

STUDY ON PREVENTION FOR SALT DAMAGES USING CA2 AND EXPANSIVE MATERIAL APPLYING DIFFERENT CEMENT TYPE

Takafumi Ito¹, Shinya Ito, Minoru Morioka² and Takeshi Iyoda³

¹Graduate Student, School of Eng, Shibaura Institute of Technology, Tokyo, Japan

²Denka Co., Ltd., Niigata, Japan

³Professor, Shibaura Institute of Technology, Tokyo, Japan

ABSTRACT: Salt damage is one of the serious causes of deterioration in reinforced concrete structures. In this research, we focused on the calcium aluminate materials (CA2 and CA aggregate) which is for salt damage prevention. Calcium aluminate materials react with calcium hydroxide from cement hydration and make hydrocalumite. Thus, the free chloride ion is reduced. Finally, concrete using calcium aluminate materials have high resistance for salt damage. The results of the test, LPC concrete using CA aggregate has low resistance for chloride ion than OPC concrete using that. So, we checked the hydration products using CA aggregate on X-ray Diffraction (XRD). As a result, CA aggregate has reacted in concrete both OPC and LPC. The cause of the difference in the result of the OPC and the LPC is difference of the size of the area of the aggregate interface.

1 INTRODUCTION

There are various types of deterioration of reinforced concrete structures. In particular, we have to care for salt damage in Japan. Salt damage causes cracks due to the expansion pressure of the rebar, leading to such as falling cover concrete.

In this research, we focused on calcium aluminate materials. Calcium aluminate materials generate hydrocalumite while reacting with calcium hydroxide at hydration. This hydrocalumite immobilize chloride ion as Friedel's salt. Thus, the soluble chloride ion is reduce. Finally, concrete using calcium aluminate materials have high resistance for salt damage.

In this research, we made and tested concrete using two types of calcium aluminate materials and expansive additive. Expansive additive is used for the purpose of suppressing shrinkage. We are considering that these materials are used at harbor structure in the future. Using these concrete, we checked the resistance for chloride ion by immersed test in salt water. And, we also confirmed compressive strength and resistance for carbonation.

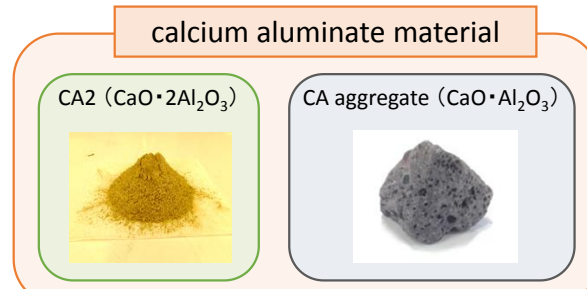


Figure 1. Calcium aluminate material

2 EXPERIMENTAL OUTLINE

2.1 Using material and specimen specifications

Figure 1 shows the two types of calcium aluminate materials. One is $\text{CaO} \cdot 2\text{Al}_2\text{O}_3$ (CA2) which is powder, the other is $\text{CaO} \cdot \text{Al}_2\text{O}_3$ (CA) which is coarse aggregate. These reactions are shown in formula (1), (2).

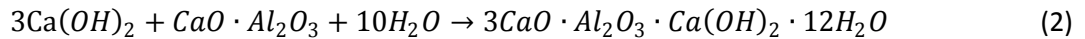
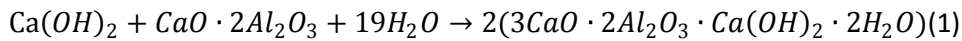


Table 1 shows the chemical composition of the binder and CA aggregate. Calcium aluminate materials are mainly composed of Al_2O_3 . The expansive additive contains much SO_3 .

Table 2 shows the mix proportion of concrete and fresh properties. Water-Binder ratio (W/B) and unit water content (W) are constant in all of concrete, and using cements are ordinary Portland cement (OPC) and low heat Portland cement (LPC). In this research, CA2 and the expansive additive were replaced with the cement. Curing method is in water for 28 days. From the results of the fresh properties, slump of concrete using CA aggregate is lower than normal concrete. This trend was confirmed by both OPC and LPC. This is because, CA aggregate has high water absorption and reacts rapidly.

