STUDY ON THE APPLICABILITY OF GEOMATERIAL USING BIODEGRADABLE PLASTIC PART 2: APPLICATION OF IMPROVED SOIL AS A CONSTRUCTION MATERIAL

Sumitomo Mitsui Construction Co., Ltd. Member ○ Dayani Sanjeewani
Member Yasuyuki Hodotsuka
Member Naoki Takahashi
Osaka City University Member Suguru Yamada

1. INTRODUCTION

Ground improvement or modification refers to the improvement of inherent properties of the soil such as strength, deformation behavior where the properties of soils in its natural state are not adequate for different civil engineering applications. Recently, biodegradable plastic was introduced to the geotechnical field as a ground improvement material. Authors conducted a series of experiments on fundamental properties of the improved soils using biodegradable plastics and silica sand [1) 2) 3)]. It was understood that the shear strength can be improved greater than 1MPa even by mixing 5 % of plastic. In addition to that, it was found that the permeability of that improved soil can be maintained same as silica sand. As explained in the part 1 of this paper, there are lots of advantages of this improvement technique in practical applications. Hence before utilizing this material as a construction material, a proper study regarding its applicability with natural soil should be done. In this study, the application of improved soil using biodegradable plastic as a construction material was discussed by comparing the physical, mechanical properties and heating procedure of improved soil made out of masado and silica sand.

2. EXPERIMENTAL PROCEDURE AND THE RESULTS

In this study, Silica sand No. 6 from Toki City, Gifu Prefecture and decomposed granite sand generally known as masado from Ibaraki prefecture was used. Since masado is widely used as a construction material or as backfill material in Japan, it is important to evaluate engineering properties as improved soil with biodegradable plastic to check its applicability as a construction material. Biodegradable plastic, PLA (polylactic acid), was used as the binder by mixing 5% by dry weight of each soil. Photos of Masado and silica sand are shown in Fig.1 (a) and (b) respectively.

The obtained grading curves of plastic, silica sand, masado and masado plastic mixture are shown in Fig.2. Fine content (<0.075mm) of masado, Silica sand and plastic were 10, 0, 28 % in respectively. The uniformity coefficient (U_c) and the coefficient of curvature (U_c^1) were evaluated for masado, silica sand and the masado plastic mixture as summarized in the Table 1. Generally, the sand with $U_c \geq 6$ and $1 < U_c^1 < 3$ is classified as well graded soil while both of these criteria are not met it is classified as poorly graded soil. In summary, masado is a well graded soil while silica sand is a poorly graded soil. In masado plastic mixture U_c and U_c^1 slightly were slightly reduced compared to masado.

In order to understand the compaction behavior, proctor compaction tests were conducted on silica sand, masado and masdo plastic mixture. The obtained results are shown in Fig.3. The dry density of silica sand did not change with the water content while in masado and masado plastic mixture clear changes were observed. The obtained maximum dry densities and optimum water contents were 1.950 g/cm^3, 10.2% and 1.862 g/cm^3, 10.5% for masado and masado plastic mixture respectively. Due to the mixing of plastic with masado, the maximum dry density was reduced by 4.5% from its original value while showing negligible change in optimum water content. This imply that a light weight geomaterial can be created by mixing masado with plastics.

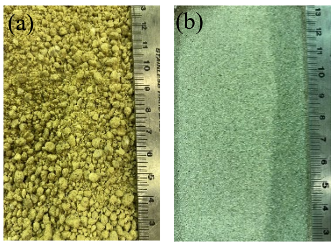

Fig.1 (a) Masado (b) Silica sand

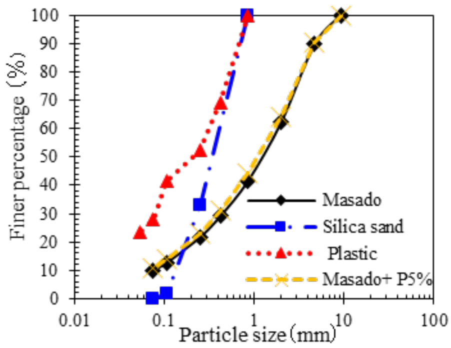

Fig.2 Particle size distributions

Table 1. Measures of gradation

	Masado	Silica	Masado + 5%P
D_{10}(mm)	0.075	0.144	0.075
D_{30}(mm)	0.44	0.21	0.4
D_{60}(mm)	1.87	0.4	1.7
D_{50}(mm)	1.27	0.32	1.1
U_c	24.9	2.8	22.7
U_c^1	1.41	0.77	1.25

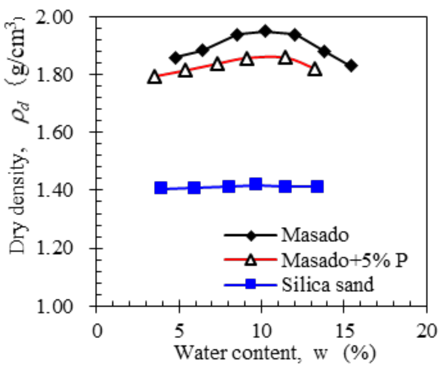

Fig.3 Compaction curves

Keywords: Masado, Grading, Heating duration, Mechanical properties
Contact address: Sumitomo Mitsui Construction Co.,Ltd, 〒270-0132 Komaki 518-1, Nagareyama-shi, Chiba. Japan, Tel: +81-50-3201-2941

© Japan Society of Civil Engineers

The mechanical properties of both sand types after improving with 5% of plastic were studied by conducting unconfined compression tests (JIS A 1216) on the specimens with 50 mm in diameter and 100 mm in height. In here, three sets of specimens were prepared. First set was prepared by mixing plastic with silica sand in dry condition (w 0%). The second and third sets were prepared by mixing plastic with masado in dry condition and with 10.5% of water respectively. Those two cases were prepared to see the effect of water content on the strength and the applicability of this improvement method in site. In all the cases, specimens were prepared using steel molds and applied same compaction energy.

