9th. International Conference on Concrete Block Paving. Buenos Aires, Argentina, 2009/10/18-21
Argentinean Concrete Block Association (AABH) - Argentinean Portland Cement Institute (ICPA)
Small Element Paving Technologists (SEPT)

UTILIZATION OF MOLTEN SLAG INTO INTERLOCKING CONCRETE BLOCK (ILCB) IN JAPAN AND RECYCLING OF 100% MOLTEN SLAG ILCB

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Note: The following is the notation used in this paper: (.) for decimals and ( ) for thousands.

Summary

Municipal (solid) waste of about 50 milion tons per annum has been made in Japan. From a viewpoint of environmental preservation, producing the molten slag from municipal waste is effective to extend the life of its disposal landfill site because of reducing remarkably its quantities. In July 2006, Japanese Industrial Standard (JIS) A 5031 was established as the regulation for the molten slag. The main purpose of JIS A 5031 is to recycle into the precast unreinforced concrete products, especially into interlocking concrete block (ILCB). The quality of recycled ILCB after using for a long term in road pavement may be changed by the recycling times of old ILCB.

The experiment was done on the virgin ILCB, the first recycled ILCB, the second one and the third one, while recycling three times of using the recycled sand crushed the virgin one, while blending 0%, 25%, 50%, 100% molten slag with 100%, 75%, 50%, 0% sand, respectively. The results lead to that the heavy metal leaching values, analyzing chemically the fine aggregate crushed the virgin ILCB and the third recycled one, were both less than the values by the environmental regulation, and the bending strength of the third recycled ILCB indicated less 20% only rather than one of the virgin ILCB with 100% molten slag. From a standpoint of sustainable utilization of molten slag ILCB, we can reuse the recycled aggregate of the three-time-recycling ILCB with 100% molten slag.

As the actual pavements using molten slag ILCB by new JIS, there are water-retaintative ILCB for reducing the heat island phenomenon, NOx-absorped ILCB against exhaust gas in roads crowded cars, landscape ILCB in parks and so on. In addition, it will be started to study the sustainable utilization of molten slag from a lot of waste TV materials very soon.

1. MUNICIPAL WASTE TREATMENT IN JAPAN AND ITS PROBLEM

The disposal of municipal (solid) waste and sewage sludge is one of serious social problems in and near the large cities and towns in Japan. Particularly, a lot of municipal waste has been occurred

during their daily life. One people make garbage (waste) about 1.0 kg per day and about 360 kg per annum, and also the waste of about 1.0 ton per annum was made by only one family with 3 peoples. The amount of municipal waste generated is currently around 50 million tons per annum in Japan, being the largest country after U. S. A. producing 0.2-billion-ton.

The landfill sites of their disposals have become rapidly narrow and then have their limited lives. From a viewpoint of environmental pollution prevention, the disposal treatment methods have been studied. In general, incineration ash from municipal waste have been carried to the controlled landfill sites and then been checked sometimes for a long time observations. Recently, they have been carried to the melting treatment plants to produce molten slag. However, depend on much waste treatment cost, industrial wastes were sometimes damped unlawfully, and their affairs became unfortunately large scale social problems with long term solutions in no small way [Shoya *et al*, 2004].

These problems are, of cause, necessary to solve rapidly, and also we must reduce waste quantity and think about their effective treatment methods seriously. Recycling waste into useful resources is effective to expand their lives of landfills. At present, these wastes have been generally treated by the incineration method in each waste treatment plant. These incineration ashes occupy about 75% of them. Sewage sludge has been accumulated year by year, while occupying almost stable quantity. After a long term discussion on the recycling molten slag from municipal waste and sewage sludge, and JIS A 5031 was lastly established in July 2006.

2. MANUFACTURING METHODS OF MOLTEN SLAG AND ITS PRODUCTION

At present, many local governments in Japan operate municipal waste treatment plants to produce incineration ash from their municipal waste. Many local governments, having landfill sites for waste treatment disposal, can dump incineration ash into the final landfill sites. However, local governments with less landfill sites must construct the melting treatment plants to melt them to reduce their quantities.

