Study of Behavior of Tubular Tall Building Subjected To Wind & Earth Forces

Yogesh S. Dhake, V. G. Sayagavi, N. G. Gore

***Abstract*— In this project, Analysis of Tubular tall building has been done using ETABS. It has been presumes that, the only periphery Columns essentially take part in resisting Wind & Earthquake forces and the interior columns transfer gravity load to foundation. This assumption work fairly well in resisting forces. When the outer tube is subjected to Wind & Earthquake forces the flange columns experience the shear lag phenomenon. Also, in this research, we tried to study the maximum deflection & Inter-storey drift, of the tube without and with shear wall and other patterns of shear panels. It has been observed that more shear panels did not cause necessarily displacement of structures but the type of arrangement had important criteria as well.**

***Index Terms*— Concrete frame, Shear lag Phenomenon, Lateral Displacement, Shear panel.**

I. INTRODUCTION

The tubular structure is a relatively new form of high rise structural system. Building got taller as the field of structural engineering progressed and engineers have been hard pressed to find a new form that efficiently and safely carries the lateral loads applied. The tubular structure was the answer to the demand for height and new architectural forms. The design of tubular structures involves engaging the entire perimeter of the building to resist the lateral loads that act on the structure. This involves closely spaced perimeter columns rigidly tied together by significantly deep spandrel beams. It allows great flexibility in the planning of the interior spaced since all the columns and the lateral system is concentrated on the perimeter of the structure.

Before going through detailed analysis let us examine some macro aspects of tubular structures:

1. Tubular structures are designed as a perforated tube comprising of oblique/orthogonal frame panels which are made of closely spaced columns linked by spandrel beams around the perimeter at each floor level.
2. The columns in framed tube structures have centre to centre spacing of 1.5 - 3.0 meters depending upon the geometry of the building
3. Spandrel beams normally 0.5 - 1.2 meter in depth and 0.3 to 1.6 m in width are provided.
4. The spandrel beams and the columns have adequate stiffness stability against lateral sway and also to provide overall strength in the system.
5. Slabs are fairly rigid in their own plane.
6. All elements of frames are taken to be prismatic and of linearly elastic material

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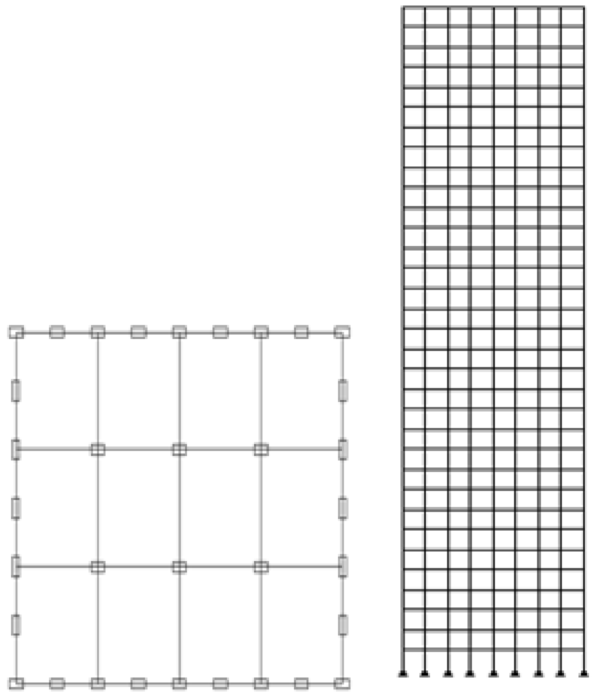
Mr. Yogesh S. Dhake, (PG Student). Department of Civil Engineering, Mahatma Gandhi Mission's College of Engineering and Technology, Navi Mumbai (Maharashtra). India.

Prof V.G. Sayagavi, Department of Civil Engineering, Mahatma Gandhi Mission's College of Engineering and Technology, Navi Mumbai (Maharashtra). India.

Prof N.G. Gore, (Guide), Department of Civil Engineering, Mahatma Gandhi Mission's College of Engineering and Technology, Navi Mumbai (Maharashtra). India.

