PERFORMANCE BASED SEISMIC EVALUATION OF MEDIUM RISE 3D BARE FRAME

Anurag D Patil
Student, MGM's College of engineering Nanded.
Dr Mohd Zameeruddin
Asst Prof, MGM's College of engineering Nanded.

ABSTRACT- PSBD has used non-linear static procedure to overcome the limitations of traditional forced based design methods. Performance based seismic engineering involves defining specific performance objectives followed by design and later evaluating the performance of structure to meet the prescribed objectives as a single or multiple level. In performance based seismic evaluation nonlinear static procedure (pushover) force controlled or deformation control is used. In pushover the structure is subjected to lateral loads generated due to seismic forced up to a targeted displacement the response properties base shear and storey displacement defines the capacities. The collapse mechanism obtained for the structure is used to define varies the state of damage state of structural and non-structural components. Thus performance level of structure is termed as immediate occupancy, life safety, collapse prevention and collapse.

This study aims to understand these performance evaluation procedure applied on the example moment resisting frames (MRF).The example MRF represents a medium rise structure located at zone 3 on type 2 of soil designed in accordance to IS 456; IS 13920 and IS 1893 guide lines. Two different configuration of RC columns were used to see the effect on structural response parameter such as modal time period, mode shapes, storey displacement, inter storey displacement , stiffness, Base shear. The Nonlinear characteristics of RC member are developed by arranging non-linear plastic hinges at both ends of beams and columns, the study focused on response of structure for these lateral load patterns viz; IS 1893;2002 lateral loads, elastic first mode and uniform load pattern. The collapse mechanism observe from the push over were used to obtained various response parameters of various building of performance levels.

In addition to this study, we have proposed damage index utilizing the change of stiffness at various performance level. The study ends with strong analytical conclusion which will help a designer for optimizing configuration of a proposed or old RC frame structure.

Keywords **PSBD,PSBE,MRF, pushover, IS 456; IS 13920 and IS 1893.**

1 INTRODUCTION

Earthquake is also known as quake, tremor or temblor, is trembling of the earth's surface resulting in abrupt release of energy in earth's lithosphere which creates seismic waves. Elastic strain energy is stored in rocks during the deformations that happen due to the gigantic tectonic plate actions in the Earth. when the rocks along a weak region in the Earth's Crust reach their strength, a sudden movement takes place there, opposite sides of the fault Suddenly slip and release the large elastic strain energy which is as high as energy released after atomic blast.It is not possible to control these actions nor these can be predicted.Based on geological investigation and historical records we can only guess where the big earthquakes are likely to happen in next 100 years. That is why earthquake resistant design plays significant role.

Seismic Design with Codes:

Ground vibrations during earthquakes cause forces and deformations in structures. Structure need to be designed to withstand such forces and deformation. Seismic codes help to improve the behavior of structures so that they may withstand the earthquake effects without significant loss of life and property. Countries around the world have procedures outlined in seismic codes to help design engineers in the planning, designing, detailing and constructing of structures and mostly all these codes are based on Forced based designs(FBD).

Load Combinations:(IS1983 Part 1) • **RCC and PSC Structures**

– 1.5(DL + LL)
– 1.2(DL + LL ±EL)
– 1.5(DL ±EL)
– 0.9(DL ±1.5EL)

•Combination for 3 component motion

– ± ELx ±0.3ELy± 0.3Elz
– ± Ely ± 0.3ELz ± 0.3Elx
– ± ELz ± 0.3ELx ±0.3Ely

Displacement based Design

To overcome the flaws in the force-based design, an alternative design philosophy named "displacement based design" which uses structural displacement as a main determinant matrix of structural and non-structural damage during earthquake has been put forth (Moehle,1992).The fundamental assumption in displacement based seismic design is for inelastic system, the strength is less important than displacement.

