Measurement of thermal conductivity of construction materials using the Hot Disk device

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In this work, the thermal conductivity values of construction materials including 3D printed samples for different directions are measured using a Hot Disk TPS 2200 (Hot Disk AB, Sweden) device. The obtained thermal properties are directly utilized to evaluate the material performance for heat flow as well as insulation and can also be utilized for numerical analysis as an input parameter. Following are some examples of the application of the Hot Disk device for building materials.

<u>Insulating cement paste specimen with Aer soilds</u>

To secure the regularly dispersed voids within the specimens, small prefabricated hollow polymetric spheres (Aer solids) are used for insulating cement paste specimens to increase the insulating effect. A series of cubic cement paste specimens with different amounts of Aer solids are produced to evaluate the effect of porosity on the thermal properties of the specimens.

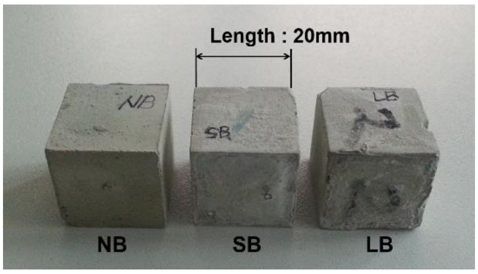

Fig. 1 Insulating specimens

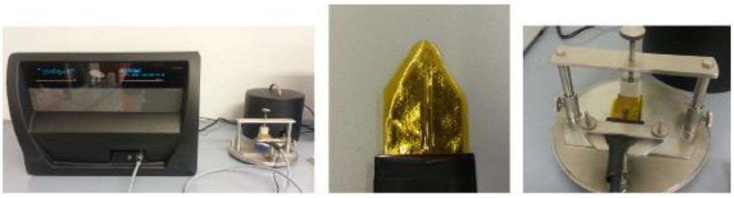

Fig. 2 Hot Disk device set for evaluating thermal property

Table 1 Thermal conductivity of insulating specimens given by FE analysis and the Hot Disk

Specimen	Void ratio [vol.-%]	Density [g/cm^3]	Simulation [W/(m·K)]	Experiment [W/(m·K)]
NB	2.27	1.625	0.5060	0.5019
SB	12.63	1.375	0.4506	0.4307
LB	20.53	1.250	0.3984	0.3644

In Fig. 1, the NB, SB, and LB denote no bubble, small amount of bubbles, and large amount of bubbles within the specimens, respectively. In Table 1, it is noticed that the differences of the results from both methods are in a reasonable range, and the properties from the methods show a similar trend; the thermal conductivity decreases as the void ratio increases.

Insulating concrete with coin-shaped insulations

The main objective of this study is to examine the effect of anisotropic pores on the thermal conductivity and strength of insulating concrete. For this purpose, a series of insulating specimens with anisotropic artificial pores as well as isotropic pores are generated to compare the physical properties of the insulating materials with different pore shapes. The thermal conductivity values of the insulating concrete specimens are measured using a Hot Disk (Hot Disk AB, Sweden) that meets ISO standard (22007-2).

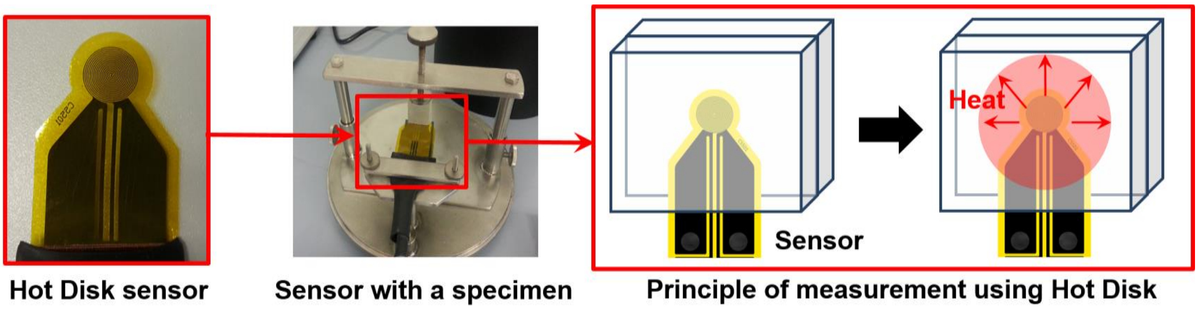

Fig. 3 Hot Disk device and its operation process for measuring thermal properties

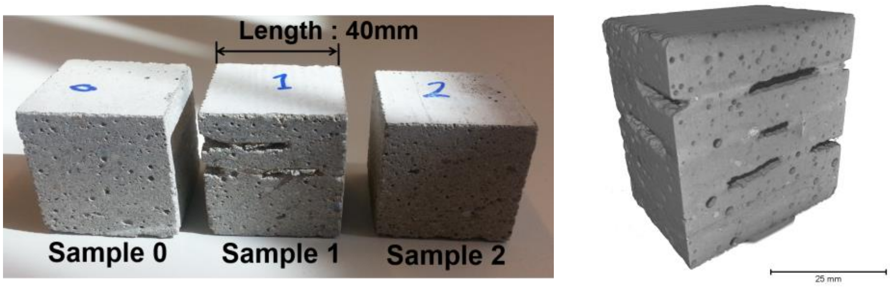

Fig. 4 Specimens with insulations (left) and μ-CT image of Sample 1 with anisotropic insulations (right)