II. FEATURES OF SAMPLING FRAMES

In present study, in this section a hypothetical 32 stories framed tube structure has been solved. The plan dimension of the tube is 24 x 18m with columns at 3m center to center and 3m floor to floor height is considered. The structure is 96m high and is assumed to be located in seismic zone III on a medium soil. The plan and elevation of the tubular tall building is shown in "Fig 1".as below



(a) Plan (b) Elevation

"Fig. 1" Plan and Elevation of the building to be considered for analysis

Table I. The Size of Beams and Columns

32-Storey Frame type	Column (m)	Beam (m)
1 – 4	0.5 x 1.00	0.5 x 0.5
5 – 13	0.5 x 0.9	0.5 x 0.5
14 – 22	0.5 x 0.8	0.5 x 0.5
23 - 32	0.5 x 0.7	0.5 x 0.5

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Table II Specification of Materials

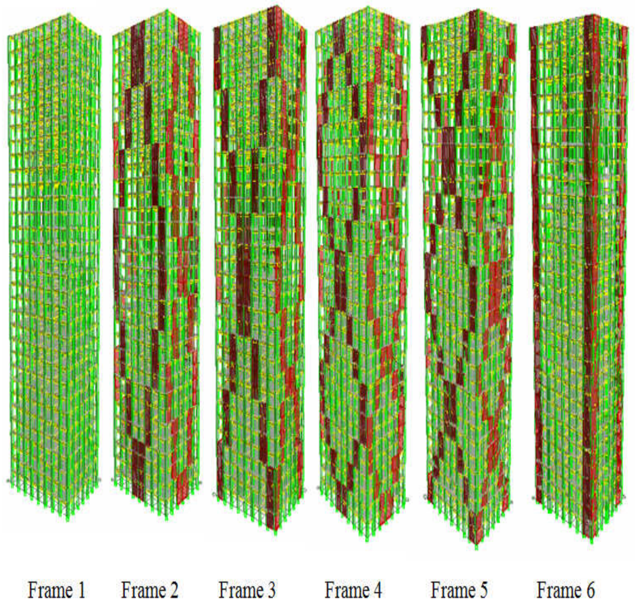
Compressive Strength of Concrete	$f_{ck} = 30$
Modulus of Elasticity of Concrete	E = 27386.127
Concrete Poisson's Ratio	$\upsilon = 0.2$
Unit Weight of concrete	W = 25 kN/m^2

The wind load its taken as per IS 875 (part3)-1987. For estimation following constants have been adopted as k1(Risk coefficient) = 1, k2(Terrain, height & structure height factor), k3(Topography factor) = 1, V_b(basic wind speed) = 44 m/s.

The earthquake load is taken as per IS 1893-2002. For estimation zone factor = 0.16, Importance factor = 1, Type of soil = medium & Response reduction factor = 5.

a. Different arrangement of shear wall panel

So our aim is to find how a framed tube structure with different types of shear wall panel can give better results than ordinary framed tube structure. For this purpose the following shear panel's arrangements were suggested for 32-Storey Frames "Fig 2".



"Fig.2" Different Arrangement of Shear Panel

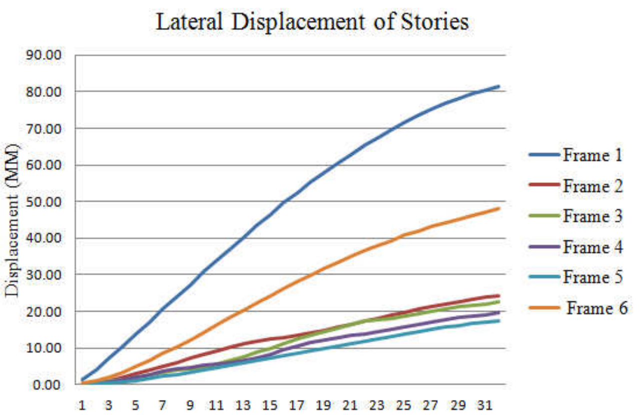
III. Structural Analysis

Structural analysis was carried out by means of well known computer program ETABS which is used for the linear structural analysis of buildings subjected to static loads and dynamic earthquake loads, is documented. Efficient model formulation and problem solution is achieved by idealizing the building as a system of frame and shear wall substructures inter connected by floor diaphragms.

The lateral displacement of the stories due to wind & Earthquake forces is shown in the following Table III & Table IV.

