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Study on strengthening of soft soil in physico-chemical treatments

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ABSTRACT: Recently,there are many attempts to reuse the soil excavated from buried construction works in the restoration of buried pipes. In general, such soil is a soft soil, which needs to be strengthened before the reuse is done. This paper describes the results of laboratory and field investigations about the effect of ionic surfactant on the strengthening of soft soil. From the results, it is found that nonionic surfactant can increase the strength of the soft soil and is suitable for using in the restoration of buried pipes.

1 INTRODUCTION

In Japan, there is a guideline to used quality soil in the construction works of buried pipes. For this reason, the enormous volume of soil excavated from such construction works have to be disposed. Under these situation many problems are occurred to the construction works and environment.

For example, it is very difficult to find at the time the quality soil in urban area of Japan, lacking of places for disposing the disturbed soil, all these increasing the construction cost, etc.

To solve such problems, there are many attempts to reuse that soil. In general such soil is softsoil, which needs to be strengthened before the reuse is done. This paper describes the results of laboratory and field investigations into the effect of ionic surface active agents(called as surfactant) on the strengthening of soft soil. Surfactants are frequently employed by many field to reduce the surface tension of aqueous solutions and bring about ready wetting of surface. Here, the effect of ionic surfactants(e.g. nonionic, anionic and cationic surfactants) on the reduction of water surface tension are employed on strengthening of soft soil in this study.

2 LABORATORY TEST

2.1 Test procedure

To investigate into the effect of surfactants on strengthening of the soft soil, the following tests are carried out in laboratory.

1. Compaction test(Japan Industrial Standard(JIS)-A-1210).
2. California bearing ratio test(JIS-A-1211).
3. Traxial compression test(American Society for Testing Materials(ASTM)-D-2850).

In these tests, two types of soft soil (silty sand and clay) and six types of ionic surfactants are used. Table 1 shows their physical properties, and Figure 1 shows the grain size accumulation curve of these samples. The surfactants used in all samples are $1\%^{w}/_{w}$. The chemical types of ionic surfactants used in these test are shown in Table 2.

Table 1 Physical properties of sample.

Property	Laboratory test		Field test
Soil	Silty sand	Silty clay	Silty gravel
Specific gravity	27.5	2.67	2.59
Water content	18%	32%	26.5%
Liquid limit	--	32.8%	NP
Plastic limit	--	27.1%	33.2%

Table 2 Chemical type of Ionic Surface active agents used in the test.

Ion	Chemical type
Cation	Lauryltrimechylammonium chloride
Anion	Dialkyl sulfosuccinic sodium
Nonion	(1)Polyoxyethylene sorbitan fatty acid ester(HLB=15.6%)
	(2)Polyoxyethylene sorbitan fatty acid ester(HLB=13.3%)
	(3)Polyoxyethylene sorbitan fatty acid ester(HLB=11.0%)
	(4)Polyoxyethylene sorbitan fatty acid ester(HLB=10.0%)

Note)HLB:Hydrophile Lipophile Balance.

