

# Seismic Performance Evaluation and Fragility Analysis of Reinforced Concrete Structures

Parkar Fouzan A.M, Shelar Vaibhav V.

M. E Student, Department of Civil Engineering, Trinity College of Engineering and Research, Pune, India

Professor, Department of Civil Engineering, Trinity College of Engineering and Research, Pune, India

**ABSTRACT:** Fragility curves deliver the conditional probability of structural effect when subjected to earthquake lots as a characteristic of ground motion intensity or maybe other design parameters. Seismic fragility curves are utilized primarily by decision makers for the evaluation of seismic losses all for pre earthquake disaster preparation and post-earthquake restoration programs. Model of fragility curves in standard techniques consists of development of large quantity of computational versions which stand for the inherent variation in the material of specific construction style as well as its earthquake time history analyses to a qualities a qualities reliable and accurate estimation of the probability of exceedance of the selected injury parameter. Since substantial damages to structures having structural irregularity of their designs had been frequently noticed during several previous earthquakes, there are actually excellent research initiatives to assess the seismic vulnerability of theirs. Although the majority of the prior studies used simplified structural representations for instance two-dimensional or one-dimensional types in the fragility analysis of plan irregular structures, easy analytical versions couldn't represent accurate seismic behavior coming from the complex nonlinear coupling between torsional and lateral responses as the level of irregularity greater. For room constructions with good irregularity, much more reasonable representations including threedimensional models are essential for proper seismic evaluation. However, the usage of computationally expensive models isn't practically doable with existing methods of fragility analysis. Consequently, in this particular study, an alternative strategy is adopted that could produce vulnerability curves efficiently, despite a three dimensional design. In this particular approach, an integrated computational framework is established that combines structural analysis and reliability analysis. This enables analysis of the limit state faction without any constructing the explicit formula of its, and the failure probability is calculated with the first order reliability technique (FORM) to cope with the computational challenge. Under the integrated framework, this particular analysis investigates the seismic vulnerability of space reinforced concrete frame structures with different plan irregularity. Material anxiety is recognized as along with much more symbolic seismic fragility curves are derived with the three-dimensional analytical models of theirs. The usefulness of the adopted approach is reviewed, and also the substantial impact of structural irregularity on seismic vulnerability is highlighted.

**KEYWORDS:** Seismic Performance, Fragility Analysis, Reinforced Concrete Structures

## I. INTRODUCTION

### 1.1 Fragility Curve

Former to an earthquake, vulnerability evaluations of structures are usually carried out for judging the necessity for strengthening important facilities and buildings against eventually earthquakes. The simplest way to do such assessments is Fragility curves. Fragility curves epitomise the conditional probability that a result of a specific framework might surpass the functionality cap in certain soil movement intensity. These curves are important resources for the valuation of probability of structural damage as a result of earthquakes as a characteristic of ground movement indices if not layout parameters. Fragility curves present the likelihood of failure verse us peak ground speed. It shows a regular fragility curve with PGA around the x-axis as well as probability of failure along y axis. A place in the curve belongs to the likelihood of exceedance of the destruction parameter that may be lateral drift, storey drift, base shear etc., over the limiting great mentioned, at a certain ground motion intensity parameter

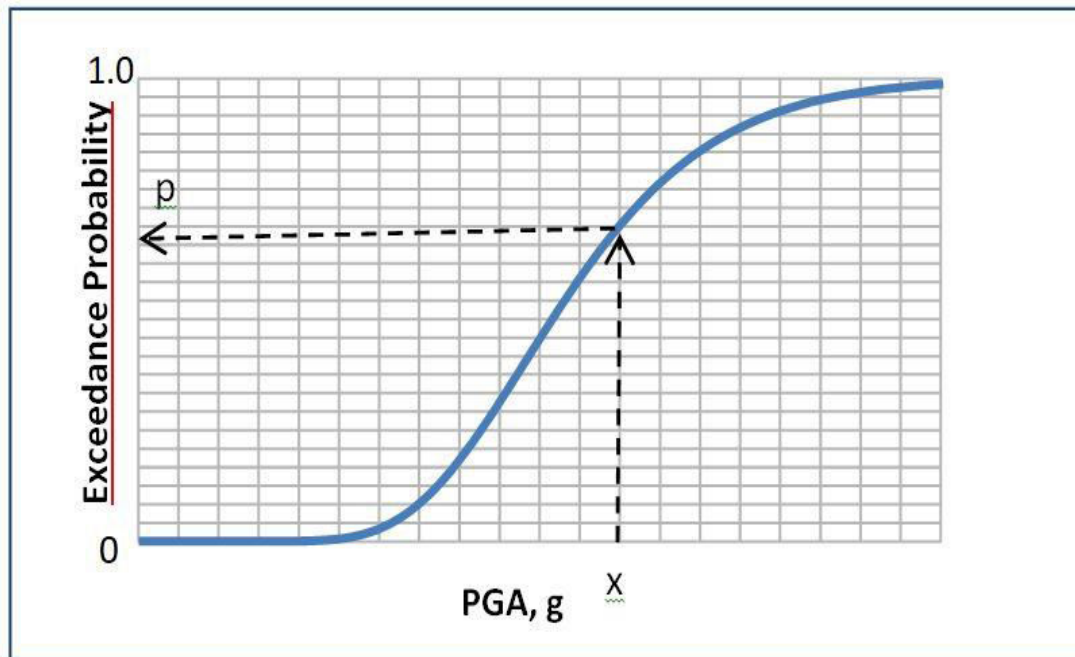


Figure 1.1 Typical Fragility Curve showing PGA vs. Probability of exceedance

For a PGA of say  $x'$ , the fragility curve gives the corresponding probability of exceedance of limiting damage parameter as  $p\%$ . It can be interpreted as if 100 earthquakes of PGA  $x'$  occur,  $p$  times the damage parameter will exceed the limiting value for which the fragility curve is plotted.

Harm analysis (Damage of system given a specific need parameter), Loss analysis (Cost needed for a specific damage) will be the 4 parts of the performance based earthquake engineering frame work launched by Deierlein and Moehle (2004). Figure 1.2 shows the parts concerned in performance-based earthquake engineering frame work. The next component in this particular frame tasks are the advancement of fragility curves.

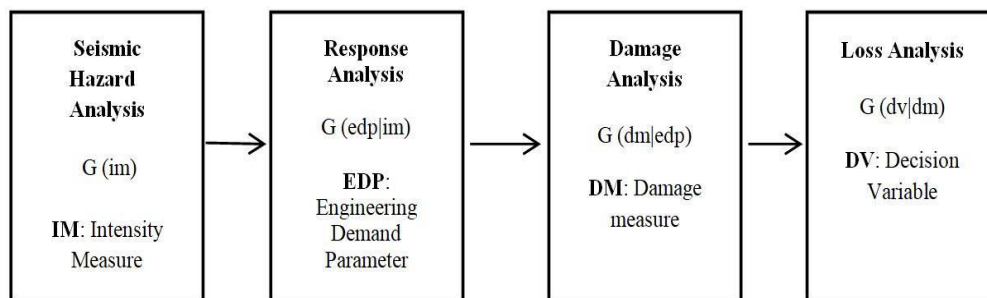


Figure 1.2 Performance-based earthquake engineering framework

It shows common fragility curves for different limiting values for damageParameter. The intensity measure here's the spectral displacement of the earthquake. As the limiting value enhances the curve shifts towards properly and gets to be more level. From the figure it could be observed that at weak shaking the probability of exceedance with the cap state corresponding to little damage is rather high. For powerful earthquakes probability of exceedance is 100 % for the very first curve, meaning small damage is extensive, moderate, and sure damages will probably occur. But probability that total damage will occur is very low. Regions of different damage states including slight, moderate, Complete and extensive damages are marked in between each fragility curves. With the severity of damage, the parameter defining the maximum state of damage improves, & the exceedance probability decreases.

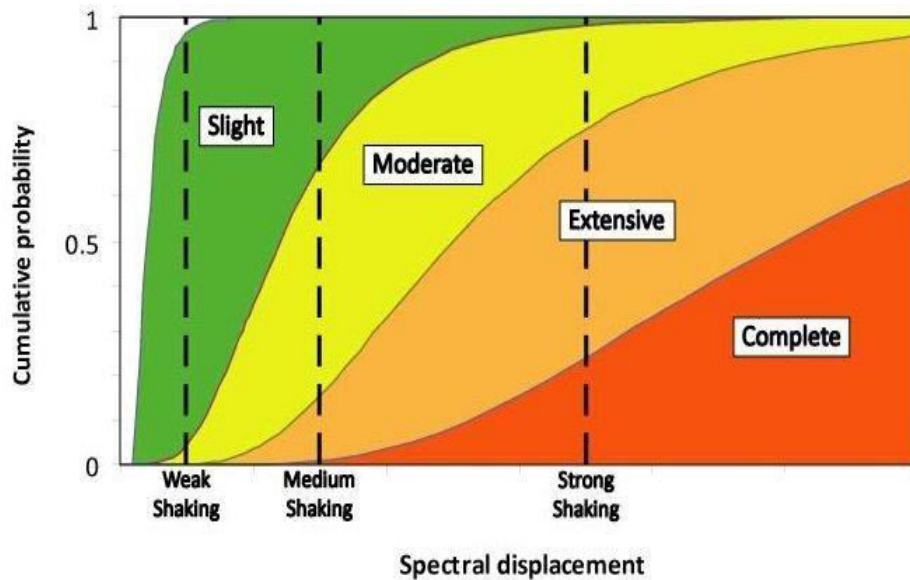


Figure 1.3 Fragility curves for 4 different limit states

### 1.2 Methods of Developments of Fragility Curves

Conventional methods for computing building fragilities are:

1. Monte Carlo simulation(MCS)
2. Cornell et al.(2002)
3. Response Surface Method
4. ATC-63

The Monte Carlo simulation is a statistical simulation process which provides reasonably accurate solutions to issues expressed mathematically. It employs a sequence of random numbers to perform the simulation. This tactic requires rather significant amount of styles to attain a satisfactorily reliable analysis of fragilities and that tends to make it computationally costly as well as time consuming.

### 1.3 Space Structures with Plan Irregularity

In plan irregular buildings, center of mass doesn't coincide with center of stiffness. Earthquake-induced inertia forces act by center of mass, as well response forces produced by lateral load resisting member's action through center of stiffness. The distance between the centers of mass as well as stiffness is described as eccentricity, which causes an extra torsional moment. The torsional response is in addition to the lateral response, leading to consider in a position rise in deformation demand. Generally, plan-irregular structures are significantly more vulner- in a position to earthquake damage. Evidently, extensive destroys to these kinds of structures because of torsional vibration were frequently noticed during several previous earthquakes. Appropriately, there have been constant research attempts to evaluate seismic vulnerability of plan irregular structures.