Table III Lateral Displacements (Wind load)

Storey	Displacement of Storey (MM)					
	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6
1	1.39	0.11	0.19	0.11	0.12	0.32
2	4.06	0.26	0.53	0.25	0.23	1.05
3	7.15	0.92	0.91	0.66	0.46	2.11
4	10.39	1.84	1.24	1.18	0.75	3.41
5	13.76	2.87	1.78	1.89	1.15	4.92
6	17.16	3.89	2.53	2.70	1.65	6.59
7	20.56	4.92	3.33	3.48	2.20	8.39
8	23.95	6.04	4.04	4.14	2.74	10.28
9	27.31	7.14	4.27	4.70	3.38	12.23
10	30.64	8.09	4.54	5.24	4.06	14.23
11	33.92	9.05	5.43	5.52	4.66	16.25
12	37.13	10.08	6.53	5.83	5.25	18.28
13	40.29	11.06	7.69	6.52	5.92	20.30
14	43.47	11.88	8.82	7.30	6.59	22.30
15	46.57	12.35	9.93	8.31	7.22	24.27
16	49.57	12.88	11.13	9.41	7.91	26.20
17	52.47	13.43	12.32	10.50	8.60	28.08
18	55.26	13.98	13.42	11.49	9.27	29.91
19	57.94	14.77	14.43	12.23	9.94	31.67
20	60.50	15.64	15.44	12.90	10.62	33.36
21	62.94	16.53	16.40	13.31	11.12	34.98
22	65.27	17.37	17.22	13.74	11.76	36.53
23	67.54	18.10	17.64	14.35	12.42	38.02
24	69.68	18.92	18.07	14.98	13.07	39.42
25	71.67	19.74	18.74	15.62	13.69	40.74
26	73.51	20.54	19.44	16.29	14.32	41.99
27	75.20	21.28	20.12	16.97	14.95	43.16
28	76.74	22.01	20.73	17.63	15.56	44.25
29	78.13	22.71	21.18	18.18	16.09	45.29
30	79.36	23.35	21.62	18.70	16.59	46.26
31	80.44	23.82	22.07	19.12	16.97	47.20
32	81.39	24.28	22.51	19.53	17.35	48.09



"Fig.3" Lateral displacement of stories (Wind load)

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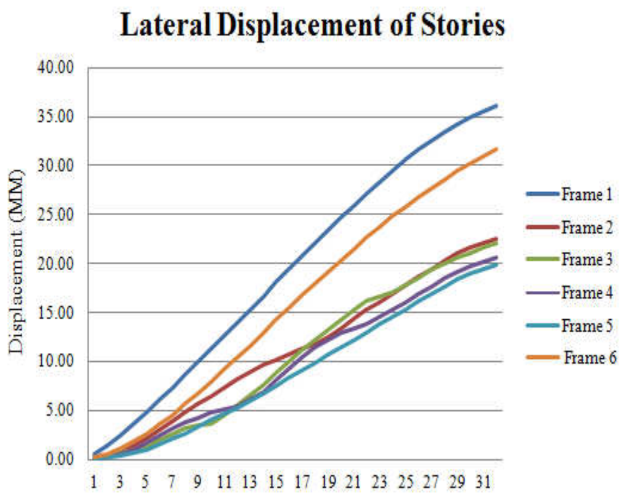
Table IV Lateral Displacements (Earthquake load)

