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REVIEW ARTICLE

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PERFORMANCE BASED SEISMIC DESIGN AND PUSHOVER ANALYSIS: A REVIEW

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ABSTRACT

Performance based seismic design is a not only a simple but also a systematic design method for structural systems to achieve the desirable and predictable performance of structure. The idea of performance based seismic design is becoming the future direction for the seismic design codes. The structural engineers are being attracted towards this new concept because of its potential, as it gives the better understanding of the insight structural behavior during the strong earthquake ground motions. The basic concept for performance based seismic design (PBSD) is to conjecture structures that perform desirably. In performance based seismic design (PBSD) the structural design depends on the structures performance during an earthquake. Present study is based on the performance based seismic design and the pushover analysis (nonlinear static analysis) literature survey.

Keywords: Performance based seismic design, Pushover analysis, Seismic, Nonlinear static analysis.

INTRODUCTION

The Performance-Based Earthquake Engineering (PBEE) is also known as Performance Based Seismic Engineering (PBSE) is a latest growing idea for designing the structures at seismic risk. This idea is published in all recent guidelines like, ATC-40 (ATC, 1996), Vision 2000 (SEAOC,1995), SAC/FEMA-350 (FEMA, 2000a), and FEMA-273 (FEMA, 1997). This type of method is required for designing the structure so as to meet a particular performance objective under the rare or moderate earthquake actions that is experienced by the structure in its lifetime.

In general the structure which seems to be strong enough, may collapse like house of cards experiencing an earthquake. The performance-based design is the modern approach for earthquake resistant design concept. It is not a very new concept but also used for automobile & airplanes, but its applications to the structure is limited. There are two key elements that are demand and capacity which are to be considered while using this methodology.

Capacity: The overall capacity of a structure depends on the deformation capacity of the structures components and the strength that it has, and determining the structural capacity beyond the elastic limits. A nonlinear analysis such as the pushover analysis is to be performed. Sequential elastic analysis is used in pushover analysis procedure in a series, superimposed to approximate a force displacement capacity diagram of the overall structure. A lateral force distribution is again applied until additional components yield. This process is continued until the structure become unstable or until a predetermined limit is reached. In short capacity is seismic demand resisting ability of structure.

Demand: During an earthquake, the ground motion produces complex horizontal displacement patterns in the structures. To determine the structural design parameters it is not practical to trace this lateral displacement at each time step. And once the capacity curve for the structure & the demand displacement are defined the performance check for the structure can be done. In short demand is, the structure is subjected to a ground shaking or an earthquake ground motion an estimation of displacements or deformations in which the structure is expected to undergo. The performance of the structure depends on this two key elements, whether the capacity of the structure is enough to resist the demand or the structure should have adequate capacity to resist the demands of the earthquake ground motions so that performance and objective of design are compatible with each other.

The pushover analysis i.e. nonlinear static analysis came into practice after 1970. This method is mainly used to estimate the drift and strength capacity of an existing structure & the seismic demand for structure subjected to an earthquake ground motion. This methodology can also be used for determining the adequacy of new structural design as well. The effectiveness of this method and its computational simplicity brought this method into several seismic guidelines i.e. in ATC-40 & FEMA-356 and design codes Euro code-8 & PCM-3274 in last decades.

Pushover analysis is a method in which mathematical model directly meeting the nonlinear load-deformation characteristics of individual components and elements of the structure is subjected monotonically increasing lateral loading pattern representing forces in an earthquake until a targeted displacement is reached. Elastic plus inelastic displacement i.e. the target displacement is the maximum displacement of the structure expected under a selected earthquake. using a nonlinear static analysis algorithm, pushover analysis determine the performance by estimation of the force capacity, seismic demand and deformation of the structure. The seismic demand parameters for buildings are storey drifts, storey forces, global displacement (at roof or at any other reference point), component deformation and component forces. The analysis accounts for the redistribution of material inelasticity, internal forces, and geometrical nonlinearity. From the pushover analysis response characteristics that can be obtained are summarized as follows:

a. Estimates of force capacities and displacement of the structure, progress of overall capacity curve and the sequence of yielding of member.
b. Estimates of force (axial, shear and moment) demands on potentially brittle elements and deformation demands on ductile elements and.
c. Estimates of corresponding damages on structural and non-structural elements and inter-storey drifts.
d. Sequences of the failure of elements and the consequent effect on the overall structural stability. e) Identification of strength irregularities (in plan or in elevation) of the building and identification of the critical regions, when the inelastic deformations are expected to be high. All these benefits are delivered by pushover analysis for an additional computational effort over the linear static analysis.

