World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

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Fragility analysis of existing RCC frame structure

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World Journal of Advanced Engineering Technology and Sciences, 2024, 13(01), 527–534

Publication history: Received on 11 August 2024; revised on 22 September 2024; accepted on 24 September 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.13.1.0430

Abstract

This In recent years, number of studies have been carried out for the evaluation of vulnerability of structure during seismic events. Fragility analysis is one of the important probabilistic approach to estimate the damage data at different damage state during seismic events. The G+7 Reinforced Concrete frame structure is considered for analysis. The structure is analyzed in ETABS by Non-linear Pushover Analysis. Fragility curve developed for Non-linear Pushover Analysis from results obtained by capacity spectrum method for different damage states. The fragility curves are derived from analytical method. The fragility points for different damage states are derived from analytical formula. Fragility curve is plotted for probability in Y-axis and spectral displacement in X-axis for 4 different damage states from Non-linear Pushover Analysis. From Incremental Dynamic Analysis fragility curve plotted for probability in Y-axis and peak ground acceleration in X-axis for five different damage state. The behavior of fragility curve after achieving the 100% probability for different damage state is constant.

Keywords: Fragility analysis; Non-linear pushover analysis; Fragility curve; IDA1

1. Introduction

Earthquakes are distinct from other disasters because they bring destruction through the collapse of man-made structures rather than direct loss of life. Buildings are the major structures that are exposed to damage when earthquakes are triggered. Earthquakes cause economic losses and also causes loss of lives. In past earthquake events, such as the Latur earthquake 1993, Bhuj earthquake of 2001, the Nepal-India earthquake in 2015, and the Kashmir earthquake in 2005, buildings and infrastructures were severely damaged and collapsed. During these events, the worst damages were often recorded in cities. For example, many people were killed and many people get injured by falling building debris. Therefore, building damage is the main source of seismic losses during earthquake. The reinforced concrete structure is extensively used now-a-days for accommodation purposes in almost all cities. These structures damages severely due to earthquake because of following reasons,

1.1. Soft and weak story's

In some R/C buildings, especially at the ground floor, walls may not be continuous along to height of building for architectural, functional, and commercial reasons. While ground floor generally encloses with glass window instead of brick infill walls, partition walls are constructed above from this story for separating rooms for teresidential usage. This situation causes brittle failures at the end of the columns. In mid-rise reinforced concrete buildings, the most common

Failure mode is soft- story mechanism, particularly at the first story. Failures can be concentrated at anystory called as weak story in which the lateral strength changes suddenly between adjacent stories due to lack of or removing of

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partition walls or decreasing of crosssection of columns. Thus, during an earthquake, partial and total collapses occur in the stores.

1.2. Inadequate transverse R/f in beams & columns

Shear forces increase during an earthquake especially at columns and beam–column joints. Consequently, special attention should be paid to construction and design of beam–column joints and columns. Seismic design requires increasing of ductility ofstructures for performance-based design approach. Therefore, structural elements which have such details show low performance against to dynamic loads and lost their shear and axial load carrying capacity.

1.3. Poor material quality and workmanship-

The other main reasons of damages are low concrete strength and workmanship. Concrete quality is an important factor for building performance against to earthquakes. Handmade concrete is used to without using vibrator in construction ofold buildings. Thus, homogeny mixing was not obtained and expected compressivestrength was not provided in these buildings. In addition to this using of Mild steel reinforcement effected strength of concrete .To overcome or solve this problem, fragility curves were introduced by researchers to serveas one of main tool in assessing damage and loss occurred during earthquakes. Seismic riskassessment is the first step within the disaster prevention strategy and in reducing the associated risks of infrastructures. The comprehensive studies of seismic risk are often divided into 3 components- Hazard, Vulnerability and Exposure. Hazard is that the event capable of inflicting harm whereas Vulnerability represents the degree of loss of a component ensuing from a hazard. Exposure is that the number of parts like population, theeconomic activities, and therefore the constructions and structures exposed to a hazard. It'swell understood that it's not the earthquake that kills however the failure of the buildings exposed to those earthquakes. So understanding the behavior of the buildings throughout Earthquake may be a growing space of research. Assessing the vulnerability of the structuresas seismic performance are often useful for risk mitigation and emergency response comingup with. In general, the curves are generated from real earthquake damage data to estimate or predict whether the damage meets or exceeds a certain performance level for a given set of ground motion parameters. In addition, the curves can be applied to predict both pre- andpost-earthquake situations. These curves are unique because every building has specific fragility analysis. There are studies have reported different methodologies used to develop fragility curves. Many previous studies, present a brief historical background of fragility curve. Fragility curves are defined as the probability of reaching or exceeding a specific damage state underearthquake. Structural Types Fragility curves were discussed based on three types of structures, namely, steel, reinforced concrete, and timber. Figure 1 shows the fragility curveof probability vs spectral displacement for different damage states. Damage States in RCC Frame Structure are as follows