There are two systems to produce molten slag; one is an ordinary treatment which they make incineration ash at first and then produce molten slag, and the other is directly to produce molten slag from the waste. In the latter system, molten slag is produced from an incinerating gas sprung up in a melting furnace, after melting the waste in the fluidized-bed gasification furnace, as shown in Figure 1. This method can lead to a remarkable reduction of the waste volume, for example the waste volume of 100 could be reduced to the volume of 2-5, depend on waste quality. Recent waste treatment plants can produce molten slag without an environmental pollution by the melting system with high temperature above about 1 300 centigrade degrees as a re-treatment system of incineration ash. These methods were already developed by the high temperature melting technologies as results of several companies' innovational challenges. Now, the technology is applied not only municipal waste and sewage sludge but also one of industrial waste. About 170 plants are running and producing about 0.6-million-ton molten slag in Japan.

3. NEWLY JAPANESE INDUSTRIAL STANDARD (JIS) FOR MOLTEN SLAG

In Japan, fine molten slag for concrete aggregate was decided the range of conditions utilizing, under the revision of JIS A 5364 in March 2004 (Japanese Industrial Standard Committee, 2004). The active utilization of molten slag was advised under "The certificated establishment of the recycled products used molten slag" in local governments, depend on the principle that they should use only where they produce. Molten slag concrete products have been spread widely, and actual

examples on molten slag utilization have been increased year by year (Hosokawa *et al*, 2005). Thus social backgrouds on molten slag utilization pushed to establish JIS A 5031. In this JIS, the values on physical and chemical qualities and environmental safety were indicated. Molten slag is actually produced every day, and it is important to effective utilization of molten slag into concrete products. However, all molten slag is not always safety environmentally. Paying the environmental attention to slag's property is important. Because the property is changeable every time as municipal waste has actually various kinds and qualities.

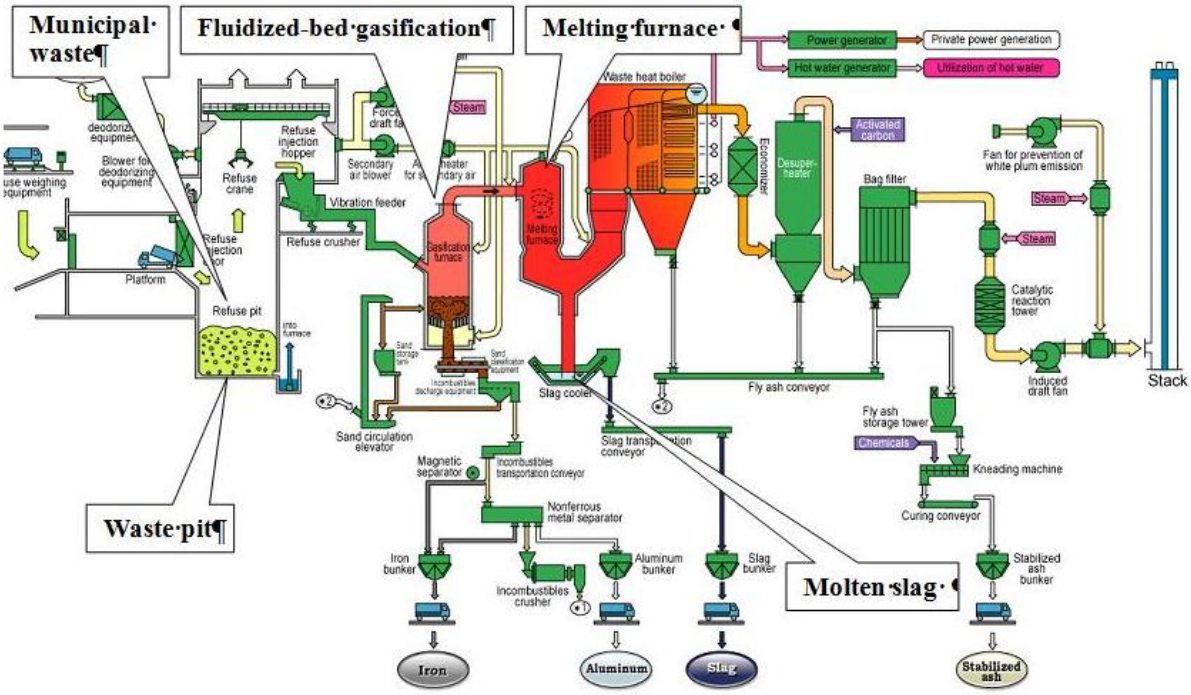


Figure 1. Flow of fluidized-bed gasification and swirl-flow melting system for waste.

