IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 2 Ver. II (Mar - Apr. 2015), PP 54-63
www.iosrjournals.org

Optimum Position of Outrigger System for Tall Vertical Irregularity Structures

Shivacharan K[1], Chandrakala S [2], Karthik N M[3],
[1](P G Student Department of civil engineering, SJCIT/VTU, India)
[2](Assistant Professor Department of civil engineering, SJCIT/VTU, India)
[3](Assistant Professor Department of civil engineering, CMRIT/VTU, India)

Abstract : *Analysis of the structure is carried out to study the behavior of outrigger and its efficiency for its optimum position at the first and second location. The three dimensional models of outrigger and belt truss system are subjected to wind and earthquake load, analyzed and compared to find the lateral displacement reduction related to the outrigger and belt truss system location. The present work is to study the use of outrigger and belt truss placed at different location subjected to wind and earthquake load. The design of wind load was calculated based on IS 875 (Part 3) and the earthquake load obtained using IS 1893 (Part-1): 2002. The location of outrigger and belt truss for reducing lateral displacement and building drift. To evaluate the performance of vertical irregularities of outrigger structure, a linear static analysis has been conducted by using ETABS2013.5. To achieve this objective, the vertical irregularities structures with 30 stories 7X7bay from 1st to 10th floor 5x5bay from 11th to 20th floor, 3x3bay from 21st to 30th floor with outriggers and belt truss at different stories were analyzed. Compression study of the displacement and drift of the structure is studied. Maximum Storey Shear and Axial Load of different columns are observed for the structure with first and second location of the outrigger.*
Keywords - *vertical irregularities, outrigger, linear static analysis Wind and earthquake load.*

I. Introduction

Mankind is always fascinated for height. At present the symbol of economic power and leadership is the skyscraper. There has been a demonstrated competitiveness that exists in mankind to proclaim to have the tallest building in the world.

The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have gotten taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now expressed in tall buildings across the globe.

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, such as wind. 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.

Vertical Geometric Irregularity

Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey (Table 5, Page 18, IS 1893-2002 Part-1). Fig.1 represents the vertical (elevation) irregularities with abrupt change in geometry.

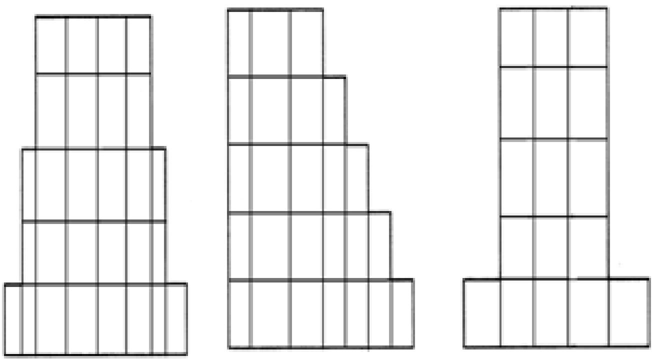

Fig1: Elevation irregularities with abrupt change in geometry

Outriggers

The lateral bracing system consisting of core with outriggers is one of the most efficient systems used for high rise construction to resist lateral forces caused by wind and earthquakes.

Outrigger beams connected to the core and external columns are relatively more complicated and it is understood that the performance of such coupled wall systems depends primarily on adequate stiffness and strength of the outrigger beams. Therefore overall rigidity is imperative in tall buildings in order to control lateral deflection and inter-storey drift.

The integration of the outrigger to the concrete core can be further optimized by guaranteeing concentrated core forces into the outriggers.

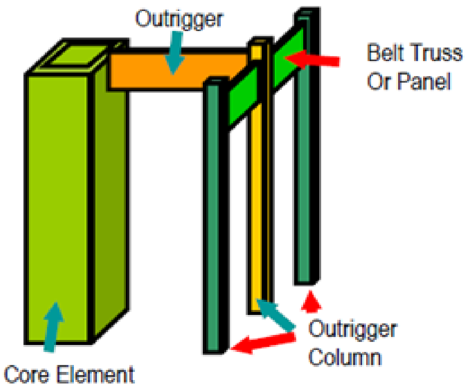

Fig2: Core with Outrigger.

The optimum location and number of the outriggers still remains a crucial but also pending question. This project implements a basic design optimization technique of tall steel structures for lateral loads, mainly wind, into trying to find the optimum locations and number of outriggers for a specific high-rise building. The structure is analyzed for an Earthquake and wind loading. Then the structure is analyzed with all the possible outrigger locations monitoring important factors, such as the drift of the building or the moments on the core.

