HK.NCCP

International Journal of Civil Engineering and Machinery Manufacture
Volume 1, Issue 2, August, 2016

Analysis of Debris Flow on Slope Surface and Simplified Calculation of Groove Bottom of V Type Drainage Structure

Qiang WANG[1], Yuli ZHAO[2], Wei GONG[1]
[1]Civil Engineering College, Chongqing Jiaotong University, Chongqing, 400074, CHINA
[2]Chongqing Tuqiang Engineering Co. Ltd, Chongqing, 400074, CHINA

Abstract: According to the type of slope collapse, erosion type, distribution regularity of landslide debris flow types and characteristics of slope debris flow on slope, a simplified calculate on method for the groove bottom of the highway drainage structure on the hillside is proposed. Compared to the traditional method it is more simple, providing technical reference for the management of debris flow.

Keywords: Highway; Debris flow; Groove bottom

1. Introduction

Debris flow is a kind of sudden natural disaster in mountainous area, which is a kind of solid liquid two phase fluid saturated with sediment rocks and boulders. It is the result of the combined effects of geology, geomorphology, hydrology, meteorology, soil, vegetation and other natural factors and human factors. And it is the product of the deterioration of the mountain environment, the most serious harm to soil and water loss form. Slope debris flow is one of the problems of railway and highway subgrade engineering, which is a kind of sudden sediment transport phenomenon in steep slope section and also a manifestation of environmental degradation. From the point of view of the form of erosion, it belongs to the general surface spalling, small slump, some sheet, strip, shaped groove shallow structure, showing a piece of water and soil loss in large area unique landscape. Surface flow is not very concentrated, to the amount of small, high frequency, and it has the characteristics of engendering new slope debris flow at any time. From the point of view of individual hazards, it is not serious, but the accumulated losses caused by traffic and transportation cannot be ignored.

Debris flow interrupted highway traffic total time accounted for 30%~40% of highway traffic time. The economic losses caused by the debris flow caused by the debris flow in our country are hundreds of millions to billions of yuan every year, and its research and effective governance is one of the key issues to promote the progress of the Western Development. It also has important economic, social and national defense significance.

2. Types and Characteristics of Debris Flow on Slope

Slope debris flow developed in the above 30 degrees' natural slopes or slope, the slope cover is usually 0.5m~4m, and the shape is mostly in strip or flake shape. Its basin area is less than 0.4km2.There is no obvious groove or some grooves whose development is not perfect, in which is often the early New The longitudinal slope is basically the same as the slope surface, and there is no obvious circulation section. Total volume of solid material involved in the movement is 100~5000m3, and more than 10000m^3 is rarely seen. Debris flow also has the characteristics of accelerating the expansion of the other roadbed diseases (such collapse, landslides) to promote each other, and characteristic of accelerated expansion [1]. Material supply can be divided into the following three categories.

(1) Topsoil slip slope debris flow. Under the continuous rain storm, natural hillside or graben slope shallow layer topsoil slip caused by debris flow phenomenon. When solid substance carrying in a debris flow is about 1000m^3, it often contains a large number of plant residues. Such a wide range of diseases, mostly happened on a steep slope covered with the grass or bushes, which has been cut down the forest.

(2) Erosion type debris flow. Strong rainstorm formation of surface runoff scour erosion slope debris flow phenomenon caused by the loose soil. It often occurs in the slope surface distribution of thick soil and broken, weathered rock mass. Gully development is not perfect, is often a new valley. The convex slope valley upstream often cuts 10° ~20° . Some gentle slopes are turned into barren slope, some farmlands, and loose soil mass under the effect of heavy rain erosion forms debris flow. Concave type of upstream slope gully cuts slope greater than 40° , the longitudinal slope of the gully bed is about 41~60%, and the strong surface flowing caused by big

rainstorm scours steep loose soil into debris flow. Such as the Chengdu Kunming railway line Leyue station slope debris flow ditch group is such a case. Due to most erosion type debris flow gullies are shallow groove, like s small stream, when the survey was mistaken for clear water ditch and set up small bridges spanning. Debris flow breaks out after operation, resulting in clogging small bridge culverts, buried lines and other hazards [2].

