Relation between amount of precipitated calcite and strength of in-situ calcite cemented sand

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1. Introduction

Precipitation Enzyme Mediated Calcite Precipitation, EMCP, may possibly be used as a novel soil improvement technique. The studied technique utilizes purified urease enzyme to dissociate urea into the carbonate compound (**Equation 1**). The carbonate compound combines with the calcium ion, supplied in the form of solution of calcium salt, to form precipitate of calcium carbonate (**Equation 2**).

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-} \quad (1)$$

$$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3 \quad (2)$$

After hardening, the precipitated $CaCO_3$ serves as the bridges among the sand particles binding them and helping to improve the mechanical properties of treated soil (Harkes…….). The increase in compressive strength ranges from 0.2-12 MPa depending upon the amount of the calcite precipitated (van Paassen et al, 2012).

2. Materials and methods

Steel drum cans, with an internal diameter of 57 cm and a height of 85 cm, are used in this experiment. A flexible tube, with an internal diameter of 3 mm (saturation tube), is placed at the bottom of each can. It will be used to inject CO_2 gas and water for saturation. A 10-cm layer of aggregate is placed at the bottom and two outlet pipes (2.5 cm in diameter and 1 m in length), with drainage holes at frequent intervals, are attached vertically along the wall of the drum cans. The inner surface of the drum cans is covered with textile to prevent the direct contact of iron rust with the sand and also to ensure the drainage through all the surfaces. Siliceous sand with e_{max}, e_{min}, and specific gravities of 0.716, 0.577, and 2.643, respectively, are used to prepare the specimen. Sand is poured in 6 layers of 10 cm each. The relative density of 50% is maintained at each layer. An injection tube is placed at the center of the sand specimen during sand pouring. Injection tube is a flexible tube with an internal diameter of 1.2 cm. It is provided with 3 cm vertical slots covered by cotton mesh at one end. After pouring all 6 layers of sand, 5-cm layer of aggregate is added above the sand specimen. The arrangement is sealed with a 3-cm layer of mortar. A schematic of the drum can is shown in Figure 6(a).

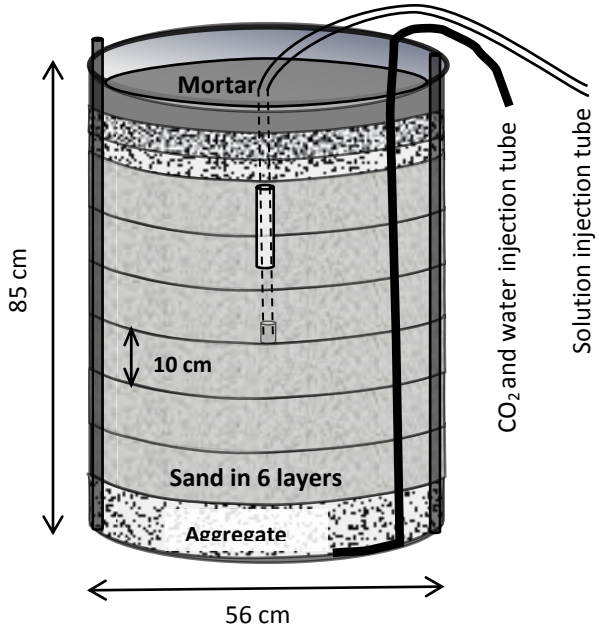

Fig.1 Schematic representation of drum can test

1.5 pore volumes of CO_2 gas are injected to replace the air in the voids. Subsequently, 90 L of water is injected so that it will dissolve the CO_2 gas and the sample will be almost saturated. 15 L of urea-$CaCl_2$ solution and 15 L of urease solution are

blended together to achieve a final urea-$CaCl_2$ concentration of 1.0 mol/L and a final urease content of 15g/L. The prepared solution is injected through the injection tube at the rate of 1.0 L per minute using a peristaltic pump. After 2 hours of first injection, another 30 L prepared solution is injected following the similar procedure. The prepared specimen is allowed to improve for 24 hours.

The wall of the drum can is cut vertically. A gentle spray of water is allowed to wash away the unimproved portion leaving only the improved portion. Samples having a diameter of 3 cm and a height of 6 cm are collected for Unconfined Compression test, UC test. UC tests are carried out and the strength and stiffness of the samples are evaluated. The amount of the precipitated calcite on these samples is evaluated.

3. Results

The improved portion of the specimen is shown in Figure 2. The stress strain diagram of the improved sand samples taken from the central portion of the specimen is shown in Figure 2. The relation between precipitated calcite content in sand and the improved mechanical properties are as shown in Figure 3. As is apparent, the strength and stiffness of the improved samples are nearly 400 kPa and 20 MPa, respectively. The corresponding amount of the precipitated calcite varies from 11 to 13 gram per 100 g of sand.

4. Conclusion

The experimental results show that the insitu calcite cementation technique may be used as a possible soil improvement technique. The strength obtained is equal to the strength of very stiff to hard soil. The control of quantity and the distribution of calcite will be considered in near future works.

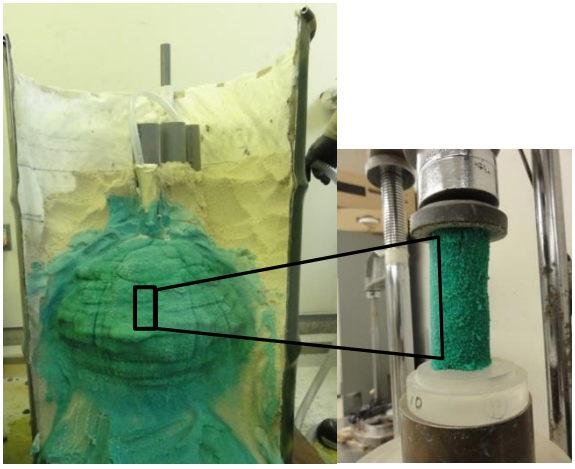

Fig.2 improved portion of the specimen

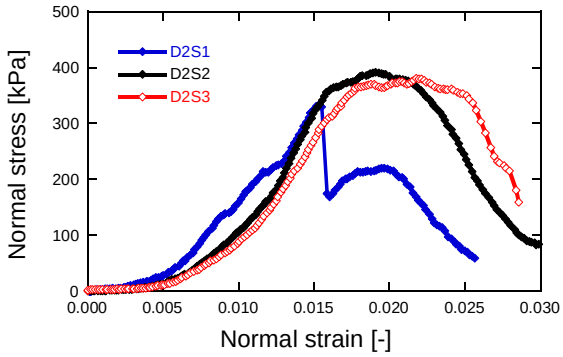

Fig.3 Stress-strain curve

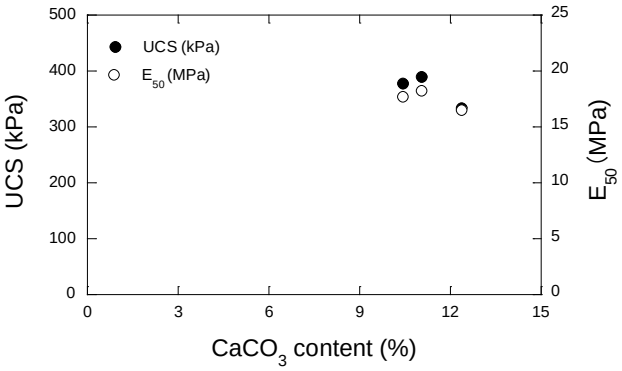

Fig.4 Relation between calcite content and mechanical properties

4. References

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