American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-12, pp-54-61
www.ajer.org
Research Paper Open Access

Application Of Performance Based Seismic Design Method To Reinforced Concrete Moment Resistant Frame With Vertical Geometric Irregularity With Soft Storey

Rajkuwar Dubal[1], Gole Neha[2], Patil G. R[3], Sandip Vasanwala[4], Chetan Modhera[5]

[1](*Research Scholar , Applied Mechanics Dept, SVNIT Surat,Gujrat,India , Pin395007)*
[2](*P.G student,Civil engg Dept, RSCOE,Pune Maharashtra India Pin411033)*
[3](*Assistant Professor, Civil engg Dept RSCOE,Pune Maharashtra India, Pin411033)*
[4,5](*Professor, Applied Mechanics Dept, SVNIT Surat,Gujrat India , Pin395007),*

ABSTRACT : *A performance-based seismic design (PBSD) method is aimed at controlling the structural damage based on precise estimations of proper response parameters. PBSD method evaluates the performance of a building frame for any seismic hazard, the building may experience. Use of this method for vertical irregular buildings is verified with comparison of conventional method. Soft storey is subjected to failures due to stiffness and strength reduction. This paper deals with application of Performance based seismic design method for soft storey RC building frames(10 storeys) . Push over analysis results show significance of PBSD method in frames having soft story at lower floor level compared to higher ones.*

KEYWORDS : *RC building, , Performance based seismic design (PBSD), Response parameters, , and Push over analysis*

I. INTRODUCTION

Earthquakes have the potential for causing the greatest damages, among all the natural hazards. Since earthquake forces are random in nature & unpredictable, need of some sophisticated methods to analyze our structures for these forces. Performance based design can relate to a new dimension in the seismic design philosophy. We need to carefully understand and model the earthquake forces to study the actual behavior of structure so that structure faces a controlled damage. India has witnessed more than 690 earthquakes of Richter magnitude ('*M*') greater than 5 during 1828 to 2010. Damage survey reports show that life and property losses occur in urban and semi-urban areas. It is uneconomical to design a building so as not to suffer any damage during strong earthquake. An engineering approach aims for achieving balance in cost and performance through controlled damage. The goal of performance-based seismic design is to ensure that performance objectives are satisfied. A successful conceptual design could hopefully reduce the impact of uncertainties on the real structural behavior.

The poor performance level, and hence the high level of structural damage in the stock of building structures during the frequent earthquakes happened in India by the last decade, increased the need to the determination and evaluation of the damages in the building type of structures, so much more than ever before. The most destructive and unfortunately the most general irregularity in stock of building structures that lead to collapse is certainly the soft story irregularity. The commercial and parking areas with higher story heights reduce the stiffness of the lateral load resisting system at that story and progressive collapse becomes unavoidable in a severe earthquake for such buildings. This situation has been verified for all of the building structures with soft stories, independently from good quality of construction and design.

Current status of seismic design procedure and its weakness : Current seismic design practice around the world is carried by elastic method even though it is acknowledged that the buildings undergo large deformations in inelastic range when subjected to large earthquakes. As a result in seismic activity, there may be severe yielding and buckling of structural members and connections, can be unevenly and widely distributed in the structure designed by elastic methods. This may result in rather undesirable and unpredictable response, total collapse, or difficult and costly repair work at best.[1] There is need for more direct design methods that would fit in the framework of PBSD and produce structures that would perform as desired.

Major weaknesses of current seismic procedure:

- Increasing base shear to reduce damage is not reliable since past earthquakes have results of total collapse due to local column failure.
- Upper story failures in buildings are not justified by elastic method which assumes lateral force distribution which does not account for nonlinear behaviour of the structure.
- Earthquake changes stiffness of the members due to cracking of concrete and yielding of steel and proportioning of members according to elastic analysis leads to major failures.
- Materials like Reinforced Concrete have hysteretic (pinched) behaviour which is not accounted.
- Many studies have shown the column undergo yielding if it is designed as per capacity approach, inelastic behaviour of the column are not considered.

