Performance Based Plastic Design Of RC Moment Resisting Frame

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***Abstract*— In today's era the objective of limiting excessive damage and to maintain functionality of the building after an earthquake is becoming more desirable. In order to forecast damage to a structure in an earthquake, performance based design method has been recently developed to achieve enhanced performance of earthquake resistant structures. It is based on the "STRONG COLUMN-WEAK BEAM" principle. The design concept uses pre-selected target drift and yield mechanism as performance criteria. The design base shear for selected hazard level is determined by equating the work needed to puss the structure monotonically up to target drift to the corresponding energy demand of an equivalent SDOF oscillator. Plastic design is performed to detail the frame members and connection in order to achieve intended yield mechanism and behavior.**

***Keywords*— performance-based plastic design, reinforced concrete moment frames, earthquake resistant design, seismic demand evaluation.**

I. INTRODUCTION

The seismic design of structure is continuously evolving. Conventional design procedures have the objective of achieving life safety in a structure by providing sufficient strength and ductility. Resist major earthquakes without collapse, but possibly with some structure and non structure damage. The unexpectedly high finance losses related to fictional downtime and non structural damage from recent large earthquakes near prime location highlight the limitations behind the modern ductile designs.
In today's ear the objective of limiting excessive damage and to maintain functionality of building after an earthquake is becoming more desirable. In order to forecast dame to a structure in an earthquake, performance based design method is a new method which is rapidly gaining popularity.

It is well known that structures designed by current codes undergo large inelastic deformation during major earthquakes. In the current India design practice, it is common to obtain design base shear from code specified spectral acceleration, with the assumption that structure to behave elastically. By the use of this force member size will be selected and then analyses sometime the structure experienced sever ground motion

II. PBPD MEHOD AND ITS ADVANTAGE

Performance based plastic design (PBPD) method has been recently developed to achieve enhanced performance of earthquake resistant structure. It is based on strong column and weak beam. Thus there are three main components of the PBPD method – determination of design base shear, lateral force distribution and plastic design.It should be noted that this design approach, the designer selected the target drifts consistene with acceptable ductility and damage, and a yield mechanism for desirable response and ease of post earthquake damage inspection and repairability. The design lateral force are determine for the given seismic hazard and selected target drift.

The method has been successfully applied to steel moment frame (Lee et al.), buckling restrained braced frame (BRBF) (Dasgupta et al.), Eccentrically braced frame (EBF) (Chao and Goel.), Special truss moment frame (STMF) (Chao and Goel.), and concentric braced frame (CBF) (Chao et al.).

The main advantage of PBPD mehod is that , it is tdirect design method without the need for iteration to achieve the desire targeted performance in terms of drift and yield mechanism control. Other advantage include the fact that innovative structure schemes can be developed by selecting suitable yielding members device and placing them at strategic location, while the the designed non yielding members can be detailed for no or minimum ductility capacity. All of these would translate into enhanced performance , safety and economy in life-cycle costs.

III..LITERATURE REVIEW

1. **W.C Liao and S.C Goel (2012)**, "Performance Based Plastic Design and Energy Based Evaluation and Seismic Resistant RC Moment Frame"

Performance-Based Plastic Design (PBPD) method, which accounts for inelastic structural behavior directly, and practically requires no or little iteration after initial design, has been developed by Goel *et al*. By using the concept of energy balance applied to a pre-selected yield mechanism with proper strength and ductility, structures designed by the PBPD

