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Earthquake Analysis of Multi-Story Steel Structure with Different Types of Bracings

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ABSTRACT: Selection of type of bracing for a structure which will be constructed in any seismic zonal area will be very important since it has to resist the effects of seismic forces and at the same time should not undergo any kind of deformations, damages and should not be responsible for any kind losses of lives during the earthquake situation since majorities of the damages or destructions will be happening during the earthquake condition. The way the structures behaviour which are situated in seismic areas depend on verities of factors like type of the structure, it's purpose, structure's shape, position of various structural members like columns and spacing between them, their orientations and sizes, their location and symmetry of shear walls and their structural strength. Sometimes all these structural elements or some of these members may have limitations may be because of either architectural needs or may be because of end user's requirements. Thus, as a structural design engineer one has to take care all these points while design the structure but at the same time it should be stronger enough to resist or take care of the worst seismic waves in that area.

KEYWORDS: Storey drift, Storey displacement, Base shear, Time History analysis, Mode shapes, Bracings, Staad.pro.

I. INTRODUCTION

Since steel bracing is comparatively economical, also easy to install, at the same time needs lesser space and also it is flexible in nature from design point of view w.r.t meet the strength and stiffness requirements. A framed structure with bracings will normally be good in resisting the lateral forces like wind load and earthquake loads. Any bracing system provides extra strength and stiffness to the structure. This help in providing or adding more stiffness to the structure in order to resist the horizontal forces like wind load for seismic loads diagonal pressing member works in in axial stress. Any structure is designed in accordance with core standards and erected the following codes in order to avoid or reduce the damages which may cause to the structural element or the entire building during the earthquake conditions. This can be addressed by adding. Very common factor which is considered in order to add bracings Twinkle the stiffness is story drift. Story drift is one of the parameters which is used to calculate and estimates the horizontal stiffness of the structure. One of the simplest parameters which could be utilized to calculate the horizontal stiffness of any structure is drift index. This can be defined as the ratio of the maximum deflection at the highest level of the structure to the total height of the building. Various types of structural forms of high-rise structures could be utilized to improve the lateral stiffness of a structure and thus reducing the drift. In this project study has been carried out to analyze the thickness of a single building with different type of bracing systems. Bracing can be considered as a highly effective and efficient system in order to arrest or reduced the lateral drift. Generally pressing consists of usually columns and Girders. The main purpose is to take care of gravity loads and the diagonal bracing system picture connected between the columns are the beams so that the total set of members for a vertical cantilever kind of a Truss in order to address or take care the horizontal forces. Bracing can be considered as efficient since the diagonal racing work in actual stress and hence call for a small member sizes. Strengthening the building to take care of seismic normally depends on the budget of the project and life safety also. Generally speaking motion of the ground can occur in any place in the world hence danger related to the structure and the life especially during severe seismic forces has to be e given an extra care during the design and execution. While providing any type of pressing system for the structure care has to be taken in such a way that it will not affect the functionality of the structure at the same time it should increase the thickness of a structure very commonly used bracing systems are XV and inverted V.



1.1 Objectives

The prime objectives of this projects to carry out the process of modeling using different bracing systems for the same building, applying loads, time history analysis and then comparing the results both in the form of tables and graphs. To understand the performance of multi-storied building with different bracing system under seismic loads.

1.2 Scope of The Study

In this study we have carried out response spectrum analysis on three models which are ten stories tall structure using commercial software Staad.pro, Conventional steel framed structure with different structural bracing systems such as X,V and inverted K are modelled. All the models are modelled in such a way that they have same floor plans and same number of floors but with different structural bracing systems.

II. STRUCTURAL DETAILS

To study the time history analysis of steel structure, G+9 Multi-storied building is considered. The modelling and analysis of work is done by using STAAD.PRO software. Story shear, story drifts and story Displacement is compared for different types of braced structural system.

2.1 Model description

Explanation of Staad models:

- Model 1-Stilt+9 floors + Terrace with X type bracings
- Model 2- Stilt + 9 floors + Terrace with V type bracings
- Model 3- Stilt + 9 floors + Terrace with K type bracings

Building details	
Type of structure	Steel frame with concentric brace
Building shape	Rectangular shape structures
Building dimension	Detailed out in subsequent pages
Total height from plinth	29.28m
Hight of typical story	3.05m
Material properties	
Grade of steel sections	Fe 250
Grade of concrete	M25 for slab
Grade of rebar steel	Fe 500
Density of concrete	25kn/m ³
Section properties	
Size of Steel beam	ISMB400
Size of Steel column	ISWB600H
Size of steel bracing	ISMC350
RCC slab thickness	250mm

