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Fragility analysis of Masonry in filled Reinforced Concrete building by Coefficient based method

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ABSTRACT

Masonry infill Reinforced concrete frames are the most common type of structures used for multi storey constructions in the developing countries. Masonry in fills, is the non-structural element, but provides resistance to the earthquake and prevents collapse of relatively flexible and weak RC structures. Seismic vulnerability of this type of structure has been studied in the earthquake ground motion. Present study focuses on the seismic fragility analysis of masonry in-filled (MI) reinforced concrete (RC) buildings using coefficient based method. The coefficient-based method, is a simplified procedure without finite element analysis, for assessing spectral acceleration demand (or capacity) of buildings subjected to earthquakes. This paper begins with validation study of the proposed coefficient-based method for masonry in filled (MI) reinforced concrete (RC) buildings. Two, four and six storey masonry in filled (MI) reinforced concrete (RC) buildings are designed considering a bare frame analysis, to estimates the inter-storey drift demand andperiodic shift factor in response to the peak ground for different set of ground motions. Using coefficient based method both spectral acceleration and spectral displacement-based fragility curves under various damage states (in terms of IDR) were then constructed. Fragility curves obtained from the coefficient based method is compared with the SAC FEMA method at the collapse state and are correspondence well. The fragility curves obtained usingboth the method can provide a satisfactory vulnerability assessment for masonry in filled reinforced concrete (RC) buildings under different prescribed damage states (or performance level).

INTRODUCTION

Masonry Infilled Frames

The construction of multi-storey masonry infill (MI) reinforced concrete (RC) buildings has beenpractice in India for the last few decades. However, the quality of design and construction remains variable in all over India. Indeed, even in earthquake-prone regions of India, basic configuration taking into account gravity burden keeps on being honed without considering the lateral load following up on to the structure and the seismic vulnerability of the RC structure. Out of all the urban development in India may be just 10% of all development comprises of reinforced cement (RC) structures of which those satisfy with seismic prerequisites are immaterial in number. A large portion of this development in India has been outlined just for gravity loads, infringing upon the Code of Indian Standards for earthquake-resistant design IS 1893. Masonry infill walls restricted by RC outlines in all the sides assume a vital part in opposing the lateral seismic loads on structures. infille walls have a high lateral stiffness and low deformability (Moghaddam and Dowling, 1987). Therefore presentation of masonry infilled walls in reinforced cement (RC) casings changes the lateral-load transfer mechanism of the structure from transcendent frame action to dominating truss action (Murty and Jain, 2000), which decreases the bending moments of the structure and increases axial forces acting up on to the individual members.

Fragility Curves

Fragility curves are graphically characterize the seismic risk and the degree of damage on to the structure under the impact of strong ground motion of different intensity. In fragility analysis the damage likelihood of RC structures are the capacity of intensity measures (IMs), for example, peak ground acceleration (PGA), spectral acceleration *(Sa)* and spectral displacement (*Sd*). In the past studies, fragility curves for masonry infilled reinforced concrete structures are gotten by both linear and non-linear analytical methods like non-linear time history analysis (NTHA), incremental dynamics analysis (IDA) and pushover analysis (POA). In this study, an explanatorymethodology i.e. coefficient based method (Lee and Su,

2012) and SAC FEMA technique(Cornell *et al*., 2002) was embraced to build up the fragility curves for masonry infilled RC structures.

Background And Motivation

With the progression of computational advances, the demands (or limits) of structures and intensity measures (IMs) can be resolved through non-linear time history analysis (NTHA), pushover analysis (POA) (ATC, 1996; Fajfar and Gašperšič, 1996; Chopra and Goel, 1999; Fajfar, 2000; Chopra and Goel, 2002; Kalkan and Kunnath, 2007) and incremental dynamics analysis (IDA) (Vamvatsikos and Cornell, 2002; Han and Chopra, 2006), which are liable to create the best estimation of a structures seismic parameters. Then again, a detailed and time- consuming well-calibrated analytical finite element method alongside nonlinear material properties of every auxiliary segment ought to require for leading the nonlinear seismic fragility analysis.

