Evolution of soil arching in embankment of high-speed railways under wetting-drying cycles by full-scale model tests

Évolution de l'archivage du sol dans le remblai de voies ferrées à grande vitesse dans des cycles de mouillage-séchage par des essais de modèles à grande echelle

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ABSTRACT: Pile supported embankment is widely used in Chinese high-speed railways due to various advantages, i.e. short construction period, small post-construction settlement. Soil arching effect affects stress distribution dramatically. Embankment experiences wetting-drying cycles in its long service life whereas scholars rarely considered the influence of wetting-drying cycles on soil arching effect. This study aimed to reveal the evolution of soil arching in embankment under wetting-drying cycles. A full-scale experimental model of high-speed railway embankment was established in a steel box. This model was designed to investigate the influence of wetting-drying cycles on soil arching evolution. Time domain reflectometers (TDR) and soil pressure cells were installed in the embankment at different depth for monitoring water content and soil pressure. Based on the model test, the influence of wetting-drying cycles on soil arching effect was obtained. Presenting the soil pressure on the pile and subsoil, stress concentration ratio under wetting-drying cycles, this paper shows how wetting-drying cycles affect dynamic stress distribution.

RÉSUMÉ: le remblai renforcé par pieux est largement utilisé dans les voies ferrées à grande vitesse en Chine, grâce aux divers avantages, comme la période courte de construction et le petit tassement après la construction. L'effet de l'arche en sol affecte la distribution de pression de façon spectaculaire. Le remblai fait expérience des cycles de mouillage-séchage pendant la longue durée de service, tandis que les chercheurs ont peu considéré l'influence des cycles de mouillage-séchage sur l'effet de l'arche en sol. Cette recherche a pour objet de révéler l'évolution de l'arche en sol dans le remblai sous les cycles de mouillage-séchage. Un modèle expérimental en grandeur réelle du remblai de voies ferrées à grande vitesse a été établi dans une boîte en acier. Ce modèle est conçu pour étudier l'influence des cycles de mouillage-séchage sur l'évolution de l'arche en sol. Les réflectomètres du domaine temporel (TDR) et les cellules de pression du sol ont été installés dans le remblai à différentes profondeurs pour surveiller la teneur en eau et la pression du sol. Basé sur le test de modèle, l'influence des cycles de mouillage-séchage sur l'évolution de l'arche en sol a été obtenue. Présentant la pression du sol sur le pieu et le sous-sol, et le ratio de la concentration de pression sous les cycles de mouillage-séchage, ce document montre comment les cycles de mouillage-séchage affectent la distribution de pression statique et dynamique.

KEYWORDS: dynamic soil arching effect, wetting-drying cycle, model test

1 INTRODUCTION

Pile supported embankment over soft soils has been increasingly employed in highway, high-speed railways. Compared to other kinds of embankment over soft soils, the geogrid-reinforced piled embankment has the advantages of rapid construction, small and controllable settlement, and global stability.Soil arching is a common phenomenon in pile supported embankments, and has been discovered in the trap-door test(Terzaghi, 1943). Consequently, several methods are proposed for the assessment of soil arching in pile supported embankment based on various concepts (Hewlett and Randolph, 1988; Chen et.al. 2008;BS8006, 2010; EBGEO, 2011; Van Eekelen et al., 2013).

Many researchers investigate the behavior of soil arching in piled embankment under static loads. Knowledge on dynamic behaviors under transient loads of moving vehicles is rather limited in the literature. Besides, during the service life heavy rains and floods may beyond the capability of drainage facilities. As a consequence, the embankment has the risk of being saturated. The influence of the wetting-drying cycle on dynamic soil arching effect should be studied.

In order to study the influence of wetting-drying cycle, a full-scale model of pile supported embankment was established. Moving train loading was simulated, and dynamic soil pressure was measured by installed earth pressure cells.

2 PHSICAL MODEL

2 .1 *Experiment equipment*

The model subgrade of high speed railways has been constructed in a steel tank with 5.5m width, 15m length and 4m height at Zhejiang university, China. The typical cross section, including foundation, geo-grid reinforced cushion, subgrade, track structure and sensors are presented in Figure 1(a). The foundation model is composed of 3-by-5 pile caps with a geometrical size of 1 m×1m×0.2 m (thickness). The center-to-center distance between the pile caps is 1.8 m as illustrated in Figure 1(b). In order to model the subsoil around the pile caps, water bags were placed around the pile caps and used to control the pile-soil differential settlement. The subgrade is 2.7 m high and 5.5 m long with a crown width of 5 m. The side slope of the embankment is 1.5 H to 1 V, as shown in Figure 1(a). The bottom layer of the subgrade is composed of well-graded compacted gravel with a thickness of 2.3 m. The maximum particle size of the gravel is 40 mm. The optimum moisture content is 5.9%. The surface layer of the subgrade is composed of well-graded compacted gravel with a thickness of 0.4 m. The loading system is composed of eight distributing beams with a center-to-center distance of 0.625 m corresponding to the distance of the fasteners, eight dynamic hydraulic jacks, and reaction beams. Eight hydraulic jacks were used to generate sequential dynamic loads to simulate train moving axle loads, and the highest train speed in the model test is up to 360km/h. Details were introduced in the text. (Bian et. al. 2014). The target value and measured value of the jack ar e illustrated in Figure 2.

Four TDR probes were installed for monitoring water content and several soil pressure cells were settled at different depth for measuring soil pressure. One column cells was above the pile cap and another column was above the subsoil. Cells on the pile plain were present in Figure1(b).

