論文の内容の要旨

論文題目　Design ground motion synthesis based on feature indices considering nonlinear response of structures
（構造物の非線形挙動を考慮した特徴指標にもとづく設計地震動の合成）

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Selection of design ground motion is an important and influential aspect of seismic design. The selection of design ground motion is affected by the uncertainties of seismic event and unpredictability of nonlinear response. To enhance the reliability of design ground motion selection, it is inevitable to incorporate the afore mentioned uncertainties in the selection/synthesis of design ground motion. For selection of a representative ground motion out of possible input ground motions, it is necessary to evaluate the effect of ground motions on the structure considering the complexity of nonlinear response. This cannot be done, however, by using conventional indices such as peak ground acceleration (PGA). Thus it is essential to outline a method for the synthesis of design ground motion by considering the effect of uncertainties of seismic event and complexity of nonlinear response of structures.

In this study, we address the selection/synthesis of design ground motion considering the important aspects nonlinear response of structure by feature indices. Due to uncertainty in seismic factors, number of possible ground motions is not limited. The ground motions which are required to be considered for the design of structure are referred to as set of input ground motions. In the proposed method of ground motion synthesis the set of input ground motions are described by feature indices. Concept of damage mechanism based indices is proposed. Since there is not a ground motion which is the most efficient in the presence of uncertainties of structural characteristics a design ground motion is artificially synthesized in an iterative modification process. It is proposed and verified that fluctuation in parameters of indices is effective to cope with nonlinear response of structure.

Chapter 1 gives the review of current situation of design ground motion selection approach. It explains why it is necessary to consider the effect of seismic uncertainties and complexity of nonlinear response of structure in the selection/synthesis of design ground motion. In chapter 2, the design ground motion selection method and approaches are reviewed. A survey of design ground motion selection procedures proposed in literature and used in design codes is carried out. Based on the discussion, the objective of this research work is elaborated.

In chapter 3, the proposed method of ground motion synthesis is outlined. In the proposed

method of ground motion synthesis, it is objected to synthesize a design ground motion by considering the effect of a large number of input ground motions and unpredictability of nonlinear response. For this purpose, first, a set of input ground motions that reflect the effect of uncertainty is considered. The set is described by feature indices that take into consideration the effect of ground motions on structural behaviors. Second, the ground motion that represents the set in terms of the feature indices is synthesized as a design ground motion. A scheme to synthesize a ground motion to represent the set is explained. The ground motion is synthesized by iteratively modifying its time-frequency characteristics using wavelet functions to improve the values of feature indexes.

In chapter 4, the efficiency of the ground motion synthesis procedure explained in previous chapter is explored. The efficiency of the method is discussed in context of design ground motion synthesis for a concrete moment resisting frame. The set of possible ground motions is consist of real ground motions records obtained from K-NET. Each member of concrete moment resisting frame is modeled by using fiber elements in OPENSEES, and same is used to conduct the dynamic nonlinear analysis of structure. Various aspects of proposed method of ground motion synthesis are discussed. For example, it is shown that the synthesized design ground motion is not sensitive to the initial selected ground motion which is to be modified in the iterative modification process. It is shown that the synthesized ground motion is not sensitive to the sampling of set of input ground motions. The results of numerical simulations show that the synthesized ground motion is robust in context of uncertain structural properties. For enhancement of performance of proposed method of ground motion synthesis, it is required to set a procedure for selection of appropriate indices, and this aspect is discussed in next chapter.

In Chapter 5, concept of damage mechanism based indices is introduced to select the most effective indices out of list of available indices. Conceptually, out of available indices, if some index/indices is/are related with expected damage mechanism(s) of structure, then such indices should be deployed for the selection/synthesis of design ground motions. Because, the ground motion tough in terms of such indices would be efficient to trigger the expected damage mechanism, hence such ground motion should be used as design ground motion. The advantages of using damage mechanism based indices over conventional index and other indices which are less correlated with expected damage mechanisms are explained through a numerical simulation. Similar to the chapter 4, here we use concrete moment resisting frame as target structure and set of input ground motions are recorded earthquakes obtained from K-NET. The results show that reliability of design ground motion selection is considerably enhanced due to inclusion of damage mechanism based indices in selection of design ground motions. Selection of parameters of indices is a critical aspect and discussed in following chapter.

In chapter 6, we discuss about the selection of parameters of indices considering the nonlinear

response of structure under consideration. In comparison with complexity and unpredictability of nonlinear response, the indices are simple. Indices may not represent the possible ground motions in context of nonlinear response of structure. To improve the performance of index based design ground motion selection approaches, the effect of nonlinear response must be reflected in the ground motion selection. We propose to consider a fluctuation to the parameters of indices to improve the performance of indices to represent the possible ground motion. Because, it is not possible to quantitatively consider the effect of complicated nonlinear response of structure in selection of design ground motions. It is considered that consideration of fluctuation to the parameters of indices will be helpful to evaluate a variety of aspects of ground motions, hence, it will increase the reliability of selection of required design ground motions. Results of numerical simulation show that a wider range of fluctuation in parameters of indices is required to cope with nonlinear response in extensively damage case.

Chapter 7 summarizes the conclusion of this study. First; feature indices based design ground motion synthesis method is proposed. Feature indices are used to describe the set of input ground motions. Proposed iterative method successfully generate the ground motion which is robust in terms of effect of: set of possible ground motion s, initially selected ground motion, etc. Second; concept of damage mechanism based indices is proposed for selection of indices. Damage mechanism based indices are related with expected damage mechanisms. Therefore the ground motion tough in terms of damage mechanism based indices is expected to trigger the expected damage mechanism and hence used as design ground motion. Inclusion of damage mechanism based indices in ground motion selection considerably enhances the reliability of design ground motion selection. Third; it is difficult to quantitatively consider the effect of nonlinear response in selection of design ground motions, so we proposed and verified that consideration of fluctuations in parameters of indices is an effective alternative to cope with effect of nonlinear response in selection/synthesis of design ground motions.