PUSHOVER ANALYSIS PROCEDURE

Pushover analysis can be performed as either force-controlled or displacement controlled. It depends on the nature of the applied load to the structure and the behavior expected from the structure. Force controlled is useful for gravity loading, and it is expected by structure to be able to support the load. Displacement controlled procedure is useful when specified drifts are sought, where the structure can be expected to become unstable or lose strength or where the magnitude of the applied load is not known in advance. Some computer programs like Seismostruct, DRAIN-2DX, SAP2000, ANSYS etc. are able to perform pushover analysis and can model nonlinear behavior so as to obtain the capacity curve for models of the structure.

LITERATURE REVIEW

M J N Priestley (2000) [1] discussed and compared 3 methods that are direct displacement based design, capacity spectrum and N2 method and concluded that in the current argument, most suggested design procedures require the addition of a displacement, or damage, check to an essentially force-based design procedure.

Peter fajar, M.eeri (2000) [2] the accuracy of the results of the N2 method was checked and concluded that this method and the procedure in the FEMA-273 are quite similar and can yield the same result if same lateral load distribution and same displacement shape are assumed.

Mario Rodriguez And Victor Rodriguez (2000) [3] lateral strength and deformation capacity of confined masonry units subjected to reversed cyclic lateral loading was studied and analyzed and concluded that analysis showed a significant higher variability on strength prediction as compared to deformation capacity prediction given by a simple procedure proposed. This suggests the convenience of implementing a PBD following a displacement-based approach for seismic design of confined masonry construction.

Silvia Bruno, Luis D Decanini And Fabrizio Mollaioli (2000) [4] four and eight storey building belongs to housing complex at Catania was analyzed and aims to extend and increase the current knowledge about the evaluation of seismic vulnerability of existing RC buildings and concluded that:

a) The seismic performance of buildings without resisting masonry panels is very poor, and the EPA corresponding to collapse conditions doesn't exceed 0.1g;

b) The presence of infilling continuous in elevation reduces the vulnerability level. The EPA corresponding to collapse conditions reaches to 0.2g, but no difference in the collapse mechanism was detected;

c) If not adequately located and distributed, concentrated inelastic strain may raise due to masonry panels, though with a strength growth with respect to the bare frames;

d) The attitude to energy dissipation globally displayed by the typologies under investigation is extremely scarce;

e) The collapse occurs as a consequence of the base columns yielding for concrete crushing; f) a comparison of the results of dynamic and pushover analysis allows to conjecture that, depending on different ductility demands correspond to substantially identical collapse mechanisms, the energy characteristics of the seismic input;

g) Seismic retrofitting of such existing buildings is of problematic realization and doubtful effectiveness. in the introduction of shear walls and dissipative bracings Satisfactory solutions may consist.

A. S. Moghdam And W. K. Tso (2000) [5] a response spectrum based pushover procedure to obtain seismic response estimates of three types of building systems that were asymmetrical was studied. The procedure included some of the 3-D effects caused by the response of torsion. The main features of the procedure were the use of elastic response spectrum analysis of the building to obtain the target displacements and the load distributions used in the pushover analyses.

R. Hasan, L. Xu, D.E. Grierson (2002) [6] presented a simple computer-based pushover analysis technique for performance based design of building frameworks subject to earthquake loads. This technique was based on the conventional displacement method of elastic analysis.

