APPLICATION OF STOCHASTIC FINITE ELEMENT METHOD FOR FAULT FORMATION ON GROUND SURFACE

Maciej Anders* and Muneo Hori†

1 Introduction

Accurate prediction of earthquake rupture phenomena is of key engineering importance. Due to the uncertainty of the soil structure, a stochastic approach may provide the only means for an unbiased analysis, where material properties are modeled as random fields. To reproduce rupture phenomena, a softening elasto-plastic constitutive law is often assumed.

This paper applies a Stochastic FEM (SFEM) to three-dimensional analysis of earthquake rupture propagation in ground surface layers. The method was formulated by Anders and Hori (1999) for the case of an ideally plastic body, as an extension of the linear SFEM formulated by Ghanem and Spanos (1990). The stochastic instantaneous elasto-plastic tensor is approximated by applying a *bounding body approximation* - see Hori and Munasinghe (1999). A simple extension of this method to the case of softening plasticity is presented in Anders and Hori (2000), who observed that their SFEM reproduces the results of Monte-Carlo simulation with respect to a particular mode of rupture taking place in the stochastic body. This mode may be regarded as the most realizable configuration of the stochastic body.

High numerical efficiency of the proposed SFEM is obtained by applying an enhanced discrete representation of the random input and considering an iterative solution of the final stochastic equations suitable for parallel processing - see Anders and Hori (2000). Therefore, the resulting code may be applied to nonlinear FEM problems requiring a large number of degrees of freedom, where Monte-Carlo simulation is no longer reasonable. See Table 1 for an efficiency comparison of the proposed method with Monte-Carlo simulation.

method	consumption $\times$FEM		
	time	memory	data
MC FEM	$>$1000	1	$>$1000
SFEM	$\sim$1	10	6

Table 1: SFEM efficiency benchmarks

2 Numerical Simulation

As an example problem of interest, we consider a stochastic analysis of echelon mode rupture propagation due to uniform strike-slip movement of base fault - see Figure 1 for problem setting and discretization. A Drucker-Prager yield criterion is assumed with isotropic softening, basing on the fracture energy approach. The source of material uncertainty is put into Young's modulus, which is modeled as a homogeneous Gaussian random field with mean equal to 20[GPa] and an exponential covariance function. The correlation length is set to 160[m], and a coefficient of variation equal to 0.10 is assumed. Other material properties are deterministic: fracture energy release rate 0.06[N mm^{-1}]; Poisson ratio 0.1667; initial tensile and compressive yield strength, 2 and 20[MPa], respectively. A homogeneous deterministic slip is applied antisymetrically at the left and right fault bases.

Figures 2 and 3 show the deformed surface mesh (displacement scale is magnified for clarity) and surface displacement standard deviation vector distribution, respectively, at a loading stage corresponding to a base slip of 0.025[m]. It is observed, that the mean rupture exhibits mainly vertical and lateral variability.

Figures 4 and 5 plot the distributions of mean and standard deviation of the rupture in terms of horizontal shear strain; the plots correspond to horizontal layers from base (bottom plot) to surface (top plot), and three stages of base slip are considered. The echelon crack propagates to the surface for base slip approximately equal to 0.015[m]. A maximum coefficient of variation of the rupture, equal to 0.05, is observed for the surface layer.

3 Concluding Remarks

It is shown that the SFEM presented in this paper, somehow, reproduces the evolution of the echelon faults together with the evolution of the stochastic characteristics. While future works for verifying the

*Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo, Tokyo 113-0032

†Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo, Tokyo 113-0032

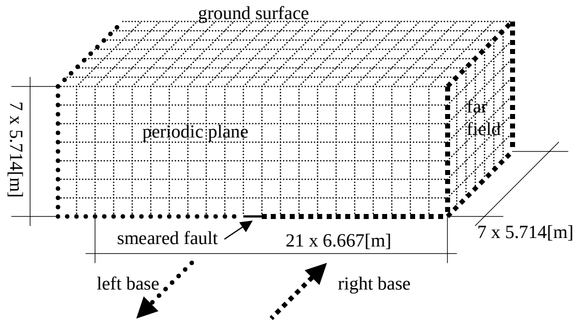

Figure 1: problem setting

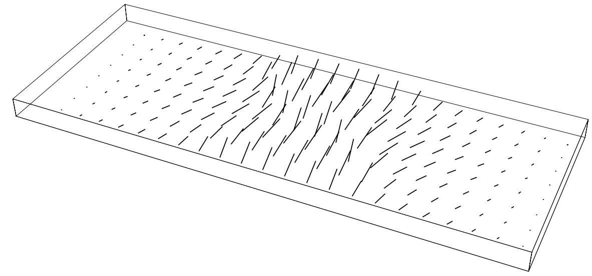

Figure 3: standard deviation for displacement vector

validity are definitely needed, the results obtained suggest the potential usefulness of the SFEM.

4 References

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4. M. Anders and M. Hori, Stochastic FEM Analysis of Rupture Propagation in Random Media, Proc. of the 8th ASCE Specialty Conference on Probabilistic Mechanics and Structural Reliability, Notre Dame - in print.

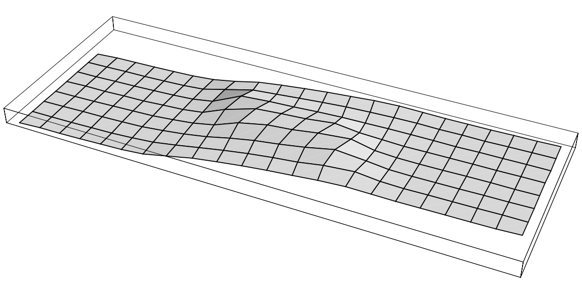

Figure 2: mean deformation of surface

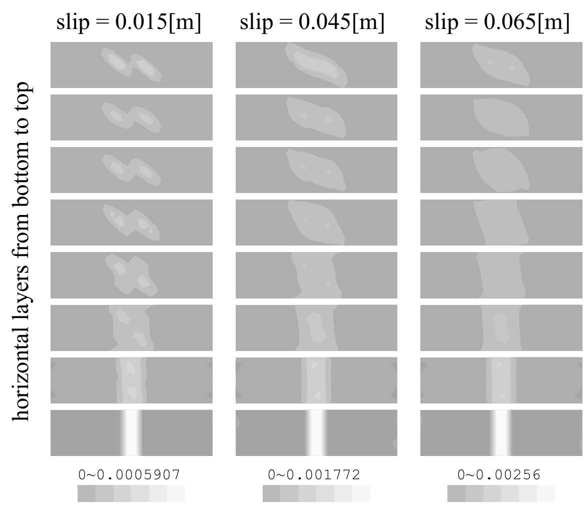

Figure 4: evolution of mean shear strain

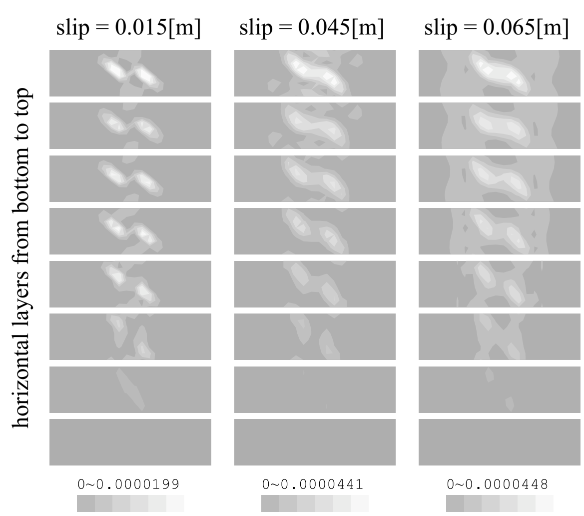

Figure 5: evolution of standard deviation of shear strain