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SIMULATION OF SHOCK WAVE PROPAGATION AND DAMAGE IN GEOLOGIC MATERIALS

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ABSTRACT A new thermodynamically consistent material model for large deformation has been developed It describes quasistatic loading of limestone as well as high-rate phenomena. This constitutive model has been implemented into an Eulerian shock wave code with adaptive mesh refinement. This approach was successfully used to reproduce static triaxial compression tests and to simulate experiments of blast loading and damage of limestone. Results compare favorably with experimentally available wave profiles from spherically-symmetric explosion in rock samples.

INTRODUCTION: Geologic materials demonstrate very complex constitutive response under large deformations. Traditionally data on quasistatic triaxial compression are available from laboratory experiments. While it is important to use this data to constrain the material model under low strain rate, it is also important to have rate-dependent material model in order to simulate dynamic damage and shock wave propagation in geologic materials.

The nonlinear thermodynamical framework developed by [Rubin, *et al*, 1996] and [Rubin, *et al*, 2000] is used to propose and analyze constitutive equations. The elastic response is based on hyperelastic free energy function. The deviatoric stresses are limited by the yield surface. Volumetric inelasticity is described by porosity change, which includes incipient porosity compaction and dilatancy (bulking) during shear plastic flow. Some of the porosity change is recoverable under unloading. In order to simplify material response at high pressures it is common to uncouple evolution of volumetric and deviatoric inelastic deformations. While it is reasonable approach for metals, rock response is more complicated. Shear enhanced compaction of rocks is usually simulated using evolving cap approach. The model developed provides correct material response using general equation of state and cap-like response at low pressures. The model is constrained by second law of thermodynamics and ellipticity (hyperbolicity) criteria. An explicit predictor-corrector type of integration is used to make an efficient and numerically stable implementation.

PROCEDURES, RESULTS AND DISCUSSION: Laboratory data were used to calibrate the model. calibrated using .that included elastic properties, unconfined compressive strength, and a pressure dependent failure surface. The model fit of to experimental data for static loading of a rock sample is depicted on figure 1. Different loading paths show complex response of the model, including strain hardening, strain softening (damage) at low pressures, dilatancy at high shear stresses and shear enhanced compaction. Dynamic properties of limestone were calibrated against velocity profiles in spherically-symmetric explosion. In the J. Gran experiment [2004] a Composition B explosive charge weighing 54.9 g was detonated at the center of an instrumented 815-mm block of dry Salem Limestone. Dremin loop velocity gauges were used to measure radial particle velocity. The comparison of experimental and simulated velocity profiles is shown on the Figure 2. The calculated profiles show good agreement with experimental data at early time, when the flow field can be reasonably viewed as spherically symmetric. The model can be extended to take into account not only porosity specific to intact lab samples, but extra porosity of large rock masses attributed to in situ crack and faults in them. Usually this secondary porosity can be compacted easier then primary porosity. Model also can be extended to describe wet material with taking into account modified comaction curve and Terzagi effective stress concept.

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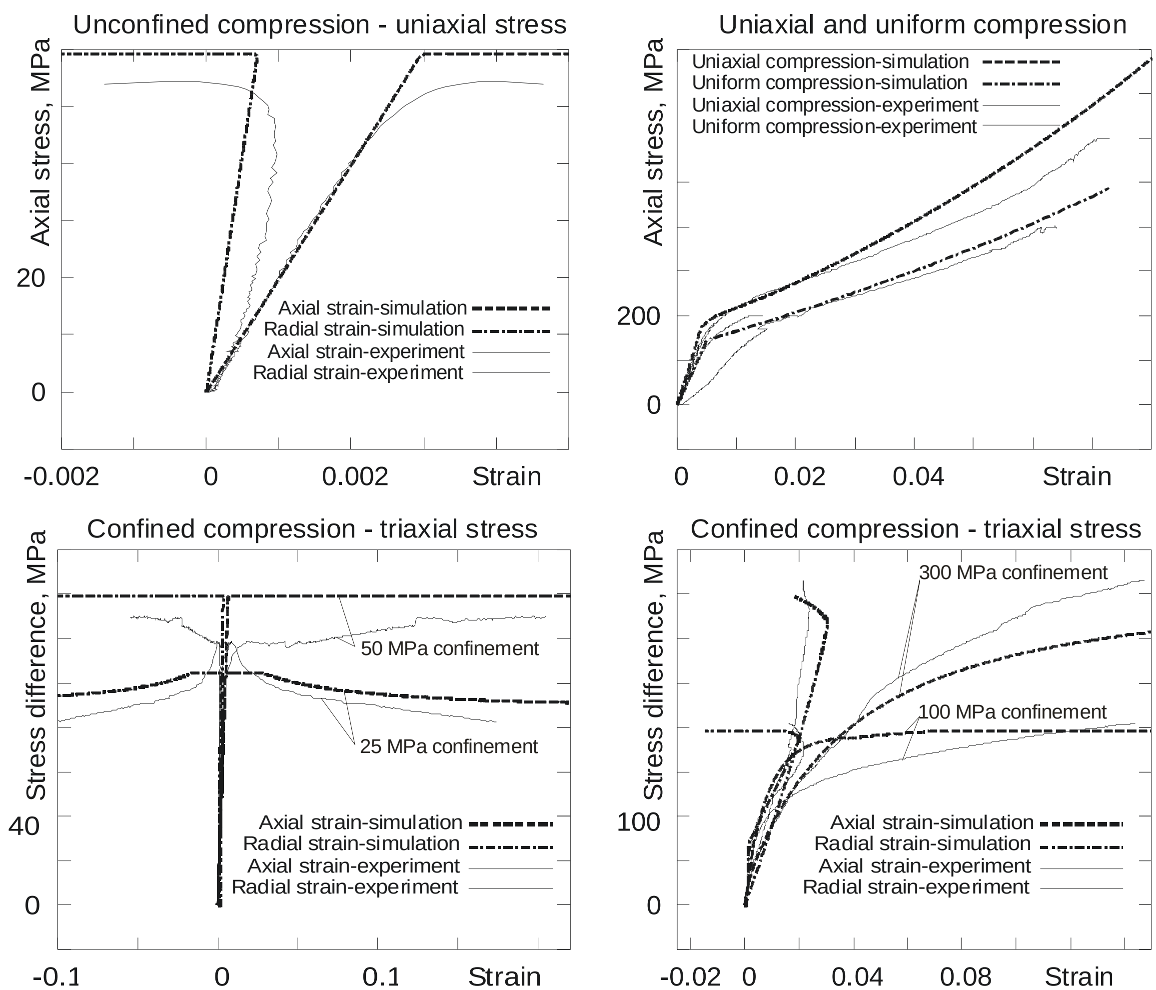