### 1.4 Seismic Fragility Curve Derivation Method

The seismic fragility curve is described as the relationship between ground movement intensity as well as disappointment probability every time a framework reaches or perhaps surpasses a particular effect amount. The failure probability may be estimated also by simulation and analytically. Accordingly, existing methods may be grouped into two categories: a simulation based method and an analytical function based method. The simulation based technique, like Monte Carlo simulation, is conceptually straightforward. The failure likelihood is driven by doing a number of numerical simulations and counting failure situations from complete cases.

$$P_f = \Phi(-\beta) \tag{1}$$

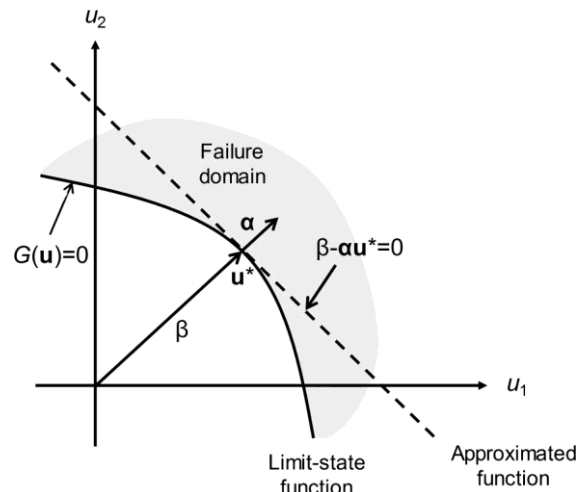


Fig.1.4 Linear Approximation in Form

**1.5 Integrated Computational Framework**

Since source codes for both software packages are open to the public, modifications that are necessary could be made to create an integrated platform of ZEUS-NL and FERUM.

The incorporated computational platform, called FERUMZEUS, is started with the improvement of linking interface between the ZEUS-NL. And FERUM The linking interface makes achievable the automatic exchange of info between two distinct analysis programs during fragility analysis, and also it enables implicit calculation of efficient derivation and failure probability of fragility curves. Fig. 1.5 presents the computational platform of FERUMZEUS. In this particular platform, FERUM supplies ZEUS NL with deterministic enter values for selected arbitrary variables depending on their distribution sorts, along with ZEUS-NL generates an analytical style with the determined enter parameters.

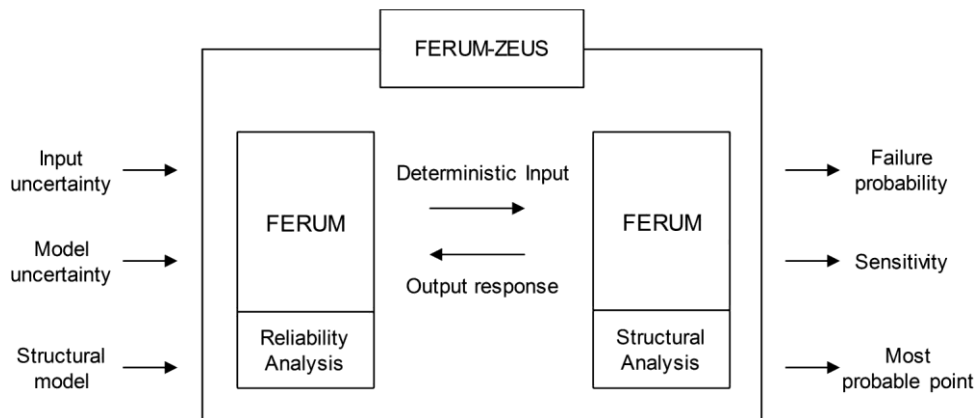


Fig.1.5. Computational Platform of Ferum-zeus

**1.6 Motivation of the Present Study**

Generation of fragility curves in conventional methods involves development of large number of computational models that represent the inherent variation in the material properties of particular building type and its earthquake time history analyses to obtain an accurate and reliable estimate of the probability of exceedance of the chosen damage parameter.

**1.7 Objective of Study**

- a) To study and analyse alternative strategy is adopted that could produce vulnerability curves efficiently, despite a three dimensional design. In this particular approach, an integrated computational framework is established that combines structural analysis and reliability analysis.
- b) To study the analysis of the limit state faction without any constructing the explicit formula of its, and the failure probability is calculated with the first order reliability technique (FORM) to cope with the computational challenge. Under the integrated framework, this particular analysis investigates the seismic vulnerability of space reinforced concrete frame structures with different plan irregularity.

c) To study Material anxiety is recognized as along with much more symbolic seismic fragility curves are derived with the three-dimensional analytical models of theirs. The usefulness of the adopted approach is reviewed, and also the substantial impact of structural irregularity on seismic vulnerability is highlighted.

### 1.5 Scope of Work

In the present study to implement the simulation of large number of computational models for fragility evaluation, The nonlinearity in the material properties are modelled using fiber models available in Open Sees platform. In this study, a different approach is adopted that can produce vulnerability curves efficiently, even with a three-dimensional model. In this approach, an integrated computational framework is established that combines reliability analysis and structural analysis.

