100% BY-PRODUCT RECYCLING IN KRAKATAU POSCO

BY

RENDY RUSMAN*

SYNOPSIS:

Sustainability of by-product analysis is necessary thing to determine best direction of by-product management in Integrated Steel Mill (ISM) of PT Krakatau Posco (PTKP) which faces challenging situation because when millions ton of by-products is being generated in annum, by-products should be managed properly, efficiently and accordingly obey environmental regulation. The identification of characteristic and chemical component contained in by-product became key factor to do the next assessment.

The next assessment is create by-product classification according to prioritizing scale of management such as internal and external utilization (alternative material and alternative fuel). Recycling ratio of by-product gradually increase consecutively from 79% in 2018 to 82.5% in 2020. In the last 2021 recycling ratio has reached 92% which consists of internal utilization 22%, Cement Industry 68%, and other purpose 2%. According to 8 years operation, PTKP has quite closed partnership with cement industry. This makes mutual beneficial to both parties which can reduce natural resources exploitation. In the other side, PTKP can maximize recycling ratio of by-product and contribute to make green product in Indonesia.

Strategically, through improvement PTKP set up by-product recycling become 100% in 2022, by developing by-product utilization to the other industries and increase the value of by-product.

Keywords: by-product, Indonesia, integrated steel mill, by-product management, recycling ratio

* Resource Recycling Engineer, PT Krakatau Posco, Cilegon, Indonesia

1. Introduction

Steel Industry has a strategic role as "mother of industries" which contributes to meet development of others industrial sector such as constructions, transportations, heavy equipment, electronics, etc [1]. It is reflected to President Regulation No. 74/2022 about Policies of National Industrial Year 2020 – 2024 to define directions and actions to execute industry development phase II Year 2020 – 2024 which Steel Industry become one of strategic plan of Indonesia It was established in Master Plan of National Industry Development Year 2015 – 2035 [2]. Steel consumption in Indonesia have reached 16 Million ton In 2021 means increase 6% YoY compared to 2020, Indonesia contributes 21.4% of total steel consumption in ASEAN according to published statistics of SEAISI [3]. In environmental consideration, Government of Indonesia also give a positive support by releasing Indonesian Regulation 22/2021 for Implementation of Environmental Protection and Management [4], which mention Steel Slag is categorized of Registered Non Hazardous Waste code N101. It encourages utilization of by- product in PT Krakatau Posco increase in 2021 becoming 92% compared to 2020 is in 82.5%. And utilization purpose can be expanded such as cement, civil, fertilizer, soft soil improvement, etc.

PT Krakatau Posco is Joint Venture between Krakatau Steel and POSCO for producing Iron and Steel with current capacity 3 million ton per annum. After signed MoU in July, 28th 2021 between Indonesia and POSCO, in the near future Steel production will increase up to 10 million. And by-product generation follows to increase double than existing. Thus, PT Krakatau Posco should focus to determine best direction for by-product management to face this challenge.

Based on category, by-product is divided on 2 hazardous and non-hazardous by-product. 87% is categorized as non-hazardous By-product, mostly consists of Steel Slag, the remain 13% is hazardous by-product which mostly Dust and Sludge. Total whole generation of by-product in PT Krakatau Posco around 1.7 million ton/year equal to 567 Kg/ton-steel.

By knowing each by-product characteristics, align with Environmental Regulation and continuous developing potential by-product utilization, PT Krakatau Posco be able to determine best utilization method annually. It affects to reduce cost and increase revenue for the company at the same time.

2. Methodology

As the initial step to determine best by-product management, find out its characteristic and identify all generated by-product refer to legal status. It can be done by conducting process mapping of whole process the Integrated Steel mill. Next step is set up by-product balance and its utilization possibility. Lastly, maintain and continuously review by-product expansion to use to the other sector through promoting and trial & error.

3. Results and Discussions

3.1 Define Characteristic By-product

After operation PT Krakatau Posco has made by-product classification and maintain its management. However, it is not enough because advance utilization or technology should be applied. The result is PT Krakatau Posco currently be able to increase the value of by-product gradually as target become 100% of recycling.

