Cold Regions Science and Technology 116 (2015) 70–77

Contents lists available at ScienceDirect

Cold Regions Science and Technology

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

Effect of freeze–thaw cycles on mechanical property of silty clay modified by fly ash and crumb rubber

Haibin Wei, Yubo Jiao *, Hanbing Liu

College of Transportation, Jilin University, Changchun 130025, PR China

ARTICLE INFO

Article history:
Received 19 November 2013
Received in revised form 25 March 2015
Accepted 14 April 2015
Available online 18 April 2015

Keywords:
Modified silty clay
Freeze–thaw cycle
Apparatus design
Performance evaluation

ABSTRACT

In seasonal frozen regions, freeze–thaw cycle is a weathering phenomenon which has great influence on engineering properties of soils. Material selection and its evaluation of freeze–thaw effect are important to guarantee subgrade stability. In this paper, a freeze–thaw testing apparatus is designed and manufactured. This apparatus can realize the measurement of strain, stress and temperature of samples and more realistically simulate the road structure. Silty clay modified by fly ash and crumb rubber is used as anti-freezing layer of subgrade. Experimental modulus is measured to evaluate the mechanical property of modified soil through the freeze–thaw testing apparatus. Effects of freeze–thaw cycles, temperature and dynamic load frequency on modulus are investigated and discussed. Comparative analysis is conducted with silty clay, it reveals that modified soil possesses more favorable mechanical performance.

1. Introduction

Seasonal frozen regions cover 53.5% of China's land area. They are widely distributed in northern China, and the northeast region is most representative such as Changchun city (Liu et al., 2012; Xu et al., 2001). Soils in these regions are exposed to at least one freezing–thawing cycle each year. Such freezing and thawing affect the engineering properties of soils such as physical features including permeability, water moisture content, and mechanical features involving strength, compressibility and bearing capacity (Hohmann, 2002; Konrad, 1989; Liu et al., 2010; Mulungye et al., 2007; Qi et al., 2008a; Zaimoglu, 2010). These changes in performances will lead to subgrade settlement and pavement frost boiling, which seriously influence the safe operation of road. Therefore, it is essential to analyze and reduce the impact of freeze–thaw cycles on subgrade soil in seasonal frozen regions.

Some studies have been conducted to discuss the influence of freeze–thaw on soils (Graham and Au, 1985; Hanay et al., 2003; Kim and Daniel, 1992; Ono, 2002; Wang et al., 2007). Wang et al. (Wang et al., 2007) presented the laboratory test of fine-grained clay exposed to a maximum of 21 closed-system freezing and thawing cycles, the physical–mechanical characteristic such as resilient modulus, failure strength and friction angle were measured and analyzed. Lee et al. (Lee et al., 1995) performed resilient modulus tests on five cohesive soils sampled from the subgrades of in-service pavements. It was found that the freeze–thaw process caused significant reduction in resilient modulus. Qi et al. (Qi et al., 2006) reviewed the latest efforts in this field.

Moreover, different additive materials (e.g., fly ash, cement and lime) are applied to improve the engineering properties of soil under freezing–thawing cycles. A few researchers have studied the mechanical properties of modified soils considering freeze–thaw effect (Ghazavi and Roustaie, 2010; Ghazavi and Roustaei, 2013; Hazirbaba and Gullu, 2010; Kalkan, 2009; Yarbesi et al., 2007). Yarbesi et al. (Yarbesi et al., 2007) stabilized two granular soils obtained from primary rock by silica fume–lime, fly ash–lime, and red mud–cement additive mixtures. The experimental results revealed that three additive mixtures all possessed higher freezing–thawing durability. The dynamic behaviors were also improved. It revealed that silica fume–lime, fly ash–lime, and red mud–cement additive mixtures, particularly silica fume–lime mixture, are suitable for road constructions and earthwork applications. Ghazavi and Roustaie (2010) investigated the effect of freeze–thaw cycles on strength properties of soil reinforced with a geotextile layer. It was found that for the investigated soil, unconsolidated undrained triaxial compressive strength of unreinforced soil decreased with increasing the number of freeze–thaw cycles, whereas reinforced samples showed better performance and the strength reduction amount decreased from 43% to 14% by reinforcing the soil. Hazirbaba and Gullu (2010) investigated the improvement of CBR of fine-grained soils by the addition of geofiber and synthetic fluid considering the freezing and thawing effect. The results indicated that the addition of geofiber together with synthetic fluid was generally successful in providing resistance against freeze–thaw weakening for unsoaked samples and the addition of synthetic fluid alone was not very effective. The results from soaked samples showed poor CBR performance for treatments involving synthetic fluid

* Corresponding author at: No. 5988, Renmin Street, City of Changchun, Jilin Province, PR China. Tel.: +86 13610790678; fax: +86 43185095446.
E-mail address: jiaoyb@jlu.edu.cn (Y. Jiao).

