Review

UDC 669 . 162 . 275 . 2 : 669 . 184 . 28

Standardization of Iron and Steel Slag Products

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Abstract

Manufacture and quality management of iron and steel slag products are carried out according to their application. Now the majority of these products are provided to the market as Japan Industrial Standard equivalent products. This paper introduces the outline of Japanese Industrial Standards and Environment standard for iron and steel slag products.

1. Introduction

Iron and steel slag is a by-product of the steelmaking process from iron ore. Slag is produced when silica (SiO_2) and other nonferrous compounds melt and combine with lime (CaO) during reduction and refining. Iron and steel products have been manufactured as important materials that support our social infrastructure. Owing to many years of research on its effective utilization, iron and steel slag are also used now as an important material in various fields.

Iron and steel slag can be roughly divided into blast furnace slag, which is produced when iron ore is melted and reduced in the blast furnace, and steelmaking slag, which is produced during the iron refining process. Both the blast furnace slag and the steelmaking slag are used for different purposes. Today, iron and steel slag products are subject to production management and quality control appropriate for their specific applications to ensure that they conform to the applicable environmental standards. They are mostly introduced in the market as items compatible with the Japanese Industrial Standards (JIS) or eco-friendly products specified in the Green Purchasing Law. Moreover, iron and steel slag products play an important role as raw materials for cement and construction materials for infrastructure (roads, harbors, airports, etc.) in various parts of the country.

In this paper, the author shall describe the latest trend of the standardization of iron and steel slag products, specifically the JIS specifications of iron and steel slag products and the quality requirements (hereafter "environmentally sound quality") specified in JIS in 2013 to ensure the environmental safety of iron and steel slag products.

2. Standardization of Iron and Steel Slag Products

2.1 JIS of iron and steel slag products

Concerning iron and steel slag products, which are used for concrete and road construction are specified in JIS, namely JIS R 5210 "Portland Cement" and JIS R 5211 "Portland Blast Furnace Slag Cement" enacted in 1950. **Table 1** shows the JIS specifications of iron and steel slag products. It can be seen that many of them concern cement and concrete and are applicable mainly to blast furnace slag. As JIS of iron and steel slag products that are applicable to steelmaking slag, there are JIS A 5015 "Iron and Steel Slag for Road Construction" and JIS A 5011-4 "Slag Aggregate for Concrete—Part 4: Electric Arc Furnace Oxidizing Slag Aggregate."

The JIS relating to iron and steel slag products shall be outlined below.

2.1.1 Blast furnace slag cement JIS R 5211: 2009 [1)]

In Japan, blast furnace slag cement has been manufactured for more than 100 years since its test production in 1910. The first na-

Table 1 Japanese Industrial Standards of iron and steel slag

Use	Denomination	Year
Cement	Portland cement JIS R 5210:2009	1950 enactment
	Portland blast-furnace slag cement JIS R 5211:2009	1950 enactment
Concrete	Ready-mixed concrete JIS A 5308:2009	1953 enactment
	Ground granulated blast-furnace slag for concrete JIS A 6206:2013	1995 enactment
	Slag aggregate for concrete – Part1: Blast furnace slag aggregate JIS A 5011-1:2013	1997 enactment
	Slag aggregate for concrete – Part4: Electric arc furnace oxidizing slag aggregate JIS A 5011-4:2013	2003 enactment
Road construction	Iron and steel slag for road construction JIS A 5015:2013	1979 enactment

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tional standard for blast furnace slag cement was developed in 1925 as the "Method of Testing Blast Furnace Slag Cement" (Notification No. 5 of the former Ministry of Commerce and Industry). In the standard, blast furnace slag cement was defined as follows.

Definition of blast furnace slag cement at that time:

Blast furnace slag 70% added with clinker and ground; addition of any other substance not allowed, with the exception of gypsum, not more than 5%, and quicklime, not more than 3%.

JIS for blast furnace slag cement was first developed in 1950, in which the content of blast furnace slag was specified to be approximately 70% or less. In 1955, blast furnace slag cement was classified into A, B, and C according to the content of blast furnace slag. In 1979, when adding Portland cement with a maximum of 5% of admixture (limestone powder, etc.) was allowed from the viewpoint of saving resources and energy, the contents of blast furnace slag for the abovementioned classification were decided as follows.

