Study on the Promotion of Steel Slags Recycling in Taiwan

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Abstract

The constant development and abuse of natural resources have led to shortage, which also causes many countries to pay attention to waste recycling issues and promote concepts in resource sustainable recycling, in order to reduce the depletion of natural resources. The current development trend in waste recycling has gradually shifted from single use in cradle to grave to the sustainable recycling in cradle to cradle (C2C), using resource recycling to achieve the economic concept of sustainable management.

Key words: Waste-to-Resource, Electric Arc Furnace Steelmaking Slag, Oxidative Slag, Reductive Slag

1. Introduction

Iron & steel are the foundation of industrial development. The construction engineering, transportation and commercial machines & tools are all closely related to the iron/steel industries. How to dispose and utilize the waste generated along with the manufacturing process shall be carefully faced and considered. Slag is the waste generated during the smelting of iron & steel. According to the different production approach, it can be categorized into: 1. The waste generated in the Blast Furnace during the iron smelting process is called『Blast Furnace Slag』. Under the high temperature, the blast furnace slag is still the liquid stage. Along with the different temperature dropping and cooling process, it will generate 『Air-cooled Blast Furnace Slag』and『Water-quenched Blast Furnace Slag』separately. 2. Steelmaking process. It can be categorized into the 『Convertor』steelmaking of integrated steelmaking plant and the 『Electric Arc Furnace』steelmaking of non-integrated steelmaking plant. Since the manufacturing process of convertor steelmaking is smelted all the way to iron and then smelted to steel, therefore, it is called the integrated steelmaking plant. The slag generated during the steelmaking process is called『Basic Oxygen Furnace Slag』.3. As to the Electric Arc Furnace (EAF) : steelmaking of non-integrated steelmaking plant, the main raw materials used for steelmaking are the recycling scrapped iron and steel. The slag generated during the steelmaking process can also be categorized into the 『Electric Arc Furnace Oxidative Slag』of front-end process and『Electric Arc Furnace Reductive Slag』of back-end process. [1, 2]

The operation of electric arc furnace smelting recycling system in Taiwan has already well completed. The main sources of scrapped iron and steel used for steelmaking are: general household scrapped steel, scrap and defective products generated during the plant manufacturing

process, rebar from demolition of plants and houses, scrapped steel from obsoleted vessels, machinery and cars/motorcycles etc. According to the smelting process, the slag of EAF can be categorized into EAF oxidative slag (hereinafter referred to as oxidative slag) and EAF reductive slag (hereinafter referred to as reductive slag) two major items. The EAF steelmaking plants in Taiwan produce around 10-million metric tons (MT) of crude steel annually and generate around 1.4-million MT of oxidative slag and 0.4-million MT of reductive slag simultaneously [3].

This study integrates the resource promoting strategy of EAF steelmaking slag and brings together the relevant technologies as the reference for promoting the slag-to-resource of EAF steelmakers.

2. Analysis & Discussion

The Taiwan government has regulated the management of related generating sources, storage, recycling, removal, disposal, reutilization and flow with respect to the general waste and industrial waste, and considered in sequence to reduce the waste generation, reuse, recycling and utilization, energy recovery and proper disposal, clearly defined the environment-friendly specification to promote the material recycling and reutilization.

2.1. Related Status of Reutilizing Waste & Construction Industries in Taiwan

In Taiwan, the wastes were categorized into the general waste and industrial waste. The general waste refers to the solid or liquid waste generated from the household or non-industry; the industrial waste refers to the waste generated from the industrial institutions. The total amount of waste was around 25.35-million MT in 2012, in which, the general waste was around 7.4039-million MT (holding 29.21%) and the industrial waste was around 17.95-million MT (holding 70.79%)【4】. The reutilizing key of waste should have the features of high and stable demand (5), and the market demand shall be greater than the generation volume of waste to facilitate the reutilization of waste resources and reduce the stacked space of waste and the amount of waste.

The aggregates are the most important bulk material for construction engineering. The material demand is high and stable which is the best way of option for promoting recycling material to the industry promoted. To proceed the better implementing approach for reutilization introduction of waste-to-resource, its indexes of assessing feasibility include the elimination of demanding amount, applied technology, process equipment, locality, product value, restriction of acts and specifications six items, shown as Table 1.