1.3.1. Structural damages

Slight Structural Damage: Flexural or shear type hairline cracks in some beams andcolumns near joints or within joints. Moderate Structural Damage: Most beams and columns exhibit hairline cracks. In ductile frames, some of the frame elements have reached yield capacity, as indicatedby larger flexural cracks and some concrete spalling. Nonductile frames may exhibitlarger shear cracks and spalling. Extensive Structural Damage: Some of the frame elements have reached their ultimate capacity, as indicated in ductile frames by large flexural cracks, spalled concrete, and buckled main reinforcement; nonductile frame elements may have suffered shear failures or bond failures at reinforcement splices, broken ties or buckled main reinforcement in columns which may result in partial collapse. Complete Structural Damage: Structure is collapsed or in imminent danger of collapse due to brittle failure of nonductile frame elements or loss of frame stability.

1.3.2. Non-Structural damages

Partition wall

Slight Nonstructural Damage: A few cracks are observed at intersections of walls and ceilings and at corners of door openings.

Moderate Nonstructural Damage

Larger and more extensive cracks requiring repairand repainting; some partitions may require replacement of gypsum board or other finishes.

Extensive/Severe Nonstructural Damage

Most of the partitions are cracked and a significant portion may require replacement of finishes; some door frames in the partitions are also damaged and require re-setting.

Complete Nonstructural Damage

Most partition finish materials and framing may have to be removed and replaced, damaged studs repaired, and walls refinished. Mostdoor frames may also have to be repaired and replaced.

1.3.3. Exterior wall panels

Slight Nonstructural Damage: Slight movement of the panels, requiring realignment.

Moderate Nonstructural Damage

The movements are more extensive; connections of panels to structural frame are damaged requiring further inspection and repairs; some window frames may need realignment.

Extensive/Severe Nonstructural Damage

Most of the panels are cracked or otherwise damaged and misaligned, and most panel connections to the structural frame are damaged requiring thorough review and repairs; a few panels fall or are inimminent danger of falling; some window panes are broken and some pieces of glasshave fallen.

Complete Nonstructural Damage

Most panels are severely damaged, most connections are broken or severely damaged, some panels have fallen and most are in imminent danger of falling; extensive glass breakage and falling.

Electrical-Mechanical Equipment, Piping, Ducts

Complete Nonstructural Damage: Most panels

Slight Nonstructural Damage: The most vulnerable equipment (e.g., unanchored or mounted on spring isolators) moves and damages attached piping or ducts.

Moderate Nonstructural Damage: Movements are larger and damage is more extensive; piping leaks occur at a few locations; elevator machinery and rails may require realignment.

Extensive/Severe Nonstructural Damage: Equipment on spring isolators topples andfalls; other unanchored equipment slides or falls, breaking connections to piping andducts; leaks develop at many locations; anchored equipment indicate stretched boltsor strain at anchorages.

Complete Nonstructural Damage: Equipment is damaged by sliding, overturning orfailure of their supports and is not operable; piping is leaking at many locations; somepipe and duct supports have failed, causing pipes and ducts to fall or hang down; elevator rails are buckled or have broken supports and/or counterweights have derailed.

