iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** III **Month of publication:** March 2018

DOI: http://doi.org/10.22214/ijraset.2018.3305

A Review - Fragility Analysis of Multi-Storey Regular R.C Building

Tanvi Apte[1], Savita Maru[2]
[1]Post-graduation Student, [2]Assistant Professor, Civil Engineering Department,
Ujjain Engineering College, Ujjain, RGPV University, Bhopal M.P., India

***Abstract:** The uncertain nature of future ground motions is leading to the development of probabilistic structural damage estimation procedures. The fragility curve method is a useful method for estimating the structural damage for certain type of structure under the effect of potential earthquakes. Earthquake response analysis is basically done either by non-linear static procedure or non-linear dynamic procedure. Non-linear static procedure may or may not be based on record to record variability, however non-linear dynamic procedure are based on record to record variability. Based on structural response results the two parameters mean and standard deviation are obtained for development of fragility curve.*
***Keywords:** Non-linear static procedure, non-linear dynamic procedure, record to record variability, probabilistic structural damage, fragility curve*

I. INTRODUCTION

Over the past 40 years, major changes regarding seismic design procedures have occurred. Historically, seismic design procedures were based primarily on forces and the strength necessary to resist them largely because that is what dead and live loads are traditionally designed for. It was believed that the strength of a structure was synonymous with the performance of a structure. Research conducted during the 1970's and 1980's focused on determining the ductility of structural systems and incorporating this into the design requirements, but the overall design methods were still based on resisting forces. In the 1990's, a new design method based on desired levels of displacements, instead of forces, was introduced and has been the focus of research since then. The new design method, referred to as performance-based design, was developed to overcome shortcomings in the previous force-based design methodology. Through history, we had recognized that earthquakes caused in big disasters to structures which hadn't any elements to resist the horizontal force produced from earthquakes. There is a concept in the design of structures that was seismic design concept based primarily on forces and the strength necessary to resist them largely because that is what dead and live loads are traditionally designed for. So, there was a need for developing the field of design for structures which will be subjected to lateral load specially earth quakes loads. For analysis of structures subjected to seismic loading, methods such as static and dynamic methods came into existence which could be performed on varied software such sap2000,ansys etc. Further, to estimate the probabilistic damage in structure, damage states are defined and fragility curves are designed on basis of certain ground motion parameters. Fragility curve is one of the novel methods to analyze the probability of yielding or failure of structures thus simplifying seismic analysis.

II. LITERATURE REVIEW

Following are the research papers studied since from force based method to displacement based method, further to identify the structural and non structural damage based on static analysis and then moving to dynamic analysis for more accurate result. Also, defining the damage states for a structure including structural as well as non-structural and further determining probabilistic damage based on fragility analysis.

Jack P. Moehle (1996)[1] discussed performance based seismic design to satisfy specific performance objectives and addresses displacement based seismic design method along with its limitations. Also, gives benefit to displacement-based seismic design criteria for being relatively simple and being direct in their applications in the design process. This approach helps in estimating both displacement demand and capacities.

Initially the method of fragility analysis was applied to bridges as seismic performance of transportation system plays an important role in post-earthquake emergency management, which is presented in papers below:

Masanobu Shinozuka, Maria Q. Feng and Sang-Hoon Kim (2000)[2] considered a sample of 10 nominally identical but statistically different bridges and 80 ground-motion time histories to account for uncertainities related to structural capacity and ground motion. Peak ground acceleration (PGA) parameter was adopted for analysis of determining fragility curve. The comparison of fragility curve by non-linear static procedure with time history analysis indicates good results for the state of at-least minor damage. However the results are adequate even in state of major damage.

Satoshi Tanaka, Hiroyuki Kameda, Nobuoto Nojima and shunsuke Ohnishi (2000) [3] presents fragility functions that can be used for post-earthquake management of transportation systems where both space and time factors are relevant. These fragility curves take account of both physical and functional aspects of seismic performance for highway systems. This paper constructs the GIS based damage database, estimates spatial distribution of ground motion as development of fragility curve for collapsed, major, and minor damage situation for reinforced concrete bridge and steel bridge. Here also Peak ground acceleration parameter is adopted for deriving fragility curve.

