Activity Summary of the JSCE T-269 Subcommittee

1. Introduction

On the occasion of the revision to JIS A 5011-2 "Slag Aggregate for Concrete—Part 2: Ferronickel Slag Aggregate」and JIS A 5011-3 "Slag Aggregate for Concrete—Part 3: Copper Slag Aggregate" in April 2016, the JSCE-269 Subcommittee (Chairman: Uji Kimitaka, Prof. in Tokyo Metropolitan University) was organized set up by Japan Society of Civil Engineers. "Recommendations for Design and Construction of Concrete Structures Using Ferronickel Slag Aggregate" and "Recommendations for Design and Construction of Concrete Structures Using Copper Slag Fine Aggregate" were revised in response to those JIS revision.

Regarding the JIS revisions, the environmental safety quality for slag aggregate was introduced. And a new standard for ferronickel slag coarse aggregate was established. The guidelines are made corresponding to these modifications.

2. Environmental Safety

2.1 Background to the establishment of environmental safety quality standard

The establishment of environmental safety quality standard for materials and products is becoming more and more important in recent years.

In March 2003, the Guideline for Introducing Environmental Aspects to the Standards in Construction Field was announced by Japanese Industrial Standards Investigation Committee, Civil Engineering Technical Expert Committee and Construction Technical Expert Committee. As annex of the guideline, two documents were announced in July 2011; Annex I, the Guideline for Introducing Environmental Safety Quality and its Inspection Method on Slag Aggregate for Concrete, and Annex II, the Guideline for Introducing Environmental Safety Quality and its Inspection Method on Slag for Road Construction. In response to these, JIS A 5011-2 "Slag Aggregate for Concrete − Part 2: Ferronickel Slag Aggregate" and JIS A 5011-3 "Slag Aggregate for Concrete − Part 3: Copper Slag Aggregate" were amended in April 2016.

2.2 Environmental Safety Quality and Inspection Method on Aggregate for Concrete

The basic concept of environmental safety quality and inspection method on aggregate for concrete are as follows.

(1) The environmental safety quality of slag aggregate should be set up to meet a wide variety of environmental standards and regulation values of the surrounding media such as soil, groundwater, seawater, etc., taking into account the lifecycle of slag aggregate in

a reasonable range including shipment, construction, use, and recycling or disposal after demolishing.

(2) The inspection method of environmental safety quality should be set up to ensure reasonably that each lot of slag aggregate to be shipped can meet the environmental safety quality requirement.

Based on the concept, two categories of the Environmental Safety Quality Standard are provided; General Use (Table−1) and Harbor Use (Table−2), which should be selected based on the purpose of concrete structure using slag aggregate.

(1) **General Use**

Environmental safety quality of slag aggregate in case the slag are to be used in general concrete structure must conform to the criteria in Table−1. General use should be regarded and the criteria in Table-1 must be applied in case the use of slag has not been specified, as well as reuse is scheduled even in harbor use.

(2) **Harbor Use**

Environmental safety quality of slag aggregate in case the slag are to be used in concrete in harbor, the tests must be carried out according to 6.5.2.1 of the JIS, and must conform to the regulations of Table−2.

Table−1 Environmental Safety Quality Standard for General Use

Items	Concentration in leachate mg/L	Content [a)] mg/kg
Cadmium	0.01	150
Lead	0.01	150
Hexavalent Chromium	0.05	250
Arsenic	0.01	150
Mercury	0.0005	15
Selenium	0.01	150
Fluorine	0.8	4000
Boron	1	4000
Note [a)] the “Content” described here is different from “Total Content” which is denoted generally.		

Table−2 Environmental Safety Quality Standard for Harbor Use

Items	Concentration in leachate mg/L
Cadmium	0.03
Lead	0.03
Hexavalent Chromium	0.15
Arsenic	0.03
Mercury	0.0015
Selenium	0.03
Fluorine	15
Boron	20

As the environmental safety inspection, the “environmental safety type inspection” which should be conducted once per 3 years and the “environmental safety delivery inspection” which should be conducted in each lot of product are specified. Shape of samples in the environmental safety type inspection is specified to apply the “use-simulated samples” or the slag aggregate samples.