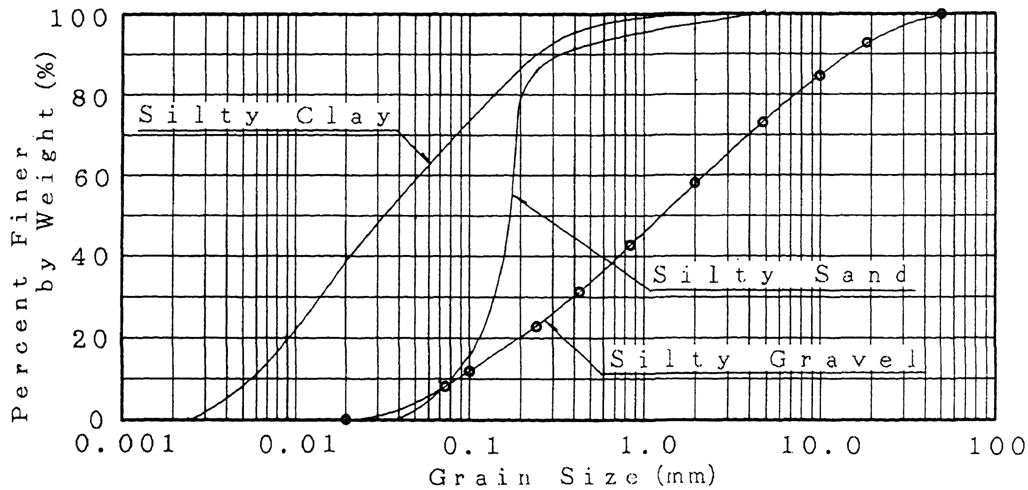


Fig. 1 Grain size accumulation curve of sample

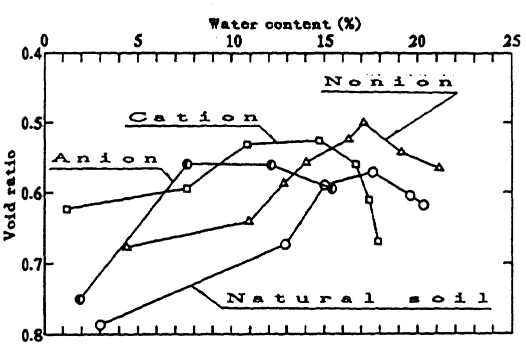


Figure 2 Relationship between void ratio and water content in silty sand.

2.2 Effect on void ratio

From the results of the compaction test of silty sand as shown in Figure 2, it is found that ionic surfactants can reduce the void ratio of the silty sand when the water content of silty sand is lower than the optimum water content of natural soil (silty sand without surfactants). Only nonionic surfactant can reduce the void ratio of silty sand when the water content of silty sand is equal to the optimum water content of natural soil or higher. This shows that when the silty sand has the lower water content than the optimum water content of natural soil, the silty sand can easily be compacted by using anionic and cationic surfactants.

However, when the water content of silty sand is equal to the optimum water content of natural soil or higher, only nonionic surfactant can beused.

Figure 3 shows the relationship of void ratio and Hydrophile-Lipophile-Balance(HLB) of nonionic surfactant. It is seen that void ratio of silty sand is decreased when the values of HLB are increased. This means that the silty sand can be compacted more easier by using the nonionic surfactant, which has the high value of HLB.

Figure 4 shows the results of the compaction test of silty clay. From the results of silty clay, the silty clay can be compacted by using ionic surfactants only

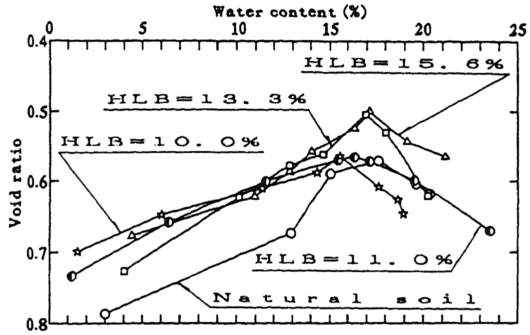


Figure 3 Diversity void ratio by difference Hydrophile-Lipophile-Balance.

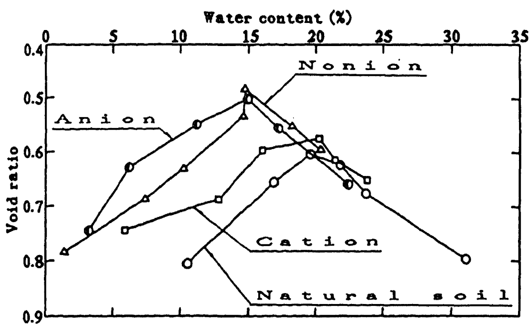


Figure 4 Relationship between void ratio and water content in silty clay.

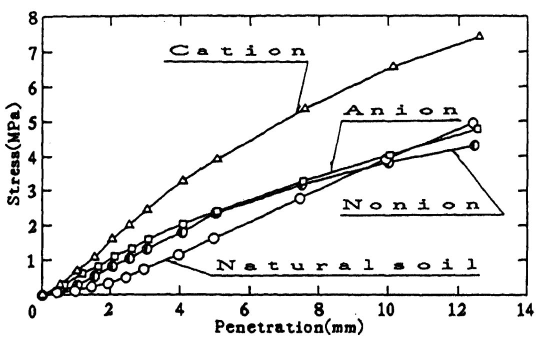


Figure 5 Results of the CBR test which samples of silty sand.

when the silty clay has the lower water content than the optimum water content of natural soil(silty clay without surfactants).

