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Water-Retentiveness of Concrete Block mixed with Rice-Husk Charcoal for Creating Ecological Environment

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Interlocking concrete block (ILB) has been used as concrete products for road pavement, especially for keeping rain well-drainage. To create ecological environment against the heat island effects, ILB needs a function of high water-retentiveness. ILB was manufactured by mixing with the ecological Portland cement (Eco-cement), the water-granulated slag and the rice-husk charcoal (RHC), as porous and wetting materials. The water-retention rate was measured for ILB after leaving for 12 hours in a room at a temperature of 20°C and humidity of 60%, after immersing it in water for 12 hours. In case of mixing with the water of 125 kg/m^3, Eco-cement of 400 kg/m^3 and RHC of 0, 25, 50, 75 and 100% (374 kg/m^3), the bending strength of ILB at 7-day age was 4.35, 3.34, 1.39, 0.69 and 0.45 N/mm^2, respectively, and the water-retention rate was 10.9, 12.2, 21.0, 34.5 and 75.7%, respectively. Increasing the quantity of RHC made the water-retention rate of ILB larger but its bending strength smaller. The quantity of RHC to manufacture ILB is recommended to be 100 kg/m^3 (25% RHC mixing) in the concrete mix proportion to keep at least the water-retention rate of 12% and the bending strength of ILB of 3 N/mm^2 for creating ecological environment.

Key words: Eco-cement, Interlocking concrete block, Rice-husk charcoal, Water-retentiveness, Water-granulated slag

1. INTRODUCTION

Concrete, being typical of construction material, is manufactured by using Ordinary Portland cement, sand, gravel, and admixture in general. Recently concrete product is manufactured by using various sands from the view of effective utilization of recycle materials, i.e. molten slag from sludge waste and from municipal solid waste, glass cullet from waste glass bottle, tile sand from waste tile, and so on [1, 2].

Thus new technology to use recycle material as construction material is remarkable in Japan. Molten slag manufactured from sewage sludge waste and municipal solid waste has been especially studied about their utilization, because the quantity of their waste increased year by year. As a result, molten slag manufactured from municipal solid and sewage sludge waste was at last regulated in Japanese Industrial Standards (JIS A 5031, 2006) [3], as we can use them into construction material.

Interlocking concrete block (ILB) has been used as concrete product for road pavements, exteriors of buildings and houses, gardening and so on. Furthermore, colored ILB has been also spread to use for the construction because of a comfortable and beautiful landscape. However, these materials for ILB are inorganic.

Recent ILB used for a road pavement in Japan is required permeability and drainage properties for better drainage, as we have much rain, especially in a rainy or a typhoon season. Today, however, the road pavement is required to keep a function of higher water-retentiveness to control the heat island phenomenon, which is one of big social problems.

To create the ecological environment with a high water retentive function, it is necessary to make many small pores to keep water by using waste biomaterials as being organic.

Rice husk is one of waste biomaterials in the rice production area in the world, and the quantity of rice husk amounts to about one hundred million tons per year in the world, and to about 2 million tons per year in Japan.

So, we should challenge the new construction material to use the former waste materials from the view point of their effective utilization.

We report in this paper about the properties of ILB manufactured by using Eco-cement, molten slag from municipal solid waste, and rice-husk charcoal (RHC) from waste biomaterial. Hosokawa reported about the eco-sand from ILB used only RHC [4], and ILB mixed with water of 124 kg/m^3, the cement of 400 kg/m^3 and RHC of 200 kg/m^3 (100% RHC mixing) showed 0.76 N/mm^2 bending strength at 7-day age and 22.0% absorbing water rate.

2. EXPERIMENTAL METHOD

2.1 Materials of ILB

As materials of the concrete of ILB, cement, sand, water and admixture were mixed. The cement to compose the ecological environment was the ecological Portland cement (Eco-cement, Taiheiyo Cement Corporation), and its physical properties are shown in Table 1. In the sand, the water-granulated slag aggregate (W-slag, Kawatetsu Kogyo Co., Ltd., Chiba Prefecture) , as shown in Fig. 1, was mixed to make the strength of ILB stronger and RHC (Bright Ceramic Co., Ltd., Nagano City), as shown in Fig.

Table 1 Physical properties of Eco-cement

Item	Density (g/cm^3)	Specific surface area (cm^2/g)	Setting time (hrs-min)		Stabitity	Compressive strenghth (N/mm^2)		
			Start	Finish		3-day age	7-day age	28-day age
Result	3.18	4100	2-21	3-29	Good	24.9	35.2	52.4
JIS	—	≥2500	≥60min	≤10hrs	Good	≥12.5	≥22.5	≥42.5

Table 2 Properties of fine aggregate for ILB concrete

Fine aggregate	Density (g/cm^3)	Absorbing water rate (%)	Fineness modulus	Bulk density (kg/l)	Solid content (%)
Water-granulated slag [1)]	2.61	0.95	3.21	1.40	55.0
Rice-husk charcoal	0.50	12.30	4.55	0.27	60.6

1) Kawatetsu Kogyo Co., Ltd.

