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Present situation of the FDM as a tool of strong-motion mapping

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Ground motion of a longer period than one or several seconds, is theoretically calculated using a finite difference method (henceforth, FDM) when strong-motion maps are created. We want to clarify the present situation and the problems of a FDM as a tool of strong-motion mapping and to offer subject for exploring future directivity in this paper.

For evaluating ground motion, three factors are required; a source model, an underground structure model (path and site), and the calculation technique. Although, when creating strong-motion map, it is necessary to 'predict' a source model and a certain amount of uncertainty is inevitable, the method of constructing a model based on a recipe from information, such as active fault investigation and a research result of a history earthquake, was proposed. Moreover, an underground structure model can be estimated in certain accuracy by investigations, although the problem of cost effectiveness may be unable to acquire detailed information. In most cases, calculation by 3-D FDM is sufficiently accurate and effective through the progress of a simulation technique and advancement of computer. Although each factor has an error factor, it can be said that the prediction accuracy of ground motion contained in the range of practical use.

For simple model like layered structure or the structure whose scale of heterogeneities is much larger than grid spacing, the accuracy of FD calculation is sufficient. For example, when the thickness of the sediment layer of 1km perturbed 100m, the effects on the waveform are much lager than the degree of calculation error of FDM. Taking the degree of accuracy of source and structure model into consideration, calculation accuracy of FD simulation is sufficient.

Under some severe condition, such as structure model including very thin superficial layers with low velocity or including a discontinuity with wave velocity ratio more than 5, accuracy of the calculation maybe insufficient. Moreover, the various optionality of the discretization for the complex model causes the various results of calculation. Thus, realistic and large-scaled simulation implies some unsolved problems. Since it is difficult to obtain the solution, whose degree of accuracy is guaranteed, like the analytical solution, and to evaluate a maximum error for general cases, it is the only way for verification the accuracy to compare the result for each other from several independent simulation codes or the methods techniques for various cases.

Together with calculation accuracy, the stability of calculation is a big problem for a large-scaled practical simulation. Tens of thousands time steps are needed to perform the simulation up to 1 Hz in a case where the edges of the structure model exceeds 100km. Error is accumulated with progress of time-step and calculation may become unstable and overflow may occur after large numbers of time steps. This phenomenon is practically a very big problem. It is known that trifling bugs of calculation code, which usually hardly affect accuracy causes, may become the cause of the instability of calculation. Although it was not solved whether this instability of calculation is essential nature of explicit finite difference formulation of a time domain and nonavoidable even with collect code, it was checked that the FD code using usual scheme endures the calculate at least up to tens of thousands time steps. It is practically very important to develop a robust calculation code.

In order to guarantee the reliability of the strong-motion map, the validation with one FD code may not adequate. It is indispensable the systematic comparison of the result from several independent calculation codes or other techniques.