Verification of chloride adsorption effect of mortar with salt adsorbent

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Abstract. In order to investigate the chloride adsorption effect of mortar mixed with chloride adsorbent, electrophoresis test using mortar specimen and immersion dry repeated test were conducted to evaluate chloride adsorption effect. As a result, it was confirmed that soluble salt content that causes corrosion of rebar in the specimen was reduced by the chloride adsorbent and corrosion inhibiting effect of the rebar was also obtained. It was also confirmed that by increasing dosage of the chloride adsorbent, the chloride adsorbing effect becomes larger as well.

1. Introduction
Recently, deterioration of the RC structure caused by corrosion of the rebar due to penetration of chloride ion is being concerned. Salt damage often causes fatal cracking and peeling of concrete member due to expansion of corroded rebar. Ground structure under construction in the high economic growth period, especially common precast products such as RC segments for bridge on the coast are aged and intruded chloride ion, as the result, deterioration by the salt damage can be observed. Therefore, countermeasures against salt damage deterioration are being required and developed restorative materials mixed with salt adsorbent [1]-[5].

At the same time, a new durable RC structure capable of suppressing salt damage deterioration is being desired for extension of lifetime of the RC structure. [6]-[12] Salt content which is a deterioration factor of the RC structure penetrates from the surface through cover portion which is the surface layer. If it is possible to immobilize the infiltrated soluble salt in the cement hydrate, it is considered that deterioration of the infrastructure by salt damage can be suppressed. In this research, focusing on the cover zone of the newly constructed RC structure, the electrophoresis test and a dry-immersion repetition test to confirm salt adsorption effect by salt adsorbent in the mortar were conducted respectively, furthermore, under severe salt damage deterioration environment, the corrosion of rebar in two tests which verified by self-potential and polarization resistance value were investigated.

2. Experiment summary
2.1. Materials used
The chloride adsorbent used in this study is a high performance salt adsorbent which is sort of layered hydroxide of magnesium-aluminum. High performance chloride adsorbent (hereinafter referred to as HPCA) has the ability of intercalation to capture an anion by layers and release retained...
a cation. In this study, in order to improve the adsorption and exchange performance, nano-sized HPCA of which crystallite size is around 10 nm, and nitrate ion (NO3\(^-\)) retained in the interlayer to prevent corrosion of rebar, and nitric acid type HPCA which simultaneously releases nitrate ions was used as a salt adsorbent. Figure 1 shows the image of chloride ion (Cl\(^-\)) adsorption and nitrate ion (NO3\(^-\)) release of the salt adsorbent.

![Figure 1: Salinity absorption image diagram](image)

### 2.2. Compounding condition

For the specimens used for the electrophoresis test, ordinary portland cement, Toyoura standard sand were used. In addition, water cement ratio of the mortal was controled to 50%. The specimens were cut to 50 mm in thickness after 14 days of sealing curing and sealed on the circumferential surface other than the test surface was used.

HPCA was replaced by volume of sand by 20% of the mass of cement. Table 1 shows the mix proportions of specimens. Table 2 shows the sample used in the dry-immersion repetition test in Table 2. Table 3 shows the formulation of the mortar in the covered part. The salt adsorbent was replaced by the volume of the fine aggregate and added 0, 5, and 10% at the end. The outline of the specimen is shown in Fig. The red part is a mortar mixed with a salt adsorbent. Epoxy resin was applied except for the cover surface. Therefore, chloride ions were adjusted so as to permeate only from the fog surface.

| Table 1: Mortar mixing method |
|-----------------------------|
| Type of specimen | W/C (%) | Unit weight (kg/m\(^3\)) |
| N-0% | 50 | 303 605 1210 0 |
| N-20% | 100 | 1072 121 |

| Table 2: Materials used |
|-------------------------|
| Material | symbol | Type | Density (g/cm\(^3\)) |
| Cement | C | Ordinary Portland cement | 3.15 |
| Fine aggregate | S1 | Land sand from the Oikawa | 2.59 |
| HPCA | S2 | High performance chloride absorbent | 2.3 |
| Coarse aggregate | G | Crushed stone from Sagamihara | 2.67 |
| Admixture | Ad | AE water reducing agent | - |
Table 3: Mortar mixing method

| W/C (%) | Unit weight (kg/m³) |
|---------|---------------------|
|         | W  | C  | S1 | S2 | Ad |
| H0 40   | 275 | 689| 1194 | 0 | C×0.23 |
| H5 34   | 1155 | 34 | 1115 |
| H10 69  | 1116 | 69 |

