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Research on Remote Automatic Monitoring System of High and Steep Slope Based on FBG Tilt Sensor

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Abstract. A remote automatic monitoring system for high and steep slope based on FBG tilt sensor was established along Shuohuang railway, and an FBG tilt sensor with a high sensitivity was developed in this monitoring system. The monitoring system is running smoothly, and the monitoring results show that the maximum deformation of the slop is less than 2 mm in the rainy season, slope slip occurs at the location of 9.5 meters above, the overall deformation of slope is small, and the slope is steady.

1. Introduction

China is a mountainous and less plains country. High and steep slope often exist along railway lines. However, landslides accident often happens in the areas of poor geological conditions[1], which seriously threatens the safety of traffic facilities and people.

Shuohuang Railway is a heavy-haul railway and it's the second largest railway to transport the coal from the west of China to the east of China, it's pass through Heng Mountain, Taihang Mountain, Yunzhong Mountain, et al. So the terrain along the Shuohuang Railway is complex with mountains and valley. Therefore the potential geological hazards such as landslide and collapse are existed along the high embankments and high and steep slopes of the Shuohuang Railway[2].

Especially the loess landslides often occur along the slope of the tableland, causing heavy casualties and serious economic losses[3]. Therefore, a remote automatic monitoring system for high and steep slope along Shuohuang railway is necessary.

With the speediness development of optical fiber sensing technology, its application in slope internal displacement monitoring has attracted a lot of attention[4, 5]. Compared to the present electrical monitoring technology, it has a strong anti-electromagnetic interference, strong corrosion resistance, long distance transmission loss and other obvious advantage[6, 7]. Therefore, a remote automatic monitoring system for high and steep slope based on Fiber Bragg Grating（FBG） tilt sensor is established along Shuohuang railway.

2. Monitoring Principle and Methods

High and steep slope monitoring section is located in Shuohuang Railway's K3+000-K3+410 section, located in the Shenchi County of the Shanxi Province, as shown in Figure 1, in the north of the Shuohuang Railway, it's a high and deep excavation slope.

Figure 1. Monitored area topography of Shuohuang Railway K3+000-K3+410 section

The change of the deep displacement of the slope is an very important information for reflecting the steady state of the slope, and is a key index for predicting when and where the landslides occurrence. Therefore, the monitoring of the high and steep slope is focused on the deep displacement. When the slope deformed, the displacement of the slope in the deep part can cause the incline of the inclinometer pipe[8], a deflection angle was generated, the FBG tilt sensors which packaged in the inclinometer pipe can sense the angle, the FBG interrogator system which mounted on the ground can demodulate the change of the FBG tilt sensor, so the angle of the each position of the slope can be calculated, and the displacement of the each position of the slope can be calculated as shown in Figure 2.

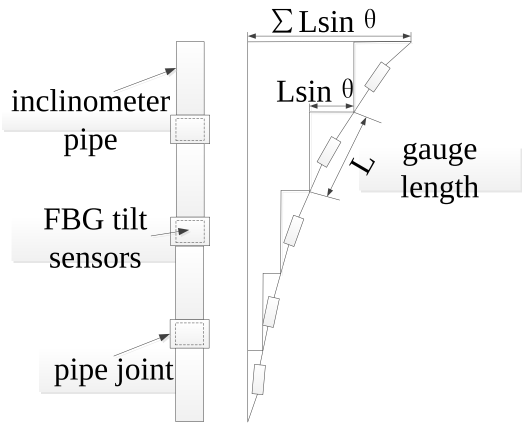

Figure 2. The landslide measuring principle

Considering the monitoring area is remote, a remote automatic monitoring system is selected, the overall monitoring system scheme as shown in Figure 3, it mainly consists of some inclinometer pipe, several FBG tilt sensors, a FBG interrogator, a base station with GPRS communication module and a solar power system. The signal of the FBG tilt sensors which installed in the inclinometer pipe is collected and demodulated by the FBG interrogator through an armored optical cable, and the data of the FBG interrogator is transmitted to the monitoring center which set in a railway station through GPRS module.

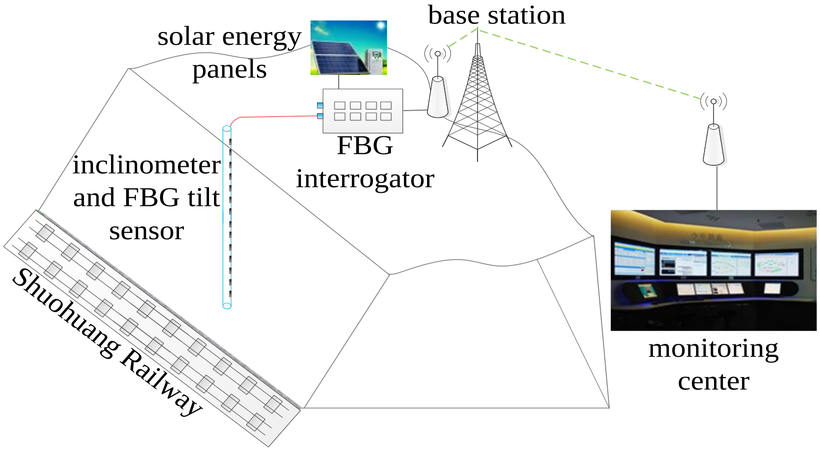

Figure 3. The landslide monitoring system

3. Monitor System Installation

Considering the advantage of the fiber optic sensing technology, a FBG tilt sensor is developed, The structure of the FBG tilt sensor is shown in Figure 4, and it's photograph is shown in Figure 5.

