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Trial of nondestructive inspection of concrete specimens by photothermal radiometry with a line heat source

線状熱源光熱放射法によるコンクリート試料の
非破壊検査の試行

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1. Introduction

Photothermal radiometry (PR) is one of the photoacoustic and photothermal phenomena (PPP) that have been applied to nondestructive inspection (NDI) of industrial products[1-3]. Due to its perfect non-contact property, PR has advantage for NDI applications especially of concrete structure such as tunnels. In this paper, a line-focused laser beam moves toward a perpendicular direction to the line heat source, and temperature variation is recorded as time-varying thermal images.

2. Experimental apparatus and specimens

1.1 Experimental apparatus

Basic experimental setup is shown in **Fig. 1.** For a heat source, second harmonics of Nd-YAG diode laser-pumped solid-state laser (DPSSL, maximum power 4.5 W) with wavelength of 532nm was used. Its beam was expanded with a beam expander (a pair of convex lenses). A collimated beam was incident into a right-angle prism and a plano-convex cylindrical lens both attached to a moving slider (Chuo Seiki). A moving line-focus beam (LFB) acts as a moving line heat source.

An infrared radiation was detected as a thermal image by a thermo-tracer (NEC Avionics, InfRec R300SR). The thermal image was recorded in real-time (30 flames/sec) by a personal computer (PC) connected with a USB bus. The thermal response was recorded as a spatial distribution ("profile analysis") and as a time-varying temperature waveform for each observation point ("trend analysis") by a PC.

1.2 Specimens

The all specimens used in this experiment were rectangular solid shaped and made with a bulk concrete block and drilled to form a simulated cylindrical void.

All specimens have the same dimension; length along which a laser scans L=40mm, width to which beam is parallel W=50mm, and the height H=60mm. A 6.5mmϕ diameter hole is drilled in each specimen such that the distances between the specimen surface and ceilings of simulated void are x=1, 2, and 3mm.

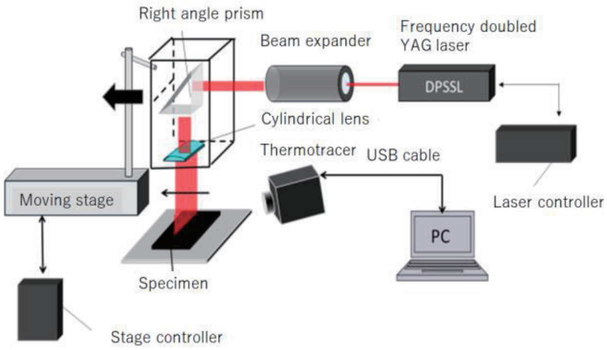


Fig. 1 Experimental setup

3. Results and discussions

1) Results with profile analysis

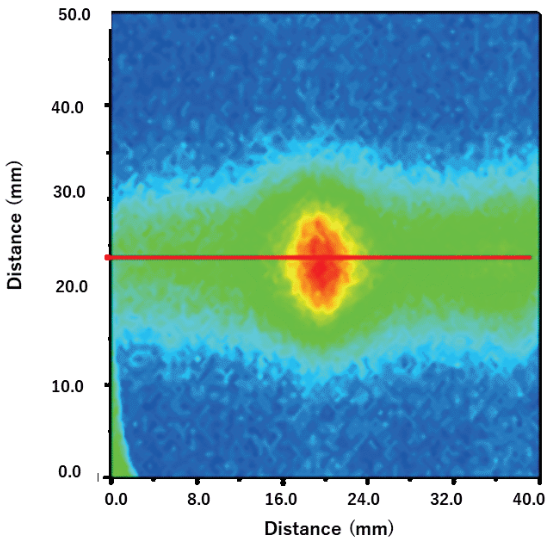
A thermal image obtained for a cylindrical void specimen with a distance x=1mm and its profile are shown in **Fig. 2** (a) and (b), respectively. The central part with a highest signal level apparently shows the existence of undersurface void.