**) on research progress*

Div.	By-product	By-product management	
		As was (2019)	To be (2022)
Non-Hazardous	Granulated Blast Furnace Slag (GBFS)	Cement as clinker substitution	Cement as clinker substitution (94%), **concrete aggregate (5%), Filler of Body Floor Tiles (1%), soil amendment***
	Air Cooled Slag (ACS)	Civil works	Civil works
	Steel making slag	Steel making & Sinter as Fe source (15%), Civil Works (23%)	Steel making & Sinter as Fe source (25%), Civil works (32%), **cement as admixture & Fe source (43%)**
	Others (used conveyor, etc.)	External utilization	External utilization
Hazardous	Dust & Sludge	Steel making & Sinter (90%), Cement as Fe Landfill (10%)	Steel making & Sinter (90%) **Cement (10%)**
	Mill scale	Steel making	Steel making
	Others (waste oil, etc.)	Landfill	**Cement as alternative fuel (77%),** incinerator & landfill (23%)
By-product Recycling ratio		**80%**	**99.9%**

Table 1. Comparison of By-Product Management PT Krakatau Posco 2019 vs. 2022

3.2 Converted type of by-product management from landfill become utilization

PT Krakatau Posco has set up plan of by-product management by annual and develop new utilization by researching and surveying update situation regarding how to increase value of by-product. In 2019 – 2022, The company has succeed to convert some value of by-product became recycle-able, such as used refractory can be used as paving block material, sludge, and others which previously treated as landfill material, now days become alternative material and fuel.

Generated dust and sludge will be mixed with other sources in cement factory before feeding into the kiln process reaching total mineral oxide 50% as minimum requirement which consist of Fe_2O_3, Al_2O_3, SiO_2. For others such as contaminated goods,

contaminated soil and activated carbon can be used as alternative fuel as 2500 kcal/kg as minimum requirement after mixing with other as shown in **Table 2**.

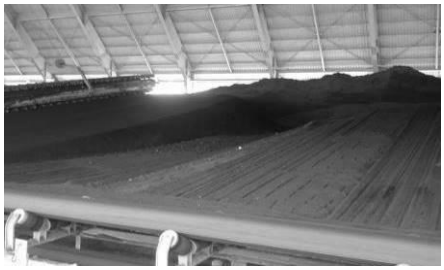
Cement as Fe source	Cement as fuel
Dust and Sludge Min. requirement 50% of total oxide  Sludge an dust put in storage in cement area before process	Contaminated goods, Tar Sludge, Slurry oil, Activated Carbon, Contaminated Soil Min. requirement 2500 Kcal/Kg   Contaminated goods (plastics) Contaminated soil

Table 2. Converted By Product From Landfill To Cement

3.3 Expand By-Product Utilization to The Other Business with High Value

Since Steel Slag was categorized as Registered Non Hazardous Waste in 2021 according to Indonesian Regulation 22/2021, Steel Players has opportunity to expand utilization of Steel Slag widely without considering whether utilizer has a Hazardous Waste Permit. Some of new utilization expansion shown below :

[GBFS] for Filler of Body Floor Tiles

Globally GBFS is utilized as a substitution of clinker and can replace OPC become Slag Cement. In Indonesia Slag Cement has a portion of GGBFS up to 36 - 70% according to SNI (Indonesian Standard) 8363:2017. In the other side, PT Krakatau Posco find opportunity to cooperate with floor tiles company. GBFS has similar chemical component with main material and colour as called “White Sand” imported from China. Max. 19% of GBFS will be mixed with White Sand. In term of unit price, PT Krakatau Posco can increase value of GBFS to 13 times than cement.

