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THE SENSITIVITY OF UNCERTAIN PARAMETERS TO FUNDEMENTAL PERIOD OF STRUCTURES IN PROBABILISTIC ANALYSIS

Panam ZARFAM[1], Mohammad SAYYAR[2] , Massood MOFID[3]

ABSTRACT

One of the most important current purposes of earthquake engineers is precisely predicting the behavior of the structures during future earthquakes. The limitation of our information about seismic parameters such as distance from the epicenter, frequency content and peak ground acceleration and also the uncertainty of the applied analytical methods caused the probability theory into the earthquake engineering. In this paper, the measure of seismic demand and capacity has been obtained, using a method based on an incremental non-linear dynamic analysis and statistical process of the results. The maximum inter story drift ratio has been used as the damage measure (DM) and spectral acceleration corresponding to the fundamental period of the structure defined as the intensity measure (IM).Because of uncertainty in calculating seismic demand and capacity, there would be some uncertainties in the results. In this research, four steel frames with 4, 8, 12 and 16 stories that are representative of structures with low to medium periods have been studied and the total uncertainty has been calculated for each of them, using a number of records which were scaled in different levels of earthquake intensity. According to the obtained results, the measure of reliability of the applied probabilistic method for structures with different periods have been calculated and compared to each other.

Keywords: Probabilistic analysis, Incremental dynamic analysis, Uncertainty, Reliability

INTRODUCTION

Structural damages observed in the Northridge and Kobe earthquakes indicated that the current design procedure could not ensure the safe performance of structures during strong ground motions. Thus new methodologies for evaluation of structure performance and design procedure were advent. The state of the statistical and reliability methods that could provide proper treatment and incorporation of uncertain parameters directly related to the mission of SAC project titled "Critical Issue in Developing Statistical Framework for Evaluation and Design" (Wen and Foutch, 1997). These parameters involve in both seismic loading and building resistance in the evaluation and design method. Statistical issues were further developed by Hamburger (2000) and Jalayer and Cornell (2000). The probabilistic framework for seismic resistant design which was expressed by Cornell et al. (2002) considers the uncertainty in structural demand and structural capacity related to uncertainty characteristic of ground motions at given hazard levels.

[1] Graduate Research Assistant, Dept. of Civil Engineering, Sharif University of Technology ,Email:zarfam@mehr.sharif.edu
[2] Graduate Research Assistant, Dept. of Civil Engineering, Sharif University of Technology ,Email:sayyar@mehr.sharif.edu
[3] Professor, Dept. of Civil Engineering, Sharif University of Technology, Email:mofid@sharif.edu

PROBABILISTIC ANALYSIS PROCEDURE

In probabilistic–based design the estimation of structural performance under seismic loads is important an subject and the estimation of the mean annual rate of exceeding a specific level of structural demand (e.g. maximum interstory drift ratio) or a certain limit state capacity (e.g. global or local dynamic instability) is the design criteria.
Practical format for the acceptance criteria for moment frame can be written as Eq.1. (Jalayer and Cornell, 2000)

$$\{exp[\ -\frac{1}{2}\frac{k}{b}\beta_c^2\ ]\}\hat{C} \geq \{exp[\ \frac{1}{2}\frac{k}{b}\beta_{D|Sa}^2\ ]\}\hat{D}^{P_\circ} \tag{1}$$

Where:

$\hat{D}^{P_\circ}$: median demand under a given ground motion of intensity $S_a^{P_\circ}$ (Spectral acceleration corresponding to the performance objective earthquake, e.g. 2% in 50 years)

$\hat{C}$: median capacity

β_C : standard deviation of natural log of capacity

$\beta_{D|Sa}$: standard deviation of natural log demand at a given Sa level

k: log-log slope of the hazard curve

Median Demand

Interstory drift ratio is assumed as the primary parameter to predict performance of the building. To obtain the median drift demand we use the incremental non-linear dynamic analysis (IDA) for several suite strong ground motion records. In this procedure a series of ground motion records is considered and each accelerogram scales on an intensity measure (IM, e.g. the 5%-damped first-mode spectral acceleration Sa (T_1, 5%) or peak ground acceleration) performs upon a structural model in several levels of intensity that include the full range of structural model's behavior. The median of interstory drift ratio among accelerations for each intensity measure (IM) indicates the median demand D related to given intensity measure (IM). In other word the median IDA curve indicates the median demand for various IMs.

Median Capacity

Local Capacity can be easily defined on the IDA curve. For each performance level the limit-state is defined in FEMA (2000). Immediate Occupancy (IO) is reached when maximum interstory drift ratio exceeds 0.02 and Collapse Prevention (CP) is assumed when local slope on the IDA curve is 20% of initial slope or maximum inter story drift exceeds 0.10; whichever first occurs.

