Seismic Analysis of High-Rise Irregular RC Frame Structure Using ETABS

Anuj D. Bhavsar[1], Deep K. Bhavsar[2], prof. Vivek P. Patel[3]
[1, 2, 3] Dept of Civil Engineering
[1, 2, 3] Alpha college of Engineering and Technology

Abstract- *In recent times skyscrapers have become usual. It is a challenging part to resist lateral loads acting on it. Our project deals with analysis of seismic characteristics in Irregular shaped R.C. frame. It is required to provide adequate stiffness for resisting the building against the lateral load. It is essential to find effective shape of a building to provide life safety and collapse prevention. We have worked on different plan irregularities of the structures and found out different parameters like storey forces, storey displacement storey shear and storey drift. Analysis of different parameters have been carried out by "ETABS" Software. By analyzing different parameters of building we will compare all types of plan irregularities by the result obtained from ETABS (2016).*

Keywords- R.C. frame, Seismic load, Plan irregularity, Diaphragm discontinuity, Re-entrant corners, Storey displacement, Storey shear, Storey drift, etc.

I. INTRODUCTION

Nowadays requirement of Irregular Building has been increased to make buildings aesthetically attractive and due to lack of land availability. It is difficult to construct Irregular shaped buildings, but due to advancement in construction technology and using different software the problem is reduced. To analyse these types of structures, it is essential to consider different type of loads. The loads which are acting on the building and structure can be classified as vertical load, horizontal load, and longitudinal loads. The vertical load such as dead load, live load, impact load. The horizontal loads (lateral forces) consist of wind load and earthquake load. In these earthquake load is most severe and unpredictable. Earthquake causes major losses of lives and property. According to severity of intensity of earthquake our nation is divided into different zones.

There are mainly two types of irregularities.

1. Diaphragm Discontinuity:

According to IS-1893:2002: Diaphragms with abrupt discontinuities or variations in stiffness, which includes those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next. Lateral loads are usually wind and earthquake loads. Two primary types of diaphragm are rigid and flexible. Flexible diaphragms resist lateral forces. Rigid diaphragms transfer load to frames or shear walls. Flexibility of a diaphragm affects the distribution of lateral forces to the vertical components of the lateral force resisting elements in a structure.

2. Re-entrant Corners:

A structure with lateral load resisting system contains Re-entrant corners. Where both projections of the structure beyond the Re-entrant corners are greater than 15% of its plan dimensions.

Introduction of ETABS:

In this modern time where computer is necessary in every phase of life, the use of traditional book system for analytical development is no longer sufficient. Construction and design are so important that use of computers has become mandatory. ETABS is a sophisticated and easy to use software. ETABS is one of the most useful tool for structural engineers in the building industry.

II. PROBLEM FORMULATION

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases must be considered for analysis:

1.5 (DL + IL)
1.2 (DL + IL ± EL)
1.5 (DL ± EL)
0.9DL ± 1.5 EL

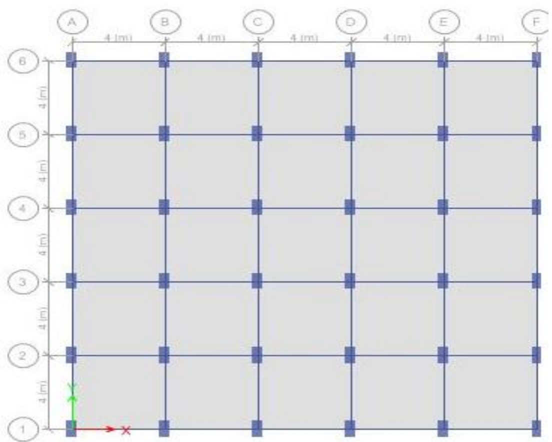
The most affecting load combination is the last one.

Frame Specifications:

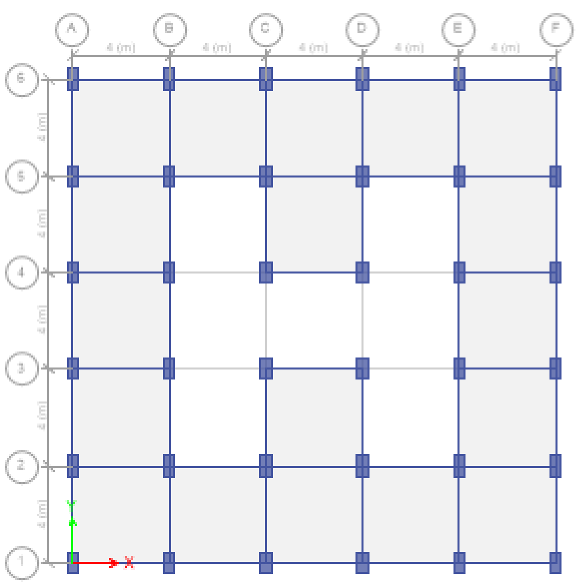
- Type of structure: Ordinary moment resisting frame
- Number of stories: 20

