Journal of Zhejiang University-SCIENCE A

Cite this as: Han-jiang Lai, Jun-jie Zheng, Rong-jun Zhang, Ming-juan Cui, 2016. Visualization of the formation and features of soil arching within a piled embankment by discrete element method simulation. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 17(10):803-817.
http://dx.doi.org/10.1631/jzus.A1500302

Visualization of the formation and features of soil arching within a piled embankment by discrete element method simulation

Key words:

Piled embankment, Numerical simulation, Discrete element method (DEM), Soil arching, Formation, Features

CHARACTERISTICS OF SOIL ARCHING

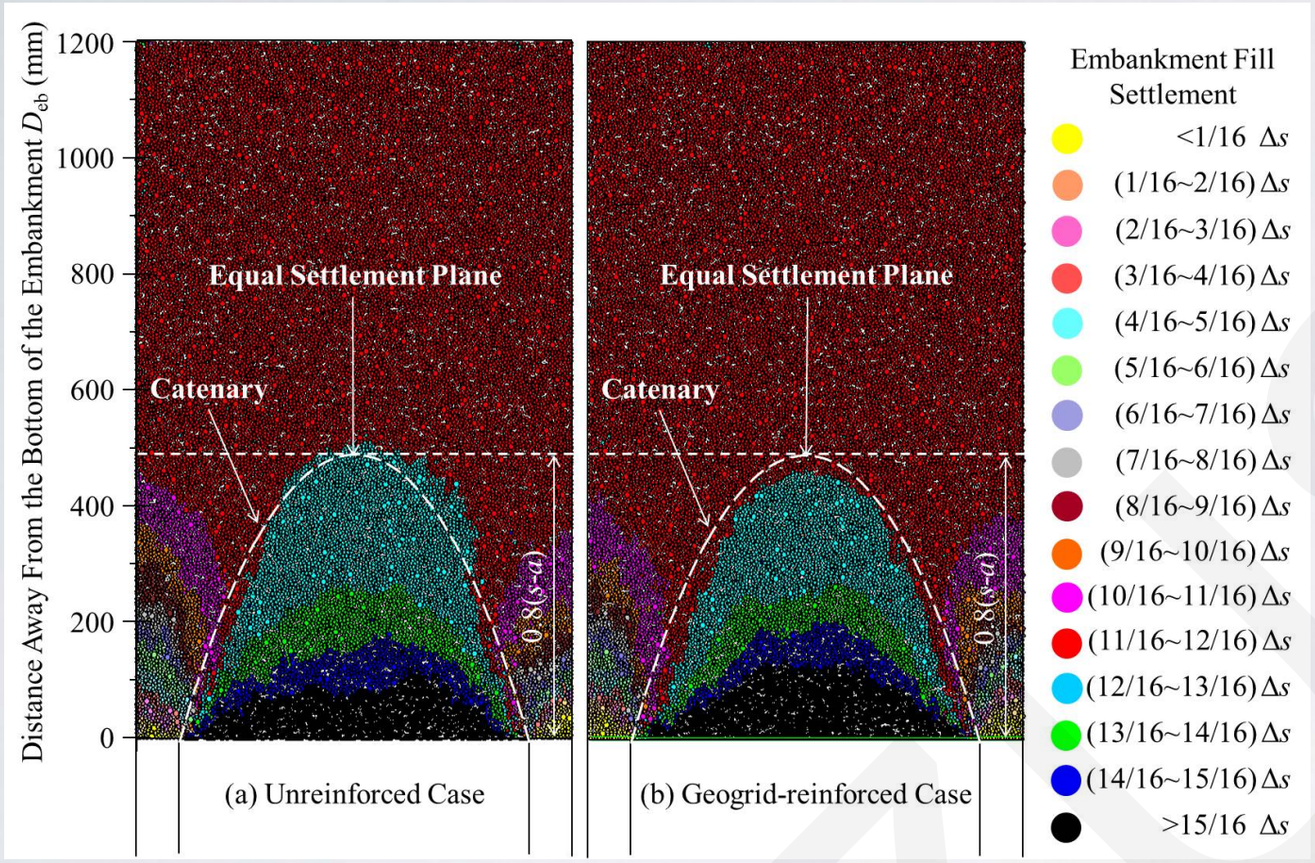

Fig. 6 Contour of settlement with Δs=2.0 mm
(a) Unreinforced case; (b) Geogrid-reinforced case