Total Uncertainty

Based on probabilistic method for safety checking of structural performance we consider the uncertainty in earthquake characteristic. By recalling the Eq.1. and rearranging we have Eq.2.

$$\frac{\hat{C}}{\hat{D}} \geq exp\left[\frac{1}{2}\frac{k}{b}(\beta_c^2 + \beta_{D|Sa}^2)\right] \tag{2}$$

The median capacity to median demand ratio indicates the reliability of analysis. The Total Uncertainty is defined to have more accurate understanding on the measure of existing uncertainty in the probabilistic methods of structural analysis against different strong motion records. Obviously if any dispersion doesn't exist in estimating of median capacity, $\hat{C}$ and median demand, $\hat{D}$ values, reliability of results will be high. Based on this issue the total uncertainty has been defined (Jalayer and Cornell, 2000) as Eq.3.

$$\beta_T = \left[\beta_C^2 + \beta_{D|Sa}^2\right]^{1/2} \quad (3)$$

If there is not any uncertainty in results, β_C and $\beta_{D|Sa}$ equal to 0, the β_T will be zero. The more dispersion in results, the less value of β_T. The measure of β_T is strongly dependent on properties of earthquake records used.

In this study we are to determine the effect of first-mode period measure on β_T values and the relationship between period and β_T.

TOTAL UNCERTAINTY EVALUATION PROCEDURE

Models

To reach our goal, we will use four model of 4, 8, 12, 16-storey steel-moment resisting frame (SMRF) designed for southern California according to the NEHRP, 1997 provision. These models are representative for short and medium period. The first-mode period values of the models are in Table 1.

Table 1. The properties of models

	4 Storey	8 Storey	12 Storey	16 Storey
Height (m)	12	24	36	48
T_1 (sec)	1.1	1.5	1.95	2.4

Ground Motion Records

We select a suite of ground motion records, listed in Table 2,that belong to a bin of magnitudes range 6.2 to 7.1 and moderate distance of 21-33 km. The all records are related to stiff soil sites.

Table 2. Set of ground motion records

No	Event	Station	$\Phi°$ [1]	Soil [2]	M [3]	R^4 (km)	PGA (g)
1	Imperial Valley,1979	Chihuahua	012	C,D	6.9	28.7	0.27
2	Loma Prieta,1989	Agnews State Hospital	090	C,D	7.1	28.2	0.159
3	San Fernando,1971	Hollywood Stor Lot	180	C,D	6.6	21.2	0.174
4	Loma Prieta,1989	Anderson Dam	270	B,D	7.1	21.4	0.244
5	Loma Prieta,1989	Hollister Diff. Array	165	-,D	7.1	25.8	0.269
6	Imperial Valley,1979	Chihuahua	282	C,D	6.9	28.7	0.254
7	Northridge,1994	Hollywood Stor	090	C,D	6.7	25.5	0.231
8	Superstition Hills,1987	Wildlife Liquef. Array	360	-,D	6.2	24.7	0.134
9	Imperial Valley,1979	Compuertas	015	C,D	6.9	32.6	0.186
10	Imperial Valley,1979	Cucapah	085	C,D	6.9	23.6	0.309
11	Superstition Hills,1987	Wildlife Liquef. Array	360	-,D	6.6	24.4	0.207
12	Loma Prieta,1989	Hollister Diff. Array	255	-,D	7.1	25.8	0.279

[1]Component [2]USGS, Geomatrix soil class [3]Moment magnitude [4]Closest distance to fault rupture

PEFORMING THE ANALYSIS

For each models a series of dynamic analysis is performed using the ground motion records listed in Table 2. Each accelerogram is scaled to fifty levels of intensity measure incrementally. Therefore for each frame we have a multi-IDA curve which by post processing on them the 16, 50 and 84% IDA curves can be obtained. The nonlinear dynamic analyses were performed by OpenSees 1.6.2. The IDA curves are mentioned in Fig. 1 to 4.

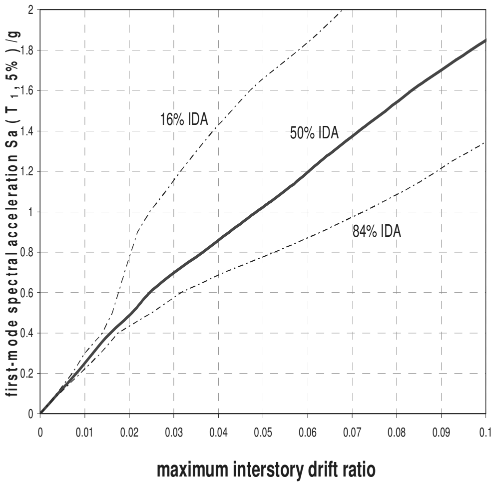

Fig. 1. 16, 50, 84% Incremental dynamic analysis (IDA) curves for four-story frame