Class A: Over 5% to 30% or less
Class B: Over 30% to 60% or less
Class C: Over 60% to 70% or less

In the 2009 revision, ground granulated blast furnace slag specified in JIS A 6206 was added as a raw material for Portland blast furnace slag cement.

2.1.2 Ground granulated blast furnace slag for concrete JIS A 6206: 2013 [2)]

In Japan, production of ground granulated blast furnace slag started in 1967. In 2013, it exceeded 3900000 tons, of which 213000 tons were used as admixtures for concrete. Thus, ground granulated blast furnace slag was mostly used as an admixture for cement. In fact, this slag has long been used as an admixture for Portland blast furnace slag cement. Research on its use as an admixture for concrete started around 1985. JIS A 6206: Ground Granulated Blast Furnace Slag for Concrete was enacted in 1995. Ground granulated blast furnace slag is classified into 4000, 6000, and 8000 according to specific surface area (cm^2/g). For each of the classes, an activity index is specified. The specifications of granulated blast furnace slag that acts as the raw material for ground granulated blast furnace slag are: magnesium oxide 10.0% or less; sulfuric trioxide 4.0% or less; ignition loss 3.0% or less; chloride ions 0.02% or less; and basicity 1.60 or higher.

Because ground granulated blast furnace slag is mostly used as an admixture for blast furnace slag cement and Portland cement, Class 4000 accounts for the majority. However, considering a growing need for a product with a specific surface area smaller than 4000 to restrain the temperature cracking in concrete, Class 3000 was newly added in the 2013 revision of JIS. The new classification is as follows:

Ground granulated blast furnace slag 3000
Specific surface area 2750 cm^2 to 3500 cm^2 exclusive
Ground granulated blast furnace slag 4000
Specific surface area 3500 cm^2 to 5000 cm^2 exclusive
Ground granulated blast furnace slag 6000
Specific surface area 5000 cm^2 to 7000 cm^2 exclusive
Ground granulated blast furnace slag 8000
Specific surface area 7000 cm^2 to 10000 cm^2 exclusive

2.1.3 Slag aggregate for concrete—Part 1: Blast furnace slag aggregate JIS A 5011-1: 2013 [3)]

Research on the application of blast furnace slag to concrete started in 1974 by the initiative of The Japan Iron and Steel Federation. With extensive research on the applicability to actual structures and reference to related standards overseas, JIS A 5011 (Blast furnace slag coarse aggregate for concrete), applicable to slow-cooled blast furnace slag, was enacted in 1977 and JIS A 5012 (Blast furnace slag fine aggregate for concrete), applicable to rapid-cooled blast furnace slag, was enacted in 1981. In addition to the general aggregate specifications, the former provides for a water immersion test for restraining the expansion of slag caused by the oxidation of the iron component and an ultraviolet irradiation test for preventing the expansion of slag caused by the transformation of dicalcium silicate. The latter provides stability to granulated blast furnace slag in storage to prevent it from concreting at high temperatures.

In the 1992 revision of JIS, blast furnace slag coarse aggregates and blast furnace slag fine aggregates were incorporated into blast furnace slag aggregate, and at the same time, ferronickel slag aggregate was included in the blast furnace slag aggregate. Consequently, they were integrated into JIS A 5011 (Slag aggregate for concrete). At that time, the decline in concrete durability caused by the alkali-silica reaction of concrete aggregate was a problem. Under that condition, the alkali-silica reactivity test of concrete aggregate was made compulsory. However, blast furnace slag aggregates were exempted from the alkali-silica reactivity test because the results of tests conducted in the past confirmed that they were stable and free from the alkali-silica reaction. Moreover, there were no reports on the occurrence of the alkali-silica reaction ascribable to blast furnace slag aggregates.

In the 1997 revision, when copper slag was included in slag aggregates, the blast furnace slag aggregate was specified in JIS A 5011-1, the ferronickel slag aggregate in JIS A 5011-2, and the copper slag aggregate in JIS A 5011-3. In addition, in 2003, electric arc furnace oxidizing slag aggregate was specified in JIS A 5011-4. Since then, with each JIS revision, these four types of slag aggregates for concrete have been discussed together.