Rahul Rana et al (2004) [7] had discussed the importance of Pushover analysis as a useful tool of performance based seismic engineering to study post-yield behavior of a structure which requires less effort and deals with much less amount of data than a nonlinear response history analysis.

Ramiro A. Sofronie (2004) [8] refers to masonry strengthened with polymer grids and concluded that Richter Gard System provides real performances in seismic strengthening of masonry. Polymer grids are as suitable for masonry as steel reinforcements are for mascrete. Ductility is indeed the ability of buildings to survive accidental loads like earthquakes, but it is based on plastic, hence irreversible strains.

Andrew King And Roger Shelton (2004) [9] provides a summary of the objectives and principles of New Zealand earthquake design standard, AS/NZS 1170 part 5 and outlines how the issues have been addressed within New Zealand, and some of the issues addressed by the review committee in preparing appendices to the standard to provide guidance to standard of materials writers to ensure the consistency with the proposed approach.

Saiful Islam, Sampson Huang, Matthew Skokan And Hui Wu (2004) [10] described the analysis performed to predict the seismic performance of two unique suspended floor slab buildings and the seismic retrofit schemes for each building. The two 14-story towers, located in regions of high seismicity, were designed and built in the early 1960's and 1970's and concluded that the gap between the suspended floors and the core walls was large enough to accommodate viscous damper elements, the application of the energy dissipation devices appeared to be the most effective and innovative method for mitigating the seismic hazard.

Chatpan Chintanapakdee, And Anil K. Chopra (2004) [11] compared the seismic demands for vertically irregular frames determined by MPA procedure and the rigorous nonlinear response history analysis (RHA), due to twenty ground motions ensembled of. 48-irregular frames, all of them were 12-story high with weak beams and strong columns, designed with three types of irregularity. And concluded that

1. Irregularity in strength, stiffness, or strength and stiffness provided the irregularity is in the mid-height story or top story.
2. The MPA procedure can be more biased, i.e. less accurate, relative to the "regular" frame in estimating the seismic demands of frames with strong or strong and stiff first story; weak, soft, or weak and soft lower half; strong ,stiff, or strong and stiff lower half. In contrast, the bias in the MPA procedure for frames with weak, soft or weak and soft first story is approximately same as for the regular frame.
3. In spite of the larger bias in estimating drift demands for some stories in Cases 6-8, the MPA procedure identifies the stories with largest drift demands and estimates them well, detecting the critical stories in such frames.
4. The MPA procedure provides usefully accurate seismic demands also for irregular frames, except for those with a strong first story or strong lower half. The seismic demands for such irregular frames should be determined by nonlinear RHA.

Hiroshi Kuramoto And Kazuyuki Matsumoto (2004) [12] discussed a mode-adaptive pushover (MAP) procedure, which uses a stiffness-dependent lateral force distribution at each loading step without the eigen value analysis, was proposed in the study. 4 and 12 story RC frame buildings and a 6 story RC building with the soft first story were analyzed using MAP procedure to estimate the responses by the Capacity Spectrum Method (CSM). Three kinds of MAP analyses with the lateral force distributions corresponding to the first to third modes of vibration are conducted for each building to consider the higher mode effect. Concluded that

1) MAP analysis for the first mode is effective to evaluate the story responses at the maximum displacement response of the equivalent single degree of freedom system for a building.
2) MAP analysis for the first mode cannot evaluate appropriately the maximum story responses of a building due to the lack of consideration of the higher mode effect.
3) A modal analysis using MAP procedure can be conducted with lateral forces applied for each story and the SRSS method.
4) Elastic analysis is more appropriate for the second and third modes, for evaluating the maximum responses of story than that with the MAP only. The modal analysis combined MAP for the first mode and this means that the higher mode effect in the responses may be elastic.

Xiao-Kang Zou And Chun-Man Chan (2004) [13] a 10 storey 2 bay frame was used for example and studied an effective computer based technique that subsume pushover analysis together with numerical optimization procedures to automate the pushover drift performance design of reinforced concrete buildings. to provide the required ductility of RC building frameworks Steel reinforcement appears to be the more cost-effective material which can be used to control the drift beyond the occurrence of first yielding.

