A Landslide Treatment Engineering Design

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Abstract: In this paper, the characteristics of the slope are described in detail, and the stability of the slope is analyzed, and the stability safety factors under different working conditions are calculated. Finally, the control measures are put forward.

Keywords: Landslide Deformation Characteristics; Stability Analysis; Governance Measures

1. Overview of Slope

As shown in **Figure 1**, the potential unstable slope is located in a north-south direction, with the mountain top as the boundary on the north side, the highway on the south side, and gullies and ridges as the boundary on both sides. the slope direction is 200 °, which is a reverse soil slope with a ground elevation of 310m-410m, a longitudinal length of 153.7m, an overall slope of 30 °, an average width of 65m, an area of about 9265 m2, and a volume of about 6.1 × 104m3. According to the location and deformation properties of the slope deformation zone, the entire slope is divided into three zones: steep slope zone A, potentially unstable slope deformation zone B, and gentle slope deformation zone C. Now it is described as follows:

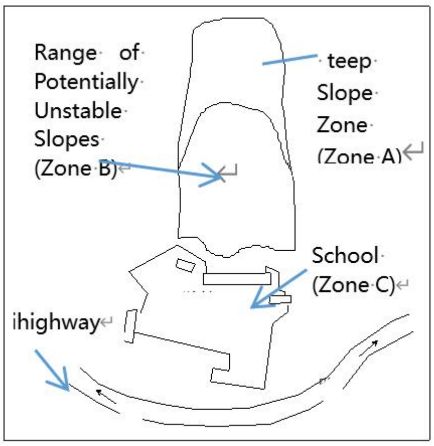

Figure 1. Overall, View of Slope

(1) Steep Slope Zone A

Distributed throughout the upper part of the slope, with a ground elevation of 357m-430m, a longitudinal length of 74.5m, a slope of about 55 °, and a zigzag slope shape. the steep slope area covers an area of 4765m2, and the volume of the landslide cover layer is about 35000m3. the bedrock near the top of the slope is directly exposed, and there is a slightly collapsed slope covering layer below, with a thickness of 0-15m. Due to its long formation time, the fragmented stone and soil have good consolidation. the vegetation in this area is lush, covered with fir trees, and there are no horse knife trees, drunken man forests, or large cracks found. the exposed part of the bedrock is relatively small and is mostly covered by vegetation. the exposed rock mass is weathered and cut into small dangerous rock blocks by primary joints. Currently, the dangerous rock blocks are basically stable, and there is a phenomenon of falling blocks in some areas. the scale is not large, and the diameter of the falling blocks on the slope is small, usually 5-20cm. Due to the lush vegetation on the slope, the falling rocks are basically blocked, and the farthest distance of collapse is still within section A. the accumulation layer is well consolidated, with a terrain slope smaller than the natural angle of repose of the gravel accumulation layer, and no signs of deformation for many years, indicating a stable state. the bedrock is mainly composed of sandstone from the Xujiahe Formation of the Triassic system, with an attitude of 200 °∠ 25 ° and a reverse slope. the stability of the bedrock mountain is good, and it can be considered that the hazard source in Zone A is relatively small.

(2) Potential unstable slope deformation in Zone B

This section is located in the middle and lower part of the overall slope, which is a soil slope with a slope direction of 200 ° and an overall slope of about 25 °. the ground elevation ranges from 357m to 324m, with a relative height difference of about 33m and a longitudinal axis length of about 72m. the rear edge is bounded by the protruding turning point of the bedrock, and the front edge is bounded by the 3.5m high free face behind the teaching building; the upper part is about 60m wide horizontally, while the lower part is slightly wider at 71m. Both sides are bounded by exposed mountain ridges and bedrock, with an area of about 4500m2. This section is covered with a thick soil layer, about 3-22m, and the thickness of the silty clay layer that may cause sliding is about 0-10m, with an average thickness of about 6m. the entire soil layer is divided into two layers, the upper layer is a layer of silty clay, which is residual slope deposits, and the lower layer is accumulated crushed stones from landslide deposits, with a potential unstable soil volume of about 2.7 × 104m 3?. the slope surface of this section is in a zigzag shape, with a stepped terrain and a height of about 0.5-1m. There is a slight bulging phenomenon in the lower part. the leading edge is the open face formed by cutting the slope of the teaching building, with a height of about 3-4 meters. Currently, a simple stone retaining wall with a height of 2 meters has been constructed, and no obvious deformation has been found, with slight bulging phenomenon. the deformation section experienced local sliding in the rainstorm season in 2007. the lower section is cultivated land, while the upper section has lush vegetation and some areas have drunken Hanlin.