The main points of the 2013 revision are as follows:

(1) The concept of environmentally sound quality was introduced.
(2) The water immersion test and ultraviolet irradiation test of blast furnace slag coarse aggregates were removed. (The tests that were introduced based on overseas standards were removed because blast furnace slag produced in Japan contains only a small amount of iron and is chemically so stable that it has never caused any quality problems.)
(3) The proportion of ground particles in blast furnace slag aggregate was newly specified.
(4) A method of analysis was added for the chemical composition of blast furnace slag aggregate.

2.1.4 Slag aggregate for concrete—Part 4: Electric arc furnace oxidizing slag aggregate JIS A 5011-4: 2013 [4)]

Steelmaking slag is unsuitable as an aggregate for concrete because it has a widely varying chemical composition and contains unassimilated lime. On the other hand, electric arc furnace oxidizing slag can be applicable to concrete because it is chemically stable. In 1996, an Electric Arc Furnace Slag Special Committee was formed in Nippon Slag Association to begin research on aggregates for concrete. After 1996, studies were conducted by experts, including people with learning and experience, users, etc. On the basis of the study results, JIS A 5011-4 (electric arc furnace oxidizing slag aggregate for concrete) was enacted in 2003. Because of the unique properties of electric arc furnace oxidizing slag, JIS A 5011-4 specifies the following.

(1) Measures to prevent the entry of reducing slag should be provided.
(2) Iron should be removed.

Similar to blast furnace slag aggregate, electric arc furnace oxidizing slag aggregate always passed the alkali-silica reaction test. However, because it was a new material, JIS mandated that the test should be performed to confirm the quality of the aggregate.

The main points of the 2013 revision of the JIS are as follows:

(1) The concept of environmentally sound quality was introduced.

(2) The method of magnetic separation of rapidly cooled fine slag aggregate was removed. (Conventional electric arc furnace oxidizing slag fine aggregate was ground slow-cooled slag. However, the rapidly cooled (air-ground) slag that was manufactured contained such a small proportion of iron that magnetic separation became unnecessary.)

(3) Fine particle content for electric arc furnace oxidizing slag aggregate was newly specified.

(4) A method for analyzing the chemical composition of electric arc furnace oxidizing slag aggregate was added.

2.1.5 Iron and steel slag for road construction JIS A 5015: 2013 [5)]

With a sharp increase in the production of iron and steel in the 1960s, it became necessary for steelmakers not only to use iron and steel slag in their own works but also to sell it to users outside. Blast furnace slag as a subbase course material that readily hardens was used for roads in the neighborhood of steelworks because of its excellent durability. In 1973, 14 million tons, or about 50% of the total production of blast furnace slag, was used in road construction. At that time, however, because slow-cooled blast furnace slag was used as a subbase course material immediately after its production, the problem of yellow water outflow caused by sulfur occurred frequently. Consequently, the consumption of blast furnace slag for road construction decreased to approximately 9 million tons in 1975. Hence, to standardize blast furnace slag for road construction, priority was given to devise measures to prevent the problem of yellow water. The iron and steel industry focused on investigating the cause of the problem and finding ways for its prevention. Eventually, it established an aging technique to first oxidize the sulfur present in slow-cooled blast furnace slag. Then, in 1979, JIS A 5015 (Slag for road construction) was enacted. As subbase course materials made of natural crushed stone, crusher-run and graded crushed stone were specified. In addition to the ready-to-harden subbase course materials made of iron and steel slag, three types of slag were newly specified, namely crusher-run slag (CS-40), mechanically stabilized slag (MS-40, MS-25), and hydraulic and mechanically stabilized slag (HMS-25). For the test items specific to blast furnace slag, the leaching test for the yellow water problem and the unconfined compressive strength test for the strength assurance of HMS-25 were specified.

On the other hand, the recycling of steelmaking slag was lagging behind. Finally, for four years from 1979, joint research on the use of steelmaking slag as a subbase course material was conducted by the Public Works Research Institute of the Ministry of Construction, the Public Works Research Center, and Nippon Slag Association. Consequently, Nippon Slag Association published the Guidelines on Design and Execution of Asphalt Pavement Works Using Steelmaking Slag in 1982 and the Guidelines on Design and Construction of Steelmaking Slag Subbase Courses in 1985. For items of expansion stability to control the expansion due to the hydration of steelmaking slag, the Association specified a minimum of six months of open-air (outdoor) aging for preliminary hydration and a maximum expansion ratio of 1.5% in the 80°C immersion test for steelmaking slag used as a subbase course material and a minimum of three months of open-air aging and a maximum expansion ratio of 2.0% in the 80°C immersion test for steelmaking slag used for asphalt concrete.