Displacement of Storey (MM)						
Floor	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6
1	0.47	0.08	0.14	0.09	0.09	0.16
2	1.38	0.19	0.39	0.21	0.18	0.55
3	2.46	0.71	0.66	0.58	0.38	1.11
4	3.60	1.42	0.90	1.04	0.65	1.82
5	4.82	2.22	1.33	1.68	1.04	2.64
6	6.07	3.04	1.93	2.42	1.54	3.57
7	7.35	3.88	2.60	3.12	2.09	4.58
8	8.64	4.79	3.20	3.73	2.64	5.66
9	9.96	5.68	3.42	4.26	3.32	6.80
10	11.28	6.46	3.69	4.79	4.05	7.97
11	12.61	7.27	4.51	5.09	4.69	9.18
12	13.95	8.15	5.53	5.42	5.32	10.42
13	15.30	9.00	6.61	6.13	6.05	11.67
14	16.68	9.74	7.69	6.95	6.78	12.93
15	18.06	10.20	8.79	8.01	7.50	14.20
16	19.43	10.71	9.97	9.19	8.29	15.47
17	20.78	11.24	11.15	10.35	9.10	16.72
18	22.12	11.77	12.24	11.42	9.88	17.96
19	23.43	12.56	13.27	12.23	10.69	19.18
20	24.71	13.45	14.32	12.97	11.52	20.38
21	25.95	14.37	15.33	13.42	12.22	21.54
22	27.16	15.25	16.19	13.89	12.94	22.67
23	28.36	16.04	16.63	14.59	13.76	23.77
24	29.52	16.91	17.07	15.32	14.55	24.83
25	30.61	17.81	17.82	16.07	15.32	25.84
26	31.64	18.67	18.61	16.88	16.12	26.80
27	32.60	19.47	19.37	17.69	16.92	27.72
28	33.48	20.26	20.07	18.47	17.68	28.58
29	34.27	21.02	20.58	19.11	18.35	29.41
30	34.97	21.71	21.09	19.71	18.98	30.18
31	35.58	22.16	21.62	20.17	19.44	30.93
32	36.10	22.61	22.14	20.62	19.90	31.64



"Fig.4" Lateral displacement of stories (Earthquake load)

The Shear lag phenomenon in the flange columns of the Frames due to wind & Earthquake forces are shown in the following Table V & Table 6. To investigate the shear-lag phenomenon in the columns of the flange frame panel, the ratio of the axial force in the central column and that in the corner column is considered. The value of ratio is greater than unity then it indicates a negative shear-lag. Otherwise, a positive shear-lag is indicated. The storey level at which ratio is equal to unity represents the level of shear-lag reversal.

Table V Shear lag in Flange Columns (Wind Load)

Shear Lag In flange Columns (Wind)						
Floor	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6
1	1.05	0.62	1.31	1.76	0.47	1.26
2	1.05	0.61	1.38	3.97	0.24	1.32
3	1.06	0.56	1.54	0.96	0.89	1.35
4	1.07	0.26	3.97	0.94	0.85	1.37
5	1.07	0.94	0.92	0.91	2.15	1.50
6	1.08	0.88	0.91	0.89	1.63	1.52
7	1.09	2.19	0.90	0.21	2.63	1.53
8	1.10	1.73	0.87	0.47	2.72	1.54
9	1.11	1.80	0.82	0.47	1.53	1.54
10	1.11	1.95	0.79	0.23	2.15	1.55
11	1.12	0.74	0.76	2.79	0.77	1.55
12	1.13	0.72	0.73	2.59	0.73	1.55
13	1.14	1.87	0.17	0.85	0.68	1.55
14	1.15	1.70	0.45	0.80	0.63	1.70
15	1.16	1.51	1.33	2.24	0.36	1.70
16	1.17	1.43	1.11	1.82	0.87	1.71
17	1.17	1.36	1.19	1.70	0.96	1.71
18	1.19	1.31	1.65	2.14	0.61	1.72
19	1.20	1.31	0.61	0.68	1.02	1.73
20	1.21	1.81	0.31	0.61	0.95	1.72
21	1.23	0.57	1.42	1.70	0.90	1.69
22	1.24	0.51	1.34	2.95	0.83	1.66
23	1.26	1.33	1.27	0.13	2.41	1.81
24	1.23	1.15	1.24	0.51	1.74	1.76
25	1.21	1.10	1.23	0.52	2.58	1.72
26	1.18	1.44	1.18	0.33	2.68	1.69
27	1.16	0.33	1.09	1.59	1.41	1.65
28	1.14	0.48	0.96	1.42	2.14	1.62
29	1.12	0.21	4.33	1.25	0.52	1.58
30	1.10	0.45	3.59	1.05	-0.96	1.55
31	1.10	0.53	3.45	3.52	-0.53	1.53
32	1.16	0.61	3.70	4.28	0.51	2.13

