Available online at www.sciencedirect.com

ScienceDirect

Soils and Foundations xxx (2018) xxx–xxx

www.elsevier.com/locate/sandf

Applicability of clinker ash as fill material in steel strip-reinforced soil walls

Motoyuki Suzuki [a,*], Akifumi Nakashita [b], Katsuji Tsukuda [b], Yoshitaka Wakatsuki [c]

[a] *Graduate School of Sciences and Technology for Innovation, Yamaguchi University, Japan*
[b] *The Chugoku Electric Power Co., Inc., Japan*
[c] *Fukken Co., Ltd., Japan*

Received 28 June 2015; received in revised form 22 September 2017; accepted 2 October 2017

Abstract

The generation of coal ash by coal-fired thermal power plants has increased in recent years. This study focuses on the use of a type of coal ash, clinker ash, in place of sandy soil as a fill material in soil structures. Clinker ash is an excellent geomaterial to use as backfill for soil structures because it is lightweight and has high shear strength and permeability. In this study, to determine the applicability of clinker ash as a backfill material for steel strip-reinforced soil walls, a series of laboratory pullout tests was conducted on different types of clinker ash to investigate the pullout behaviour of a ribbed strip from a layer of clinker ash and to evaluate the influence of the overburden pressure and the degree of compaction on the maximum pullout resistance. The correlation between the physical properties of clinker ash and the maximum pullout resistance was investigated on the basis of the test results. Additionally, the results of the pullout tests were compared with those of in-situ pullout tests. Furthermore, the usefulness of clinker ash was evaluated by applying the pullout test results to the standard design method for reinforced soil walls and comparing the results with the material constants for commonly used sandy soil. The main conclusions of the study are as follows: (1) The tests performed here confirmed that clinker ash has excellent frictional properties compared with sandy soil. (2) The frictional properties of clinker ash exceed the proposed design values given in the manual describing the reinforced soil wall method. (3) The application of clinker ash in reinforced soil walls is effective from the viewpoint of frictional properties.

Keywords: Bottom ash; Reinforced soil wall; Physical property; Pullout resistance; Friction coefficient (**IGC:** E-12/H-2)

1. Introduction

The reinforced soil wall technique is a useful method for the construction of embankments at narrow sites. These walls are composed of facing walls, backfill material, and reinforcing material, as well as other additional components. Reinforced soil walls generally demonstrate a good anti-earthquake performance (Koseki et al., 2006; Suzuki et al., 2015). Additionally, they have shown good workability in many construction cases in Japan, because the factory-made walls are easy to assemble at construction sites. Thus, the quality of this method is very high, resulting in the increased construction of such walls. In steel strip-reinforced soil walls, such as those built using the Terre Armée method, sandy soil with a fine content of 25% or less, which exhibits high frictional resistance when in contact with the steel strip, has often been used as a backfill material (Miyata et al., 2001; PWRC, 2003). In recent years, however, it has become increasingly difficult to obtain such sandy soil. Since the amount of coal ash

Peer review under responsibility of The Japanese Geotechnical Society.
* Corresponding author at: 2-16-1 Tokiwadai, Ube 755-8611, Yamaguchi, Japan.
E-mail address: msuzuki@yamaguchi-u.ac.jp (M. Suzuki).

https://doi.org/10.1016/j.sandf.2017.11.001
0038-0806/© 2018 Production and hosting by Elsevier B.V. on behalf of The Japanese Geotechnical Society.

produced by coal-fired thermal power plants has been increasing in Japan, this study focused on the possibility of using clinker ash instead of sandy soil as a backfill material for reinforced soil walls.