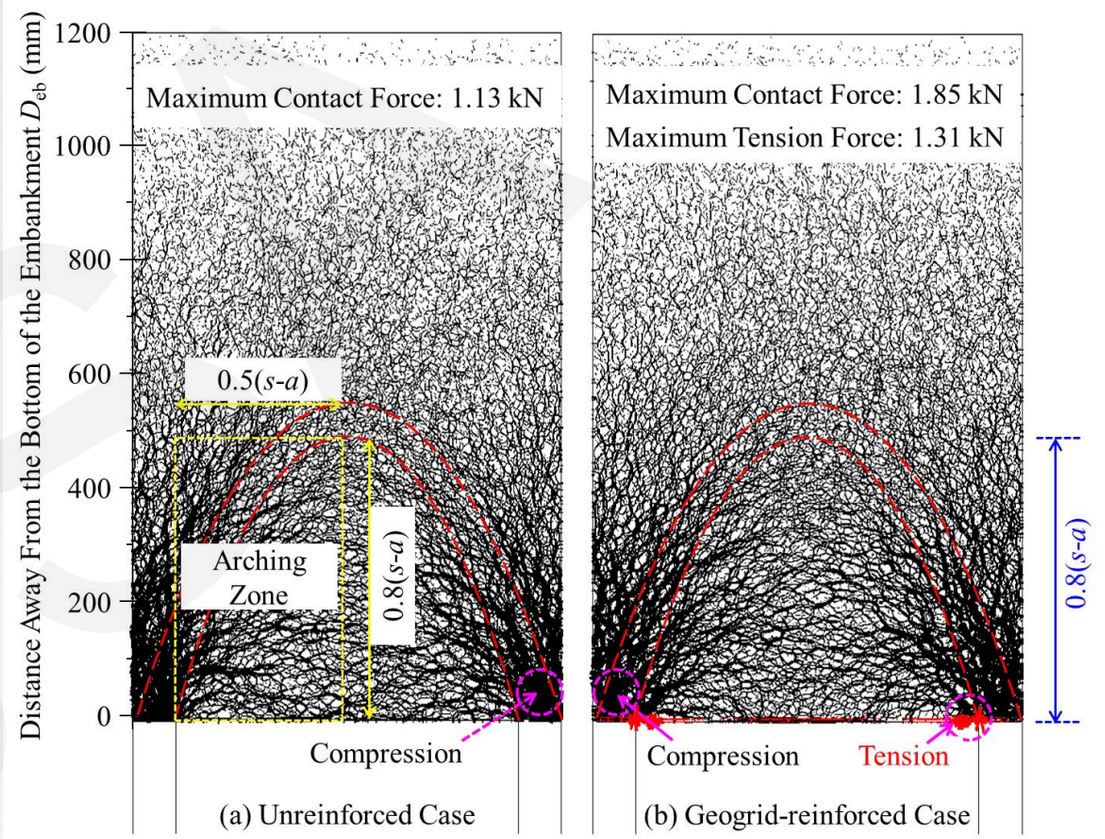

Fig. 7 Distribution of contact forces with Δs=2.0 mm
(a) Unreinforced case; (b) Geogrid-reinforced case

- The soil arching in a piled embankment is in a catenary shape and the maximum height is approximate 0.8(s−a).