Bruno Palazzo, Luigi Petti And Massimiliano De Iuliis (2004) [14] had discussed new reduction factors i.e. q-factors of elastic spectra demand for linear seismic design within the performance based seismic engineering philosophy. Such new q-factors take directly into account structural damage levels, viscous damping and ductility in the case of A, B and C linear seismic spectra defined in EC8 – ENV 1998-1-1 for rare events. Structural damage was considered through the use of the Park and Ang damage index. This three design problems were defined and discussed:

1. Direct Problem: To evaluate q-factors to design new structures equipped with extra-structural dissipation devices;
2. Inverse Problem: To design extra-structural dissipation devices for existing buildings;
3. Mixed Problem: To design extra-structural dissipation devices and strength for both new or existing buildings according to technological and economical constraints.

R. Bento, S. Falcao And F. Rodrigues (2004) [15] had discussed the three non-linear static procedures for the seismic assessment of a four storey reinforced concrete structure and the N2 method was chosen as the non-linear static procedure for the seismic assessment of the eight-storey building. Some conclusions were drawn regarding the structures and the results obtained:

1. The modal lateral loads (including only the mode 1 or the first three modes) show similar results, and for the structures studied the modal pattern (defined for the first mode) was very close to a triangular pattern;
2. The uniform load pattern seems to indicate conservative results regarding the base shear evaluation but they may be misleading in some cases. Concluding, and regarding the non-linear static analysis, one can say that:
3. More appropriate for low rise and high frequency structures, i.e. for structures that vibrate primarily in the fundamental mode;
4. It may expose design weaknesses that may remain hidden in an elastic analysis, like the excessive deformation demands and strength irregularities, weaknesses due to story mechanisms;
5. It is not able to represent accurately dynamic phenomena, without the use of more sophisticated lateral load patterns;
6. It is not possible to account for phenomena like stiffness and strength degradation, the duration of the seismic action and P-Δ effects;
7. It cannot detect some of the important deformation modes that may occur in a structure which is subjected to severe level earthquakes, and it may magnify others;
8. The Inelastic dynamic response could be differ significantly from predictions based on invariant or adaptive static load patterns, particularly if higher mode effects become important.

Tomaso Trombetti, Giada Gasparini And Stefano Silvestri (2004) [16] concluded that the determination of the probability density functions (PDF) of the peak ground acceleration (PGA) and peak ground velocity (PGV) due to the seismic activity was developed for the Italian territory according to an original procedure based upon Cornell's methodology. The procedure was characterized by the treatment of the distance R from the epicenter to the site as a Continuous random variable. This leads to the identification of the Cumulative Distributive Functions of both the PGA and PGV that can readily be used to create an effective Intensity measure to be used in the incremental dynamic analysis for procedures of performance based seismic design.

Prabuddha Dasgupta, Subhash C. Goel, Gustavo Parra-Montesinos And K. C. Tsai (2004) [17] briefly presented the energy-based approach developed at UM (University of Michigan) as well as a modal displacement based design procedure which was adopted by the research team at NCREE for calculating the design base shear for the frame. Results from inelastic response analyses of frames designed by the two methods for a Taiwan earthquake were compared. For a U.S. location also the same frame was designed and analyzed. For both U.S. and Taiwan ground motions the frames designed by the UM approach exhibited satisfactory dynamic responses.

M.J.N. Priestley, G.M. Calvi And M.J.Kowalsky (2007) [18] discussed that to assessment of designed structures a broad based probability approach is more appropriate than to the design of new structures and described major coordinated research project in the study which present an alternative approach to current force based design.

