A STUDY ON RESPONSE OF SOIL DEPOSITS IN THE NEAR-FAULT REGIONS USING APPLIED ELEMENT METHOD

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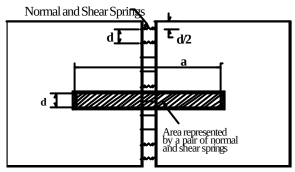
1. INTRODUCTION

In this study, we focus on the response of soil deposits due to the underlying bedrock fault displacement. In the conventional attenuation relationship, peak ground acceleration shows maximum value at the closest distance from the fault. However, in the real observations, sometimes it is found that the damage near to the surface fault is not maximum; instead it is high little away from the surface rupture zone. However, this is not yet proved because of the sparse distribution of the recording stations. Even with the occurrence of the major earthquakes in the recent times, the amount the data available for studying the near fault effects is not so high. Hence, for showing the numerical evidence to explain this phenomenon, we modelled fault rupture zone using the newly developed numerical model called Applied Element Method (AEM)[1) ~ 3)].

It is found from the extensive literature review that many studies on the widely noted fault rupture problem have been performed using either experimental method by carrying out the model tests or by using the numerical models by making suitable approximations of the complex dynamic fault rupture propagation problem. However, to have the clear insight, investigation should be carried out in a dynamic way. As a first attempt, dynamic fault rupture propagation in non-linear case is carried out. From the present study, it is found that the peak responses are not maximum near the surface fault trace instead they are maximum little away from it, towards the hanging wall direction.



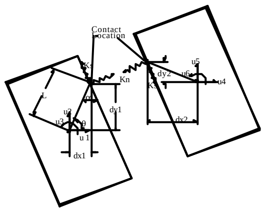


Fig. 1 Element formulation **Fig. 2** Spring connectivity

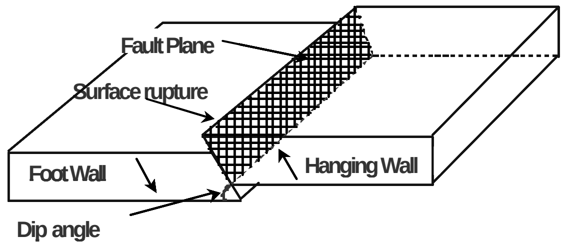


Fig. 3 Terminology

2. NUMERICAL MODEL

Applied Element Method (AEM), which was developed recently as a general method for structural analysis in both small and large deformation ranges has shown good accuracy in predicting the structural behavior. In AEM, the media is modelled as an assembly of small elements which are made by dividing the structure virtually. Two adjacent elements shown in **Fig. 1** are assumed to be connected by pairs of normal and shear springs set at contact locations that are distributed around element edges. Stresses and strains are defined based on the displacements of the spring end points which are located along the axis passing through centroid. Three degrees of freedom as shown in **Fig. 2** are assumed for each element. For other details, please refer to Refs. 1-3. By using the advantage of AEM's simplicity in formulation and accuracy in non-linear range, fault rupture zone, which is shown in **Fig. 3**, is modeled.

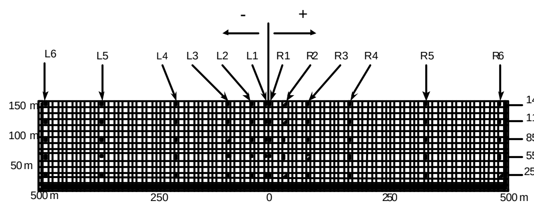


Fig. 4 Numerical model

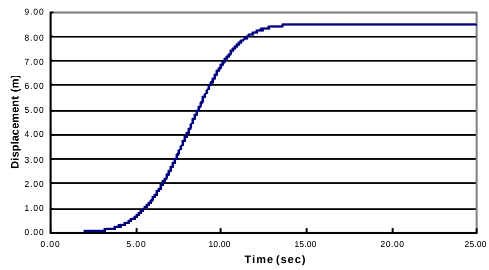


Fig. 5 Input displacement

3. DYNAMIC ANALYSIS

To analyse the mechanism of surface fault rupture zone, the numerical model shown in **Fig. 4** is prepared. Length of the model is assumed as 1 km and depth is 150 m. The location of the base fault is assumed to lie exactly at the centre of the model. Response is measured at some observation points on the left and right sides of the point exactly above the location of the underlying base fault. These points (L1 ~ L6 and R1 ~ R6) are located unevenly (i.e. at 5m, 25m, 65m, 145m, 305m, 485m) on each side. Properties of the soil deposit are assumed as follows; Young's modulus, E = $2.5x10^5$ kN/m^2, s_t = $1.5x10^3$ kN/m^2 and s_c = $1.5x10^4$ kN/m^2. Effect of the slip rate of the fault is studied first and then analysis is carried out to understand some real fault rupture propagation case studies. Displacement (shown in **Fig. 5**) based on the probability distribution function[4), 5)] is given to the hanging wall side of the bedrock and the response on the surface is