- Number of Grid Lines in X direction: 6
- Number of Grid Lines in Y direction: 6
- Spacing Between Grids: 4 m
- Seismic zone: V
- Floor height: 3 m
- Grade of concrete: 30 MPa
- Grade of steel: Fe500
- Size of columns: 400mmx800mm
- Size of beams: 300mmx600mm
- Depth of slab: 150mm
- Floor Finish: 1Kn/m^2
- Imposed load: 2Kn/m^2
- Importance factor: 1.5
- Site Type: 1
- Response reduction factor: 3

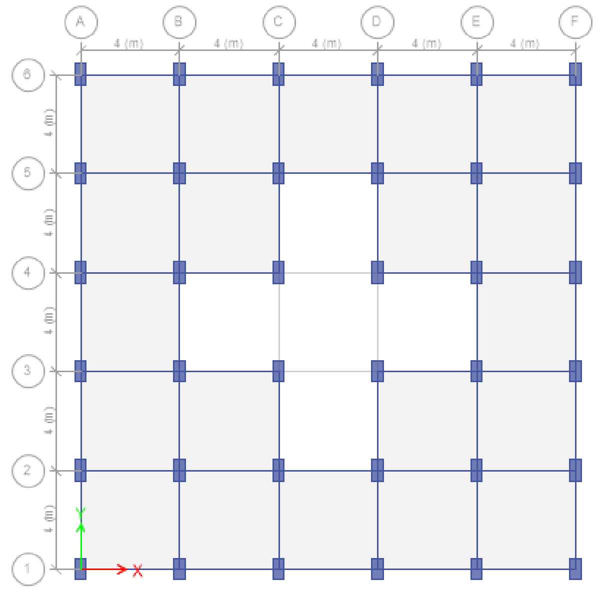
Plans we have analyzed for diaphragm discontinuity:



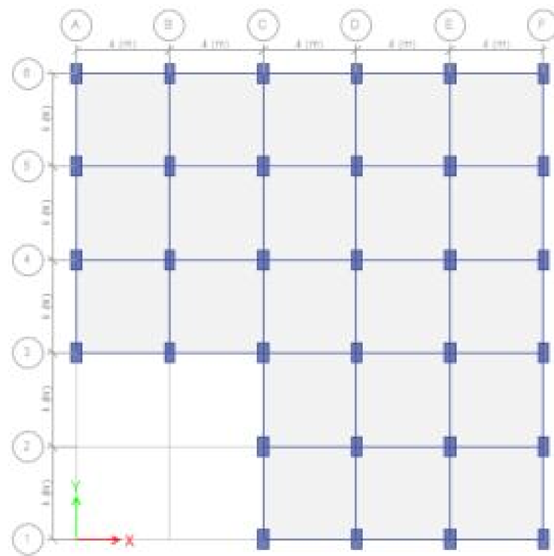
"Regular Shape"



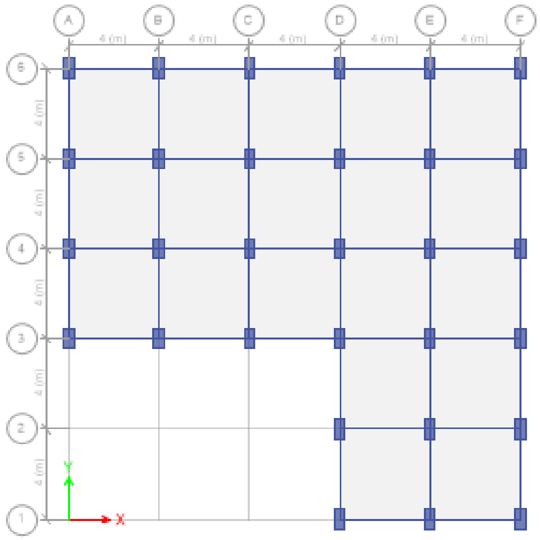
"H-Shape"



