Ni SLAG VALORISATION IN INDONESIA: A CASE STUDY

Sotya ASTUTININGSIH, Bambang SUHARNO

Department of Metallurgical and Material Engineering, Faculty of Engineering, Universitas Indonesia, Kampus UI, 16424 Depok, Indonesia

sotya.astutiningsih@ui.ac.id, bambang.suharno@ui.ac.id

Introduction

Indonesia is one of the biggest nickel producers in the world with an estimated average production growth of 8.1% in the period 2018-2027. Referring to the Ministry of Energy and Minerals, the Republic of Indonesia, at the end of 2017 there were already 24 smelters operated in Indonesia, 15 of which were nickel smelters. With the increasing production capacity, currently, 5 million tonnes per year (TPY) nickel production towards 17 million, an enormous amount of 32 million TPY waste in the form of slag produced will become a great concern.[1]

The processing of lateritic nickel ores into nickel pig iron was invented in China in the year of 2016.[2] The ores processed were imported mainly from Indonesia and the Philippines. The import from Indonesia was stopped in 2014 due to Indonesian Government regulation. Studies on the valorisation of slag produced *via* this process were mainly as a building material, more specifically as (Portland) cement or aggregate substitutes[3-5] and as geopolymer precursors[6-8]. Two types of slag were produced depending on the furnace used, which are electric furnace slags and blast furnace slags. Compositions and reactivity between these two slags varied.[7]

The slag used throughout this experiment was ground granulated blast furnace slag (GGBFS) supplied by one of the Ni smelting industries in Indonesia. This company produced 360 000 TPY ground granulated blast furnace slag (GGBFS) and 300 000 TPY of slag from electric furnace. They already obtained a government permit for GGBFS valorisation, however, only 10% of the capacity is consumed. Consumers of this GGBFS includes the Portland cement industry, the ready-mix concrete, the precast concrete, and the mortar industry. To increase the consumption, GGBFS will be used as the main solid precursor for geopolymer.

Slag characterisation

The chemical composition using XRF spectrometry of the slag supplied was shown in Table 1 as analysis 2 compared to analysis 1 provided by the company supplying the slag. In the analysis 2, the XRF technique was applied to the as-received slag and to the slag passed #200 sieve. The slag contains predominantly silica, calcium, magnesia,

and alumina. Considering the X-ray diffraction pattern of the slag, as presented in Figure 1, the slag was assumed to be in the form of a multicomponent glassy oxide solid solution with some crystalline oxides of akermanite. A scanning electron micrograph of the slag was presented in Figure 2 and it showed that slag particles were sharp and irregular. Based on the composition and particle geometry, there was no significant variation between the #200 sieved GGBFS and the as-received one.

Table 1: Chemical composition of GGBFS

Parameter	Analysis 1		Analysis 2 (XRF)	
	wt%	Method	wt%	
			#200*	As-received
Ni	0.09	XRF	0.02	0.02
Co	0.02	XRF	n/a	n/a
Fe	2.24	By calculation	2.78	2.87
Fe_2O_3	3.20	XRF	1.70	1.71
CaO	24.83	XRF	24.73	24.71
MgO	18.81	XRF	19.40	19.29
Na_2O	0.44	XRF	0.22	0.24
Al_2O_3	6.23	XRF	9.60	9.69
SiO_2	40.69	XRF	41.18	41.24
P_2O_5	0.21	XRF	0.00	0.00
SO_3	0.37	XRF	0.93	0.90
K_2O	0.24	XRF	0.2	0.17
TiO_2	0.19	XRF	0.25	0.26
Cr	0.68	By calculation	1.04	1.07
Cr_2O_3	0.99	XRF	0.66	0.67
MnO	0.68	XRF	0.82	0.83
Moisture	0.22	Gravimetry	n/a	n/a
LOI	1.25	Gravimetry	n/a	n/a

