On the crush worthiness of laterally confined structures under axial compression

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Thin-wall elements such as plates and tubes are widely used as crush absorbers, whether individually or as an integral part of structural components. From a standpoint of energy absorption per unit volume, such entities are not very much efficient because in addition to the occurrence of a considerable unused space, energy dissipation is mostly limited to isolated regions such as in plastic hinges. Other concerns that may arise in the application of such elements are their tendency to collapse in a low-energy asymmetric mode or undergo global buckling

Crush studies on honeycombs, polymeric foams and balsa wood, to name a few, indicate that tighter packing or greater material density may be a promising approach for enhancing the specific crush energy. A somewhat similar approach is the use of various types of fillers in a single or multiple tube design. Such helps stabilize the deformation, decrease the wavelength of the deformation, and reduce the likelihood of Euler buckling. A simple and instructive prototype of this class of designs is offered by laterally confined plates or tubes. An important function of the lateral confinement is to reduce the wavelength of the characteristic buckle, thereby soliciting additional energy dissipation in the form of axial deformation, shearing and friction between contacting surfaces. This concept is studied in this work.

The specific crush energy of laterally confined bars or tubes under axial compression is studied as a function of the geometric parameters of the system as well as degree of confinement. In-situ testing and FEM simulations are used to elucidate energy dissipation modes and basic geometric features of the deformation process. This information is then incorporated into analytic models employing a rigid-plastic and incompressible material response to derive closed-form expressions for the crush energy as a function of the system parameters.

Lateral confinements tend to reduce the wavelength of the characteristic buckle, thereby soliciting additional energy dissipation mechanisms over the common plastic hinging and circumferential extension, including axial compression, shearing and friction. It is shown that this approach may greatly enhance the specific crush energy as compared to common cellular structures.

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