Measurement Capabilities and Equipment at the Building Material Characterization Laboratory of Aalborg University (2020)

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by

Hicham Johra

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1. Foreword

The aim of this short communication report is to provide synthetic information concerning the measurement capabilities and equipment of the Building Material Characterization Laboratory of Aalborg University - Department of Civil Engineering [1]. This laboratory uses state-of-the-art equipment to determine the thermophysical properties and the heat-air-moisture transport characteristics of materials, and especially construction materials.

2. Density, Mass and Volume

The bulk density of material at room temperature and atmospheric pressure can rapidly be measured by assessing the volume (dimensions) of a sample with a precision ruler, a caliper or a micrometer, and the mass of that sample with a precision scale. For a very accurate measurement of the density of small-size samples (few millimeters or centimeters), one can use a specific experimental setup mounted on a precision scale and based on the Archimedes' principle of buoyancy [2].

- Precision **caliper** "Mitutoyo": measurement up to 300 mm; resolution 0.01 mm.
- Precision **micrometer** "Mitutoyo": measurement up to 25 mm; resolution 0.001 mm.
- Precision **scale** "Sartorius Entris": measurement up to 2200 g; resolution 0.01 g.
- Precision **scale** "Sartorius Entris" with protection glass enclosure: measurement up to 220 g; resolution 0.0001 g.
- Precision **scale** "Sartorius Cubis": measurement up to 5200 g; resolution 0.1 g.
- "Sartorius" **kit** for small-size sample density measurement with **Archimedes**' principle of buoyancy: sample diameter up to 40 mm.

Figure 1: *Measurement of dimensions and volume with a precision caliper (left); accurate measurement of mass with a precision scale [3] (center); accurate measurement of the density of small-size samples with the Archimedes' principle of buoyancy on a precision scale [2] (right).*

3. Thermal Conductivity

The thermal conductivity of various types of material or entire construction elements can be measured with the appropriate equipment. The choice of the equipment mainly depends on the size of the sample to be tested: Small-size samples are tested with the Laser Flash Analysis Apparatus, medium-size samples are tested with the Guarded Hot Plate Apparatus [4], large full-scale construction elements are tested with the Guarded Hot Box, and very large full-scale construction elements are tested with the Big Guarded Hot Box. The smaller the sample the faster the measurement.

- **Laser Flash Analysis** Apparatus LFA 447 [5] (see *Figure 2*):
  - Thin sample of uniform thickness with smooth surfaces (no fibers or large pores structures).
  - Powder, liquid, slurry, layered material, graded material, anisotropic material.
  - Thermal conductivity range 0.1 – 2000 W/m.K.
  - Temperature range 10 – 300 °C.
  - Round sample of diameter 6 mm*; 8 mm*; 10 mm*, 12.7 mm*, 25.4 mm*. Thickness 0.5 – 3 mm. *can be diameter down to 1.2 mm less than prescribed diameter.
  - Scanning mode local measurement of large sample: round diameter 40 mm; square 50 x 50 mm. Resolution of 0.1 mm.
  - Measurement speed: ~ 3 min/measurement.

- **Guarded Hot Plate** Apparatus EP500 [4][6] (see *Figure 2*):
  - Cubical sample of uniform thickness with flat surfaces (compression of sample is controlled).
  - Thermal conductivity range 0.005 – 2 W/m.K.
  - Temperature range 10 – 40 °C.
  - Compression pressure range 0.05 - 2.5 kN/m² (5000 - 25000 Pa).
  - Sample dimension : 15 x 15 cm for conductive material, 50 x 50 cm for insulating material.
  - Sample thickness range 1 – 12 cm.
  - Measurement uncertainty always below 1 % and mostly below 0.5 %.
  - Measurement speed: ~ 5 hours/measurement.

Figure 2: *The Laser Flash Analysis Apparatus LFA 447 from Netzsch Gerätebau GmbH [5] (left); the Guarded Hot Plate Apparatus EP500 from Lambda-Messtechnik GmbH Dresden [6] (right).*

- **Guarded Hot Box** (see *Figure 3*):
    - Large full-scale vertical construction element.
    - Square element with dimensions ranging from 1 x 1 m to 2 x 2 m.
    - Thickness of test element up to 70 cm.
    - Temperature range -20 – 80 °C.
    - Measurement speed: ~ 1 day/measurement.

- **Big Guarded Hot Box** (see *Figure 4*):
    - Very large full-scale vertical construction element.
    - Square element with dimensions 4 x 4 m.
    - Thickness of test element up to 1 m.
    - Temperature range -20 – 80 °C.
    - Measurement speed: ~ 2 day/measurement.