Content	White Sand	GBFS
CaO (%)	39.5	43.3
SiO_2 (%)	33.2	35.2
Material Photo	 White Sand	 GBFS

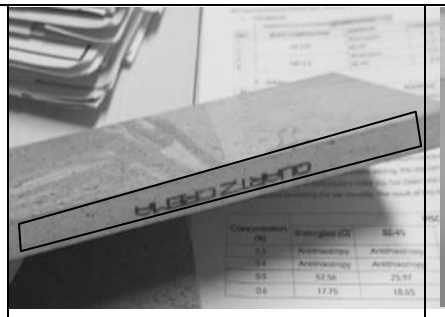
Body tiles Photo		
	Using white sand	Using GBFS

Table 3. Comparison of White Sand vs. GBFS

[GBFS] for Concrete Aggregate

GBFS also is utilized as fine aggregate in concrete because it has similarity with natural sand which limited sources in nature. The application is by mixing GBFS with fine aggregate (portion 50 : 50), then it generates compressive strength 52.36 MPa in 28 days observation.

Mixing Comparison	Compressive strength (MPa)
Natural Sand + M-Sand (50 : 50)	56.32
GBFS + M-Sand (50 : 50)	52.36
Requirement Standard	50.00

Table 4. Comparison of Compressive Strength original material vs. using GBFS

[GGBFS] as Soil Amendment

Considering chemical content and alkali characteristic of slag, it also can be used as soil amendment as dolomite substitution. Lime contains in GGBFS 43%, it is fulfilled 18 % as minimum requirement. PT Krakatau Posco applies GGBFS as soil amendment to corn farm by cooperated with Local Agriculture Agency. The result shows productivity yield of corn with GGBFS is higher than dolomite. Thus, in the future Slag can be one of option to be used as alternative Soil Amendment.

Comparison	Productivity (ton/Ha)	Gap (%)	Remarks
Soil (as reference)	9.07	-	
Soil + dolomite	11.2	23.5	By dose 4 tons/Ha
Soil + GGBFS	15.28	68.4	By dose 2 ton/Ha

Table 5. Comparison of Soil amendment dolomite vs. GBFS

Item	% CaO	Remarks
Dolomite as fertilizer	Min. 29	SNI 02-2804-2005
GGBFS	43	

Table 6. Chemical components dolomite and GGBFS

Soil Amendment using GGBFS

Pouring fine GBFS | Corn plant before harvest (2 weeks) | Corn with GGBFS

Table 7. Soil Amend process using GGBFS

[Steel Making Slag] as the Soft Soil Improvement

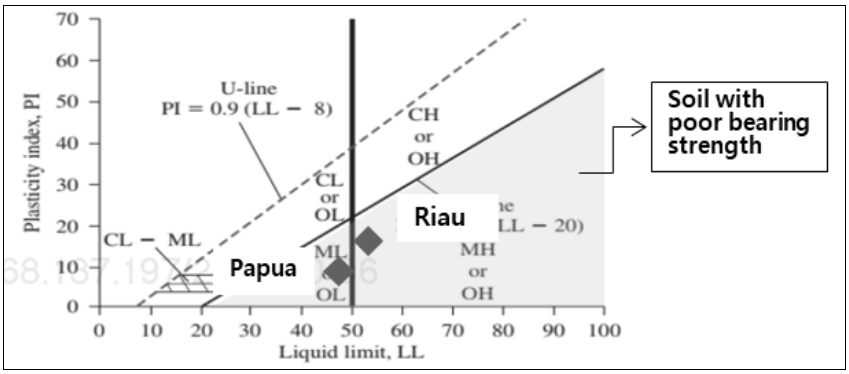
As we know, after raw steel making slag through metal separation facility, the products is divided on 2, as a metal slag 20% and non-metal slag 80%. metal slag can return to the internal as substitution of iron and steel making process. In the other side, non-metal slag is mostly utilized as an aggregate for road base. However, there is an opportunity to use this Slag for soft soil improvement as potential project in the future because around 10% of land in Indonesia is categorized as soft soil. It can replace common material such as cement and mortar which is expensive and non-renewable material. Mixing design of 70% of Slag -8 mm and 30% of original Soil can generates CBR of soil up to 9.4%. It achieves more than minimum standard. As a trial test, PT Krakatau Posco tested soil located in Papua.