The coefficient-based technique (Lee and Su, 2012) does not oblige a dreary or prolonged finite element analysis; rather, it is a simplified methodology for evaluating the spectral acceleration and displacement of structures subjected to tremors. These coefficient-based methods concentrate in determining the seismic capacity or demand of structures in terms of the inter- story drift ratio by multiplying drift factors (λ). The precision of these coefficient-based seismic evaluation systems depends emphatically on the proposed drift-related factors, which are regularly decided and aligned through numerical simulation results acquired from the nonlinear time history analyses of structures subjected to different earthquake motions.

RESEARCH OBJECTIVES

The present study is focused on the comparison of fragility curves two established methods for RC frames.

- Validate and Develop fragility curves of Typical RC frames with number of stories ranging from two to six stories using coefficient based method (Method I) proposed by Lee and Su (2012)
- Development of seismic fragility curves for the same frames based on SAC FEMA method (Cornell *et al*., 2002) (Method II).
- A critical comparison of the fragility curves between two methods (Method I and II)

Scope Of The Study

- The present study is limited up to six-storey masonry infilled RC frame structures.
- The masonry infilled RC structures consider in design are regular in p and uniformelevation.
- The plan asymmetry arising from infill walls or the out-of-plane action of infill walls arenot considered in this study.

METHODOLOGY

In order to achieve the objectives the step by step procedure is worked out as given below.

- Validation study of coefficient based method for different seismic performance level using published results obtained from shaking table test.
- Design of two, four and six storey masonry infilled reinforced concrete building and assigning its geometry and material property.
- Estimation the coefficient based parameters i.e. inter storey drift ratio (IDR) and period shift factor (PSF) and drift factor (λ) of the designed structure using coefficient based method for synthetic ground motions.
- Determination spectral acceleration and spectral displacement of the RC building for various performance levels.
- Development of seismic fragility curves for two, four and six storey masonry infilled reinforced concrete building for various performance level are obtained using coefficient based method.
- Comparison of the fragility curves obtained from coefficient based method with SACFEMA method at the damage state (CP state) performance level.

LITERATURE REVIEW & VALIDATION

Introduction

In this study, the advancement of fragility characteristics masonry infilled (MI) Reinforced Concrete (RC) structures are exhibited. Fragility examination is to gauge the seismic vulnerability of structures under the impact of ground movement. Fragility curves (or characteristics) are critical for evaluating the general seismic damage to the structures and to foresee the monetary misfortune assessment, debacle reaction arranging, retrofitting of structures for a past quake occasions. Fragility curves, which graphically speak to the seismic risk to a structure, which characterizes the probabilities of surpassing distinctive recommended damage levels as a component of the intensity measures (*IMs*) and the peak ground acceleration (PGA), spectral acceleration (*Sa*) or spectral displacement (*Sd*) of a tremor. The fragility analyses (Casciati and Faravelli, 1991; Mosalam *et al.*, 1997; Cornell *et al*., 2002; Lang and Bachmann, 2004; Akkar *et al*., 2005; Kircil and Polat, 2006; Ramamoorthy *et al.,* 2006; Ellingwood *et al*., 2007; Lagaros, 2008; Seyedi *et al*., 2010; Howary and Mehanny, 2011), for assessing the seismicdangers of structures has been generally examined.

In the fragility investigation, the demands (or limit) of the structures are lognormally distributed (Cornell *et al*., 2002) i.e. the relationship between the demand and IMs can be ordinarilyanticipated by a two-parameter model (Cornell *et al*., 2002; Choi *et al*., 2004; Ramamoorthy *et al*., 2006; Ellingwood *et al*., 2007; Konstantinidis and Makris, 2009). In view of the lognormal distribution, the scatter plots of the demands of structures and comparing IMs are articulated on a logarithmic scale; consequently, a regression analysis can be performed to acquire the best- fitting straight regression comparison, bilinear regression equation (Ramamoorthy *et al*., 2006), or quadratic relapse mathematical statement (Pan *et al*., 2010) from the power model. The logarithmic middle and standard deviation of the information concerning the relapse comparisons can be acquired by a basic factual examination. The likelihood of surpassing distinctive damage states for a predetermined IM can be resolved once the logarithmic mean and standard deviation are discovered utilizing the standard ordinary dispersion capacity (Casciati and Faravelli, 1991). The damage conditions of structures are immediate occupancy (*IO*) state, life safety (*LS*) state, and collapse prevention action (*CP*) are indicated by different IDR levels for the execution based configuration proposed by outline rules (ATC, 1996; ASCE, 2000).