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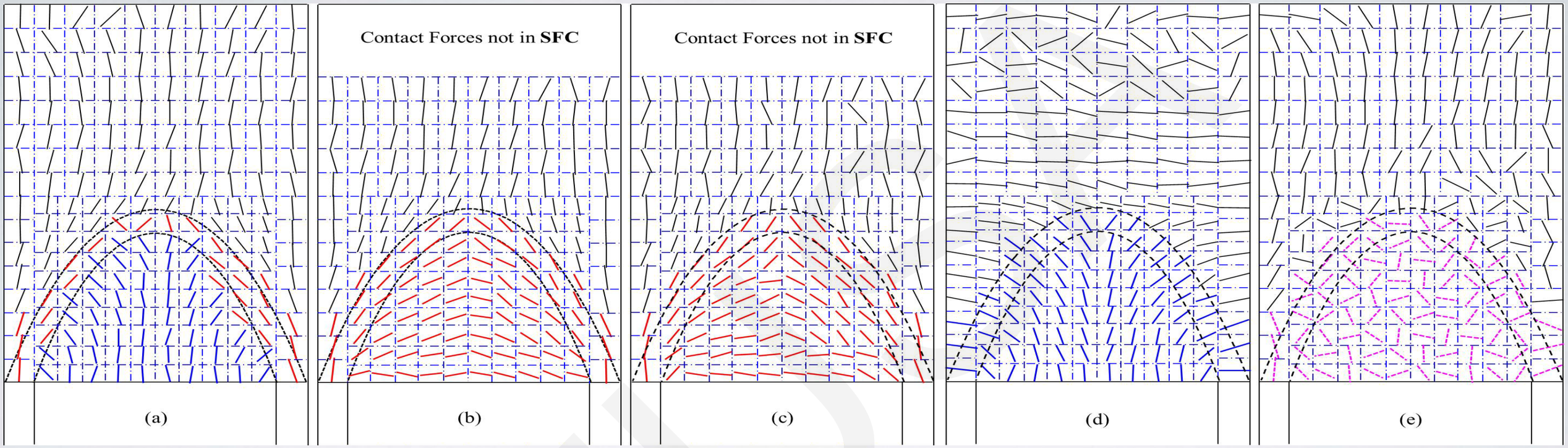

Fig. 9 Distribution of θmax, θc, and θn in unreinforced case with Δ*s*=2.0 mm
(a) Distribution of θmax in the initial state; (b) θc in SFC; (c) θn in SFC; (d) θc in WFC; (e) θn in WFC

- The major structure of the “soil arching” is constructed by the contacts in SFC (Strong Force Chain), while the contacts in WFC (Weak Force Chain) serve as the support system for the “soil arching”.

FORMATION OF SOIL ARCHING

- The development of soil can be divided into three stages.
- Stage 1: Formation of soil arching.
- Stage 2: Further development of soil arching.
- Stage 3: Relatively stable stage of soil arching.

