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EFFECT OF LOCAL VARIATIONS ON THE TENSILE STIFFNESS AND STRENGTH OF FIBER NETWORKS

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A number of biological and man-made materials comprise a network of bonded fibers. One of the most common materials of this kind is paper and paper board. There are several theoretical and empirical predictions for the stiffness and strength of fiber networks. Among the parameters used for such predictions for a given density of the network are the fiber mechanical properties including fiber strength, fiber dimensions, fiber orientation, the critical fracture energy of the fiber bonds and the relative bonded area. All of these parameters are subjected to variations over the network and getting reliable statistical data describing these variations is a formidable task as the tools for performing the mechanical and structural characterizations on the fiber scale are not yet developed to the required extent.

In this work, we study the effect of the variations in fiber and fiber bond properties on the average mechanical properties of a 3D fiber network having a random isotropic in-plane fiber orientation. We utilized a finite element model [1] in which fibers are discretized with 3D beam elements and the contact between the fibers is described with beam-to-beam contact elements [2, 3]. Debonding of fiber bonds is described with a cohesive zone model.

By using the simulation results, we concluded that the variation in the critical fracture energy of the fiber bonds has a major impact on the average strength of the fiber network. Meanwhile, the variation in fiber length does not significantly affect the mean strength. The average network tensile stiffness, which is largely independent of the bond fracture, is also insignificantly affected by the variations of the fiber elastic properties and fiber dimensions.

These results have important implications for the fiber bond measurements. Using the average critical fracture energy of fiber bonds is insufficient for assessing its impact on the paper strength.

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