

## New Standards on Recycled Aggregates and Molten-Slag in Japan

According to an estimate by the Development Bank of Japan [Development Bank of Japan 2002], the total amount of concrete masses to be generated in 2025 is estimated to be 210 million tons, which is a twofold increase of the 112 million tons generated in 2005. These amounts are extremely high, considering that the total concrete production for Japan in 2005 was approximately 285 million tons. While most concrete masses have been used as base course materials, their demand is expected to decrease dramatically. Since the use of these as recycled aggregate is crucial considering the pressure on waste disposal sites and the preservation of aggregate resources, the development of technologies for recycled aggregate production is being promoted.

In Japan, JIS (Japanese Industrial Standard) A 5021 [Japanese Standards Association 2005] was established in 2005 as a standard for high-quality recycled aggregate H for concrete, which is produced through advanced processing, including crushing, grinding and classifying, of concrete masses generated in the demolition of structures. Recycled aggregate H must have physical properties satisfying the requirements listed in Table 1. There are also upper limits for the amounts of deleterious substances contained in recycled aggregate H, as shown in Table 2. JIS A 5023 has also been established as a standard for recycled concrete using low-quality recycled aggregate L. This type of concrete includes backfilling, filling and leveling concrete, and the use of Type B blended cement and admixture is required as a measure against alkali-silica reactivity.

Table 1 Physical Properties Requirements for Recycled Aggregate H

Items	Coarse aggregate	Fine aggregate
Oven-dry density, g/cm <sup>3</sup>	not less than 2.5	not less than 2.5
Water absorption, %	not more than 3.0	not more than 3.0
Abrasion, %	not more than 35	NA
Solid volume percentage for shape determination, %	not less than 55	not less than 53
Amount of material passing test sieve 75μm, %	not more than 1.0	not more than 7.0
Chloride ion content	not more than 0.04	

Table 2 Limits of Amount of Deleterious Substances for Recycled Aggregate H

Category	Deleterious substances	Limits (mass %)
A	Tile, Brick, Ceramics, Asphalt	2.0
B	Glass	0.5
C	Plaster	0.1
D	Inorganic substances other than plaster	0.5
E	Plastics	0.5
F	Wood, Paper, Asphalt	0.1
Total		3.0

In recent years, melting treatment of waste and sewage sludge has become common in Japan due to pressures on waste treatment sites and problems related to the disposal of dioxin and heavy metals. Molten slag is generated as a residue after melting treatment. In 2004, 144 waste and 18 sewage sludge melting treatment facilities were in operation throughout Japan, producing 480,000 and 44,000 tons of molten slag, respectively. Waste molten slag production is estimated to reach as high as 2.7 million tons in the future. Melting treatment was also commenced in 2005 for 600,000 tons of illegally dumped industrial waste in Teshima, Kagawa Prefecture. Approximately 300,000 tons of molten slag are to be produced for 10 years, and the prefectural government has decided to use the entire amount as aggregate for concrete. Basic studies on the application of municipal solid waste and Teshima molten slag to concrete have been conducted. Molten slag is characterized by low water retentivity since it is vitreous. When it is used in large amounts, bleeding increases and leads to a decrease of the strength of concrete and, in the case of reinforced concrete, a decrease in the bond of reinforcing bars to concrete. The permissible replacement ratio of molten slag for fine aggregate thus varies according to the performance required for concrete. It is also necessary to pay attention to aluminum, which is a metal contained in molten slag, since it may cause expansion and deterioration of concrete as it reacts with the alkali of cement and generates hydrogen. In Japan, JIS A 5031 [Japanese Standards Association 2006] was established for molten slag aggregate for concrete. Table 3 lists the physical properties of molten slag required by this standard.

Table 3 Physical Properties Requirements for Molten Slag Aggregates

Items	Molten slag	Coarse aggregate	Fine aggregate
Oven-dry density, g/cm <sup>3</sup>		not less than 2.5	not less than 2.5
Water absorption, %		not more than 3.0	not more than 3.0
Soundness, %		not less than 12	not less than 10
Solid volume percentage for shape determination, %		not less than 55	not less than 53
Amount of material passing test sieve 75μm, %		not more than 1.0	not more than 7.0