(3) Landslide debris flow. Under the action of rainstorm, slope debris flow formed directly by the collapse and shallow landslides. When solid substance carrying in a debris flow is over 1000m³, debris often contains original state structure of the soil and plant residues.

During the heavy rain, the collapse and landslides are transformed into two kinds of debris flow on slope. One is the slide slope rock mass, water increased to make the earthrock suspension. The structure of the various components of soil damage, or sliding body in the process of movement, part of the upper rock collapse, under the influence of water into slope debris flow. The other is that slope is loose, weathered broken rock fall collapse, a large number of rock and soil slope down or dumped into the shallow ditch groove slope, mixed with water to form debris flow on slope. This kind of concentration appeared in the area of large scale and medium size of the fracture zone and soft broken lot.

3. The Distribution Law of Debris Flow on Slope

(1) The slope debris flow is closely related to the rainfall process, and the location of the occurrence of debris flow is basically consistent with the location of the storm center. So the distribution law of debris flow on the slope is closely related to the spatial and temporal distribution of the storm center.

(2) The distribution of debris flow on slope is consistent with the main fault zone, seismic zone and the distribution of the soft rock soil layer which is easy to slip and flow. Slope debris flow is the most concentrated, the most intense place, and is also the most active tectonic movement of the mountain tectonic belt and seismic activity zone [3].

The relationship between slope debris flow and lithology is closely related. Slope debris flow is mainly developed on the slope of weak rock and soil, including metamorphic rocks (phyllite, slate, schist), magmatic rock with rich mud, the loess. The geotechnical layer contains quite rich clay mineral (such as montmorillonite, illite and kaolinite), which is easy weathered and the shear strength is very low, thus it is easy to slide, easy to flow properties of slope stability, the residual diluvial layer is developed, full water slide after the slice, once displacing, the liquefaction phenomenon is obvious, almost all to participate in the activities of debris flow.

(3) The irrational economic activities of human beings have a certain impact on the distribution of debris flow on slope, such as deforestation, steep slope reclamation, road construction, quarrying, mining and other engineering activities. The balance of slope stability under different degree of damage, causing extensive geotechnical bare hillsides lose water soil fixation ability, improper selection of mining drainage design and mine. Slope stockpiling have lots of loose solid material, under the effect of heavy rain, the burden of water and sand, thus causing slope debris flow. It also causes large area of rock and soil exposed, and slope loses solid ability of soil to hold moisture. Improper selection of mining drainage design and mine, the slope has lots of loose solid material storage, under the effect of heavy rain, the burden of water and sand, thus causing slope debris flow [4].

4. Simplified Calculation of Groove Bottom of V Type Drainage Structure

For the treatment of large debris flow, the whole basin comprehensive treatment should be carried out. When restricted by the scope of the red line of highway construction and cannot carry on the comprehensive management of the whole river basin, we can use comprehensive management mode of blocking combined with drainage. And V type structure is an effective method to control the debris flow on slope. The calculation method of the precise solution of the bottom of the V type row structure slot is established as Winkler model follows:

The characteristic coefficient B of structure is calculated by the following formula:

$$\beta^4 = \frac{k}{4EI} \tag{1}$$

In the formula, E is the elastic modulus of the beam (Mpa); I is beam cross section moment of inertia (m^4).

