I-631 EARTHQUAKE RUPTURE SIMULATION BY EXTENDED D.E.M.

M.R.Rimal	Graduate Student	The University of Tokyo
K.Meguro	Research Associate	The University of Tokyo
H.Higashihara	Professor	The University of Tokyo
M.Hakuno	Professor	Toyo University

Introduction

The advancement of computer systems has made it possible to conduct numerical experiments using more and more realistic models. The Extended Distinct Element Method (EDEM), which makes use of *pore-springs* or *joint-springs*, set between neighboring elements, enables one to simulate progressive development of cracks inside a medium in a very natural way. We used this method for simulating some of the fundamental processes of rupture of earth.

Model Preparation

A model is prepared in this study to simulate propagation of rupture from a small region where it is incited and to closely observe the results of inclusion of strength barriers ahead of the advancing rupture front. In preparing this model, 1500 circular elements all with a radius of 2.5m were placed in 5 rows as shown in Figure 1. The first step was to apply compressive stress to the model by bringing the top and the bottom walls close to each other. Use of viscous damping was made to bring the model to a practically at-rest condition. Next, the bottom row of elements was moved in the horizontal direction gradually in order to apply shear stress to the region. Again, viscous damping was used to bring the model to a practically at-rest condition. These steps were made to simulate the stressed state of the earth's crust prior to rupturing.

Observations and Discussion

Critical parameters–for which a pore-spring would break in the stressed model–were found after a few trials in order to determine a relevant set of parameters for simulating the rupture propagation. After this, one pore-spring at the left bottom corner of the model was destroyed to incite rupture. The critical parameters obtained were utilized in the subsequent analysis.

Figure 2 shows distribution of cracks at different selected time stations. The rupture velocity in this case was measured to be approximately 2.67 km/s. As can be seen from this figure, the rupture propagated from the left corner of the model to the right with a uniform speed.

In order to study the effect of a strength barrier when it is encountered by an advancing rupture front, a region starting nearly from the middle to the right end of the model, was made stronger. This was done by increasing the shear strength parameters c and μ successively by 10%, 20% and 30% in three different cases. The results of the simulations are shown in Figure 3 which plots the location versus time of crack occurrence in the model in different cases. It was observed in each case that the rupture slowed down when it encountered a stronger region ahead. As can be noted from Figure 3, the rupture velocities became smaller and smaller and the cracks could not penetrate the barrier in the 30% strong case. However, for this case, one can see that the total force has been transmitted toward the right as shown in Figure 4.

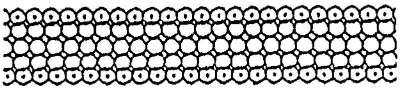
Next, the barrier region of the previous cases was treated as having random strength, with the shear strength parameters varying in the range 0%-50% in excess of the standard values. Figure 5 shows the progress of cracks in the region of random strength. Each of the ordinates in this figure represents the time difference–from the instant of rupture initiation to the time of occurrence of a particular crack–at the corresponding location. The abscissa, representing the crack location, runs parallel to the model. This case resulted in a few interesting results: the rupture speed varied at different locations giving a zigzag-type plot of the crack location and the time of occurrence; the rupture stopped to propagate after some time which might be attributed to the existence of a stronger barrier, and it was seen that only a few initially unbroken pore-springs were ruptured at later time steps.

References

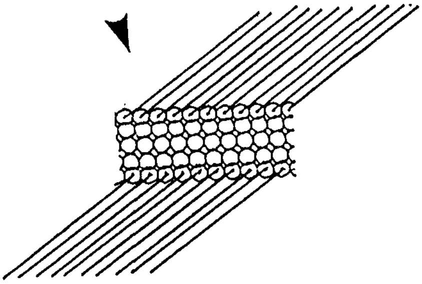
1) Aki, K. 1979. Characterization of barriers on an earthquake fault J.Geophys.Res. 84:6140-6148

2) Cundall, P.A. 1971. A computer model for simulating progressive, large-scale movements in blocky rock systems. Proc.v.2:129-136. Symp.ISRM.Nancy:France

3) Meguro, K. & Hakuno, M. 1989. Fracture analyses of concrete structures by the modified distinct element method. Structural Eng./Earthquake Eng. Japan Society of Civil Engineers. vol.6 No.2:283-294