Performance Based Seismic Building design(PBSD)

PBSD is an approach to the design of any complexity of building, from single-detached homes up to and including high-rise apartments and office buildings. A building constructed in this way is required to meet certain measurable or predictable performance requirements, such as energy efficiency or seismic load, without a specific prescribed method by which to attain those requirements. This is in contrast to traditional prescribed building codes, which mandate specific construction practices, such as stud size and distance between studs in wooden frame construction.Such an approach provides the freedom to develop tools and methods to evaluate the entire life cycle of the building process, from the business dealings, to procurement, through construction and the evaluation of results (FEMA 445,aug 2006).

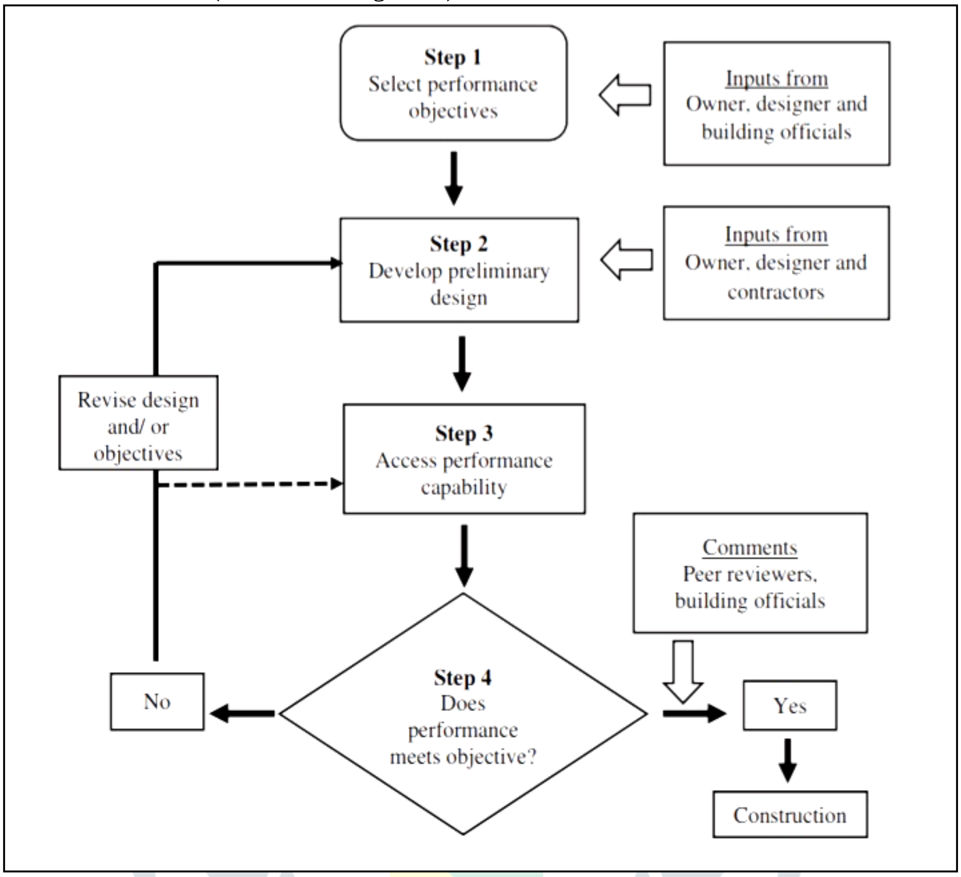


Fig. 1 PBSD flow diagram((Zameeruddin and Sangale 2016)

Important Terms in the Performance Based Seismic Design

Immediate Occupancy:

The earthquake damage state in which only very limited structural damage has occurred. The basic vertical and lateral forces resisting systems of the building retain nearly all of their pre- earthquake characteristics and capacities. The risk of life threatening injury from structural failure is negligible. Permanent drifts not allowed. Strength and stiffness has less reduction factor. Non-structural component has more damages and other utility of the building in working condition.

