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A STUDY OF RESTRAINT TECHNIQUES FOR CEMENT TREATED SOIL'S DETERIORATION BY MICROBIAL FUNCTIONS

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ABSTRACT: Cement treated soil is used as a countermeasure for poor ground. But, cement treated soil deteriorate by calcium leaching because of exposing seawater. This study considered a technology of reducing deterioration of cement treated soil by using urease-producing bacteria. Authors tested seawater exposure tests using 2 types of the urease-producing bacteria of *Sporosarcina aquimarina* isolated from the sea off the coast of Korea and *Bacillius pasteurii* isolated from land. The purpose of those tests is checking effect of reducing deterioration of cement treated soil by the urease-producing bacteria. At the same time, we performed tests to confirm the growth of the bacteria in cement treated soil. We tested seawater exposure tests 2 types of conditions of temperature 20℃ is used for exposure tests, and 30℃ is a temperature that is suitable for the growth of bacteria, the purpose of those tests is checking relation temperature and deterioration speed. The main outcomes are as follows: 1) 2 types of the urease-producing bacteria have an effect of reducing deterioration 2) 2 types of condition of temperature have relation to deterioration speed.

Keywords: cement treated soil, reducing deterioration, seawater exposure test, Micro Carbonate Precipitation

1. INTRODUCTION

In Japan, an alluvial bed develops in coastal zone, there are poor grounds. Therefore, Ground improvement is necessary to build the structure. Today, cement treated soil is used as a countermeasure for poor ground [1]-[2]. But, cement treated soil is deteriorate by the exposure of seawater. Cement treated soil exposures to seawater, deteriorate by calcium leaching because of exposing seawater [3]-[6]. Therefore it is necessary to examine long-term stability. This study considered a technology of reducing deterioration of cement treated soil by using urease-producing bacteria. Urea is hydrolyzed by urease, generates ammonia, carbonate ion, and hydrogen ion. This carbonate ion reacts with leaching calcium to form $CaCO_3$ in cement treated soil. Eq. (1) is hydrolyzing urea by urase-producing bacterium. Eq. (2) is formation of $CaCO_3$'s precipitation mechanisms [7].

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_3 + CO_3^{2-} + 2H^+ \quad (1)$$

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \downarrow \quad (2)$$

In addition, It had been reported that relations of strength and the condition of temperature, but the relations of deterioration and condition of temperature was unknown [8]. In this study, We tested seawater exposure tests 2 types of conditions of temperature 20℃ is used for exposure tests, and 30℃ is a temperature that is suitable for the growth of bacteria, the purpose of this tests are checking relation temperature and deterioration speed, relations of deterioration and condition of temperature were discussed.

2. MATERIAL AND METHOD

2.1 Seawater exposure test

In this study, author examined seawater exposure test of cement treated soil. Authors tested seawater exposure tests using 2 types of the urease-producing bacteria of *Sporosarcina aquimarina* isolated from the sea off the coast of Korea and *Bacillius pasteurii* isolated from land [9]. Table 1 shows both bacteria's characteristics [10]. Table 2 shows physical properties of potter's soil [11], and in Table 3 shows chemical composition and Particle size distribution of silica sand. Authors made test pieces by combination to show in Table 4 (case C's liquid medium include *B.pasteurii,* Case D's liquid mediums include *S.aquimarina*), Authors tested it according to a test flow to show in Fig.1. This test

Table 1 Characteristics of bacteria

	B.pasteurii	*S.aquimarina*
isolate source	land	coast
salinity tolerance (NaCl %)	10	13
optimum pH	9	6.5～7
anaerobiosis	+	+

