Performance Based Design Of Reinforced Cement Concrete Framed Structures By Using SAP Software

Priya K Chintanwar[1]

Assistant Professor, Dept. of Civil Engineering,
Bharati Vidyapeeth Institute and Technology, Maharashtra, India

---

Abstract – *Now a days, Most of the structures are designed which is depends on the results of a Static analysis and the principle of superposition. Although, a Practical evaluation of an existing structure requires a nonlinear analysis. This is especially important in the process of seismic analysis, retrofitting and upgrading the structures for various reasons. `In present study, a building frame is analysis preliminary for the seismic forces using Non-linear static pushover analysis. FEMA 356:2000, "Pre-standard and commentary for the seismic rehabilitation of buildings" and FEMA 440:2005, "Improvement of Non-linear Static Seismic Analysis Procedures" are mainly used for the analysis purpose. In linear analysis 2-storied steel building frame was analyzed against the sway force. Then the same whole frame was analyzed by Kani's method. The same frame was analysis by SAP (2000) and the results of both the analysis were found to be same till 1/10th of fraction. The 2 storied frames was analyzed non-linearly and found that there is not much difference in result. Therefore the multistoried frame of 6 storeys was linearly analyzed and designed by SAP 2000 directly. The section obtained by this design is again Non-linearly analyzed using FEMA displacement co efficient method and SAP 2000.*

Key Words**: STAAD PRO, SAP, FEMA 356:2000, PUSHOVER ANALYSIS, IS 456:2000, SEISMIC ANALYSIS,**

1. INTRODUCTION

The Buildings, which appeared to be strong enough, may crumble like houses of cards during earthquake and deficiencies may be exposed. Experience gained from the Bhuj-earthquake of 2001 demonstrates that the most of buildings collapsed were found deficient to meet out the requirements of the present day codes. The concept of Performance based design is a systematic method of designing structural systems to achieve predictable and desirable performance of both structural and non-structural elements. Performance based seismic engineering is the modern approach to earthquake resistance design. The objective of performance-based analysis is to produce structures with predictable seismic performance. The applications of the performance based analysis to the buildings were limited. In order to utilize performance-based analysis effectively and intelligently, one need to be aware of the uncertainties involved in both structural performance and seismic hazard estimations. Key requirement of any meaningful performance based analysis is the ability to assess seismic demands and capacities with a reasonable degree of certainty. The overall capacity of a structure which depends on the strength and deformation capacity of the individual components of the structure. Pushover analysis is a performance based analysis that refers to a methodology in which structural criteria are expressed in terms of achieving a performance objective. In order to determine capacities beyond the elastic limits, some form of nonlinear analysis, such as the pushover procedure, was required. In this, linear and Non-linear analysis of four bay Four-storied concrete frame was presented. Initially this frame was linearly analyzed without Earthquake and designed in **SAP2000** and this frame was also analyzed with Earthquake and designed in **SAP2000.** After that this both frame was Non-linearly analyzed and designed in **SAP**2**000** in 3D. Finally the results were compared.

This procedure uses a series of sequential elastic analysis. The Objectives of the studies are as follows:

1. To design and evaluate a RC framed building using performance based design approach.
2. To check the performance based design of various RCC Framed structure with pushover analysis method.
3. To produce structures with predictable seismic performance

1.1 Methodology

The general methodology adopted for this study was as follows

1. The various method of structure and evaluation of performance of structure with pushover analysis was studied.
2. The various models of 2D RCC frames were analyzed by using pushover analysis to check the performance by changing the various parameters.
3.The 3D frame structure of G+4 were analyzed and design by using IS-456 and IS-1893 and the same Structure were analyzed by using pushover analysis to evaluate the performance of various models.
4. The performance levels of various design model was compared and some of the elements of a structure design by IS-456 2000 were revised so that the structure attends required Performance level.

