Application of Performance based Seismic Design Method to Column Discontinued RC Frames

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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 building is verified with comparison of conventional method. Vertical irregular frame is subjected to failures due to stiffness and strength reduction. This paper deals with application of performance based seismic design method for vertical irregular RC building frames(10 storied).Performance evaluation of conventional frames designed by conventional code method is compared with performance based seismic designed frames. The evaluation is carried out by Nonlinear Time History Analysis and Nonlinear Static analysis. The vertical irregular frames considered for study are with column discontinuity.

Keywords
Performance Based Seismic Design Method, Vertical Irregular frames, Performance Evaluation, Nonlinear Time History Analysis.

1. INTRODUCTION
It is very clear that major contribution to structural damage is discontinuities or irregularities in the load transfer path. This path is important to transfer of seismic force, which develops due to accelerations of individual elements to ground. Development of distress is result of vertical irregularity may lead to complete collapse of structure[1]. The examples of load path irregularities are discontinuous columns, shear walls, bracing etc. To study the effect of discontinuities we have considered 10 storey building frame with column discontinued in each storey which were modified into 10 different model cases. All the selected models were designed as per I.S 456;2000 considering lateral forces in accordance to I.S 1893;2002 and redesigned using Performance based Seismic design method [7].The method incorporates nonlinear behavior of concrete and accounts for actual lateral force distribution which enhances performance of building in given Seismic hazard. The study focuses on application of Performance based Seismic design method to 10 storied frames with floating columns. This may lead to guidelines for next generation Performance based codes [3].

Table 1: Column discontinued cases

Case/Model	**Type**
Case 1	Column discontinued in first floor
Case 2	Column discontinued in second floor
Case 3	Column discontinued in third floor
Case 4	Column discontinued in fourth floor

1.1Building model details
The basic plan and elevation for all 10 models is kept same. Frames are considered of 12m x 09m area. Height of building is 30m. Following table gives generalized details of frame considered for dimensions of the frame

Table 2: Design Parameters

Type of frame	Moment Resistant frame
Size of column	500x500mm
Size of beam	300x600mm
Thickness of Slab	125mm
Bay	4mx3m
Reinforcement	Fe500
Concrete Grade	M30
Load Type(D.L)	Self Weight
Load Type(L.L)	$2KN/m^2$
Floor finish	$1KN/m^2$
Earthquake Loads	I.S 1893-2002
Response Reduction Factor	5
Importance Factor	1
Damping	5%

2. ETABS OVERVIEW
Innovative and revolutionary software by Computers and Structures, ETABS (Extended Three Dimensional Analysis of Building Systems) is regarded as ultimate software package for structural analysis and design of buildings. A sample frame is shown in figure below with floating column at first floor.All model frames are designed as per I.S method and redesigned as per Performance Based Seismic Design method.Following parameters are considered for design. The procedure for Performance based Seismic Design is considered from ASCE 7(2005).The steps describes the PBSD procedure implemented for the frames [7]

1) Selection of Target Yield Mechanism
2) Determination of Fundamental Time period
3) Calculate Design Base Shear
4) Design Lateral Forces
5) Design of Designated Yielding Members(DYM)
6) Design of Non Designated Yielding Members(Non DYM)

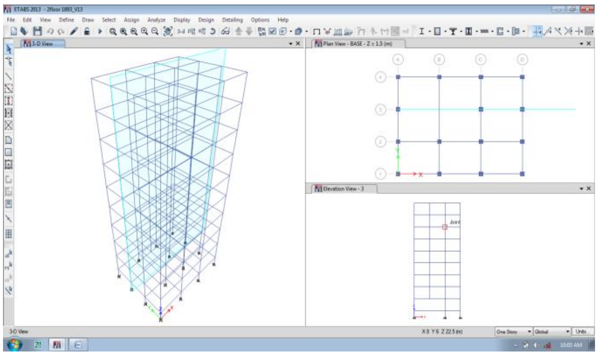

Fig.1. Plan and Elevation of 10 storied irregular frames considered for study

Table 3: Performance based seismic design parameters considered for study

Seismic zone factor Z	0.24
Soil Profile Type	Type 2 Medium
Importance factor, I	1
Sa Inelastic	0.1875 g
T	0.8s
Yield drift ratio θy	0.5%
Target drift ratio θu	2%
Inelastic drift ratio (θu - θy)	1.5%
Ductility factor	4
Energy Modification Factor	0.43

The frames are designed considering inelastic spectra prescribed by ASCE 7, 2005 and using shear distribution factor and energy modification factor[6].This also includes designing the frame with modified base shear and consideration of stiffness degradation of concrete. Performance evaluation is done using nonlinear static analysis, Response Spectrum and Nonlinear Time History analysis.