II. PERFORMANCE BASED SEISMIC DESIGN OF REINFORCED MOMENT RESISTANT FRAMES

Reinforced Concrete Building stock in India is mainly classified from low to medium rise buildings. Approach of I.S 1893,2002 is in tune with typical code practice followed by many other countries. In spite of knowing drawbacks of force based seismic design procedures, the practice is in vogue due to its simplicity and non-availability of the alternative. We can use guidelines given by FEMA and ATC documents by modifying them for Indian condition. An outline of the step-by-step Performance-Based Seismic Design (PBSD) procedure is given in the following.[1]

Design procedure

An outline of the step-by-step Performance-Based Seismic Design (PBSD) procedure is given in the following.

[1] Initially desired yield mechanism is selected.

[2] Fundamental period ‘*T*’ of the structure is estimated, along with yielding drift ‘θy’.[2]

[3] Determine inelastic spectral acceleration

[4] Calculate the ductility reduction factor and the structural ductility factor.

With the assumed yield drift ‘θy’ for different structural systems from tables in ASCE (2006)the energy modification factor, ‘γ’ , depends on the structural ductility factor (‘μ_s’) and the ductility reduction factor (‘ R_μ’) and can be obtained from the following relationship.:[3]

$$\gamma = \frac{2\mu_s - 1}{R_\mu^2} \tag{2.1}$$

To consider the hysteretic (degradation of strength and stiffness) behaviour, the coefficient ‘C_2’ (modification factor) is determined which represents the effect of pinched shape of hysteretic loops, stiffness degradation, and strength deterioration on the maximum displacement response according to FEMA 356. Ductility reduction factor ‘R_μ’ and energy modification factor ‘γ’ can be calculated as follows:

$$\theta u = \frac{\theta t}{C2} \qquad \mu_s = \frac{\theta u}{\theta y} \qquad \gamma = \frac{2\mu_s - 1}{R_\mu^2} \tag{2.2}$$

5. Determine actual lateral forces

Shear distribution factor for the respective story factor for the respective story is calculated by using following equation:

$$\frac{V_i}{V_n} = \beta_i = \left(\frac{\sum_{j=1}^{n} w_j h_j}{w_n h_n}\right)^{0.75T^{-0.2}} \tag{2.3}$$

V_i = shear force at i^{th} level ; β_i = Shear distribution factor at ith level

w_j = Seismic weight atlevel j; h_j = height of level j from the base

w_n = Seismic weight at top level ; h_n = height of roof level from the base

Then, the lateral force at level *i*, *Fi* , can be obtained as:

$$F_i = (\beta_i - \beta_{i+1}).V_n \qquad (2.4)$$

F_i = Lateral force at ith levl ;V_n = Story shear at roof level;V_y = Design base shear

Substituting the values of V_n we get following equation:

$$F_i = (\beta_i - \beta_{i+1})\left(\frac{w_n h_n}{\sum_{j=1}^{n} w_j h_j}\right)^{0.75T^{-0.2}}.V_y \qquad (2.5)$$

6. Design of designated yielding and Non-designated yielding members.

For Reinforced Concrete moment frames, beams are designed as Designated Yielding members because of strength contribution from slabs and non-rectangular beam shapes (ie, T shape beam), as well as the use of different amounts of top and bottom reinforcement, plastic moments in positive and negative direction of DYM may be different:

$$\sum_{i=1}^{n} F_i h_i \theta_p = 2.M_{pc}\theta_p + \sum_{i=1}^{n} \beta_i.(M_{pb-positive} + M_{pb-negative})\gamma_i$$

$$(2.6)$$

$$\sum_{i=1}^{n} F_i h_i \theta_p = 2.\sum_{i=1}^{n} F_i h_i \theta_p + \sum_{i=1}^{n}(1+x)\beta_i.(M_{pb-positive})\gamma_i$$

$$\beta_i(M_{pb-positive}) = \beta_i \frac{\sum_{i=1}^{n} F_i h_i - 2M_{pc}}{(1+x)\sum_{i=1}^{n} \beta_i \frac{L}{L'_i}} \qquad (2.7)$$

Where x is the ratio of the absolute value of negative Bending moment to positive Bending moment. Members that are not designated to yield (Non-DYM), such as columns in, must be designed to resist the combination of factored gravity loads and maximum expected strength of the DYM by accounting for reasonable strain-hardening and material over strength. The columns must be designed for maximum expected forces by including gravity loads on beams and columns and by considering a reasonable extent of strain-hardening and material over strength in the beam plastic hinges.