2.3 Effect on strength of soft soil

Figure 5 shows the results of the California Bearing Ratio(CBR) test in which samples of

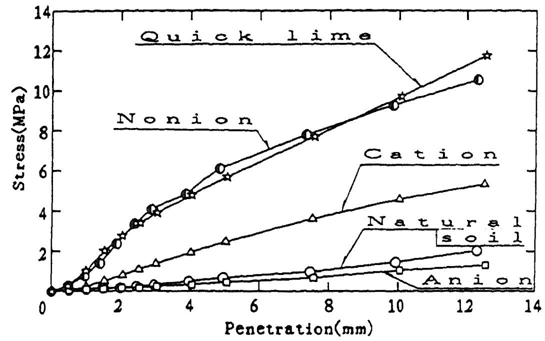


Figure 6 Results of the CBR tests which samples of silty clay.

silty sand are compacted at each optimum water content. It is found that the strength of silty sandtreated by cationic surfactant is higher than thatof natural soil and others. This is because the samples of silty sand used in the test include little fine grained soil. For this reason, the effect of the concentration by cationic surfactant is higher than the effect of decreasing the friction force among soil particules by the other surfactants.

Figure 6 show the results of the CBR tests in which samples of silty clay are compacted at each optimum water content. It is found that the strength of silty clay treated by surfactants are higher than that of natural soil, especially, nonionic surfactant. Since the soil treated by nonionic surfactant has the same strength as that by quick lime and the effect of nonionic surfactant on clay mineral in soft soil is small(Ariizumi,A., Maki,T. and Wada,S.),it can be said that nonionic surfactant will be the most proper surfactant for using in the strengthening of the soft soil.

3 FIELD TEST

3.1 Test procedure

In the field test the effect of nonionic surfactant on strengthening of the soft soil is investigated. This test is carried out on buried fills, which have dimension of 0.75 m in width, 1 m in depth, 4 m in length. The sample of softsoil obtained from these buried fills are silty gravel, which the grain size accumulation curve is shown in Figure 1. The nonionic surfactant (HLB=15.6 %) is used at concentration of $1\%^{w}/_{w}$ and added to the sample by mixer, back hoe shovel, spreading methods. After the mixing, the samples are buried in the buried fill by dividing into 5 layers and the field density test measured at each layer is carried out.

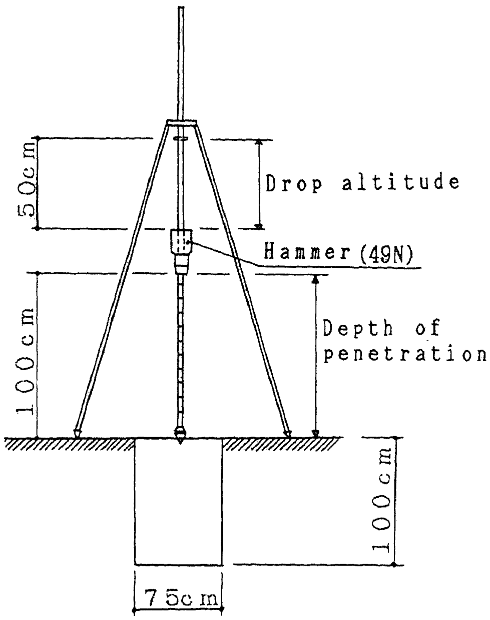


Figure 7 Penetorometer

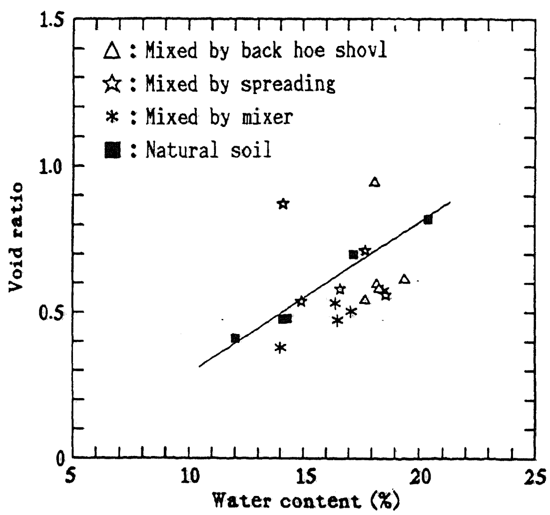


Figure 8 Relationship between void ratio and water content of each layer on the day of test.