2.2 Loading

a. dead loads: as per IS875 part-1 1987

b. live loads: as per IS875 part-2 1987. For seismic live load taken by IS1893-2002

c. earthquake loads: All frames are analyzed for zone 3. The earthquake load calculation is as per IS1893-2002

d. seismic factors for lateral load analysis

- Soil profile type = medium
- Seismic zone factor = 0.24(Zone 3)
- Response reduction factor = 5.0
- Importance factor = 1.0
- Damping = 5.0 %

2.3 Load combinations

SL No	Factored Load Combinations
1	1.5(DL+WLZ1+WLX1)
2	1.5(DL+WLZ2+WLX2)
3	1.5(DL-WLZ1-WLX1)
4	1.5(DL-WLZ2-WLX2)
5	1.2(DL+LL+WLZ1+WLX1)
6	1.2(DL+LL+WLZ2+WLX2)
7	1.2(DL+LL-WLZ1-WLX1)
8	1.2(DL+LL-WLZ2-WLX2)
9	0.9DL+1.5(WLZ1+WLX1)
10	0.9DL+1.5(WLZ2+WLX2)
11	0.9DL-1.5WLZ1-1.5WLX1
12	0.9DL-1.5WLZ2-1.5WLX2
13	1.2(DL+LL+TH)
14	1.2(DL+LL-TH)
15	0.9DL+1.5 TH
16	0.9DL-1.5 TH

SL No	Un-factored Load Combinations
1	1.0(DL+WLZ1+WLX1)
2	1.0(DL+WLZ2+WLX2)
3	1.0(DL-WLZ1-WLX1)
4	1.0(DL-WLZ2-WLX2)
5	1.0(DL+1.0LL+WLZ1+WLX1)
6	1.0(DL+1.0LL+WLZ2+WLX2)
7	1.0(DL+1.0LL-WLZ1-WLX1)
8	1.0(DL+1.0LL-WLZ2-WLX2)
9	1.0(DL+0.8LL+0.8TH)
10	1.0(DL+0.8LL-0.8TH)
11	1.0(DL+LL+TH)
12	1.0(DL+LL-TH)
13	1.0DL+0.8TH
14	1.0DL-0.8TH
15	1.0DL+0.8 LL +0.8TH
16	1.0DL+0.8 LL +0.8TH

III ANALYSIS AND MODELING

3.1 Modeling

The building has been modelled as 3D Space frame model with six degree of freedom at each node in STAAD.PRO, software for stimulation of behavior under gravity and seismic loading. The isometric 3D view and plan of the building model is given below.

