This thesis focuses on the development of a streamlined process used to create novel meso-scale patterns that can induce negative Poisson's ratio (NPR) behavior at the bulk scale. This process includes the development, optimization, and implementation of a candidate pattern. Currently, the majority of NPR structures are too porous to be used in conventional applications. For others, manufacturing methods have yet to realize the meso-scale pattern. Consequently, new NPR meta-materials must be developed in order to confer transformative thermos-mechanical responses to structures at high temperature. Additionally, patterns that take into account manufacturing limitations, while maintaining the properties characteristically attached to negative Poisson's Ratio materials, are ideal in order to utilize the potential of NPR structures. A novel NPR pattern is developed, numerically analyzed, and optimized via design of experiments. The parameters of the meso-structure are varied, and the bulk response is studied using finite element analysis (FEA). The candidate material for the study is Medium-Density Fiberboard (MDF). This material is relevant to a variety of applications where multiaxial stresses, particularly compressive, lead to mechanical fatigue. Samples are fabricated through a laser cutting process, and a comparison is drawn through the use of experimental means, including traditional tensile loading tests and digital image correlation (DIC). Various attributes of the elasto-plasticity responses of the bulk structure are used as objectives to guide the optimization process.