Study on the relationship between de-icing material and concrete durability

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Abstract

The purpose of this study is to evaluate the influence of some types of de-icing material used for improving road surface friction on concrete durability. Specifically, anti-frost-damage to concrete caused by CMA (Calcium Magnesium Acetate) and NaCl when they were used as de-icing agent were studied by investigating past researches, conducting substantiation tests and analyzing the resultant data. The main causes of deterioration were clarified and an appropriate deterioration prediction equation was thus obtained.

1. Introduction

In snowy and cold region, the friction between road surface and tires must be keep in the safety level in winter season. de-icing agents used to prevent sliding, NaCl (Sodium chloride) and CMA (Calcium Magnesium Acetate) influenced durability of concrete by freezing and thawing in winter.

The purpose of this study is to evaluate the influence of some types of deicing material used to improve road surface friction on concrete durability by investigating past researches, conducting substantiation tests, and analyzing the resultant data. The main causes of deterioration was clarified, and an appropriate deterioration prediction equation was theses obtained.

2. Method

2.1 Study method

The flow chart of study method is shown in Fig. 1.

2.2 Experiment method

The properties of CMA and NaCl as de-icing agents in the substantiation test are shown in Table 1. The test was conducted in accordance with ASTM C672. The specimens were cured after 14 days in water and 14 days in air. Mix proportion and property of fresh concrete of sustainable test specimens are shown in Table 2. The freeze-thaw test was done

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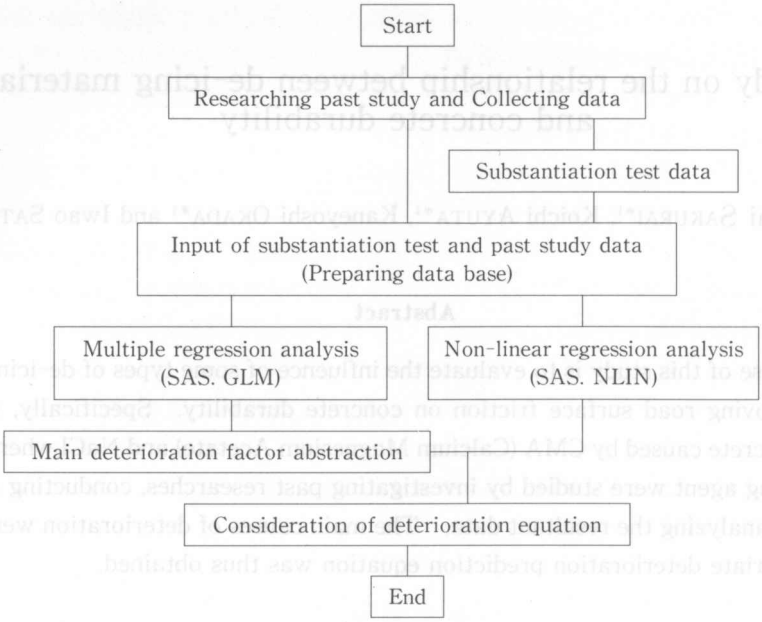

Fig. 1 Flow chart of study mehod

when the center of the specimen reached 8 °C to −18 °C. The evaluation of surface scaling by visual measurement were graded at 11 levels, which is more detailed than as prescribed ASTM C672. The scaling weighed 0.1 g.

Table 1 Ingredients of de-icing material in substantiation test

Element	Content		Element	Content	
	CMA (wt.%)	NaCl (wt.%)		CMA (wt.%)	NaCl (wt.%)
O	43	—	Cl	0.034	60
C	38	—	S	0.031	<1
Mg	9.8	<0.1	K	0.012	<0.1
Ca	8.6	<1	Na	—	38
Si	0.17	traces	Br	—	<0.1
Al	0.078	—	Cr	—	<0.1
Fe	0.058	—	Ni	—	traces
Cu	—	traces	Sr	—	traces
Zr	—	traces	—	—	—

Table 2 Mix proportion and property of fresh concrete of substantiation test specimen

Case	Mix proportion							Property of fresh concrete	
	W/C (%)	s/a (%)	Unit weight (kg/m³)					Slump (cm) (%)	Air content
			W	C	S	G	AE agent (cc/m³)		
1	40	33.2	139	348	620	1251	107.9	2.5	4.1
2	50	35.2	142	278	678	1251	58.4	3.5	4.1
3	60	39.2	139	232	771	1198	39.4	2.5	4.2

2.3 Analysis method

The analysis were done by the Statistical Analysis System (SAS). In order to grasp the main deterioration factors and their tendency of plus and minus, they were abstracted by correlation analysis and multiple regression analysis. In order to be able to predict deterioration precisely, the exponent functions of 3 populations parameter and 2 populations parameter as following equation (1) and equation (2) were assumed. The coefficients of population parameters were estimated by non-linear regression analysis.

3 populations: $SCAL = A \cdot CYCL \cdot Exp(-C \cdot CYCL) + B$ ·····Equation (1)

2 populations: $SCAL = A \cdot (1 - Exp(-B \cdot CYCL))$ ·····Equation (2)

where SCAL: Surface scaling weight (g/cm²), CYCL: Cycles of freeze-thaw, A, B and C: Parameters.

