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Technology

Processing and Reusing Technologies for Steelmaking Slag

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Abstract

About 40 million tons of steel slag a year, which is the by-product of iron and steel manufacture, is generated in Japan and the almost all the slag is reused for the materials, e.g. cement raw material, road base course material and civil engineering material, by effectively utilizing its characteristics such as chemical components and mechanical properties. Most of its purposes of uses are to replace the functions of the newly mined raw materials from nature and promoting the use of steel slag is an effort to contribute to environmental conservation in this regard. On the other hand, due to the changes in social situation, supply-demand structure in the steel slag market is changing and Nippon Steel Corporation is developing the technologies to create new features of steel slag and to utilize them, especially in the field of Basic Oxigen Furnace (BOF) slag. In this report, the current production and sales status, processing and reusing technologies of BOF steelmaking slag are mentioned.

1. Introduction

Iron and steel ("Iron/steel") slag is a by-product of manufacturing iron/steel products.[1] Almost all iron/steel slag generated in the course of iron/steel manufacture is effectively used in multiple ways, such as a raw material for cement, a road base course material, a civil engineering work, and a raw material for fertilizer. However, the supply–demand structure in the iron/steel slag market has been rapidly changing in recent years reflecting not only the sluggish demand for domestic public works and construction projects but also social changes (e.g., governmental policies encouraging the use of other recyclable materials and ever-tightening environmental regulations). Under these conditions, Nippon Steel Corporation ("our company") has been advancing the development of new technologies for expanding the processing and reuse of iron/steel slag, especially the use of BOF steelmaking slag (BOF slag) as an "environmental material".[2]

In this report, we first review the most recent production and sales information for iron/steel slag, the processes for manufacturing slag products, and then describe the conventional applications of BOF slag and the current status of development of new application technologies.

2. General Condition of Iron/Steel Slag

2.1 How iron/steel slag is produced

As a by-product of the manufacture of steel from iron ore, iron/steel slag originates from veinstone that is contained in the raw materials (iron ore, coal, coke, etc.) and the flux that is added in the steelmaking refining process for removal of impurities (Si, P, S, etc.) and composition adjustment. The yield of iron/steel slag is about 300 kg/t-p per ton of pig iron for blast furnace slag and about 100 - 150 kg/t-s per ton of molten steel for steelmaking slag. In Japan, some 40 million tons of iron/steel slag are presently produced annually (**Table 1**).

Table 1 Production and sales of steel slag (2010Fy)

			Production		Sales	
			Japan	NSC	Japan	NSC
Pig iron			82,915	32,180	-	-
Crude steel			110,792	32,716	-	-
Production	Blast furnace	Air cooled	5,085	1,495	4,362	1,000
		Granulated	19,839	8,279	19,202	8,361
		Sub total	24,924	9,774	23,564	9,360
	Steelmaking	BOF	11,674	4,508	10,460	3,445
		EAF	2,842	-	2,254	-
		Sub total	14,516	4,508	12,714	3,445
Grand total			39,440	14,282	36,278	12,805

(kton)

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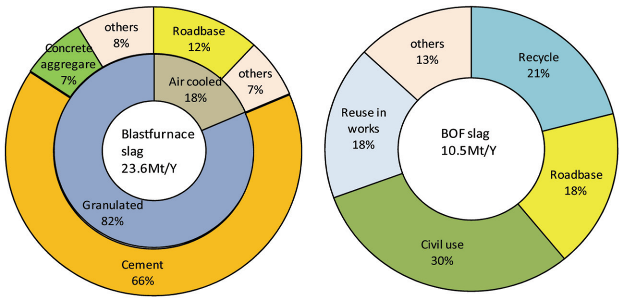

(a) BF slag (b) BOF slag

Fig. 1 Utilization and sales of slag (in Japan, 2010Fy)

2.2 Properties of iron/steel slag

Iron/steel slag is composed mainly of CaO and SiO_2. In addition, blast furnace slag contains Al_2O_3, MgO, and S, and steelmaking slag contains iron oxides (FeO, Fe_2O_3), MnO, P_2O_5, etc.

