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Applications of Thermal Images for Monitoring Surficial Temperature Changes of Naked Slope

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Abstract

Global climate change causes increases in the torrential rainfall brought by typhoons and the monsoon in Taiwan. Torrential rain in turn causes landslides, debris flows, and the formation of earth dams. Most dams were formed in remote mountainous areas and are difficult to reach for safety evaluation at the beginning of their formation. A long distance and non-destructive testing methodology is necessary for evaluating the safety of landslide dams. This study used an infrared imager for monitoring naked slopes. The thermography can detect surficial radiation temperature changes in the slope to locate potential unstable areas for further monitoring. This study proposes radiation temperature change (T) per unit of time (Δt) as an index (T /Δt) for nondestructive monitoring. The index was used for monitoring and analysis of artificial earth dams constructed at Huishun farm in Nantou County. The results of the analysis show that the failure zone of the artificial dam exhibited the greatest change in the index and the potential failure mode could be predicted once the dam breached. The proposed model could be used for potential unstable slope monitoring.

Keywords: thermography, landslide, monitoring

1. Introduction

Typhoon Morakot hit Taiwan in 2009 and brought torrential rainfall in southern Taiwan. The typhoon caused 17 landslide dams [1]. The failure modes of landslide dams include piping, overtopping, and complex modes [2]. Stream flow blocks by landslides could cause ponding water upstream and flood disasters downstream once they are breached.

Natural dam stability evaluation is urgent for dam breach disaster prevention and mitigation. Thermal images have been used to examine a wide variety of problems [3-4]. It has been commonly used for monitoring activities of landslides in recent years [5-7]. It has the advantages of non-contact and long distance as camera-like characteristics, and is suitable for both long-term monitoring and short-term inspection for sites with surficial radiation temperature changes.

2. Field model test

The artificial earth dam field test was conducted at Huishun farm in Nantou County in central Taiwan. The test procedure included construction of an artificial earth dam in the downstream region of Landou creek. The dam size was 25 m in length and

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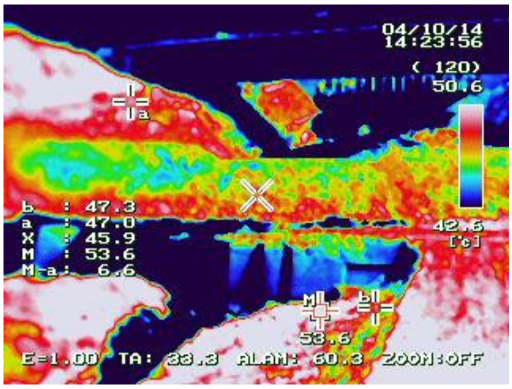
2 m in height and it blocked the entire creek [8]. Water was stopped upstream first and released during tests. The test was made on 10 April 2014, and modeled the failure processes and modes of natural earth dams. The thermal imager was set up on a bridge for monitoring of the upstream face of the dam and at the side bank for the downstream face (Fig. 1). Thermal images were taken every few minutes with the increasing water table during the test until the dam breached.

(a) Field photography



Corresponding thermography

Fig. 1 The artificial earth dam and corresponding thermal image (taken 10 April 2014)

3. Methodology

The study proposed a new index for monitoring the surficial changes of soil slope by water infiltration using thermal images. The index (T /Δt) is a measurement of the surficial radiation temperature changes (T) in the time period between the times the two images were taken (Δt). The changes of surficial radiation temperature over time are used for monitoring during the field test for potential failure mode evaluation.

The surface of the earth dam downstream was divided into grids for monitoring the temperature changes. There are 27 grids monitored as marked in the image from left to right: a1~a3, b1~b8, c1~c8, and d1~d8 (Fig. 1). The temperature is taken as an average within the grid. Fifteen successive images were taken for the analysis. A positive value of the index shows the temperate is increasing. A negative index shows reduction in the temperate due to seepage and piping with the increasingly blocked water table.

