Use of Slag in The Wash Water to Restore The Concrete Properties

Amir Fauzi [1], Aulia Rachman [2], Edi Majuar[3], Sulaiman [4], Fauzi A Gani [5], Ibrahim [6], Mulizar [7], Syarwan [8], Erna Yusniyanti [9]

{amirfauzi@pnl.ac.id[1], siaulia.rachman@gmail.com[2], edimajuar@pnl.ac.id, sulaiman.ar@pnl.ac.id, fauziabdul62@gmail.com, ibrahim@pnl.ac.id, mulizar@pnl.ac.id, syarwan@pnl.ac.id, ernayusniyanti@pnl.ac.id}

[1,3,4,5,6,7,8] Civil Engineering Department, Politeknik Negeri Lhokseumawe, Acheh, Indonesia
[1,2,3,7,9] Geopolymer and Green Technology Research Centre (2GTechRC), Politeknik Negeri Lhokseumawe, Acheh, Indonesia

Abstract. Steel slag is a by-product material from the combustion of steel in the electric-arc furnaces. The previous study mentioned the steel slag with 3% cement replacement improved the concrete properties. In addition, the disposal of wash water to the landfill had an impact on the environment. So, there was a desire to reuse the wash water as the mixing water in the concrete. However, it caused a decrease in the concrete properties. This study analyzed 50% wash water of the total mixing water with support of 1% and 2% steel slag of cement replacement. The wash water consisted of the cement water from the previous concrete mixing. This study used the mortar with the w/c of 0.52 as the sample. The results showed that the steel slag with 1% and 2% in 50% wash water in the mixing water had similar properties to conventional concrete, especially setting time, compressive strength, and ion rapid chloride permeability. Yet, it improved the hydration heat and shrinkage of concrete.

Keywords: Steel slag, Setting time, Heat of hydration compressive strength, Ion rapid chloride permeability test, Drying shrinkage

1 Introduction

Steel slag (SS) is a by-product material from the combustion of steel in the electric-arc furnaces during the production of steel making. The data recorded that there was 2% SS generated and discharged to the environment during the steel production. It was an issue in the environment and society [1]. So, it was required to prevent them from the disposal of SS in the landfill as the use of SS in the concrete industry.

The previous study revealed that the use of SS up to 3% of cement replacement in the concrete had many advantages [2], which improved the long-term in the concrete properties, including compressive strength, ion rapid chloride permeability, and durability [3,4]. The replacement of SS in the concrete brought the prolonged setting time up to more than 24 hours [2]. Furthermore, the concrete wash water was poison water in the landfill. It was another environmental issue

ABEC 2023, September 21, Bengkalis, Indonesia

DOI 10.4108/eai.21-9-2023.2342900

due to its ingredients of caustic soda, potash, and a high pH. It was a special treatment to reduce the discharger of wash water to the landfill. The cement contained in the wash water was hard soon after a few times. The material of SS delayed the hardening of cement. So, it was used as the mixing water of concrete the next day [5].

