Simple single-scale interpretations of optimal designs in the context of extremal stiffness

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It is well-known that rank-N laminates can reach the theoretical bounds on strain energy in the context of linear elasticity. The theory of homogenization-based topology optimization using this class of composite materials is well-developed, and can therefore be used to find an overall optimal material distribution at low computational cost. A downside of these optimal multi-scale designs is that features exist at several length-scales limiting the manufacturability. The main contribution of the presented work is to develop and extend on new methods, to interpret these designs on a single scale, while still being close to what is theoretically possible. Using these methods high-resolution near optimal designs can be achieved on a standard PC at low computational cost. Several modifications are given, such as a method to locally adapt microstructure spacing and a method to interpret the single-scale designs as a frame structure.

Furthermore, simple microstructures are presented that are optimized for multiple anisotropic loading conditions. This is done by approximating optimal microstructures on a single-scale, resulting in a performance that is close (*e.g.* 10-15%) to the theoretical bounds. When used as starting guess for topology optimization these proposed microstructures can be further improved, outperforming topology optimized designs using classical starting guesses both in performance and simplicity.

Finally, a class of simple periodic truss lattice structures is presented that exhibit near-optimal performance in the high porosity limit. The performance difference between closed and open-walled microstructures is presented for anisotropic loading situations, where it is demonstrated that the maximum difference occurs when isotropic microstructures are considered.