

EFFECTS OF CRUMBLING AND PARTICLE SIZE ON PH NEUTRALIZATION OF CONSTRUCTION SLUDGE TREATED BY PAPER SLUDGE ASH AND CO₂ CURING

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1. INTRODUCTION

Construction sludge generated from underground works frequently exists as liquid state and is commonly treated by cement for hardening. This process induces the increase of pH of construction sludge, which usually cannot satisfy the environmental regulation for recycling. In this regard, Trung et al. (2021) investigated the effectiveness of the combination of using CO₂ gas and paper sludge ash (PSAS) to accelerate the pH neutralization of alkaline construction sludge. The authors pointed out that the granulation by PSAS could accelerate the carbonation, and the D_{50} of PSAS treated sludge might affect the pH neutralization rate. Based on the findings, this research aims to study the effect of crumbling and particle size on pH neutralization of PSAS treated construction sludge.

Table 1. Mixing cases

Type of specimen	Crumbled sludge	Un-crumbled sludge
Ratio of BFCB to clay in weight	3%	3%
Ratio of PS ash to clay in weight	0, 10, and 20%	0, 10*, 20, 30, 40*, 50, 60, and 70%

* The cases have investigated the effect of particle size on t_N

2. MATERIALS AND EXPERIMENT PROCEDURE

In the laboratory, alkaline construction (AC) sludge was prepared by adding 3% of BFCB to Kasaoka clay ($w_L=60.4\%$, $w_p=26.0\%$) in weight. Before the addition, the initial water content of Kasaoka clay, w_i was adjusted to the liquid limit, w_L . To study the effect of crumbling on the accelerated carbonation of the simulated sludge, PSAS was added to AC sludge with the ratio of 10, 20, 30, 40, 50, 60, and 70% of clay. The materials were mixed by using a bench-top mixer. Samples were cured under sealed curing conditions for 7 days. Then, the lumpy treated sludges with $A_{PS} = 0, 10, \text{ and } 20\%$ were crumbled prior to the accelerated carbonation as presented in Table 1. The particle size distribution of sludges as shown in Fig. 1 was determined after sealed curing and crumbling for the uncrumbled and crumbled sludges, respectively. Sludge samples were poured into plastic cups and the height in cup was adjusted to 30 mm. Sludge samples were cured under CO₂ curing at concentration of 10% and temperature of 25°C by using a CO₂ incubator. After arbitrary CO₂ curing periods, pHs of sludges were measured.

To investigate the effect of particle size of sludges with different water contents on pH neutralization rate, the mentioned procedure of preparation was also applied to sludges with $A_{PS} = 10$ and 40%, except 1) the separation of particles to three categories ($0.85 \text{ mm} \leq D < 2.0 \text{ mm}$, $2.0 \text{ mm} \leq D < 4.75 \text{ mm}$, and $4.75 \text{ mm} \leq D < 9.5 \text{ mm}$) prior to accelerated carbonation, and 2) water content of sludge, w_{mud} was adjusted to around 30, 40, and 50% in accordance with $w_i = 0.78, 1.0, \text{ and } 1.26w_L$ for the $A_{PS}=40\%$ sludges, and $w_i = 0.62, 0.8, \text{ and } 1.0w_L$ for the $A_{PS}=10\%$ sludges. The pH neutralization rate was evaluated by t_N which is the needed CO₂ curing period to attain the pH = 8.6 as shown in Fig. 2.

