Development of a Diagnostic Technique of the Historic Structures Using a Thermal Infrared Camera

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Abstract: The establishment of the investigation and the maintenance technique is required for preservation of old structures in Japan. This study attempts to diagnose the deterioration status of the historic structures using the thermal infrared camera. In some structures, the difference of the spatio-temporal change was observed in the surface temperature. For example, the cold joint of concrete was examined using this method effectively. As a result of this study, we have found useful guidelines in developing methodology to conduct diagnosis of historic buildings by using thermal infrared camera.
Keywords: Historic Structures, Thermal Infrared, Diagnostic Technique of Structure.

1. Introduction

Recently, in Japan, research studies for developing the maintenance and management techniques to save the historical structures are highly demanded. These structures have high historical and social value to Japan for reasons such as: supported the modernization of Japan from the beginning of the 20th century, contributed during the high growth era, important evidence of civil engineering history of Japan, place of tragic history atrocities, such as place where foreigner's were forced to work as labors during World War II and so on. Thus these structures contain both good and bad memories of Japan, which must be preserved for historic lesson of Japan.

But monitoring of historical structures for their preservation and maintenance is a difficult task as physical movement inside these structures might cause fatal damage to them. As a result of this problem, this study aimed to examine the possibility of monitoring historical structures from a reasonable distance by using the thermal infrared camera, so that the physical damage to the invaluable structure can be avoided. As a case we have investigated the vertical shaft oar of the Shime Coal Mine and the Hario Radio Tower located at Fukuoka and Nagasaki prefecture of Kyusyu, Japan, respectively. The location of the study area is shown in **Fig.1**.

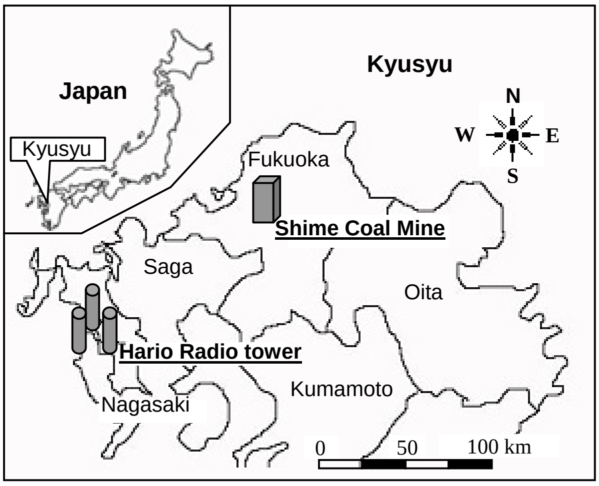

Fig. 1. Location of the study area

2. Study Area

1) Vertical Shaft Oar of Shime Coal Mine

Shime Coal Mine was first started in the year 1889 under the direct management of then Japan Navy. By demolition of Japan Navy due to the consequences of World War II in 1945, the management of Shime Coal Mine was transferred to the Ministry of Transport. In 1949, it was taken over by the Japanese National Railways, and finally was closed in 1964. In Japan, it was the only national coal mine, and the total coal output from start till end was about 22 million tons. The construction of Vertical Shaft Oar of Shime Coal Mine was started in 1941 and completed in the year 1943. Having Ferro-concrete structure, it possesses the dimensions of 17.3m x 12.9m x 48.6m. Vertical Shaft Oar of Shime Coal Mine is Japan’s oldest existing

Fig 2. **Vertical Shaft Oar of Shime Coal Mine**

Fig 3. **Hario Radio Tower**

winding tower type vertical shaft. Currently it is in the possession of New Energy and Industrial Technology Development Organization, Japan. The vertical shaft oar of the Shime Coal Mine image is shown in **Fig.2**.

2) Hario Radio Station

The construction works of three radio towers and a transmitting station office of Hario Radio Station were started under the control of ex-Japan Navy in November 1918 and were completed in November 1922. It was used for national defense and law and order maintenance of Japan, marine safe security etc, until it became abolished in March 1997. There are three radio towers, arranged by an equilateral triangle having 300m distances between them. The height of the 1st and 2nd towers is 135m each and 137m for the 3rd one. The base and top diameters of towers are 12.12m and 3.17m respectively. The base circumference is 33.0m and the thickness of the tower walls is 76cm. These towers are reflecting the highest technology of Ferro-concrete structure construction of those days. The Hario Radio Tower image is shown in **Fig.3**.

3. Method

In this study, authors targeted the study objects from the remote place, using thermal infrared camera (TH3100). The observations were conducted at both study areas from 15 to 30 minutes at each site. In order to grasp the degradation state, the thermal infrared shadow method was used. This method is already put in practical use for mortar spraying slopes. It observes the subject by thermal infrared camera and judges the differences of surface temperature distribution and surface temperature change relatively. Also it judges a deterioration state. The analysis changed the state of thermal images, so that it became apparent to judge the portions of relatively high and low temperature. Moreover, in order to observe the amount of temperature change, subtraction processing of the images was carried out at the starting and ending time of an observation. Also the size of temperature change was shown. All observations were performed at daytime. The vertical shaft oar of the Shime Coal Mine and the 1st tower of Hario radio tower were observed at the distances of 150 and 100 meters respectively. The 2nd and 3rd towers of Hario Radio Tower were observed at the distance of around 200m - 300m.

