Numerical simulation of underground explosions near a buried structure

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Abstract:

The problem of a buried explosion, subsequent propagation of the shock waves, and their attenuation with distance is of substantial interest and great complexity. The interaction of these waves with a buried obstacle is of an even greater interest for many applications, yet it presents a further increase in complexity.

There exists a rather well developed theory for explosions in air and liquids, and a number of methods are available to assess the blast loads acting on a structure above the ground as a function of the explosive characteristics and the geometrical data. A similar problem of explosions in soils and rocks is not nearly as well understood due to its considerably higher complexity. The propagation of shock waves in such media is a rather intricate phenomenon, it is strongly affected by a much more sophisticated constitutive model, including irreversible bulk compaction (with or without full locking) and deviatory elastic plastic behavior (that depends on the current pressure). An additional difficulty is associated with the soil porosity and water content.

In the talk, we will address a number of issues related to the blast response of a lined buried structure due to an underground explosion. The constitutive modeling of the soil medium is based on a bulk irreversible compressible elastic plastic medium, including full bulk locking and dependence of the current deviatoric yield stress on the pressure. We are currently working on extending this model to account for its solid, air and water fractions. The structure is represented either as a rigid inclusion of a given shape or as an elastic plastic structural element, often with the circular shape of a tunnel lining. We will present a coupled 2D Godunov − variational difference approach for the soil-structure interaction due to a nearby explosion, including the process of soil-structure real contact conditions, e.g., transient separation of the soil from the structure's boundary. The approach is based on coupling the shock and rarefaction waves with finite difference equations of the shell motion by means of a simple iteration method. It allows the reduction of the contact problem to a self-similar symmetric Riemann problem.

The contact stress distribution and the soil free surface motion are studied as they depend on the soil and lining properties, and on the scaled distance between the charge and the structure. Some of the observations with regard to the interaction stresses, deformation patterns, and explosion's crater shape will also be presented.