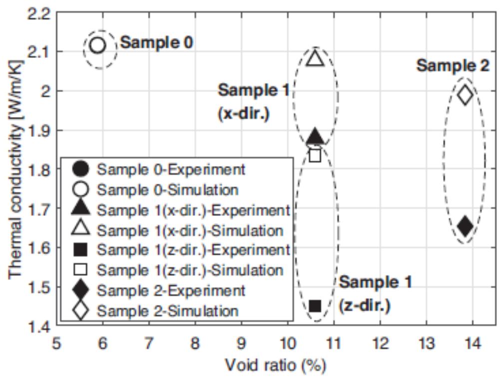

Fig. 5 Comparison of the thermal conductivity

In the experimental evaluation, 6 repeated measurements for the samples in Fig. 4 are performed for each sample and direction to enhance accuracy, and the mean value is calculated by excluding the extreme values. In Fig. 5, the thermal conductivity values obtained from experiments and simulations are presented. The differences of the properties in this figure can be considered in a reasonable range, even though a difference exists as the void ratio increases.

Lightweight concrete with different aggregate sizes

Liaver® (Ilmenau, Germany), an expanded glass granulate, is used as lightweight aggregates for lightweight concrete specimens (LWC) according to its very low density and water absorption characteristics.

Fig. 6 Liaver® lightweight aggregate

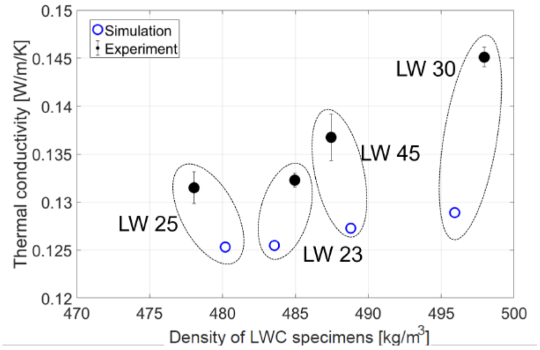

Fig. 7 Thermal conductivities of the LWC samples

Fig. 7 presents thermal conductivity values of the samples obtained from both experimental and numerical methods with respect to the specimen density. In this figure, each number denotes a grading coefficient. A general trend of the thermal conductivity related to the density and grading can be identified. Numerical data and experimental data obtained from the Hot Disk show almost identical trend, which denotes that the device can be effectively used to predict the relative thermal properties of LWC specimens with different grading curves.

Foamed concrete with different densities

This study performed to investigate the correlation between the pore characteristics and material responses of foamed concrete using both numerical and experimental approaches. The physical properties of foamed concrete specimens are measured experimentally using the Hot Disk instrument compatible with the ISO standard (22007-2).

Fig. 8 Foamed concrete with different densities

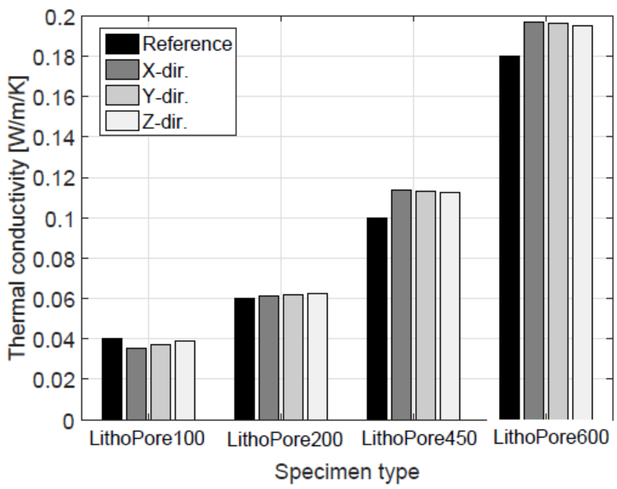

Fig. 9 Thermal conductivity in different directions

In Fig. 9, the thermal conductivity increases as the specimen density increases. The relationship of the pore characteristics and the thermal conductivity can be examined; the thermal conductivity is larger as the specimen contains larger pore clusters along that direction because more solid areas can be secured for the direction so that heat can flow. These results confirm that the thermal conductivity of the foamed specimen is strongly affected by the material density, as well as the pore shapes and distributions.

3D printed samples with anisotropic voids

The objective of this study is to examine the effect of anisotropic voids on the thermal conductivity and directional modulus of an insulating medium. For this purpose, a series of insulating media containing anisotropic (ellipsoidal) voids are designed to compare the material properties of the samples with different void ratios, sizes, and shapes. An Ultimaker 3D printer (Ultimaking Ltd., Netherlands) is used to generate samples with different anisotropic voids and distributions. The samples with anisotropic voids are printed using acrylonitrile butadiene styrene (ABS), the most widely used raw material for 3D printing, and the effects of anisotropic voids as well as void clustering sizes are experimentally investigated using the printed samples at the material level.

