Abstract

Once rock slope under the earthquake effect is instability, it will cause huge economic damage and casualties. Therefore, it is necessary to study the mechanism of the collapse analysis of jointed rock slope based on UDEC Software and practical seismic load. As an example that Lan-Cheng-Yu product oil pipeline in K0526+300 jointed rock slope, this geological model of the slope is established on the geological and structure feature of the slope. It is easy to establish the numerical model of rock slope considering the structure characteristics with the UDEC software. The practical 5.12 earthquake loads and the related constraints are inputted to carry through the slope dynamic analysis. It verifies that is feasible to use the UDEC software in the collapse analysis of the crack development of rock slope, through the comparison and analysis between the simulation results and slope body actual damage. results presented in the paper indicates that the effects of earthquake makes the interface between rocks decrease, then damage the integrity of rock mass, ultimately lead to rock slope collapse. It is important significance to prevent and mitigate disaster in areas where earthquakes are common for this study.

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1. Introduction

The triggered slope slide and collapse in mountainous area is one of the common secondary geological disasters of the big earthquake. It has characteristics of wide distribution and large number, serious harm, etc. For example, the 7.8 earthquake in Tonghai country of Yunnan province in 1970 caused a lot of landslides, collapse disasters. Its influence area reached 85 km² and led to more than 15000 people died. The 7.6 earthquake in Ruhuo country of Sichuan province in 1973 induced various scale 137 landslides, the area of landslides reached 90 km² and led to more than 2175 people died [1]. In 2008, the 8.0 earthquake in Wenchuan of Sichuan province caused a lot of landslides and collapse disasters of slope rock mass [2]. At the same time, all roads of Dujiangyan to Wenchuan were interrupted. The side slope in the highroad of Yingxiu to Wenchuan damaged severely, which the collapse protruding points were more than 40 and the extent of serious collapse were about 8 km which the sites that the volume of collapsed body more than 100,000 m³ were 13, and the biggest volume was nearly 2 million m³, and the 30% roadbed were buried. It brought along with enormous difficulties to the earthquake relief work [3].

Rock mass is geological body composed of rocks with various kinds of shapes and structural planes, so the stability of rock slope will inevitably suffer the influence of the strength of rocks and structure planes and the combinations [4]. The stability of rock slope is connected with the earthquake intensity under seismic load. Failure mechanism of rock slope was characterized by dynamic slide, translation motion, and rolling between rocks and complex process which changes original open and close condition, forms and roughness of structure plane and characters of filling material, with the macro randomness and discontinuity. Study the collapse failure mechanism of rock slope under seismic load, adopt the theory analysis of discrete element method, consider discontinuity of rock medium, allow looseness and even empty existed in the rock mass movement process. This is the advantage which the finite element simulation and limit equilibrium calculation don't have that, and one of the effective ways that simulates collapse destruction mechanism of rock slope under the action of earthquake.

At present, most scholars put into use UDEC to analyze stability of rock slope and stability of mining roadway. Such as Leijian Wang and Shuilin Wang, etc, analyze stability of rock slope based on Shear strength reduction of discrete element [5]; Chunyin Guo, etc, Numerical simulation analysis of sinking of especially thick and heavy pitch coal seam mining [6]. However, analysis failure mechanism of rock slope based practical seismic load is so less.

Taking Lan-Cheng-Yu product oil pipeline in K0526+300 jointed rock slope for an example, this numerical model of the slope is established on the geological and structure feature of the slope. It is easy to establish the numerical model of rock slope considering the practical 5.12 earthquake loads with the UDEC software and analyze the rock collapse base on the dynamic analysis of discrete element method.

2. Project status and establishment of slope geological model

Lan-Cheng-Yu product oil pipeline in K0526+300 jointed rock slope located in Renjiaba village, Anle River Township, Ningqiang County. Ningqiang County is in the southwest corner of Shaanxi province, south joint Sichuan province and west meet Gansu province. It is adjacent to Luoyang country, Mianxian country and Nanzheng country from the north to the east and in turn.

K0526+300 jointed rock slope develops in the right bank of Anle river, the formation stratum is the preceding silurian system bikou group sub-medium group (Pz bk) which is the grey yellow and grey white tuff of medium-thick state mixing limestone lens and purplish green phyllite. Rock slope inside 10 to 20m high is formed because of the excavation of pipeline and construction of the road partnering with
pipeline. Its macroscopic gradient is generally 60°-75°, and its length is about 100m. The slope presents a shape of protruding north which direction turn to the east segment of NW-SE trend from the west segment of NE-SW trend. The road surface elevation is about 796m, and the outboard road is steep bank formed with limestone and early collapse deposit with 5m high.

The geological model of slope is a reverse slope formed by artificial excavation. The rock mass of slope is hard. The attitude of rock is 175° -30°. The rock mass of slope mainly developed two groups of joint fissures. The attitudes of joint fissures are 75° -75° and 300° -68° separately. The intersecting line attitude of it is 357° -55°, and its attitude trends out of the slope, then the dip angle is less than the slope angle. The extension length of joint fissures is 2-20 m on average, and the development interval of crack is generally 0.5 -2.0 m. Joint planes is relatively coarse and its open degree is 1~10mm. It is rigid structure surface owing to be without fillings.

