A Study on the Effectiveness of Heat Infrared Imaging Method for Monitoring the Physical Condition of the Mortar Walls

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Abstract: In Japan for protecting the slides of steep sloped areas covering the face of slopes by sprayed mortar became popular since 1970s. But, these mortar walls are getting older now. In this background, this study aims to find ways to develop a diagnostic technique of these faces of slope without physically contacting or destroying them.In doing so, we have used heat infrared imaging processing method and developed a simulation model to predict the weak portion of the wall. The results revealed that, by following the model vacuum of mortar wall can be detected having thickness up to 15cm.

Keywords: Mortar wall, Thermal infrared, Heat conducting simulation.

1. Introduction

The sprayed mortar method of covering slopes to prevent slides is very much popular in Japan since several decades, because it is comparatively easy to construct quickly at lower cost. A vast area of such type of mortar wall exists in Japan as still now approximately 7 to 8 million square meters of sloped areas are covered every year through this method. However, with the passage of time these mortar walls are getting older and requires repair to avoid the danger of cracks. But detecting the weak portion of wall calls for physically contacting and breaking, which is very time consuming and uneconomic. Also it is very dangerous to investigate the face of slope sprayed mortar, as these walls extend up to very elevated areas and accidents also occurred while investigating them physically. Thus diagnostic technique, which extracts weak point of these mortar walls without physically contacting or destroying them are needed recently.

In this background, this study aims to find ways to develop a diagnostic technique for the sprayed mortar wall without physically contacting or destroying them. In doing so, heat infrared imaging method has been used. For conducting the investigative study we have selected Tsushima Island of Nagasaki prefecture, Japan as a case (see **Fig. 1** showing the location of the investigation). In this study, we have used the infrared images obtained from the investigation site to develop a simulation model, which later can be used as a model to predict the condition of the sprayed mortar walls on varying conditions and locations.

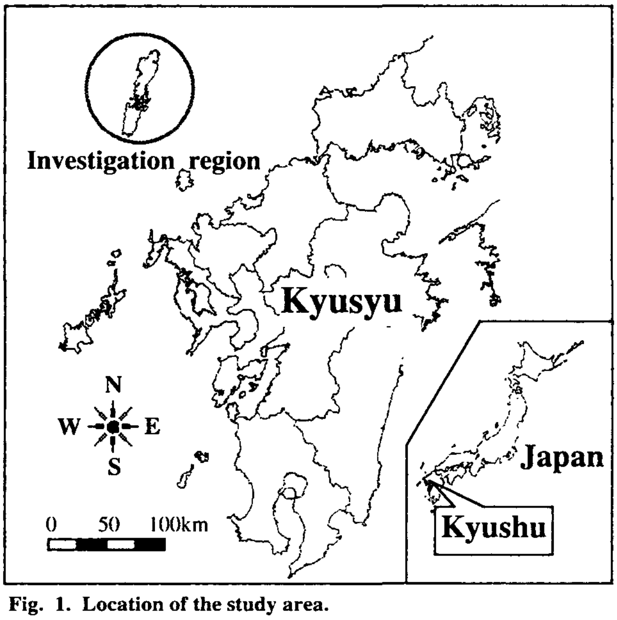

Fig. 1. Location of the study area.

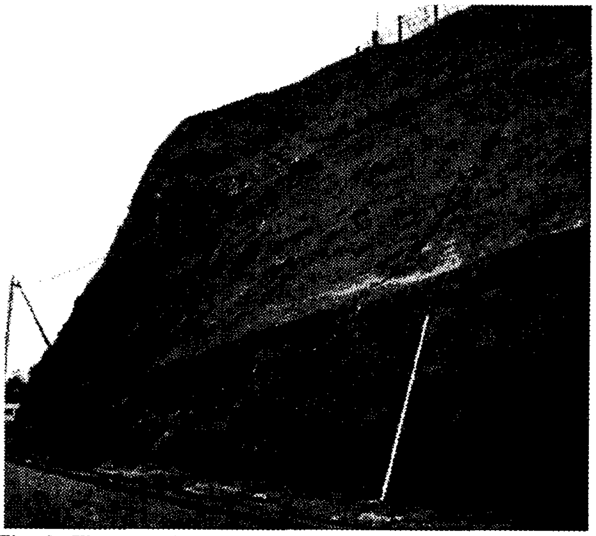

Fig. 2. The investigation site.