*particles passed #200 sieve

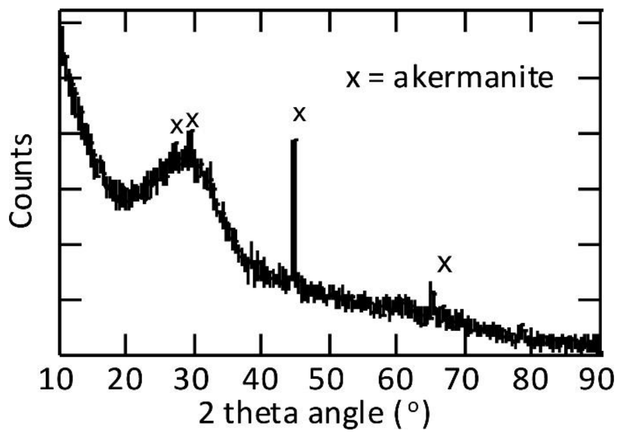

Figure 1: X-ray diffraction pattern of the as-received GGBFS

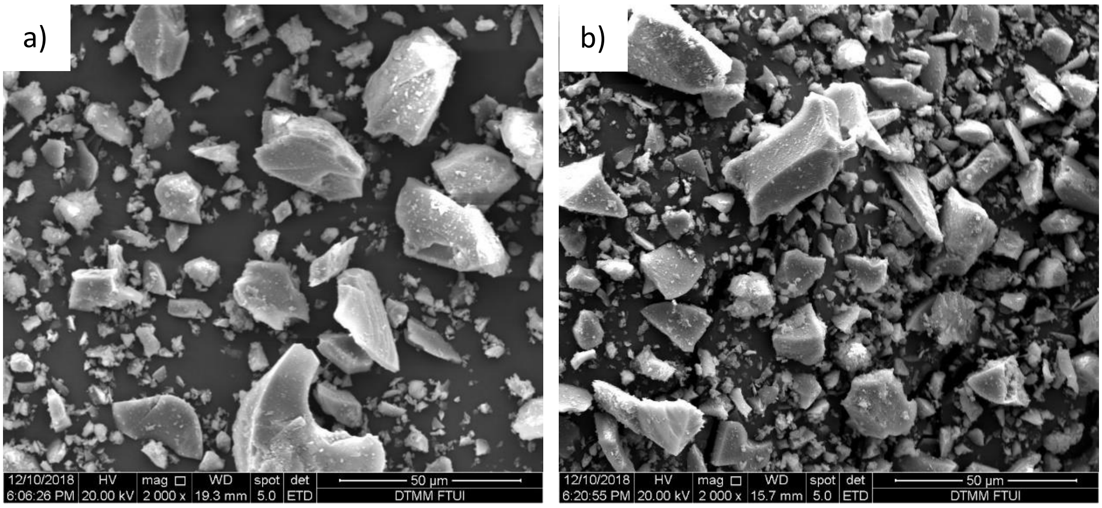

Figure 2: Scanning electron image of slag particles, with a) of the as-received slag, and b) the slag particles passed #200 sieve

Geopolymerisation of GGBFS

Geopolymer mortar was prepared by mixing GGBFS, quartz sand, and sodium silicate solution. The solution was made from technical grade NaOH, water glass and water. The solution to the powder, *i.e.* GGBFS and quartz sand, ratio was ~ 0.33. The fresh paste was cast into steel moulds of 50 mm x 50 mm x 50 mm and cured for 24 hours at room temperature, 60°C and 90°C. The compressive strength of the cured mortar, tested referring to ASTM C942-15, is shown in Figure 3. Three samples were tested for each curing condition. Curing of the mortar at room temperature (RT) for 24 hours failed to produce sound samples. Curing was optimum at 60°C, while curing at 90°C resulted in lower strength than the 60°C curing.

To find out the feasibility of GGBFS-based geopolymer as building materials, a trial was performed with a similar GGBFS mortar cast into a concrete slab of approximately 100 cm x 50 cm x 30 cm. The composition of the concrete was approximate, in wt%, 35 coral; 22 quartz sand, 27 GGBFS, and 16 sodium silicate solution. Core samples of 68 mm diameter were drilled from the slab and were cut into 136 mm height for a compression test. The compressive strength of the concrete core samples tested according to the Indonesian standard SNI 03-3403-1994 is presented in Figure 4. Three core samples were drilled for each curing time. In general, early strength of the concrete was sufficient for structural application and the strength showed a tendency to increase with time until 28 days.