Further, more parameters such as peak ground velocity (PGV), spectral acceleration (S_a), Spectral displacement (S_d) were adopted along with peak ground acceleration for deriving fragility curves. And research was extended to structural reliability index as well as derivation of reliability curves.

Fariborz NATEGHI-A and Vahhid L.SHASAVAR (2004) [4] addresses the physical aspects of the seismic performance of bridges by developing fragility functions or damage probability matrices. The modelling of bridge is done using 3D nonlinear models and the result is generated in MATLAB. The results are represented in form of vulnerability and structural reliability relations based on two damage functions.

Murat Serdar Kircil, Zekeriya Polat (2006) [5] used IDARC for non-linear dynamic analysis and defined a method for obtaining fragility curve. Here, three parameters spectral acceleration, spectral displacement and peak ground acceleration were adopted for deriving fragility curves. It is observed from fragility curve that there is an effect on fragility curve parameters due to number of stories in building. Regression analysis is performed to find relationship between fragility curve parameters and number of stories, and extended fragility curve were developed with the help of results.

An earthquake loss estimation methodology was developed by Department of homeland security federal Emergency Management Agency (FEMA) Washington, D.C in form of Hazus-MH 2.1 which is a Technical and User's Manual. Thus, different methodologies were adopted or transformed for defining of damage states and in derivation of fragility curves. Also, the method was now applied to multi-storey buildings.

Xiaonian Duan and Jack W. Pappin (2008) [6] presents a procedure for establishing fragility curves by HAZUS Methodology for various damage states for estimating potential losses of an existing building stock based on nonlinear pushover analysis results.

K. A. Korkmaz (2008) [7] probabilistic seismic analyses are evaluated to define the structural seismic behaviour. A representative RC frame structure is taken in to consideration in the analytical part. A comparison is realized with the results of different methodologies as Monte Carlo Simulations and analytical based analysis.

Aishwarya S, Nandita Mohan [8] analyzed five-story reinforced concrete (RC) flat-slab building structure in the central United States. For the development of fragility curves, inelastic time history analysis was performed to analyze the structure subjected to the earthquake records in terms of spectral acceleration in ETABS V 9.7.3. To improve the seismic performance of the structure retrofitting was done by the addition of shear walls. Fragility curves were also developed for retrofitted structure. The fragility curves developed from this study were used to compare the seismic performance of retrofitted and unretrofitted structure.

F. Colangelo (2008) [9] reviews first order reliability method and a fuzzy random method for development of fragility curve. These methods are applied to deterministic infilled reinforced concrete frame. It is concluded that if a damage state is assosciated with a deterministic drift range ,then fragility steeply increases with peak ground acceleration.

Davide Bolognini, Barbara Borzi and Rui Pinho (2008) [10] analyses precast RC structures whose application has been targeted almost to industrial buildings, whereas other material and techniques are usually preferred for residential buildings or multi-storey structures. The structural behaviour is evaluated through pushover analysis and vulnerability curves are generated based on displacement capacity limit of the structures and on the displacement demand. Peak ground acceleration (PGA) is used as input motion severity. The probability of exceedance of the limit states was further determined story-wise for multi-storey structures.

M. Rota, A. Penna and G. Magenes (2008) [11] considers Monte Carlo simulation to define the input parameters for the model of masonry building. Non linear static (pushover) analysis and nonlinear dynamic time history analysis are performed to obtain fragility points which are fitted further by lognormal distribution to obtain fragility curves

V. Silva, H. Varun, H. Crowley,R. Sousa and R. Pinho (2012) [12] proposes an extensive study of static and dynamic procedures for estimating the non linear response of buildings to evaluate the impact of chosen methodology on the resulting vulnerability and risk outputs. The vulnerability curves were developed and compared based on Capacity Spectrum method (CSM) , Displacement Coefficient method (DCM) and N2 method. A conclusion was obtained regarding which method offers optimal balance between accuracy and complexity.

V. Silva, H. Varun, H. Crowley and R. Pinho (2012) [13] presents a new procedure to derive fragility function for buildings that relies on the displacement-based earthquake loss assessment (DBELA) methodology. This methodology is demonstrated for ductile and non ductile Turkish reinforced concrete frames with masonry infills.