4. Results and Analysis

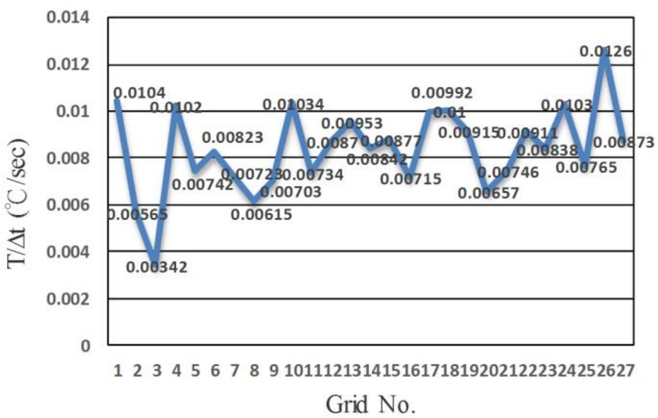


Fig. 2 Monitoring of surficial radiation temperature changes on 14:15:56

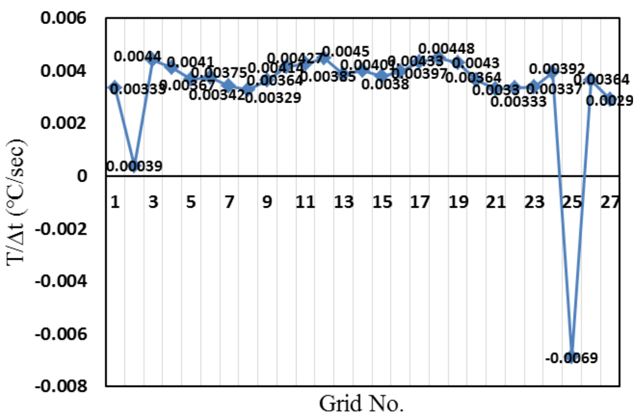
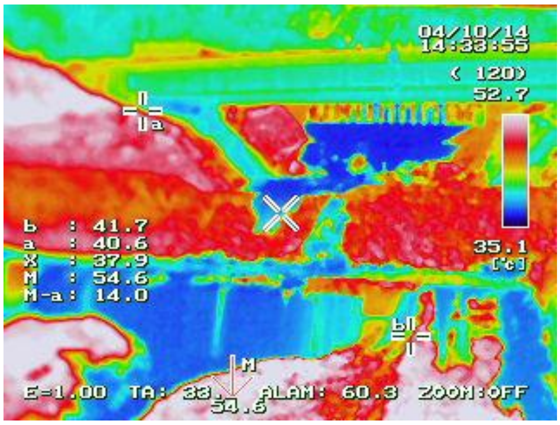


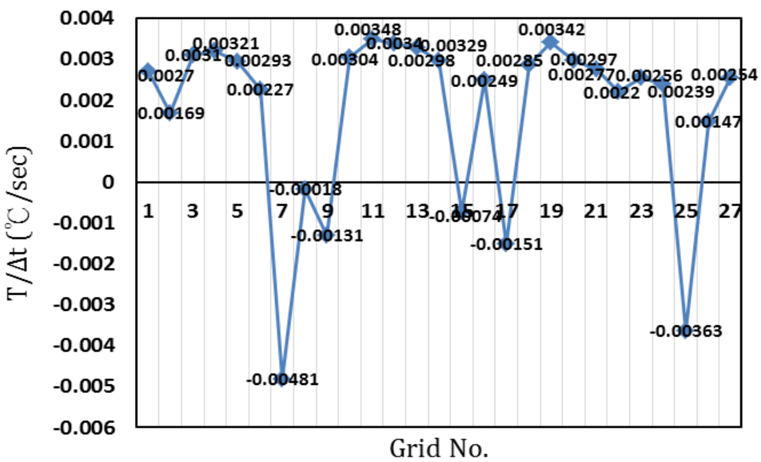
Fig. 3 Monitoring of surficial radiation temperature changes on 14:28:39