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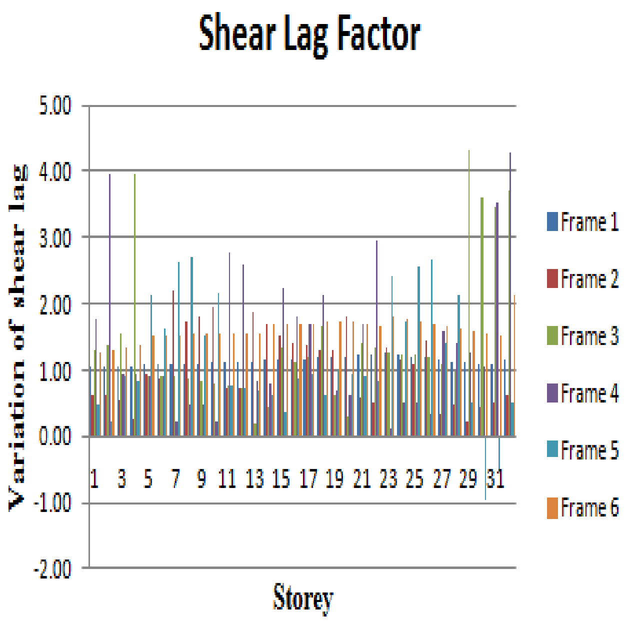
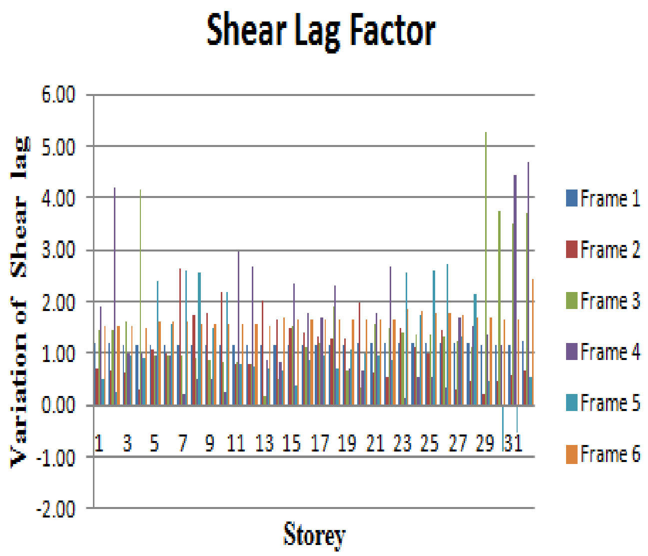


"Fig.5" Shear lag in Flange columns (Wind Load)

Table VI Shear lag in flange columns (Earthquake force)

Shear Lag In Flange Columns (EQ)						
Floor	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**
1	1.19	0.69	1.45	1.88	0.50	1.51
2	1.18	0.68	1.47	4.21	0.26	1.52
3	1.18	0.64	1.59	1.00	0.96	1.51
4	1.17	0.30	4.17	0.99	0.91	1.50
5	1.17	1.08	0.97	0.95	2.38	1.61
6	1.17	1.02	0.97	0.93	1.58	1.60
7	1.17	2.62	0.95	0.22	2.58	1.59
8	1.16	1.75	0.93	0.49	2.57	1.58
9	1.16	1.78	0.87	0.49	1.48	1.58
10	1.16	2.19	0.84	0.25	2.20	1.57
11	1.16	0.80	0.81	2.96	0.79	1.56
12	1.16	0.77	0.78	2.68	0.75	1.55
13	1.16	2.03	0.19	0.88	0.70	1.54
14	1.16	1.63	0.49	0.84	0.65	1.68
15	1.16	1.48	1.53	2.35	0.38	1.67
16	1.17	1.40	1.12	1.77	0.88	1.67
17	1.17	1.34	1.19	1.68	0.95	1.66
18	1.17	1.29	1.91	2.31	0.69	1.66
19	1.18	1.29	0.65	0.73	1.08	1.66
20	1.18	1.99	0.34	0.65	1.01	1.66
21	1.19	0.63	1.55	1.79	0.94	1.66
22	1.19	0.56	1.47	2.69	0.87	1.66
23	1.20	1.50	1.40	0.14	2.53	1.85
24	1.20	1.12	1.36	0.52	1.72	1.81
25	1.21	1.00	1.36	0.54	2.61	1.79
26	1.21	1.43	1.31	0.35	2.72	1.76
27	1.19	0.29	1.22	1.69	1.34	1.74
28	1.18	0.45	1.11	1.52	2.16	1.71
29	1.17	0.22	5.26	1.37	0.45	1.69
30	1.17	0.48	3.75	1.15	-0.91	1.66
31	1.17	0.57	3.49	4.45	-0.53	1.66
32	1.24	0.65	3.71	4.68	0.53	2.44



"Fig.6" Shear lag in flange columns (Earthquake Forces)

The Inter-Storey Drift due to wind & Earthquake forces are shown in the following Table VII & Table VIII.