A. Reveillere, P. Gehl, D. Seyedi and H. Modaressi (2012) [14] presents procedure to derive fragility curves for previously damaged structural systems. This procedure is based on application of sequences of ground motion records to the undamaged structure and permanent residual drift of damaged structure to derive the fragility functions. The dynamic simulations are carried out using OpenSees software.

A. Bakhshi, P.Asadi (2013) [15] evaluates effect of different parameters like PGA, importance factor (I) and inherent overstrength and global ductility capacity (R) on probability of structural damage. Structures having 4 and 6bays with 3, 7, 10 and 15 stories were considered. Fragility curves are employed for various probability parameters. The effect of the uncertainity of the PGA is displayed. It is found that by increasing the global ductility capacity(R), the probability of damage exceedance is decreased. However, an increase in importance factor cannot guarantee a decrease in the probability of damage exceedance.

Nor Hayati Abdul Hamid and Nor Mayuze Mohamad (2013) [16] presents employment of fragility curve to determine Confident interval for a precast house based on experimental work. The damage limit states are defined according to HAZUS 99-SR2. Colour coded system is utilized in identification of performance level, damage level, drift damage and ductility factors.

Marco Vona (2014) [17] reviewed a total of 216 building classes considering different ages, number of storeys, infill panels, plan dimensions, beam stiffness, and concrete strength. A relationship established among structural performance, damage levels and inter-storey drift ratios, which is calibrated using damage levels described in EMS98.

Adrian Fredrick C. Dya, Andres Winston C. Oretaa (2015) [18] considers soft storey as vertical irregularity according to National Structural Code of Phillipiness (NSCP). In the study, it is assume that the properties and number of structural members for each story is constant. The study is also limited to a single soft story at the first story. The severity of the soft story is varied by increasing the height of the soft story. A static pushover analysis is utilized to determine the performance of the building under different irregularity conditions. The output of the study may be used to improve existing level 1 seismic risk assessments. Data from the pushover analysis is translated to be used for preliminary risk assessment tools.

Mitesh Surana, Yogendra Singh and Dominik H Lang (2015) [19] focuses on fragility analysis of step back hill buildings, which is the most common configuration in the Himalayas. Incremental Dynamic Analysis is used for obtaining dynamic capacity curves, which are further used for fragility curve development. The performance of such buildings can be improved by making minor changes in the structural configuration. The research work is further extended to comparison of fragility curves.

D.J.Chaudhari, Prajakta T.Rajpure (2015) [20] analyzed open ground storey (OGS) reinforced concrete building designed with three different multiplication factors given by Indian code and Israel code, by non-linear dynamic time history analysis on a G+9 building and further developed fragility curves. It is concluded that while applying multiplication factor to the ground storey performance of upper storeys needs to be checked. The first storey is more vulnerable than the ground storey except for Israel Code.

Siti Nur Aqilah Saruddin and Fadzli Mohamed Nazri (2015) [21] presents study on development of fragility curve for low and mid-rise building which are reinforced concrete and steel moment resisting frame. Incremental dynamic analysis (IDA) was conducted on three and six storey frame structure with different type of material with design based on Eurocodes. Sap2000 software was used to perform IDA. Fragility Curves developed were based on five level of performance for the structural models.

C. Casotto, V.Silva, H.Crowley, R. Nascimbene and R. Pinho (2015) [22] analyzes precast RC buildings in Italy and develop fragility curve to be used in earthquake loss estimation and seismic risk assessment. The building population generated considered both material and geometric variability. Pushover analysis is used to establish a number of damage limit states as well as non linear dynamic analysis to allocate a structure in a damage state. Limit states were estimated according to both strain levels and maximum top drifts. The differences in fragility curve were observed when a 2D or a 3D modelling environment was adopted. A comparison with empirical fragility function on field data was also observed.

Junwon Seo, Jong Wan Hu and Burte Davaajamts (2015) [23] evaluates the seismic performance of a twelve storey reinforced concrete moment resisting frame structure with shear walls using 3Dfinite element models. Two standard approaches response spectrum analysis and nonlinear time history analysis were used for seismic performance evaluation. Both approaches were used to compute inter-storey drift ratios of the structure. The findings revealed that floor level fragility decreased with an increase in height and the ratio from both approaches satisfied the codified limits.

