STRENGTH CHARACTERISTICS OF PS ASH-TREATED SAND FOR APPLICATION AS BACKFILL SAND AROUND UNDERGROUND PIPES AND MANHOLES

Yokohama National University Student Member ○Maliki Otieboame Djandjieme
Yokohama National University Regular Member Kimitoshi Hayano
DOMI Environmental Solutions Regular Member Hiromoto Yamauchi

1.INTRODUCTION

So far, cement or lime has been often added to increase the strength of backfill sand. However, the treated sands sometimes induce high alkalinity or excessive solidification after a long curing period which can be a concern in the re-excavation ability. To solve these issues, this paper attempted to evaluate the short- and long-term strength development of PSAS-treated sand by conducting unconfined compression test and interpreting its strength mechanism using XRD diffraction profiles.

2.MATERIALS AND EXPERIMENT PROCEDURE

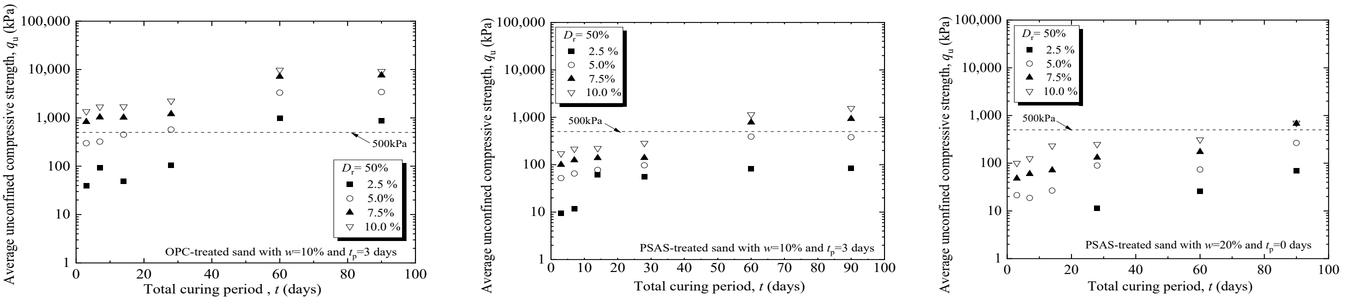
Toyoura sand and a PS ash-based stabilizers (hereafter PSAS) were used. The PSAS-treated sand specimens were prepared with and without primary curing. To prepare the specimens with primary curing, PSAS was mixed with Toyoura sand at addition ratio of PSAS, A_{PS}, of 2.5%, 5.0%, 7.5%, and 10.0%, and the water content w was adjusted to 10%. The mixtures were then placed into cylindrical plastic molds (50 mm in diameter and 100 mm in height), compacted to achieve relative density, D_r, of 50% and 90%, and the molds were sealed for t_p = 3 days for primary curing. Then, the specimens in the molds were cured in water for specified periods t_s after the primary curing, as shown in Table 1. For comparison, OPC-treated sand specimens with addition ratio of OPC, A_{OPC}, of 2.5%, 5.0%, 7.5%, and 10.0% were also prepared under the same conditions. For specimens without primary curing, PSAS was mixed with Toyoura sand at A_{PS} = 2.5%, 5.0%, 7.5%, and 10.0%, and the w was adjusted to 20% to prepare the specimens as shown in table 1. Subsequently, the mixtures were placed in molds, compacted to achieve D_r = 50% and 90%, and cured in water for specified periods t_s, as shown in Table 1. Three specimens were prepared for each treatment condition.