Life safety:

This level is intended to achieve a damage state that presents an extremely low probability of threat to life safety, either from structural damage or from falling or tipping of non-structural component. The post-earthquake damage state in which significant damage to the structure may have occurred but in which some margin against either total or partial collapse remains.

Collapse Prevention:

This damage state addresses only the main structure frame or vertical load carrying system and requires only stability under vertical loads.

Collapse

The structure is not able to provide any life safety and It is not in state which can be utilized for any type of service.

Damage Indices

The damage states, with clear definition of the damage and failure mechanisms, allow users to evaluate post-earthquake status of buildings and also provide categorization of the damage for further use, such as for assessing seismic intensity. The quantification of damage to reinforced concrete buildings due to earthquakes has utmost importance. Seismic damage indices are widely used to predict possible damage. The stiffness damage index is calculated as

$$DI_K = 1 - \frac{K\ final}{K\ initial} \quad \text{.............} \quad \text{(Zameeruddin and Sangale 2016).}$$

Where $K\ initial$ represents the initial slope of base shear-top deflection relationship resulting from pushover anlysis of frame before subjecting it to the earthquake ground motion and $K\ final$isinitial slope of the same relationship but after subjecting to earthquake.(Zameeruddin and Sangale 2016).

2 SYSTEM DEVELOPMENT

Modelling of buildings involves the modelling and assemblage of its various load-carrying elements. The model must ideally represent the mass distribution, strength, stiffness and deformability. Modelling of the material properties and structural elements used in the Present study is discussed below.

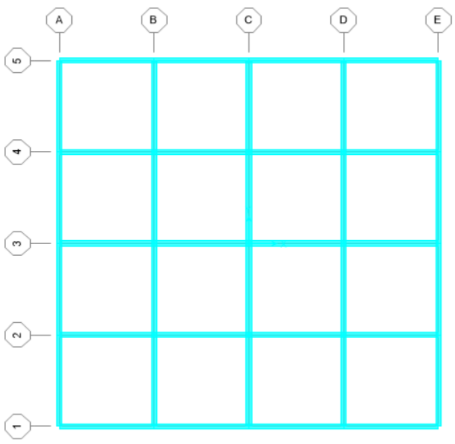
Structural Elements

For the present study, structures of (G+6) stories with different orientation of columns are chosen. These structures are designed according to Indian Standards. The details of structure are shown below.

To perform analysis of structure, the next step after modeling is applying loads. Design response spectrum should be available in order to perform pushover analysis. A 5% damped response spectrum for accelerations is used.

Building Geometry

The structural analysis program, SAP 2000 Version (16.0.0) was used to performance analyses. Regular medium rise building frame of (G+6) storey is selected for presented study.



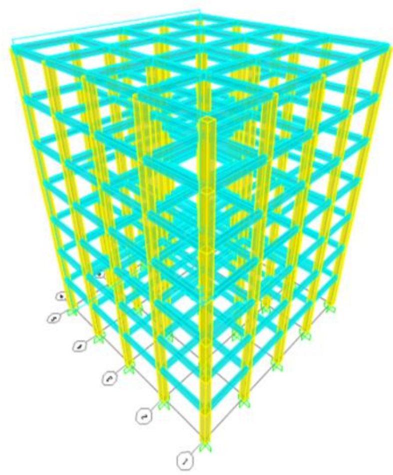


Fig 2-Frame Geometry

Data used for Frames with different Shapes of column (Square and rectangular shape)

The scope of this study is limited to the change in the orientation of the columns. Two different shapes which are taken are as follows:

i. Rectangular Shape
ii. Square shape

Table 1- Frame configuration

No. of storey	Seven storey		**b) Steel**	
Plan dimension	16.0m×16.0m		i) Yield strength of Fe 500 grade	4150 MPa
No. of bays in X-dir	4		ii) Modulus of elasticity (E_s)	2×10^5 MPa
No. of bays in Y-dir	4		i) Size of RC beam	0.23 m × 0.45m
Length of each bay in X-dir	4.0 m		ii) Size of RC column frame I	0.45 m × 0.45m
Length of each bay in Y-dir	4.0 m		iii) Size of RC column frame II	0.3 m ×0.5m
Total height of building	21.0 m		iv)Thickness of external and internal wall	0.23m
Typical storey height	3.0 m		**a) Dead load**	
Bottom storey height	3.0 m		i) Floor Finishes	1.5 kN/m^2
a) Concrete			**b) Live load intensities**	
i) Characteristic compressive strength (f_{ck})	25 MPa		Seismic zone factor	0.24
ii) Density	25 kN/m^3		Seismic Zone	III
iii) Modulus of elasticity (E_c)	5000 x $\sqrt{25}$ = 25000 MPa		Importance factor	1.2
iv) Poisson's ratio	0.2		Medium soil, Soil type	II

3 PERFORMANCE ANALYSIS

Capacity Spectrum (ATC 40) Results from SAP 2000 by PUSHOVER Analysis

The following table shows results obtained from SAP 2000 by Capacity spectrum method (ATC 40) for Push 1 analysis. Performance point, Displacement, Spectral acceleration, spectral displacement, and Time period are obtained directly from the software.

Table 2 Results from Capacity Spectrum(ATC-40)

	SQUARE COLUMN 450*450			RECTANGULAR COLUMN 300*500		
	PUSH 1	PUSH 2	PUSH 3	PUSH 1	PUSH 2	PUSH 3
VP	903.796	1248.721	1259.72	1507.288	2333.547	2333.547
DP	0.167	0.121	0.236	0.149	0.109	0.109
Sa	0.111	0.137	0.069	0.129	0.18	0.18
Sd	0.123	0.097	0.181	0.107	0.084	0.084
Time period	Teff=2.11	Teff=1.692	Teff=3.255	Teff=1.828	Teff=1.365	Teff=1.365
	Beff=0.264	Beff=0.272	Beff=0.336	Beff=0.263	Beff=0.235	Beff=0.235

Corelative study of all the parameters on the basis of performance levels

The following results for important parameters are obtained after push 1and Push 2 load cases to both the frames and their results are compared on the basis of performance points. Similarly results are obtained and compared for Push 3 load case.

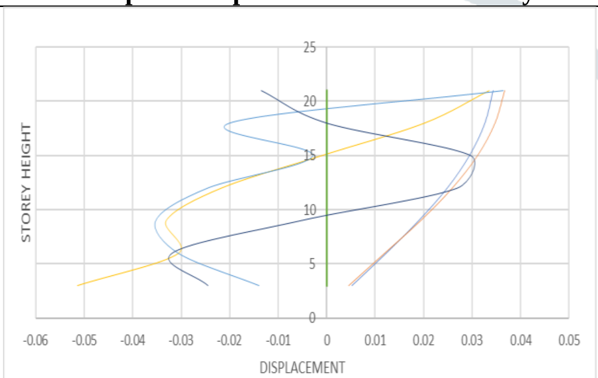
Table 3Corelative study of parameters on the basis of performance levels for Push1

SQUARE COLUMN					RECTANGULAR COLUMN				
	Disp	**Stiffness**	**% drifts**	**Di**		**Disp**	**Stiffness**	**% drifts**	**Di**
IO	0.013	28140.7	0.06640	0.174	**IO**	0.013	28140.7	0.06640	0.174
LS	0.170	5292.82	0.8125	0.82103	**LS**	0.170	5292.82	0.8125	0.82103
CP	0.375	2289.5	1.7887	0.92056	**CP**	0.375	2289.5	1.7887	0.92056
C to D	0.475	1766.62	2.2638	0.96489	**C to D**	0.475	1766.62	2.2638	0.96489
D to E	0.462	987.99	2.20	1	**D to E**	0.462	987.99	2.20	1
Beyond E	0	--	0	--	**Beyond E**	0	--	0	--

