DEVELOPMENT OF A PRACTICAL SYSTEM FOR SIMULATING EARTHQUAKE GROUND MOTIONS PAYING ATTENTION TO VOLCANIC ZONE AND ASPERITY ON A FAULT

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論 文 名：DEVELOPMENT OF A PRACTICAL SYSTEM FOR SIMULATING EARTHQUAKE GROUND MOTIONS PAYING ATTENTION TO VOLCANIC ZONE AND ASPERITY ON A FAULT
「火山地帯と断層のアスペリティに着目した地震動における実用的なシミュレーションシステムの開発」

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論 文 内 容 の 要 旨

Earthquake ground motions, such as acceleration time series and peak ground acceleration (PGA), are important and necessary data in earthquake engineering. Although these data can be obtained by seismic observations, they need to be simulated for the regions where records were not available during a past earthquake or for a future potential earthquake. For example, acceleration time series and PGA are necessary in hazard assessment of landslides induced by a potential earthquake on a specific active fault. However, there is no practical simulation system established for this purpose.

The key issues in simulating earthquake ground motion are how to consider the source effect, path effect and site effect. Up to now, the effect of asperity, one of the important factors in estimating source parameters, and the effect of volcanic zone on estimating path parameters have not been well investigated. Also, how to estimate the site effect for the location without seismic sensors remains an unsolved problem although site amplification can be estimated based on the seismic observations from both the surface and borehole sensors at the same station. For these reasons, this study aims at developing a practical system for simulating earthquake ground motions based on the so-called stochastic finite-fault method (SFFM), especially, paying attention to volcanic zone and asperity. The system consists of four modules: (1) a module for estimating the site amplification based on a new method proposed even for the location without strong ground-motion observations; (2) a module for estimating shear-wave attenuation based on a new analysis approach which can distinguish volcanic zone from non-volcanic; (3) a module for estimating slip distribution field by considering the characteristics of the asperity on a fault; (4) the SFFM module for calculating ground motions. Also, the system is applied to simulate the PGA distribution for landslide hazard assessment in Aso-bridge region, Kumamoto, Japan. It is shown that the assessment accuracy is improved using the simulated PGA than the conventional assumed PGA based on landslides induced by the 2016 Kumamoto earthquake.

The thesis consists of the following chapters.

Chapter 1 introduces the background and objectives of the thesis. The needs and applications of ground motion data in earthquake engineering are introduced. Two popular methods for the generation of simulated acceleration time series are reviewed and their strengths and limitations are briefly summarized. The organization of the thesis is shown at the end of this chapter.

Chapter 2 reviews the stochastic finite-fault method in detail. The principle of the stochastic finite-fault method is introduced in detail. The above mentioned three key issues are clearly addressed.

Chapter 3 proposes a method for estimating the site amplification in considering site effects. Seismic site effects are related to the amplification of seismic waves in surficial geological layers. Firstly, a module is made for calculating site amplifications based on the spectral ratios between acceleration waves recorded by surface and borehole sensors in the same station. The site amplifications of 53 KiK-net stations in Kyushu

Island are calculated. And then, in order to estimate the site amplification for the location without strong motion records, an empirical relationship between site amplification and V_{s30} (a parameter of time-averaged shear-wave velocity to 30 m) is established. Since V_{s30} is one of the widely-used measures and can be accessed in a regional scale, it is possible to estimate the site amplification just based on V_{s30}. By comparing the estimated results with those directly calculated from the records of both surface and borehole sensors, the good agreement shows the proposed method is reasonable and adaptable.

Chapter 4 proposes a method for determining the path parameter Qs (the S-wave attenuation) by considering the volcanic effect. Qs values are usually estimated without distinguishing volcano zone from non-volcanic zone. In fact, it has been reported that there is a lower Qs in the region with active volcanoes relative to the normal values. Therefore, how to clarify the lateral Qs heterogeneities effect on the ground motions and how to estimate Qs in such regions are important issues. In this chapter, a method for calculating Qs by considering volcanic effect is presented and validated by simulating ground motions of the 2016 Kumamoto earthquake. It has been shown that the accuracy of simulated ground motions is improved by using the proposed method. A module for estimating Qs is developed based on the proposed method.

Chapter 5 discusses the accuracy of the PGA simulated by using the slip distribution fields inversed from different kinds of data. The slip distribution field is one of the critical source parameters and it is related to the pattern, dimension and location of the asperity. Firstly, the effect from asperity is discussed by purely assumed asperities. And then, since the asperity of an earthquake can be inversed from the following three kinds of data: regional strong ground-motion data, teleseismic body-wave data, and geodetic GPS data, it is not clear which one can provide better results. By a lot of practical comparisons, it is found that the accuracy of simulated PGA based on anyone of the three kinds of slip distribution is not good enough. Thus, a combination of the three results is proposed. It has been shown that the accuracy of the simulated PGA based on the combination analysis is much improved by practical simulations.

Chapter 6 proposes a method for estimating the slip distribution of a potential earthquake on a specific fault. Many earthquake engineering problems need to estimate seismic waves induced by an expected future earthquake. Since the slip distribution field before the earthquake occurs is unknown, the above proposed method cannot be applied. For this reason, a method is proposed for estimating the asperity on a specific fault for an expected magnitude of the potential earthquake. The slip distribution is then obtained by using the assumed probability distribution in the asperity and rupture area. By analyzing 17 shallow crustal earthquakes in Japan from 1995 to 2016, it is found that a rectangle-ellipse asperity can be assumed. The scaling relations of asperity versus seismic moment are investigated, and empirical formulas are statistically obtained for estimating the dimension and location of the asperity. The approach is validated by estimating the ground-motion simulations of the 2016 Kumamoto earthquake. A module for estimating asperity and slip distribution is developed based on the proposed approach.

Chapter 7 develops the system by combining the SFFM module for calculating ground motions with the other three modules and presents an application of the developed practical system to the landslide hazard assessment for a potential earthquake on a specific fault. In conventional landslide hazard mapping, an approximate PGA value in an area is used, which makes the accuracy very low. In this study, the PGA for each mesh is calculated based on the slip distribution field of the target earthquake on a specific fault by using the developed system. Slope stability analysis is carried out using the PGA of each mesh in landslide hazard mapping. Thus, a landslide hazard map related to a potential earthquake on a specific fault can be made. A landslide hazard map induced by a M7.0 earthquake assumed on the Futagawa fault is made. It is shown that the assessment accuracy is improved using the simulated PGA than the conventional assumed PGA based on the landslides induced by the 2016 Kumamoto earthquake.

Chapter 8 summarizes the conclusions of the study, and makes recommendations for future work.