## II. LITERATURE REVIEW

### 2.1 Introduction

As the present study works with fragility curve development, a comprehensive literature assessment was performed on different traditional techniques concerned in fragility curve development, strategy suggested by

**Cornell et al. (2002)**[5], Latin Hypercube Sampling, Response Surface Method etc.. In the later part a overall evaluation of High Dimensional Model Representation method and the application of its in Fragility curve evaluation are talked about.

**Deodatis and Tantala et.al (2002)**[7] A reinforced concrete 25 story moment resisting structure with three bays was thought by Fragility curves are created for wide sequence of surface motion intensities. Time histories evidenced by stochastic methods have been used. The nonlinear evaluation was conducted by considering the P- $\Delta$  effects and disregarding soil structure collaboration.

**Schotanus et.al(2002)** [31] put on an urbane and general method for seismic fragility analysis of systems earlier suggested by Veneziano et.al (1983) to some reinforced concrete frame. Response surface was accustomed turn the capability component in an analytical limit state function (g- function), with a categorical practical relationship that fits a second order polynomial, and can be used as input for SORM analysis. Such an explicit function highly lowers the variety of pricey numerical analyses required when compared with classical techniques which figure out the failure domain.

**Franchin et al. (2004)**[18] A numerical method was recommended by for seismic reliability issues which may be used in the evaluation of an RC frame structure. The procedure determined a response surface area, characterized by a statistical design of the diverse style, to stand for the seismic capability within an analytical limit state function.

**Polat and murat et al. (2006)** [25] created the fragility curves for midrise RC frame structures located in Istanbul, that had been developed based on the 1975 edition of the Turkish seismic design code which was influenced by numerical replication with regard to the amount of accounts of the structures. Buildings of 3, 5 and 7 story were designed based on the Turkish seismic design code.

**Craig et al. (2007)** [6] labelled the outcomes of study to create a technique to rapidly assess the fragility of geostructures and structures over a specified area by creating a process depending on the usage of computationally effective metamodels to stand for the all-round structural conduct of the compilation.

**Ellingwood et.al (2001)**[21] assessed the earthquake danger calculation of the structure by using the probabilistic risk searching tools. The job concentrated on the 3- probability grounded codified designed and reliability based condition valuation of existing buildings. Weld connected metal frames have been designed.

**Ji et al. (2007)** [15] presented an analytical agenda and also sample application for the seismic fragility assessment of reinforced concrete tall buildings. A basic lumped-parameter prototype was provided for a current skyscraper structure with two core wall surfaces and a reinforced concrete frame.

**Altay and Guneyisi et.al (2008)** [3] detected the behaviour of currently existing R/C office structures through fragility plots thinking about the circumstances as before and after retrofitted by liquid viscous (VS) dampers The R/C building



was modeled as a 3- dimensional analytical style and was started in ETABS version 7.2 Structural Analysis Program for the evaluation.

**Samoahet, al (2012) [32]** analyzed the fragility overall performance of non-ductile RC frames in very low and moderate seismic zones. The structural ability of the structures was studied by inelastic pushover analysis and seismic demand is examined by inelastic time history analysis followed by analysis of fragility curves. 3 non ductile RC frames symmetrical and also routine in program and also elevation had been studied that had been developed rendering to BS 8110 (1985).

**Buratti et al. (2010) [5]** Response Surface (RS) models have been utilized by with arbitrary block effects to assess seismic fragility curves in an approximate manner with good computational efficacy. The RS models have been controlled through numerical information obtained by nonlinear incremental dynamic analyses conducted utilizing different sets of ground-motions, strength allocations in frame components, along with values of the arbitrary variables taken away for describing the ambiguities within the structural behavior.

**Jeong and Elnashai et,al (2006) [12 ]**The fragility evaluation for an irregular RC frame under bi directional earthquake burdening has premeditated by. For the contemplation of the anomalies in framework, bidirectional response and the torsion had been used as 3- Dimensional structural response attributes to stand for the destruction states of the structure irregularities is bestowed through a reference derivation.

**Asadi and Bakhshiet,al (2012)[3]**Fragility curves have been created by to be able to evaluate many probability variables such as, PGA, crucial factor (I) and normal overstrength plus worldwide ductility capacity (R). These drawings were used to show when a number or a coefficient of variables were utilized to enhance the overall performance capacity of a framework.

**Towashiraporn et, al(2004)[37]** advised an alternative strategy for implementing the structural simulation. The utilization of Response Surface Methodology in connection with the Monte Carlo simulations abridges the procedure of fragility computation. The convenience on the result surface metamodels gets to be more obvious for promptly deriving fragility curves for structures in a portfolio.

### III. METHODOLOGY

#### 3.1 Seismic Vulnerability Analysis- Analytical Models

Three-dimensional regular and irregular three-story moment- resisting RC structures were investigated. The three-dimensional analytical models were developed based on the two-dimensional model the selected structure was designed mainly for gravity loads, and it can serve as a typical low-rise RC structure with limited ductility and no seismic details in many regions,The studied structures had three bays in the longitudinal and transverse direction. The length of each bay was 5.486 m (216 in.), and the total height was 10.744 m (423 in.). Fig. 3.1 shows the plan and elevation view of the studied RC frame structures

