Analysis of temperature differences due to cracks and voids in concrete structures.

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Abstract

About 20% of bridges in Japan have been 50 years since construction. In addition, after 20 years about 70% of the bridges in Japan have passed 50 years since construction. Visual inspection is required once every five years to prevent accidents. However, visual inspection is expensive and requires many technicians. Therefore, efficient and low cost diagnostic methods are required. The periodic inspection guidelines were revised in 2019, and it was decided that alternative technology could be used if it was equivalent to visual inspection. So, we focused on infrared thermography which is used in civil engineering survey in recent years. Before performing visual inspection, infrared thermography is used to sort out structures that are sound and do not require visual inspection and structures that are deteriorated and that require visual inspection. By inspecting only the structures that require visual inspection, cost and personnel can be reduced. However, a survey method of civil engineering structures using infrared thermography has not been established. Therefore, in this study, we examined the most suitable conditions for infrared thermography investigation. First, concrete specimens with different protection up to the air gap were made. Second, concrete specimens with different crack widths were made. Check protection of Air gap thickness and crack width to which infrared thermography can be applied. The temperature of the concrete sample was changed by the active method, and the temperature difference between the air gap and the concrete and the temperature difference between the crack and the concrete sample were observed by thermography. Resultly, the suitable conditions under which cracks and voids in the concrete structure can be observed were clarified.

INTRODUCTION

In Japan, aging social infrastructure is progressing. About 20% of bridges in Japan have been 50 years since construction. In addition, after 20 years about 70% of the bridges in Japan have passed 50 years since construction. Therefore, the importance of maintenance and management of concrete structures has increased, and improvement of defect detection technology is desired. Road structures were required to be inspected by close visual inspection once every five years to prevent accidents. However, since inspection by proximity visual inspection requires close access to the structure, traffic regulation, arrangement of an aerial work vehicle, and the like are required, which requires high cost and a large number of engineers. Therefore, there is a need for an efficient and low-cost method for making judgments. In 2019, the periodic inspection procedures for road structures were revised, and a policy was adopted to enable the proximity visual inspection requirements to be replaced with equivalent technology. So, we focused on infrared thermography which is used in civil engineering survey in recent years. Infrared thermography is capable of non-contact and extensive inspections for diagnosing peeling, cracking, and is therefore increasingly applied to civil engineering structure surveys. The inspection method using infrared thermography measures the spatial distribution and temporal change of the object temperature. When a specific temperature distribution on the concrete surface caused by internal defects in the structure appears, it can be applied to inspection and diagnosis. However, a survey method for civil engineering structures using infrared thermography has not been established since the necessary observation conditions have not been fully studied. Therefore, in this study, in order to clarify one of the conditions, concrete specimens with different void depths were made and the concrete specimens were heated by the active method using a halogen lamp. During heating and natural cooling, the temperature difference between the gap and other locations was examined.

RESEARCH METHOD

2.1 Creating a void model specimen

A concrete specimen having a length of 20 cm, a width of 20 cm, and a height of 10 cm was prepared. In order to simulate the void, the concrete specimen is filled with 5 cm long, 5 cm wide and 2 cm high polystyrene foam. We prepared conditions for 5 cases with 1 cm, 2 cm, 3 cm, and 5 cm depth of polystyrene as the case of the void depth (Figure 1).

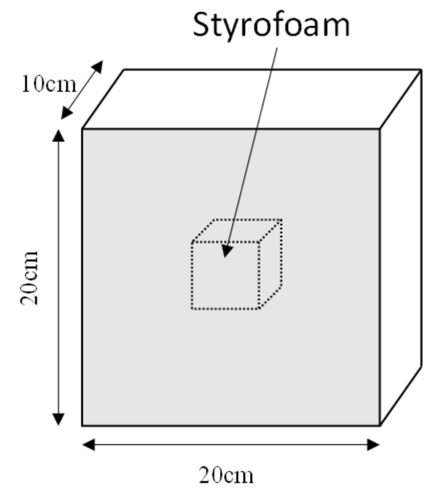

Fig.1 Placement of concrete specimen and void

2.2 Experimental method

In order to investigate the detection accuracy by infrared thermography, the surface of the concrete specimen was overheated by the active method using a halogen lamp. When the sound part of the concrete specimen reached 40 degrees, the halogen lamp was turned off and natural cooling was performed for 1 hour.

