

EFFECTS OF BLEEDING OF WATER AND COMPACTING WAY ON CHLORIDE DIFFUSION INTO CONCRETE

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ABSTRACT: Improvement of defect caused by bleeding of water plays an important role to construct durable concrete structure. Distribution of chloride ion diffused in concrete is very complex, because path of bleeding of water remains as the path of diffusion of chloride ion in hardened concrete. To make the path smaller by decreasing bleeding water or revibration must be an effective way for the chloride diffusion to be uniform and smaller. On the other hand, chloride will diffuse easily from crack section compared with cut section by concrete saw, because the aggregate near the crack section must be loosened. And the degree of the loosening will be depending on the bleeding water movement.

In this study, the effects of bleeding of water in concrete on chloride diffusion into concrete were investigated.

Following 1), 2) and 3) were concluded in this study.

- 1) It is very difficult to make chloride diffusion in concrete isotropic and uniform, because complex path formed under bleeding of water must remain in hardened concrete. To achieve more isotropic concrete, the remixing to reduce the bleeding and the revibration to distribute the path of bleeding are very effective ways, and proportioning to reduce the bleeding is also effective.
- 2) Chloride diffuses faster at the part where the bleeding water tends to remain, corner of T section and bottom surface of flange for example. This influence can be improved by the revibration and/or the decrease of bleeding by mix proportion and/or mixing technique i.e. SEC mixing method.
- 3) Chloride diffusion from the cracked surface was much faster than that from the cut surface by concrete saw. This tendency was remarkable when the water-cement ratio was higher and also when the remix and the recompaction were not done. The reason is considered that the interface between aggregate and cement paste loosened easier under cracking when the more bleeding water remains around the aggregate.

KEYWORDS: concrete, bleeding water, chloride diffusion, mix proportion, compaction, isotropic, uniform

1. INTRODUCTION

Improvement of defect caused by bleeding of water plays an important role to construct durable concrete structure. Concrete is one of composite material which consists of water, cement particles and aggregate as gravitation causes bleeding water,

the anisotropic movement of water make the difference between vertical and lateral properties.

Thus, distribution of chloride ion diffused in concrete is very complex, because path of bleeding of water remains as the path of diffusion of chloride ion in hardened concrete. To make the path smaller by decreasing bleeding water or revibration must be

Table 1 Raw materials of concrete

Cement	Ordinary Portland cement (Density: 3.16g/cm ³ , Blain value: 3320cm ² /g)
Fine aggregate	River sand (Density under saturated surface-dry condition: 2.59g/cm ³ , Water absorption: 2.33%, Fineness modulus: 2.68)
Coarse aggregate	Crushed stone (Maximum size: 20mm, Density under saturated surface-dry condition: 2.72g/cm ³ , Water absorption: 0.66%, Fineness modulus: 6.50)
Chemical admixture	Air-entraining agent

Table 2 Specified mix of concrete

Mix No.	Slump (cm)	W/C (%)	Air content (%)	s/a (%)	Unit content (kg/m ³)				Ad** (ml/m ³)
					W	C	S	G	
Mix 1	8.0	45	4.5	42	183	407	701	1013	40.7
Mix 2		55		44		333	761	1014	33.3
Mix 3		65		46		282	815	1001	28.2
Mix 4*	1.5	55	1.1	33	165	299	642	1341	0

* Cement, sand and gravel were mixed with a bulk volume of 1:2:4, respectively (1:2:4)

**Air-entraining admixture

Table 3 Method of placement and compaction

Mix No.	Compaction No.	Compacting method
Mix 1	Case 1	Compaction with internal vibrator
Mix 2	Case 1	Compaction with internal vibrator
	Case 2	Compaction with internal vibrator and revibration at 90 minute past placement
	Case 3	Compaction with internal vibrator of concrete remixed at 90 minute past mixing
Mix 3	Case 1	Compaction with internal vibrator
Mix 4	Case 4	Compaction with rammer

an effective way for the chloride diffusion to be uniform and smaller. On the other hand, chloride will diffuse easily from crack section compared with cut section by concrete saw, because the aggregate near the crack section must be loosened. And the degree of the loosing will be depending on the bleeding water movement.

In this study, the effects of bleeding of water in concrete on chloride diffusion into concrete were investigated.

