分散型光ファイバーセンシングを用いた深部基盤岩内の地質水文モニタリング

(Geohydrological monitoring in deep basement rocks using distributed fiber-optic sensing)

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1. Introduction

Rapid landslides such as steep channel debris flows can devastate populations and economies because of their high flow velocities, high impact forces and long run-out distances. Monitoring and development of early warning for such landslides needs quick data acquisition which is still a challenging task with traditional monitoring tools. The development of novel distributed fibre-optic sensing (DFOS) techniques has made significant technological advancements, from traditional slope monitoring tools to real-time measurements of multiple parameters such as strain or temperature. These sensing methods fulfil the demands of extensive and distributed monitoring of geological structures across vast distances, offering measurements with excellent resolution. DFOS-based fibre-optic sensors, when embedded into sliding masses, function akin to the nerves in the human body, adeptly capturing extensive information to assess the health condition of the landslide. As a novel step towards predicting the occurrence of deep landslides, this study attempts to monitor the strain (to examine the deformation characteristics of basement rocks) and temperature changes (to locate seepage phenomenon) within a deep slope.

2. Laboratory feasibility study

This study demonstrates the ability of the Rayleigh-based phase-noise compensated optical frequency-domain reflectometry (PNC-OFDR) sensing method to monitor the distributed temperature field with an ultra-short data acquisition period of 2 ms, a spatial resolution of 2 cm, and a temperature resolution of 0.1 °C. Two FR PVC cables, as illustrated in Fig. 1, were used in the experiments. One was for heating (heating cable; H-cable) and the other for temperature sensing (temperature measurement cable; T-cable). The H-cable was embedded within a cylindrical concrete mortar specimen and subjected to various heating powers. The T-cable was placed adjacent to the heating cable to monitor the temperature distribution continuously. Two water-holding boxes were installed along the specimen at two positions to retain water. The copper wire in the H-cable implanted inside the specimen is the heat source for the distributed temperature profile registered by the T-cable. Due to the high heat

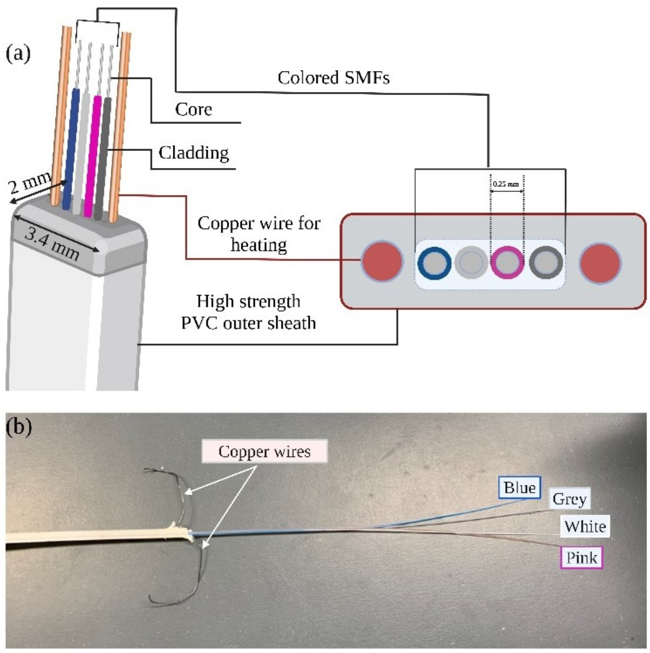

Fig. 1 (a) Structure of the optical cable and (b) an image of the optical cable used in this study

capacity and thermal conductivity of water in the PET boxes, the local temperature field of the specimen will be affected by the presence of the water boxes. If the anomaly of temperature fields is identified with the FO sensing system by measuring the local spectral shift, the water-supplied position can be located and monitored. Fig. 2 presents the temporal evolution of temperature along the specimen during a heating period of 3 hrs at four different electrical powers.