Tiziana Rossetto ,Pierre Gehl, Stylianos Minas,Carmine Galasso, Philippe Duffour, John Douglas, Oliver Cook (2016)[24] describes development of fragility curve based on capacity spectrum assessment method as FRACAS.A comparison of maximum inter-storey drift (MIDR) response obtained from FRACAS and non linear time history analysis for two case-study buildings subjected to 150 natural accelerograms. The fragility curve demonstrates well the inelastic record-to-record variability obtained based on FRACAS.

G Navya, Pankaj Agarwal (2016) [25] exhibits seismic retrofitting to improve the system behaviour or its components strengthening upto the performance it is expected. Compares building designed with two different philosophies which are IS456 and IS 1893(Part1):2002 and is retrofitted with steel bracing. Further fragility analysis was carried out to indicate probability of damage under different states which considerably reduces after retrofitting of building.

M. Raghunandan, A. Liel (2017) [26] evaluates the aftershock collapse vulnerability of a non-ductile reinforced concrete frame building designed according to the 1976 Uniform Building Code. Incremental dynamic analysis on non-linear analytical building models is used to generate damage and collapse fragility curve for intact and main-shock damaged buildings. It is observed that the structure's ability to withstand collapse and further damage are decreased as the extent of damage after the main-shock increases.

Linda Astriana, Senot Sangadji, Edy Purwanto and S.A.Kristiawan (2017) [27] considers a structure with moment resisting frame and frame-shear wall structure with design based on Indonesian Code and employed nonlinear pushover analysis yielding capacity spectrums. For each capacity spectrum, the damage states were defined based on HAZUS-MH MR5 and ATC-40. A comparison was carried out for fragility curve based on Hazus-MH MR5 and ATC-40.

Rajeshprasad B S (2017) [28] modelled structure with and without infill walls and spectral displacement at performance point is used to determine probability of a particular damage state .The study is further extended to understand the effect of varying soft storey levels on fragility assessment.

III.METHOD

A. To develop fragility curve ground motion parameters like spectral displacement (Sd), spectral acceleration (Sa), peak ground acceleration (PGA) etc are required.

B. For obtaining such parameters several methods like incremental dynamic analysis, time history, non linear pushover analysis etc no. of methods and software like ETABS, SAP2000, IDARC-2D, and OPENSEES are available.

C. Here, the parameters spectral displacement and spectral acceleration are obtained through pushover analysis on SAP2000 v.18.

D. The curves for fragility are plotted in Microsoft Excel based on mean and standard deviation of ground motion parameters mentioned above.

