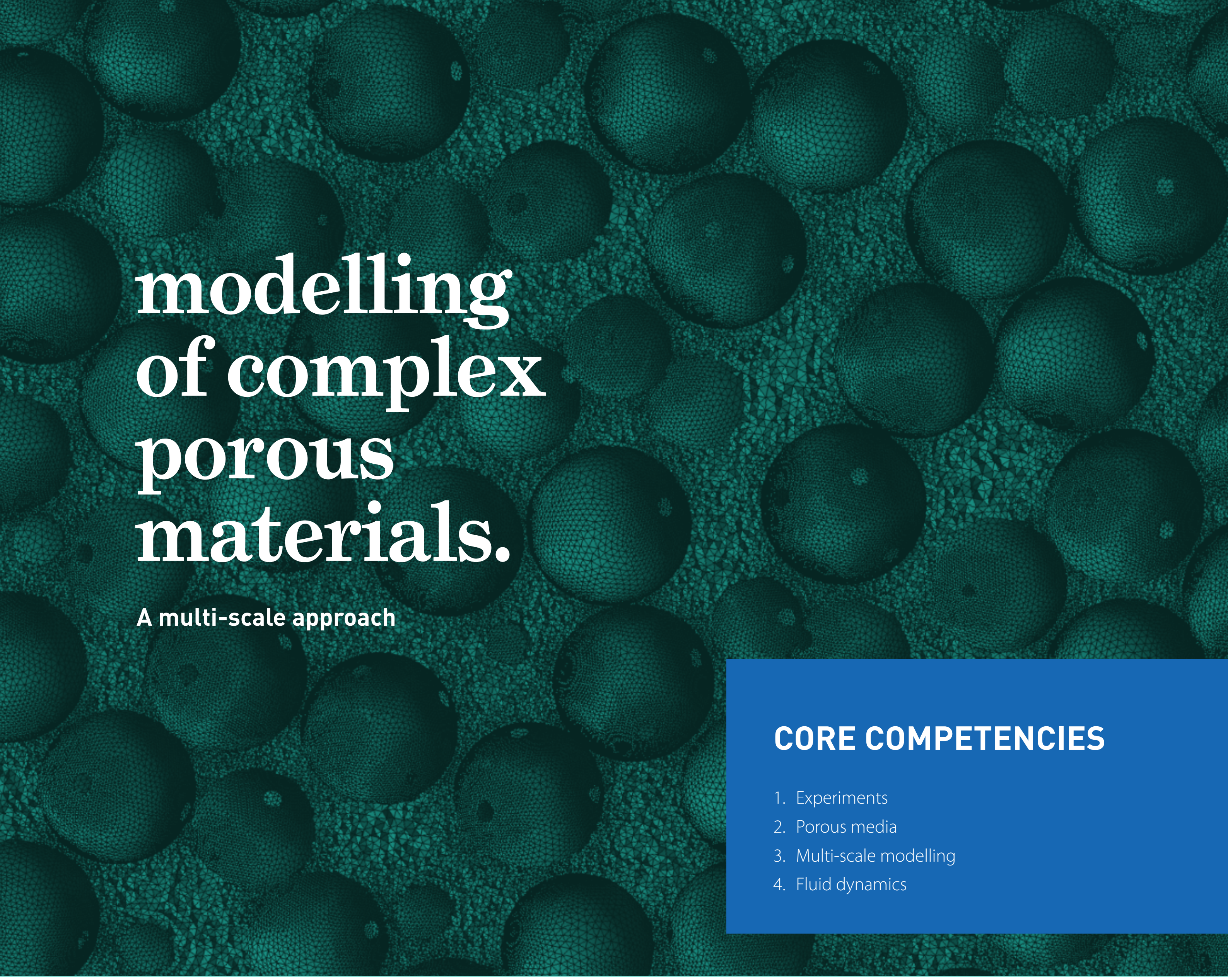

modelling of complex porous materials.

A multi-scale approach

CORE COMPETENCIES

1. Experiments
2. Porous media
3. Multi-scale modelling
4. Fluid dynamics

Analyzing flow through porous media

Porous media are widely applicable in for example filtration, ventilation, heat transfer, bio-engineering, drainage, oil extraction and drying processes. Fluid flow through porous media is an interesting but also complex field of study. This kind of flow consists of an interpenetrating liquid or gas through a labyrinth of solid material, for example, a randomly packed bed of beads, rocks, sand or straws. It could also be one solid material with holes or canals (such as a sponge).

Often, porous media are components in larger fluid flow systems. To analyze such systems, macro-scale flow and micro-scale flow are distinguished, where macro-scale flow runs through pipes, chambers and machinery and micro-scale flow occurs at the complex structure of porous components. Accurately simulating the micro-scale flow is difficult and time consuming. Instead, the porous component can be modelled as a black box, in which the main characteristics of the micro-scale flow are represented. These characteristics are the pressure drop over the porous medium and corresponding flow rate or flow velocity. To determine these, an experimental or a numerical approach can be used.

