The cause analysis of landslide disaster

Yubin Zhang

1National Earthquake Response Support Service, Beijing 100049, P. R. China
2Corresponding author’s e-mail:617650460@qq.com

Abstract. In this paper, the mechanism of landslides, induced factors, geological characteristics and environmental characteristics of historical landslides are analyzed. The application of geographic information technology in landslide prediction and evaluation is introduced. The indexes combined with the GIS system are then extracted for the data simulation by analyzing the relationship between the internal factors and geomorphology in the landslide occurrence. On the other hand, it is pointed out that the by-product of civil engineering is the important risk source of increasing landslide disaster. This improves the reliability of the prediction and evaluation for landslide disaster and is of great significance for future observation and prevention of landslide.

1. Characteristics of landslide

1.1. Causes of landslide

In natural disasters, earthquakes are dreadful disasters. Generally, the disaster caused by earthquakes includes mainly the primary disaster and secondary disaster. The primary disaster can directly cause damage to buildings, surface rupture, liquefaction of sand and soil and so on. The secondary disaster consists of the collapse, landslide (a common secondary disaster after an earthquake), and mudslide [1]. The earthquake landslide refers to the geological event that the triggering of earthquake causes the cracking of the mountain and the loosening of soil, so that the slope is close to the critical state of fracture and movement, and the sliding may occur at any time or at the same time as the earthquake, with the hysteresis [2]. In the mountains of southern China, landslides caused by earthquakes do more damage than earthquakes themselves [3]. On the other hand, with the large-scale development of the city, a large number of construction debris is produced in civil engineering. The disposal method of these dregs is mainly accumulation, forming the dregs mountain with unstable soil structure. Under the action of rainfall or strong wind, the deformation and movement of the slag soil mountain may occur, forming landslide risk.

1.2. Hazards of landslides

Landslide is a phenomenon that the vertical stress of slope surface is less than the horizontal stress and displacement occurs after the main structure is destroyed by the vibration in the deep stratum. This state is unstable and may be affected by various environmental factors. The strong wind causes the gravel to collapse, the precipitation may cause the debris flow, the river channel silts up to form the barrier lake. Compared with primary disasters, secondary disasters may cause more lasting and serious disasters.

For example, in the M 8.0 earthquake in Wenchuan, Sichuan province on May 12, 2008, the depth of the epicenter is 14km, and the duration of the earthquake is about 2 minutes. It triggered a large
number of landslides in the disaster area and is the most devastating earthquake in China’s mainland. According to the disaster statistics in Sichuan province in 2008, there were about 10,000 dangerous points of landslides and collapses caused by Wenchuan earthquake, which seriously threatened the safety of nearby towns. As of 12:00 a.m. on 24 July 2008, the direct economic loss reached 845.1 billion yuan, of which about 1/3 came from secondary geological disasters caused by the earthquake [3].

2. Research methods of landslide

2.1 Application of geographic information technology
In the early days, many scholars mainly studied the internal principle of earthquake landslides, and paid attention to the mechanism and law of earthquake landslides [4]. However, in recent years, with the development of satellite observation technology and the improvement of computing power, the remote sensing technology (RS), GIS (Geographic Information System) and mathematical model have used in some researches to analyze the seismic landslide data. GIS is a computer system based on geospatial database by using the geographic model analysis methods to provide dynamic geographic information and decision-making services for geographic research and disaster relief.

2.2. Application of GIS technology in landslide genesis analysis
(1) GIS can store and manage a large number of historical landslide data by establishing a basic database. Presently, the geological structure and environmental factors of historical landslides have been processed by index data since records began.
(2) GIS can analyze environmental factors of landslide disaster and perform the data mining, which can serve as a benchmark for evaluation.
(3) GIS can integrate information collection, spatial analysis and decision-making process into a comprehensive system in landslide disaster research to improve the efficiency and reliability of disaster researches.
(4) The simulation evaluation of geological disaster risk can be realized by taking the external and internal factors of landslide as the influencing factors, and then combining GIS technology and matching mathematical model.

3. Landslide analysis

3.1. Analysis of landslide mechanism
The slope instability caused by strong earthquake is not only determined by the earthquake itself, but also related to the landform, slope structure, geological background, lithology, hydrogeological conditions, precipitation and other factors. Under different geological conditions, the mechanism and influencing factors of earthquake triggered landslides will be different. [5]. From the perspective of mechanics, it is generally believed that the causes of seismic landslides include the two aspects, namely, the increase of shear stress and the decrease of shear strength of slope rock mass, or the combination of them [6].

