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Development of Ultra-Lightweight High Strength Trench Using Lightweight Polymer Concrete

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Abstract

The ultra-lightweight high strength polymer concrete could be used for the drain structures under severe condition. In this study, materials used were unsaturated polyester resin, heavy calcium carbonate, artificial lightweight coarse aggregate and perlite. In the test results, the unit weight of the ultra-lightweight high strength polymer concrete was 946 kgf/m^3 and the compressive strength was appeared in 34.5 MPa. The compressive strength, splitting tensile strength, flexural strength, acid resistance and weather resistance were shown in excellently than that of the normal cement concrete. The draining trench had 1m length, 0.24 m width, 0.02 m thickness and 0.07 m height. The developed trench could be effectively used at the draining structures.

Keywords : Ultra-lightweight high strength polymer concrete, Artificial lightweight aggregate, Strengths, Acid and weather resistance, Draining trench

I. Introduction

Demand for concrete material supply has been widening with the rapid growth of construction industry. Supply of natural materials from river beds and mountains are not sufficient. Environmental problems associated with the material collection from river beds and mountains have caused strong protests from environmentalists.[3] And with the growth of construction industry, the supply of materials in construction industry have been pressing question to solve.[1]

Accordingly, utilizing study of artificial lightweight aggregate, recycled aggregate and by-products are very important.

Also, the use of polymer concrete has been increasing because its superior mechanical properties, chemical resistance, durability, strong adhesion and rapid curing.[2),6]

This study is performed to develop the ultra-lightweight high strength trench using artificial lightweight aggregate and unsaturated polyester

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resin.

The objectives of this study are (1) to find a way to use artificial lightweight aggregate for polymer concrete that has lightweight and high strengths, (2) to evaluate the physical and mechanical properties of the ultra-lightweight high strength polymer concrete(ULPC), and (3) to apply on draining structures for improving corrosion problem of cement concrete trench.

Ⅱ. Materials

1. Unsaturated Polyester Resin

An ortho-type unsaturated polyester resin is used and its general properties is shown in Table 1.

Table 1 General properties of unsaturated polyester resin

Specific gravity at 20℃	Viscosity at 20℃ (poise)	Styrene content (%)	Acid value
1.12	3.5	37.2	26.5

2. Hardener

The general properties of hardener used is shown in Table 2.

Table 2 General properties of hardener

Component		Specific gravity at 20℃	Active oxygen (%)
MEKPO	55%	1.13	10.0
DMP	45%		

3. Lightweight Aggregates

Coarse aggregate used is artificial lightweight aggregate made of expanded clay. Also, aggregate is dried at 100±5℃ for one day before use. Physical properties of aggregate is shown in Table 3 and SEM of artificial lightweight aggregate is shown in Photo 1.

Table 3 Physical properties of artificial lightweight coarse aggregate

Size (mm)	Specific gravity at 20℃	Absorption (%)	F.M	Unit weight (kgf/m^3)
3~8	0.68	21	5.6	386

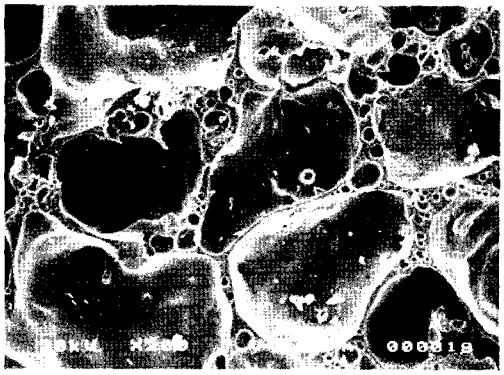

Photo 1 SEM of artificial light-weight aggregate

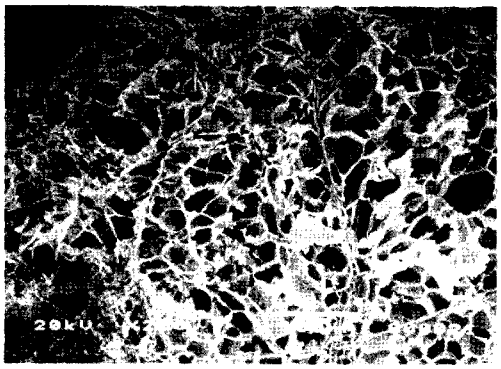

Photo 2 SEM of perlite

4. Filler

Common fillers are powders as fly ash, heavy

calcium carbonate, alumina, blast furnace slag powder, silica, cement, stone dust and so on. Among the fillers, perlite and heavy calcium carbonate are used in this study because they are relatively cheap and easy to buy. Fillers are dried at 100±5℃ for one day before use. General properties of fillers are shown in Table 4 and SEM of perlite is shown in Photo 2.

Table 4 Physical properties of fillers

Filler	Size (mm)	Specific gravity at 20℃	Color	Unit weight (kgf/m^3)
Perlite	0.15~1.2	0.4	White	80
Heavy calcium carbonate	⟨0.15	2.91	White	620

5. Mix Design

In mix design of the ultra-lightweight high strength polymer concrete(ULPC), proportions of artificial lightweight aggregate, perlite and heavy calcium carbonate are decided through preliminary test. The compressive strength and unit weight of ultra-lightweight high strength polymer concrete is designed more than 350 kgf/cm^2 at the curing age 7 days and below than 1,000 kgf/m^3, respectively.

