The 2016 World Congress on
Advances in Civil, Environmental, and Materials Research (ACEM16)
Jeju Island, Korea, August 28-September 1, 2016

Application Analysis of Flexible Supporting System of Sheet-Pile Wall and Support-Plate with Prestressed Anchor on High Filled Slope

*Yan-Peng Zhu[1)], Xiao-Rui Ma [2)], Xiao-Yu Yang[3)] and Jing-Bang Li[4)]

[1), 2), 3), 4)] *College of Civil Engineering, Lanzhou University of Technology, Lanzhou 730-050, China*
[1)] *zhuyp1@163.com*

ABSTRACT

The methods of protection and governance of the high fill slope is diversity, generally, single retaining structure cannot meet the requirements of stability and deformation, due to the factors such as landform and filler etc.. In this paper, in view of the characteristics of loess area high fill slope engineering, a kind of flexible supporting system of sheet-pile wall and support-plate with prestressed anchor that suitable for collapsible losses area embankment and large settlement post-construction of high fill engineering is proposed, and this system safeguard the stability of the retaining structure via a the passive earth pressure of the pile under the ground and the friction between support-plate and filler of slope. And then the paper take the northwestern high fill slope engineering as an example, carried out the finite element analysis for deformation characteristics, the tendency of displacement field and the most dangerous sliding surface of flexible supporting system of sheet-pile wall and support-plate with prestressed anchor in process of the application. The numerical simulation analysis shows that flexible supporting system of sheet-pile wall and support-plate with prestressed anchor has good applicability for high filled slope and the flexible anchor can avoid the negative influence caused by soil collapsed or the large post-construction settlement. The flexible supporting system could make a reasonable, permanent management and utilization of the high fill slope.

Key words: support-plate with prestressed anchor; finite element method; flexible supporting system; high filled slope

---

[1)] Professor
[2)] Graduate Student

1. INTRODUCTION

Slope is one of the most common natural geological environments in human engineering activities, and the slope treatment is a kind of complicated and difficult disaster preventions. The mountain gully longitudinal in Western China, collapsible loess is widely distributed in these sections, cutting mountain and land reclamation are used to further expand the development space, and produced a large number of high filled slope engineering projects. Moreover, the form of filling along the slope direction is a common thing in this process. The slope built along the slope direction is more unstable than natural slope, and these also happened in horizontally filled. If not handled properly, it is easy to cause the project accident. (Cheuk 2005) researched the influence of rainfall infiltration on the stability of the slope. So, the stability of the high filled slope made along the slope direction has become a technical problem that must be solved in the engineering of slope treatment.

At present, the anchor plate is widely used to reinforce slope in the filled slope treatment engineering. Through the lateral bearing capacity produced by soil and anchor fixed on the plate surface to maintain the balance of structure. The failure surface shape of the supported slope by anchor plate likes polyline, if the supporting structure is damaged, the top of slope will appear obvious cracks, meanwhile external environment (rainfall, freeze thaw cycles) will accelerate the damage of supporting structure, which brings a huge challenge to the slope stability issue. In the anchor plate supporting system, the steel rod of passing anti-pulling force can be easily broken off in the collapsible loess collapsibility process and the settlement after construction of high filled slope, which cannot meet the safety requirement of the filled slope. This paper is based on the research achievement of the flexible supporting system, in addition, the property of the existing achievement and their limitation of high filled slope retaining system are taken into account, and then puts forward a new anchorage system, that is the flexible supporting system of sheet-pile wall and support-plate with prestressed anchor.

2. SUMMARY OF NEW ANCHORAGE FLEXIBL SUPPORTING SYSTEM

This new flexible retaining system concludes plie, crown beam, anchor hole, tied rod, anchor plate et al which are illustrated in Fig. 1.

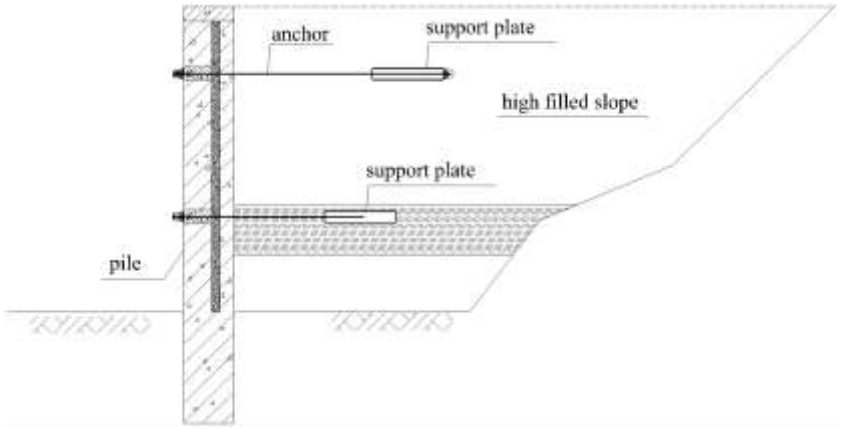

Fig. 1 Flexible supporting system of Sheet-pile wall and Support-plate with Prestressed anchor

The shape of support-plate is rectangle or circle, and is made of reinforced concrete, the thickness is general 80cm-100cm, its area is determined by the needed anti-pull force. To increase the friction force, the surface of support-plate can be shaped to be corrugated type or groove type and so on.

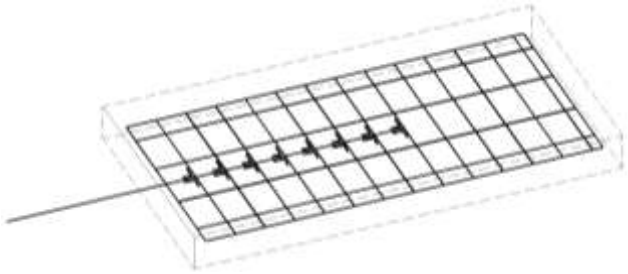

Fig. 2 Support-plate

Collapsible loess and post construction settlement of high embankment can adopt the anchor cable with the small prestressed loose and better deformation ability. The project is not in the area of wet sinking, the thickness of the soil is not big and the settlement after construction is small which can be replaced by anchor rod instead of anchor cable. The pile is below the ground digging holes into the pile, the above ground and the retaining plate using cast in place, and obligated the anchor (rod) hole.

Pile of prestressed anchor flexible supporting system aimed at for supporting the collapsible loess area and high filled engineering. Engineering production collapse and the large post construction settlement is not affected the structure system. The system through the pile below the surface of the insertion depth range of passive pressure, filler and anchor plate between the friction work together to provide the anti-pulling force. Destruction form is circular sliding failure, and the existence of the potential slip surface will not be wider cracks. Large machinery is suitable for construction. The spacing

between the supporting boards is not affected by the pile spacing. Large-scale compaction machinery (vibration compaction, impact compaction, etc.) can be used in to fill the soil compaction and support construction.

3. GENERAL SITUATION AND GEOLOGICAL CONDITIONS

Filled slope mainly consists of miscellaneous fill soil, Malan loess layer and silty soil with a serious collapsibility, and locally doped strong weathered red sandstone. The top is a large area of open space, relatively flat, slope adjacent to the drainage ditch. The overall slope of about 30 meters high, about 1250m long and slope of about 32 degrees to 47.5 degrees, local lager than 50 degrees, under natural conditions, most of the area is not stable or unstable slope, soil slope has the possibility of losing steady, as shown in Figure 3. The calculation parameters of the soil slope are shown in Table 1 and Table 2.

Table .1 Parameters of undisturbed rock and soil of the slope

Group	name	Gravity γ （kN/m^3）	cohesion force c（kPa）	friction angle $\varphi(^o)$	interfacial bond strength τ （kPa）
①	miscellaneous fill	17.2	10	24	25
②	ma Lan loess	16	14	27	25
③	silty soil	16	19	27	25

Table .2 Parameters of undisturbed soil in filled slope

Group	name	Gravity γ （kN/m^3）	cohesion force c（kPa）	friction angle $\varphi(^o)$	interfacial bond strength τ （kPa）
①	loess-like soil	18	18	30	25

Fig. 3 Current situation of the Slope

4. TREATMENT SCHEME OF THE SLOPE

Taking the factors of the slope height, slope road red line, red line, building avoidance distance control, field construction situation, on-site construction difficulties conditions into account, and considering the specific characteristics that filled slope possess, adopt the pile retaining wall with prestressed anchor plate flexible supporting system to carry on the support governance of the slope.

Specifically: using the method that combining the slope with flexible supporting system of sheet-pile wall and support-plate with prestressed anchor. Then, first, second and third level slope using compacted natural sloping, slope ratio adopted as 1:1.3, Intermediate table width is 1.0m, on the platform masonry rubble retaining wall are set. Slope behind the retaining wall filled with humus soil then plant grass, to come into being ecological slope protection; at the foot of the slope with flexible supporting system of sheet-pile wall and support-plate with prestressed anchor supported, and pile spacing is 3m, the pile top set top crown beam and in it top surface below 2.0m design a horizontal prestressed support plate to control the deformation, as shown in Figure 4, after treatment, the effects as shown in Figure 5.

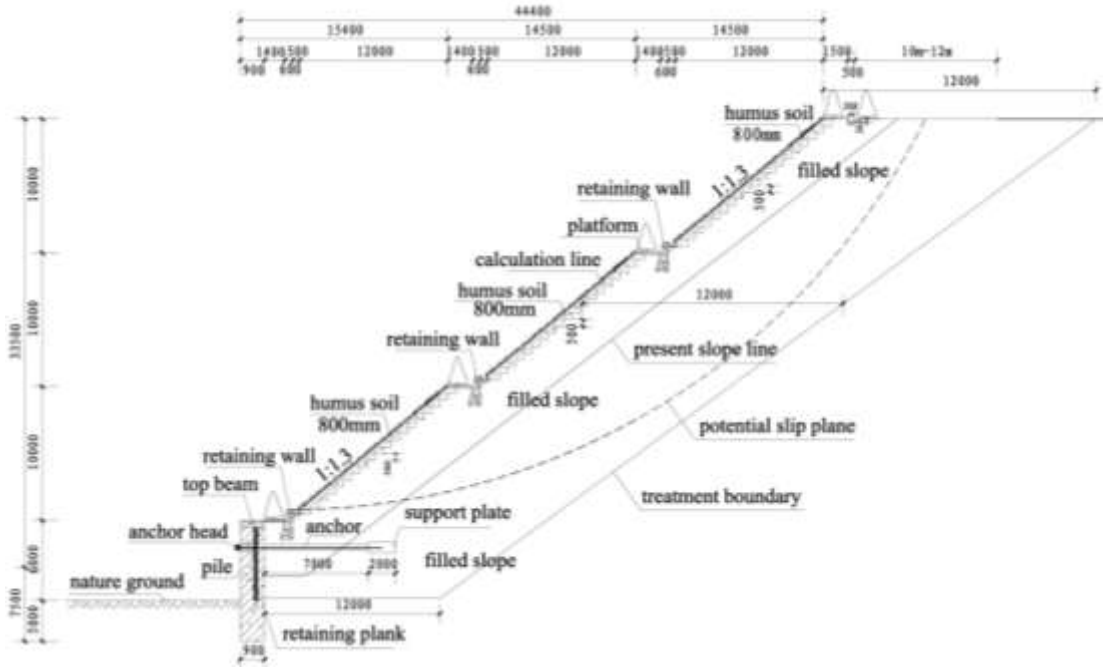

Fig. 4 Treatment Scheme of the high filled slope

Fig. 5 Treatment effect of the high filled slope

5. NUMERICAL SIMULATION ANALYSIS

(Griffiths 1999) researched the slope stability analysis by finite elements. (Zhou 2009) carried a numerical modelling of the slope filled on loose soil. (Chen 2011) studied the slope stability with reduction FEM method. (Song 2005) researched high slope stability by In-situ dynamic monitoring. In order to evaluate the supporting effect of flexible supporting system of sheet-pile wall and support-plate with prestressed anchor, the finite element software PLAXIS is adopted, which could simulate complex engineering geological conditions, and also have a stronger applicability for simulation analysis. The calculation model is simplified to plane strain problem, the horizontal displacement is 0, the vertical displacement in the bottom is 0, after the constraint on both sides. Yield criteria of rocks and soils is Mohr - Coulomb criterion, the initial stress field according to the weight, and the size of the model is 60 m× 50 m. 15 node plane strain model were chosen, the model were divided into 847 units, so the model meet the requirements of the analysis. Finite element analysis model is set up as shown in figure 6, the model the soil parameters adopted in the model are shown in table 2.

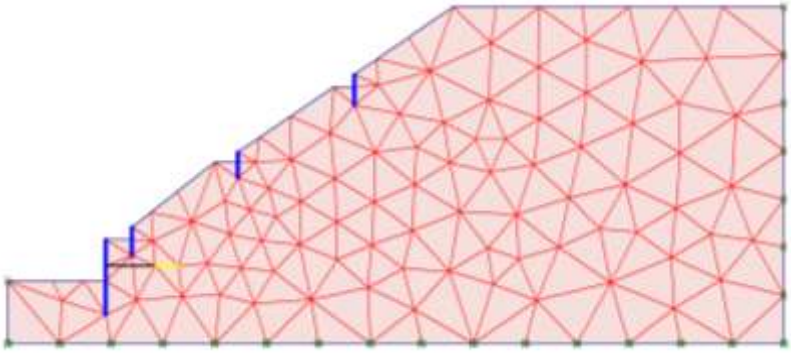

Fig. 6 Numerical calculation model

The physical and mechanical parameters of soil, which numerical model used, were considered from a security point of view, as the reason that the construction process has negative effects on slope stability. The pile top load considered as 20 kPa, according to

the slope self-weight stress and construction load. Through numerical simulation, it is found that the filled slope reinforced by sheet-pile wall flexible supporting system, the maximum displacement occurs on the top of pile wall, the maximum displacement is 12.83mm, as shown in Figure 7. According to figure 7 shows, the slope deformation vector diagram, the prestressed anchor plate has obvious restricting effects on the deformation of the pile. The deformation of slope soil, which around support plate, is small, and it can effectively control deformation of the filled slope, as it the situated outside the most dangerous slip surface. In the actual filled slope, the support plate with prestressed anchor could be set in a flexible way through calculation, like the distance, layout and size.

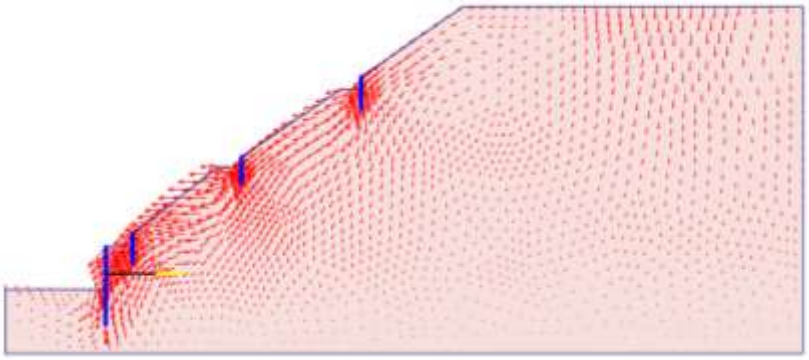

Fig. 7 Vector graph of total deformation of supporting-slope

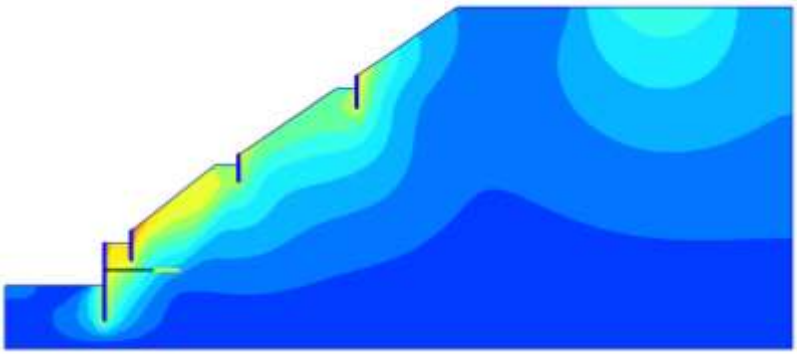

Fig. 8 total deformation of supporting-slope

The high filled slope arises the slip surface according to different forms of supporting structure, flexible supporting system of sheet-pile wall and support-plate with prestressed anchor is generally circular sliding failure in this paper, as shown in Figure 8. Circular sliding failure can effectively reduce or avoid the negative impact of the potential slip surface of the high filled slope (the slip surface at the junction of filling soil and undisturbed soil), embodies the superiority of this flexible supporting system.

Flexible supporting system of sheet-pile wall and support-plate with prestressed anchor is a supporting structure for the collapsible loess area and high filled engineering.

The collapsibility and larger settlement of the structure system will not have a significant impact on the construction of the project. The system through the pile below the surface of the block solid depth range of passive earth pressure and the friction between the filler and the support plate work together to provide the anti-pulling force, and the main damage form is circular sliding failure. The spacing between the supporting boards is not affected by the pile spacing, applicable to large machinery construction and construction process is simple and is conducive to further expand.

6. CONCLUSIONS AND RECOMMENDATIONS

The pull rod (like anchor rod, anchor cable) tension provided by the friction between anchor plate surface and filled soil in the flexible supporting system of sheet-pile wall and support-plate with prestressed anchor, and then coordinate and limit the displacement of sheet-pile wall. In the final, the supporting and governance of high filled slope will be achieved.

(1) Accurate selection of embankment soil shear strength index is in the key place to improve the stability filled slope, which supported by flexible supporting system of sheet-pile wall and support-plate with prestressed anchor. Then the compaction process should be strictly treatment, or large shear test should be adopted to determine the actual physical and mechanical parameters of filling soil.

(2) The key factor controlling high fill slope stability is the potential slip surfaces, which in the border of filling soil and undisturbed soil. Then should set steps overlap in the filling soil and undisturbed soil, and use the mechanical compaction, according to the requirements of the corresponding consolidation coefficient.

(3) The uncertainty of sliding failure of filled soil, supported by flexible supporting system of sheet-pile wall and support-plate with prestressed anchor, mainly influenced by internal structure of filled soil and environmental factors, including the uncertainty of filling soil, geometrical characteristics of the filled slope, and rainfall, earthquake and artificial loading, etc.

(4) Flexible supporting system of sheet-pile wall and support-plate with prestressed anchor has obvious superiority in supporting and governance filled slope. In practice, we should determine the trend of the displacement field change first, combined with the finite element analysis, when the system is working. Then confirm the position of the supporting plate with prestressed anchor, and ensure it is located in the stable region.

REFERENCES

Cheuk CY, Ng CWW, Sun HW. (2005). “Numerical experiments of soil nails in loose fill slopes subjected to rainfall infiltration effects”. *J. Computers and Geotechnics*. **32**(4):290-303.

Chen Jinfeng, Song Erxiang, Xu Ming. (2011). “Application of strength reduction FEM to stability analysis of high fill slope in Kunming
new airport”. *J. Rock and Soil Mechanics*, **32**(1):636-703.
Griffiths D V, Lane PA. (1999),”Slope stability analysis by finite elements” .*J . Geotechnique* , **49**(3):387-403 .
Song Xiu-guang, Zhang Si-feng, Li Ying-yong. (2005), “In-situ dynamic monitoring and analysis of high slope stability ” J. Rock and Soil Mechanics, **26**(7):1153-1156.
Zhou YD, Cheuk CY, Tham LG. (2009). “Numerical modelling of soil nails in loose fill slope under surcharge loading”. *J. Computers and Geotechnics.* **36**(5):837-50.