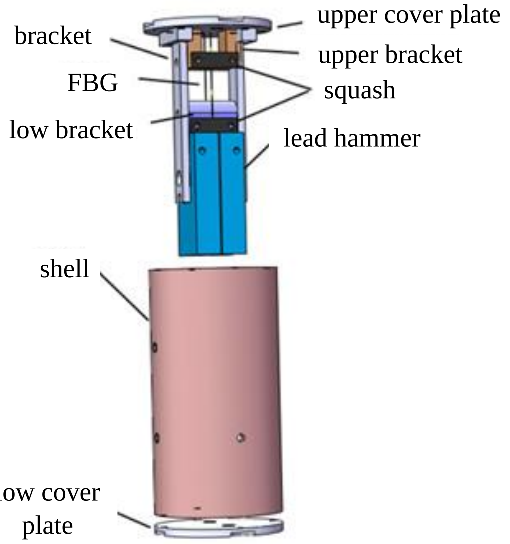

Figure 4. The structure diagram of the FBG tilt sensor

Figure 5. The photo of FBG tilt sensor

When the FBG tilt sensor is tilted, the hammer still keep the trend of plumb, under the force of gravity, so, the optical fiber is stretched by the gravity component of the hammer that along the optical fiber direction, therefore, the center wavelength of the FBG changed with the stretched of the optical fiber. By building the relationship between the center wavelength length of the FBG and the angle of the FBG tilt sensor, and building the relationship between the displacement of the slope and the angle of the FBG tilt sensor, the displacement of the slope can be monitored by measuring the wavelength of the FBG. According to the test result, the sensitivity of the designed FBG tilt sensor is about 400 pm/deg.

The measure hole was drilled by the drilling machine with a diameter of 110 mm, and the non-perpendicularity of the measure hole is less than 3°. The inclinometer pipe with a diameter of 70 mm is installed immediately after the drilling of measure hole is completed, as shown in Figure 6. The space between the measure hole and the inclinometer pipe is filled with gravel, and the FBG tilt sensors are installed after the inclinometer pipe is stabilized, as shown in Figure 7. All optical cable that connects the FBG tilt sensor to the FBG interrogator protected by steel pipe.

Figure 6. The install of inclinometer pipe

Figure 7. The install of the FBG tilt sensor

4. Monitoring results

The remote automatic monitoring system for high and steep slope of Shuohuang Railway was established in August 2017, and the depth of the measure holes is about 14 m, 8 FBG tilt sensors were installed. The remote automatic monitoring system is running smoothly, and the real-time monitoring data have been obtained. The monitoring results as shown in Figure 8, in the summer (rainy season), the slope sliding speed is fast, while in the autumn and winter, the sliding speed is slow and tends to be stable. Slope slip occurs at the location of 9.5 meters above, the location below 9.5 meters is relatively stable.

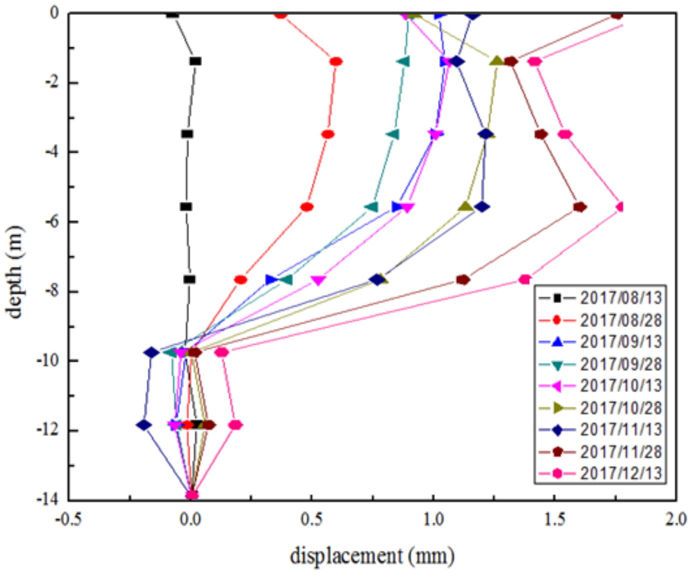

Figure 8. The monitoring results of the slope

5. Conclusions

The remote automatic monitoring system for high and steep slope of Shuohuang railway based on FBG tilt sensors is builded, and it's working well.

The FBG tilt sensor with a high sensitivity, strong anti-electromagnetic interference, strong corrosion resistance, long distance transmission loss, was developed in this monitoring system.

The monitoring results shows that the displacment of slope is small, which indicating that the slope of the Shuohuang railway is steady.

Acknowledgements

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