Layers of Strength

Simulation helps develop thinner composite materials using natural fibers.

By M. Nithiyakumar, Department of Textile Technology, SSM Academy of Textiles & Management, Erode, India
D. Gopalakrishnan, South India Institute of Fashion Technology, Coimbatore, India

Image © iStockphoto/jhorrocks

Fiber-reinforced composites have come a long way in replacing conventional materials like metals and woods. These types of composites are derived by combining fibrous material, which serves as the reinforcing material that primarily carries the load in the composite, with a matrix material, which bonds the fibers together, supports them and is responsible for transferring the load from fiber to fiber. The purpose of combining materials in this manner is to achieve superior properties and performance when compared to the individual materials. As truly engineered materials, designers of composites can select the composition to generate particular performance specifications based on individual application needs.

To improve the performance and durability of timber structures specifically, fiber-reinforced polymer (FRP) composites are one option that is increasingly used. Typical FRP composites found in the wood industry are composed of coir-ply boards with oriented jute (as face veneer) or coir combined with waste rubber wood (used as an internal layer). In these materials, phenol formaldehyde is often used as the matrix material.

To develop a design that meets the cost, weight and safety requirements for a specific application, a composite material's mechanical properties — especially its failure point — must be understood. In recent years, computer simulation has emerged as an effective approach for predicting load distribution and failure of composite materials.

Since each layer in a composite material may have different orthotropic material properties, special care is required in setting up the analysis. This includes choosing the proper element type, defining the layered configurations, and specifying failure criteria and individual layers' material properties. Solving fracture mechanics problems computationally involves performing a linear elastic or elastic–plastic static analysis and then using specialized post-processing commands or macros to calculate desired fracture parameters. Each of the products in the ANSYS family of mechanical simulation solutions allows for the modeling of composite materials with specialized elements, called layered elements, that support nonlinearities such as large deflection and stress stiffening. To learn more about FRP composites, researchers used these elements in the creation of five finite element (FE) models of varying thickness and layer configurations for analysis.

For each model, the tensile stress and deforming behavior were analyzed. Input data — such as density, Young's modulus, shear modulus and Poisson's ratio — was provided. The coir and jute, which was impregnated with phenolic resin, were considered as isotropic materials. Wood was considered as an orthotropic material.

The simulations were divided into two sets of material combinations. Set 1 included three simulations of FRP composites that were composed of an increasing number of layers of phenolic coir and wood. Set 2 used two of the three compositions from Set 1 but replaced a wooden layer in the composition with a phenolic jute layer.

The Young's modulus of the phenolic coir is only 4.3 GPa, while the modulus value of the wood is as much as 16 GPa in the direction of the grain — but only 1 GPa in the direction perpendicular to the grain. The modulus of jute is up to 40 GPa, and that of phenolic jute is 7.5 GPa, which is higher than that of phenolic coir. When deformed, the elongation of the coir is as much as 40 percent, while the elongation for jute is only 1.5 percent. This indicates that the introduction of the phenolic jute layers into the FRP composite should lead to significant improvement in tensile stress values.

The simulation results showed that the load was distributed to all the layers and throughout the entire parts. The edges were well gripped and there was no deformation. The deformations were controlled by the composite energy of the material. Even though the layers were individually separate, their movement or tendency for separation was controlled by the adjacent layers.

From the results of the simulation, it also appeared that, regardless of composition, the tensile stress gradually increased with thickness. The deflections seen in the models that did not include phenolic jute layers (those in Set 1) were higher than those seen in the equivalent models from Set 2. One thing that was noted was that the thicker of the two models in Set 2 used a thicker phenolic jute layer than the other to replace the wood layer. This was important because it explained what appeared to be a reduction in deflection that occurred with an increase in overall material thickness, which did not otherwise match the trend seen in the data.

The thickest composite model from Set 2 was found to have a tensile stress greater than its equivalent case from Set 1, though the deformation was the same. The same model from Set 2 was also found to have tensile strength equivalent to a thicker model from Set 1, but with the same deformation. This meant that, in comparison, the option from Set 2 could provide a decrease in the amount of material used without a significant variation in tensile strength and deformation.

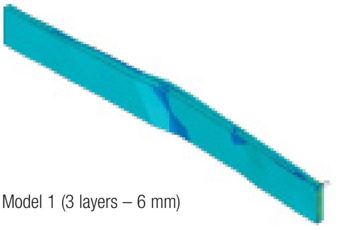
Using mechanical simulations and coordinated experimentation, it was concluded that even though the tensile stress values of computational models cannot be accurately compared to the real boards, due to the non-homogeneous nature of the real material, the deformation tendency is the same for both. In this way, mechanical behavior could be correlated. In this study, it was also demonstrated that inclusion of the phenolic jute layers gave composite boards higher stiffness and eliminated the need for one layer of wood in these particular materials. Simulation helped demonstrate that stronger mechanical properties could be obtained at lower thicknesses, leading to benefits such as reduction in cost and weight. ■

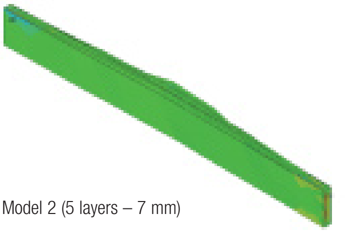
References

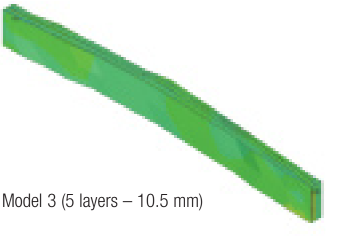
[1] Nithiyakumar, M.; Gopalakrishnan, D., "Development and analysis of jute and coir reinforced composites," www.fibre2fashion.com/industry-article/1/89/development-and-analysis-of-jute-and-coir-reinforced-composites1.asp, 2007.

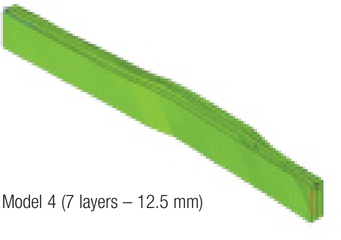
Model	Set	Description	Total Thickness of Model (mm)	Max. Stress (Mpa)	Deflection (mm)
M1	1	3 layers (2 phenolic coir + 1 wood)	6	90.9	2.14
M2	2	5 layers (2 phenolic coir + 1 wood + 2 phenolic jute)	7	184	4.3
M3	1	5 layers (3 phenolic coir + 2 wood)	10.5	215	6.9
M4	2	7 layers (3 phenolic coir + 2 wood + 2 phenolic jute)	12.5	241	3.8
M5	1	7 layers (4 phenolic coir + 3 wood)	15	264	8

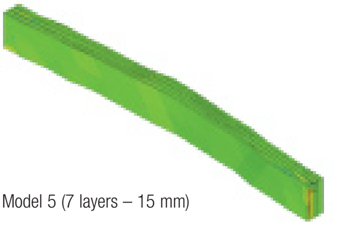
Description of simulation models and results for FEA simulations of FRP composites


Model 1 (3 layers – 6 mm)


Model 2 (5 layers – 7 mm)


Model 3 (5 layers – 10.5 mm)


Model 4 (7 layers – 12.5 mm)


Model 5 (7 layers – 15 mm)

Tensile stress for the five models of jute and coir reinforced composites studied