4. EFFECTIVE UTILIZATION OF MOLTEN SLAG INTO CONCRETE PRODUCTS, ESPECIALLY INTERLOCKING CONCRETE BLOCK (ILCB)

Molten slag have distinctive physical properties, i.e. big specific gravity, a little water absorption and small solid content of grain-form judgment. These properties are not influenced to the manufacture of ILCB. However, the chemical property of molten slag is slightly different by the melting system and the kind of municipal waste and sewage sludge. In general, it is reported that SiO_2, CaO and Al_2O_3 are mainly included in molten slag [Nagano *et al*, 2007] and Fe_2O_3 and P_2O_5 are especially included in sewage sludge molten slag.

Precast unreinforced concrete products using molten slag are concrete curb block for road pavement, concrete plate for sidewalk and park, interlocking concrete block (ILCB) and so on. Especially, various colored and modified ILCB are increasing for road pavement with a high landscape function. In case of manufacturing molten slag ILCB, it is in principle reccomended that block makers (plants) had better mix 50% general aggregate with 50% molten slag in a volume, keeping the recommended aggregate sieving range of them.

5. RECYCLING ILCB REUSED AGGREGATE, RECYCLED MOLTEN SLAG ILCB

5.1 Purpose of this experiment

The manufacturing method and several properties of ILCB mixing with molten slag and eco-cement were already reported by Hosokawa *et al* (2001). Recent ILCB is used into road pavement materials in public works by local governments, mentioned above. s/a,120 kg/m^3 water and 400 kg/m^3 cement are same in all mix proportions. Table 2 shows physical properties of aggregates to use ILCB mixing. The molding of ILCB was treated by the same method in ILB Concrete Plant. Table 3 shows the concrete mix proportion, while classifying ILCB as below. However, the study on recycling technology of molten slag ILCB is not found, whether we can reuse them as re-useful resources. Therefore, it is necessary to make clear the characteristics of recycled aggregate after crushing the virgin ILCB, the first recycled ILCB, the second one and the third one, using 100% molten slag and aggregate recycled from each ILCB, and to study about the properties of each ILCB, as being assumed for a long term. On the other hand, checking the heavy metal leaching values from molten slag are required in the environmental aspect.



Figure 1. Eco-cement (left) and molten slag.

5.2 Material and Method

5.2.1 Concreet mix proportion of ILCB

As the concrete materials, we used eco-cement (3.16 g/cm^3 specific gravity, 4 100 cm^2/g specific surface area, Taiheiyo Cement Corporation), some aggregates: crushed sand, crushed stone and molten slag, and admixture: a high water-reducing agent (Kao Co., Ltd.). The admixture was mixed 0.8% of cement quantity in a weight. The concrete mix proportion of ILCB is shown in Table 1.

The blending rate of molten slag with crushed sand (CS) was 4-kind type, i.e. 0:100, 25:75, 50:50 and 100:0 in a volume, respectively. After testing the bending strength for the virgin ILCB, the species were crushed to make next aggregate (RS) to manufacture ILCB. In the mix proportion of ILCB, values of 30% W/C, 50% s/a,120 kg/m^3 water and 400 kg/m^3 cement are same in all mix proportions. Table 2 shows physical properties of aggregates to use ILCB mixing. The molding of ILCB was treated by the same method in ILB Concrete Plant. Table 3 shows the concrete mix proportion, while classifying ILCB as below.

Table 1. Design of concrete mix proportion.

