Influence of fine shredded paper on the compaction properties of natural soil

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1. INTRODUCTION

In Japan, utilization of huge amounts of sludge and/or silty soils discharged from construction activities is decreasing over the past decades due to its high moisture content and compressibility (Inazumi et al., 2002). This in turn, increases the cost for processing and disposal. Solidification and deterioration of fluidity has been mainly achieved by hydration reaction using cement and lime-based agents, however, problems such as time for solidification and load on surrounding environment is encountered (Sawamura et al., 2017).

Recently, fine shredded powder (FSP) which is produced from shredding and fine processing of waste paper, has been considered for decreasing the fluidity of natural soils and mud. FSP has a strong crystal-like structure consisting of hemicellulose and lignin compounds which are intricately intertwined with each other to form fibre cells, as illustrated in Figure 1.

Treatment of mud with high water content can be achieved by employing FSP, as shown in Figure 2**.** Mechanism for mud treatment by FSP is considered to be a physical reaction due to water absorption by the FSP. Sawamura et al., (2017) found out that high content of FSP significantly affects the water absorption capacity of mud, as shown in Figure 3.

The treatment of high moisture soils using FSP can be applied to many fields, such as transportation, disaster countermeasures for reservoirs, as well as re-use of treated mud. However, it is prudent to investigate the behaviour change on the physical properties of the treated soil. In this study, we evaluated the effect of employing FSP on the compaction properties of decomposed granite soil.

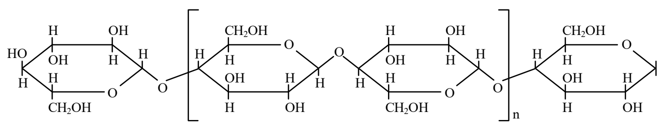

Figure 1. Chemical structure of FSP (Sawamura et al., 2017).

Figure 2. Treatment of mud with high water content using FSP (Sawamura et al., 2017).

2. MATERIALS AND METHODS

Decomposed granite soil, which is widely distributed in Japan, was used after sieving with a 4.75 mm opening sieve, as parent material. Figure 4 shows its particle size distribution curve. This soil has a particle density of 2.67 g/cm^3 and a natural water content of 6.5%, as summarized in Table 1. It can be classified as GS-F (Gravel sand with fine fraction) according to JGS 0051 (2009).

FSP which is shown in Figure 5, is a recycled powder material of shredded used paper products. It was employed in this study as a stabilizing agent.

Soil was manually mixed with FSP in different mixing proportions of 0%, 5%, 10%, and 20% on dry mass basis (e.g. mix proportion of 5% = 5 g FSP per 100 g soil). Figure 5 shows appearance of the mixtures.

Particle size distribution and particle density of the mixtures were determined according to the Japanese Geotechnical Standards: JGS 0131 (2009) and JGS 0711 (2009) respectively. Standard Proctor compaction tests were carried out according to JGS 0711 (2009) (A-a method).

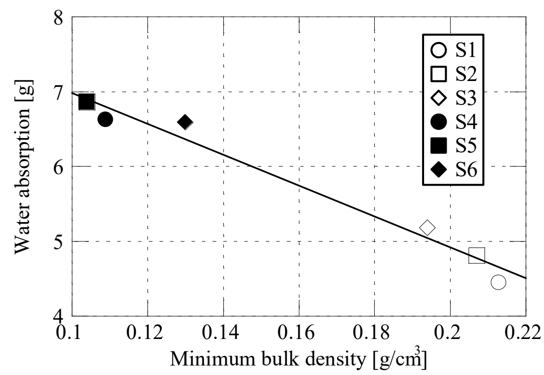

Figure 3. Relation of water absorption capacity to minimum bulk density of soil (Sawamura et al., 2017).

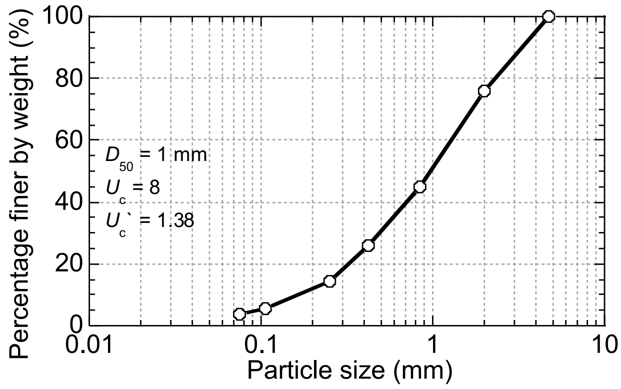

Figure 4. Particle size distribution curve of soil.

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Table 1. Physical properties of soil.