Table VII Inter-Storey Drift (Wind Load)

Inter-Storey Drift (MM)						
Floor	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**
1	0.705	0.053	0.096	0.055	0.058	0.160
2	1.365	0.076	0.171	0.070	0.059	0.367
3	1.583	0.332	0.188	0.207	0.116	0.526
4	1.658	0.459	0.163	0.258	0.143	0.651
5	1.731	0.515	0.274	0.356	0.199	0.755
6	1.743	0.512	0.372	0.404	0.251	0.836
7	1.743	0.515	0.402	0.388	0.273	0.899
8	1.738	0.561	0.355	0.333	0.269	0.945
9	1.725	0.548	0.113	0.277	0.320	0.978
10	1.706	0.477	0.134	0.269	0.343	0.999

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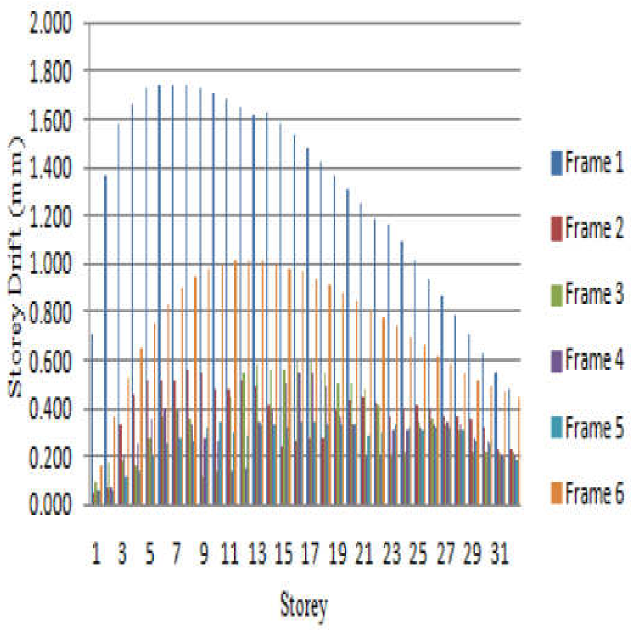
11	1.681	0.481	0.449	0.140	0.300	1.010
12	1.650	0.511	0.546	0.155	0.292	1.013
13	1.618	0.490	0.579	0.345	0.337	1.009
14	1.629	0.411	0.566	0.394	0.333	1.002
15	1.586	0.237	0.558	0.503	0.318	0.986
16	1.538	0.263	0.598	0.550	0.343	0.965
17	1.485	0.277	0.595	0.546	0.349	0.940
18	1.430	0.275	0.549	0.493	0.336	0.911
19	1.371	0.391	0.505	0.370	0.335	0.880
20	1.311	0.438	0.508	0.335	0.337	0.847
21	1.249	0.446	0.478	0.207	0.282	0.812
22	1.188	0.419	0.409	0.212	0.293	0.776
23	1.162	0.368	0.210	0.308	0.329	0.741
24	1.091	0.404	0.214	0.315	0.324	0.701
25	1.016	0.415	0.338	0.321	0.309	0.662
26	0.941	0.399	0.351	0.336	0.317	0.623
27	0.864	0.368	0.337	0.340	0.316	0.585
28	0.786	0.366	0.305	0.327	0.307	0.549
29	0.706	0.351	0.224	0.275	0.265	0.517
30	0.627	0.322	0.222	0.260	0.250	0.488
31	0.549	0.233	0.223	0.208	0.191	0.466
32	0.483	0.229	0.222	0.206	0.187	0.449



"Fig.7" Inter-Storey Drift (Wind Load)

