Key Factors of Metastable Phase Formation for Strength Development in Steel Slag-Dredged Soil Mixtures

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Introduction

The usage of by-products from industrial activities as construction resources is awaited in Japan to decrease the environmental impact by solving the problem of land filling site shortage for any wastes due to the limited land area. Both steel slag from ironworks and dredged soil extracted beneath the ports are one of them. While the most of steel slags achieved to be utilized as a construction material resource, the majority of dredged soil’s utilization is not yet achieved. Dredged soils have soft physical properties and therefore are difficult to be utilized as construction resources. They are landfilld or dumped in other sea floor. Dredged soils are mainly composed of minerals including clays, organic debris and seawater. Therefore, its characteristics differ greatly depending on the sampling areas due to the variation of its composition. Recently, it is discovered that mixtures of steel slag with dredged soil are hardened. This discovery may expand their application into building materials for undersea construction such as refilling, reclamation and constructing tideland which may solve the problem. Nonetheless, different combinations of a type of steel slag and dredged soil from various areas show gaps in the strength development even under an identical mixing condition. The relationship between mixing condition and strength development is not yet clarified, making the mixture difficult to be utilized for the above application.

Understanding of the hardening mechanism of the steel slag-dredged soil mixture will enable the prediction of the strength with a particular combination of steel slag and dredged soil. To achieve it, clarifying the secondary mineral formation that contributes to hardening is essential. Previous studies suggested that the strength development was 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 are the increase in pH of the pore water and the supply of calcium and silica ions to pore water. While Ca supply is determined to be Ca(OH)₂ in steel slag which also increases pH by its hydration. Silica supply is suggested to be originated in dredged soils, but clarification of the source is not yet achieved disabling the prediction of the strength development.

Objective

Focusing especially on the amorphous phases contained in variety of dredged soils, the objective of this study is set to understand the effects of silica-bearing phases in dredged soil on the strength development of steel slag-dredged soil mixture.

Samples

In this study, dredged soils from various sampling locations (A, B, C and D) and a steel slag from ironworks 1 were mixed for the investigation. The unconfined compressive strength showed mixtures with soil A exhibits the highest strength, followed by those with B, C and D.

Results and Discussion

Through 3-day cured sample’s cross-sectional area observation, formation of C-S-H in mixture A was found to be denser than mixture D, filling up pores in the mixture. In addition, the measurement of mixtures’ pore water pH transition showed decreasing trend in pH from 12.5 in only mixtures A and B but not C and D during 0day-91days curing time. This suggests stronger mixtures’ (A and B) pore water’s pH was dominated by formed secondary minerals, such as C-S-H which expels H⁺ when the reaction goes forward for the formation of it, indicating that the secondary mineral formation was notably greater in stronger mixture. Firstly, the effect of humic acid, that is a kind of organic substance, which may limit the supply of soluble calcium is quantified and its functional groups are analysed to see the effect on strength development of the mixtures. Further, the silica ion was most likely supplied from dredged soils so the biogenic silica content is also clarified by the dissolution experiment. Inorganic amorphous silica such as volcanic glass content had positive correlation with strength development. XRD analysis showed no significant difference between the mineralogical compositions of all the dredged soils before mixing including clay minerals. Through geochemical modeling for estimation of C-S-H formed from above silica supply, we suggest that the silica supply from each silica-bearing phase of dredged soils may be the driving force for the pozzolanic reaction during strength development.