(3) Slope deformation zone C

The construction of schools and residential buildings has been carried out on the original slope in this section. Currently, the overall slope of the terrace in this section is gentle, with a terrain slope angle of 2 ° -5 °; the ground elevation in the deformation zone is 320m-310m. Due to the primitive terrain and human activities such as building houses, a three-level platform staircase has been formed. the first step from top to bottom is the teaching building and school playground, with a ground height difference of about 5.14m. the second step is the school playground and office building, with a ground height difference of about 5.5m. the third step is the office building, town market, and highway, with a ground height difference of about 5.53m. the three terraced buildings have no significant deformation and are generally stable. Local cracks are mainly caused by uneven settlement of the foundation and sliding deformation of the edge of the free face.

2. Characteristics of Deformation and Failure of Slope

The different deformation characteristics of slopes are divided into three zones:

(1) Vertically, the A area has stable landslide deposits and no signs of surface deformation, making it a naturally stable slope; the surface of Zone B is mainly characterized by residual slope silty clay forming creep deformation; Zone C is mainly characterized by uneven settlement of the foundation and local steep slope collapse deformation, with no obvious signs of deformation or damage.

(2) the deformation time has the characteristic of suddenness. According to the survey, in September 2007, the rainstorm season in Area B appeared local slip deformation, which destroyed the school kitchen below. Except for historical deformation cracks, the deformation time in Zone C was mainly concentrated around September 6, 2011, and the deformation rate was relatively fast.

(3) Characterized by significant harm. the deformation of the slope this time poses a huge threat, not only causing the teaching building to become a dangerous building, but also causing cracks and deformations in the toilet walls, affecting the normal operation of the school.

3. Slope Stability Calculation

The results of slope stability calculation and thrust calculation are shown in Table 1 and Table 2.

Table 1. Calculation Results of Slope Stability and Thrust

number	Calculation condition	Stability coefficient (Fs)	Safety factor (Ks)	Residual sliding force (KN/m)	Stability state
1—1′	Working condition I (natural working condition)	1.30	1.30	0	stable
	Working condition II (rainstorm condition)	1.04	1.15	308.12	Understability
2—2′	Working condition I (natural working condition)	1.43	1.30	0	stable
	Working condition II (rainstorm condition)	1.06	1.15	168.74	Basically stable
3—3′	Working condition I (natural working condition)	1.26	1.30	93.91	stable
	Working condition II (rainstorm condition)	1.02	1.15	326.09	Understability

For section A-A of slope, the most dangerous slip surface is searched by arc, and the stability calculation results are shown in the following Table 2:

Table 2. Calculation Results of Slope Stability and Thrust

number	Calculation condition	Stability coefficient (Fs)	Safety factor (Ks)	Residual sliding force (KN/m)	Stability state
Toilet office A-A profile	Working condition I (natural working condition)	1.12	1.30	95.348	Basically stable
	Working condition II (rainstorm condition)	0.98	1.15	82.305	unstable

It can be seen that the potential unstable slope is stable under natural conditions, and unstable under rainstorm conditions.

4. Engineering Governance Design

4.1 Anti Slip Pile

According to the calculation results of slope thrust, different types of anti slip piles were used for slope support in different profile control sections and slope thrust sections. A total of 4 support sections, 4 types of piles, and 13 anti slip piles were installed (see Table 3).

