SEISMIC PERFORMANCE EVALUATION AND FRAGALITY ANALYSIS OF REINFORCED CONCRETE STRUCTURES

Dange Shiva Vilas, PG Student, Department of Civil Engineering, MGM's College of Engineering, Nanded, Maharashtra, India. shivadange100@gmail.com

Mohd. Zameeruddin, Associate Professor, Department of Civil Engineering, MGM's College of Engineering, Nanded, Maharashtra, India. md_zameeruddin@mgmcen.ac.in

Shimpale P.M., Associate Professor Department of Civil Engineering, Nanded, Maharashtra, India. shimpale_pm@mgmcen.ac.in

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 torsion and lateral responses as the level of irregularity greater. For room constructions with good irregularity, much more reasonable representations including three dimensional 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 fraction 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

For 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 epitomize the conditional probability that a result of a specific framework might surpass the functionality cap in certain

 DOI : 10.35291/2454-9150.2022.0429

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 versus 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

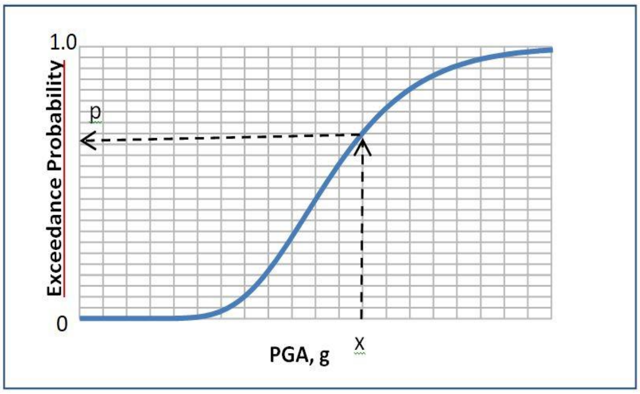

Figure 1 Typical Fragility Curve showing PGA vs. Probability of exceedance

1.2 Space Structures with Plan Irregularity

In irregular buildings, the center of mass doesn't coincide with the 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 a position rise in deformation demand. Generally, plan-irregular structures are significantly more vulnerable in a position of earthquake damage. Evidently, extensive destruction to these kinds of structures because of torsional vibration was frequently noticed during several previous earthquakes. Appropriately, there have been constant research attempts to evaluate seismic vulnerability of plan irregular structures. These procedures provide the information about nonlinear responses using the collapse mechanism and transfer of plastic hinges from one performance level to another, but fail to provide any associated damage values. In this study, we attempted to associate the building performance level at global and local level with a damage state using the vulnerability index. The vulnerability index is defined in terms of the engineering demand parameters obtained from the results of POA. Such integration will provide a rational approach to designers to predict damage state level at the iterative stage of the design process.

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.

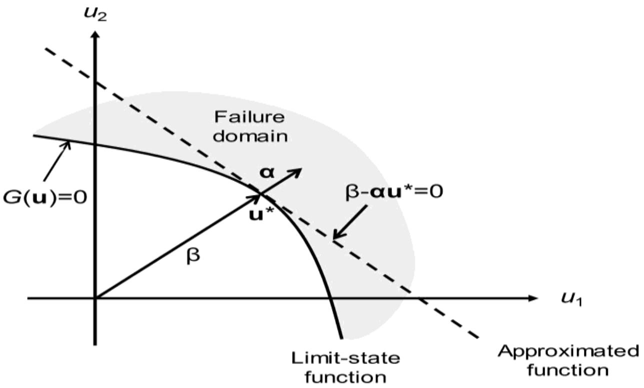

Figure.2 Linear Approximation in Form

II. LITERATURE REVIEW

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-Δ 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

 DOI : 10.35291/2454-9150.2022.0429

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 Geo structures and structures over a specified area by creating a process depending on the usage of computationally effective met models 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 behavior 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.

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

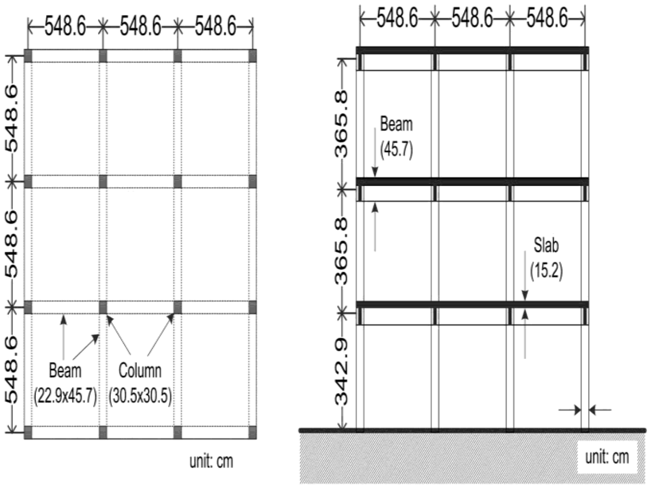

Fig. 3.1 Plan and elevation view of studied RC frame structures.

