Seismic performance evaluation of high-rise steel frame with eccentric K- and V-bracings

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Abstract - *In past decades, the steel structures have played an important role in growing construction industry. It is essential to design a structure to perform well under earthquake loads, especially in seismic prone areas. The seismic design of a multi-story steel frame building is carried as per IS 800: 2007. By introducing steel bracings in a structure, its shear capacity can be increased. They can be also used as strengthening an existing building. In various patterns steel bracings can be arranged. A 15-story steel frame building is designed for eccentric K- and V- bracings as per the IS 800: 2007. Eccentric K and V type bracings in a steel frame having different configurations are selected for this study. Performance of the each frame is studied under Response Spectrum and Time History analysis. The results of analysis have shown that, performance of the eccentric V-bracing system is better than eccentric K-bracing system.*

Key Words: High-rise steel frame, Eccentric bracings, Displacement, Story drift ratio, Story shear

1. INTRODUCTION

Steel is a vital progress material and plays a very significant role in growing social orders. Most of structures for e.g., home, parking lots, educational institutes and skyscrapers rely on steel because of its high strength and good ductility. Steel likewise affords high-quality engineering perspective and it offers a greater possibility of outline for auxiliary experts.

Steel structures must be designed and guarded against corrosion and fireplace. They ought to be designed for easy fabrication & erection. To restrict the progress of crack under fatigue and earthquake loads, the connections particularly the welds must be properly designed. Special steels and protecting measures for corrosion and fireplace are available and the designer should be aware of these options.

Steel is playing the major role in structures. Steel has higher strength, good ductility and toughness compared to alternative construction materials. Its properties makes it most suited material for earthquake and blast loading. Steel usage in infrastructure allows quicker and safer installation with least impact on surrounding. [1]

Simply stated, earthquakes are vibrations emanating from a source of disturbance within the earth crust which release energy in form of seismic waves. These travel through earth's surface leading to a greater destruction of property and also increase the death toll. Poor construction practices are more prone to such damages. So structural components must be designed carefully. [2]

Steel braced frames are the widely used for their structural adequacy in providing sufficient lateral strength and stiffness to a structure. The steel braces contribute to seismic energy dissipation by deforming elastically under ground motion. Various steel braces are used in practice, such as x-braces, diagonal braces, V-braces, and eccentric braces. Steel brace can be designed to resist only tensile forces, or to resist both tensile and axial compressive force. Recent earthquakes and experiments have shown that the tension-compression braces provide better performance under cyclic loading (during an earthquake) as compared with tension only braces having almost no compressive strength. [3]

1.1 Objectives

Following are the main objectives of present study,

a) To compare the natural time period and frequency of the eccentric K- and V-bracing models with various configurations.
b) To compare the story displacement of eccentric K- and V-bracings with different configurations.
c) To evaluate the inter-story drift and base shear various frames by performing Response Spectrum and Time History analysis in Etabs 2013.
d) To identify the efficient lateral load resisting system.

2. METHODOLOGY

2.1 Response spectrum analysis

The seismic design of a structure at any location requires actual time records. It is not possible to have time records at all required locations. It is a system to evaluate peak response of structure during an earthquake without the need of time history is referred to as Response Spectrum evaluation. A typical design response spectrum (IS: 1893) is shown below.

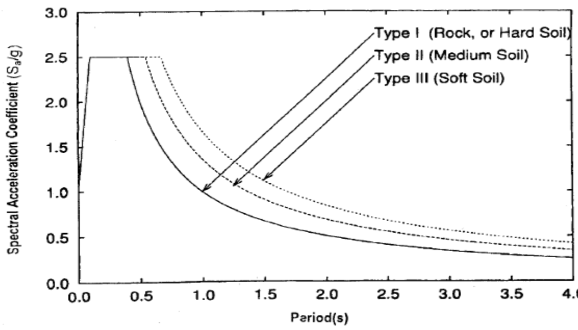

Chart -1: Response spectra for rock and soil sites (5% damping)

2.2 Time history analysis

In this the response of a structure is computed at a number of next time instants. Time history analysis provides for linear or nonlinear evaluation under seismic loading. In time history analysis, the structural response is computed at a number of subsequent time instants. In other words, Time history of structural response to a given input are obtained as a result. In this, the structural response is evaluated as a time function considering inertial effects.