Intensity measures

An Intensity Measures (IMs) is the ground motion parameter against which the probability of exceedance of a given damage state is plotted. There are two main classes of IMs: the empirical and the instrumental. The empirical IMs, different macroseismic intensity scales are derived for qualitative assessments of the damage. Such intensity scales are: the Mercalli- Cancani-Sieberg Intensity Scale (MCS), the Modified Mercalli Intensity Scale (MMI), the European Macroseismic Scale (EMS-98) etc. Macroseismic intensity scales have a wide range of applications in the field of fragility analyses. The instrumental IMs, the severity of the ground shaking can be recorded by accelerograms. The preferred IMs that are used forseismic vulnerability assessment of buildings are:

a) Peak ground acceleration, *PGA*
b) Peak ground velocity, *PGV*
c) Spectral acceleration, S_a
d) Spectral displacement, S_d

Building performance levels

These execution attributes of a building will be specifically identified with the degree of damage maintained by the building amid a seismic tremor. The Structural Performance of a building should be chosen from four Structural Performance Levels Ranges characterized in this segment (ASCE, 2000).The Structural Performance Levels of a building are Immediate Occupancy, Life Safety, Limited Safety Range and Collapse Prevention. The four Structural Performance Levels characterized in this standard have been chosen to correspond with the most usually determined basic execution necessities. The Structural Performance Ranges helps clients to redo their building Rehabilitation Objectives.

(a) Immediate Occupancy (*IO*) Structural Performance Level

Structural Performance Level, Immediate Occupancy, should be characterized as the post-quake damage state in which just extremely restricted auxiliary damage has been happened and that remaining parts safe to involve, basically holds the configuration quality and firmness of the structure. The basic damage is low, and albeit some minor auxiliary repairs may be suitable, these would for the most part not be needed before re inhabitance.

(b) Life Safety (*LS*) Structural Performance Level

Structural Performance Level, Life Safety, should be characterized as the post-tremor damage state in which critical harm to the structure has happened, yet some edge against either incomplete or complete auxiliary breakdown remains. Some basic components and parts are extremely harmed, however this has not brought about huge perils, either inside or outside the building. Damages may happen amid the seismic tremor; then again, the general danger of life- undermining harm as an aftereffect of basic damage is relied upon to be low .It ought to be conceivable to repair the structure or introduce interim propping before reoccupancy.

(c) Limited Safety Structural Performance Range

Structural Performance Range, Limited Safety should be characterized as the ceaseless scope of damage states between the

Life Safety Structural Performance Level and the Collapse PreventionStructural Performance Level.

(d) Collapse Prevention (*CP*) Structural Performance Level
Structural Performance Level, Collapse Prevention, might be characterized as the post-tremor damage state in which the building is very nearly halfway or aggregate breakdown. Considerable harm to the structure has happened, including significant degradation in the stiffness and strength of the lateral-force resisting system and also large permanent lateral deformation in vertical-load-carrying capacity. The structure may not be actually technically practical to repair and is not alright for reoccupancy.

Seismic fragility function methods
In the estimation of the fragility capacities there is an awesome level of instability included in every progression of the technique. This vulnerability is because of the variability in the groundmotion qualities, the analytical modelling, the materials utilized and the meaning of the damaged states. The different routines for the seismic vulnerability has been grouped into four categories: empirical, expert opinion based, analytical and hybrid.
(a) Empirical methods

Experimental fragility curves (Calvi *et al.*, 2006) are built utilizing insights of the watched damage from past seismic tremor occasions, , for example, information gathered by post- quake overviews. This technique utilizes the observational information in the most practical route to model fragility curves however it is hard to deliver the fragility curve because of the inadequacy and inadequacies in the study and the blunders created in the reckoning of the seismic information and the post-preparing. The main types of empirical methods are:

a) The Damage Probability Matrices (DPM)

b) The Vulnerability Index Method

c) The Continuous Vulnerability Functions

(b) Expert opinion-based methods
Expert opinion-based fragility curves depends on the judgment and the information of the experts. These experts are asked to give the detail estimation of the probability of damage for different types of structures and several levels of ground shaking from the past earthquake events. This method is not affected by the limitations regarding the quantity and quality of structural damage. However, the results are strictly correlated with the individual experience of the experts for the better estimation of fragility curve.
(c) Analytical methods
Analytical methods describe the step by step algorithms for detailed study of seismic vulnerability of the structures and to estimate various characteristics of building stock and hazard. Analytical fragility curves are constructed for prescribed damage states and are simulated from analyses of structural models under increasing earthquake intensity. The application of the analytical methods might be limited by the computational effort of the analyses. To reduce the computational effort, simplified analytical models are often used, with large number of analyses, such that the uncertainties can be adequately predicted.

Seismic vulnerability can be evaluated using one of the following methods:

a) Lateral force analysis (linear)

b) Modal response spectrum analysis (linear)

c) Non-linear time history dynamic analysis (NTHA)

d) Non-linear static (pushover) analysis (POA)

e) q-factor approach

Especially in the last few decades many studies focused on the seismic fragility functions for RC structures were based on analytical methods.(Dumova-Jovanoska, 2000; Erberik and Elnashai, 2004; Akkar *et al.*, 2005; Kircil and Polat, 2006; Oropeza *et. al*., 2010) are some literature studies based on analytical methods.

(d) Hybrid methods

Hybrid fragility curves are based on the combination of different methods for damage prediction and loss evaluation. This method aim is to compensate the lack of observational data,
the deficiencies of the structural models and the subjectivity in expert opinion data. (Barbat *etal*., 1996; Kappos *et al*., 2006) are some literature studies based on hybrid methods.

REVIEW OF PREVIOUS STUDIES BY ANALYTICAL METHOD

Lee and Su (2012) studies the seismic fragility investigation of masonry infilled (MI) reinforced concrete (RC) structures utilizing a coefficient-based system. The coefficient-based system is an improved technique without finite element analysis for assessing the spectral acceleration and displacement of buildings subjected to earthquakes. The coefficient based parameters, for example, inter-storey drift ratio (IDR) and period shift factor (PSF) are obtained from the shaking table tests. A regression analysis was performed to acquire the best-fitting mathematical statements for the inter-storey drift ratio (IDR) and period shift factor of masonry infilled (MI) reinforced concrete (RC) structures because of the peak ground acceleration. The spectral acceleration and spectral displacement demand is obtained from seismic coefficient. Spectral acceleration- and spectral displacement-based fragility curves for different damaged states were then built utilizing the coefficient-based strategy.

Mosalam *et al.* (1997) delivered vulnerability curves for low-ascent masonry infilled RC structures for gravity loads. Pushover analyses were performed, to focus the properties of cement, steel and masonry properties, in request to acquire trilinear capacity curves. The fragility investigation were accepted to take after a lognormal conveyance with expected coefficients of variety. Nonlinear examination is done of 800 fake accelerograms information for a SDOF structure. The Monte Carlo procedure was performed to create 200 capacity curves for each accelerogram. Relationship was found with fragility curves acquired from the ATC-13 damage probability frameworks.

Cornell *et al.* (2002) built up a probabilistic system for seismic outline and appraisal of structures in a demand and capacity format tending to the vulnerabilities in hazard, structural, damage, and loss analyses. Demand and capacity were expressed in terms of the maximum inter-story drift ratio with a nonlinear dynamic relationship using ground motions. The median with logarithmic standard deviation obtained from lognormally distributed function. The SAC FEMA method used to provide the framework for probabilistic recommendations of design guidelines.

Ellingwood (2001) studies the seismic fragilities examination of regular low-to-mid-ascent steel and reinforced concrete structures and its plan and development works on utilizing SAC FEMA technique. This paper delineated a straightforward strategy for the probabilistic investigation of building reaction to comprehend the building conduct. Uncertainty in response of structures to seismic tremor ground movement is because of the peak ground motion intensity, time-varying amplitude and strong motion duration and frequency content, and design and construction practices. Fragility curve depicts the probability of exceedance of damage and are vital for annihilation and loss expectation and hazard response projection. Additionally, an examination investigation of these fragilities curves consolidated in HAZUS conveys suggestions for damage and loss estimation.

