Graduate School of Creative Science and Engineering,
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博 士 論 文 概 要
Doctor Thesis Synopsis

論 文 題 目
Thesis Theme

Study on Earthquake Ground Motion Prediction and its Application to Structural Response of Bridge in Vietnam

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Tectonically, northern Vietnam is located in the most seismically active region at the boundary between the Indochina and South China plates. Most of the main faults in northern Vietnam are strike-slip faults. This region is tectonically active, as demonstrated by the occurrence of moderate earthquakes in the countryside and adjacent areas. Earthquakes with magnitudes of 5.0 to 6.8 on the Richter scale were recorded during the 20th century, including the Dien Bien earthquake (1935, M = 6.8 and 2001, M = 5.3), the Luc Yen earthquake (1953, 1954, M = 5.4), and the Tuan Giao earthquake (1983, M = 6.7). These earthquakes have occurred in northern Vietnam, and they are a mostly shallow crustal earthquake type. In 2005, a seismic network consisting of 24 broadband seismographs was deployed in Vietnam in a cooperative effort between the Vietnam Institute of Geophysics (*VIG*) and the Institute of Earth Sciences at Academia Sinica, Taiwan (*IESAS*). However, there is a limited number of ground motion records for strong earthquake events in Vietnam. Time history of ground motion was not mentioned for seismic design of the bridge in Vietnam, and Vietnam had not enough the observed ground motions to apply the seismic response analysis of structures. The characterizations of time histories of earthquake ground motion have considerably in the structural analysis, but it is unlikely those recordings of earthquake ground motion will be available for all sites. Therefore, studies on earthquake engineering are experiencing great challenges due to insufficient observed earthquake records in Vietnam.

Each structure will be most sensitive with frequencies near its natural frequency. Damage to a bridge thus depends on its properties and on the character of an earthquake ground motion, such as peak acceleration and velocity, duration, frequency, etc. Besides, evaluation on dynamic behaviour of bridge structure demands the representation of seismic action in terms of the acceleration time-histories (dynamic analysis) or a response spectrum (push-over analysis). It led to be necessary to reliable input seismic waves. The major goals in this study consist of the ground motion prediction and application to structural dynamic response analysis of bridges under seismic excitation. Therefore, this study addresses the problems of characterizing strong ground motion for computing the dynamic response of bridge structures to earthquakes in Vietnam.

The whole thesis consists of six chapters. In Chapter 1, we introduce the aim of this study consists of the literature reviews and a necessary to research. This chapter described a qualitative and quantitative comparative study of seismic design requirements in four specifications for bridge design; these are the specifications in Vietnam (*22TCN 272-05*), American (*AASHTO LRFD 1998* and *LRFESEIS-1, 2009*), Europe (*EC 8*), and Japan (JRA-2002). This comparative study includes the applicability and design objective of each code, and the response spectrum specified by each one. It also includes the effects of soil type in situ, the structural system of the bridge, the bridge utilization, and other factors affecting the analysis of seismic actions on bridges. The study discusses the differences and similarities between the codes under consideration. It has also shown that not only *JRA-2002* introduced the static and the dynamic analysis methods in detail, but also proposed seismic waveforms such as Level one and Level two earthquake ground motions (in here, Level one is an earthquake ground motion with high probability of occurrence for the bridge service life, Level two is an earthquake ground motion by a strong earthquake with low probability of occurrence for the bridge service life) for the different zones and soil conditions. Therefore, study on earthquake ground motion and its application for seismic design is really necessary and important for bridge design in Vietnam.

Chapter 2 introduces the historical earthquake, earthquake activities and records of earthquake in Vietnam. This chapter described that Vietnam lies in a low-to-moderate aseismic region in the world. The high probability of earthquakes almost concentrates in the magnitudes of 4.5 to 5.5 on the Richter scale. The earthquake magnitude with M = 5.8 is computed with 95% confidence interval for the mean. Besides, the previous studies also shown the earthquake occurred with a low probability and maximum earthquake of magnitude of M = 7.0 may occur in Vietnam in the future (e.g., *Phuong, 1991*; *VIG, 2005*; *Trieu et al., 2008*).

Given the different geology and earthquake activity, establishing a regional attenuation relationship is deemed important for the seismic design of structures. A new PGA attenuation relationship for northern Vietnam is established in Chapter 3. The ground motion attenuation relationship, which is used to estimate the ground maximum acceleration values for a seismic design, is very important for probabilistic seismic hazard analysis (*PSHA*). The attenuation of ground motion is represented and modeled using empirical attenuation equations of *PGA*. This equation is related to the source/site parameters such as source magnitude, source distance, and site condition. Most of the relationships are developed based on widely distributed magnitudes, peak ground motions, distances, and source mechanisms acquired from many earthquakes. The current attenuation relationships have been developed for many countries and regions. Their relationships are not appropriate for seismic hazard analyses in Vietnam because it does not reflect local conditions. In particular, the relationship currently used

does not consider any earthquake records obtained in Vietnam. Thus, this study constructed a new attenuation relationship that considers Vietnamese conditions. This chapter presents a new equation in place of the relationship currently used in Vietnam for horizontal ground motion based on database sets compiled from strike-slip and shallow crustal earthquakes with magnitudes ranging from $3.0 \leq M_w \leq 6.9$ and source distances of up to 300 km for northern Vietnam. This new equation estimates the ground motion in terms of moment magnitude, distance and site conditions for strike-slip earthquakes. The equation is derived based on a regression analysis of earthquake records; in this study, the database consists of earthquake records from Japan, Vietnam and adjacent areas. This study also assumed a few simple relationships, such as the relationship between M_w and M_s, the closest distance to the fault and the effects of shallow site conditions on the average shear-wave velocity in the upper 30 m (V_{s30}) to develop a comparison with existing relationships. The new equation for northern Vietnam corresponds better with other equations for near and far-field distances than the equations currently used for seismic design in Vietnam.