The state during heating and natural cooling was taken every minute with an infrared thermography camera, and the concrete surface temperature change due to the difference in the gap depth and the temperature difference between the gap and the surrounding area were compared.

3 Experimental result

3.1 Measurement result of concrete specimen surface temperature

Figure 2 shows the process during heating and natural cooling of the void for each case when the concrete surface of the healthy part reaches 40 degrees. In the case of a gap depth of 1 cm, when the healthy part was 40 degrees, the gap part was 44.3 degrees. In the case of a gap depth of 2 cm, when the sound part was 40 degrees, the gap part was 42.6 degrees. When the cavity depth was 3 cm, the healthy area was 40 degrees, and the void area was 42.7 degrees. In the case of a gap depth of 5 cm, when the sound part was 40 degrees, the gap part was 40.6 degrees.

3.2 Consideration from temperature graph

When the gap depth was 1 cm, the temperature difference when the healthy area reached 40 degrees was the largest compared to the other three cases. When the gap depth was 2 to 3 cm, the difference between the healthy area and the gap part was 2.6 to 2.7 degrees. The natural cooling time was slower than in the case of 1 cm. When the gap depth was 5cm, unlike the other three cases, the temperature difference when the healthy area was 40 degrees was not so much. When the gap depth was 1 to 3 cm, the temperature difference became maximum when the healthy part was 40 degrees Celsius. However, when the gap depth was 5 cm, the temperature difference became maximum 10 minutes later.

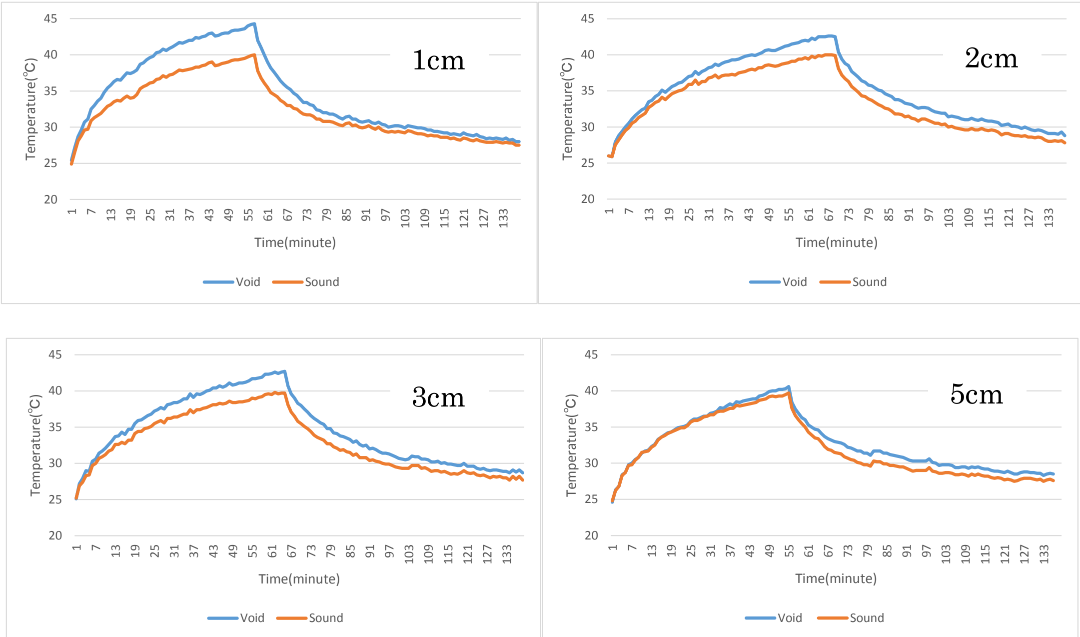

Fig 2　Surface temperature of concrete specimens with different void depths

3.3 Consideration from temperature difference graph

Figure 3 is a graph showing the temperature difference between the healthy part and the gap part. When the air gap depth is 1 cm, the temperature rises rapidly and the natural cooling time is faster than in other cases, so the temperature difference rises sharply and falls sharply from the peak. There was a slight difference in the temperature difference between the healthy area and the gap part at the gap depths of 2 cm and 3 cm, but there was no significant change in the course of heating and natural cooling. When the gap depth is 5cm, there is not much temperature difference until around 30 minutes. Furthermore, the decline from the peak was lower than in the other cases.