ITEM	W/C (%)	S/A (%)	UNIT CONTENTS							
			W (kg/m^3)	C (kg/m^3)	SAND´S RATE (%) CS/RS BLENDING RATE OF MOLTEN SLAG				GRAVEL´S RATE (%)		ADMIX. (ml)
					0%	25%	50%	100%	CTG	RG	
Virgin ILCB	30	50	120	400	100/-	75/-	50/-	0/-	100	-	4
1st Recycled ILCB					-/100	-/75	-/50	-/0	-	100	4
2nd Recycled ILCB					-/100	-/75	-/50	-/0	-	100	4
3rd Recycled ILCB					-/100	-/75	-/50	-/0	-	100	4
W: Water, C: Eco Cement, CS: Crushed Sand *RS: Recycled Sand (< 5 mm), CG: Crushed Stone (5-10 mm), Recycled Gravel (5-10 mm)*											
The virgin ILCB in the blending molten slag vs CS, A=0:100, B=25: 75, C=50:50, D=100:0. The first recycled ILCB in the same above, R_{1A}=0:100, R_{1B}=25:75, R_{1C}=50:50, R_{1D}=100:0. T the second recycled ILCB in the same above, R_{2A}=0:100, R_{2B}=25:75, R_{2C}=50:50, R_{2D}=100:0. The third recycled ILCB in the same above, R_{3A}=0:100, R_{3B}=25:75, R_{3C}=50:50, R_{3D}=100:0.											

Table 2. Physical properties of aggregates.

ILCB	AGGREGATE		SPECIFIC GRAVITY (g/cm^3)	WATER ABSORPTION (%)	BULK DENSITY (kg/L)	SOLID CONTENT (%)	FINENESS MODULUS
Virgin	**Fine**	**CS**	**2.64**	**1.34**	**1.40**	**54.2**	**3.49**
		Molten Slag* A	**2.73**	**0.41**	**1.68**	**54.2**	**3.55**
		Molten Slag* B	**2.80**	**0.54**	**1.40**	**61.8**	**2.97**
	Coarse	**CG**	**2.67**	**0.49**	**1.53**	**57.6**	**6.22**
1st Recycling	**Recycled fine aggregate**	**RS_{1A}**	**2.42**	**8.30**	**1.51**	**67.6**	**3.79**
		RS_{1B}	**2.43**	**7.80**	**1.53**	**67.9**	**3.70**
		RS_{1C}	**2.45**	**7.20**	**1.57**	**68.7**	**3.89**
		RS_{1D}	**2.48**	**6.60**	**1.62**	**69.6**	**3.88**
	Recycled coarse aggregate	**RG_{1A}**	**2.53**	**4.00**	**1.38**	**56.7**	**---**
		RG_{1B}	**2.52**	**4.20**	**1.37**	**56.6**	**---**
		RG_{1C}	**2.51**	**4.50**	**1.36**	**56.6**	**---**
		RG_{1D}	**2.49**	**4.60**	**1.34**	**56.3**	**---**
2nd Recycling	**Recycled fine aggregate**	**RS_{2A}**	**2.38**	**7.50**	**1.47**	**66.4**	**2.65**
		RS_{2B}	**2.41**	**7.10**	**1.49**	**66.2**	**3.27**
		RS_{2C}	**2.45**	**6.50**	**1.51**	**65.6**	**3.53**
		RS_{2D}	**2.53**	**5.20**	**1.54**	**64.0**	**3.86**
	Recycled coarse aggregate	**RG_{2A}**	**2.34**	**7.80**	**1.21**	**55.7**	**---**
		RG_{2B}	**2.36**	**7.20**	**1.23**	**55.9**	**---**
		RG_{2C}	**2.38**	**6.30**	**1.25**	**55.8**	**---**
		RG_{2D}	**2.42**	**5.80**	**1.29**	**56.4**	**---**
3rd Recycling	**Recycled fine aggregate**	**RS_{3A}**	**2.29**	**12.50**	**1.62**	**79.6**	**3.17**
		RS_{3B}	**2.33**	**12.10**	**1.51**	**72.6**	**3.75**
		RS_{3C}	**2.38**	**9.50**	**1.55**	**71.3**	**3.70**
		RS_{3D}	**2.42**	**8.20**	**1.40**	**61.8**	**4.04**
	Recycled coarse aggregate	**RG_{3A}**	**2.29**	**6.50**	**1.26**	**56.1**	**---**
		RG_{3B}	**2.44**	**5.60**	**1.31**	**56.7**	**---**
		RG_{3C}	**2.47**	**5.10**	**1.33**	**56.6**	**---**
		RG_{3D}	**2.51**	**4.30**	**1.36**	**56.5**	**---**
A: Omiya West E. C., B: Weastern Area E. C.							