Deflection expression basing on the elastic foundation beam:

$$y = e^{\beta x}(c_1 \cos\beta x + c_2 \sin\beta x) + e^{-\beta x}(c_3 \cos\beta x + c_4 \sin\beta x) + \frac{q(x)}{k} \tag{2}$$

The deflection, bending moment, shear expression of the beam's any arbitrary section can be gotten by the formula as follows:

$$\theta = \frac{dy}{dx} = \beta e^{\beta x}\left[c_1(\cos\beta x - \sin\beta x) + c_2(\cos\beta x + \sin\beta x)\right] - \beta e^{-\beta x}\left[c_3(\cos\beta x + \sin\beta x) + c_4(\cos\beta x - \sin\beta x)\right] \tag{3}$$

$$M = -EI\frac{d^2y}{dx^2} = 2\beta^2 EI\begin{bmatrix} e^{\beta x}(c_1 \sin\beta x - c_2 \cos\beta x) \\ +e^{-\beta x}(c_3 \sin\beta x + c_4 \cos\beta x)\end{bmatrix} \tag{4}$$

$$Q=-EI\frac{d^3y}{dx^3}=2\beta^3EI\left\{\begin{array}{l}e^{\beta x}\left[\begin{array}{l}c_1(\cos\beta x+\sin\beta x)\\-c_2(\cos\beta x-\sin\beta x)\end{array}\right]\\-\beta e^{-\beta x}\left[\begin{array}{l}c_3(\cos\beta x-\sin\beta x)\\+c_4(\cos\beta x+\sin\beta x)\end{array}\right]\end{array}\right\} \quad (5)$$

Putting boundary conditions into the above formulas can obtain C1, C2, C3, C4.

The inverse force line method is an approximate method, the method assumes that the ground reaction force is distributed in a straight line. The figure of the ground reaction force is rectangular under symmetrical load. Under eccentric load, the assumption is that there is no consistency between the foundation and the foundation deformation. Therefore regardless of load and its distribution, the mechanical properties of the foundation stiffness and soil how can directly calculate the ground reaction force with material mechanics of central or eccentric compression formula, which has the advantages of simple calculation. However, due to this method doesn't consider the deformation coordination between the foundation beam and the ground, so the calculation result is not accurate [5]. The simplified calculation model of the drainage structure is shown below, and the bottom of the line is taken as the research object.

In order to determine the linear distribution pattern of the ground reaction force, just need to seek out the beam end of the foundation of the degree of P1 and P2 firstly, the two unknowns can be determined by the equation of equilibrium $\sum Y=0$ and $\sum M=0$. Thus the slot bottom of the arrangement of the guiding structure can be simplified as a statically determinate problem to solve the problem, as shown in Figure 1.

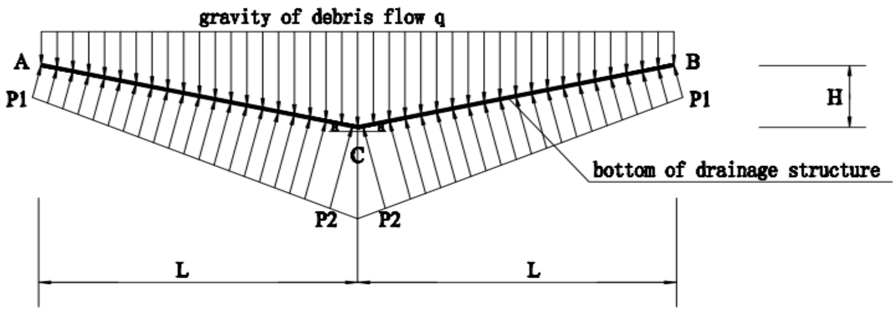

Figure 1. Simplified calculation model of tank bottom

According to $\sum M_A=0$

$$\frac{p_1L^2}{2\cos^2 a}+\frac{(p_2-p_1)L^2}{6\cos^2 a}+\frac{3p_1L^2}{2\cos a}+\frac{2(p_2-p_1)L^2}{3\cos a}=\frac{q_AL^2}{2}+\frac{4q_AL^2\cos a}{3}+\frac{(q_C-q_A)L^2}{3}+\frac{2(q_C-q_A)L^2\cos a}{3}$$

According to $\sum Y=0$

$$p_1L\cos a+\frac{(p_1-p_2)L\cos a}{3}=q_AL+\frac{(q_C-q_A)L}{3}$$

Using the above two formulas can be obtained P1 and P2, the internal force of any section of the groove bottom can be obtained by P1 and P2.