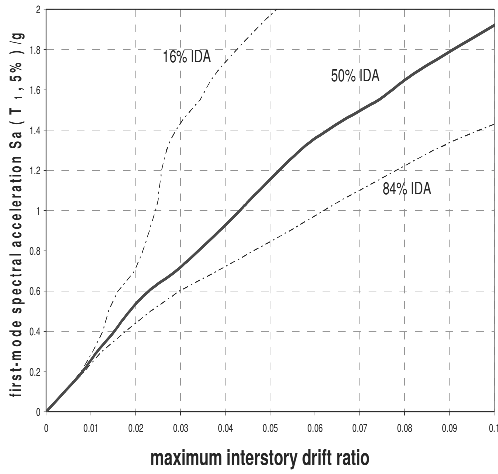

Fig. 2. 16, 50, 84% Incremental dynamic analysis (IDA) curves for eight-story frame

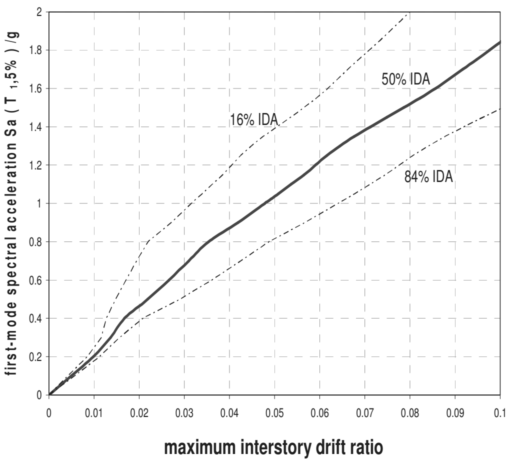

Fig. 3. 16, 50, 84% Incremental dynamic analysis (IDA) curves for twelve-story frame

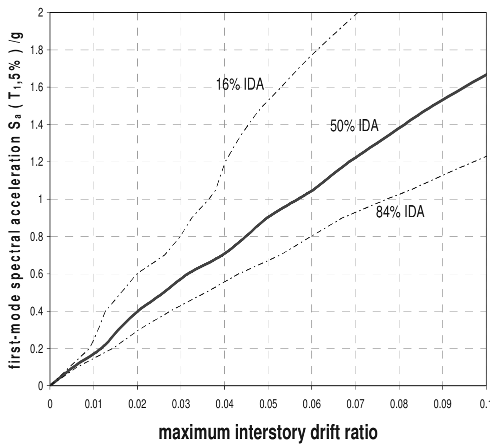

Fig. 4. 16, 50, 84% Incremental dynamic analysis (IDA) curves for sixteen-story frame

The magnitude of total uncertainty is greatly dependent on the similarity of the earthquake records used for incremental non-linear dynamic analysis. The important aim is responding to this question: which type of structures (short period or medium period) is more sensible to variety of records used? With this answer we can determine that by the constant number of accelerogram involved in the probabilistic method the more reliable answer is related to which structures. The post processing of IDA curves are demonstrated to calculate β_T for two hazard levels: 2% in 50 years and 10% in 50 years. The Fig. 5. shows the relationship between models' structural first-mode period and β_T values.

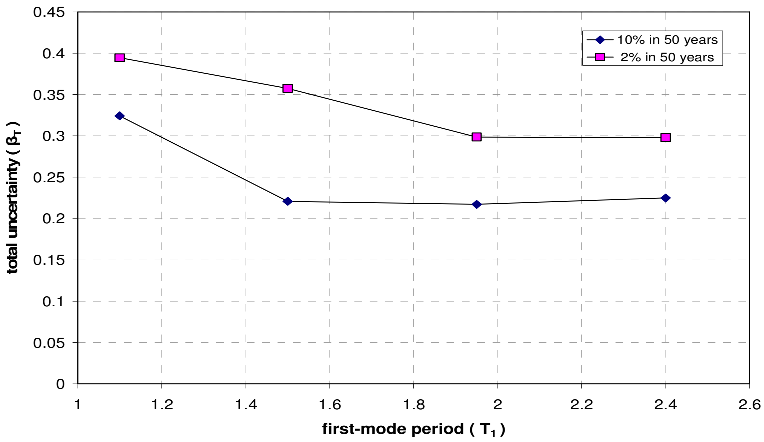

Fig. 5. The relation between total uncertainty and structural first-mode period

CONCLUSION

As a result of β_T values calculated for two hazard levels and four models, the higher hazard level our target is, the greater values the β_T has. This matter is reasonable whereas the higher level of intensity of earthquake causes the models to behave nonlinearly more and the nonlinear behavior of models is one of the most important factors in dispersion of results. The chief result of this research is that in low-period structures effects of uncertain parameters are high. In the structures having moderate period the β_T value decreases and by increasing period it remains relatively constant. In other words the low rise models are more sensible to variety of records than the moderate period structures. This means in probabilistic-based design method if we want to reach same reliability in both short and long period structures we have to use more number of records in low rise structures than taller structures.

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