Geotextiles and Geomembranes 46 (2018) 897–903

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

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

Technical note

Laboratory evaluation of a new device for water drainage in roadside slope along railway systems

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ARTICLE INFO

Keywords:
Geosynthetics
Laboratory
Drainage device
Perforated PVC pipe
Installation angle
Clogging

ABSTRACT

The majority of the existing railway systems in China, from roadside slopes to retaining walls, suffered from poor drainage induced failures. Recently, a new drainage device was proposed to tackle these problems. Preliminary field implementations indicated that the new drainage device could effectively remove groundwater from the surrounding soil without any clogging effect. However, at present, most existing designs are purely based upon the engineers' personal experience and judgement; there is no well-established design method to take full advantage of the device.

In this study, a series of laboratory modeling tests were conducted to investigate flow rates, and the optimum installation angle of the drainage device. After that, the long-term performance of the drainage device and conventional perforated PVC pipe under multiple wetting-drying cycles was also evaluated and compared. The results indicate that during the constant head tests, the flow rates in the new drainage device initially increased with an increase in the installation angles of the drainage device from 0° to 15°, and then decreased from 15° to 60°. An inclination angle from 5° to 15° is recommended for this new drainage device when installed in the exiting railway cut slope. The clogging effect was not a primary concern for the applications of this new device. The proposed drainage device provides an alternative way to tackle the poor drainage problem in the exiting railway cut slopes and retaining walls.

1. Introduction

The annual report of China Railway Corporation (2013) concluded that the majority of the existing railway systems in China, from roadside slopes to retaining walls, suffered from poor drainage induced failures. Polyvinyl chloride (PVC) pipes wrapped with nonwoven geotextile are conventionally installed as drainage pipes to lower groundwater table to improve the stabilities of roadside slopes and retaining walls. Although PVC pipes wrapped with nonwoven geotextile have proven to be an efficient and economical dewatering option (Cook et al., 2008a, 2008b; Mininger et al., 2011), they can easily lose function due to clogging of nonwoven geotextile caused by poor design (McIsaac and Rowe, 2007) and construction quality control. For these reasons, Cornforth (2005) recommended that drainage pipes be regularly cleaned and inspected. Once the drainage pipes lose their functions, they are very difficult to maintain or repair since the drainage ditch between the railway road embankment and the roadside slope/retaining wall is generally designed to be 0.6 m wide in China. Meanwhile, Mininger et al. (2011) reported that even if routine inspection and maintenance are performed, the drainage pipes' functionality cannot be assured.

Drainage composite has been applied successfully as a drainage material to transport water due to their large open structures (Ling et al., 1993; Zornberg and Mitchell, 1994; Tan et al., 2001; Garcia et al., 2007; McCartney and Zornberg, 2010; Lin et al., 2016; Broda et al., 2017; Zornberg et al., 2017). However, a few field and laboratory studies demonstrated that the clogging effect could be a primary concern for the application of the drainage composite (Palmeira and Matheus, 2000; Fleming et al., 2010). Recently, Zhang and Belmont (2009), Zhang and Presler (2012), and Zhang et al. (2014) have conducted a series of tests in both laboratory and field to evaluate the long-term performance of a wicking geotextile in Alaskan pavement. The results indicated that the wicking geotextile could provide high wettability and high capillary force and the clogging effect was not a primary problem for the application of the wicking fabric (Han and Zhang, 2014; Guo et al., 2016; Lin et al., 2016; Wang et al., 2017). The vast

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https://doi.org/10.1016/j.geotexmem.2018.08.005
Received 23 June 2018; Received in revised form 25 June 2018; Accepted 3 August 2018
0266-1144/