Table 1. Conditions of treated specimens for UCT

A_{PS} (%)	A_{OPC} (%)	w (%)	D_r (%)	t_p (d)	t_s (d)	$t = t_p + t_s$ (d)
2.5, 5.0, 7.5, 10.0		10		3	0, 4, 11, 25, 57, 87	
		20	50, 90	0	3, 7, 14, 28, 60, 90	3, 7, 14, 28, 60, 90
	2.5, 5.0, 7.5, 10.0	10		3	0, 4, 11, 25, 57, 87	

3.RESULTS AND DISCUSSION

The average unconfined compressive strength q_u of the three specimens against the total curing days t for each treatment condition are shown in Figs. 1 and 2. Here, the values of q_u are plotted on a log scale to make it easier to compare the q_u of PSAS-and OPC-treated sands. The results for the specimens with D_r = 50% and 90% are shown in Figs. 1 and 2, respectively. In each figure, (a) shows the results of OPC-treated sands with w = 10% and t_p = 3 d, (b) shows the results of PSAS-treated sands with w = 10% and t_p = 3 d, and (c) shows the results of PSAS-treated sands with w = 20% and t_p = 0 d. The q_u of the specimens increased with t for PSAS- and OPC-treated sands.



(a) OPC-treated sand with w=10% and t_p=3 d

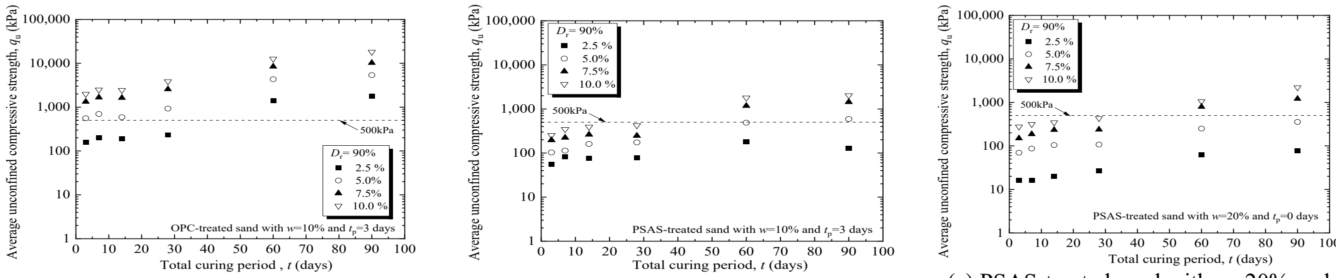
(b) PSAS-treated sand with w=10% and t_p=3d

(c) PSAS-treated sand with w=20% and t_p=0d

Fig.1 Relationship between the q_u and total curing period $t=t_s+t_p$ (D_r=50%)

However, the q_u of the OPC-treated sands was significantly higher than that of the PSAS-treated sands under the same mixing conditions. The q_u of the OPC-treated sands with w = 10% and t_p = 3 d was compared to the q_u of the PSAS-treated sands with w = 10% and t_p = 3 and 0 d, as shown in Fig. 3(a). Similarly, the q_u of the OPC-treated sands with w = 10% and t_p = 3 d was compared to the q_u of the PSAS-treated sands with w = 20% and t_p = 0 d, as shown in Fig. 3(b). The q_u of the OPC-treated sands were approximately 7.4 to 14.1 times larger than those of the PSAS-treated sands. Hosoya et al. (1993) has demonstrated that a q_u of 500 kPa or less was desirable for efficient manual excavation without using a pick or breaker. Therefore, the q_u values of 500 kPa shown as dashed lines in Figs.1 and 2 expressed the maximum value for a backfill sand to be easily re-excavated. The q_u of OPC-treated sand with A_{OPC} = 5% either exceeded 500 kPa from the beginning (Fig.2(a)) or exceeded 500 kPa in the middle of curing (Fig.2(b)). Conversely, the q_u of PSAS-treated samples with

A_{PSAS} = 5% barely exceeded 500 kPa during 90 d of curing. This indicates that PSAS-treated sand may be more easily re-excavated than OPC-treated sand.



