08 May 1984, 8:00 am - 10:00 am

Case History on Prevention of the Landslide at Luoyiqi by Means of Rigid Frame Retaining Structure

Xu Fenghe

Wang Jinsheng

Case History on Prevention of the Landslide at Luoyiqi by Means of Rigid Frame Retaining Structure

Xu Fenghe

Vice Chief Engineer, Geotechnical Engineering Department

Wang Jinsheng

Engineer of Geotechnical Engineering

SYNOPSIS This paper presents a new special type of retaining structure which prevents the large-scale landslide. It is named the rigid frame retaining structure. The author in this paper proposed a new computation method, i.e, analysis of the rigid frame within elastic foundation. The new formulations have been performed according to E. Winkler's theory and the difference principle and with the help of fundamental knowledge of strength of material and matrix algebra. The descriptions of the design and construction of the rigid frame retaining structure were given.

INTRODUCTION

The Zhicheng-Liuzhou Railway line passes the flat mountain side with very good vegetation. Not far from here Louyiqi major bridge is set.

The surface layer consists of loose clay and crushed stones. The deeper ground are the gray and yellow-green shales of the Cambrian, which were weathered seriously and broken.

The ground water is well developed. At the mountain side 3 springs were found.

In 1975, the slope foot here was being excavated for constructing the branch railway with blasting procedure. A large-scale landslide accured accidentally. Many houses on it were destryed. The tongue of the slide has heaved more than one meter. This landslide would promptly endanger Luoyiqi bridge.

A lot of field works, such as boring, excavating test pits, visual investigation, penetrometer tests, soil sampling and ground water observations, have been used.

The length, width and thickness of the slide are 270, 250 and 20m, respectively. The volume of the slipping mass amounted about 1,000,000m^3. This landslide is a insequent and deep slide (Fig.1).

Many methods can be used to prevent landslides. In order to reach an economical and safe prevention of this large-scale landslide a new special type of retaining structure, the slide- prevention rigid frame, was **finally** adopted. It was composed of 2 piles and 1 transverse beam connected as a rigid frame to retain the thrust of the slide (Fig 2).

The length of the left pile (inner side), transverse beam and right pile are 33, 9 and 33m, the sections 2 x 3, 2 x 2 and 2 x 2m, respectively.

