【III－10】

Utilization of mineralized phosphates and carbonates to enhance engineering properties of porous materials

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1. Introduction

The mixture of $CaCO_3$ and phosphate minerals of alkaline earth metals may bind the sand grains improving the mechanical and physical properties. The phosphate minerals are easy to obtain, non-toxic, and suitable for geotechnical application (Akiyama & Kawasaki, 2012). The phosphate minerals can be obtained by the reaction of metal salts with soluble inorganic salts of phosphates. The reaction taking place is shown below. However, this paper does not address the composition of the chemicals used.

$$M1S1 + M2PO_4 \rightarrow M1PO_4 + byproduct \quad (1)$$

$$M1S2 + M2PO_4 \rightarrow M1PO_4 + byproduct \quad (2)$$

M1S1 and M1S2 in **Equations (1)** and **(2)** represent soluble metal salts, while $M2PO_4$ represents soluble metal phosphate. The $M1PO_4$ in the product side is the insoluble mineral of phosphate, hence it gets precipitated. The precipitated material obtained soon after mixing is in the form of gel. The gel is mixed with silica sand along with some binding agents, i.e., $CaCO_3$ to evaluate its efficacy to bind the sand particles.

2. Materials and Methods

At first, various combinations of the reagents are studied in 50 mL centrifuge tubes. The combinations of the reagents producing appreciable amount of hard gels are selected. The selected combinations are shown in **Table 1**. The precipitated materials are prepared from the selected combinations. Afterwards, sand samples are prepared to evaluate the improved mechanical properties. Silica sand (Tohoku keisa #6) is utilized in this study. The physical properties of sand are given in **Table 2**. 1, 5 and 10 % by weight of $CaCO_3$ powder (purity > 95 %) are thoroughly mixed with sand. About 70 mL of the freshly prepared gel is evenly mixed with the sand $CaCO_3$ mixture. Samples are prepared in PVC molds with a diameter of 5 am and a height of 10 cm. The samples are prepared by gently tamping the mixture in four layers of each 2.5 cm.

Table 1: Combinations of chemicals, and proportions of sand and $CaCO_3$

Sample Name	A [1.0 mol/L]	B [0.5 mol/L]	Tris [1.0 mol/L]	Sand [g]	$CaCO_3$ [g]
N1	M1S1	$M2PO_4$	1.0	300	0
N2	M1S1	$M2PO_4$	1.0	297	3
N3	M1S1	$M2PO_4$	1.0	285	15
N4	M1S1	$M2PO_4$	1.0	270	30
A1	M1S2	$M2PO_4$	1.0	300	0
A2	M1S2	$M2PO_4$	1.0	297	3
A3	M1S2	$M2PO_4$	1.0	285	15
A4	M1S2	$M2PO_4$	1.0	270	30

The tamping rod has a diameter of 25 mm and weights 350 g. The height of tamping is about 10 cm. The specimen is cured for 3 days in air proof container at 20° C. The compressive strength of the cured sample is evaluated.

3. Results and discussion

The precipitated material obtained from one of the selected combinations is shown in **Figure 1**. From the visual observation we can say that the selected combinations give harder gels.

Relation between the compressive strength and the amount of $CaCO_3$ in sand is depicted in **Figure 2**. As shown in the figure, compressive strength increases with the amount of $CaCO_3$ in sand. However, an unconfined compressive strength of about 20 kPa is obtained from the samples treated with only phosphate minerals. The samples treated with M1S2 type salt are found to attain higher strength than the samples treated with M1S2 type salt.

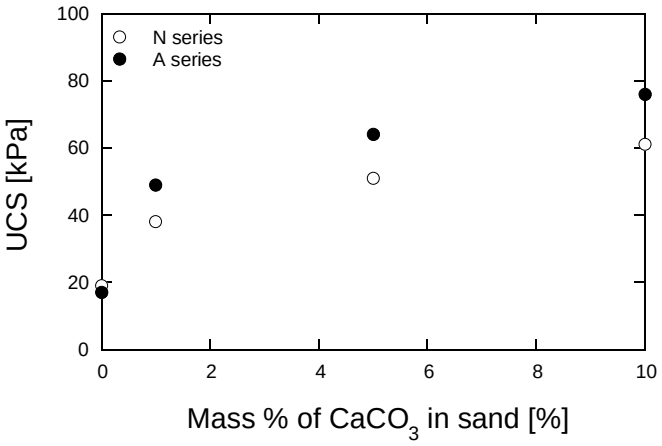

Figure 2. Relation between $CaCO_3$ content and compressive strength

Table 2: Properties of sand

Properties	Values
D_{10} [mm]	0.200
D_{50} [mm]	0.340
Gs	2.653
e_{max}	0.899
e_{min}	0.549
k* [cm/s]	0.044

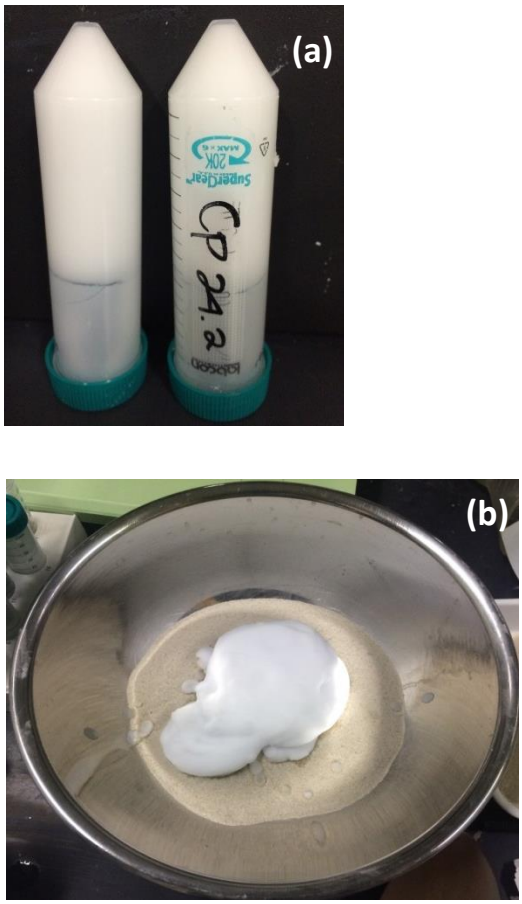

Figure 1. (a) Precipitation in centrifuge tube, (b) hard gel being mixed with sand

4. Conclusion

The experimental results show that a noticeable cementation of sand can be achievable by utilizing the precipitated minerals of phosphates and carbonates. However, mixing method is not preferred over injection method. Therefore, *insitu* mineral precipitation by injection rather than mixing will be considered in the near future works.

5. References

Akiyama, M. and Kawasaki, S., (2012), "Microbially mediated sand solidification using calcium phosphate compounds", *Engineering Geology*, 137-138, 29-39.