Numerical Simulation of Block Sliding Problem based on UDEC

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Abstract

With the rapid development of China's modernization, various rock engineering is built. Three kinds of elastic block sliding models are established in this thesis by UDEC: horizontal sliding model, slope sliding model and circular arc sliding model, and the shear stress, velocity and displacement at contact points are studied during block sliding process. The study found that, the shear stress variation with time is very complex, but eventually will become zero. For the horizontal sliding model, the velocity decreases linearly, and the displacement is parabolic. For the slope sliding model and the circular arc sliding model, the velocity changes at higher frequencies over time.

Keywords

Horizontal Sliding, Slope Sliding, Circular Arc Sliding, UDEC.

1. Introduction

Along with the rapid development of our country's modernization construction, various rock mass engineering were more and more being built. When the rock mass is cut into various types of discontinuous blocks by the structural plane, the blocks exposed to the surface may slip along the joint surface after excavation. If no measures are taken, it will cause the entire slope failure. Wang S J and Wu A Q [1,2] discussed the stability analysis method under the earthquakes, groundwater, anchoring force and other external loads, in which the Pseudo-static method was adopted to consider the seismic force and the hydrostatic pressure model to consider the role of groundwater on the block. Gan K R[3]considered the stability of the block under the action of anchoring, and put forward some suggestions on the analysis of anchoring force. Fang Y S [4]analyzed the stability of block in surrounding rock of underground engineering by using Stereographic projection , and put forward the calculation methods of bolt support, shotcrete support and shotcrete-bolt support for unstable block. Wang Y X and Wang J N [5]studied friction coefficient of structural plane, the mathematic expression of block reliability under stochastic distribution of cohesion, and some engineering example. A. Shapiro, J.L. Delport [6] carried out a joint network simulation, and random block search, but these works were done in two dimensions. Nakai T [7] used photographic technology, to investigate and record the structural plane after excavation, and to identify key blocks. This method can play an efficient and accurate role in the structural surface survey statistics, but there was a problem in to identify key blocks, because the structural plane data obtained by photographic survey is actually the structural surface trace information on the excavation surface ,so it can not judge whether the structural plane intersects within the rock mass. There may be large errors in key block identification. In this paper, three kinds of elastic block sliding models are established with UDEC, This law, the variation of shear stress, velocity and displacement with time in the sliding process, has been studied.

2. Sliding model of elastic block

2.1 The calculation principle of UDEC

UDEC is based on the discrete element method as the theoretical basis. The finite difference method is used to deal with the elastic body in this paper, and the method divides the solution domain into a differential grid, and uses a finite number of mesh nodes in place of the continuous solution domain. The finite difference method is based on the Taylor series expansion, and the derivative in the control equation is replaced by difference quotient of the function value on the grid node. The algebraic equations with unknown values on the grid nodes are established. The method is an approximate numerical method which directly transforms the differential problem into an algebraic problem. The mathematical concept is intuitive and the expression is simple. It is the development of earlier and more mature numerical methods. The forces of the interaction between the elements can be determined from the relationship between forces and displacements, and the motion of the individual elements is determined