II. Methodolgy

The Vertical Irregularities building was designed to the gravitational load in a three dimensional model to the structural elements and was analyzed by Etabs software. The concrete core is assigned in the middle of the building, which is surrounded by columns. As of the location of the outriggers, one of them was fixed at the top of the building, incorporating a basic design decision in agreement with the concept of this structural scheme. The goal of this Project is to find the optimum location for the outrigger and that is why the Structure was analyzed "moving" the second outrigger along the height of the building and placing it in all the possible locations. It must be noted here that outrigger trusses are normally one floor high and coincide with mechanical levels, so that they do not interfere with usable space elsewhere.

The basic structural idea behind this scheme is the following. As the lateral loads deform the concrete core into a cantilever, the stiffness of the outrigger levels forces the participation of the exterior columns with the development of a couple of axial forces. The deformation of the core and in extent the drift at the top of the building is restrained by the system of columns and outriggers. The columns act as a couple of axial forces while the outriggers act as very stiff trusses transferring the bending moment of the core into the system of the columns. This is obvious from the comparison of the free cantilever deflection line and the real structure deflection line.

The degree of stiffening and the level of drift control depend on the number of the outrigger trusses. For medium rise and high rise buildings, mechanical floors are generally provided once in 25 stories and provide opportunities for these trusses at those intervals. Although the rule of thumb for the building of is to place the second outrigger at the mid-height of the building, there is no clear indication why this rule applies or where exactly the outrigger should be designed.

Details Of The Model:

Table 1: Model Dimensions

STOREY	DESCRIPTION
1-10	7 X 7 Bay Spacing 5.5m
11-20	5 X 5 Bay Spacing 5.5m
21-30	3 x 3 Bay Spacing 5.5m

Section Properites

- Beam Details:
  Breadth – 230 mm
  Depth – 450 mm
- Slab Details: Thickness – 150 mm
  Live load - 3 kN/m^2
  Floor Finish – 1 kN/m^2
- Shear Wall: Thickness – 300 mm
- Column Details: 1^{st} and 2^{nd} storey 800 x 800mm
  3^{rd} to 5^{th} storey 700 x 700mm
  6^{th} to 10^{th} storey 600 x 600mm
  11^{th} to15^{th} storey 500 x 500mm
  16^{th} to 30^{th} storey 400 x 400mm
- Load Combinations: (DL X LL) X 1.5
  (DL + LL + FL) X 1.5
- Outrigger Property: 300 x 300mm with Belt truss
- Concrete Grade: M_{40}.
- Steel: Fe_{500}.
- Wind load: (IS: 875(Part 3) -1987) – Bhuj
  Design Speed – 50 m/s
  Terrain Category – 3
  Class – B
  Diaphragms – Rigid
- Earth Quake Load:
  (1893(Part 1): 2002) – Bhuj
  Zone V – 0.36
  Importance factor – 1
  Type of soil – Medium Soil
  Reduction Factor – 5
  Mass Source Definition
  Dead Load - 1
  Floor Finish- 1
  Live Load- 0.25

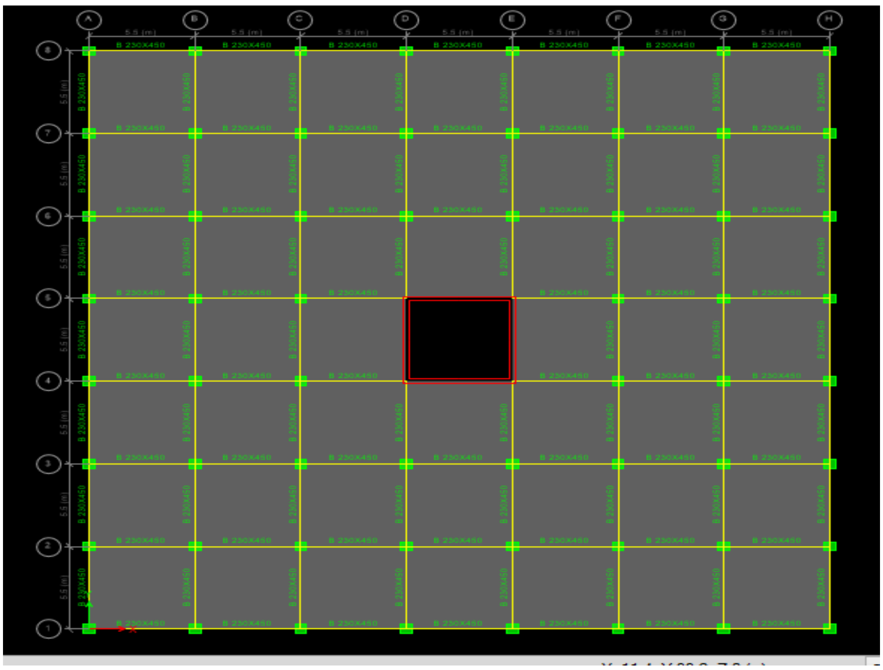

Fig 3: Plan of the Structure.