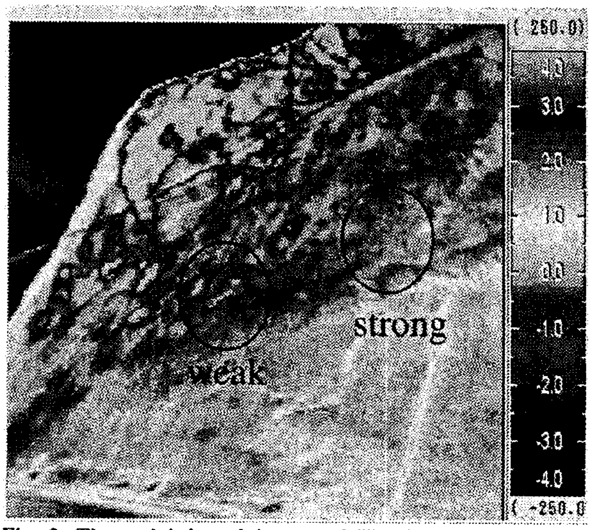

Fig. 3. Thermal infrared images of Fig. 2.

2. Heat Infrared Imaging Method

Heat infrared imaging method is a technique used to investigate the object without physically contacting or destroying it. Through this technique of imaging, the inner situation of an object can be predicted by taking the image of the surface with heat infrared imaging camera.Heat infrared imaging camera can measure the temperature of the object through infrared image unlike the usual camera, which only grasp the appearance of the object. When this heat infrared imaging method is used to measure the surface temperature of the sprayed mortar walls, normally it would show higher temperature if vacuum exists behind the wall, indicating the danger of possible crack. This is because the heat containing capacity of air is generally very small compared with that of soil. Thus if mortar wall has vacuum behind, it would easily get warm or cool when it comes in contact with sunlight or open air, respectively. Accordingly, subtracted infrared image obtained for the same object during high day temperature time and again during low temperature time would reveal the existence of vacuum behind the mortar wall through high fluctuation in temperature. On the other hand walls having no vacuum behind would not show fluctuations in temperature derived from subtracted infrared image.

3. Study Area

In this study, the investigation site is a slope sprayed mortar in Mitsusima town, Shimoagata district, Nagasaki prefecture, Japan. Investigation is conducted on 29 November 2002 and the weather condition was sunny observation by heat infrared imaging camera was performed from 11:35 to 14:48. The mortar wall investigated is shown in **Fig. 2**. During the observation period highest level of temperature was observed on 14:02 and the lowest on 11:42. Infrared images taken on these times are used to get the subtracted image. The subtracting image obtained is shown in **Fig. 3**.

4. Methods for Heat Conduction Simulation Analysis

The limited element analysis system Quick Field was used for heat conduction simulation analysis. Analysis was performed by the model of **Fig. 4**. The mortar wall investigated had mostly rocks on their backside. Thermal reflectance of mortar wall, change in the daily sunlight heat volume and temperature were added to the simulation model as parameters. The procedure of dividing the limited element of mesh is shown in **Fig. 4**.

The average value of sunlight heat volume and temperature were calculated by adding the data obtained from the Nagasaki Meteorological Observatory [2] through June to August in 2002 in sunny weather days only and used the average value for inserting into the model as winter data in the simulation model. Then analysis for both summer and winter is conducted by setting the condition of sprayed mortar surface given temperature at 7:00 a.m as boundary condition. Furthermore, unsteady analysis was performed by varying the sunlight heat volume. Analysis was conducted from 7:00 a.m to 7:00 p.m by setting the time lag as 60 seconds and the rate of thermal reflectance of the face of slope sprayed mortar surface as 0.94. The result discussed in this paper represents the value on the central point of the model surface during the highest level of temperature during the day. The thickness of the mortar wall is varied to see the impact on the model as shown in **Table1**. Again to see the difference in the model due to the backside content of the walls the analysis is conducted by changing the conduction for four types: granite, clay soil, dried soil, and wet soil. We have selected granite as backside content of the mortar wall as this particular type of rock decomposes quickly compared to other rocks.

5.Analytical Results

1) Thermal Infrared Image Results

The investigation site shown in **Fig. 2** corresponds to the thermal infrared image shown in **Fig. 3**. The high temperature change in the upper left part of the Fig.3 is considered to be the influence of sunlight that hit the location directly on that day. **Fig. 5** shows the change in temperature in weak and strong portion of the wall with the conditions that investigation is conducted in winter and behind the face of slope sprayed mortar is rock. If we compare the temperature of the weak and strong parts the maximum level of difference between the two were observed in 14:26 as 3.7℃.