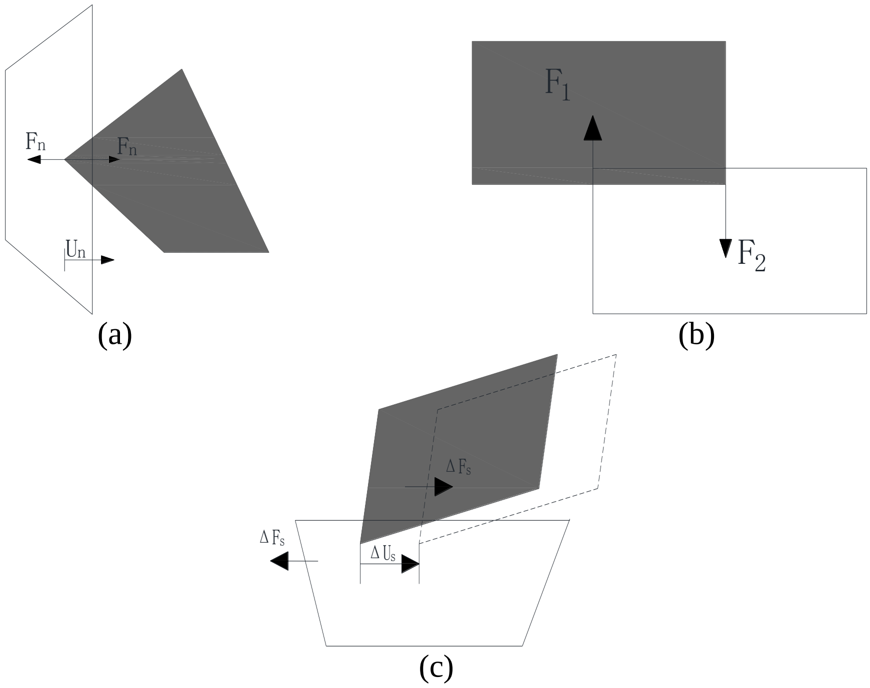


Fig.2-1The diagram of force between discrete elements

entirely by the magnitude of the imbalance force and the unbalanced moment of the element.

As shown in Figure 2-1 (a), assuming that K_n is the normal stiffness factor, the normal force of F_n between the blocks is proportional to the normal overlap of U_n between them, $F_n = K_n U_n$. If the boundaries of two discrete elements overlap each other, the two corner points will contact the interface, and the force at the two ends of the interface can be used to replace the interface force, as shown in Figure 2-1 (b). Since the shear force on the block is related to the history or path of the block movement and loading, the shear force is expressed in increments of ΔF_s, as shown in Figure 2-1 (c). The relative displacement between the two blocks is ΔU_s, K_s is the shear stiffness coefficient of the joint, then the shear force increment formula is $\Delta F_s = K_s \Delta U_S$.

2.2 Constitutive model of material

In this simulation, the mechanical parameters of rock materials and joints are shown in Table 2-1 and Table 2-2, respectively. The shear strength of the joint follows the Coulomb slip criterion.

Tabel.2-1 The basic mechanical properties of rock material

Mechanical properties	Value
density /($kg \cdot m^{-3}$)	2675
Elastic Modulus /GPa	90
Poisson's ratio	0.16

Tabel.2-2 The basic mechanical properties of rock joint

Mechanical properties	Value
Normal stiffness /($GPa \cdot m^{-1}$)	1.0
Tangential stiffness /($GPa \cdot m^{-1}$)	1.0
Cohesion /MPa	0
Friction angle /(∘)	5
tensile strength /MPa	0

3. Simulation analysis of elastic block sliding

3.1 Horizontal sliding model

3.1.1 Geometric model of horizontal sliding

The model consists of two parts, one part is a square, the other part is a rectangle. The square part is arranged above the rectangle and is subjected to the action of gravity and uniform force, and the position of the uniform force acts on the right side of the square. The bottom of the rectangular section is constrained by the displacement in the vertical direction, and the right side of the rectangular section is constrained by the displacement in the horizontal direction and the rectangular section is subjected to gravity. The schematic diagram of the horizontal sliding model is shown in Figure 3-1.

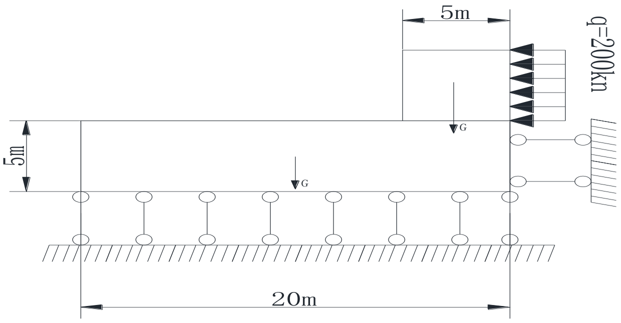
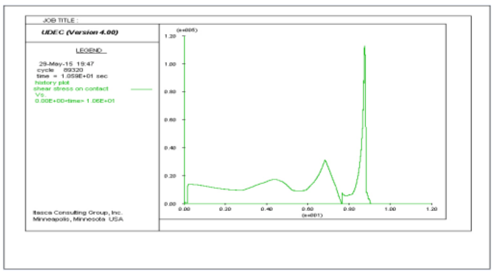