Goulet *et al.* (2007) Seismic execution evaluation of RC moment resisting-frame composed per current (2003) construction law procurements. The nonlinear dynamic structural simulations utilized for the damage investigations, and misfortune estimation. The chose ground movement records for nonlinear dynamic analyses that are communicated as far as a response spectral valueat the building's fundamental period. It is critical to consider the response spectral shapes, particularly when considering higher risk levels. The nonlinear dynamic simulation results are utilized for computing the methods and coefficients of variety. The fragility functions used to express the probabilities of segment damage.

Özer and Erberik (2008) Produced vulnerability curves for RC frames in Turkey. 3, 5-, 7 and 9-story RC outlines with poor, medium and great seismic outlined rules with shifting Concrete and steel quality and modulus of flexibility. Four damage states were presents as slight or no damage , huge damage , extreme damage and breakdown or collapse . The seismic interest were acquired regarding most extreme between inter-storey drift ratio for distinctive arrangements of ground movement records by performing non-linear time-history analyses.

Akkar *et al.* (2005) created vulnerability curves for low-ascent and mid-ascent infilled RC outline structures. Pushover analyses of 32 current structures were performed to characterize the base shear limit, period and extreme story drift of the structures with low-level of seismic outline. Nonlinear dynamic analyses were then performed for 82 recorded accelerograms. The quantity of stories was found to have a noteworthy impact on the likelihood of surpassing the moderate and the extreme severe damage limit states (LS). Spectral displacement (*Sd*) corresponded preferable with PGV over PGA up, for larger amounts of damage.

Kappos *et al.* (2006) presents vulnerability curves for RC frame structures, and for unreinforced masonry (URM) structures, as per a hybrid method. This strategy consolidates measurable information as far as PGAs and/or spectral displacements which got from non-linear dynamic or static analyses. Vulnerability curves were determined regarding PGA, and spectral displacement (*Sd*). Investigations of a few distinctive Low-ascent, mid-ascent and high-ascent Reinforced Concrete (RC) structures were considered; everyone was accepted to have three diverse setups (bare, regularly infilled and soft delicate ground story building). Four classes of seismic outline were considered: no code, low code, moderate code and high code. Inelastic static and dynamict time-history investigations were done.

METHODOLOGY

Coefficient-based method (Lee and Su, 2012)

The coefficient based strategy is a simplified method that does not oblige much concentrated finite element analysis to survey the spectral acceleration and displacement of building subjected to a quake ground movement. Coefficient-based techniques for deciding the seismic inter-story drift demand and limit of structures have been considered broadly (Miranda, 1999; Gupta and Krawinkler, 2000; Zhu *et al.*, 2007; Tsang *et al.*, 2009; Lee and Su, 2012; Su *et al.*, 2012). The precision of these coefficient-based seismic appraisal systems depends firmly on the proposed drift related factors, which are regularly decided and aligned through numerical simulation results acquired from the nonlinear time history investigations of structures subjected to differenttremor movements.

SUMMARY

This chapter presents the detail study of the masonry infilled reinforced concrete buildings. The detail literature study on the different methods through which fragility curves can be obtained. This study depicts about the Intensity Measures, the building performance level or(the Damage States), the Damage Measures and the methods that has been used for the fragility analysis. This chapter describes the detail literature review of the fragility analysis of masonry in-filled reinforced concrete building. The fragility analysis procedure and different analytical methods to obtain the fragility curve are described in the literature review section.

The study concentrate on the seismic vulnerability assessment of masonry infilled reinforced concrete buildings and to distinguishing the damage risk of a structure influenced by ground motion of different intensity. This chapter explains the detailed step by step procedure of seismic risk assessment in a probabilistic framework using lognormal distribution. Fragility curves used to explain probabilities of exceeding different prescribed damage states (or performance levels).Finally this chapter briefly explains the coefficient based method and SAC FEMA technique used in the present study to obtain the fragility curves for the buildings. Later towards the end the validation of coefficient based method considering Lee and Su (2012) literature to design the fragility curve for different storey buildings.