Benefit using Slag to improve soft soil: bearing strength of original soft soil, Soft soil stabilized with Slag can be utilized as subgrade for road construction (CBR min. 6%), Slag reduced potential of swelling and shrinkage of soil caused by water with the increase of Slag ratio, Slag inclusion reduce required water for compaction as shown with Optimum Moisture

*)*CBR : California Bearing Ratio*

Comparison	CBR* (%)	
	Papua	Riau (Sumatra)
Original Tested Soil	5.6	4.9
Slag -8 + Original Soil	7.4	9.4
Requirement soil layer (General Spec' 2018)	Min. 6	

Table 8. CBR Comparison of original soil material vs. Soil mixed with Slag



Graph 1. Soft soil properties

[Steel Making Slag] for Cement material (Fe and Mineral Source)

PT Krakatau Posco continuously to closed partnership with cement industry, because cement industry can consume steel industry by-product stably with significant consumption. Steel making slag aggregate size (0 – 70 mm) has total mineral similar with Pozzolana, which can utilize as cement admixture after grinding to the cement grinding company which has no Kiln Plant. Total mineral in steel making slag 96%. It can be added for Portland Composite Cement (PCC) around 15%

The same consideration is applied for under size (0 – 8 mm) of steel making slag which still contain enough Fe as iron sand substitution. It can be used for cement company which has Kiln Plant. **Table 9.** shows comparison of Fe and total mineral contain in slag and main sources.

Comparison		Chemical component (%)	Remarks
Cement Admixture	Slag 0 – 70 mm	96	SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO
	Pozzolana	86	
Fe Source	Slag 0 – 8 mm	~50	Fe_2O_3
	Slag 0 – 3 mm	~69	
	Iron Sand	79.9	

Table 9. Comparison of Slag vs. main material

In case of slag as cement admixture, the result of compressive strength is fulfilled the requirement as mention in SNI (Indonesian Standard) SNI 7064-2014 [5].

Requirement for admixture		SNI	Actual
Compressive strength (kg/cm^2)	3 days	Min. 130	200
	7 days	Min. 200	260
	28 days	Min. 280	350
Blain (cm/g)		280	413
Mixture (%)		Clinker min. 65, Additive : -Gypsum 3, -Limestone 20, -Pozzolana 12	Clinker min. 65, Additive : -Gypsum 3, -Limestone 17, -BOF Slag 15 -Pozzolana 0