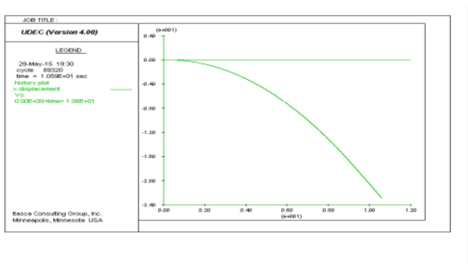
Fig.3-1 Horizontal sliding model

3.1.2 Horizontal sliding simulation results analysis

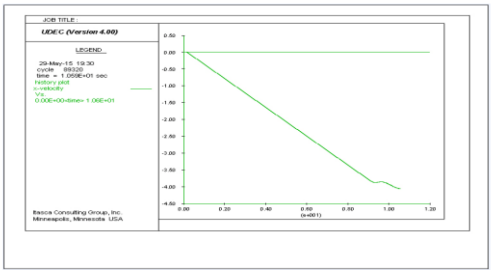
As shown in Fig.3.2 (a) , the shear stress at the contact point in the horizontal sliding model fluctuates little in the first 7 seconds, and the size is about 17000 Pa. The shear stress begins to decrease until the shear stress becomes zero between 7 and 8 seconds. The shear stress increases rapidly, then decreases rapidly, and the maximum shear stress is about 1.185×10^{5} Pa after 8 seconds. As shown in Fig.3.2 (b) ,the displacement time-history curve is parabolic, which can be verified from the velocity-time curve in Fig. 3-2 (c). Because the velocity is approximated to a straight line, the displacement is derived from the velocity integral, and the integral of the linear function is a quadratic function, so the displacement curve should be parabolic. In addition, as shown in Figs. 3-2 (b) and 3-2 (c), the maximum displacement is about 23.8 m and the maximum velocity is about $4.3 m/s$.



(a) History plot shear stress



(b) History plot horizontal displacement



(c) History plot horizontal velocity

Fig.3-2 Numerical results of horizontal sliding models

3.2 Slope sliding model

3.2.1 Geometric model of Slope sliding

The model consists of two parts, one part is a small trapezoid, the other part is a large trapezoid. The small trapezoid is arranged above the large trapezoid. The bottom of the large trapezoid is constrained by the horizontal and vertical directions , and both trapezoids are subjected to gravity. Small trapezoid under gravity, will slide along the sloping surface of large trapezoid. The schematic diagram of the Slope sliding model is shown in Figure 3-3.

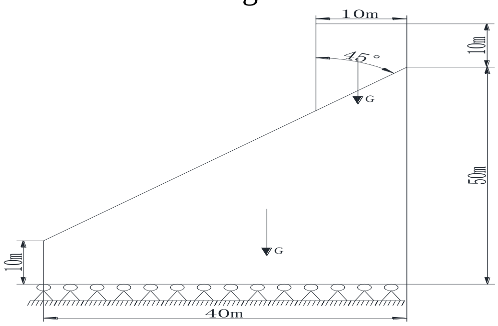
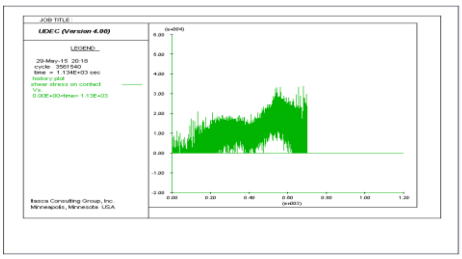


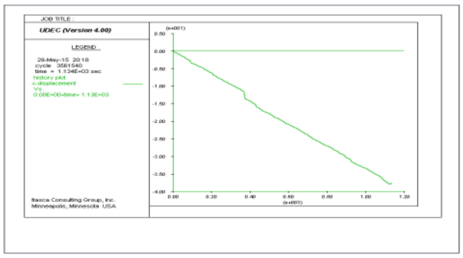
Fig.3-3 slope sliding model

3.2.2 Slope sliding simulation results analysis

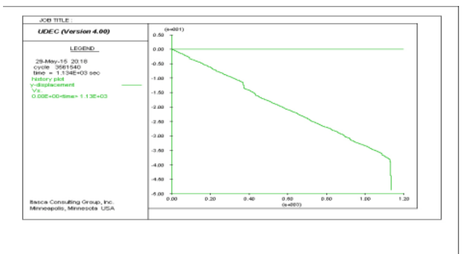
As shown in Fig.3-4(a),the shear stress at the contact point continual fluctuates, the peak value of each fluctuation is increasing ,and the maximum shear stress is about