$$M_p = \xi M_{pb} = 1.25.M_{pb} \qquad (2.8)$$

III. STRUCTURAL MODELLING AND IT'S RESULTS

To study the effect of soft storey we have compared 10 storey frames which was modified into 10 different models by considering soft storey in each storey with conventional and Performance based Seismic design method, we have considered 10 storey models. The basic plan and elevation for all 10 models is kept same. Frames are considered of 12mx12m area. Height of building is32m.. Basic Dimensions for the frames and general design parameters were taken commonly as .Type of frame: Moment Resistant frame, Size of Column = 500 x 500mm, Size of Beam = 300 x 600 mm, Thickness of Slab = 120mm thick Wall thickness = 150mm, Floor Finish = 1 KN/m2 ,Live load at all floor levels = 2 KN/m2,Zone IV, Medium type of soil

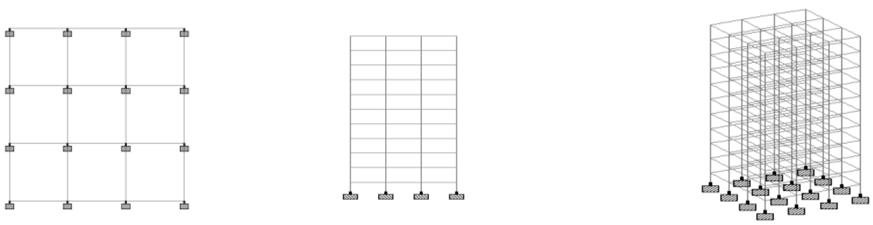


Fig 3.1 Plan and Elevation of 10 storied irregular frames with Soft Storey considered for study

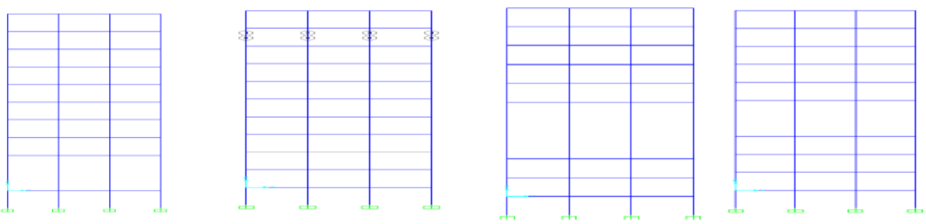


Fig 3.2 Soft Storey At First, Second, Third And Fourth Floor

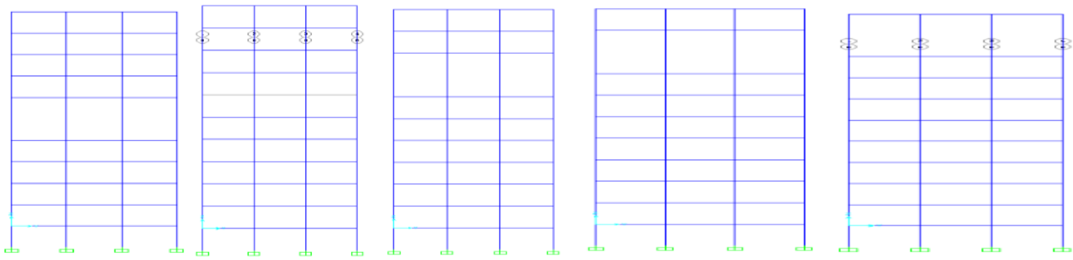


Fig 3.3 Soft Storey At Fifth, Sixth, Seventh, Eight and Nine Floor

Following Nine Soft Storey cases have been framed for analysis purpose.

Table 3.1 Soft story cases for analysis

Case I	Soft storey at first floor
Case II	Soft storey at second floor
Case III	Soft story at third floor
Case IV	Soft story at fourth floor
Case V	Soft story at fifth floor
Case VI	Soft story at sixth floor
Case VII	Soft story at seventh floor
Case VIII	Soft story at eighth floor
Case IX	Soft story at ninth floor

Table 3.2 Seismic parameters considered for design

Seismic zone factor '*Z*'	0.16
Importance factor, '*I*'	1
Sa Inelastic	0.1875 g
'*T*'	0.8s
Yield drift ratio 'θ_y'	0.5%
Target drift ratio 'θ_u'	2%
Inelastic drift ratio '$(\theta_u - \theta_y)$'	1.5%
Ductility factor	4
Reduction Factor due to Ductility '$R\mu$'	4
Energy Modification Factor 'γ'	0.43

Comparative evaluation of 10 story irregular frames (with soft storey in each storey) with respect to I.S 1893-2002 and PBSD method : Capacity spectrum curve is actual plot representing the performance point i.e. intersection point of spectral displacement and spectral acceleration. It is clear that in PBSD method performance point (intersection of demand and capacity curves) shifts due to extra confined steel which is normally incorporated in design. Hence provision for extra ductility is avoided since this care is already taken while designing.