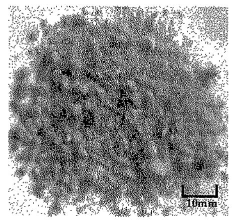

Fig. 1 Water-granulated slag aggregate

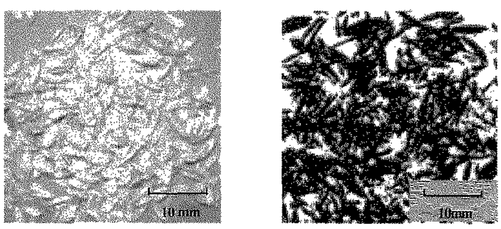

Fig. 2 Rice husk (left) and rice-husk charcoal (RHC, right)

2, was mixed to increase the water-retentiveness of ILB because of containing the charcoal's apertures. RHC was manufactured by roasting the bentnite-covered rice husk completely in some angled dram, after mixing them enough in the bentnite solution. The properties of fine aggregate as the sand for ILB concrete are shown in Table 2. The density and bulk density of RHC were very small but the absorbing water rate was very high. As an admixture, the high-range water-reducing admixture (Kao Co., Ltd.) was used for 1.0% of the cement quantity.

2.2 Concrete mix proportion of ILB

In this paper, the properties of five concrete mixtures of ILB using W-slag and RHC are described. The concrete mix proportion by the mixing rates of RHC weight is shown in Table 3. In this table, for example, 100%-RHC mix proportion in 1 m^3 concrete indicates water of 125 kg, cement of 400 kg and RHC of 375 kg by their weight but its concrete is formed by the volume of water of 0.125 m^3, cement of 0.125 m^3 and RHC of 0.750 m^3. Thus the weight of RHC in this concrete mix proportion is not large but its volume is large because of small density of RHC.

Table 3 Concrete mix proportion of ILB

Mixing rate of RHC [1)] (%)	W [2)]	C [3)]	W-slag [4)]	RHC	Ad [5)]
	Unit content (kg/m^3)				
0			1955	0	
25			1466	94	
50	125	400	977	187	4
75			489	281	
100			0	375	

1) Rice-husk charcoal, 2) Water, 3) Eco-cement, 4) Water -granulated slag, 5) High-range water-reducing admixture.

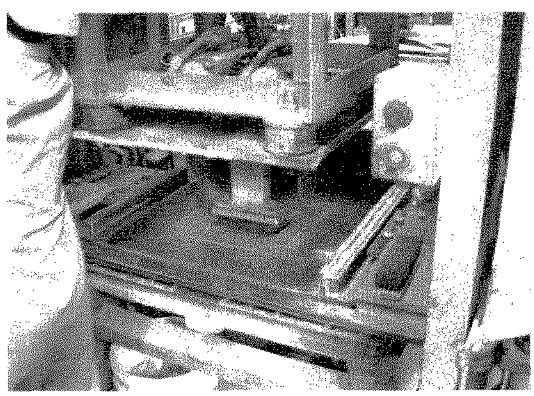

Fig. 3 The vibrating press machine to manufacture ILB

After mixing each material in the concrete mixer, the concrete was put into the angler mold of the vibrating press machine (Kumagaya Plant of ILB Co., Ltd.), as shown in Fig. 3, to make ILB whose dimensions are 20cm × 10cm × 8cm. The ILB test pieces of five concrete mixtures were manufactured one by one using this machine. They were cured in the space on the plant floor until the test, and the curing period of ILB test pieces was 7 and 28 days.

2.3 Test of the filling rate of ILB

The filling rate of ILB may influence to the strength, the absorbing water rate, and so on. To calculate the filling rate of ILB, the oven-dry weight and their length, width and height for each ILB test piece were measured.

The filling rate of ILB is calculated by the following equation.

$$P = m_D / (m_V \times V_B) \times 100$$

where P: the filling rate (%), m_D: the oven-dry condition weight (kg), m_V: the theoretical unit mass (kg/m^3), and V_B : the volume (m^3), for ILB.