2.3. Experimental condition

Exam. 1
In the electrophoresis test, a specimen with a diameter of 100 mm and a thickness of 50 mm was placed between the electrodes using a 0.5 mol / L sodium chloride aqueous solution on the cathode side and 0.3 mol / L sodium hydroxide aqueous solution on the anode side, and a direct current constant voltage of 15 V was applied. The outline of the test is shown in Figure 3. To verify the salt adsorption effect of HPCA, each solution at both poles was not exchanged. Afterwards, the solution was collected and measured the chloride ion concentration.

Exam. 2
During dry-immersion repetition test, penetration of chloride ion into specimen used was observed by soaking the specimens in a 3% brine solution at a temperature of 40 °C and a humidity of 60%, repeating dry and humidity, immersing them for 3 days and 4 days drying was defined as one cycle and natural potential and polarization resistance were measured at each cycle, and a total of 19 cycles were performed.

Figure 2: Schematic of the specimen

Figure 3: Electrophoresis test summary
3. Results and discussions

Exam. 1
Changes with time of the chloride ion concentration on the cathode side and the anode side are shown in Figure 4.

Changes over time of the nitrate ion concentration on the anode side are shown in Figure 5. As shown in Figure 4, in compare with the control, it was confirmed that specimen with HPCA were effective to decrease amount of chloride ion, but from the result of Figure 5, it was also confirmed that the increase of chloride ion in HPCA mixed specimens was smaller than control.

Exam. 2
Figure 6 shows the polarization resistance of each specimen, and Figure 7 shows the natural potential of each specimen. From the result of Figure 6, it was observed that each sample shows the same corrosion tendency until the 12th week.

There was a difference in each specimen from 13 weeks, and corrosion proceeded with H 0 at each subsequent cycle number, but it can be seen that the HPCA-added mortar (H 5, H 10) maintained a relatively natural potential. This phenomenon is presumed to be a result caused by chloride ion adsorption effect by HPCA.

In Figure 7, each specimen did not show in a state of corrosion tendency until week of 12. There is a difference in each sample, and H 0 tends to corrode even if the next cycle number overlaps from week of 13 to week of 18, H 5 showed a slightly higher polarization resistance than H 0. On the other hand, H 10 showed significantly higher polarization resistance value than the other two samples, therefore this indicates that HPCA has good potential of corrosion control effect.

However, in both H 5 and H 10, the polarization resistance value decreased at 19 weeks. This is thought to be due to the effect of salt adsorbent decreasing at week of 19.

4. Conclusion
Chloride adsorption effect of mortar with HPCA which is chloride adsorbent was verified by the electrophoresis test.

As a result, and it was verified that the penetration of the chloride ion was suppressed.

Dry-immersion repetition test was conducted to verify the effect of chloride adsorption under severe salt damage deterioration environment. As a result, it can be confirmed from the natural potential that the corrosion of rebar is alleviated by adding HPCA to the cover layer of the mortar. From the polarization resistance value at the cover layer of the mortar, it is verified that when the salt adsorbent is added by 10% of the cement amount, the effect increases.

By the two tests, it is considered that addition of HPCA to the mortar prevents chloride ions infiltration from the surface to the depth of rebar embedded and adsorbs chloride ion and releases...
corrosion inhibitor to suppression of rebar corrosion. Furthermore, it was verified that adsorption effect of HPCA was greatly improved as the dosage of HPCA increases.

![Figure 6. Natural potential](image6.png)

![Figure 7. Polarization resistance value](image7.png)

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