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**Melt-solidified slag aggregate for
concrete derived from municipal
solid waste and sewage sludge**

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently **JIS A 5031**:2010 is replaced with this Standard.

However, **JIS A 5031**:2010 may be applied in the **JIS** mark certification based on the relevant provisions of Article 19 Clause 1, etc. of the Industrial Standardization Law until October 19, 2017.

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Melt-solidified slag aggregate for concrete derived from municipal solid waste and sewage sludge

Introduction

This Japanese Industrial Standard was established in 2006 for the purpose of facilitating the efficient utilization of melt-solidified slag aggregate. It was then partly revised in 2010 as a tentative measure for preventing the occurrence of popouts in concrete buildings that became a social problem in 2008.

This revision was initiated to incorporate into this Standard the popout test using melt-solidified slag aggregate for concrete which was newly developed, and the contents of “Guidance for introducing environmentally sound quality and inspection method to slag aggregate for concrete” issued on July 12, 2011 as Annex 1 of “Guide for the inclusion of environmental aspects in architecture sector standards” (decision on March 28, 2003 by Technical Committee on Civil Engineering and Technical Committee on Architecture) by Technical Committee on Civil Engineering and Technical Committee on Architecture under Japanese Industrial Standards Committee. The comparison table between previous and current editions of this Standard on technically significant revisions is given in Annex F.

No corresponding International Standard has been established at this point.

1 Scope

This Standard specifies the melt-solidified aggregate for concrete manufactured by melting the municipal solid waste, sewage sludge and their burned ashes at a temperature at least as high as 1 200 °C and cooling and solidifying them (hereafter referred to as molten slag aggregate).

The molten slag aggregate is an aggregate manufactured for the purpose of efficient utilization of the municipal solid waste, sewage sludge, etc. in their melt-solidifying facilities, and includes the following.

- a) The molten slag aggregate produced in private melt-solidifying facilities which are entrusted by the municipal authorities to treat municipal solid waste, or that produced when municipal solid waste is treated together with industrial waste whose reuse is approved by the municipal authorities
- b) The molten slag aggregate subjected to magnetic selection, particle size adjustment, etc. property modification in the melt-solidifying facilities or separate facilities
- c) Slag manufactured from melting furnace fly ash, though not normally included in the molten slag aggregate, which has been produced in melt-solidifying facilities equipped with control system meeting the environmental safety quality criteria specified in **5.7**.

The application of molten slag aggregate for concrete shall be as follows.

d) The molten slag aggregate can be used for concrete satisfying all of the conditions below.

- 1) Design standard strength of 35 N/mm² or lower.
- 2) Water-cement ratio of 55 % or smaller, for ensuring durability

However, the molten slag aggregate can be used for precast unreinforced concrete products specified in **JIS A 5371** and precast reinforced concrete products specified in **JIS A 5372** whose design standard strength is above 35 N/mm², provided that the purchaser of the molten slag aggregate is familiar with the application conditions such as the characteristics of the precast concrete product, required strength and durability, and environment in which the product is to be placed, and also provided that the purchaser of the precast concrete product has specifically requested the use of the molten slag aggregate.

e) The molten slag aggregate cannot be used for the following.

- 1) Prestressed concrete for all applications (e.g. precast prestressed concrete specified in **JIS A 5373**, prestressed concrete to be installed on site, etc.)
- 2) Precast concrete used for buildings, more specifically for their foundation, principal structural parts and parts that are significant in terms of safety, fire prevention or hygiene.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS A 0203 *Concrete terminology*

JIS A 1102 *Method of test for sieve analysis of aggregates*

JIS A 1103 *Method of test for amount of material passing test sieve 75 µm in aggregates*

JIS A 1109 *Methods of test for density and water absorption of fine aggregates*

JIS A 1110 *Methods of test for density and water absorption of coarse aggregates*

JIS A 1122 *Method of test for soundness of aggregates by use of sodium sulfate*

JIS A 1145 *Method of test for alkali-silica reactivity of aggregates by chemical method*

JIS A 1146 *Method of test for alkali-silica reactivity of aggregates by mortar-bar method*

JIS A 1158 *Method for reducing samples of aggregate to testing size*

JIS A 1804 *Methods of test for production control of concrete—Method of rapid test for identification of alkali-silica reactivity of aggregate*