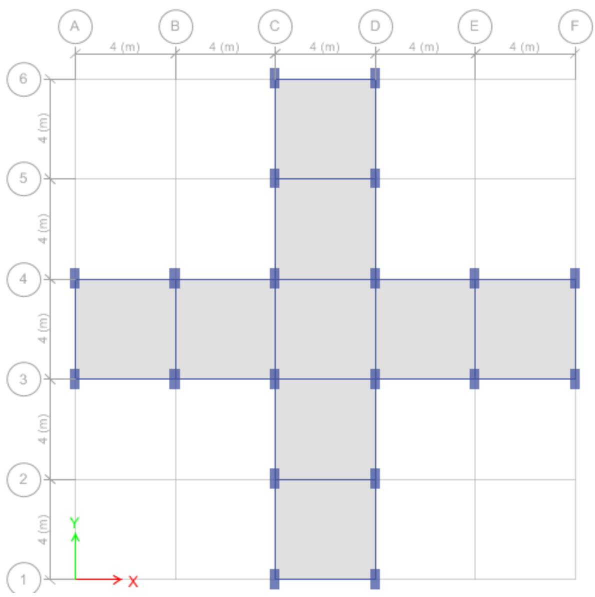
"+-Shape"



"40% Re-entrant"



"60% Re-entrant"



"+ Shape Re-entrant"

Storey Displacement in X-Direction						
No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	56.27	79.92	82.24	83.40	86.68	83.35
19	54.93	78.20	80.32	81.65	84.65	81.13
18	53.27	75.99	77.97	79.39	82.13	78.57
17	51.30	73.30	75.14	76.61	79.11	75.56
16	49.03	70.18	71.88	73.38	75.64	72.14
15	46.50	66.69	68.24	69.76	71.78	68.36
14	43.74	62.87	64.27	65.79	67.58	64.26
13	40.79	58.77	60.02	61.53	63.09	59.90
12	37.69	54.44	55.54	57.02	58.37	55.32
11	34.46	49.93	50.87	52.32	53.46	50.57
10	31.13	45.27	46.06	47.47	48.41	45.70
9	27.74	40.51	41.15	42.51	43.26	40.74
8	24.31	35.69	36.19	37.47	38.06	35.74
7	20.87	30.84	31.20	32.41	32.84	30.74
6	17.43	26	26.23	27.34	27.63	25.78
5	14.03	21.19	21.31	22.31	22.48	20.88
4	10.68	16.44	16.47	17.34	17.42	16.09
3	7.42	11.79	11.75	12.45	12.46	11.44
2	4.301	7.265	7.192	7.689	7.655	6.974
1	1.545	2.977	2.917	3.164	3.135	2.815
0	0	0	0	0	0	0