As shown in Figure 7, the penetration test presented by the Public Works Research Institute Ministry of Construction (Tanifuji, S.1952) is carried out at the first day, fourth day and thirty sixth day.

3.2 Effect on void ratio

Figure 8 shows the relationship between void ratio and water content of each layer on the day of test. It is found that void ratio of silty gravel treated by surfactant is smaller than that of natural soil. This shows the compaction of silty gravel treated by surfactant is higher than that of natural soil.

Figure 9 shows the relationship between void ratio and penetration index of each layer on the first day of the test. It is seen that penetration index of soil treated by nonionic surfactant(HLB=15.6%) is smaller than that of natural soil when the void ratio is the same. It is because the water content of the samples(silty gravel) are higher than optimum water content leading to the decrease of the penetration index of the soil treated by nonionic(HLB=15.6%) surfactants.

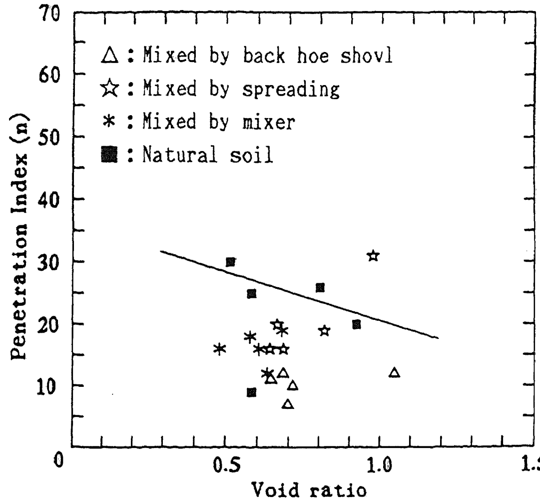
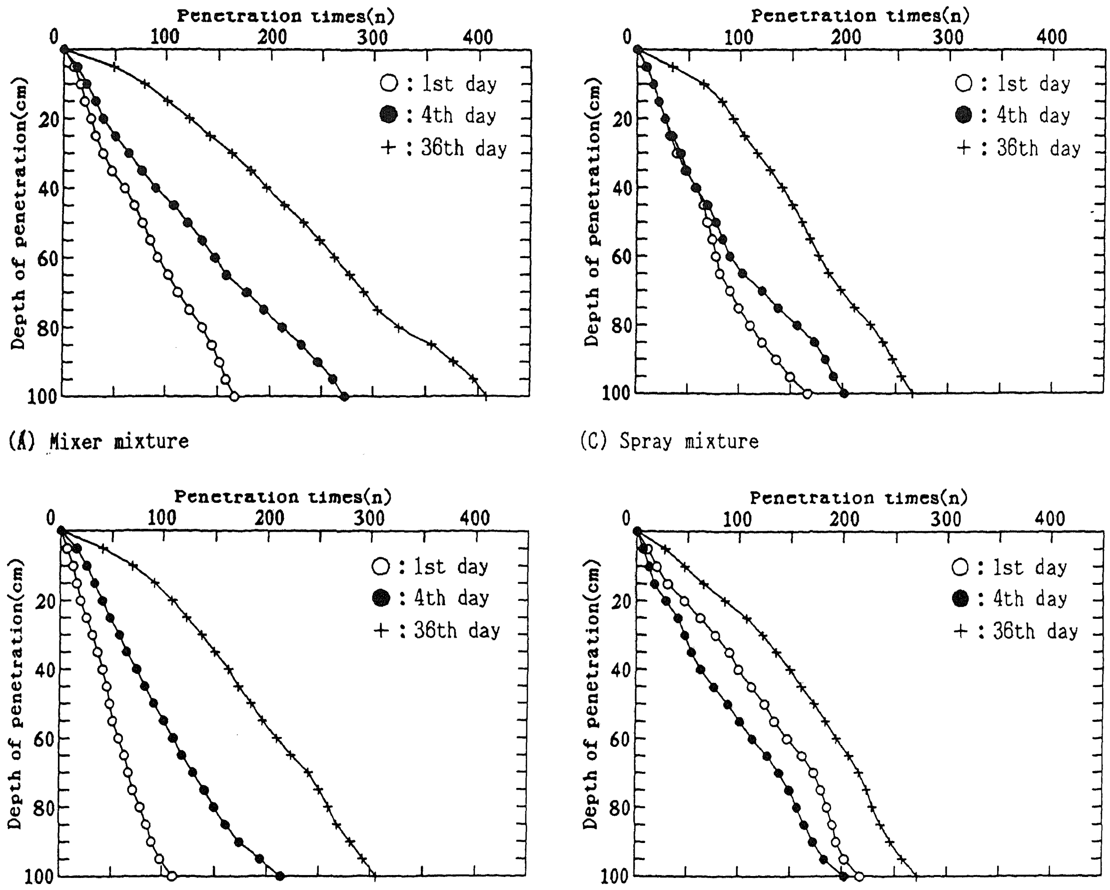