2. Experiments

2.1 Materials and Mix Proportion of Concrete

Ordinary Portland cement, river sand and crushed stone were used to mix concrete. The properties of materials prepared for this experiment are shown in Table 1. The specified mixes with water-cement ratio of 45%(Mix 1), 55%(Mix 2, Mix 4) and 65%(Mix 3) were selected as shown in Table 2. Mix 4 is the mix which was generally applied to reinforced concrete structure until almost 60 years

Table 4 Test result of bleeding in accordance with JIS A 1123

Mix No.	Compaction No.	Mixing technique	Amount of bleeding (cm ³ /cm ²)	Bleeding rate in percent (%)
Mix 1	Case 1	Con	0.20	5.96
Mix 2	Case 1	Con	0.25	7.43
		SEC	0.03	0.77
	Case 2	Con	0.22	6.46
	Case 3	Con	0.11	3.05
Mix 3	Case 1	Con	0.29	8.51
Mix 4	Case 4	Con	0.00	0.00

Con: conventional

SEC: sand enveloped with cement

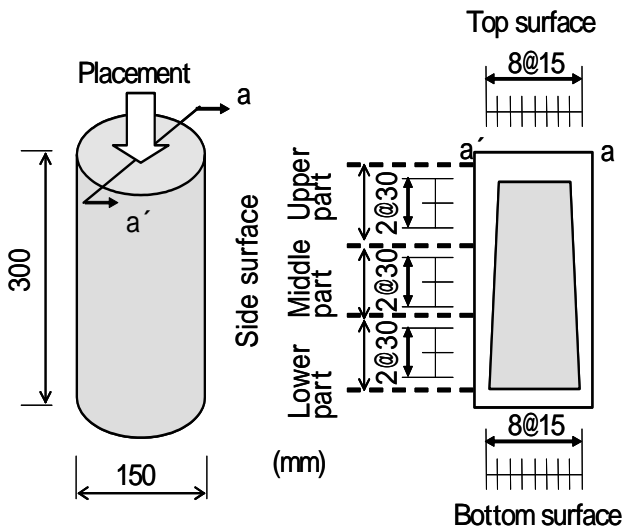


Fig.1 Cylindrical specimen and cross section split for measurement of chloride penetration

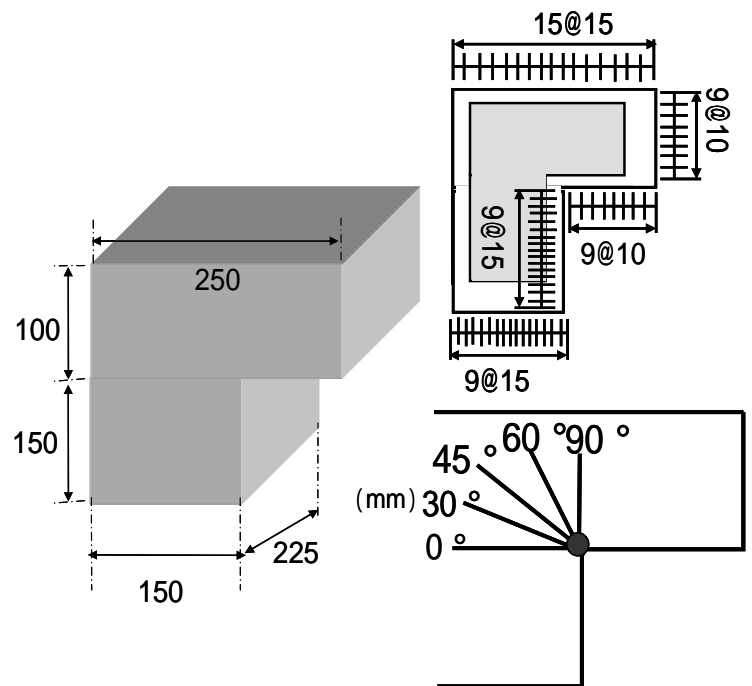


Fig.2 T-section specimen and cross section split for measurement of chloride penetration

ago, and the mix proportion whose ratio of bulk volume of cement, sand and gravel are 1:2:4, respectively.

The methods of placement and compaction of the concrete are shown in Table 3. In case of Mix 2, three cases were conducted. The Case 2 is placed to distribution the bleeding water remaining in concrete by revibration. The Case 3 is planned to make the amount of bleeding water less even when the mix proportion is same. The Case 4 is old style compacting method and applied to only Mix 4.

The amounts of bleeding and bleeding rate are shown in Table 4.

2.2 Experiments

2.2.1 Effects of Bleeding Water on Chloride diffusion

In this experiment, cylindrical specimens sized 150 by 300mm were prepared in all mix proportions and compaction cases as shown in Fig.1. T-section specimens as shown in Fig.2 were prepared for the test on Case 1 Con-Mix 1, Case 1

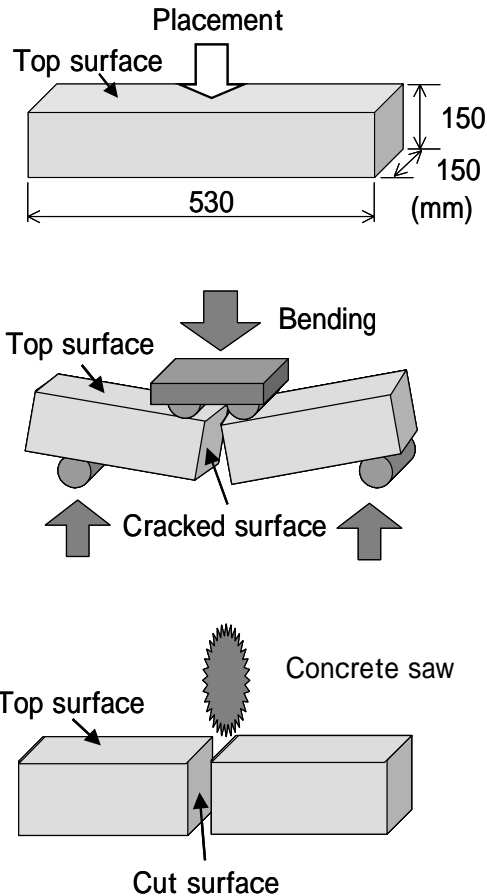


Fig.3 Procedure of making cracked surface or cut surface (rectangular specimen)