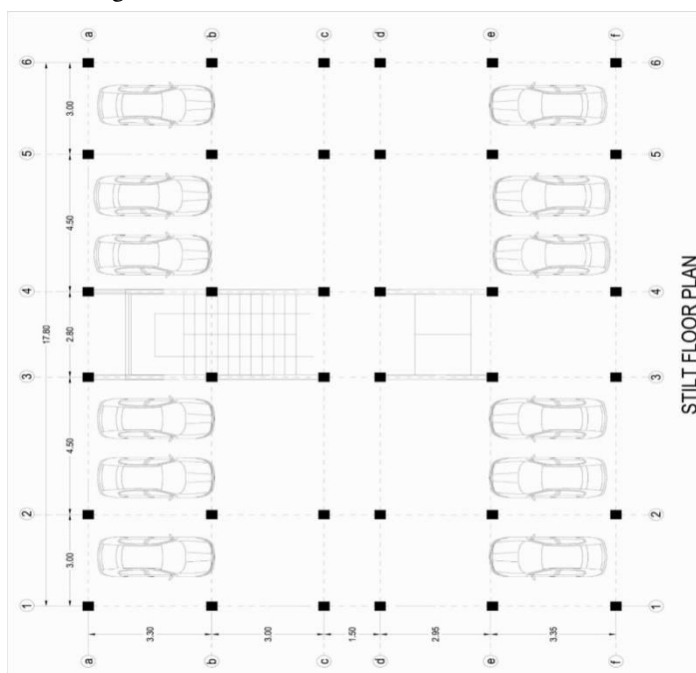


fig 1 Stilt floor plan

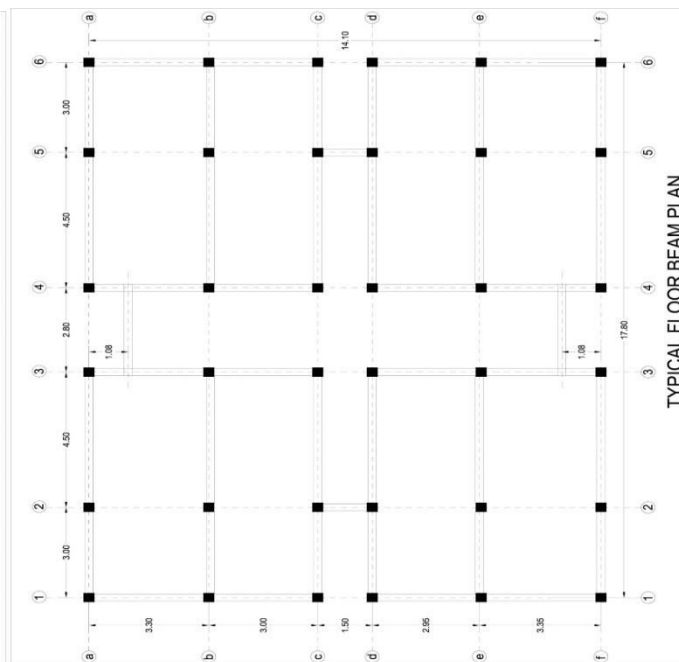


fig 2 Typical floor beam plan

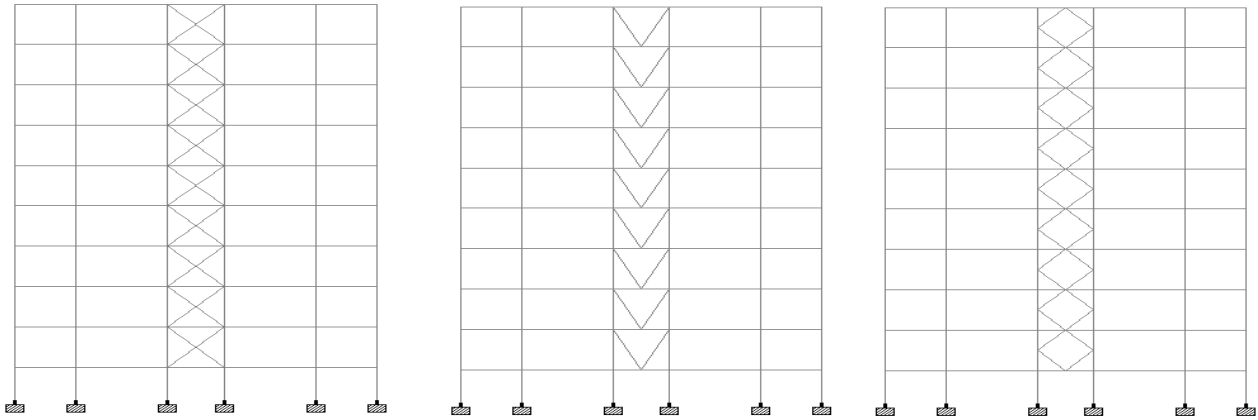


Fig 3 Building with X V and K Bracing

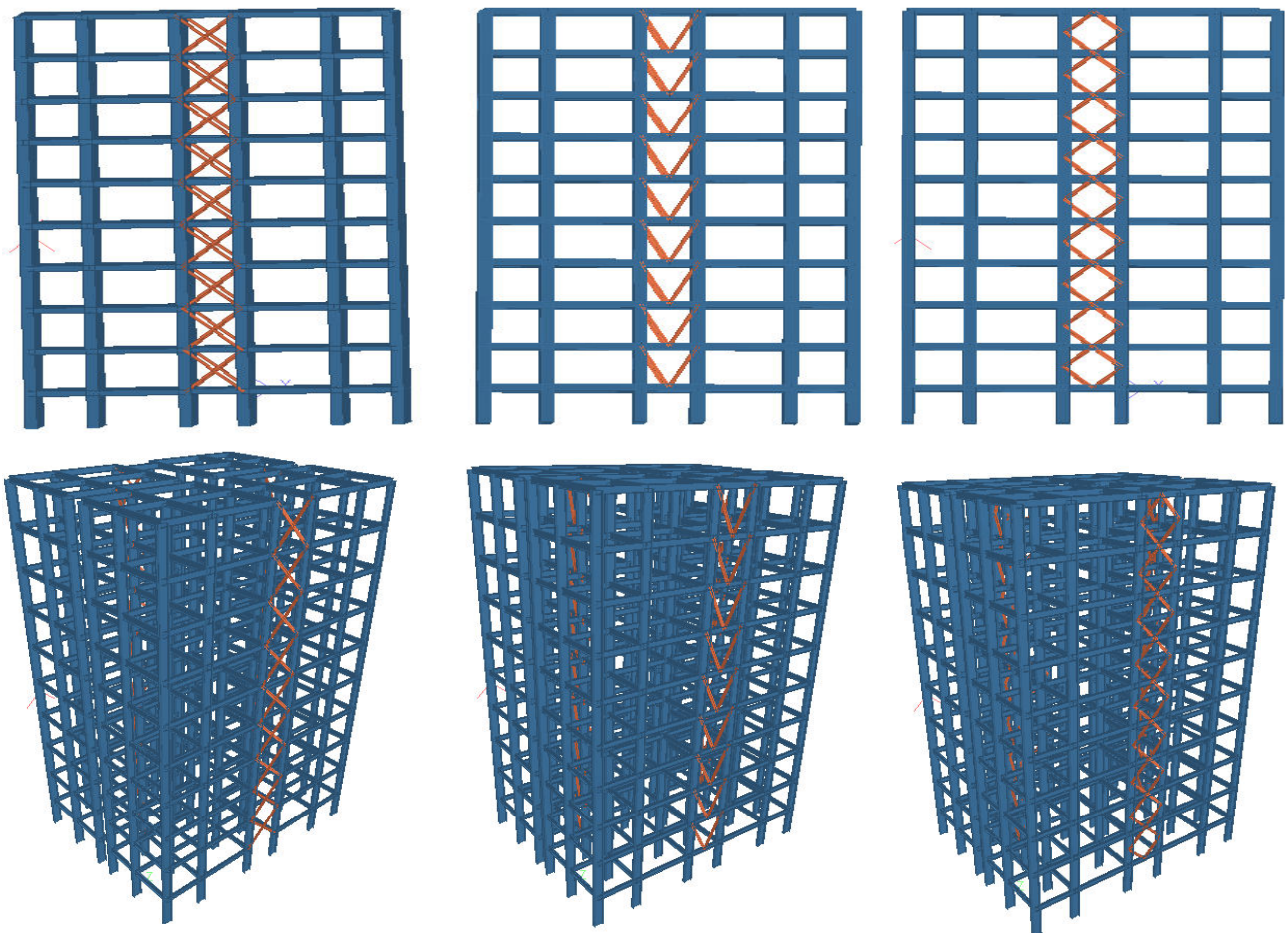


Fig 4 3D View of Building with X V and K Bracing

BUILDING WITH X BRACING						
STORY	HEIGHT, M	LOAD CASE	AVG. DISP(CM)	DRIFT(CM)	RATIO	STATUS
BASE=-2.5				ALLOW. DRIFT = L / 250		
1	0					
		113	-1.50	3.62	L/ 1663	PASS
		114	1.50	3.62	L/ 1663	PASS
2	3.05					
		113	-4.90	3.40	L/ 897	PASS
		114	4.90	3.40	L/ 897	PASS
3	6.1					
		113	-8.97	4.06	L/ 750	PASS
		114	8.97	4.06	L/ 750	PASS
4	9.15					
		113	-13.24	4.28	L/ 713	PASS
		114	13.24	4.28	L/ 713	PASS
5	12.2					
		113	-17.48	4.24	L/ 720	PASS
		114	17.48	4.24	L/ 720	PASS
6	15.25					
		113	-21.48	4.00	L/ 762	PASS
		114	21.48	4.00	L/ 762	PASS
7	18.3					
		113	-25.10	3.62	L/ 843	PASS
		114	25.10	3.62	L/ 843	PASS
8	21.35					
		113	-28.22	3.12	L/ 978	PASS
		114	28.22	3.12	L/ 978	PASS
9	24.4					
		113	-30.77	2.55	L/ 1195	PASS
		114	30.77	2.55	L/ 1195	PASS
10	27.45					
		113	-32.75	1.98	L/ 1537	PASS
		114	32.75	1.98	L/ 1537	PASS