To secure the expansion stability of steelmaking slag, Kokura Works of Nippon Steel & Sumitomo Metal Corporation, in 1990, developed a new steam aging process that permits shortening of the aging period from six months or more to only about one week. Today this aging process is employed at many steelworks. In addition, in 1995, Wakayama Works developed pressurized steam aging technology for stabilizing the expansion of steelmaking slag in several hours. This technology has already been incorporated in commercial equipments.

In the 1992 revision of JIS, slag for road construction was renamed to the present iron and steel slag for road construction because it became common practice to use blast furnace slag and/or steelmaking slag either independently or in combination as a subbase course material.

In the 2013 JIS revision, the concept of environmentally sound quality was introduced.

2.2 Background to the introduction of environmentally sound quality

In recent years, it has become increasingly important to devise new standards for eco-friendly materials and products.

In August 2001, the Technical Committee on the Environment and Recycling of Resources of the Japanese Industrial Standards Committee proposed that in the future enactment/revision of JIS, with due consideration given to JIS Q 0064 "Guidelines for Introducing Environmental Aspects into Product Standards," efforts should be made to enhance the environmental impact by the JIS that contributes to environmental conservation by securing the functions of products and the balance between them as well as the environment throughout the product lifecycle.

In April 2002, the "Action Program for Promoting Enactment of Environmental JIS" was formulated to clarify the standardization strategy aimed toward spread products allowing the 3Rs (reduce, reuse, recycle), energy-saving devices, etc., as well as to protect the environment by preventing the use of harmful substances in products, environmental pollution control, etc. In this program, the basic idea regarding the formulation of environmental safety standards (standards for products that introduce environmental aspects and standards for methods of testing and evaluation of such products) was presented. JIS was expected to clarify priority fields and introduce environmental aspects into product standards with major effects on environmental safety. At the same time, a medium-term plan for the formulation of environmental JIS was presented, and each individual technical committee was requested to formulate a policy for establishing environmental standards. In March 2003, in response to the request, the "Guidelines on Introduction of Environmental Aspects into Standards of the Construction Sector" was jointly formulated by the Technical Committee on Civil Engineering and the Technical Committee on Architecture of the Japanese Industrial Standards Committee. Now, the conditions were set for the enactment of environmental JIS in the field of construction.

In July 2011, the Technical Committee on Civil Engineering and the Technical Committee on Architecture devised the "Guidelines for Introducing Environmentally Sound Qualities and Inspection Methods into the JIS of Slags for Concrete and Road (Text and Explanations)." These guidelines are presented as annexes to the "Guidelines on Introduction of Environmental Aspects into Standards of the Construction Sector" of March 2003.

In 2013, based on the abovementioned Guidelines for Introducing Environmentally Sound Qualities and Inspection Methods into the JIS of Slags for Concrete and Road, criteria and inspection methods related to environmentally sound qualities were included in “Slag Aggregates for Concrete—Part 1: Blast Furnace Slag Aggregates” JIS A 5011-1, “Slag Aggregates for Concrete—Part 4: Electric Arc Furnace Oxidizing Slag Aggregate” JIS A 5011-4, and “Iron and Steel Slag for Road” JIS A 5015, respectively.

Incidentally, in March 2012, the “Conference on Guidelines for Introducing Methods of Evaluating Chemical Substances in Aggregates for Concrete or Slags for Road” presented, in the form of a general report, the basic ideas for introducing environmentally sound qualities and inspection methods that are applicable to all recyclable materials including slags.[6)]

2.3 Basic concept of guidelines for introduction of environmentally sound qualities and inspection methods applicable to them

2.3.1 Basic ideas regarding environmentally sound qualities of recyclable materials and their inspection methods

In the March 2012 General Report of the Conference on Guidelines for Introducing Methods of Evaluating Chemical Substances in Aggregates for Concrete or Slags for Road, the basic ideas for introducing environmentally sound qualities and inspection methods applicable to all recyclable resources were presented. The underlying concept is that any object should be evaluated in the most critical exposure environment under the condition simulating the manner in which it is used in that environment.

