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Orthotropic Tetrakaidecahedral Foams: A Micromechanics-based Study

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ABSTRACT

Natural evolution has favored optimal spatial hierarchies to achieve multifunctionality. To decrypt the role of hierarchies on effective properties in cellular solids or foams, we derive the effective properties of tetrakaidecahedral cells (TKD) as a first step. The TKD configurations statistically mimic real-world stochastic foams. Any hierarchical arrangement of TKD cells as realizations with marginally increased connectivity requires orthotropic cells as the first-order building blocks. Therefore, we focus on Orthotropic Tetrakaidecahedral Foams (OTKD) and their structure-property relations.

We will derive closed-form expressions for effective elastic properties of OTKD foams that include Young's Moduli, Shear Moduli and Poisson's ratio by using a micro-mechanics-based approach involving energy methods. We apply Castigliano's second theorem and principle of minimum potential energy to derive expressions and showcase that all reported earlier works in literature are special cases of the effective property relations presented. Moreover, we also derive the well-known (2/9) factor that scales the Young's modulus to approximate the Bulk modulus. In summary, our work demonstrates the predictive capabilities of these relations to engineer and tailor architectures with specific property requirements.