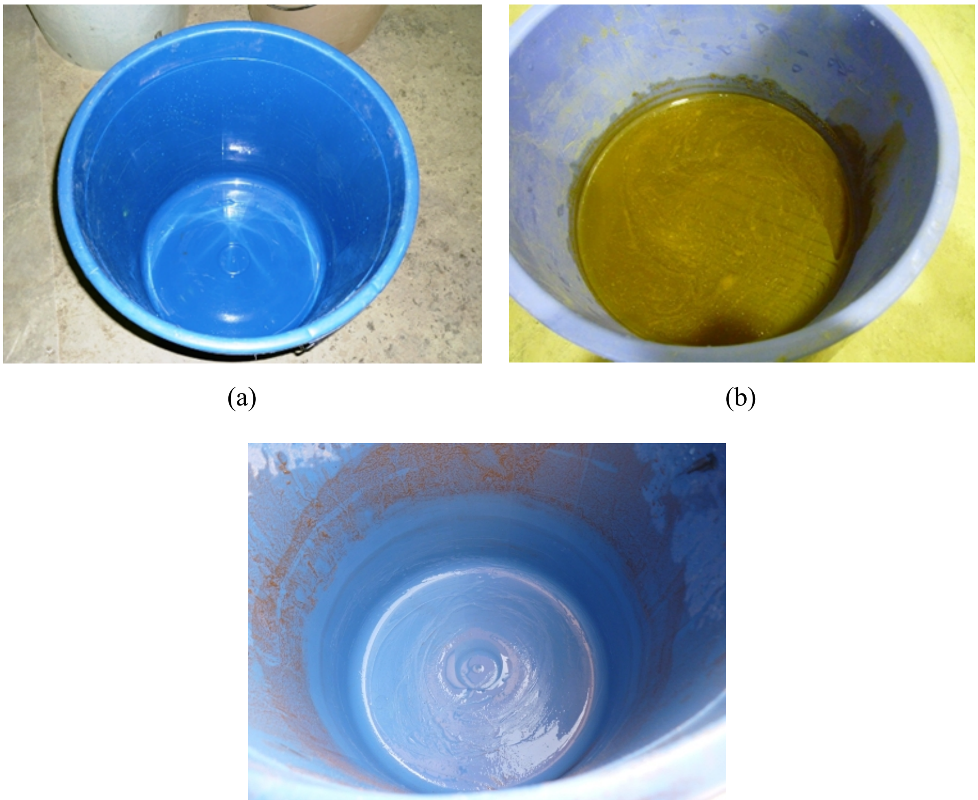
2 Literature Review

Steel is a raw material used in infrastructure projects, manufacturing, and machinery industries. In 2012, the steel production of 1,545 million tons worldwide contributed to the waste material of SS [6]. The material of SS is from fume gas during steel scrap melting. The production of one ton of steel generated the material of SS about 15 to 20 kg. The Environmental Quality Regulation, 2014, recorded that Malaysia produced about 8.8 million tons of steel from 2010 to 2012, which caused the production of SS about 154 million kg [1,6]. The material of SS was a heavy metal that had the chemical composition of zinc, Lead, Chromium, and Cadmium [7]. It was a reason of Best Available Techniques Economically Achievable (BAT) in Malaysia that categorized the material of SS as hazardous waste. So, the material of SS was not allowed to be disposed of at landfills without treatment.

Some investigations used the material of SS in the concrete industry to solve the environment issue. The replacement of SS improved the mechanical properties in the concrete but prolong the final setting time [4]. The replacement of SS about 1%, 3%, and 5% provided a setting time of 9 hours, 27 hours, and 54 hours, respectively [8]. The use of wash water speeded up setting time and reduce the flowability in the fresh concrete. Yet, it did not impact the compressive strength [9,10]. The use of wash water also reduced the capillary water absorption and microporosity in the concrete. These properties improved the durability of concrete [11,12]. Ghrair et al. revealed that the wash water did not use as the mixing water in the concrete even after dilution. It caused the reduction of compressive strength and workability on the concrete [13]. The applied of wash water with zeolite in the concrete increased the compressive strength of 4.6% at 7 days curing and up to 30% at 28 days. It proved that the microstructure of concrete with wash water and zeolite was denser than the wash water only. [14,15].

3 Experimental Program

The wash water was from the previous concrete washing water and poured into the plastic bucket. The material of SS about 1% and 2% was poured into the concrete wash water, stirred for 2 minutes, and stored overnight. The mixing water was from 50% wash water and 50% potable water. The investigation in this study refers to The ASTM standard C-192. It began to pour the aggregate, cement, and some mixing water into the concrete mixer. Then, run the mixer for 3 minutes, rest for 3 minutes, and run back for 2 minutes. The fresh concrete was prepared to evaluate the setting time and heat of hydration. While, the hardened concrete was prepared to evaluate the compressive strength, ion chloride permeability, and drying shrinkage.



(a) (b) (c)

Fig. 1. The condition of: (a) original plastic bucket (b) plastic bucket during applied the material of SS in the wash water, and (c) plastic bucket after removed the wash water.

4 Results and Discussion

4.1 Setting Time

The setting time of 50% wash water with the support of SS in the mixing water shows the linear curve relation to the increase of SS percentage as seen in Figure 2. It is seen that the use of wash water increases the setting time in the fresh concrete. It is linked to the effect of SS in the wash water that prolonged the setting time. The use of SS up to 2% of cement replacement retarded the reaction of hydration in the concrete. It was attributed to the release of zinc element from the material of SS. It was opposite to the previous result mentioned that the use of wash water in the concrete caused a speed up of setting time. Nevertheless, the wash water with 2%SS was still acceptable as the setting time in the concrete.

