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Assessment of an RC existing hospital building with special moment frame using fragility curve

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Abstract

In this study, an existing hospital structure has been evaluated with incremental dynamic analysis (IDA). This building is accommodated in Karaj with soil type II. At first, two 2-D frames along X, Y direction are selected. Then, five performance levels are determined according to "Rehabilitation Code for Existing Buildings (Publication No. 360) including Immediate Operational (IO), Limited Damage (LD), Life Safety (LS), Limited Life Safety (LLS), and Collapse Prevention (CP). The Peak Ground Acceleration (PGA) as earthquake intensity and relative displacement (Drift) as the failure index has been used for incremental dynamic analysis method via seismo- struct software. In the next step, the probability of reaching or exceeding of the structure to a limit state was determined. Results of incremental dynamic analysis for fragility curves show that PGA was 0.6g, the probability of reaching or exceeding from IO level is approximately%99. This probability is almost %96 for LD, %82 for LS, % 53 for LLS, and %43 for CP. It has been signified that the probability of fragility is raised with increasing in PGA

Keywords: *Fragility curve, Incremental dynamic analysis, Vulnerability, Seismo Struct*

1. Introduction

Iran is a populated country with high seismic hazard and relative poor earthquake resistant buildings [1]. The seismic potential has been developed by earthquake hazard in structures [2, 3]. Buildings in this country are designed for earthquake forces accordance with the code Standard 2800. There is the base acceleration for designing in high risk areas is equally 0.35g [4]. Also, the analysis procedures are by way of linear design and the applied loads are static; these building are strengthened on the basis Iran Seismic Rehabilitation Journal (Publication No. 360). The purpose of this study is to examine and evaluate the performance level of concrete structure with special moment frame of existing building (the view of which is indicate in Fig. 1) with the clinical use. Also, to determine the probability of damage due to its high importance in immediate service at the time of strong earthquakes by way of incremental dynamic analysis from the results of fragility curves. Fragility curve functions are one of the most important application means in seismic hazard estimation which is also used in seismic risk management. The development of the fragility curve in fact show that the probability the occurrence of reach or exceeding of the structure, from a certain amount of damage, is based on one of the characteristics of the earthquake, such as the PGA. The extraction of such a curve began from the nuclear installations system because of their importance's and The first curve was drafted in 1980 for a nuclear power plant. These curves are widely used for structures including buildings, bridges and etc. Most methods for assessing the development of fragility curves have been used only an incremental dynamic analysis method.

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This method was used by Siti Nur and Fadzli in 2015 on the steel and concrete frame systems. [5] The result shows that the height and type of material play an important role in structure behavior and fragility curve pattern. [5] In this study, the fragility curve is extracted by way of incremental dynamic analysis then probability of reaching or exceeding the structure from a specific damage limit is determined in different accelerations of ground motion.

Figure 1. Building view

2. Structural model

A two-dimensional model from a concrete special moment frame have been used by incremental nonlinear dynamic analysis, which are designed in accordance with Iran's code for building design against earthquake (standard 2800) on soil type II in six stories. The plan and two-dimensional model are shown in figures (2) and (3). Two frames are along x and y directions, which frame span has 6 meters width and 4 meters height. The building importance factor is $I = 1.4$ and Response Modification coefficient is $R = 10$. The material specifications including the compressive strength of the concrete, the steel failure tension, and the steel final stress are $350\ \mathrm{kg/cm^2}$, $4000\ \mathrm{kg/cm^2}$, and $6000\ \mathrm{kg/cm^2}$ respectively. The sections of concrete members are presented in Table (1).