Con-Mix 2, Case 1 SEC-Mix2, Case 1 Con- Mix 3 and Case 2 Con- Mix 2.

After curing in water until at the age of 28 days, the cylindrical specimens were soaked in salt solution until the age of 208 days, and T-section specimens were soaked in salt solution for 1 month, whose concentration of NaCl is 10% by weigh.

After soaking in the salt solution, the specimens were split and silver nitrate solution (0.1 mol/l) was sprayed on the failed section. And then in case of cylindrical specimens, the depth of chloride penetration at top surface, side surface and bottom surface were measured as shown in Fig. 1. In case of the side surface, the depth of area containing salt was distinguished to 3 parts as the upper part, the middle part and the lower part.

In case of T-section specimens, the depth of

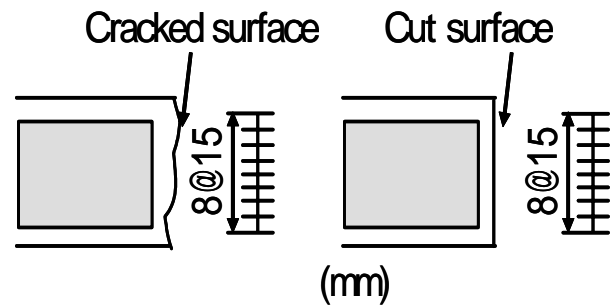


Fig.4 Measurement of chloride penetration from cracked surface and cut surface

chloride penetration at top surface of flange, side surface of flange, bottom surface of flange, side surface of web and bottom surface of web were measured. At the corner between flange and web, the depth of area containing salt was measured in the direction of $0^\circ, 30^\circ, 45^\circ, 60^\circ$ and 90° to horizon as shown in Fig.2.

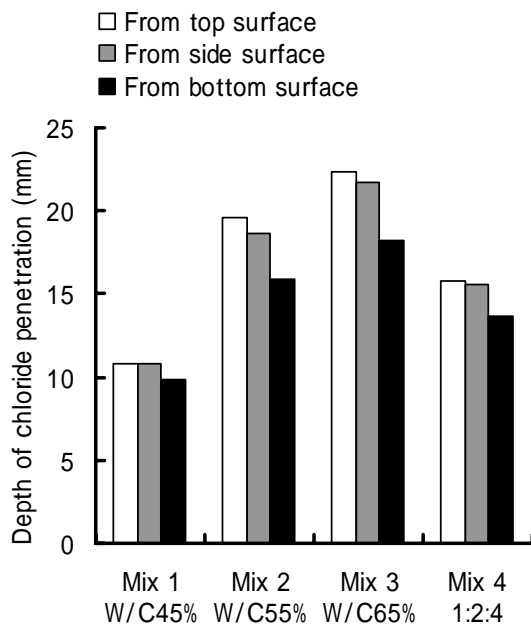
2.2.2 Comparison between chloride diffusions from crack section and cut section

The rectangular prism molds sized $150 \times 150 \times 530$ mm were prepared. In this experiment, cracked surface was failed section by bending, and cut surface was performed by cutting with concrete saw. These were operated at the age of 28 days after curing in water. The procedure of making cracked surface and cut surface are shown in Fig.3. Then, the specimens were soaked in the salt solution whose concentration of NaCl is 10% by weight for 2 months. After soaking in the salt solution, the specimens were split and the depth of chloride penetration from each surface was measured as shown in Fig.4.