<Basic ideas about environmentally sound qualities of recyclable materials and inspection methods applicable to them>

(1) Evaluation based on the most critical exposure environment
The environmentally sound qualities of any recyclable material should be evaluated in the most critical exposure environment in terms of environmental safety that can be rationally expected to occur in the lifecycle of that material.

(2) Test items adapted to the discharging routes of chemical substances
The test items, such as the amount of elution and chemical composition, should be adapted to the route of discharge of the chemical substance in the exposure environment mentioned in (1).

(3) Test method simulating the mode of use of given material
The individual tests of a given material, including sample preparation, should be performed using methods simulating the mode of use of the material in the exposure environment mentioned in (1).

(4) Environmentally sound qualities compatible with environmental standards
Items and criteria of environmentally sound qualities should be set in such a manner that they conform to the applicable environmental standards, criteria, etc.

(5) Rational inspection system for assuring environmentally sound qualities
The series of inspections from sample collection to the inspection results should consist of an “environmental safety type inspection” for confirming conformity to the environmentally sound quality standards and an “environmental safety delivery inspection” for rapidly assuring the environmentally sound qualities on a manufacturing-lot basis. Both the inspections shall be conducted at a reliable test institute.

The environmental safety type inspection refers to the determination of whether or not the material that has been subjected to certain types of treatment (particle size adjustment, mixing with other material, etc.) for making it recyclable has environmentally sound qualities. (This is not an inspection of a given material, but is an inspection of the material as is used under a specific condition.) On the other hand, the environmental safety delivery inspection refers to the assurance of, at the time of delivery, the environmentally sound qualities of a specific recyclable material manufactured under the same conditions similar to the one that passed the type inspection.

Environmentally sound qualities are assured by the environmental safety type inspection based on the abovementioned basic ideas, (2)–(4). However, simulating the condition under which a specific recyclable material is used (including the preparation of a sample of the material) requires a significant amount of time and labor. Therefore, as a more suitable method of product inspection, the environmental safety delivery inspection that allows rapid product inspection on a lot-by-lot basis was specified. Basically, in the environmental safety delivery inspection, a recyclable material manufactured under the same conditions as the one that passed the environmental safety type inspection is assumed to be used as one unit. This inspection is then expected to assure that the considered recyclable material has the same qualities as the one that passed the environmental safety type inspection. To implement this, it is necessary to set suitable values as criteria for assuring conformity to environmentally sound qualities using an appropriate recyclable material sample during acceptance inspection. The values set as criteria are used in the environmental safety delivery inspection.

2.3.2 Basic ideas on environmentally sound qualities of iron and steel slag and their inspection methods

In the July 2011 Guidelines for Introducing Environmentally Sound Qualities of Slags for Concrete and Road and Inspection Methods into JIS, the basic ideas for introducing environmentally sound qualities and inspection methods for iron and steel slag were presented. These basic ideas are reflected in the JIS for iron and steel slag.

<Basic ideas regarding environmentally sound qualities and inspection methods for iron and steel slag>

With attention paid to the exposure environment that should be considered carefully in the rationally expected lifecycle of iron and steel slag, the environmentally sound qualities should be specified in such as manner that environmental media, such as groundwater and seawater, in that exposure environment can meet the applicable environmental standards. Then, a sample preparation method simulating the condition of slag in the abovementioned exposure environment and inspection methods that are appropriate to the discharge routes of chemical substances from the slag shall be specified.

The inspection should consist of “environmental safety type inspection” and “environmental safety delivery inspection.” In the environmental safety type inspection, the conformity of iron and steel slag to the environmentally sound qualities shall be confirmed. The environmental safety delivery inspection is implemented as a simpler inspection for assuring environmentally sound qualities when slag manufactured under the same conditions as the slag that passed the inspection type is used under the same conditions as those applied in the inspection type.

The abovementioned inspections shall be implemented by competent people to rationally assure the environmentally sound qualities of iron and steel slag.

(1) Basic ideas regarding environmentally sound qualities of slag aggregate for concrete

According to the guidelines, the most critical exposure environment of slag aggregate used for general purposes is the reuse of a demolished concrete structure as a subbase course material. In this case, environmentally sound qualities of the slag aggregate shall be specified in accordance with the applicable soil environment standards, groundwater environment standards, and specified standards (elution levels, chemical compositions) on the basis of the Soil Contamination Countermeasures Law. Then, the samples prepared by simulating the condition of slag aggregate reuse as a subbase course material shall be subjected to an elution test as well as a chemical analysis.

It should be noted, however, that for slag aggregate used in concrete port facilities, which will not be demolished, the most critical exposure environment shall be the condition of the standing concrete structure. In this case, the environmentally sound qualities of the slag aggregate should be specified based on the Environmental Quality Standards for Water Pollution, and samples prepared simulating a concrete structure should be subjected only to an elution test.

(2) Basic ideas regarding environmentally sound qualities of slag for road

According to the guidelines, the most critical exposure environment of slag for road is either the condition of slag reuse as a subbase course or subgrade material when the slag was used for subbase or the condition of slag reuse as a subbase course material after mixing in asphalt when the slag was used for hot asphalt mix. In either case, environmentally sound qualities of the slag should be specified in accordance with the applicable soil environment standards, groundwater environment standards, and specified standards (elution levels, chemical composition) based on the Soil Contamination Countermeasures Law and samples prepared by simulating the condition of slag reuse as a subbase course material shall be subjected to an elution test and a chemical composition analysis.

The inspection flow of concrete slag aggregate is outlined in **Fig. 1**.

2.3.3 Environmentally sound qualities of iron and steel slag specified in JIS

Outlined below are the environmentally sound qualities of iron and steel slag specified in JIS (Slag aggregate for concrete—Part 1: Blast furnace slag aggregate JIS A 5011-1; Slag aggregate for concrete—Part 4: Electric arc furnace oxidizing slag aggregate JIS A 5011-4; and Iron and steel slag for road construction JIS A 5015).

(1) Premises (exposure environments to be considered)

For slag aggregate used for general purposes, the most critical

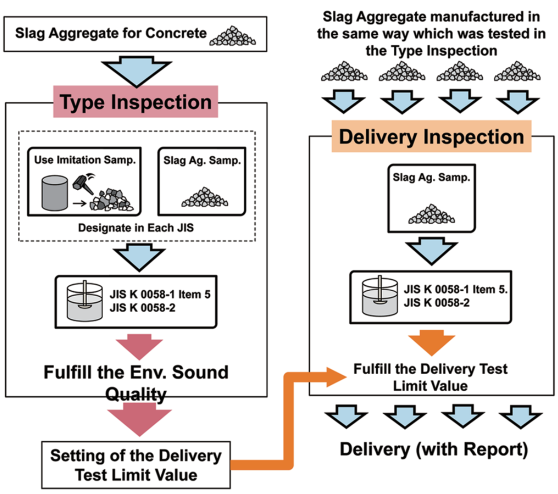

Fig. 1 Inspection flow chart for environmental standard of slag aggregate for concrete

exposure environment shall be the condition of slag reuse as a subbase course material after it is used as an aggregate of a concrete structure. With respect to slag for road construction, the most critical exposure environment shall be the condition of slag reuse as a subbase course or subgrade material when it is originally used for subbase or the condition of the slag reuse as a subbase course material when it is originally used for hot asphalt mix. The environmentally sound qualities of slag are specified in JIS based on the abovementioned conditions.

(2) Test items

The test items for general-purpose blast furnace slag aggregate are shown in **Table 2**, and the test items for blast furnace slag aggregate for port/harbor are shown in **Table 3**. The test items for electric arc furnace oxidizing slag aggregate and iron and steel slag for road are shown in **Table 4**, and **Table 5** shows the test items for electric arc furnace oxidizing slag aggregate for port/harbor.

If it can seen from the raw materials, manufacturing process, and the accumulated data that there is no possibility of the specified limit being exceeded; the appropriate test item may be omitted. For example, even if VOC, agricultural chemicals, PCB, etc. are present, they are thermally decomposed in the steel slag manufacturing process. Moreover, among the heavy metals, cyanide is converted to a volatile gas. Therefore, it was omitted from the test items. Consequently, the test items included in the type inspection are the following eight elements: cadmium, lead, hexavalent chromium, arsenic, mercury, selenium, fluoride, and boron.

