book

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Comparison for permeability resistance between concrete and mortar

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ABSTRACT: Mortar using for repairing on reinforced concrete structures. The substances such as carbon dioxide and chloride ion will be penetrated into the concrete or mortar. However, it is existing the interfacial transition zone between the aggregate interface and paste in the concrete. In this study, using a mortar obtained by removing the coarse aggregate from concrete, it was carried out a comparison of resistance of permeability between concrete and mortar. As a result, it decreases the permeability resistance by the water cement ratio is increased in ordinary Portland cement and blast furnace slag cement by carbonation resistant. The permeability resistance of concrete tends to decrease significantly compare to mortar by the interfacial transition zone. On the other hand, in case of the salt resistant, it is not clear the effect of it. Thus, it becomes formed pores like water reservoir to the lower surface aggregates by bleeding.

Ordinary Portland cement (N) and blast furnace slag cement (B) as added with blast furnace slag 4,000 Blaine, replacement 45%. This is because the use of blast furnace slag cement, fine capillary porosity are formed, and in which the characteristics of porosity is expected to change. The aggregate prepared that the fine aggregate is crushed sand, the coarse aggregate is limestone crushed stone. Considering the mechanism of the generation for interfacial transition zone, we changed the water cement ratio to produce mortar and concrete, which is varied with 45, 55 and 65%. It shows the planning mix proportion into the Table-1,2. It was prepared on the same day with concrete and mortar on the same mix proportion. Packed into

Table 1. Mix proportion of Concrete (Series 1)

	W/C (%)	s/a (%)	Unit weight (kg/m³)					Fresh Concrete		
			W	OPC	BFS	S	G	Slump	Air(%)	C.T(℃)
N	45	48	168	373	–	848	943	9.5	4.0	26.9
BB				205	168	842	936	17.0	4.9	26.1
N	55	50		305	–	911	935	4.5	5.5	26.5
BB				168	137	906	930	9.5	4.1	25.1
N	65	52		258	–	968	917	10.0	3.7	22.1
BB				142	116	964	913	12.0	3.5	22.8

Table 2. Mix proportions of Mortar (Series 1)

Kind of Cement	W/C (%)	Unit weight (kg/m³)			
		W	OPC	BFS	S
N	45	277	615	–	1396
BB		276	337	276	1381
N	55	275	501	–	1494
BB		275	275	225	1482
N	65	273	419	–	1570
BB		272	230	188	1559

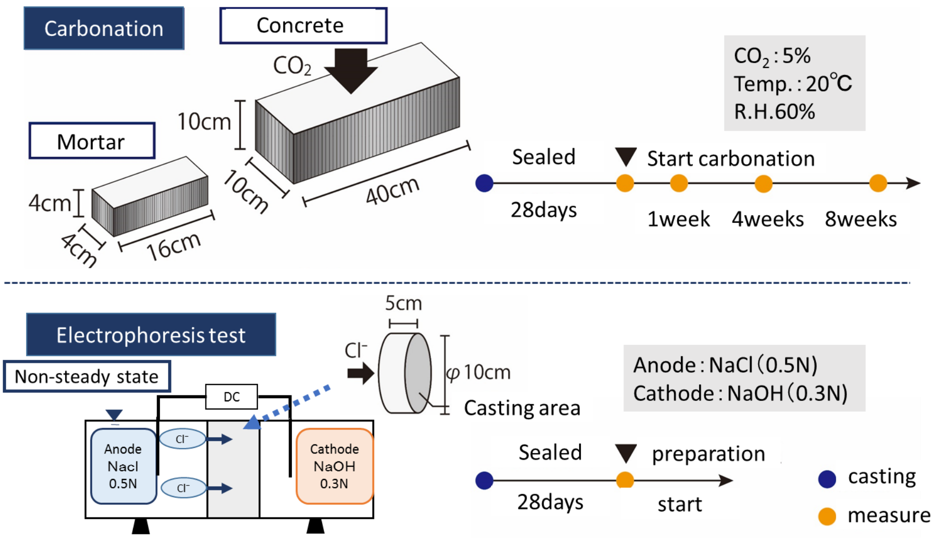

Figure 1. Outline for experiment test

a mold, and then the next day demolding, then was conducted 28 days sealed curing under a constant environment temperature 20 degree Celsius. It shows the test items and specimen size of each test in Figure 1.

