

Role of amorphous silica in forming calcium silicate hydrate for strength development of steel slag-dredged soil mixtures

*Kanako Toda¹, Yu Arai¹, Tsubasa Otake², Tsutomu Sato², Haruna Sato¹, Nilan Weerakoon¹, Nishimura Satoshi²

1. Graduate School of Engineering, Hokkaido University, 2. Faculty of Engineering, Hokkaido University

Dredged soils consists of minerals including clays, organic debris and seawater, and are excavated beneath ports to maintain the waterways. Partially they are landfilled due to its soft physical properties disabling its usage as construction materials. Indeed its characteristics differ greatly depending on the sampling areas due to the variation in its composition. Recently, it is discovered that mixing dredged soil with steel slag, that is also partially treated as waste produced as iron smelting process' s by-products, develops strength. This discovery may turn dumped fraction of both materials to resources by expanding their application into building materials for undersea constructions. Nonetheless, different combinations of a type of steel slag and dredged soil from various areas show gaps in the strength development even in under the identical mixing condition. The relationship between mixing condition and strength development is not yet clarified, making it difficult to be utilized for the above application.

Clarifying the hardening mechanism of the steel slag-dredged soil mixture will enable prediction of the strength with a particular combination of steel slag and dredged soil. In order to achieve it, clarifying the secondary mineral formation that contributes to hardening is essential. Previous studies suggest that the strength development is related to the pozzolanic reaction, which results in cementation by the formation of calcium silicate hydrates (C-S-H). Key factors in the pozzolanic reaction include the increase in pH of the pore water, and the supply of calcium and silica ions to pore water. Steel slag contains Ca(OH)_2 , which supplies calcium and increases pH of the mixture. Silica is said to be supplied from the dredged soils, but it is not clarified what is being the silica supply.

Focusing on the variation of dredged soil affecting the strength development, the objective of this study is to understand the effects of amorphous silica in dredged soils, which has faster dissolution rate compared to crystalline silica phases, to the early strength development of steel slag-dredged soil mixture.

In this study, dredged soils from various sampling locations (A, B, C and D) and steel slag from iron works 1 were mixed for the investigation. XRD analysis showed no significant difference between the mineralogical compositions of all the dredged soils. The unconfined compressive strength showed mixtures with soil A exhibits the highest strength, followed by those with B, C and D. Formation of C-S-H in mixture A was found to be denser than mixture D through scanning electron microscope, filling up pores in the mixture. In addition, the measurement of mixture' s pore water pH transition showed decreasing trend in pH from 12.5 in only mixtures A and B but not C and D from 1 day curing onward. This suggests stronger mixtures' (A and B) pore water' s pH were influenced by formed secondary minerals, such as C-S-H which expels H^+ when it forms, indicating that its formation was notably greater in stronger mixture. In our mixtures, the silica ion was most likely supplied from dredged soils. The silica concentration dissolved from diatom frustules were measured. Soils A and B showed higher dissolved silica concentration compared to C and D. Inorganic amorphous silica such as volcanic glass content is also discussed. From geochemical modelling which treats amorphous silica dissolution kinetically, it was clarified that stronger and weaker mixtures show significant difference in the volume of C-S-H forming. We suggest that the silica supply from amorphous silica in dredged soils may be the driving force for the pozzolanic reaction for early strength development.

Keywords: pozzolanic reaction, dredged soil, steel slag, Amorphous silica