Earth Dam Monitoring by Using Infrared Thermography Detection

Chien-Yuan Chen[1,*], Su-Chin Chen[2], Kuan-Hua Chen[1]

[1]Department of Civil and Water Resources Engineering, National Chiayi University, Chiayi, Taiwan.

[2]Department of Soil and Water Conservation, National Chung-Hsing University, Taichung, Taiwan.

Received 13 January 2016; received in revised form 10 February 2016; accepted 03 March 2016

Abstract

Infrared thermography is applied for artificial earth dam surface monitoring. Using an infrared thermal imager is a nondestructive testing method for determining internal material changes by examining surface changes in radiation temperature. This study was conducted at the artificial earth dam experimental test site located in Landao Creek in Huisun Forest, Nantou County, and central Taiwan. Infrared thermography analysis found different zones with larger radiation temperature changes. The seepage caused the earth dam soil to be wet, as can be reflected by thermography. The seepage failure zone was found to coincide with dramatic changes in radiation temperature recorded using thermography. This study found that dam surface areas with large radiation temperature changes could be failure areas, and that the potential earth dam failure mode could be identified.

Keywords: infrared thermography, earth dam, monitoring

1. Introduction

Infrared thermography detectors are commonly used for military purposes. Their applications also extend to industry, with the devices used for electric equipment maintenance and industrial inspections. Using the detectors is a type of nondestructive testing method for monitoring internal material changes of a large area.

Landslide dams (e.g., earth dams) are attributed to topographic and geologic conditions. Dams can cause water to pond upstream and inundate inhabited areas downstream if breached [1]. Most natural dams are attributed to rainfall or earthquake-induced landslides, riverbank slope slips, or debris flows damming the river underneath. Typhoon Morakot made landfall in Taiwan in 2009, bringing torrential rainfall to Southern Taiwan. The storm created 18 natural dams attributed to landslides and debris flows [2]. These natural dams are inaccessible, thus they are unable to be surveyed in the first stage for their safety evaluation. Evaluating the stability and potential failure mode of these dams would be valuable for disaster prevention and mitigation; therefore, a long-distance nondestructive test for conducting such evaluation would be highly desirable.

Infrared thermography has been used as a nondestructive testing methodology for shotcrete slopes. The infrared temperature changes of shotcrete slope surfaces reflect the internal differences. The caves inside shotcrete slopes exhibit large differences in infrared temperature [3]. Infrared thermography has been applied for mapping open fractures in deep-seated rockslides and unstable cliffs [4]. It has revealed the existence of open cracks, loosened areas, and nonkarst caves. Optimal conditions for infrared thermography include an environment temperature lower than the average surficial rock temperature, a favorable field of vision, to avoid direct solarization, no heavy snow cover, and good for bold rock surface [4].

The failure mode of natural a dam depends on the characteristics of dam material, mechanics strength of the dam, soil permeability, and upstream discharge conditions. Dam failure modes include overtopping erosion with peak flow, progressive erosion by seepage, and slope slide [5-7]. The most landslide dam failures (more than 50%) are attributed to overtopping, followed by piping and slope failure [6].

2. Study Area and Methodology

The field experiment site was located in Landao creek of Huisun Forest in Nanotu County, Central Taiwan (Fig. 1). The test site was a modi-

*Corresponding author. Email: chienyuc@mail.ncyu.edu.tw

fied experimental sediment discharge station used for observing the dam breach process [8]. The creek is one of the potential debris flows in Taiwan. At the time of the study, the creek was 2,792 m long and had a slope between 44° and 55°. The creek was the site of a debris flow in 2001 during Typhoon Toraji and in 2004 during Typhoon Mindulle.

Fig. 1 Site location of the field test at Landao Creek in middle Taiwan

An artificial earth dam was constructed to model a landslide-induced earth dam (Fig. 2). The field test was located at the downstream of the creek. The artificial earth dam was constructed to be 25 m long and 2 m high. The discharge was released upstream toward the earth dam. The dam failure process was monitored using the infrared thermography detector.

Fig. 2 Size of the artificial earth dam

3. Results and Discussion

Preliminary infrared thermography detection conducted shortly after construction of the earth dam is shown in Fig. 3. Because of the topographic characteristics, the dam surface temperature appeared to be lower on the left side of the upstream and highly susceptible to ponding. The average radiation temperature was 32.5 °C on the left side, lower than the 33.5 °C recorded on the right side; this difference is attributed to ponding-induced high water content.