III. Results And Discussion

Case 1: Bare Frame Analysis and Design

Case 2: Analysis of Bare Frame with outrigger system for the first optimum location.

- Outrigger with Belt truss at 0.25 Position
- Outrigger with Belt truss at 0.33 Position
- Outrigger with Belt truss at 0.5 Position
- Outrigger with Belt truss at 0.67 Position
- Outrigger with Belt truss at 0.75 Position
- Outrigger with Belt truss at top Position

Case 3: Analysis of Bare Frame with outrigger system for Second position keeping first position common at 0.67.

- Outrigger with Belt truss at 0.25 Position
- Outrigger with Belt truss at 0.33 Position
- Outrigger with Belt truss at 0.5 Position
- Outrigger with Belt truss at 0.75 Position
- Outrigger with Belt truss at top Position

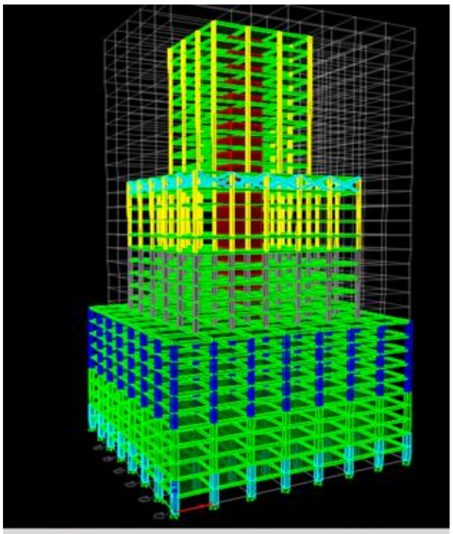

Fig 4: 3D view of structure with outrigger system for the first optimum location.

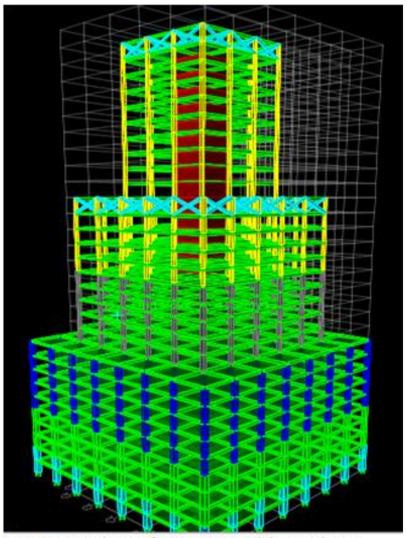

Fig 5: 3D view of structure with outrigger system for the secound optimum location.

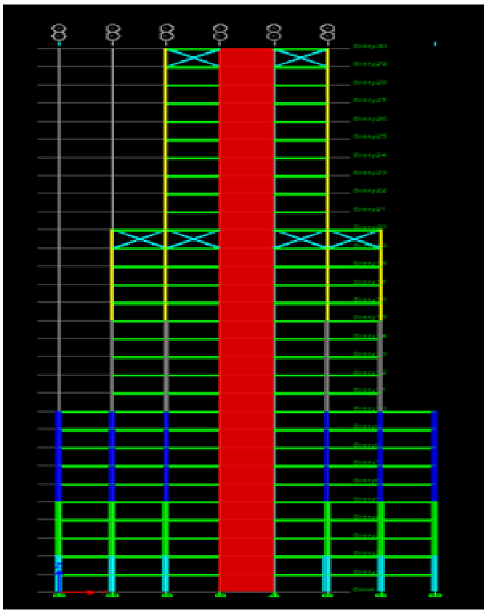

Fig 6: Elevation of a structure near shearwall.