Even Taiwan has already permitted the import of sand and gravel, however, the main source still depends on the nature sand and gravel obtained from the local rivers. Due to the rising of environmental consciousness, the concept for maintaining natural landscape, the weak concept of quarrying industry to the mining environment and preventing various disasters, etc., that cause the imbalance of supply and demand, and even trigger the price escalation of aggregates which becomes the major potential concern of construction industries. Therefore, the development of aggregates supply source shall be coordinated with the demand, adopt the diversified supply source development and reutilization to achieve the target of sustainable development.

The promotional approach for waste reutilization is to proclaim the appropriate ways of using material through the environmental protection department; incorporate the recycling material items and using specification & proportion in the engineering guidelines through the engineering application end to induce the market channels of construction resource recycling. Most of the waste generated from the industrial manufacturing may suitable for using in the civil engineering including the properties of hardness and anti-wear which is suitable for using as the aggregate; with the hydration property and large internal friction angle which is suitable for using as the ground material or the ground improvement material; if the chemical composition contains FeO, CaO, SiO2 etc., it may use as the cement additive; in addition, if the chemical composition contains the fertilizing elements of CaO, SiO2, MgO, FeO etc., it is suitable for using as the agricultural compost material. Accumulate the resource material suitable for the aggregate material produced yearly in Taiwan, and assess the constructions with large demand of aggregate material, and then utilize the

strategy approach that will be able to link the reutilization of waste to the construction adequately.

Table 1 Waste-to-Resource Introducing Engineering Reusing Feasibility Assessment [1]

Item	Assessment Criteria	Description of Benefits
1	Eliminate Demanding Amount	High Demand and stable market.
2	Applied Technology	Mature technology and able to ensure quality.
3	Process Equipment	No need additional investment of high technology or complicated equipment to avoid increasing cost.
4	Locality	Nearby use to lower transportation cost.
5	Product Value	Shall exceed disposal cost.
6	Restriction of Acts & Specifications	Shall comply with reuse purpose act, CNS national standards, construction outlines and the related operating specification standards.

2.2. Construction Application Market Analysis of EAF Steelmaking Slag

The direct reutilization pathways of oxidative slag are road subgrade layer, asphalt pavement, non-structural concrete respectively (such as Controlled Low Strength Material, CLSM) [6]. The annual demand of road subgrade layer is around 1.5-million MT, the asphalt pavement is around 12-million MT, however, the recycling of reclaimed asphalt pavement has already up to 40%. The annual demand of CLSM is around 2.2-million MT, the market demand is far beyond the generating amount of oxidative slag waste and has already reached the reutilizing effect of waste resource. The annual generating amount of reductive slag is around 0.4-million MT. The reutilizing pathway of reductive slag is distinguished by if the stabilization is to be applied, mainly used for the cement material without requiring the stabilizing treatment and stabilizing the expansion of slag. The reutilizing pathways and relative total demand of EAF slag are shown as Table 2.

2.3. Resource Technology Assessment of EAF Steelmaking Slag

(1) Promoting Pathway of EAF Steelmaking Slag

Taiwan has already accumulated quite rich research with respect to the reutilization study of EAF slag including the cement material, asphalt concrete aggregate, CLSM aggregate material, basic layer of pavement construction or bottom level aggregate material etc. Under the restriction of Waste Reuse Types of Soil Pollution Control Standards and Industries issued by Taiwan government, the reutilizing amount of EAF slag was limited and could not be effectively promote.

