

Influence of Earthquake on Deformation and Stability of a Certain Landslide

Yinger Deng^{1, a}, Zhimin Zhao^{1, b} and Xin Peng^{1, c}

¹State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu 610059, China

^a546730457@qq.com, ^bzhaozhimin@cdut.cn, ^c2250656391@qq.com

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Abstract. This paper focused on change characteristics of deformation and stability of certain a landslide under conditions of earthquake. The mathematical model of dynamic analysis of earthquake was utilized for deformation and stability of the landslide with weak permeable media. This paper studied change characteristics of deformation and stability of the landslide with changes of conditions of earthquake intensity. Results show that: (1) the landslide displacement and maximum shear strain increase with earthquake intensity; (2) the excess pore water pressure resulted from earthquake rises fast in a short time and decrease with elevation; and (3) the stability decreases and number less than the critical value increase with earthquake intensity. Prevention measures should be adopted for the landslide. The results can provide stability evaluation and engineering treatment of the landslide with scientific basis.

Introduction

Influence of earthquake on a landslide involves geological engineering and geotechnical engineering. Research on the Influence has important theoretical and practical significance. Some scholars have considered earthquake effect on a landslide such as Celebi [1], Hartzell [2], Papadopoulos [3] and Chigira *et al.* [4]. Zhou *et al.* [5] researched some characteristics of earthquake-induced landslide in southwestern china. Earthquake takes place frequently in the southwest of China. It is one of the important reasons why geohazard occurs repeatedly in the southwest of China [5]. Sun *et al.* [6] presented developing and distributing characteristics of collapses and landslides during strong historic earthquake in China. Liu *et al.* [7] reviewed advance on topographic amplification effects of seismic response.

In this paper, we take certain a landslide as a research object and focused on deformation and stability of the landslide. We will carry out dynamic analysis of earthquake in the landslide with weak permeable media by a mathematical model. Moreover, we will calculate change characteristics of deformation and stability of the landslide with earthquake intensity. All the researches will provide evaluation of engineering safety of the field with scientific basis.

Area Range and Basic Characteristics of Certain a Landslide

Certain a landslide with weak permeable media was selected. Range of the research area is shown in Fig. 1. The landslide is composed of Quaternary loose sediment accumulation, belongs to large soil landslide of large accumulation. And it is porous media with weak permeable media. Landforms characteristic of the landslide belongs to a typical erosion structure. Landslide front is located at the edge of the slope. The trailing edge of the landslide is hollow. The relative elevation difference between of the front and the trailing edge of the landslide is about 265m. The north side and the south side are bounded by gullies. The slope angle of the interface between the bedrock and overburden is large and provides the terrain conditions for the landslide. Sliding bed is bedrock. The slide surface shape is a broken line. Slip zone is yellow plastic clay. The landslide has tension cracks because of deformation. Seismic activity is frequent and provides dynamic conditions for the landslide.

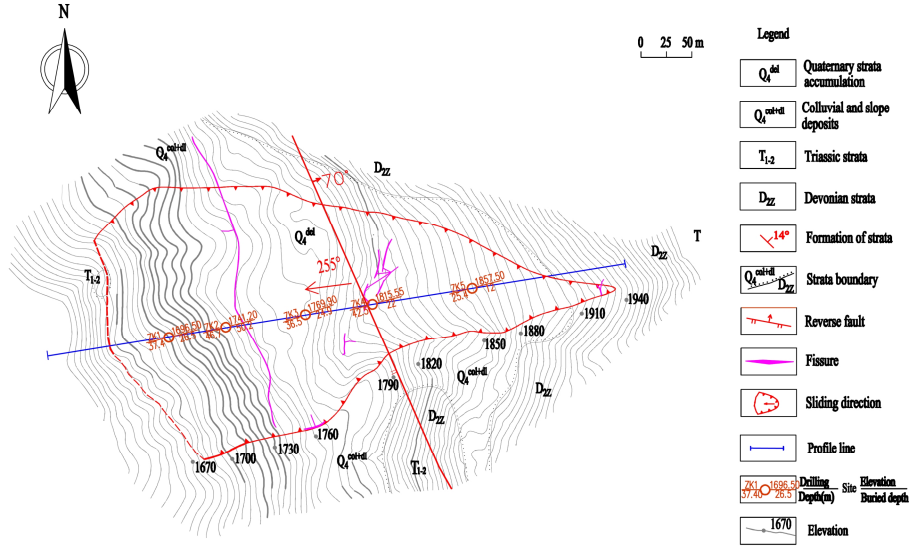


Fig. 1 Research area range (N: North)

Mathematical Model of Dynamic Analysis of Earthquake

An equation of motion under condition of dynamic earthquake is given by equation (1).

