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Analysis of the out-of-plane compression and shear response of paper-based web-core sandwiches subject to large deformation

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Abstract: The mechanical response of three different structural core sandwich panels in out-of-plane compression and shear has been analyzed. Specific core shapes examined are arc-tangent, wavy trapezoidal and hemispherical. Unit cells consisting of representative elements of the core attached to face sheets were selected for analysis. Both face sheets and core were assumed made from paper. Finite element analysis employing large deformation and rotations and orthotropic elastic–plastic behavior was used. The results show that the arc-tangent and trapezoidal cores are prone to collapse by extensive bending and buckling, whereas the hemispherical core behaved more stably in compression and shear. Core sheets with a hemispherical shape were prepared from copy paper sheets in a specially designed forming machine. Sandwich test specimens were prepared from this core and tested in out-of-plane compression, and the load-displacement response was compared to predictions from finite element simulations. The experimental and finite element results were consistent.

1 Introduction

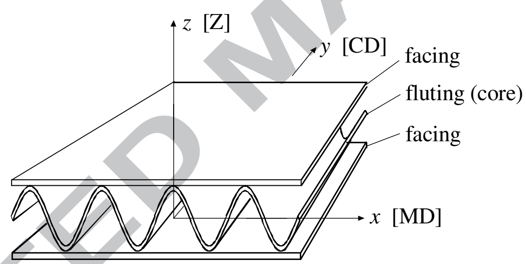

Figure 1. Corrugated core sandwich.

The structure known as corrugated paperboard is made in a converting process in which three or more layers of paper are laminated together. The core, which is called fluting, is shaped into a sine-wave in a corrugator and glued to the outer layers, called the liners, thus forming a sandwich panel. The resulting structure is strong and stiff with respect to its weight. Corrugated board is considered orthotropic, i.e. having three mutually perpendicular planes of symmetry. The principal directions of material symmetry of a corrugated core sandwich are defined as machine direction (MD), cross direction (CD), perpendicular to MD in the plane, and the out-of-plane thickness direction (Z), Fig. 1.

In service, a corrugated paperboard box will be subject to a number of different loading situations. Typically, compressive loads are involved. This might be the case when e.g. a number of filled boxes are stacked on top of each other. This loading might then cause a global instability due to in-plane compressive loads acting on the vertical panels so that they fail due to buckling. Such loading will also cause out-of-

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