3. Result and Consideration

The relationship between visual measurement evaluation and cycles of freeze-thaw is shown in Fig. 2. The relationship between surface scaling weight (g/cm²) and cycles of freeze-thaw is shown in Fig. 3. In the case of NaCl, visual measurement evaluation and the surface scaling weight increased remarkably as the water-cement ratio (W/C) was increased such as 60 %. On the other hand in the case of CMA, little surface scaling occurred in high water-cement ratio such as 60 %. But its scaling was less than in the case of NaCl. The comparatively high correlation factors such as W/C and air content of internal deterioration factor, and cycles of freeze-thaw of external deterioration factor were abstracted by correlation analysis to the data base. The results of multiple regression analysis with the factors are shown in Table 3. According to the results, cycles of freeze-thaw and W/C were positive correlation factors. The air content was negative correlation factor. The reason that the ratio of variance in the case of NaCl is smaller than that of CMA seems to be due to the population of NaCl being larger and due to its distribution is better than that of CMA.

The result of non-linear regression analysis and ratio of visual measurement evaluation are shown in Table 4 and Fig. 4, in order to be able to predict deterioration precisely. The 2 populations function seems to be better than that of 3 populations, because the scaling weight did not decrease and there was no peak theoretically.

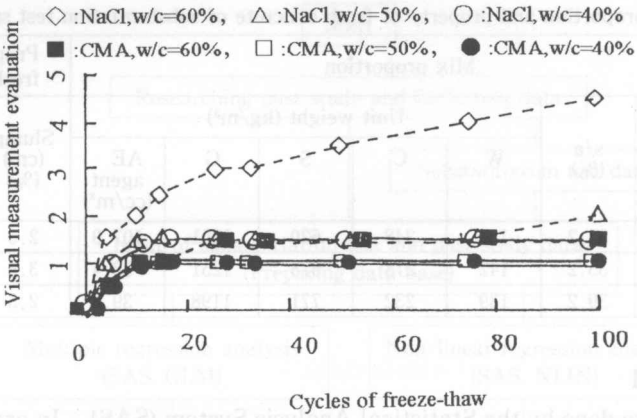

Fig. 2 Relationship between ratio of visual measurement evaluation and cycles of freeze-thaw

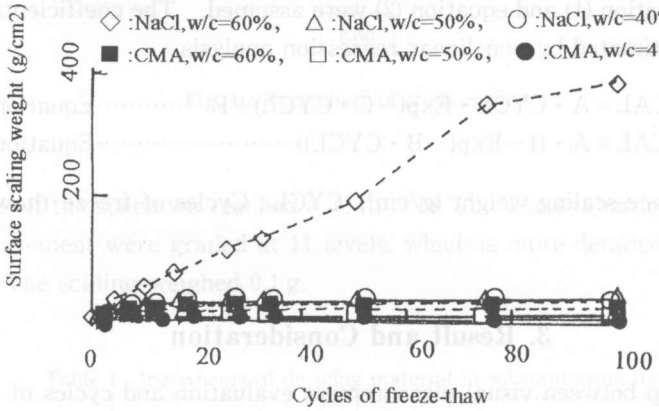

Fig. 3 Relationship between surface scaling weight (g/cm^2) and cycles of freeze-thaw

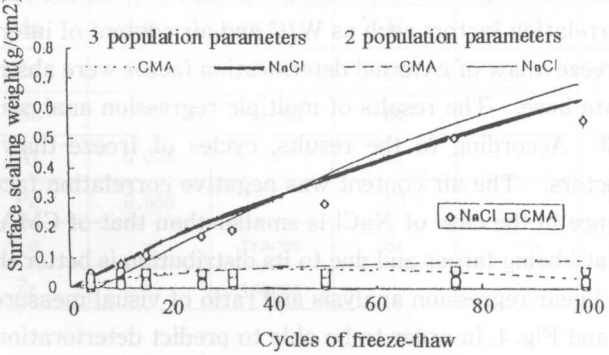

Fig. 4 Result of non linear regression analysis and ratio of eye measurement evaluation

Table 3 Result of multiple regression analysis (upper ; coafficients, lower : the ratio of variance)

Case	Subordination variable			Term of constant	Multiple correlation coefficients : (R^2)	F test value
	W/C	Air content	Cycles of freeze-thaw			
Nacl	0.024595 0.0001	−0.123259 0.0001	0.003694 0.0001	−0.688004 0.0001	0.5401	0.0001
CMA	0.002175 0.0024	−0.060930 0.3198	0.000498 0.5545	0.148292	0.1690	0.0041

Table 4 Results of non-liner regression analysis

Parameters	De-icing material	Coefficient of parameters		
		A	B	C
3 populations	NaCl	0.0105930987	−0.071716446	0.0037888800
	CMA	0.3381604497	−0.003723895	0.0332524967
2 populations	NaCl	1.132021081	0.007866780	−
	CMA	0.0452181027	0.1220690211	−

Photo-1 Result of substantiation test with solution of CMA 3% wt. (w/c=60%)

Photo-2 Result of substantiation test with solution of Nacl 3% wt. (w/c=60%)

4. Conclusion

The following conclusion can be drawn from the study on the relationship between deicing material and concrete durability.

1) The internal factors which influenced surface scaling weight were water cement ratio and air content. Those of external factor were cycles of freeze-thaw and type of de-icing agent.

2) CMA, a de-icing agent without salt, had very few surface scaling weight at water cement ratio : 40% and 50% and controlled enough at 60% than the de-icing agent with salt.

3) An appropriate deterioration prediction equation to surface scaling was obtained by non-linear regression analysis with 2 populations exponented function where the surface scaling weight was variable product and the cycle of freeze-thaw was variable subordinate.

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