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POWER-LAW SCALING OF STIFFNESS/STRENGTH/CONDUCTIVITY OF ENGINEERING MATERIALS WITH HIGHLY POROUS MICROSTRUCTURE

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A wide range of natural and engineering materials is characterized by a highly-porous microstructure, i.e. may be regarded as foam at least on one scale of observation when characterized by a multiscale hierarchical composition. The spatial configuration of foams is generally classified as (i) open-cell or (ii) closed-cell microstructure.
In this contribution we discuss our recent contributions on scaling relations for select effective engineering properties - Young's modulus, compressive strength, and thermal/electrical conductivity - of highly-porous materials [1-5]. These scaling relations were obtained by analysis of unit cell-based microstructural models based on the arrangement of thin spherical shells, struts, and folded plates more or less prone to bending and/or buckling. In the highly-porous regime, the obtained scaling relations of power-law type - with effective material properties proportional to the n-th power of the volume fraction of the solid material phase - seem to represent the experimentally observed behaviour better than classical homogenization schemes from continuum micromechanics (Mori-Tanaka scheme, differential scheme, self-consistent scheme, etc.). The obtained scaling relations are compared to test data on two-scale materials: aluminium foam [1,2], graphitic foam [4], polymeric foam [1,2], and porous ceramics [1,3]. Furthermore, the power-law scaling relation was incorporated in a continuum-micromechanics based multiscale description of concrete [5], the most widely used engineering material characterized by (at least) four scales of observation, with the lowest scale characterized by high, water-saturated porosity in the tens of nm-range, and with the exact microstructure (granular, needle-like, etc.) elusive in direct experimental observation and still topic of on-going debate in the scientific community.

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