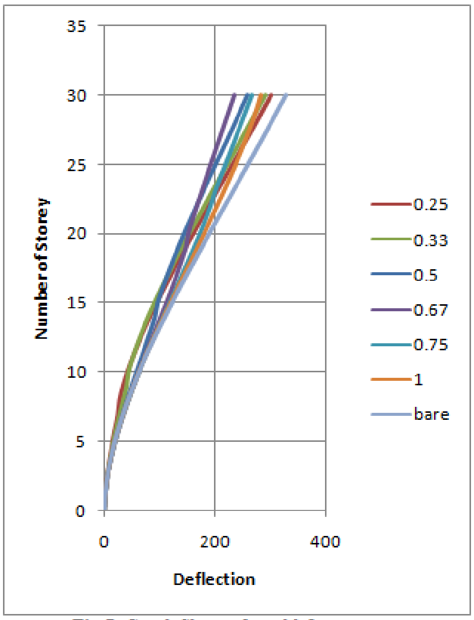

Fig 7: Graph Shown for table2

Table 2 Deflection for Case 1 and Case 2

Story	Outrigger Position						Bare frame
	0.25	0.33	0.5	0.67	0.75	1	
30	300.9	288.6	257.4	233.3	264.5	281.6	326.7
29	287.1	275.2	246.1	224.9	255.1	274.4	313.3
28	273.3	261.7	234.8	216.5	245.6	265.7	299.7
27	259.3	248.1	223.3	208.1	236	256.4	286.1
26	245.2	234.4	211.8	199.6	226.5	246.6	272.4
25	231	220.7	200.2	191.1	217	236.3	258.6
24	216.8	206.9	188.6	182.7	207.6	225.6	244.7
23	202.5	193.1	177.1	174.4	198.3	214.4	230.7
22	188.3	179.3	165.7	166.3	190.7	203	216.7
21	174.2	165.7	154.5	158.4	181.1	191.2	202.8
20	160.2	152.2	143.6	151	171.3	179.6	188.9
19	146.5	139.1	133.1	146.8	161	167.7	175.2
18	133	126.3	122.9	138.6	150.3	155.6	161.7
17	119.8	113.7	113.2	130	139.3	143.4	148.2
16	106.9	101.5	104.1	120.9	128.1	131.2	134.9
15	94.3	89.9	95.9	111.4	116.7	119	121.8
14	82.4	78.8	91.2	101.5	105.4	107	109.1
13	71	68.5	83.3	91.5	94.2	95.2	96.7
12	60.3	59	74.9	81.4	83.1	83.7	84.7
11	50.5	50.5	66.3	71.4	72.4	72.6	73.2
10	41.6	43.3	57.7	61.5	62.1	62.1	62.3
9	34.1	40.2	49.4	52.3	52.5	52.4	52.4
8	27.8	34.4	41.3	43.4	43.4	43.1	43
7	25.1	28.3	33.5	35	34.8	34.5	34.2
6	20.2	22.3	26.1	27.1	26.8	26.5	26.3
5	15.2	16.7	19.3	19.9	19.7	19.4	19.2
4	10.7	11.7	13.3	13.7	13.4	13.2	13
3	6.7	7.2	8.2	8.3	8.1	8	7.8
2	3.4	3.7	4.1	4.1	4	3.9	3.8
1	1.1	1.1	1.3	1.3	1.2	1.2	1.2
0	0	0	0	0	0	0	0

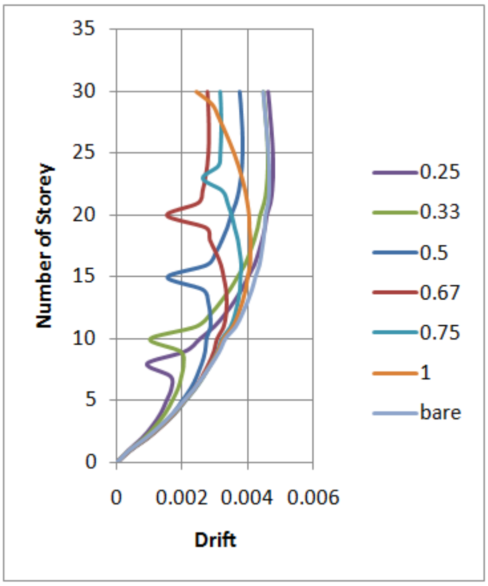

Fig 8: Graph shown for table 2

Table 4: Story shear for Case 1 and case 2

Structure type		Base Shear (kN)
Bare frame		9277.127
Outrigger position	0.25	10854.19
	0.33	11257.26
	0.5	11421.43
	0.67	10974.9
	0.75	10090.48
	1	9632.74