Steelmaking slag includes the following: slag produced in the hot-metal pretreatment processes (desiliconization, dephosphorization, desulfurization, etc.), slag flowing out from the converter into the molten steel ladle, and slag formed during the secondary refining treatment (this slag is sometimes called "secondary refining slag" or "ladle slag").

As shown in **Fig. 1**, nearly 80% of blast furnace slag is granulated slag produced by rapidly cooling hot molten slag (initially at a temperature of about 1,500°C) with a jet of high-pressure water. Granulated slag is vitreous and looks sandy. It is similar in chemical composition to Portland cement and hardens when it reacts with water. Therefore, about 80% of granulated slag is used as a raw material for cement. The remaining about 20% of blast furnace slag is air-cooled, produced by subjecting hot molten slag to air cooling and moderate water sprinkling. Air-cooled slag is similar in appearance and properties to crushed stone. It is a substitute for natural crushed stone used as a road base course material, concrete aggregate, etc. On the other hand, hot steelmaking slag is mostly cooled naturally on an exclusive yard to be made into crush stone. The processing and usage of steelmaking slag shall be described in detail later.

3. Steelmaking Slag Processing Technology

The iron/steel slag processing flow is schematically shown in **Fig. 2**. Steelmaking slag is subjected to the following four processes: ① solidify and cooling of the hot molten slag, ② crushing and magnetic separation treatment of the slag to recover the metal iron, ③ crushing and classification of the slag for grain size adjustment to manufacture the slag product, and ④ aging treatment of the slag product for improving its quality and volumetric stability. Each of the above processes shall be explained below.

3.1 Cooling of the steelmaking slag

As steelmaking slag is formed, it is in a molten or red-hot state at a temperature of 1,300 - 1,700°C. Therefore, steelmaking slag must be immediately subjected to the cooling process upon removal. Ordinarily, this is performed in a cooling yard by air cooling and moderate water sprinkling. However, this method requires a considerable amount of time to cool the hot slag down to a workable temperature and demands the allocation of a spacious yard. Therefore, a number of more efficient cooling processes have been put into practical use. They include the air granulation process, whereby a high-pressure gas is blown onto the molten slag to solidify and granulate the slag while it is being cooled; ISC process,[3] whereby the hot slag is first poured into a steel box for accelerated cooling/solidification and then subjected to water sprinkling and immersion cooling; and the rapid cooling process,[4] whereby the molten slag is poured into a special drum and cooled rapidly by sprinkling water over the slag. In addition, research and development has been applied to a new process whereby molten slag is poured between twin-rolls and cooled very rapidly.[5] There is the possibility that this process will allow for effective control of slag solidification and provide for the recovery of a large portion of the heat loss in the cooling process.

3.2 Crushing and magnetic separation

Steelmaking slag contains about 10 - 40wt% metal iron (excluding iron oxides), which is derived from the refining process or from some processing vessel (e.g., the converter, hot metal/molten steel ladle, or tundish). It is advantageous to separate this iron from the slag for the purpose of using the iron recovered as a substitute for scrap iron and/or making effective use of the slag for applications where iron would be an impurity. Therefore, after cooling, the steel slag is crushed and the iron is recovered by magnetic separation. In

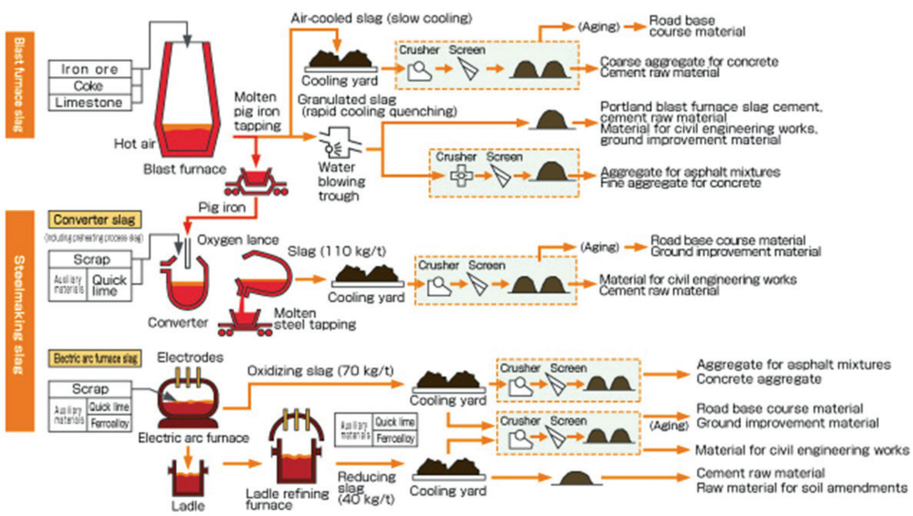

Fig. 2 Schematic of slag processing flow [1]