1.2 List of Methods:

Linear analysis
Pushover analysis

Methods of Linear Analysis:

1.First of all Taking a Single Bay, Single storey Frame with 50 KN External Load, 20KN uniformly distributed load having height 3m & width 6m & analyze the Frame in software Sap2000 V14. The Linear analysis is to be done by Kani's Method

Design Methods:

1. Force Based Design
2. Performance Based Design/ Displacement Based Design

Linear analysis & Pushover Analysis

Analysis of single bay single frame

B = 0.3m x 0.4m
C = 0.3m x 0.4m
E = 25 kN/m

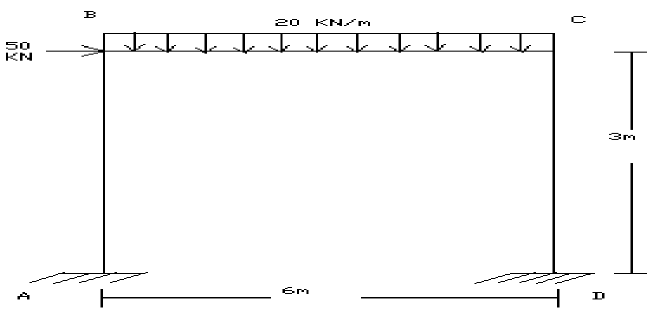

Fig-1 : Single bay single storey frame

Table -1: Comparative Results

curvature at loaded corner (Φ)		
linear analysis		nonlinear analysis
hand calculation	sap	Sap
0.00047 rad	0.0004701 rad	0.002172 rad

Various Linear and Pushover Analysis

Four kinds of R.C.C. buildings were taken for analysis:

1. Three Bays Single Storey Frame:
2. Three Bays Double storey frame
3. Three bays three storey frame
4. Three bays four storey frame

In all the models, the support conditions are assumed to be fixed & all the models are analyzed with earthquake analysis. All structural members were of M20 grade concrete. The geometrical properties are listed in table.1.

Table -2: Section Properties

Structural Member	Beam	Column	Slab	Height
Three Bays Single Storey Frame	230x350	230x300	125	3.1
Three Bays Double storey frame	230x350	230x350	125	3.1
Three bays three storey frame	230x350	230x400	125	3.1
Three bays four storey frame	230x350	230x400	125	3.1