Virote Boonyapinyo,Norathape Choopool and Pennung Warnitchai (2008) [19] nine storey RC building was analyzed and TH (time history), MPA (modal pushover analysis) and pushover analysis were compared and concluded that:

1. The 9 storey RC building deforms into the inelastic range which leads to yielding of some beams at Bangkok site for a return period of five hundred year. However, the building will not collapse when subjected to this earthquake ground motions expected in Bangkok despite the fact that while designing the building there were no seismic loading consideration . Building's ductility can be estimated to be 1.65, 2.02 and 2.40 by Lee, Chopra and Fajfars methods respectively.
2. The pile foundations were relatively stiff and did not significant affect the building capacity and response.
3. The selection of an appropriate load shape for any nonlinear static procedure is the key issue in accurate prognosis of the structural responses.
4. Seismic demands of high-rise buildings can be remarkably improved by considering higher modes.
5. When compared to nonlinear dynamic analysis, MPA including three modes slightly overestimates the lower floors story drift and agree generally well for the story drift of the upper floors at Bangkok site for simulated ground motions.

Houssam Mohammad Agha, Li Yingmin , Oday Asal Salih and A'ssim Al-Jbori (2008) [20] ten-storey building was used for the study and concluded that variation of lateral load patterns in the height-wise distribution is not very significant for ten storey frame and none of the invariant lateral load patterns could capture the approximate dynamic behavior globally and at story levels

M.R. Willford and R.J. Smith (2008) [21] using performance based procedures for seismic and wind actions the structural design of two similar 60 storey towers in Manila was described and concluded that damping system can reduce wind load effects, permitting more economical structural design and reducing the risks associated with uncertain intrinsic damping.

A. Kadid and A. Boumrkik (2008) [22] using Algerian code, five, eight and twelve storey buildings were analyzed and studied and concluded that results obtained in terms of capacity, demand and plastic hinges which gives the real behavior of structures. And also found that building failed at Boumerdes was due to use of low quality construction material and strong column weak beam mechanism.

S.R. Satish Kumar and G Venkateswarlu (2008) [23] concluded that:

1. Revision of the design procedure is required due to the wide different performance of the frames which are designed and detailed according to the current codal provisions.
2. Considerable effect on the seismic performance due to the longitudinal reinforcement percentage so it must be considered in the performance based seismic design.
3. To achieve desired performance, the relationships obtained between response parameters namely ductility, drifts and damage indices with system parameters such as response reduction factor, time period and longitudinal reinforcement percentage, can be used.

M. Seifi, J. Noorzaei, M. S. Jaafar and E. Yazdan Panah (2008) [24] in this study nonlinear static pushover (NSP) analysis to nonlinear dynamic time-history analysis was compared and concluded that:

I. For estimating the capacity and deformation problems for certain types of structures pushover analysis is a good solution.
II. More investigation is required for steel structures, 3D structures and high rise frames.
III. NSP method is a well known method in the society of civil engineers but the conventional code based method has many deficiencies
IV. Several methods such as MPA (modal pushover analysis), APA, N2, MT, MMC etc. were proposed to overcome the deficiencies of the conventional method in recent decade.

Ioannis P. Giannopoulos (2009) [25] typical five storey non-ductile RC frame building was designed with past seismic regulations in Greece and analyzed using a nonlinear static (pushover) analysis. Few critical sections were selected and the rotational ductility supply at various limit states as predicted by FEMA 356 and Annex A of EC8 Part 3 was calculated and observed that for beams the EC8 limit states are increasing with roof displacement, while in columns they remain almost constant.

Pwint Thandar Kyaw Kyaw (2010) [26] studied pushover analysis (Static Non-linear Analysis). Seven types of case study were considered which were depending on construction practice and detailing. 3D frame buildings were modeled located in seismic zone 2A. As target displacement at each case study different percentages(%) of building height of displacement magnitude were used and concluded that displacement amplification factor Cd varied mostly with the changes in system ductility factor i.e. (the extent of yield displacement and maximum inelastic deformation).

Mansour Bagheri and Mahmoud Miri (2010) [27] future seismic design needs based on defined multiple performance objectives and earthquake hazard levels was discussed and benefits of performance based seismic design is that there is the possibility of achieving a predictable seismic performance of structure with a very uniform risk.