COMPUTATION AND DESIGN OF THE RIGID FRAME

The rigid frame is a complex redundant frame in

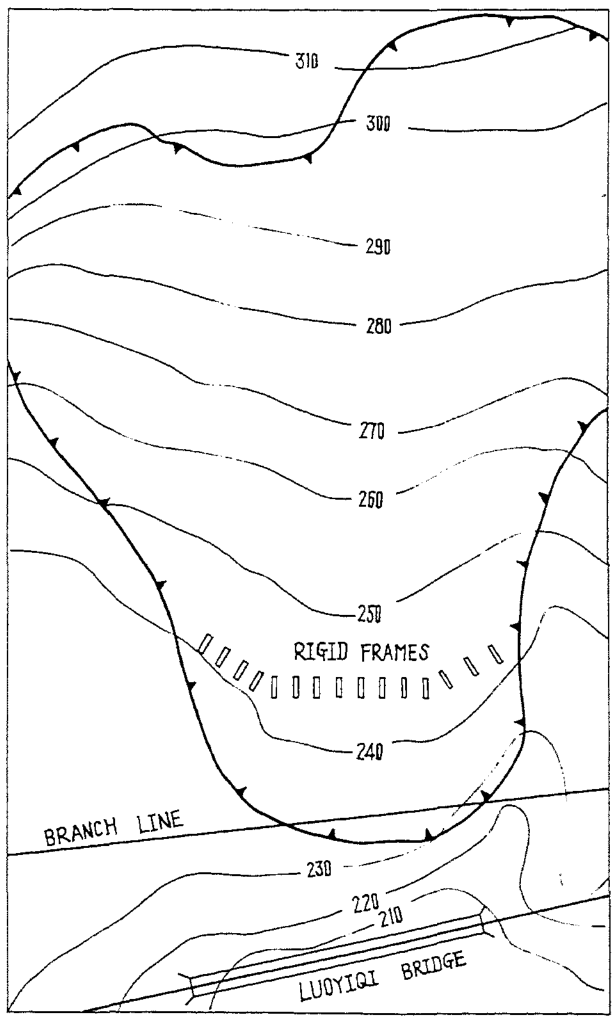


Fig. 1. Luoyiqi landslide

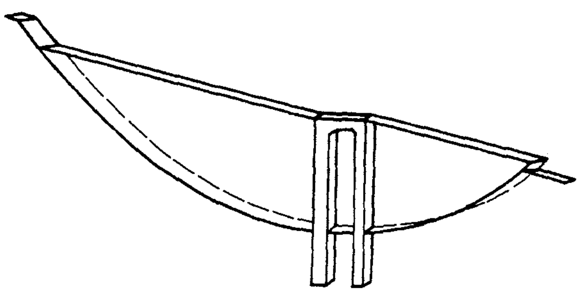


Fig. 2. Sketch of Slide-Prevention Frame

elastic foundation. The interaction between the rigid frame and the elastic foundation must be considered.

First of all the computation diagram should be given (Fig. 3, left). The boundary conditions of the lower ends of the piles could be consideredas fixed or hinged ends. After removing the connection of the left pile point the frame would be a broken-line cantilever beam in elastic foundation (Fig.3, right).

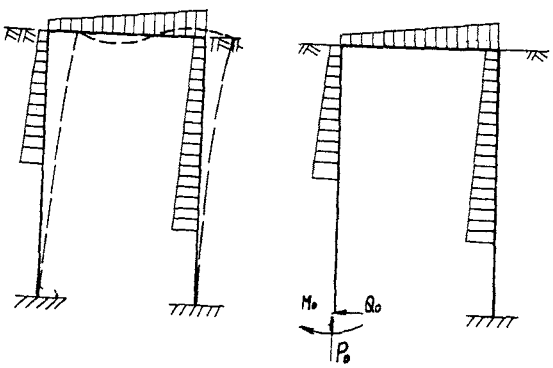
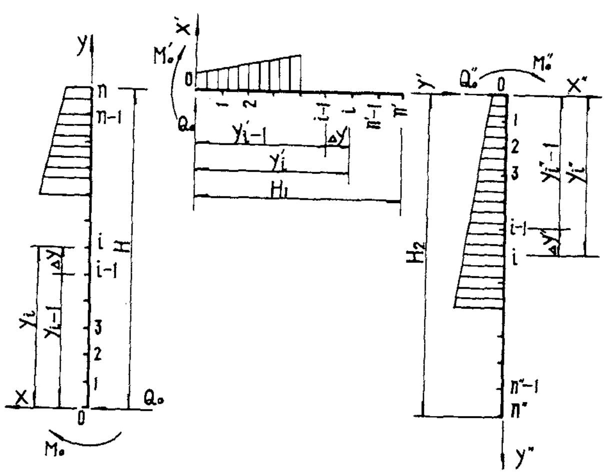


Fig.3. Computation Diagram

The left pile, the transverse beam and the right pile are divided into the finite parts n, n' and n", respectively (Fig.4)



.g.4. Division of Frame

In accordance with the first difference equati(of the difference theory

$$X_i = X_{i-1} + \frac{dx_{i-1}}{dy_{i-1}} \Delta Y \qquad (1$$

the relationships of the transverse displacemer X, deflection angle $\emptyset$, bending moment M and she force Q at the section i and section i-1 can be approximately written as

$$X_i = X_{i-1} + \frac{dx_{i-1}}{dy_{i-1}} \Delta Y$$

$$\emptyset_i = \emptyset_{i-1} + \frac{d\emptyset_{i-1}}{dy_{i-1}} \Delta Y$$

$$M_i = M_{i-1} + \frac{dM_{i-1}}{dy_{i-1}} \Delta Y \qquad (2$$

$$Q_i = Q_{i-1} + \frac{dQ_{i-1}}{dy_{i-1}} \Delta Y + d_{i-1}$$

where d_{i-1} is the product abtained by multiplic tion of the intensity of loading g_{i-1} and the s ΔY, that is

$$d_{i-1} = g_{i-1} \Delta Y \qquad (3$$

In accordance with the strength of material the following ordinary differential equation are

$$\frac{dx_{i-1}}{dy_{i-1}} = \emptyset_{i-1}$$

$$\frac{d\emptyset_{i-1}}{dy_{i-1}} = \frac{M_{i-1}}{(EJ)_{i-1}}$$

$$\frac{dM_{i-1}}{dy_{i-1}} = Q_{i-1} \qquad (4$$

$$\frac{dQ_{i-1}}{dy_{i-1}} = q_{i-1}$$

where $(EJ)_{i-1}$ and q_{i-1} are the bending stiffness and the resistance force of the surrounding medium, respectively.