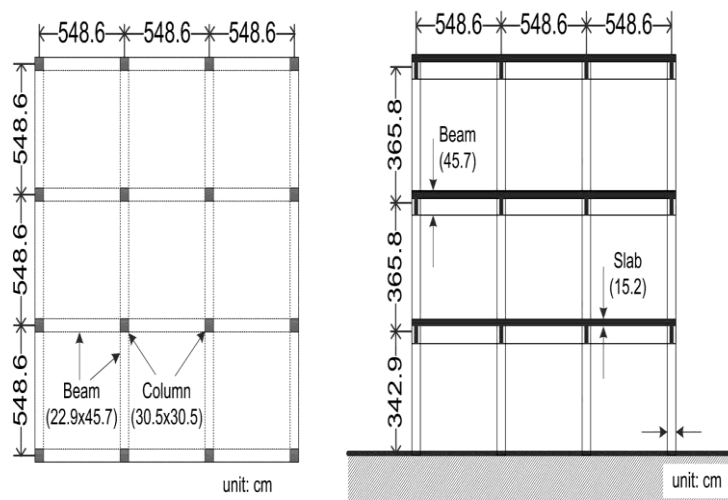
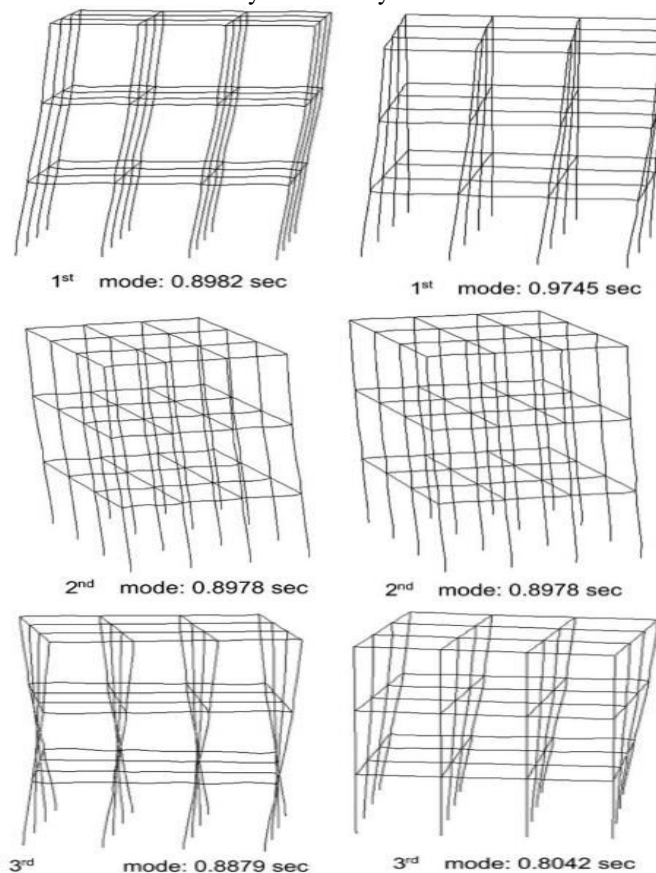


Fig. 3.1 Plan and elevation view of studied RC frame structures.

**Table 3.1 Eccentricities and fundamental periods of analytical models**

	Regular			Irregular			
Model property	ME000		ME025	ME050		ME075	ME100
Eccentricity (mm)	0		137.15	274.3		411.45	548.6
Dimensionless eccentricity (%)	0		2.5	5		7.5	10
First period (s)	0.8982		0.9148	0.9349		0.9549	0.9745
Second period (s)	0.8978		0.8979	0.8978		0.8978	0.8978
Third period (s)	0.8879		0.8712	0.8494		0.8271	0.8042

Five various kinds of analytical models have been explored; one was for a typical framework, and four had been for irregular structures. The regular framework design had coincident centers of mass and stiffness, while the irregular versions had different eccentricity from the non-coincident centers. Eccentricity is described as the distance between center of center and stiffness of mass, along with dimensionless eccentricity is identified as the ratio of the eccentricity to the floor dimension. Irregular models have eccentricities that differ from 2.5 to 10 % of the floor dimension in the transverse path. In the irregular versions, stiffness is dispersed symmetrically, but mass features a nonsymmetrical division under the assumption that reside lots are asymmetrically distributed across the slabs.



**Fig. 3.2 First three mode shapes of selected analytical models: (a) regular model (ME000); and (b) 10% irregular model (ME100)**

The numerical models are created in the nonlinear finite element analysis application ZEUS NL. They consisted of forty eight columns as well as 72 beams, and each beam and column member had six and seven components, respectively. The reinforced concrete columns had a Square cross section with 30.5 cm (12 in.) side width.

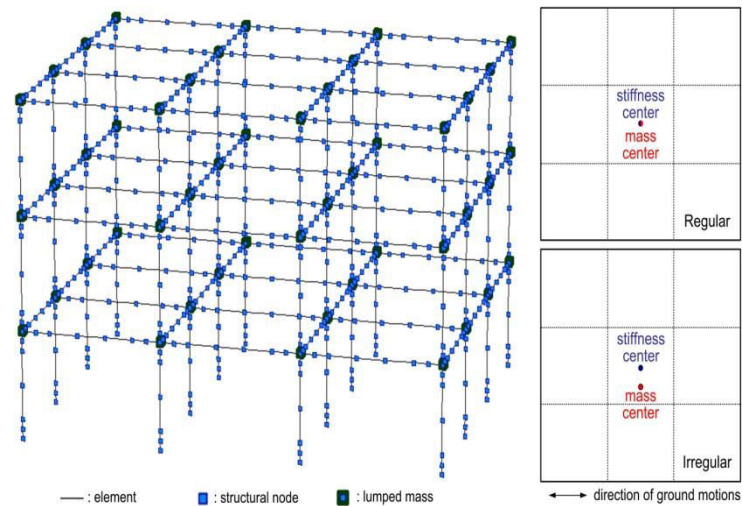


Fig. 3.3 Three-dimensional numerical model and schematic locations of mass and stiffness centers .