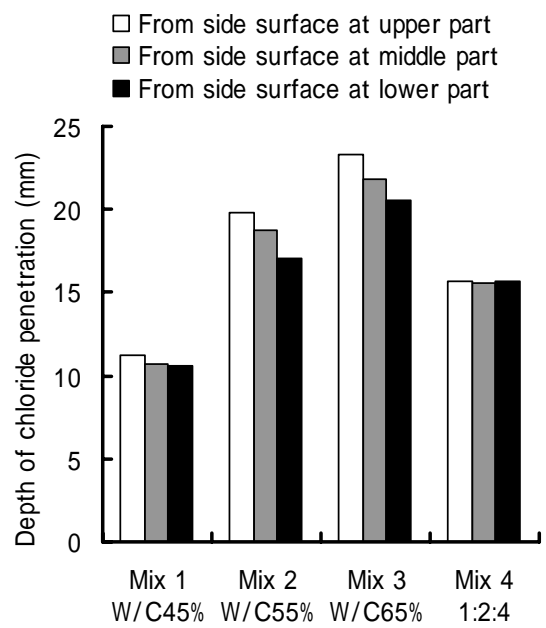
3. Test Result and Discussion

3.1 Effects of Bleeding Water on Chloride diffusion

The effects of mix proportions on chloride

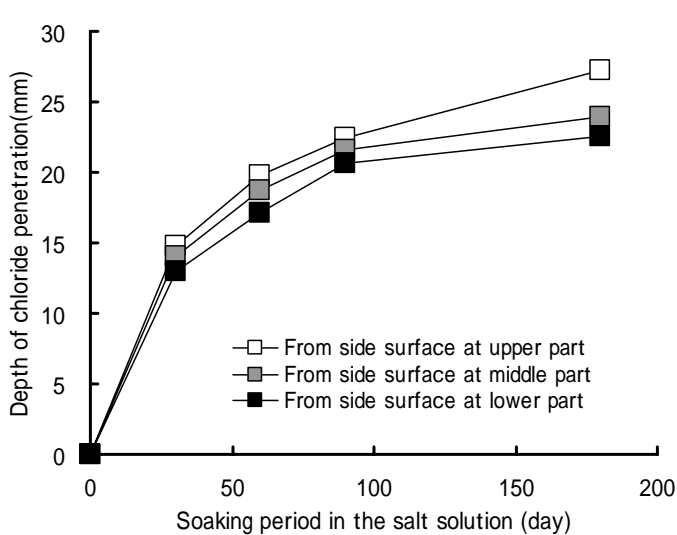


(1) Depth of chloride penetration from each surface

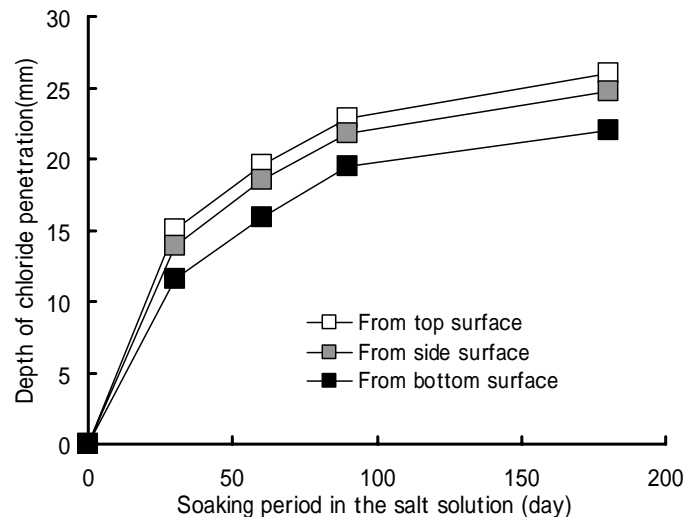


(2) Depth of chloride penetration from Side surface at each height

Fig.5 Accelerated test results for chloride penetration into cylindrical specimen soaked in NaCl solution for 2month (Mix1 ~ 4, Case1,4)



(1) Depth of chloride penetration from each surface

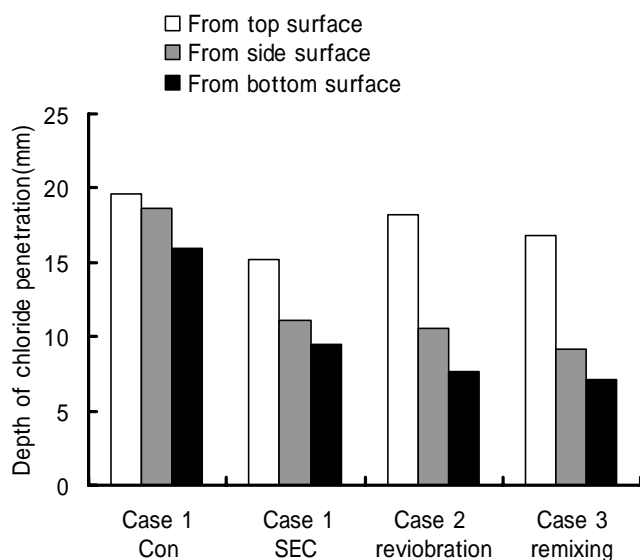


(2) Depth of chloride penetration from Side surface at each height

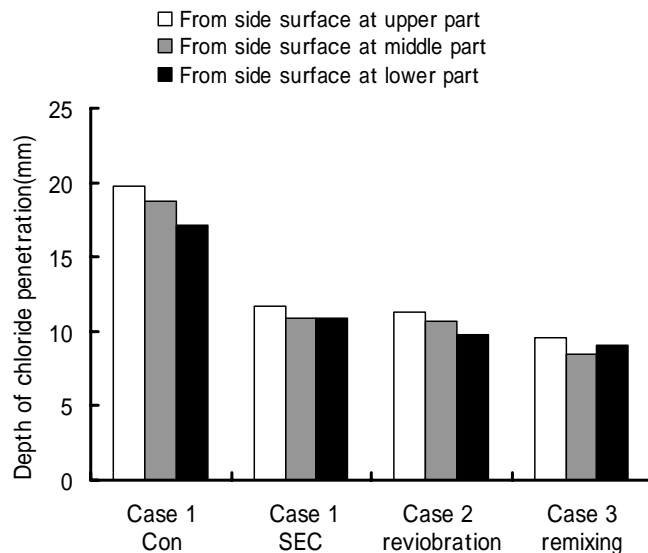
Fig.6 Accelerated test results for chloride penetration into cylindrical specimen