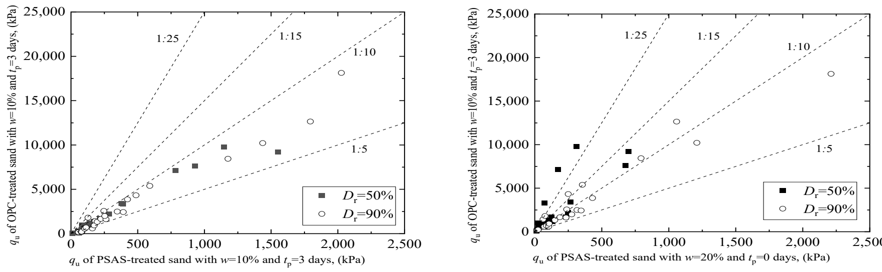
(a) OPC-treated sand with w=10% and t_p=3 d

(b) PSAS-treated sand with w=10% and t_p=3 d

(c) PSAS-treated sand with w=20% and t_p=0 d

Fig.2 Relationship between the q_u and total curing period $t = t_s + t_p$ (D_r=90%)

4.XRD PROFILES AND HYDRATES CONTRIBUTING TO THE STRENGTH INCREASE WITH TIME

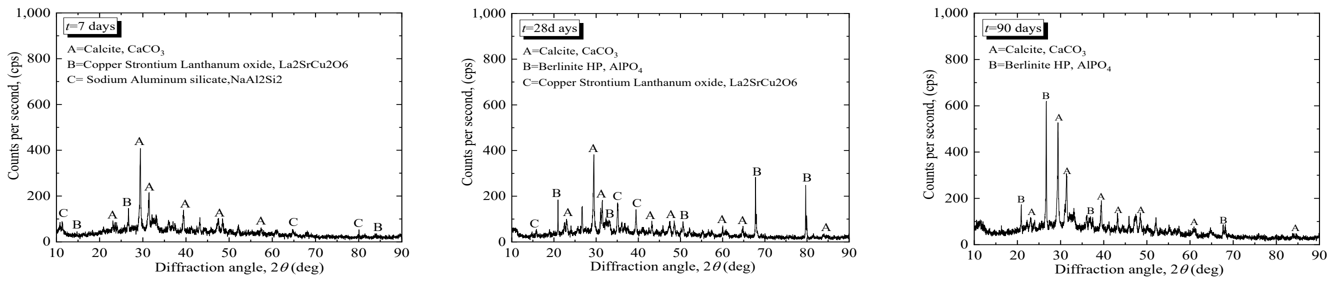


(a) PSAS-treated sand with w=10% and t_p= 3 d

(b) PSAS-treated sand w=20% and t_p=0

Fig.3. Comparison of UCS of PSAS-treated and OPC-treated sand with w=10% and t_p=3d

XRD tests were conducted on PSAS-treated sand that was prepared by mixing PSAS with Toyoura sand with an A_{PS} of 10% to investigate the hydrates contributing to the strength increase with time. The water content of the mixture was adjusted to 20%. Consequently, the mixtures were placed in molds, compacted to achieve D_r = 90%, and cured in water for 7, 28, and 90 days. The XRD results are shown in Fig.4. The XRD pattern revealed that the formation of calcite ($CaCO_3$) was dominant in the PSAS-treated sand at curing periods of 7, 28, or 90 days. In addition, berlinite ($AlPO_4$) may be an additional contributor to the increase in the strength of PSAS-treated sand in the long term. The observation of berlinite was similar to that of soils treated with coal ash, as reported by (Zhou et al., 2019).



(a) t=7 d

(b) t =28 d

(c) t=90 d

Fig. 4 XRD profiles of PSAS-treated sand with w = 20% and t_p = 0 d

5.CONCLUSIONS

The unconfined compressive strength q_u of the PSAS-treated sands increased with the total curing period t. However, the q_u of the PSAS-treated sands was significantly lower than that of the OPC-treated sands under the same mixing conditions. The q_u of the OPC-treated sands was approximately 7.4 to 14.1 times higher than that of the PSAS-treated sands. These observations suggest that PSAS-treated sand is easier to re-excavate than OPC-treated sand. The XRD pattern showed that the formation of calcite ($CaCO_3$) and berlinite ($AlPO_4$) was dominant in the PSAS-treated sand in the long term.

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Contact address: 79-10 Tokiwadai, Hodogaya Ward, Yokohama, Kanagawa 240-0067, Japan, Tel: +81 045 339 4037
E-mail address: maliki-djandjieme-mv@ynu.ac.jp