OPTIMUM POSITION OF OUTRIGGER SYSTEM FOR HIGH RAISED RC BUILDINGS USING ETABS 2013.1.5 (PUSH OVER ANALYSIS)

Karthik.N.M[1], N.Jayaramappa[2]

[1] *Assistant Professor, Dept. of Civil Engineering*
Chikka Muniyappa Reddy Institute of Technology (CMRIT), Bangalore, Karnataka, (India)
[2] *Assistant Professor, Dept. of Civil Engineering*
University Visvesvaraya College of Engineering (UVCE), Bangalore, Karnataka, (India)

ABSTRACT

Pushover analysis is a non linear static analysis becoming a popular tool for seismic performance evaluation of existing and new structures and used to determine the force-displacement relationship for a structural element. To evaluate the performance of RC frame structure, a non linear static pushover analysis has been conducted by using ETABS 9.13.5. To achieve this objective, eight RC frame structures with 30 stories 7X7bay, without and with outriggers at different stories were analyzed. Compression study of the base force and displacement of RC frame structure with 30 storie,s 7X7bay with outriggers at different stories.

Keywords: ETABS 9.13.5, Outrigger System, Non Linear Static Analysis, Pushover Analysis.

I. INTRODUCTION

The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading. The overall geometry of a building often dictates which factor governs the overall design. As a building becomes taller and more slender, drift considerations become more significant. Proportioning member efficiency based on maximum lateral displacement supersedes design based on allowable stress criteria. Innovative structural schemes are continuously being sought in the field. Structural Design of High Rise Structures with the intention of limiting the Drift due to Lateral Loads to acceptable limits without paying a high premium in steel tonnage. Various wind bracing techniques have been developed in this regard; one such is an Outrigger System, in which the axial stiffness of the peripheral columns is invoked for increasing the resistance to overturning moments. This efficient structural form consists of a central core, comprising either Braced Frames or Shear Walls, with horizontal cantilever trusses or girders known as outrigger Trusses, connecting the core to the outer columns. The core may be centrally located with outriggers extending on both sides (Fig.1.a) or it may be located on one side of the building with outriggers extending to the building columns on one side (Fig.1.b).

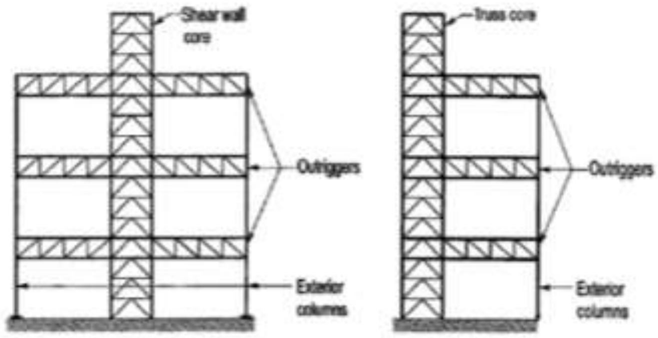


Fig 1: (a) Outrigger system with a central core (b) Outrigger system with offset core

Analysis is carried out by using push over analysis. Pushover analysis is non linear static analysis in which provide 'capacity curve' of the structure, it is a plot of total base force vs. roof displacement. The analysis is carried out up to failure; it helps determination of collapse load and ductility capacity of the structure. The pushover analysis is a method to observe the successive damage state of the building. In Pushover analysis structure is subjected to monotonically increasing lateral load until the peak response of the structure is obtained as shown in fig 2.

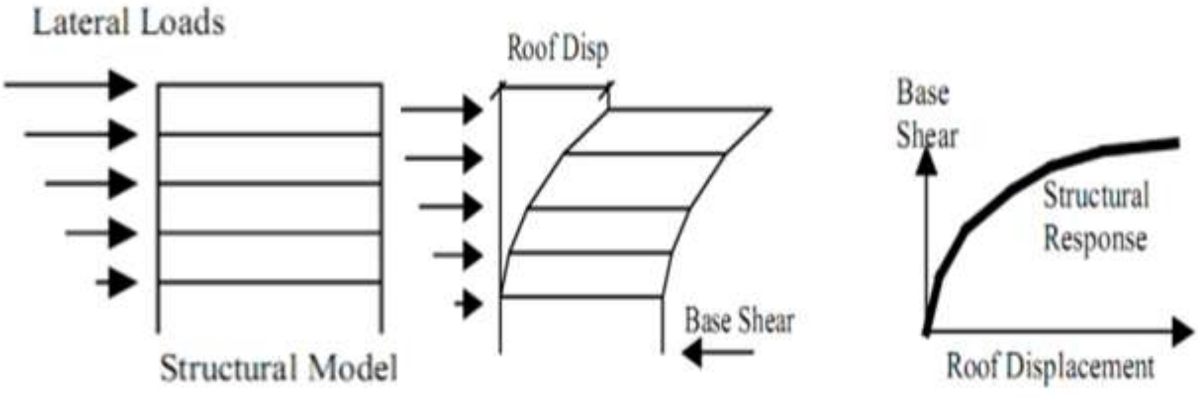


Fig 2. Static Approximation Used In the Pushover Analysis.

In the present study push over analysis is carried out for all different type models, and then the minimum displacement among those models (analysis I) is taken in to account. That minimum displacement is applied to controlled displacement, and then the models are re analysed (analysis II) to find the maximum base shear for minimum displacement. Features at performance point are also noted.

II. PUSHOVER ANALYSIS

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design earthquakes. The evaluation is based on an assessment of important performance parameters, including global drift, inter story drift, inelastic element deformations (either absolute or normalized with respect to a yield value),deformations between elements, and element connection forces (for elements and connections that cannot sustain inelastic deformations), The inelastic static pushover analysis can be viewed as a method for predicting seismic force and deformation demands, which accounts in an approximate manner for the redistribution of internal forces that no longer can be resisted within the elastic range of structural behavior. In pushover analysis after assigning all properties of the models, the displacement –controlled pushover analysis of the models are carried out. The models are pushed in monotonically increasing order until target displacement is reached or structure loses equilibrium. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA- 273 for steel members.

- Locate the pushover hinges on model. ETABS provides hinge properties and recommends PMM hinges for columns and M3 hinges for beam as described in FEMA-356.
- Define pushover load cases. IN ETABS more than one pushover load case can be run in the same analysis.
- Locate the performance points and analysis details of structure at the point.

III. DATA TO BE USED

3.1 Material Properties

Grade of concrete = M40

Grade of steel = Fe-500

Number of stories: 30 stories

Building height: 120 mts

3.2 Description of Frame Structure

The RC frame structure 30 stories is considered in this study. In the modal, in X- direction and Y-direction, each of 42m in length and the support condition was assumed to be fixed and soil condition was assumed as medium soil. All slabs were assumed as Membrane element of 150 mm thickness. The typical floor height is 4m.The details of beams and columns are shown below. Live load on slab is $3KN/m^2$.