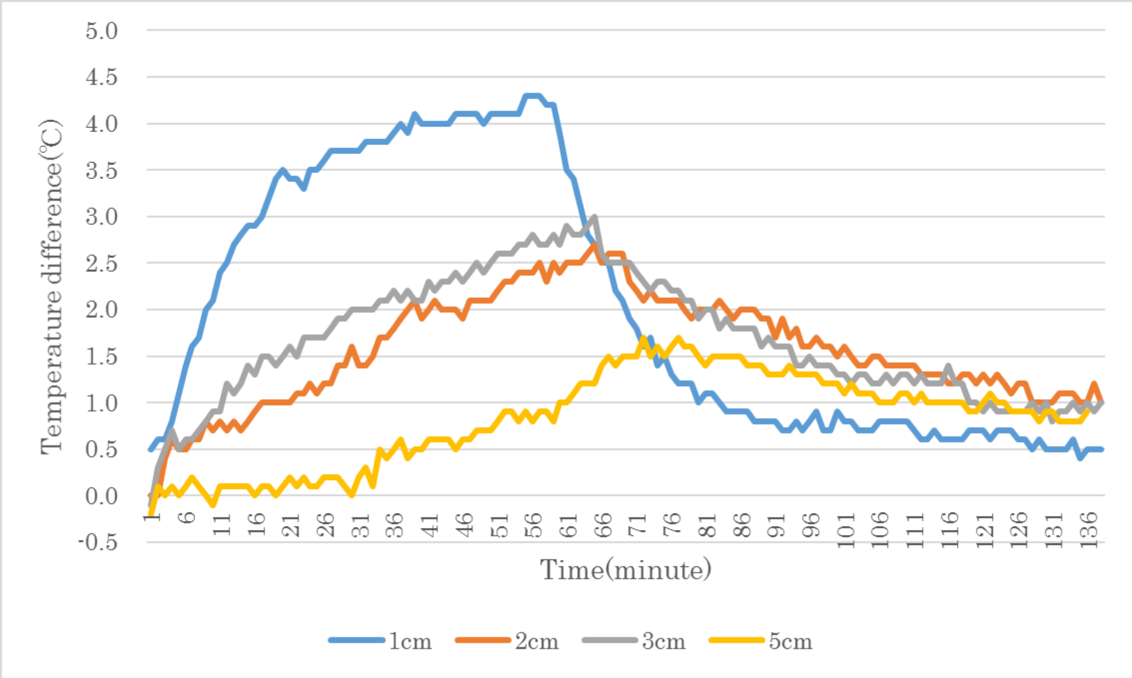

Fig. 3 Temperature difference between healthy area and void part of concrete specimen

4 conclusions

In this study, we focused on natural cooling from the rise in surface temperature of concrete specimens with different gap depths using halogen lamps. As a result, it was possible to grasp the characteristics of natural cooling and the temperature difference between the healthy area and the gap part from the temperature rise at each gap depth. When the gap depth is about 1 cm, the temperature difference is greatly different. Even when the gap depth was 2 to 3 cm, the temperature difference could be read between the healthy part and the gap part. Therefore, it is thought that it can be discovered by infrared thermography. However, when the gap depth is 5 cm, the temperature difference is very small and it is considered difficult to use infrared thermography. Therefore, when infrared thermography is applied, the higher the concrete surface temperature, the easier the measurement, and when the concrete surface temperature is 40 degrees, it can be applied if the void depth is 4 cm or less.