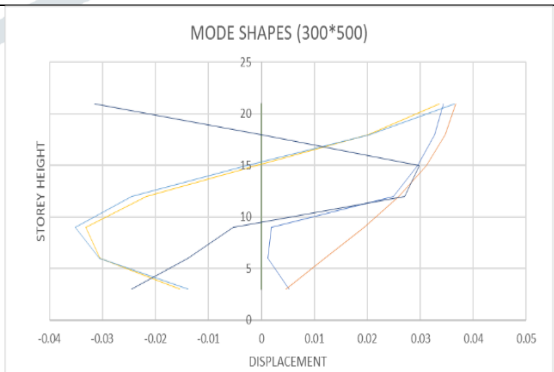
Table 4Corelative study of parameters on the basis of performance levels for Push2

SQUARE COLUMN					RECTANGULAR COLUMN				
	Disp	**Stiffness**	**% drifts**	**Di**		**Disp**	**Stiffness**	**% drifts**	**Di**
IO	0.012017	41966.7	0.5722	0.158684	**IO**	0.0205	47650.25	0.010	0
LS	0.14608	8609.48	0.69566	0.805624	**LS**	0.183	8488.5	0.87	0.822
CP	0.34999	3556.92	1.638	0.917411	**CP**	0.334	5330.85	1.59	0.888
C to D	0.4358	2745.54	2.07	0.942032	**C to D**	0.418	4561.31	1.99	0.904
D to E	0.4345	2432.74	2.069	1	**D to E**	0.414	3825.37	1.97	0.92
Beyond E	0	--	0	--	**Beyond E**	0	--	0	--

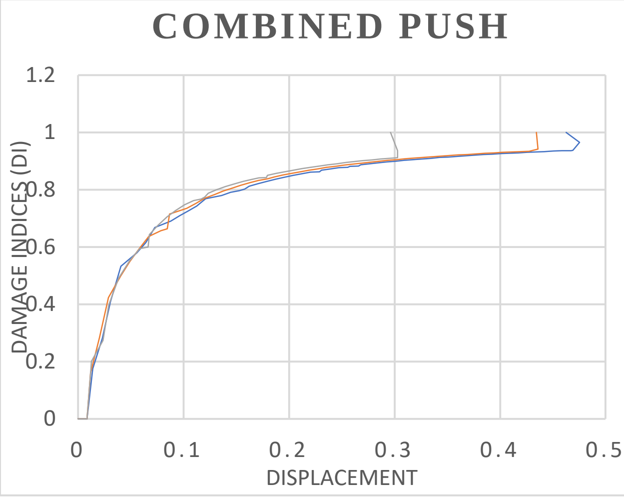
Combined Graphical Representation of Push analysis Results



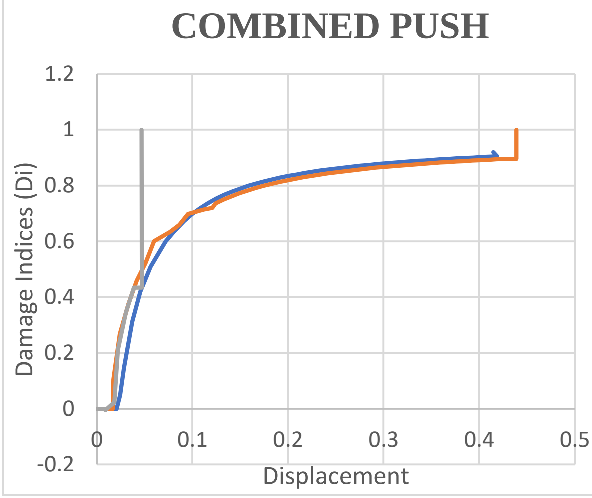
Mode shape for square column frame (450mmx450mm)