Table3. List of Design Parameters for Anti Sliding Pile

Pile type	Pile section(m^2)	Pile length(m)	Design selection of thrust (KN/m)	Section number	Number of piles
A-type pile	1.5×2.0	13.5	500	1—1′、3—3′	6
B-type pile	1.5×2.0	17	450	1—1′、2—2′	2
C- type pile	1.5×2.0	24	450	1— 1′	3
D-type pile	1.5×2.0	22	4500	2— 2′	2

The anti slip piles are all rectangular section piles, and the concrete strength grade of the pile core is C30. the pile concrete protective layer is 100mm, and the protective layer of the wall reinforcement is 50mm. the pile body is poured with C30 concrete and reinforced with HRB335 steel bars. the bottom of the pile is considered as hinged end, and the internal force of the pile body is calculated using the Lizheng geotechnical calculation software. According to the calculation results of the internal force, longitudinal load-bearing steel bars and section stirrups are configured in accordance with the "Code for Design of Concrete Structures" (GB 50010-2002) and the "Technical Code for Design and Construction of Landslide Prevention and Control Engineering" (DZ/T0219-2006) (the design process is detailed in the anti slip pile design calculation book). the internal force of the pile body is calculated using the Lizheng Geotechnical Calculation Software. Based on the internal force calculation results, longitudinal load-bearing steel bars and section hoop bars are configured according to the "Code for Design of Concrete Structures" (GB 50010-2002) and the "Technical Code for Design and Construction of Landslide Prevention and Control Engineering" (DZ/T0219-2006) (the design process is detailed in the anti slip pile design calculation book).

Anti sliding piles are all manually excavated with jumping piles. C20 concrete retaining wall is used in the soil layer, and the first section of the retaining wall must be 200mm higher than the ground. the use of retaining wall measures can be determined based on the specific situation in highly weathered bedrock and fractured rock bodies.

The steel bars for the inter pile baffle are set throughout the length, and the plate and pile are cast in situ as a whole. Before pouring anti slip piles and panels, concrete test blocks should be made according to the designed mix proportion, and compressive strength tests should be conducted. Only after the strength design value meets the specification requirements, can concrete be mixed and poured according to the designed mix proportion. Pile concrete should be poured continuously and compacted by vibration. Special personnel should be assigned to maintain the anti slip piles and baffle concrete exposed above the surface after pouring.

The main reinforcement of the anti slip pile adopts mechanical connection joints. the joint position shall not be placed on the fracture surface or the rock soil interface. the area of the stressed steel bar joint from the center of any joint to a length of 35d (and not less than 500mm) shall not exceed 50% of the total area of the stressed steel bar, and shall be staggered from each other. the extension length of the main reinforcement is ≥ 50d.

After verification, it has been shown that after the implementation of anti slip pile support, the balance of forces on the slope has been met, and its stability coefficient has reached the relevant regulatory requirements.

A-type anti slip pile (6 pieces): section 1.5m × 2.0m, pile length 13.5m. the reinforcement in the compression zone and on both sides shall be arranged according to the structure, with the steel bar model of HRB335. the compression zone shall be equipped with 4 φ 16, and the two sides shall be equipped with 4 φ 16 respectively, with a full length configuration. the longitudinal reinforcement configuration in the tensile zone is as follows: 30 φ 32 full-length configuration, arranged in double rows, with the inner row of longitudinal stress bars fixed with 1 φ 12 transverse tension bars at a spacing of 1m. the reinforcement configuration is as follows: the top of the pile is 0-13.5m downwards, with a diameter of 1 μ m 12@200 (A closed double branch hoop) with hoop reinforcement, appropriately densified 1m above the bottom of the pile.

B-type anti slip pile (2 pieces): section 1.5m × 2.0m, pile length 17m. the reinforcement in the compression zone and on both sides shall be arranged according to the structure, with the steel bar model of HRB335. the compression zone shall be equipped with 4 φ 16, and the two sides shall be equipped with 4 φ 16 respectively, with a full length configuration. the longitudinal reinforcement configuration in the tensile zone is as follows: 38 φ 32 full-length configuration, arranged in double rows, with the inner row of longitudinal stress bars fixed with 1 φ 12 transverse tension bars at a spacing of 1m. the reinforcement configuration is as follows: from 0 to 17m below the pile top, it is arranged in a 1 φ direction 12@200 (A closed double branch hoop) with hoop reinforcement, appropriately densify the 1m section above the pile bottom.