Figure 2. Plan of the building under study

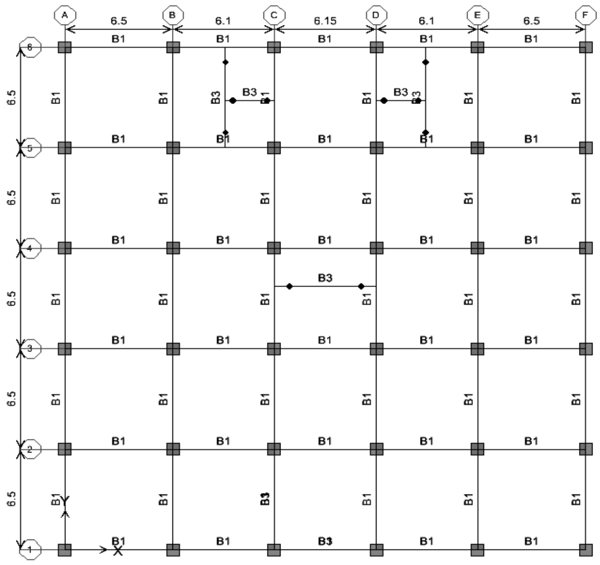
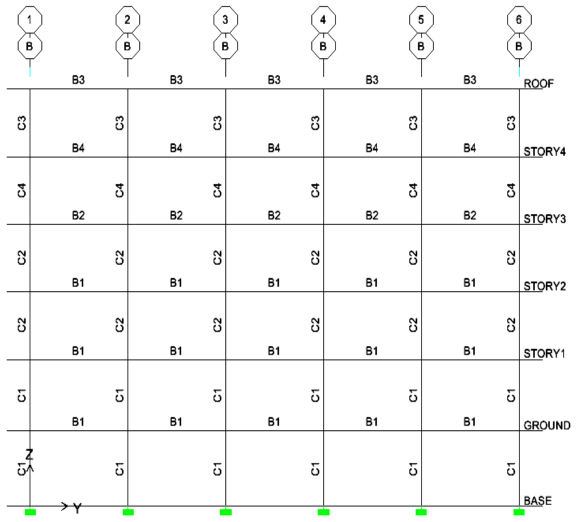


Table 1. Characteristics of the beams and columns

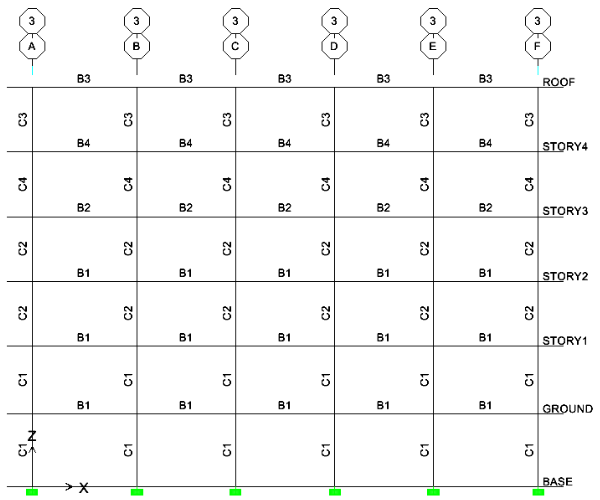
Section	Width cm	Height cm	Longitudinal bars		Confinement bars	
			Value	Size	Distance cm	Size
B1	60	75	14	Ø20	10	Ø12
B2	60	75	10	Ø20	10	Ø12
B2	60	75	4	Ø25	10	Ø12
B3	60	70	14	Ø20	10	Ø12
B4	60	70	14	Ø20	10	Ø12
C1	75	75	24	Ø25	10	Ø14
C2	65	65	20	Ø25	10	Ø14
C3	60	60	16	Ø25	10	Ø14
C4	55	55	12	Ø25	10	Ø14

3. Incremental dynamic analysis (IDA)

In this analysis, the structure is affected by some series of seismic records, that the intensity of which gradually is increased. The maximum acceleration of the earth has been used as the loads



(a)



(b)

Figure 3. Structure frames (a) x-direction (b) y-direction

intensity, which has been begun and gradually grown from lower to upper values. So, the behavior of the structure has been changed from the elastic up to yield state. This analysis can be applied for derive the failure index curves. These curves represent failure index of structures on the basis of the intensity measure. The analysis outputs are included various results such as drift, the maximal rotation in the plastic joint, the maximum base shear etc, that is based on the maximum acceleration of the earth. The relationship between the drift with earth's motion can be determined according to the incremental dynamic analysis (IDA) curve. Also, this relationship shows a range of behavior with large variation from each earthquake record [6].