2.3 Validation

A bare steel building with ten stories having plan dimension 20m x 12m is considered. Typical story height is 3m. The horizontal and vertical beam spacing is taken as 3m and 4m respectively. [4]

3. STRUCTURAL MODELLING

For present study, steel building with 15 stories is adopted. The dimension in plan of the building is 40 m X 20 m. The structural models have the same story height of 3m and have a uniform mass distribution over the height. Bay width is of 5m in both X- and Y- directions. Building plan is shown in fig2.

3.1 Types of models

The types of models considered are,
1. Bare model
2. Eccentric K-bracing model
3. Eccentric V-bracing model

Table -1: Description of building

No of Stories	G+15
Story Height	3m
Base Story	1.5m
Type of Soil	Medium
Seismic Zone	3
Importance factor	1
Response reduction factor	5
Material Property	
Column	Steel
Beam	Steel
slab	Concrete
Grade of Concrete	M25
Grade of Steel	Fe415
Thickness of Slab	150
Live Load	4 kN/m²
Live Load on Roof	1.5 kN/m²
Floor Finish	2 kN/m²

Table -2: Sample Table format

Story	Column	Beam	Brace
S-6 to S-15	400X750	400X600	ISB172X92X4.8
Story5	400X750	400X600	ISB172X92X4.8
Story4	400X750	400X600	ISB172X92X4.8
Story3	400X750	400X600	ISB172X92X4.8
Story2	400X750	400X600	ISB172X92X4.8
Story1	400X750	400X600	ISB172X92X4.8
GF	400X750	400X600	ISB172X92X4.8

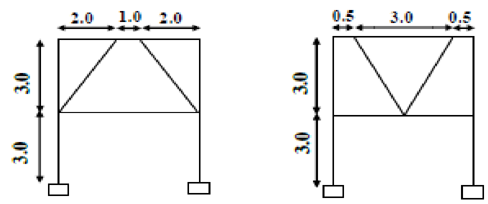

Fig -1: Eccentricity of the K-and V-frames (m)