The thickness of the slab was 15.2 cm (6 in.), and beams possessed a reinforced concrete T aisle with complete level of 45.7 cm (18 in.). Lumped masses corresponding to the calculated gravity loads were placed solely at the beam column connections to minimize the dimensions of the mass matrix. Nonlinear material actions depending on a bilinear elastic-plastic model with a kinematic hardening and modified Mander's model (Martínez-Rueda and Elnashai 1997) were used for steel and concrete, respectively, and hysteretic damping was considered. Fig. five shows a three dimensional numerical model developed in ZEUS-NL as well as the schematic places of the centers of stiffness and mass in irregular and regular model

#### IV. RESULT AND DISCUSSION

##### 4.1 Input Ground Motions

The ground motions have been selected based upon the ratio of the peak ground acceleration (PGA) on the peak ground velocity (PGV). The PGA/PGV ratio is known to correlate perfectly with the frequency attributes of the ground motion and also to account for many seismo-tectonic features and seismic site effects. A total of fifteen ground motion records have been chosen to get various PGA/PGV proportions, moreover the selected files fell in three groups based on the PGA/PGV ratio decreased (less than 0.8 g/m/s), moderate (between 0.8 and 1.2 g/m/s), and excessive (greater than 1.2 g/m/s). Each team included 5 ground movements. For non-region-specific programs, choosing ground motion documents from every PGA/PGV ratio range is essential to force feasible seismic requirements on buildings from different earthquake scenarios. The PGA of selected movements was scaled from 0.02 to 1 g; the increment was 0.02 g up to 0.08 g and it is 0.04 g after. The acceleration time-history documents of the selected ground motions in each group and also the averaged response spectra for 3 distinct groups are revealed in Fig. 4.2. Information on selected ground motions are provided in Table 4.1, and also the statistical summary of PGA/PGV ratios for earthquake data in every team is provided with Table 4.3.

##### 4.2 Definition of Uncertainty and Limit State

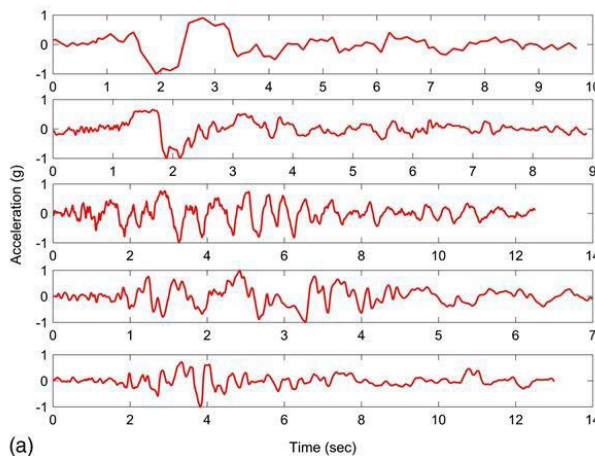
Uncertainties in structural capability as well as earthquake hazard were considered in deriving the seismic vulnerability curves of space RC frame structures. Uncertainty in structural capability, and supply, was taken into consideration by considering concrete supreme power as well as steel yield strength as arbitrary variables. The style concrete best strength was 24 MPa, and also the in place strength of concrete was assumed to enjoy a regular distribution of a hostile of 33.6 MPa along with a coefficient of variation of 18.6 % depending on the results of The reinforcement was designed with grade forty steel, and also the yield strength of reinforcing steel was assumed to adhere to a regular distribution with a hostile of 337 MPa along with a coefficient of variation of 10.7 %, as indicated from the strength evaluation results of steel bars and also used in a few scientific studies. Table 4.4 summarizes the statistical qualities of



the random variables regarded as in the study. The anxiety in earthquake loads, and demand, was taken into consideration by utilizing several ground motion data in the analysis.

**Table4.2. Properties of selected ground motions**

Earthquake	Date	Magnitude	PGA (g)	PGA/PGV (g/m/s)	PGA/PGV category	Reference name
Bucharest	03/04/1977	6.4	0.19	0.28	Low	01-Jan
Erzincan	03/13/1992	Unknown	0.39	0.38	Low	01-Feb
Montenegro	05/24/1979	6.2	0.12	0.63	Low	01-Mar
Kalamata	09/13/1986	5.5	0.22	0.66	Low	01-Apr
Kocaeli	08/17/1999	Unknown	0.31	0.75	Low	01-May
Friuli	09/15/1976	6.1	0.08	1.04	Medium	02-Jan
Athens	09/07/1999	Unknown	0.11	1.09	Medium	02-Feb
Umbro-Marchigiano	09/26/1997	5.8	0.1	1.11	Medium	02-Mar
Lazio Abruzzo	05/07/1984	5.7	0.06	1.14	Medium	02-Apr
Basso Tirreno	04/15/1978	5.6	0.07	1.18	Medium	02-May
Gulf of Corinth	11/04/1993	4.7	0.07	1.43	High	03-Jan
Montenegro	05/24/1979	6.2	0.07	1.53	High	03-Feb
Montenegro	05/24/1979	6.2	0.17	1.56	High	03-Mar
Friuli	05/06/1976	6.3	0.36	1.73	High	03-Apr
Umbro-Marchigiana	11/09/1997	5	0.04	1.9	High	03-May