DEVELOPMENT OF FRAGILITY CURVES

Introduction

In this chapter we discuss the development of the fragility curves by two methods such as Coefficient based method and SAC-FEMA method for masonry infilled (MI) reinforced concrete (RC) buildings having number of stories two, four and six. The Chapter starts with the description of ground motion data used for both the methods. Following the ground motion data, this chapter discuss about the development of the fragility curves using coefficient based method (Lee and Su, 2012) for various performance levels in particular Immediate Occupancy (*IO*), Life Safety (*LS*) and Collapse Prevention (*CP*). A comparison study of fragility curves developed using coefficient based method and SAC-FEMA method (Cornell et *al*., 2002) for different storey frames in the last part of this Chapter.

Methodology

The step wise procedure to develop the fragility curves as per the coefficient based method is given below.

- Estimate the maximum Inter-storey drift (IDR) ratio values for different peak ground acceleration (PGA) values for the frame selected from a number of ground motions. This may be obtained from existing shake table experiment or computational methods such as nonlinear dynamic analysis of the selected frame. Minimum four pair of values of PGA and IDR drift is required. Fit a logarithmic relationship for PGA values in terms of IDR, PGA = f (IDR).
- Period shift factor (β) using Eq.2.10. The fundamental time period (T_0) and time period ofthe damaged building (T_e) can be obtained either from shake table test or computationally. For each PGA values the corresponding period shift factors are computed. Fit a logarithmic linear expression for β in terms of PGA as β = f (PGA).

- Compute drift factor (λ) for the masonry infilled RC building using Eq. 2.17 from the maximum, average inter-storey drift ratio for first mode shape and maximum inter-storey drift ratio from combined mode shape.
- Generate PGA values for IDR values varying from 0.1% to 6% in a uniform interval.

  Compute PSF (β) values for each PGA values. Compute spectral acceleration (S_a) values for each set of values of IDR, PSF (β) and drift factor (λ). Estimate the spectral acceleration and spectral displacement demand for the frame using Eq. 2.8 and 2.9. Compute the mean (mX) and standard deviation (σX)
- Construct fragility curve based on coefficient based method using Eq. 2.5a, where P_f isthe exceedance probability of IDR.
- Development of seismic fragility curves for the same frames based on SAC FEMAmethod (Cornell *et al*., 2002) using Eq. 2.19 for the same frames.
- A critical comparison of the fragility curves between coefficient based method and SACFEMA method

Earthquake Ground Motion Data

Generation of fragility curves by both seismic coefficient based and SAC FEMA method require ground motion data. Thirteen pairs of ground motion data are selected from past earthquakes events in different location in India. All the selected ground motion records are available at Indian region in CESMD website (http://strongmotioncenter.org/). All the ground motion earthquake records selected with PGA ranging from 0.1g to 1.48g are located with hypo-central distance 10km away from the faults.

Fragility Curves Using Coefficient Based Method

According to the approach portrayed in previous segment fragility curves are produced utilizingcoefficient based method for various performance levels. In the fragility analysis the demands of the structures are log normally distributed i.e. the demands and the IMs can be prophesied by a power model .The fragility curve which graphically signify the seismic risk of the structure, as the probability of exceeding prescribed damage state.

Two Storey Buildings

A two storey two bay masonry infilled reinforced concrete building having storey height 3.2m and bay width 5m model is designed. The computational model is subjected to earthquake ground motion recorded in Table 3.1 and the fundamental time period to the structure is calculated according to the code *IS 1893*. The nonlinear dynamic analysis is performed on the structure to obtain the storey drift and periodic shift of the building for each value of PGA.

Summary

This chapter detail discussed about the fragility curve for two, four and six storey masonry infilled reinforced concrete buildings using coefficient based method. This chapter started with the selecting ground motion data from different region from past earthquake in India from CESMD website. The computational model of two, four and six storey building is subjected to earthquake ground motion recorded in Table 3.1 and nonlinear dynamic analysis is performed onthe to obtain the inter storey drift ratio and the period shift (or the stiffness deterioration) of the building.

The spectral acceleration and spectral displacement based fragility curves are plotted of masonry infilled reinforced concrete buildings for probability of exceeding various damage state or performance level (IDR of 0.5%, 1% and 2%) and various number of stories (two, four and six storey) buildings using coefficient based method. The fragility curve that graphically represent the seismic risk of structure used for seismic performance evaluation and seismic vulnerability assessment of building. Finally, the fragility curves for masonry infilled reinforced concrete buildings with various number of stories at the CP state (IDR=0.2%) performance levels are compared for both the coefficient based method and SAC FEMA method and the comparison results are correspond well for estimating the seismic risk of the structure.

