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A REVIEW ON PERFORMANCE BASED PLASTIC DESIGN METHODOLOGY

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Abstract — *Structure designed by Limit State Method (LSM) by using seismic design philosophy as mentioned in IS: 1893 do not clearly consider the inelastic response of structure when subjected to Strong Ground motion. PBPD is one of the methods which explicitly incorporate the inelastic response of the structure. This Paper presents a review on Performance Based Plastic Design Methodology. In this method the performance objectives are defined in the design from the very start itself, here the performance criteria are expressed in terms of target drift and yield mechanism.*

Keywords- *Performance Based Plastic Design Method; Target drift; Yield mechanism; performance point.*

I. INTRODUCTION

This paper presents latest review on PBPD method, Performance based Plastic design method is a rapidly growing design methodology based on the probable performance of the building under different ground motions. The structures designed by current codes undergo large inelastic deformations during major earthquakes. IS 1893 does not explicitly incorporate the inelastic response of a structure in the design methodology, nonlinear behaviour is taken into account in rather indirect manner by using Response Reduction factor (R) and Importance factor (I) [1]. Hence not accounting for nonlinear behaviour in reasonable manner may lead to undesirable response of the structure resulting into total collapse of structure PBPD is one of the Direct Design method in which desired safety level could be obtained. Contrary to IS Code method, PBPD method uses pre-selected target drift and yield mechanism as performance criteria. PBPD method is useful as it prevents the total collapse of structure as it is based on pre-determined failure at beam and not at columns.

II. CONCEPT, PROCEDURE AND APPLICATION OF PBPD

PBPD method has energy balance concept at its core, the energy balance concept is very similar to that of Housner's concept which was used before many years. Here Base shear is calculated by Equating the work needed to push the structure monotonically up to the target drift to that of EP-SDOF system to reach the same state, which eliminates factors such as Response Reduction Factor (R) and Importance factor (I) which are uncertain. The Response reduction factors do not predict the exact inelastic response of the structure [3] because same value of "R" is assigned to all the systems falling under a defined category for available ductility Hence PBPD is more rational compared to current Force Based System.

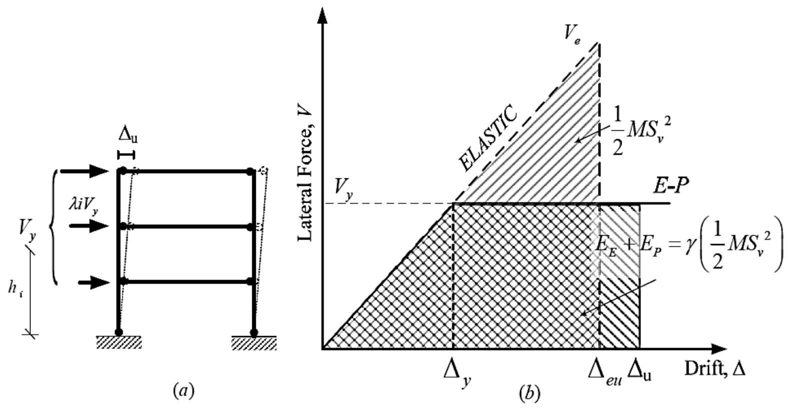

Fig. 1. PBPD Concept

Lateral Force distribution is based on inelastic state of structure by using shear distribution factor derived from the relative distribution of maximum Storey shear of a large number of steel moment subjected from earthquake [4]. further one of the parameter in shear distribution factor was modified based on more nonlinear dynamic analysis on eccentrically braced frame and special moment resisting frames [5].

Here, Beams are designed as Designated Yielding members and columns as Non-Designated Yielding members, so that yield mechanism is developed only at beams and not at columns ensuring Strong Column - Weak Beam principle beam moments are calculated with the help Work-Energy theorem (i.e. External Work = Internal Work) assuming beams have failed, similarly Column moments are calculated based on Column Tree using basic equilibrium equations (i.e. $\sum M=0$) assuming that beams have also failed. To ensure yield mechanism in beams, they are designed as Reduced Beam Sections at certain predetermined points for steel frames [9]

This method was successfully applied to variety of framing system (Steel Moment Resisting Frame [4], buckling restrained braced frame, Eccentrically Braced Frame [6], Special Truss Moment Frame [2], concentric braced frames [6] and composite buckling restrained braced frame) assuming ideal EP force-deformation Behavior and Full Hysteresis loop. But for the frames which do not possess such hysteretic property (RC Frames), a modification was introduced which represent the effects of pinched hysteresis shape, stiffness deterioration and strength deterioration on maximum displacement response. Thus, the target design drift for a given structural system with degrading hysteretic behavior can be divided by that factor that would give design target drift for an equivalent non-degrading system [7].

Target Drift is obtained by finding the performance point which is intersection of Capacity spectrum and demand spectrum [8]. The force displacement (capacity) curve of the structure is converted into energy capacity plot which is superimposed over the corresponding energy demand plot for the given hazard level to determine the expected peak response. The intersecting point of the energy demand and capacity curves determines the target displacement [4]. The structure could be pushed upto the desired safety level i.e. Intermediate occupancy (IO), Life safety (LS), Collapse prevention (CP), etc.

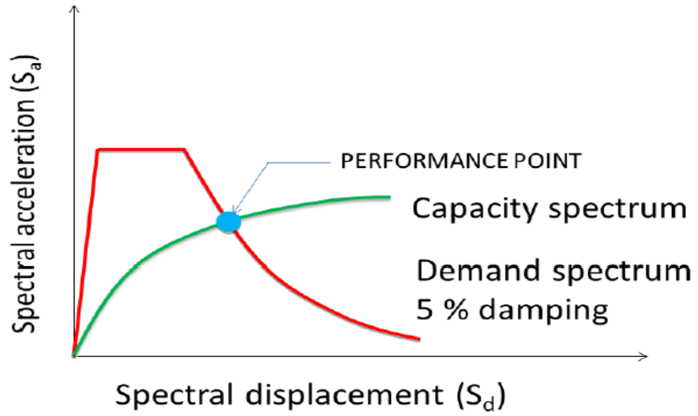

Fig. 2. Procurement of performance point

The detailed stepwise procedure for Performance Based Plastic Design has been mentioned below

Step-1: To estimate gravity loading and seismic loading for the structure (using IS-875 parts I to VI).

Step-2: To select a desired yield mechanism and target drift for the structure for design earthquake hazard.

Step-3: Calculation of shear distribution factor "β_i" of each floor.

In PBPD method lateral force distribution is based on maximum storey shears as observed in nonlinear time history analysis results [5] as follows

$$\beta_i = \left(\frac{V_i}{V_n}\right) = \left(\frac{\sum_{i=1}^{n} W_j h_j}{W_n h_n}\right)^{\alpha T^{-0.2}}$$

where
βi = Shear distribution factor at level i
W_j= seismic weight at level j
hj= height of level j from base
W_n= seismic weight at the top level
h_n= height of roof level from base
T= Natural Time Period

Step-4: Calculation of dimensionless parameter α

The value of α was proposed to be 0.5 but to encounter for more eccentric nonlinear analysis on eccentrically braced frames (EBFs) and special truss moment frames (STMFs) it was revised to be 0.75 by Chao and Goel [6].

Step-5: Calculation of Storey shear V

Base shear is calculated by Equating the work needed to push the structure monotonically up to the target drift to that of EP-SDOF system to reach the same state. For evaluating pinched hysteretic response of a structure energy modification factor needs to be considered [6].

$$V_b = W\frac{(-\alpha + \sqrt{\alpha^2+4\gamma Sa^2})}{2}$$

Step-6: Calculation of lateral force "F_n" of roof floor

$$F_n = \frac{V_b}{\sum(\beta_i - \beta_{i+1})}$$

Where

Fn =Lateral Force at roof level (n^{th} level)

Step-7: Calculation of the lateral force "F_i" of each level

$F_i = F_n\,(\beta_i - \beta_{i+1})$

Where

Fi =Lateral Force at i^{th} level

Step-8: Calculation of required Beam moment capacity and Beam Shear forces at each level

As beams are to be designed as designated yielding members, the required moment capacity at each floor is determined by plastic design approach with help of figure-3.