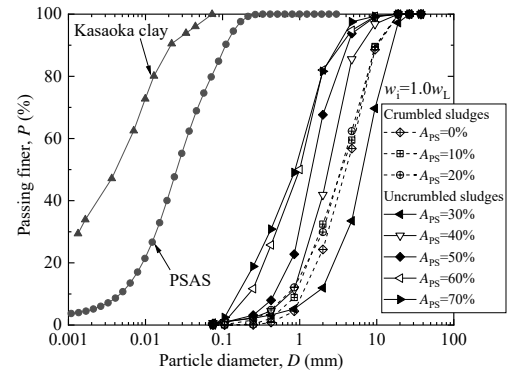


Fig. 1 Particle size distribution of sludges

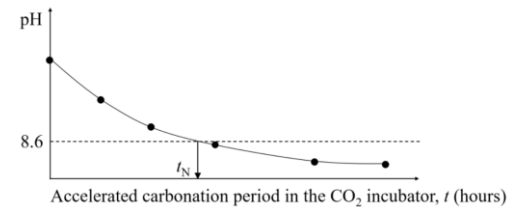


Fig. 2 Definition of t_N

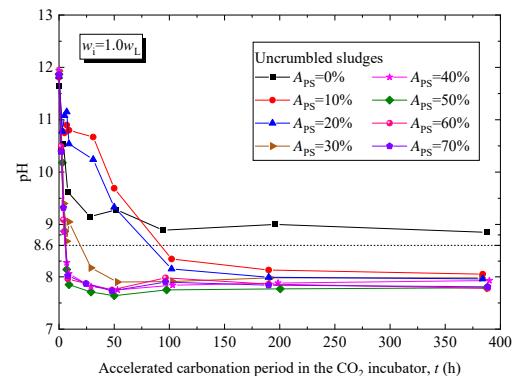


Fig. 3 pH neutralization of uncrumbled sludges under CO₂ curing

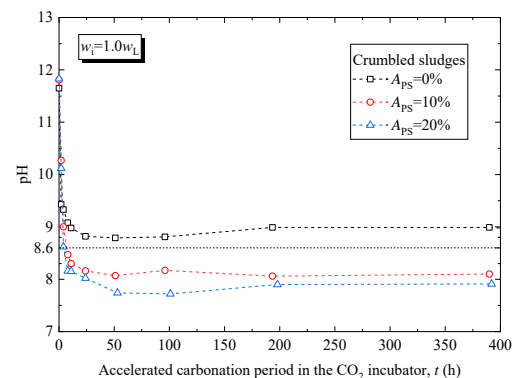


Fig. 4 pH neutralization of crumbled sludges under CO₂ curing

Keywords: Alkaline construction sludge, PS ash-cement-treated clay, pH neutralization, Particle size, Accelerated carbonation
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3. RESULTS AND DISCUSSION

As shown in Fig. 1, the addition of PSAS with $A_{PS} \geq 30\%$ significantly granulated the AC sludge whereas the sludges with $A_{PS}=0, 10, \text{ and } 20\%$ were lumpy and needed to be crumbled to determine the particle size distribution.

As shown in Fig.3, the accelerated carbonation showed the effectiveness in neutralizing the sludges having sand and gravel-like particle size and their pHs were quickly fallen to 8.6. In contrast, the lumpy sludges (the uncrumbled sludges with $A_{PS}=10 \text{ and } 20\%$) spent a very long curing periods to decrease the pH to 8.6. Especially, pH of the uncrumbled AC sludge could not be neutralized to 8.6 after up to nearly 400h of CO_2 curing.

However, by crumbling, the needed CO_2 curing period to attain the $\text{pH}=8.6$, t_N of lumpy sludges ($A_{PS}=10 \text{ and } 20\%$) was significantly reduced from around 100h to less than 10 hours as shown in Fig. 4. Fig. 5 shows the t_N of crumbled sludge with $A_{PS}=10 \text{ and } 20\%$ which were almost equal to that of granulated sludges. Note that even being crumbled, pH of the AC sludge quickly fell at the initial CO_2 curing period but could not be neutralized to 8.6.

Figure 6 (a), (b), (c) demonstrate the effect of particle size on t_N for the D range of each sludge with $w_{\text{mud}} \approx 30, 40, \text{ and } 50\%$, respectively. Generally, sludge samples with larger particle sizes produced the higher t_N . The low t_N of sludges having smaller particles could be explained by the facilitation of carbonation by the larger surface area. CO_2 gas carbonated the particle surface, and pH neutralization progressed gradually from the surface to the particle interior. Therefore, a smaller particle size facilitated pH neutralization of the entire particle.

Moreover, Fig. 6 expressed that the effect of particle size on t_N was affected by A_{PS} . The higher A_{PS} produced the smaller change in t_N . This is probably due to the differences in structure of particles. By mixing with PSAS, the intra-opened voids of particles could be produced (Dong et al., 2011) which facilitates the penetration as well as the approached surface area of CO_2 gas, and hence the change in t_N caused by the difference in D could be small.

