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A STUDY ON GROUND IMPROVEMENT TECNIQUE WITH IN-SITU MICROOGANISMS ISOLATED FROM JAPAN

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ABSTRACT: Damage by a liquefaction phenomenon was a problem in recent years, and the Great East Japan Earthquake occurred on March 11, 2011 in Japan, and liquefaction damage occurred frequently. There is also more adoption of Paris agreement in COP21 of the end of last year, and correspondence to a global warming problem is also desired reduction in greenhouse effect gas amount of emission in the construction field. Therefore considered ground improvement technology is necessary for the environment in Japan an earthquake-ridden country. So we considered for practical use ground improvement techniques based microorganism. That is watched as new liquefaction countermeasure technology for reduction in cost and the point of view by which material and construction waste are reduction. In that ground improvement techniques, it is difficult to using specific microbes. So we aimed at Microbial carbonate precipitation using in-situ microorganism as the method to solve this problem. We made solidify sand using isolated microorganisms in japan and *Bacillus pasteurii* the solidification ability becomes clear. We measured to urease activity values of each microorganism. And we making of the test pieces, undrained cyclic triaxial test and acid decomposition for using $CaCO_3$(0.5mol/L). And we compared results. We understood two things from examination results. 1) The difference occurs to liquefaction strength by urease activity value. 2) The improvement effect of the liquefaction strength was admitted in Microbial carbonate precipitation using in-situ microorganisms in the spots selected by this research.

Keywords: Microbial carbonate precipitation, Urease activity, Undrained cyclic triaxial test, Liquefaction

1. INTRODUCTION

The Great East Japan Earthquake occurred on March 11, 2011. There are many damages caused by tsunami and liquefaction phenomenon. The damage by the liquefaction in particular was beyond 20,000 cases. Many earthquakes also occur to others in Japan which is an earthquake-ridden country. The liquefaction phenomenon which occurs with those earthquakes in recent years is a problem, and it's said that they need liquefaction countermeasure technology which corresponds to various cases. Correspondence to a global warming problem is also desired reduction in greenhouse effect gas amount of emission in the construction field. For example, Japanese carbon dioxide emissions are great many. And about 15% carbon dioxide emissions in Japan, fume emitted from the construction field. So reduction in greenhouse effect gas amount of emission was expected more than conventional technology by this research. And the calcium carbonate way which is the soil stabilization technology for which the microorganism solidification watched as new liquefaction countermeasure technology was used was considered for practical use.

2. BACKGROUND

To use the microorganism with the higher urase activated value (U/L), when doing microorganism solidification by a calcium carbonate way in the past, the case for which the microorganism from which unlined clothing was separated already (alien species) is used is seen much. But we can think the use of a foreign microorganism is difficult from influence to a local ecosystem when making a practical use of. We aimed at utilization of a in situ microorganism as the method to settle this problem by this research.

The soil stabilization technology for which microorganism solidification was used was made a practical use of with a final goal in Japanese whole and Abashiri city, Hokkaido was selected as a Japanese northern end by this research. Imizu city, Toyama was selected as the spot where the dangerous degree of the liquefaction is higher than Toyama-ken liquefaction map and isolation of a urase activated positive microorganism where each spot lives in the ground and the liquefaction strength improvement effect were inspected. We write down the point that isolated a microbe in figure -1. We also inspected about *Bacillus pasteurii* it's said that the solidified effect is clear where at the same time and considered the validity of the suggestion technology for which a in situ microorganism is used through comparison of a result.

3. MATERIALS AND METHODS

By the calcium carbonate method which we paid my attention to in this study, we produce hydrolysis of the urea by the metabolism of the microbe and let you precipitate calcium carbonate all over the gap of the sand. We write down a chemical reaction formula in expression (1),(2). In hydrolysis in expression (1), an enzyme activity level of the microbe becomes important.

$$CO(NH_2)_2+2H_2O \rightarrow 2NH_4^{+}+CO_3^{2-} \quad (1)$$

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

We write down our experimental procedure in figure -2.

We carried out an examination about four kinds of the Toyoura sand which saturated in pure water, the Toyoura sand which we solidified by an isolated microbe from all over the soil in Abashiri city, Hokkaido, the Toyoura sand which we solidified by an isolated microbe from all over the soil in Imizu city, Toyama, solidification ability solidified using *Bacillus pasteurii* which became clear in this study. We write down in list of examination cases table -1, composition of the solidified liquid table -2, an enzyme activity level of the microorganisms which measured it using LCR meter in composition of the solidification solution, table -3. We made test pieces by the three-stage column. We write down three-stage column’s picture in figure -3.