Table 1. Chemical composition of the binder and CA aggregate

	contents(mass%)							Specific surface area [cm ² /g]	Density [g/cm ³]
	CaO	SiO ₂	Al ₂ O ₃	SO ₃	Fe ₂ O ₃	MgO	R ₂ O		
OPC	64.09	20.45	5.15	2.09	3.04	0.89	0.57	3240	3.16
LPC	63.08	26.18	2.73	2.33	3.11	0.95	0.41	3760	3.24
CA2	23.96	0.64	67.73	0.01	7.09	0.27	0.21	3100	2.96
Ex	70.6	1.0	7.2	18.5	0.8	-	-	2840	3.05

	contents(mass%)						Density [g/cm ³]
	CaO	SiO ₂	Al ₂ O ₃	S	FeO	MgO	
CA aggregate (G')	31.7	4.6	55.6	0.18	0.9	0.89	3.16

Table 2. Mix proportion of concrete and fresh review

	Cement Type	W/B (%)	Unit Weight (kg/m ³)							Fresh Properties		
			W	C	CA2	Ex	S	G	G'	Slump	Air	
N0	OPC	50	170	340	-	-	835	955	-	15	3.5	
N100					-	-	924	-	917	3.0	4.5	
N0-CA2				320	20	-	834	955	-	10	6.0	
N100-CA2					20	-	922	-	917	2.0	5.2	
N0-CA2-Ex				300	20	20	833	955	-	18.0	5.0	
N100-CA2-Ex					20	20	922	-	917	4.0	6.0	
L0	LPC		50	170	340	-	-	833	955	-	20	3.2
L100						-	-	922	-	917	10	5.2
L0-CA2					320	20	-	832	955	-	13	4.8
L100-CA2						20	-	921	-	917	4.0	5.1
L0-CA2-Ex					300	20	20	832	955	-	18.0	4.5
L100-CA2-Ex						20	20	920	-	917	4.5	5.4

2.2 Testing method

2.2.1 Compressive strength test

After 28 days of water curing, we had a compressive test of concrete reference to JIS A 1108-2006. The specimen size is $\phi 100 \times 200$ (mm).

2.2.2 Salt water immersion test

Figure 2 shows the method of salt water immersion test. After 28 days of water curing, the specimen (100×100×400mm) was coated with epoxy resin except one side surface. Then, the specimen was immersed in NaCl 10% solution. The specimen was split in the age of 1, 2, 4, 8 weeks, and was sprayed 0.1N silver nitrate solution on the split surface. After that, the part which was colored in white was measured as the penetration depth of chloride ion. Penetration depth is an average of seven point's measurement.

2.2.3 Accelerated carbonation test

Calcium aluminate materials consume calcium hydroxide at hydration, so the concrete addition of calcium aluminate materials may be lowered alkaline. So, we checked the resistance for carbonation.

Figure 3 shows the method of accelerated carbonation test. After 28 days of water curing, the specimen (100×100×400mm) was coated with aluminum tape except one side surface. Then, the specimen was put in the carbonation testing chamber. It was kept at temperature was 20 degree Celsius, Relative humidity was 60% and concentration of carbon dioxide was 5%. The specimen was split in the age of 1, 2, 4, 8 weeks, and sprayed 1% phenolphthalein solution on the split surface. After that, the part which was not colored in purple was measured as carbonation depth. Depth is an average of seven point's measurement.