Table 2 Physical properties of potter's soil

Soil particle density (g/cm^3)	2.47
Liquid limit (%)	43.2
Plastic limit (%)	12.1

Table 3 Chemical composition and Particle size distribution of silica sand

Chemical composition	SiO_2 (%)	93.3
	Fe_2O_3 (%)	0.3
	Al_2O_3 (%)	3.7
	L.O.I (%)	0.4
Particle size distribution	Particle size (µm)	(%)
	53	0.1
	75	0.5
	106	2.3
	450	9
	212	40
	300	46.9
	425	1.2

Table 4 combination table

Case	A	B	C	D
pure water (%)	21.05	20.99	14.43	
blast-furnace slag cement type B (%)	6.58	6.56		
potter's clay (%)	6.58	6.56		
silica sand (%)	65.79	65.57		
Urea (%)	0.00	0.33		
liquid medium (%)	0.00	0	6.56	6.56

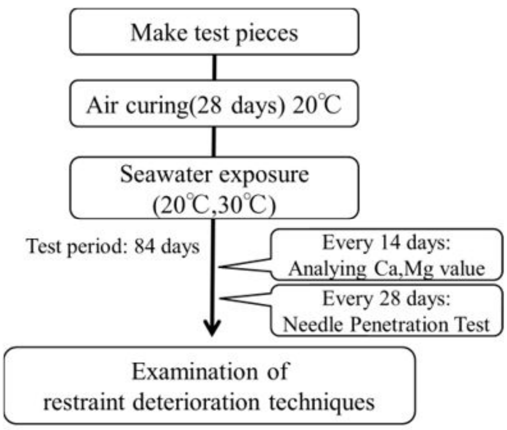


Fig.1 Test flow

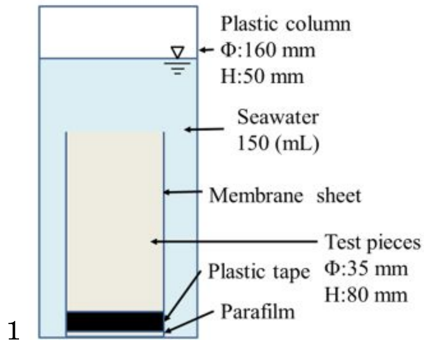


Fig. 2 seawater exposure test setup

Table 5 Seawater's composition table

Including elements	Cl, N, C, Na, Ca, Sr, Mg, K, B, S,Br
Ca^{2+} concentration (ppm)	125
Mg^{2+} concentration (ppm)	830
pH	8.32

Table 6 Combination of NH4-YE medium

Yeast extract (g)	20.0
$(NH_4)_2SO_4$ (g)	10.0
0.13 M Tris buffer (pH 9.0) (L)	1.0

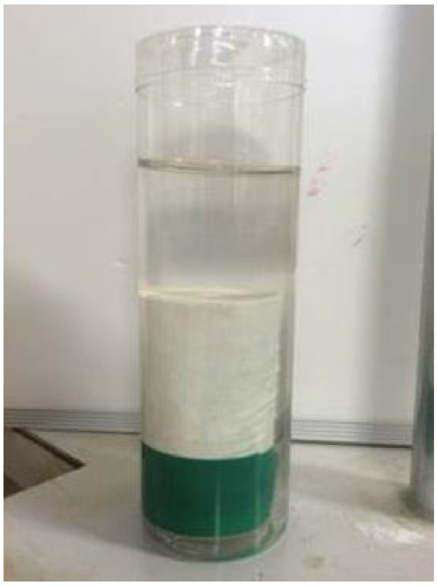


Fig. 3 The conditions of exposure test

pieces were sealed the side and the base like Fig.2, only the top surface of test pieces exposure seawater. Seawater used artificial seawater of commercially available. Table 5 shows Seawater's composition table.