BUILDING WITH V BRACING						
STORY	HEIGHT, M	LOAD CASE	AVG. DISP(CM)	DRIFT(CM)	RATIO	STATUS
BASE=-2.5				ALLOW. DRIFT = L / 250		
1	0					
		113	-1.53	0.00	L/ 1634	PASS
		114	1.53	0.00	L/ 1634	PASS
2	3.05	0.00		0.00		
		113	-5.09	3.56	L/ 856	PASS
		114	5.09	3.56	L/ 857	PASS
3	6.1	0.00		0.00		
		113	-9.31	4.22	L/ 722	PASS
		114	9.31	4.22	L/ 722	PASS
4	9.15	0.00		0.00		
		113	-13.72	4.40	L/ 692	PASS
		114	13.71	4.40	L/ 693	PASS
5	12.2	-0.01		0.00		
		113	-18.06	4.34	L/ 703	PASS
		114	18.05	4.34	L/ 703	PASS
6	15.25	-0.01		0.00		
		113	-22.15	4.10	L/ 744	PASS
		114	22.14	4.09	L/ 745	PASS
7	18.3	-0.01		0.00		
		113	-25.87	3.72	L/ 821	PASS
		114	25.85	3.71	L/ 822	PASS
8	21.35	-0.01		0.00		
		113	-29.07	3.21	L/ 951	PASS
		114	29.05	3.20	L/ 953	PASS
9	24.4	-0.01		0.00		
		113	-31.68	2.61	L/ 1170	PASS
		114	31.65	2.60	L/ 1172	PASS
10	27.45	-0.06		0.05		
		113	-33.92	2.24	L/ 1363	PASS
		114	33.79	2.13	L/ 1431	PASS



III RESULTS AND DISCUSSION

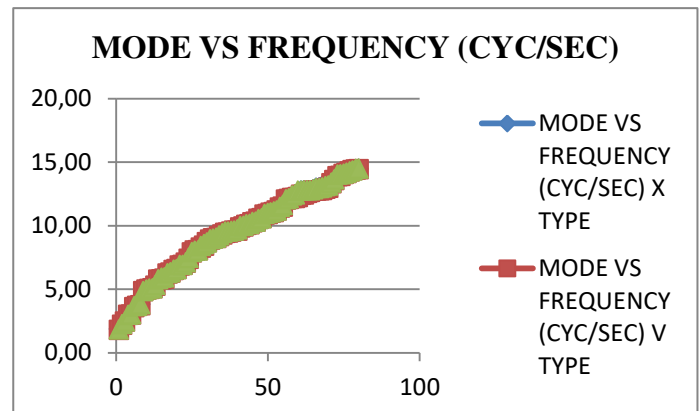
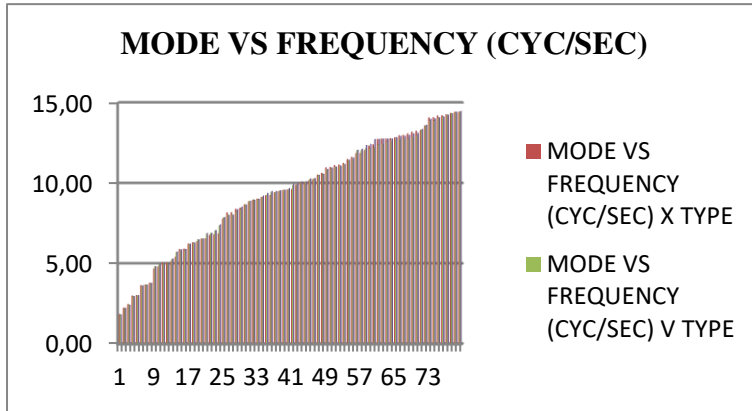
3.1 Story drift for the bracing X and V similarly for K bracing is taken

3.2 Eigen values for different types of Bracings

MODE VS FREQUENCY (CYC/SEC)			
MODE	X TYPE	V TYPE	K TYPE
1	1.86	1.78	1.83
2	2.26	2.18	2.25
3	2.48	2.45	2.44
4	3.00	2.97	2.97
5	3.03	3.01	3.03
6	3.65	3.59	3.65
7	3.70	3.69	3.69
8	3.81	3.73	3.81
9	4.69	4.84	4.84
10	4.83	4.98	4.98
11	5.08	5.01	5.04
12	5.09	5.07	5.06
13	5.16	5.28	5.31
14	5.43	5.73	5.77
15	5.91	5.77	5.89
16	5.94	5.81	5.92
17	6.24	6.22	6.25
18	6.33	6.30	6.32
19	6.41	6.51	6.52
20	6.56	6.57	6.57
21	6.57	6.86	6.91
22	6.80	6.91	6.92
23	6.84	7.07	7.10
24	6.91	7.37	7.45
25	7.80	7.89	7.90
26	8.20	8.03	8.02
27	8.21	8.05	8.03
28	8.42	8.26	8.39
29	8.49	8.42	8.55
30	8.69	8.70	8.67