Gomase O.P, Bakre S.V (2011) [28] under real earthquake TH (time history) motion, seismic response of multistory building which was supported on base isolation, was studied and concluded that seismic effects can be reduced by seismic base isolation technique and therefore base shear, inter story drifts, and floor accelerations by lengthening the natural period of vibration of a structure via use of rubber isolation pads between the columns and the foundation.

P. Poluraju, and P. V. S. Nageswara Rao (2011) [29] the performance of reinforced concrete frames was investigated using the pushover analysis, concluded that the behavior of properly detailed reinforced concrete frame building is adequate as indicated by the intersection of the demand and capacity curves and the distribution of hinges in the columns and the beams. Hinges were mostly developed in the beams and few in the columns but with limited damage.

Dalal Sejal P , Vasanwala S. A. and Desai A. K. (2011) [30] observed that for various other different types of structures more research work is needed, especially for development of PBPD (Performance Based Plastic Design) method.

N. Choopool and V. Boonyapinyo (2011) [31] studied the effect on cost estimates and the investigation of seismic performance for nine-story reinforced concrete moment resisting frames with various ductilities by the nonlinear static analyses and nonlinear dynamic analysis under seismic loadings in Bangkok according to the newly proposed seismic specifications of Thailand (DPT 1302-52).

Mrugesh D. Shah, Atul N. Desai and Sumant B Patel (2011) [32] to cover the broader spectrum of high rise and low rise building construction G+4 and G+10 storey R.C.C. buildings were analyzed. Through nine model for G+4 storey and G+10 storey comparative study made for bare frame (without infill), having infill as membrane, replacing infill as a equivalent strut and concluded that G+4 and G+10 storeys in bare frame without infill having lesser lateral load capacity (Performance point value) compare to bare frame with infill as membrane and bare frame with infill having lesser lateral load capacity compare to bar frame with equivalent strut. Also conclude that as the no. of bays increases lateral load carrying capacity increases but with the increase in bays corresponding displacement is not increases.

P.Poluraju, T. Durgabhavani, K. Mounika, M.Nageswari, and K. Soni Priya (2012) [33] using SAP2000 studied the performance of the push over analysis on flat slabs and concluded that the resulting pushover curve for the G+2 building is initially linear but start to deviate from linearity as the columns undergo inelastic actions. Curve again became linear when the building was pushed well into the inelastic range, but with a smaller slope.

A. Kiran, G. Ghosh and Y. K.Gupta (2012) [34] Different, five types of ground motions compatible to the MCE and DBE response spectrums had been considered and studied the response of the asymmetrical and symmetrical building structures and the results from nonlinear static (Pushover)
analysis and nonlinear dynamic time history analysis methods have been compared and concluded that:

1. The results obtained from the pushover analysis were on the safe side, as compared with the time history results in most of the cases.
2. In case of symmetrical building, ELM method with modal pattern of loads is quite better or ELM is quite accurate, but DMM can also be used.
3. In case of asymmetrical building, DMM as well as ELM both gives good results for few cases, but pushover results are quite higher than the time history in most of the cases.

K. Rama Raju, A. Cinitha And Nagesh R. Iyer (2012) [35] studied the nonlinear static analysis (Pushover Analysis) for a typical 6-storey office building designed for 4-types of load cases, considered 3-revisions of the Indian codes that are IS:1893 and IS:456. In this study, stress–strain (nonlinear) curves for confined concrete and user defined hinge properties as per CEN Eurocode 8 were used and concluded that the model with user defined hinge was more successful in capturing the hinging mechanism.

Wen-Cheng Liao and Subhash C. Goel (2012) [36] studied the application of the performance based plastic design (PBPD) approach to seismic resistant reinforced concrete special moment frames. Four baseline reinforced concrete special moment frames (4, 8, 12 and 20-story) as used in the FEMA P695, selected for the study and concluded that the performance based plastic design method is a direct design method which uses previously selected targeted drift and the yield mechanism as a key performance objectives.

Dr. Suchita Hirde and Ms. Dhanshri Bhoite (2013) [37] studied the effect of modeling of infill walls on the performance of multi storey reinforced concrete frame building and concluded that lateral load resisting mechanism of the masonry infill frame is essentially different from the bare frame. The bare frame acts primarily as MRF (moment resisting frame) with the formation of plastic hinges at the joints under lateral loads.

