Monitoring on Earthquake Induced Landslides - A case study in northwest Chengdu, China

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ABSTRACT: Many after-shock slopes covered by loose deposits, when heavy rain comes, the slope easily slides and turns into debris flow. Thus, the slope movement and the moisture of slope are most important factors for landslide and debris flow. For these style landslides, real-time monitoring is a good way for local people. After analysed the system requirements, the authors proposed an easy-to-use and low power consumption monitoring system. This system consists of two parts, field part and data processing part. The field part includes a few sensors and a data transferring unit. The sensors are made up of tilt sensor, soil moisture meter and rain gauge. A demo system was setup on a sliding slope in Taziping, northwest of Chengdu city. After a field test with artificial rainfall, a criterion for warning was drawn. The demo system has proved it's effective. It is an economy and simple solution for similar area.

1. INTRODUCTION

Lots of landslides occurred during the 5-12 Wenchuan Earthquake of China, especially in the rainy season of 2010. These landslides including rock falling, debris flow and shallow landslide which distributed widely over people expected and bring great damage. However, because of the small volume and large amount, it is difficult to forecast and avoid casualties. Then careful monitoring of slope's activities and release warn is reasonable as alternatives than the engineering method.

2. REQUIREMENTS OF MONITORING DEVICE IN EARTHQUAKE AREA

2.1 Sensor requirements

Low cost is the first requirement. Traditional monitoring will cost a lot; many developing communities can barely afford it. Not like other style landslides, the earthquake induced landslide will need to install a large amount of sensors, for example, in a middle-scale debris flow gully; it will need 10 sensors at least. However, there are hundreds of debris flow gullies in this area. If the sensors price is too high; the total cost is still unaffordable for many districts.

Second, monitoring device is usually located outside and difficult to get normal power supply, so the devices should consume power as low as possible.

Third, the monitoring device should be water-proof and its case should difficult deform. Because all sensors will be put outside and the wind, rain, sunshine and wet moisture will cause damage.

The last requirement is it should be easy to install and to operate.

2.2 Power supply requirements

A monitoring system is usually including two parts, the field and the office. The office unit have much space to do. The field unit need especially treat.

For the field unit, both sensors and data transferring device need power supply. And most time they are continue changing from idle to active (Berman, P. 2004). For simply install and low-cost, the power supply should be out-of-the-box and efficient.

One method uses the civic power. However, it is tough work to keep steady power supply in the wild. The voltage swing is common, especially in Chinese country area.

The alternative method is using batteries, but the battery should change before its life.

2.3 Data transferring requirements

All monitoring data usually transferring by wireless network automatically and the data sampling frequency can be adjusted remotely. The actual problem is when landslide occurs, the network is liable to be damaged or interrupted by rainstorm. Hence, how to keep the network working during rainstorm is important for a monitoring system.

2.4 Predict and alarm requirement

The landslides are mainly consisting of debris and deposits. Many of these slopes failed after heavy rain (Aulakh and Kaler (2008). And most monitoring systems will predict landslides. Therefore, the features selected for operational monitoring should provide a timely indication of status of slope, be readily measured and provide opportunity for an appropriate response.

3. MONITORING SYSTEM AND DEVICES

With the above features of requirements, an improved monitoring system based on MEMS (Micro Electronic Mechanical System) (Uchimura, et. al. 2009, 2010) was proposed. This system could be feasible countermeasures for small-scale slope disasters.

A Large earthquake will produce much loose, surficial sediment (David K. Keefer, 1999), which were easy to slide down after heavy rain. These landslides seldom slide or displace as single block. Therefore, the central sensor is a tilt sensor, 3 to 5 tilt sensor can feel the mobility of a slope surface. With data repeaters and a data server can build a simple monitoring system. When a deep landslide is included, the authors suggest adding an underground inclinometer for the inner deformation.

3.1 Ground inclinometer

The ground inclinometer (Figure 1) measures the tilt of the slope surface. It combines a MEMS tilt sensor (nominal resolution is 0.04mm/m), a wireless communication unit, antenna, battery, data storage part and a control circuit.

3.2 Underground inclinometer

The underground inclinometer will measure the displacement inside a slope. It consists of a tilt sensor, a geomagnetic sensor (digital compass, nominal resolution is 0.5 degree), a wireless communication module, temperature sensor, antenna, battery, data storage part and a control circuit. All the parts are in a stainless steel pipe, both end is in waterproof connector/ sealed (Figure 3). Many underground inclinometers can assembled connected one by one from ground to sliding surface.

Figure 1 Ground inclinometer

It can link a soil moisture meter (figure 2) to measure soil moisture.