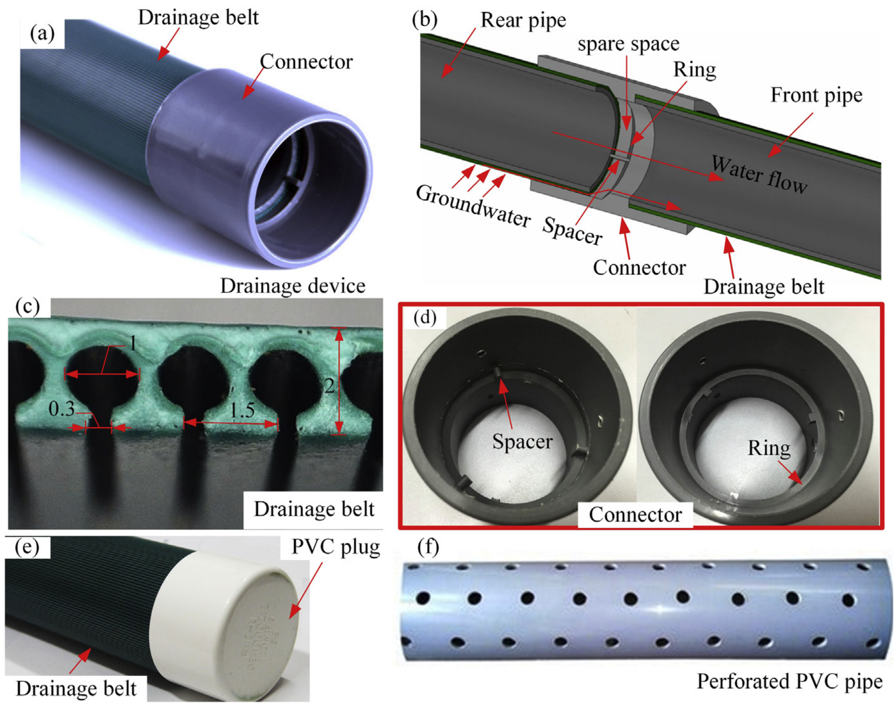

Fig. 1. Drainage materials and the cross section (unit: mm): (a) drainage device, (b) groundwater flow path, (c) cross-section of the drainage belt, (d) the connector, (e) the PVC plug, (f) conventional perforated PVC pipe. ((a), (b) were modified from Smart Drain LLC, 2018).

majority of geosynthetics performed well in newly built constructions and were easy to install. However, it is very difficult and not economically feasible to install the geosynthetics for the infrastructures along the railway, such as cut slopes and retaining walls, due to the inherent flexibility in the geosynthetics materials. In addition, the construction time may also be elongated due to the limited operational space and possible traffic interruption. As a result, an alternative drainage system is needed to tackle this problem in existing railway cut slopes.

In this study, a new device was proposed to tackle those drainage issues of roadside cut slopes and retaining structures along the railway. This new drainage device was installed into the cut slopes and retaining structures by drilling a hole, angled slightly upward. The device includes a PVC or HDPE pipe wrapped with drainage belt as shown in Fig. 1a. Fig. 1b shows the schematic plot of the device profile, which includes the drainage belt (the detailed dimensions of the drainage belt are shown in Fig. 1c). The connector is shown in Fig. 1d, and a PVC plug is shown in Fig. 1e. The abovementioned drainage device was invented by Hu and Xu (2002). In the past few years, a few studies have been performed to investigate the behavior of this device for water-related applications including its (1) installation method, performance, and possible clogging effect (Zhang et al., 2013); (2) seepage rates in different types of soil (Ling et al., 2011); and (3) its potential as an antifilter material (Ling et al., 2011). Fig. 2 shows the implementation of the drainage device at Beijing-Guangzhou Railway (K2058 + 130 ~ + 700). Preliminary field implementation indicated that the drainage performance of the proposed device was efficient, and it could effectively remove groundwater from the surrounding soil without any clogging effect (Leng et al., 2017). At present, there is a strong desire to increase the use of the device in more railway projects in China due to its advantages. However, there are some concerns regarding the optimum installation angle, and the long-term performance of the device in the field due to limited existing studies on this topic for this device. At present, there is no well-established design method to take full advantage of the device, and most existing designs are purely based upon the engineers' personal experience and judgement.

In this study, laboratory model tests were performed to investigate the flow rates of the new device in sand. The new device was studied to find the optimum installation angles for designing in an existing railway system in China. In addition, the long-term performance of the proposed device and conventional perforated PVC pipe (as shown in Fig. 1f) under multiple wetting-drying cycles was compared by using sand, and some conclusions and recommendations were made from this comparison.

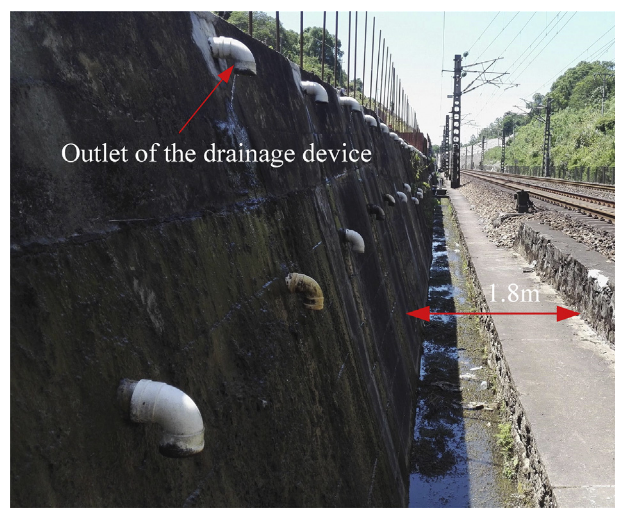

Fig. 2. Implementation of the drainage device at Beijing-Guangzhou railway.

2. Comparisons of the working mechanisms

In this section, the detailed design and the working mechanism of the drainage device are introduced.

2.1. Drainage belt

As shown in Fig. 1c, the drainage belt is made of a 2-mm thick plastic belt with many Ω-shaped holes inside. One side of the drainage