2.2 *Testing methods*

2.2.1 *Accelerated Carbonation test*

Accelerated carbonation test is in compliance with JIS. After curing period, open the one side except casting side, specimen was placed in accelerated carbonation test equipment (Carbon dioxide concentration: 5%, temperature 20 degree Celsius, humidity RH60%). Carbonation depth was measured at 1, 2, 4, 8, 13 weeks by brown part using phenolphthalein solutions in split area. Then, it was calculated the coefficient of carbonation ratio using these results. Note that the prismatic specimen size is mortar 40 * 40 * 160mm, concrete 100 * 100 * 400mm.

2.2.2 *Electrophoresis test in non-steady state*

In order to evaluate the permeability of chloride ions in the short term, it was performed non-steady state electrophoresis test. Specimen size was created by φ100 × 50mm in both mortar and concrete using a mold made by chloride pipe. The test specimens were sealed curing until 28 days. Pre-treatment was carried out water-saturated processing in a vacuum state. Sodium chloride aqueous NaCl solution in the cell on the cathode side (0.5N), the anode side using aqueous sodium hydroxide NaOH (0.3N). The applied voltage was 30V. And fracturing the specimens in a predetermined energization time, by spraying the solution of silver nitrate (0.1N) to split crack surfaces, white in the partial measured 7 points colored by white area, and the average value was used as the chloride ion penetration depth.

2.3 *Results of these test*

2.3.1 *Accelerated Carbonation test*

The results of accelerated carbonation test in Figure 2. In the water cement ratio is 55, 65%, carbonated to immediately deep position to start the carbonation test. Then, progress in the depth direction with time became gentle. In addition, carbonation depth of the mortar using BB was much the same as water cement ration on 45% in N. However, it showed a 55, 65% in N. As this cause, for alkali content of the

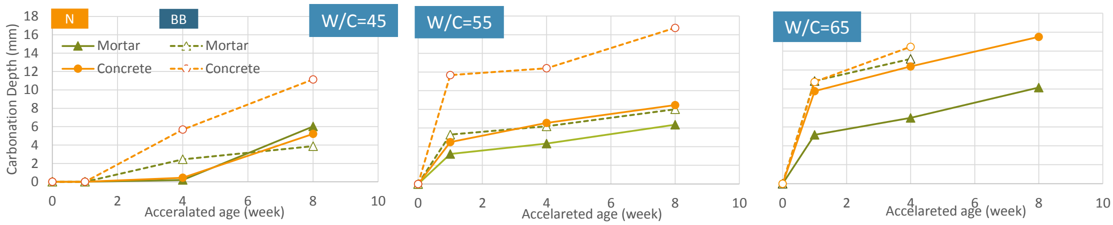

Figure 2. Results of accelerated carbonation test

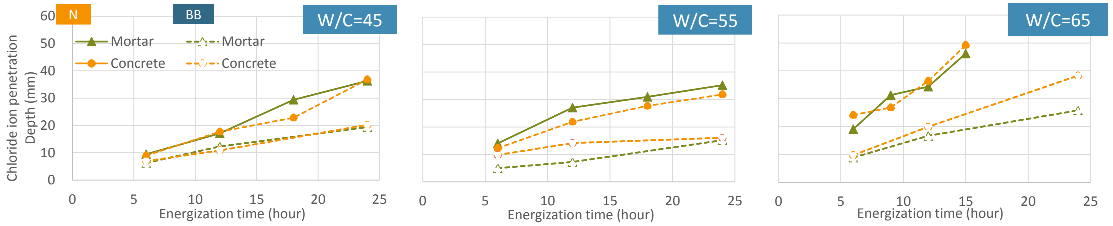

Figure 3. Results of chloride ion penetration by non-steady state electrophoresis test

Table 3. Coefficient of carbonation rate

Coefficient of carbonation rate (mm/√week)			
W/C (%)		N	BB
45	Mortar	1.34	1.22
	Concrete	1.20	3.30
55	Mortar	2.30	3.10
	Concrete	3.19	6.45
65	Mortar	3.68	7.44
	Concrete	6.03	7.94