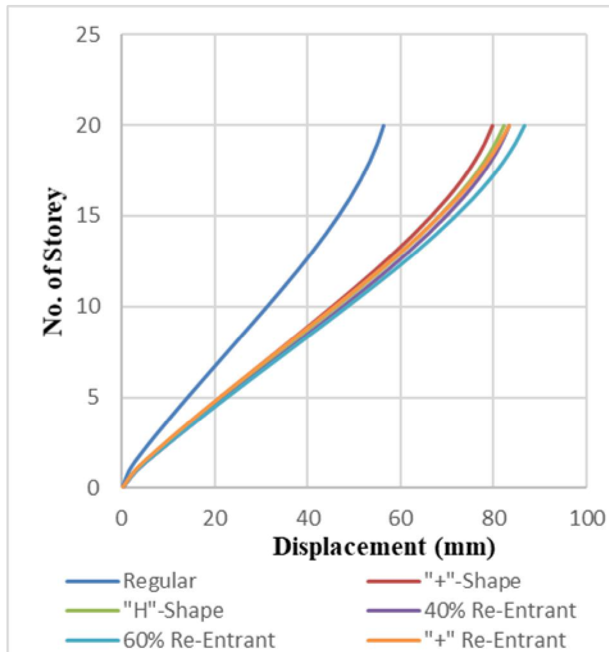


Fig: Comparison Graph of Displacement in X Direction

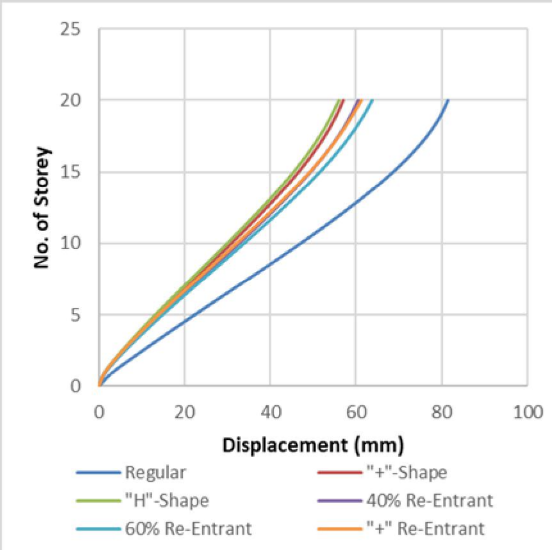


Fig: Comparison Graph of Displacement in Y Direction

Lateral Loads in X-Direction

No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	447.33	391.22	367.54	383.07	350.93	190.26
19	464.91	414.36	393.03	400.13	367.75	205.81
18	417.26	371.89	352.75	359.12	330.05	184.72
17	372.18	331.72	314.64	320.33	294.40	164.76
16	329.68	293.84	278.72	283.75	260.78	145.95
15	289.76	258.26	244.96	249.39	229.20	128.27
14	252.41	224.97	213.39	217.24	199.66	111.74
13	217.64	193.98	183.99	187.32	172.16	96.35
12	185.45	165.28	156.78	159.61	146.69	82.09
11	155.82	138.88	131.73	134.11	123.26	68.98
10	128.78	114.78	108.87	110.84	101.87	57.01
9	104.31	92.97	88.18	89.78	82.51	46.18
8	82.42	73.46	69.68	70.93	65.19	36.48
7	63.10	56.24	53.34	54.31	49.91	27.93
6	46.36	41.32	39.19	39.90	36.67	20.52
5	32.19	28.69	27.21	27.71	25.46	14.25
4	20.60	18.36	17.42	17.73	16.29	9.12
3	11.59	10.33	9.79	9.97	9.16	5.13
2	5.15	4.59	4.35	4.43	4.07	2.28
1	1.28	1.14	1.08	1.10	1.018	0.57
0	0	0	0	0	0	0

Storey Displacement in Y-Direction

No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	81.364	57.066	56.071	60.483	63.72	61.233
19	79.798	55.548	54.444	58.846	61.876	59.25
18	77.7	53.751	52.614	56.922	59.742	57.138
17	75.09	51.648	50.494	54.675	57.287	54.753
16	72.023	49.262	48.103	52.132	54.533	52.09
15	68.554	46.625	45.476	49.327	51.517	49.177
14	64.738	43.774	42.646	46.296	48.277	46.049
13	60.623	40.741	39.646	43.078	44.85	42.744
12	56.26	37.56	36.509	39.705	41.273	39.295
11	51.694	34.263	33.265	36.213	37.582	35.737
10	46.969	30.88	29.947	32.634	33.809	32.104
9	42.126	27.443	26.581	28.998	29.987	28.428
8	37.201	23.978	23.196	25.335	26.149	24.738
7	32.232	20.511	19.817	21.673	22.323	21.065
6	27.251	17.069	16.469	18.038	18.536	17.438
5	22.287	13.676	13.175	14.456	14.817	13.885
4	17.367	10.356	9.961	10.951	11.193	10.436
3	12.516	7.142	6.859	7.557	7.698	7.133
2	7.765	4.103	3.934	4.343	4.405	4.055
1	3.222	1.455	1.394	1.535	1.549	1.419
0	0	0	0	0	0	0