Mix design of the ultra-lightweight high stre-ngth polymer concrete for draining trench is shown in Table 5.

Also, Mix design of the normal cement con-crete(NCC) and the high strength concrete (HCC) are shown in Table 6.

Table 5 Mix design of ultra-lightweight high strength polymer concrete (Unit: wt %)

Binder	Filler		Coarse aggregate	Total
	Perlite	Heavy calcium carbonate		
71.3	13.8	3.4	11.5	100

Table 6 Mix design of normal cement concrete and high strength concrete (Unit: kgf/m^3)

Mix type	Cement	Coarse aggregate	Fine aggregate	W/C	S/a (%)
NCC	297	1,069	892	52	76
HCC	372	1,131	754	51.6	66

6. Manufacture and Curing of Specimens

Specimens are prepared according to the Korean Standard Testing Methods, KS F 2419 (Specimen preparation methods for strength measure of polyester resin concrete). All the specimens are demolded after cured at 20℃ for three hours and cured again at 20℃ for 7 days.

7. Manufacture of Draining Trench

The section of trench is greatly reduced because the physical and mechanical properties of the ultra-lightweight high strength polymer concrete is excellent than that of the normal cement concrete, and the trench is made with 1m length, 0.24 m width, 0.02 m thickness and 0.07 m height.

Also, bottom of trench is formed projection with artificial lightweight aggregate and sealing material that is superior chemical resistance and waterproof is used on joint at trench connection.

Ⅲ. Methodology

1. Unit Weight

The unit weight of the ultra-lightweight high strength polymer concrete is evaluated from the following equation at the curing age 7 days.

$$UW = \frac{W_C}{V_C}$$

where, UW is unit weight(kgf/m^3), Wc is weight and Vc is volume of the ultra- lightweight high strength polymer concrete.

2. Strengths

The compressive, splitting tensile strength and flexural strength tests are carried out according to the KS F 2481 (Compressive strength test method for polyester resin concrete), KS F 2480 (Splitting tensile strength test method for polyester resin concrete) and KS F 2482 (Flexural strength test method for polyester resin concrete) at the curing age 7 days, respectively. The sizes of specimens are ø75x150 mm and 60x60x240 mm.

3. Acid Resistance

The acid resistance is measured at an interval of 7 days after deposit in sulfuric acid (H_2SO_4) 5% solution with specimen in the curing age 7 days and compared with weight difference in surface dry condition after polished surface of specimen with iron brush.

4. Weather Resistance

The weather resistance test is used specimens of 10×50 mm size according to the KS F 2274(Weather resistance test method for concrete) with specimen in the curing age 7 days. Also, sunshine exposure test(WS type) is carried for 250 hours and investigated of color difference.

Ⅳ. Results and Discussion

1. Unit Weight

Test results of the ultra-lightweight high strength polymer concrete are shown in Table 7.

Table 7 Test results of the ultra-lightweight high strength polymer concrete

Item	Unit weight (kgf/m^3)	Compressive strength (MPa)	Splitting tensile strength (MPa)	Flexural strength (MPa)
ULPC	946	34.5	6.0	14.4
NCC	2,300	20.6	2.1	4.1
HCC	2,320	31.4	2.9	6.9

The unit weight test result of the ultra-lightweight high strength polymer concrete (ULPC) is shown in 946 kgf/m^3, and it was decreased by 59% than that of the normal cement concrete(NCC) (2,300 kgf/m^3) and high strength cement concrete (HCC) (2,320 kgf/m^3).

The major cause reduced unit weight of the ULPC is because the artificial lightweight aggregate, perlite are much smaller than that of the natural coarse and fine aggregate.

2. Compressive Strength

The compressive strength of concrete is depended greatly on strength of aggregate used usually.

The compressive strength test results of the ULPC, NCC and HCC appeared in 34.5 MPa, 20.6 MPa and 31.4 MPa, respectively. The ULPC is increased by 67% and 10% than those of the normal cement concrete and high strength concrete, respectively.

In spite of the artificial lightweight aggregate is used, the compressive strength of the ULPC is appeared higher than that of the normal cement concrete by bonding strength of polymer.[7]

Accordingly, the ultra-lightweight high strength polymer concrete used artificial lightweight aggregate is developed.

3. Splitting Tensile Strength

The splitting tensile strength of the ULPC, NCC and HCC are appeared in 6.0 MPa, 2.1 MPa and 2.9 MPa, respectively. The ULPC is showed in 2.9 times and 2.03 times higher than those of the normal cement concrete and high strength concrete, respectively.[5]

In the ratio of splitting tensile strength to compressive strength, the NCC is 1/10, HCC is 1/10.6 and ULPC is 1/5.7. Accordingly, the ULPC is shown higher the increase of splitting tensile strength than increase of compressive strength is appeared greatly.