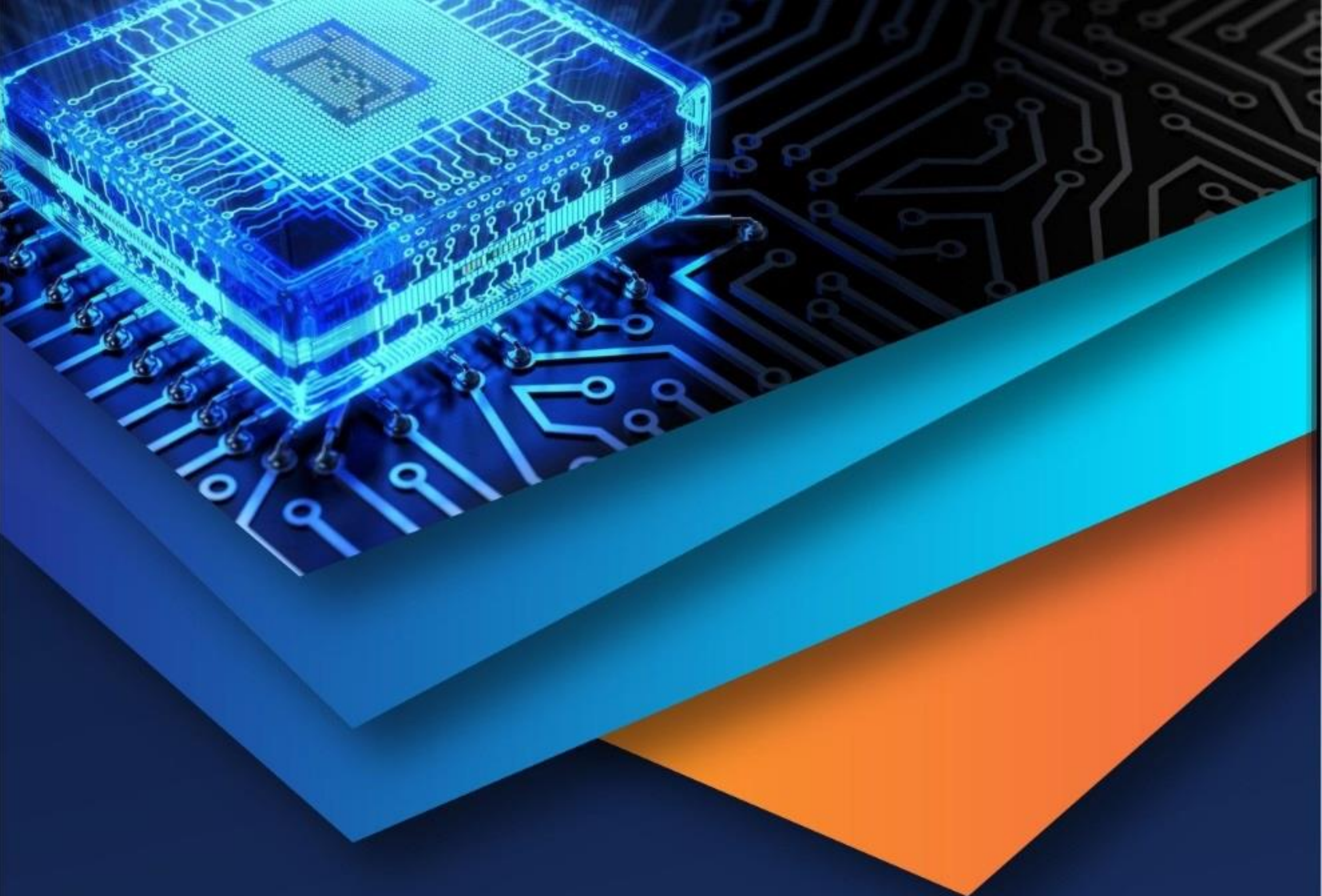
IV.CONCLUSIONS

Each year earthquakes occur in several countries, killing many people and causing extreme losses so that, evaluating the seismic performance of buildings and proposing some effective methods to rehabilitate them against earthquakes is an essential step toward hazard mitigation and risk assessment. The procedure of developing analytical fragility curve development gives computational efficiency and a quick way of seismic risk analysis against failure of building components and also for mild, moderate and collapse damage of building. However, all these studies require further research and need to be compared with experimental curves based on real life earthquake data.

REFERENCES

[1] Jack P. Moehle, "Displacement-based seismic design criteria", 11WCEE, Acapulco, Mexico, 1996.
[2] Masanobu Shinozuka, Maria Q. Feng and Sang-Hoon Kim, "Nonlinear Static Procedure For Fragility Curve Development", ASCE, 2000.
[3] Satoshi Tanaka, Hiroyuki Kameda, Nobuoto Nojima and shunsuke Ohnishi, "Evaluation of Seismic Fragility For Highway Transportation Systems", 12WCEE, 2000.
[4] Fariborz NATEGHI-A and Vahhid L.SHASAVAR, "Development Of Fragility and Reliability Curves For Seismic Evaluation of A Major Prestressed Concrete Bridge", 13WCEE, Vancouver, Canada, 2004
[5] Murat Serdar Kircil, Zekeriya Polat, "Fragility analysis of mid-rise R/C frame buildings", Engineering Structures, 28, pp. 1335-1345, 2006.
[6] Xiaonian Duan and Jack W. Pappin, "A procedure for establishing fragility functions for seismic loss estimate of existing buildings based on nonlinear pushover analysis", 14WCEE, Bejing, China, 2008.
[7] K. A. Korkmaz, "Evaulation of seismic fragility analyses", 14WCEE, Bejing, China, 2008.
[8] Aishwarya S, Nandita Mohan, "Vunerability analysis by the development of fragility curves", IOSR.
[9] F. Colangelo, "On The computation of seismic fragility curves", 14WCEE, Bejing, China, 2008.
[10] Davide Bolognini, Barbara Borzi and Rui Pinho, "Simplified Pushover-Based Vulnerability Analysis of Traditional Italian RC precast structures", 14WCEE, Bejing, China, 2008.
[11] M. Rota, A. Penna and G. Magenes, "A procedure for deriving analystical fragility curves for masonry buildings", 14WCEE, Bejing, China, 2008.
[12] V. Silva,H. Varun, H. Crowley,R. Sousa and R. Pinho, 'Evaluation of Analytical Methodologies to derive vulnerability functions", 15WCEE, Lisboa, Portugal, 2012.