Table 4. Coefficient of chloride ion penetration

Coefficient of chloride ion penetration (cm^2/year)			
W/C (%)		N	BB
45	Mortar	11.64	5.22
	Concrete	13.15	4.77
55	Mortar	8.42	3.59
	Concrete	9.43	4.00
65	Mortar	5.59	2.79
	Concrete	5.39	4.69

large value as compared with water cement ration as cement is low, carbonation was considered likely to progress. On the other hand, N is the difference between the mortars becomes larger as water cement ratio is increased. The difference between the concrete and mortar in the case BB in water cement ratio is small. However, the difference was a result not seen when the water cement ratio increases. More √t-law using the test results, the results of calculating the coefficient of carbonation rate coefficient as shown in Table 3.

2.3.2 *Non-steady state electrophoresis test*

It shows the results of the non-steady state electrophoresis test in Figure 3. With the increase of the water cement ratio, penetration depth of N is larger in both of concrete and mortar. On the other hand, in the case of BB, as water cement ratio increases, the penetration depth in the concrete and mortar did not change significantly. The porous structure becomes dense by using the blast furnace slag. Further immobilization of chloride ions to occur. These show that the chloride ion penetration is suppressed. Looking at the difference between the mortar and concrete in chloride ion penetration, it can be said that the difference is small compared with the results of the carbonation test. It was found that chloride ion penetration is greater in the concrete. Here, it is shown in Table 4 the calculated diffusion coefficient using NT BUILD 492 method.

2.4 *Evaluation of penetration properties on unit paste*

Between the mortar and the aggregate, the interfacial transition zone is present. This interfacial transition zone is to give a major impact on the penetration of the deterioration factor. Therefore, we compared the coefficient of carbonation ratio and coefficient of chloride ion diffusion due to differences in the unit amount of paste in this study. Figure 4 shows the relationship between the unit amount of paste and the coefficient of carbonation ratio, coefficient of chloride ion diffusion. With the increase of the unit amount of paste, it was lower in the carbonation and chloride ion penetration. However, the change is not seen in chloride ion penetration of BB concrete. Take a look for each cement. In case of N, as the amount of unit paste is small, there is a difference in permeability properties of concrete and mortar. On the other hand, in case of BB, the difference of permeability properties is often seen large as large amount of unit paste. Here, the difference of material

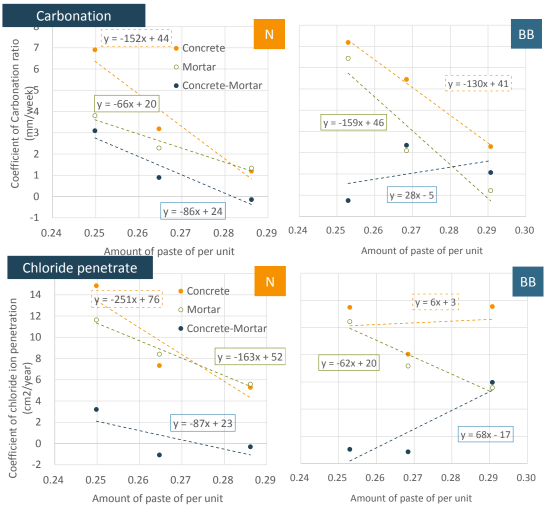

Figure 4. Results durability on amount of unit paste

permeability of concrete and mortar has been assumed the impact of the interfacial transition zone. These relationships shown by the approximation formula in Figure 4. It does not depend on the type of deterioration factor. Amount units paste in N is suppressed enough to increase. With the increase of the BB in the unit amount of paste tends to penetrate. In this way the results by cement type showed a different trend. Therefore, the mechanism of formation of the interfacial tradition zone is different from that predicted by the cement type.