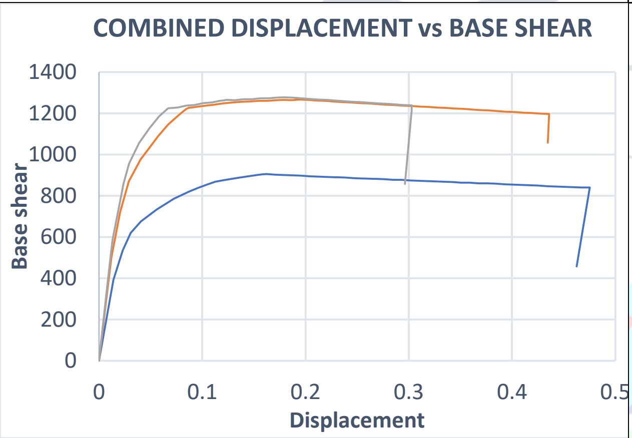
Mode shape for rectangular column frame(300*500)

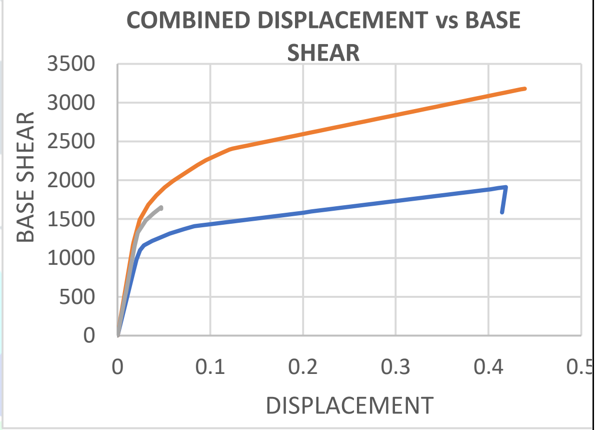


DISPLACEMENT vs DAMAGE INDEX



DISPLACEMENT vs DAMAGE INDEX





4 CONCLUSION

Force based seismic procedure(FBD) are taken over by displacement based seismic designs (DBSD) and now performance based seismic designs(PBSD) has emerged as best alternative over FBD and DBSD. PSBD has provided various performance evaluation procedure which properly address the nonlinear behaviour of RC members under seismic demand than that of force based designs. In this study we have applied Performance based seismic evaluation (PSBE) methods to reinforced concrete moment resisting frames of seven storey with different orientation of column. The evaluation is carried out by using non-linear static analysis push over method for displacement controlled. The nonlinear response parameter like modal time period, mode shapes, storey displacement, inter storey displacement, stiffness, damage index are studied and discussions are made. This dissertation work take effort to a damage state of structure at various performance levels and predict the damage states of bare frame. It was observed from the past research work that, most damage indices adequately predict the undamaged and collapse damage states of the building. However, the damage indices fail to predict the gradual increase in damage between undamaged to slight, moderate and extensive damage states.

From this study following concluding remarks has been made;

1) In case of rectangular shaped column frame for push 1 load case it was observed that less displacement was address by frame at collapse to that of square shapes column frame. Since more stiffness is available for rectangular column.
2) When stiffness were compared it was observed that for push 2 load case structure bears higher values compared to push 1 and push 3 load cases. In push 2 load case structure exhibits brittle behavior, while in push 1 and push 3 remaining elastic range.
3) The damage index uses non linear responses obtained from collapse mechanism and sequence of plastic hinge are followed to trace various building performance level. Hence there is direct integration between the damage value and building performances.
4) When drift orientation defined in FEMA 440 was compared with results obtained from push over showed close agreement for all performance levels. This has been illustrated in response graph mentioned in chapter 4.
5) The stiffness degradation of example MRFs were found to have down fall curve irrespective of increase in storey height. Which showed that there has been significant fail in stiffness due to damage sustained by various structural components traced by collapse mechanism.
6) A damage index has been evaluated by using this trend of fall in stiffness by comparing stiffness value at operational level with instantaneous stiffness at respective performance levels.
7) When natural time period of example MRFs were compared they show fall from rectangular column configuration to square column configuration ,there by showing loss in stiffness as they are inversely related to each other.

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