$$[M]\{\ddot{a}\} + [D]\{\dot{a}\} + [K]\{a\} = [F] \quad (1)$$

where, $[M]$ is mass matrix, $[D]$ is damping matrix, $[K]$ is stiffness matrix, $[F]$ is load vector, $\{\ddot{a}\}$ is acceleration, $\{\dot{a}\}$ is velocity, $\{a\}$ is displacement. $[F]$ can be written as

$$\{F\} = \{F_b\} + \{F_s\} + \{F_n\} + \{F_g\} \quad (2)$$

where, $\{F_b\}$ is volume force, $\{F_s\}$ is pressure, $\{F_n\}$ is concentrated force, $\{F_g\}$ is earthquake force. Concentrated mass matrix is

$$[M] = \int_v r[y]dv \quad (3)$$

Consistent mass matrix is

$$[M] = \int_v r\langle N \rangle^T \langle N \rangle dv \quad (4)$$

where, r is mass density, $\langle N \rangle$ is row vector of difference function, $[y]$ is diagonal matrix of mass distribution factor. Damping matrix can be written as

$$[D] = a[M] + b[K] \quad (5)$$

where, a and b are coefficient. Damping ratio is

$$h = \frac{a + bw^2}{2w} \quad (6)$$

where, w is vibration frequency. Stiffness matrix is

$$[K] = \int_v [B]^T [C] [B] dv \quad (7)$$

where, $[B]$ is stress strain matrix, $[C]$ is natural characteristic matrix. Shear strain is

$$\{e\} = \begin{Bmatrix} e_x \\ e_y \\ e_z \\ g_{xy} \end{Bmatrix} \quad (8)$$

Relationship between shear strain vector and displacement is

$$\{e\} = [B] \begin{Bmatrix} u \\ v \end{Bmatrix} \quad (9)$$

where, $[B]$ is stress matrix, u, v are nodal displacement in the direction of x and y. $[B]$ is

$$[B] = \begin{bmatrix} \frac{\partial N_1}{\partial x} & 0 & \frac{\partial N_3}{\partial x} & 0 \\ 0 & \frac{\partial N_1}{\partial y} & 0 & \frac{\partial N_3}{\partial y} \\ 0 & 0 & 0 & 0 \\ \frac{\partial N_1}{\partial x} & \frac{\partial N_1}{\partial y} & \frac{\partial N_3}{\partial x} & \frac{\partial N_3}{\partial y} \end{bmatrix} \quad (10)$$

Linear elastic constitutive equation is

$$[s] = [C] \{e\} \quad (11)$$

$$[C] = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 \\ \nu & 1-\nu & \nu & 0 \\ \nu & \nu & 1-\nu & 0 \\ 0 & 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix} \quad (12)$$

where, E is Young's modulus, ν is Poisson's ratio. Linear elastic model is

$$\begin{Bmatrix} s_x \\ s_y \\ s_z \\ t_{xy} \end{Bmatrix} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 \\ \nu & 1-\nu & \nu & 0 \\ \nu & \nu & 1-\nu & 0 \\ 0 & 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix} \begin{Bmatrix} e_x \\ e_y \\ e_z \\ g_{xy} \end{Bmatrix} \quad (13)$$

where, e_z is 0 for plane strain.

Basic Parameters

Basic parameters of rock and soil mechanics are shown in the table 1. Horizontal peak accelerations of earthquake are shown in the table 2.

Results and Discussion

The deformation and stability of the landslide under conditions of earthquake have some characteristics. The maximum shear strain of the landslide increases gradually with earthquake intensity. The maximum

shear strain of the initial state is located at the foot of the landslide. The maximum shear strain is in the upper part of the landslide under the condition of earthquake. The excess pore water pressure resulted from earthquake rises fast in a short time and decrease with elevation. The permanent displacement of the landslide increases and stability of the landslide coefficient decreases gradually with earthquake intensity. The number less than the critical value increase with earthquake intensity. Cumulative permanent displacement and minimum stability coefficient is shown in table 3.

Table 1 Basic mechanics parameters

Media	Density (g/cm ³)	Elastic modulus (Pa)	Shear modulus (Pa)	Damping ratio	Poisson's ratio
Gravel soils	2.0	2.0×10^7	8.3×10^6	0.15	0.2
Schist- Slate	2.5	2.0×10^{10}	8.0×10^9	0.15	0.15
Marble	2.7	3.0×10^{10}	1.25×10^{10}	0.15	0.15

Table 2 Horizontal peak accelerations of earthquake

Serial number	Earthquake intensity	Horizontal peak acceleration (m/s ²)
1	7	0.15
2	8	0.2
3	9	0.4

Table 3 Cumulative permanent displacement and minimum stability coefficient

Earthquake intensity	minimum stability coefficient	Number less than critical value	Cumulative permanent displacement (mm)	Stability
7	1.15	0	288.2	stable
8	1.08	4	384.2	metastable
9	0.92	7	768.4	unstable

Conclusions

The landslide displacement and maximum shear strain increase with earthquake intensity. The excess pore water pressure resulted from earthquake rises fast in a short time and decrease with elevation. The stability decreases and number less than the critical value increase with earthquake intensity.

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