2.1 Performance Evaluation using Non-Linear Response Spectrum Analysis

In order to get still clear picture of the performance enhancement Non linear Dynamic Analysis is proposed for verification of result [2]. Response Spectrum method estimates the forces in the members of a building corresponding to each natural periods and mode shapes. It requires free vibration analysis to determine natural periods and mode shapes. Peak spectral acceleration of building corresponding to each natural mode is computed using same design spectrum. Peak responses of individual modes are then combined using a suitable modal combination rule to estimate the total peak response of the building. Number of modes to be considered must be such that sum total of modal masses is at-least 90%of total seismic mass of the building. Following are the results for Response Spectrum Analysis for Story Drift, Diaphragm displacement and Base shear

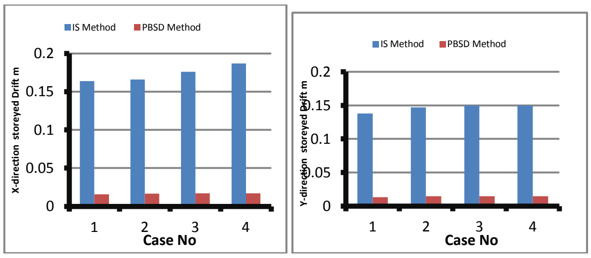

Fig.2. Comparison of Storey Drift in X,Y direction I.S 1893-2002 (force based method) method and PBSD

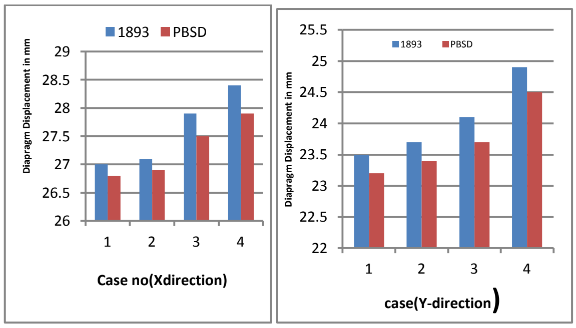

Fig 3 Comparison of Diaphragm Displacement in X and Y direction I.S 1893-2002(force based method) method and PBSD

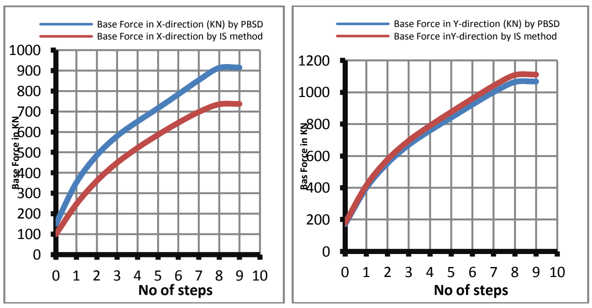

Fig4 Comparison of Base shear in X and Y direction I.S 1893-2002(force based method) method and PBSD

2.2 Comments on results from Response Spectrum Analysis

In case of Response Spectrum Analysis, Base force for PBSD method in all 5 models is more than IS method .The major difference is seen in first floor model having a difference of 100kN in Xdirection and 150 kN in Y direction. Inversely the displacement is reduced in PBSD models to a range of 0.025m in both directions. Displacement in both directions of PBSD models is 5mm less than IS models, which interprets the enhanced performance of the building frame. Storey Drift which is major concern is directly reduced to 0.02m in all 5 models for PBSD in both directions.Diaphragm displacement in all models is considerably low in PBSD method compared to IS models in both directions. Roof drift reduction in all models is also considerable i.e 10mm in all models. As static over strength ratio is governed by member sizes it is less in PBSD method than IS method .For the columns which are discontinued on the floors above sixth floor level ,there is no proper significant difference achieved in design done by I.S 1893-2002 method and Performance based Seismic Design method. Hence models having column discontinuity up till fifth floor level are considered for detail study.

