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The Slop Disaster Early Warning System Of Fiber Bragg Grating Anchor Bar Sensor Based On RFID

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Abstract: The technique for accurate monitoring of frequent slope disaster is long-term problem of engineering and technical personnel. RFID technology and optical fiber Bragg grating sensing technology development provides technical support to solve this problem. In depth study of the RFID technology and the principle of fiber Bragg grating sensor, combining the two technologies with traditional anchor bar, designs optical fiber Bragg grating sensor bolt based on the RFID technique. In lab experiments and field engineering practice of slope disaster early warning monitoring, the effect is very well. The practice gives full play to the advantages of the two technologies.

Keywords: RFID, optical fiber Bragg grating, anchor bar, monitoring, early warning

1 Introduction

China is a mountainous country, mountain occupy countrywide gross area about 2/3, is one of the countries landslide frequently in the world. Because of the geological disaster caused by slope instability is frequent, highly destructive and influential, it is necessary timely, efficient, real-time, long-term monitoring to reduce damage to a minimum. Currently geotechnical engineering monitoring is widely used traditional mechanical and electrical testing technology in the domestic, but these test techniques cannot exert their expertise due to geotechnical engineering specific constraints, and even difficult to meet the requirements of geotechnical engineering test.

In recent years, with the advent of optical fiber sensing technology, it is becoming more and more popular in the field of geotechnical engineering, and has been widely used in, the bridge, dam, tunnel, highway construction, etc. geotechnical engineering safety monitoring [1–3]. However, optical fiber sensor technology has not been sufficient attention in slope disaster warning area.

2 Fiber Bragg grating sensing technology and sensing principle

In 1978, K. O. Hill, etc. [3] made the world's first optical fiber Bragg grating (FBG). R. L. Idriss laid a number of fiber optic displacement sensors and the temperature sensors in the bridge to monitor the pre-stress loss of bridge [4]. P. Kronenberg applied optical fiber sensor on the Emosson dam health monitoring in Switzerland, the French border [5]. D. Inaudi installed 8 different distance optical extensometers on the wall of the building tunnel in a distance of 30 meters with another tunnel to monitor tunnel construction and the soil rock pressure [5]. E. Udd used the fiber grating on bridge health monitoring [6]. At home, Ou Jinping applied the fiber grating sensor on the pre-stressed concrete box girder in Hulan River Bridge to monitor steel strain increment and distribution in pre-stressed box girder tensioning process [7]. T. H. Chan mounted the optical fiber sensor in the Tsing Ma Bridge to real-time monitor the structure health [8]. F. A. Tavenas proposed detection lateral deformation of embankment soft soil applied inclinometer in rock and soil engineering [9]. Since the nineteen eighties, scholars have begun using optical fiber sensing technology for rock and soil structure health monitoring. M. Hisham used distributed sensor for

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monitoring the bar displacement [10]. Zhu Honghu used an optical fiber sensor monitoring system for Hongkong highway side slope long time monitoring [10]. However, optical fiber Bragg grating technology in geotechnical engineering are not yet widely applied at home and abroad, is a new research focus. The optical fiber strain sensor is the dominant product of fiber Bragg gratings, it is a kind of new type optical fiber devices inscribed grating refractive index changing along the axial in the single mode fiber with UV laser directly [11,12]. Fiber Bragg grating used fiber photosensitivity to form the space phase grating in the core of fiber, the grating likes narrowband filter or reflector. Fiber Bragg grating cycle or the core refractive index changes with the environmental temperature, stress, strain and other physical quantity, which led the wavelengths of the reflected light to change. Thus measuring the wavelength of reflected light changes can measure change in a physical quantity. The reflected light wavelength should satisfy the equation (1).

$$\lambda_B = 2n_{eff}\Lambda, \tag{1}$$

λ_B The core reflected light wavelength; n_{eff} Refractive index; Λ The grating cycle. The wavelength shift of fiber Bragg gratings simply caused by stress and strain satisfy equation(2).

$$\Delta\lambda_{B\varepsilon} = \lambda_B(1-P_\varepsilon)\Delta = K_\varepsilon\Delta\varepsilon, \tag{2}$$

P_ε Photo-elastic coefficient; K_ε Sensitivity of measurement strain (nm/$\mu\varepsilon$);$\Delta\varepsilon$ Stress and strain. The wavelength shift change herpes caused by temperature variation.

