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Waste Materials in Construction: Putting Theory into Practice

CONSTRACTION MATERIALS MANUFACTUARING BY THE TECHNOLOGY OF MELTING

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1. Preface

Most municipal waste is incinerated first ; then the residue is buried at landfill sites equipped with waste water treatment facilities. This is the general waste disposal way in Japan.
50,304 thousand tons of wastes are generated every year, and 73 % of them are burnt. Subsequently, 6,013 thousand tons of incineration residue is left to be buried.
Obviously, refuse incineration, which reduces the bulk of waste, is an indispensable treatment method for Japan in view of the small land area and the need for effective land use.
However, it is also true that much dioxin is emitted to the environment during the incineration process.
In January 1997, the MHW (Ministry of Health and Welfare) announced its policy to reduce dioxin emitted to the environment to 5 μ g or less per 1 ton of waste incinerated. In order to attain this target, not only dioxin in flue gas generated through incineration is reduced, but also dioxin contained in bottom ash and fly ash must be decomposed through exposure to a high temperature atmosphere for example.
Because the most effective method for this is a melting furnace system, the MHW recommends the introduction of the melting furnace facility to each municipal government. The melting furnace system inevitably generates slag, but only dumping slag will make no contribution to prolonging the lifetime of landfill sites. On the contrary, this slag can be utilized as a material resource for products used in daily life, because it contains almost no dioxin and extremely small quantities of heavy metals.
Substitution for sand will be the simplest and easiest utilization of the slag as material resources. In addition, it can be used as a raw material for sintered products such as tiles, taking advantages of its thermal characteristics.
The paper presents the experimental results of tile production from the slag.

2. Test Method

(1) Test Samples

As test samples, we used the slag obtained after melting bottom ash of municipal waste and the slag after melting fly ash generated during incineration. The analytical results of constituents are shown in the Table-1. Furthermore, the constituents of the clays and frits used as additives are also listed.

Table 1 : Analytical Results of Constituents of Slag & Others

Constituents	Units	Aggregate		Molding Mat'l	Additive
		Molten Slag		Ordinary Clay	Frit
		Bottom Ash	Fly Ash		
SiO_2	(%)	38.4	35.51	60.16	50.28
Al_2O_3	(%)	19.1	15.35	26.96	5.8
CaO	(%)	25.38	31.05	0.18	0.49
Fe_2O_3	(%)	3.3	3.3	0.88	N.D.
MgO	(%)	3.1	3.95	0.13	0.8
Na_2O	(%)	2.8	1.87	0.21	7.89
K_2O	(%)	1.1	0.65	2.8	0.11
T-S	(%)	0.25	0.41	–	–
T-Cl	(%)	N.D.	N.D.	–	–
Cu	(mg/kg)	1600	4100	–	–
Cd	(mg/kg)	N.D.	N.D.	–	–
Pb	(mg/kg)	140	170	–	–
As	(mg/kg)	1.7	1.2	–	–
Zn	(mg/kg)	1600	830	–	–
T-Hg	(mg/kg)	N.D.	N.D.	–	–
Cr	(mg/kg)	520	230	–	–

(2) Trial Manufacturing of Sintered Products

Fig. 1 shows the trial manufacturing procedures. First of all, clay, frits, and water were added to the slag pulverized by a ball mill. Then, they were mixed and kneaded to make a test piece through press molding. After drying, we sintered it in an electric furnace at 1000℃. Table 2 shows the manufacturing conditions for the test piece.

The test pieces used for the Bending Test are shown in Photo 1.

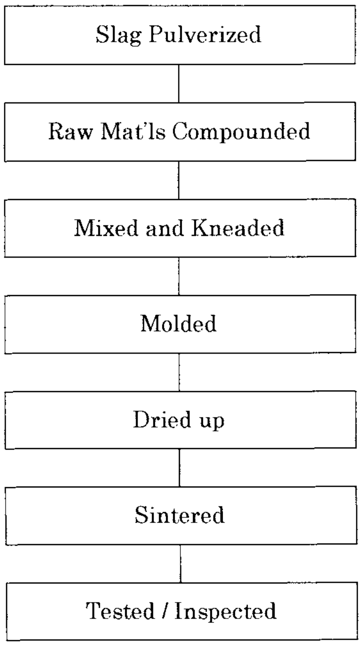

Fig. 1 : Trial Manufacturing Procedures of Sintered Product

Table 2 : Manufacturing Conditions of Sintered Products

Compound Ratio of Each Material	Slag : Clay : Frit = 60 : 20 : 20 (%)
Water Content during Mixing & Kneading	8 %
Test Piece Dimensions	100mm × 30mm (for bending test) 100mm × 100mm
Molding Pressure	500 kgf/cm^2
Heating-up Speed	100℃/hr
Sintering Temperature	1000℃
Retention	1 hr

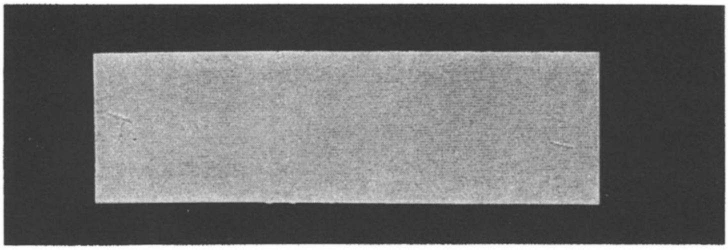

Photo 1 : The Test Pieces Used for The Bending Test

(3) Measuring Methods

Dimensional accuracy, bending strength, and water absorbance were measured respectively to find the characteristics of the sintered products.