Clinker ash is a type of coal ash that is discharged from coal-fired power plants. Clinker ash is a by-product generated by burning coal at a temperature of approximately 1500 °C and then dropping its residue into a water tank at the bottom of the boiler. As a result of this formation process, numerous microscopic holes appear in the clinker ash. The shear resistance of clinker ash is increased by the interlocking effect made possible by the shape of the particles. Several studies have been conducted to investigate the physical properties, the compaction properties, the hydraulic conductivity, the shear strength, and the deformation properties of bottom ash and similar materials (Kim et al., 2005; Consoli et al., 2007; Kim and Do, 2012; Yoshimoto et al., 2012, 2014; Güllü, 2014; López et al., 2015). In particular, clinker ash has the advantages of a small unit weight, high shear strength, and high permeability; and thus, it may be an excellent construction material (Wakatsuki et al., 2007, 2009; Winter et al., 2013). It has been reported that clinker ash can be used as a fill material because the apparent friction coefficient of clinker ash is much larger than that of natural soil, as was reported in a previous study (Ogawa et al., 1992). The results of field pullout tests verified that clinker ash can be used at overburden depths of up to 4 m. Laboratory pullout tests conducted under high overburden pressures confirmed that clinker ash can be used as a fill material because of its high apparent friction coefficient, which is approximately two times higher than that of commonly used sandy soil. The use of clinker ash may contribute to a reduction in costs due to a decrease in the amount of steel strips required for reinforced soil walls. These experiments, however, were conducted using only one type of clinker ash obtained from only one power plant under fixed conditions (degree of compaction: 90%). The characteristic performance of clinker ash remains comprehensively unclarified. Therefore, it is necessary to conduct further tests using different types of clinker ash and a commonly used soil for comparison under different overburden pressures and degrees of compaction.

Thus, the purpose of this study is to elucidate the pullout resistance characteristics of steel reinforcing strips used in conjunction with clinker ash. This paper describes the pullout behaviour of six types of clinker ash with different physical properties and the influence of the overburden pressure and the degree of compaction on the maximum pullout resistance, and investigates the correlation between the physical properties of the ash and its apparent friction coefficient. In addition, the usefulness of clinker ash is also evaluated in a layout design of strips in the steel strip-reinforced soil wall method.

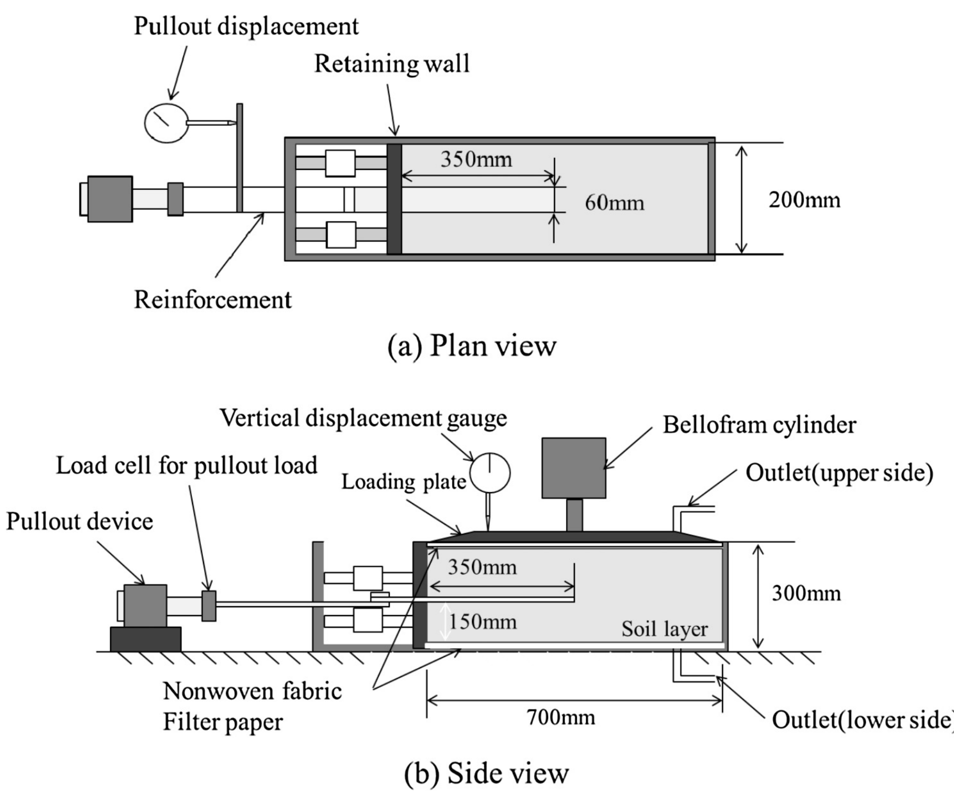

Fig. 1. Schematic diagrams of pullout test apparatus (after Tasaka et al., 2010).

Please cite this article in press as: Suzuki, M. et al., Applicability of clinker ash as fill material in steel strip-reinforced soil walls, Soils Found. (2018), https://doi.org/10.1016/j.sandf.2017.11.001