Shear stress characteristics of fine shredded paper investigated by direct shear box test

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1. INTRODUCTION

Wastepaper is one of the largest solid wastes which pollutes the environment world wide[1]. At some construction site, reuse of large amount of high-water content muddy soil after treatment practiced for decades in Japan and other part of the word[2]. To recycle this soil economically, the high amount of water should be reduced or be improved using any stabilizers. Due to its abundant availability and burden to the environment, utilization of fine shredded paper (here in after called FSP) is one of the materials for improving the high-water content muddy soils. Our research group has found that the addition of certain amount of FSP to such muddy soils improves the transportability of the treated soils because the FSP shows great water-absorption capability[3].

It is possible that the shear strength property of the treated soil is improved by adding FSP because of not only the water absorption but also the fiber-reinforcement effect of the FSP itself. However, such a stabilization mechanism is not clearly understood. In order to clarify its mechanism, the investigation of the shear strength of FSP itself is important. In addition, the shear strength of the FSP may be different when the water content and the bulk density of FSP is changed because the component of the FSP is fine paper particles like geomaterials.

The present study investigates the shear strength of the FSP. Direct shear box tests are conducted for the FSP samples with the different water contents and void ratios.

2. EXPERIMENTAL SETUP

2.1 MATERIALS

The material used for this study is papers which are shredded and processed. The FSP fiber and powder shows 1.78 g/cm^3 of particle density, and it is air dried before the experiment. Particle size distribution of the FSP is shown in in Fig.1. More than 60% of the FSP used in this study has particle size less than 0.106 mm. Figure 2 presents a SEM image of the FSP, which indicates that FSP is made up of fibers and powder. In addition, it has an average water absorption of 575%[3].

2.2 METHODS AND SAMPLE PREPARATION

Figure 3 shows pictures of specimen at mixing, assembling and after test states. The specimen conditions are listed in Table 1. Deaired water is mixed with air dried FSP at water content of 0%, 50%, 100% and 200%. The mixed specimen is placed in the direct shear box whose height is 20 mm and diameter is 60 mm. In order to obtain a similar void ratio for each specimen, the density is carefully monitored before and after consolidation under each level of vertical stress. The shearing rate is 1.0mm/min.

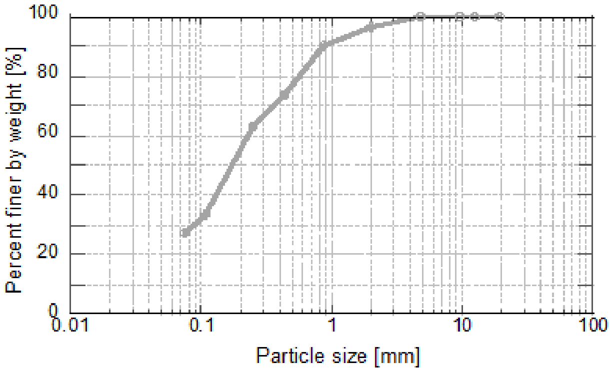

Figure 1: Particle size distribution of FSP

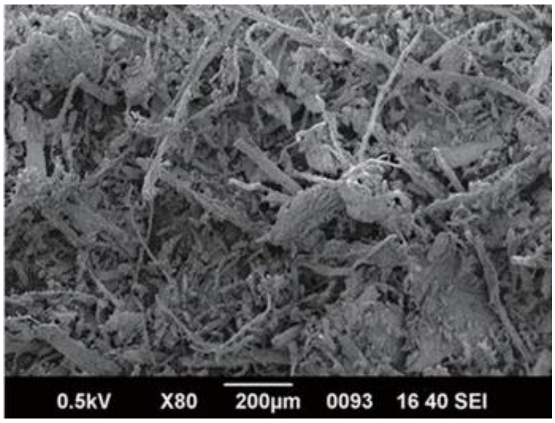

Figure 2: SEM image of FSP

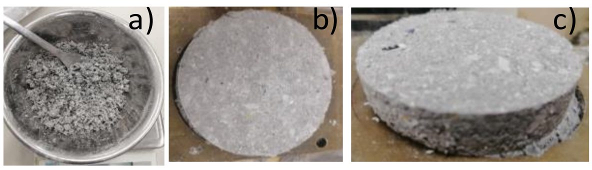

Figure 3: specimen a) mixing b) assembling c) after test

Table 1: Test cases used in the experiment.

Test Cases	Void ratio after consolidation e_0	water content w [%]	Normal stress, N [kPa]
1	5.1	0, 50, 100, 200	39.2
3	4.5	0, 50, 100	78.5
4	3.9	0, 50, 100	78.5
2	3.4	0, 50, 100, 200	39.2