http://dx.doi.org/10.1016/j.coldregions.2015.04.004
0165-232X/

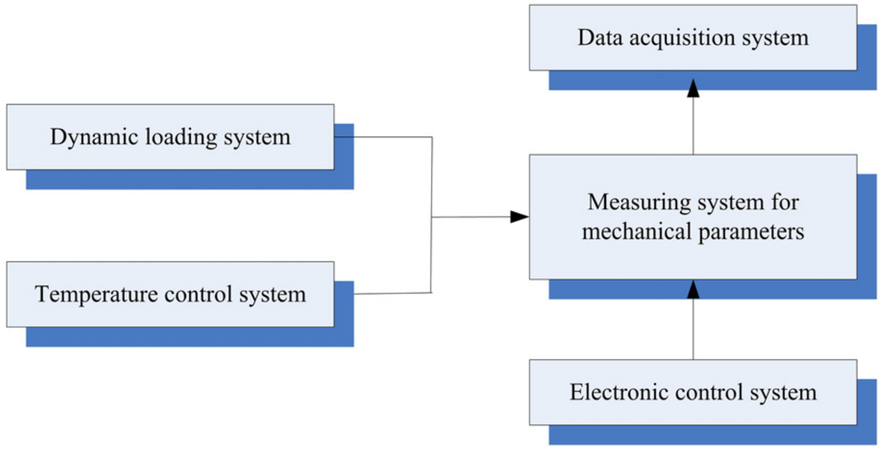
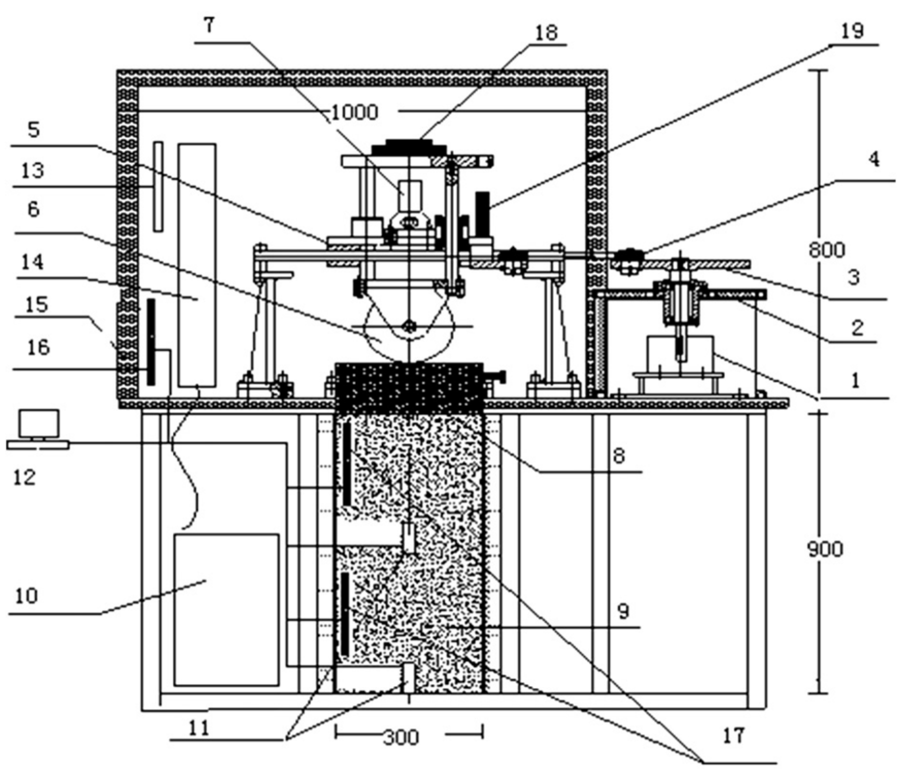


Fig. 1. System architecture of designed freeze–thaw testing apparatus.

while samples improved with geofibers alone generally produced better performance.

Previous studies of soils are mainly modified by lime, cement, fly ash, fiber, etc. There is limited information about soil modified by rubber. With the development of transportation, million tons of waste tires were generated. If the abandoned tires are grinded into small particles (crumb rubber) and used in road engineering, it can generate significant economic values and environmental benefits (Ganjian et al., 2009; Xiao et al., 2009; Yilmaz and Degirmenci, 2009). Jafari and Esna-ashari (2012) carried out a series of unconfined compression tests to investigate the effects of tire cord waste products on mechanical characteristics of a lime stabilized and unstabilized clayey soil subjected to freezing and thawing cycles. Kalkan (Kalkan, 2013) investigated the influence of silica fume–scrap tire rubber fiber mixture inclusion on geotechnical properties of clayey soils.

Furthermore, properties of subgrade soil vary significantly under the effect of freeze–thaw, which put forward high requirements for a testing instrument. In many freeze–thaw tests, the samples are placed in a freezer, freezing cabinet, digital refrigerator or oven, the freezing and thawing processes are realized through adjusting internal temperatures below and above specific temperatures, respectively. Then, the material properties including compressive strength, resilient modulus, etc. are measured and determined by MTS or other related testing machines according to ASTM, etc. (Ghazavi and Roustaei, 2013; Gokhan and Altug, 2012; Liu et al., 2010; Zaimoglu, 2010). In this process, specimens after freeze–thaw cycles are placed in the testing machines for



1-motor; 2-insulation panels; 3-pivot arm; 4-connecting bar; 5-connecting plate; 6-rolling wheel; 7-lifting member; 8-road surface material; 9-subgrade material; 10-compressor; 11-strain gauge; 12-computer; 13-electric fan; 14-radiator; 15-incubator; 16-temperature sensor (1); 17-temperature sensor (2); 18-weights; 19-displacement sensor

Fig. 2. Overall structure of testing apparatus.