Table 3.1 Eccentricities and fundamental periods of analytical models

	Regular				Irregular		
Model property	ME000		ME025	ME050		ME07 5	ME100
Eccentricity (mm)	0		137.15	2 74.3		411.45	5 48.6
Dimensionless eccentricity (%)	0		2.5	5		7.5	1 0
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

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

 DOI : 10.35291/2454-9150.2022.0429

PGA/PGV ratios for earthquake data in every team is provided.

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.

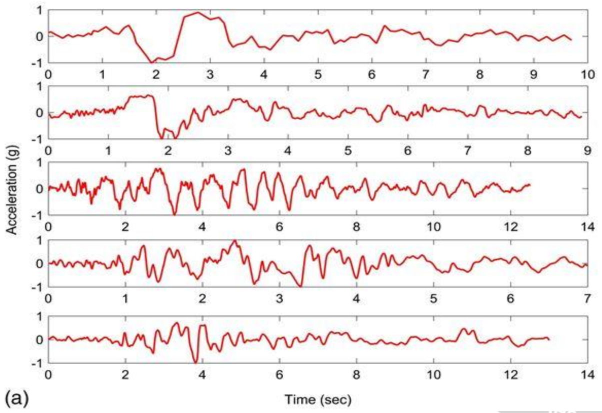

Fig. 4.1 Selected ground motion records: (a) low PGA/PGV; (b) medium PGA/PGV; (c) high PGA/PGV; and (d) average response spectrum

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.

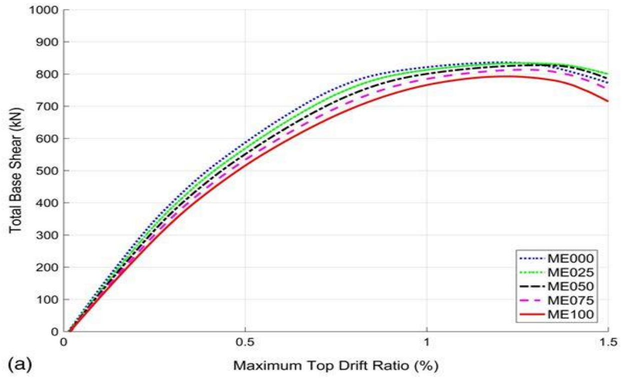

Fig. 4.3 Total base shear versus maximum top drift ratio curves from adaptive pushover analyses: (a) inverted triangle lateral load distribution; and (b) uniform lateral load distribution.

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.

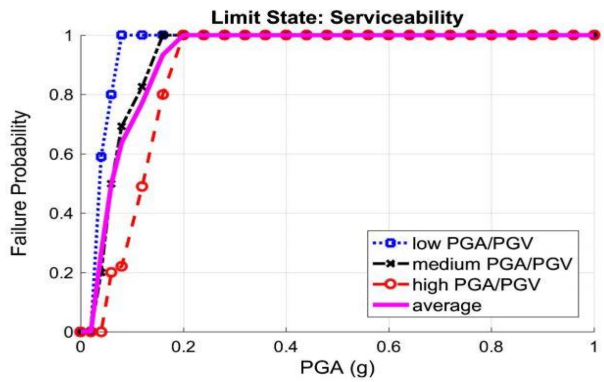

Fig. 4.4 Seismic fragility curves derived with three-dimensional analytical models: (a) without structural irregularity (ME000); and (b) with structural irregularity (ME100).

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 take into account real nonlinear coupled lateral torsional replies. To deal with the considerable computational problem regarding

 DOI : 10.35291/2454-9150.2022.0429

the usage of three dimensional models, this particular study establishes a computational framework which 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 that 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 the 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 frame structures with various amounts of approach irregularity are successfully 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.

FUTURE SCOPE

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 declared definition.

ACKNOWLEDGMENT

The authors of this paper acknowledge the research contributions of all the citations under reference and the support of faculty members and by the Chairman, MGM College of engineering, Nanded, India.

REFERENCES

[1] Alis, O.F. and Rabitz, H. (2001) Efficient Implementation of High Dimensional Model Representations. Journal of Mathematical Chemistry; 29(2):127-142.