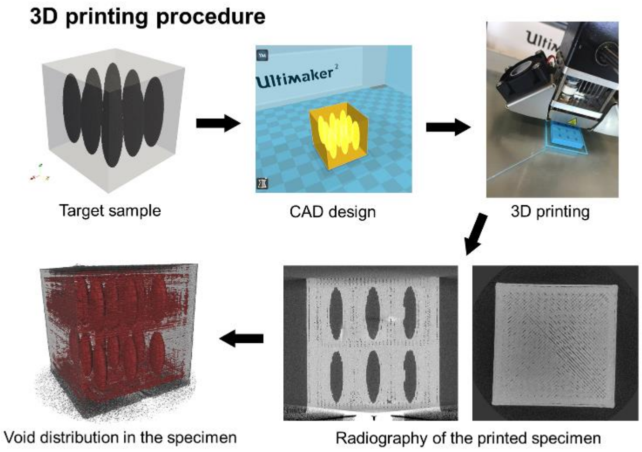

Fig. 10 3D printing procedure

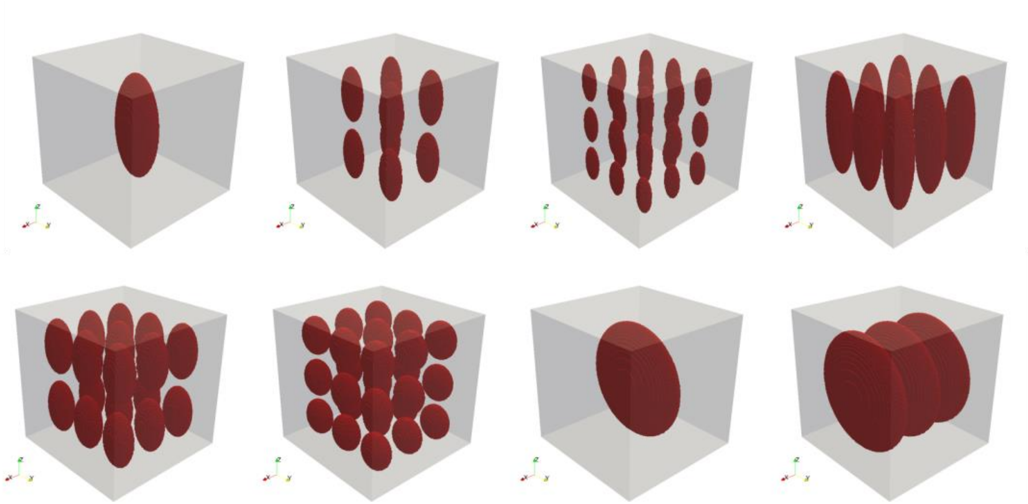

Fig. 11 Designed specimens with different anisotropic voids

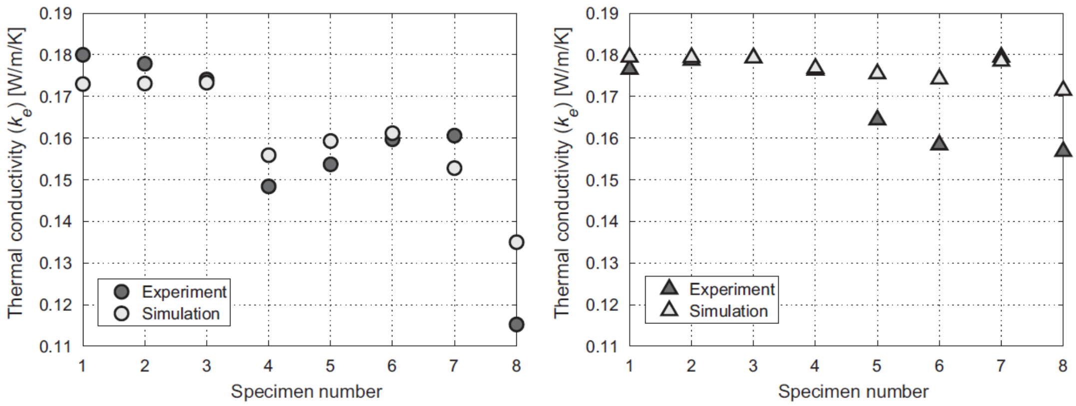

Fig. 12 Comparison of thermal conductivity for the x and z directions measured from experimental and numerical methods (left: for x-direction, right: for z-direction)

Comparison of the thermal conductivity values between the experimental and numerical methods is presented in Fig. 12; it can be confirmed that both experimental and numerical results for the thermal conductivity are in reasonable agreement. From the results, it is confirmed that the direction and the size of anisotropic pores strongly affect the thermal conductivity, and the thermal characteristics can be effectively measured using the Hot Disk device.

References

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