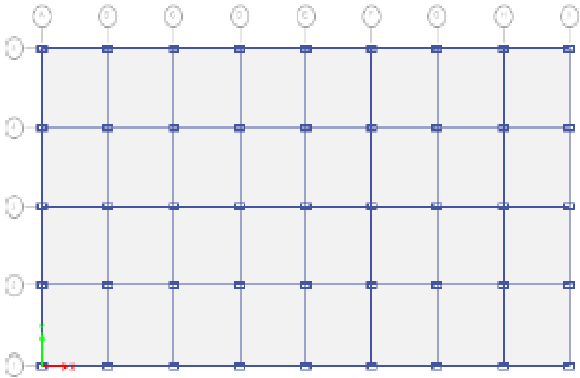

Fig -2: Plan of steel building

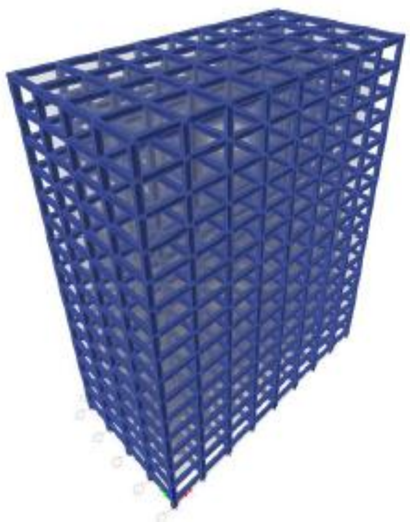

Fig -3: 3-D view of bare model

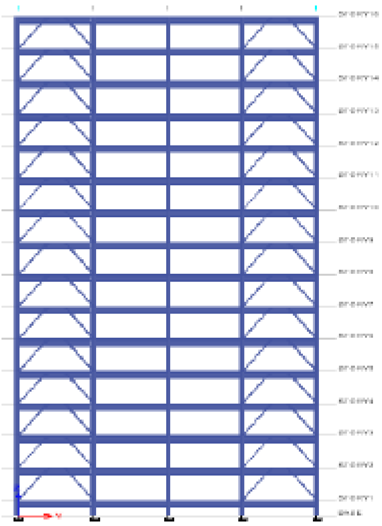

Fig -4: Typical side elevation of K1 model

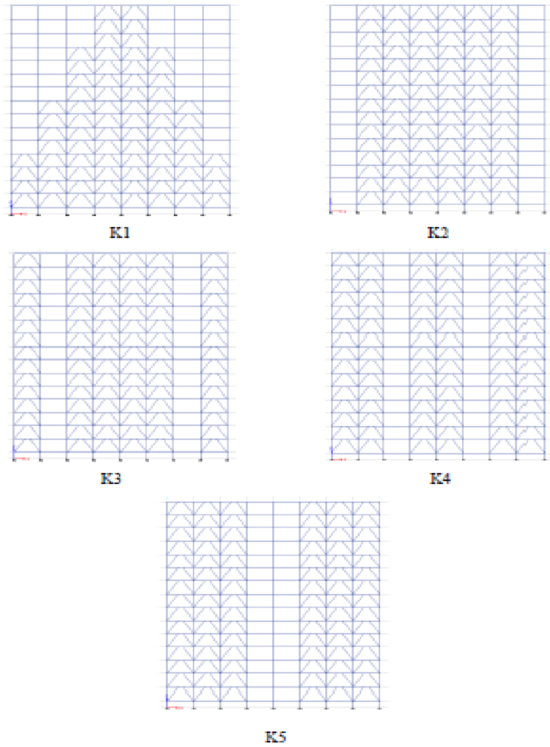

Fig -5: Front elevation of K-frames with different configurations

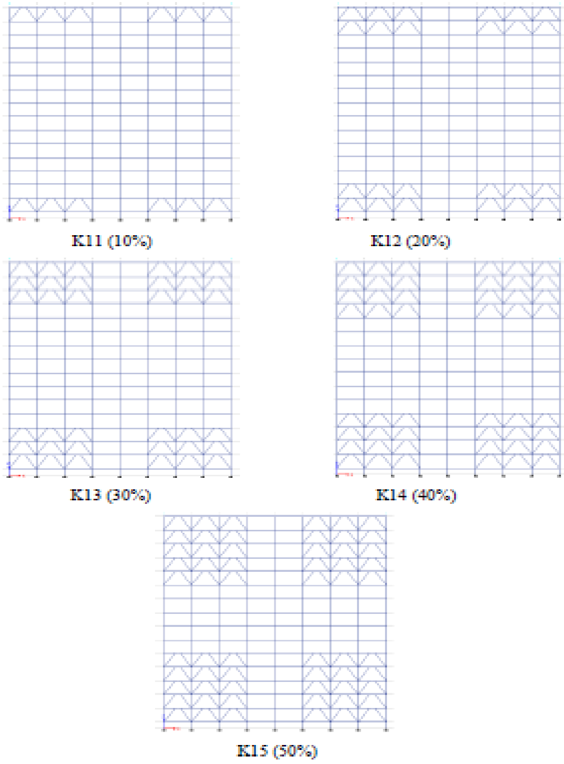

Fig -6: Front elevation of varying percentage of K-bracing at corners in a frame (Type 1)