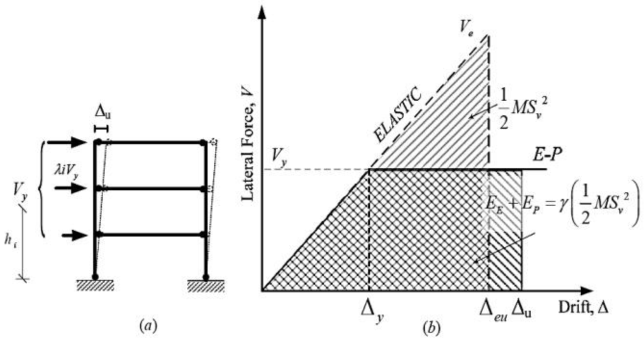

Fig. 1.the energy equating concept for deriving design base shear of PBPD method

method can achieve more predictable structural performance under strong earthquake ground motions. It is important to select a desirable yield mechanism and target drift as key performance limit states for given hazard levels right from the beginning of the design process. The distribution and degree of structural damage are greatly dependent on these two limit states. In addition, the design base shear for a given hazard level is derived corresponding to a target drift limit of the selected yield mechanism by using the input energy from the design pseudo-velocity spectrum: that is, by equating the work needed to push the structure monotonically up to the target drift (Fig. 1(a)) to the energy required by an equivalent elastic-plastic single-degree-of-freedom (EP-SDOF) system to achieve the same state (Fig. 1(b)). Furthermore, a better representative distribution of lateral design forces is also used in this study, which is based on inelastic dynamic response results. This lateral design force distribution accounts for higher mode effects and inelastic behavior better than the distribution prescribed by the current codes.

Mechanism based plastic analysis is used to determine the required of the designated yielding frame members, such as beams in RC SMF, to achieve the selected yield mechanism. Design of non-yielding members, such as columns, is then performed by considering the equilibrium of an entire "column
tree" in the ultimate limit state to ensure formation of the selected yield mechanism. It is also worth mentioning that the PBPD method has been successfully applied to steel moment frames, concentrically braced frames, buckling restrained braced frames, eccentrically braced frames and special truss moment frames. The theoretical background and detailed design procedures of the PBPD method can be found in several publications.

Determination of the design base shear for a given hazard level is a key element in the PBPD method. It is calculated by equating the work needed to push the structure monotonically up to the target drift to that required by an equivalent elastic-plastic single degree of freedom (EP-SDOF) system to achieve the same state. Assuming an idealized E-P force deformation

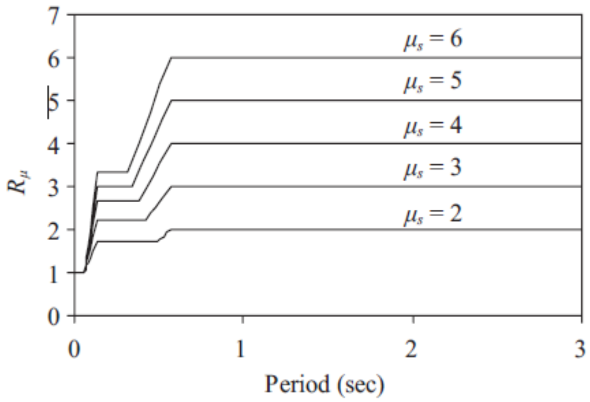

Fig.2 idealized in elastic spectra by newmark and hall for EP-SDOF.

behavior of the system (Fig. 1), the work-energy equation can be written as:

$$E_E + E_P = \Upsilon\left(\frac{1}{2} M\, S_v^{\,2}\right) = \frac{1}{2}\Upsilon M\left(\frac{T}{2\pi}\frac{S_a}{g}\, g\right)^2 \qquad (1)$$

where Ee and Ep are, respectively, the elastic and plastic components of the energy (work) needed to push the structure up to the target drift. Sv is the design pseudo-spectral velocity; Sa is the pseudo spectral acceleration; T is the natural period; and M is the total mass of the system.

The energy modification factor, γ, depends on the structural ductility factor (μ_S) and the ductility reduction factor (R_μ), and can be obtained by the following relationship:

$$\Upsilon = \frac{2\mu_S - 1}{R_\mu^{\,2}} \qquad (2)$$

Because of its simplicity, spectra proposed by Newmark and Hall [13] as shown in Fig. 2 were used to relate R_μ and μ_S, for EP-SDOF. Plots of energy modification factor γ as obtained from Eq. (4) are shown in Fig. 3.

The work-energy equation can be re-written in the following form:

$$\frac{V_b}{W} = \frac{-\alpha + \sqrt{\alpha^{\,2} + 4\,\gamma\left(\frac{S_a}{g}\right)^2}}{2}$$