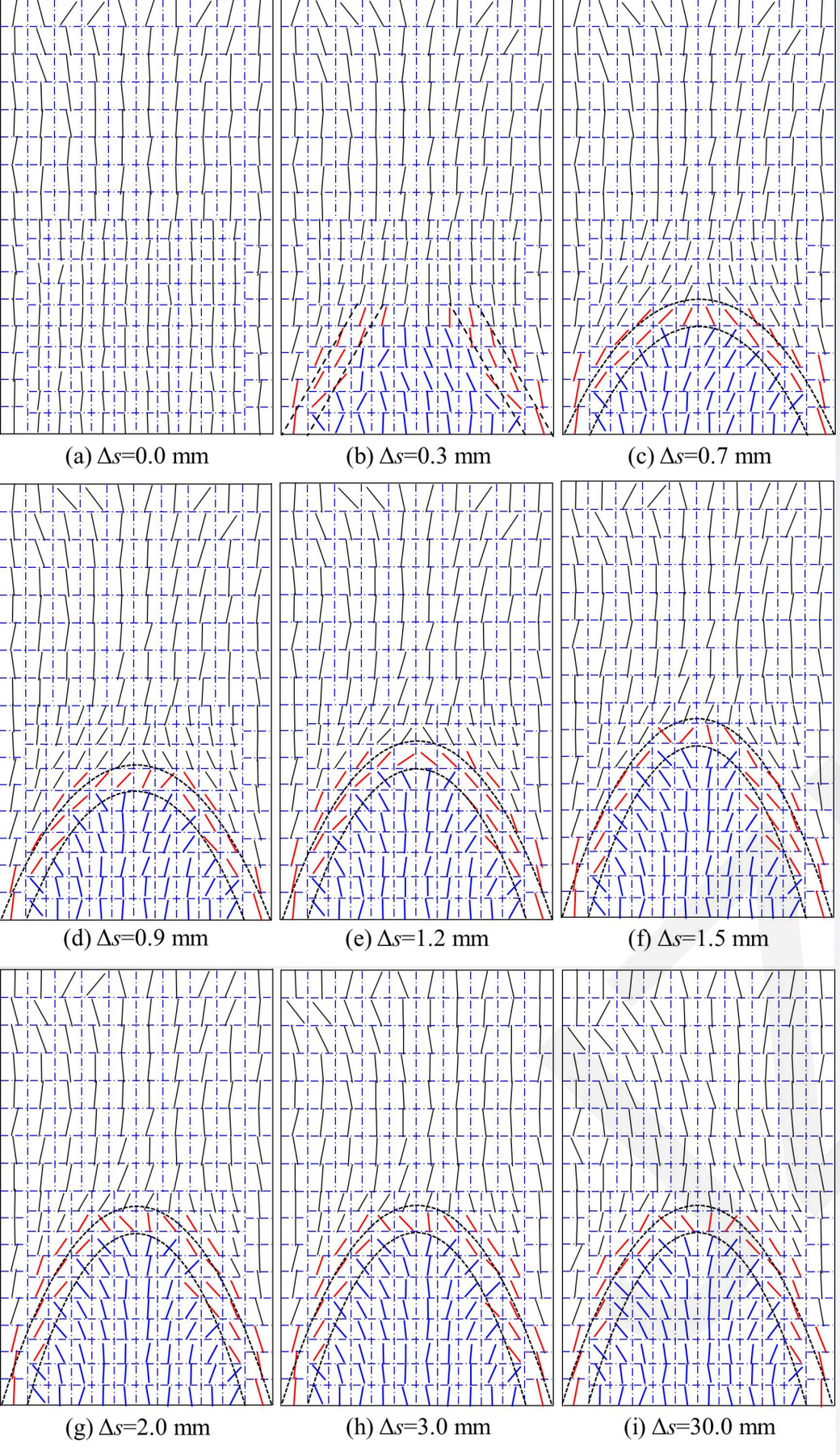

Fig. 10 Evolution of direction of the maximum principal stress θ_{max} in Unreinforced Case