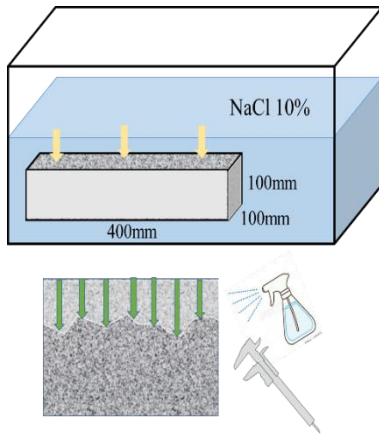


Figure 2. Salt water immersion test method

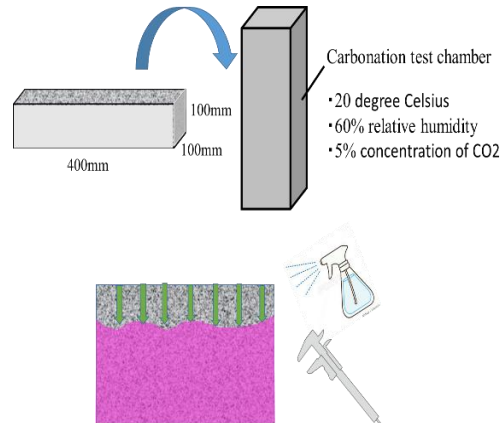


Figure 3. Accelerated carbonation test method

3 RESULTS AND DISCUSSIONS

3.1 Compressive strength test

Figure 4,5 show the result of compressive strength in water 28 days. Figure 4 shows result of OPC concrete, and Figure 5 is LPC. Compressive strength of concrete addition of CA2 are not decreased both OPC and LPC. In the case of adding CA aggregate, strength in OPC is not decreased, the strength in the LPC is reduced. On the other hand, in the case of adding expansive additive, strength was lower than other concrete both in OPC and LPC. In this research, CA₂ and the expansive additive was replaced with cement as binder ratio is constant. Therefore, decreasing in strength is affected that the decreasing of total cement content.

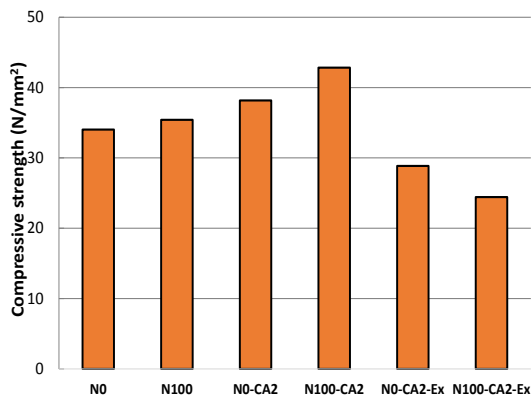


Figure 4. Compressive strength at 28 days (OPC)

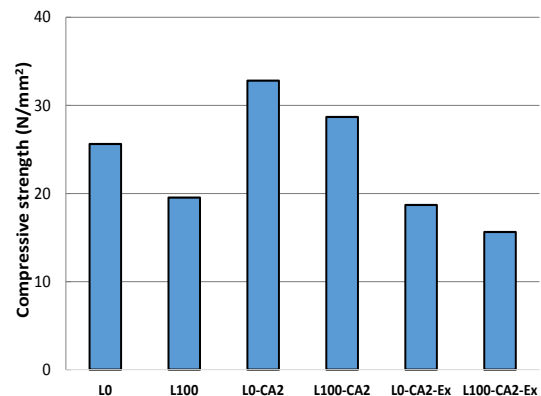


Figure 5. Compressive strength at 28 days (LPC)

3.2 Salt water immersion test

Figure 6 shows the penetration depth of chloride ion during 8 weeks at OPC concretes. The resistance to chloride ion is increased by addition of calcium aluminate material. In the case of adding expansive additive, the concrete can keep the ability for chloride ion.

Figure 7 shows the penetration depth of chloride ion during 8 weeks at LPC concretes. The concrete addition of CA2 has high resistance for chloride ion. However, the effect of the improvement is small by addition of CA aggregate. In the case of adding expansive additive, the concrete can keep the ability for chloride ion as well as OPC.

