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Parallel Dynamic Analysis of a Mixed Model of Beam and Solid Elements by the BDD Method

Chuanrong JIN, Weihong ZHANG, Tsuyoshi KODAMA, Souichi MABUCHI,
Takatoshi KIRIYAMA and Hitoshi NAKAMURA[1)]

1) Science & Engineering Systems Division, ITOCHU Techno-Solutions Corporation
(3-2-5, Kasumigaseki, Chiyoda-ku, Tokyo 100-6080, Japan)

This paper presents a parallel dynamic analysis of a mixed model of beam and solid elements using the balancing domain decomposition (BDD) method. The construction of the coarse problem in the BDD method for the linear beam element is proposed. A seismic soil-structure interaction problem is solved in the time domain by a parallel BDD solver, and the efficiency is verified.

Key Words*: Parallel computing, seismic analysis, soil-structure interaction, BDD*

1. INTRODUCTION

For the soil-structure interaction analysis, some approaches such as the substructure method have been proposed [1, 2]. The most accurate is to calculate the response using a full finite element model of all the building, foundation, piles and soil. In order to take nonlinear effects into account and to study details of the damaging of a concrete building, the building structure needs to be modeled by 3D solid elements. Since the number of time steps in a nonlinear seismic response analysis is usually 3 to 15 thousand, the computer time becomes a big hurdle when using a full 3D large finite element model and the parallel computing is applied to speed up.

Among parallel structural analysis methods, the balancing domain decomposition (BDD) method [3], the conjugated gradient method with the coarse grid (CGCG) [4] and the finite element tearing and interconnecting (FETI) method [5] are promising algorithms. They have been applied for solid elements models [6] [7], shell structures [8, 9], and plate problems [9] with good performances. However, their implementation for a mixed model of solid elements and beam or shell elements, which is required in many cases of practical analyses, is not reported.

In this paper, we try to solve a seismic soil-structure interaction problem modeling the building and the soil by 3D solid elements and modeling the piles by beam elements using a parallel BDD solver originally developed by the authors.

2. COARSE PROBLEM

How to construct the coarse problem is very important in the BDD method. In this analysis, the rigid movements of each subdomain are employed as the coarse degrees of freedom (DOF). Since the model consists of solid elements and beam (Euler-Bernoulli beam) elements, there are two kinds of node, one has only 3 displacement DOFs and the other has 3 displacement DOFs and 3 rotation DOFs. For the former, the transformation matrix between local DOFs and coarse DOFs is given as

$$Z = \begin{bmatrix} 1 & 0 & 0 & 0 & x_3 & -x_2 \\ 0 & 1 & 0 & -x_3 & 0 & x_1 \\ 0 & 0 & 1 & x_2 & -x_1 & 0 \end{bmatrix},$$

and for the latter, it is given as

$$Z = \begin{bmatrix} 1 & 0 & 0 & 0 & x_3 & -x_2 \\ 0 & 1 & 0 & -x_3 & 0 & x_1 \\ 0 & 0 & 1 & x_2 & -x_1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

3. ANALYSIS MODEL AND RESULTS

The dynamic direct integration method is applied to analysis the response of the integration model of a building and piles and soil to earthquake excitation in the time domain. The height of 30 stories building is 140m and the soil size is given as $530\times330\times150$m. The soil consists of 7 layers as listed in Table 1. The whole model consists of 510,241 nodes and 364,200 elements, as shown in Figure 1. Viscous boundary condition is applied around the soil boundary.

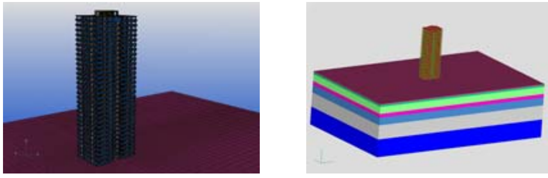

Figure 1 Model mesh

Table 1 Soil property

No	Soil Type	Bottom Depth(m)	Density(kg/m³)	Shear Wave Velocity(m/s)
1	fill	1836.7	1836.7	120
2	silt	3469.4	1632.7	150
3	sandy soil	5306.1	1836.7	220
4	silt	6938.8	1632.7	180
5	sandy soil	8775.5	1836.7	270
6	clay	10510.2	1734.7	220
7	sandy soil	12449.0	1938.8	300

The seismic wave recorded at the JR takatori station during the 1995 Hanshin Earthquake is adopted as input excitation. The acceleration time histories and its spectral response accelerations are shown in Figure 2.

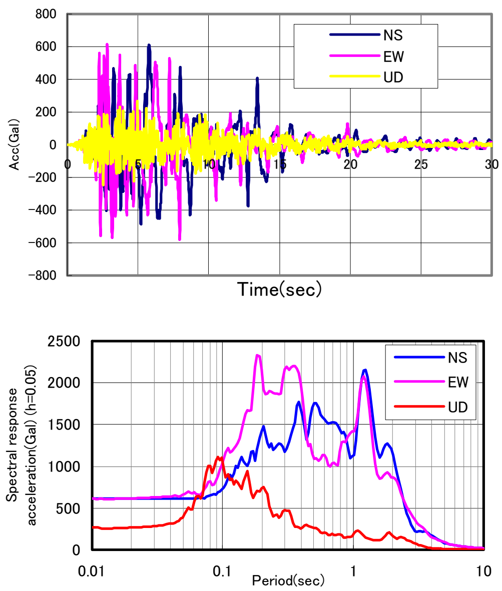

Figure 2 Input excitation wave

This calculation of 3000 steps took 54.5 hours on a computer server SunFire4600 with 8CPUs. 10 times expanded transformation and strain contour at 15s are shown in Figure 3. Discussion about the result will be presented in [10].

3. CONCLUSIONS AND FUTURE WORK

The BDD method is applied for parallel dynamic analysis of a mixed model of beam and solid elements, to solve a seismic soil-structure interaction problem using a full 3D finite element model. That this kind of analysis in the time domain of 1.5M DOFs and 3000 steps can be performed practically on a popular multi-core computer or cluster is confirmed.

The nonlinear analysis of this problem will to be tested.

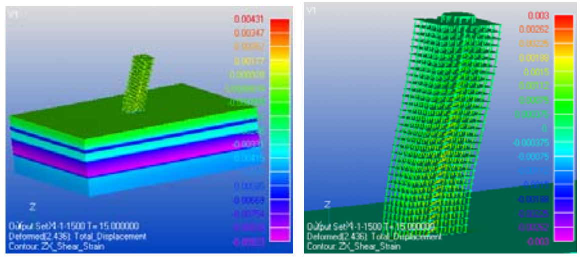

Figure 3 Transformation and strain

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