Example analysis

The bottom of a row of guide structure of a V line is as follows Figure 2.

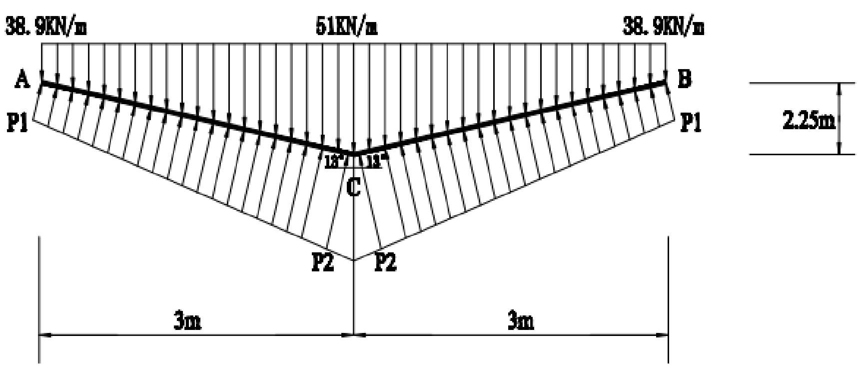

Figure 2. Groove bottom of force diagram

Internal force calculation of groove bottom structure (inverse force line method):

According to $\sum M_A=0$ 10.86P1+7.74P2=736.93

According to $\sum Y = 0$

1.5(P1+P2) =138.5

Getting P1=7.13kN/m P2=85.2kN/m

The internal force of any section can be got. So we only calculate the internal forces of x=1.5m and x=3m, and make the internal force diagram as shown in Figure 3, Figure 4.

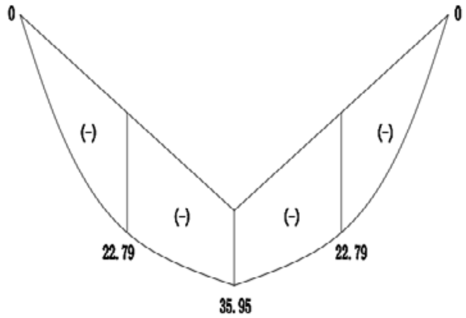

Figure 3. Groove bottom bending moment diagram M(unit: KN/m)

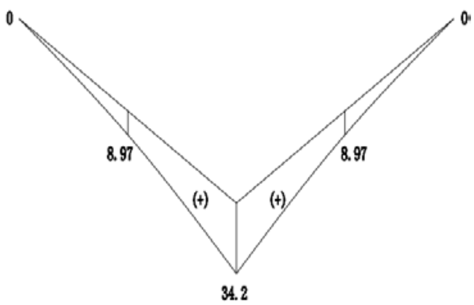

Figure 4. Groove bottom shear diagram Q (unit: KN)

Internal force calculation of bottom structure (exact solution).Taking half of the v shaped speed chute structure, as shown in Figure 5. Setting up coordinate system, according to its initial condition, it is known that the A is a free end, B is a fixed end, thus the boundary condition is gotten.

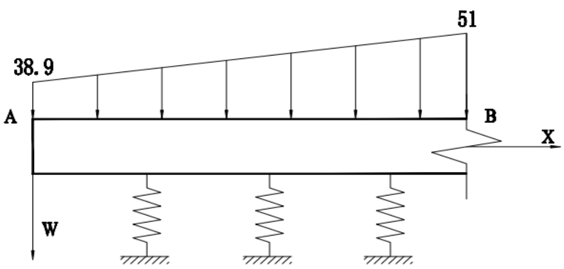

Figure 5. The bottom elastic beam diagram (KN/m)

A end: when X=0, bending moment M=0, shear Q=0

B end: when X=3, displacement y=0, nook H=0

Straight in the cross section direction to take the 1m, that is, the b=1m. modulus of subgrade reaction taking 30N/cm^3

$$E = 2.85\times10^4 Mpa, I = \frac{bh^3}{12} = 5.33\times10^{-3} m^4$$

$$\beta^4 = \frac{k}{4EI} = \frac{30\times10^6}{4\times2.85\times10^{10}\times5.33\times10^{-3}} = 0.04937,$$

$$\beta = 0.4714$$

The distribution of load on the bottom of the tank is considered as a linear change, $q(x) = 38900 + 4030x$

Taking boundary conditions into formulas (1) and (4) gets C1=0.0016, C2=0.00043, C3=0.00102, C4=0.00043.