At first step, IDA must be considered before developing of fragility curves. A suitable set of ground motion records are needed to conduct IDA. A few Parameters, such as event magnitude, PGA, distance from fault, and soil type must be considered in selection of ground motion [7]. According to Iran's standard code (2800), at least seven earthquake records are required for this analysis, which are given in Table (2).

IDA is under each earth motion, and the elastic response spectra were incrementally developed from 0.1 g to 0.6 g with increment of 0.05g. Incremental dynamic analysis was carried out under each ground motion. It was performed with Seismic Struct software that shown in figures (4) and (5) with seven sets of earthquake records, related to two X- and Y-axis frames.

Five performance levels are considered according to "Instruction for Seismic Rehabilitation of Existing Buildings" (Publication No. 360), which include Immediate Operational (IO), Limited Damage (LD), Life Safety (LS Limited Life Safety (LLS), and Collapse Prevention (CP)) [8, 9], respectively with relative drifts of %0.5, %1, %1.5, %2, and %2.5.

Table 2. The Selected ground motion records

PGA	Magnitude (Mw)	Year	Record
0.28	6.53	1942	Imperial Valley
0.12	6.61	1971	San Fernando
0.10	7.35	1978	Tabas
0.24	6.93	1989	Loma prieta
0.51	7.37	1990	Manjil
0.24	6.69	1994	Northridge
0.86	6.6	2003	Bam

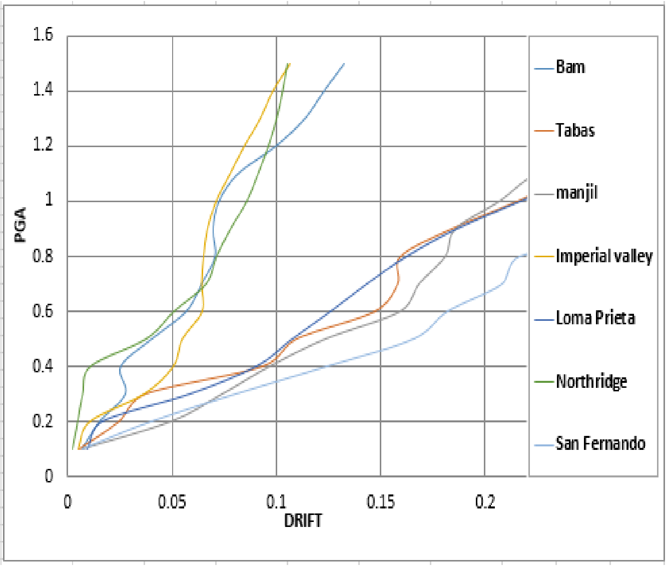


Figure 4. Incremental dynamic curves under seven earthquake records in x-direction

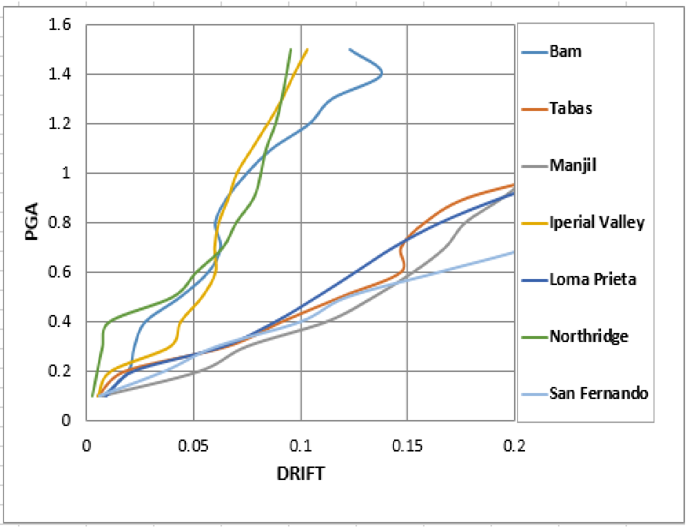


Figure 5. Incremental dynamic curves under seven earthquake records in y-direction