4. CONCLUSIONS

The enhancement of pH neutralization rate of alkaline construction sludge treated by PSAS was investigated previously. In this study, pH neutralization of alkaline construction sludge treated by PSAS was further improved by crumbling. By crumbling, t_N of lumpy sludges with $A_{PS}=10 \text{ and } 20\%$ were significantly decreased from around 100h to less than 10h, and almost equal to that of granulated sludges. However, t_N of sludge with $A_{PS}=0\%$ could not be obtained even after being crumbled.

In addition, the effect of particle size on pH neutralization of alkaline construction sludge was investigated. The results showed that the pH neutralization period decreased with the particle size, which can be attributed to the following: CO_2 gas carbonated the particle surface, and the pH neutralization progressed gradually from the surface to the particle interior. Therefore, a smaller particle size facilitated pH neutralization of the entire particle. However, when the addition ratio of PSAS increased, the difference in the pH neutralization period induced by the change in particle size became less significant.

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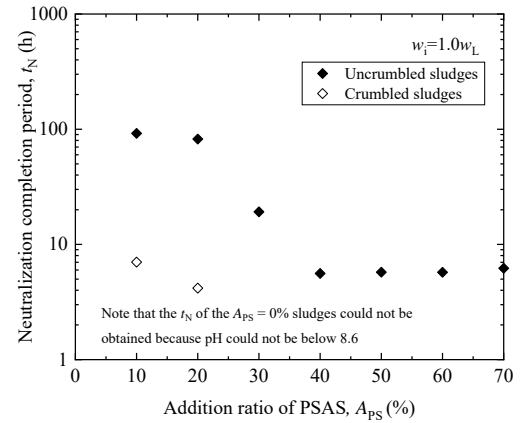
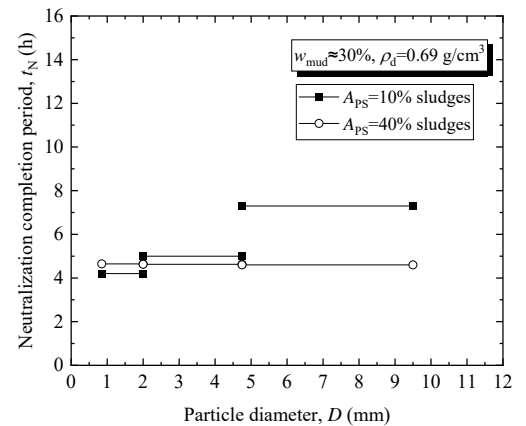
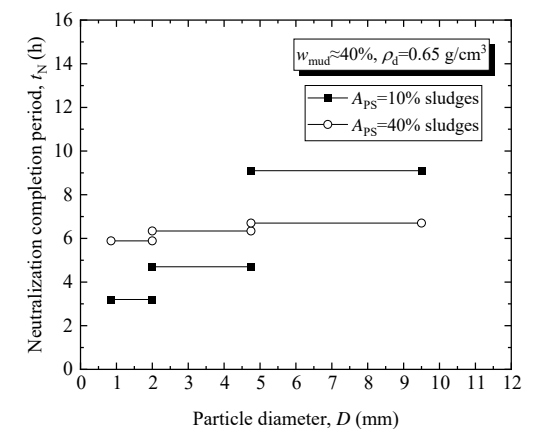


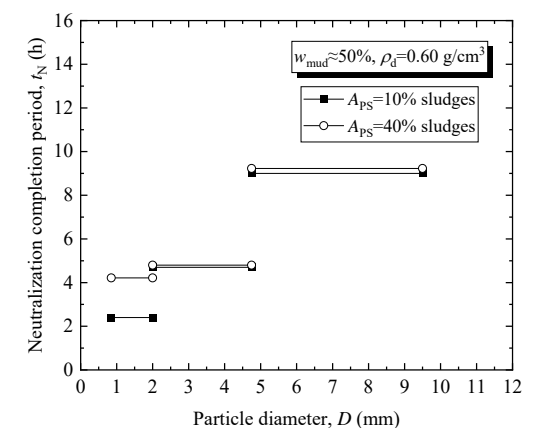
Fig. 5 Relationship between A_{PS} and t_N



a) Sludges with $w_{\text{mud}} \approx 30\%$



b) Sludges with $w_{\text{mud}} \approx 40\%$



c) Sludges with $w_{\text{mud}} \approx 50\%$

Fig. 6 Effects of particle size on t_N