We performed repetition Undrained cyclic triaxial test (DA=5%) of the soil with the test specimen which we made and found the repetition stress amplitude ratio of each test specimen, the repetition loading number of times. Furthermore, we demanded R_{L20} and compared the improvement effect of the liquefaction strength.

In addition, we performed acid decomposition using HCl (0.5 mol/L) about the test specimen after the examination. We considered liquefaction strength and a $CaCO_3$ separation rate, the relations of the enzyme activity level.

And we performed the surface observation of the grain of sand particle with the aid of an electron microscope (KEYENCEVE-8800). We take the pictures by the electron microscope about Toyoura sand, CASE B and CASE C.

Table 1 List of examination cases

	CASE A	CASE B	CASE C
Bacterial strain	Microbe of the Abashiri city, Hokkaido origin	Microbe of the Imizu city, Toyama origin	*Bacillus pasteurii*
Sand class	Toyoura sand		
Relative density	Dr=50%		
Test specimen height	100mm		
Test specimen diameter	50mm		
The passing solidified liquid number of times	Three times		
Passing water interval	72 hours		

Table 2 Composition of the solidified liquid

Reagent name	Weight
Nutrient Broth	0.3g
NH_4Cl	1.0g
$NaHCO_3$	0.21g
$CO(NH_2)_2$	1.80g
$CaCl_2$	3.33g
Pure water	100ml

Table 3 An enzyme activity level of the microorganisms

	Microbe of the Abashiri city, Hokkaido origin	Microbe of the Imizu city, Toyama origin	*Bacillus pasteurii*
Enzyme activity level(U/L)	28	74	654

Fig. 1 Point that isolated a microbe

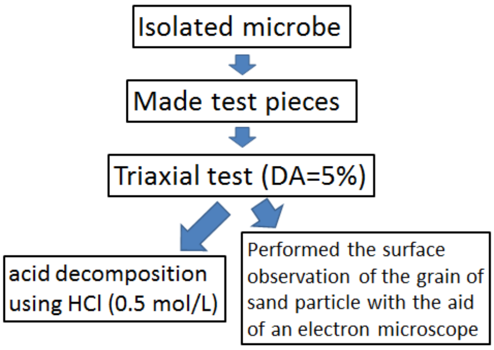


Fig. 2 Experimental procedure

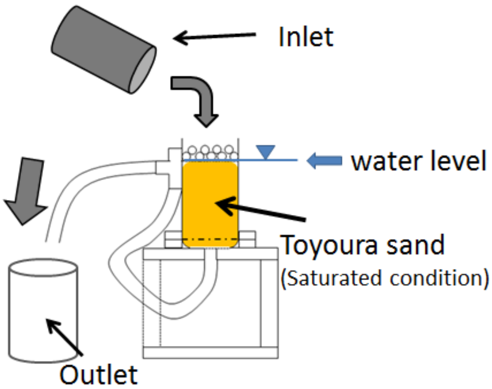


Fig. 3 Three-stage column

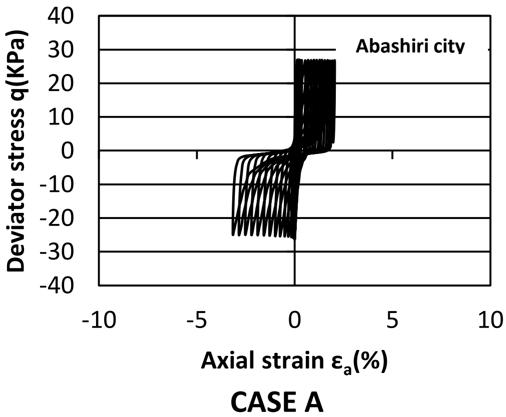
4. RESULTS

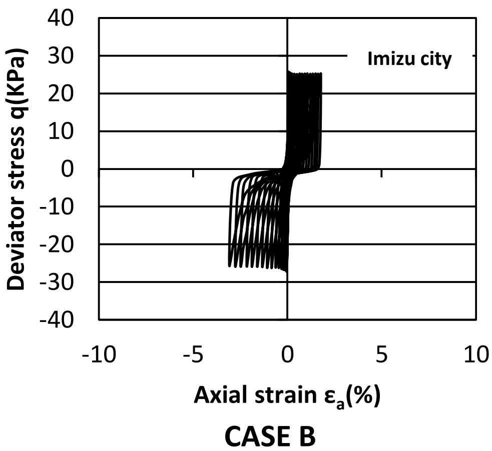
(1) Comparison of liquefaction properties