4. Fragility curve

Fragility curve shows probability to express of damage at specified ground motion records. Some parameters, such as PGA, spectral acceleration, and peak ground velocity, can be used to develop fragility curve. PGA was selected because it is used to conduct nonlinear history analysis. the analysis explains the probability of occurrence a structure's reach or exceed from a damage measure (drift) with due attention to one of the characteristics of the earthquake (PGA) [10]. Two important factors play a role in creating the fragility curve, one of which is the damage in the structure, which is expressed by a probability, and the second is the motion of the earth which fragility curve can be drawn based on one of its indices, such as the Peak Ground Acceleration, the Peak Ground velocity, and the Peak Ground Displacement [7, 11]. Fig (6) shows the stages of development of curve in this study. Calculation of the mean and standard deviation of PGA is essential for development of fragility curve. Calculated parameters are tabulated in Table 3.

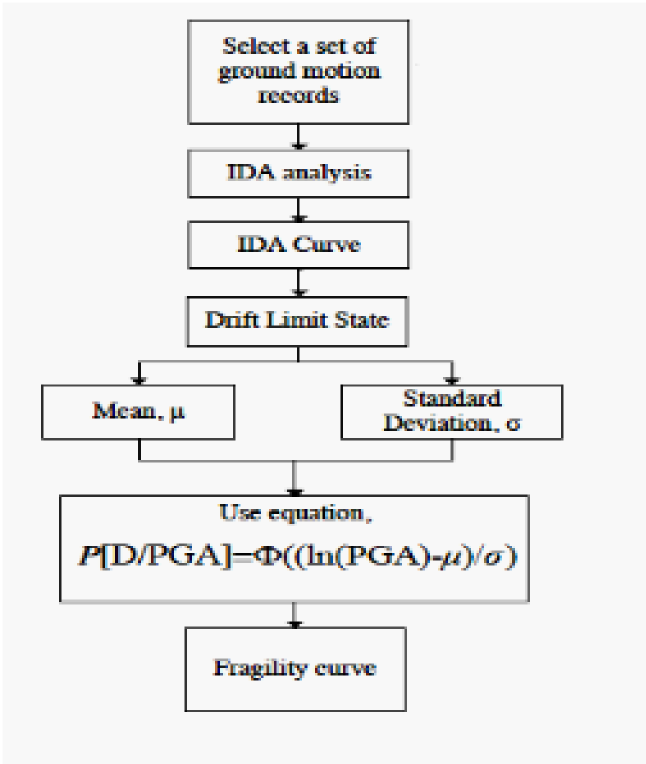
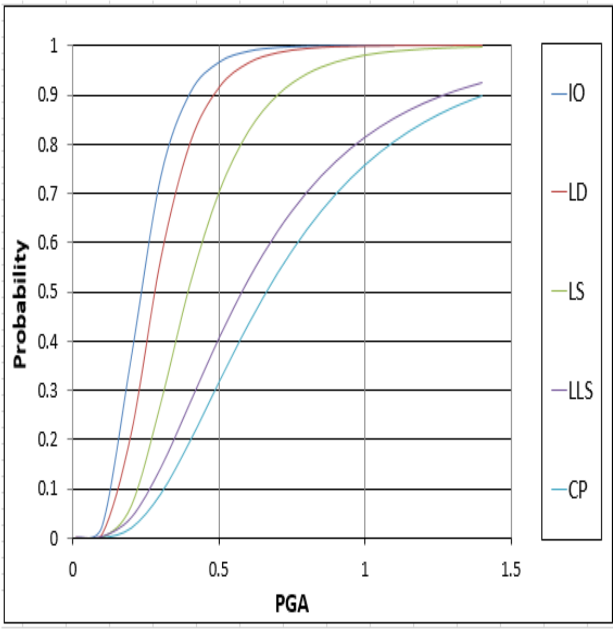