Onur Merter and Taner Ucar (2013) [38] six and ten-story RC frame structures were studied and analyzed using linear and nonlinear dynamic analyses. Turkish seismic design code was used for primary design, performed by using seven ground motions recorded at different sites of soil at Turkey and concluded that inter story drift ratios obtained from nonlinear time history analyses are generally larger in upper stories.

Kavita Golghate, Vijay Baradiya And Amit Sharma (2013) [39] a four storey building in seismic zone IV was designed and constructed using IS-456:1978 and the revised code IS-1893:2000 provisions. Studied pushover analysis, carried out for default hinge and user defined hinge properties, which is available in some of the programs which are based on the guidelines of FEMA-356 and ATC-40. To conduct the non linear static analysis this study was aimed to evaluate the zone –IV selected RC building. Pushover analysis shows the plastic hinges, pushover curves, capacity spectrum, and performance level of the building and concluded that to explore the nonlinear behavior of the buildings, pushover analysis is a simple way. The results obtained in terms of demand of pushover, plastic hinges, capacity spectrum and the real behavior of structures. Hinges were developed in the beams and columns showing the three stages immediate occupancy, Life safety, Collapse prevention. The hinges in the column limited the damage.

Syed Ahamed And Dr. Jagdish.G.Kori (2013) [40] using ETABS 9.7 version G+3 and G+5 storey unsymmetrical building model was compared and summarizes the review in the performance based seismic analysis and concluded that base shear increases with the number of storey of building and increase in mass, also the base shear obtained from equivalent static analysis is much more lesser than base shear obtained from pushover analysis.

Ms. Nivedita N. Raut & Ms. Swati D.Ambadkar (2013) [41] under strong ground motions using nonlinear static pushover analysis effect of the layout of masonry infill panels was investigated over the elevation of masonry infilled RC frames on the seismic performance and potential seismic damage of the frame based on realistic and efficient computational models and compared base shear vs. displacement in bare frame, infill wall frame and ground. At roof level in bare frame it was seen that displacement was more than other two frames and at ground floor in weak story displacement was more than other two frames. Less hinges were formed in column than beam.

Mr. A. Vijay and Mr. K.Vijayakumar (2013) [42] for performance based design of steel building frame work study was focused on a computer based pushover analysis technique which was subjected to earthquake loading. 2D frames were modeled for solid and hollow sections, for various stories with constant bay width and storey height which was analyzed and concluded that;

1. When the no. of storey decreases corresponding base shear increases and also when the no. of stories increases corresponding displacement increases.
2. Drift to height ratio is limited to thirty five stories.
3. Comparing the results of solid and hollow sections base shear vs. displacement curve indicates that the hollow sections are far better than solid ones.

Sofyan. Y.Ahmed (2013) [43] analyzed a ten storey five bay reinforced concrete frame (2D beams and columns system) subjected to seismic hazard of the Mosul city Iraq. Plastic hinge was used to represent the failure mode in the beams and columns and concluded that most of the hinges were formed in beams.

CONCLUSION

Performance based seismic design is a very new and modern approach for seismic analysis and seismic engineering of structures, under different levels of earthquake motions in performance based seismic (PBSD) the aim of the design is to deliver a structure which is capable of meeting certain predictable performance objectives. Using nonlinear static analysis (pushover analysis) performance based design, which involves exhaustive and intricate computational effort, is a very iterative process to meet designer specified and code requirements. Structural system performance can be evaluated by non-linear static analysis. This method involves the comparison with the available capacities at desired performance levels, and the estimation of the structural strength and deformation demands. Performance based seismic design (PBSD) is based on a set of dedicated performance requirements. This approach is a mean to increase the client orientation and the professionalism of the design sector. A brief review of the available literature shows that important and precise advancements have been made in the past decades, there are so many fundamental issues still arrearage and even some of the basic ingredients of the approach are not tackled.

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