JIS A 5005 *Crushed stone and manufactured sand for concrete*

JIS A 5011-2 *Slag aggregate for concrete—Part 2: Ferronickel slag aggregate*

JIS A 5011-3 *Slag aggregate for concrete—Part 3: Copper slag aggregate*

- JIS A 5308 *Ready-mixed concrete*
- JIS A 5371 *Precast unreinforced concrete products*
- JIS A 5372 *Precast reinforced concrete products*
- JIS K 0050 *General rules for chemical analysis*
- JIS K 0058-1 *Test methods for chemicals in slags—Part 1: Leaching test method*
- JIS K 0058-2 *Test methods for chemicals in slags—Part 2: Test method for acid extractable contents of chemicals*
- JIS K 0115 *General rules for molecular absorptiometric analysis*
- JIS K 0119 *General rules for X-ray fluorescence analysis*
- JIS K 0121 *General rules for atomic absorption spectrometry*
- JIS K 8001 *General rule for test methods of reagents*
- JIS Q 17025 *General requirements for the competence of testing and calibration laboratories*
- JIS Q 17050-1 *Conformity assessment—Supplier's declaration of conformity—Part 1: General requirements*
- JIS Q 17050-2 *Conformity assessment—Supplier's declaration of conformity—Part 2: Supporting documentation*
- JIS R 5201 *Physical testing methods for cement*
- JIS Z 8801-1 *Test sieves—Part 1: Test sieves of metal wire cloth*

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in **JIS A 0203**, and the following apply.

3.1 popout

generation of conical cavities occurring after the concrete surface has fractured due to expansion pressure

3.2 environmentally sound quality

quality which molten slag aggregate should have so that all environmental media such as soil, ground water and sea water which are influenced by molten slag aggregate can meet their applicable environmental standards, in the rationally expected lifecycle of the molten slag aggregate that extends from shipment, construction of concrete structure, production and use of concrete product through to the reuse after dismantling and final disposal

3.3 environmental safety type inspection

inspection performed to judge whether the molten slag aggregate satisfies the environmentally sound quality criteria, after it has been subjected to certain types of treatment such as particle size adjustment for making it suitable for use in concrete, and then validated to satisfy all other quality requirements (hereafter referred to as type inspection)

For this inspection, a use simulation sample is used to perform applicable tests so that the aggregate's conformance to the environmentally sound quality criteria can be determined.

For purposes of increased efficiency of sample preparation, molten slag aggregate sample can be used ¹⁾.

Note ¹⁾ Either sample is sufficient for ensuring conformance to the environmentally sound quality criteria.

3.4 environmental safety delivery inspection

inspection performed for assurance of, at the time of delivery, the environmentally sound qualities of the molten slag aggregate manufactured under the same conditions as the one that passed the type inspection (hereafter referred to as delivery inspection)

For this inspection, molten slag aggregate sample is used to perform applicable tests so that the aggregate's conformance to the specified criteria values for environmental safety delivery inspection. The assurance of environmentally sound quality using the simulation sample which has been used in the type inspection is only valid if the aggregate is to be used in the same mix proportion ²⁾ as used in the type inspection.

Note ²⁾ If the only change from the mix proportion used in the type inspection is reduction in the unit mass of molten slag aggregate (mass of molten slag aggregate used to produce 1 m³ of concrete), the mix proportion is regarded as the same as the type inspection.

3.5 use simulation sample

sample prepared simulating the condition of molten slag aggregate in the most critical exposure environment in terms of environmental safety that can be rationally expected to occur in the lifecycle of the molten slag aggregate that extends from shipment, use, all through to the reuse after dismantling and final disposal

It is used for type inspection.

3.6 molten slag aggregate sample

sample extracted by an adequate method from the tested bulk of molten slag aggregate to be supplied for the type inspection or delivery inspection

3.7 environmentally sound quality criteria

criteria such as elution levels and contents of chemical components specified as test items necessary to be evaluated for assuring the environmentally sound quality

The type inspection results are evaluated against this criteria.

3.8 criteria values for environmental safety delivery inspection

criteria values which the molten slag aggregate sample should satisfy in the delivery inspection in order to validate its conformance to the environmentally sound quality criteria (hereafter referred to as delivery inspection criteria)

If a use simulation sample has been used in the type inspection, the manufacturer of the molten slag aggregate shall lay out the criteria values for the required inspection items based on the data of environmental safety type and delivery tests. If a molten

slag aggregate sample has been used in the type inspection, the same values as specified for the environmentally sound quality criteria shall be used.