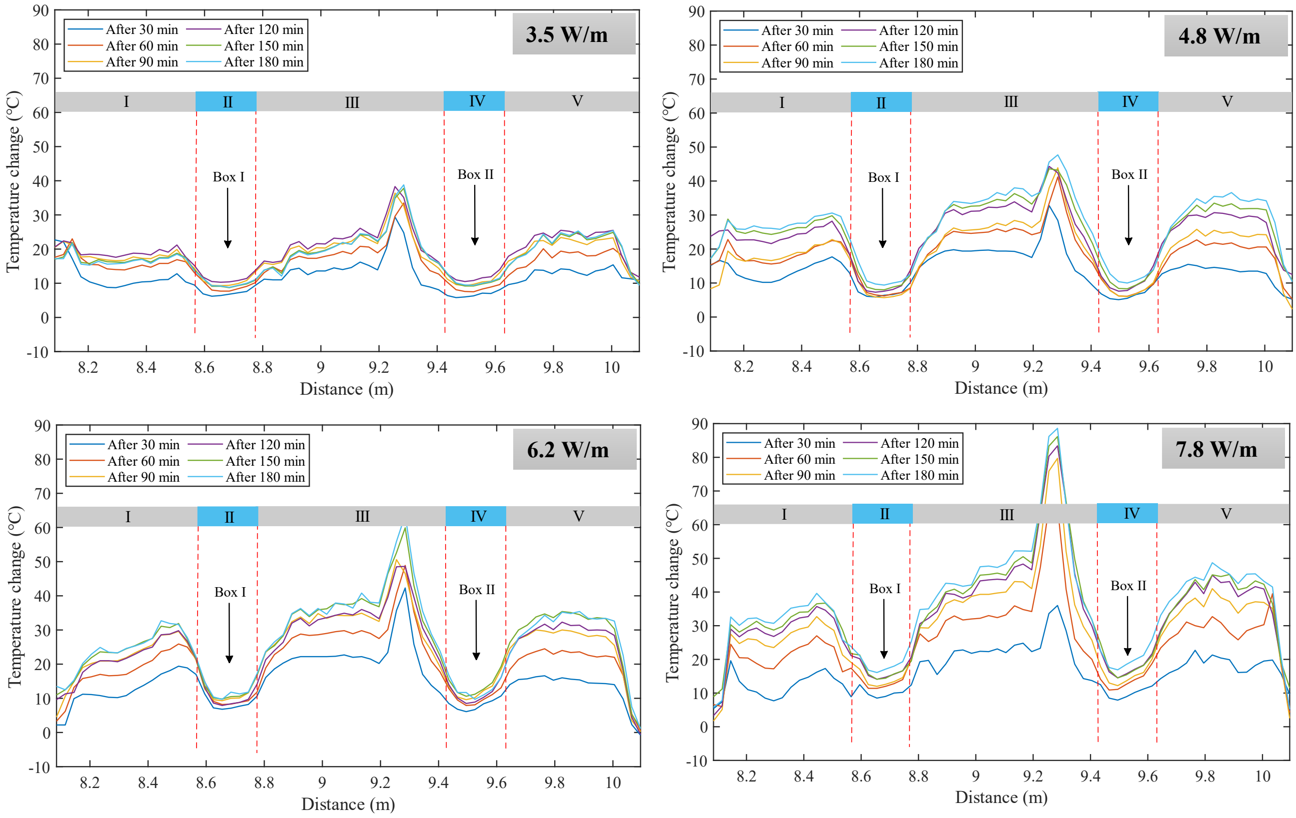

Fig. 2 Temperature change along the specimen detected by the PNC-OFDR system

3. Field study

Field deployment involved installing monitoring systems within a 50-meter-deep borehole, where optical cables for heating, temperature sensing, and strain sensing were embedded (Fig. 3). The hardened anchorage formed by cement slurry backfill facilitates both seepage detection through active heating and rock deformation monitoring via strain sensing. Our future tasks involve the heating tests of boreholes at different electrical powers to locate the groundwater and other seepage phenomena. We continuously record strain and temperature within the borehole and delve into the relationship between bedrock deformation, seasonal variations, and groundwater flow levels.

(a) Drilling borehole

(b) Installing optical cables

(c) Backfilling of borehole

(d) Final top view of the borehole with installed cables

Fig. 3 Various steps of drilling and cable installation

The insights gained from this study have broad applications beyond landslide prediction, extending to groundwater management, civil engineering projects, and urban infrastructure development.