3 EFFECT OF AMOUNT OF AGGREGATE FOR THE RESISTANCE OF MATERIAL [SERIES 2]

3.1 *Mix proportions*

Considering the interfacial transition zone generation mechanisms maybe produced by bleeding water accumulates such as the lower surface of the aggregate. Therefore, the water cement ratio was set at 65%, it was changed aggregate amount as shown in Figure 5. And more the using kinds of cements are N and BB as same as Series 1 test. It should be noted that, in order to make the nature of the mortar and the same, and the volume percentage of the material such as water, cement, fine aggregate and air forming the mortar constant. It was prepared concrete by varying the aggregate amount to a constant mortar. With respect to the fundamental of the mortar (s/a 100%), it was set concrete of the general aggregate amount (s/a 48%). The aggregate amount of up 10 percent from there (s/a 44%), the aggregate amount of 25% decrease (s/a 58%), was set to the mix proportion and the aggregate amount of one-half (s/a 70%). Concrete and mortar of the same mix proportion, was produced on the same day, and the next day removed from the mold. Then it went for 28 days

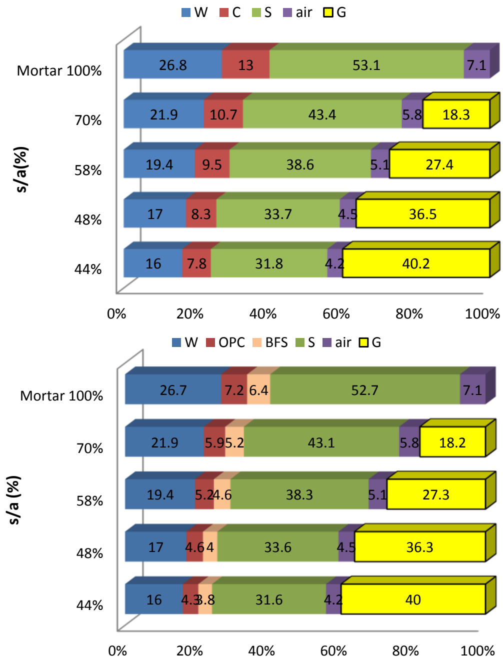

Figure 5. Mix proportion (Series 2)

sealed curing in constant temperature and humidity chamber of 20 degree Celsius.

3.2 *Testing methods*

3.2.1 *Bleeding test*

Bleeding test in compliance with JIS. Test vessel was using φ270 × 300mm for concrete, φ140 × 130mm for mortar. Measurement of the amount of bleeding was carried out at 10-minute intervals for 60 minutes from casting, then was carried out at 30-minute intervals. It was calculated the bleeding rate in dividing the amount of final bleeding by the amount of water in the container.

Bleeding rate generated from the mortar was assumed to be the same. Therefore, the difference between the bleeding rate of the produced concrete and mortar bleeding rate was assumed to be a gap generated on the lower surface aggregates.

3.2.2 *Strength test*

Mortar prepared is the test of the 40 * 40 * 160mm based on the JIS, concrete is produced in specimens of φ100 * 200mm based on the JIS, it was subjected to water curing for 28 days. We measured for compressive strength and splitting tensile strength.

3.2.3 *Measurement of porosity*

The cylindrical specimen was cut with each 50mm height, with samples further split it. It named from the upper A, B, C, as D areas, compares the four are

Figure 6. Sample of water absorption test in vacuum

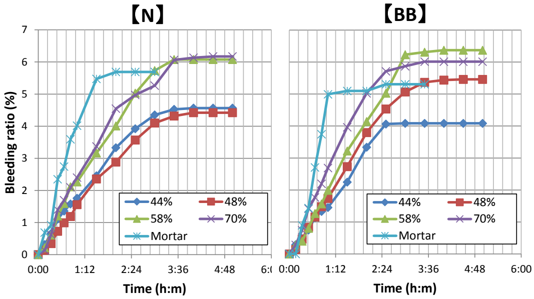

Figure 7. Results of Bleeding test

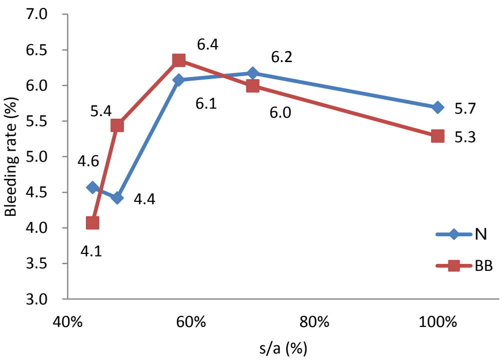

Figure 8. Relationship s/a and Bleeding rate

as was evaluated the effect of moisture rise due to bleeding has on porosity. Surface drying density, drying density and the water-saturated density was measured, the porosity was measured by the Archimedes method.

3.2.4 *Accelerated Carbonation test*

The testing method is same to 2.2.1.

3.2.5 *Chloride ion penetration test*

The test specimen was immersed in salt water on concentration 10% of chloride ion. Removed from salt water at measuring age, it was splitting and sprayed with silver nitrate 1% solution in the cross-sectional area. Thereafter, it was measured the exhibited parts in white, such as assuming the chloride ion penetration depth. In addition, it was calculated to approximate the chloride ion penetration ratio in $\sqrt{\ }$t law in the same way as the carbonation ratio.

3.2.6 *Water absorption test in vacuum condition*

In order to measure the continuity of porosity, it was

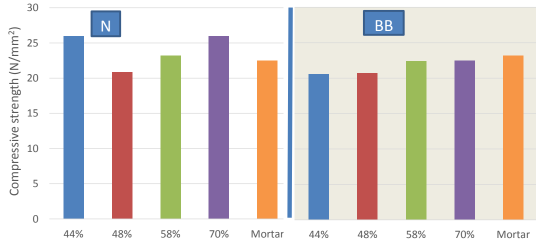

Figure 9. Compressive strength

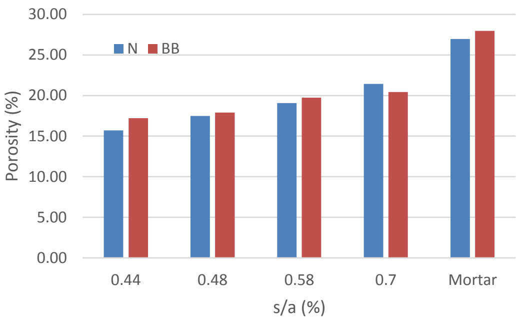

Figure 10. Porosity on each samples

performed this test. The method, to absolutely dry state a cylindrical specimen in five days in oven at 40 degree Celsius. After drying, paste the aluminum tape as shown in the Figure 6, to fix the water absorption area and exhaust area. Thereafter, it allowed to stand for 5 hours under vacuum, it was measured area of water absorption from below. They were evaluated for pores formed using this result.

3.3 *Results for tests*

3.3.1 *Bleeding test*

Figure 7 shows the results of the bleeding rate determined from the bleeding test. Mortar for 2 hours, the concrete for 4 hours has a bleeding of all mix proportions were completed. Figure 8 shows the relationship between s/a and bleeding rate. In any of the N and BB, when mixed a small amount of coarse aggregate as compared to the mortar, bleeding rate is rose. On the other hand, less than 55% in s/a such as a normal concrete mix proportion, showed a tendency to bleeding rate is reduced. Thus, bleeding ratio was shaped with peaks by s/a. This is because, in the case of a small amount of coarse aggregate addition, bleeding of the mortar rises slip through the surrounding aggregate. On the other hand, in case of a large amount of coarse aggregate addition, bleeding is blocked in aggregate suspect a phenomenon that the bleeding couldn't be increased.

3.3.2 *Compressive strength*

The strength test results are shown in Figure 9. Both N and BB, influence on the strength due to replace-

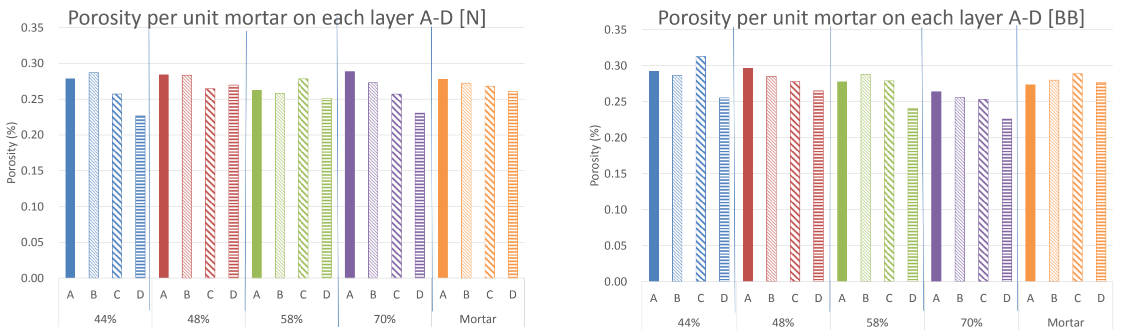

Figure 11. Results of porosity per unit mortar on each layers

ment ratio of the aggregate was not observed clearly.