We write down the stress distortion relations that the loading number of times compared about a case becoming equal repeatedly of test specimen and CASE A,B,C which saturated only Toyoura sand in pure water in figure -4. Because a tendency that axis distortions gradually increase together and liquefy CASE A,B,C from a figure is recognized, we am guessed when a solidification effect by the $CaCO_3$ separation promotion derived from a microbe is provided. Then, we write down the repetition loading number of times in DA=5% in each examination CASE and the relations of the shear stress ratio in figure -6. It followed that we could expect a liquefaction strength improvement effect most about CASE C using *Bacillus pasteurii* where the effectiveness became clear than a study of the past from a figure. In CASE A,B, an improvement effect of the liquefaction strength was accepted equally, but less than CASE C it followed. It is thought that an enzyme activity level of the microbe which we used for CASE A,B as a cause is low.

(2) Comparison of the $CaCO_3$ separation rate

We write down the value of the $CaCO_3$ precipitation rate for the sand weight of each test specimen which we got from acid decomposition in table -4. It was intended to clarify the influence that the difference in microbe class gave for crystal separation. But it was revealed that a $CaCO_3$ separation rate did not have a big difference by a microbe class as we showed it in table -4. Influence by the solidification situation (including the unevenness in crystal size and the test specimen of calcium carbonate) is thought about than the above.





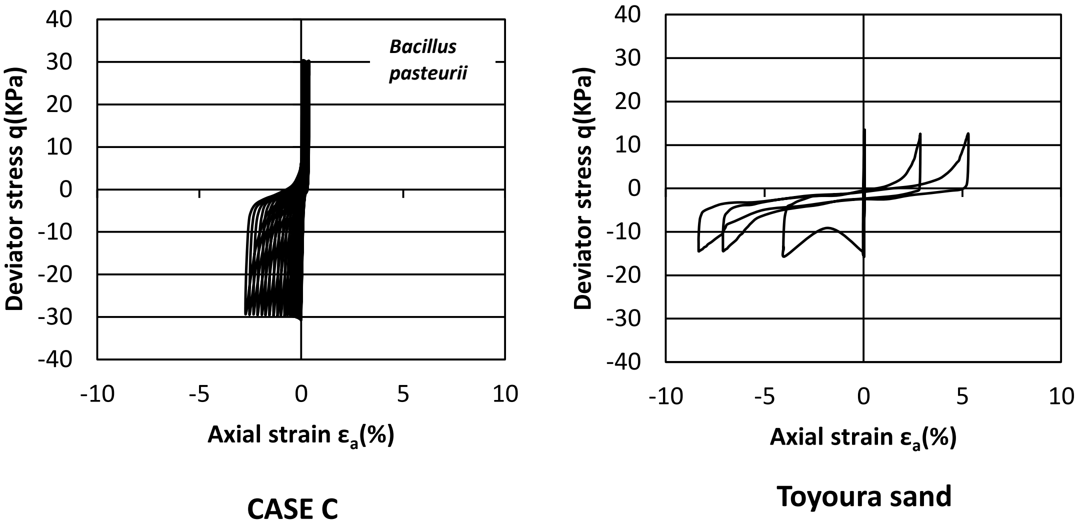
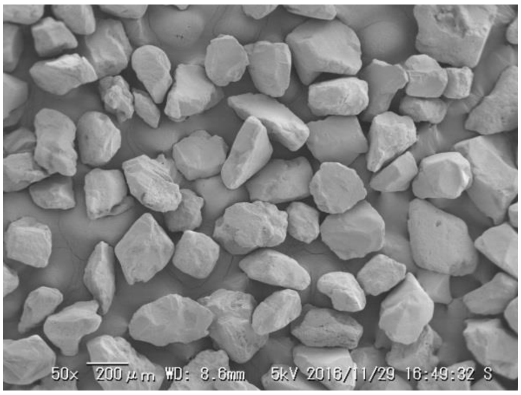