MODE VS FREQUENCY (CYC/SEC)			
MODE	X TYPE	V TYPE	K TYPE
31	8.87	8.90	8.91
32	8.98	8.99	8.96
33	9.04	9.02	9.03
34	9.15	9.17	9.23
35	9.25	9.30	9.40
36	9.28	9.43	9.51
37	9.43	9.45	9.52
38	9.52	9.53	9.57
39	9.59	9.59	9.59
40	9.61	9.60	9.69
41	9.65	9.86	9.96
42	9.90	9.93	9.98
43	10.05	10.05	10.11
44	10.07	10.10	10.12
45	10.19	10.26	10.29
46	10.29	10.31	10.31
47	10.53	10.52	10.52
48	10.64	10.58	10.59
49	10.98	10.87	10.90
50	11.01	10.91	10.98
51	11.11	11.01	11.03
52	11.16	11.06	11.11
53	11.25	11.19	11.20
54	11.51	11.42	11.45
55	11.64	11.49	11.60
56	11.88	12.05	12.07
57	11.90	12.08	12.14
58	12.05	12.17	12.36
59	12.33	12.17	12.45
60	12.42	12.23	12.75

MODE VS FREQUENCY (CYC/SEC)			
MODE	X TYPE	V TYPE	K TYPE
61	12.75	12.42	12.75
62	12.78	12.45	12.77
63	12.78	12.57	12.77
64	12.78	12.66	12.78
65	12.85	12.74	12.86
66	12.98	12.75	12.94
67	13.00	12.77	12.95
68	13.10	12.80	12.99
69	13.20	12.90	13.09
70	13.27	12.98	13.14
71	13.30	13.32	13.38
72	13.58	13.57	13.63
73	14.09	13.89	14.01
74	14.10	13.91	14.04
75	14.21	14.06	14.09
76	14.22	14.14	14.15
77	14.27	14.26	14.26
78	14.36	14.35	14.35
79	14.44	14.41	14.45
80	14.45	14.44	14.49



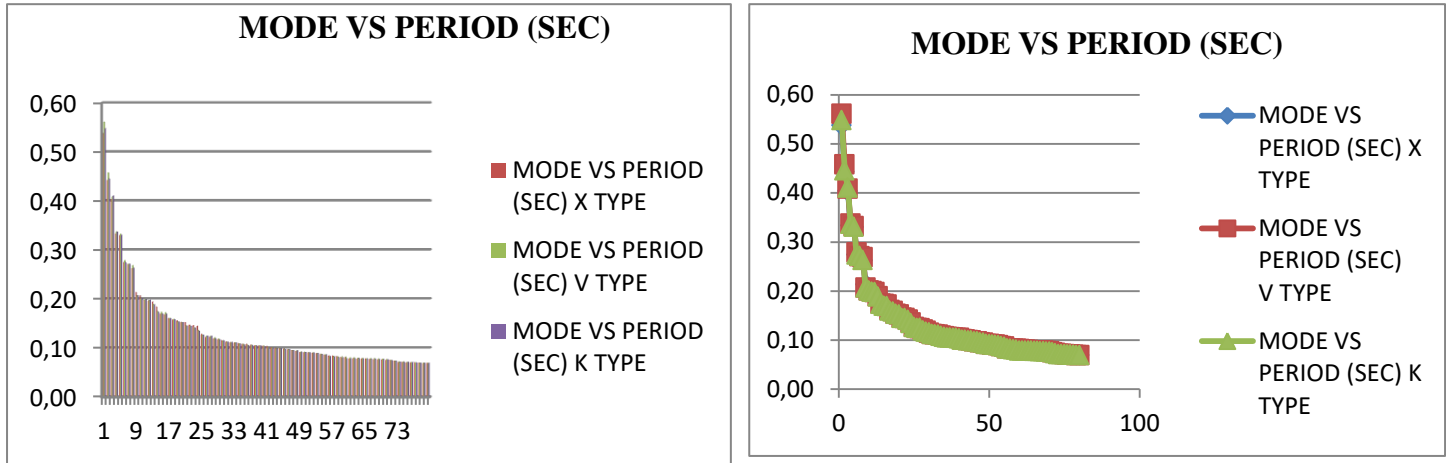
Graph-1 Mode v/s frequency

MODE VS PERIOD (SEC)			
MODE	X TYPE	V TYPE	K TYPE
1	0.54	0.56	0.55
2	0.44	0.46	0.45
3	0.40	0.41	0.41
4	0.33	0.34	0.34
5	0.33	0.33	0.33
6	0.27	0.28	0.27
7	0.27	0.27	0.27
8	0.26	0.27	0.26
9	0.21	0.21	0.21
10	0.21	0.20	0.20
11	0.20	0.20	0.20
12	0.20	0.20	0.20
13	0.19	0.19	0.19
14	0.18	0.17	0.17
15	0.17	0.17	0.17
16	0.17	0.17	0.17
17	0.16	0.16	0.16
18	0.16	0.16	0.16
19	0.16	0.15	0.15
20	0.15	0.15	0.15
21	0.15	0.15	0.14
22	0.15	0.14	0.14
23	0.15	0.14	0.14
24	0.14	0.14	0.13
25	0.13	0.13	0.13
26	0.12	0.12	0.12
27	0.12	0.12	0.12
28	0.12	0.12	0.12
29	0.12	0.12	0.12
30	0.12	0.11	0.12