Table 10. comparison of SNI Requirement vs. Actual

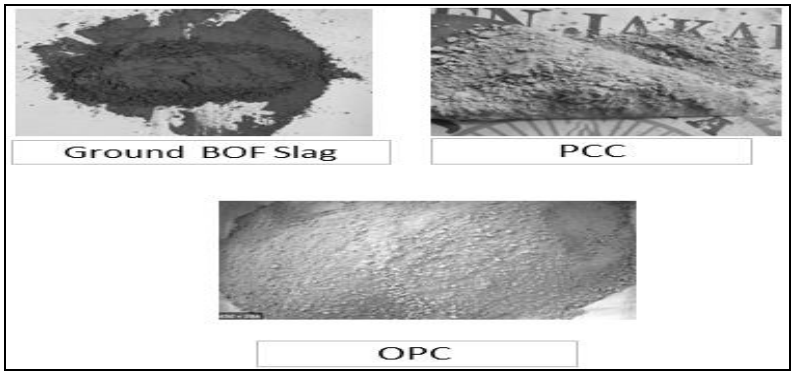


Figure 1. Ground BOF Slag, PCC and OPC

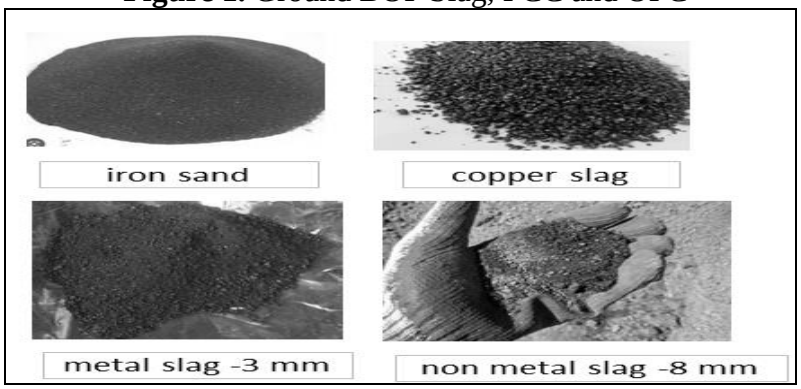


Figure 2. Iron Sand, Copper Slag, Steel Slag

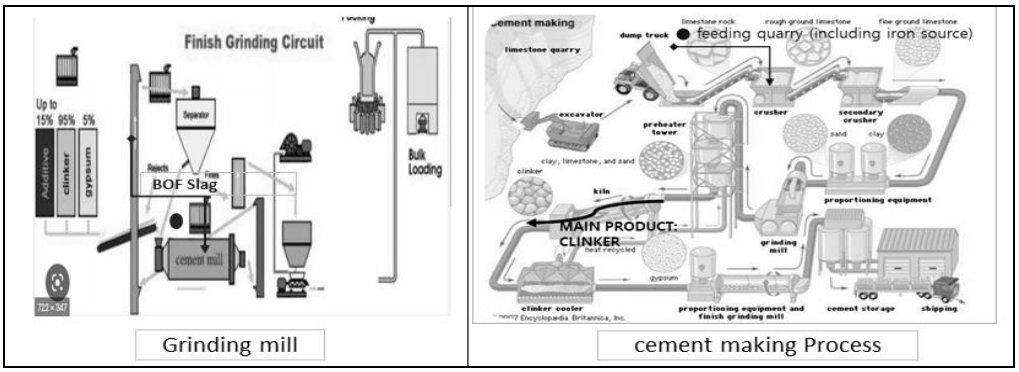


Figure 3. Cement Process Grinding mill and Kiln Plant

[Steel Making Slag] for Paving Block

Slag 0 – 8 mm has characteristic with fine aggregate in term of size and physically. It can reduce and eliminate usage of sand and fine aggregate as raw material as shown in **Table 11**. Mostly application of paving block in Indonesia is for residential and pedestrian area.

Paving Block	Composition (%)			Strength Test (Kg/cm^2)
	Fine Aggregate	Sand	Slag	
Original	70	30	-	≥ 250 (SNI 03-0691-1996)
Modification	35	-	65	265

Table 11. Paving Block Composition and Strength Test Result

Figure 4. Paving Block Making Process

4. Conclusions

According to target to increase by-product value, PT Krakatau Posco always develop and conduct mapping to find best method of utilization. Because Total by-product is being generated from steel industry is around 56% of total production. It means innovative and creative approach needed to keep utilization of by-product on the track and leading 100% utilization.

5. References

[1] Press Release. 2022. *Investasikan Rp. 1 triliun, Industri Baja Dongkrak Kapasitas Produksi 500 Ribu Ton*. Retrieved from https://kemenperin.go.id/artikel/23354/Investasikan-Rp1-Triliun,-Industri-Baja-Dongkrak-Kapasitas-Produksi-500-Ribu-Ton. Indonesia

[2] President Regulation No. 74/2022.2022. Policies of National Industrial Year 2020 – 2024

[3] SEAISI. ASEAN-6 Steel Consumption to Grow 6% YoY in '21.2021.Retrieved from https://www.seaisi.org/details/2541?type=news-rooms

[4] Government Regulation Number 22. 2021. Implementation of Environmental Protection and Management.Indonesia

[5] Standar Nasional Indonesia 7064-2014.2014.Semen Portland Komposit.Indonesia