

# Honeycomb Structures as a Helmet Liner Material: Use of Artificial Neural Network Modeling to Predict Helmet Liner Safety for Known and Experimental Helmet Liner Materials

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Despite advancements in helmet technology, traumatic brain injury is still a grave threat to health and safety. Polymer foams, including expanded polystyrene (EPS), are today's common energy absorbers. Honeycomb structures also appear to have the desired properties for an effective helmet liner material. This research intended to quantify the relationship between impact velocity, thickness, density, and industry standard safety criteria (Peak Linear Acceleration (PLA), Head Injury Criterion (HIC), Gadd Severity Index (GSI), and strain) for both materials separately and in layered hybrids. The safety criteria were collected by dynamic drop tests at impact velocities between 0.86 and 7.0m/s for EPS (n=243), ALHC (n=370), and layered hybrid samples (n=663) at varying density and thickness combinations. Neural network models were then trained with these data using GMDH software. Correlations for these models ranged from 0.87 to 0.99 (R-squared ranged from 0.72 to 0.99). The trends of the models were generally consistent with published literature on the subject: as thickness increases, the helmet liner becomes safer and as the material becomes denser, the helmet liner becomes safer at higher-impact velocities while sacrificing some performance at low-impact velocities. Furthermore, when compared at overlapping densities and thickness, ALHC were able to maintain safer impact criteria than EPS, particularly at higher impact velocities. Hybrids tended to favor one of the materials in regards to thickness combinations, steering away for evenly split thickness combinations. Since ALHC were able to maintain better safety criteria, it is reasonable to conclude that honeycombs could contribute to an improved helmet liner.