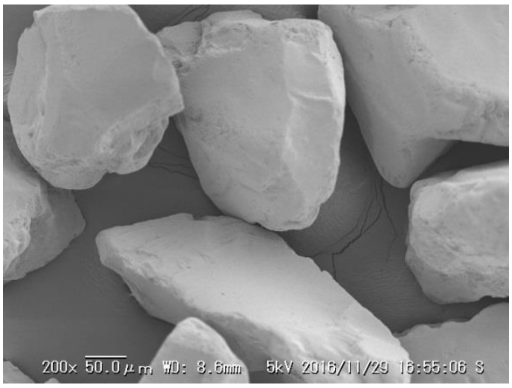
Fig. 4 The stress distortion relations that the loading number of times

(3) The surface observation of the grain of sand particle with the aid of an electron microscope (KEYENCEVE-8800)

We write down the surface observation of the grain of sand particle with the aid of an electron microscope (KEYENCEVE-8800) in figure -5. There are pictures about Toyoura sand, CASE B and CASE C. These diameter are ×50,200,1000. In the CASE C, there are many calcites, but it is very small size. In the CASE B, there are a little of calcites, but it is bigger than CASE C. So we think the difference by the microbe class or urease activity value affects the form of the calcite.

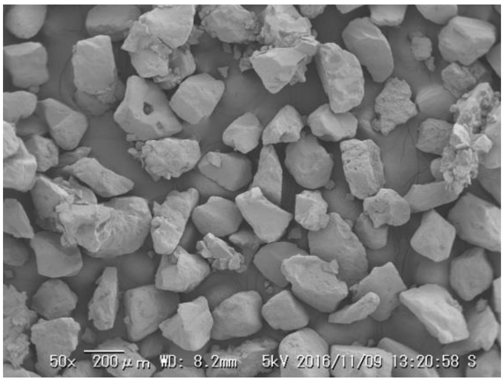


Toyoura sand ×50

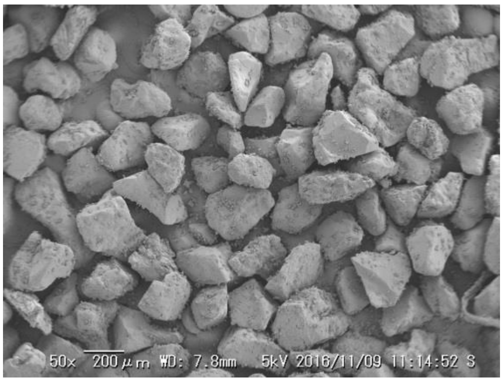


Toyoura sand ×200

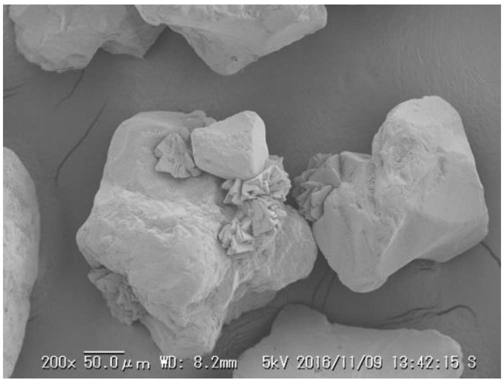
Toyoura sand ×1000



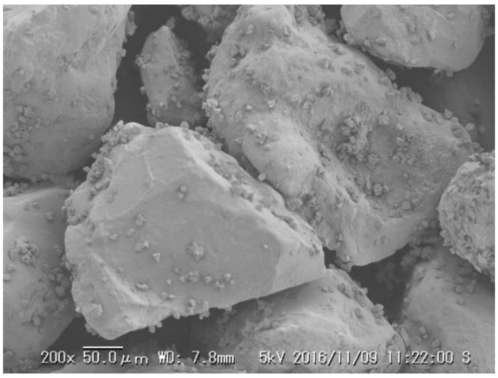
CASE B(Imizu city) ×50



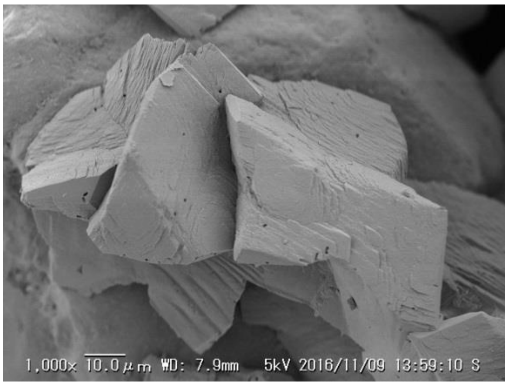
CASE C(*Bacillus pasteurii*) ×50



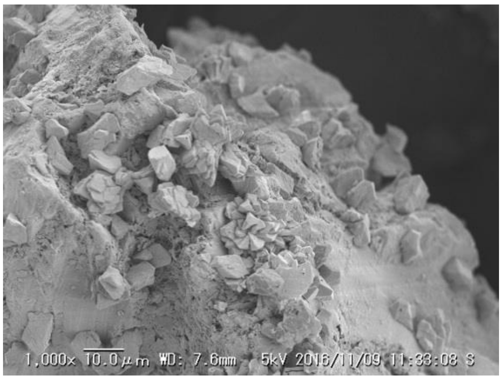
CASE B(Imizu city) ×200



CASE C(*Bacillus pasteurii*) ×200



CASE B(Imizu city) ×1000



CASE C(*Bacillus pasteurii*) ×1000

Fig. 5 The surface observation of the grain of sand particle with the aid of an electron microscope

5. DISCUSSION

From this test result, an improvement effect of the liquefaction strength due to the isolated microbe became clear from all over the soil in Abashiri city, Hokkaido and Imizu city, Toyama. The improvement of the liquefaction strength due to the original position microbe is guessed regardless of a point when at the same level. About both points the value of