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Engineering Properties of Eco-Permeable Polymer Concretes Using Blast Furnace Slag Powder and Stone Dust

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Abstract

Permeable polymer concrete can be applied to roads, sidewalks, river embankments, drain pipes, conduits, retaining walls, yards, parking lots, plazas, interlocking blocks, etc. This study was to explore a possibility of using blast furnace slag powder and stone dust of industrial by-products as fillers for Eco-permeable polymer concrete. Different mix proportions were tried to find an optimum mix proportion of the Eco-permeable polymer concrete. The tests were carried out at 20±1 ℃ and 60±2% relative humidity. At 7 days of curing, unit weight, coefficient of permeability, dynamic modulus of elasticity, compressive, flexural and splitting tensile strengths ranged between 1,821～1,955 kg/m^3, 0.056～0.081 cm/s, 114×10^2~157×10^2 MPa, 17.6~24.7 MPa, 5.98~7.94 MPa and 3.43~4.70 MPa, respectively. It was concluded that the blast furnace slag powder and stone dust can be used in the Eco-permeable polymer concrete.

Keywords : Eco-permeable polymer concrete, Blast furnace slag powder, Stone dust, Unit weight, Coefficient of permeability, Dynamic modulus of elasticity, Strengths

I. Introduction

Demand for concrete material supply has been widening with the rapid growth of the construction industry. Supply of natural materials from river beds and mountains are not sufficient. Environmental problems associated with the material collection from river beds by dredging and from mountains by excavation have caused strong protests from environmentalists. With the growth of construction industry, the supply of materials in the construction industry have been pressing problems to solve in the near future. Application of blast furnace slag powder and stone dust as an additive or filler of concrete has widely increased, and recent studies have found to the excellent compatibility between those

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industrial by-products and polymers.[5),7)]

The use of polymer concrete as an alternative to cement concrete products has been increasing because of its superior mechanical properties, chemical resistance, durability, strong adhesion and rapid curing.[2)]

This study initiated to find a way to reuse industrial by-products as precious resource. A way to reuse the industrial by- products is to use them as construction material. The objectives of this study are (1) to find a way to reuse industrial by-products as filler for Eco-permeable polymer concrete that have properties of high strengths, (2) to test the Eco-permeable polymer concrete that use an industrial by-products as filler with respect to physical properties, and (3) to provide the test data for factory production of Eco-permeable polymer concrete products.

Ⅱ. Materials

1. Unsaturated Polyester Resin

An ortho phthalate-type unsaturated polyester resin with an accelerator was used in this study, and its general properties are shown in Table 1.

Table 1 General properties of unsaturated polyester resin

Density (g/cm³, 20℃)	Viscosity 20℃ (poise)	Styrene content (%)	Acid value
1.12	3.5	37.2	26.5

2. Catalyst

Catalyst used for normal hardening in this study was 55% dimethyl phthalate solution of methyl ethyl ketone peroxide (MEKPO), and its general propreties are shown in Table 2.

Table 2 General properties of catalyst

Density (g/cm³, 20℃)	Active oxygen (%)
1.13	10.0

3. Aggregates

Coarse aggregate used was crushed stone which was collected from stone mountain of Daejeon. The aggregate was dried at 100 ± 5 ℃ for one day before use.[3)] Physical properties of the coarse aggregate are shown in Table 3.

Table 3 Physical properties of coarse aggregate

Size (mm)	Density (g/cm³, 20℃)	Water absorption (%)	Fineness modulus	Unit weight (kg/m³)
4.76~10	2.66	1.25	6.00	1,400

4. Filler

Blast furnace slag powder and stone dust were used in this study because it is relatively cheap and easy to buy. Fillers were dried at 100 ± 5 ℃ for one day before use.[3)] Chemical composition and physical properties of the fillers are shown in Table 4.

5. Mix Proportions of Eco-Permeable Polymer Concrete

After many preliminary tests, five mix proportions were tried to determine an optimum mix proportions of Eco-permeable polymer con-

Table 4 Chemical compositions and physical properties of fillers

Item		Blast furnace slag powder	Stone dust
Chemical compositions (Unit : wt. %)	SiO_2	27.16	56.56
	Al_2O_3	9.34	28.57
	K_2O	-	0.24
	Fe_2O_3	3.40	6.04
	Na_2O	-	0.41
	MgO	5.90	0.59
	CaO	48.48	7.50
	SO_3	2.00	0.09
	Ig.loss	0.18	5.09
Bulk density (kg/m^3)		1,066	1,490
Specific gravity (20 ℃)		2.91	2.66
Blaine's specific surface area (cm^2/g)		4,411	3,054
Grain size (mm)		<0.150	<0.195
Color		White	Gray

cretes using blast furnace slag powder and stone dust contents of unsaturated polyester resin-based binder with the hardening system, fillers and coarse aggregate were fixed as seen in Table 5.

