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Simulation of Surface Acoustic Wave in Shallow Layer of Heated Mortar Under Multi-frequency Ultrasound Irradiation

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1. Intoroduction

Fire damage depth assessments of concrete structures is very important in determining the scale of repair and re-use of buildings. We have studied the diagnosis of fire damage depth in shallow mortar layers using airborne ultrasounds[1-3]. In this report, a numerical simulation based on the finite element method is used to investigate the diagnosis of fire damage depth in shallow layer of mortar using multi-frequency surface acoustic waves[4-6].

2. Proposed fire damage depth assessment

Concrete under high temperatures during fire changes its chemical composition. As the result of the above changes, the elastic modulus of the concrete decreases. On the other hand, since heat is transferred from the surface, the elastic modulus in regions close to the surface layer is lower than that in deeper regions. Here, for the sake of simplicity in the analysis, we discuss mortar instead of concrete, which has a more complex composition.

Figure 1 shows a model of the elastic modulus distribution inside the mortar when exposed to high temperatures[7]. The color map shows the magnitude of the elastic modulus as high and low. Here, surface acoustic waves have the characteristic of propagating through the surface layer as much as the wavelength. Therefore, in the case of the mortar has the modulus distribution shown in the figure, surface acoustic waves are expected to have a lower sound velocity at higher frequencies. Using this phenomenon, the depth of fire damage can be estimated by measuring the change in sound velocity of multi-frequency surface acoustic waves.

Based on the above principle, a numerical simulation of sound velocity of surface acoustic waves is conducted using the model(Fig. 1).

3. Numerical simulation

Figure 2 shows the analytical model. **Table** Ⅰ shows the dimensions and material constants of the sample (simulating mortar) and the vibration

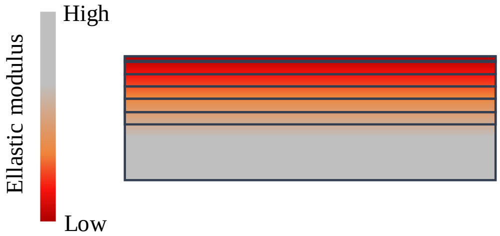


Fig.1 Fire-damage model.

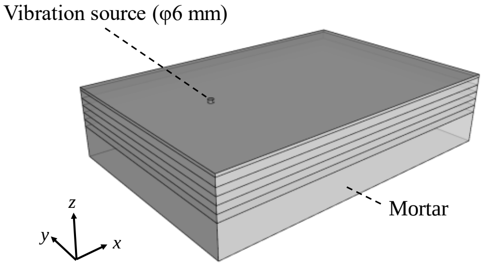
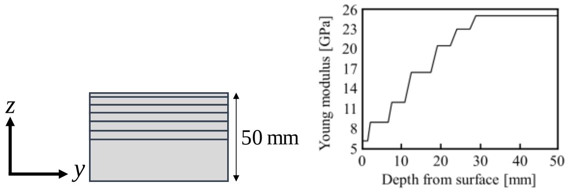


Fig.2 Schematic view of analysis model.



(a) (b)

Fig.3 Cross view of analysis model and elastic modulus distribution inside mortar.

Table 1. Analysis condition.

Elastic modulus[GPa]	6.2 ~ 25.0
Size[mm]	220 × 150 × 50
Mesh shape	Tetrahedron
Number of meshes	About 210,000
Mesh size[mm]	0.03 ~ 3
Circle diameter of vibration source [mm]	6
Time resolution[μs]	1

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conditions. The sample has a layered structure (Fig. 3), using the model shown in Fig. 2, and the elastic modulus of each layer was set to vary in steps as shown in Fig. 3(b). The frequency of the vibration source was varied from 40 to 160 kHz. The source of the vibration was at the position shown in Fig. 2. The materials used were isotropic and linearly elastic materials.

4. Result and discussion

Figures 4 and 5 show the numerical simulation results of surface acoustic wave propagation at frequencies of 40 kHz and 80 kHz. Figs (a) and (b) show the results for each time period. The results were shown in the color map. The results show that the amplitude near the surface layer is larger in all results, indicating that the surface acoustic waves propagate near the surface layer. It can also be confirmed that the higher the frequency, the surface acoustic waves propagate in the shallower layer. The sound velocity was calculated from the results of the numerical simulation and evaluated. The results are shown in **Figure 6**. For comparison, the analysis results for the healthy sample are also shown. The results show that the sound velocity of the healthy sample does not change for each frequency. On the other hand, it can be seen that the sound velocity of the fire-damaged sample decreases from low to high frequencies. In particular, above the frequency of 100 kHz, the sound velocity of the fire-damaged sample decreases to approximately 50% of that of the healthy sample. Therefore, the very large decrease in the elastic modulus is expected in the propagating layer (from the surface layer to the depth equal to the wavelength) of surface acoustic waves in these frequency bands.

5. Conclusion

The diagnosis of fire damage depth in shallow layer of mortar using multi-frequency surface acoustic waves was investigated by numerical simulation using the finite element method. As the result, the possibility of diagnosing the depth of fire damage based on changes in the sound velocity of surface acoustic waves was obtained.

Acknowledgment

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References

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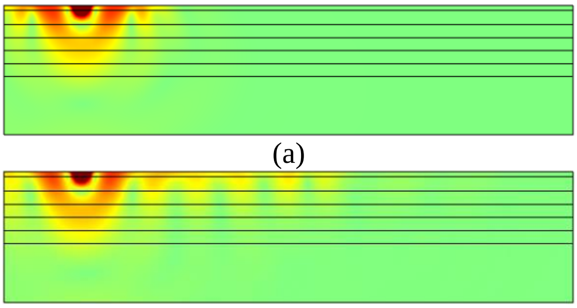
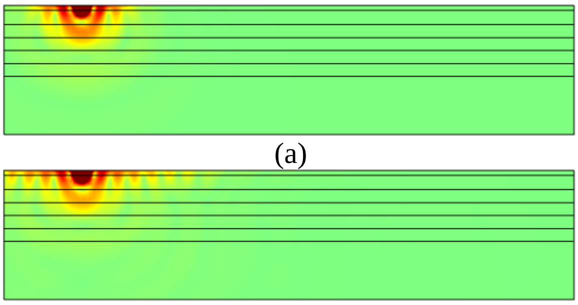

(a)

(b)

Fig.4 Propagation image of surface acoustic wave at 40 kHz.


(a)

(b)

Fig.5 Propagation image of surface acoustic wave at 80 kHz.

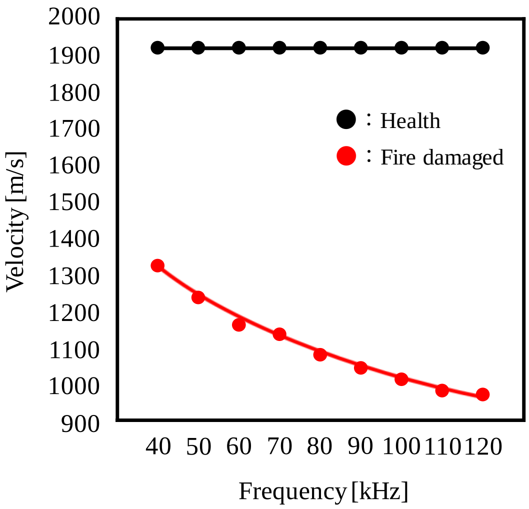


Fig 6. Relationship surface acoustic wave velocity and frequency.