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Estimation of Scour Using a Coupled Computational Fluid Dynamics and Discrete Element Model

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Abstract : Scour has been identified as the most common threat to bridge stability worldwide. Traditionally, scour around bridge piers is calculated using the empirical approaches that have considerable limitations and are difficult to generalize. The multi-physic nature of scouring which involves turbulent flow, soil mechanics and solid-fluid interactions cannot be captured by simple empirical equations developed based on limited laboratory data. These limitations can be overcome by direct numerical modeling of coupled hydro-mechanical scour process that provides a robust prediction of bridge scour and valuable insights into the scour process. Several numerical models have been proposed in the literature for bridge scour estimation including Eulerian flow models and coupled Euler-Lagrange models incorporating an empirical sediment transport description. However, the contact forces between particles and the flow-particle interaction haven't been taken into consideration. Incorporating collisional and frictional forces between soil particles as well as the effect of flow-driven forces on particles will facilitate accurate modeling of the complex nature of scour. In this study, a coupled Computational Fluid Dynamics and Discrete Element Model (CFD-DEM) has been developed to simulate the scour process that directly models the hydro-mechanical interactions between the sediment particles and the flowing water. This approach obviates the need for an empirical description as the fundamental fluid-particle, and particle-particle interactions are fully resolved. The sediment bed is simulated as a dense pack of particles and the frictional and collisional forces between particles are calculated, whilst the turbulent fluid flow is modeled using a Reynolds Averaged Navier Stocks (RANS) approach. The CFD-DEM model is validated against experimental data in order to assess the reliability of the CFD-DEM model. The modeling results reveal the criticality of particle impact on the assessment of scour depth which, to the authors' best knowledge, hasn't been considered in previous studies. The results of this study open new perspectives to the scour depth and time assessment which is the key to manage the failure risk of bridge infrastructures.

Keywords : bridge scour, discrete element method, CFD-DEM model, multi-phase model
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