3.3.3 *Porosity*

Fig 10 shows the results of porosity on each concrete. The results calculated by the Archimedes method. Mortar has a lot of pores and aggregate does not have pores.

Therefore in view of the formation of porosity due to bleeding, the results of porosity per unit mortar on the difference between upper and lower on specimen of the hardened concrete and mortar illustrated in Fig 11. Porosity of the amount of concrete that was mixed with aggregate with the exception of mortar, it became the same level regardless of the mix proportions. From this result, the pore volume of the total concrete is influenced by the mixing amount of the aggregate. So, it was assumed that there is no pore in the coarse aggregate. In addition the performance of the mortar is equivalent, and is in the mortar to assume that there is no interfacial transition zone, it can be assumed the difference between the porosity of concrete and the porosity of mortar is just pore due to the interfacial transition zone.

We focus on each layer, generally specimens of N and BB, the pore volume of a top layer A has become larger in comparison to the pore volume of lower layer D. This is believed due to moisture migration by bleeding. In detail, in the case of mortar and the small amount of aggregate contents, the upper layer as pore is a large amount. On the other hand, when the amount of aggregate is about concrete, the upper layer in both of A and B, almost pore volume does not change. This bleeding does not rise until the upper layer is inhibited by the aggregate are considered to be constrained to a lower surface aggregate which means that it is an air gap.

The relationship between the results obtained by converting porosity per unit mortar and s/a or bleeding rate shown in Figure 12. The porosity of the unit mortar, mortar and aggregate mixing ratio is small, as s/a is large, were the same pore volume as compared to the mortar. On the other hand, s/a is small, that is enough to become concrete mix proportion, resulted in pore volume of mortar increases. This is

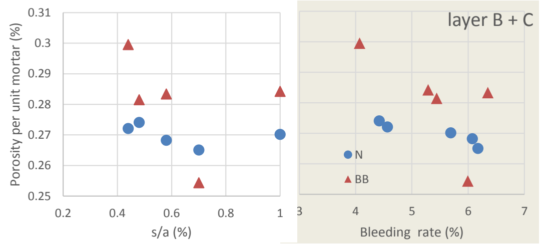

Figure 12. Results of s/a or Bleeding rate and Porosity unit mortar on layer B and C

considered an interfacial transition zone is formed. Further, Figure 12 showing the relationship between the interfacial transition zone in concrete and the captured on the lower surface aggregate according to the calculated amount of water bleeding in 3.3.1. From this result, it can be seen that the amount of prevented the increase of the bleeding water is in the interfacial transition zone.

3.3.4 *Accelerated Carbonation test*

Figure 13 is showing the results of accelerated carbonation test. In case of N, carbonation depth on concrete such as adding the aggregate as compared to the mortar has progressed a little at the initial time. However, in the age of 4 weeks, in case of s/a is 58, 70% and mortar, carbonation depth is suppressed. However, carbonation depth of concrete is progressed. This is considered that the influence of the interfacial transition zone is generated on the lower surface aggregate. On the other hand, carbonation speed of mortar on BB is fast up to 4 weeks. However, carbonation depth of concrete mix proportion such as s/a 44 and 48 % is large as mortar due to the presence of interfacial transition zone in eight weeks. In comparison the N and BB, BB by differences amount of alkali is fast progress of carbonation.

3.3.5 *Accelerated Chloride penetration test*

Figure 14 shows the results of the chloride ion penetration test. Although N and BB has been obtained slightly different trend which mortar appears to be