(1) Ferronickel Slag Aggregate

Regarding the ferronickel slag aggregate, because all the results of raw materials and slag samples over the past five years are less than or close to the lower limit value of reports, the type inspection was decided to conduct by slag aggregate sample. All items specified in Table−1 and 2 are necessary to be conducted in the type inspection. The delivery inspection must be conducted in each lot which is specified by the manufacturer, and the testing item is limited to the leaching concentration of fluorine only. The delivery inspection judgement value is equal to the criteria in Table−1, 2 in the case of slag samples.

(2) Copper Slag Aggregate

Because all the test results in terms of content values regarding mercury, hexavalent chromium, fluorine, boron and selenium has been lower than respective quantitative limit value during the past five years, copper slag does not contain mercury, hexavalent chromium, fluorine, boron and selenium. Besides, cadmium has been detected in the slag from some manufacturers even though they were below the environmental safety limit value. Regarding arsenic and lead, copper slag from every

smelter show a higher value than the limit value. Based on them, cadmium, lead and arsenic are selected as testing items in the environmental safety delivery inspection.

3. Summary of "Recommendations for Design and Construction of Concrete Using Ferronickel Slag Aggregate" and "Recommendations for Design and Construction of Concrete Using Copper Slag Fine Aggregate".

3.1 Structure of Guideline

The contents of guideline is shown below, the chapter structure of both guidelines is the same. The summary of each chapter will be described from the next section on. In addition, in order to facilitate the readers, 「Technology Information」, 「Sales Guideline of Non-Ferrous Slag Products」 and 「Estimation Method of Mixing ratio of Ferronickel Slag Fine Aggregate and Copper Slag Fine Aggregate」 as well as 「Literature List」 are published as appendix.

Chapter 1	General Provisions
Chapter 2	Quality of Ferronickel Slag Aggregate Concrete/Copper Slag Fine Aggregate Concrete
Chapter 3	Environmental Safety
Chapter 4	Performance Verification
Chapter 5	Design Value for Material
Chapter 6	Aggregate
Chapter 7	Mix Proportion Design
Chapter 8	Concrete production
Chapter 9	Ready-mixed Concrete
Chapter 10	Transportation・Placing and Curing
Chapter 11	Quality Management
Chapter 12	Inspection
Chapter 13	Concrete Requiring Special Consideration
Appendix Ⅰ	Technology Information Relating to Ferronickel Slag Aggregate /Copper Slag Fine Aggregate
Appendix Ⅱ	Guidelines for management of iron and steel slag products
Appendix III	Estimation Method of Mixing ratio of Ferronickel Fine Aggregate and Copper Slag Fine Aggregate

Appendix IV Literature List Relating to Ferronickel Slag Aggregate/ Copper Slag Fine Aggregate

3.2 Quality and Performance Verification of Slag Aggregate Concrete (Chapter 1-5)

The characteristic of concrete using non-ferrous slag aggregate and non-ferrous slag was shown in「Chapter 2 Quality of Ferronickel Slag Aggregate Concrete/Copper Slag Fine Aggregate Concrete」. The characteristic of ferronickel slag aggregate/copper slag aggregate is high density. Compared with ordinary sand with the density of 2.5~2.8 g/cm^3, the density of ferronickel slag aggregate is 2.9~3.1 g/cm^3, in addition, the copper slag fine aggregate with the density of 3.4~3.6 g/cm^3 is mostly in circulation. The richness in iron content leads to a high density of these slag aggregate. In this guideline, the mixing use of ordinary aggregate and the slag aggregate meeting the specified quality requirements of JIS is regarded as standard. Regarding the ferronickel slag, the aggregate mixing ratio of less than 50% in volume ratio is regarded as standard.