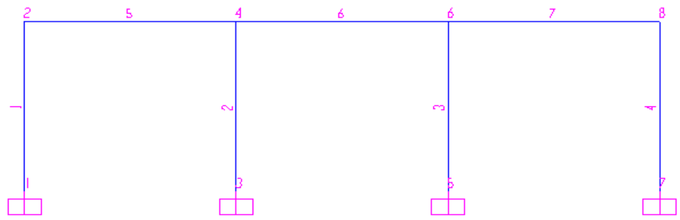

Fig -2: Three Bays Single Storey Frame

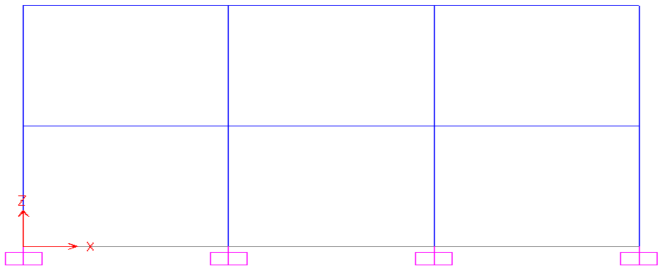

Fig -3: Three Bays Double storey frame

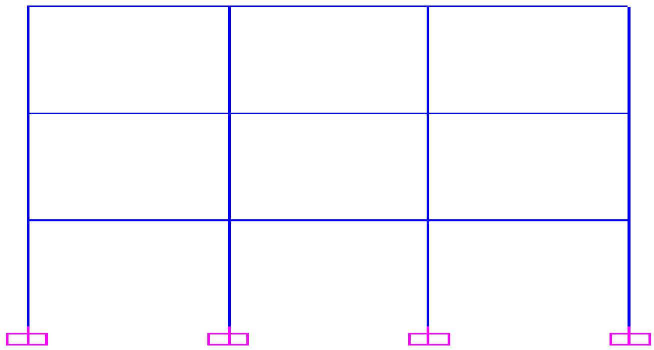

Fig -4: Three bays three storey frame

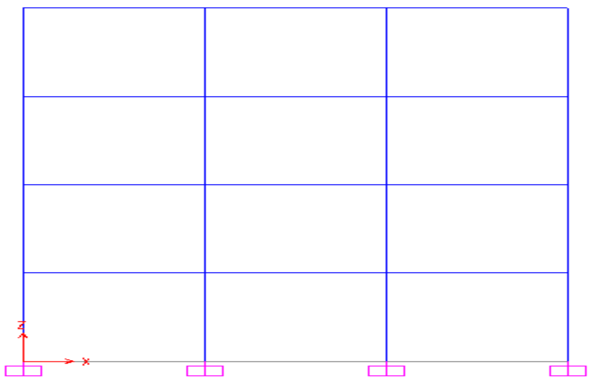

Fig -5: Three Bays Four Storey Frame

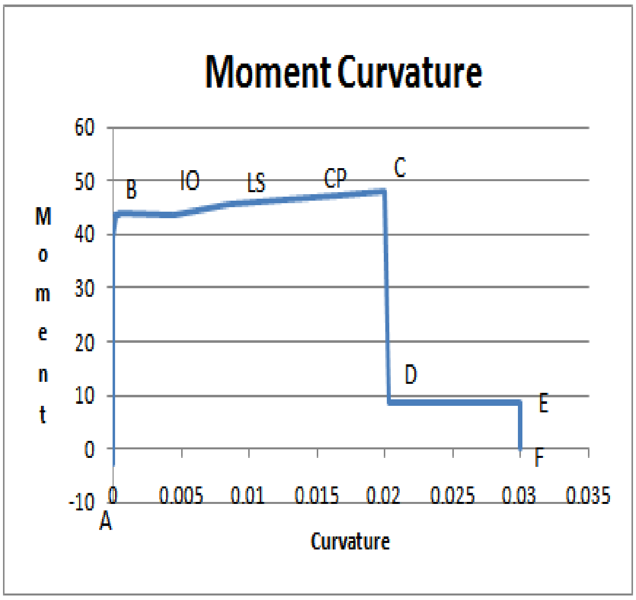

Chart -1: *Moment- Rotation curve*

Table -3: Comparative Results

Frame types	Linear Analysis			Nonlinear Analysis			
	P KN	M KN.m	V	P KN	M KN.m	V	Performance Point
G(1bay, 1storey)	87.332	21.559	156.00	85.184	23.265	153.75	(14.163,7.502E-050
G(3bay, 1storey)	128.631	7.7282	327.797	93.411	4.663	230.156	(31.086,1.445E-03)
G+2 (3bay, 2storey)	252.931	5.0773	756.289	135.242	2.669	393.523	(54.992,4.829E-04)
G+3 (3bay ,3storey)	442.115	7.7448	1340.303	344.49	0.179	1145.01	(89.985,3.765E-03)
G+4 (3bay, 4storey)	525.21	7.5442	2430.304	395.46	395.46	1245.02	(90.950,3.660E-03)

Linear and Non-Linear Analysis of 3D Four -Storey Concrete Frame

In this, linear and Non-linear analysis of four bay Four-storied concrete frame is presented. Initially this frame was linearly analyzed without Earthquake and designed in **SAP2000** and this frame was also analyzed with Earthquake and designed in **SAP2000.** After that this both frame was Non-linearly analyzed and designed in **SAP2000** in 3D. Finally the results are compared.

Linear and Nonlinear Analysis of 3D frame with and without Earthquake:

As per **IS-456**, the Four Bays four Storied frame is Linearly analyzed and design in **SAP2000** and The same model is analyzed and design in SAP2000 as per IS 1893-2000 by taking all combinations. Also the both frame is nonlinearly analyzed upto their performance level. The Frame is subjected to Dead load, live load and earthquake load. The section properties of both frame are taken as same as given below:

Table -4: Section Properties:

Structural Member	Beam	Column	Height
Four Bays Four Storey Frame(Ground)	300x350	350x500	3.0

All storey having same section properties.