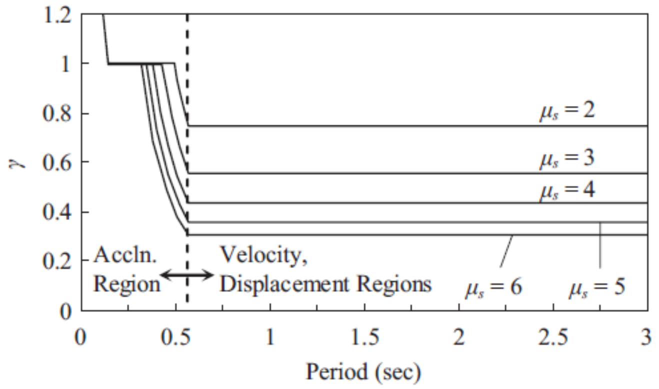

Fig.3 Energy modification factor versus period

where α is a dimensionless parameter given by ,

$$\alpha = (h^* \cdot \Theta p \; 8\pi^2/T^2 g)$$

And

$$h^* = \Sigma (\lambda\iota \; hi)$$

2. Goel S.C et al. (2009), "Performance Based Plastic Design Method For Earthquake Resistant Structure**:** An Overview"
This paper presents a brief overview of performance-based plastic design method as applied to the seismic design of building structures. The method uses pre-selected target drift and yield mechanisms as key performance criteria. The design base shear for a selected hazard level is calculated by equating the work needed to push the structure monotonically up to the target drift to that required by an equivalent single degree of freedom to achieve the same state. Plastic design is performed to detail the frame members and connections in order to achieve the targeted yield mechanism and behaviour. The method has been successfully applied to a variety of common steel framing systems and, more recently, to Reinforced Concrete (RC) moment frames. Results of extensive inelastic static and dynamic analyses showed that the frames developed desired strong column-sway mechanisms, and the storey drifts and ductility demands were well within the target values, thus meeting the desired performance objectives.

3. S.H.Chao et al (2007), "A Seismic Design Lateral Force Distribution Based On Inelastic State Of Structure"
Lateral force distributions given in the seismic design codes are typically based on results of elastic-response studies. It is concluded that code lateral force distributions do not represent the maximum force distributions that may be induced during nonlinear response, which may lead to inaccurate predictions of deformation and force demands, causing structures to behave in a rather unpredictable and undesirable manner. A new lateral force distribution based on study of inelastic behavior is developed by using relative distribution of maximum storey shears of the example structures subjected to a wide variety of earthquake ground motions. The results show that the suggested lateral force distribution, especially for the types of framed structures investigated in this study, is more rational and gives a much better prediction of inelastic seismic demands at global as well as at element levels. Higher mode effects are also well reflected in the suggested design lateral force distribution.

4. Leelataviwat et al (2008), "An Energy Based Method For Seismic Evaluation Of Structures"
This paper presents a seismic evaluation procedure based on an energy concept that has been recently developed and successfully used for design purposes called Performance-Based Plastic Design (PBPD). The method is applied to a number of example single-degree-of-freedom (SDOF) and multi-degree-of-freedom (MDOF) structural systems with excellent results. The results are compared with those obtained from nonlinear dynamic analyses as well as those from methods proposed by other investigators including the Modal Pushover Analysis Method and the FEMA Displacement Coefficient Method. For SDOF systems, the results indicate that the proposed method provides response values that are identical to those obtained from a well-established procedure using inelastic design spectrum. For MDOF systems also, the proposed method provides response values that are reliable when compared to the results from non-linear dynamic analysis and other well established nonlinear static procedures. The target displacement is determined based on the intersection of energy demand and capacity curves. The main feature of the proposed method is that the demand and capacity curves are produced in terms of energy.

5. Chao S. H. and S.C.Goel (2008), "Performance Based Plastic Design Of Special Truss Moment Frames"
The special truss moment frame (STMF) is a relatively new type of steel framing system suitable for high seismic areas. A direct performance-based plastic design (PBPD) approach, which requires no iterative evaluation or refi nement such as by nonlinear static (pushover) or dynamic analysis after the initial design, has been presented. Based on an energy (work) concept and plastic design method, the proposed approach gives the design base shear by using the elastic design spectral value for a given hazard level, a preselected global structural yield mechanism, and a preselected target drift. The design lateral force distribution employed in the proposed method is based on nonlinear response history analysis results using a number of ground motions. STMFs designed by the proposed PBPD method resulted in the formation of a yield mechanism as intended. Overall, STMFs designed by the proposed performance based plastic design (PBPD) method can be expected to satisfy the required performance objectives when subjected to a major earthquake. This is because the selected performance objectives in terms of the yield mechanism and maximum drift are explicitly built into the determination of design lateral forces and design of the frame members.

CONCLUSIONS

1. These lateral forces are distributed according to new distribution factor defined on the basis of real ground motion.
2.Value lateral force is higher compared to code specified lateral force distribution which gives conservative results and better performance.
3. Columns are designed for higher moments compared to beam which fulfill the “strong column-weak beam” principle.

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