COLUMN SIZE:

Square columns:

1000mm X 1000mm	First to Third Floor
900mm X 900mm	Fourth and Fifth Floor
800mm X 800mm	Sixth to Eighth floor
700mm X 700mm	Ninth to 12th Floor
600mm X 600mm	13th to 16th Floor
500mm X 500mm	17th to 30th Floor

BEAM SIZE:

300mmx600mm.

BRACING SIZE:

Square size of 300mmx300mm.

SHEAR WALL THICKNESS:

RC Building frame Brick wall thickness is 600mm.

GRID DATA: 7 X 7 Bay. 6 mts Spacing (fig 3)

3.3 Analysis Model Types

Bracing has been provided as the structure has been divided in to 1/3rd and 1/4th height of the buildings total height.

Type 1: Bare frame with shear wall.

Type 2: Bracing at 30th story. (fig 4)

Type 3: Bracing at 23rd story. (fig 5)

Type 4: Bracing at 20th story. (fig 6)

Type 5: Bracing at 15th story. (fig 7)

Type 6: Bracing at 10th story. (fig 8)

Type 7: Bracing at 8th story. (fig 9)

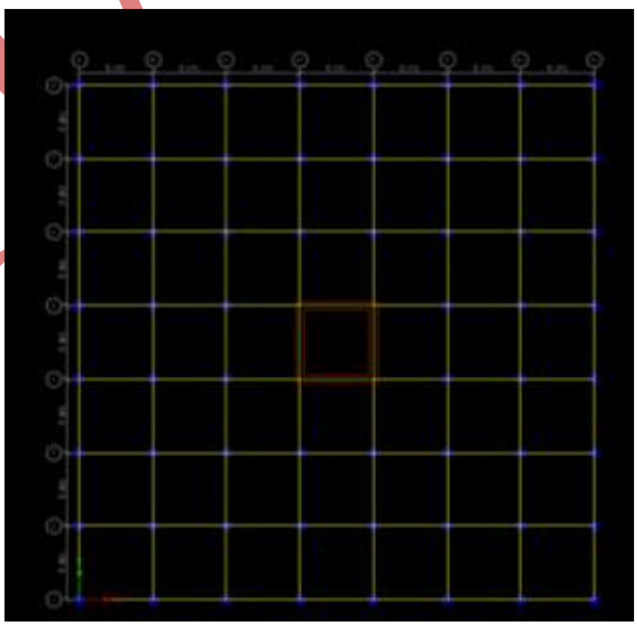


Fig -3: Plan of the Structure

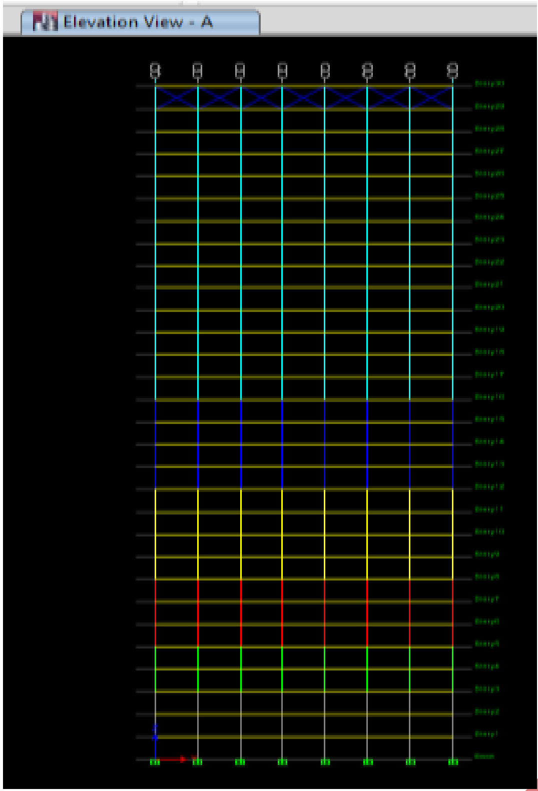


Fig 4: Outriggers at 30th Story

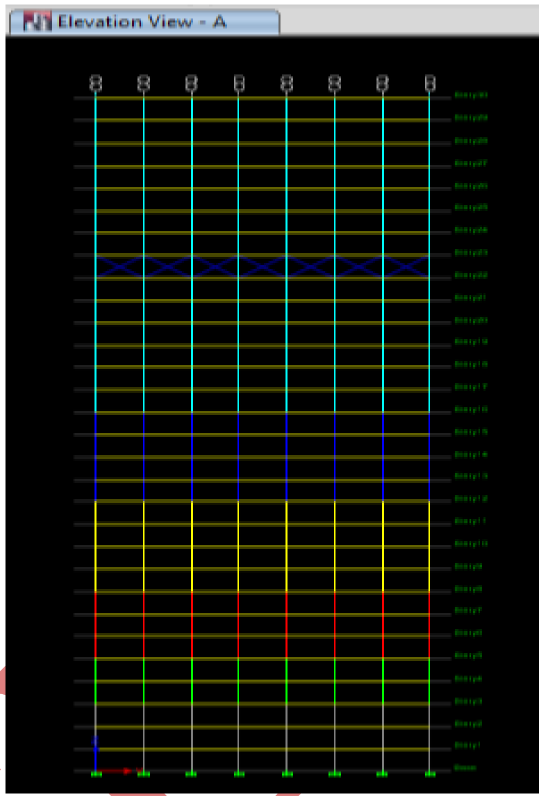


Fig 6: Outriggers at 23th Story

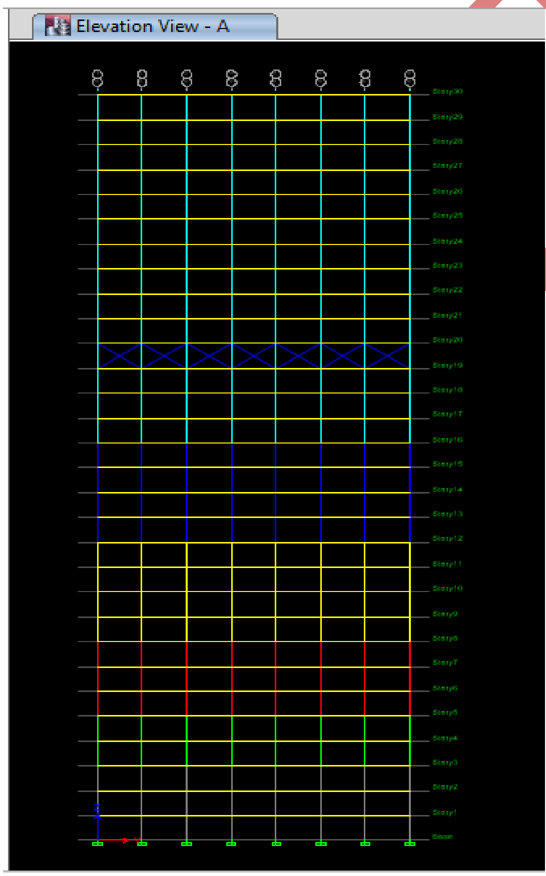


Fig 5: Outriggers at 20th Story

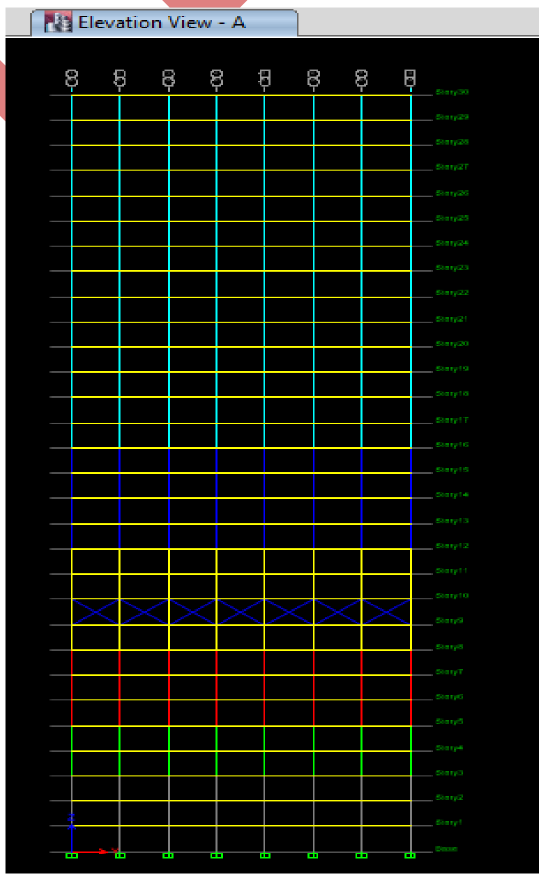


Fig 8: Outriggers at 10th Story

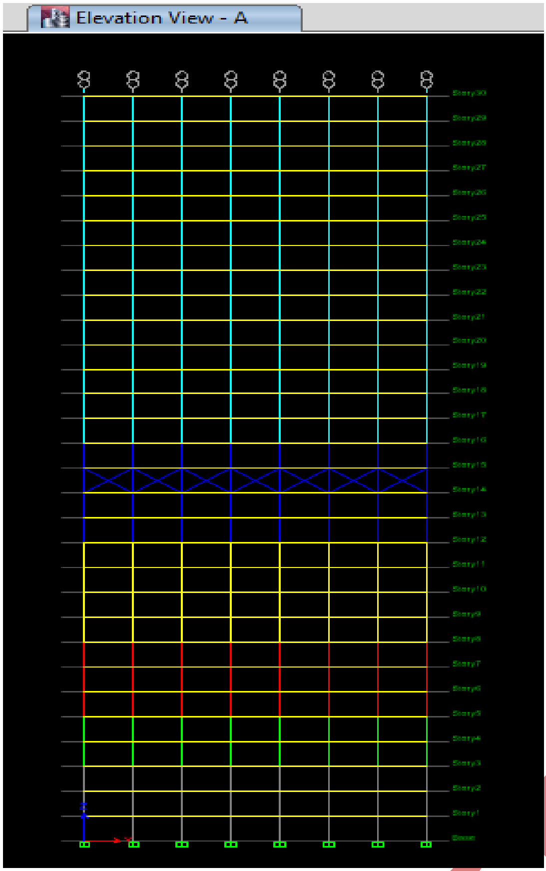


Fig 7: Outriggers at 15th Story

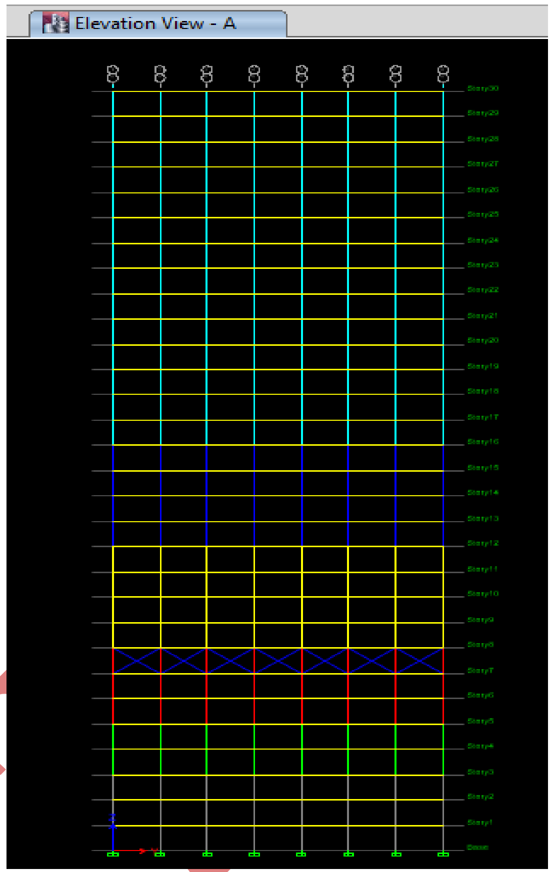


Fig 9: Outriggers at 8th Story

IV. RESULTS AND GRAPH

Analysis I: Tables showing push over curve results.

Bare RC Frame	
Monitored Displ	**Base Force**
mm	**kN**
0	0
68.8	6247.0218
154.4	12759.299
270.6	17071.15
750.8	24969.029
1333.9	33502.342
1844.3	40886.837
2345.4	47944.737
2836.4	53758.019
3267.7	58579.571