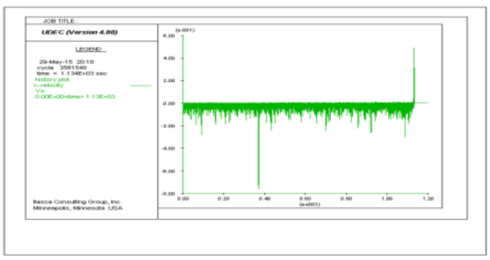
(a) History plot shear stress



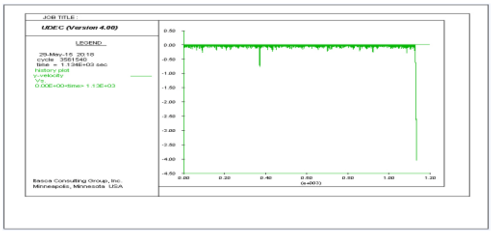
(b) History plot horizontal displacement



(c) History plot vertical displacement



(d) History plot horizontal velocity



(e) History plot vertical velocity

Fig.3-4 Numerical results of slope sliding model

3.82×10^{4} Pa before 700 seconds. Shear stress value is reduced to zero, no more fluctuations after 700 seconds. As shown in Fig.3-4(b), 3-4(c), 3-4(d) and 3-4(e), the speed of horizontal and vertical direction continual fluctuates in the high frequency, and the peak of their basic equal. The velocity peak in the horizontal direction is approximately $0.08\mathrm{m/s}$, and the velocity peak in the vertical direction is approximately $0.35\mathrm{m/s}$. The displacement-time histories of the horizontal and vertical directions are approximately linear, which is mainly caused by the high frequency fluctuation and the similarity of the respective peaks. As shown in Fig.3-4(c), In the vicinity of 1100s, the displacement in the vertical direction is drastically increased and both the horizontal and vertical velocities are increasing rapidly, because the block has been disengaged from the slope.

3.3 Circular arc sliding model

3.3.1 Geometric model of circular arc sliding

The model consists of two parts, one part is a small rectangle, the other part is in a large rectangle dug a semicircle obtained. The small rectangle is arranged above the circular arc and the two parts are subjected to gravity. The bottom of the arc-shaped sliding part is constrained by the displacement in both the horizontal and vertical directions at the same time. The schematic diagram of the circular arc sliding model is shown in Figure 3-5.

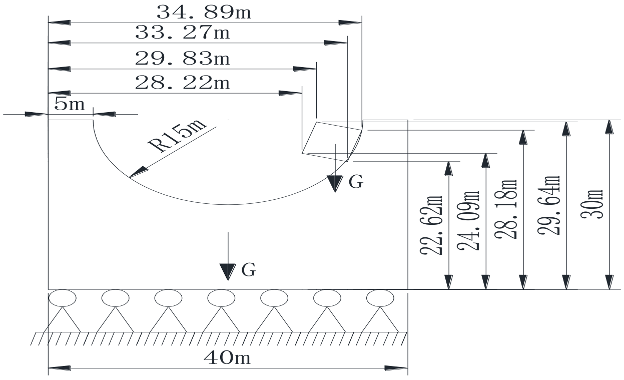
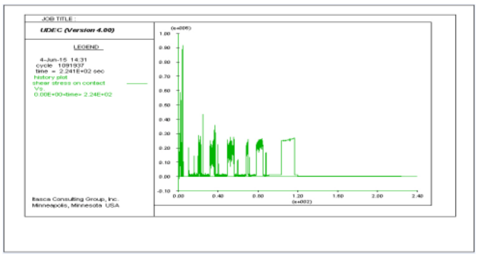