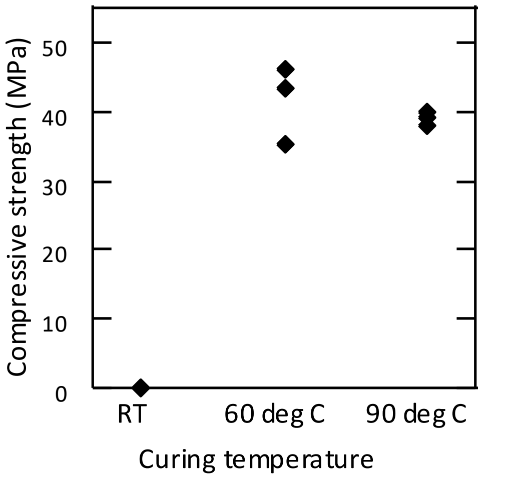

Figure 3: Compressive strength of geopolymer mortar cured for 24 hours

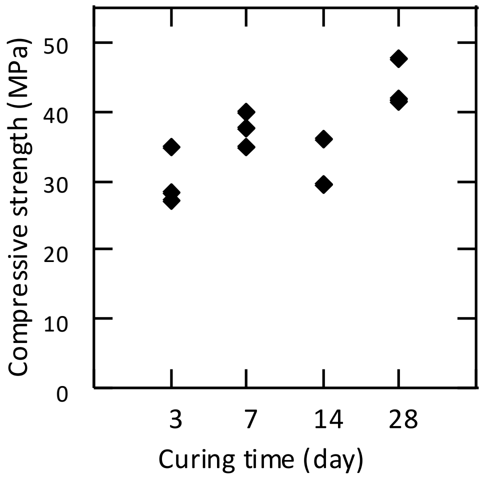

Figure 4: Compressive strength of geopolymer concrete cured at room temperature

Conclusion

GGBFS from nickel smelting has the potential to be utilised as building materials. Compressive strength of both the geopolymer mortar and concrete were sufficient for use as building materials. The consumption of GGBFS using geopolymer technology is significantly higher than as Portland cement substitutes. However, extensive study on other aspect of the material characteristics must be done before commercialisation. Very importantly is the study on the stability of the material structure, durability and heavy metal leachability.

References

1. KEMENPERIN, 2018. Dukungan Kebijakan Pemanfaatan Slag Untuk Sektor Industri Hilir dan Infrastruktur. (2018).
2. https://www.theglobeandmail.com, January 2018
3. Y.C. Choi, S. Choi, “Alkali-silica Reactivity of Cementitious Materials Using Ferro-nickel Slag Fine Aggregates Produced in Different Cooling Conditions”, *Constr Build Mater*, **99** 279-87 (2015).
4. Y. Huang, Q. Wang, M. Shi, “Characteristics and Reactivity of Ferronickel Slag Powder”, *Constr Build Mater*, **156** 773-89 (2017).
5. Q. Wu, Y. Wu, W. Tong, H. Ma, “Utilization of Nickel Slag as Raw Material in the Production of Portland Cement for Road Construction”, *Constr Build Mater*, **193** 426-34 (2018).
6. T. Yang, X. Yao, Z. Zhang, “Geopolymer Prepared with High-magnesium Nickel Slag: Characterization of Properties and Microstructure”, *Constr Build Mater*, **59** 188-94 (2014).
7. T. Yang, Q. Wu, H. Zhu, Z. Zhang, “Geopolymer with Improved Thermal Stability by Incorporating High-magnesium Nickel Slag”, *Constr Build Mater*, **155** 475-84 (2017).
8. Z. Zhang, Y. Zhu, T. Yang, L. Li, H. Zhu, H. Wang, “Conversion of Local Industrial Waste into Greener Cement through Geopolymer Technology: A Case Study of High-magnesium Nickel Slag”, *J Clean Prod*, **141** 463-71 (2017).