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A unified constitutive model bridging Critical State soil mechanics and $\mu(I)$ - $\phi(I)$ rheology

Granular materials exhibit distinct mechanical regimes governed by deformation magnitude and rate, yet constitutive models remain regime-specific. Critical State Soil Mechanics (CSSM) describes plastic yielding and failure across small to large quasi-static deformations, while the $\mu(I)$ - $\phi(I)$ rheology captures rate-dependent steady flow from slow to fast deformation rates. This work unifies these approaches into a single framework by reformulating both as product functions of a shared critical state line, with consolidation history and grain inertia treated as independent corrections related to the distinct regimes. The resulting model is thermodynamically consistent, incorporates non-associated plasticity naturally, and transitions smoothly between quasi-static and inertial regimes without additional parameters. Benchmark via drained and undrained triaxial tests across varying consolidation histories and strain rates confirms that the model recovers both parent theories in their limits and captures transitional behaviours. It also predicts rate-dependent responses in normally and overconsolidated clays.