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Fractional order plasticity modelling of state-dependent behaviour of granular soils without using plastic potential

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ABSTRACT: The strength and deformation behaviour of granular soil is strongly 15 16 dependent on its stress state and loading history. Due to the change of soil state, the plastic flow direction and loading direction are usually non-coaxial and a plastic potential different 17 from the plastic loading function is generally mandatory for capturing correctly volumetric 18 deformation. For that, some state variables have been involved phenomenologically in plastic 19 equations, bringing about some complexity in model formulations and physically 20 meaninglessness of certain parameters. This paper presents a new approach to describing the 21 state-dependent stress-dilatancy behaviour of granular soil using fractional order derivations. 22 Unlike integer-order derivative in the classical plasticity theory, the fractional order 23 derivative is defined in an integral form. Originally, we relate the description of soil state to 24 the definition of the integral lower and upper limits respectively as the current and critical 25 stress states. By performing a fractional order derivative of the plastic yield function, a state-26 dependent stress-dilatancy equation is set up without additional state variables. As the 27 integration range increases, the flow direction deviates gradually from the loading direction. 28 However, they coincide with each other when critical state is reached where the lower and 29 upper limits merge. For validation, an elastoplastic constitutive model is developed by 30 incorporating the fractional equation into the modified Cam-clay model. A series of drained 31 and undrained triaxial test results for different granular soils are simulated, and the issue of 32 plastic energy dissipation in each simulation is also addressed. 33

34 KEYWORDS: Fractional plasticity; Constitutive modelling; State dependence; Soils

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