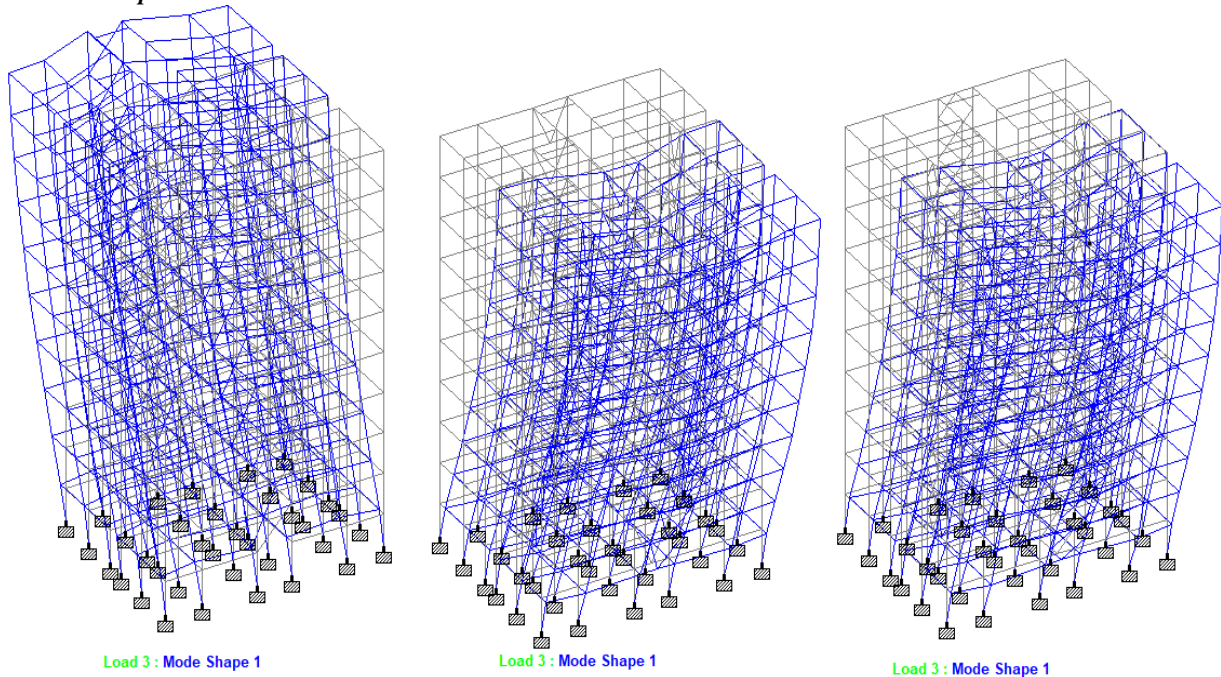
MODE VS PERIOD (SEC)			
MODE	X TYPE	V TYPE	K TYPE
31	0.11	0.11	0.11
32	0.11	0.11	0.11
33	0.11	0.11	0.11
34	0.11	0.11	0.11
35	0.11	0.11	0.11
36	0.11	0.11	0.11
37	0.11	0.11	0.11
38	0.11	0.10	0.10
39	0.10	0.10	0.10
40	0.10	0.10	0.10
41	0.10	0.10	0.10
42	0.10	0.10	0.10
43	0.10	0.10	0.10
44	0.10	0.10	0.10
45	0.10	0.10	0.10
46	0.10	0.10	0.10
47	0.09	0.10	0.10
48	0.09	0.09	0.09
49	0.09	0.09	0.09
50	0.09	0.09	0.09
51	0.09	0.09	0.09
52	0.09	0.09	0.09
53	0.09	0.09	0.09
54	0.09	0.09	0.09
55	0.09	0.09	0.09
56	0.08	0.08	0.08
57	0.08	0.08	0.08
58	0.08	0.08	0.08
59	0.08	0.08	0.08
60	0.08	0.08	0.08