R_{L20} less than *B.pasteurii* it followed. We paid my attention to a $CaCO_3$ separation rate as a cause, but the value of the acidolysis became at the same level. Based upon the foregoing, it is guessed that an enzyme activity level of the microbe to use for microbe solidification affects the separation place of $CaCO_3$ in the test specimen. Furthermore, it is different in a trend after having injected it in a test specimen, and the possibility that a difference and the deflection of the movement place affect the $CaCO_3$ separation place is thought about by a microbe class. Based on the above-mentioned situation, we perform similar examination using the microbe varying in the enzyme activity level, and it is thought that it is necessary to make an enzyme activity level and relations of the liquefaction strength clear more.

6. CONCLUSIONS

We understood two things from examination results.

1) The difference occurs to liquefaction strength by urease activity value.

2) The improvement effect of the liquefaction strength was admitted in Microbial $CaCO_3$ precipitation using in-situ microorganisms in the spots selected by this research.

In addition, we divide a test specimen into the upper part, the central part, the lower part and perform acid decomposition about each plans pushing forward further examination about the infusion methods to get a homogeneous solidification effect.

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Table 4 Value of the $CaCO_3$ separation rate for the sand weight

	CASE A	CASE B	*CASE C*
$CaCO_3$ separation rate(%)	2.044	2.236	2.038

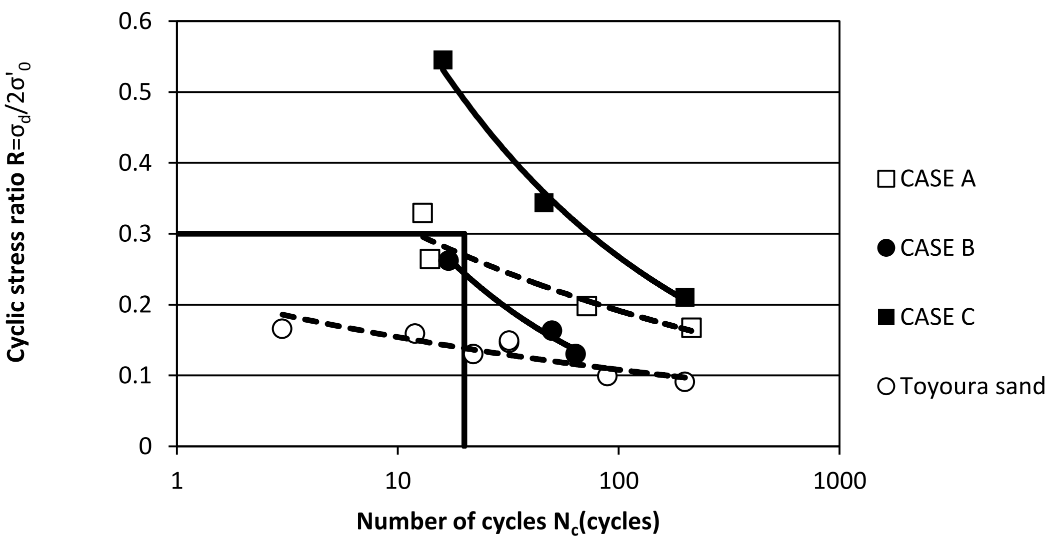

Fig. 6 Repetition loading number of times in DA=5%