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INFLUENCE OF AGGREGATE INTERFACE IN CONCRETE ON PERMEABILITY

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ABSTRACT

Various factor that reduce the durability of concrete move through the pores in concrete. Therefore, the durability of concrete depends on the size and continuity of the pore. It is said that there is a large pores called interfacial transition zone between aggregate and paste in concrete. In past studies comparing permeability of concrete and mortar, concrete has higher permeability than mortar. It is unknown how the interfacial transition zone generated at the coarse aggregate interface affects the permeability of concrete. In this research, we focused on the influence of aggregate interface on permeability of concrete. So, we was prepared concrete with the coarse aggregate volume ratio changed. It measured porosity and bleeding ratio in this experiment. In addition, permeability of concrete was evaluated with penetrated carbon dioxide and chloride ion. As a result of experiments, concrete with high coarse aggregate volume ratio has high porosity and permeability. When calculating the pores of concrete by the porosity per unit mortar, the porosity of concrete with high coarse aggregate volume ratio is high. When the porosity per unit mortar is higher than the pores of mortar, it is considered to pores at the aggregate interface are generated. From the relationship between the bleeding ratio and the porosity per unit mortar, it is considered that the bleeding water was restrained by the coarse aggregate in the concrete. We used accelerated agent using C-S-H nanoparticles as a countermeasure for aggregate interface pores. As a result of experiments, porosity and air permeability of the mortar with C-S-H nanoparticles added does not change. However, porosity and air permeability of concrete was improved by adding C-S-H nanoparticle agent. Therefore, C-S-H nanoparticles are thought to have the effect of filling the aggregate interface in concrete.

Keywords: *the pore at the aggregate interface, volume ratio of coarse aggregate, permeability, bleeding, C-S-H nanoparticles*.

1. INTRODUCTION

In order to use concrete structures for a long time, it is necessary to consider the durability of concrete. Factors that reduce the durability of concrete include penetrated carbon dioxide and chloride ion. These factor move through pores in concrete. Therefore, the durability of the concrete depends on the size and continuity of the pore. The size of pore is classified into several types. There is a discontinuous region between cement paste and aggregate in concrete. The pores at the aggregate interface is called the interfacial transition zone. A large continuous pores of 50 nm or more in diameter is formed. Therefore, the pores at the aggregate interface can be a factor of decreasing the durability of the concrete. In a previous study comparing the permeability of concrete and mortar, concrete has higher permeability than mortar. Concrete has coarse aggregate as compared to mortar, so it is considered that there are many pores at the aggregate interface. There are various factors that decrease the permeability of concrete. However, the influence of pores at the aggregate interface is unknown. It is important to clear the influence of the pores at the aggregate interface in concrete. In this research, we focused on the influence of aggregate interface on permeability in concrete. Concrete was prepared by changing the volume ratio of coarse aggregate with the same composition ratio of mortar. We used accelerated agent of C-S-H nanoparticles as a countermeasure for aggregate interface pores. C-S-H nanoparticle agent is an accelerating agent for concrete. C-S-H nanoparticles of accelerated agent act as a nucleus for hydration reaction. The addition of C-S-H nanoparticle agent is expected to have the effect of densifying the pores in concrete.

2. OUTLINE OF EXPERIMENT

This study includes the two phases of experiment. In Phase 1, it is aimed to quantitatively evaluate the pores at the aggregate interface using a concrete mix proportion generating pores at the aggregate interface. In Phase 2, C-S-H nanoparticles were used as a countermeasure to the pores at the aggregate interface of concrete. It is aimed to clear whether C-S-H nanoparticles can fill the pores at the aggregate interface of concrete that generated pores at the aggregate interface using the Phase 1 concrete mix proportion method.