Additionally, there is another view that the causes of landslides can be divided into the basic and inducing factors. The basic factors mainly include elevation, slope structure, strati-graphic lithology, structural complexity, hydro-geological conditions, vegetation development and existing dynamic geological phenomena, which are internal factors for the generation and development of seismic landslides [7]. The inducing factors mainly include earthquake, rainfall, human engineering activities and so on.
3.2. Factor analysis of forming landslide

3.2.1. Slope. The topographic slope value is equal to the ratio of the vertical height of the slope body fracture surface to the horizontal length, which refers to the degree of steepness and slowness of the surface and can reflect the slope of the slope body [8]. Slope is the basic condition of landslide. Because of the inclination angle, the slope body forms an effective free surface. There is a close relationship between the effective free surface and the terrain slope (the relationship between the topographic slope and the inclination angle of the structural surface of the slope with potential sliding surface). Additionally, the gradient of the slope body is the main factor determining the sliding force of the slope body. It affects not only the residual sliding force of the existing or potential sliding surface inside the slope, but also the form and mechanism of the slope deform and destruction[9]. In general, the shear stress is positively correlated with the slope. As the slope increases, it not only increases, but also the probability of occurrence of landslides increases. The DEM can generate the slope by applying the gradient tool in ARCGIS, where the progressive gradient is generally set to 10°. Based on the statistical analysis of landslides in China since 1990, it is found that 25% of the landslides are distributed in the range of 0° - 20°, 38% of the landslides are distributed in the range of 20°-30°, 31% of the landslides are distributed in the range of 30° - 40°, and 6% of the landslides are distributed in the range of 40° - 60°. As a whole, with the increase of slope, the number of landslides reduces after increasing.

3.2.2. Elevation. Generally, the elevation has no direct control over geological hazards, but has indirect influence. It can be shown in two aspects: (1) The underground water in the mountain slope is mostly the shallow groundwater. There is a negative correlation between the distribution of groundwater and the elevation. The lower the elevation is, the more extensive the shallow groundwater distribution is and the greater the impact on the landslide is. (2) Elevation affects the range of human activities. Taking Southwest China as an example, because the higher the altitude is, the steeper the mountain is, and the less flat the land is, the more human activities are in low altitude areas. Building houses, roads and tunnels will change the original stable topography. Human engineering activities have affected the development of landslides to a certain extent. [8].

3.2.3. Slope position. On the slope surface of natural slope, different positions have different topographic and geomorphic features, resulting in different characteristics of rock mass, hydrology and other geographical factors [10]. Many scholars divide the slope into several parts and study each part independently. Slope location factors gradually play an important role in many terrain related geographical or ecological process models [11].

3.2.4. Slope aspect. The slope direction has no direct impact on the landslide, but it can influence the hillside water heat and climate. There is a huge difference in temperature or vegetation between the sunny slope and the shady slope. At the same altitude, their high and low temperature difference is as high as 3°C to 4°C, and the temperature difference between the east slope and the west slope is between the south slope and the north slope [12]. In high altitude areas, the upper forest boundary of the south slope is 100m ~ 200m higher than that of the north slope. However, the lower limit of permanent snow line varies from place to place, and can be lifted up within 150m-500m of the south slope [13]. The slope direction has obvious influence on precipitation. Due to the comprehensive effects of light, rainfall, temperature, soil structure, wind speed and other factors, the slope orientation can have a certain impact on vegetation and rock mass moisture content, which has a certain impact on landslides. The slope direction is generated by the slope direction tools in digital elevation model (DEM). It is divided into the following five categories: flat land, east, south, west, north. The results from the statistics of landslides in China since 1990 show that 37% of landslides occurs in the north side and 29% in the east side. There is little vegetation coverage and a high probability of landslides under the same geological structure.
The causes of landslides are processed firstly by the index data, the evolution trend of the disaster is then obtained by combining with the data products provided by geographic information system (GIS), global positioning system (GPS) and remote sensing (RS) and applying mathematical model to multi-objective optimization, which is conducive to guide our works of post-disaster response.