The infrared thermography revealed that the ponding area had a lower radiation temperature than did the other areas. As the water level increased with the upstream discharge, the soil water content increased and the infrared temperature decreased (Fig. 4). Even after the water level increased to its highest point, the dam was not breached, but seepage occurred at the foot of the dam, as reflected in the infrared thermography (Fig. 5). The failure mode of progressive erosion by seepage was observed in the field test.

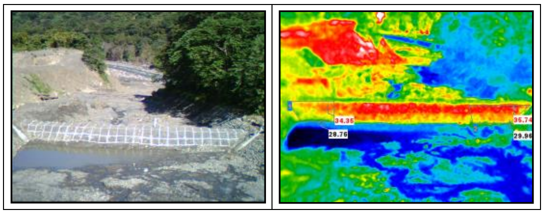

Fig. 3 Upstream ponding of the earth dam

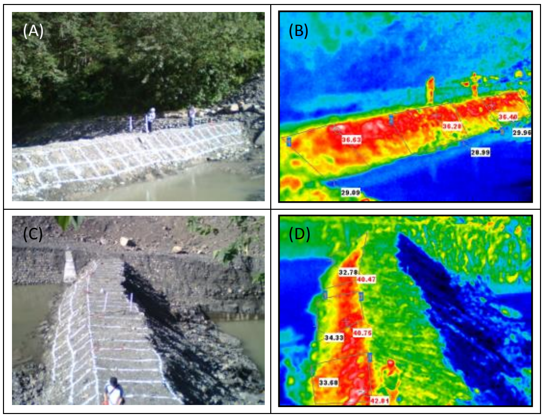

Fig. 4 Rising of water level of the earth dam: (A)(B) upstream face and (C)(D) dam top view

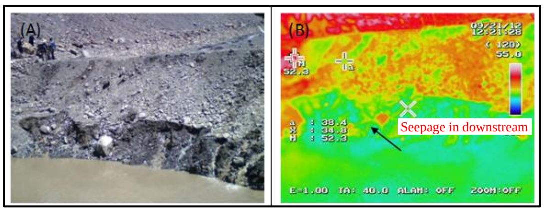

Fig. 5 Downstream seepage of the earth dam

4. Conclusions

The infrared thermography detector is capable of conducting the long-distance and large-area nondestructive motoring of objects. It is capable of identifying potentially unstable areas by examining short-term temperature changes. Dam soil with high water content exhibits dramatic radiation temperature changes and is prone to fail because of seepage. The seepage failure zones are indicated by dramatic changes in radiation temperature, as measured using infrared thermography. The potential failure mode of an earth dam can be predicted after the failure zone has been identified. The failure mode of progressive erosion by seepage was observed in the field test.

References

[1] O. Korup, "Geomorphic hazard assessment of landslide dams in South Westland, New Zealand: fundamental problems and approaches," Geomorphology, vol. 66, pp. 167-188, 2005.

[2] Forestry Bureau, Council of Agriculture, Executive Yuan. News Release http://www.forest.gov.tw/mp.asp?mp=204 (retrieve date 2012/11/21). (In Chinese)

[3] S. C. Fang, "Alishan highway slope failure characteristics and failure potential evaluation," National Cheng Kung Univ., Dept. of Civil Engineering, Doctoral thesis, 2009. (In Chinese)

[4] I. Baroň, D. Bečkovský, and I. L. Míča, "Application of infrared thermography for mapping open fractures in deep-seated rockslides and unstable cliffs," Landslides, vol. 36, pp. 265-275, 2012.

[5] R. L. Schuster, "Landslide dams in the western United State," Proceedings of IVth International Conference and Field Workshop on Landslides, Tokyo, pp. 411-418, 1985.

[6] R. L. Schuster and J. E. Costa, "A perspective on landslide dams," Landslide Dams, Processes, Risk and Mitigation, Geotechnical Special Publication, no. 3, ASCE, pp. 1-2, 1986.

[7] I. Miyagi, T. Mizuyama, and K. Inoue, Natural Disasters, Tokyo: Kokon, 2002. (In Japanese)

[8] S. C. Chen, S. P. An, T. Y. Hsu, and C. Wang, "High precision and adjusted discharge sediment, the experimental station in Landao Creek, Huisun Forest," Journal of Chinese Soil and Water Conservation, vol. 46, no. 1, pp. 1-6, 2015. (In Chinese)