Table VIII Inter-Storey Dift (Earthquake Load)

Floor	Inter-Storey Drift (MM) Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6
1	0.197	0.018	0.032	0.019	0.019	0.056
2	0.387	0.028	0.058	0.026	0.018	0.132
3	0.457	0.123	0.064	0.078	0.040	0.191
4	0.488	0.170	0.055	0.099	0.052	0.240
5	0.519	0.193	0.101	0.138	0.079	0.282
6	0.533	0.196	0.140	0.156	0.100	0.317
7	0.544	0.201	0.154	0.150	0.110	0.346
8	0.552	0.218	0.140	0.131	0.111	0.369
9	0.559	0.213	0.053	0.113	0.135	0.387
10	0.564	0.187	0.062	0.112	0.146	0.402
11	0.568	0.195	0.192	0.064	0.129	0.413
12	0.571	0.211	0.235	0.071	0.126	0.421
13	0.572	0.205	0.252	0.152	0.146	0.427
14	0.589	0.176	0.251	0.175	0.145	0.432
15	0.588	0.110	0.256	0.227	0.145	0.433
16	0.583	0.123	0.275	0.250	0.158	0.432
17	0.577	0.128	0.274	0.250	0.162	0.429
18	0.569	0.127	0.254	0.227	0.157	0.424
19	0.558	0.189	0.240	0.173	0.163	0.417
20	0.545	0.215	0.245	0.159	0.165	0.409
21	0.531	0.221	0.234	0.097	0.140	0.399
22	0.515	0.210	0.201	0.099	0.145	0.388
23	0.514	0.190	0.101	0.151	0.163	0.376
24	0.493	0.211	0.103	0.155	0.161	0.362
25	0.467	0.217	0.174	0.162	0.154	0.347
26	0.439	0.207	0.185	0.172	0.160	0.331
27	0.409	0.191	0.179	0.175	0.160	0.314
28	0.375	0.192	0.161	0.168	0.154	0.298
29	0.340	0.183	0.121	0.137	0.134	0.282
30	0.301	0.165	0.121	0.129	0.126	0.268
31	0.261	0.110	0.123	0.097	0.095	0.256
32	0.224	0.108	0.122	0.097	0.093	0.247

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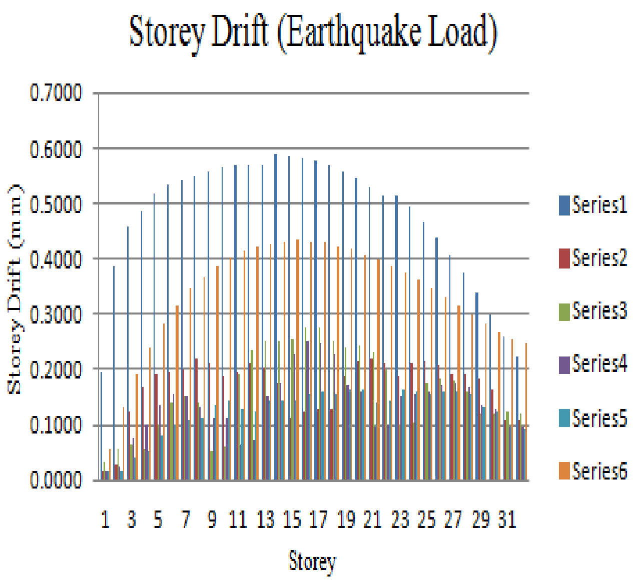

"Fig.8" Inter-Story Drift (Earthquake Load)

IV. CONCLUSION

Based on present investigation the following conclusions are drawn

- In a general point of view, the lateral displacement in mentioned frames due to Wind & Earthquake forces, the performance of the frame 5 was found to be more effective than other frames.
- The above investigation also help us to understand the Shear Lag Phenomena in high rise framed tubular building having columns with different cross sections & with different types of shear wall panel arrangement, the results obtained were in terms of variation of axial forces along height which indicates the occurrence of both Positive & Negative Shear Lag.
- In case of Inter-Storey Drift in the mentioned frames due to Wind & Earthquake Forces, the performance of the frame 5 was found to be more effective as compared to other frames.
- The conclusion indicates that more shear panels did not cause necessarily displacement of structures but the type of arrangement had important criteria as well.

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