penetration in to concrete are shown in Fig. 5. In case of same water content that is mix 1 ~ 3, the larger the water-cement ratio, the deeper the chloride penetration. And also, the difference of depth of chloride penetrations between the top surface, the side surface and the bottom surface is larger, when the water-cement ratio is higher, as shown in Fig. 5 (1). As shown in Fig.5 (2), the depth of chloride penetration from the side surface at each part shows

the tendency that the depth is getting to be larger when the part comes to be higher. These tendencies will be caused by the reason that the bleeding water was remained in hardened concrete as the path for chloride diffusion. Extremely consistent concrete of Mix 4 was compacted with rammer as in the old days, and shows the smaller difference of the depth of chloride penetration, because of very small bleeding. Fig.6 shows the depth of chloride

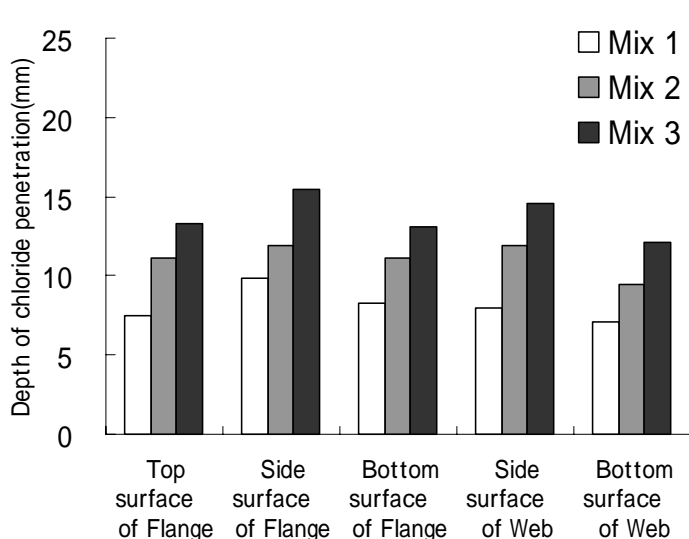


(1) Depth of chloride penetration from each surface

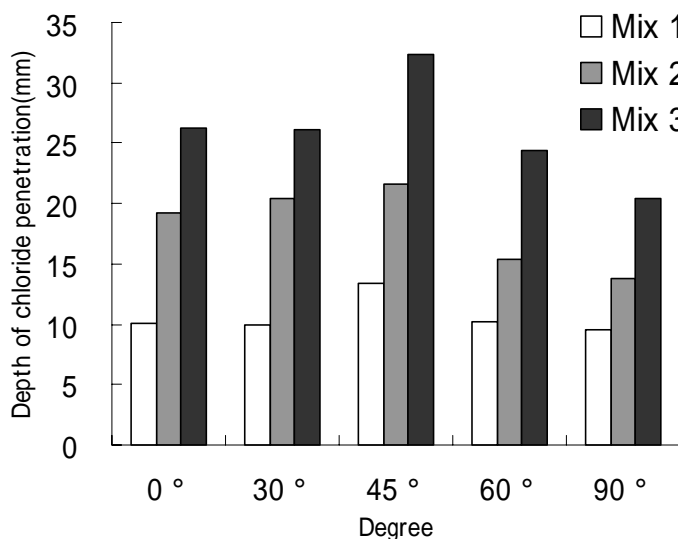


(2) Depth of chloride penetration from Side surface at each height

Fig.7 Accelerated test results for chloride penetration into cylindrical specimen for 2months (Mix 2)



(1) Depth of chloride penetration from each surface



(2) Depth of chloride penetration in each degree at the corner between flange and web

Fig.8 Accelerated test results for chloride penetration into T-section specimen soaked in NaCl solution for 1month (Mix 1 ~ 3, Case 1)

penetration depending on soaking period in the salt solution. The depth of chloride penetration was increasing for 6 months, and also the chloride penetrate deeper from higher surface at higher part. However, the difference of the depth of chloride penetration between the all surfaces shown in Fig.6 (1) seems to be almost constant.

The effects of revibration and mixing technique on chloride penetration into concrete are shown in Fig.7. The mixing technique to reduce the bleeding, revibration and/or remixing must be very effective ways. However, these ways could not make the depth of chloride penetration from top surface less.