IV. PERFORMANCE POINT COMPARISON FOR IRREGULAR FRAME WITH SOFT STOREY IN EACH STOREY

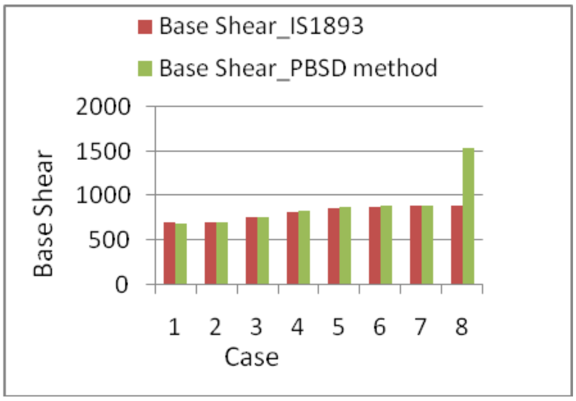


Fig 3.4 Performance point in I.S 1893-2002(force based) and PBSD method for all models with soft story (Base shear)

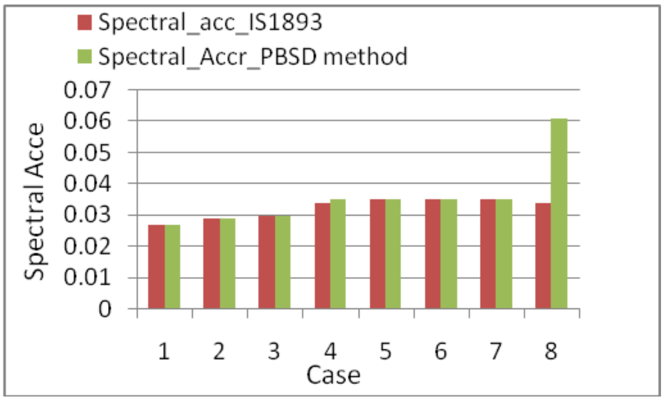


Fig 3.5 Performance point in I.S 1893-2002(force based) and PBSD method for all models with soft story (Spectral acceleration)

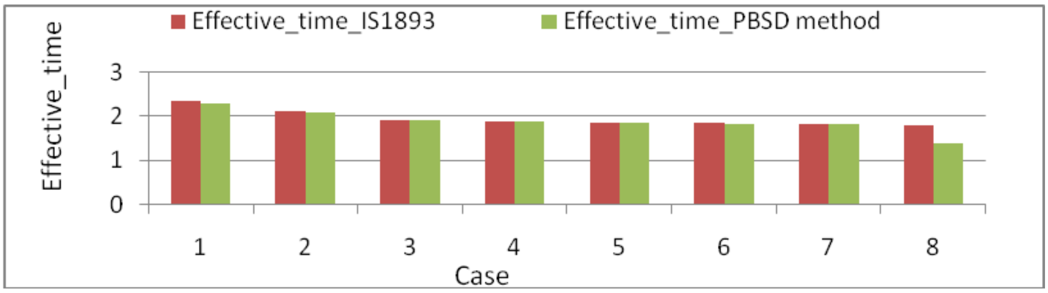


Fig 3.6 Performance point in I.S 1893-2002(force based) and PBSD method for all models with soft story (Effective time)

Some comments on push over curve nature are, in case of soft storey there is no significant achievement with respect to spectral acceleration and spectral displacement entities but with respect to displacement and effective time period performance point is enhanced.

Roof Drift Ratio : Deformed shape of any pushover curve is based on roof drift ratio. In our case normally roof drift in all soft story models designed by PBSD method are near about same or less compared to all models designed by conventional method. That means PBSD models have same deformable capacity like conventional models.