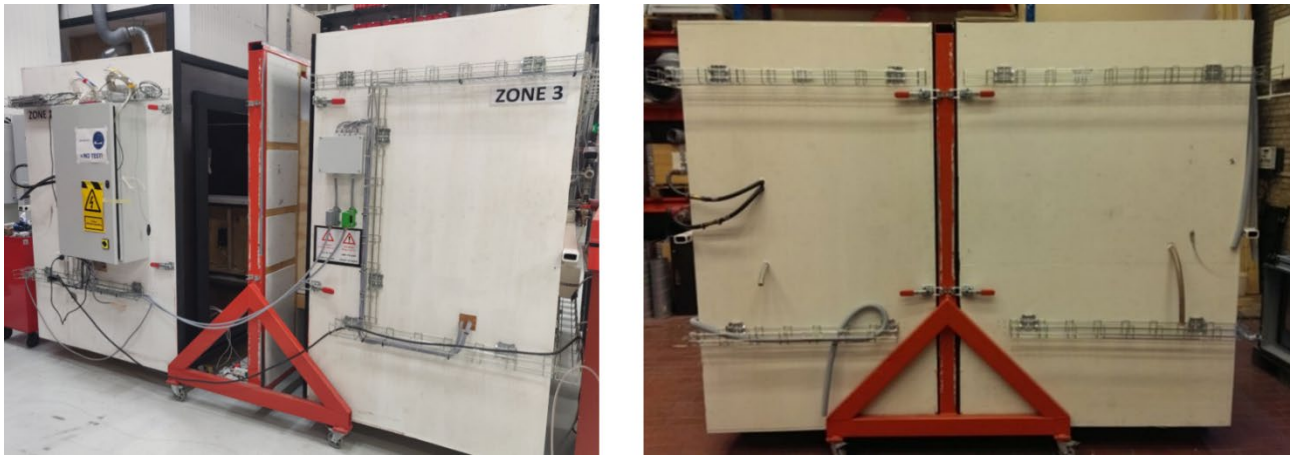

Figure 3: *The Guarded Hot Box setup at Aalborg University, Department of Civil Engineering.*

Figure 4: *The Big Guarded Hot Box setup at Aalborg University, Department of Civil Engineering.*

4. Specific Heat Capacity

The specific heat capacity of small samples can be measured with the Laser Flash Analysis Apparatus LFA 447 [5]. It is also possible to measure the local specific heat capacity of a larger sample with the scanning mode.

- **Laser Flash Analysis** Apparatus LFA 447 [5] (see *Figure 5*):
  - Thin sample of uniform thickness with smooth surfaces (no fibers or large pores structures).
  - Powder, liquid, slurry, layered material, graded material, anisotropic material.
  - Temperature range 10 – 300 °C.
  - Round sample of diameter 6 mm*; 8 mm*; 10 mm*, 12.7 mm*, 25.4 mm*. Thickness 0.5 – 3 mm. *can be diameter down to 1.2 mm less than prescribed diameter.
  - Scanning mode local measurement of large sample: round diameter 40 mm; square 50 x 50 mm. Resolution of 0.1 mm.
  - Measurement uncertainty: 5 %.
  - Measurement speed: ~ 3 min/measurement.

Figure 5: *Laser Flash Analysis Apparatus LFA 447 (Netzsch Gerätebau GmbH) [5].*

5. Thermal Diffusivity

The thermal diffusivity of small samples can be measured with the Laser Flash Analysis Apparatus LFA 447 [5][7]. It is also possible to measure the local specific heat capacity of a larger sample with the scanning mode.

- **Laser Flash Analysis** Apparatus LFA 447 [5][7] (see *Figure 5*):
  - Thin sample of uniform thickness with smooth surfaces (no fibers or large pores structures).
  - Powder, liquid, slurry, layered material, graded material, anisotropic material.
  - Thermal diffusivity range 0.01 – 1000 mm^2/sec.
  - Temperature range 10 – 300 °C.
  - Round sample of diameter 6 mm*; 8 mm*; 10 mm*, 12.7 mm*, 25.4 mm*. Thickness 0.5 – 3 mm. *can be diameter down to 1.2 mm less than prescribed diameter.
  - Scanning mode local measurement of large sample: round diameter 40 mm; square 50 x 50 mm. Resolution of 0.1 mm.
  - Measurement uncertainty: 3 %.
  - Measurement speed: ~ 3 min/measurement.

Figure 6: *Laser Flash Analysis Apparatus LFA 447 (Netzsch Gerätebau GmbH) [5].*

6. Humidity Content

The humidity content of a moist material is measured by continuously monitoring the mass loss of the test sample (with a precision scale) when it is drying in an oven (see *Figure 7*).

- Oven temperature range room temperature - 300 °C.
- Interior volume 115 L.
- Measurement method speed: ~ 1 week.

Figure 7: *Drying oven FP 115 (BINDER GmbH) [8].*

7. Hygrothermal Properties: Water Vapor Sorption and Desorption Capacity

The moisture transfer, retention and release capacity of materials can be determined by measuring water vapor sorption and desorption isotherms. This can be done by the AquaLab VSA [9] with both the static and the dynamic isotherms methods: Dynamic Vapour Sorption (DVS) and Dynamic Dew Point Isotherm (DDI). The VSA Apparatus is much faster and simpler than other conventional methods.