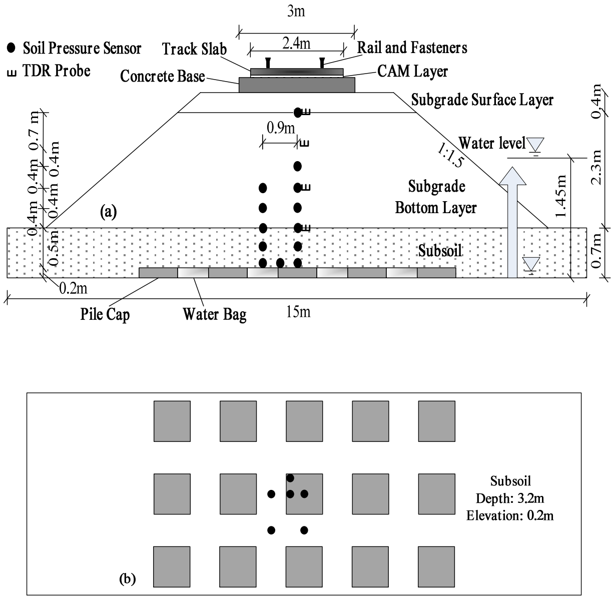

Figure 1. Layout of sensors. (a) cross section and geometric characteristics of the physical model (b) earth pressure cells arrangement on pile cap plane

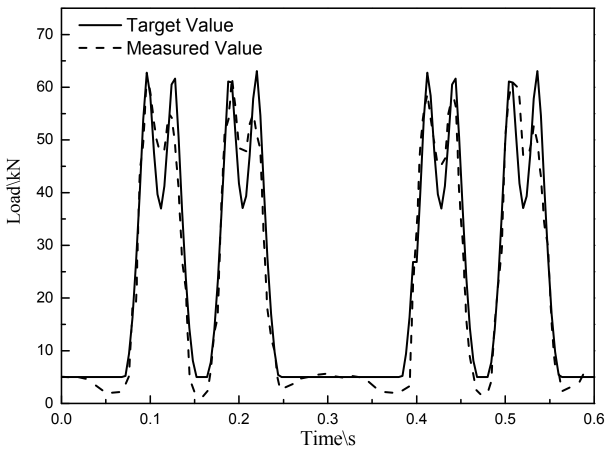

Figure 2. Loading of hydraulic jacks

2 .2 *Test procedure*

Firstly, water in waterbags was pumped out to simulate the settlement of subsoil and then dynamic loading was applied. Secondly, Wetting-drying cycle was achieved by pumping water in and out the tank via pipes buried under the foundation. The water level was 1.45m from the bottom (See Figure 1). After three days saturation, train loading was implemented again. Dynamic soil pressure along depth before and after wetting at different poison was measured.

2 .3 R*esults*

Figure 3 displays the distribution of dynamic soil pressurea long depth before and after wetting. As shown in this gra- ph, whether wetting or not, dynamic stress on pile is larg- er than that on subsoil, which means dynamic soil arching effect still affects the distribution. However, stress distributi on trends are different for different water level. Before w- etting, dynamic stress at depth 1.5m is quite close, indicat- ing the dome of the arching is at 1.5m. Stress above sub- soil decrease gradually. Finally, at the toe of the arching, dynamic stress is close to zero because the differential set- tlement between subsoil and pile is large. Most stress is t- ransferred to the pile. Dynamic stress declines first and in- creases later.

After wetting, dynamic stress above pile is much larger th- an that above the subsoil at depth 1.5m. In other words, the arching moves up. Owing to the arrangement of earth pressure cells, the height of arching is not observed. How- ever, dynamic stress above subsoil is bigger than the origi- nal situation below 2.6m. Dynamic stress above pile below 2.6m decreases slightly.

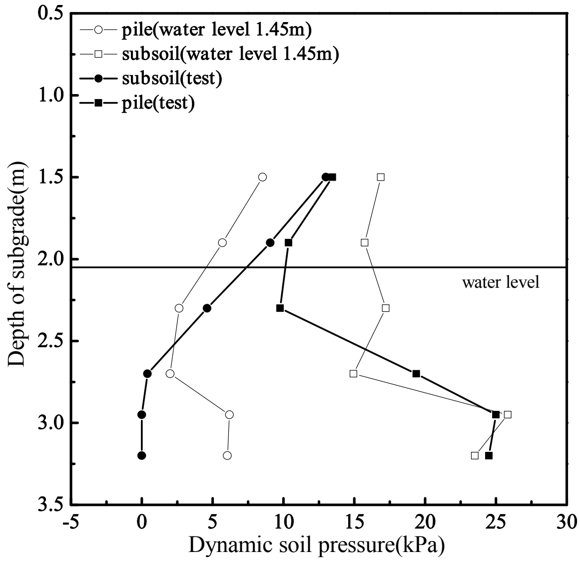

Figure 3. Dynamic soil pressure along depth before and after wetting

3 CONCLUSION

Soil arching in the load transfer of the pile supported embankment draws a lot of attention, and has been well investigated in the last few decades. However, most of the studies have been done are focused on the behavior of soil arching effect under static loads, meanwhile very limited research has been conducted for that under dynamic loads, especially considering the wetting-drying cycle.

A full-scale model test about wetting-drying cycle influence on soil arching effect in high-speed railway was conducted. After wetting, the arching moved up, more cells should be installed if we wish to observe the height of the arch. Meanwhile the lower part soil above the subsoil carried more dynamic stress.

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