Objective of Review

- To analyze the RCC frame structure by Fragility Analysis.
- To analyze the RCC frame by Pushover method.
- 3. To compare behavior of damage states of RCC frame structure according to fragility curve.
- To analyze probable damage of RCC structure.
- To ensure the durability & serviceability of structure by fragility analysis throughout the designed lifespan of the structure.

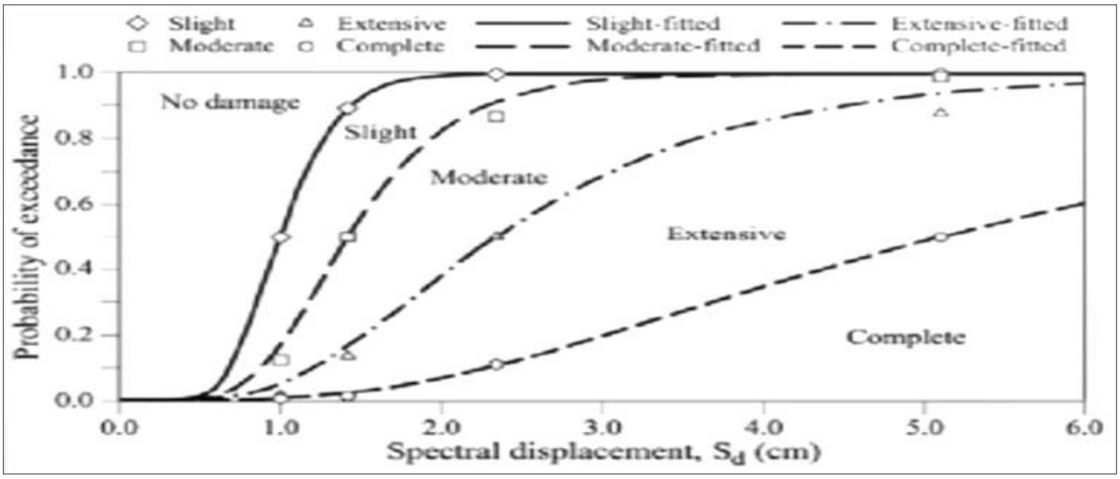

Figure 1 Fragility curve

2. Literature review

- Nibas Apu and Ravi Sinha (2020): - "Seismic Fragility Assessment of Ductile Reinforced Concrete Building Frames"They analyzed the total of 4, 8 and 20 stories RC moment resisting two-dimensional frames. The ground motions (GM) were selected as per the conditional mean spectrum and these were conditioned on a target spectral acceleration at the concern time period. RC frames were designed and detailed as per Indian standards. A concentrated plasticity approach was adopted for non-linear analytical modeling of the RC frames. Fragility functions derived following a lognormal distribution from incremental dynamic analysis curves and maximum estimation of the response is obtained for fitting curves with observed fragility. The fragility functions of the three structures showed that under critical or extreme conditions of GM the taller buildings had higher fragility than the shorter buildings for each level of limit states even though both were designed to meet their code-level design forces.
- Pratyush Kumar and Avik Samant (2020): - "Seismic Fragility Assessment of existing Reinforced Concrete Building "For modeling uncertainties, they considered the material, geometrical, and design as random parameters. In this study, they selected the random parameters were purely based on the investigation of buildings in the Patna region. The buildings were modeled and analyzed using nonlinear static (NLS) pushover analysis. The monotonic load in a triangular pattern was applied for NLS analysis to get pushover curves. The pushover curves were subsequently converted into capacity curves considering the dynamic characteristic of the first mode of vibration. The obtained capacity curves were utilized to derive the variability in the capacity spectrum for different categories of RC buildings. By calculating for both the uncertainties, lognormal variability functions were determined, and seismic fragility assessment was performed for different building categories in Patna, India.
- Carlo del Gaudio etal (2019): - "Seismic Fragility assessment of Italian based on damage data of last 50yrs. building "The capacity spectrum method and developing the fragility curve for seismic damage scenarios were discussed. From the capacity spectrum method, the seismic risk of the buildings of was analyzed. The information on the buildings was obtained by collecting, arranging, improving and completing a broad database of the dwellings and current buildings. They investigated the vulnerability of the buildings was significant and the expected seismic risk was considerable in spite of low to moderate seismic hazard.
- Swarup Ghosh, Shyamal Ghosh, Subrata Chakraborty (2019): - "Seismic fragility analysis (SFA) in the probabilistic performance-based earthquake engineering framework" They presented the progress in SFA, the related developments were, the analytical SFA based on probabilistic seismic demand, capacity models and the statistical simulation based SFA based on non-linear PBEE using random field theory and statistical simulation. The Bayesian approach in SFA studied and the critical observations on the developments were summarized in this research.
- J. Karthik and Dr. B.S Swamy (2018): - "Fragility analysis of RC Framed Structure for different seismic zone " The building chosen was a commercial complex of G+5 story considering height 3m situated in Yadagiri, Karnataka, India. The building was analyzed in SAP2000 by Nonlinear Pushover analysis for different Zones such as ZONE II, ZONE III, ZONE IV, and ZONE V and also for different soil conditions such as TYPE I, TYPE II and TYPE III. The results were obtained from capacity spectrum and FEMA 356 co-efficient method, the target shear force was obtained from the software itself and by manually calculating the value of base shear, target