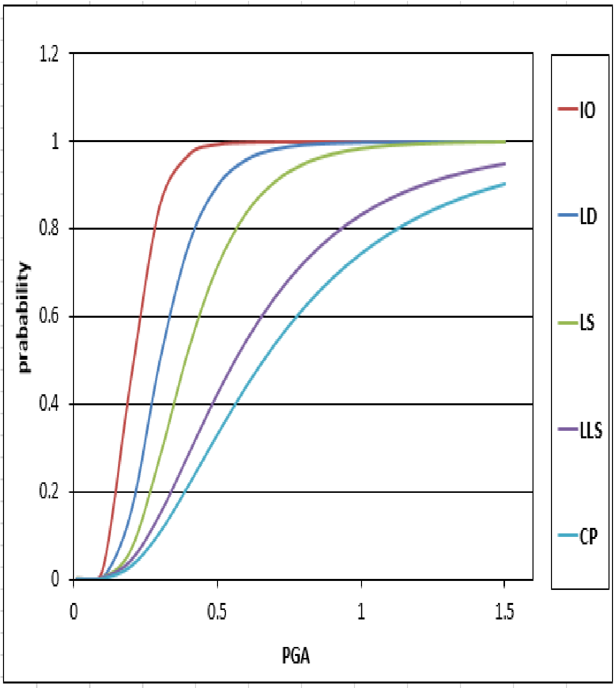
Figure 6. procedure to obtain Fragility curve

Table 3. Parameters of log-normal distribution

Performance level / frame	IO		LD		LS		LLS		CP	
Mean and standard deviation	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
x-direction	-1.46	-0.42	-1.27	0.42	-0.93	0.45	-0.55	0.61	-0.41	0.59
Y-direction	-1.57	0.35	-1.27	0.39	-0.94	0.44	-0.57	0.59	-0.40	0.63



(a)



(b)

Figure 7.(a) in x-direction (b) in y-direction

Equation (1) was used in the developed fragility curve for this structure. Where P is the probability, D is the damage, is the normal standard cumulative distribution, PGA is the peak ground acceleration, μ is the mean, and σ is the standard deviation of the natural logarithm of PGA, respectively [5,12].

$$P= [D/PGA] = ((LN (PGA)-\mu)/\sigma) \qquad (1)$$

Fig (7) shows the development of fragility curve for two frames, one in X-direction (a) and the other in Y- direction (b) that have almost similar results. The horizontal axis is the PGA and the vertical axis is the occurrence probability in percent. These figures, for example, illustrates that at acceleration of 0.6g, the probability of its reaching or exceeding from the OP is approximately %99, this probability for LD is %96, for LS is %82, for LLS is %53, and finally for CP is %43

5. Conclusion

in this paper, Fragility curve was developed for the existing structure with concrete special moment frame with clinical use, according to publication No. 360 and Iran's standard code 2800 and according to specifications presented in the second section of this study. In this assessment, probability of reaching or exceeding of a structure from a certain damage level is expressed in of the earthquake specifications. In other words, the probability of occurrence of each damage case due to relative displacement was determined versus different values of the PGA, and the following conclusions were made:

1. In the fragility curve, fragility increases when PGA grows.
2. Changes in the probability of reaching or exceeding a failure state are seen more at lower values of PGA than higher PGA values. This means that the slope of fragility curve is more at lower PGA values, and less at higher PGA values.
3. In this evaluation, it can be concluded that probability of structure reaching from OP to CP stages increases at higher earth acceleration
4. This structure is not suitable to get IO performance level in the more intensity earthquake
5. Iran's Standard No. 2800 can be a reliable design reference for this structure at the LS performance level, but structures of very high importance (with clinical use) require the IO performance level.

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