Fig.1 Experimental and calculated stress profiles for different static tests.

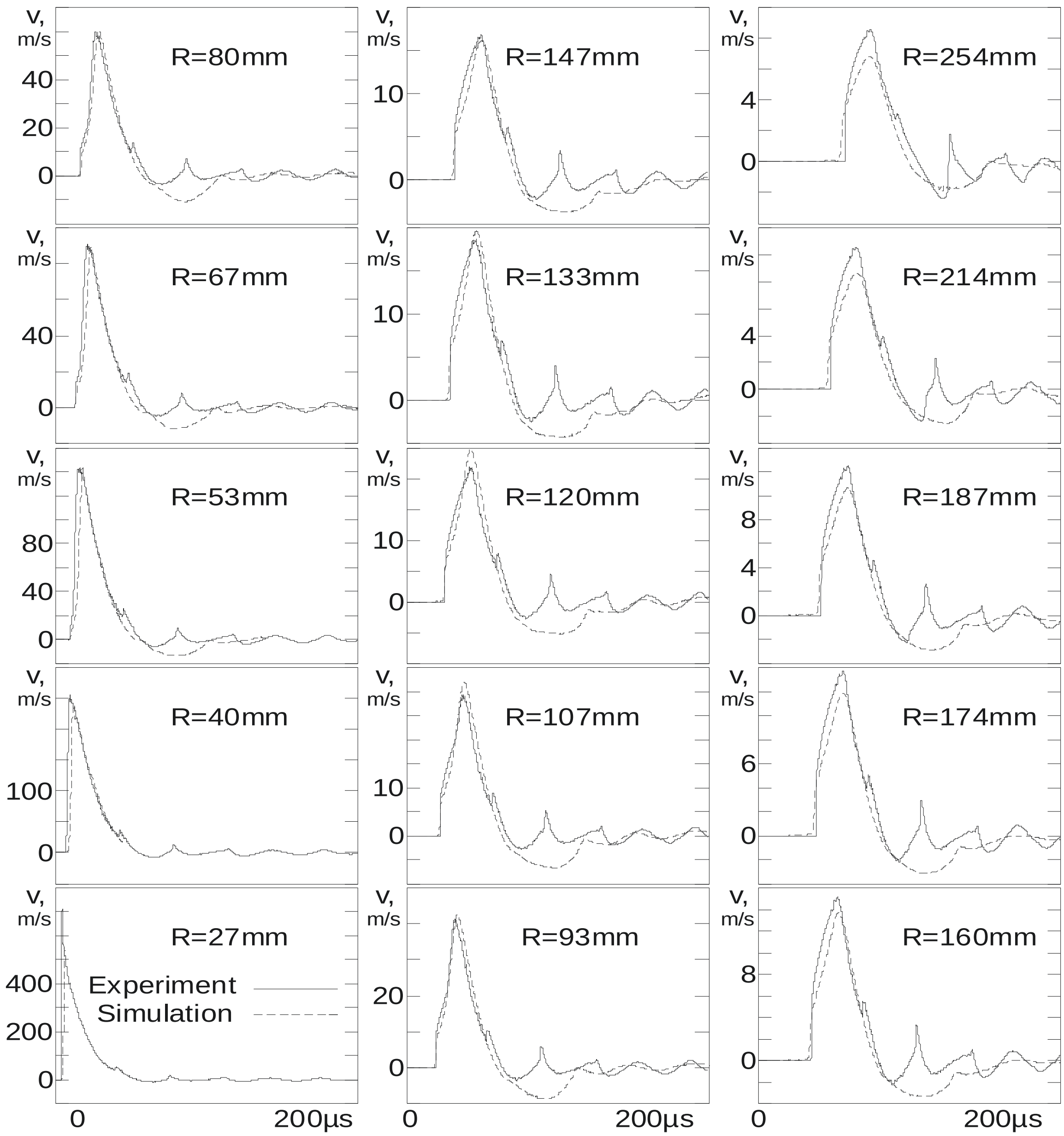

Fig.2 Calculated and experimental velocity profiles at different distances from explosive

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