2.4 Test of the absorbing water rate, the water-retention rate and the evaporation rate of ILB

To obtain the absorbing water rate of ILB test pieces, they were dried at 110°C for 24 hours in the oven and then their oven-dry condition weights were measured after several hours until the weight became almost constant in the room controlled at a temperature of 20±1°C and a humidity of 60±5%. Secondly, while the test pieces were immersed in the water (temperature: 20±1°C) in a stainless vessel, the saturated surface-dry condition weights after picking up them from the water were measured every 30 minutes until 3 hours from the start and then every one hour until 12 hours. The absorbing water rate at each measuring time is obtained by the following equation, when a water density is 1.00 kg/l.

$$W_1 = (m_1 - m_D) / m_D \times 100$$

where W_1: the absorbing water rate of ILB at each measuring time (%), m_1: the saturated surface-dry condition weight of ILB at each measuring time (kg), and m_D: the oven-dry condition weight of ILB (kg).

After the absorbing water rate test for 12 hours, the amount of water-retention at the measuring time was measured every 30 minutes until 3 hours from the start and then every one hour until 12 hours, while leaving the wetting test pieces on two small rollers in the same room at a temperature of 20±1°C and a humidity of 60±5%. The water-retention rate is obtained by the following equation.

$$W_2 = (m_2 - m_D) / m_D \times 100$$

where W_2: the water-retention rate of ILB at each measuring time (%), m_2: the wetting weight of ILB at each measuring time (kg), and m_D: the oven-dry condition weight of ILB (kg).

The evaporation rate of ILB is obtained by the following equation, based on the wetting weight of ILB at the start in the water-retention test for 12 hours.

$$W_3 = W_{start} - W_2$$

where W_3: the evaporation rate of ILB at each measuring time (%), W_{start}: the water-retention rate of ILB at the start (%), and W_2: the water-retention rate of ILB at each measuring time (%).

2.5 Bending test of ILB

The bending test of ILB was done based on JIS A 1116 using the test pieces after aging for 7 days and 28 days. The bending strength is calculated by the following equation.

$$\text{Bending strength (N/mm}^2) = 24 \times P / b / h^2$$

where P: the maximum load (N), b: the width of broken section of ILB test piece (mm), and h: the height of broken section of ILB (mm).

3. RESULTS AND DISCUSSION

3.1 The bending strength and the absorbing water rate of ILB

Table 4 shows the physical properties of ILB. When mixing with the water of 125 kg/m^3, the Eco-cement of 400 kg/m^3 and the RHC of 0, 25, 50, 75 and 100% (100% RHC: 374 kg/m^3), the bending strength of ILB was 4.35, 3.34, 1.39, 0.69 and 0.45 N/mm^2 at 7-day age and also 5.59, 4.06, 1.90, 0.95 and 0.56 N/mm^2 at 28-day age, respectively, and the absorbing water rate at the 12-hour test was 13.5, 13.7, 22.8, 36.8 and 79.6%, respectively. The ratio of strength between 28-day and 7-day ages ranges between 1.22 and 1.38, and the bending strength after 28 days must be extended over 1.2 times of 7-day strength. Therefore, as the increase of the strength of ILB will be expected, it is enough to design by using the 7-day aged strength in case of thinking an environment of actual ILB pavement condition.

The filling rate of ILB was increased from 79.5% at 0% of mixing rate for RHC to 96.4% at 100% of that, but the unit weight of ILB was decreased from 1.98 kg/l to 0.93 kg/l at the same condition. The filling rate of ILB influenced to decrease both unit weight and bending strength as a little W-slag and much RHC.

3.2 Changes of the absorbing water rate, the water -retention rate, and the evaporation rate of ILB

Fig. 4 shows the changes of the absorbing water rate for 12 hours (0-12 hours) and the water-retention rate for 12 hours (12-24 hours) of ILB. After immersing ILB in water, it absorbed water within 30 minutes immediately from starting the absorption test, and the absorbing water rate of ILB during 6-12 hours became almost constant.

Table 4 Physical properties of ILB

Mixing rate of RHC (%)	Bending strength (N/mm^2) 7-day age	Bending strength (N/mm^2) 28-day age	Absorbing water rate (%)	Filling rate (%)	Unit weight (kg/l)
0	4.35±0.41	5.59±0.40	13.5±0.2	79.5±0.4	1.98±0.01
25	3.34±0.26	4.06±0.16	13.7±0.2	89.6±0.2	1.87±0.00
50	1.39±0.11	1.90±0.25	22.8±0.9	91.8±0.7	1.62±0.01
75	0.69±0.06	0.95±0.16	36.7±0.5	96.0±1.0	1.31±0.01
100	0.45±0.02	0.56±0.07	79.6±0.6	96.4±1.3	0.93±0.01

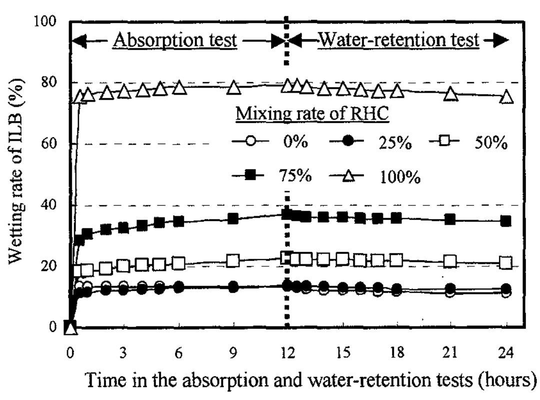

Fig. 4 Changes of the absorbing water rate and the water-retention rate of ILB

After 12 hours, the absorbing water rate of ILB by mixing of RHC with 0, 25, 50, 75 and 100% was indicated 13.5, 13.7, 22.8, 36.7 and 79.6%, respectively.