2) Heat Conducting Simulation Results

The result of the simulation analysis is summarized through **Figs. 6～10**. The thermal infrared image camera used in this study can record temperature interval up to 0.1℃ and accordingly this study continued the simulation on this basis. **Fig. 6** shows that when mortar thickness is 5cm, even vacuum of few centimeter can be detected. While, **Fig. 7** shows that when mortar thickness is 10cm, though vacuum of few centimeters would be hard to detect, small vacuum (larger than that can be detected in 5cm mortal wall) can be detected. Again when mortar thickness is 15cm or more it becomes difficult to detect vacuum inside regardless of its size (see **Fig. 8**). Next, the simulation results of varying the backside material of the mortar wall by fixing mortar thickness to 10cm and width to 30cm is shown in **Fig. 9**. From the figure we can see that in case of granite or simple clay soil vacuum behind the wall is comparatively easy to detect, as the difference in temperature is high. On the other hand, in case of dried or wet soil such vacuums are difficult to detect, as the difference in temperature is comparatively lower. Again in order to see the difference in summer and winter, simulation is conducted by setting mortar thickness to 10cm, width to 30cm and behind the mortar wall as granite (see **Fig. 10**).

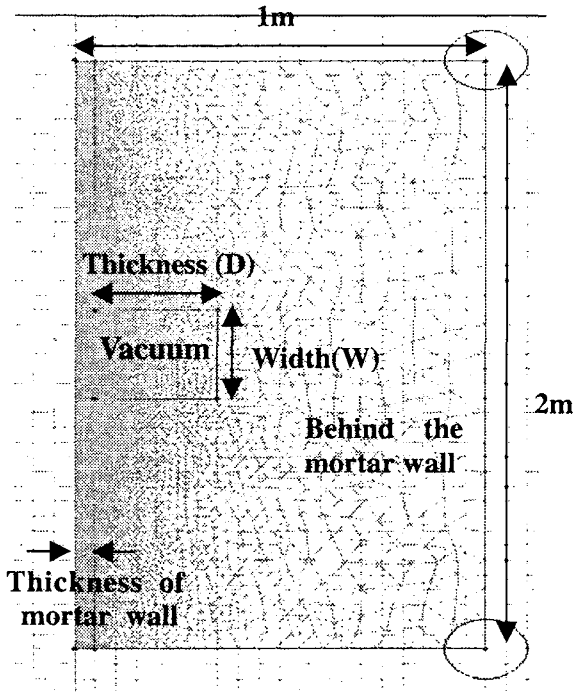

Fig. 4. Simulation model.

Table 1. Thickness and width of vacuum.

Thickness D(cm)	0.1	0.25	0.5	0.75	1.0	2.5	5.0	10.0	20.0
Width W(cm)	5.0	10.0	15.0	20.0	30.0				

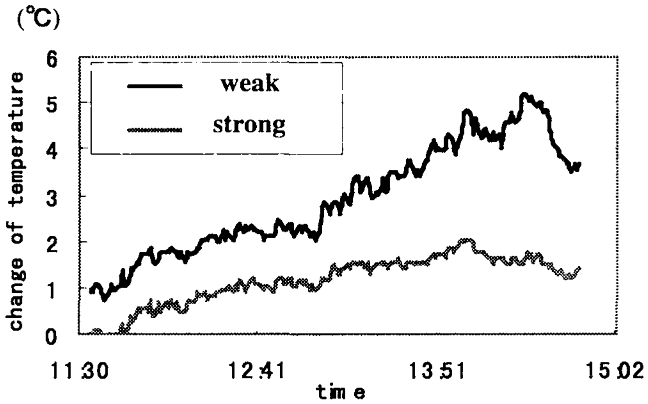

Fig. 5. Change of temperature in investigation.