Table 3 Concrete mix proportion.

ILCB	MIXING TYPE	UNIT CONTENTS (kg/m^3)						ADMIX. (ml)
		W	C	MOLTEN SLAG	CS	RS	G	
Virgin	**A**	120	400	0	986	---	1 005	4
	B			257*	739	---	1 005	
	C			514*	493	---	1 005	
	D			1 027*	0	---	1 005	
1st Recycled	**R_{1A}**	120	400	0	---	911	952	4
	R_{1B}			264	---	686	949	
	R_{1C}			527	---	461	945	
	R_{1D}			1 053	---	0	937	
2nd Recycled	**R_{2A}**	120	400	0	---	895	879	4
	R_{2B}			264	---	680	887	
	R_{2C}			527	---	461	895	
	R_{2D}			1 053	---	0	910	
3rd Recycled	**R_{3A}**	120	400	0	---	861	898	4
	R_{3B}			264	---	657	917	
	R_{3C}			527	---	448	929	
	R_{3D}			1 053	---	0	944	

W: Water, C: Eco-cement, CS: Crushed sand, RS: Recycled sand (< 5mm)
** Omiya West E. C., Other: Weastern Area E. C.*

Table 4 Bending strength of ILCB.

ILCB		BENDING STRENGTH (N/mm^2)		STRENGTH INCREASING RATE FROM 7-DAY TO 28-DAY (%)
		7-DAY AGE	28-DAY AGE	
Virgin	**A**	7.24	7.89	109
	B	7.01	8.05	115
	C	7.21	7.80	108
	D	6.76	7.87	116
1st Recycled	**R_{1A}**	5.37	6.39	119
	R_{1B}	5.49	6.36	116
	R_{1C}	5.35	6.69	125
	R_{1D}	4.84	6.19	128
2nd Recycled	**R_{2A}**	6.02	6.35	105
	R_{2B}	7.14	7.74	108
	R_{2C}	6.94	7.26	105
	R_{2D}	6.66	6.95	104
3rd Recycled	**R_{3A}**	5.67	7.07	125
	R_{3B}	6.17	7.48	121
	R_{3C}	6.45	6.82	106
	R_{3D}	7.04	7.40	105

5.2.2 Filing rate, bending strength and mean water absorption of recycled aggregate

The filling rate was calculated after measuring the weight and the height of each ILCB. The bending strength test was done depend on JIS A 1106 at 7 and 28 day ages for each three specimens of cured ILCB after measuring their size and weight. The mean water absorption of total aggregate was required to evaluate the quality of aggregate for ILCB.

5.2.3 Heavy metal leaching test

The heavy metal leaching test was done on the crushed aggregate of the virgin ILCB and the third recycled ILCB mixed 0, 25, 50, 100% molten slag, depend on the special method (Ministry of Welfare, 1998). Each crushed aggregate, sieved by fine grinds under 2.0 mm size, was conducted the chemical analysis of pH and leaching heavy metals; Cd, Pb, Cr^{6+}, As, T-Hg and Se.