Figure 2 Soil moisture meter

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Figure 3 underground inclinometer

3.4 Data transferring part

A data collection transponder can collect the data transferred from both inclinometers and stored into a flash memory such as SD (Secure Digital) card. Also, it can link a simple rain gauge (Figure 4).

Figure 4 Data repeater and rain gauge

After the data collection transponder sends a command to Data Transfer Unit (Figure 5), the monitoring data will send to the data server by GPRS/GSM network.

Figure 5 Data Transfer Unit of GPRS /GSM network

3.5 Data server

A PC data server can meet the data processing requirement.

4. DEMO MONITORING SYSTEM IN TAZIPING

4.1 Introduction of Taziping landslide

Taziping locate in the northwest of Chengdu (figure 6), China. One mountain situates between the field site and Yingxiu- the epicenter of Wenchuan Earthquake. The straight distance of two sites is only 19km. It is 3.5km from the Yingxiu fault to Taziping. The slope slide down during Wenchuan Earthquake. The slide body is mainly deposit, which is 530m long, 145m wide, 363m high (elevation level) and 20-25m thick (Figure 7), the deposit volume is nearly $116\times10^4 m^3$. The bedrock is mainly andesite rock. the landslide belongs to thrust load caused landslide.

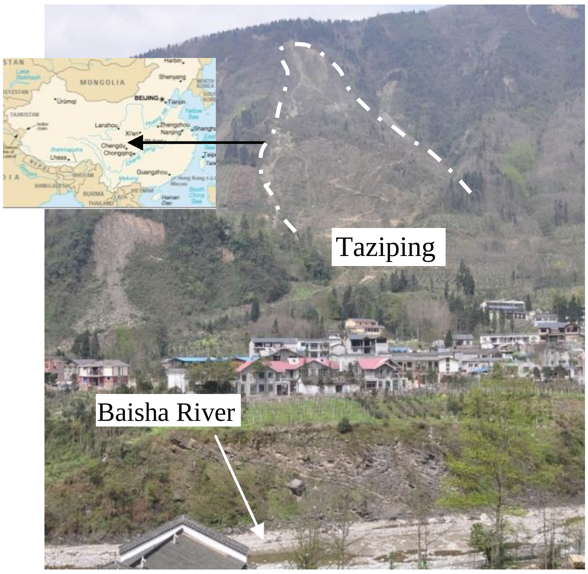

Figure 6 Taziping landslide site and its location

A post-earthquake investigation found Taziping landslide deposition is possible to slide. Below the slope, there are 109 person, 55 houses, 300m village road, and 2.9 hectare woodland were in danger. After 2 years evolution, rain and aftershock made the slope keep deforming. Both engineering preventions and a small monitoring network were adopted to reduce the sliding risk.

4.2 Monitoring design

According to the features and deformations of landslide, one rain gauge, three surface inclinometers and two underground inclinometers were installed on the slope (Figure 7, Figure 8). A data collection transponder is outside the slope for data collecting and transferring. A data server was put in the data analysis center (Figure 9).

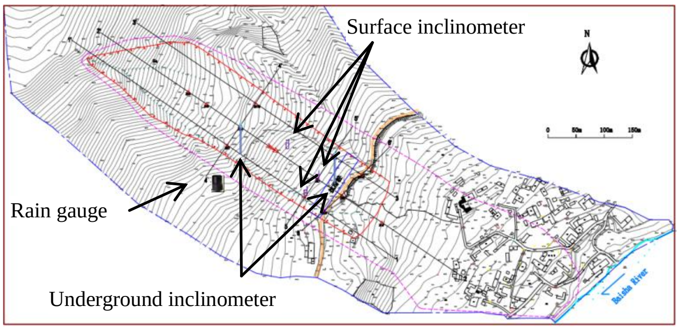

Figure 7 Plan view and monitoring layout of Taziping landslide

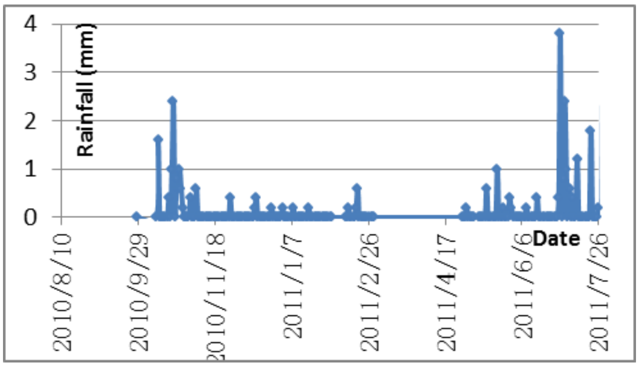

Figure 10 Rainfall hyetograph of Taziping (2010~ 2011.7)