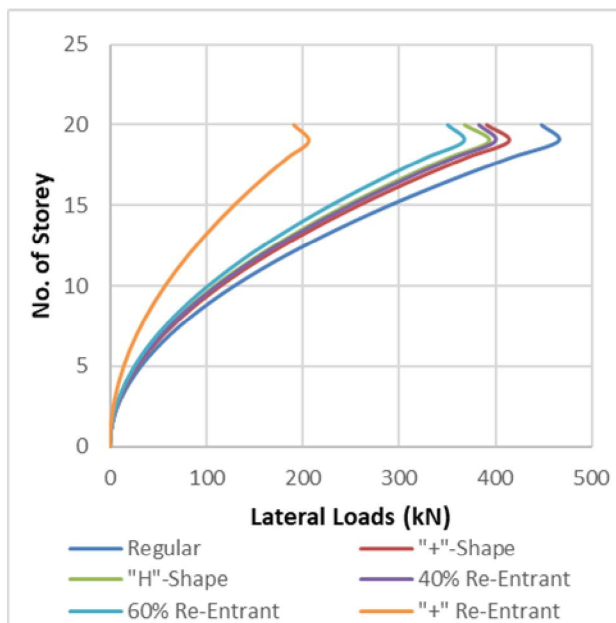


Fig: Comparison Graph of Lateral Loads in X Direction

Lateral Loads in Y-Direction

No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	447.3328	391.2233	367.5423	383.0703	350.9384	190.2642
19	464.913	414.3657	393.0394	400.1384	367.7512	205.8174
18	417.2626	371.8961	352.7556	359.127	330.0593	184.7226
17	372.1879	331.7221	314.6493	320.3324	294.4047	164.768
16	329.689	293.8438	278.7205	283.7546	260.7876	145.9536
15	289.7657	258.2612	244.9692	249.3937	229.2078	128.2796
14	252.4181	224.9742	213.3954	217.2497	199.6655	111.7458
13	217.6462	193.9828	183.9991	187.3224	172.1605	96.3522
12	185.45	165.2871	156.7803	159.612	146.693	82.0989
11	155.8295	138.8871	131.739	134.1184	123.2629	68.9859
10	128.7847	114.7827	108.8752	110.8417	101.8701	57.0131
9	104.3156	92.974	88.1889	89.7817	82.5148	46.1806
8	82.4222	73.4609	69.6801	70.9387	65.1969	36.4884
7	63.1045	56.2435	53.3488	54.3124	49.9164	27.9364
6	46.3625	41.3218	39.1951	39.903	36.6733	20.5247
5	32.1962	28.6957	27.2188	27.7104	25.4675	14.2533
4	20.6056	18.3652	17.42	17.7347	16.2992	9.1221
3	11.5906	10.3304	9.7988	9.9757	9.1683	5.1312
2	5.1514	4.5913	4.355	4.4337	4.0748	2.2805
1	1.2878	1.1478	1.0888	1.1084	1.0187	0.5701
0	0	0	0	0	0	0

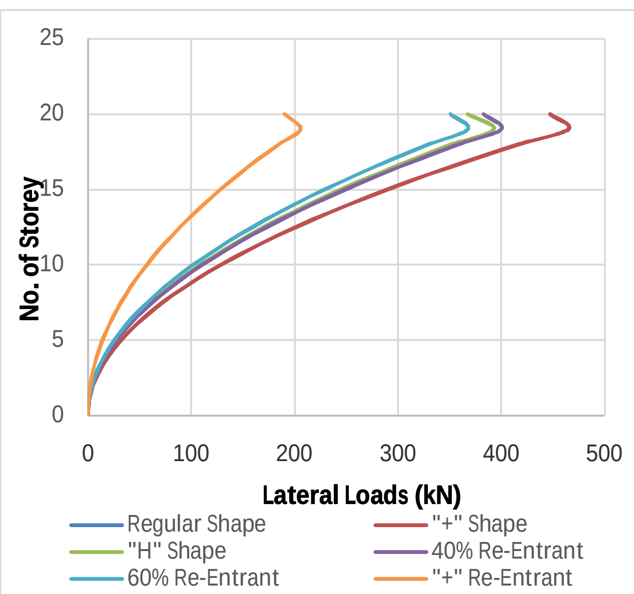


Fig: Comparison Graph of Lateral Loads in Y Direction

Storey Shear in X-Direction

No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	3628.31	3226.35	3056.75	3120.85	2867.13	1598.48
19	3627.02	3225.20	3055.67	3119.75	2866.11	1597.91
18	3621.87	3220.61	3051.31	3115.31	2862.03	1595.63
17	3610.28	3210.28	3041.51	3105.34	2852.86	1590.50
16	3589.68	3191.92	3024.09	3087.60	2836.56	1581.38
15	3557.48	3163.22	2996.87	3059.89	2811.10	1567.13
14	3511.12	3121.90	2957.68	3019.99	2774.42	1546.60
13	3448.01	3065.66	2904.33	2965.68	2724.51	1518.67
12	3365.59	2992.20	2834.65	2894.74	2659.31	1482.18
11	3261.27	2899.22	2746.46	2804.96	2576.80	1436.00
10	3132.49	2784.44	2637.59	2694.11	2474.93	1378.98
9	2976.66	2645.55	2505.85	2560.00	2351.66	1310.00
8	2791.21	2480.26	2349.07	2400.38	2204.97	1227.90
7	2573.56	2286.28	2165.07	2213.06	2032.81	1131.55
6	2321.15	2061.31	1951.67	1995.81	1833.14	1019.80
5	2031.38	1803.05	1706.70	1746.42	1603.94	891.52
4	1701.69	1509.20	1427.98	1462.66	1343.15	745.57
3	1329.50	1177.48	1113.33	1142.33	1048.74	580.80
2	912.24	805.58	760.58	783.20	718.68	396.08
1	447.33	391.22	367.54	383.07	350.93	190.26
0	0	0	0	0	0	0