6. Preparation and Curing of Specimens

Specimens were prepared according to the Korean Standard Testing Methods, KS F 2419 (Specimen preparation methods for strength measure of polyester resin concrete). Eco-permeable polymer concretes were mixed by using a high performance concrete mixer. Two types of specimen, i.e., cylindrical and block specimens, were made depending on test. Specimens were molded by putting permeable polymer concrete into a cylindrical and block molds, and the molds were put on a table vibrator and compacted sufficiently by vibration. All the specimens were demolded after curing at a room temperature of 20±1 ℃ for three hours, and cured again at 20±1 ℃ for up to 7 days.

Ⅲ. Methodology

1. Unit Weight

Unit weight of Eco-permeable polymer concrete was evaluated from the following equation.

$$UW = \frac{Wc}{Vc}$$

where, UW is unit weight (kg/m^3), Wc is weight and Vc is volume of Eco-permeable polymer concrete.

Table 5 Mix proportions of Eco-permeable polymer concrete (Unit: wt.%)

Mix type	Binder	Aggregate	Filler		Total
	Unsaturated polyester resin	Coarse aggregate	Blast furnace slag powder	Stone dust	
BS1	9.96	67.63	22.41	-	100
BS2	8.45	69.11	17.20	5.24	100
BS3	8.44	69.50	11.52	10.54	100
BS4	8.39	69.89	5.82	15.90	100
BS5	8.34	70.32	-	21.34	100

The size of the cylinderical specimens was Ø 75×150 mm.

2. Coefficient of Permeability

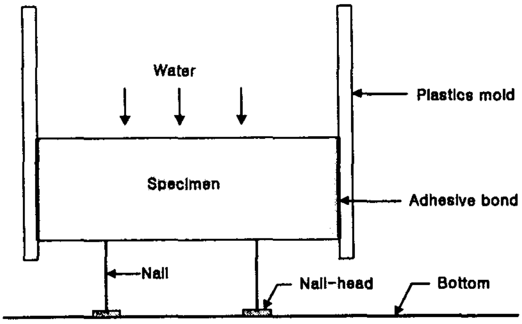

Fig. 1 Schematic drawing of coefficient of permeability testing apparatus

The water level was about 5cm, the amount of permeated water was 6 ℓ, and the experiments were repeatedly performed 5 times. Coefficient of permeability was measured by volume of permeated water(cm/s). The size of block specimens was 20×20×7 cm. The permeability testing apparatus for Eco-permeable polymer concrete used in this study is shown in Fig 1.

3. Dynamic Modulus of Elasticity

Dynamic modulus of elasticity test was carried out according to the BS 1881 part 209 (recommendation for the masurement of dynamic modulus of elasticity).[4] The test was conducted by excitation in the longitudinal mode of vibration. The size of cylindrical specimen was Ø7.5×15 cm.

4. Strengths

Compressive, flexural and splitting tensile strength tests were carried out according to the KS F 2481 (Compressive strength test method for polyester resin concrete), KS F 2482 (Flexural strength test method for polyester resin concrete), and KS F 2480 (Splitting tensile strength test method for polyester resin concrete), respectively. The sizes of cylindrical and block specimens were Ø10×20 cm and 6×6×24 cm, respectively.

Ⅳ. Results and Discussion

1. Unit Weight

Table 6 shows the results of unit weight tests on Eco-permeable polymer concrete. Unit weight of Eco-permeable polymer concrete ranged from 1,821~1,955 kg/m^3 and it was largely dependent upon the mix proportions, and it was decreased from 15 to 20% than that of normal cement concrete (2,300 kg/m^3). Unit weight of Eco-permeable polymer concrete was mainly affected by coefficient of permeability.[6]

Table 6 Test results of Eco-permeable polymer concrete

Mix type	Unit weight (kg/m^3)	Dynamic modulus of elasticity (×10^2 MPa)	Coefficient of permeability (cm/s)
BS1	1,883	127	0.077
BS2	1,924	137	0.063
BS3	1,955	157	0.056
BS4	1,865	131	0.070
BS5	1,821	114	0.081

2. Coefficient of Permeability

Table 6 shows the coefficient of permeability of Eco-permeable polymer concrete. Measured coefficient of permeability of Eco-permeable polymer concrete was ranged from 0.056 to 0.081 cm/s, and it was largely dependent upon the mix proportions. The highest coefficient of permeability was shown by 100% filled stone dust (BS5) as a filler, and the lowest coefficient of permeability was shown by 50% filled blast furnace slag powder and stone dust as fillers for Eco-permeable polymer concrete. It proved that the permeability of Eco-permeable polymer concrete was superior. Accordingly, the Eco-permeable polymer concretes can be used for structures which needs appropriate strength and coefficient of permeability.[5)]

3. Dynamic Modulus of Elasticity

Dynamic modulus of elasticities of Eco-permeable polymer concrete are shown in Table 6. Dynamic modulus of elasticity ranged 114×10^2~157×10^2 MPa, which were approximately smaller than that of normal cement concrete (150×10^2 MPa). Dynamic moulus of elasticity was interrelated with the compressive, flexural and splitting tensile strengths and coefficient of permeability.[7)] This technique offers potentially useful nondestructive test methods to identify the physical condition concrete.