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Experimental approach

If the material of the porous component to be analyzed is already produced and easily available, an experimental setup is a fast and realiable way to obtain flow characteristics. In several projects, we used the setup shown in Figure 1, to experimentally measure the pressure loss through a porous medium. From the experimental data, the relation between pressure drop, flow rate and material length can be extracted.

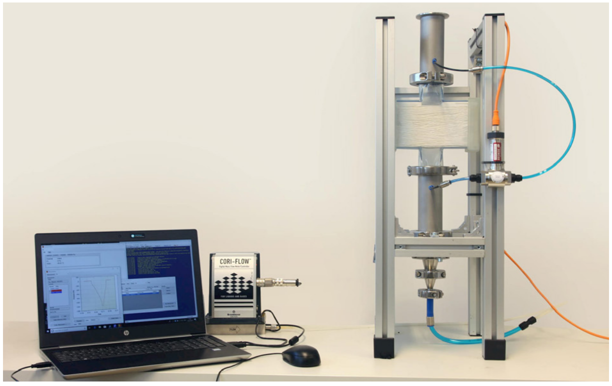

Figure 1 Experimental setup to measure pressure loss for given flow rate over a porous medium.

Numerical approach

If the porous material is not physically available or is still conceptual, a micro-scale simulation of the porous material can be used. To this end, some knowledge of the material structure is needed.

Figure 2 shows the result of a particular micro-flow simulation. Here, the flow was modelled through only a small part of the total material, incorporating a suitable void fraction and grain or pore size. Again, the relation between pressure drop, flow rate and length of the material is derived and scaled to match the total porous component.

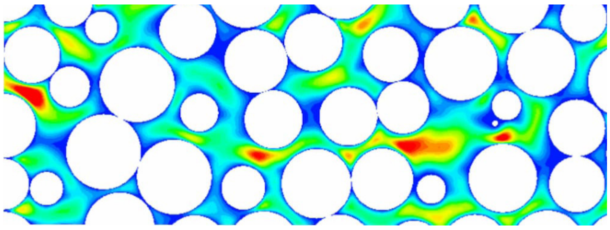

Figure 2 Flow velocity in a micro-scale flow simulation.

Comparison to analytical relations

The next step in analyzing a porous medium, is to compare the obtained characteristics from either an experimental or numerical approach to analytical relations for porous flow, such as Darcy's law or the Ergun equation. For the example in Figure 2, we were able to find a good match between the simulation and the Ergun equation (Figure 3), validating the performed simulation. Additionally, the micro-scale simulation results matched experimental data as well. Hence, we can conclude that a numerical approach works well in this case.

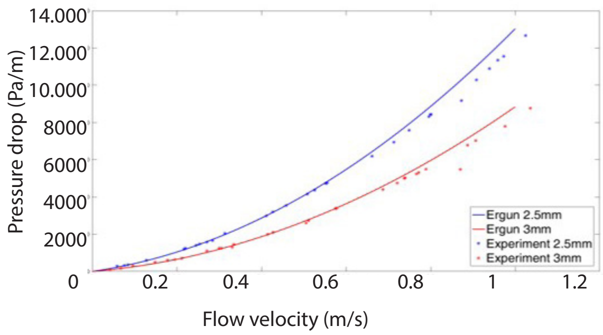

Figure 3 Measured pressure drop for two grain sizes (blue and red dots) compared to Ergun equation (blue and red lines).

Replacing the porous component by a 'black box' with the obtained flow characteristics, saves extensive simulation effort in the analysis of the larger system. This can be implemented both in a system analysis (Figure 4) as well as in a macro-scale CFD simulation.

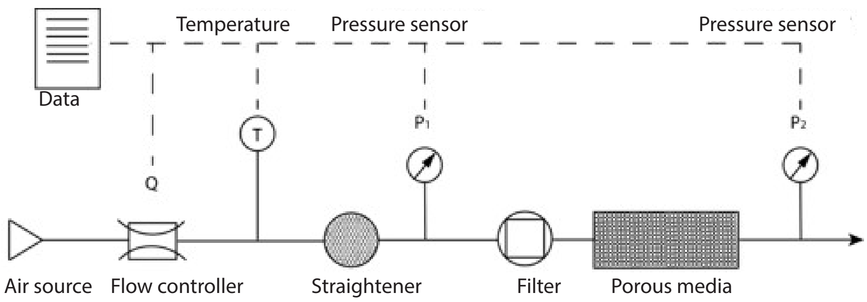

Figure 4 Flow circuit of the experiment to simulate pressure loss over the porous medium.