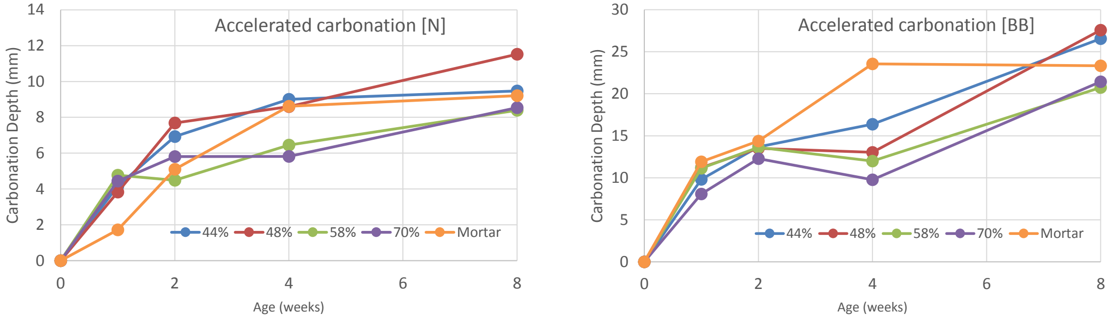

Figure 13. Results of accelerated carbonation test on different s/a

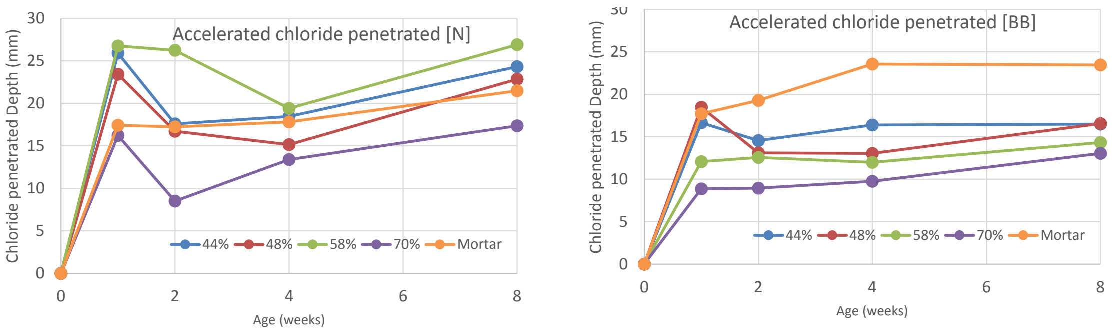

Figure 14. Results of accelerated chloride ion penetration test on different s/a

easy to chloride ion penetration compared to the concrete. On the other hand, a small amount of aggregate mixing, it was suppressed chloride ion penetration. However, it looks like penetration depth closer to the concrete mix is increased. Moreover, it is highly resistant towards BB is against chloride ion penetration than N.

3.3.6 *Water absorption test in vacuum condition*

Figure 15 shows the results of the water absorption test in vacuum. The mix proportion close to mortar, it can be seen that the water absorption depth in the upper surface is sharply increased. On the other hand, if the concrete mix, the gradient of water absorption depth is gentle. This is the effect of interfacial transition zone generated by the aggregate mix can imagine that pore characteristics is changed.

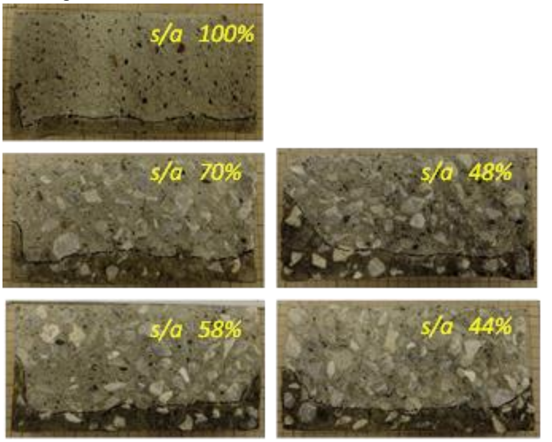

Figure 15. Result of water absorption test in vacuum

3.4 *Relationship between pore and these properties*

To examine the relationship between the generated interfacial transition zone and the coefficient of carbonation ratio and chloride ion diffusion coefficient. Carbonation ratio coefficient is determined from the $\sqrt{t}$ law, it shows the relationship between the pore volume of per unit mortar and the carbonation rate coefficient in Figure 16. From this, with the increase in the pore volume, it is understood that the carbonation rate coefficient is large. In shorts, the greater the number the amount of the interfacial transition zone, carbonation rate coefficient is larger. This interfacial transition zone indicates that it is a movement path of the material. Here, since the bleeding discharged to the upper believed to reduce the unit water content, uniformly assuming mortar W/C is changed, the real subtracts the discharged bleeding water from the unit water amount the relationship of W/C and a neutral rate coefficient shown in Figure 17.