2.3 Performance Evaluation using Non-Linear Time History analysis

Non-Linear Time History analysis for Bhuj Time history is shown to compare with Response Spectrum Analysis. The results are shown in following figures. The story drift and Diaphragm displacement are given[8].

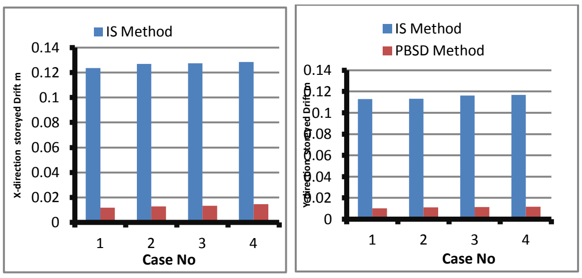

Fig5 Comparison of Story Drift in X and Y direction I.S 1893-2002(force based method) method and PBSD

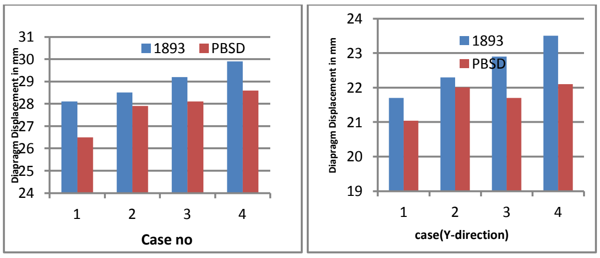

Fig6 Comparison of Diaphragm Displacement in X and Y direction I.S 1893-2002(force based method) method and PBSD

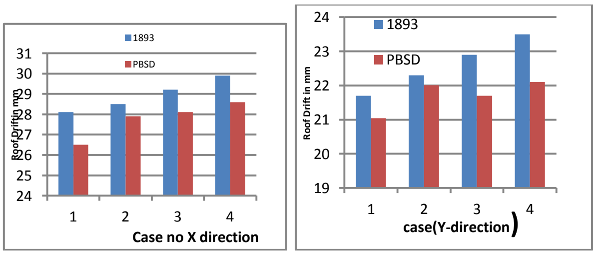

Fig7 Comparison of Roof Drift in X and Y direction I.S 1893-2002(force based method) method and PBSD

2.4 Comments on results from Non-Linear Time History Analysis

In case of Time History Analysis also Base force for PBSD method in all 5 models is more than IS method .This depicts actual force and its effects on performance after the design[1].The major difference is seen in first floor model having a difference of 109kN in X direction and 155 kN in Y direction. Inversely the displacement is reduced in PBSD models to a range of 0.05m in both directions. Displacement in both directions of PBSD models is 5mm less than IS models, which interprets the enhanced performance of the building frame. The performance level of the frame is represented with respect to Storey Drift. Storey Drift which is major concern is directly reduced to 0.02m in all 5 models for PBSD and 0.12m in I.S method in both X and Y directions. Diaphragm displacement in all models is considerably low in PBSD method compared to IS models in both directions. Diaphragm displacement is reduced by 2mm for all models in PBSD models than I.S models in both directions. Roof drift reduction in all models is also considerable i.e 10mm in all models in both directions.

2.5 Comparison of Response Spectrum and Non-Linear Time history Analysis

Comparative analysis is done in order to whether the values of both the methods are having any co relevance or not .It is seen that through both the analysis we get same trend which is shown in following figures. Overall values in both the methods have difference of about 2mm respectively Diaphragm displacement in I.S models have values from 21mm to 22mm for Time History Analysis and 23mm to 25mm for Response Spectrum Analysis in Y direction Roof values from 21mm to 22mm for Time History Analysis and 23mm to 25mm for Response Spectrum Analysis in X and Y direction are seen. Inversely the displacement is reduced in PBSD models to a range of 0.025m in both directions. Displacement in both directions of PBSD models is 5mm less than IS models, which interprets the enhanced performance of the building frame. Storey Drift which is major concern is directly reduced to 0.02m in all 5 models for PBSD in both directions. This gives empowerment to use PBSD method for RC frames with stiffness irregularity[9]. The reduced stiffness makes the other components of frame subjected to additional forces which are not included in force based seismic design practiced normally up till now. This weakness is eliminated in PBSD method [5]