4. Strengths

Strength developments of Eco-permeable polymer concrete were assumed to be related to the content of blast furnace slag powder and stone dust as fillers. Thus, strength tests were performed with respect to the different content of fillers. Table 7 shows the compressive, flexural and splitting tensile strength. The highest strength was achieved by 50% filled blast furnace slag powder and stone dust as fillers, and the choice of filler is very important.[1)] It was increased 20% by compressive strength, 93% by flexural strength and 129% by splitting tensile strength than that of normal cement concrete (f_c=20.5 MPa, f_b=4.1 MPa, f_t=2.05 MPa), respectively.

Table 8 shows the strength ratio of Eco-permeable polymer concrete with different mix proportions. The strength ratio is one of the important properties on the permeable polymer concrete. The ratio of flexural strength to compressive strength on Eco-permeable polymer concrete was between 0.294 and 0.339, and it was 1.5 times higher than that of normal cement concrete(0.2). Also, the compressive and flexural strength of Eco-permeable polymer concrete were much higher than that of normal cement concrete. It could be explained that the polymer has a particular property and thus, the toughness of polymer concrete was higher than that of normal cement concrete.

Accordingly, the application of Eco-permeable polymer concrete in the structures for bending would be very useful.

Table 7 Strengths of Eco-permeable polymer concrete

Mix type	Strength (MPa)		
	Compressive (f_c)	Flexural (f_b)	Splitting tensile (f_t)
BS1	20.8	6.17	3.62
BS2	23.1	7.15	4.01
BS3	24.7	7.94	4.70
BS4	21.6	6.37	3.82
BS5	17.6	5.98	3.43

Table 8 Strengths ratio of Eco-permeable polymer concrete

Mix type	f_t / f_c	f_b / f_c	f_t / f_b
BS1	0.174	0.296	0.587
BS2	0.174	0.309	0.562
BS3	0.190	0.321	0.593
BS4	0.176	0.294	0.600
BS5	0.194	0.339	0.574

V. Conclusions

This study was performed to evaluate engineering properties of permeable polymer concrete using industrial by-products. An unsaturated polyester resin was used as binder, and blast furnace slag powder and stone dust were used as fillers. The following conclusions were drawn from the test results ;

1. Unit weight of Eco-permeable polymer concrete ranged from 1,821 to 1,955 k/m^3 and it was largely dependent upon the mix proportions. It was mainly affected by coefficient of permeability.

2. Coefficient of permeability of Eco-permeable polymer concretes was in the range of 0.056~0.081 cm/s, and it was largely dependent upon the mix proportions. It was inversely dependent upon the value of the concrete strengths. The Eco-permeable polymer concretes can be used for structures which needs appropriate strength and coefficient of permeability.

3. Dynamic modulus of elasticity ranged 114×10^2~157×10^2 MPa, which was approximately smaller than that of normal cement concrete.

4. Compressive, flexural and splitting tensile strengths of Eco-permeable polymer concretes ranged between 17.6~24.7 MPa, 5.98~7.94 MPa and 3.43~4.70 MPa, respectively. The highest strength was achieved by 50% filled blast furnace slag powder and stone dust as fillers. It was increased 20% by compressive strength, 93% by flexural strength and 129% by splitting tensile strength than that of normal cement concrete, respectively. An increasing rate of the flexural strength on Eco-permeable polymer concrete was higher than that of the compressive strength, and the concrete to the structure that is subject to flexural stress can be used.

5. f_t / f_c , f_b / f_c and f_t / f_b of Eco-permeable polymer concrete were 0.174~0.194, 0.294~0.339 and 0.562~0.600, respectively, and were higher than that of normal cement concrete (f_t / f_c =0.1, f_b / f_c =0.2, f_t / f_b =0.5). The ratio of flexural strength to compressive strength of Eco-permeable polymer concrete was 1.5 times higher than that of normal cement concrete. It suggests that the Eco-permeable polymer concrete have a great advantage for the design and production of concrete structures. Also, the compressive, splitting tensile and flexural strength, unit weight, dynamic modulus of elasticity were increased with decreasing the coefficient of permeability, respectively.

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