5.3 Results and Discussion

5.3.1 Comparison of bending strength of ILCB, Virgin ILCB

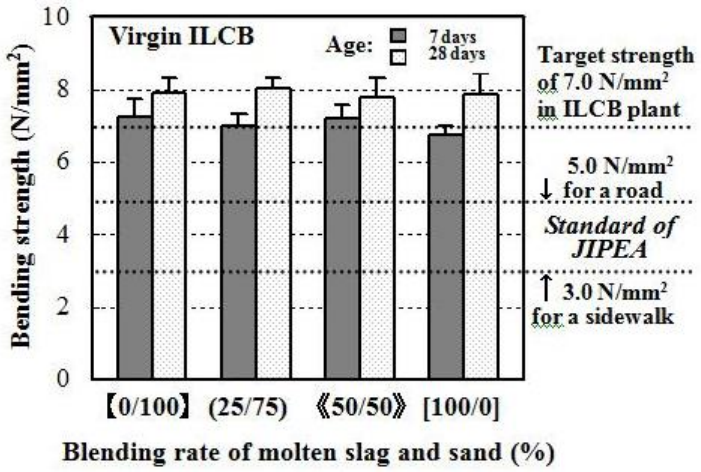


Figure 2. Comparison of bending strength of molten slag virgin ILCB

The bending strength of ILCB is shown in Table 4 and the comparison of them of the Virgin ILCB is indicated in Figure 2. The target strength in the ILB concrete plant is generally 7.0 N/mm^2 at the minimum, and the standard strength of Japan Interlocking Block Pavement Engineering Association (JIPEA) is 5.0 N/mm^2 for a road and 3.0 N/mm^2 for a sidewalk. The bending strength at 7-day age increased totally to 104-128% until 28-day age. In each ILCB group, the strength of first recycled ILCB at 7-day age was low, compared with the other ILCB groups, but the strength-increasing rate to 28-day age was averaged 122%, being the highest increasing rate. The strength difference among four blending rates of molten slag was very small as shown in Figure 2, though the strength of 100% molten slag ILCB at 7-day age was slightly low than the other ILCB.

5.3.2 Changes of fineness modulus of fine aggregate

Figure 3 shows the changes of fineness modulus (F. M.) of fine aggregate crushed each ILCB for next stage's ILCB. F. M. blended molten slag was indicated the range of 3.0-3.5, but F. M. without slag in the recycled ILCB was indicated about 4.0, being a little bigger than the other. As molten slag is the quality of glass by the producing process in the melting system (in Figure 1), the border of molten slag surface become weak when crushing the block, and then the grain of fine aggregate become smaller than the ILCB without molten slag.

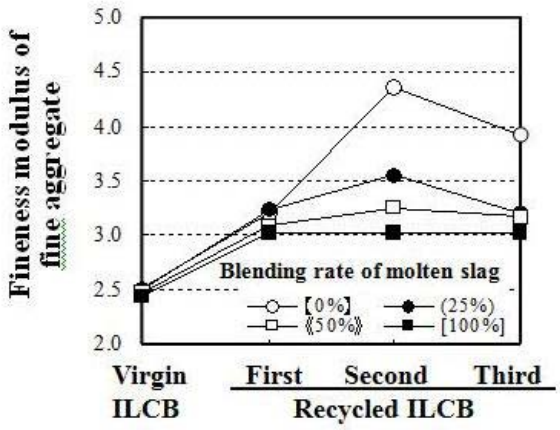


Figure 3. Changes of fineness modulus of fine aggregate in the recycling process.

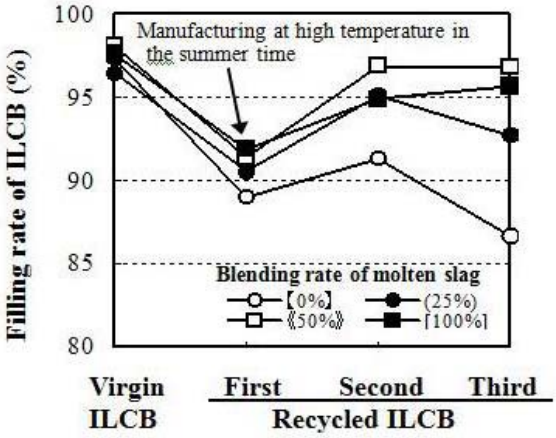


Figure 4. Changes of filling rate of ILCB in the recycling process.