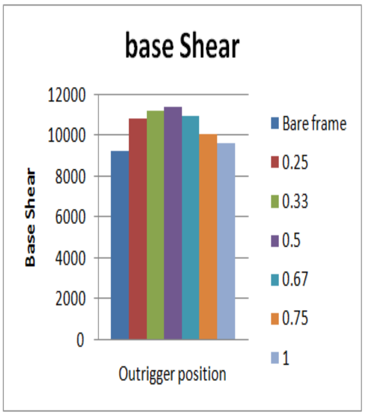

Fig 9: Graph of table 4

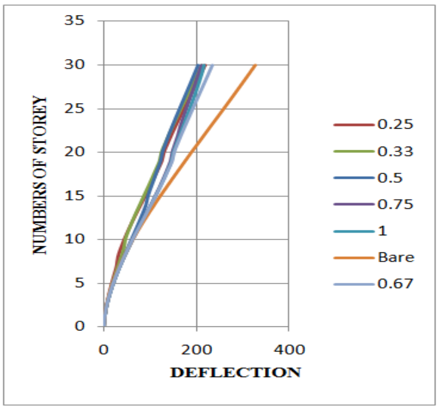

Fig 10: Graph Shown for table5

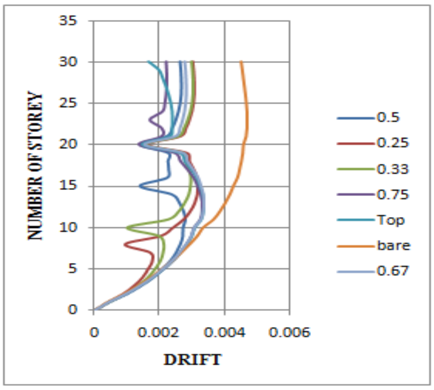

Fig 11: Graph Shown for table

Table 5: Deflection for Case 1 ,Case 2 and Case 3

Story	Outrigger Position					Bare frame	First optimum position
	0.25	0.33	0.5	0.75	1		
30	219.1	211.5	203.5	210.7	215.4	326.7	233.3
29	210	202.6	195.6	204.1	210.5	313.3	224.9
28	200.8	193.7	187.6	197.4	204.6	299.7	216.5
27	191.6	184.7	179.6	190.8	198.3	286.1	208.1
26	182.3	175.6	171.5	184.1	191.7	272.4	199.6
25	173.1	166.6	163.5	177.5	184.9	258.6	191.1
24	163.9	157.7	155.5	171.1	177.9	244.7	182.7
23	154.9	148.9	147.8	164.8	170.8	230.7	174.4
22	146.1	140.4	140.2	159.7	163.6	216.7	166.3
21	137.6	132.2	133	153.5	156.5	202.8	158.4
20	129.7	124.5	126.3	147.3	149.6	188.9	151
19	125.3	120.3	122.4	143.6	145.6	175.2	146.8
18	116.8	112.2	115.6	136.2	137.8	161.7	138.6
17	108	103.8	108.8	128.3	129.5	148.2	130
16	98.8	95.2	101.9	119.8	120.6	134.9	120.9
15	89.3	86.4	95.2	110.6	111.2	121.8	111.4
14	79.7	77.6	91	101.2	101.5	109.1	101.5
13	70.2	69	83.8	91.4	91.6	96.7	91.5
12	60.9	60.7	75.9	81.5	81.6	84.7	81.4
11	52	52.9	67.7	71.6	71.6	73.2	71.4
10	43.7	46.2	59.3	61.9	61.8	62.3	61.5
9	36.5	43.2	51.1	52.7	52.6	52.4	52.3
8	30.3	37.3	42.9	43.8	43.6	43	43.4
7	27.5	30.9	34.9	35.3	35.2	34.2	35
6	22.3	24.6	27.4	27.4	27.3	26.3	27.1
5	17	18.6	20.3	20.2	20.1	19.2	19.9
4	12	13.1	14.1	13.9	13.8	13	13.7
3	7.6	8.1	8.7	8.4	8.4	7.8	8.3
2	3.9	4.2	4.3	4.2	4.2	3.8	4.1
1	1.2	1.3	1.3	1.3	1.3	1.2	1.3
0	0	0	0	0	0	0	0