[13] V. Silva, H. Varun, H. Crowley and R. Pinho, "Extending displacement-based earthquake loss assessment (DBELA) for the computation of fragility curves", 15WCEE, Lisboa, Portugal, 2012.
[14] A.Reveillere, P. Gehl, D. Seyedi and H. Modaressi, "Development of seismic fragility curves for mainshock-damaged reinforced-concrete structures", 15WCEE, Lisboa, Portugal, 2012.
[15] A.Bakhshi, P.Asadi, "Probabilistic evaluation of seismic design parameters of RC frames based on fragility curves", Scientia Iranica A, 20, pp. 231-241,2013.
[16] Nor Hayati Abdul Hamid and Nor Mayuze Mohamad, "Seismic assessment of a full-scale double-storey residential house using fragility curve", Procedia Engineering 54, pp. 207-221, 2013.
[17] Marco Vona, "Fragility curves of existing RC buildings based on specific structural performance levels", Scientific Research, 4, pp.120-134, 2014.
[18] Adrian Fredrick C. Dya, Andres Winston C. Oretaa, "Seismic vulnerability assessment of soft storey irregular buildings using pushover analysis",Procedia Engineering 125, pp. 925-932, 2015.
[19] Mitesh Surana, Yogendra Singh and Dominik H Lang, "Seismic fragility analysis of hill-buildings in Indian Himalayas", SECED, Cambridge UK, 2015.
[20] D.J.Chaudhari, Prajakta T.Rajpure, "Fragility analysis of open ground storey RC building designed using various multiplication factors", IJRET, 2015.
[21] Siti Nur Aqilah Saruddin and Fadzli Mohamed Nazri, "fragility curves for low- and mid-rise buildings in Malaysia", Procedia Engineering 125, pp. 873-878, 2015.
[22] C. Casotto, V.Silva, H.Crowley, R. Nascimbene and R. Pinho, "Seismic fragility of Italian RC precast industrial structures", Engineering Structures 94, pp.122-136, 2015.
[23] Junwon Seo, Jong Wan Hu and Burte Davaajamts, "Seismic performance evaluation of multistory reinforced concrete moment resisting frame structure with shear walls", Sustainibility, 7, pp. 14287-14308, 2015.
[24] Tiziana Rossetto, Pierre Gehl, Stylianos Minas, Carmine Galasso, Philippe Duffour, John Douglas, Oliver Cook., "FRACAS: A capacity spectrum approach for seismic fragility assessment including record –to-record variability", Engineering Structures 125, pp. 337-348, 2016.
[25] G Navya, Pankaj Agarwal, 'Seismic retrofitting of structures by steel bracings", Procedia engineering 144, pp. 1364-1372, 2016.
[26] M. Raghunandan, A. Liel, "Aftershock collapse vulnerability assessment of an older reinforced concrete frame", 16WCEE, Santiago, Chile, 2017.
[27] Linda Astriana, Senot Sangadji, Edy Purwanto and S.A.Kristiawan, "Assessing seismic performance of moment resisting frame and frame-shear wall system using seismic fragility curve", Procedia Engineering 171, pp. 1069-1076, 2017.
[28] Avinash A R, Rajeshprasad B S, Kiran Kamath, "A comparative study on seismic fragility assessment of RCC structure with varying soft storey level with and without infill", IJCIET,2017.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY