◆Research Paper◆

Design and Application of Pressure Dispersed Anchor Cable in High Soil-like Slope

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Abstract: Reinforcement of high soil-like excavation slope as an example, this paper introduces the stress mechanism, design and calculation, application effect for pressure dispersed anchor cable. It has reference value for similar projects.
Key words: high soil-like slope,pressure dispersed anchor cable,design and calculation

0 Foreword

Although the soil-like slope retains some characteristics of the parent rock, it is with loose structure, joint development and the soil property. When the original soil-like slope is excavated, the mechanical equilibrium is destroyed.Then the stress in the slope is changed and adjusted. If there is water into the slope during the period and the slope has not be reinforced, the slope can not reach the new mechanical equilibrium. Therefore landslide will occur, and the high soil-like slope should be reinforced in advance.

As a light retaining structure, the prestressed anchor cable has the advantages of little disturbance, large anchoring force, and it is applied widely

1 Stress Mechanism and Characteristics of Pressure Dispersed Anchor Cable

1.1 Stress Mechanism

At present, the common type of cable in the project can be divided into tension type and pressure type. The characteristics of tension type anchor cable is to use interface friction between injecting cement paste and cable, and between injecting cement paste and the soil,to provide anchoring force for the retaining structure.

But a lot of experiments prove that bond stress of tension type cable along the anchorage section is extremely uneven.

There is serious stress concentration at the proximal end of the anchorage section, and effective tension length of anchorage section is limited. When the anchorage length is more than 8 ~ 10 m, it is not usefull to improve anchoring force through increasing the anchorage length. Therefore, the traditional tension type cable can not get higher anchoring force [1].

Pressure dispersed anchor cable is multiple anchor system of single bore,which is composed of multi-anchoring units. Firstly, it transmits tension to the separate bearing carriers.Then tension force is converted into pressure, pressure reached in the vicinity of the cement mortar.Cement mortar under pressure produces micro compression expansion and compression deformation.

Finally, the pressure is transmitted to the rock and soil mass, so that it withstands the shear.

1.2 Stress Characteristics

(1) The concentrated force is dispersed into several smaller pressure zone by pressure dispersed anchor cable, which make the bond stress value of anchorage section greatly reduced, and well-distributed. Stress concentration is decreased, and the formation strength around the anchor is fully mobilized.

Then anchoring ability is improved, so as to compensate the shortage of tensile type anchor.

(2) For pressure dispersed anchor cable, injecting cement paste is not easy to crack, which is subjected to compression not tension. It is beneficial to be waterproof and anticorrosion for the cable body.

Pressure dispersive anchor cable for weak rock, especially for the soil permanent reinforcement of low bearing capacity has an irreplaceable role[2].

Pressure dispersed anchor cable structure, see figure 1. The stress distribution of the friction around the anchorage section, see figure 2.

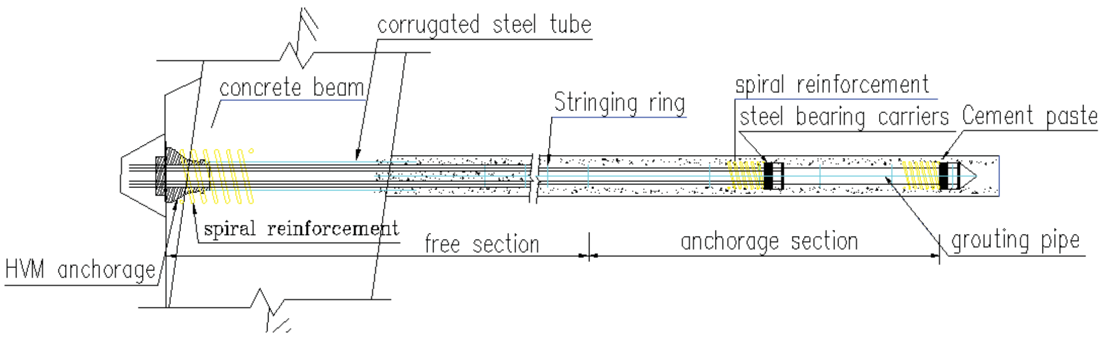

Figure 1 Pressure dispersive dispersed anchor cable structure (unit:mm)

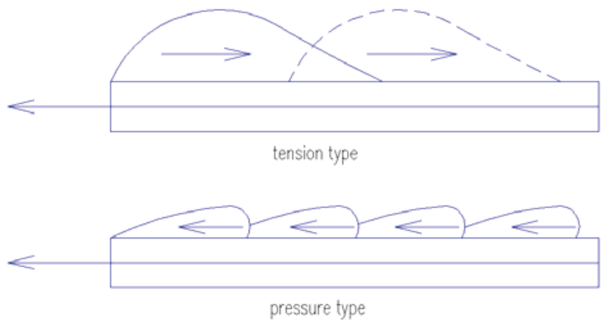

Figure 2 The stress distribution of the friction around the anchorage section

2 Engineering Situation

A factory is located in the hilly area. Leveling way of the site is "digging the mountain to fill out the ditch", and in the factory on the eastern side of the slope is cutted to backfill gully to form the platform. After the excavating,the two parts of slope (A, B) are formed.

Main features of slope A:

(1) The excavation height is large, and the field is narrow. The maximum excavation height is about 40m , but due to the land boundary, only about 40m is available for the horizontal distance.

(2) Strict safety requirements for the slope are needed. The traffic flow and people flow are large at the foot of slope. Once the landslide occurs, consequences will be unbearable.

(3) The project is located in the southern region, with annual rainfall of more than 1900mm.

(4) Seismic fortification intensity vi is not considered in the design.

3 Engineering Geological Conditiona & hydrogeology condition

3.1 Engineering Geological Conditiona

According to the drilling exposure, formation of the site from top to bottom as follows:

(1) ②-2 Silty clay (Q4el + dl), thickness of 8.5m, brown-yellow, containing iron oxide stripes and Fe-Mn nodules, lots of gravel, and clay interlayer.

Natural moisture content(w): 19.0% ~ 33.9%, natural void ratio(e): 0.616 ~ 0.945, liquid index(I_L): 0~ 0.45, compression coefficient (a_{1-2}): 0.11 ~ 0.33MPa^{-1}, waxiness to hard plastic state, medium compressibility.

(2) ④-1 Fully weathered shale (T_3r-J_1), thickness of about 24m, yellow-brown, the whole structure has been unable to be identified, soil-like .

Natural moisture content(w): 15.6% ~29.6%, natural void ratio(e): 0.506 ~ 0.835, liquidity index(I_L): 0.02 ~ 0.42, extremely soft rock, rock basic quality level Ⅴ.

(3) ④-2 Strongly weathered shale (T_3r-J_1), yellow-brown ~gray-brown, strongly weathered, calcareous cementation, sandy and lamellar structure, shiver chunky and soil-like, extremely soft rock, rock basic quality level Ⅴ.

Some drilling has dolomitic limestone (⑤-1)and (⑤-2)weathered dolomitic limestone (C_{1m}), separately belonging to extremely soft rock and hard rock, and a small amount of karst cave is found.

3.2 Hydrogeological Conditions

There are no groundwater in the slope A and slope B, so the influence of groundwater is considered.

4 Slope Reinforcement Scheme

Comprehensive consideration,reinforcement scheme of slope A is anti- slide pile, slope cutting + pressure dispersed anchor cable. The typical section of the slope stability calculation and reinforcement design,see figure 3.

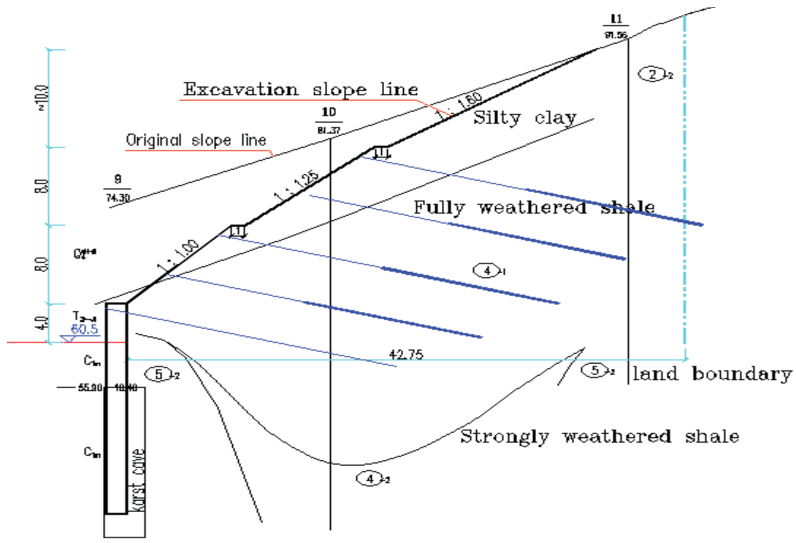

Figure 3 The typical section of the slope stability calculation and reinforcement design (unit:m)

5 Design and Calculation of Pressure Dispersed Anchor Cable [3]~[6]

5.1 Choice of Bond Strength of Anchorage Section

Generally, the selection of calculation parameters has indoor test, field test method, empirical parameter method and index back calculation method. The selection of the calculation parameters for the project is mainly based on the basic test of anchor cable in the field, and combined with the engineering experience and the recommended data of the exploration units. The parameter is very important for anchor cable design, so it should be carefully chosen. It is recommended bond strength of anchorage section should be determined by field test.

As the anchoring section is mainly in the fully weathered shale, eventually the standard value of the bond strength between the grout body and the rock-soil layer is 120kPa.

5.2 Design and Calculation of Anchoring Force

design anchoring force P_t:

$$P_t = \frac{F}{\left[\lambda \sin(\alpha+\beta)\tan\varphi + \cos(\alpha+\beta)\right]} \quad (1)$$

Among them:

P_t :design anchoring force;

F :dwnslide strength(By calculation):200kN/m;

φ :internal friction angle of sliding surface:24° ;

α :inclination of anchor cable and sliding surface intersection:31° ;

β :Angle between the cable and the horizontal plane: 15° ;

λ :reduction factor,for soil slope 0.5;

design anchoring force by calculation: P_t=234kN/m.

5.3 Determination of Anchor Spacing

horizontal spacing of anchor cable:4.0m

The design of anchoring force within the 4m width

P_T : P_T =234kN/m×4.0m=936kN

effective anchorage force each bundle of anchor cable :[F] =300kN

line number :

$$n = \frac{P_T}{[F]} = 3.1 \approx 4 \quad (2)$$

5.4 Anchor Cable Structure Calculation

5.4.1 Design and calculation of anchorage section

The grouting material adopts M30 unmixed cement mortar.

According to the following two kinds of method to calculate bond strength, and choose the maximum value.

(1) according to the bond strength of cement paste (bond strength between cement paste and steel strand is far greater than between mortar and the borehole wall), so it don't be calculated.

(2) according to the shearing strength between the anchorage body and borehole wall.

$$L_s = \frac{F_{s2}[F]}{\pi \cdot d_h \cdot \tau} \tag{3}$$

Among them:

F_{s2} :anti-pulling safety factor of the anchorage body,2.5;

d_h :diameter of anchorage cable hole,150mm;

τ :bond strength between the grout body and the rock-soil layer,120kPa.L_s=13.3 m

As a result, the anchor length L = 14 m, the length of free section of anchor cable have to pass through the depth of the slip surface greater than 1.0 m, so anchor cable have to pass through the length of the sliding surface not less than 15.0 m.

The number of bearing carriers:2, each anchorage length: 7 m

5.4.2 The Choice of the Number of Steel Strand

Considering two bearing carriers, each bearing carrier adopts two steel strands. Each bundle of anchor cable is with 4-Φ15.2 mm unbonded steel strand.

limit tensile load:

$$P_u=4\times259kN=1036kN \tag{4}$$

safety factor:F_{s1}=2,effective pull:

$$\frac{P_u}{F_{s1}} = \frac{1036}{2} = 518kN > 220kN \tag{5}$$

So steel strand won't be pulled apart.

5.5 Total Length of Anchor Cable

The total length of the cable=the length of the anchorage section + the length of free section+ the length of tension section

5.5.1 The Length of Free Section

Determination principle: in order to prevent the pre-tension of anchor cable from significant attenuation due to anchor head loosen and soil creep, and to increase the stability of anchoring formation, the length of free section of anchor cable should be no less than 5 m, and pass through the sliding surface of slope.

5.5.2 The Length of Tension Section

The length of tension section should be determined according to tension machine, and exposed length of anchor cable is generally about 1.5m.

6 Reinforcement Effect of Pressure Dispersed Anchor Cable

The construction of slope A has been completed in April 2012, and has experienced the test of the south rainy season. The displacement of the slope A is in the standard range, which indicates that the reinforcement measures are safe and feasible.

Reinforcement effect diagram of pressure dispersed anchor cable, see figure 4.

Figure 4 Reinforcement effect diagram of pressure dispersed anchor cable

7 Conclusions

(1) Pressure dispersed anchor cable used in soil-like slope of overburden being thicker , can fully mobilize the formation strength around the anchor, and significantly improve the anchor bearing capacity.It is a very effective way for the loose and broken rock and soil mass,for which anchoring force is insufficient,.

(2) In the design, the standard value of the bond strength between the grout body and the rock-soil layer should be determined by the basic test when there is no enough experience of the project.

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