Table 3 Drift for Case 1 and case 2

Story	Outrigger Position						Bare frame
	0.25	0.33	0.5	0.67	0.75	1	
30	0.004593	0.004461	0.003765	0.002775	0.003144	0.002429	0.004475
29	0.004631	0.004498	0.003797	0.002799	0.003163	0.002902	0.004511
28	0.004662	0.004528	0.003821	0.002815	0.003174	0.003094	0.004542
27	0.004694	0.004559	0.003842	0.002825	0.003178	0.003268	0.004576
26	0.004722	0.004583	0.003855	0.002823	0.003169	0.003431	0.004608
25	0.004742	0.004598	0.003854	0.002806	0.003147	0.00358	0.004634
24	0.00475	0.0046	0.003837	0.00277	0.003089	0.003711	0.004653
23	0.004743	0.004585	0.003799	0.00271	0.002615	0.003823	0.004661
22	0.004718	0.004551	0.003739	0.002629	0.003204	0.003916	0.004656
21	0.004665	0.004486	0.003646	0.002487	0.003368	0.003982	0.004628
20	0.004552	0.004362	0.0035	0.001537	0.003494	0.004033	0.004544
19	0.004499	0.004291	0.003384	0.00273	0.003582	0.004047	0.004527
18	0.004413	0.004185	0.003224	0.002853	0.003682	0.004078	0.004484
17	0.004305	0.004053	0.003036	0.003034	0.003738	0.004074	0.004428
16	0.004177	0.003897	0.002763	0.00319	0.003783	0.004064	0.004363
15	0.00398	0.003669	0.001556	0.003274	0.003758	0.003987	0.004236
14	0.003794	0.003445	0.002632	0.003347	0.003743	0.003929	0.004134
13	0.003557	0.003164	0.002802	0.003368	0.003684	0.00383	0.003996
12	0.003283	0.00285	0.002861	0.003347	0.003592	0.003704	0.003833
11	0.002957	0.002406	0.00287	0.003274	0.003457	0.003538	0.003636
10	0.00252	0.001021	0.002748	0.003069	0.003196	0.003247	0.003316
9	0.002073	0.001937	0.00271	0.002975	0.003062	0.003094	0.00314
8	0.000922	0.002037	0.002603	0.002813	0.002865	0.002879	0.002905
7	0.00163	0.001972	0.002456	0.00262	0.002644	0.002644	0.002654
6	0.001662	0.001868	0.002265	0.002388	0.002391	0.00238	0.002377
5	0.001511	0.001689	0.002004	0.002092	0.00208	0.002062	0.00205
4	0.001338	0.00148	0.001723	0.001784	0.001763	0.001742	0.001724
3	0.001088	0.001192	0.001363	0.001398	0.001374	0.001352	0.001332
2	0.000772	0.000838	0.000939	0.000954	0.00093	0.000911	0.000893
1	0.000357	0.000383	0.000419	0.000421	0.000404	0.000393	0.000385
0	0	0	0	0	0	0	0

Table 4: Story shear for Case 1 and case 2

Structure type		Base Shear (kN)
Bare frame		9277.127
Outrigger position	0.25	10854.19
	0.33	11257.26
	0.5	11421.43
	0.67	10974.9
	0.75	10090.48
	1	9632.74