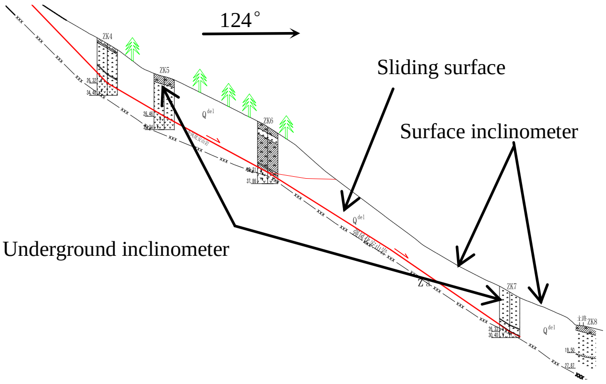

Figure 8 Cross sections of the Taziping landslide

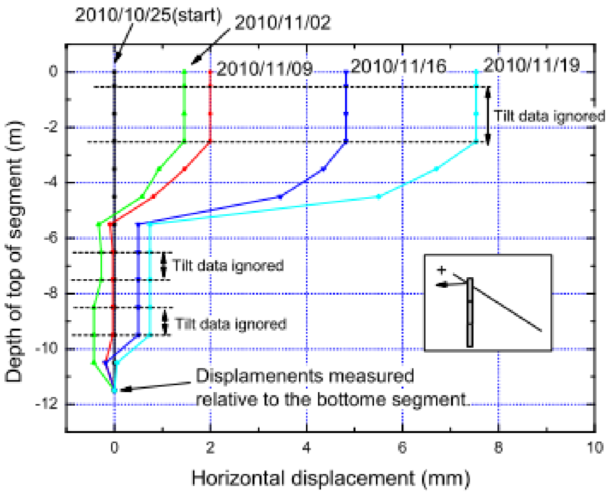

Figure 11 Deformations of underground soil strata (Uchimura, 2011)

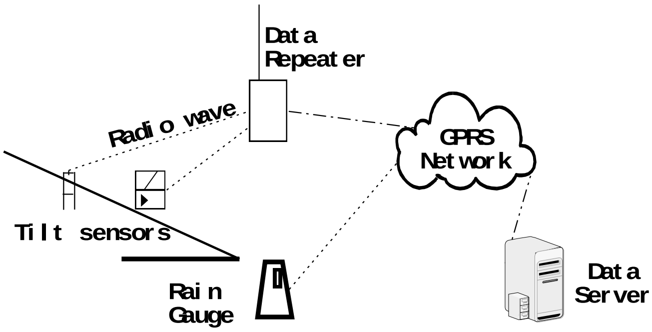

Figure 9 Schematic diagram of monitoring system

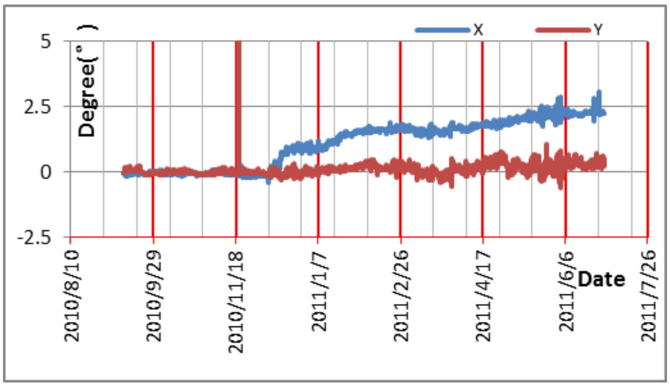

Figure 12 deformation of ground surface

4.3 Slope slide test in artificial rainfall

Although many papers have discussed predicts landslide by displacement and time curve (Aleotti 2004) (Corominas, Moya et al. 2005). It is still difficult to predict the exact time of landslide. For this reason, a field experiment aim to learn the condition of landslide was run under the Taziping slope in the previous summer (Uchimura et al. 2012). Tilt rate between 0.1-0.5 degree/hour can be criteria for early warning.

5. DATA AND DEFORMATION TREND

Although the rainfall in the last year (2010~2011) is not rich (Figure 10), the monitoring data (Figure 11 and Figure 12) shows Taziping deformation is increasing but no signal of acceleration. Since the risk did not reduce or removed, the monitoring will continue.

6. CONCLUSION

Earthquake made many deposits and debris, to learn the movements and displacements of the dangerous slopes are important for disaster mitigation. The following principles should is useful in monitoring the shallow landslide in basin scale.

1) Low power consumed will decrease the time of install and maintenance, as well as the total cost.
2) Easy to install and setup is essential for deploy in big area.
3) fficient wireless data transferring is the key to alarm.
4) The alarm criterion is depended on geology environment. One similar area should make a field test before prediction.

7. ACKNOWLEDGMENTS

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