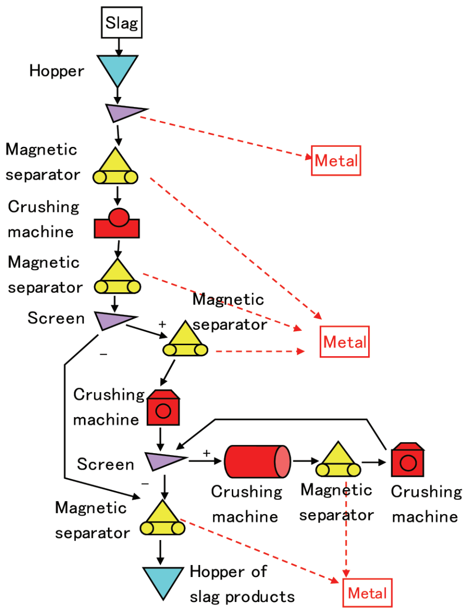

Fig. 3 Schematic flow of crushing, magnetic separation and classification

general, with the aim of increasing the metal iron recovery ratio and improving the quality of metal iron recovered, the above crushing and magnetic separation process is repeated several times, as illustrated in **Fig. 3**.

3.3 Crushing and classification

To commercialize the slag produced, it is necessary to process it to the grain size specified by the customer. Therefore, the slag is adjusted to the customer-specified grain size through a process of crushing and classification. In the real process, as illustrated in Fig. 3, an efficient process using crushers, magnetic separators, and screens (they are arranged in such a way to allow for simultaneous recovery of iron (see Section 3.2) and adjustment of slag grain size) has been designed.

3.4 Aging treatment

As mentioned in Section 2.1, the flux added to refine the steel forms a component of the steelmaking slag. It is particular significance that CaO and MgO contained in the flux remain partly inactive and reside in the slag or crystallize while the slag is solidified and cooled. These inactive materials, referred to as free-CaO and free-MgO, react with water, and, in the process, their volume nearly doubles through hydration. As a measure to prevent that, the steelmaking slag is subjected to the aging treatment process, whereby the following hydration reaction is completed by the time the slag is shipped:

$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$MgO + H_2O \rightarrow Mg(OH)_2.$$

There are two representative methods of aging treatment: normal aging treatment, whereby the hydration reaction is allowed to take place by natural rainfall on the yard, and accelerated aging treatment, whereby the hydration reaction is induced to complete in a shorter period of time. The accelerated aging treatment processes that have been put into practical use include "steam aging treatment" that uses high-temperature steam, "hot water aging treatment" that immerses the slag in hot water, and "high pressure aging treatment" that causes the slag to react with steam in a vessel under high pressure (e.g., 0.6 - 1 MPa). In recent years, in Japan, steam aging treatment or high pressure aging treatment is often applied to steelmaking slag before shipment to ensure moderate, uniform expansion of the slag, especially when the slag is to be used (for example, for road base course material) where expansion can become a major problem.

4. Status of the Present Use of Steelmaking Slag Product: Conventional Use

4.1 Steelmaking slag as material used in road construction (road base course material)

In road construction, aggregate (road base course material) is spread and compacted under the pavement surface to reinforce the road's load-bearing capacity. In 1979, air-cooled blast furnace slag was specified as iron/steel slag for road base course material in road construction (JIS A 5015).[6] In 1992, steelmaking slag was also designated for use as road base course material. Because steelmaking slag is hard and has good wear resistance, it is also used as an aggregate for asphalt mixtures. In 2002, together with use for road base course material, steelmaking slag as aggregate for asphalt mixtures was included in the specified procurement items under the Green Purchasing Law.