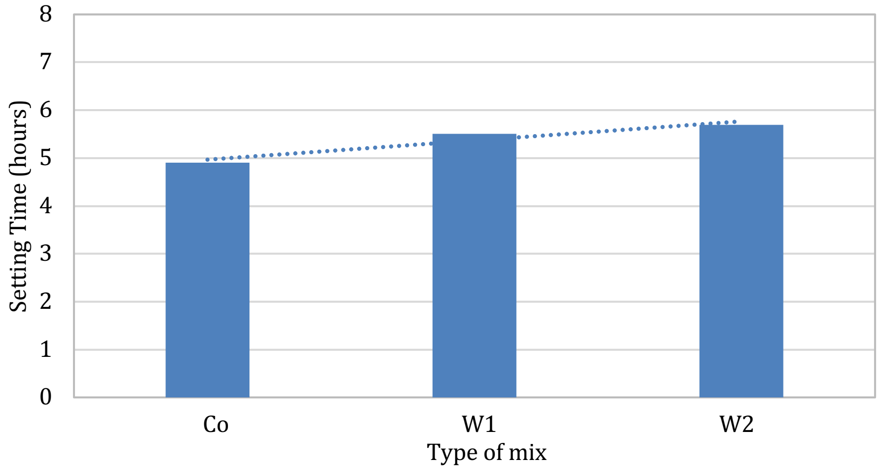


Fig. 2. Setting times of concrete using wash water

4.2 Heat of Hydration

The heat of hydration used 1% and 2% SS in 50% wash water as the mixing water in the concrete is shown in Figure 3. The use of SS in the wash water increases the heat of hydration in the fresh concrete. It was attributed to the chemical content of SS including the content of Ca. Furthermore, the peak temperature of 1% and 2% SS in the 50% wash water shifted for a longer time compared to the potable water. The shifting time of peak temperature was the consistent reason why the replacement of SS caused prolonged setting time in the concrete. It means that the percentage of SS retarded the hydration process in the concrete.

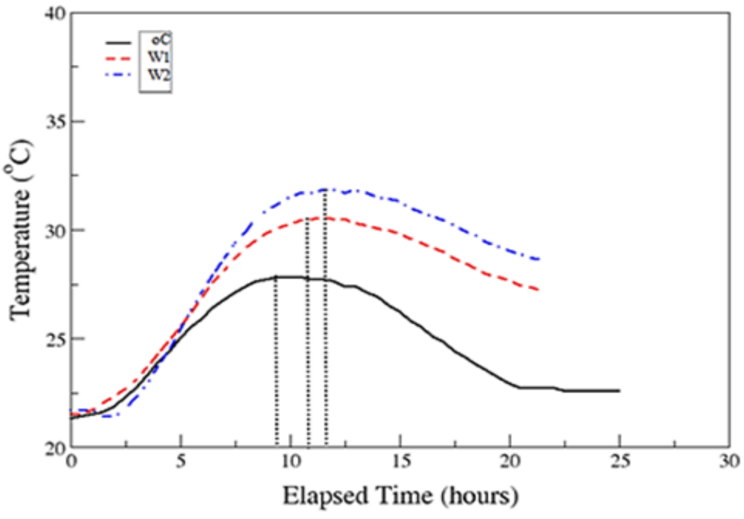


Figure 3. The hydration heat of concrete using wash water

4.3 Compressive Strength

Figure 4 shows that the use of 1% and 2% SS in 50% wash water in the mixing water did not affect the compressive strength in the concrete. The wash water was too bad as the mixing water in the concrete due to the interfered with the setting of the concrete, stained the concrete surface, adversely affected the strength of the concrete, and caused corrosion in reinforcement. This result proves the use of SS up to 2% of the wash water as the mixing water can bring back the compressive strength similar to the conventional concrete. It is a novelty to restore the properties of concrete. It was due to the zinc element in the material of SS that retarded the reaction of cement water to precipitate before being used in the mixing water.