4. Flexural Strength

The flexural strength of the ULPC, NCC and HCC are appeared in 14.4 MPa, 4.1 MPa and 6.9 MPa, respectively. The ULPC is showed in 3.5 times and 2.1 times higher than those of the normal cement concrete and high strength concrete, respectively.

The ULPC is appeared greatly increase of splitting tensile strength and flexural strength than that of the NCC. It can be explained that the polymer has strong adhesion.[4]

5. Acid Resistance

In acid resistance test result, the high strength cement concrete(HCC) is occurred much surface falling than that of the normal cement concrete (NCC) by a lot of cement amount. But the ultra-lightweight high strength polymer concrete (ULPC) did not occurred.

Also, the ultra-lightweight high strength polymer concrete(ULPC) is not appeared any change after deposit in sulfuric acid 5% solution. The reason why the ULPC did not suffer any changes is that it is excellent waterproofing and polymer between sulfuric acid do not occurred to chemical reaction.

6. Weather Resistance

In sunshine exposure test, the change of color for the ultra-lightweight high strength polymer concrete can not judged easily with the naked eye by color chart of 3~4 degree. Also, it is shown that the weather resistance is very excellent because the form and color are not changed.

7. Manufacture of Draining Trench

The trench of the ultra-lightweight high strength polymer concrete used artificial lightweight aggregate, perlite, unsaturated polyester resin and heavy calcium carbonate is developed.

The developed trench can be effectively used at the draining structures because it is very excellent such as lightweight, high strength, waterproof, acid resistance and weather resistance.

The developed trench products and connected trench are shown in Photo 3, 4.

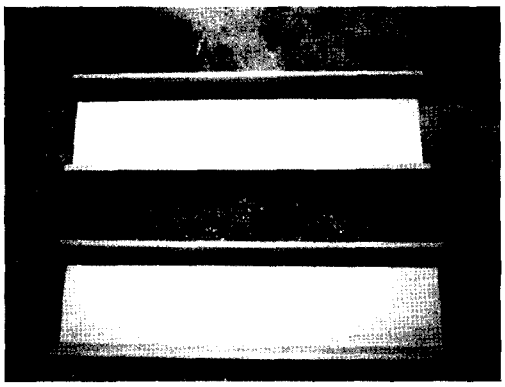

Photo 3 Trench products

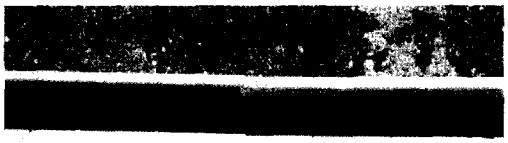

Photo 4 Connection of trench

V. Conclusions

This study was performed to develop ultra-lightweight high strength trench using artificial lightweight aggregate and unsaturated polyester resin for draining structures. Main results were as follows ;

1. The unit weight of the ultra-lightweight high strength polymer concrete (ULPC) was 946 kgf/m^3, and it was decreased approximately by 59% than that of the normal cement concrete (NCC) and high strength cement concrete (HCC).

2. The compressive strength, splitting tensile strength and flexural strength of the ULPC were appeared in 34.5 MPa, 6.0 MPa and 14.4 MPa, respectively. The compressive strength, splitting tensile strength and flexural strength of the ULPC showed higher than those of the NCC and HCC, respectively.

3. In acid resistance and weather resistance, the ULPC did not show erosion and surface falling in spite of deposition for a long time and was appeared excellently as color chart of 3~4 degree and change of form did not occurred.

4. The developed trench could be effectively used at the draining structures because it was very excellent such as lightweight, high strength, waterproof, acid resistance and weather resistance.

Acknowledgements

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References

1. Anthony Kelly and Carl Zweben., 2000, Comprehensive composite materials, *Cambridge University Press*, Vol. 2 : 18-35.
2. Fowler. D. W., 1994, Current uses of polymer concrete in the united states, Proceedings of the First East Asia Symposium on Polymers in Concrete, Chuncheon, Korea, May 2-3 : 3-9.
3. Julian Salas., Marina Alvarez and Janer Veras., 1986, Lightweight insulating concretes with rice husk, *The International Journal of Cement Composites and Lightweight Concrete*, Vol.8, No.3 : 171-180.
4. Klink, S. A., 1985, Actual elastic-modulus of concrete, *ACI Journal*, Vol.82, No.5, : 630-633.
5. Oluokun, F. A., 1991, Prediction of concrete tensile strength from compressive strength : evaluation of existing relations for normal weight concrete, *ACI Materials Journal*, Vol.88, No.3 : 302-309.
6. Sung, Chan Yong, 1994, Engineering properties of permeable polymer concrete, Proceedings of the First East Asia Symposium on Polymers in Concrete, Chuncheon, Korea, May 2-3 : 271-281. (in Korean)
7. Vipulanandan, C., N. Dharmarajan and E. Ching., 1988, Mechanical behavior of polymer concrete system, *Materials and Structures*, Vol.21, No.124 : 268-277.