3.9 environmental safety type test

test performed for the type inspection of the molten slag aggregate to verify its conformity to the environmentally sound quality criteria (hereafter referred to as type test)

It consists of a leaching test and a chemical analysis.

3.10 environmental safety delivery test

test performed for the delivery inspection of the molten slag aggregate to verify its conformity to the delivery inspection criteria (hereafter referred to as delivery test)

It consists of a leaching test and a chemical analysis.

4 Classification, division and designation

4.1 Classification

The molten slag aggregates are classified as given in Table 1.

Table 1 Classification

Classification	Symbol	Summary
Coarse aggregate	MG	Aggregates obtained by cooling and solidifying the fused material derived from melt-solidifying facilities of municipal solid waste and sewage sludge for the purpose of efficient utilization of them, and then adjusting their particle size
Fine aggregate	MS	

4.2 Division according to grain size

The division of molten slag aggregates according to the grain size is as follows.

- a) The division of molten slag coarse aggregates according to the grain size is as given in Table 2.

Table 2 Division of molten slag coarse aggregates according to grain size

Division according to grain size	Range of grain size mm	Symbol
Molten slag coarse aggregate 2005	20 to 5	MG20-05
Molten slag coarse aggregate 2015	20 to 15	MG20-15
Molten slag coarse aggregate 1505	15 to 5	MG15-05

- b) The division of molten slag fine aggregates according to the grain size is as given in Table 3.

Table 3 Division of molten slag fine aggregates according to grain size

Division according to grain size	Range of grain size mm	Symbol
5 mm molten slag fine aggregate	5 or under	MS5
2.5 mm molten slag fine aggregate	2.5 or under	MS2.5
1.2 mm molten slag fine aggregate	1.2 or under	MS1.2
5 mm to 0.3 mm molten slag fine aggregate	5 to 0.3	MS5-0.3

4.3 Division according to alkali-silica reactivity

The division of molten slag aggregates according to the alkali-silica reactivity is as given in Table 4.

Table 4 Division according to alkali-silica reactivity

Division	Summary
A	Those judged to be “innocuous” in the alkali-silica reactivity test.
B	Those judged to be “deleterious” in the alkali-silica reactivity test, or those not subjected to this test

4.4 Designation of products

The molten slag aggregates are designated by symbol for classification, symbols representing the division according to grain size and division according to alkali-silica reactivity (see example below).

Example: MS 2.5 B

Symbol representing the division according to alkali-silica reactivity

Symbol representing the division according to grain size

Symbol representing the classification

5 Quality

5.1 General

The molten slag aggregate, when in storage or used in concrete, should not contain harmful amount of substances that may adversely affect the using environment or quality of concrete (including appearance).

NOTE : Harmful substances include waste, sludge, organic impurities, chlorides, metallic iron, metallic aluminium or any substance inducing popouts (e.g. quicklime grains).

5.2 Chemical composition and physical properties

The molten slag fine aggregate shall, when tested in accordance with 6.2 to 6.6, conform to the requirements in Table 5.

Table 5 Chemical composition and physical properties

Item		Molten slag aggregate		Applicable test subclause
		MG (Coarse aggregate)	MS (Fine aggregate)	
Chemical composition	Calcium oxide (as CaO) %	45.0 max.		6.2
	Total sulfur (as S) %	2.0 max.		
	Sulfur trioxide (as SO ₃) %	0.5 max.		
	Metallic iron (as Fe) %	1.0 max.		
	Chloride (as NaCl) %	0.04 max.		
Physical properties	Density in oven-dry condition g/cm ³	2.5 min.	2.5 min.	6.3
	Water absorption %	3.0 max.	3.0 max.	
	Stability %	12 max.	10 max.	6.4
	Solid volume percentage for shape determination %	55 min.	53 min.	6.5
	Content of particulates %	1.0 max.	7.0 max. ^{a)}	6.6
Note ^{a)} It shall be 5.0 % or under in the case of the molten slag fine aggregate to be used in concrete subjected to abrading action.				

5.3 Alkali-silica reactivity

The alkali-silica reactivity of molten slag aggregate shall be in accordance with either of the following.

- The aggregate shall be subjected to the test specified in **6.7**, and its alkali-silica reactivity shall be judged to be “innocuous”.
- If not subjected to the test specified in **6.7** or judged to be “deleterious” in the said test, the aggregate shall be given one of the restraining measures specified in Annex B of **JIS A 5308**.