According to the physics mechanics character of rock mass on similar geological condition, physics mechanics parameter of natural limestone were given as follow, its uniaxial compressive and tensile strength strengths were 2.5 MPa and 0.25 MPa, and its deformation modulus and poisson’s ratio is 4.0 MPa and 0.25 separately, and unit weight is 25.0 kN/m³, and standard value of bearing capacity is 2000 kPa, and shear strength parameters C and ψ is 800 kPa and 38° separately.

3. Establishment of numerical model

Because III-III’ typical profile is the dangerous section of the rock slope, determine discrete element model with 120m width, 100m height, 60° slope angle is set up (see fig.1) based on the most dangerous profile. The model also considers the attitudes of main joint fissures 75° -75° and 300° -68° separately. How to select the accurate mechanical parameters of structure planes is difficult, on the one hand, the test results and effective dates were considered. On the other hand, mechanical parameters to achieve the desired results were needed to adjust appropriately, such adjustment parameters process is reasonable [7]. The parameters of structure planes are as follows. The normal joints stiffness is 2000MPa, and the tangential joints stiffness is 180 MPa, The joints cohesion is 0.5MPa, the internal friction angle is 25°. Based on comprehensive consideration of the practical 5.12 earthquake load and seismic fortification intensity in the project area, the earthquake load adopts earthquake peak level acceleration 0.2g.

4. Simulation results and analysis

The material model of deformation block adopts plasticity model of Mohr-Coulomb; and the material model of joints adopts joints surface contact-the coulomb sliding model in the numerical model of discrete element. An appropriate condition need to be put on the artificial numerical boundary depending on numerical method of discretization in the space limited area while simulate semi-infinite body like slope. The fixed boundary or elastic boundary is used by static analysis, so the seismic waves spreading out reflects back inside the model and boundary does not allow the necessary energy to be diffused in the dynamic analysis. To solve this problem, the viscous and free-field boundaries are employed in the dynamical analysis of discrete element numerical simulation. Then the model uses viscous boundary on the bottom, and free-field boundary on both sides [8].

Before analyze seismic action, the model of slope need to be analyzed statically until it reaches equilibrium state firstly. As shown in figure 2, the initial unbalance force is approximate 1 MN. When it fall to 0.5 kN after 100 000 steps, so the model reaches equilibrium state.
A, B and C dynamic monitoring points are set at the slope toe, the intermediate position of slope surface and the vertex position of slope respectively. The A, B and C level and vertical displacement are shown in figure 3, 4, 5.

As shown in the figure 3–5, it is known that the maximum level and vertical displacement of A point are $4.97 \times 10^{-1}$ m and 6.25m respectively. The maximum level and vertical displacement of B point are $4.14 \times 10^{-1}$ m and 6.28m respectively. The maximum level and vertical displacement of C point are 1.23m and $9.05 \times 10^{-1}$m respectively. By the seismic load, the rock of slope surface move to the direction of leaving out of the slope surface, then the rock slope collapse. The horizontal displacement at the top of slope is greater than other positions, it damages obviously as shown in fig 6.
The rock mass of surface at the intermediate and toe position of slope both move vertically, and its exercise forms are accordance. Due to the seismic load and the slope body gravity, the sliding rock mass creep along the glide plane, and the stress continuously focus on the slope toe, and then the rock mass of the slope toe are embedded to foundation of the slope.

Therefore, the top position of the rock slope is destroyed primarily comparing with other parts. By the seismic load, the form collapse destruction of the slope is from the top to the toe and from the rock mass of surface to the interior slope. It is easy to collapse and fall for the slope under the seismic load, while the rocks of the free face exist in the completely crack development slope and it is loose among the rocks. Due to the effects of earthquake load for the crack development slope, it makes the structure plane of the slope appear dip offset and tension crack, and the interface between rocks decrease, and damage the integrity of rock mass, then reduce the shear strength of the slope body or completely lose the structural strength, ultimately lead to rock slope collapse.

5. Conclusions

As an example that Lan-Cheng-Yu product oil pipeline in K0526+300 jointed rock slope, the geological model and numerical model was established. The practical 5.12 earthquake loads and the related constraints are inputted to carry out the slope dynamic analysis. The main conclusions are as follows.
1. When the repeating seismic load work on the rock slope, the form collapse destruction of the slope is from the top to the toe and from the rock mass of surface to the interior slope.
2. The effects of seismic load makes the interface between rocks decrease, then damages the integrity of rock mass, ultimately leads to rock slope collapse.
3. In this paper, as the background of Lan-Cheng-Yu product oil pipeline in K0526+300 jointed rock slope, it verifies that is an effective method to use the UDEC software in the collapse analysis of the crack development of rock slope, taking advantage of discrete element method to carry out dynamic analysis of rock slope based on practical seismic load.

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References