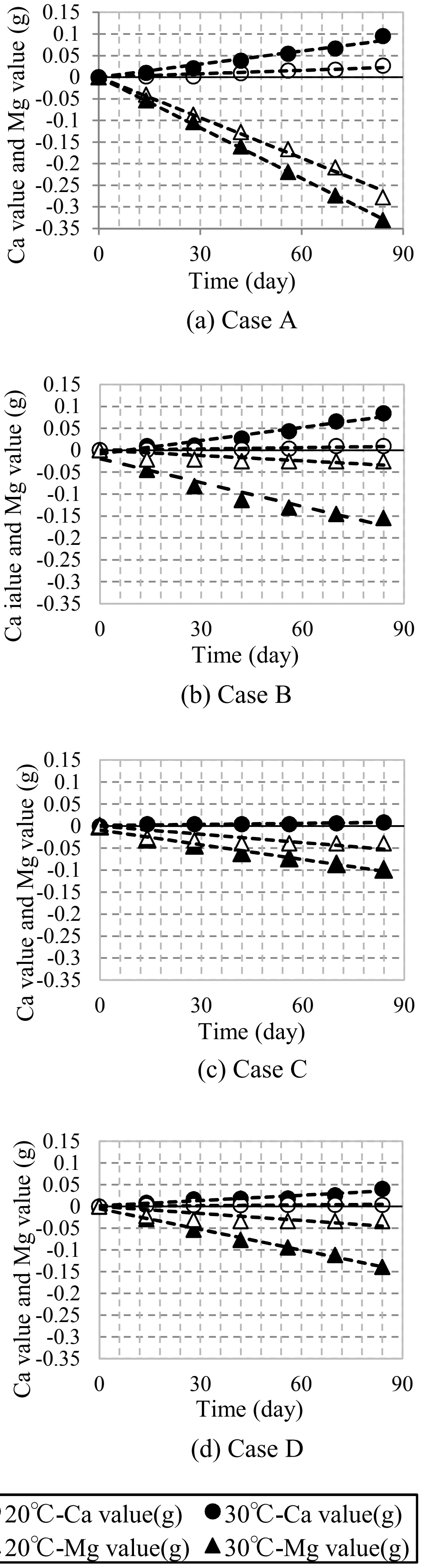


Fig.3 Ca value and Mg value

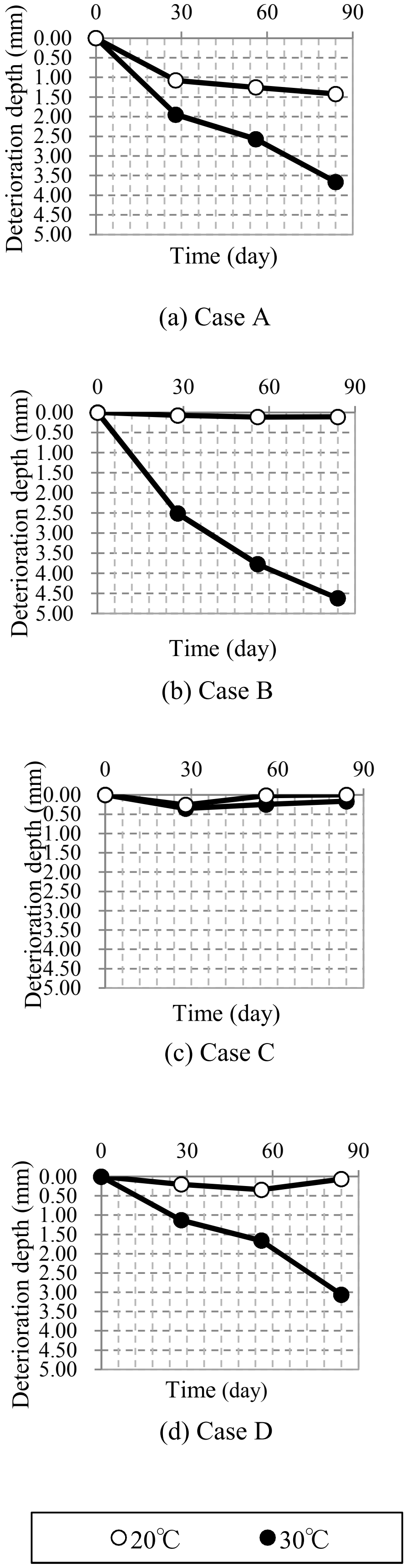


Fig.4 Deterioration depth

Test period is 84 days, seawater was sampled every 14days, changing water and testing needle penetration test every 28 days.

