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Ground motion prediction for the Nankai & Tokai earthquake -3D ground motion evaluation method for large-scale structures-

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(1) Objectives

Evaluation of 3-D ground motions in the urbanized city during the future Tokai and Nankai earthquakes requires not only the modeling of the subsurface structure in a wide area, but also enormous numerical operation. This study provides the efficient method to evaluate the theoretical 3-D ground motions considering both the seismic fault and the sedimentary basin structure, where the storage and computational effort can be reduced. This method uses FEM in space and the explicit algorithm in time.

(2) Methodology

The rectangular FE region is expressed by non-uniform mesh grid in three directions resulting in rectangular solid elements with 8 nodes. This is similar to nonuniform grid spacing in finite-difference modeling [Pitarka(1999)]. The relationship between strains and displacements can be controlled only by length of 3 sides of the rectangular, which reduces computational effort in calculating nodal forces.

In the 3-D ground motion calculation for the large-scale subsurface structures including seismic faults, low velocity near-surface sediments possibly exist in the local area of the entire space. Use of the non-uniform grid spacing contributes to the reduction of the computational effort to some extent. As the entire analyzing region gets larger, number of elements due to small grids spacing for the local soft area is no more negligible. The small grid spacing also requires small time increment, which requires large number of operation.

In the proposed method, the entire region is divided into main and sub regions having different grid spacing. Though this is similar to the discontinuous grids in FD technique [Aoi and Fujiwara(1999)], the proposed method uses nonuniform grid spacing for each region. The sub region including low velocity structure is divided by finer spacing than the main region. On the overlapping plane of two regions, additional nodes of the sub-region are defined on the 4-noded rectangular plane of the main region. Continuous condition of the displacements and the equilibrium of the nodal forces are considered using the shape function. Time increment is also varied according to the grid spacing of each region, which significantly contributes to the reduction of the computational operation.

(3) Validation and Application

We explore the accuracy of the proposed method by using simple models, a layered half-space and a simple sedimentary basin. The 3-D ground motions are evaluated for 1- and 2- region models due to a double couple point source, which is preferably consistent with each other in both cases. The CPU time for the 2-region model is one-third that of the 1-region model.

We apply the proposed method to evaluation of the 3-D ground motions during the future Nankai and Tonankai earthquakes by modeling entire soil region of Kansai area. The whole area is 600km(EW), 400km(NS) and 90km(depth). The sub-region including Osaka Plane is 90km, 75km and 10km. The remaining part is the main region with a grid spacing 7 times that of the sub-region. The sedimentary basin structure of Osaka Plane is determined by previous studies [Miyakoshi et al.(1997), Kurimoto et al.(2000)] and the minimum S-wave velocity is set to 0.5km/s. The main region consists of bedrock with an S-wave velocity of 3.2km/s. The minimum period of ground motions is 1.6s considering the 5 grids per a S-wave length. Seismic parameters, such as region, asperities and epicenter etc., are determined from the Headquarters for Earthquake Research Promotion(2002). The velocity waveforms are evaluated in the Osaka Plain, which has large PGV and long duration. The total number of elements is about 30M, which is one third of 1-region model. Duration is 250s with time increment of 0.07s for the main region and 0.01s. for the sub-region. The total number of operation is about 10% that of 1-region model, which emphasizes the computational efficiency of the proposed method.