Taking the four coefficients into formulas (3) and (4) gets the shear and bending moment available at any point.

Calculating the bending moment and the shear when x=3m and x=1.5m gets the internal force diagrams as shown in Figure 6 and Figure 7.

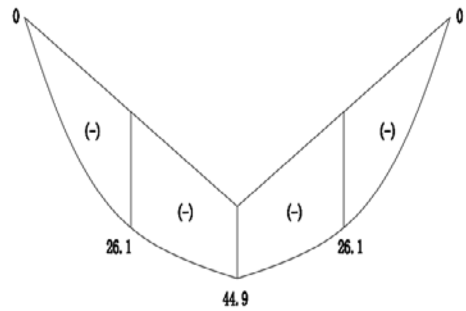

Figure 6. Groove bottom bending moment diagram M(unit: KN/m)

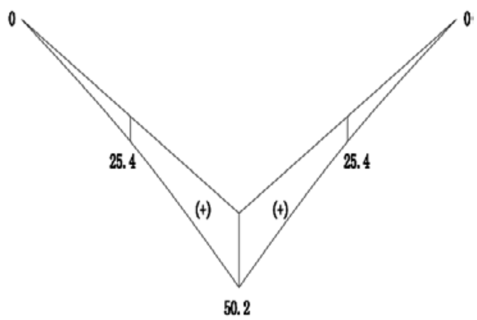

Figure 7. Groove bottom shear diagram Q (unit: KN)

In the design calculation, the calculation is simplified, using the inverse force straight line method to solve the problem. At the same time in order to ensure the safety of engineering, on the basis of the simplified solution to be multiplied by the coefficient of increase, an example is not enough to draw the coefficient of increase ,and the simplified solution can be obtained by multiplying the coefficient of 1.3~1.5 of the solution.

4. Conclusion

(1)Forming slope debris flow has close relation with rainfall, soil and other factors, when designing road should avoid such topography as far as possible.
(2)Human factors also affect the production of debris flow on the slope, avoiding excessive deforestation, and we should conserve soil and water.
(3)Because the calculation theory of Winkler elastic foundation beam is more complicated, it is difficult to apply to the actual project, so the calculation method is simplified in the paper. Based on a large amount of calculation, a simplified coefficient is given, which provides a reference for the design of debris flow control structure.

References

[1] Bagnold, R.A. Experiments on a gravityfree dispersion of large solid sphere in a Newtonian fluid under shear. Proc, Royal Soc. of London, Ser. A, 225(1954):4963.

[2] Hongkai Chen, Hongmei Tang, Sifei WU. Research on Abrasion of Debris Flow to Highspeed Drainage Structure[J]. APPLIED MATHEMATICSAND MECHANICS.2004, 25(11).

[3] Chao Dang, Peng Cui, Zunlan Cheng, The formation and failure of debris flowdams, background, key factors and model tests: case studies from China[J], Environmental Geology, 2009, 57,(8):19011910.

[4] Kolumban Hutter, Lukas Schneider. Important aspects in the formulation of solid-fluid debrisflowmodels. PartII. Constitutive modeling[J]. Continuum Mechanics and Thermo dynamics, 2010, 22 (5): 391411.

[5] Yong You, Huali Pan, Jinfeng Liu, Guoqiang Ou, The optimal crosssection design of the TrapezoidV shaped drainage canal of viscous debris flow[J], Earth and Environmental Science, 2011, 8(1):103107.