Chapter 4 uses new attenuation relationship in Chapter 3 to quantify ground motion based on PSHA. This method is the most widely used approach for the determination of seismic design loads for engineering structures. The equations generally rely on the basic assumption that ground motion prediction equations (*GMPEs*) have been developed for other regions with similarly tectonic. The accelerograms obtained from small magnitude earthquakes can be used as the basis for predicting ground motions due to the larger magnitude events considered in seismic hazard analysis. Current seismological network is monitoring the earthquake events with magnitudes of more than 3.0 on the Richter scale in Vietnam. The study of tectonic stress field and dynamic-geometric characteristics of the faults is especially the importance for seismic assessment. However, these studies are very limited in Vietnam. The network of broadband seismograph stations has just established in recent years. Even though, the stochastic method was used to predict earthquake ground motion may occur in Vietnam based on continuously collected seismic data by Vietnam Institute of Geophysics such as an earthquake catalogue from 114 to 2005 an earthquake record of Dien Bien and Tuan Giao earthquakes. When considering some seismic codes around the world, the contents of the seismic design for bridge are compared in order to find limited points in the current specification of bridge design in Vietnam. After that, the simulation of prediction ground motion based on the results from probabilistic seismic hazard analysis in Vietnam following to the Weibull extremely distribution is also discussed.

Chapter 4 also proposes the generation of artificial earthquake motion, which is one of the main objects of this study. Two techniques to predicting earthquake ground motion of physics-based models and stochastic models. Physics-models simulate ground motions by modeling the fault rupture, the resulting wave propagation, and the near-surface site amplification since they require precise information about the earthquake source, wave propagation path, and soil structure. However, that is difficult and computationally expensive to produce simulations that cover the range of possible future earthquakes. Thus, the stochastic method is to be used to simulate ground motion with various epicenter distances from small earthquake events and insufficient strong earthquake data. *Boore (1983, 2003)*, *Atkinson and Somerville (1994)*, *Atkinson and Boore (2006)* and others have demonstrated the well-known stochastic approach. The studies were based on simple physical models of the earthquake process, wave propagation and are estimated by analyzing many seismograms. In contrast, this method is empirically calibrated approaches that directly simulate the ground motion instead modeling fault rupture, wave propagation, and site amplification. In general, this approach is computationally inexpensive, and is equally applicable to high and low frequencies. However, almost stochastic models are based on modified Gaussian white-noise processes; it is difficult to simulate the coherency in the low-frequency region and frequency non-stationary. Simulated ground motions are sometimes useful as input motions because unlike recorded motions they are not limited in a number and because their properties can be varied systematically to understand the impact of ground motion properties on structural response (*Yamamoto and Baker, 2011*).

Chapter 5 provides a brief generation of artificial ground motion procedures. The simulated waveforms were employed to synthesize seismogram of strong ground motion. The artificial waveforms of the target earthquake were performed based on the stochastic model. This method is very useful for prediction of the strong ground motion in a region without observed seismic waveforms. This purpose of the present work consists in the validation of stochastic method for generating artificial ground motion and determines a ground response spectrum due to moderate magnitude earthquakes from available historical earthquakes in Vietnam. The next step of this study proposes the seismic waves and response spectral acceleration spectrum for seismic design of the bridge that is corresponded to earthquake activities in Vietnam.

Regarding performance-based design, dynamic response analysis of bridges for various types of input ground motions is required. This analysis method using of a selected set of ground motion time-histories is available for nonlinear dynamic analysis of structures subjected to earthquakes. The most reliability method for determining, verifying the response of a designed structure to the design intensity is using on the time-history analysis. In addition, the dynamic response of a structure is predicted by time histories of earthquakes having a specified spectral acceleration at a given period. The prediction is often obtained by selecting ground motions that match a target response spectrum, and using those ground motions as input to dynamic analysis. Therefore, Chapter 5 describes the dynamic response analysis method of a bridge and comparison of the seismic analysis of the bridge when applying predicted ground motions of this research. In this study, dynamic behaviour of a typical bridge model is investigated in Chapter 5.

Finally, Chapter 6 gets the summary for the thesis, discussion of the results, conclusions, and recommendations for future required studies. The research works on verification of dynamic response analysis for bridge design based on research on earthquake ground motion has been carried out in this study. The undertaken study has revealed that research on earthquake is necessary and interest to seismic design for bridge design is very important in Vietnam.

The great limitation of study is dataset, because strong earthquakes in Vietnam occurred with low frequency. Moreover, bridges are designed on an unstable ground such as across a fault, near-fault zone on a lateral spreading ground due to liquefaction, etc. It is necessary to research on ground motion within these conditions and to consider the interaction between the ground and the foundation structure. These are essential issues for further research.

早稲田大学　博士（工学）　学位申請　研究業績書

(List of research achievements for application of doctorate (Dr. of Engineering), Waseda University)

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