Figure 9 Relationship between void ratio and penetration index of each layer on the day of test.

3.3 Effect on the strength

Figure 10 shows the results of penetration test when the silty gravel treated by the nonionic surfactant(HLB=15.6%) are mixed by mixer, back hoe shovel, spreading methods. It is seen that when the number of days are increased, the penetration times are increased in silty gravel treated by nonionic surfactant(HLB=15.6%) but are slightly changed in natural soil. It is also found that the maximum penetration numbers are obtained when the nonionic surfactant (HLB=15.6%) are mixed by mixer. This shows that the strength of silty gravel treated by nonionic surfactant(HLB=15.6%) are higher than that of natural soil and the best



(A) Mixer mixture

(C) Spray mixture

(B) BacK hoe shovl mixture

(D) Natural soil

Figure 10 Results of penetration test when the soil treated by the nonionic surfactant.

method for mixing the surfactant with the silty gravel is mixer method.

CONCLUSIONS

To investigate the effect of surfactants on strengthening of soft soil, the laboratory test and field test are carried. From the results of them the following conclusions are obtained.

1) By using the surfactants, void ratio of the soil can be decreased under optimum water content condition, especially, by using nonionic surfactant which has the high value of HLB. This shows that water surface tensions of silty sand can be reduced by surfactants. When the silty sand has the water content lower than the optimum water content of natural soil, the silty sand can easily be compacted by using anionic and cationic surfactants. The same results can also be found in the case of silty clay. And when the water content of silty sand is equal to the optimum water content of natural soil or higher, only nonionic surfactant can be used. However, this result can not be found in case of silty clay.

2) From CBR test, it is found that the strength of silty sand treated by cationic surfactant is higher than that of silty sand treated by nonionic surfactant. Conversely, the strength of silty clay treated by nonionic(HLB = 15.6%) surfactant is higher than that of silty clay treated by cationic surfactant. From the above results, it can not be said that which one of surfactant is the better one. However, if the effect on clay mineral in soft soil is considered and since the soil treated by nonionic surfactant has the same strength as that treated by quick lime, it can be said that nonionic surfactant will be the most proper surfactant for using in the strengthening of the soft soil.

3) The same results are also found on field test. but, on the first day of the

test, penetration times of the silty gravel treated by nonionic surfactant are decreased in comparison with the result of natural soil. This is because the water content of samples are higher than the optimum water content of natural soil. However, when the number of days are increased, the penetration times are increased. This result shows that nonionic surfactant can increase the strength of the soft soil and is suitable for using in the restoration of buried pipes or other soil structures.

Nonionic surfactant will be the most proper surfactant for using in the strengthening of the soft soil, but the effect of strengthening may be uneffective if the water content of the soil is over optimum water content. Therefore, in the future strengthening the soft soil having the water content more than the optimum water contents hould be studied.

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