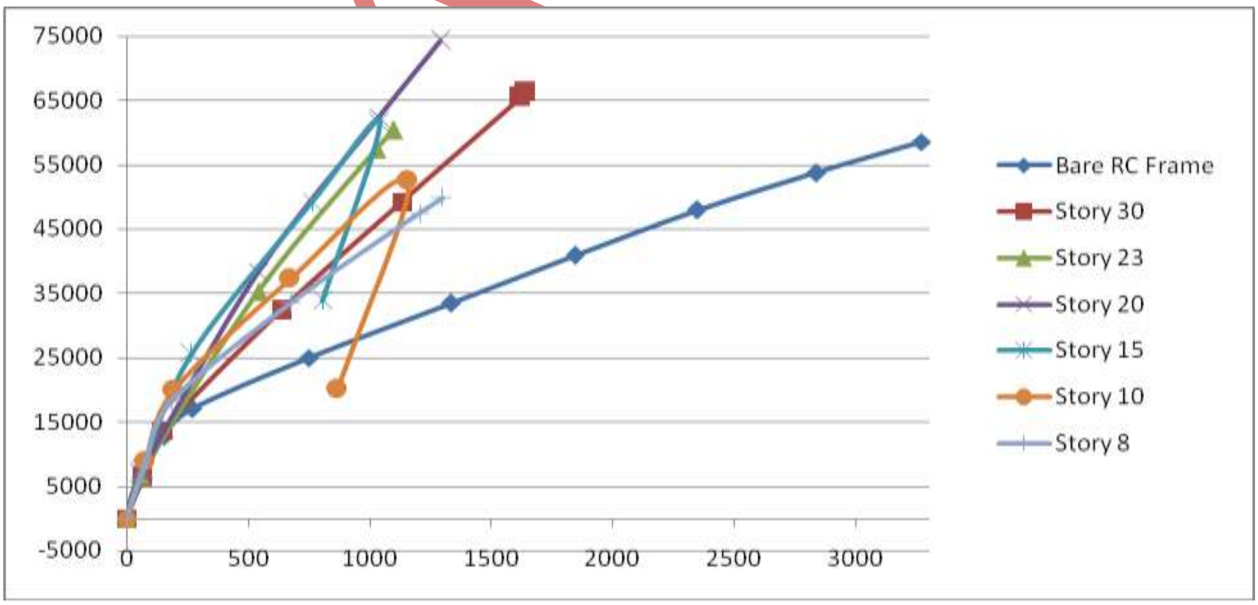
Table 1a: Push over Table for Bare RC Frame Structure.

Story 30		Story 23		Story 20	
Monitored Displ	**Base Force**	**Monitored Displ**	**Base Force**	**Monitored Displ**	**Base Force**
mm	**kN**	**mm**	**kN**	**mm**	**kN**
0	0	0	0	0	0
63.1	6385.5453	59.8	6680.8614	60.2	6986.4447
152.2	13752.651	542	35281.408	542.2	38367.658
637.7	32382.956	1027.7	57396.197	1038.4	62411.775
1132	49198.858	1095.3	60418.686	1289.8	74345.205
1619.3	65559.319				
1640.4	66259.239				

Table 1b: Push Over Table For Structure With Outriggers at Different Positions.

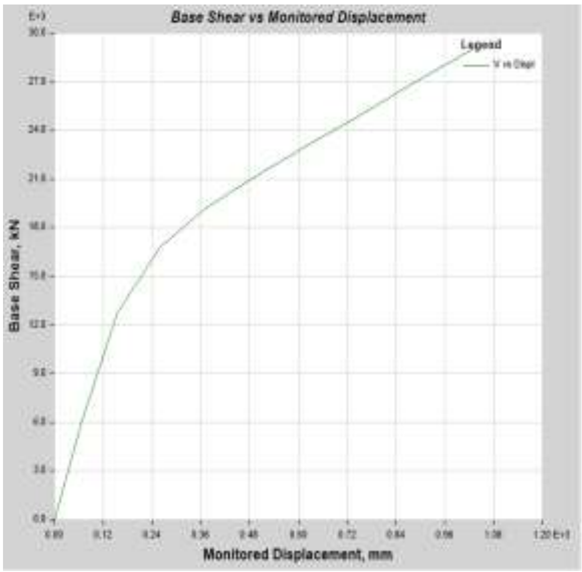
Story 15		Story 10		Story 8	
Monitored Displ	**Base Force**	**Monitored Displ**	**Base Force**	**Monitored Displ**	**Base Force**
mm	**kN**	**mm**	**kN**	**mm**	**kN**
0	0	0	0	0	0
65.8	7848.5276	76.9	8836.8785	72.7	8055.1682
267.1	25651.768	193.5	19879.489	185.6	18247.17
763.7	49235.425	673.5	37288.521	677.6	33567.216
1040.6	61531.505	1156.8	52533.564	1206.8	47468.35
806.3	33899.617	866.3	20105.279	1298.8	49873.066
				1298.8	49873.126

Table 1c: Push over Table for Structure with Outriggers at Different Positions.

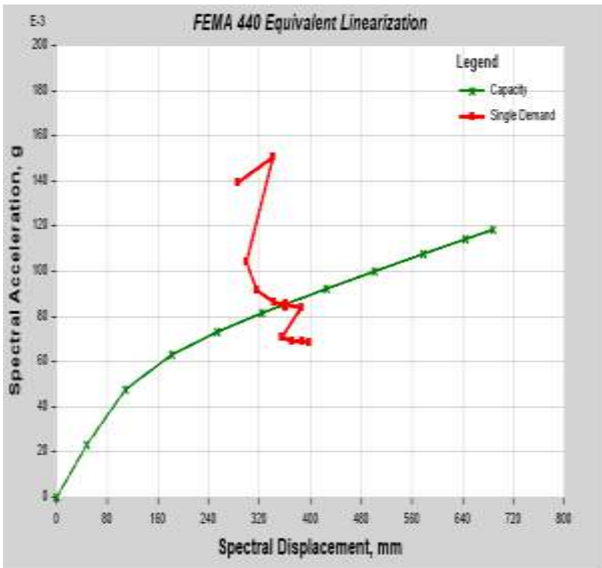


Graph 1: Push Over Curve for Structure with Outriggers at Different Levels and Bare RC Frame