Equation (4) can be stated in a matrix equation

$$A_i = B_{i-1} A_{i-1} + D_{i-1} \qquad (5$$

where A_i and A_{i-1} are the matrixes of the transverse displacement, deflection angle, bending moment and shear force at the section i and sec tion i-1, respectively; B_{i-1} is the coefficient matrix; D_{i-1} is the matrix of the constant term for distribution loads.

From equation (5) the following equation for the left pile, the transverse beam and the right pile are abtained, respectively.

$$A_n = F_{n-1}A_o + G_{n-1}$$

$$A'_n = F'_{n-1}A'_o + G'_{n-1} \qquad (6)$$

$$A''_n = F''_{n-1}A''_o + G''_{n-1}$$

where F_{n-1}, F'_{n-1}, F''_{n-1} and G_{n-1}, G'_{n-1}, G''_{n-1} are the parameter matrixes and the constant matrixes having influence on the transverse displacement, the deflection angle, the bending moment and shear force at the ends of the left pile, respectively.

According to the boundary conditions of the tips of the two piles and in consideration of the equilibrium of all forces acting upon the frame the simultanneous equation (6) can be solved. Finally the transverse displacement, deflection angle, bending moment and shear force at any section of the two piles and the beam can be abtained.

Here the thrust force above the slip surface is well-distributed along the left pile, q=2,180kN/m. The ratioes of the variation of the bedding value with depth for the slipping mass and the stable rock are 15,000kN/m^4 and 800,000kN/m^4, respectively. The elastic modulus of the piles and beam is 26,000 MN/m^2. The points of the two piles both are hinged.

The computation has been completed with the help of ALGOL Language by computer. The transverse displacements, bending moments and shear forces are shown in Figure 5

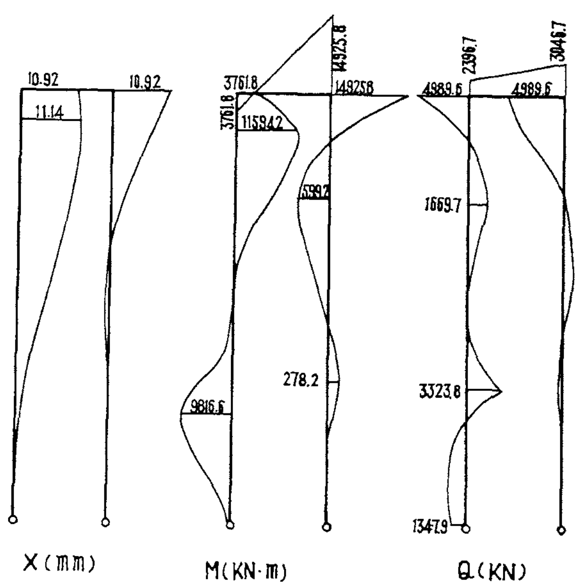


Fig.5. Diagram of Displacement X, Bending Moment M and Shear Force Q

The reinforcement of the frame has been designed according to Chinese Reinforced Concrete Code TJ10-74. The quality of concrete is No.200. The class of distribution steel and main steel are G-I and G-II, respectively. The distribution of reinforcement of the rigid frame has been shown in Figure 6.