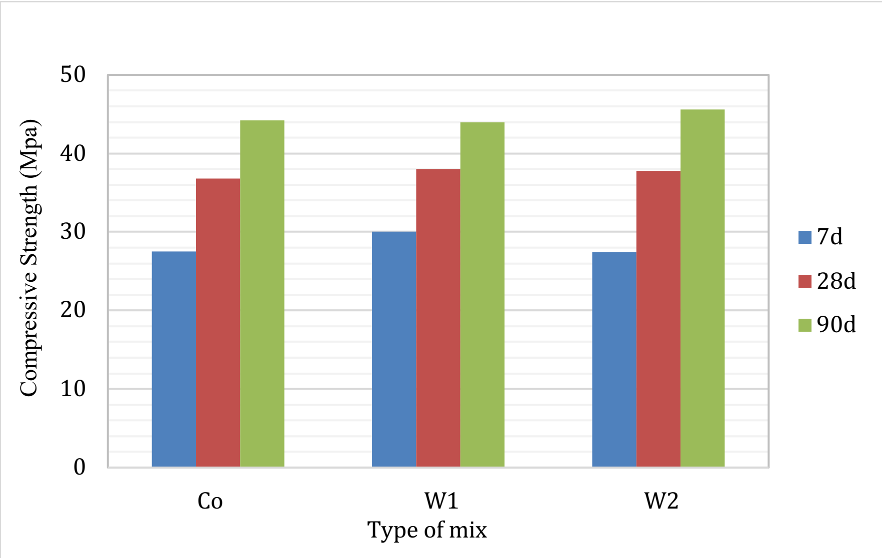


Figure 4. The compressive strength of concrete using 1% and 2% SS in 50% wash water in the mixing water

4.4 Ion Rapid Chloride Permeability Test

Figure 5 shows the ion rapid chloride permeability test (ion RCPT) in the concrete. The material of SS with 1% and 2% in the 50% wash water as the mixing water in the concrete decreases the ion RCPT compared to the conventional concrete using potable water. Yet, the material of SS with 2% SS in the 50% wash water as the mixing water is higher than using 1% SS in the 50% wash water. It means that the increase of ion RCPT retarded the hydration reaction due to the increase of zinc element in the wash water. However, the lower ion RCPT due to the increased percentage of SS was beneficial in slowing down the corrosion rate.

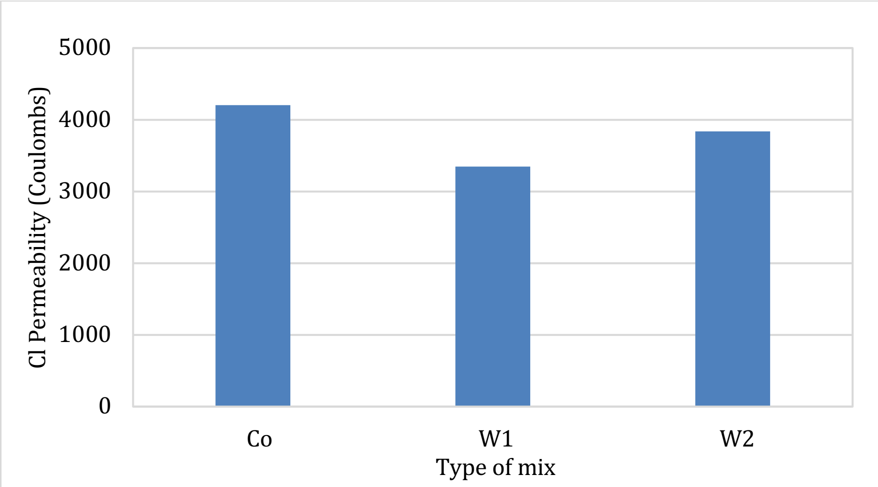


Figure 5. The ion RCPT of concrete using wash water

4.5 Drying Shrinkage

Drying shrinkage is the last parameter used to evaluate the material of SS with 1% and 2% in 50% wash water as the mixing water in the concrete. Figure 6 shows the increase of SS percentage in the 50% wash water decreases the drying shrinkage of concrete. The increased percentage of SS in the 50% wash water increased the particles of SS in the concrete. It reduced the concrete pore and decreased the water access in and out of the concrete pore. However, this result is opposite to the ion RCPT, in which the drying shrinkage of concrete was linear with its drying shrinkage. It is due to the zinc element in the material of SS that caused the retarded hydration reaction. So, the access to an ion RCPT of cation and anion connected from the pore.