2.2 Needle penetration test

In needle penetration test, authors pricks the top surface and bottom surface with a needle, measure 2 types of penetration value. 2 types of penetration values difference assumed deterioration depth. Sampled water was analyzed Ca ion and Mg ion by Atomic Analyzer.

2.2 Condition of temperature

Authors tested seawater exposure tests 2 types of conditions of temperature 20℃ is used for exposure tests, and 30℃ is a temperature that is suitable for the growth of bacteria, the purpose of those tests is checking relation temperature and deterioration speed.

2.4 Growth of bacteria in cement treated soil

In case D, authors measured urease activity when finished air curing 28days for confirming the growth of bacteria under high alkali condition in cement created soil. Put part of test pieces in NH4-YE mediums (ATCC medium: 1376), grow for a week, measured urease activity. Table 6 shows combination of NH4-YE mediums.

3. RESULTS AND DISCUSSIONS

3.1 Ca leaching and Mg absorption

Fig.3 shows Analyzing results of Ca value and Mg value. This figure shows that it is leaching from test pieces when plots are increasing, and it is absorption from test pieces when plots are degreasing. In case A to D, Ca's plots are increasing, so Ca is leaching from test pieces. On the other hand, Mg's plots are decreasing, so Mg is absorption to test pieces.

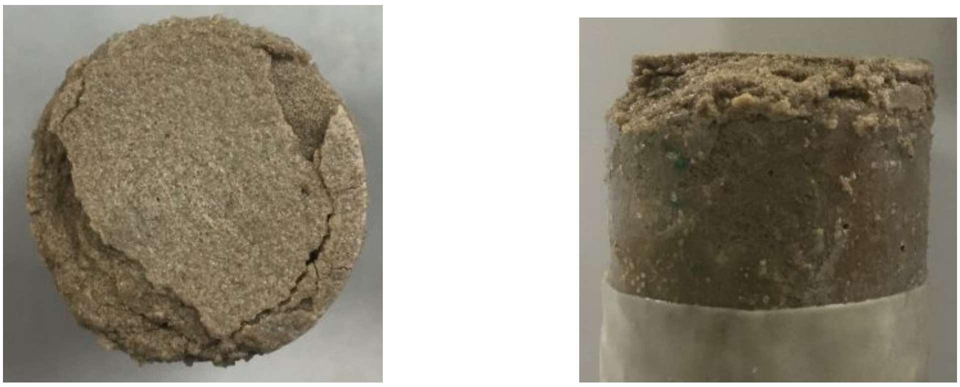
Moreover, 30℃ of temperature condition's Ca leaching and Mg absorption is more than 20℃ of temperature condition. From those trends, it is thought that temperature condition has relation to deterioration.

Therefore, in case C and D of including urease-producing bacteria, Ca leaching and Mg absorption value restrain in compared with case A and B that case without urease-producing bacteria.

3.2 Deterioration depth

Fig.4 shows deterioration depth of case A~D. in case A~D, 30 ℃ of temperature condition's deterioration depth is more than 20℃ of temperature

(a) Case A (20℃)



(b) Case A (30℃)

Fig.5 Condition of case A (84 days later)

Table 7 Urease activity of case D (including *S.aquimarina*)

	Before add to test pieces	After air curing 28days
Urease activity(U/L)	110.08	22.02