Table 3.3 Comparison Of Roof Drift Ratio W.r.t I.S. 1893 & PBSD

Case no.	Roof drift as per I.S 1893	Roof drift as per PBSD	Roof drift ratio
09	0.031	0.03	1.03
08	0.006	0.007	0.857
07	0.006	0.005	1.2
06	0.005	0.005	1
05	0.004	0.004	1
04	0.003	0.003	1
03	0.0031	0.002	0.155
02	0.002	0.002	1
01	0.058	0.066	0.878

Table 3.4 Comparison Of Base Shear w.r.t I.S. 1893 & PBSD

Case no.	Base Shear as per I.S 1893;2002	Base Shear as per PBSD
09	1083.38	2035.9325
08	1215.93	1215.93
07	1106.44	1486.10
06	840.678	1171.52
05	1255.93	986.44
04	1001.69	1093.22
03	1381.017	1290.847
02	1319.32	1309.83
01	645	840

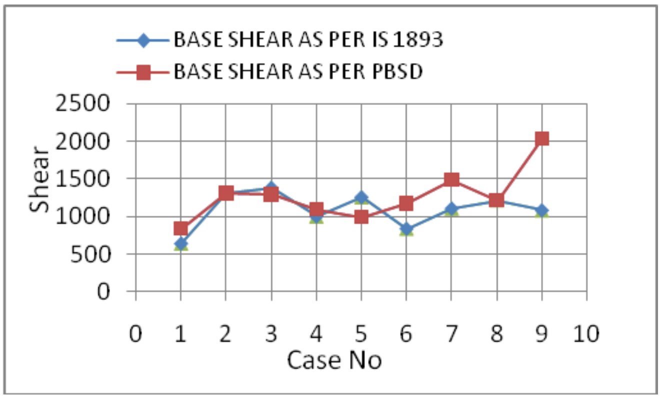


Fig 3.7 Comparison of Roof drift ratio w.r.t IS1893-2002 & PBSD method

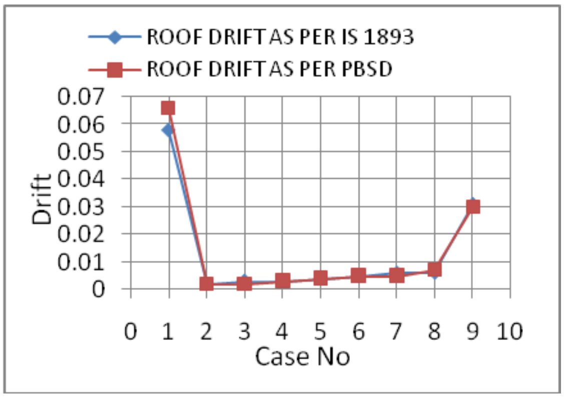
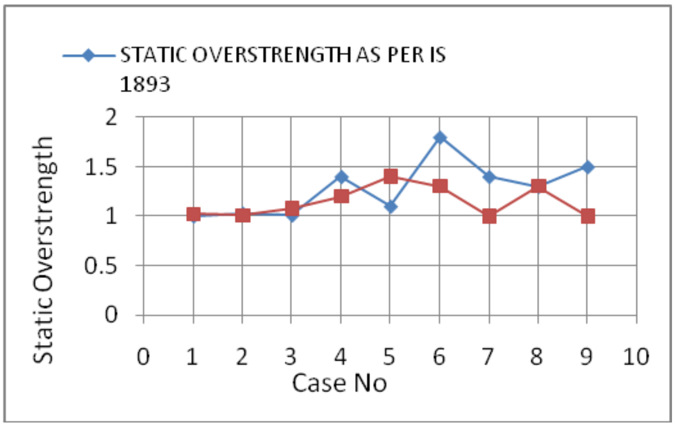


Fig 3.8 Comparison of Base Shear wrt IS1893-2002 & PBSD method

Static Over-strength Ratio : All pushover curves show that even though the design base shear for each baseline frame is smaller than that of corresponding PBSD frame, the ultimate strength of conventional frame .This is due to fact that the design of baseline frame was governed by drift which required major revision of member sizes after having been designed for strength. The iteration is not needed in PBSD method. The static over strength ratio of ultimate strength to design base shear for all frames is summarized in following table.

