

## Mechanical Behavior of Square Honeycomb Core Sandwich Cylindrical Shells under Radial Compressive Load (Postprint)

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### Abstract

By combining metal thin-walled tubes with honeycomb structures, a square honeycomb sandwich cylindrical shell structure is proposed. The mechanical behavior of the square honeycomb sandwich cylindrical shell under radial compressive loads is investigated through experiments and finite element analysis software ABAQUS/Explicit. The accuracy of the finite element model is verified through comparison, the deformation modes of the structure under radial compressive loads are analyzed, and the enhancement mechanism of the structure is discussed. The study demonstrates that the square honeycomb sandwich cylindrical shell structure undergoes three deformation stages under radial compressive loads: elastic stage, plastic stage, and folding collapse; the structure dissipates more crush energy primarily through the formation of plastic hinges and core wrinkling; compared with the simple superposition of single-layer cylindrical shells and cores, both the load-bearing capacity and energy absorption of the square honeycomb sandwich cylindrical shell are improved, and the structure achieves coupling enhancement mainly through the formation of plastic hinges. Further parametric discussion results show that increasing the dimensionless core wall thickness will enhance the peak force and specific energy absorption of the square honeycomb sandwich cylindrical shell.

### Full Text

## Study on the Mechanical Behavior of Square Honeycomb Sandwich Cylindrical Shells Under Radial Compression Loading

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Honeycomb structures have been widely applied in numerous load-bearing and blast-resistant engineering applications. Cylindrical shell structures in service environments are frequently subjected to radial compression loads. The honeycomb core configuration determines the deformation mode of honeycomb sandwich cylindrical shells. Compared with traditional hexagonal honeycomb structures, square honeycomb structures exhibit higher structural efficiency during crushing processes. Over the past decade, research has focused on improving the crashworthiness of these cylindrical shell structures to reduce damage to personnel and equipment.

Zeng Jie [3] investigated the deformation behavior and energy absorption modes of metallic cylindrical shells under radial impact, finding that energy absorption through plastic deformation was relatively inefficient. To enhance the energy absorption performance of cylindrical shells, researchers have explored various reinforcement methods. bINN et al. [ ] conducted experimental studies on aluminum foam-filled cylindrical shells under radial compression, demonstrating that the specific energy absorption under radial loading showed greater improvement compared to axial loading, particularly for thin-walled metallic cylindrical shells. 7bI,M et al. [ "&] fabricated all-metallic sandwich cylindrical shells with square honeycomb cores using brazing techniques, revealing substantial enhancements in energy absorption performance compared to monolithic cylinders. However, no research has yet investigated their mechanical behavior in the radial direction. Therefore, this study aims to obtain comprehensive compression mechanical properties to provide reference data for practical applications and structural design.

## Experimental Methods

The fabrication process began with machining inner and outer cylinders via turning operations. Rectangular and annular slotted metal strips were then assembled together through an interlocking process. Subsequently, TA+ $\Gamma$  adhesive was uniformly applied to the outer cylinder, inner cylinder, and prepared components. Under identical conditions, the assembly was heated to 1&% v to volatilize the polymer binder. The brazing temperature was maintained at '% "% v, followed by annealing at this temperature for 1% 9;C. The relevant geometric parameters of the experimental specimens are listed in Table '. Specifically, the core thickness of sandwich cylindrical shell specimen 6' was %+" 99, while specimen 6" had a core thickness of %+& 99.

Quasi-static radial compression experiments were conducted at room temperature on specimens 6' and 6" using a hydraulic testing machine. Figure " presents the tensile stress-strain curve for 1% stainless steel material, including the elastic modulus >Pk' 23 Mc: and numerical data for the plastic stress-strain segment.

## Finite Element Modeling

To ensure simulation accuracy, a ductile metal damage constitutive model (4QCP)C0/)H was incorporated into the 1% stainless steel material model. Based on this constitutive relationship and according to reference [“], specific parameters are detailed in Table “. Additionally, /)Q.P;U. element models were introduced to simulate the adhesive bonding between the three components through A;. tie constraints, as illustrated in Figure !. Following reference [ “3], manufacturing imperfections were neglected. Two rigid panels were employed to simulate the indenters. The modeling approach is shown in Figure 1 [Figure 1: see original paper].

Four-node shell elements (6!O) with & integration points were used to mesh the surfaces. The compression speed was set to ’ 99DP, and the friction coefficient was defined as %+ “. Since minimal angles may exist during actual experiments, to accurately simulate the physical conditions, an angle of ’ i% was introduced between the indenter displacement direction and the symmetry plane of the square honeycomb sandwich cylindrical shell.

## Results and Discussion

Figure 2 [Figure 2: see original paper] compares the collapse modes of monolithic inner/outer cylinders, square honeycomb core, and square honeycomb sandwich cylindrical shell under radial compression. The overall failure patterns of the monolithic cylinders and sandwich structure are broadly similar. However, the sandwich cylindrical shell exhibits significantly more plastic deformation zones, particularly at the interfaces between the square honeycomb core and the inner/outer cylinders. The structure achieves coupling enhancement primarily through the formation of plastic hinges.

The following conclusions were drawn: (1) The square honeycomb sandwich cylindrical shell undergoes three distinct stages under radial compression loading—elastic stage, plastic stage, and folding collapse stage. (2) For the sandwich structure, pronounced debonding occurs between the square honeycomb core and the inner/outer cylinders, accompanied by core wrinkling and fracture. Nevertheless, the load-bearing capacity and energy absorption of the square honeycomb sandwich cylindrical shell are substantially improved, with numerous additional plastic deformation zones contributing to enhanced performance.

*Note: Figure translations are in progress. See original paper for figures.*

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