**Fig. 4.1 Selected ground motion records: (a) low PGA/PGV; (b) medium PGA/PGV; (c) high PGA/PGV; and (d) average response spectrum**

This particular study used three levels of cap state: serviceability, collapse prevention, and damage control. The serviceability limit state was identified at the very first yielding of reinforcing steel in column participants. The analyzed analytical models had forty eight columns (i.e., 16 columns on every story), along with a limit state state was assumed to be achieved once the ISD of any column come to the specified drift criteria. Though the failure of just one column might not necessarily match to the disappointment of the structure as an entire, this particular more conservative definition of failure limit state condition is utilized in the study. The limit state function  $g(x)$  is described as follows:

$$G(x) = ISL_{LS} - \max(|ISD_{C01}(x)|, |ISD_{C02}(x)|, \dots, |ISD_{C48}(x)|) \leq 0 \quad 4.1$$



Where ISDLS = threshold ISD value of the limit state; and ISDC01; ISDC02; :::; ISDC48 denote the ISDs of the 48 columns (C01–C48). In this equation, ISDLS represents the seismic capacity provided by a structure, and the maximum ISD of columns represents the seismic demand imposed by the earthquake. Table 5 shows the threshold ISD ratio values of three limit states for all analytical models. The threshold value decreases with the increase of eccentricity.

**Table 4.3. Statistical summary of PGA/PGV ratios of earthquake records**

	Low	Medium	High
Statistical property	PGA/PGV	PGA/PGV	PGA/PGV
Range	0.275–0.750	1.040–1.183	1.432–1.902
Mean	0.54	1.111	1.631
Coefficient of variation	0.373	0.048	0.114

**Table 4.4. Statistical properties of random variables**

Random Variable	Distribution type	Mean (Mpa)	Coefficient of variable
Concrete Ultimate strength	Normal	33.6	0.186
Steel yield strength	Normal	336.5	0.107

**Seismic Vulnerability Curves**

Seismic vulnerability curves of space RC frames with different degrees of structural irregularity were successfully derived with their three-dimensional analytical models. With the help of the computational platform discussed in the prior section, the usage of more computationally challenging designs gets practically feasible.

**Table 4.5 Threshold ISD ratio values of limit states**

Limit state	ISD ratio (%)				
	ME000	ME025	ME050	ME075	ME100
Serviceability	0.58	0.56	0.55	0.53	0.51
Damage control	1.09	1.07	1	0.96	0.93
Collapse prevention	2.26	2.04	1.83	1.73	1.62

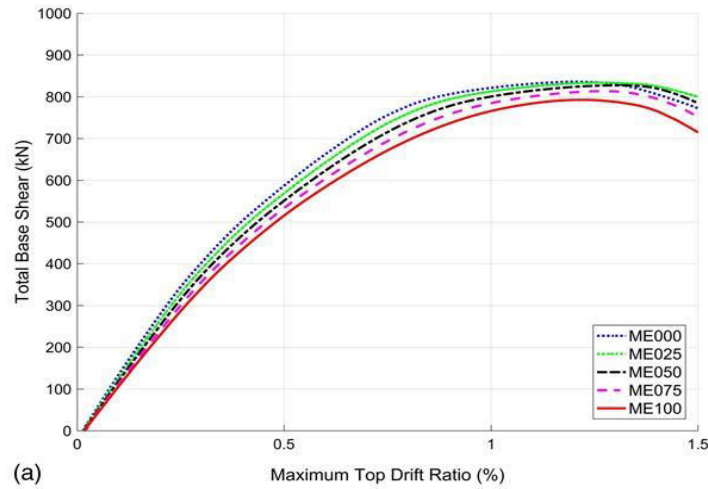
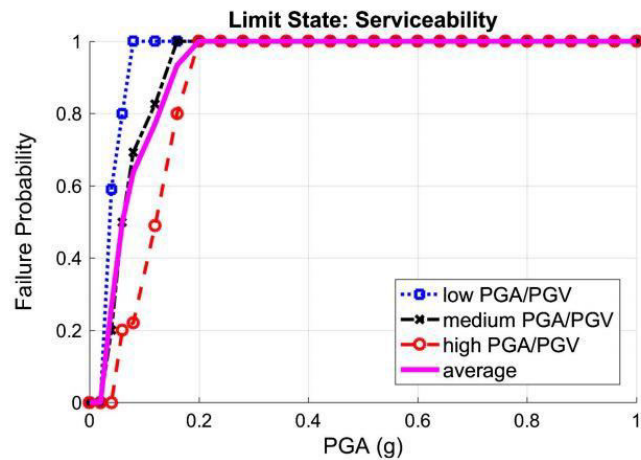


Fig. 4.3 Total base shear versus maximum top drift ratio curves from adaptive pushover analyses: (a) inverted triangle lateral load distribution; and (b) uniform lateral load distribution.