Table 2 Resource Market Analysis of Taiwan EAF Steelmaking Slag [1]

Dividing Mode		Feasible Pathway	Annual Demand (10-Thousand MT)	Aggregate/Material (10-Thousand MT)	Introduce to Restriction Assessment
Oxidative Slag 【0.7-million MT, the statistics of year 2013 is 1.4-million MT】	Same as water-quenched blast furnace slag, directly introduce to reutilizing purpose	1.Road Subgrade Layer	150	150	Newly built road, decreased year by year
		2.Asphalt Pavement	1,200	1,000	Reclaimed material already up to 40%
		3.Non-structural Concrete (CLSM or cement products)	220	165	Other waste resources have elimination demand as well
		4. Carboundum	Less demand elimination		Less demand elimination
		5. Other reutilizing approaches			-
Reductive Slag 【0.4-million MT, the statistics of year 2013 is 0.4-million MT】	Stabilization is not required	1.Cement	1,200	1,920 (Raw material)	1.Able to add raw material 10% 2.Transportation cost is high
		2.Melt down process	Reduce reductive slag 20～40%		Application Technology has not skillful
	Stabilization is required	1.CLSM	220	165	Other waste resources have elimination demand as well
		2. Other reutilizing approaches (such as Mainland China steel slag cement, Southeast reutilization etc.)			Disposal & transporting finished product are to be assessed

In addition, the industry lacks of knowledge about the non-toxic steelmaking slag and the hazardous steelmaking ash collection, blended handling and improper disposal results the trouble to the domestic steel/iron industries as well.

Therefore, for the promotion of slag reutilization shall be able to overcome the corroded situation created by the expansion property of slag and the metallic iron remained on the surface, other than through the stabilization treatment and strengthening the magnetic separation efficiency, shall be further promoted through the planning of selecting the applicable construction purpose to avoid further negative perception caused to the slag from the public.

The types of slag produced in Taiwan include the basic oxygen furnace slag, oxidative slag and reductive

slag. After completing the assessment in accordance with the material properties and applicable construction purposes, the reutilization of EFA slag is mainly selected the asphalt concrete pavement with coverage and CLSM backfill material, additional assessment is implemented to use as the additive for cement raw mix.

(2) Technology Research for Oxidative Slag

The Los Angeles abrasion rate and soundness of EAF oxidative slag are equivalent to the general natural gravel , however, the specific gravity is higher than the natural gravel due to higher iron content. The water absorption is greater than the natural gravel due to more porosity of slag itself. However, the results of running water quality standard, radiation dose test and toxicity dissolution test have all complied with the current specification values, and will not cause any hazard to the environment. Therefore, it can be considered as the general industrial waste and reutilized for the application of road pavement.

(3) Technology Research for Reductive Slag

The main ingredients of reductive slag are categorized into 3 parts (1) active ingredient (2) oxidized metal and (3) other materials. The active gradient is mainly SiO_2 and CaO, and its gradient is similar to the cement raw mix, however, itself contains free calcium oxide which results its instable characteristics. Therefore, the reductive slag is used as the cement raw mix, and place in the rotary kiln with high kilning temperature to lower its instability in order to ensure its stability and practicality.

3. Assessment & Discussion

Construction industries, the promotional pathways would be mainly locked on the road subgrade layer, asphalt pavement, CLSM and cement additive. The strategy is to provide the complete technical data and promote the implementation of verification system in order. For the part of build-up technology, the stage is to proceed from the asphalt concrete pavement of oxidative slag and cement raw mix of reductive slag two aspects.

As to the assessment aspect of applying the original slag to the cement raw mix, since its chemical contents are similar to the cement raw mix, and after replacing partial cement raw mix in accordance with the different content of reductive slag, and proceeding the thermomechanical analysis (TMA) test in accordance with the different cement proportion, the impact change to the burning temperature of rotary kiln becomes less after adding the reductive slag to the cement raw mix, it proves the feasibility of replacing partial cement raw mix.

4. Conclusion

(I). The annual capacity of EAF steelmaking slag was almost fixed, propose the appropriate reutilization source and transparentize the elimination flow, and cooperate with the government policy toward the direction of diversified reutilization in order to develop the pathway.

(II). The product of oxidative slag has the features of high stability, low silt content, low abrasion rate and good soundness, to improvement of stabilization and the main promotional purposes shall be locked on the asphalt pavement, road subgrade layer and non-structural concrete.

(III). The implementation concept of waste resource recycling management, it will be handled and processed by each industry competent authority based on the announced related acts; the engineering unit is responsible for maintaining the on-site quality. If the prescribed use restrictions are followed, it may indicate that resource product has no doubt about the impact to the environmental aspect.

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