2.1 Concrete mix proportion (Phase1)

Table 1 shows the concrete mix proportions in this experiment. Fig.1 shows the concrete volume ratio. The maximum size of aggregate used is 20mm and it is crushed aggregate. Fineness modulus of fine aggregate is 2.56. In this study, concrete with volume ratio of coarse aggregate changed to compare the effect of aggregate interface on permeability of concrete. The pore structure in the concrete was controlled by changing the ratio of fine aggregate and coarse aggregate. All concrete was made to have the same water cement ratio and the volume ratio of the mortar part was made constant. The mix proportion is the performance of the mortar is constant. Base mix proportion was 4.5% air volume, which is a general concrete mix proportion (coarse aggregate volume: 100%). Five mix proportion were prepared by increasing or decreasing the coarse aggregate from the base mix proportion. Concrete specimens were placed in two layers. Concrete specimens were sealed for 28 days in a constant temperature and humidity chamber.

2.2 Bleeding test

For the bleeding test, an experiment was conducted with reference to JIS A 1123. Bleeding water was collected every 30 minutes until bleeding was completed. The Bleeding rate was calculated using Equation (1), (2)..

$$B_r = (V \times \rho_w) / W_s \times 100 \qquad (1)$$

$$W_s = (W \times S) / C \times 1000 \qquad (2)$$

B_r : Bleeding rate [%]
ρ_w : Density of water at test temperature [g/cm^3]
W_s : The mass of water in the sample [g]
C : Concrete unit volume mass [kg/m^3]
W : Unit water amount of concrete [kg/m^3]
S : Mass of sample [kg]

2.3 Porosity test

Porosity tests were carried out using ϕ100×50 ㎜ size specimens. Porosity was calculated from the Archimedes method (3).

$$P_o = (W_s - W_d) / (W_s - W_u) \times 100 \qquad (3)$$

P_o : Porosity [%]
W_s : Saturated water weight [g]

Table 1. Concrete mix proportion (Phase1)

Cement type	W/C (%)	s/a (%)	air (%)	Unit weight (kg/m³) W	C	S	G	slump (cm)	slump Flow (cm)	Coarse aggregate volume (%)
				1.00	3.16	2.58	2.70			
N	65	44	4.2	160	246	820	1085	8.5		110
		48	4.5	170	262	870	986	16.5		100
		58	5.1	194	299	995	739	20.5		75
		70	5.8	219	337	1120	493	22.5		50
		100	7.1	268	412	1370			23×22	0

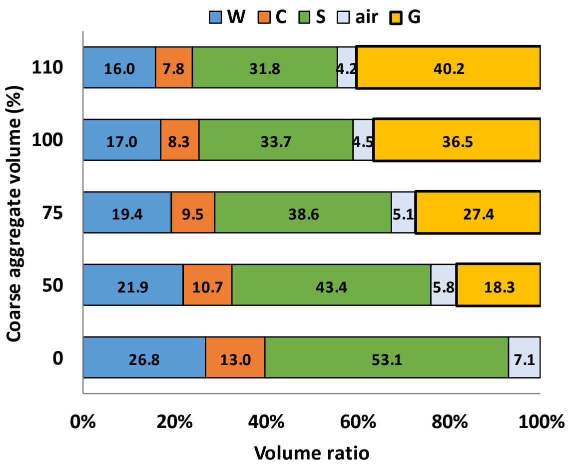

Fig 1. Concrete volume ratio (Phase1)

Table 2. Concrete mix proportion (Phase2)

Cement type	W/C (%)	s/a (%)	air (%)	Unit weight (kg/m³) W	C	S	G	Coarse aggregate volume (%)
				1.00	3.16	2.62	2.70	
N	50	40	4.5	150	300	752	1141	120
		48		170	340	852	951	100
		56		190	380	951	761	80
		100		269	539	1350		0

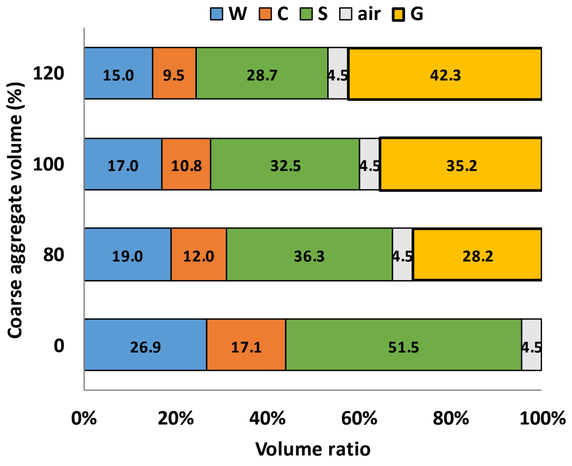

Fig 2. Concrete volume ratio (Phase2)