① Dimensional Accuracy

We measured the side of 10 sample pieces to compute an averaged value. The difference between the actual length of the sides and the average value was defined to be dimensional tolerance.

$$\text{Dimensional Tolerance (mm)} = \frac{L1 + L2 + \cdots L9 + L10}{10} - Ln$$

Ln : Side Length of n th sampe (mm)

② Bending Test

We applied the testing method of 3-points bending.
Calculation was made as follows :

$$\text{Bending Strength (kgf/cm}^2\text{)} = \frac{3\,PL}{2\,wt^2}$$

P : Maximum Destruction Loading (kgf)
L : Span Length (cm)
w : Width of Test Piece (cm)
t : Thickness of Test Piece (cm)

③ Water Absorbance

$$\text{Water Absorbance (\%)} = \frac{W - W_0}{W_0} \times 100$$

W : Weight after Absorption (g)
W_0 : Dried Weight (g)

3. Test Results

(1) Dimensional Accuracy
Table 3 shows test results.

Table 3 : Test Results of Dimensional Accuracy (mm)

	1	2	3	4	5	6	7	8	9	10	Average
Sintered Product ①*1	93.30	92.60	93.40	93.20	93.65	93.30	92.80	92.90	93.05	93.25	93.145
Difference from Average	+0.15	-0.55	+0.25	+0.05	+0.50	+0.15	-0.35	-0.25	-0.10	+0.10	±0.55
Sintered Product ②*2	91.70	92.15	91.40	92.20	92.35	91.20	91.90	91.65	92.25	92.15	91.895
Difference from Average	-0.20	+0.25	-0.50	+0.30	+0.45	-0.70	0.00	-0.25	+0.35	+0.25	±0.70

*1 : Sintered products made of bottom ash slag
*2 : Sintered products made of fly ash slag

As a test result, it is found that the dimensional tolerance of the sintered material made of bottom ash is ±0.55mm and that of the one made of fly ash slag is ±0.70mm. Both tolerances stay within ±2mm as those specified by JIS Standards.

(2) Bending Strength
Tables 4 and 5 show the test results of each sample.

Table 4 : Measurement Result of Bending Strength

		1	2	3	4	5
Sintered Product made of bottom ash slag	Width(mm)	29.85	29.35	29.30	29.35	29.30
	Thickness(mm)	8.20	7.95	7.90	8.25	8.05
	Load(kgf)	100.9	98.3	95.1	109.7	114.2
	Bending Strength(kgf/cm²) *1	538.7	556.4	546.1	576.6	631.5
Sintered Product made of fly ash slag	Width(mm)	29.10	29.05	29.00	29.15	29.05
	Thickness(mm)	8.35	7.50	7.45	7.90	8.05
	Load(kgf)	170.5	147.5	135.5	156.1	177.0
	Bending Strength (kgf/cm²) *1	882.4	947.8	883.9	900.9	987.2

*1 : Bending Strength was measured at 70mm span length.

Table 5 : Bending Strength of Slag-made Sintered Products (kgf/cm^2)

Type of Tile	Averaged Bending Strength
Sintered Product made of bottom ash slag	570
Sintered Product made of fly ash slag	920
Presently marketed sample tiles	330

As shown in the above table, the sintered product has a strength of 570kgf/cm^2 or more. Slag-made sintered product is in no way inferior to the tiles presently marketed. Therefore, it is considered to be an appropriate material not only for walls and roofs but also for floors which require higher strength.

(3) Water Absorbance
Table 6 shows the test results of water absorbance.

Table 6 : Water Absorbance of Sintered Product (%)

Type of Tile	Water Absorbance
Sintered Product made of bottom ash slag	10.5
Sintered Product made of fly ash slag	0.2
Presently marketed sample tiles	0.4

As shown in the above, water absorbance of sintered product made of incinerated ash slag and sintered product made of fly ash slag is 10.5% and 0.2%, respectively.

4. Conclusion

The following advantages of slag-made sintered product were found through these tests ;
① It is possible to sinter even at relatively low temperature of 1000℃.
② The strength is comparable to ordinary tiles.
③ Dimensional accuracy is superior due to small shrinkage.

Meanwhile, it is ascertained through other tests that some crystals such as anorthite ($CaO \cdot A\lambda_2O_3 \cdot 2SiO_2$), diopside($CaO \cdot MgO \cdot 2SiO_2$), gehlenite($2Cao \cdot A\lambda_2O_3 \cdot SiO_2$) are formed in the slag. Generation of these crystals are probable factors which increase the strength of slag-made sintered products, but this phenomenon has not been fully elucidated yet.

In any event, it is a fact that low temperature sintering is possible. Obviously this will bring about new practical uses for the slag such as tiles as a construction material.