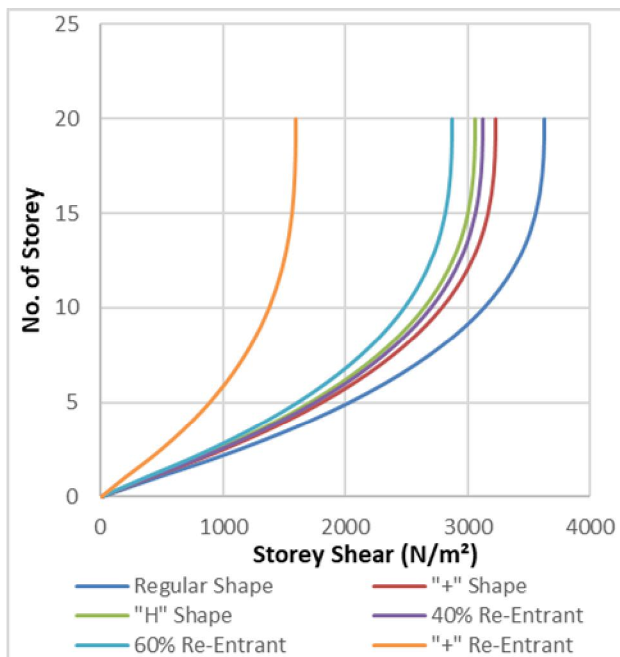


Fig: Comparison Graph of Storey Shear in X Direction

Storey Shear in Y-Direction

No. of Storey	Regular Shape	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	3628.31	3226.35	3056.75	3120.85	2867.13	1598.48
19	3627.02	3225.20	3055.67	3119.75	2866.11	1597.91
18	3621.87	3220.61	3051.31	3115.31	2862.03	1595.63
17	3610.28	3210.28	3041.51	3105.34	2852.86	1590.50
16	3589.68	3191.92	3024.09	3087.60	2836.56	1581.38
15	3557.48	3163.22	2996.87	3059.89	2811.10	1567.13
14	3511.12	3121.90	2957.68	3019.99	2774.42	1546.60
13	3448.01	3065.66	2904.33	2965.68	2724.51	1518.67
12	3365.59	2992.20	2834.65	2894.74	2659.31	1482.18
11	3261.27	2899.22	2746.46	2804960	2576.80	1436.00
10	3132.49	2784.44	2637.59	2694.11	2474.93	1378.98
9	2976.66	2645.55	2505.85	2560.00	2351.66	1310.00
8	2791.21	2480.26	2349.07	2400.38	2204.97	1227.90
7	2573.56	2286.28	2165.07	2213.06	2032.81	1131.55
6	2321.15	2061.31	1951.67	1995.81	1833.14	1019.80
5	2031.38	1803.05	1706.70	1746.42	1603.94	891.52
4	1701.69	1509.20	1427.98	1462.66	1343.15	745.57
3	1329.50	1177.48	1113.33	1142.33	1048.74	580.80
2	912.24	805.58	760.58	783.20	718.68	396.08
1	447.33	391.22	367.54	383.07	350.93	190.26
0	0	0	0	0	0	0