shear force and calculated base shear for different Zones and different soil conditions was compared. The fragility curves were derived from both analytical and theoretical method. The fragility points were derived from that the curve was plotted for probability in Y-axis and spectral displacement in X-axis. In this study the building was safe in Zone II and Zone III and for Zone IV and Zone V, to withstand the structures in any damage due to lateral forces the structures should be designed as earthquake resistant structures, by providing bracings, ductile detailing, etc.

- Mark Mahesh Patil and Yogesh Sonawane (2018): - “Seismic Analysis of Multi-storied building” The efficiency of the software was checked. The seismic coefficient method as per IS 1893- 2002 was used for seismic analysis. The results obtained manually as well as obtained in software are compared. The complete procedure for seismic analysis manual as well as software for seismic coefficient method was discussed.
- Vazurkar U.Y and Chaudhari D.J (2016): - “Development of fragility curves for RC Buildings” Fragility curve described the probability of damage being exceeded a particular damage state. The fragility curves were developed based on the, guidelines given by HAZUS technical manual. The RC building was modeled and analyzed using SAP2000. For the analysis of RC buildings non-linear static analysis procedure was used. The pushover analysis was carried out. Push over analysis was conducted and the capacity curve was plotted. Results obtained from pushover analysis were used for plotting the fragility curves. For plotting the Fragility Curves Spectral Displacement were considered as the ground motion parameter. The damage states were described as per the HAZUS technical manual. Finally, based on the obtained fragility curves the spectral displacement values that satisfy the predefined performance level requirements were estimated. From this plotted fragility curves studied the seismic performance of building models.
- Tarannum Yasmin, Ajay Chourasia, S.K. Bhattacharya (2015): - “Fragility analysis for seismic vulnerability assessment of buildings “The vulnerability curves can be categorized into three groups-empirical, analytical and hybrid. Empirical approach includes Damage Probability Matrices and Vulnerability Functions, which depend on the damage motion relationship statistics observed after an earthquake. Analytical curves adopted damage distributions simulated from the analyzed structural models. Hybrid curves overcome the deficiencies of the above two approaches by combining post-earthquake damage statistics with simulation techniques. They reviewed the importance of fragility analysis using existing methodologies. The methodologies focused on their key features highlighting limitations and suggests the way forward for selection of appropriate assessment method for seismic vulnerability assessment of existing buildings and the incorporation of experimental vibration-based methods.

3. Research gap

The existing literature on the development of pushover curve by making use of bracing system in column in over to provide stiffness to the building at the time of earthquake. Use of various bracing system such as X-bracing, V-bracing, & Chevron bracing. For various mid and high rise buildings has been done. In various earthquake zones.