When steel slag is used as a road base course material, preventing the expansion thereof is the most important factor in quality management. In fact, studies have concluded that in the past, the expansion of slag owing to the hydration phenomenon discussed previously was the primary cause of trouble with the use of steelmaking slag as a road base course material. Therefore, it has become common practice to subject steelmaking slag to a suitable aging treatment (steam aging treatment, etc.) and confirm that the steelmaking slag meets the specified residual expansion ratio of 1.5% or less by a 80°C hot water expansion test prior to shipment of the steelmaking slag.

4.2 Steelmaking slag as material used in ground improvement material

In the coastal regions of Japan, the deposit of soft clayey soil is observed at many locations. To improve such soft ground, the sand compaction pile (SCP) method, whereby tightly compacted sand piles are driven into the ground, has been widely carried out. On the other hand, in view of the depletion of natural sand and the environmental conservation, applying some substitute for natural sand began to be studied in the middle of the 1990s. So research and development of technology for apply steelmaking slag as a construction material for port facilities has been conducted. For this application, the physical properties of steelmaking slag were considered; however, more importantly, the influence of steelmaking slag on neigh boring sea area that were used was also investigated. As a result, it was confirmed that the local rise in the pH value of the sea area due to the elution of alkaline components of the steelmaking slag was minimal. This topic is discussed in depth in Section 5.3.1. Therefore, the possibility of substituting steelmaking slag for natural sand in the SCP method was favorably evaluated.[7] In particular, in the Setonaikai district, more and more local governments were forbidding the collection of sea sand from the standpoint of protecting the nature of the district. Under these conditions, steelmaking slag came to be used in the soil improvement of grounds of many fishing ports in in the Setonaikai district. In addition, our company developed a new hydrated SCP "Eco-Gaia-Stone®" (compaction type) that is capable of positively displaying a superior compaction property unique to steelmaking slag, and this has fostered a new design method using the officially approved, highly compacting SCP pile.[8-11)]

4.3 Steelmaking slag as material used in of fertilizer/soil improvement

Looking at the FY 2010 consumption of iron/steel slag, the amount of blast furnace slag and steelmaking slag used in 2010 for agricultural fertilizer and soil improvement was about 230,000 tons, or only about 0.5% of the total consumption of iron/steel slag. Concerning the effect of iron/steel slag used as a fertilizer, testing on the application of air-cooled blast furnace slag as a calcium silicate fertilizer was conducted in 1964.[12] The research determined that fertilizer derived from slag helped increase the yield of paddy rice because of the following factors: ① silicic acid settles on the surfaces of leaves and culms of the rice plant, thereby preventing the invasion of disease-causing bacteria and harmful insects and ② it promotes photosynthesis by setting the leaves upright and improving their light receiving posture.[12] In the following year of 1965, the Ministry of Agriculture, Forestry and Fisheries approved the use of silicic acid fertilizer, derived from air-cooled blast furnace slag, for the first time in the world and blast furnace slag was repositioned as an ordinary fertilizer when the Fertilizer Control Law was revised.

Through subsequent research and development,[13] BOF slag, too, was approved as an ordinary lime-based fertilizer in 1981. Since then, an affiliate of our company has been manufacturing and supplying three types of fertilizer to agricultural producers: silica fertilizer (blast furnace slag and BOF slag), lime fertilizer (BOF slag), and special fertilizer containing iron (BOF slag). In particular, BOF slag contains not only calcia, magnesia, and silica but also many trace elements such as iron oxide and manganese oxide. Thus, it is capable of supplying both a fast-acting alkali component coming from calcia and a slow-acting, though enduring, alkali component derived from calcium silicate. Compared with ordinary fertilizers such as dolomite lime and slaked lime, BOF slag fertilizer has a more lasting effect on the improvement of acidic soils.[14]

In recent years, with the rise in the practice of repeated cultivation of the same crop on the same ground, the germ-caused damage to cruciferous plants (Chinese cabbages, cabbages, etc.), called clubroot, has become a significant problem. Goto et al. at Tokyo University of Agriculture have conducted tests[15] using BOF slag fertilizer as a material that may prevent clubroot by supplying the required alkali and trace elements in a balanced way on a lasting basis.[16, 17] Our company, a manufacturer of BOF slag fertilizer, expects that the test will prove that the BOF slag fertilizer is really effective to prevent the plant disease.