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observed. It is found from the analysis results that the ground motion in general has larger magnitudes on the hanging wall side than on the footwall side, which is evident from the previous experiences during the earthquakes. In general, the attenuation takes places from the shortest distance from the fault towards the farther distances. This is true when we discuss in large scale but when we look at the places very close to the fault trace, the scenario becomes different. **Figure 6** show that the attenuation of peak ground acceleration (PGA) with respect to distance from the surface fault trace. It can be seen from the figure that the PGA increases first and attains the peak value and then attenuates towards hanging wall direction. In general, the amount of destruction exactly on the fault is more because of the large relative permanent displacement. However, little away from the fault, the damage is less because the amplitude of strong ground motion is not so high. And at farther distances, PGA attains greater magnitude and then decreases with distance. This phenomenon is sometimes observed during the past earthquakes. However, due to the sparse distribution of the seismometers, this could not be represented by actual recorded data. But with the help of the newly developed numerical model, we can show this phenomenon. The reason for this can be, near the surface fault rupture, the material becomes highly non-linear (refer **Fig. 7**) and the response of this region becomes low compared to the adjacent areas response.

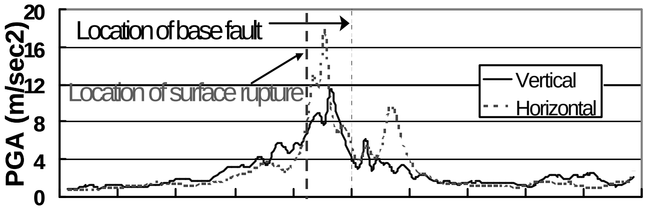


Fig. 6 Attenuation of PGA with distance

4. PARAMETRIC STUDY

A parametric study is conducted in order to study the influence of soil properties on the attenuation of responses. **Figure 8** shows the propagation of the shear and tension cracks in materials having shear wave velocities (a) Vs = 745 m/s and (b) Vs = 264 m/s, respectively. From these figures, it can be said that the thickness of the shear band reduces with the reduction in the shear wave velocity because in the softer material, the shear cracks gets localised. It can also be said from the results that the vertical displacement is more in case of harder soil and horizontal displacement is more in case of softer soil. In case of softer soil, the bedrock deformation gets absorbed in the soil deposit and in case of harder soil, the deformation on the surface will be exposed in the form of tension cracks at distinct locations.

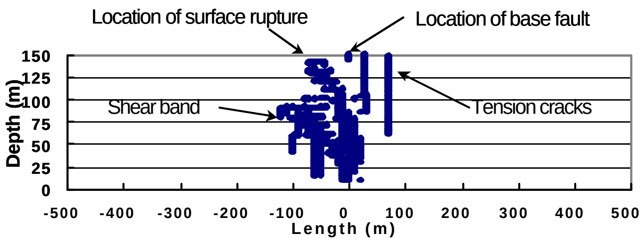
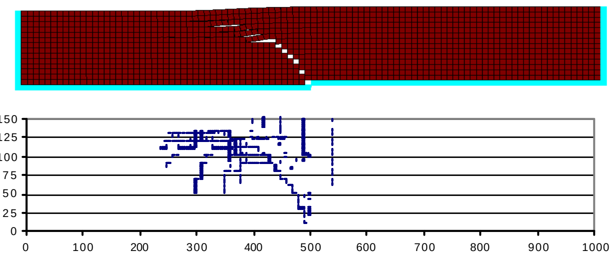
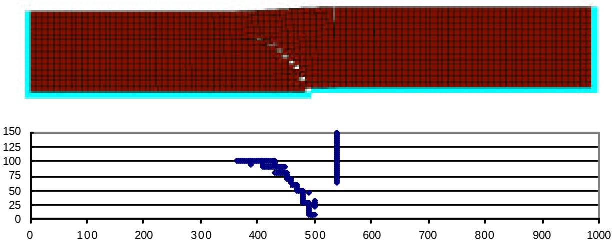


Fig. 7 Distribution of shear and tension cracks



(a) For shear wave velocity, Vs = 745 m/s



(b) For shear wave velocity, Vs = 264 m/s

Fig. 8 Propagation of the cracks and the elements location

5. CONCLUSIONS

A new application to Applied Element Method (AEM) is proposed in this paper. Numerical modelling of fault rupture propagation in dynamic condition is done using 2D AEM. It is found from the results that the PGA very near to the fault trace becomes relatively smaller and increases to peak value and then attenuates towards the hanging wall side. This information can give some insights to the actual phenomenon.

REFERENCES

1. Meguro K. and Tagel-Din H: Applied element method for structural analysis: Theory and application for linear materials, Structural Eng./Earthquake Eng., Vol. I-50 No. 640, Japan Society of Civil Engineers, 2000-04.
2. Tagel-Din H.: A new efficient method for nonlinear, large deformation and collapse analysis of structures, Ph.D. thesis, Civil Eng. Dept., The University of Tokyo, Sept. 1998.
3. Meguro K. and Tagel-Din H: A new efficient technique for fracture analysis of structures, Bulletin of Earthquake Resistant Structure, No. 30, 1997.
4. Hall, J.F., Heaton, T.H., Halling, M.W. and Wald, D.J. [1995]. Near-source ground motion and its effects on flexible buildings, "Earthquake Spectra, 11(4), 569-605.
5. Mladen V. K. [2000]. Utilization of strong motion parameters for earthquake damage assessment of grounds and structures, A dissertation submitted to the department of civil engineering (Ph.D. Thesis), University of Tokyo.