Table 1 Structural Parameter's

Beam Size	**230mmx 600mm**
Slab Thickness	S1-150mm, S2-125mm, S3-100mm,
Column Sizes	C1-230mm x 680mm
	C2-230mm x 680mm
	C3-230mm x 680mm
Materials used	M25 & Fe 415

However, a research gap exist in the analysis of existing building of life more then 20 years which has not been design for earthquake loading. Fragility analysis of existing Rcc frame structure by Pushover analysis. Analysis of probable damage of Rcc structure if the seismic condition occurs. Checking the behavior of damage state of Rcc frame structure according to fragility curve. To ensure the durability & serviceability of structure by fragility analysis throught the design lifespan of the structure. Study the aging of building by performing the Non-Destructive test for the existing building that is Rebound Hammer & Ultra Sonic Pulse Velocity (UPV).

4. Methodology

4.1. Problem statement

The building is modelled for G+7 and height of building is 3m.

The analysis of G+7 is carried out using ETABS software for Special Moment Resisting Frame situated on Zone III. Following Table shows the structural parameters.

Table 2 Seismic Parameter's

Seismic Zone	III
Zone Factor	0.16
Importance Factor	1
Response Reduction Factor	5
Soil Type	II-Medium
Building Frame System	SMRF
Damping Ratio	0.05

4.2. Seismic parameters

Seismic Parameters such as Seismic Zone, Zone Factor, Importance Factor, Response Reduction factor, Soil type are considered as criteria for earthquake resistance design of structure as per IS 1893-2016. Following Table shows the Seismic Zone, Zone Factor, Importance Factor, Response Reduction Factor, Soil Type and considered Damping Ratio.

4.3. Methods of analysis of structure

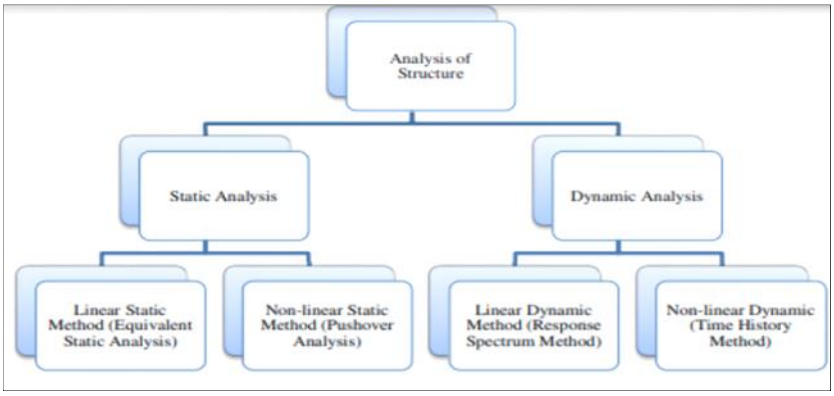

Figure 2 Methods of analysis of structure

4.4. Methods of static analysis

The seismic actions on the portion of structures are evaluated by equivalent static analysis by considering a design seismic coefficient. The design seismic coefficient include factor such as,

- Soil foundation factor
- Response reduction factor
- Zone factor

4.5. Equivalent Static Analysis

In this analysis, an array of forces is used to represent the consequence of earthquake ground motion. It follows the assumption that the building is responsive in its fundamental mode. This is applicable for low rise building and the building which do not rotate significantly about its axis. The static method is simplest one requires less computational efforts and is based on formulae given in code of practice. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces. Tall buildings, where second and higher modes can be important, or buildings with torsional effects, are much less suitable for method. Further researches have been made to increase its application to high rise buildings and low level of rotation about its axis.

