Application of the Granular Micromechanics Approach to Bimodulus Materials in Structural Members

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Abstract

Many materials, such as masonry and concrete, exhibit bimodulus behavior characterized by different stiffness properties in tension and compression. Classical beam models for such materials often assume sharp transitions and neglect the effects of axial forces. In this study, a granular micromechanics framework is adopted to overcome these limitations. The model is first applied to simple beam configurations to examine its impact on criteria such as the neutral axis position, stress distribution, and stiffness variation. Additionally, the key topic of the thrust line (LT) in masonry arch structures is computed based on the stress field.

The results clearly show that in beam structures, unlike monomodular materials (where the neutral axis remains centered), bimodular materials demonstrate a noticeable shift in the neutral axis. The granular micromechanics model captures this shift accurately and provides a physically consistent basis for understanding its cause. Moreover, the framework enables a smooth transition of stiffness from tension to compression regions.

Applying this model to arch structures, we determine a representative stiffness ratio (n) that governs the asymmetry between tension and compression. As n increases, the LT path converges toward the theoretical trajectory defined by Heyman's no-tension model, providing a solid bridge between microstructural mechanics and classical theory. Finally, the robustness of the identified stiffness ratio is verified by applying it to arches with varying geometries. For each configuration, the LT obtained through granular micromechanics is compared with Heyman's solution. The results confirm that once n exceeds a critical threshold, the LT remains consistently aligned with the idealized no-tension formulation, validating the model across a wide range of structural forms.

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