W_d : Absolute dry weight [g]
W_u : Underwater weight [g]

2.4 Accelerated neutralization test

The accelerated neutralization test was conducted according to JIS A 1153. After curing, one side was opened and the other side sealed. And placed in an accelerating neutralization chamber (CO_2 concentration: 5%, Temperature: 20℃, Humidity: 60%). Progress of neutralization was confirmed by spraying a phenolphthalein solution.

2.5 Salt water immersion test

Salt water immersion test was conducted according to JSCE-G 572-2013. After curing, one side was opened and the other side sealed. It was placed in water with salt concentration of 10%. Progress of depth of chloride ion was confirmed by spraying a Silver nitrate solution.

2.6 Concrete mix proportion (Phase2)

Table 2 shows the concrete mix proportions in this experiment. Fig.2 shows the concrete volume ratio. The volume ratio of coarse aggregate was changed by the same mix proportion method as Phase 1. 5% of C-S-H nanoparticle agent was added to cement weight. The admixture used in this experiment is only C-S-H nanoparticles. Concrete specimens were put for 7 days in a constant temperature and humidity chamber.

2.7 Air permeability test

Air permeability tests were carried out using ϕ100 ×50 ㎜ size specimens. The specimens was dried in a drying oven until the weight loss became constant. Measurement was carried out using an air permeability testing machine.

3. RESULTS AND DISCUSSION (Phase1)

3.1 Bleeding test

Fig 3 shows the results of the bleeding test. As a result of experiments, Bleeding rate varies depending on the volume ratio of aggregate in concrete. Concrete with high coarse aggregate volume ratio became smaller in bleeding ratio.

3.2 Porosity test

Fig 4 shows the results of the porosity test As a result of experiments, concrete with high coarse aggregate volume ratio became smaller porosity. The voids of the concrete are mainly present in the cement paste part. The concrete having different aggregate volume ratio has different cement paste volume ratio. Therefore, the porosity depend on the cement paste volume ratio in concrete.

Fig 5 shows the results of the porosity per unit mortar. The porosity per unit mortar was calculated. The calculation method divided the porosity of concrete by the

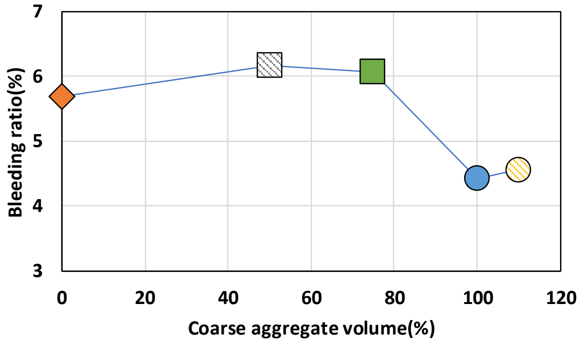

Fig 3. Bleeding test.