With respect to the test items in the delivery inspection, the substances which are rarely mixed in the slag have been omitted. Consequently, there are three test items (selenium, fluoride, boron) for the delivery inspection of slag aggregate for concrete—Part 1: Blast

Table 2 Inspection substances of environmental standards for blast furnace slag aggregate (general use)

	Type inspection		Delivery inspection	
	Leaching	Content	Leaching	Content
Cd	○	○	–	–
Pb	○	○	–	–
Cr (VI)	○	○	–	–
As	○	○	–	–
Hg	○	○	–	–
Se	○	○	○	○
F	○	○	○	○
B	○	○	○	○

Table 3 Inspection substances of environmental standards for blast furnace slag aggregate (harbor use)

	Type inspection	Delivery inspection
	Leaching	Leaching
Cd	○	–
Pb	○	–
Cr (VI)	○	–
As	○	–
Hg	○	–
Se	○	○
F	○	○
B	○	○

Table 4 Inspection substances of environmental standards for electric arc furnace oxidizing slag aggregate and iron and steel slag for road construction (general use)

	Type inspection		Delivery inspection	
	Leaching	Content	Leaching	Content
Cd	○	○	–	–
Pb	○	○	○	○
Cr (VI)	○	○	○	○
As	○	○	–	–
Hg	○	○	–	–
Se	○	○	○	○
F	○	○	○	○
B	○	○	○	○

Table 5 Inspection substances of environmental standards for electric arc furnace oxidizing slag aggregate (harbor use)

	Type inspection	Delivery inspection
	Leaching	Leaching
Cd	○	–
Pb	○	○
Cr (VI)	○	○
As	○	–
Hg	○	–
Se	○	○
F	○	○
B	○	○

furnace slag aggregate JIS A 5011-1 and five test items (lead, hexavalent chromium, selenium, fluoride, boron) for the delivery inspection of slag aggregate for concrete—Part 4: Electric arc furnace oxidizing slag aggregate JIS A 5011-4 and iron and steel slag for road JIS A 5015.

(3) Test methods

JIS provides that for evaluating environmentally sound qualities of both slag aggregate for concrete and slag for road, samples simulating the conditions of their application may be used. Therefore, it is also possible to evaluate them using unit samples of slag. Because samples simulating the condition of application can be used, the leaching test should be performed in accordance with JIS K 0058-5 "Agitation test of sample as it is used" and a chemical analysis should be carried out in accordance with JIS K 0058-2.

(4) Standards for environmentally sound qualities

The standards for environmentally sound qualities for general use (in land areas) are shown in **Table 6**, and those for slag aggregate for concrete for port/harbor are shown in **Table 7**. The standard values of environmentally sound qualities for general use are equivalent to those of the soil environment standards for the leaching test and equivalent to those of the Soil Contamination Countermeasures Law for the composition analysis.

The environmentally sound qualities standards for port/harbor use are three times of the environmental standards for water quality (sea areas) because considerable dilution by seawater is expected and environmental standards (sea areas) for fluoride and boron are not specified.

Table 6 Environmental standards (general use)

	Leaching (mg/L)	Content (mg/kg)
Cd	≦ 0.01	≦ 150
Pb	≦ 0.01	≦ 150
Cr (VI)	≦ 0.05	≦ 250
As	≦ 0.01	≦ 150
Hg	≦ 0.0005	≦ 15
Se	≦ 0.01	≦ 150
F	≦ 0.8	≦ 4000
B	≦ 1	≦ 4000

Table 7 Environmental standards (harbor use)

	Leaching (mg/L)
Cd	≦ 0.03
Pb	≦ 0.03
Cr (VI)	≦ 0.15
As	≦ 0.03
Hg	≦ 0.0015
Se	≦ 0.03
F	≦ 15
B	≦ 20

3. Conclusion

Today, a wide variety of iron and steel slag products are manufactured and subjected to quality control, and are mostly sold and used as JIS-compatible products. This paper outlined the JIS of iron and steel slag products and described the contents of provisions on environmentally sound qualities introduced into JIS in 2013.

Needless to say, to secure a stable market for iron and steel slag products, it is important to develop new technologies and new applications of slag products. For iron and steel slag products, standardizing them on the basis of development results will become increasingly important in the future.

Acknowledgments

The author wishes to express his heartfelt gratitude to technical advisor Hiroaki Okumura at Nippon Slag Association for his generous cooperation in the preparation of this paper.

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