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Encapsulated OSB Energy Absorption Potential: A preliminary analysis

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1. Introduction

The transport of radioactive substances is, in many ways, necessary in the context of the nuclear fuel cycle that aims to generate energy or radioisotopes. The packages responsible for transporting and storing used fuel elements and radioactive waste are equipped with bolted or welded locking systems, and mainly, supplied with shock absorbing parts. In the event of a possible accident, the shock absorbing parts reduce the mechanical stresses on the other components of the transport packaging, since a large part of the kinetic energy is absorbed by the shock absorber, which, compared to the container and the impact body, is more resilient [6].

The container must provide shielding to protect workers, the public and the environment from the effects of radiation, to prevent an unwanted chain reaction, heat damage and also to protect against dispersion of the contents. To standardize the design of the fuel assembly transport devices by numerical analysis, a set of dynamic analyzes was conducted to representatively converge the phenomena found in the drop tests used in project qualification [7].

This study aims to present a comparison of different ways of applying wood as a useful and accessible impact absorbing material. The necessary numerical modeling characteristics are validated and the phenomena present in non-isotropic materials are discussed.

2. Methodology

To start interpreting the phenomena and characteristics of wood, it is first necessary to define what cellular solids are. Composed of an interconnected network of supports or solid plates that form the edges and faces of cells. Typically, in one of three different formations, as shown in Fig. 1.

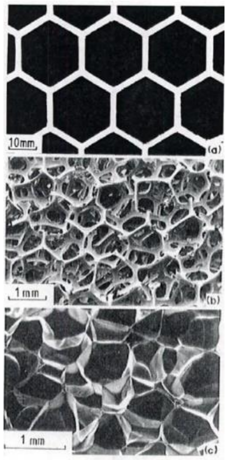

Figure 1: Main cellular solid formations, [3].

The simplest, Fig.1(a), is formed by a two-dimensional array of polygons that group together to fill a flat area with hexagonal cell materials such as honeycombs. Most commonly, cells are made up of polyhedrals that cluster in three dimensions to fill space; also called three-dimensional cellular materials foams. if the solid from which the foam is made is contained only at the edges of the cells (so that the cells connect through open faces), the foam is said to be an open cell, Fig. 1(b). If the faces are also solid, such that each cell is sealed off from its neighbors, it is said to be a closed cell, Figure 1(c); and, of course, some foams are partially open and partially closed [3].

The control of the different properties of wood is such that it is hard to write constitutive equations in order to cover each variation, species, formation, characteristic or origin. However, it is possible to propose a progression in adding different complexities allowing to study their effects at each step. Fig, 2 tries to summarize this procedure, so that the most recommended step is chosen for a given application, considering the properties of the Material (elasticity, viscoelasticity, plasticity, humidity, temperature), the Anisotropy (longitudinal, radial and tangential), the Structure (Polar Orthotropic, Grain Direction, Density, Cell Structure, Knots) and Heterogeneity (Earlywood, Latewood, Fibers, Ray Cells, Heartwood, Knots).

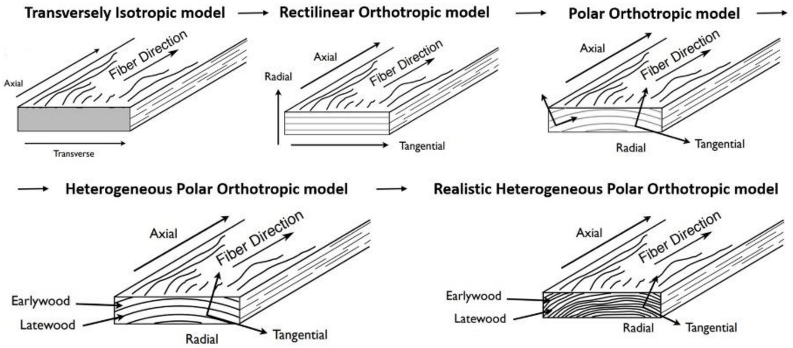

Figure 2 : Mapping Wood Complexities, modified from [5].

The most direct wood factors to be considered in numerical modeling are: *Fiber Position* – Axial to radial/tangential curves can vary widely, by a factor of up to 10, depending on species. However, statistically, when a lower percentage of Latewood, the greater the resistance in the radial component, in a higher percentage it presents greater resistance in the tangential direction; *Density* – density variation, densification; *Temperature* – The effect of temperature is due to the variation of intermolecular forces of attraction (hydrogen bridges), which are weakened by the frequency of atomic or molecular oscillations caused by temperature. The magnitude of influence is additionally a function of the shape of the sample with which the characteristics are determined (-20°C to 60°C – 40%; -20°C to 150°C – 55% of the Modulus of Elasticity); *Moisture* – Wood should be understood as a partially porous, hygroscopic (absorbs moisture from the air) and capillary substance. The proportion of cavities on average is 50 to 60% of the volume. Wood can acquire and store water through capillary absorption and transport processes;

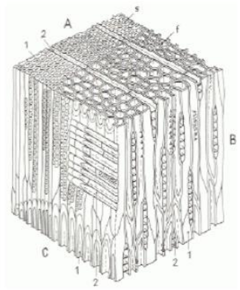

Figure 3 : Wood microstructure, [7].