- **AquaLab VSA** apparatus [8] (see *Figure 8*):
  - Small-size test sample: mass range 500 – 5000 mg.
  - Sample holder volume 10 cm^3.
  - Dynamic Vapour Sorption (DVS) and Dynamic Dew Point Isotherm (DDI).
  - Relative humidity range 3 – 95 %.
  - Temperature range 15 – 60 °C.
  - Measurement accuracy of relative humidity 0.5 %.
  - Temperature stability ± 0.1 °C.
  - Mass resolution 0.5 mg.
  - Measurement speed: ~ 2 days/full isotherm.

Figure 8: *AquaLab VSA (METER Group) [9].*

8. Gas Diffusion Coefficient

The gas diffusion coefficient characterizes how permeable to gas is a porous material. It can be measured with the Oxygen Diffusion Apparatus ODA 20, an instrument that has developed at Aalborg University [10].

- **ODA 20** (see *Figure 9*):
    - Small-size cylindrical test sample: diameter 53 mm, length 50 mm.
    - Measurement speed: ~ 1-3 hour/measurement.

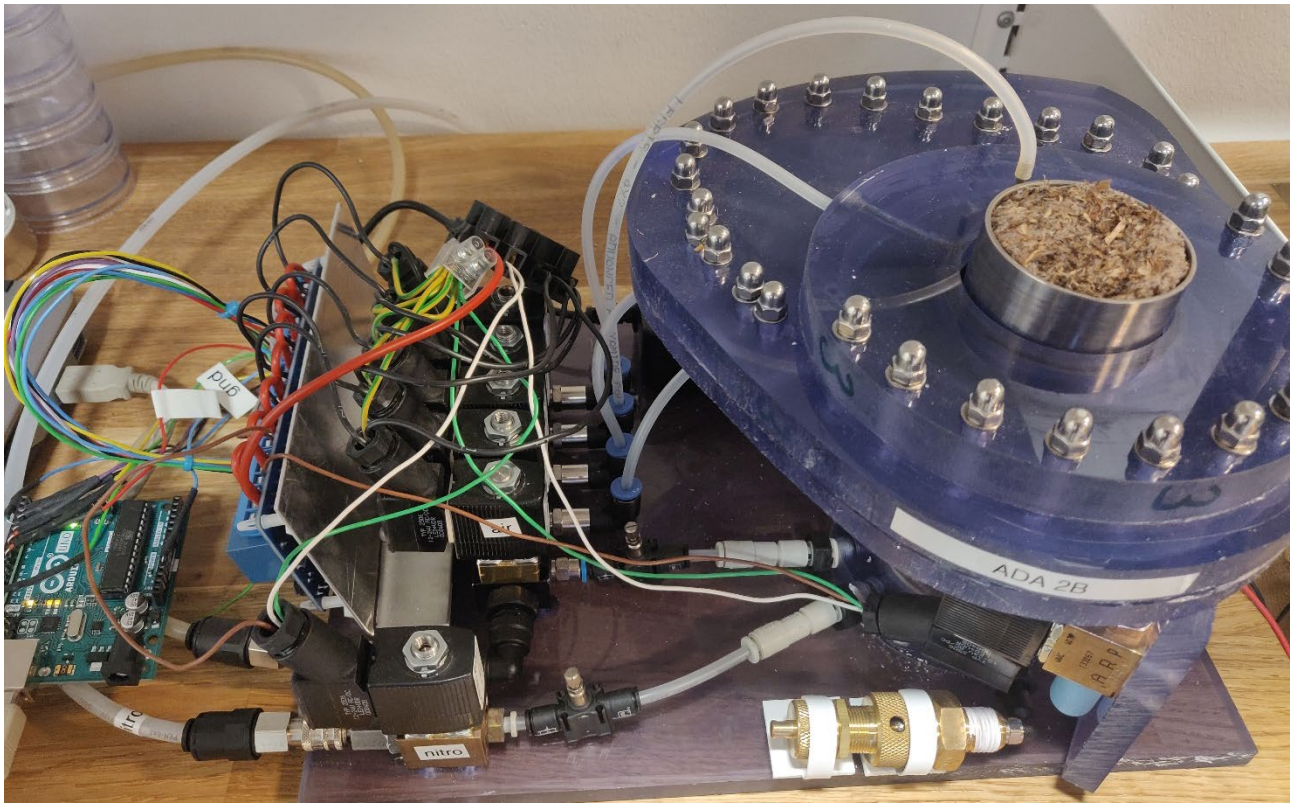

Figure 9: *The oxygen diffusion apparatus ODA 20 for the measurement of the gas diffusion coefficient in porous materials [10].*

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