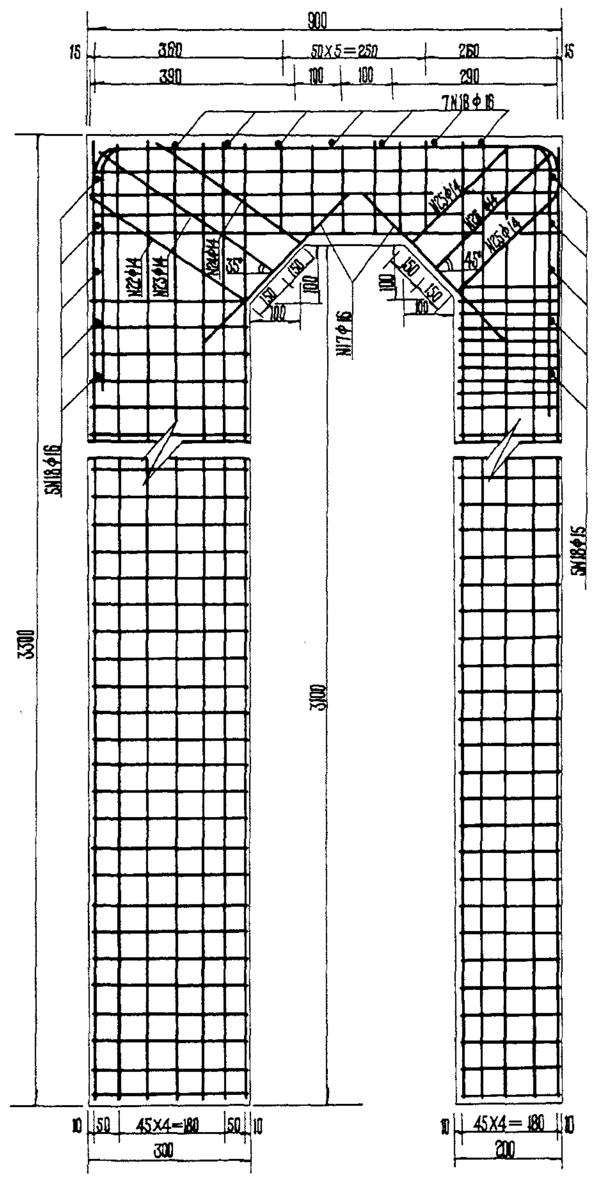


Fig.6. Distribution of Reinforcement

Figure 7 is the sketch of main steel.

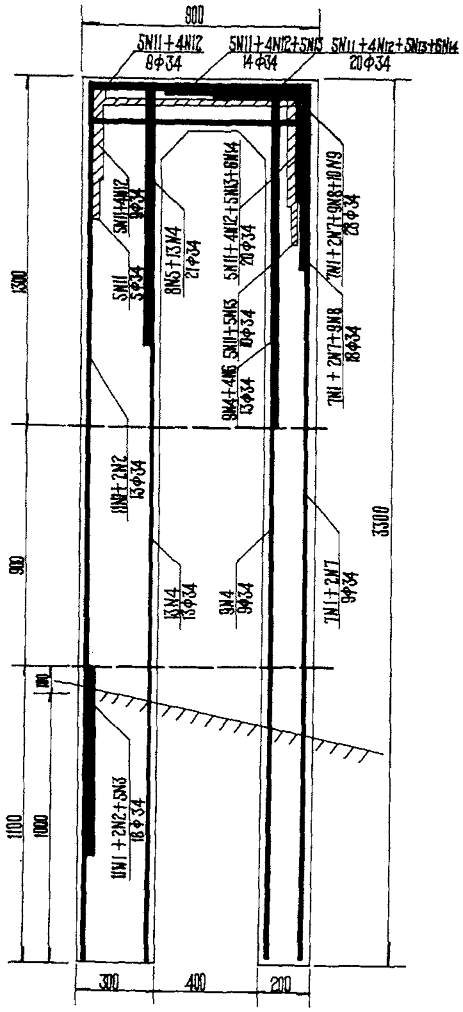


Fig.7. Sketch of Main Steel

CONSTRUCTION OF THE RIGID FRAME

The construction of the rigid frame started in December, 1981. All of the 15 frames completed in December,1982. The space between each two frames is 6 meters.

In order to ensure the safety of excavation for the foundation shaft the protective wall of lean concrete with 30cm thick was poured. The wall which was used to stabilize the surrounding soil or crushed rock was concreted along with excavation of the shaft.

The sequence of construction is first excavating the shaft and pouring concrete for the left pile, then the right pile and finally transverse beam. The 15 frames were constructed in order of every the other.

:he rebars were erected by a crane.The reinforce-ient cage were made in the foundation shaft. Be-'ore concrete placement the water at shaft bottom .ad to be drained. The mixed concrete was trans-orted into the shaft through a special tube and ompacted with vibrators.

In order to monitor the possible movement of tl landslide and rigid frames 13 displacement gau were installed. A lot of measured values demon trate this landslide has been stabilized.

CONCLUSIONS

Preventing the large-scale landslide at Luoyiq by means of rigid frame retaining structure wa a great success. It might hence be recommended for futher application on slide-prevention eng neering, especially large-scale landslides.

The computation method presented in this paper is reasonable since the interaction between th frame and the surrounding elastic foundation.

REFERENCE

Xu Fenghe (1981), " The Method for Computation Anchor Pile with a Pull Rod", Chinese Journal c Geotechnical Engineering, Vol.3, No.4 (Total 9 China.