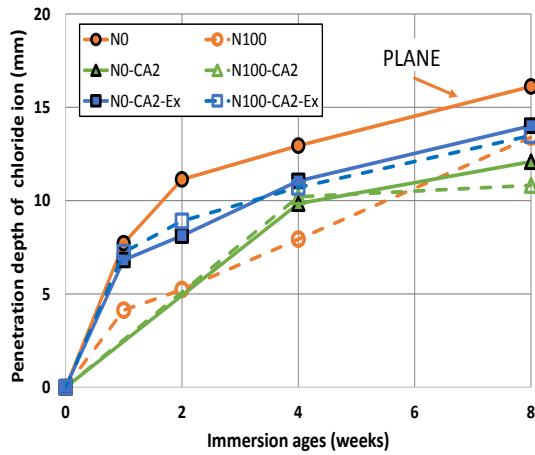


Figure 6. Penetration depth of chloride ion (OPC)

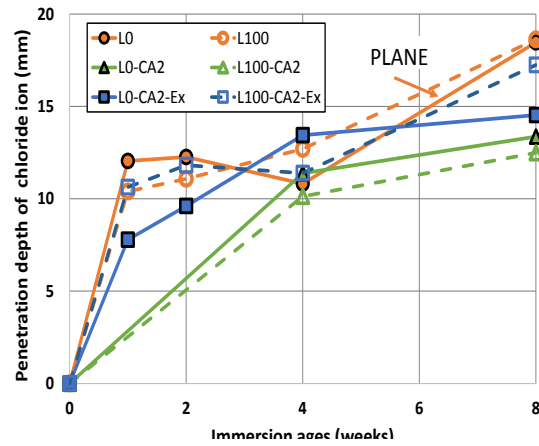


Figure 7. Penetration depth of chloride ion (LPC)

3.3 Accelerated carbonation test

Figure 8, 9 show the carbonation depth during 8 weeks. In the case of adding CA aggregate, the resistance for carbonation is reduced. This is because consuming $\text{Ca}(\text{OH})_2$ by the reaction of CA aggregate. In addition, the concrete's addition of CA2 and expansive additive are also not good for carbonation. This is because decreasing of $\text{Ca}(\text{OH})_2$ by decreasing of total cement content and consumption by the addition of calcium aluminate materials.

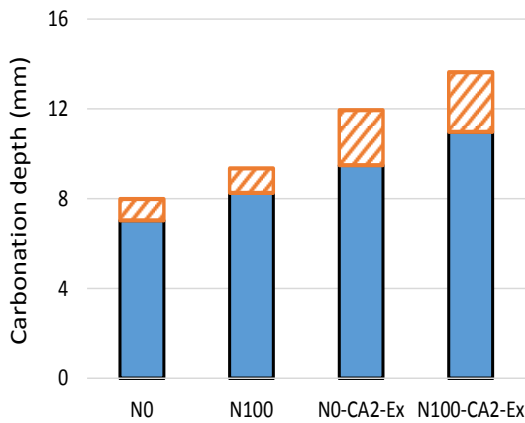


Figure 8. Carbonation depth (OPC)

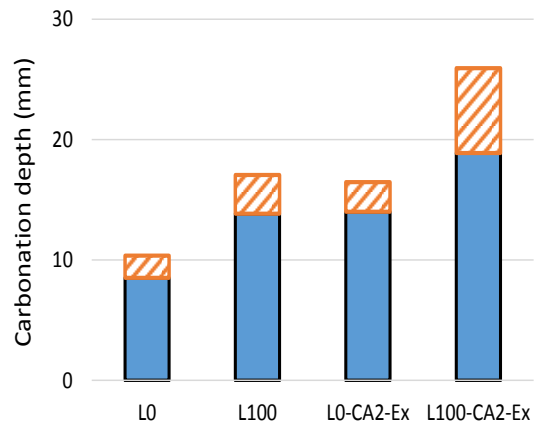


Figure 9. Carbonation depth (LPC)

4 CHEMICAL ANALYSES

From these test results, we find that the concrete with addition of CA aggregate is different between LPC and OPC at resistance for chloride ion. So, we have examined the differences in the reactivity of CA aggregate between LPC and OPC.