2)Results with trend analysis

Temporal temperature waveforms or trend at the point located at the central undersurface void and a region far apart from the void are shown in **Fig. 3** (a) and (b), respectively. Recording frame-rate was as real-time, or 30 frames/sec.

3)Theoretical consideration

In ref [1], Favro et al. derived a theoretical waveform for a point-focus beam (PFB) moving heat source with a large velocity. The similar method can be applied to the LFB moving heat source in the present case using thermal parameters for cement [4]. The result shows a moving cylindrical wave form obtained for a reflection-free specimen similar to that obtained from experiment shown in Fig. 3 (a).



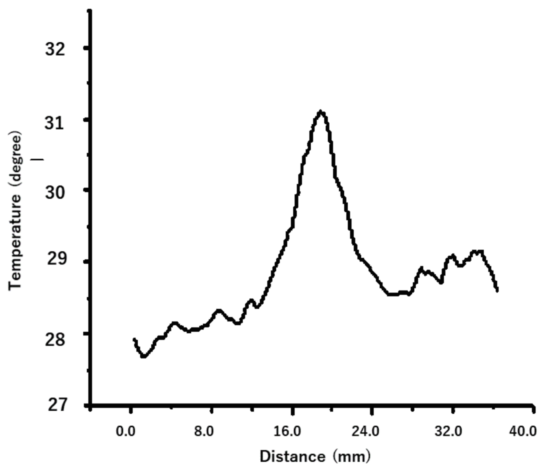


Fig. 2 (a) Thermal image (upper)
(b) Temperature distribution (lower)

4. Conclusion

In the present paper, LFB moving heat source apparatus was well designed and fabricated. Realtime measurement using thermo-tracer realized both profile and trend analyses for cylindrical shaped void-buried concrete specimens.

Each thermal images show the existence of a void-buried specimens apparently and the profile analysis shows spatial distribution of temperature. Furthermore, trend analysis shows the difference in waveforms obtained between bulk area and the defect area. Theoretical consideration supports the results.

Photothermal radiometry or active thermography using a moving LFB heat source shows its advantage in NDT for concrete specimens.

References

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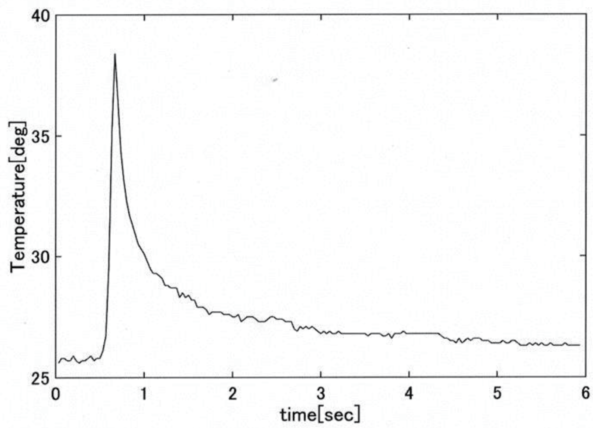

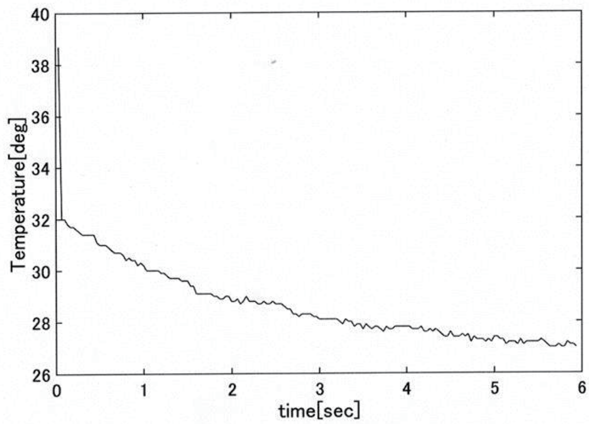

Fig. 3 (a) Upper: Temperature trend (apart from defect)
(b) Lower: Temperature trend (at the defect)
(30 frames corresponds to 1 sec.)

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