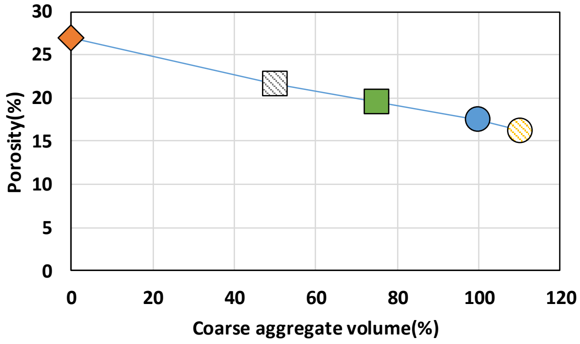

Fig 4. Porosity test

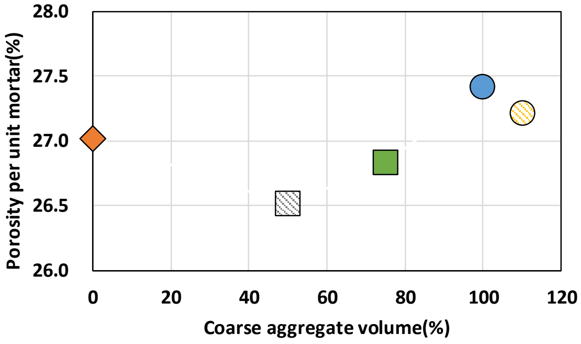

Fig 5. Porosity per unit mortar

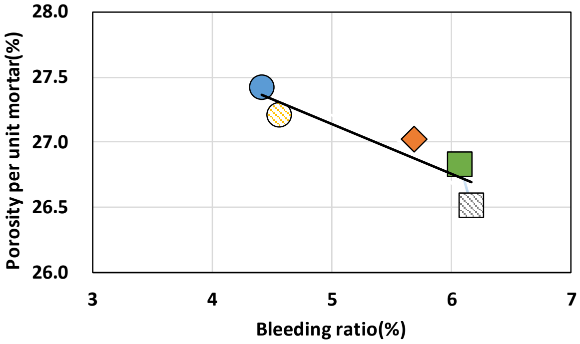

Fig 6. Relation between bleeding rate and porosity per unit mortar

ratio of mortar. It was assumed that the coarse aggregate had no voids. The porosity per unit mortar is equal because mortar's performance is the same. However, concrete with high coarse aggregate volume ratio became higher in porosity per unit mortar. So, the result shows that the porosity per unit mortar varies by the coarse aggregate volume ratio. The difference in porosity per unit mortar is considered to mean the voids at the coarse aggregate interface. Concrete with high coarse aggregate volume ratio is presumed to have many voids at the coarse aggregate interface.

3.3 Relation between bleeding rate and porosity per unit mortar

Fig 6 shows Relation between bleeding rate and porosity per unit mortar. Concrete with a low bleeding ratio tends to have a high porosity per unit mortar. This reason is that bleeding water was caught at the coarse aggregate interface. Then, the bleeding water caught in the aggregate interface dries to form voids. Therefore, the void at the aggregate interface depends on bleeding.

3.4 Relation between porosity per unit mortar and neutralization depth

Fig 7 shows relation between porosity per unit mortar and neutralization depth. The neutralization depth is large when the porosity per unit mortar is high. When there is the many void at the aggregate interface is large, CO_2 gas tends to permeate. Therefore, the depth of neutralization of concrete with high coarse aggregate volume ratio increases with the progress of neutralization of concrete.

3.5 Relation between porosity per unit mortar and salt penetration depth

Fig 8 shows relation between porosity per unit mortar and salt penetration depth. The salt penetration depth is large when the porosity per unit mortar is high. When there is the many void at the aggregate interface, chloride ions tends to permeate. Therefore, concrete having a large coarse aggregate volume increases salt penetration depth.

4. RESULTS AND DISCUSSION (Phase2)

4.1 Porosity test of concrete with C-S-H nanoparticles added

Fig 9 shows porosity test of concrete with C-S-H nanoparticles added. Compared to concrete with C-S-H nanoparticles added and concrete without additives, the concrete with C-S-H nanoparticles added decreased the porosity. This result shows that C-S-H nanoparticles fill the pores in concrete.

