Seismic Response Analysis of Fault-Structure System with Fine Resolution Using Multiscale Analysis and Parallel Computing

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1. Introduction

The input ground motion to large structures located on the surface is affected by fault rupture, the heterogeneity of the crust structure, and local soil conditions. To estimate the response of the structure with high accuracy, a model of fault-structure system that includes all the factors (the fault, underground model, local soil conditions, and the target structure) that can affect the response is desired. However, since the problem encompasses the geologic- and the engineering-length scales, analysis is still computationally-expensive even for the current best computers. A multiscale approach, the Macro-Micro Analysis (MMA) method leads to an efficient computation by decomposing the problem to be solved sequentially. However, simulation of large earthquakes in high resolution further requires additional improvement of currently available analysis methods.

2. Macro-Micro Analysis (MMA) and Parallel Computing

MMA is a multiscale analysis method proposed by Ichimura and Hori (2006) which is based on applying singular perturbation expansion to the elastodynamic problem. The result is a two-step analysis that significantly reduces the computation cost. The first step analyzes a large domain in coarse-resolution (macro analysis); and the second step uses the results of the first step as boundary condition to the local domain in high resolution, to compute the response at the location of the target structure with suitable correction (the micro analysis).

However, when solving MMA for large scale domains using Finite Element (FE) method, further cost reduction is required. Thus, domain decomposition and parallel computing were implemented. In order to avoid the limitation in the available resources of a single computing machine, distributed-memory computing approach is used. A prepartitioning approach (domain decomposition before mesh generation) suitable for hybrid-grid (tetrahedral and hexahedral) FE meshing (to reduce the mesh generation of fine-resolution underground model) is also introduced.

3. Application Example and Results

The response of a model of a nuclear power plant (NPP) building subjected to a near-field earthquake is analyzed. The target region is a part of Niigata in northwestern Japan. The earthquake source is the Niigata-Chuetsu offshore earthquake (Mw 6.9). The domain size is 69.12×69.12×45 km.

The target frequency set to 1.0 Hz. The smallest resolution for the macro and micro models are 45 m and 0.01 m, respectively. Parallel computing with 128 processors were used. The norm of displacement at the surface at several time durations is shown in Figure 1. The corresponding deformations of the NPP building are shown in Figure 2. Results show that the NPP building deformed irregularly due to complicated ground motion resulting from the effect of the fault rupture, crust and local soil, and building geometry.

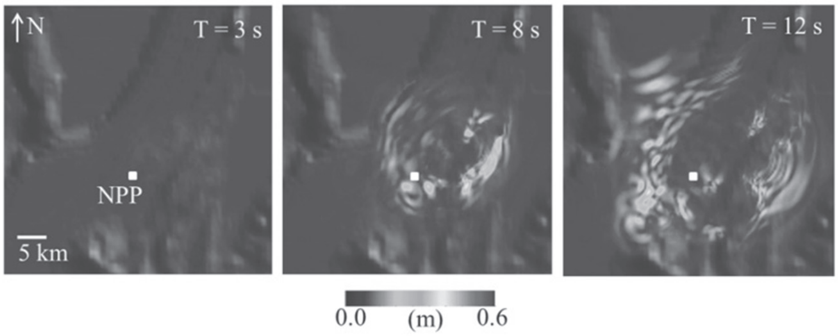

Figure 1. Displacement norm at the ground surface of simulation domain.

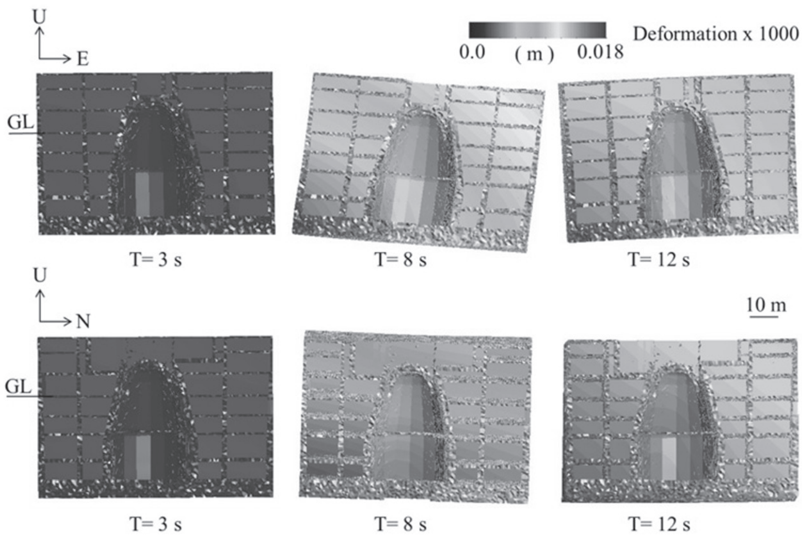

Figure 2. Deformation of building model.

* This study is a collaborative research work with Assoc. Prof. Tsuyoshi Ichimura, Prof. Muneo Hori, Prof. Shinobu Yoshimura (University of Tokyo) and Dr. Akemi Nishida (Japan Atomic Energy Agency)

References

1) Tsuyoshi Ichimura, Muneo Hori (2006). Macro-micro analysis method for wave propagation in stochastic media, Earthquake Engineering and Structural Dynamics, Vol. 35, pp. 419-432.

2) Quinay Pher Errol Balde, Tsuyoshi Ichimura, Muneo Hori, Akemi Nishida, Shinobu Yoshimura, (accepted), Seismic Structural Response Estimates of a Fault-Structure System Model with Fine Resolution Using Multiscale Approach with Parallel Simulation of Seismic-Wave Propagation, Bulletin of Seismological Society of America, doi: 10.1785/0120120216.