After compaction, heating was applied using cooking oven until the temperature inside of the specimen reach up to 210^{0}C (melting temperature) and kept 30 minutes in the same temperature. After heating, the specimens were cooled at room temperature and then mold was removed and used for the experiment.Fig.4 shows the heating history obtained inside of the dummy specimen and the oven for both improved soils using masado. Heating duration for both silica sand and masado dry cases were 130 minutes. On the other hand, that duration was 220 minutes in the case of masado with water. Because, the temperature inside the specimen did not increase beyond 100^{0}C until water evaporated as shown in Fig.4. It was found that the water content of these specimens after heating as 0.2%. This means almost all water had evaporated and that process took time. In this improvement technique, the bonding between soil particles are created by melted plastics. Hence it is important to increase the temperature up to melting point. However, as the time duration which take to reach that temperature is depended on the water content which is required to consider in practical application.

The obtained stress strain relationship for all the cases are shown in Fig.5. Although the stress-strain curves vary slightly, relatively clear yield points were recognized in almost all the cases. The highest unconfined compressive strength, q_u, was observed in improved masado with water. The relationships between q_u, secant modulus (E_{50}) and the dry density are shown in Fig. 6 (a) and (b) respectively. Though the same compaction energy was applied, the obtained densities were different from each other by depending on the soil type and the availability of water. In the case of improved soil with masado, the highest density and the highest strength were obtained in the specimens which were made with water. It was clearly understood that the availability of water improves the compactivity of the soil plastic mixture and result in higher strength after heating. In the case of improved soil with dry silica and masado, there was no clear difference in E_{50} even though the obtained densities were different. However, clear increment in E_{50} was observed in the improved masado with water.

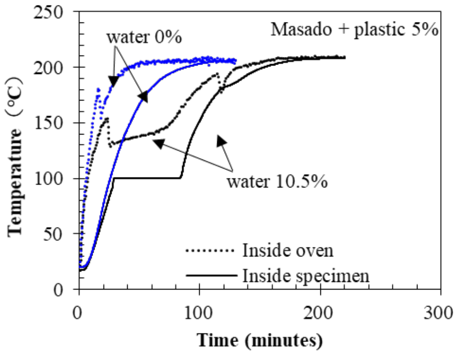

Fig.4 Heating history

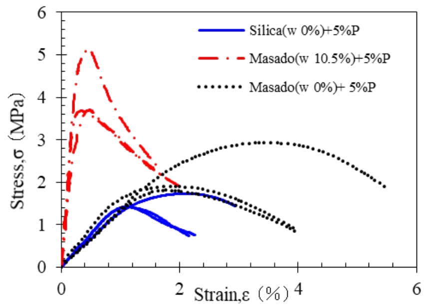

Fig.5 Stress strain relationship

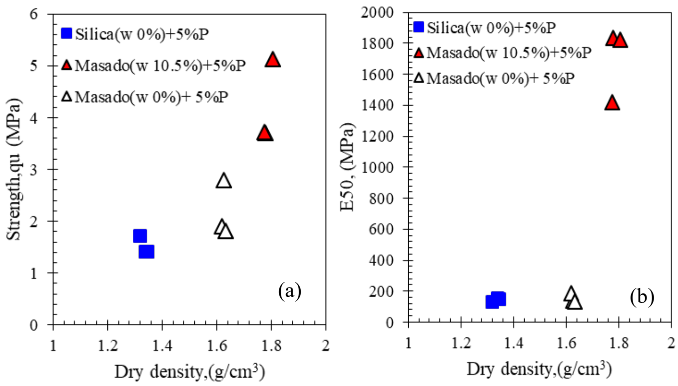

Fig.6 Relationship between dry density and (a) Unconfined compressive strength (b) secant modulus

3. SUMMARY

In this study, the application of improved soil using biodegradable plastic as a construction material was discussed by comparing the physical, mechanical properties and heating procedure of improved soil made of masado and silica sand. It was found that the grading distribution and the availability of water play a major role in the mechanical properties of improved soil even water evaporate during the heating procedure. In addition to that, the availability of water effect on the time duration that need to reach melting temperature of plastic. As a conclusion, it can be said that biodegradable plastic can be used to improve mechanical properties of, masado, general construction soil.

REFERENCES

1) Hodotsuka et al. : Fundamental study of geomaterial using biodegradable plastic-Part 1: Preparation method and mechanism of strength development-, 55th JGS domestic annual conference, Kyoto, Japan, 2020. (to be published)
2) Sanjeewani et al. : Fundamental study of geomaterial using biodegradable plastic-Part2: Factors affecting on mechanical properties of improved soil with biodegradable particles-, 55th JGS domestic annual conference, Kyoto, Japan, 2020. (to be published)
3) Torigoe et al. : Fundamental study of geomaterial using biodegradable plastic-Part 3: Characteristics of shear strength and permeability-, 55th JGS domestic annual conference, Kyoto, Japan, 2020. (to be published)

© Japan Society of Civil Engineers