Of the 5 mixture variations, the optimum compressive strength value of 26.31 MPa was achieved in the BST 15 mixture with a 15% substitution of tailings for sand.

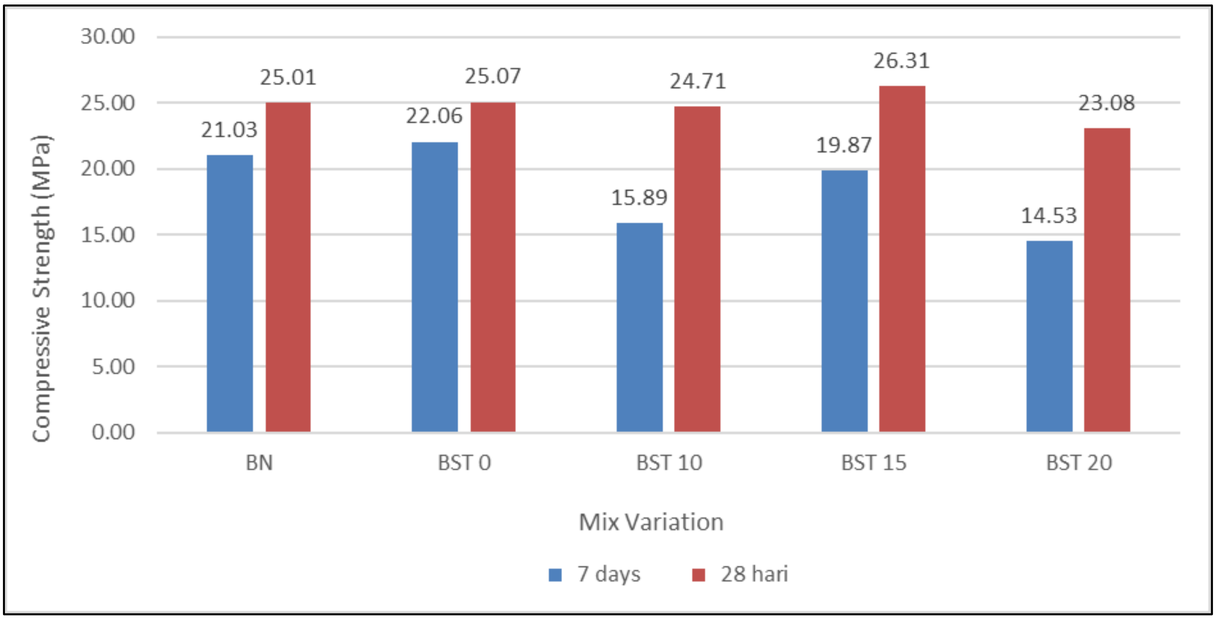

Figure 3 Compressive Strength

3.3. Density

The test results in Figure 4 show that the concrete densities of BN, BST 0, BST 10, BST 15, and BST 20 were 2241 kg/m3, 2247 kg/m3, 2268 kg/m3, 2272 kg/m3, and 2290 kg/m3, respectively. Concrete density increased after the use of tailings by 10%, 15%, and 20%. Another study [21] using iron ore waste and tailings in concrete found that the use of tailings increased strength, but also increased density. Overall, the concrete density still falls within the criteria for normal concrete, namely 2200–2400 kg/m3.

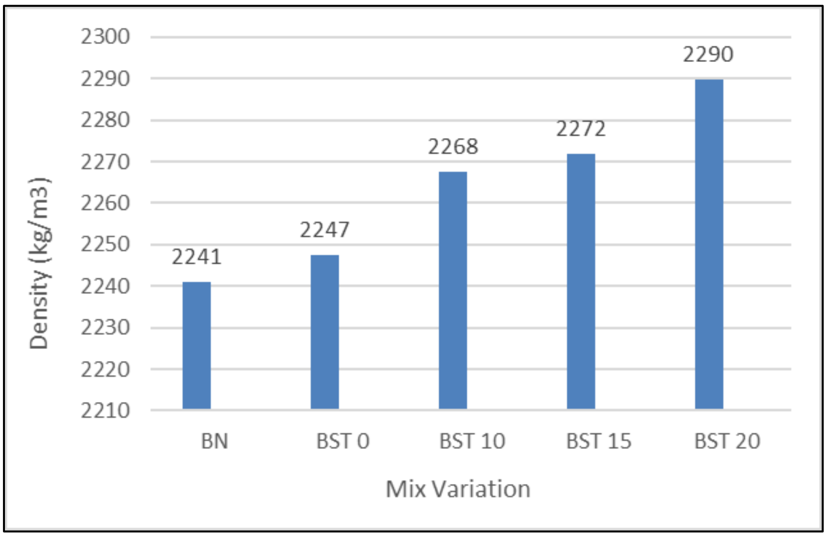

Figure 4 Density

3.4. Absorption

Absorption is the ability of concrete to absorb water, which depends on the volume of pores or voids in the concrete. A higher absorption value indicates a greater volume of voids in the concrete that can be filled with water, and vice versa [22]. The results shown in Figure 5 demonstrate the effect of tailings substitution in the concrete mixture on the concrete absorption value, namely BN, BST 0, BST 10, BST 15, and BST 20, respectively, of 6.11%, 5.83%, 5.92%, 5.63%, and 5.30%. The greater the tailings substitution, the lower the concrete absorption value. Based on the gradation examination (Table 1), the sand used falls into the zone 2 category, or rather coarse sand. Therefore, substitution with tailings with a finer grain size can provide interlocking properties and make the mixture denser. This reduces the void volume, which results in a lower concrete absorption value.

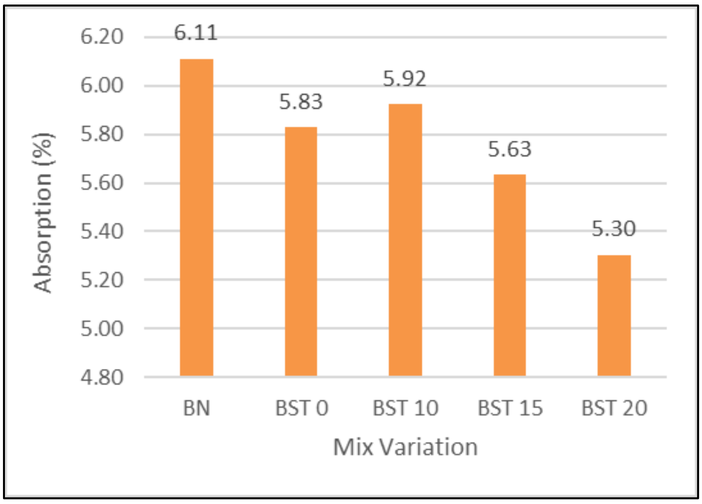

Figure 5 Concrete absorption with tailing variations

4. Conclusion

The results of this study concluded that the characteristics of tailings-based concrete with the addition of Sika Grout 215 New showed that the higher the tailings percentage, the longer the initial and final setting times. The concrete compressive strength increased up to 15% tailings percentage, the density increased, and the absorption rate decreased.

Compliance with ethical standards

Acknowledgments

The author would like to thank all parties who have helped with the research process and to the Manado State Polytechnic for funding this research through the 2025 Vocational Product Basic Research Scheme.

Disclosure of conflict of interest

There is no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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