On the other hand, it calculates the chloride ion diffusion coefficient as in the carbonation with $\sqrt{t}$ law, Figure 18 shows the relationship between the pore volume per unit mortar and chloride ion diffusion coefficient. From this, it can be seen that no observed correlation with each other. Figure 19 shows

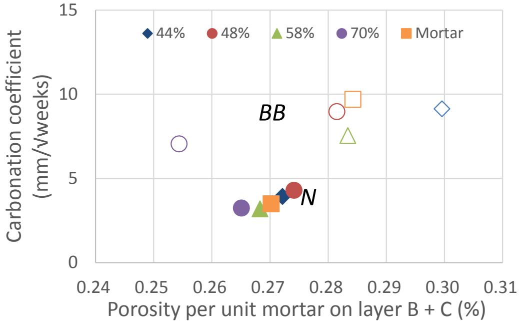

Figure 16. Relationship porosity by carbonation

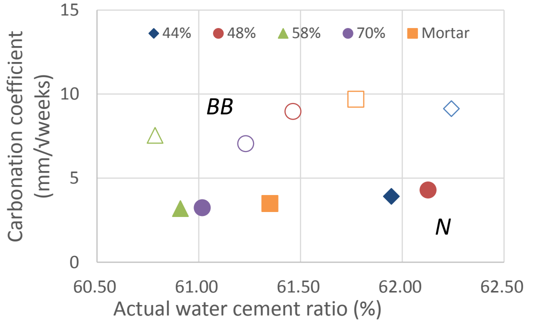

Figure 17. Relationship actual W/C by carbonation

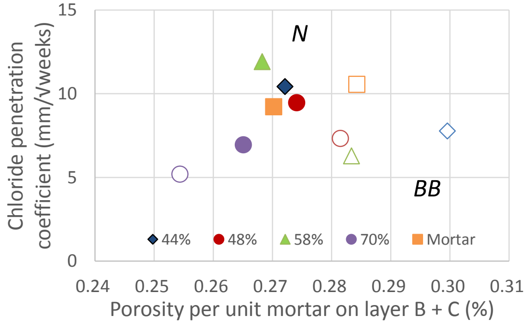

Figure 18. Relationship porosity by salt penetration

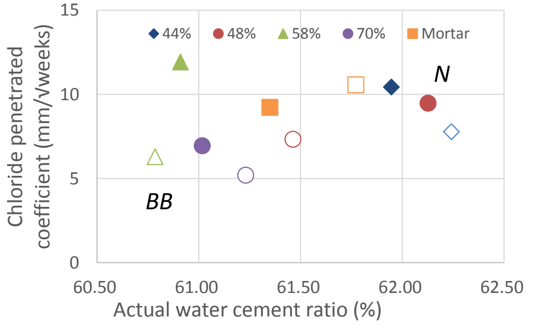

Figure 19. Relationship actual W/C by salt penetrate

also relationship between actual water cement ratio and coefficient. The penetration of chloride ions is not only diffusion phenomena, but it can be seen that it is necessary to consider the immobilized chloride ion and adsorption ion performance.

Thus, if the concrete mix, it becomes formed pores like water reservoir to the lower surface aggregates by bleeding (named the interfacial transition zone), it can be seen that affect mass transfer.

4 CONCLUSIONS

The results obtained in this study a comparison of the mass transfer resistance of mortar and concrete is as follows.

(1) The presence of coarse aggregate is different from the effect on the material permeability on water cement ratio.

(2) The difference between the substance permeability of the mortar and concrete is assumed to be the effect of the interfacial transition zone. And it has the different tendencies depending on the type of cement.

(3) The presence of coarse aggregate, that prevent the moisture rise due to bleeding, then the interfacial transition zone is generated.

(4) The presence of the interfacial transition zone is affected the pore gap and the great influence on the mass transfer.

(5) Carbonation and moisture movement is seen to be highly dependent on the interfacial transition zone and the pore characteristics. Meanwhile chloride ion penetration, it is difficult to understand the only pore properties.

In the future works, for the improvement of the lower surface aggregate, we want to consider the following method.

a. Use of aggregate with reaction activity

b. Use of ultra-fine powder that was aimed at fine powder effect

c. Enhancement of the interface by reaction with C-S-H Nano-particles.

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