(a) Distribution of elements (only a small part is shown)



(b) Total force vector

Figure 1 Model having 1500 circular elements each of radius 2.5m arranged in 5 rows (Model Length = 1500m)

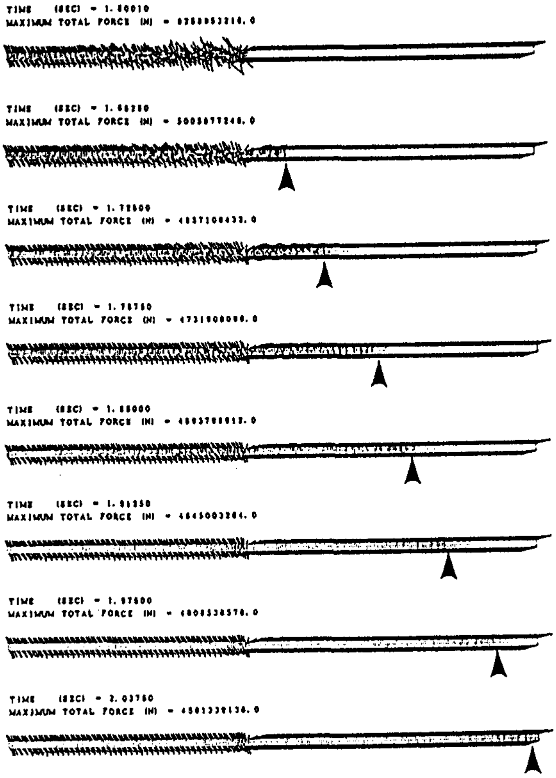
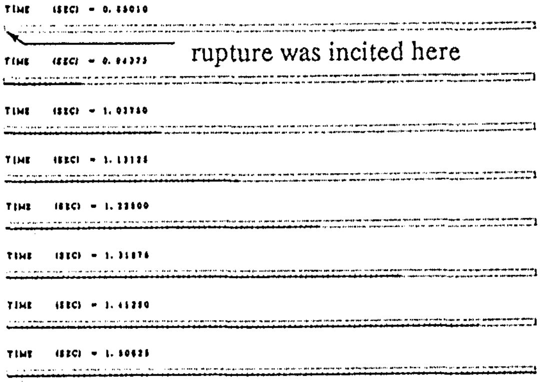


Figure 4 Distribution of total force vectors in case of 30% strong barrier (the propagation of total force can be seen from this figure although cracks could not penetrate this barrier region)



rupture was incited here

Figure 2 Propagation of cracks from the left bottom corner of the Model towards right

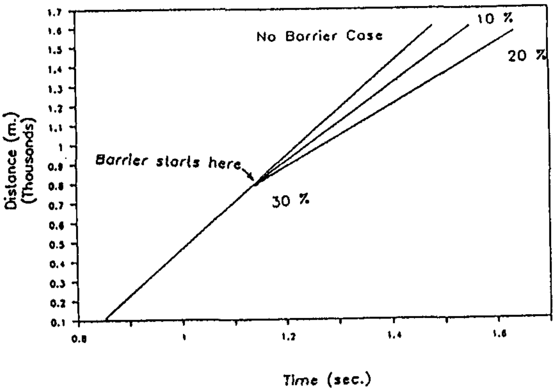
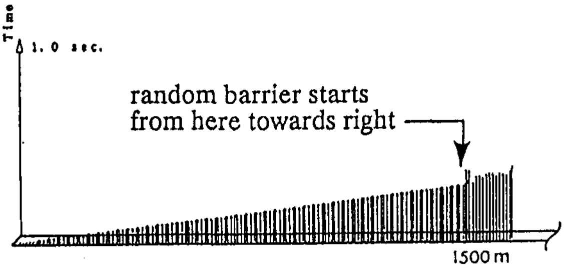


Figure 3 Plot of location versus time of crack occurrence in the Model (standard case as well as different cases of strength barriers)



random barrier starts from here towards right

Figure 5 Location versus time of crack occurrence in the Model (case of barriers having random shear strength parameters). The cracks propagated in the barrier region in a zigzag manner and stopped finally.