To check the difference in OPC and LPC, we remove CA aggregate from specimen of salt water immersion test. CA aggregate was removed from area which chloride ion was penetrating. After removing the CA aggregate, it was all crushed. And we checked the hydration products by X-Ray diffraction (XRD). Figure 10 shows the results of XRD test. There is the peak of Friedel's salt close of 11° both OPC and LPC. Therefore, CA aggregate is reacted in concrete both OPC and LPC.

From this result, the LPC concrete with addition of CA aggregate has resistance potential for chloride ion. First of all, CA aggregate was expected to improve the aggregate interface (interfacial transition zone). LPC concrete curing 28 days of water, interfacial transition zone is bigger than OPC. So, even if we used CA aggregate, it can't fill the area of the aggregate interface. However, this is an issue that should be considered in the future.

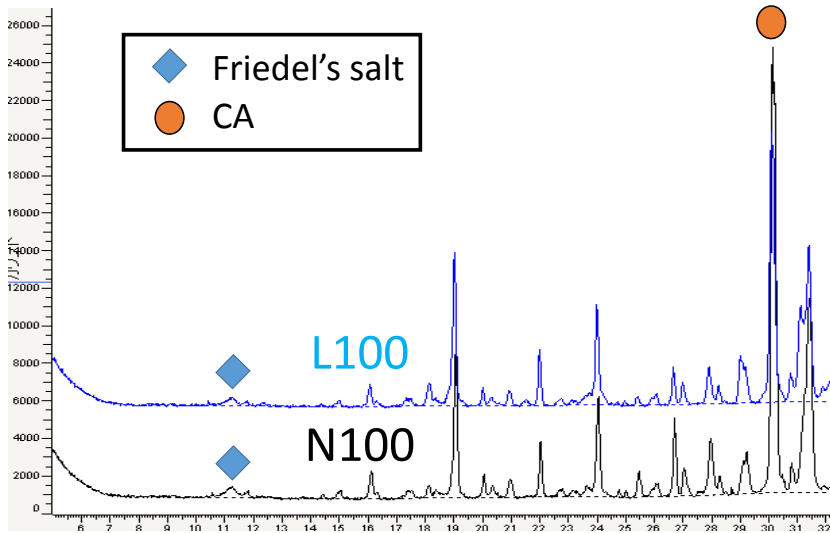


Figure 10. XRD result (OPC and LPC)

5 CONCLUSION

- 1) Slump of concrete using CA aggregate is lower than normal concrete. The reason for this, CA aggregate has high water absorption and reacts rapidly.
- 2) At compressive strength test, strength was increased in the case of adding CA2 both OPC and LPC. In the case of adding expansive additive, strength was lower than other concrete both in OPC and LPC. This is because of decreasing of total cement content. In the case of adding CA aggregate, strength of OPC was increased, but the strength of LPC decreased.
- 3) At accelerated carbonation test, CA aggregate, CA2 and expansive additive reduce the resistance of carbonation. This is because of decreasing of total cement content and Ca(OH)_2 .
- 4) At salt water immersion test, concrete with addition of CA2 has high resistance for chloride ion. On the other hand, concrete with addition of CA aggregate has low resistance for chloride ion only LPC concrete. However, CA aggregate has reacted in concrete both OPC and LPC. The reason for low resistance at only LPC concrete, there is a need for additional experiments.

6 REFERENCES

- (1) K Tahara, K Yamamoto, H Ashida, M Morioka. (2010) "Immobilization ability of chloride ion of the cement hardened body which mix the $\text{CaO} \cdot 2\text{Al}_2\text{O}_3$." Cement Science and Concrete Technology, No 64.
- (2) K Tahara, K Miyaguti, M Morioka, K Takewaka. (2011) "Immobilization ability of hydration behavior and chloride ions of the cement hardened body in a variety of types of mixed the $\text{CaO} \cdot 2\text{Al}_2\text{O}_3$." Cement Science and Concrete Technology, No 65.

- (3) T Ito, T Iyoda, S Ito, M Morioka.(2015) "Study on effect of prevention for chloride ion using both of CA2 and expansive additive to Low heat Portland cement" The 16th JSMS Symposium on Concrete Structure Scenarios.