Keywords: Muddy soil, FSP, shear stress
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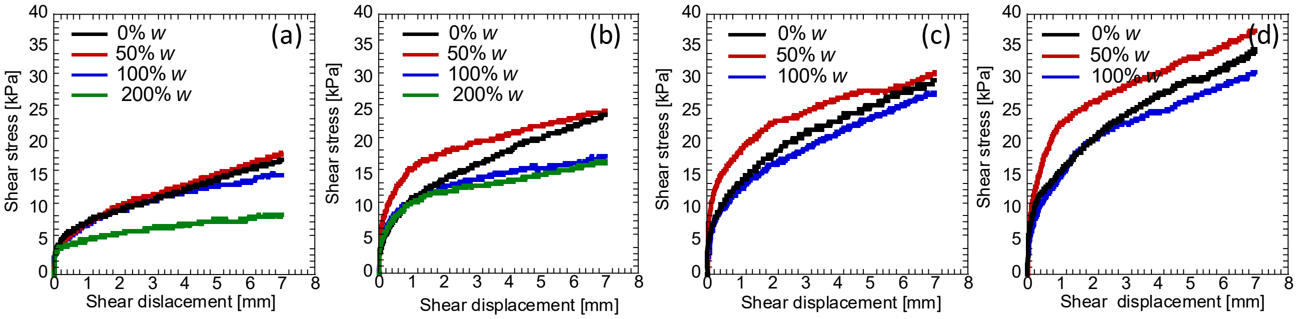

Figure 4 Shear stress-shear displacement relationships of FSP at: a) case 1, b) case 2, c) case 3, d) case 4

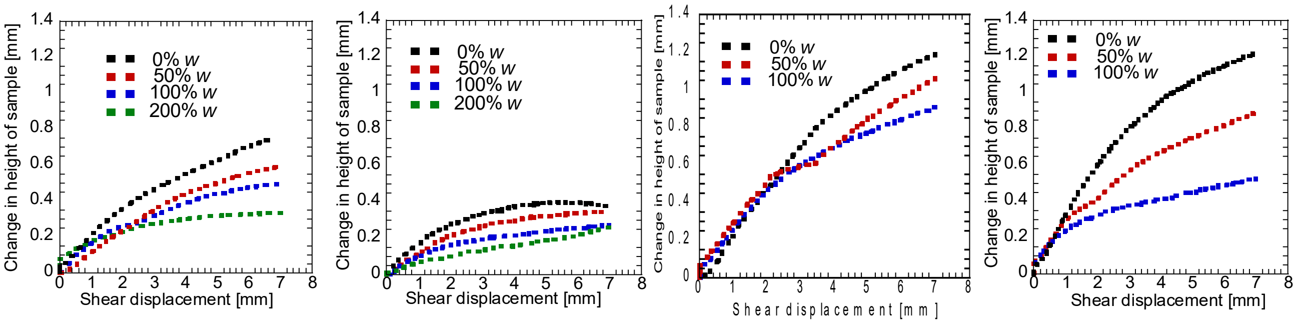

Figure 5 Volume change characteristics of FSP at: a) case 1, b) case 2, c) case 3, d) case 4

3. RESULT AND DISCUSSIONS

During the experimental process, the moisture is kept within specimen while using optimum moisture for each case as shown in Table 1.

Figure 4 shows shear stress-shear displacement relationship of FSP. It is found from the comparison between Figs. 4(a) and 4(b) that, under the same normal stress, the shear stress in Fig. 4(b) is higher than that in Fig. 4(a) at each water content because the FSP specimens are denser condition. This tendency is identical to the density dependence of geomaterials. The same tendency is observed from the comparison between Figs. 4(c) and 4(d), i.e., the denser sample in Fig. 4(d) shows higher shear stress than the looser sample in Fig. 4(c). In addition, it is clearly observed from Fig. 4 the highest shear strength value of FSP is obtained when 50% moisture content is utilized. This probably indicates that suction value is higher at the given moisture content of 50% irrespective of void ratio and normal stress, which enhances shear strength of the FSP. On the other hand, the lowest shear stress is observed when the water content is 200% since water content is too high to reduce suction, leading to the lowest shear stress of the FSP. Unlike some common soil properties, the shear stress increases up to maximum shear displacement. This might be that FSP is composite of powder and fibers as shown in Fig 2 that interlocks the FSP matrix, remaining shear stress. Such kind of unique characteristics of FSP may change the mechanical properties of muddy soil, which will be investigated as a future work.

Figure 5 shows vertical displacement-shear displacement relationship of FSP. The positive value shows dilation. The common tendency observed from each figure is that the dilative characteristic is significant in water content of 0%, and the dilative characteristics is not significant in water content of 50% where the highest shear stress is observed. The dry FSP power and fiber can behave like soil particles during shearing, i.e., rearrangement of structure is exhibited and then volumetric change happens. On the other hand, the fiber and powder of FSP strongly fixed with each other when they contain a certain amount of water. At this condition, the rearrangement of structure may be restricted, so that the volume change might be less significant in higher water content.

CONCLUSIONS

There is an optimum water content that effectively enhances the shear strength of the FSP itself, as the same with geomaterials.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support provided by the SATREPS, Grant No.JPMJSA1807.

REFERENCES

1) Gundu M., Abhaysinha S.:Experimental study on the performance of concrete mix with paper waste, waste plastic, quarry dust, and fly ash, *Journal of Engineering Sciences*, Vol. 8(1), pp. 1–7, 2021.

2) Tabassum, N. , Hashino, T., Phan, B. , Hayano, K and Hiromoto Yamauchi, H: Effects of primary curing conditions and subsequent crumbling on properties of compacted soils treated with paper sludge ash-based stabilizers, *Soils and Foundations,* Vol.62, 2022.

3) Sawamura, Y., Yano, T. and Kimura, M.:Property variation of high moisture sludge by fine powder mainly composed of cellulose, *12th Environmental Geotechnical Engineering Symposium*, pp.505–510, 2017. (In Japanese).