5.3.3 Relationship between the filling rate and the bending strength of ILCB

Figure 4 shows the changes of filling rate of ILCB in the recycling process. In the first recycled ILCB, i.e. R1A~R1D, the filling rate became 6-8% small from the virgin ILCB. Next filling rate in the second recycled ILCB became slightly 2-6% big from them of the first recycled ILCB. Finally, in the third recycled ILCB, the filling rate of recycled aggregate without molten slag became 4% small, but the one with 100% molten slag became only 1% up. The recycled aggregate with bigger F. M. influenced to smaller filling rate of block. The recycled aggregate from 0% molten slag ILCB became bigger aggregate grain because of slightly hard ILCB, and its filling rate changed small because aggregate grain became bigger. Blending 50% molten slag with 50% sand can manufacture the ILCB with a higher filling rate by the better combining grain range.

Figure 5 shows the relationship between the filling rate of ILVB and the bending strength of one. Both indicate a very high correlation ($P<0.001$). When the filling rate becomes higher, the bending strength makes stronger. Figure 6 shows the changes of the bending strength ratio of ILCB in the recycling process. This figure is almost similar in Figure 5 which indicates their good correlation. Especially, it is recommended that blending 50% molten slag with 50% sand can manufacture the recycled ILCB keeping slightly lower strength after three times recycling. Of course, 100% molten slag ILCB after three-time-recycling had only 10% strength reduction.

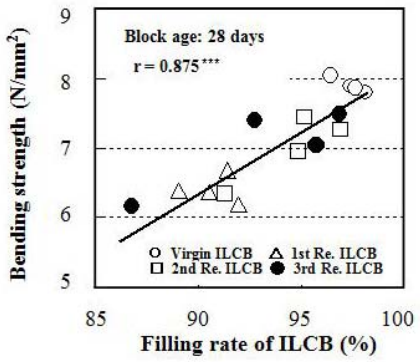


Figure 5. Relationship between filling rate and bending strength.

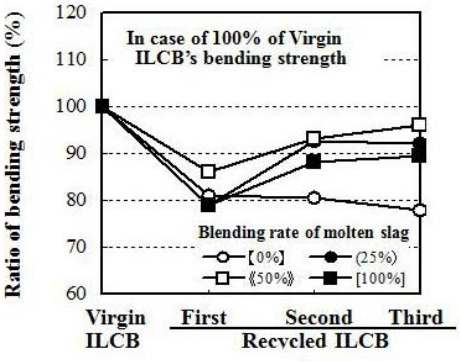


Figure 6. Changes of bending strength ratio of ILCB in the recycling process.

5.3.4 Quality evaluation of recycled aggregate by water absorption

Table 5 shows the mean water absorption of total aggregate. The strength and the binding condition by mortar and cement paste around its aggregate generally influence to the quality of recycled aggregate. The binding condition cannot measure easily. Although there is a good correlation between the binding condition and the water absorption of aggregate, it is able to evaluate the quality of total of recycled aggregate. In Table 5, the range of their values in four-type mix proportions were 5.9-9.9%, and these values indicated that the recycled aggregate had not inferior characteristics.

5.3.5 Result of heavy metal leaching test

Table 5. Mean water absorption of total aggregate.

	MEAN WATER ABSORPTION OF TOTAL AGGREGATE (%)			
Process of recycled aggregate	RA	RB	RC	RD
1st recycled aggregate	6.2	6.1	5.9	5.7
2nd recycled aggregate	7.6	7.1	6.4	5.5
3rd recycled aggregate	9.9	9.1	7.5	6.3

Table 6 shows the result of heavy metal leaching test. The leaching values of each heavy metal did not change from the virgin ILCB to the third Recycled ILCB. The leaching values of all heavy metal indicated clearly lower than the values of the regulation in Notice 46: Environment Quality Standards for Soil Pollution [Ministry of Welfare, 1998]. However, only Cr6+ in each four-type blending rates after the third recycled ILCB increased about 0.002mg/l each. The accumulation of Cr^{6+} quantity in eco-cement influenced to the increasing of Cr6+ leaching value.

Table 6. Result of heavy metal leaching test on crushed aggregate of ILCB.