As shown in Fig.8 (1), the higher the water

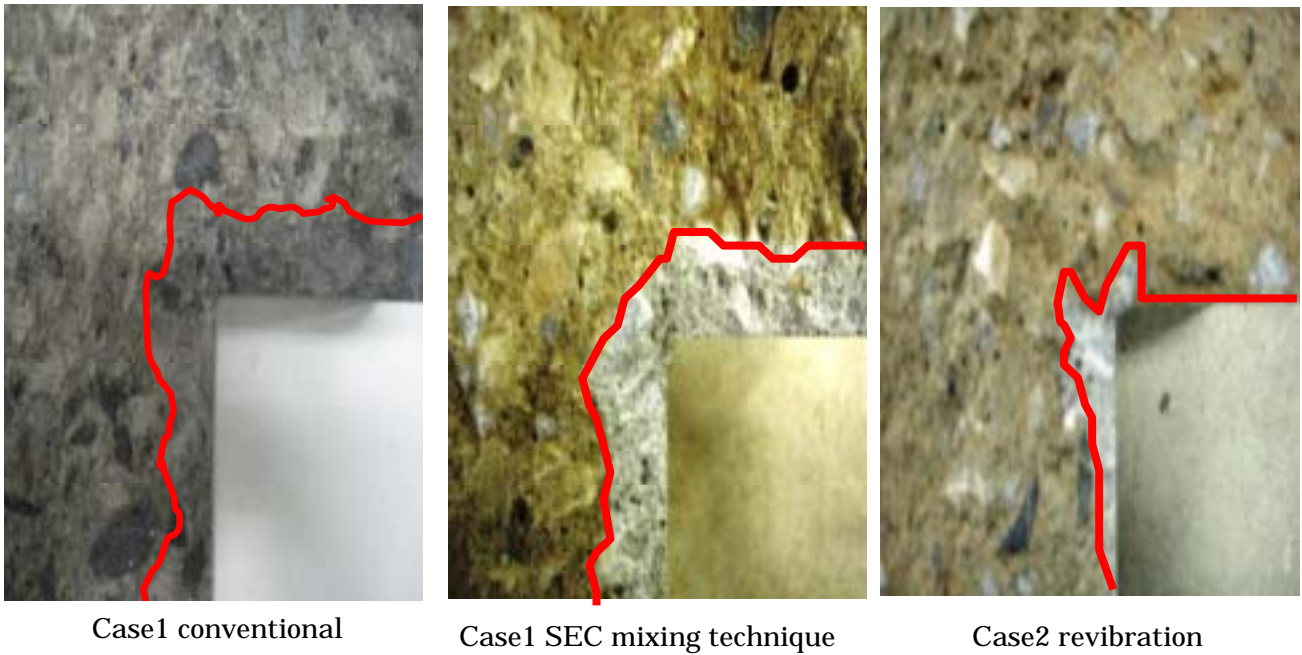


Fig.9 Distribution of chloride at the corner between flange and web

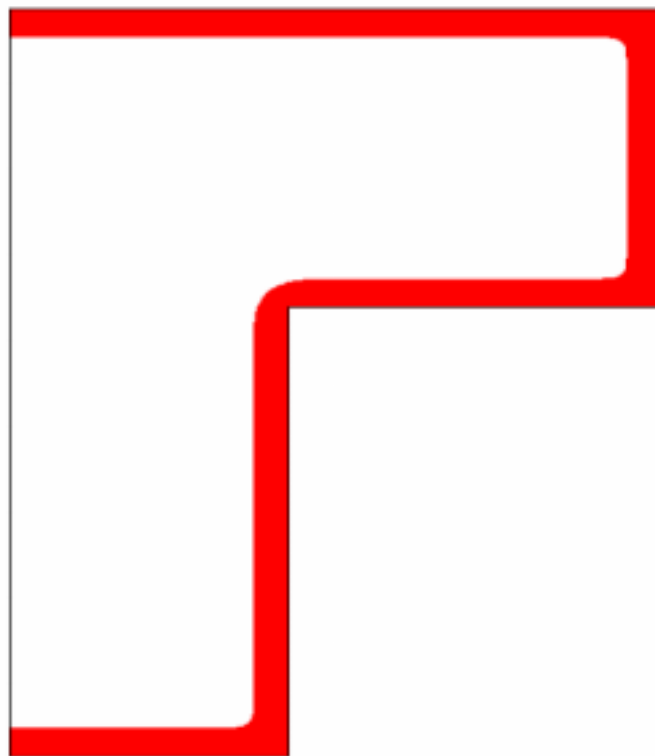
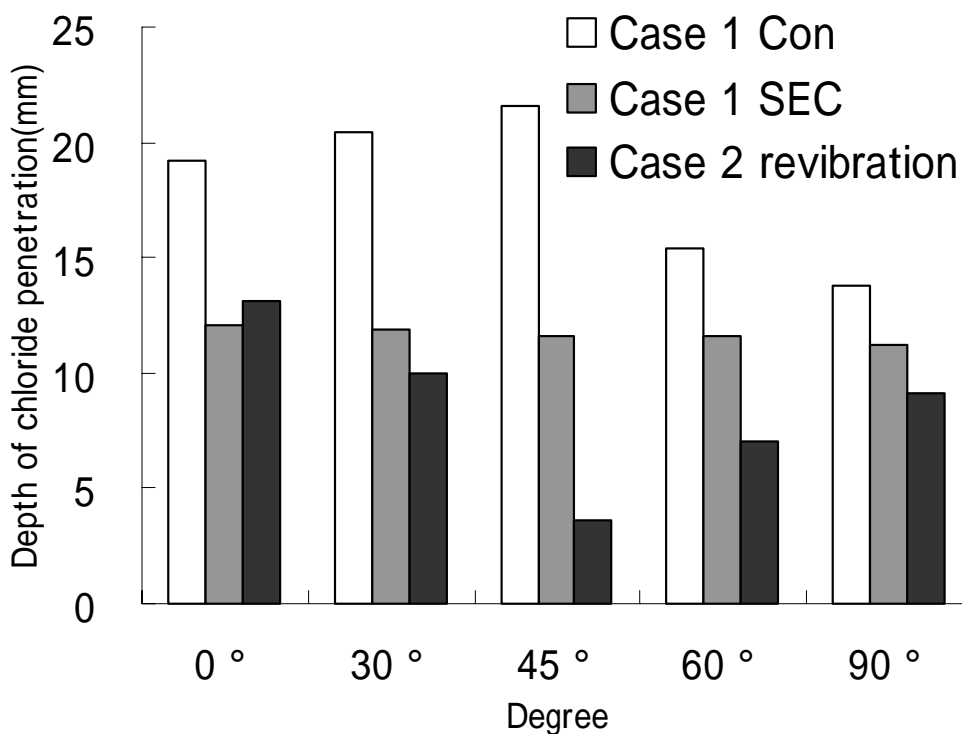
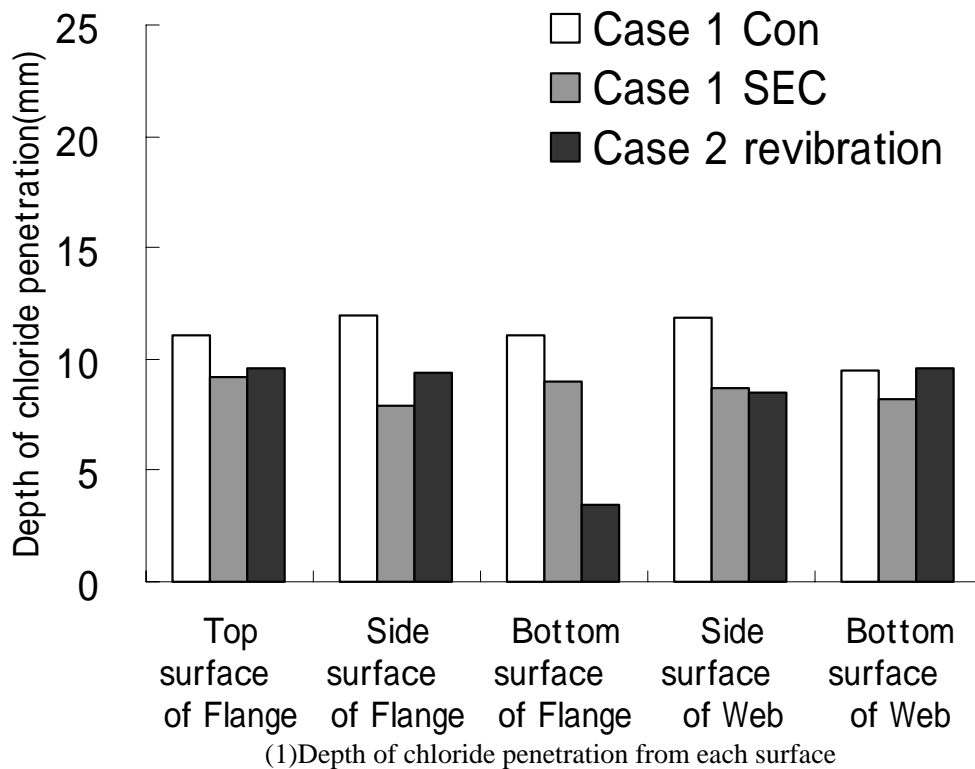


Fig.10 Distribution of chloride estimated assuming constant diffusion coefficient of chloride ion

–cement ratio, the deeper the chloride penetration from every surface. As shown in Fig.8 (2) and Fig.9, at the corner between flange and web of T-section, chloride penetration deeper in direction of 45° compared to the other direction, however the distribution of chloride estimated by assuming the constant diffusion coefficient of chloride ion is shown in Fig.10. On the other hand, as shown in