If the mixing ratio of ferronickel slag aggregate is less than 50%, the increase of the mass per unit volume of concrete is lower than about 100kg/m^3, it is equivalent to ordinary aggregate concrete and no necessary to specifically consider. However, because there is no sufficient reliability on the suppression countermeasure of ASR, it is considered that ferronickel slag fine aggregate and ferronickel slag coarse aggregate should not be used in combination. Regarding the copper slag, the aggregate mixing ratio of less than 30% in volume ratio is regarded as standard. If the mixing ratio of copper slag aggregate is less than 30%, the increase of the mass per unit volume of concrete is lower than about 100kg/m^3, it is able to meet the standards requirements of environmental safety quality.

Environmental safety quality and its design perspective meet the requirements are shown in Chapter 3 Environmental Safety. As for the ferronickel slag aggregate, even though without mixing with ordinary aggregate, it also can meet the standard of environmental safety quality, it also can meet the standard of environmental safety quality. However, it is likely that these will be elution amount of fluorine detected, so the aggregate buyers also must confirm its environment safety quality by the delivery note .etc. Regarding the copper slag, the contents of cadmium, lead and arsenic are detected at a high level. But in the case of using the copper slag fine aggregate with the copper slag mixing ratio of below 30% in volume ratio, there is no environmental safety quality problem.

Chapter 4 Performance Verification and Chapter 5 Design Value for Material show that in the case of using the copper slag fine aggregate with mixing ratio of below

30% or in the case of using the ferronickel slag aggregate with mixing ratio of below 50%, it is not necessary to specially consider, the performance verification can be conducted as same as ordinary aggregate concrete.

3.3 Quality of Aggregate and Mix Proportion Design (Chapter 6-7)

The detailed quality information of aggregate and mix proportion design were described in Chapter 6 and 7 including the two guidelines, respectively. As a focus point, the alkali silica reaction should be paid attention for the ferronickel slag aggregate (fine aggregate, coarse aggregate), while the environmental safety quality should be paid attention for the copper slag aggregate.

The ordinary aggregate mixing with the two kinds of slag aggregate, except for the particle size and chloride content, can only be specified sand and gravel of JIS A 5308 annex A or specified crushed sand and crushed stone of JIS A 5005. In the case of ferronickel slag aggregate, it is limited to the harmless of ASR reaction for the mixed ordinary aggregate.

The mix proportion design follows the current Japan Society of Civil Engineers Concrete Standard Specifications 【Materials and Construction】. In particular, taking the increase of bleeding into accounts due to the large density of both two kinds of slag aggregates, the unit cement content and unit powder content are described in detail. Because the fine powder content of aggregate also will affect the bleeding characteristics, in the case of the high fine powder content of aggregate and the use of high performance water reducer admixture and so on, also including the mixing ratio of slag aggregate, the mix proportion based on experiment can be determined basically.

3.4 Manufacturing • Construction • Concrete Requiring Special Consideration (Chapter 8-13)

The transportation, placing, compaction, finishing and curing of slag aggregate concrete are explicitly described in Chapter 10 "Transportation • Placing and Curing", in additional to the bleeding characteristics, they are the same as that of ordinary aggregate concrete. The previous experimental results showed that the construction performance of ferronickel slag aggregate concrete was better than that of ordinary aggregate concrete when the volume mixing ratio of ferronickel slag fine aggregate was lower than 50%. In the case of compacting the ferronickel slag aggregate concrete, it is described that grasping the vibration time and compaction condition, the setting of appropriate vibration time is very important.

According to recent research reports, it is better to consider it as same as ordinary

aggregate concrete in the case that the mixing ratio of copper slag fine aggregate is lower than 30%.

In Chapter **13** Concrete Requiring Special Consideration, the case that mixing ratio of ferronickel slag fine aggregate exceeds 50% and the case that the combination use case of ferronickel slag fine aggregate and ferronickel slag coarse aggregate are admitted and these focus points are also discussed.