Parameter	Value
Particle density	2.67 g/cm^3
Initial water content	6.5%
Particle size distribution	
Gravel fraction (4.75 – 2 mm)	24.3%
Sand fraction (2 – 0.075 mm)	71.9%
Fine fraction (< 0.075 mm)	3.8%
Uniformity coefficient	8
Coefficient of curvature	1.38

Table 2. Physical properties of mixtures.

FSP(%)	w_{opt} (%)	$\rho_{d\,max}$ (g/cm^3)	ρ_s (g/cm^3)
0	11.5	1.98	2.67
5	15.0	1.75	2.59
10	20.0	1.45	2.55
20	25.0	1.15	-

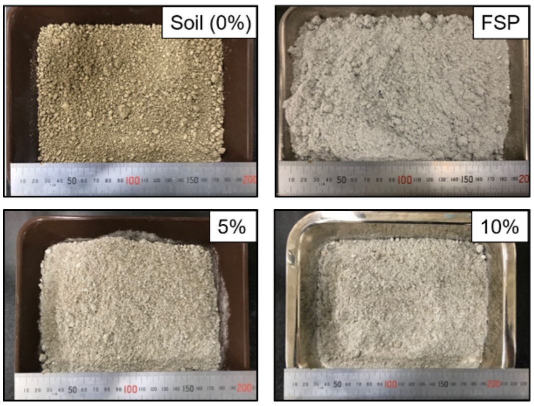

Figure 5. Appearance of materials used (in dry state).

3. RESULTS AND DISCUSSION

Particle density of soil reduced when FSP was added to it, which is due to the low density of FSP (1.64 g/cm^3). Particle density of soil (2.67 g/cm^3) reduced by 6% when 10% FSP was employed (2.55 g/cm^3). Figure 6 shows the compaction curve of the soil, in which the optimum water content (11.5%) and maximum dry density (1.95 g/cm^3) were determined. Increase in FSP led to a decrease in the maximum dry density and an increase in the optimum water content.

Table 2 summarizes the maximum dry density and optimum water content for the mixtures. It was found that the optimum water content increased by about 3.5% when 5% FSP was used. After which, it increased by 5% with further addition of FSP. On the other hand, maximum dry density decreased by 11% when 5% FSP (1.75 g/cm^3) was used, and by 41% when 20% FSP was used (1.15 g/cm^3). One of the reasons for this is that the FSP is confined within the voids and separates the coarse particles of the soil (Thevanayagam, 2007). Therefore, increasing the amount of FSP will increase the void ratio of the mixture. Correlation of maximum dry density and/or optimum water content to FSP can be described as a non-linear relationship, as shown in Figure 7.

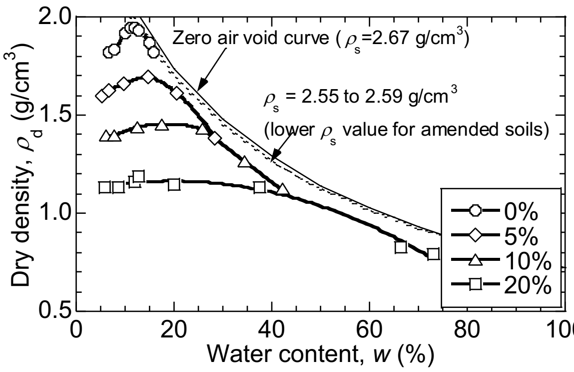

Figure 6. Compaction curves mixtures.

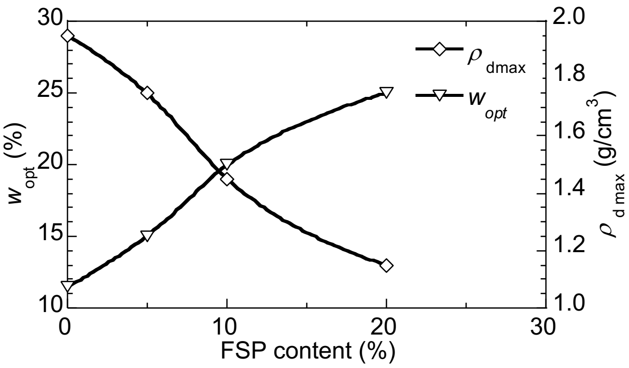

Figure 7. Variation trend of optimum water content and maximum dry density to FSP content.

4. CONCLUSIONS

To improve the physical properties of a natural soil, FSP was considered for use as a stabilizing agent. From this study, it was found out that the maximum dry density decreases by 41% and optimum water content increase by 54%, when 20% FSP content was used. A non-linear relationship described the correlation of maximum dry density and/or optimum water content to FSP.

5. FUTURE WORKS

The main purpose of this research is to investigate the water absorption capabilities of silty sand and high moisture mud when treated with FSP, for the purpose of transportability, disposal or re-use. Therefore, effects on other physical properties such as hydraulic conductivity and strength, as well as the degradation and variations of odor with time, need to be investigated to give conclusive results.

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