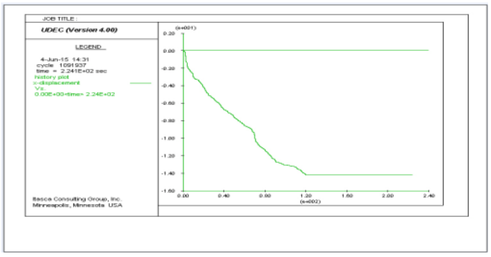
Fig.3-5 Circular sliding model

3.3.2 circular arc sliding simulation results analysis

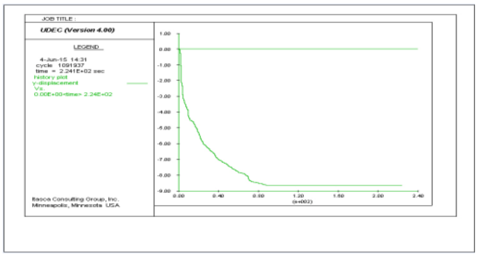
As shown in Fig.3-6(a), the shear stress at the contact point fluctuates in the first 120s, but the frequency is not high, and the peak value of the maximum shear stress is about 9.2×10^{5} Pa .Shear stress is reduced to zero after 120 seconds. As shown in Fig.3-6(b) and 3-6(d), the speed of horizontal direction continual fluctuates in the high frequency, and the average peak value is $0.12\mathrm{m/s}$ before 120 seconds, so the displacement time-history curve in the horizontal direction is approximated to a linear function with the slope of about 0.012. The speed in the horizontal direction is reduced to zero after 120 seconds, so the horizontal displacement does not increase. As shown in Fig.3-6 (c) and 3-6(e), the speed of vertical direction continual fluctuates in the high frequency, and the peak value gradually decreases before 120 seconds. When connecting the points at the individual peaks, the linear function curve of velocity is obtained, so the displacement time-history curve in the vertical direction is approximately parabola.



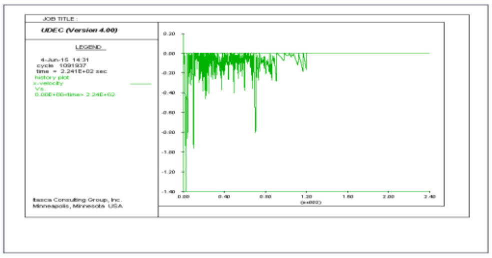
(a) History plot shear stress



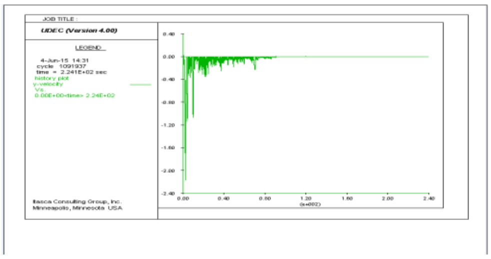
(b) History plot horizontal displacement



(c) History plot vertical displacement



(d) History plot horizontal velocity



(e) History plot vertical velocity

Fig.3-6 Numerical simulation results of circular slide model

4. Conclusion

Three kinds of elastic block sliding models are established in this thesis by UDEC: horizontal sliding model, slope sliding model and circular arc sliding model, and the shear stress, velocity and displacement at contact points are studied during block sliding process.

(1) The variation of shear stress over time is complex, but will eventually tend to zero.

(2) For the horizontal sliding model, the shear stress is stable for the first 7 seconds, and the shear stress begins to decrease between 7 and 8 seconds, resulting in a final shear stress of zero. The shear stress increases rapidly, then decreases rapidly, and the maximum shear stress is about 1.185×10^{5} Pa after 8 seconds. The velocity time-history curve is a linear function, and the displacement is derived from the velocity integral, so the displacement time-history curve is a parabola.

(3) For both the Slip Sliding model and the Circular arc Sliding model, the speed continual fluctuates over time in the high frequency.

(4) For the slope sliding model, the peak values of the speed in the horizontal direction are almost the same, and the size is about $0.08\mathrm{m/s}$. the peak values of the speed in the vertical direction also are almost the same, and the size is about $0.35\mathrm{m/s}$. The horizontal and vertical displacement time-history curves are all linear functions.

(5) For the circular arc sliding model, the peak values of the speed in the horizontal direction are almost the same, and the size is about $0.12\mathrm{m/s}$ and the horizontal displacement time-history curves is a linear functions. The individual peaks of the velocity in the vertical direction decrease linearly, so the displacement time-history curve in the vertical direction is approximately parabola.

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