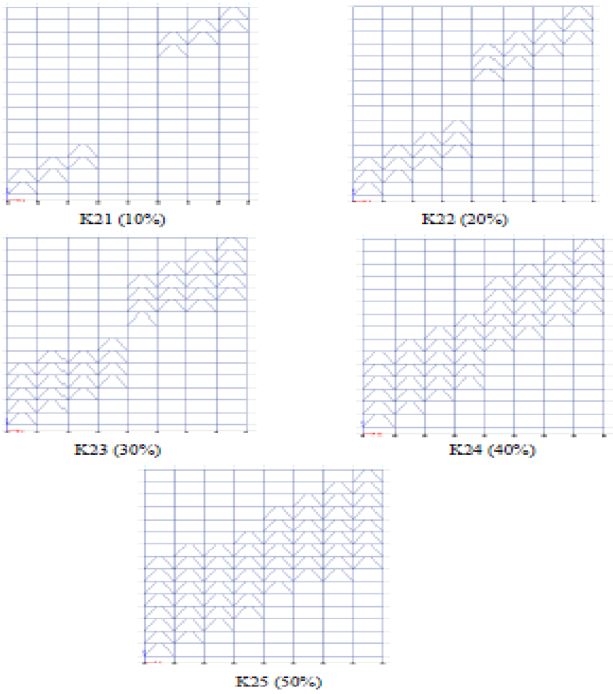

Fig -7: Front elevation of varying percentage of K-bracing from left bottom to right top diagonally in a frame (Type 2)

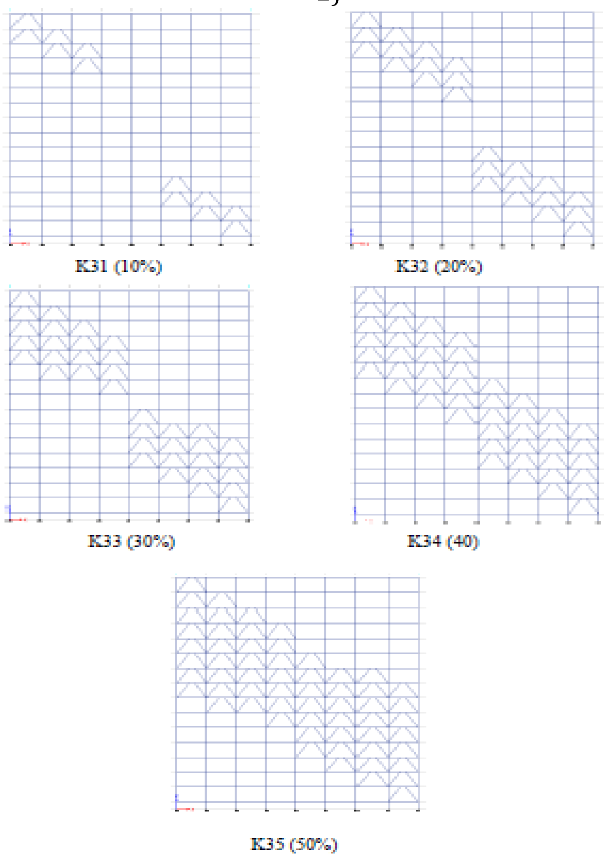

Fig -8: Front elevation of varying percentage of K-bracing from left top to right bottom diagonally in a frame (Type 3)

