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Evaluation of the Ground Motion Record Selection Method for Structure Groups In Case Of Generic Steel Moment-Resisting Frames

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ABSTRACT: Rapid growth of performance-based earthquake engineering has caused increasing interest in Non-linear Time History Analysis (NLTHA) as an effective tool for the estimation of engineering demand parameters (EDPs) and capacity. Focusing on the selected set of strong ground motions (SGMs) as an important source of uncertainty on the results; there are a variety of studies, the purpose of which is to introduce a standard scheme for efficient selection of appropriate SGMs as the input of NLTHA. A part of existing differences, most of these methods suffer from a common limitation that is the application of simplifying assumptions in their contextual framework that may not be correct always. Although, the use of such simplifications is unavoidable, the effect of them on the reliability of the results estimated by performing NLTHA under proposed set of SGMs by method must be evaluated. In this paper, a recently proposed structure-specific record selection method is investigated in terms of its ability to keep the claimed efficiency in case of structures that may challenge the correctness of reducing a MDOF nonlinear system to an equal SDOF. Among different influencing parameters that are considered in this study such as the type and pattern of irregularities, as well as, initial stiffness of the frames; the results confirm that ductility plays the chief role on the selection output. Also, the application of the proposed subsets by the selection method does not necessarily result in the reduction of the statistical dispersion in the estimated EDPs.

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1- Introduction

Considering the fact that the computational cost of non-linear time history analysis (NLTHA) has been reduced significantly, specially, during last decade, this type of analysis has been promoted among civil engineering society. On the other hand, basic shift from conventional design approach to the performance-based method highlights the essential need for the estimation of different engineering demand parameters (EDPs) with as highest reliability as possible. Focusing on the selected set of strong ground motions (SGMs) as an important source of uncertainty on the results, there are a variety of studies in the earthquake engineering literature the purpose of which is to introduce a standard scheme for efficient selection and preparation of appropriate SGMs as the input of NLTHA. A part of existing differences, most of these methods suffer from a common limitation that is the application of simplifying assumptions in their contextual framework that may not always be correct. For example, there are several structure-specific scaling and selection methods using an equivalent single degree of freedom system (SDOF) as the representative of the target structure that must be analyzed. Although, the use of such simplifications is unavoidable, their effect on the reliability of the results estimated by performing NLTHA under proposed set of SGMs by the method must be evaluated.

In this paper, a recently proposed structure specific record selection method is investigated in terms of its ability to keep the efficiency in case of structures that may challenge the assumption of reducing a MDOF nonlinear system to an equal SDOF.

2- Structural Models

For a comprehensive study, a group of 2-D one bay vertically irregular frames has been used in this study. For this purpose, at first a group of 2-D one bay vertically regular frames of five different heights (i.e. 3, 6, 9, 12, and 15 stories) has been designed. The height-wise distribution of stiffness was tuned to achieve equal drifts in all stories that are calculated using the Iranian code of practice for seismic resistant design of buildings forces (Standard 2800). The overall procedure that is relatively similar to all force-based seismic code can be summarized as:

$$F_i = V_b \frac{W_i h_i^k}{\sum_{j=1}^{N} W_i h_i^k} \quad (1)$$

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Where: $$k = \begin{cases} 1 & T_1 \le 0.5\,\text{sec} \\ \dfrac{T_1 + 1.5}{2} & 0.5 < T_1 < 2.5\,\text{sec} \\ 2 & T_1 \ge 2.5\,\text{sec} \end{cases}$$

The yield strength distribution was chosen such that the yielding is observed almost simultaneously at all plastic hinges under the lateral force distribution described in Equation 1. To cover a variety of ductility values, nonlinear response spectra with constant ductility equal to 1, 2, 4, and 6 have been utilized as the design spectra. Thus, eight different designs (two values of T1 and four values of μ) are considered for each fixed height, leading to a total of 40 frames. The development of the structural database follows similar principles as those can be found in [1-3].

Corresponding to each regular frame, 24 vertically irregular frames were extracted by modifying stiffness and/or strength in four different locations along the height, i.e. top story, middle story, first story, and lower half of the frame. To obtain a soft or stiff story, the story stiffness was divided or multiplied by a modification factor; and to obtain a weak or strong story, the story strength was divided or multiplied by the modification factor. The modification factor which is considered in this study is 2.

3- Ground Motions

A set of 22 pairs of horizontal SGMRs selected from a specific far-field set, which was used in the FEMA P. 695 [4] as the suggested SGMs for NLTHA. Detailed information about the selected SGMRs and selection criteria, are provided in [5]. Figure 1 shows the magnitude–distance distribution, as well as the 5% damped acceleration response spectra of the general set.

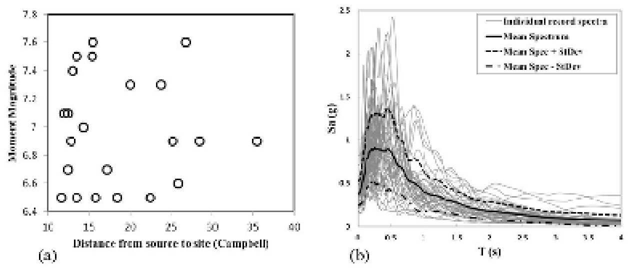

Figure 1. a) The magnitude–distance distribution; and b) the 5% damped acceleration response spectra of the general set of SGMRs

4- Evaluated Method

Ghafory-Ashtiany et al. [6] have proposed an a priori set of SGMRs selected from a commonly used general set, which is introduced for collapse assessment [4]. The method first utilizes the statistical exploration of a collapse capacity database that is constructed by analyzing numerous SDOF systems each of which represents specific combination of structural features such as ductility and period. Then, by defining a quantitative similarity measure, the whole database is refined to find the optimum subset representing the general set well for any predetermined structural characteristics. The step-by-step procedure, illustrated in Figure 2, shows the validity of proposed method in collapse simulation of a first mode dominant benchmark structure.

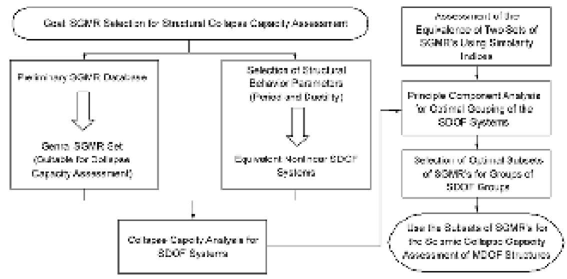

Figure 2. Steps of strong ground motion record selection for the reliable prediction of the mean seismic collapse capacity of a structure group

5- Conclusions

The most important results that can be concluded from designed comprehensive evaluation of the mentioned selection method can be listed as;

- In the proposed subsets by selection method in most cases underestimate seismic demands of irregular frames compared to the estimations by using the reference set of 44 SGMs; this can be attributed to the fact that many of steel frames don’t experience severe levels of nonlinearity of side-sway collapse.
- The application of the proposed subsets by the selection method does not necessarily result in the reduction of the statistical dispersion in the estimated EDPs.
- Comparing the estimated EDPs by the proposed subset with those of other possible subsets, almost in all cases does not show significant superiority of the selection method in terms of accuracy and reliability. This can be interpreted by noting to the fact that the goal of selection method is the reliable collapse simulation of the structures and it cannot easily be generalized to the other performance levels.
- Among different influencing parameters that are considered in this study such as the type and pattern of irregularities, as well as, initial stiffness of the frames; the results confirm that ductility plays the chief role on the selection output. Therefore it is suggested that the provision of a new selection process involving ductility of target structure is investigated as a future complementation of the current method.

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