$$\Delta\lambda_{B\varepsilon} = \lambda_B(\alpha+\xi)\Delta t = K_\varepsilon\Delta t, \tag{3}$$

Then, α Thermal expansion coefficient of the optical fiber grating; ξ Fiber Bragg grating thermo-optic coefficient, K_t Sensitivity of measurement temperature ($nm/^\circ C$). But in the practical application the wavelength variation measured with fiber Bragg grating is always the interaction of strain and temperature in the same time. Its wavelength expression shows in formula (4).

$$\Delta\lambda_B = K_\varepsilon\Delta\varepsilon + K_t\Delta t, \tag{4}$$

3 Optical fiber Bragg grating sensing slope disaster early warning system

Optical fiber grating sensing slope disaster early warning system based on Browser / server structure, its system frame as shown in Fig.1. The system consists of 4 subsystems, data acquisition subsystem, the distributed fiber Bragg grating sensor network and wireless transmission devices;Data storage and support portion consists of database, knowledge base and file data; Data processing and application layer included data query, data

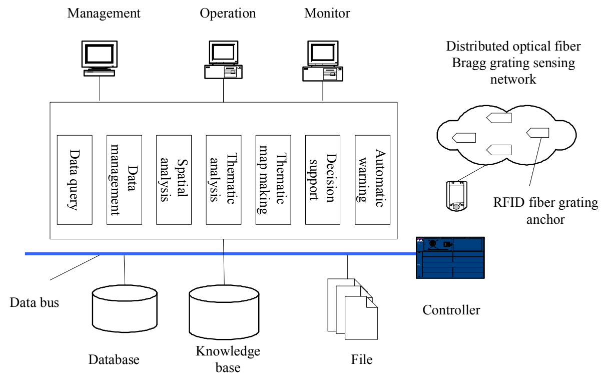

Fig. 1 Optical fiber grating sensing slope disaster warning system

management, spatial analysis, thematic analysis, decision support, and automatic warning; Web application layer realizes the client browser through the interaction with the system function. The system development thought of the overall is combining with the engineering monitoring the actual needs design and development on the basis of virtual reality and things of network technology. Combining network technology and safety monitoring, the network system of engineering application was developed which consists of space information, project information, visualization space management, intelligent analysis. According to the specific features of the engineering safety early warning, comprehensive consideration of landslide and its monitoring network, monitoring data, comprehensive geological information, design requirements, to meet the information management, the system structure should include 4 modules of data establishment and management, space display and query, spatial analysis, and decision support. Reasonable installation technology of FBG bolt sensor is the security for accurately measuring project environmental strain produced by field stress, but also meet the requirements of long-term monitoring and early warning. The author puts forward a new installation method of BFG sensor, its basic points. A. Groove processing. Respectively opening two groove in steel axially symmetric surfaces With slotting machine, then polishing the groove surface smooth with sandpaper; to avoid dust, oil cleaning the surface with absorbent cotton balls dipping acetone or alcohol; B. Pasting. Arranging sensor along the direction of the groove-axial, to make the sensor close contact measuring point surface with adhesive; C. Spot welding. Welded the mounting feet of sensor on the bolt firmly with welded machine; D. RFID tag. Connecting the transmission optical fiber and RFID tab welded on the anchor rod end; E. Anchor. Before the bolt installation anchoring with fast curing adhesive to make the bolt, optical fiber sensors, and transmission optical fiber become one. According to the bolt diameter and anchoring agent diameter reasonable selecting the diameter of installation hole, the hole diameter should be bigger generally than bolt diameter 5-6 nm advisable, anchoring agent should select paper packaging high strength quick anchoring cartridge, filling cement mortar in a borehole after anchoring. Installation diagram as shown in Fig.2. It is greater difficulty for to layout