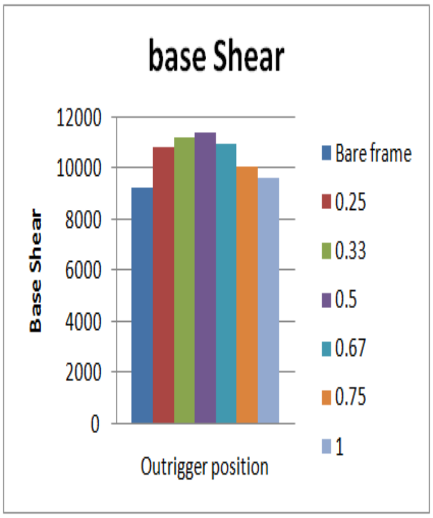

Fig 9: Graph of table 4

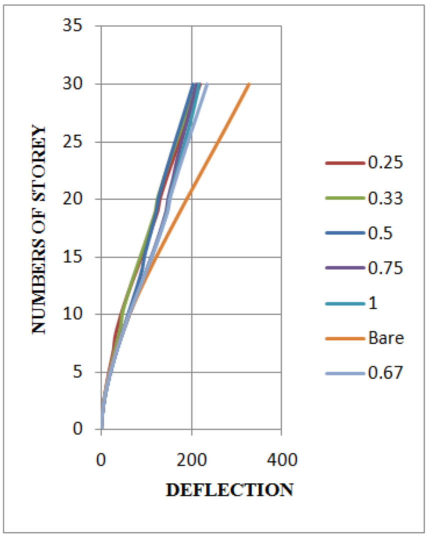

Fig 10: Graph Shown for table5

Table 5: Deflection for Case 1 ,Case 2 and Case 3

Story	Outrigger Position					Bare frame	First optimum position
	0.25	0.33	0.5	0.75	1		
30	219.1	211.5	203.5	210.7	215.4	326.7	233.3
29	210	202.6	195.6	204.1	210.5	313.3	224.9
28	200.8	193.7	187.6	197.4	204.6	299.7	216.5
27	191.6	184.7	179.6	190.8	198.3	286.1	208.1
26	182.3	175.6	171.5	184.1	191.7	272.4	199.6
25	173.1	166.6	163.5	177.5	184.9	258.6	191.1
24	163.9	157.7	155.5	171.1	177.9	244.7	182.7
23	154.9	148.9	147.8	164.8	170.8	230.7	174.4
22	146.1	140.4	140.2	159.7	163.6	216.7	166.3
21	137.6	132.2	133	153.5	156.5	202.8	158.4
20	129.7	124.5	126.3	147.3	149.6	188.9	151
19	125.3	120.3	122.4	143.6	145.6	175.2	146.8
18	116.8	112.2	115.6	136.2	137.8	161.7	138.6
17	108	103.8	108.8	128.3	129.5	148.2	130
16	98.8	95.2	101.9	119.8	120.6	134.9	120.9
15	89.3	86.4	95.2	110.6	111.2	121.8	111.4
14	79.7	77.6	91	101.2	101.5	109.1	101.5
13	70.2	69	83.8	91.4	91.6	96.7	91.5
12	60.9	60.7	75.9	81.5	81.6	84.7	81.4
11	52	52.9	67.7	71.6	71.6	73.2	71.4
10	43.7	46.2	59.3	61.9	61.8	62.3	61.5
9	36.5	43.2	51.1	52.7	52.6	52.4	52.3
8	30.3	37.3	42.9	43.8	43.6	43	43.4
7	27.5	30.9	34.9	35.3	35.2	34.2	35
6	22.3	24.6	27.4	27.4	27.3	26.3	27.1
5	17	18.6	20.3	20.2	20.1	19.2	19.9
4	12	13.1	14.1	13.9	13.8	13	13.7
3	7.6	8.1	8.7	8.4	8.4	7.8	8.3
2	3.9	4.2	4.3	4.2	4.2	3.8	4.1
1	1.2	1.3	1.3	1.3	1.3	1.2	1.3
0	0	0	0	0	0	0	0

Table 6 : Drift for Case 1 ,Case 2 and Case 3

Story	Outrigger Position					Bare frame	First optimum position
	0.25	0.33	0.5	0.75	1		
30	0.003032	0.002643	0.00296	0.002196	0.001655	0.004475	0.002775
29	0.00306	0.002667	0.002987	0.002212	0.001971	0.004511	0.002799
28	0.003077	0.002681	0.003004	0.00222	0.002089	0.004542	0.002815
27	0.003086	0.002686	0.003012	0.002216	0.002189	0.004576	0.002825
26	0.003081	0.002677	0.003005	0.002196	0.002273	0.004608	0.002823
25	0.003056	0.002648	0.002978	0.002158	0.002336	0.004634	0.002806
24	0.003008	0.002595	0.002927	0.002086	0.002375	0.004653	0.00277
23	0.00293	0.002514	0.002846	0.001703	0.002386	0.004661	0.00271
22	0.002825	0.002405	0.002736	0.002056	0.002373	0.004656	0.002629

21	0.002652	0.002235	0.002558	0.002062	0.002297	0.004628	0.002487
20	0.001623	0.001412	0.001556	0.001363	0.001463	0.004544	0.001537
19	0.002843	0.002278	0.002712	0.002463	0.002615	0.004527	0.00273
18	0.002929	0.002271	0.002772	0.002637	0.002763	0.004484	0.002853
17	0.003067	0.002295	0.002879	0.002856	0.002962	0.004428	0.003034
16	0.003168	0.002237	0.002945	0.003045	0.003132	0.004363	0.00319
15	0.003184	0.001406	0.002927	0.003159	0.00323	0.004236	0.003274
14	0.003175	0.002388	0.002878	0.003257	0.003314	0.004134	0.003347
13	0.003099	0.002621	0.002756	0.003302	0.003346	0.003996	0.003368
12	0.002963	0.002745	0.002581	0.0033	0.003333	0.003833	0.003347
11	0.002756	0.002808	0.00226	0.003244	0.003267	0.003636	0.003274
10	0.002422	0.002733	0.001005	0.003055	0.003068	0.003316	0.003069
9	0.002048	0.002729	0.001965	0.002972	0.002979	0.00314	0.002975
8	0.000946	0.00265	0.002117	0.00282	0.00282	0.002905	0.002813
7	0.001718	0.002523	0.002092	0.002633	0.00263	0.002654	0.00262
6	0.001788	0.002345	0.002014	0.002406	0.002399	0.002377	0.002388
5	0.001655	0.002089	0.001846	0.002112	0.002104	0.00205	0.002092
4	0.001486	0.001807	0.001635	0.001804	0.001795	0.001724	0.001784
3	0.001224	0.001438	0.001331	0.001417	0.001408	0.001332	0.001398
2	0.000881	0.000997	0.000946	0.000969	0.000962	0.000893	0.000954
1	0.003032	0.002643	0.00296	0.002196	0.001655	0.004475	0.002775
0	0.00306	0.002667	0.002987	0.002212	0.001971	0.004511	0.002799