Type 1: Bare RC frame



Graph 2a: Pushover Curve for Bare RC Frame

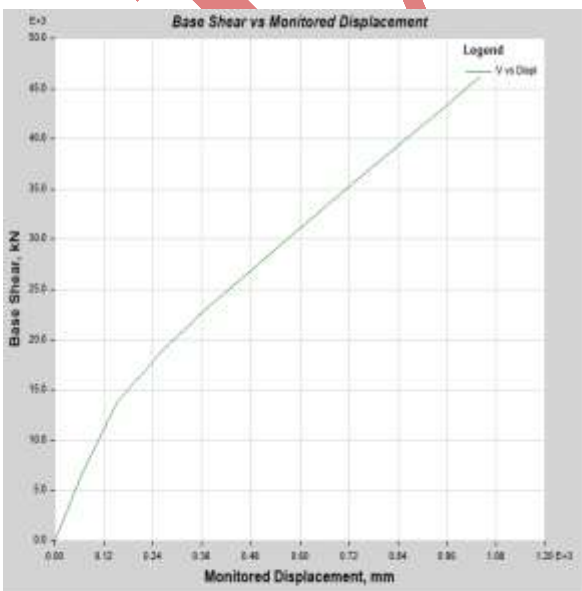


Graph 2b: Capacity-Demand Curve for Bare RC Frame

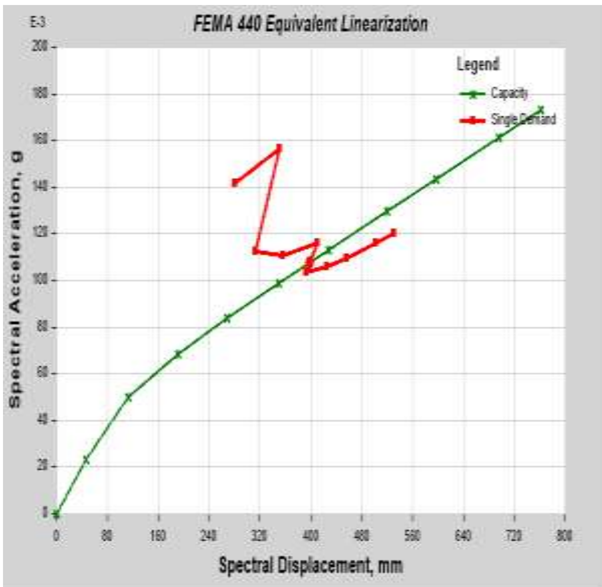
Table 2: Performance Point Levels of Bare RC Frame

Point Found	Yes	T secant	4.106 sec
Shear	21.7392 kN	T effective	4.641 sec
Displacement	532.2 mm	Ductility Ratio	3.389994
Sa	0.0854	Effective Damping	0.1759
Sd	359.7 mm	Modification Factor	1.276108

Type 2: Outriggers at Story 30



Graph 3a: Pushover Curve for Outriggers at Story 30

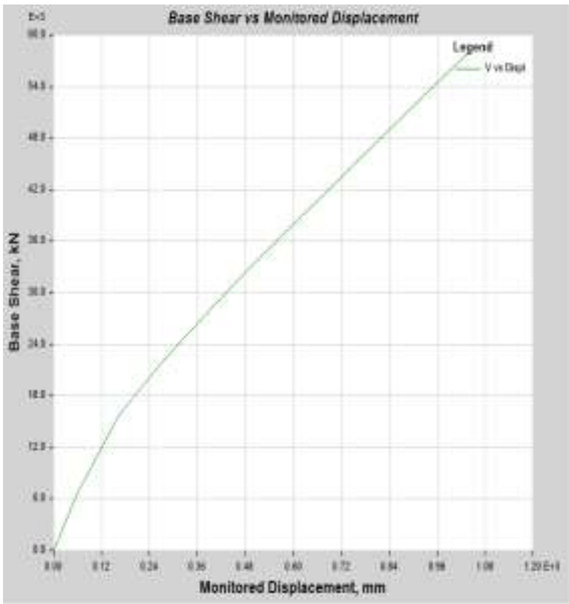


Graph 3b: Capacity-Demand Curve for Outriggers at Story 30

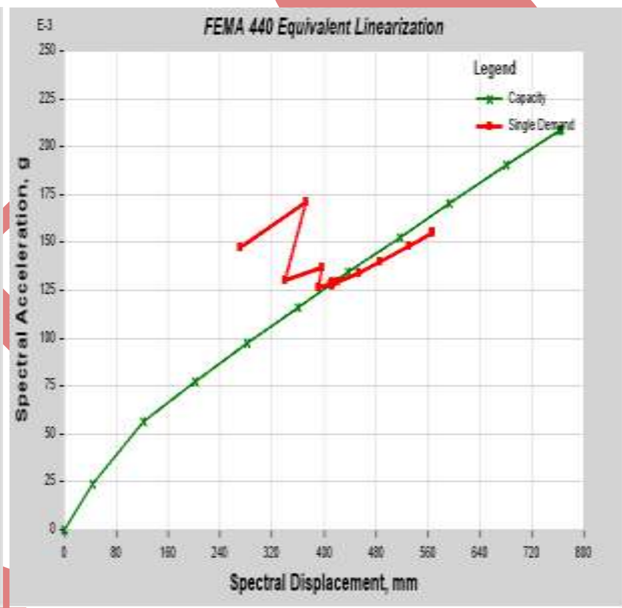
Table 3: Performance Levels for Outriggers at Story 30

Point Found	Yes	T secant	3.851 sec
Shear	29.0268 kN	T effective	4.843 sec
Displacement	540.4 mm	Ductility Ratio	4.116782
Sa	0.107809	Effective Damping	0.197
Sd	398.2 mm	Modification Factor	1.582307

Type 3: Outriggers at story 23



Graph 4a: Pushover Curve for Outriggers at Story 23

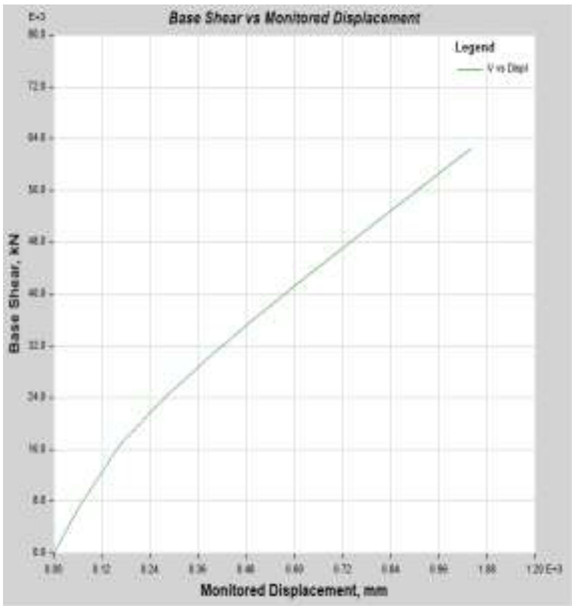


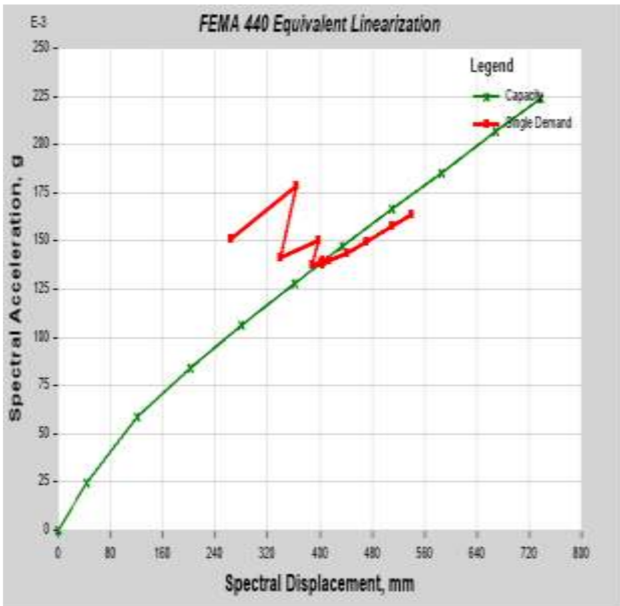
Graph 4b: Capacity-Demand Curve for Outriggers at Story 23

Table 4: Performance Point Levels for Outriggers at Story 23

Point Found	Yes	T secant	3.591 sec
Shear	35.7878 kN	T effective	4.767 sec
Displacement	553 mm	Ductility Ratio	4.631755
Sa	0.128349	Effective Damping	0.2016
Sd	411.8 mm	Modification Factor	1.761993

Type 4: Outriggers at story 20



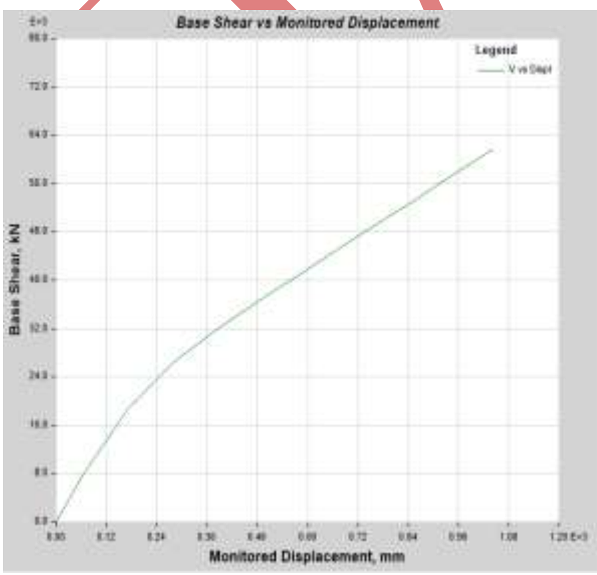


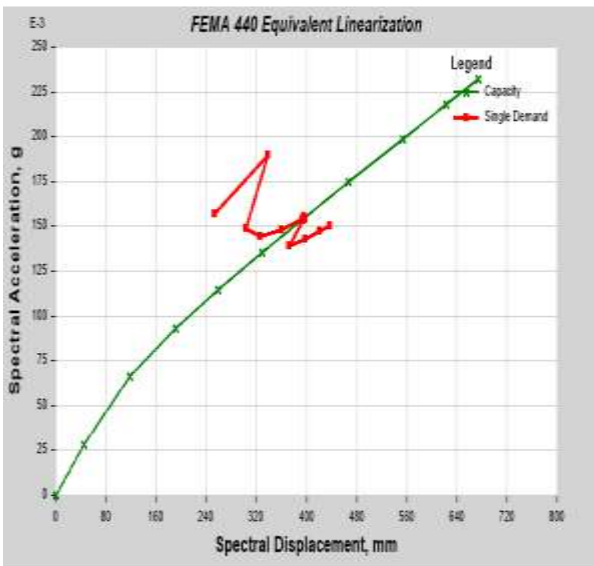
Graph 5a: Pushover Curve for Outriggers at Story 20 **Figure 5b**: Capacity-Demand Curve Outriggers at Story 20

Table 5: Performance Levels for Outriggers at Story 20

Point Found	Yes	T secant	3.419 sec
Shear	39.0965 kN	T effective	4.604 sec
Displacement	557.3 mm	Ductility Ratio	4.506466
Sa	0.13881	Effective Damping	0.2012
Sd	403.7 mm	Modification Factor	1.81315

Type 5: Outriggers at Story 15



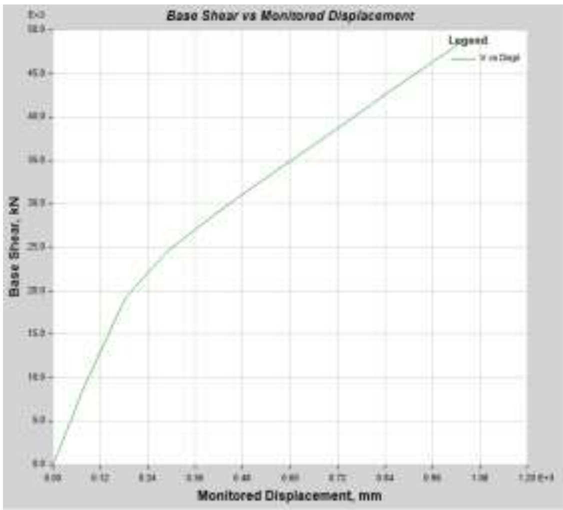


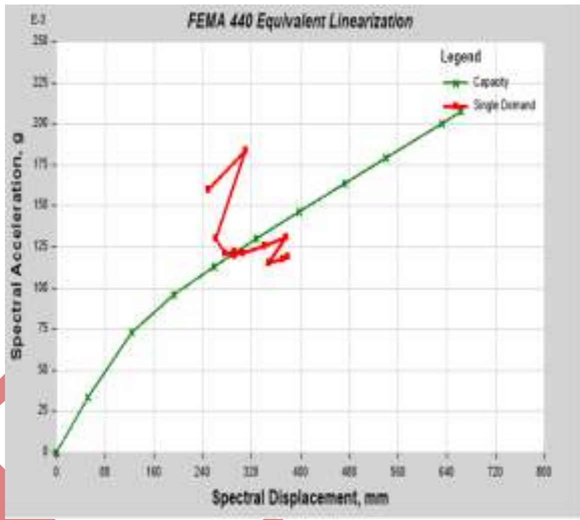
Graph 6a: Pushover Curve for Outriggers at Story 15 **Graph 6b:** Capacity-Demand Curve for Outriggers at Story 15

Table 6: Performance Levels for Outriggers at Story 15

Point Found	Yes	T secant	3.212 sec
Shear	41.8445 kN	T effective	4.384 sec
Displacement	598.8 mm	Ductility Ratio	3.758616
Sa	0.154447	Effective Damping	0.1918
Sd	395.9 mm	Modification Factor	1.862363

Type 6: Outriggers at Story 10



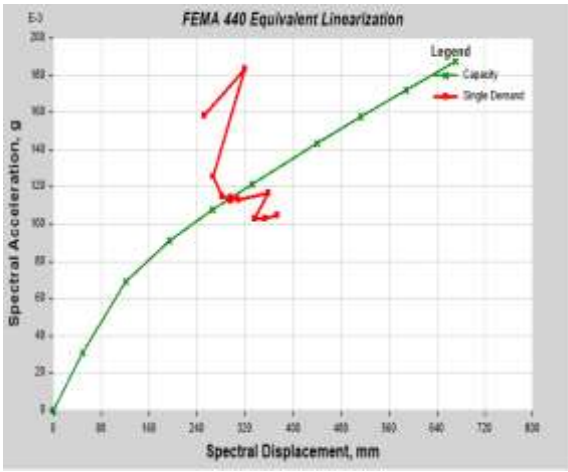


Graph 7a: Pushover Curve for Outriggers at Story 10 **Graph 7b:** Capacity-Demand Curve for Outriggers at Story 10