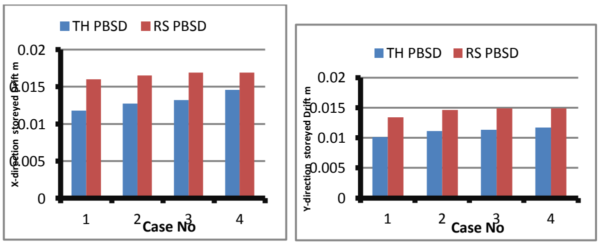

Fig8 Comparison of Storey drift in X and Y direction in Response Spectrum and NLTH analysis.

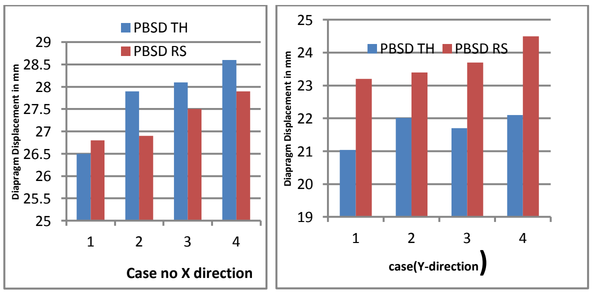

Fig 9 Comparison of Diaphragm displacement in X and Y direction in Response Spectrum and NLTH analysis

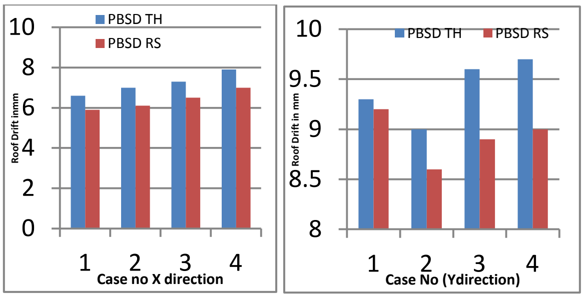

Fig 10 Comparison of Roof drift in X and Y direction Response Spectrum and NLTH analysis

The graphs represented in above mentioned section are shown to clearly indicate the difference in the outcomes for PBSD models and I.S models. Enhancing performance for seismic loads is prime concern for structural designers which faces the challenges of ever-changing earthquake scenario. One more parameter is considered for member sizes as the constraints must be considered thoroughly. As static over strength ratio is governed by member sizes it is less in PBSD method than IS method[4].As member size ratio is less in PBSD than member sizes in I.S method the over strength ratio is plotted in graph below.

Assessment of frames also includes acceleration responses, displacement responses and hinge results which also address the performance of both methods. Since the major concerns are story drift, base shear and roof drift the plots are shown with this context [10].

Table 3: Static Over strength Ratio

Case no.	Static Over Strength as per I.S 1893;2002	Static Over Strength as per PBSD
05	0.512	0.28
04	0.9	0.28
03	0.32	0.0095
02	0.932	0.36
01	0.5	0.147

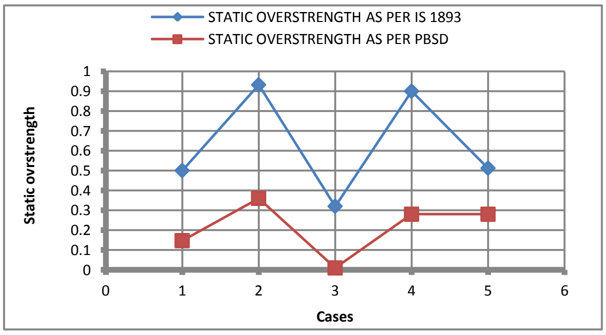

Fig 10 Comparison of static over strength in X and Y direction I.S 1893-2002 (force based method) and PBSD method for model with floating columns

3. CONCLUSION

Performance Based Seismic Design method implements proper distribution of lateral forces which is dependent on nonlinear behavior and stiffness degradation of material which is not addressed by any conventional method practiced up till now. Performance Based Seismic Design when used to column discontinued frames or floating column frames give better performances as that of frames designed as pr I.S method.

4. REFERENCES

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