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RESEARCH ARTICLE
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Engineering Characteristics at Early Age of Cemented Silica Fume Paste for Peat Compaction Grouting

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Abstract:

Introduction: Cemented Silica Fume Paste (CSFP) is currently being investigated for compaction grouting material to improve peat ground engineering properties. The CSFP is made in the laboratory using a proportional mixture of silica fume, cement binder, and tap water. The silica fume material is a byproduct of the metal processing industry, which critically requires a better alternative utilization in the near future in order to cut the storage cost and minimize the environmental impact.

Aims: This paper aims to present preliminary results on the engineering characteristics of CSFP at an early age through a series of rheological and strength tests. A general observation of the physical properties and microstructure of CSFP is also presented.

Methods: The CSFP specimens with cement binder range from 0% to 30% with the increment of 5% and Water-to-Solid (W/S) ratio ranges from 0.8, 0.9 and 1.0 were prepared and tested. A series of rheology test and Unconfined Compressive Strength (UCS) tests were carried out for the CSFP specimens at an early age. The data were analyzed statistically and mathematical formulation is presented.

Results: The results indicate that CSFP mixtures behave as pseudoplastic or shear thinning fluid, where the shear stress and viscosity depend highly on the shear rates. The higher the shear rates, the higher the shear stress and the lower the viscosity. Curve fitting showed that the best relationship between shear stress and shear rate is the power law function (Ostwald–de Waele relationship). Statistical parameters, k, n, R^2 of the power law functions are reported. There was no good correlation found between the power law function statistical parameters and the cement content. The UCS tests showed that the shear strength increases with the amount of cement content. The actual W/S reduces as the cement content increases, which is attributed to the cement hydration.

Conclusion: The CSFP mixtures were found to be a pseudoplastic or shear thinning fluid at an early age that provides an advantage during the material injection on the ground. Cemented Silica Fume Paste can be potentially used as compaction grout to improve peat. The current findings provide a better understanding of the CSFP characteristics and to better design CSFP to be injected into peat ground.

Keywords: Cemented silica fume paste, Rheology, Strength, Peat, Compaction grouting, Pseudoplastic.

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1. INTRODUCTION

Infrastructure development often requires expansion into peat areas due to the decline in areas with good soil conditions. Construction in peat grounds requires better methods in order to sustain load from the above infrastructure such as road embankment. Several construction methods have been proposed and a few of them have been practically implemented [1, 2]. In general, the construction methods for peat grounds can be categorized as the following: removal and replacement, staging and filling technique, expediting consolidation, load transferring, and peat mixing. The best choice to apply depends on the peat properties, the ground condition, the type of construction, the availability of material and facilities, and cost.

On the other hand, industrial development in the metal processing industry has been exponentially increasing due to the technology demands. Metal processing generates by-products (wastes) that require either a proper storage or an appropriate utilization in order to reduce storage cost and to minimize the impact to the environment, respectively. As the by-product accumulates over time, the storage cost will increase and the impact on the environment will potentially increase as well. Therefore, the accumulation of the byproduct will eventually necessitate the appropriate utilization to be implemented.

Cemented Silica Fume Paste (CSFP) is a newly proposed material to be used as one of the construction methods to increase the strength and compressibility of peat. The material is similar to paste-fill which has been successfully and popularly used for the last two decades in order to stabilize underground stope [3, 4]. The CSFP will be used as a grout material by injecting it into the peat ground in order to densify the peat from within (the inside) such that the bearing capacity of the peat increases that suffices to support the external load from the road embankment. Such densification process will reduce the void within peat, and will increase the normal stress and the shear stress of the peat. Injecting the grout material into the soil is generally called compaction grouting [5, 6]. Models showed that compaction grouting increases mechanical properties of soil, such as dry unit weight, apparent cohesion, friction angle, and dilatancy [7, 8]. It has been successfully used to improve the characteristics of the sand to clay soils, such as densification, reducing liquefaction potential, increasing pullout capacity in soil nailing, *etc*. [9-11]. However, the study on the application of compaction grouting in peat is lacking. It is expected that compaction grouting solves not only the problem of peat but also reduces the accumulation of industrial by-product at the same time. Fig. (**1**) illustrates how the CSFP will be used to support peat as a road embankment foundation.

The silica fume has been so far utilized and marketed commercially as an additive to produce and improve high strength concrete [12, 13]. The silica fume assists in pozzolanic reaction and acts as a pore filler to reduce the void and permeability of concrete owing to its extremely small size particles [14]. However, the utilization rate for such an application is much smaller than the production rate of the silica fume. The utilization of some other applications is required to balance or to surpass the production rate.

This paper presents the preliminary results on the engineering characteristics of CSFP, which focuses on rheology and strength behaviour at early age. The rheology and strength behaviour at early age are important aspects to be understood for the injectability (flowability) of the CSFP during its application. The finding is useful for engineers and academics to better understand the CSFP engineering behaviour as an alternative improvement of peat ground.

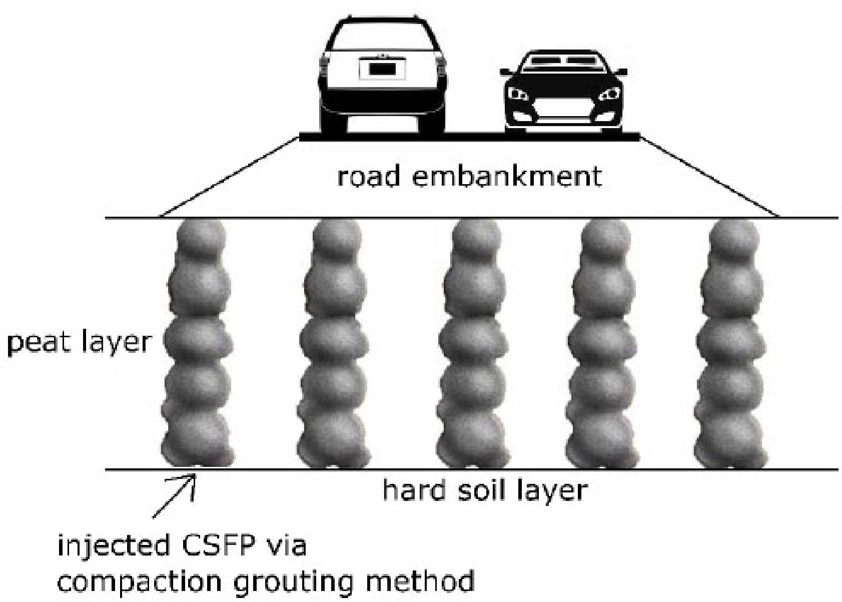

Fig. (1). Injecting CSFP *via* compaction grouting method.