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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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Mr. Hung's dissertation presents earthquake design method, especially input earthquake records, for the bridges in Vietnam. He reviews the current situation of earthquake activities and obtained records in Vietnam at first. Tectonically, northern Vietnam is in the position of the Indochina and southern China plates' boundary and at the most seismic region. Most of the main faults are strike-slip faults; these faults are tectonically active and give the occurrence of moderate earthquakes in the country and adjacent areas. The historical earthquakes with large magnitudes of 5.0 to 6.8 on the Richter scale were recorded in the 20th century such as earthquakes at Dien Bien (1935, M = 6.8 and 2001, M = 5.3), earthquakes at Luc Yen (1953, 1954, M = 5.4), earthquake at Tuan Giao (1983, M = 6.7) and so on. These earthquakes have occurred in northern Vietnam, and they are a mostly shallow crustal earthquake type. Presently, a seismic network consists of 24 broadband seismographs has been deployed in Vietnam since 2005 by the cooperation between the Vietnam Institute of Geophysics (VIG) and the Institute of Earth Sciences at Academia Sinica, Taiwan (IESAS). Although the records of strong ground motion of earthquakes are still lacking and limiting 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 time histories of earthquake ground motion are considerably required in the structural analysis, and those recordings of earthquake ground motion will be available for all sites. Therefore, his studies on earthquake engineering to make design wave records are great challenges due to insufficient observed earthquake records in Vietnam.

He presents the necessity of the earthquake records for bridge seismic designs 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 behavior of bridge structure demands the representation of seismic action in terms of the acceleration time-histories in dynamic analysis or a response spectrum analysis. The major goals in his study consist of the ground motion prediction and its application to structural dynamic response analysis of bridges under seismic excitation. Therefore, his study addresses the problems of characterizing strong ground motion for computing the dynamic response of bridge structures to earthquakes in Vietnam.

His thesis consists of six chapters beginning with an introduction aim of research of the thesis in the Chapter 1. He explains the literature reviews about current situation on earthquake engineer in Vietnam in this chapter. Chapter 1 introduces 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. His study discusses the differences and similarities between the codes under consideration. It has also shown that not only JRA-2002 introduced both the static and dynamic analysis method in detail, but also proposed seismic waveforms such as Level one and Level two earthquake ground motions (in here, Level one is earthquake ground motion with high probability of occurrence for the bridge service life, Level two is 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, he insists on necessity of research on earthquake ground motion and application for seismic design of the bridge in Vietnam.

He introduces the historical earthquake: earthquake activities and records of earthquake in Vietnam in chapter 2. He explains that Vietnam lies in the low to moderate aseismic region in the world. Besides, he also explains the earthquake occurred with a low probability and maximum earthquake of magnitude of M = 7 may occur in Vietnam in the future.

Chapter 3 is one of major objects in his study. Aim of this chapter is to predict ground motions which are peak ground accelerations, acceleration response spectra, and acceleration time-histories that will be used in dynamic response analysis. The prediction of the earthquake ground motion is carried out with the required detailed description of the earthquake source, fault, and site effects. One of most important things to predict the ground motion is the relationship of ground motion attenuation that is used to estimate the maximum acceleration values for a seismic design. Thus, the attenuation of ground motion is represented and modeled using empirical attenuation equations of peak ground accelerations (PGAs). They are related to the source/site parameters such as source magnitude, source distance, and site condition. The relationships have been developing with widely distributed magnitudes, strong ground motions, distance and source mechanism acquired from many strong earthquakes for many countries and regions in the world, but the developments of current attenuation relationships are not appropriate for using of seismic hazard analysis in Vietnam because the characteristics of earthquakes in Vietnam do not reflect in these current relationships. Especially, no earthquake records obtained in Vietnam were considered in these current relationships. To solve these problems, he rebuilds the attenuation relationship considered various Vietnam conditions. His study has derived the PGA attenuation relationship for northern Vietnam using data set from Japan, Vietnam and adjacent regions in place of old current relationship in Vietnam. He developed the new relationship for shallow strike-slip earthquake by a regression technique with the range of magnitudes of $3.0 \leq M_w \leq 6.9$ and source distances up to 300 km. In this relationship, shearing wave velocity below 30m depth (V_{s30}) is adopted to estimate of ground motion with linear site effects.

He uses above attenuation relationship to quantify ground motion in probabilistic seismic hazard analysis (PSHA) in chapter 4. PSHA is the most widely used approach for the determination of seismic design loads for the bridge. It generally relies on the basic assumption that ground motion prediction equations (GMPEs) developed for other similar tectonic regions can be adopted in the researched areas. The accelerograms obtained from small magnitude earthquakes that occur in moderate earthquake activity zone can be used as the basis for predicting ground motions due to the larger magnitude events considered in seismic hazard analysis. Current seismological network in Vietnam is monitoring the seismic events of magnitude larger than 3.0 in the territory of Vietnam. The study of tectonic 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 (VIG) such as an earthquake catalogue from 114 to 2005 an earthquake record of Dien Bien and Tuan Giao earthquake. 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.

He makes the generation of artificial earthquakes motion in another major object of his study. He mentions it in chapter 4. There is consistence with both the physical condition and the characteristics of the actual ground motion recordings. There are two general techniques of ground motion simulation: 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. It is difficult and computationally expensive to produce simulations that cover the range of possible future earthquakes. He mentioned a stochastic method to be used to simulate ground motion with various epicenter distances from small earthquake events and insufficient strong earthquake data as in Vietnam. His study is based on simple physical models of the earthquake process, wave propagation and is estimated by analyzing many seismograms. Stochastic models in contrast are empirically calibrated approaches that directly simulate the ground motion instead modeling fault rupture, wave propagation, and site amplification. This approach is in general computationally inexpensive, and is equally applicable to high and low frequencies zone of acceleration records. 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 recorded motions 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.

He explains a brief generation of artificial ground motion procedures in chapter 5. The simulated waveforms are employed to synthesize seismogram of strong ground motion. The artificial waveforms of the target earthquake are performed based on the stochastic model. This method is very useful for prediction of the strong ground motion in a region where observed seismic waveforms are not obtained. So his 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 his study is to make seismic waves and response spectral acceleration spectrum for seismic design of the bridge that is corresponded to earthquake activities in Vietnam. He also mentions that 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 acceleration spectrum 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, he 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 chapter 5. In his study, dynamic behavior of a typical bridge model is also investigated in chapter 5.

Finally, he mentions the summary for the thesis, discussion of the results, conclusions, and recommendations for future required studies in chapter 6. 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. His undertaken study reveals that the research on earthquake is necessary and interest to seismic design for bridge design is very important in Vietnam. In spite of great limitation of the database of earthquake events that strong earthquakes occur with low frequency in Vietnam. Moreover, bridges should be 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.

His dissertation proposes a new ground motion attenuation relationship, acceleration response spectrum and seismic waves according to historical earthquake activities in Vietnam. His research gives scientific proofs about earthquake levels as two levels of earthquake ground motions corresponding to high and low probability of earthquake occurrence. Based on the results of his research, probabilistic seismic hazard in northern Vietnam is analyzed. In addition, his dissertation has significant application in seismic design, especially, its application to structural response analysis of bridge in Vietnam. This research work is not only important for seismic design of the bridges in Vietnam but devotes to the field of earthquake engineering in Asian countries. Thus, referees recognize that his paper devotes the development of earthquake engineering in many countries where the earthquake activity is not vigorous and meets given requirements of a doctoral degree (Doctor of Engineering).

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