3.3. Civil engineering increases landslide risk

With the increase of population, the scale of cities is expanding. In the past decade, real estate construction has become the driving force for the development of emerging cities. Real estate construction will produce a lot of construction debris. The disposal method of construction waste soil is mainly accumulation, which eventually forms artificial waste soil mountain. The internal structure of these slag hills is very unstable. Under the condition of rainfall and snow melting, landslide risk will be caused. Take Shenzhen, China as an example. From 2013 to 2016, there were more than 100,000 new apartments, covering an area of 9,000,000 square meters. As shown in Figure 1.

![Figure 1 Shenzhen housing construction](image)

Construction waste comes from various large projects. Such as building construction, underground parking lot construction, subway construction, etc. As a result of the above reasons, more than 2,000,000 cubic meters of construction debris are added every year in Shenzhen. A number of spoil dump sites are set up around Shenzhen, with an average stacking height of more than 120 meters, forming a potential safety hazard. On December 20, 2015, a landslide occurred in the slag mountain of Hongao slag accumulation site in Shenzhen. The landslide lasted for 13 minutes, more than 20 buildings were buried or collapsed, and 73 people died.

This accident tells us that we should prevent the occurrence of man-made landslides as well as natural landslides. The deeper problem is that with the rapid growth of land value, people's overexploitation of land will produce more hazard sources.

4. Conclusion

In this paper, the harmfulness and mechanism of landslide are analyzed. This paper introduces the geological conditions of historical landslide cases by GIS, which are digitized and standardized, and the index data processing of the characteristic elements (slope, elevation, slope position and slope direction) is carried out in combination with the characteristic elements (slope, elevation, slope position and slope direction) outside the mountain slope. Then GIS technology is used to assess the landslide location and disaster range. This has a positive effect on the emergency rescue after the earthquake disaster and the prevention of landslide disasters.

On the one hand, with the development of computer technology and satellite technology, the accuracy of landslide disaster in simulation and evaluation will be further improved. On the other hand, the use of legal and technical means to control urban construction planning, especially to limit the construction of large-scale projects. The risk of land development and utilization should be controllable.
References

[1] Wen, H.J., Zhang, Y.X., Liu, Y. (2004) Geological Disasters and Their Damage in Three Gorges Reservoir Area. Journal of Chongqing Architecture University, 20(1):1-4.

[2] Wen, H.J., Zhang, J.L., Zhang, M.A. (2009) Comprehensive way of safety assessment of high slopes in Three Gorges Reservoir area, International Journal of Terra Space Science and Engineering, 1(2):83-86.

[3] Liu, X.R., Hu, Y.X., Qi, D.H. (2011) Analyses of earthquake - induced landslide inventory in Yingxiu metizoseismal area of 5.12Wenchuan earthquake, Journal of Chongqing University 4(10): 86-96.

[4] Li, W.L., Wu, J., Lv, B.X. (2011) Research on Landslide Triggered by Earthquake: Review and Prospect, Journal of catastrophology, 26(3):103-108.

[5] Ragozin, A. L. (2000) Landslide hazard, vulnerability and risk assessment: Landslide in research, theory and practice, Thomas Teford, London.

[6] Papadopoulos, G.A., Plessa, A. (2000) Magnitude-distance relations for earthquake-induced landslide in Greece [J].Engineering Geology, Special Issue, 58(3-4).

[7] Xu, C., Dai, F.C., Yao, Y., Chen, J., et al. (2009) GIS-based landslide susceptibility assessment using analytical hierarchy process in Wenchuan earthquake region, Chinese Journal of Rock Mechanics and Engineering, 28(Z2):3978-3985.

[8] Li, G., Yao, D.Q., Zhang, Y.L. (2008) Characteristics of the collapse and landslides in Wenchuan M8.0 earthquake, Journal of Institute of Disaster Prevention, 10(3):131-134.

[9] Wang, Z.H. (1999) Reviewing and prospecting for applying remote sensing to landslide and debris flow investigation, Remote sensing for land & resources, (3):10-15.

[10] Ye, R.Q., Deng, Q.L., Wang, H.Q. (2007) Landslide recognition and feature extraction based on image classification, Chinese journal of engineering geophysics, (6):574-577.

[11] Hu, D.Y, Li, J., Chen, Y.H., Zhang, J.S. (2007) GIS-based landslide spatial prediction methods, a case study in Cameron highland, Malaysia, Journal of remote sensing,11(6): 852-859.

[12] Lu, Z.Q. (2001) Engineering geology. China water & power press, Beijing.

[13] Wang, L.Q., Lai, T.W., Luan, H. (2008) Engineering geology. China Railway Publishing House, Beijing.