How disorder affects the failure: Fractures on models inspired by Bamboo Guadua angustifolia

José-Daniel Muñoz

Simulation of Physical Systems Group, Department of Physics, Universidad Nacional de Colombia, Bogotá

Guadua angustifolia is an Andean Bamboo extensively employed in Colombia as building material and in the elaboration of furniture and handicrafts that uses to develop cracks in the parenchymatous tissue as a consequence of either a poor drying process or mechanical stresses like traction or bending. This talk discusses statistical-mechanics models of fracture inspired on of *G. angustifolia*, both for the drying processes and the mechanical stresses. Our first set of models resembles the cellular structure of the parenchymatous tissue on a transversal cut and are employed to model both the initial drying stage – dominated by capillarity – and the final one – dominated by uniform contraction – with finite-element and discrete-element methods [1]. Our results for the initial drying stage suggest that these fractures are driven by invasion percolation, as the drying front advances from cell to cell. In contrast, our models for the final drying stage show a critical behavior for specific values of the structural disorder, represented either by random cells or as unequal values of braking thresholds [3, 4, 6]. In fact, a phase transition between two well-defined behaviors was clearly identified: the setting of a large initial crack at low structural disorder levels and, the slow aggregation of small cracks and better resistance to failure at large disorder levels [5]. The average size of the larger avalanche can be identified as the transition order parameter and the associated susceptibility, with the average ratio between the second and the first moments of the distribution of avalanche sizes. Our second set of models resembles with discrete elements the parenchymatous tissue on the axial longitudinal direction, where large cells alternate with smaller ones at random [2]. We also found that wider distributions of breaking thresholds give better resistance to failure by bending. In addition, the random sequence of large and shorter cells increases that resistance at narrow threshold distributions. The overall conclusion is that structural disorder, whether represented in broader failure thresholds or in diverse element sizes or shapes, increases the resistance to failure, a quality that has been adopted by the parenchymatous tissue of *G. angustifolia*.

References

[1] G. V. Camargo. "A statistical model of drying-induced fractures applicable to the bamboo Guadua angustifolia". Ph.D. dissertation in Physics (Summa Cum Laude). Universidad Nacional de Colombia, 2012.

[2] J. A. Pérez Rangel. "A Molecular Dynamics study of the resistance to failure under traction for a statistical model inspired by Bamboo Guadua angusifolia". M.Sc. dissertation in Physics. Universidad Nacional de Colombia, 2016.

[3] G. Villalobos. "Acoustic emission signals resulting from the drying-induced fractures of *Phyllostachys pubescens* bamboo: evidence of scale-free phenomena". *Wood Sci. and Technol.* 50.3 (2016), p. 489. DOI: 10.1007/s00226-016-0798-0.

[4] G. Villalobos, F. Kun, D. L. Linero, and J. D. Muñoz. "Size distribution and waiting times for the avalanches of the Cell Network Model of Fracture". *Comp. Phys. Comm.* 182 (2011), p. 1824.

[5] G. Villalobos, F. Kun, and J. D. Muñoz. "Effect of disorder on temporal fluctuations in drying-induced cracking". *Phys. Rev. E* 84 (2011), p. 041114.

[6] G. Villalobos, D. L. Linero, and J. D. Muñoz. "A statistical model of fracture for a 2D hexagonal mesh: The Cell Network Model of Fracture for the bamboo Guadua angustifolia". *Comp. Phys. Comm.* 182 (2011), p. 188.