5. Status of the Development of Application Technology: New Uses

As described in the preceding sections, the development of BOF slag application technology in Japan has been primarily promoted in the fields of road base course material and civil engineering. However, in view of declining investments in construction projects, including public works projects, in recent years, promoting effective utilization of BOF slag while responding to environmental demands that have become increasingly severe requires creating new uses for BOF slag on the basis of keen insights into the social needs of the future.

In many of the coastal areas of Japan, two contradictory environmental problems have become conspicuous. They are "eutrophication," which causes red tides/blue tides in closed sea areas, and "oligotrophication," which is considered one of the causes of reduction of useful seaweed beds, called sea desertification, observed mainly in the coastal areas of Hokkaido on the Japan Sea side. From the standpoint of helping solve the above problems, the application of BOF slag in the affected sea areas has been studied. In view of the technical difficulty involved in utilizing iron/steel slag proper as a sand-capping material, our company has conducted several R&D projects with the aim of solving both materials-related and sea-area environmental problems simultaneously.

5.1 Steel slag hydrated matrix

Steel slag hydrated matrix ("SSHM") is intended to be an environmentally friendly concrete block substitute that use no natural aggregate (sand and gravel). Instead, this product utilizes a fine powder of granulated blast furnace slag, as an equivalent of the cement binder in concrete, and BOF slag, as an equivalent of the aggregate.[18] An alkali stimulant is added to promote hardening as required. By mixing the above materials with water, it is possible to use the mixture as a substitute for plain concrete using a form, an artificial stone product of desired shape, etc. Because the principal binder is a fine powder of blast furnace slag, it is possible to reduce the specific surface area by agglomeration. It is also possible to restrain the rise of pH of seawater because the elution of alkali components into the seawater is minimal. This topic is discussed in depth in Section 5.3.1.

Using this technology, our company has developed and commercialized "Frontier Rock®"and "Frontier Stone®" *1 as substitutes for natural stones used in back-filling, inclined-surface embankment, and armour stone, and "Beverly® Block" and "Beverly® Rock" that are suitable for use in creating seaweed beds because silicic acid and iron contained in the raw material slag facilitate attracting seaweeds and benthic animals.

In addition, as a further application of the property of become harden due to hydrated reaction, our company has advanced the development of an inexpensive, easy-to-use pavement material that can replace conventional asphalt pavement. This pavement method uses a mixture of BOF slag and blast furnace granulated slag that is spread over the site and compacted by a road roller while water is sprinkled over the mixture to create a hard surface layer. This simple pavement material assures sufficient strength to forestry roads, farm roads, parking lots, etc.; for these uses, the mixture (Katama® SP) was approved as a recyclable product by Oita prefecture in 2010.[19] Since then, the application of the product has been expanding steadily. Incidentally, this method has the secondary effect of preventing the growth of weeds on paved roads, slopes alongside railway tracks, idle lots, and photovoltaic generation (mega-solar) sites.

5.2 Material that supplies iron for creation of seaweed beds

Since the 1970s, seaweed beds have extensively disappeared at various parts of the coastal regions of Japan[20] owing to a phenomenon known as "sea desertification." This phenomenon has exerted an extremely adverse effect on fisheries. It is said that the cause of sea desertification is a complicated interaction of several effects: the rise in temperature of seawater due to global warming; oligotrophication, the increasing pressure of animals feeding on seaweed (biological phase change), and the change in seawater properties as a result of river/embankment improvement works that impede the supply of nutrients to the sea area via rivers (involvement of human activities).

Sadakata, Emeritus Professor at the University of Tokyo, hypothesized that the oligotrophication of seawater is because of an insufficient concentration of iron,[21] and he considered it necessary to supply an iron-containing nutrient salt to the seawater as a tentative

*1 "Frontier Rock®" and "Frontier Stone®" are fruits of joint research with JFE Steel.

measure to curb oligotrophication until measures designed to help heal the natural world, such as forest conservation[22] and embankment reinforcement, could be fully instituted. Professor Sadakata took an interest in BOF slag as a source of ferrous ions that can easily be taken in by seaweed and, in 2002, began studying the use of BOF slag to curb the oligotrophication of seawater. When BOF slag is added to seawater, the seawater turns into milky turbid water because of the elution of alkali from the slag. However, a process has been developed whereby the elution of alkali could possibly be restrained, through carbonization.[23] As a result, the University of Tokyo, Eco Green, Nishimatsu Construction, and our company decided to launch a joint development of technology for the application of BOF slag as a means of supplying iron as a nutrient to sea areas.