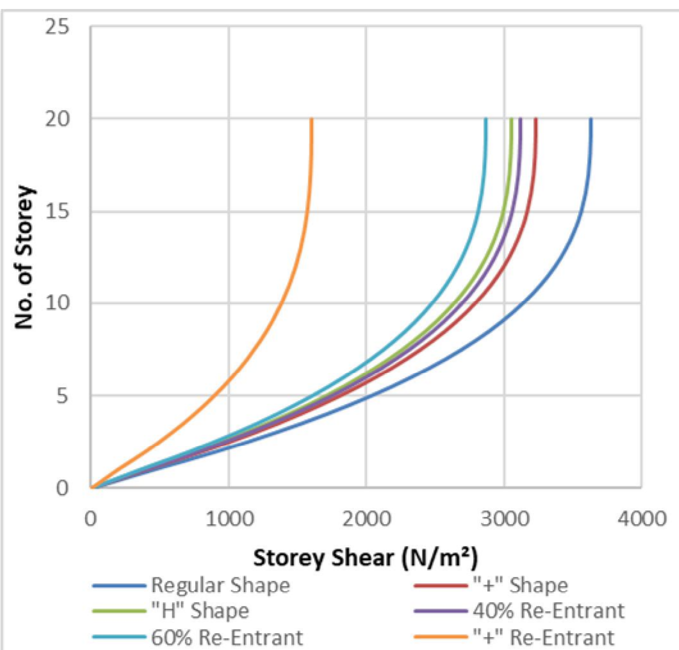


Fig: Comparison Graph of Storey Shear in X Direction

Storey Drift in X-Direction

No. of Storey	Regular	"+" Shape	"H" Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	0.00058	0.0006	0.0007	0.000449	0.000573	0.00064
19	0.00075	0.0008	0.0008	0.000551	0.000737	0.000784
18	0.00092	0.0010	0.0010	0.000658	0.000897	0.000943
17	0.00107	0.0011	0.0011	0.000757	0.00104	0.001087
16	0.00120	0.0012	0.0012	0.000844	0.001165	0.001213
15	0.00132	0.0014	0.0013	0.000919	0.001274	0.001323
14	0.00142	0.0014	0.0014	0.000982	0.001366	0.001416
13	0.00150	0.0015	0.0015	0.001035	0.001443	0.001494
12	0.00156	0.0016	0.0015	0.001077	0.001505	0.001556
11	0.00161	0.0016	0.0016	0.001108	0.001552	0.001603
10	0.00165	0.0017	0.0016	0.00113	0.001586	0.001637
9	0.00167	0.0017	0.0016	0.001144	0.001607	0.001656
8	0.00168	0.0017	0.0016	0.001148	0.001617	0.001663
7	0.00168	0.0017	0.0016	0.001145	0.001615	0.001657
6	0.00167	0.0017	0.0016	0.001134	0.001603	0.00164
5	0.00165	0.0016	0.0015	0.001116	0.001581	0.001612
4	0.00162	0.0016	0.0015	0.001089	0.001551	0.001574
3	0.00158	0.0016	0.0014	0.00104	0.00151	0.001523
2	0.00151	0.0015	0.0013	0.000922	0.001433	0.001432
1	0.00105	0.0010	0.0009	0.000515	0.000992	0.000972
0	0	0	0	0	0	0