5.4 Grain size and fineness modulus

5.4.1 Grain size and fineness modulus of molten slag coarse aggregate

The grain size and fineness modulus of molten slag coarse aggregate shall be as follows.

- The grain size of the molten slag coarse aggregate, when tested in accordance with **6.8**, shall conform to the requirements in Table 6.

Table 6 Grain size of molten slag coarse aggregate

Division	Mass fraction of particles which have passed through sieve %					
	Nominal aperture size of sieve ^{a)} mm					
	25	20	15	10	5	2.5
Molten slag coarse aggregate 2005	100	90 to 100	—	20 to 55	0 to 10	0 to 5
Molten slag coarse aggregate 2015	100	90 to 100	—	0 to 10	0 to 5	—
Molten slag coarse aggregate 1505	—	100	90 to 100	40 to 70	0 to 15	0 to 5
Note ^{a)} The above nominal sizes of sieve correspond to nominal aperture sizes 26.5 mm, 19 mm, 16 mm, 9.5 mm, 4.75 mm and 2.36 mm, respectively, that are specified in JIS Z 8801-1 .						

- b) The fineness modulus of molten slag coarse aggregate shall be within ± 0.30 from the value agreed between the purchaser and the manufacturer.

5.4.2 Grain size and fineness modulus of molten slag fine aggregate

The grain size and fineness modulus of molten slag fine aggregate shall be as follows.

- a) The grain size of the molten slag fine aggregate, when tested in accordance with **6.8**, shall conform to the requirements in Table 7.

Table 7 Grain size of molten slag fine aggregate

Division	Mass fraction of particles which have passed through sieve %						
	Nominal aperture size of sieve ^{a)} mm						
	10	5	2.5	1.2	0.6	0.3	0.15
5 mm molten slag fine aggregate	100	90 to 100	80 to 100	50 to 90	25 to 65	10 to 35	2 to 15
2.5 mm molten slag fine aggregate	100	95 to 100	85 to 100	60 to 95	30 to 70	10 to 45	5 to 20
1.2 mm molten slag fine aggregate	—	100	95 to 100	80 to 100	35 to 80	15 to 50	10 to 30
5 mm to 0.3 mm molten slag fine aggregate	100	95 to 100	45 to 100	10 to 70	0 to 40	0 to 15	0 to 10
Note ^{a)} The above nominal sizes of sieve correspond to nominal aperture sizes 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 μ m, 300 μ m and 150 μ m, respectively, that are specified in JIS Z 8801-1 .							

- b) The fineness modulus of molten slag fine aggregate shall be within ± 0.20 from the value agreed between the purchaser and the manufacturer.

5.5 Expansibility

The expansibility of the molten slag aggregate shall be such that, when the test specified in **6.9** is carried out, mortar shall be free from expansion 24 h after the start of measurement.

5.6 Popout

The molten slag aggregate, when tested according to **6.10**, shall be free from popouts.

5.7 Environmentally sound quality criteria

The molten slag aggregate, when tested in accordance with **6.11**, shall conform to the quality criteria given in Table 8.

Table 8 Environmentally sound quality criteria

Item	Leaching amount mg/L	Content ^{a)} mg/kg
Cadmium	0.01 max.	150 max.
Lead	0.01 max.	150 max.
Hexavalent chromium	0.05 max.	250 max.
Arsenic	0.01 max.	150 max.
Mercury	0.000 5 max.	15 max.
Selenium	0.01 max.	150 max.
Fluorine	0.8 max.	4 000 max.
Boron	1 max.	4 000 max.
Note ^{a)} It should be noted that the content given above is different from the "total content" as it would generally mean.		

6 Test methods

6.1 Sampling and reduction of sample

Sample representative of the tested material shall be taken, and reduced according to the method specified in **JIS A 1158**.

6.2 Chemical analysis

The chemical analysis shall be carried out in accordance with Annex A of **JIS A 5011-3**. However, the analysis of metallic iron (as Fe) shall be carried out in accordance with **A.10** of **JIS A 5011-2**.

If, in the above method, the metallic ion content determined is found to be excessively high, the analysis method specified in Annex B shall be used.

6.3 Test of density in oven-dry condition and water absorption test

The tests shall be carried out in accordance with **JIS A 1109** or **JIS A 1110**.

6.4 Stability test

The test shall be carried out in accordance with **JIS A 1122**.

6.5 Test of percentage of absolute volume in grain size determination

The test shall be carried out in accordance with **JIS A 5005**.