Table 7: Base Shear For Case 1, Case 2 and Case 3

STRUCTURE TYPE		Base Shear (kN)
Bare frame		9277.127
Outrigger position	0.25	13153.08
	0.33	13380.01
	0.5	12542.077
	0.75	11286.27
	1	11116.1
	0.67	10974.9

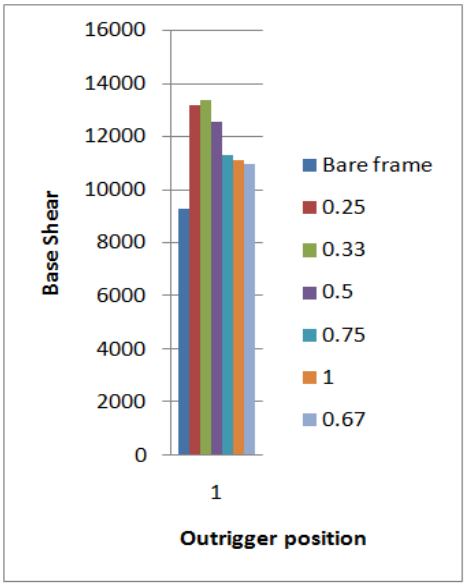

Fig 12: Graph of table 7

Table 8 Deflection of Outrigger Position

optimum position	Deflection
0.25	219.1
0.33	211.5
0.5	203.5
0.75	210.7
1	215.4
Bare	326.7
0.67	233.3

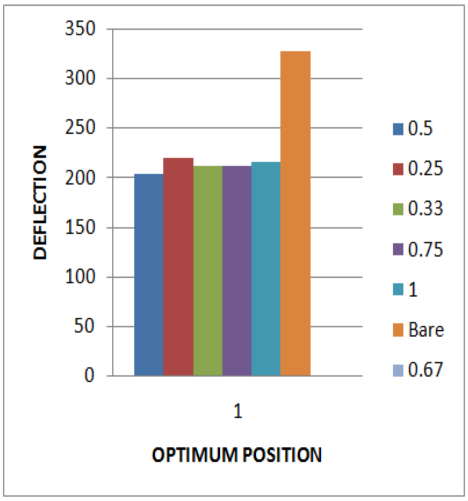

Fig 13: Graph of table 8

IV. Discussion And Conclusion

The most significant basic parameter monitored throughout the whole analysis process was drift and deflection of the building. The following fig 7 and fig 8 shows the variation of drift and deflection: It is observed that 28.58% and 27% of the deflection and drift is controlled by providing one position outrigger at 0.67 height compared to Bare frame. 37.7% and 36.11% of the Deflection and drift is controlled by providing outrigger with belt truss at 0.67 and 0.5 when compared with bare frame. 12.78% and 11.5% of the deflection and drift is controlled by comparing first position outrigger system and second position of outrigger system of the building.

The following conclusions are made from the present study

1- The use of outrigger and belt truss system in high-rise buildings increase the stiffness and makes the structural form efficient under lateral load.
2- The maximum drift at the top of structure when only core is employed is around 326.7 mm and this is reduced by suitably selecting the lateral system. The placing of outrigger at 0.67 height is 233.33mm.
3- Using second outrigger with 0.67h gives the reduction of 11.5% and 12.78% for drift and deflection. The optimum location of second outrigger is middle height of the building.
4- It can be conclude that the optimum location of the outrigger is between 0.5 times its height.
5- For the second optimum position of outrigger base shear is significantly high compared to first optimum position and bare frame with shear wall.(fig 12) shear wall stress and axial load in the columns to the opposite side of the earthquake direction.

References

[1] P.M.B. Raj Kiran Nanduri, B.Suresh, MD. Ihtesham Hussain (2013) "Optimum Position of Outrigger System for High-Rise Reinforced Concrete Buildings Under Wind And Earthquake Loadings"
[2] Mohd Irfan Moinuddin& Mohd Afroz Khan Conducted (2013)"A Study for the Optimum Location of Outriggers for High-Rise Concrete Buildings".
[3] Gerasimidis S., Efthymiou E. & Baniotopoulos C. C. (2009) "Optimum outrigger locations of high-rise steel buildings for wind loading".
[4] N. Herath, N. Haritos, T. Ngo & P. Mendis (2009) "Behaviour of Outrigger Beams in High rise Buildings under Earthquake Loads".
[5] Karthik.N.M, N.Jayaramappa (December 2014)"optimum position of Outrigger system for High Raised RC Buildings using etabs 2013.1.5 (push over analysis)".
[6] WIND LOAD (IS: 875(Part 3) -1987).
[7] EARTHQUAKE LOADS (1893(Part 1): 2002).