4.2 Porosity test of concrete with C-S-H nanoparticles added

Fig 10 shows air permeability test of concrete with C-S-H nanoparticles added. Air permeability of the mortar

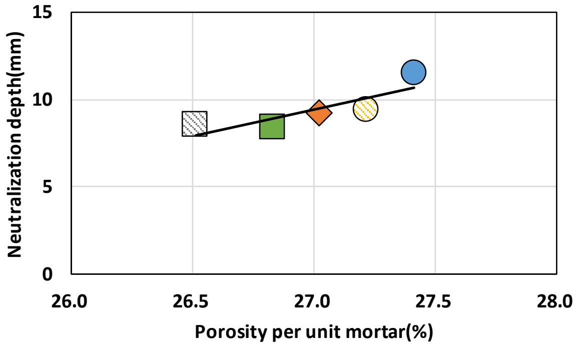

Fig 7. Relation between porosity per unit mortar and neutralization depth

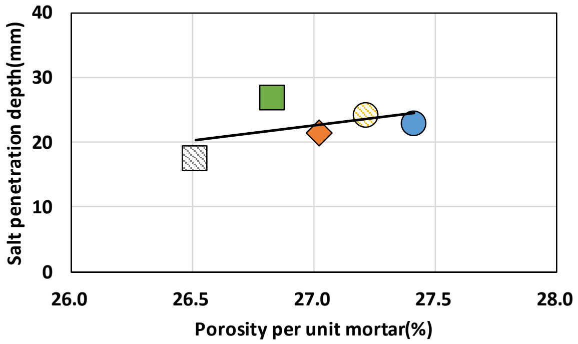

Fig 8. Relation between porosity per unit mortar and salt penetration depth

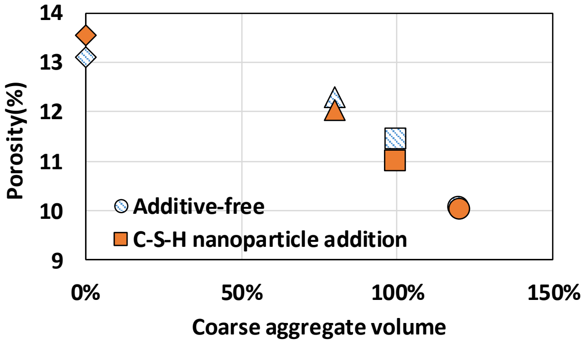

Fig 9. Porosity test of concrete with C-S-H nanoparticles added

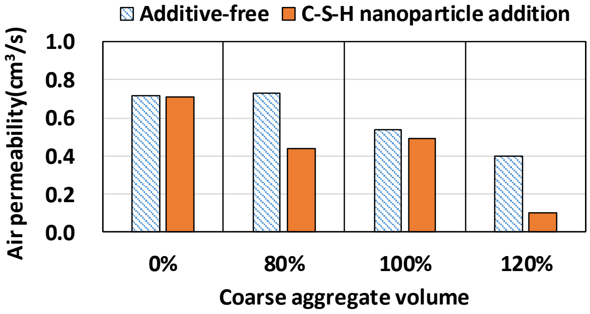

Fig 10. Air permeability test of concrete with C-S-H nanoparticles added

with C-S-H nanoparticles added does not change. However, air permeability of concrete with C-S-H nanoparticles added decreased. From this result, the C-S-H nanoparticle mixture improves permeability of concrete. It is considered that the C-S-H nanoparticles fill the pores of the aggregate interface.

The future work is to clear the influence of the coarse aggregate interface on permeation when the water cement ratio is changed.

5. CONCLUSIONS

1) The bleeding rate of concrete with a different volume ratio of coarse aggregate is different. Concrete with high coarse aggregate volume ratio has low bleeding rate.
2) When calculating the pores of concrete by the porosity per unit mortar, the porosity of concrete with high coarse aggregate volume ratio is high. When the porosity per unit mortar is higher than the pore of mortar, it is considered to pores at the aggregate interface are generated.
3) From the relationship between the bleeding rate and the porosity per unit mortar, it is considered that the bleeding water was restrained by the coarse aggregate in the concrete. Accordingly, the pores at the aggregate interface depend on bleeding water.
4) The pores at the aggregate interface promotes permeation of penetrated carbon dioxide and chloride ion. As a result, it decreases the durability of concrete.
5) Concrete with C-S-H nanoparticles added decreased air permeability and porosity than concrete without added. C-S-H nanoparticles are thought to have the effect of filling the aggregate interface in concrete.

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PHOTOS AND INFORMATION

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