(2) Depth of chloride penetration in each degree at the corner between flange and web
Fig.11 Accelerated test results for chloride penetration into T-section specimen soaked in NaCl solution for 1 month (Mix 2, Case 1,2)

Fig.9 and Fig.11, revibration or SEC mixing technique make the chloride penetration from every surface and corner between flange and web shallow. The reason of these tendencies may explain that the bleeding water going up through the boundary between form and concrete surface of web runs into the space formed by settlement of cement and

aggregate against bleeding of water at the corner between web and flange in the direction of 45°. In conventional case, so that the small bleeding concrete, is case 1 SEC mixing technique, can improve the distribution of chloride to be uniform. And also the revibration tends to distribute again the remained bleeding water in concrete, but the

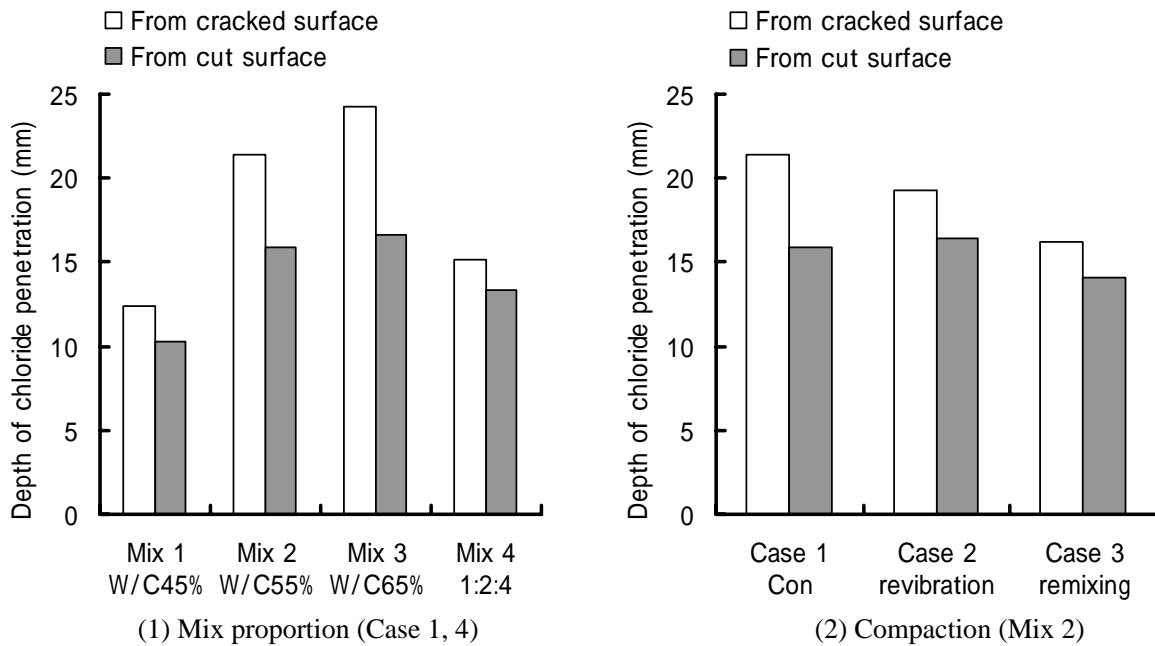


Fig.12 Accelerated test results for chloride penetration from cracked surface and cut surface of rectangular specimen soaked in NaCl solution for 1month

distribution is not so effective at the corner compared to the other part.

3.2 Chloride diffusion from cracked section and cut section

The comparison between the depths of chloride penetration from cracked section and cut section is shown in Fig.12. The chloride diffusion from the cracked section was much faster than that from the cut section by the concrete cutter. This tendency was remarkable when water-cement ratio was higher as shown in Fig.12 (1). As shown in Fig.12 (2), even in case of same mix proportion, revibration or remixing can make the difference between cracked section and cut section smaller. The reason is considered that the interface between aggregate and cement paste loosened easier under cracking when the more bleeding water remains around the aggregate, re-distribution of bleeding water by revibration or remixing to reduce bleeding of water is effective to reduce the difference.

4. Conclusion

Based on the results obtained from the

experiment, the following conclusions can be drawn.

1) It is very difficult to make chloride diffusion in concrete isotropic and uniform, because complex path formed under bleeding of water must remain in hardened concrete. To achieve more isotropic concrete, the remixing to reduce the bleeding and the revibration to distribute the path of bleeding are very effective ways, and proportioning to reduce the bleeding is also effective.

2) Chloride diffuses faster at the part where the bleeding water tends to remained, corner of T section and bottom surface of flange for example. This influence can be improved by the revibration and/or the decrease of bleeding by mix proportion and/or mixing technique i.e. SEC mixing method.

3) Chloride diffusion from the cracked surface was much faster than that from the cut surface by concrete saw. This tendency was remarkable when the water-cement ratio was higher and also when the remix and the recompaction were not done. The reason is considered that the interface between aggregate and cement paste loosened easier under cracking when the more bleeding water remains around the aggregate.