4. Analysis result

1) Vertical Shaft Oar of Shime Coal Mine

In this investigation, vertical shaft oar of the Shime Coal Mine was observed from west towards east for 30 minutes. While observation, the sunrays were also striking the vertical shaft structure. As for the southwest side (SIDE A, **Fig.4**) the highest radiation temperature was 40.2°C and for the northwest side (SIDE B, **Fig.4**) the highest radiation temperature was 35.0 °C. In the thermal images, the difference of temperature relative to a circumference portion has been checked at the joint of concrete. **Fig.4** shows the subtraction process between the final image and initial image. The final image was taken 30 minutes later than that of the initial image. While observing SIDE A of **Fig.4**, authors experienced a significant change in the temperature under the upper part of window frames, and the overhang portion of the center of an image. That significant change in the temperature is difficult to detect with naked eye. Almost 10cm joint was visually seen at the upper part of windows and authors presume that it might damage those upper parts of windows. Moreover, although there is little temperature change, a large temperature change can be seen at SIDE B as compared with the circumference in the left-hand side portion of the 2nd step of window frame.

2) Hario Radio tower

In this research, authors observed all three towers with the help of thermal infrared camera. Each scene was observed for 30 minutes in shiny rays of sun covering

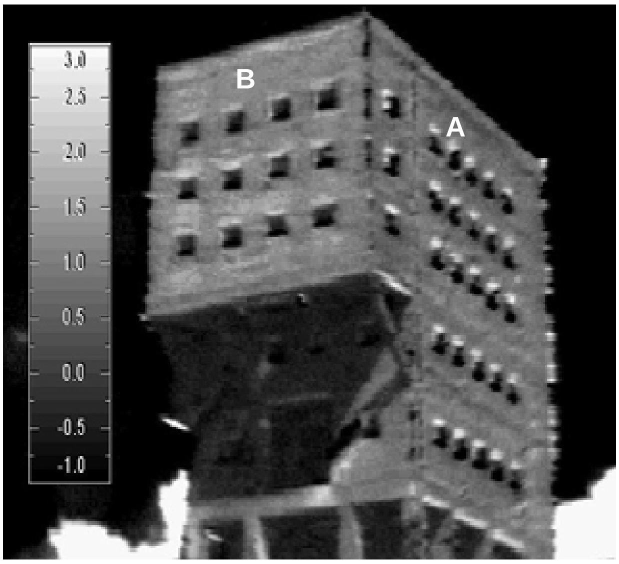

Fig. 4. The Vertical Shaft Oar of Shime Coal Mine-after subtraction process

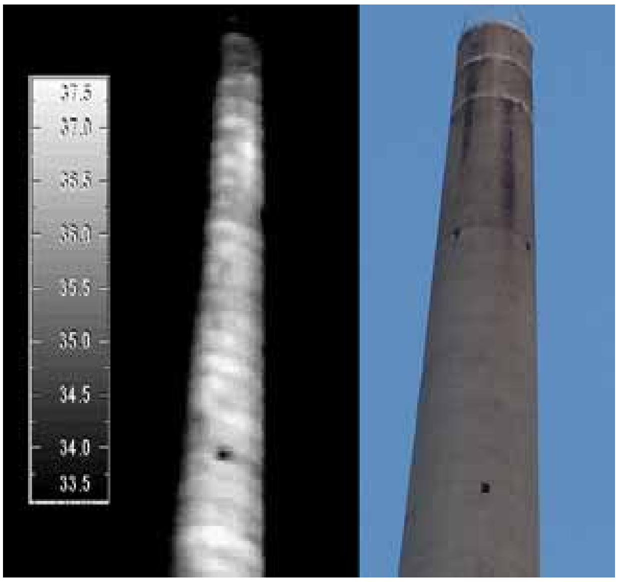

Fig. 5. Thermal infrared images of Hario Radio Tower

the whole portions of towers. The thermal photograph of a portion is shown in **Fig.5**. This picture is the topmost part of 1st tower. The thermal image showed a tendency of temperature change that goes spirally upwards. That tendency of temperature change is neither regarded as the influence of wind nor the influence of shiny sunrays. It can be suggested that it was the execution process of construction those days. After carrying out the subtraction process of thermal images, i.e. subtracting the initial image by the image taken after 30 minutes, a difference of temperature change was being observed. However, the temperature change was appeared slightly, the portion that can be judged to be a degradation part, has not been checked. It is assumed that it is because of the concrete thickness. We are going on the further research to find out the reasons of the temperature changes in concrete structure.

5. Conclusions

In this study, Authors studied the historical structures in Kyushu region. Some analysis results clearly show the temperature change and the portion considered to have deteriorated was shown in surface distribution or surface temperature change. As a result of this study, we have found useful guidelines in developing methodology to conduct diagnosis of historic buildings by using thermal infrared camera. In order to modernize the historical inheritances, it is highly suggested to continue research work. By doing this, it not only helps us to make proper judgments on the degradation state of historical inheritances, but also to improve the maintenance management.

Due to the heavy management costs and negative economic trend in Japan, most of the companies and groups owning modernization inheritance are passive against save and maintenance management of historical structures. Moreover, in a worn out intense structure, it is difficult to make reservations for the safety of neighborhood residents and tourists visiting those structures.

Authors believe that it is necessary to inherit the history and culture of structural developments of the 20th century, not only for the present century but also for the next coming centuries. Not to repeat the miserable history once again, it is necessary to save monuments in their original shape.

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