**Dynamic Behavior of Heterogeneous Materials: Integrating Experiments and Digital Twin Numerical Modeling at Different Length Scales**

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**Brief Biographical Sketch**

Dr. Sohanjit Ghosh's expertise lies in the high-strain rate behavior of materials with applications in defense, industry, and planetary sciences. Sohanjit has developed novel experimental techniques and computational models to understand deformation in geomaterials such as rocks, sand, and concrete under hypervelocity impact (velocities on the order of a few km/s). Sohanjit completed his B.Tech. from IIEST Shibpur in 2019 and his M.Tech. from IIT Kanpur in 2021. Subsequently, Sohanjit moved to Johns Hopkins University to pursue his PhD in Mechanical Engineering, graduating recently. He is about to start his postdoctoral research at the California Institute of Technology, beginning in August 2026.

**Abstract**

Understanding the behavior of heterogeneous materials, like naturally occurring granular sand, rocks, and artificial concrete, has critical applications in modern-day society, from defense to industry. The macroscopic response of these materials under dynamic loading is dictated by mechanisms at lower length scales and the inherent heterogeneity of their microstructure, for example, the porosity, grain network, grain morphologies, grain size distribution among others. In the first part of this work, we discuss experiments using in-situ X-ray imaging on various granular materials subjected to plate impact. To obtain 3D grain-scale information, we complement the in-situ experimental imaging with numerical simulations initialized with data from X-ray computed tomography (XRCT). The simulations help address several long-standing problems in rapid granular compaction. For example, we examine the transition from quasistatic to dynamic deformation regimes as the impact velocity increases. We also provide a detailed assessment of the capabilities and limitations of theoretical pore collapse models, in predicting the crush response of these materials. At a much larger length scales, we use laser sheets coupled with ultra high-speed video imaging to quantify the 3D velocities of ejecta particles from concrete subjected to different gas-gun impact conditions. We demonstrate that the ejecta velocities are strongly correlated with the kinetic energy of the incoming projectile and that ejecta feature ballistic fast-moving grains, slower fine dust, and even slower spallation fragments. We then develop a predictive continuum framework in the multiphysics code GEOS to investigate the role of strength variability in the impact cratering response of concrete. We validate our model predictions with experimental data for crater dimensions, subsurface damage, and ejecta velocities. In summary, this work employs experimental and numerical approaches to investigate the dynamic behavior of heterogeneous materials at various length scales, establishing a pathway to link these phenomena.