Construction and Building Materials 165 (2018) 541–547

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Technical note

Field in-situ stabilization of bored pile mud: Engineering properties and application for pavement

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ARTICLE INFO

Article history:
Received 5 October 2017
Received in revised form 16 December 2017
Accepted 2 January 2018

Keywords:
Waste bored pile mud
In-situ stabilization
Ordinary Portland cement (OPC)
Fly ash (FA)
Pavement

ABSTRACT

This paper discusses the behaviour of field-stabilized bored pile mud and the feasibility of its application in pavement. The geotechnical properties of field-stabilized mud on different curing days were evaluated by a series of laboratory tests including compaction, California Bearing Ratio (CBR), modified unconfined compressive strength (MUCS), axial compression tests and scanning electron microscopy (SEM). A field roadbed 80 cm thick and 50 m long was paved successfully using the in-situ stabilized mud treated by the proposed in-situ stabilization system. The stabilized mud displayed a favourable fill performance in regards to the compactness and deflection values of the test pavement. Maximum dry density for improved mud increased while optimum water content decreased over time. A linear relationship between CBR and curing time was identified. The main role of fly ash (FA) is filling void in stabilized mud rather than reacting with other parts.

1. Introduction

During bored pile construction, the original mud and soil residue are removed in large quantities from the pile hole and transformed into waste soil. This mixture contains native soil, water, bentonite, carboxymethyl cellulose, fibrous matter, and other material. The complexity of these constituents, the material's high water content ($w > 100\%$ of solids), and its high fluidity make it extremely difficult to manage. Conventional treatment strategies for waste soil involve removal or in-situ stacking. The former strategy introduces high transport fees and is damaging to the ecosystem; the latter one is challenging because the high water-holding capacity of the mud does not lend well to spontaneous evaporation. Land occupation, poor environmental compatibility, high transport costs, and similar issues related to pile hole waste mixtures have attracted the attention of the Chinese government.

Soil improvement is well recognized as a reasonable and an efficient approach for managing waste soil. It produces filling materials with dramatically enhanced performance [1–7]. Most of the extant research on waste mud has centered around drilling mud [8–10] or wastewater sludge [11]. Nevertheless, to the knowledge of the authors, there have been few studies on bored pile mud [12]. There is urgent demand for efficient management strategies for the waste mud produced from bored piles. However, bored pile waste mud cannot be treated conventionally (dehydration before stabilization) due to its high water content. The conventional field stabilization method also requires the use of an excavator or other mixing machines, which are not suited to bored pile mud and necessitate available land for stacking and transportation.

The primary goal of this study was to improve upon existing waste bored pile mud treatments by adding additives. Field bored pile mud was field stabilized via an advanced in-situ stabilization system as opposed to conventional stabilization. The properties of field-stabilized mud were also explored in this study, as discussed below.

2. Experimental programs

2.1. Materials

The virgin mud stabilized in this study was located in Jiaxing City, China as-produced by bored pile construction. A mud pit adjacent to the test pavement was selected as test mud. The original quantity of water compared to the amount of dry mud ranged from 90 to 120%. Its basic properties are listed in Table 1.

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https://doi.org/10.1016/j.conbuildmat.2018.01.006
0950-0618/

Table 1
Basic properties of virgin soil.

Properties	Water content	Specific gravity	Liquid limit	Plastic limit	Clay	Silt	Sand
Value	90–120%	1.225 g/cm^3	45%	17.5%	36%	58%	6%

The ordinary Portland cement (OPC) and fly ash (FA) were used as stabilizer in this study. The OPC used is P.O. 42.5 and the FA is Class-I FA (Chinese classification) as described in Table 2.

2.2. Preparation of field-stabilized mud

The field-stabilized mud was investigated in this study to replace the conventional laboratory-stabilized mud, which is more representative and valuable in stabilization construction. A stabilization system consists of a power mixer (PMX300), data acquisition control, and pressure feeder, being used to dispose the mud. The former two parts were purchased from ALLU Finland Oy and the last one was produced independently in China (Fig. 1). This system can achieve a soil treatment operational efficiency up to 500 m^3 per hour and at a maximum depth of 3 m. A stabilizer composition of 6% OPC and 5% FA was added into the waste mud by the in-situ stabilization system and the field temperature during the entire test ranged from 20 to 26 °C.

The specific in-situ stabilization procedures were as follows.

1) The test areas were separated into meshes approximately 8 m long and 3 m wide based on the effective area of the stabilization equipment.
2) The first operation location to support the stabilization machine was selected. The total amount of the OPC and FA of each operated point (1.5 m long and 1 m wide) was calculated and set in the automatic stabilizer supply system before operation.
3) The in-situ stabilization system mixture was slowly injected into the mud to the designated depth and raised while spraying the stabilizers. All the quantitative stabilizers were transported by compressed air from the container into the middle of the mix through the hose.
4) After one point was finished, the processes from steps 1–3 were repeated on the next point. The overlapping width among adjoining meshes did not exceed 10 cm. Complete stirring was conducted after the last mesh was finished (Fig. 2).

Fig. 1. In-situ mud stabilization system.

Fig. 2. Field-stabilized mud.

2.3. Laboratory tests for the field-stabilized mud

To estimate the improvement effects of the field mud, it is necessary to carry out some related experiments which contain compaction, California Bearing Ratio (CBR), modified unconfined compressive strength (MUCS), axial compression tests and scanning electron microscopy (SEM). After the field mixing finished, the treated mud was left in the mud pit without any protection, except for a waterproof canvas cover in rainy days.

The optimum water content (ω_{opt}) and maximum dry density ($\gamma_{d,max}$) of virgin and field-stabilized mud (field curing over 1, 7, 14, and 28 days) was determined using a Proctor compaction test. The same samples were subjected to CBR tests on different curing days (1, 3, 7, 14, and 40 days).

During the field construction of roadbed in which the stabilized soil filled, various stages are involved mixing, curing and filling. These field processes are inconsistent with traditional laboratory strength tests (mixing to sampling (filling) to curing). Accordingly, a modified laboratory UCS (MUCS) test was carried out. Specifically, in MUCS when 6, 13, 27, and 39 days of field curing ended, the in-situ stabilized mud was sampled and brought to the laboratory. The cylindrical samples (50 mm diameter × 50 mm height) were then prepared by static compaction at a rate of 0.1 mm/min, and were measured on an electro-hydraulic servo universal testing machine (WAW-1000A). In addition, another set of samples were prepared once the in-situ stabilization was complete, and cured in laboratory conditions (temperature 20 ± 2 °C, humidity 95 ± 2%). These samples were for conventional unconfined com-

Table 2
Chemical analysis of FA.

Oxide	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O+K_2O	SO_2	Loss on ignition	Fineness
Percentage	55	27.5	7.5	6.05	1.3	1.75	0.9	3.5	10.8