MODE VS PERIOD (SEC)			
MODE	X TYPE	V TYPE	K TYPE
61	0.08	0.08	0.08
62	0.08	0.08	0.08
63	0.08	0.08	0.08
64	0.08	0.08	0.08
65	0.08	0.08	0.08
66	0.08	0.08	0.08
67	0.08	0.08	0.08
68	0.08	0.08	0.08
69	0.08	0.08	0.08
70	0.08	0.08	0.08
71	0.08	0.08	0.07
72	0.07	0.07	0.07
73	0.07	0.07	0.07
74	0.07	0.07	0.07
75	0.07	0.07	0.07
76	0.07	0.07	0.07
77	0.07	0.07	0.07
78	0.07	0.07	0.07
79	0.07	0.07	0.07
80	0.07	0.07	0.07

Graph-2 Mode v/s period



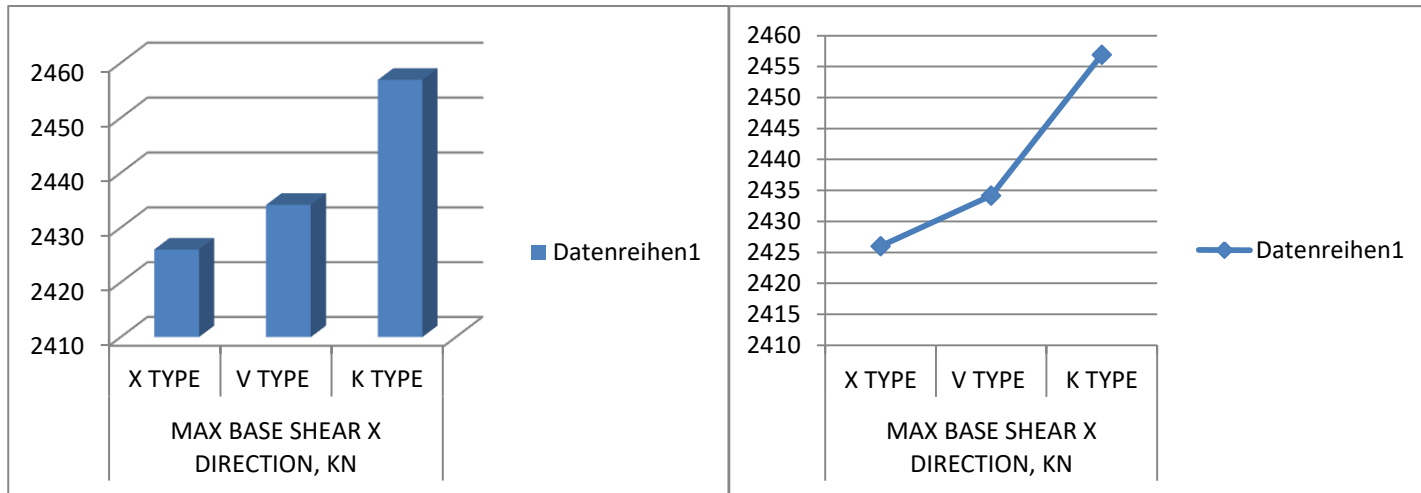
3.3 Mode shapes



3.4 Base shear

Base shear in any direction (X-direction)

MAX BASE SHEAR X DIRECTION, KN		
X TYPE	V TYPE	K TYPE
2426.015	2434.165	2456.923



Graph-3 Max Base shear in X-direction

IV. CONCLUSIONS

Modelling of 3 steel structures was carried out. Various entities like height between the floors, column sections, beam sections, slab thickness, staircase dimensions etc were retained the same. However, only difference was type of bracings. First model was provided with X bracing, second one with V bracings and the third one with K type bracings. All the 3 steel structures were of stilt + 9 floor and terrace. Response spectrum analysis method was used. Based on various analysis results conclusions were listed below

1. In X direction maximum joint displacement for node 373 is 30.86mm for X type bracing, 31.72 mm for V type and 31.69 for K type. This is ascending as the bracing type has changed from X to V and V to K. But the difference is 2.62% between K and X type
2. In Z direction maximum joint displacement for the node 382 is also ascending as the bracing type has changed from X to V and V to K. The difference is slightly higher as the dimension of the building in Y direction is lesser compared to X direction. The value is 13.2%.
3. At terrace level the displacement of 20.3 mm has occurred at 42.5 sec for X bracing. For V bracing it is 23.0 mm at 42.5 sec and it is 21.2 mm at 42.5 sec for K type bracings.
4. Base shear for building with X bracing is 2426.015; with V bracing is 2434.165 and with K bracing is 2456.923. The variation is 1.26% between K and X bracing.
5. Story drift for all the three structures is within the limit as it is evident from the tables above. Story drift for un-factored load case 113 and 114 are shown as examples.
6. From the above values we can say X type bracing is marginally stiffer, safer and better for this particular building. However, all three type of bracings are safe w.r.t story drift, displacement for this building.

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