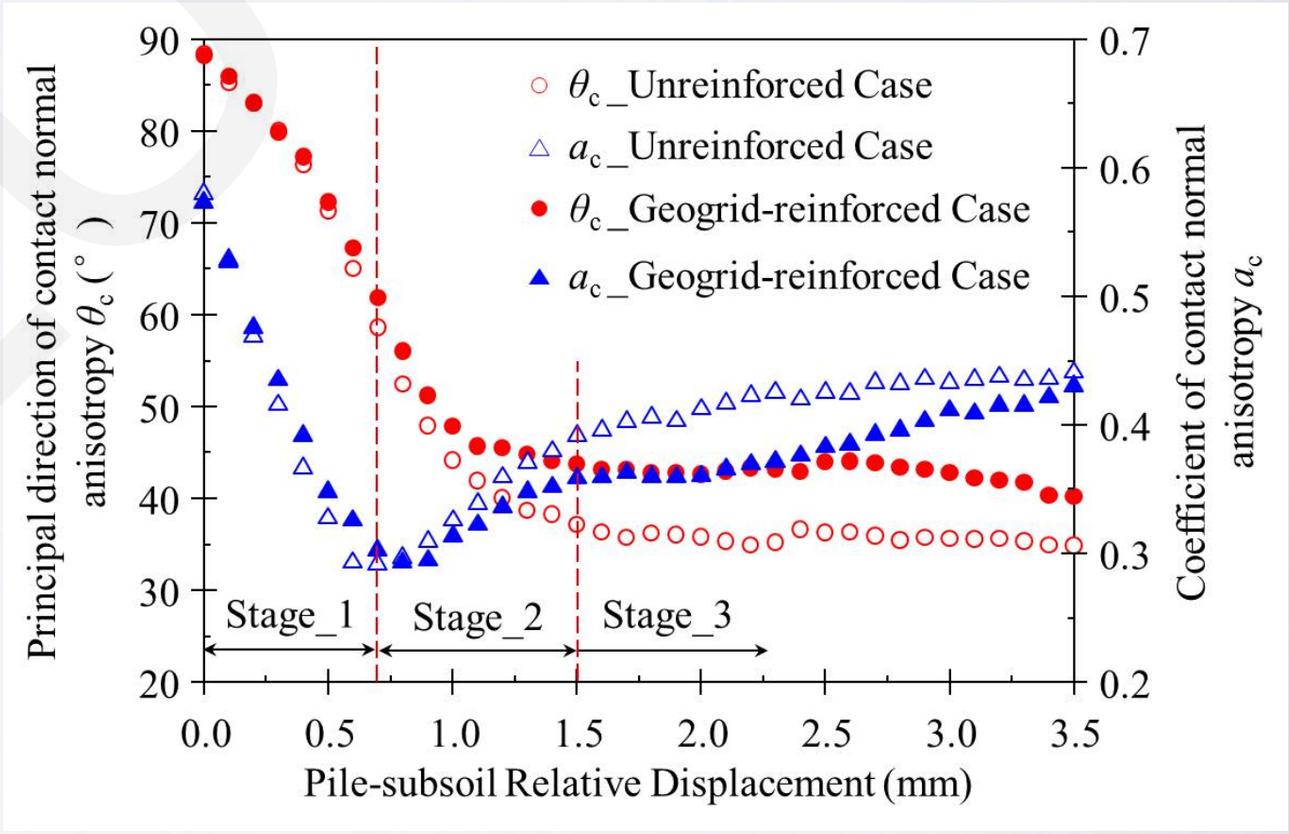

Fig. 11 Variation of contact normal anisotropy of SFC in "arching zone" for unreinforced and geogrid-reinforced cases.

RESULTS AND CONLUSIONS

- Pile-subsoil relative displacement (Δs) has a significant influence on the formation and features of soil arching in the piled embankments with or without geosynthetic reinforcement. The soil arching in embankment is formed by the **S**trong **F**orce **C**hain (**SFC**) with contact forces above 1.5 times mean contact force ($1.5[f_c]$) of the whole assembly; while the **W**eak **F**orce **C**hain (**WFC**) acts as a support system. At smaller Δs, the "soil arching" is comprised of two inclined shear planes rather than the arch. Then, with an increase in Δs, the inclined shear plane is transformed into a hemispherical soil arching, due to the rotation of the principal directions of contacts and forces. With a further increase in Δs, the height of the hemispherical soil arching gradually increases. Finally, the height approaches to the maximum value of $0.8(s\text{-}a)$, and then, maintains a relatively stable state within the Δs range of interest in this study. For a given case, a higher height of soil arching gives rise to a greater degree of soil arching effect. However, the presence of geosynthetic has a negligible influence on the formation and features of soil arching.
- Parametric studies indicate that the friction coefficient (corresponding to the friction angle in macroscopic scale) of embankment fill has a negligible influence on the formation and features of soil arching, though it has a significant influence on the degree of soil arching effect. As expected, the degree of soil arching effect increases gradually with the embankment height. Meanwhile, it should be noted that the embankment height is a key factor governing the formation and features of soil arching. To be specific, only two shear planes are formed if $h<0.7(s\text{-}a)$; a partial arching is formed if $0.7(s\text{-}a)\leq h\leq 1.4(s\text{-}a)$; and a full arching is formed if $h>1.4(s\text{-}a)$. In addition, a smaller pile clear spacing gives rise to a greater degree of soil arching effect. However, the pile clear spacing has a significant effect on the formation of soil arching, but not on the features.