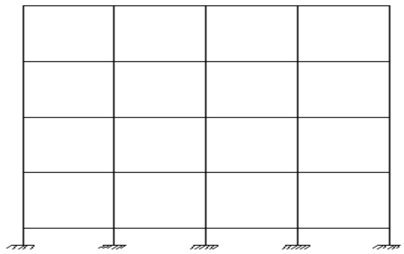

Fig -6: Four storied four bays frame

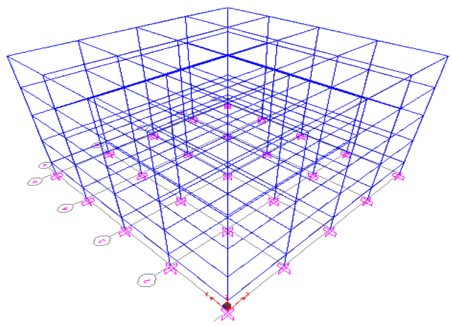

Fig -7: 3D frame of four storied four bays Frame

SAP 2000 is used for Non-linear static pushover analysis of four storey four bays concrete frame. SAP2000 is capable of tracing the hinge formation. Thus we can predict the collapse mechanisms of the frame.

Load combinations used for analysis purpose is:

Combination 1: 1.5(D.L+L.L)
Combination 2: 1.2(D.L+L.L+E.L)
Combination 3: 1.2 (D.L+L.L– E.L)
Combination 4: 1.5(D.L+E.L)
Combination 5: 1.5(D.L – E.L)
Combination 6: 0.9D.L + 1.5E.L
Combination 7: 0.9D.L – 1.5E.L

The Target displacement of the structure is calculated upto their desired limit. The hinges formed at various stages are also noted which denotes the collapse mechanism of the structure. And compare the target displacement of a 3d model without and with earthquake. The hinges formation are compare with 3d model with earthquake and Revised design with 3d model with earthquake for calculating performance Based Design.so deformed shapes for various design are:

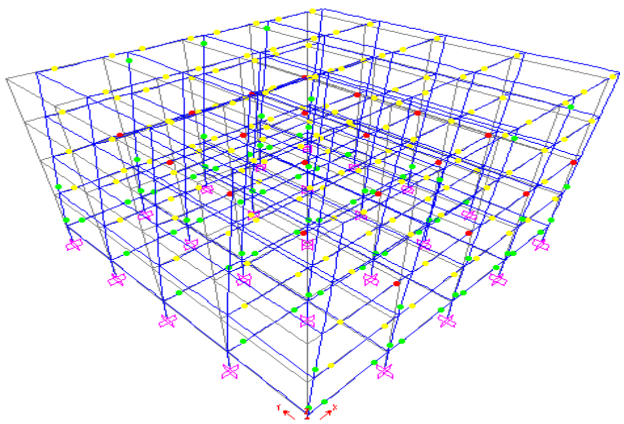

Fig -8: Hinges formation of model with Earthquake (IO, LS level)

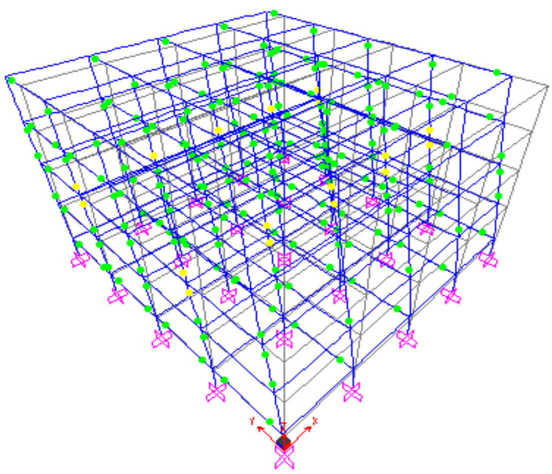

Fig -9: Hinges formation of revised model with Earthquake (IO level)

2 Results

Pushover analysis is carried out to evaluate the performance of structure considering various models of RCC frame structure as given in tables, results obtained from analysis is presented below

Table -5: The Performance point of 3d model without Earthquake and 3d model with Earthquake are comparatively shown below according to ATC-40 and FEMA-343:

Frame Type	G+4(Atc 40)		G+49Fema-343)	
	Performance Pt.(KN)	Displacement (m)	Performance Pt.(KN)	Displacement (m)
Design 1 as per IS-456 (Damage level)	1481.588	0.197	1481.588	0.197
Revised Design 1 as per IS-456 (IO level)	4807.138	0.093	5351.986	0.171
Design 2 as per IS-1893 (LS level)	3195.797	0.097	3525.643	0.189
Revised Design 2 as per IS-1893 (IO level)	3197.485	0.097	3527.870	0.189
Revised Design 2 as per IS-1893 (IO level)	4848.008	0.093	5477.259	0.179

Table -6: Reinforcement details of design 1 and Revised design 1 as per IS 456

Element	Size	Original Design R/F.			Size	Revised Design R/F.		
		Top		Bottom		Top		Bottom
		Left	Right			Left	Right	
B-09	300x350	4#12	5#12	3#16	300x400	4#12	4#12	3#16
B-10	300x350	4#12	4#12	3#16	300x400	3#16	3#16	3#16
B-11	300x350	4#12	4#12	3#16	300x400	3#16	3#16	3#16
B-12	300x350	5#12	4#12	4#12	300x400	3#16	3#16	4#12

Fig -10: The detailing of Beam and Column in staad -pro are:

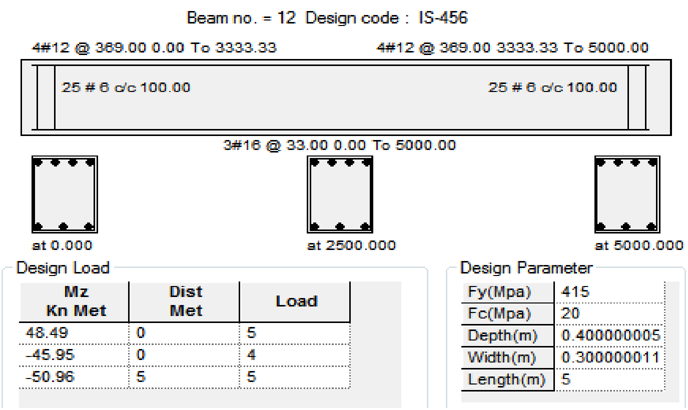

Table-7: The Reinforcement details of Original design and New Revised design are compared

Element	Size	Revised Design	Revised size	New Revised Design
C-33	0.35x0.5	8#16	0.35x0.45	12#12
C-34	0.35x0.5	8#16	0.35x0.45	12#12
C-37	0.35x0.5	8#16	0.35x0.45	12#12
C-38	0.35x0.5	8#16	0.35x0.45	12#12
C-39	0.35x0.5	8#16	0.35x0.45	12#12
C-42	0.35x0.5	8#16	0.35x0.45	12#12
C-43	0.35x0.5	8#16	0.35x0.45	12#12
C-44	0.35x0.5	8#16	0.35x0.45	12#12

Table-8: The Performance level as per Is-456 and IS-1893 are as follows

Frame Type	Performance Levels	
Design 1 as per IS-456-2000	IO	LS
Revised Design 1as per IS-456-2000	IO	-
Design 2 as per IS-1893-2000	IO	LS
Revised design 2 as per IS-1893-2000	IO	-
New Revised design 2 as per IS-1893-2000	IO	-

Table-9: The comparison of Target displacement with software and manually as per ATC-40 are as follows:

Frame Type	code	Target displacement		Difference
		Sap2000	Manually	
Design 1as per IS-456 -2000	ATC-40	0.093	0.090	0.03
Design1as per IS-1893-2000	ATC-40	0.093	0.0933	0.003

Table-10: The Quantity of Material and Percentage variation as per IS-456 are as follows:

Material	Design 1 as per IS-456 (Beam)	Revised Design 1 as per IS-456(Beam)	% variation As per IS-456 (Beam)	Design 1 as per IS-456 (Column)	Revised Design 1 as per IS-456 (Column)	% variation As per IS-456 (Column)
Concrete	52.5cu.m	60 Cu.m	14.2 %	90 Cu.m	81 Cu.m	10%
Steel	1902.840 KN	4845 KN	154.6 %	1326.336 KN	1162.428 KN	12.3%