Furthermore, the water-retention rate of ILB decreased slightly with increasing the time, while leaving ILB in the room. The water-retention rate became almost constant after 12 hours except for the ILB with 100% RHC, which tended to decrease during 9-12 hours. After 12 hours, the water-retention rate of ILB with RHC of 0, 25, 50, 75 and 100% was indicated 10.9, 12.2, 21.0, 34.5 and 75.7%, respectively. The water-retention rate of ILB was calculated by subtracting the evaporation rate from the absorbing water rate after immersing ILB in water for 12 hours.

The changes of evaporation rate of ILB for 12 hours are shown in Fig. 5. The evaporation of ILB with 100% RHC after 12 hours indicated 3.5% but still increase slightly because of keeping water in ILB. The changes for other ILBs became almost constant within the range of 0.5% evaporation rate until 12 hours.

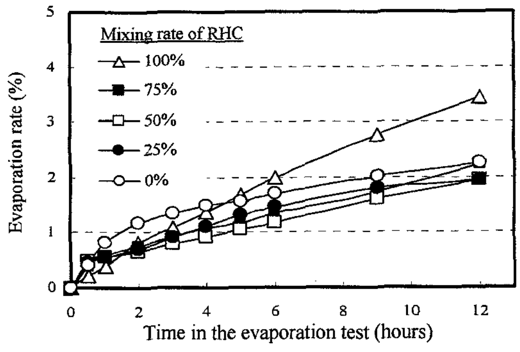

Fig. 5 Changes of the evaporation rate of ILB

3.3 Relationship between the water-retention rate and the bending strength of ILB

Fig. 6 shows the relationship between the water -retention rate after 12 hours and the bending strength at 7-day age of ILB. It is suggested that increasing the RHC quantity makes the water-retention rate of ILB larger but its bending strength smaller.

Japan Interlocking Block Association (JIBA) recommends 3 N/mm^2 as the minimum bending strength at 7-day age for the sidewalk pavement. To manufacture ILB with the bending strength of 3 N/mm^2 at 7-day age, the quantity of RHC is recommended 100 kg/m^3 (25% RHC mixing) in the concrete mix proportion to keep at least the water-retention rate of ILB of 12% for creating ecological environment, for example for reducing the heat island effects.

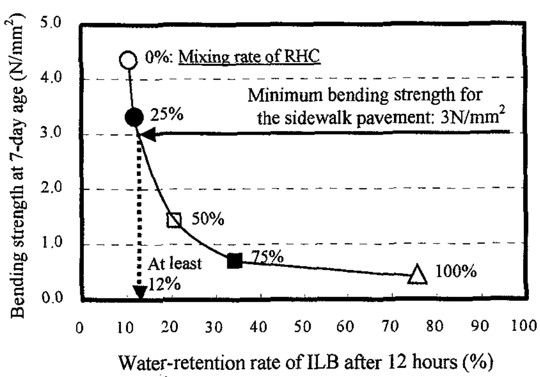

Fig. 6 Relationship between the water-retention rate and the bending strength at 7-day age of ILB

4. CONCLUSIONS

ILB for creating ecological environment needs a function of high water-retentiveness. We manufactured ILB mixed with RHC while using the ecological Portland cement (Eco-cement) and the water-granulated slag. ILB mixed with the water of 125 kg/m^3, Eco-cement of 400 kg/m^3 and RHC of 0, 25, 50, 75 and 100% (374 kg/m^3) had the bending strength at 7-day age of 4.35, 3.34, 1.39, 0.69 and 0.45 N/mm^2, respectively, and the water -retentiveness was 10.9, 12.2, 21.0, 34.5 and 75.7%, respectively. Consequently, the water-retention rate of ILB increased with increasing the quantity of RHC in ILB.

The quantity of RHC is recommended 100 kg/m^3 (25% RHC mixing) in the concrete mix proportion to keep at least water-retention rate of 12% and bending strength of 3 N/mm^2 (the minimum at 7-day age recommended by JIBA) of ILB for creating ecological environment.

5. ACKNOWLEDGMENT

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