

Damage evolution in thin adhesive layer with tension–compression asymmetry: predictive asymptotic models

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In structural engineering, accurate modeling of material damage is crucial, particularly the tension–compression asymmetry observed in quasi-brittle materials and adhesive joints. While cohesive interface models are commonly employed in the analysis of bonded structures, the parameters of these models frequently lack a direct correlation with the physical properties of the adhesive layer. To address this issue and capture the tension–compression asymmetry, this study uses asymptotic analysis to derive two new interface damage models (termed F1d and F2d) from a thin damaging interphase [1]. The proposed models are formulated within a thermodynamically consistent framework [2]. The F1d model uses a single damage variable with an asymmetric evolution law, whereas the more advanced F2d model uses separate variables for tensile and compressive damage, enabling independent evolution kinetics [3]. To bridge the gap between scales and link macroscopic damage to micro-defect evolution, the new models are coupled with two micromechanical schemes: the non-interacting Kachanov–Sevostianov model and the Mori–Tanaka–Benveniste model, the latter of which accounts for defect interactions. The theoretical formulations of the models are presented, and their predictive capabilities are demonstrated through numerical simulations of a bonded joint under axial loading.

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