[2] Altay &Guneyisi. (1975) Probability Concepts in Engineering Planning and Design: Volume 1 – Basic Principles (Vol 1). John Wiley & Son‘s, Inc: New York.

[3] Asadi & Bakhsi (2012), Recommended Methodology for Quantification of Building System Performance and Response Parameters - 75% Interim Draft Report, Applied Technology Council, Redwood City, CA..

[4] Balakrishnan, S, Ierapetritou, A.R., Marianthi, G., Flach, G.P. and Georgopoulos, P.G. (2005) A comparative assessment of efficient uncertainty analysis techniques for environmental fate and transport models: application to the FACT model. Journal of Hydrology; 307(1-4):204-218.

[5] Cornel Buratti, N., Ferracuti, B. and Savoia, M. (2002) Response Surface with random factors for seismic fragility of reinforced concrete frames. Structural Safety; 32(1):42-51.

[6] Craig, J., Frost, D.J. and Goodno, B. (2007) Rapid assessment of Fragilities for Collections of Buildings and Geostructures. Georgia Institute of Technology.

[7] Deodatis & Tantala FEMA (2002) Pre-standard and commentary for the seismic rehabilitation of buildings (FEMA-356). Washington (USA): Federal Emergency Management Agency.

[8] Franchin Haselton, C.B. and Baker, J.W. (2004) Ground motion intensity measures for collapse capacity prediction: Choice of optimal spectral period and effect of spectral shape. Proc. 8th NCEE, San Francisco.

[9] MurtIS 13920 (1993) Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces. Bureau of Indian Standards, New Delhi

[10] IS 1893 Part 1 (2002) Indian Standard Criteria for Earthquake Resistant Design of Structures. Bureau of Indian Standards. New Delhi. 2002.

[11] IS 456 (2000) Indian Standard for Plain and Reinforced Concrete - Code of Practice, Bureau of Indian Standards, New Delhi. 2000.

[12] Jeong Karim, C. and Yamazaki, F. (2001) Effect of earthquake ground motions on fragility curves of highway bridge piers based on numerical simulation.

 DOI : 10.35291/2454-9150.2022.0429

ISSN : 2454-9150 Vol-08, Issue-06, Sep 2022

Earthquake Engineering & Structural Dynamics, 30(12):1839-56.

[13] Kircher, C.A. and Heintz, J.A. (2008) Overview and Key Concepts of the ATC- 63 Methodology. Proceedings of 2008 ASCE-SEI Congress, 10 pgs., in press.

[14] Li, G. Wang, S.W., Rabitz, H., Wang, S. and Jaffe, P. (2002) Global Uncertainty Assessments by High Dimensional model representations (HDMR). Chemical Engineering Science; 57(21):4445-4460.

[15] Li, G., Rosenthal, C. and Rabitz H. (2001) High Dimensional Model Representations. Journal of Physical Chemistry; A105:7765-7777.

[16] Li, G., Wang, S.W. and Rabitz, H. (2001) High Dimensional Model Representations Generated from Low Dimensional Data Samples I. mp – Cut- DMR. Journal of Mathematical Chemistry; 30(1):1-30.

[17] Mander, J.B., Priestley, M.J.N. and Park, R. (1988) Theoretical Stress-strain Model for Confined Concrete. Journal of Structural Engineering, ASCE; 114(8):1804-1823.

[18] Mann, N. R., Franchin Schafer, R. E., and Singpurwalla, N. D. (1974), Methods for Statistical Analysis of Reliability and Life Data. John Wiley & Sons, Inc., New York., NY.

[19] McKay, M.D., Beckman, R.J. and Conover, W.J. (1979) A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output From a Computer Code. Technometrics; 21(2):239-245.

[20] McKenna, F., Fenves, G.L., Jeremic, B. and Scott, M.H. (2000) Open system for earthquake engineering simulation. <http://opensees.berkely.edu>.

[21] Menjivar, M.A.L. (2004) A Review of Existing Pushover Methods for 2-D Reinforced Concrete Buildings. Ph.D. Thesis ROSE School, Italy.

[22] Moehle, J. and Deierlein, G. (2004) A Framework Methodology for Performance-Based Earthquake Engineering, 13th World Conference on Earthquake Engineering, Vancouver, British Columbia.

[23] Montgomery DC. (1997) Design and Analysis of Experiments (4th edn). John Wiley & Son's, Inc: New Jersey, USA.

[24] Myers, R.H. and Montgomery, D.C. (2002) Response Surface Methodology. Wiley: Newyork,798.

 DOI : 10.35291/2454-9150.2022.0429