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A New Material Point Method Cohesive Zone Treatment for Problems of Large Deformation

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When modeling granular compaction with dilute binder phases, the limiting numerical length scale is often the wetted binder thickness. Sufficiently resolving these thin interfaces significantly increases the computational cost. Moreover, these phases are often several times more compliant than the bulk granular material. To circumvent this restriction, we introduce a new cohesive zone treatment compatible with the material point method for problems of large deformation, fracture, contact and plasticity. Contrary to previous cohesive zone treatments involving the introduction of massless cohesive particles, this approach involves computing the cohesive displacements and tractions inside a reference grid configuration from which cohesive forces are mapped back to cohesive surface particles. During standard particle to grid mapping, these cohesive forces are remapped to the current grid configuration. Importantly, this method requires no additional particles and permits cohesive zones to act across an arbitrarily large number of grid cells. The additional computational overhead of the cohesive zones is limited by computing relevant cohesive nodal properties in the reference grid configuration only and updating them dynamically. We demonstrate its integration with damage field partitioning and contact in complex loading problems. We also touch upon improvements to contact calculations of nanoindentation and granular compaction involving severe plastic flow that arise from explicitly defined particle surface normals and positions required by the cohesive zone method. All work demonstrated here is implemented in the open-source GEOS Material Point Method solver.