Table-11: The Quantity of Material and Percentage variation as per IS-1893are as follows:

Material	Design 2as per IS-1893 (Beam)	Revised Design 2 as per IS-1893 (Beam)	% variation As per IS-1893 (Beam	Design 2 as per IS-1893 (Column)	Revised Design 2 as per IS-1893 (Column)	% variation As per IS-1893 (Beam
Concrete	52.500 cu.m	60.000 cu.m	14.2 %	105.000 cu.m	94.500 cu.m	10%
Steel	1980.555 KN	2088.885 KN	5.46 %	2381.376 KN	2984.256KN	25.3%

Table-12: The comparison of Quantity of steel & concrete are as follows:

Quantity	As per IS -456	As per IS-1893
Steel	157959.78 KN	2675154.4 KN
Concrete	4101.5 Cu .m	8203.28 Cu. m

3. CONCLUSIONS

Conclusions on 2D models

1. From Table 1, it is conclude that the curvature in case of nonlinear analysis of frame is greater than linear analysis of frame.
2. Also it is conclude that the no. of bays increases, lateral load carrying capacity increases but with increasing in bays corresponding moments is not increases.
3. Also it conclude that no. of storey increases lateral load carrying capacity, base shear and performance point also increases.

4. Also, it is conclude that the nonlinear analysis of frame is greater than linear analysis of frame in case of Lateral load, moment, base shear and performance point.

Conclusions on 3D models:

1. From table, it conclude that the maximum displacement .i.e. (Target displacement) is nearly same with software and manually calculation.
2. The structure design as per IS-456 without considering earthquake load can perform equal to the structure design as IS-1893 after making modification in some of elements.
3. The cost of structure in a performance based design is optimum and it is less as compare to structure design considering earthquake forces.
4. From table 7.6, it conclude that the Maximum displacement .i.e. (Target displacement) is nearly same with software and manually calculation.
5. Also, it conclude that the quantity of steel and concrete as per IS-1893 is increases as compared to IS-456.

REFERENCES

[1] Bertero, V.V., **(1997),** "Performance-based seismic engineering", A critical review of proposed design methodologies for the Next generations of codes Bled Slovenia.

[2] Aschheim. M., **(2004),**"A Pragmatic Approach for Performance-Based Seismic Design, "Performance-Based Seismic Design Concepts and Implementation, Proceedings of The International Workshop, Bled, Slovenia, 28 June-1 July, 2004 and PEER Report 2004/05, September 2004, pp. 481-492.

[3] Bayrak, O., Sheikh, S.A., **(2001)** "Plastic Hinge Analysis," Journal of Structural Engineering, ASCE.

[4] Browning, J., L., Lynn, A., and Moehle, J. P., **(2000)** "Performance Assessment for a Reinforced Concrete Frame Building,"

[5] Nalamwar M.R., Ingale chetan, **(2017),** "Performance Based seismic analysis of RCC Building' Civil Engineering Department, Yavatmal.

[6] Giberson, M. F., **(1967)** "The response of nonlinear multi-story structures subjected to earthquake excitation,"EERL Report, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasaden

[7] Sheikh, S.A. and Khoury, S.S. **(1997)** "Performance-Based Approach for the Design of Confining Steel in Tied Columns," ACI Structural Journal.

[8] Teplý, B. **(2007)** Introduction to the Performance-Based Approach (in Czech), Materiály prostavbu 8/2007, 16-18fib Model Code (2008), Part: Service Life.

[9] Washington, D.C., **(2008)** FEMA, "Improvement of Nonlinear Static Seismic Analysis Procedures." FEMA 440, Federal Emergency Management.

[10] Xiao, Y. and Martirossyan, A., **(1998)** "Seismic Performance of High-Strength Concrete Columns," Journal of Structural Engineering, ASCE.

AUTHOR

Priya K Chintanwar
Assistant Professor ,
Department of civil Engineering ,
BVIT college CBD Belapur,
New Mumbai