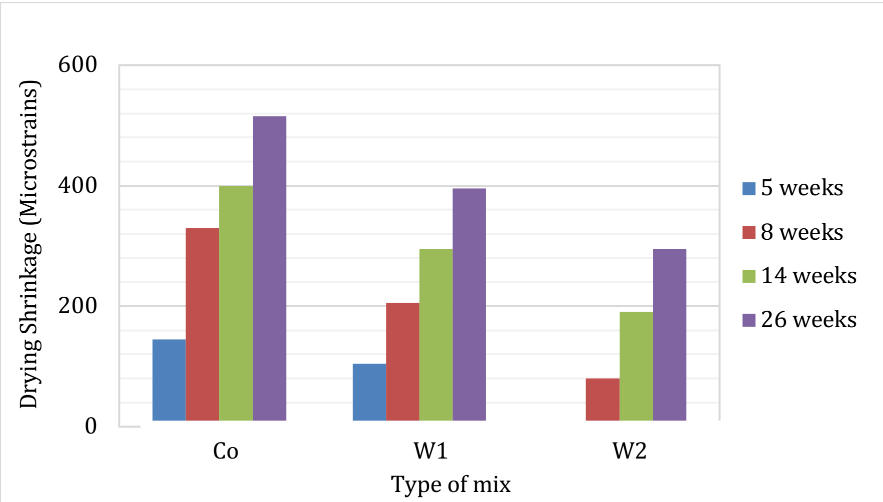


Figure 6. Drying shrinkage of concrete using wash water

5. Conclusion

This study analyzed the feasibility of using 1% and 2% SS in 50% wash water as the mixing water with six parameters. It concluded that the applied of SS in 50% wash water restored the properties of concrete. It can help to save the environment from steel slag as the waste material and wash water as the poison water in the environment.

References

[1] Yi, H., Xu, G., Cheng, H., Wang, J., Wan, Y., and Chen, H., "An Overview of Utilization of Steel Slag," Procedia Environ. Sci, 16, pp. 791–801 (2012).

[2] Parron-Rubio, M. E., Perez-Garcia, F., Gonzalez-Herrera, A., Oliveira, M. J., and Rubio-Cintas, M. D., "Slag Substitution as a Cementing Material in Concrete: Mechanical, Physical and Environmental Properties," Materials, 12, pp. 1–15 (2019).

[3] Xuequan, W., Hong, Z., Xinkai, H., and Husen, L., "Study on Steel Slag and Fly Ash Composite Portland Cement," Cem. Concr. Res, 29, pp. 1103–1106 (1999).

[4] Rosales, J., Agrela, F., Entrenas, A., and Cabrera, M., "Potential of Stainless Steel Slag Waste in Manufacturing Self-Compacting Concrete," Materials, pp. 1–17 (2020).

[5] Devi, V. S., and Gnanavel, B. K., "Properties of Concrete Manufactured Using Steel Slag," Procedia Eng, 97, pp. 95–104 (2014).

[6] Mousa, E., Wang, C., Riesbeck, J., and Larsson, M., "Biomass Applications in Iron and Steel Industry : An Overview of Challenges and Opportunities," Renew. Sustain. Energy Rev, 65, pp. 1247–1266 (2016).

[7] Syahyadi, R., Fauzi, A., Majuar, E., Rizal, F., and Reza, M., "Effect of Electric Arc Furnace Dust Treatment on the Properties of Fresh and Hardened Mortar Effect of Electric Arc Furnace Dust Treatment on The," *IOP Conference Series: Materials Science and Engineering*, pp. 1–6 (2020).

[8] Bouikni, A., Swamy, R. N., and Bali, A., "Durability Properties of Concrete Containing 50 % and 65 % Slag," Constr. Build. Mater, 23(8), pp. 2836–2845 (2009).

[9] Asadollahfardi, G., Asadi, M., Jafari, H., Moradi, A., and Asadollahfardi, R., "Experimental and Statistical Studies of Using Wash Water from Ready-Mix Concrete Trucks and a Batching Plant in the Production of Fresh Concrete," Constr. Build. Mater. J, 98, pp. 305–314 (2015).

[10] Sandrolini, F., and Franzoni, E., "Waste Wash Water Recycling in Ready-Mixed Concrete Plants," Cem. Concr. Res., 31, pp. 1–16 (2001).

[11] Yao, X., Xu, Z., Guan, J., Liu, L., Shangguan, L., and Xi, J., "Influence of Wastewater Content on Mechanical Properties, Microstructure, and Durability of Concrete," buildings, 12, pp. 1–24 (2022).

[12] Wulaningtyas, A. H., and Marleni, N. N. N., "Wastewater Characterization and PH Neutralizing Effect of Adsorbents : A Case Study of Concrete Wash Wastewater from a Ready-Mix Plant," J. Civ. Eng. Forum, 9(2), pp. 209–216 (2023).

[13] Ghrair, A. M., Heath, A., Paine, K., and Kronz, M. Al, "Waste Wash-Water Recycling in Ready Mix Concrete Plants," Environments, 7(108), pp. 1–16 (2020).

[14] Kaboosi, K., and Emami, K., "Interaction of Treated Industrial Wastewater and Zeolite on Compressive Strength of Plain Concrete in Different Cement Contents and Curing Ages," Case Stud. Constr. Mater., pp. 1–25 (2019).

[15] Kantautas, A., Manhanga, F., Ivanauskas, E., and Gaudutis, A., "The Using of Concrete Wash Water from Ready Mixed Concrete Plants in Cement Systems," Materials, 14, pp. 1–12 (2021).