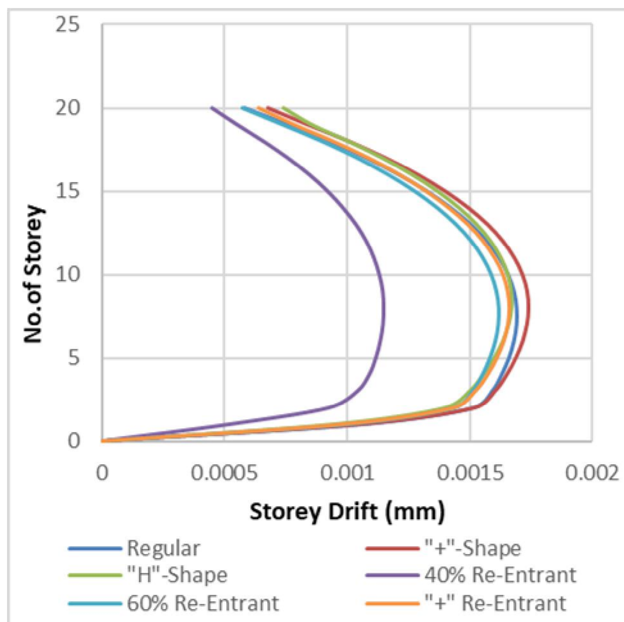


Fig: Comparison Graph Storey Drift in X direction

Storey Drift in Y-Direction						
No. of Storey	Regular	"+"- Shape	"H"- Shape	40% Re-Entrant	60% Re-Entrant	"+" Re-Entrant
20	0.000524	0.000507	0.000543	0.000546	0.000615	0.000661
19	0.0007	0.0006	0.000611	0.000641	0.000711	0.000705
18	0.00087	0.000701	0.000708	0.000749	0.000819	0.000797
17	0.001022	0.000795	0.000797	0.000848	0.000918	0.000889
16	0.001156	0.000879	0.000876	0.000935	0.001005	0.000971
15	0.001272	0.000951	0.000943	0.00101	0.00108	0.001042
14	0.001371	0.001011	0.001	0.001073	0.001142	0.001102
13	0.001454	0.00106	0.001046	0.001124	0.001192	0.00115
12	0.001522	0.001099	0.001081	0.001164	0.001231	0.001186
11	0.001575	0.001127	0.001107	0.001193	0.001258	0.001212
10	0.001615	0.001146	0.001122	0.001212	0.001274	0.001227
9	0.001641	0.001155	0.001129	0.001221	0.00128	0.001231
8	0.001656	0.001156	0.001127	0.001221	0.001275	0.001226
7	0.001661	0.001147	0.001116	0.001212	0.001262	0.001211
6	0.001655	0.001131	0.001098	0.001194	0.00124	0.001186
5	0.00164	0.001107	0.001072	0.001168	0.001208	0.001152
4	0.001617	0.001072	0.001035	0.001131	0.001165	0.001107
3	0.001584	0.001014	0.000977	0.001072	0.001098	0.001035
2	0.001517	0.000886	0.00085	0.000938	0.000954	0.00088
1	0.001074	0.000485	0.000465	0.000512	0.000516	0.000473
0	0	0	0	0	0	0

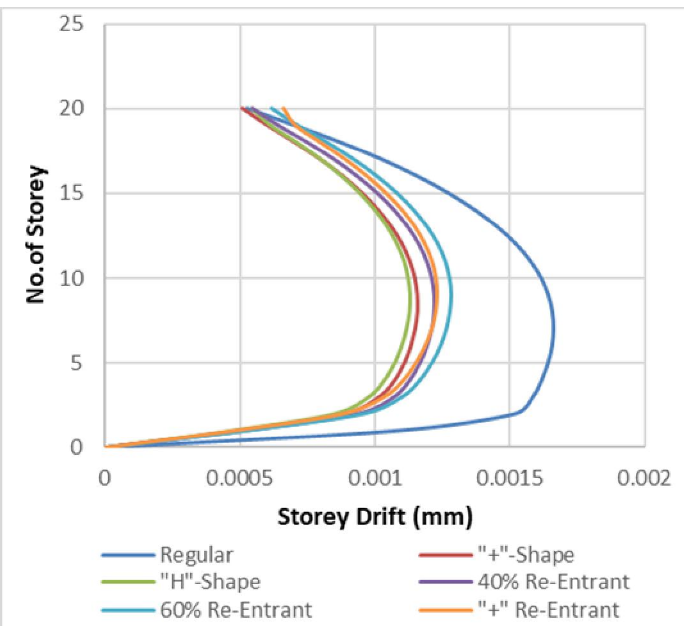


Fig: Comparison Graph Storey Drift in Y direction

III. CONCLUSION AND RESULTS

Conclusion:

- ETABS and Manual Calculations gives almost same results, thus the Modeling done in ETABS can be considered Correct.
- Models Containing Re-entrant corners may undergo more damage than models having Diaphragm Discontinuity and Regular Models.
- After Comparing all the Models Maximum Displacement in X Direction Occurs in the model having Re-entrant Corners 60% Irregularity. Which is 54% more than Regular model. So, model Having Re-entrant corners having 60% Irregularity is most vulnerable than any other model, when it is under go to the severe Earthquake.
- Models Having Diaphragm discontinuity in “H” shape and Re-Entrant corners in “+” shape gives identical Results in terms of Storey forces, storey displacement and storey drifts.
- Storey Drifts are maximum at 8^{th} floor in all the Models.
- According to calculations we conclude that Regular model without any type of discontinuity gives minimum displacement and storey drift.
- Thus, the model having diaphragm discontinuity in “+” shape can be considered most effective for G+20 irregular models.

REFERENCES

[1] IS 1893:2002(part-1) Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings
[2] IS 456:2002 for Plain and Reinforced Concrete
[3] S.K. Duggal, Earthquake resistance design of structures
[4] IJRET- International Journal of Research in Engineering and Technology, study of lateral load resisting system
[5] IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308
[6] Journal of Civil Engineering and Environmental Technology Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 10; April-June 2015 pp. 1-6
[7] International Journal for Research in Applied Science & Engineering Technology (IJRASET) Volume 3 Issue VII, July 2015 IC Value: 13.98 ISSN: 2321-9653