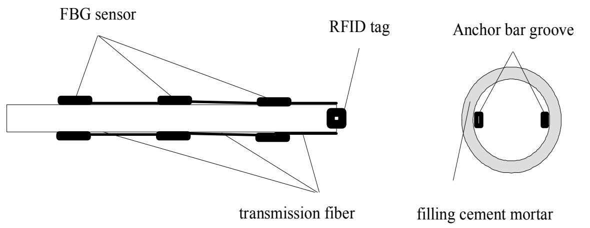

Fig. 2 FBG anchor sensor installation diagram

transmission fiber for every bolt in a large range slope in detection warning system, the system applied RFID technology, placed a passive RFID tags on the end of every detect anchor, setting a different number of active RFID reader based on the detection size of the region in the detection range, the working frequency of reading and writing is 2.4 GHz, the working distance is 0-100 meters, a reader can read and write maximum detecting range to 62832 square meters. Read / write device connecting with early warning system through the wireless communication network. When need to release early-warning, system issue warning through wired and wireless two ways. System arrangement shows in Fig.1. equation (5) gets from equation(4) deformed.

$$\Delta \varepsilon = \frac{1}{K_\varepsilon} \Delta \lambda - \frac{K_t}{K_\varepsilon} \Delta t = K \Delta \lambda - T, \quad (5)$$

K calibration coefficient, got from experimental measurement, T wavelength shift by temperature, FBG sensor is a temperature self compensation sensor in the experiments, therefore, T is zero. With experimental data fitting, K got with the equation(6).

$$K = kL(D^2 - \phi^2) l^{-1} d^{-2} \quad (6)$$

L anchorage length(mm);D borehole diameter(mm); ϕ anchor bar diameter(mm); l anchor agent length(mm); d anchor agent diameter(m m); k filling length(1.05-1.10).

4 Application examples

According to the actual need of the Yunnan Xiaolongtan open-pit slope detection warning, in its eastern slippery slope, arranged 50 FBG anchor bolt with 3 temperature self compensation sensors, grating demodulator produced by America Micro Optics Co. Wavelength resolution is 1pm, the scanning range is 1520-1565nm, the instrument has a network interface, the host computer software and computer network help remote monitoring and analysis. The whole slope anchor strain monitoring system adopt the FBG anchor sensing between series or parallel based on the FBG bolt quantity, and extended channel through the optical switches or optical fiber coupler. Before field installation, the indoor bolt axial compressive strain test had been done with designed FBG bolt fixed its two ends on tensile machine, the experimental results as shown in Fig.3. Fig.4. shows the displacement monitoring results of

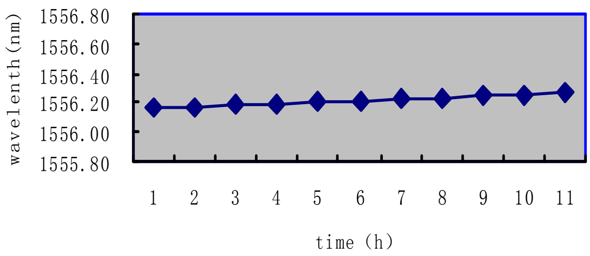

Fig. 3 The indoor bolt axial compressive strain test results

several FBG anchor bolt. Engineering staff can analyze displacement change tendency in different parts of the monitor region with the monitoring map. When the displacement change reaches the critical value of warning, the system will automatically send alarm, which response can be made according to based on the pre-emergency-plan to avoid the economic losses caused by serious landslide disaster, or minimize loss.

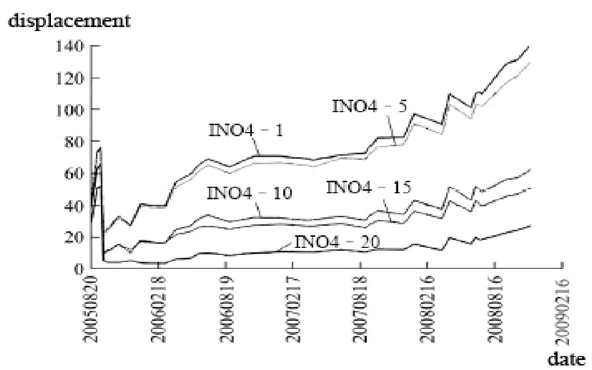

Fig. 4 Displacement monitoring

5 Conclusions

The suggested warning system can monitor slope disaster and early warn, which has the advantage of small affected by weather and environment, monitoring results accurate, large-scale monitoring and remote monitoring and others. Things of network and FBG technology are the future popular monitoring technology in slope hazards and geotechnical engineering field. Combing geographic information system and virtual reality technology, the system can also be used for the visualization monitoring and analysis of engineering on internal structure. The technology has strong vitality and broad application prospects with its own advantages and technical characteristics.

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