JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING (ENGLISH EDITION) 2017; X (X): 1–9

Available online at www.sciencedirect.com

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

Journal of Traffic and Transportation Engineering (English Edition)

Original Research Paper

Cement improved highly weathered phyllite for highway subgrades: A case study in Shaanxi province

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HIGHLIGHTS

- Weathered phyllite belonged to soft rock, and its property was easily affected by the water.
- The resilient modulus and deflection were analyzed with the cement content increasing.
- Water content and soaking time are key factors affecting the seepage depth and resilient modulus.
- The recommend values for cement addition and water content are given out.

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Highly-weathered phyllite
Cement admixture
Soaking time
Wetting deformation
Resilient modulus

ABSTRACT

In a cost-saving move, the soft rocks composed of highly-weathered phyllites available on-site were used to fill the subgrade in the eastern Ankang section of the expressway of Shiyan to Tianshui, China. Cement admixture was used to improve the performance of the weathered phyllites. In order to determine the best mix ratio, values corresponding to compaction performance, unconfined compressive strength, and the California bearing ratio (CBR) were analyzed for variable cement content weight percentages (3%, 4%, 5%, and 6%) using test subgrade plots in the field. Field measurements of resilience modulus and deflection confirmed that the strength of the subgrade increased as the cement ratio increased. In order to further evaluate the cement/phyllite mixture, the performance of the 3% cement ratio sample was evaluated under saturated conditions (with various levels of moisture addition and soaking time) using both the wetting deformation and resilient modulus values. Results suggest that moisture added and soaking time are key factors that affect the seepage depth, water content, and resilient modulus. The recommend values for the cement addition and for the water content are given out. This study can aid in prevention of highway damage by improving the foundation capacity and lengthening the lifecycle of the highway in phyllite distributed region at home and abroad.

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Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2017.07.003

Please cite this article in press as: Mao, X., et al., Cement improved highly weathered phyllite for highway subgrades: A case study in Shaanxi province, Journal of Traffic and Transportation Engineering (English Edition) (2017), http://dx.doi.org/10.1016/j.jtte.2017.07.003

1. Introduction

The rocks along the eastern Ankang section of the highway from Shiyan to Tianshui are primarily composed of weathered phyllite. The phyllite rocks in this region are severely weathered, with very low strength. However, due to the absence of other favorable alternatives for subgrade material for highway construction, the weathered phyllite was selected for this purpose. The weathered phyllite is belonged to soft rocks according to the mechanical properties. Soft rocks are critical geotechnical materials since they present several undesirable behaviors, such as low strength, disaggregation, crumbling, high plasticity, slaking, fast weathering, and many other characteristics.

In recent years, the use of soft rocks has been geomaterials investigated from physical, mechanical, classification, and other aspects at home and abroad. In China, Zhou et al. (2003) has discussed mechanical properties of several typical types of soft rock in south China which contain red sandstone, mudstone, and black carbonaceous mudstone. Zheng et al. (2005), Zhao et al. (2005), Nie et al. (2008), and Qing et al. (2006) studied the feasibility of using soft rock as filling material for highway and railway systems. Liu et al. (2006), Wang et al. (2011) studied the wetting deformation of the soft rock under laboratory conditions. Pu et al. (2017) carried out the study on rupture and energy characteristics of phyllites under triaxial compression. Yang et al. (2010) studied the deformation characteristics of roadbed filling of soft metamorphic rock before and after soaking by compression tests in Qinling—Bashan mountainous region. Mao et al. (2012), Zhang et al. (2014a) carried out the experimental study on subgrade filling material of phyllite spoil improved with cement. Xin et al. (2014), Guo et al. (2014), Zhang et al. (2014b), He and Zhang (2014) studied the geomechanical and water vapor absorption characteristics properties characterization of deep soft rocks with experiments. Mao et al. (2016, 2017) analyzed the moisture migration mechanism of strongly weathered phyllite subgrade filling and studied factors influencing modified phyllite stuffing CBR value. Qiu et al. (2017) discussed the dynamic failure of a phyllite with a low degree of metamorphism under impact of Brazilian test.

Foreign researchers also have done some experiments on the soft rock. By experiments and modeling, Ramamurthy et al. (1993) and Arnold et al. (2001) studied the sorption behavior of U(VI) on phyllite. Mohamed et al. (2007) developed the e-SSC test, and established a systematic and computerized testing method with laboratory procedure to quantify the shrink and swell characteristics of soft rock for classification. Manasseh and Olufemi (2008) analyzed the effect of lime on some geotechnical properties of Igumale shale. Adom-Asamoah and Afrifa (2010), Mark and Russell (2010) investigated the physical and mechanical properties of phyllite aggregate concrete compared to granite (conventional) aggregate concrete. Sadisun et al. (2002), Bornert et al. (2010), Nara et al. (2012), Yang et al. (2012), and Nahazanan et al. (2013), studied the hydro mechanical behavior of the soft rock, such as the elastic properties, the shear strength, the shrinkage and swelling induced by suction variation. Ulusay and Erguler (2012) evaluated the method to predict the strength of weak and soft rocks using the needle penetration test. Besides, Ulusay and Erguler (2012) also evaluated the soft rock performance and possible uses by needle penetration test. Regmi et al. (2012) did the research on the effect of rock weathering, clay mineralogy, and geological structures in the formation of large landslide, and applied the method for the Dumre Besei landslide, Lesser Himalaya Nepal. Cantarero et al. (2014) investigated the fluid flow in fractures and host rocks in shallow buried Miocene alluvial fan deposits. Giambastiani (2014) carried out the study of soft rocks in Argentina and gave out the category according to the clastic sedimentary rocks and pyroclastic volcanic rocks. Garzón et al. (2010, 2016) studied the physical and geotechnical properties of clay phyllites and researched the effect of lime on stabilization of phyllite clays.

From the previous analysis above, it is clear that there is a knowledge gap relating to soft rock improvement technology for subgrade fill. There was quite little research about using the phyllite as the subgrade filling material at home and abroad. The present investigation, described in this paper, describes the use of cement admixture to improve the performance of weathered phyllite as subgrade fill. The field performance of the improved fill was evaluated based on the measured resilience, deflection, and wetting deformation. This evaluation confirms the feasibility of using the improved weathered phyllite as a subgrade material.

2. Experimental evaluation

2.1. *Mineral component of phyllite*

The rocks along the eastern Ankang section of the highway from Shiyan to Tianshui are primarily composed of weathered phyllite as shown in Fig. 1. The mineral composition of the weathered phyllite is shown in Table 1. The main mineral components of the rock are quartz and mica, at 42% and 50% composition by weight, respectively. The quartz and

Fig. 1 – Highly weathered phyllite near the highway construction site.

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