The Oriented Strand Board (OSB) is made from fine wood flakes primarily from commercially grown trees. The predominant orientation of the flakes gives it relatively higher mechanical properties in the direction of the flakes (the longitudinal direction of a board) than in the transverse direction. OSB is therefore an orthotropic material [2].

The results of the work carried out in [8] demonstrate that OSB is an orthotropic material with its strongest properties in the direction of wire orientation. So OSB is stronger in compression than tension. In traction, OSB behaves linearly to near failure, while in compression it exhibits plasticity. In elastic-plastic behavior in compression, it exhibits a stress-strain curve similar to a parabola. There is little difference in the OSB's modulus of elasticity in tension and compression, which allows a single value to be used in both cases. Thus, it was proposed through Benchmark 3 of [7], once the methodology and phenomena were validated through a solid model, to quantitatively predict the difference in the orientation of the flakes, or here also called fibers.

The fibers were studied in two orientations, parallel and perpendicular to compression.

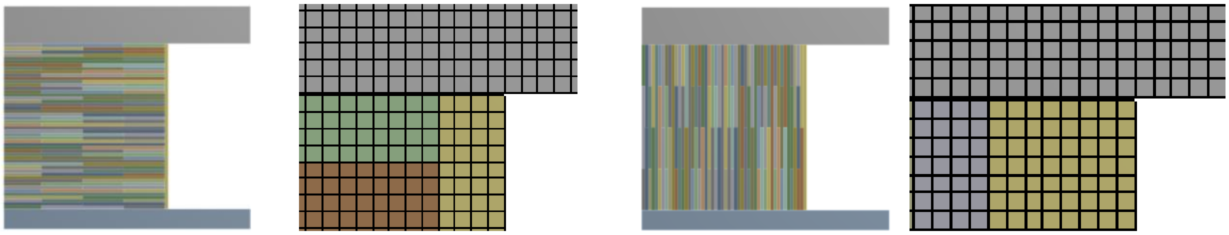

Figure 4 : Finite element models, parallel (left) and perpendicular (right) – element size of 0.25 mm.

From finite element method angle, the material model 24 (MAT024 – MAT_PIECEWISE_LINEAR PLASTICITY) of LS-DYNA [4] is widely used in the simulation of shock-type events as an isotropic material model with the VON MISES stress flow criterion [4].

3. Results and Discussion

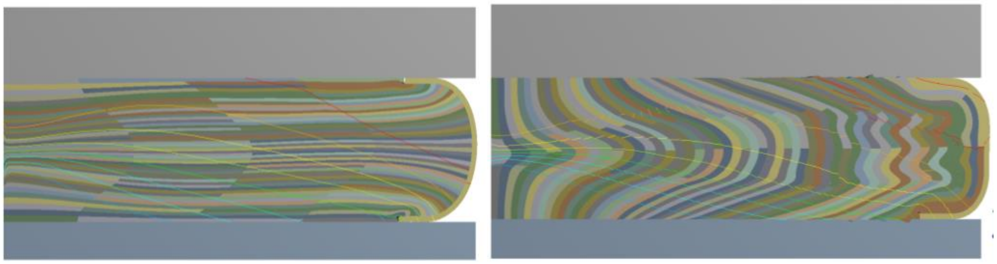

Figure 5 : Finite element models, parallel (left) and perpendicular (right).

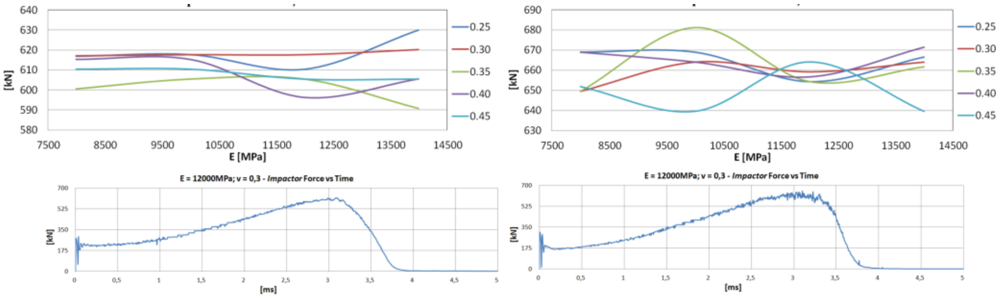

Figure 6 : Results varying the Poisson and modulus of elasticity for both compression cases.

Through this study it is possible to comparatively notice the difference in the fiber deformation process and when observing the development of strength over time in both cases, one can infer the influence of the fiber's torsion on the energy absorption potential, increasing the absorption capacity by approximately 10%.

4. Conclusions

In summary, it was possible to satisfactorily estimate the gain in energy absorption capacity and to study the influence in varying the Poisson and the modulus of elasticity for wood in a crash set. Thus, it is possible to design a shock absorber using OSB as the filling material, suitable for different situations in a way to ensure maximum performance and protection.

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