In our test conducted under actual sea conditions, a mixture of artificial humus soil, obtained by fermentation of waste wood chips, and BOF slag, subjected to the process of carbonization, was used. The mixture was placed in water-permeable coconut bags (Beverly® Unit) and uniquely shaped steel cases (Beverly® Box), and the bags and cases were settled at suitable points in the experimental sea area. The purpose of the experiment was to investigate the possible effect chelating ferrous ions eluted from the BOF slag by humic acid (organic acid) contained in the artificial humus soil had upon the restoration of seaweed beds through the supply of ferrous ions to the seawater. The test was initiated on the Shaguma coast at Mashike Town in Hokkaido in the autumn of 2004, and the seabed from the coastline toward the offing was again observed in May 2005, about eight months after start of the test. The observations confirmed that groups of tangles (Laminalia religiosa), which had once existed in this sea area, were taking root and flourishing again.[24-27] To confirm the durability of the above effect, fixed-point observations have been conducted annually.[28] It was confirmed in 2011, seven years after start of the test, that the tangle beds, observed early on, remain and continue to flourish.[29]

With the cooperation of Motomura, Professor at Hokkaido University, our company made an academic study to determine the extent to which the restoration of seaweed beds mentioned above was attributable to the supply of ferrous ions. This study verified that iron is required in the life cycle of tangle, for the zoospore (seed) discharged from the parent tangle to grow into male and female gametophytes (sperm and egg),[30] and that the elution of iron from the iron supply units assisted in the completion of this life cycle.[31]

During the early stages of our actual sea-area experiments discussed earlier, a very precise analysis of the ferrous ion concentration of seawater could not be made. Therefore, we conducted a series of additional studies[32, 33] and succeeded in increasing the detection sensitivity of ferrous iron from the order of parts-per-million (ppm) to the order of parts-per-billion (ppb). As a result, we could confirm that a ferrous ion concentration of 5 ppb or more is required for fertilization and growth of tangle and that on the beach of Mashike Town, the iron supply units installed are supplying that concentration of iron in the sea area from the coastline to the offing.

In addition, the experimental installation of iron supply units in the sea area discussed previously required that various types of field measurements and objective data be collected to assess the possible positive and negative effects of the supply units on the natural environment and seawater ecosystems. Thus, we opened a sea-area environment simulation facility ("Sea Lab")[34] in our company's research laboratory in Futtsu City in Chiba in 2009[35, 36]. Owing to the accumulation of extensive scientific data,[37] the Beverly® Series products (Units, Blocks, and Rocks), designed for creation/restoration of seaweed beds, secured a safety product certification under the Product Safety Verification & Certification System enacted by the National Federation of Fisheries Co-operative Associations. Through the above research activities and demonstration tests conducted at Mashike Town, our company has received many inquiries about the Beverly® line of products from persons engaged in fisheries throughout the country. These products are distributed in conjunction with substantial consultation with prospective customers, and till now, the number of projects, including the joint test project with the Fisheries Agency, has reached about 30[28] in Japan.

5.3 Technology for reusing dredged soils

During the period 2004 - 2007, concurrently with the development of technology for creating seaweed beds described above, Japan Iron and Steel Federation, too, was entrusted with "R&D on the Application of Slag" as a research project subsidized by the Ministry of Economy, Trade and Industry. Through laboratory and field experiments on the positive and negative environmental impacts of using BOF slag in sea areas, the following results were obtained.

5.3.1 Compatibility with environmental standards for safe use

(1) Restraining rise of pH value of seawater

The elution of alkali from BOF slag in a sea area causes the seawater pH value to rise. Therefore, when BOF slag is used in a sea area where it makes direct contact with the seawater, it is necessary to provide suitable safety measures. In this respect, the safety measures that have proved effective include ① producing the steel slag hydrated matrix, ② subjecting the BOF slag to stabilization treatment (carbonization, grain size adjustment by removing powder, etc.), and ③ using the BOF slag in the form of a mixture with dredged clayey soil.