CONCLUSIONS

The main goals of this study are to estimate seismic vulnerability of masonry in filled reinforced concrete structures through seismic fragility analysis and to assess the seismic risk of a structure. To achieve the desire objective the problem is being divided into different sub parts:

- Validate and Develop fragility curves of Typical RC frames with number of stories ranging from two to six stories using coefficient based method (Method I) proposed by Lee and Su (2012)
- Development of seismic fragility curves for the same frames based on SAC FEMA method (Method II).
- A critical comparison of the fragility curves between two methods (Method I and II).

To achieve the above desire objectives, an extensive literature review is carried out on following area are (a) the various methodologies for the seismic vulnerability assessment of masonry infilled reinforced concrete buildings as per various international codes and literatures, (b) study of the building performance level or (the Damage States) of the building and (c) fragility curves on masonry infilled (MI) reinforced concrete (RC) framed buildings using coefficient based method (Lee and Su, 2012) and SAC FEMA method (Cornell *et al*., 2002).

The chapter 2 presents the detailed procedure of seismic risk assessment in a probabilistic framework using lognormal distribution and briefly explains the coefficient based method and SAC FEMA method used in the present study to obtain the fragility curves for the buildings. Thevalidation study of coefficient based method using published experimental shaking table test results obtained for different storey buildings.

This ground motion data is selected from different region from past earthquake in India from CESMD website. The computer based model of two, four and six storey building are design by and the building model subjected to receded earthquake ground motion intensity. Nonlinear dynamic analyses is carried out to the model to obtain the inter storey drift ratio and the period shift (or the stiffness deterioration) of the building. The spectral acceleration and spectral displacement based fragility curves for two, four and six storey masonry infilled reinforced concrete buildings are plotted using coefficient based method. Finally, the fragility curves for masonry infilled reinforced concrete buildings at the damage state for both the coefficient based method and SAC FEMA methods are compared.

CONCLUDING REMARKS

This study proposed the coefficient based method for seismic fragility analysis of masonry infilled reinforced concrete building, for selected ground motion intensity in rock or soil condition in different region from past earthquakes in India. The coefficient based method is a simplified technique without finite element analysis for estimating the spectral acceleration and spectral acceleration demand of the structure. The spectral acceleration and displacement fragility curves are plotted for various number of stories and various performance level for specified damage state of inter storey drift ratio of 0.5%, 1% and 2% by coefficient based method. The fragility curves for masonry infilled (MI) reinforced concrete (RC) building at the collapse state obtained from coefficient based method is compared with SAC FEMA method. The fragility curves obtained can provide a good vulnerability assessment for masonry infilledreinforced concrete buildings at different damage state performance level.

Based on the results and analyses the following conclusion are obtained:

1) The spectral acceleration and spectral displacement for two, four and six storey masonry infilled reinforced concrete building are obtained using regression analyses and coefficient based parameters such as IDR and PSF are calculated from PGA values and the drift factor predicted from Eq. 2.17 as λ=3.14.
2) The spectral acceleration and spectral displacement based fragility curves for two, four and six storey masonry infilled reinforced concrete building for various performance level are obtained using coefficient based method and median, lower bound and upper bound spectral acceleration and displacement are calculated for inter-storey drift ratio of 0.5%, 1% and 2%. The fragility curves achieved can afford a satisfactory vulnerability assessment of buildings for different damage state performance level.
3) The fragility curves obtained from coefficient based method is compared with SAC FEMA method at the damage state (CP state) and a good correlation is obtained for both the method for evaluating seismic performance of building

LIMITATION OF PRESENT STUDY AND SCOPE OF FUTUREWORK

The present study is limited to masonry infilled reinforced concrete buildings up to six-storey that are regular in plan and plan asymmetry arising from infill walls are not considered in the analysis. This study can be extended for bare frame building and open ground storey (OGS) buildings for multi-storey frame structures. Only the spectral acceleration and displacement fragility curves are obtained using coefficient based method in this study. Also Reliability curves can be developed for the masonry infilled reinforced concrete building for the seismic hazard determination using this method.

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