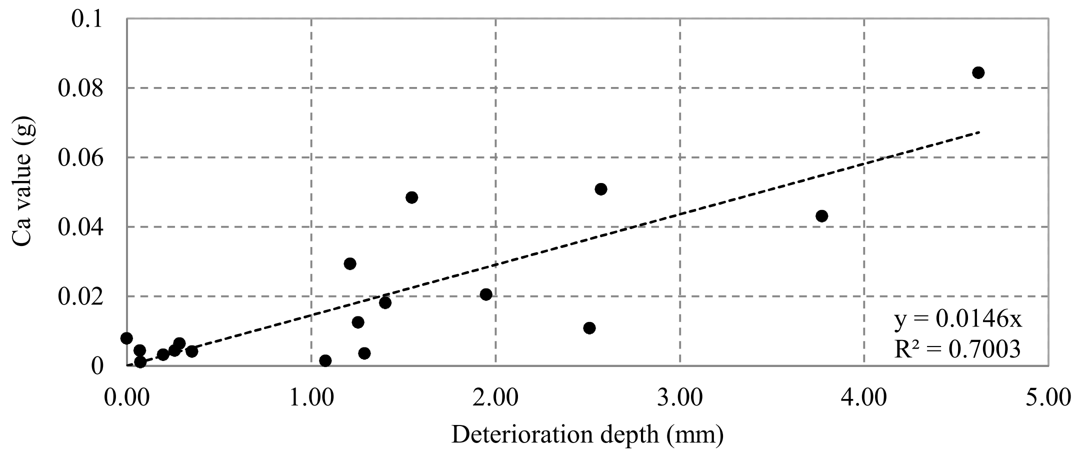


Fig.6 Relationship between Ca value and deterioration depth

condition. In addition, Fig.5 shows condition of case A at the time of the experiment end. As shown in Fig.5, Case A (20℃) was broken, but top surface of Case A(30℃) exfoliated. From those trends, it is also thought that temperature condition has relation to deterioration.

Therefore, in case C and D of including urease-producing bacteria, deterioration depth restrain in compared with case A and B that case without urease-producing bacteria. The factor affecting is $CaCO_3$ precipitated in test pieces' gap.

Especially, in both temperature conditions, case C is effective most in those cases.

3.3 Growth of bacteria in cement treated soil

Table 7 shows urease activity of case D. Urease activity of after air curing is 22.02 (U/L). Urease activity of after air curing decreased a one-fifth of urease activity of liquid mediums before add to test pieces, authors could be confirmed growth of bacteria.

3.4 Relation to Ca leaching value and deterioration depth

Fig.6 shows a relationship between Ca leaching value and deterioration. As shown in Fig.6, there are scattering, deterioration value increases with increase in calcium leaching value. Ca leaching value related to deterioration value. From this, authors thought to be able to estimate deterioration value by analyzing calcium leaching value in non-destruction.

4. CONCLUSIONS

In this study, Authors considered a technology of reducing deterioration of cement treated soil by using urease-producing bacteria. Authors tested seawater exposure tests using 2 types of the urease-producing bacteria of *S.aquimarina* and *B.pasteurii*. At the same time, we performed tests to confirm the growth of the bacteria in cement treated soil. We tested seawater exposure tests 2 types of conditions of temperature 20℃ is used for exposure tests, and 30℃ is a temperature that is suitable for the growth of bacteria. In addition, in case D, authors measured urease activity when finished air curing 28days for confirming the growth of bacteria under high alkali condition in cement created soil.

The main outcomes are as follows:

1) 2 types of the urease-producing bacteria have an effect of reducing deterioration. Especially, case C is effective most in those cases, *B.pasteurii* can be expected restraint techniques for cement treated soil's deterioration.
2) 2 types of condition of temperature have relation to deterioration speed. Deterioration speed becomes higher with temperature condition become higher.
3) Urease-producing bacteria growth under high alkali condition in cement treated soil, urease-producing bacteria may show restraint deterioration effects for a long term.
4) Analyzing calcium leaching value can estimate deterioration value in non-destruction.

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