Table 3.5 Comparison of static over-strength ratio w.r.t is1893 & PBSD method

Case no.	**Static Over-strength as per I.S1893 ;2002**	**Static Over-strength as per PBSD**
09	1.5	1
08	1.3	1.3
07	1.4	1
06	1.8	1.3
05	1.1	1.4
04	1.4	1.2
03	1.01	1.08
02	1.03	1.01
01	1	1.02



V. DISCUSSION

- Performance point in PBSD and I.S 1893 2002 is near same for all 10 cases .For Soft story to ninth floor varies maximum with 72.08 % increment.
- Displacement in first model is 0.012m less than conventional model so this elates performance point.
- Spectral acceleration is greater only in 9th case is increased up to 50% (0.06) in PBSD method and (0.04) in conventional method.
- Hinges developed in both cases have individual significance; however numbers of hinges developed are same in both cases for all 10 models.
- Base shear in both methods does not show much difference except in last case .The difference is 600KN
- Storey drift for model with ninth floor soft storey is less 0.04mm and largest for storey for which value is 0.4mm for first floor.
- Roof drift ratio (PBSD: I.S method) for ninth storey is maximum i.e1and least for model having soft storey at third floor i.e. 0.857.
- Base shear in all models in both methods is gradual and does not vary much except in ninth model it varies by 1000 KN.

VI. CONCLUSION

Performance Based Seismic Design involves distribution of lateral forces according to new distribution factor which is defined on basis of real ground motion. Initial design process includes utilization of optimum sections which sustain the earthquake loads hence iterative trials are avoided and this method proves to be practical than current practice of designing earthquake resistant structures. Non Linear static analysis for frames gives comparison of performance of buildings even if they are irregular with respect to soft storey. Performance point of the frames (vertical irregularity of soft storey) designed by PBSD method is enhanced than for all frames designed by conventional method. Time period is one of the effective means to check the reliability of PBSD method. Time period for all vertical irregular frames with soft story is lowest than the frames designed by conventional method. These results will help design engineers in fast and reliable assessment of the effects of soft storeys.

REFERENCES

Journal Papers:

[1] Newmark, N.M. and Hall, W.J. Proceedings and Criteria for Earthquake Resistant Design. Building Practice for Disaster Mitigation, Building Science Series 46, National Bureau of Standards, Washington, D.C., 209-23646,

[2] Athanassiadou C.J, Seismic performance of R/C plane frames irregular in elevation. Engineering Structures,30 ,2008,1250–126..

[3] Mo Y.L., Chang Y.F. Application of base isolation concept to soft first storey buildings; Computers & Structures, Volume 55, Issue 5,1995,Pages 883-896.

[4] Vipul Prakash, Whither Performance-Based Engineering in India, ISET Journal of Earthquake Technology, 41(1),2004, pp. 201-222.

[5] Goel, S. C., Stojadinovic.B., and Leelataviwat SEnergy-based Seismic Design of Structures using Yield Mechanism and Target Drift, Journal of Structural Engineering 2009

[6] Gaurav Joshi, K.K. Pathak & Saleem Akhtar Seismic analysis of soft storey building considering structural & geometric parameterst", Journal on today's idas tomorrows technologies volume1,no2, dec2013, pp73-84

Books:

[7] Chopra .A.K. Dynamics of Structures, (Prentice Hall Pvt Ltd , 2006).

[8] Kappos A.J, Penelis G. G, Earthquake-resistant Concrete Structures. (London: E & FN SPON Chapman & Hall 1997).

[9] ASCE Standard Methodology for Seismic Evaluation of Buildings. Standard No. ASCE-31. American Society of Civil Engineers, Reston, Virginia. . 2006

[10] ATC), NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings, FEMA 274 Report, prepared by the Applied Technology Council, for the Building Seismic Safety Council, published by the Federal Emergency Management Agency, Washington, D.C.1997

Theses:

[11] Chopra A.K, Goel R.K; Chintanapakdee C). Evaluation of a modified MPA procedure assuming higher modes as elastic to estimate seismic demands. Earthquake Spectra,20(3), 2004,757-778.

Proceedings Papers:

[12] Liao W.C. and Goel S. C .Performance-Based Plastic Design (PBPD) of Reinforced Concrete Special Moment Frame Structures. The 3rd Congress of the International Federation for Structural Concrete (fib), Washington DC. 2010

[13] Goel, S. C., Liao, W. C., Mohammad R. B., and Leelataviwat S An Energy Spectrum Method for Seismic Evaluation of Structures. Conference on improving the seismic performance of existing buildings and other structures, ATC & SEI Conference, San Francisco, CA.2009