Table 7: Performance Levels for Outriggers at Story 10

Point Found	Yes	T secant	3.103 sec
Shear	30.053 kN	T effective	3.479 sec
Displacement	447.4 mm	Ductility Ratio	2.696378
Sa	0.121426	Effective Damping	0.1369
Sd	291.6 mm	Modification Factor	1.256552

Type 7: Outriggers at Story 8



Graph 8a: Pushover Curve for Outriggers at Story 8 **Graph 8b:** Capacity-Demand Curve for Outriggers at Story 8

Table 8: Performance Levels for Outriggers at Story 8

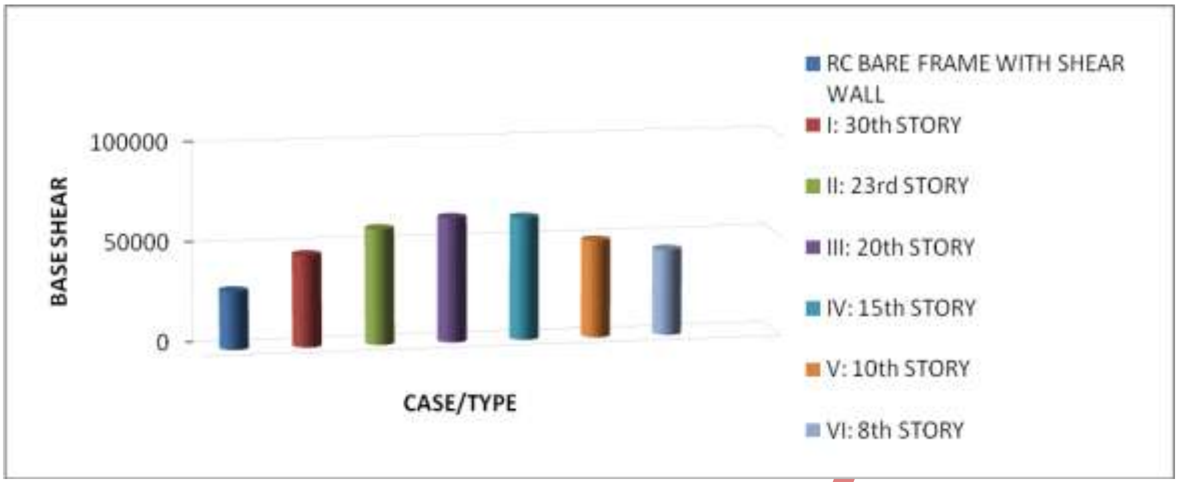
Point Found	Yes	T secant	3.22 sec
Shear	27.4319 kN	T effective	3.59 sec
Displacement	447.3 mm	Ductility Ratio	2.78349
Sa	0.113969	Effective Damping	0.143
Sd	294.8 mm	Modification Factor	1.242043

Table 9: Table Showing Base shear of Bare RC Frame with and without Shear Wall and RC Frame with Outriggers

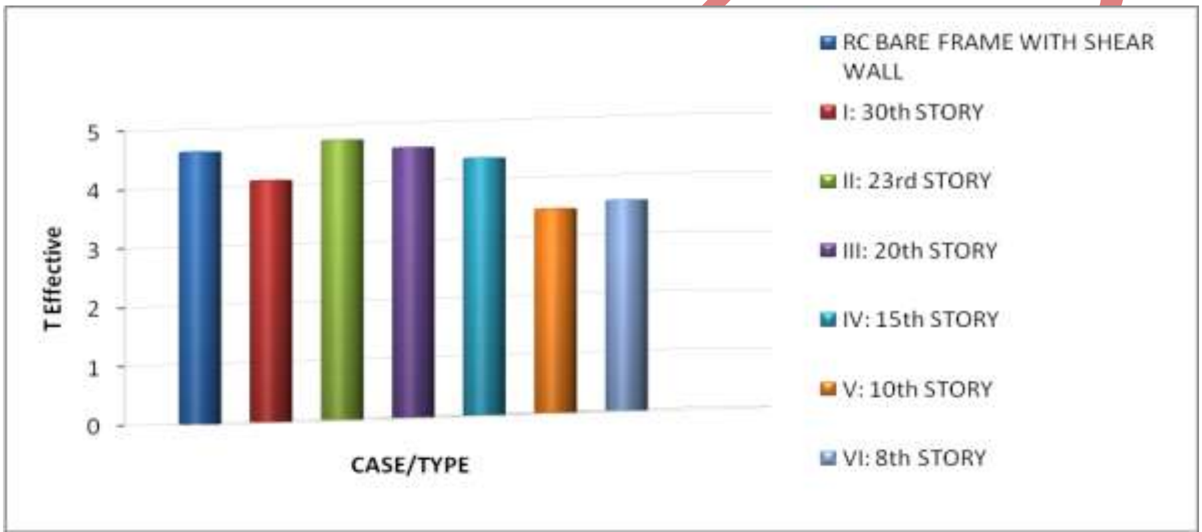
CASE	TYPE	BASE FORCE(KN)
RC BARE FRAME WITH SHEAR WALL		29211.5357
OUTRIGGERS	I: 30th STORY	46108.0616
	II: 23rd STORY	57975.5867
	III: 20th STORY	62516.3765
	IV: 15th STORY	61531.0218
	V: 10th STORY	48880.9934
	VI: 8th STORY	43114.6472

Table 10: Table Showing Values from Capacity Demand Curve of RC Bare Frame and RC Frame with Outriggers