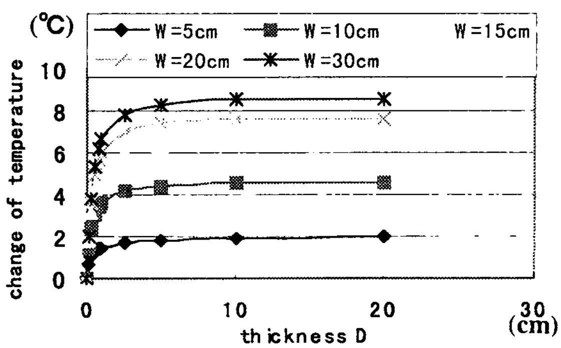

Fig. 6. Change of temperature by the difference in vacuum width.
(Thickness of mortar wall is 5cm)

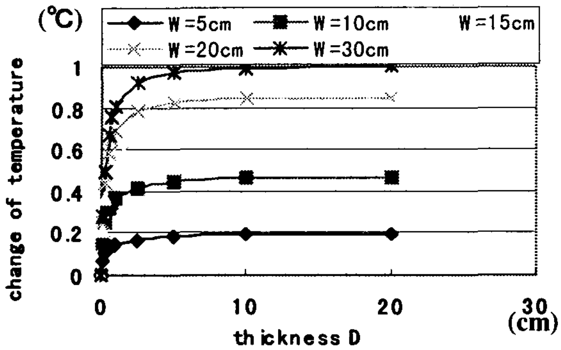

Fig. 7. Change of temperature by the difference in vacuum width.
(Thickness of mortar wall is 10cm)

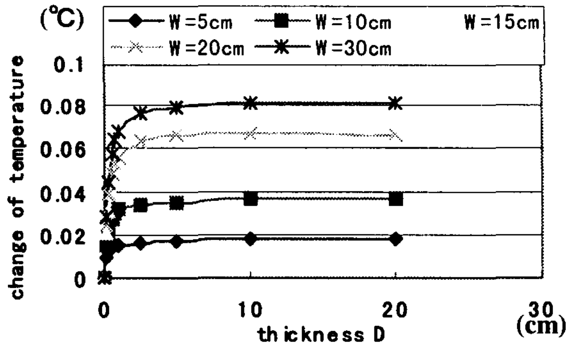

Fig. 8. Change of temperature by the difference in vacuum width.
(Thickness of mortar wall is 15cm)

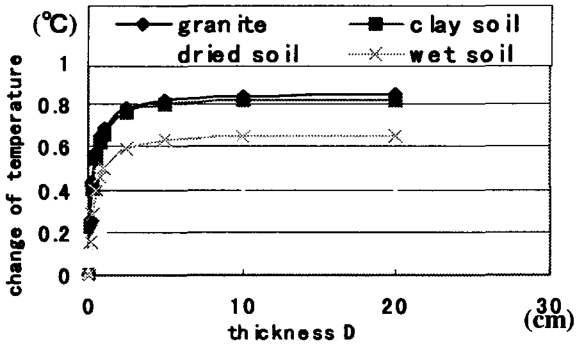

Fig. 9. Change of temperature by the difference in vacuum width.
(Thickness of mortar wall is 10cm)

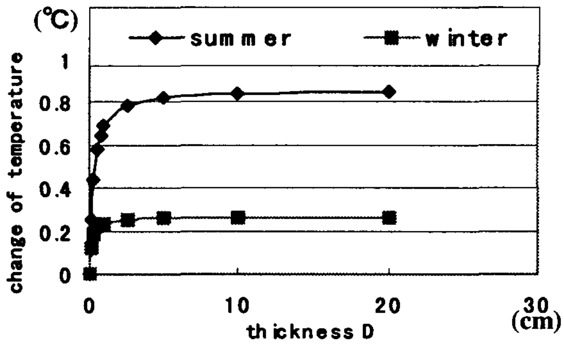

Fig. 10. Change of temperature by the difference in vacuum width.
(Thickness of mortar wall is 10cm)

6. Conclusions

It is observed in other studies that the heat infrared imaging method can effectively detect vacuum up to mortar wall thickness of 15cm [1]. The results of the simulation study also confirmed this result that, by following this method vacuum of mortar wall can be detected having thickness between 10cm~15cm. This study also revealed that, in addition to the thickness and width of the mortar wall, contents of the backside of the walls e.g., granite, clay soil etc. and seasonal variation also influence the effectiveness of heat infrared imaging method in detecting vacuum. However, other conditions such as: clouds, the influence of wind, heat reflectance in the vacuum, change of sunlight volume by the inclination of sprayed mortar walls should also be considered in the simulation model.

By incorporating all these above mentioned additional factors we believe it is possible to investigate the physical condition of sprayed portal walls more accurately without destroying or even physically contacting them. This area leaves the amole scope for future studies.

References

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[2] Nagasaki Marine Meteorological Observatory, 2002. Meteorological Agency Annual Report.