(2) Safety against elution of heavy metals

BOF slag itself is subject to quality control in the steelmaking process at the steelworks and shipped as a product that meets the prescribed environmental standards. However, when BOF slag is used for the improvement of the bottom sediment or mixed with dredged soil for the development of a tideland or for the back-filling of a dredged pit, there is the concern that the concentrations of substances eluted by the slag already contained in the existing bottom sediment or dredged soil could increase. Therefore, we conducted elution tests using various types of dredged soil and BOF slag from different steelmakers. As a result, it was confirmed that this use of BOF slag is compatible with environmental standards.

5.3.2 Environment improving effects, including the prevention of occurrence of substances causing eutrophication

Calcium ions that are moderately eluted from BOF slag into seawater make phosphorus insoluble in water and adsorb a part of the insoluble phosphorus. In addition, they impede the activity of sulfur-reducing bacteria and lower the sulfate concentration of seawater, thereby restraining the generation of hydrogen sulfide. Thus, calcium ions eluted from steelmaking slag effectively improve bottom sediments that have become eutrophied.[38]

5.3.3 Effect of strengthening soft dredged clayey soil

Research results described in the "Guidebook for Oceanographic Application of BOF Slag"[39] published in 2008 discussed the effects of a process whereby a calcium-oxide-based reformer obtained by subjecting BOF slag to composition control and grain size adjustment is mixed with soft dredged soil that always occurs during a fairway dredging operation indispensable for the navigation of large vessels. The study indicated that mixing the reformer with clayey soil helps control the elution of alkali from the slag, and thus, it was possible to use BOF slag safely.[40] The above study also confirmed that in the process of restraining the elution of alkali from the slag, Ca eluted from the reformer and Si eluted from the dredged soil form a hydrate, whereby the material strength after the reform process increased. The above reformer was commercialized as "Calcia-improved soil," which is a material applicable to the back-filling of dredged pits and for the improvement of water qualities in eutrophied sea areas. This product has three advantageous features: it restrains the rise in pH value of seawater, it restrains the occurrence of phosphates and sulfides, and it increases the strength of the reformed material.

6. Applicability of Iron/Steel Slag in Support for Recovery from the Great East Japan Earthquake

The Great East Japan Earthquake, which occurred on March 11, 2011, and the tsunami that followed caused extensive property damage and loss of life. According to the "Guidelines on Handling of Tsunami Deposits Produced after the Great East Japan Earthquake,"[41] published by the Ministry of Environment in July 2011, it is estimated that the quantities of waste materials (large blocks of debris, etc.) in the six tsunami-stricken prefectures were some 23 million tons and the quantities of mixtures of debris, sand, and colloidal sediment (tsunami deposits) were 13 - 28 million tons. With the aim of assisting with the disposal of tsunami deposits that has become a substantial challenge to many of the local communities, our company and Nippon Steel Engineering Co., Ltd. have developed a technology for adding our commercialized "Calcia Reformer" to the soft, muddy, debris containing tsunami deposits, removing the debris, from the deposit by a rotary crushing and mixing process, and processing the fragile tsunami deposit soil into a high-quality construction material.

The reformed tsunami deposit soil was evaluated and found to be widely applicable and effective for the backfilling of grounds for port facilities, creation of embankments in road construction, etc. In January 2012, it was experimentally used as a sub-grade material for raising the ground level in the Sendai Port Restoration Work undertaken by the Ministry of Land, Infrastructure and Transport.[42] To help encourage the restoration work, we intend to assist the administration and local governments to expand the application of the above technology in the future.

7. Conclusion

Steelmaking slag is a by-product of the steelmaking process. Nevertheless, as has been described so far, almost all steelmaking slag that produced is effectively utilized as a material for road base course material in road construction and other civil engineering projects, calcium-oxide-based reformer (for ground improvement, soil improvement), and raw materials for cement, fertilizer because of its excellent mechanical properties and functions. Because many of these uses represent natural substitutes for man-made materials, we consider that the expansion of the applications of slag is an activity that greatly contributes to environmental conservation. In the future, we wish to further contribute to our society by pressing ahead with the development of new functions for steelmaking slag and further expanding its application.

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