Item	Rlending rate of molten slag	Cd (mg/L)	Pb (mg/L)	Cr $^{6+}$ (mg/L)	As (mg/L)	T-Hg (mg/L)	Se (mg/L)	pH
Crushed aggregate of Virgin ILCB	0%	< 0.001	< 0.001	0.012	< 0.001	< 0.0005	< 0.001	12.4
	25%	< 0.001	< 0.001	0.010	< 0.001	< 0.0005	< 0.001	12.4
	50%	< 0.001	< 0.001	0.008	< 0.001	< 0.0005	< 0.001	12.3
	100%	< 0.001	< 0.001	0.006	< 0.001	< 0.0005	< 0.001	12.4
Crushed aggregate of 3rd Recycled ILCB	0%	< 0.001	< 0.001	0.014	0.001	< 0.0005	< 0.001	12.4
	25%	< 0.001	< 0.001	0.012	< 0.001	< 0.0005	< 0.001	12.4
	50%	< 0.001	< 0.001	0.009	< 0.001	< 0.0005	< 0.001	12.4
	100%	< 0.001	< 0.001	0.010	< 0.001	< 0.0005	< 0.001	12.4
Regulation*	---	≤ 0.01	≤ 0.01	≤ 0.05	≤ 0.01	≤ 0.0005	≤ 0.01	---
* Regulation for reuse of melting slag by the Ministry of Welfare in Japan								

5.4 Conclusions

The virgin ILCB with 100% molten slag has a better bending strength compared with the other ILCB, while being slight low strength. The heavy metal leaching values, by the leaching test using the fine aggregate after crushing the virgin ILCB and the third recycled one, were both less rather than these values of the environmental regulation. and the bending strength of the third recycled ILCB indicated less 20% only rather than one of the virgin ILCB with 100% molten slag. From a standpoint of the sustainable utilization of molten slag ILCB, we can reuse the recycled aggregate of the three-time-recycling ILCB with 100% molten slag.

6. OVERVIEW OF MOLTEN SLAG ILCB IN JAPAN

6.1 Trend and principle in the utilization of molten slag ILCB in public works

ILCB reused molten slag is almost same as the general ILCB using sand and gravel. Although the concrete slumps, the air content, the mortar bleeding and so on are different in the general concrete product, molten slag ILCB not influenced because of zero-slump concrete. However, they say that the strength of molten slag ILCB is slightly lower rather than general ILCB. The requirement of various corporation objects became stronger recently to reuse molten slag ILCB. Manufacturing companies of ILCB are imposed the duty to use molten slag and eco-cement, especially by the Metropolis of Tokyo and Chiba prefecture. The price of molten slag ILCB is as the same as general ILCB. The condition of reusing of molten slag ILCB increased in public works.

The utilization of molten slag as concrete material is generally obeyed a principle of local supply and local consumption, i.e. they have to reuse molten slag from their municipal waste into concrete products inside their producing district only. To perform their purpose, local governments establish the authorization system on the recycling products as reusing molten slag as useful recycled resources (Hosokawa *et al*, 2004), by stamping or marking like Figure 7. For example, Edogawa district in the Kanto area, including the Metropolis of Tokyo and Chiba prefecture, reused molten-slag concrete products like ILCB in the road pavement as public works. However, reusing molten slag is not favorable every time because of their changeable qualities. It is very important for us to reuse molten slag, while watching their qualities in the environment, the safety, and the long-term condition.



Figure 7. Eco-mark in Japan, Sewage sludge mark in Kobe City, and Recycling marks in Aichi prefecture and in Yamagata prefecture, to stamp or mold on concrete products, from the left.

6.2 Now and future molten slag ILCB

Now in Japan, we can introduce various developing molten slag ILCB for road pavement by establishing newly JIS. For example, they are water-retaintative ILCB for reducing the heat island phenomenon in larger cities, NOx-absorped ILCB against exhaust gas in roads crowded cars, landscape ILCB in parks and so on. In near future, we are faced sustainable utilization of molten slag from a lot of analog-mode TV waste, i.e. monitor panels and cathode-ray tubes. The system of dididtal-mode TV has been started already in Japan, but the broadcasting system of analog-mode TV is closed by all means in July 24, 2011. Thus, we must correspond to various materials in near future increasingly.

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