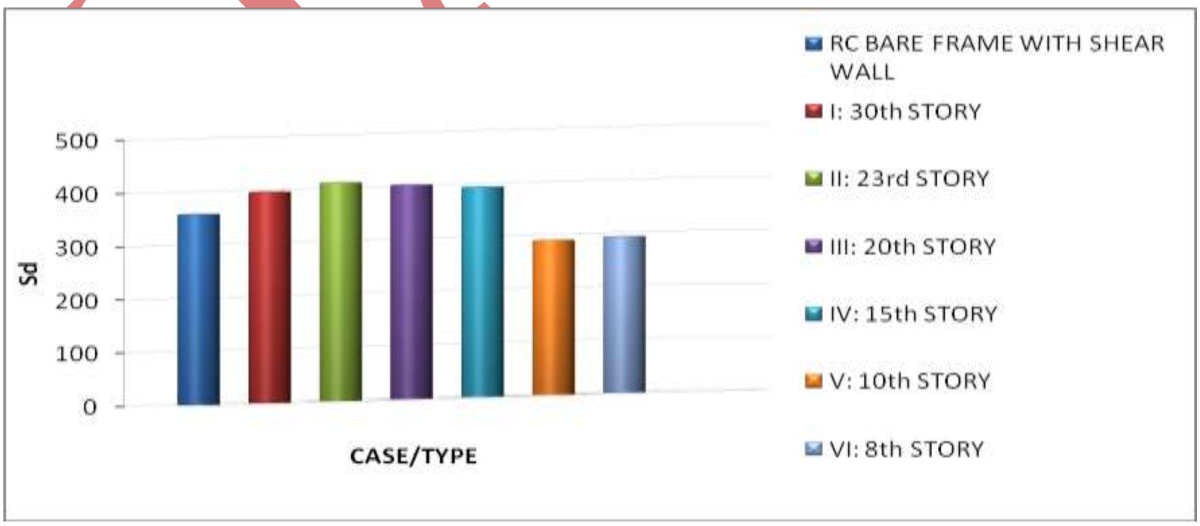
CASE	TYPE	Sd	T efective	Ductility ratio
RC BARE FRAME WITH SHEAR WALL		359.7	4.641	3.389
OUTRIGGERS	I: 30th STORY	398.2	4.117	4.112
	II: 23rd STORY	411.8	4.767	4.632
	III: 20th STORY	403.7	4.6	4.5
	IV: 15th STORY	395.9	4.384	3.758
	V: 10th STORY	291.6	3.48	2.7
	VI: 8th STORY	294.8	3.59	2.78



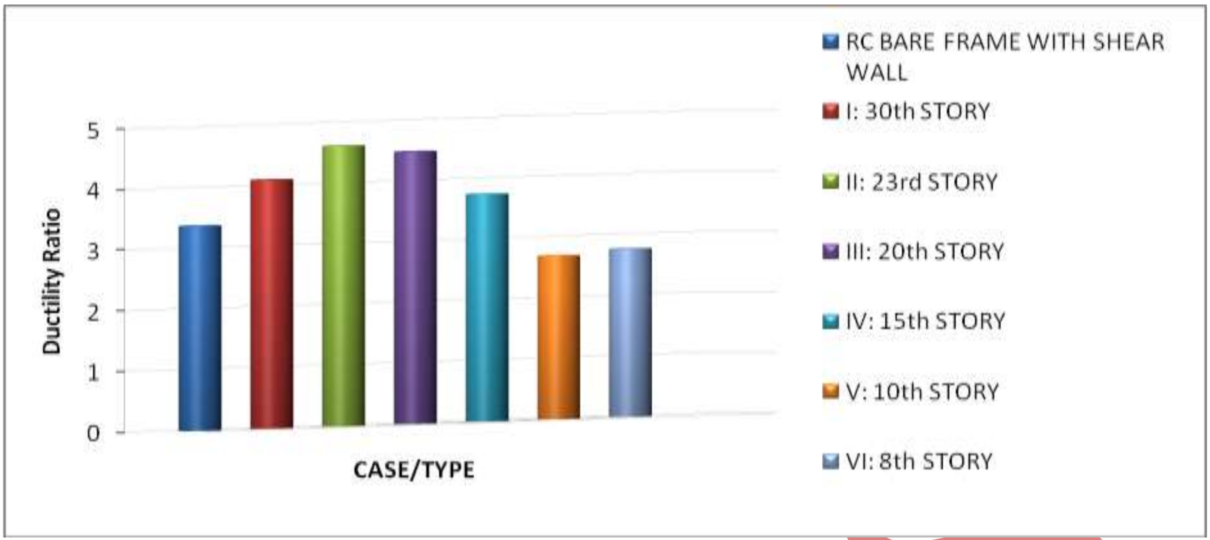
Graph 9: Graph Showing Comparison between the Base Shear of RC Bare Frame and RC Frame with Outriggers



Graph 10: Graph Showing Comparison between the T Effective of RC Bare Frame and RC Frame with Outriggers



Graph 11: Graph Showing Comparison between the SD of RC Bare Frame and RC Frame with Outriggers



Graph 12: Graph Showing Comparison between the Ductility Ratio of RC Bare Frame and RC Frame with Outriggers

V. CONCLUSION

- Graph 1 gives the pushover curve obtained for the RC bare frame and table 1a describes that the maximum base force is 58579.5711KN for a corresponding displacement of 3267.7mm.
- Graph 1 gives the results of displacement and base shear obtained for the analysis I of different positions of the out triggering system, table 1a and 1b describes that the minimum displacement is1040.6mm for corresponding base shear of 61531.50kN for an outrigger.
- Graph 9 gives the results of base shear obtained for controlled displacement of 1040.5mm of the analysis II of different positions of out triggering system. Table 9 describes the base shear of different position of outrigger system; the highest base shear of 62516.3765kN is obtained for out trigger at 20^{th} story.
- It is feasible to provide the Outrigger system at 20^{th} story for highest base shear, displacement of 1040.6mm.
- With reference to capacity demand curve values in table 10, the structure has the spectral acceleration (Sa) of 0.138m/s^2, spectral displacement (Sd) of 403.7mm for the Outriggers at 20^{th} story.
- The values obtained from capacity demand curve of outrigger system at 20^{th} story are within the permissible limits.

REFERENCES

[1] P.M.B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain "Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind And Earthquake Loadings" American Journal of Engineering Research (AJER) Volume-02, Issue-08, pp-76-89

[2] Santhosh D, Pushover Analysis of RC frame structure using ETAB 9.7.1, IOSR journal of mechanical and civil engineering

[3] (IOAS-JMCE)– Volume 11 issue 1-Feb 2014.

[4] Srinivasu A and Dr.Panduranga Rao.B, Non-Linear static analysis of multi-storied building, International journal of engineering trends and technology (ILETT) – volume 4 issue 10-Oct 2013.

[5] M. Seifi., J. Noorzei., and M. S. Jaafar (2008).Nonlinear Static Pushover Analysis in Earthquake Engineering: State of Development.ICCBT

[6] Chopra AK.Dynamics of structure: theory and application to earthquake engineering.(ERnglewood cliffs,NJ:1995)

[7] FEMA-273 (1997)," NEHRP guidelines for the seismic rehabilitation of buildings", developed by the building seismic safety council for the federal emergency management agency , Washington D.C

[8] FEMA-356 (2000), Prestandard and commentary for the seismic rehabilitation of buildings

[9] ATC(1996), "seismic evaluation and retrofit of concrete buildings", volume 1, applied technology council (report no 40), redwood city, California

[10] IS 456-2000, Plain and reinforced concrete code of practice.

[11] IS 1893 (part 1):2002,"criteria for earthquake resistant design of structures" part 1 general provisions and buildings