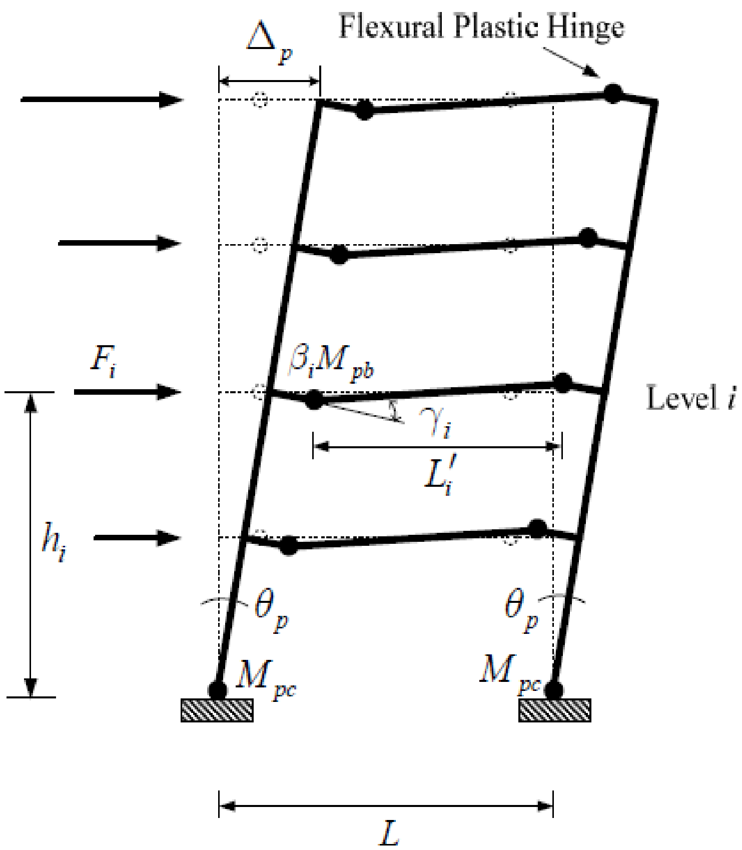

Fig. 3. Target yield mechanism of moment frame with beam plastic hinges away from column faces

