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An Assessment of Eco-Friendly Controlled Low-Strength Material

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Abstract

The present study aims to investigate the fresh and hardening properties of a soil-based controlled low-strength material (CLSM) containing stainless steel slag as a cementitious material. This type of CLSM primarily uses in construction as a trench-fill material. Four levels of the cement substitution (i.e. 0%, 10%, 20%, and 30%) and three amounts of binder content (80-, 100-, and 130 kg/m3) were generated for the experimental work. Fresh and hardening properties of the recommended CLSM were examined in the laboratory. The results show that the proposed CLSM could be employed for eco- friendly trench fills.

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Keywords: trench fill; stainless steel slag; flowability; cement substitution; controlled-low strength material

1. Introduction

The construction of infrastructures or pipeline projects usually generates a huge amount of unused soil needing to be removed, while a considerable quantity of natural materials (e.g. river sand, granular soil), is likely transported to jobsite for backfills. Nowadays, controlled low- strength material (CLSM), commonly used as granulated compacting soil, subgrades or trench fills, would be a eco-friendly material because it effectively consumes a massive quantity of waste materials such as combustion fly ash, foundry sand, rubber tires, and other industrial by-products. CLSM typically consists of small amount Portland cement, supplementary, fine aggregates, and a large amount of mixing water. Self-compacting/ -leveling, low strength,

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as well as almost no measured settlement after hardening are remarkable characteristics of CLSM. By definition, CLSM has a compressive strength of 8.3 MPa or less and slightly higher than that of compacted soil [1]. Moreover, recent studies have reported that maximum CLSM strength of approximately up to 1.4 MPa is suitable for most of backfilling applications that re-excavation with simple tools in future is desired [2, 3]. Literature has documented that on-site residual soil after pipeline excavation could be an alternative source for fine constituent in production of soil-based CLSM, which is effectively used as backfill material around buried pipelines [4, 5].

On the other hand, stainless steel reducing slag (SSRS) discharges from reducing condition of basic refining process, called as secondary steel making operation. It usually contains several toxic ingredients such as chromium, lead, nickel, cadmium, which would be harmful for not only environment, but also human health. Chemically, stainless steel slag is mainly a compound of several metal oxides (e.g., CaO, SiO2, and Al2O3), which is similar to GGBFS. Recent studies have been concluded that steelmaking slag generally exhibited both cementitious and pozzolanic characteristics when it was ground into very fine particles [6, 7].

In this paper, residual soil generated from a specific construction site and SSRS were employed to develop a CLSM primarily used as backfill. For the proposed CLSM, the effect of SSRS amount replacing Portland cement on the characteristics of CLSM is investigated. This cementitious material would achieve both benefits of ecological and low-cost solution. In the testing program, several major engineering properties of the proposed CLSM were examined. The findings from the study are expected to provide a corrected usage of excavated soil and hazardous by-product as recycled sources for making green construction materials.

2. Experimental program

Materials for the CLSM mixture consist of fine aggregate, cement, SSRS, and mixing water:

- Cement: Ordinary Portland cement (OPC) Type I with the specific gravity of 3.15 and specific surface area of 3851 cm^2/g.
- SSRS: The properties of the SSRS and OPC are shown in Table 1.
- Soil: Taken from local jobsite and classified as poorly graded sand with silt (SP−SM).
- River sand: Fine modulus of 2.51.

Table 1. Chemical and physical properties of OPC and SSRS

Analysis results	OPC Type I	SSRS
Chemical constituents (%)		
- Silicon dioxide, SiO_2	20.87	22.97
- Aluminum oxide, Al_2O_3	4.56	4.00
- Ferric oxide, FeO/Fe_2O_3	3.44	0.08
- Calcium oxide, CaO	63.14	51.26
- Magnesium oxide, MgO	2.82	8.1
- Sulfur trioxide, SO_3	2.06	0.09
Physical properties		
- Loss of ignition, L.O.I (%)	2.30	-
- Fineness (cm^2/g)	3851	4551
- Specific gravity	3.15	2.84

Three mix groups (12 mixtures) containing 80-, 100-, and 130 kg/m3 binder were provided for mix design, namely as B80, B100, and B130, respectively. Fine aggregate for CLSM was formed by well blending between river sand and residual soil with a given proportion (e.g., 6:4, by volume). Fig. 1 shows the grading curves of the collected sand, soil and combination. In each group, four percentages of SSRS substitute for OPC such as