C-type anti slip pile (3 pieces): section 1.5m × 2.0m, pile length 24m. the reinforcement in the compression zone and on both sides shall be arranged according to the structure, with the steel bar model of HRB335. the compression zone shall be equipped with 4 φ 16, and the two sides shall be equipped with 4 φ 16 respectively, with a full length configuration. the longitudinal reinforcement configuration in the tensile zone is as follows: 41 φ 32 full-length configuration, arranged in double rows, with the inner row of longitudinal stress bars fixed with 1 φ 12 transverse tension bars at a spacing of 1m. the reinforcement configuration is as follows: from 0 to 24m downwards from the pile top, it is arranged in a 1 φ direction 12@200 (A closed double branch hoop) with hoop reinforcement, appropriately densified 1m above the bottom of the pile.

D-type anti slip pile (8 pieces): section 1.5m × 2.0m, pile length 22m. the reinforcement in the compression zone and on both sides shall be arranged according to the structure, with the steel bar model of HRB335. the compression zone shall be equipped with 4 φ 16, and the two sides shall be equipped with 4 φ 16 respectively, with a full length configuration. the longitudinal reinforcement configuration in the tensile zone is as follows: 48 φ 32 full-length configuration, arranged in double rows, with the inner row of longitudinal stress bars fixed with 1 φ 12 transverse tension bars at a spacing of 1m. the reinforcement configuration is as follows: from 0 to 22m downwards from the pile top, it is arranged in a 1 φ direction 12@200 (A closed double branch hoop) with hoop reinforcement, appropriately densify the 1m section above the pile bottom.

4.2 Retaining Board

Set up a retaining plate between two piles, with a width of 600, a thickness of 300, and a length of 4.4 meters. the longitudinal configuration of the slab is reinforced with HRB335 φ 12 load-bearing bars, and the transverse configuration is reinforced with HRB335 φ 12 stirrups (see the structure of the retaining plate for details). A lifting hole with a diameter of 75mm is set up at a distance of 1m from both ends of the retaining plate, and a PVC pipe is pre embedded. After installation and molding, it also serves as a drainage hole.

4.3 Anti Slip Retaining Wall

At the slope where the H2 sliding body is located, a retaining wall is set up for support. the retaining wall adopts a gravity type block stone retaining wall with a height of 3.5m, a face slope gradient of 1:0.3, a back slope gradient of 1:0.3, a bottom slope ratio of 0.2:1, and a top elevation of 307.7m. the foundation of the retaining wall is buried in gravel soil, and a 150mm thick C15 concrete is laid on the foundation. A drainage ditch is set at the foot of the wall, with a top width of 500mm, a bottom width of 400mm, a height of 400mm, and a wall thickness of 250. the retaining wall is constructed with M7.5 mortar. A ф 110 PVC pipe drain hole is installed 2m below the top of the retaining wall, with a horizontal spacing of 2.0m. An expansion joint is set every 15 meters on the wall, with a width of 15mm, and filled with asphalt hemp thread. A platform shall be set up behind the top of the retaining wall, with a width of not less than 2m. the platform shall have a slope of 2%, and the slope behind the platform shall be cut (filled) at a ratio of 1:1.4.

4.4 Intercepting and Drainage Ditch

(1) Intercepting ditches should be arranged along the contour lines of the terrain as much as possible; Drainage ditches should be arranged along natural gullies or low-lying areas in the direction of the maximum slope of the vertical contour line as much as possible, so that the ditch can intercept water to the maximum extent possible while also being easy to drain.
(2) the bottom of the interception and drainage ditch should ensure that the ditch is not washed or silted, that is, to ensure a certain water velocity, so that it neither flushes the ditch structure nor causes sedimentation.
(3) Try to avoid crossing with other structures, minimize bends, and occupy less or no farmland.

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