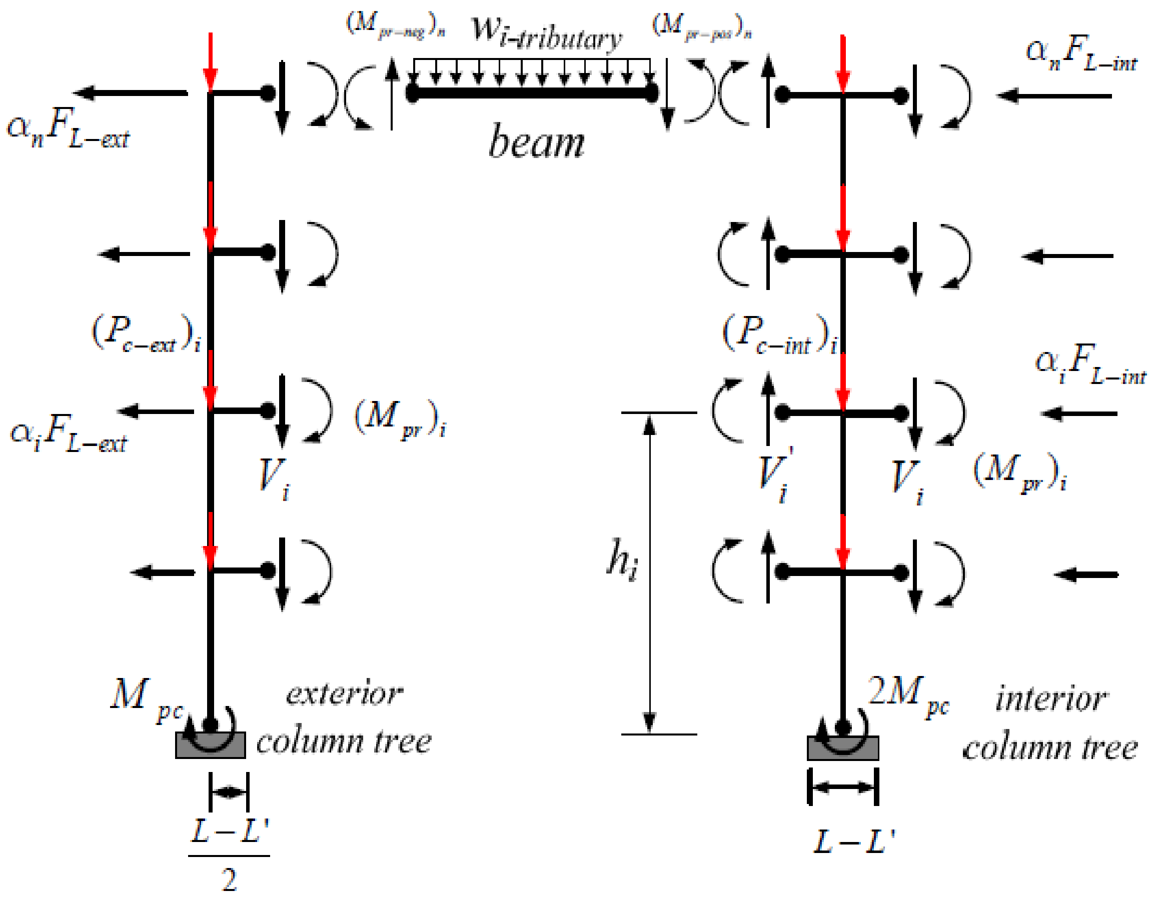

Fig.4. Free body diagrams of beam, exterior column tree and interior column

Step -9: Calculation of Column forces
Shear forces, Axial forces and moments for interior and exterior columns could be determined by free body diagram shown in figure -4. the "column tree" concept and PBPD force distribution, gives a very good estimation of maximum column moment demands when matched with severe ground motions.

III. SUMMARY AND DISCUSSION

The Highlights of PBPD method are summarized as below: -

1. Seismic hazards are met with greater confidence as the performance of the building is guaranteed to behave well considering inelastic behavior.
2. It eliminates the use of factors such as R and I over which debate exists and hence it is more rational method compared to current force-based method.
3. PBPD method is more advantageous for tall frames as cumbersome and lengthy iterative design work is totally eliminated.
4. As plastic hinges are formed only at beams and not at columns fulfilling Strong Column – Weak Beam principle, Total collapse of building is prevented.

PBPD provides an option for selecting different safety levels and level of property protection considering needs of a project. To implement the PBPD in conjunction with the Indian code, it is suggested that the design base shear and distribution of the lateral force can be done using the above stated method which is well established. It should be noted that Target drift and yield mechanism are defined at the start of design itself. Beams are designed as designated yielding members and could be placed at strategic location and so non-yielding members could be designed for no or minimum ductility. Hence, PBPD is used for enhancing performance, safety and economy of a structure.

REFERENCES

1. IS 1893:2000, "Criteria For Earthquake Resistant Design of Structures", Bureau Of Indian Standards, New Delhi, India.
2. S.C. Goel, W.C. Liao, M.R. Bayat, S.H. Chao, "Performance-based plastic design (PBPD) method for earthquake-resistant structures: an overview", The Structural Design of Tall and Special Building 19, 115–137 (2010).
3. Victor Gioncu and Federico Mazzolani., "Ductility of Seismic Resistant Steel Structures 2003"; CRC Press.
4. S.S. Lee, S.C. Goel, S.H. Chao, "Performance-based seismic design of steel moment frames using target drift and yield mechanism", 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, (2004), 266.
5. S. H. Chao, S. C. Goel, S. S. Lee," A seismic design lateral force distribution based on inelastic state of structures", Earthquake Spectra, Volume 23, No. 3, Earthquake Engineering Research Institute (2007) 547-569.
6. S. H. Chao, S. C. Goel, S. S. Lee, "Performance Based Design of eccentrically braced frames using Target Drift and Yield Mechanism", AISC Engineering Journal, Second quarter, (2006), 227.
7. W.C. Liao, S.C. Goel, "Performance-based plastic design and energy-based evaluation of seismic resistant RC moment frame", Journal of Marine Science and Technology, Vol. 20, No. 3, (2012), 304-310.
8. ATC 40, "Seismic evaluation and retrofit of concrete buildings", Applied Technology Council, California, Vol.1.
9. S.P. Dalal , S.V. Vasanwala, A.K. Desai, "Applying Performance based plastic design method to steel moment resisting frames in accordance with the Indian Standard code." International Journal of Engineering and Technology, Volume 2 No. 3, March 2012.
10. S.P. Dalal , S.V. Vasanwala, A.K. Desai, "Comparison of Elastic Design and performance Based Plastic Design Method based on the Inelastic Response Analysis using SAP 2000", International Journal of Computer Applications 2012; Vol 45(9): p 1-13.