Table 4.6 Lognormal mean and variance values for seismic fragility curves with three distinct groups of ground motions

Model	PGA/PGV	Serviceability		Damage control		Collapse prevention	
		Mean	Variance	Mean	Variance	Mean	Variance
ME000	Low	0.053	0.0003	0.086	0.00146	0.148	0.00471
	medium	0.093	0.00026	0.19	0.00134	0.474	0.01457
	High	0.122	0.00092	0.268	0.00259	0.79	0.0431
ME025	Low	0.052	0.00027	0.088	0.0016	0.137	0.00459
	medium	0.092	0.00039	0.179	0.00077	0.401	0.01047
	High	0.114	0.00075	0.25	0.00208	0.623	0.02322
ME050	Low	0.05	0.00031	0.077	0.00126	0.13	0.00372
	medium	0.085	0.00054	0.162	0.00178	0.343	0.0122
	High	0.115	0.00038	0.244	0.00205	0.521	0.01668
ME075	Low	0.045	0.0003	0.072	0.00181	0.126	0.00306
	medium	0.083	0.00007	0.162	0.0019	0.325	0.00896
	High	0.121	0.00015	0.239	0.00223	0.485	0.013
ME100	Low	0.041	0.0003	0.072	0.00179	0.122	0.00318
	medium	0.085	0.00025	0.163	0.00227	0.271	0.00375
	High	0.119	0.00023	0.234	0.00286	0.451	0.00946



**Fig. 4.4 Seismic fragility curves derived with three-dimensional analytical models: (a) without structural irregularity (ME000); and (b) with structural irregularity (ME100).**

Fig. 4.4 illustrates seismic fragility curves of space RC frame structures with no irregularity and with 10 % irregularity just for the given 3 limit states. Within each graph, fragility curves derived with 3 distinct categories of ground motions are compared moreover the averaged fragility curve with all ground motions is depicted. It is apparent that various ground motion sets as well as structural problems create extensive disparities in seismic fragility curves. As anticipated, the failure probability decreases with a stricter characterization of the destruction state. The fragility curves in the figure are drawn by hooking information points where every point is a failure likelihood estimated out of a number of structural and dependability analyses.

**Fig. 4.5 Seismic fragility curves of space RC frame structures with different degrees of plan irregularity: (a) 2.5% eccentricity (ME025); (b) 5% eccentricity (ME050); (c) 7.5% eccentricity (ME075); and (d) 10% eccentricity (ME100).**

**Table 4.7 Log normal parameters for seismic fragility curves of studied structures**

Model	Mean	Variance	Mean	Variance	Mean	Variance
ME000	0.0934	0.0017	0.1893	0.0099	0.541	0.2463
ME025	0.0889	0.0015	0.1785	0.0085	0.420	0.1034
ME050	0.0857	0.0016	0.1653	0.0099	0.350	0.0656
ME075	0.087	0.0018	0.1645	0.0108	0.329	0.0527
ME100	0.0858	0.002	0.1625	0.0105	0.293	0.0378

#### 4.3 Effect of Structural Irregularity on Seismic Vulnerability

The result of structural irregularity on seismic vulnerability is examined by comparing fragility curves and the statistical parameters of theirs. Table 4.7 summarizes lognormal parameters for seismic fragility curves of space RC frame structures. The proportions of the ME100 (10 % abnormal model) mean to ME000 (regular model) mean had been 91.9, 85.8, along with 54.2 % for serviceability, damage control, then collapse prevention limit states, respectively.

### V. CONCLUSION

This particular analysis aims to derive much more correct as well as proper seismic fragility curves for space RC frame structures with various degrees of plan irregularity with the three-dimensional models of theirs and check out the impact of structural irregularity on the seismic vulnerability of theirs. Rather than simplified designs, three dimensional analytical models are adopted to have into account real nonlinear coupled lateral torsional replies. To deal with the considerable computational problem regarding the usage of three dimensional models, this particular study establishes a

computational framework which in degrades structural and also reliability evaluation. FERUM as well as ZEUS-NL are selected as the dependability as well as structural analysis programs, along with a linking interface is so long as allows automated interchange of the required information between 2 analysis equipment. Form is utilized to calculate the failure probabilities. With the entire adopted framework, seismic vulnerability of different space RC frame components, with as well as with no approach irregularity, is examined. Five distinct versions of RC frame system are analyzed, with different program problems from 0 to 10 % with a 2.5 % increment. A total of 15 ground motions are utilized, & they're classified in three groups depending on the ratio of PGA to PGV. Uncertainties in structural capability as well as earth quake demand are both considered. Three limit states are identified, damage control, serviceability, then collapse prevention. The corresponding values of interstory drift ratio for every cap state are obtained from a number of adaptive pushover analyses. Under the incorporated framework, seismic fragility curves of garden RC fame structures with various amounts of approach irregularity are success completely derived with the three-dimensional models of theirs on a regular private pc. This agrees nicely with a lot of the prior investigation results as well as the actual damage observed in previous earthquakes. Structural irregularity is definitely the one of the main factors behind the failure or maybe collapse of components, therefore significant focus must be paid out when conducting seismic vulnerability evaluation.

The primary contributions of this particular research are as follows:

- (1) It establishes an integrated computational framework for effective fragility analysis,
  - (2) It derives much more symbolic fragility curves with the usage of three dimensional analytical versions,
  - (3) It offers purposeful types of seismic fragility curves for space RC frame structures with different program irregularity, and
  - (4) It investigates the impact of approach irregularity on seismic vulnerability with far more reasonable fragility curves.
- The proposed method is anticipated to be extremely helpful when more precise seismic vulnerability for intricate buildings is needed. This particular analysis provides seismic fragility curves for typical low rise space RC frame structures with different program irregularity, though the normal application program might be restricted because seismic performance might be different with regards to the structural setup as well as the harm declare definition.

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