Monitoring began at 14:15:56 and ended at 14:34:26. The surficial temperature variations with time at the monitoring grids for the first two images are shown in Fig. 2. All the grids showed a positive index with increasing surficial temperature during the sunshine, at the beginning of the test. Soil erosion and piping occurred at gird No. 26 (d7 in Fig. 1) 12 minutes later with a negative value for the index (Fig. 3). With increasing time, another piping occurred in grid No. 8 (b5) (Fig. 4). It is speculated that the type of failure mode is seepage caused piping if the blocked water table is not rising at the current stage. The dam breached in a complex mode with piping first followed by overtopping failure (Fig. 5). The thermal images showed a clear lower index in the grids with potential seepage-induced piping failure, though the dam failed by overtopping with increasing river flow. Piping failure occurs in low permeability dam material with high soil shear strength under high discharge flow. It should be note that the piping water in the upper grids could flow down to the lower grids without piping, causing a lower index in all these grids. The results show that the index (T /Δt) is suitable for monitoring surficial radiation temperature changes of naked slopes in a given time period and may be applied for monitoring potential landslide slopes.

(a) Field photography



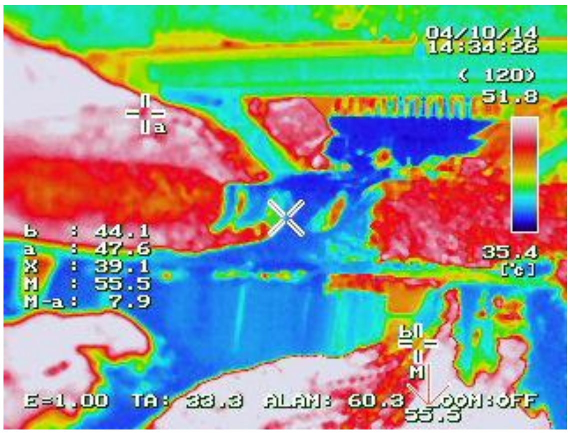
(b) Corresponding thermography



(c) The index (T /Δt) changes

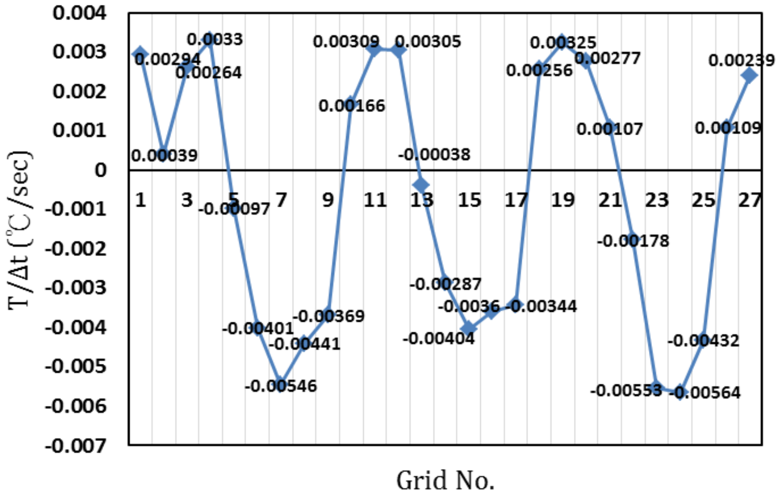
Fig. 4 Monitoring of surficial radiation temperature changes on 14:33:55

(a) Field photography



(b) Corresponding thermography

Fig. 5 Monitoring of surficial radiation temperature changes on 14:34:26 (continued)



(c) The index (T /Δt) changes

Fig. 5 Monitoring of surficial radiation temperature changes on 14:34:26

5. Conclusions

A long distance and non-destructive testing methodology using an infrared imager is adopted for monitoring the safety of artificial dams. The thermography can detect surficial radiation temperature changes in the slope to locate potential unstable areas for further monitoring. The radiation temperature change per unit of time is proposed as an index (T /Δt) for nondestructive monitoring. The index was used for monitoring and analysis of artificial earth dams constructed at Huishun farm in Nantou County. The results of the analysis show that the piping failure zone of the artificial dam exhibited the greatest change in the grid and the potential failure mode could be predicted. The indexreflects the surficial radiation temperature changes and can be used for monitoring the stability of naked slopes.

Acknowledgement

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