4.6. Non-linear Static Analysis (Pushover Analysis) -

Linear procedures are applicable when the structure is expected to remain nearly elastic for the level of ground motion or when the design results in nearly uniform distribution of nonlinear response throughout the structure. As the performance objective of the structure implies greater inelastic demands, the uncertainty with linear procedures increases to a point that requires a high level of conservatism in demand assumptions and acceptability criteria to avoid unintended performance. Therefore, procedures incorporating inelastic analysis can reduce the uncertainty and conservatism. This approach is known as "pushover" analysis. A pattern of forces is applied to a structural model that includes non-linear properties (such as steel yield), and the total force is plotted against a reference displacement to define a capacity curve. This can then be combined with a demand curve typically in the form of an acceleration displacement response spectrum. This essentially reduces the problem to a single degree of freedom (SDOF) system. Nonlinear static procedures use equivalent SDOF structural models and represent seismic ground motion with response spectra. Story drifts and component actions are related subsequently to the global demand parameter by the pushover or capacity curves that are the basis of the non-linear static procedures. The pushover analysis is used to estimate the strength and drift capacity of existing structure and the seismic demand for the structure subjected to selected earthquake. It can be used for checking the adequacy of the structural design. It is an analysis in which, a mathematical model incorporates the nonlinear load-deformation characteristics of individual components and elements of the building which shall be subjected to increasing lateral loads representing inertia forces in an earthquake until a target displacement is exceeded. In Pushover analysis the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern alone the height of the building. Building is displaced till the control node reaches target displacement or building collapses. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed. The relation between base shear and control node displacement is plotted for all the pushover analysis. Pushover analysis may be carried out twice -a) first time till the collapse of the building to estimate target displacement b) Next time till the target displacement to estimate the seismic demand. The seismic demands for the selected earthquake are calculated at the target displacement level. The seismic demand is then compared with the corresponding structural capacity to & not that performance the structure till exhibit. Figure shows the Pushover Curve for Base Shear Vs Roof Displacement.

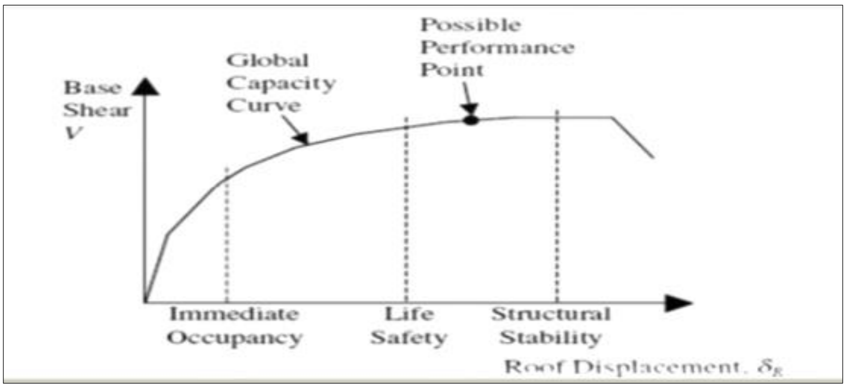

Figure 3 Pushover Curve

5. Results and discussion

In this research utilizing Pushover Analysis Method (PAM) in ETABS, this study investigates thedevelopment of Fragility curve which show the deformation of structure at different phases, at Different floor and by making use of various bracing system. Comparing the results of fragility curve at each building but different type of bracing system at different dame states such as damage state-1, 2, 3.

6. Conclusion

From the literature study based on fragility analysis of RC structure following conclusions are made.

- The design for base shear, steel-braced RC dual system better performance and large capacities in the unbraced RC frames otherwise stronger brace and weaker frame both of reduced the damage in dual system.
- The fragility curve to select frame with and without p-delta effect in the increase in damage probability and increase taller frame.
- The steel braced building of bae shear increase compared to without steel bracing indicates that stiffness of building was increases.
- Overall result of analytically was supplement to procedures on empirical formulation generally was calibrated on observed behavior and damage data surveyed after earthquake.
- The building yielding and collapse state more rapidly when column was taller regarding p-Δ effect in the effect of the number of stories height.
- The building comparing fragility curves in the yielding state, when it is shorter structure yield more rapidly and then capacity was lower than taller structure.
- The intensity measure for masonry building and the validation of the capacity spectrum method, current frequently used for the development of fragility function require an extensive use incremental non-linear analysis (IDA) can be carry out.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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