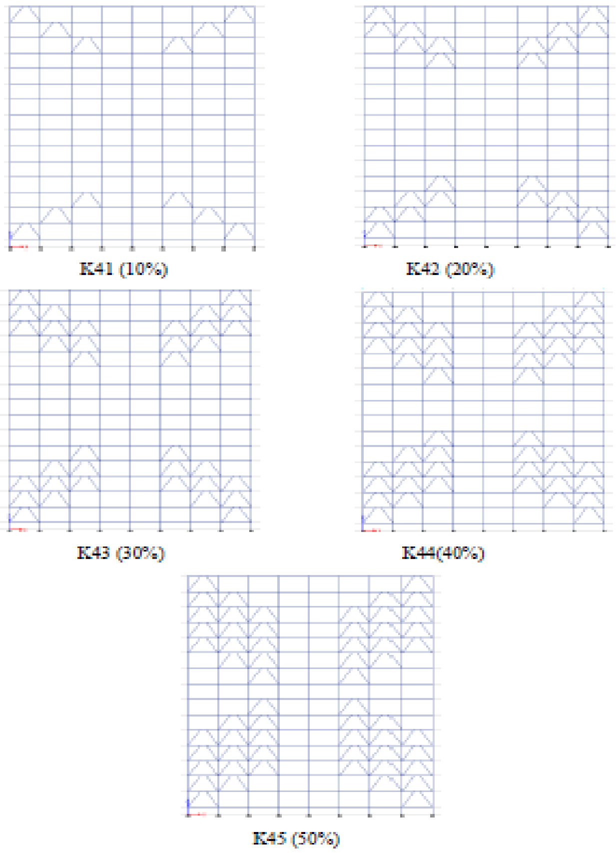

Fig -9: Front elevation of varying percentage of V-bracing at corner diagonally in a frame (Type 4)

Similarly, the V-braced frame with all above configurations have been considered for this study.

3.2 Analysis input

Table 3: Input for response spectra analysis for various types of models

Types of models	All models
R value	5
Function input	0.1
Spectrum case name	SpecX
Structural and function damping	0.05
Model combination	CQC
Directional combination	SRSS
Input response spectra	981
Eccentricity ratio	0.05

For Time History analysis, ground motion record of 1940 El-Centro is used.

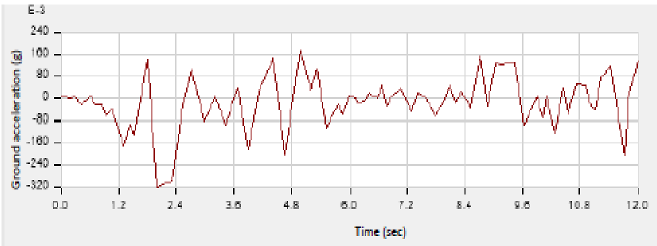

Chart-2: Ground motion record of El-Centro

4. RESULTS

For Response spectrum method,

4.1 Eccentric K- & V-frames

4.1.1 Time period (sec)

The estimation of time period relies upon the building adaptability and mass. Higher the flexibility, the longer is time period and greater mass.

Table -4: Time period of K-frames

MODES	K0	K1	K2	K3	K4	K5
1	1.311	1.277	1.277	1.277	1.277	1.277
2	1.096	1.001	1.004	1.007	1.008	1.008
3	1.024	0.957	0.961	0.967	0.968	0.968
4	0.43	0.418	0.418	0.418	0.418	0.418
5	0.362	0.334	0.332	0.333	0.333	0.333
6	0.335	0.318	0.315	0.317	0.317	0.317
7	0.247	0.24	0.24	0.24	0.24	0.24
8	0.212	0.196	0.195	0.195	0.195	0.195
9	0.193	0.184	0.182	0.182	0.182	0.182
10	0.174	0.169	0.169	0.169	0.169	0.169
11	0.149	0.138	0.137	0.137	0.137	0.137
12	0.133	0.129	0.129	0.129	0.129	0.129

Table -5: Time period of V-frames

MODES	V0	V1	V2	V3	V4	V5
1	1.311	1.271	1.271	1.271	1.271	1.271
2	1.096	0.973	0.977	0.981	0.983	0.982
3	1.024	0.932	0.937	0.946	0.95	0.949
4	0.43	0.415	0.415	0.415	0.415	0.415
5	0.362	0.326	0.323	0.324	0.324	0.324
6	0.335	0.311	0.307	0.309	0.31	0.31
7	0.247	0.238	0.238	0.238	0.238	0.238
8	0.212	0.191	0.19	0.19	0.19	0.19
9	0.193	0.18	0.177	0.178	0.178	0.178
10	0.174	0.167	0.167	0.167	0.167	0.167
11	0.149	0.135	0.134	0.134	0.134	0.134
12	0.133	0.128	0.128	0.128	0.128	0.128

It can be seen from table 4 that, the maximum time period is in K0 model and least in K1 model as compared to other models. The K1, K2, K3, K4 and K5 models have reduction in time period at first (2.59%) and last modes (3.0%) as compared to bare frame. There is a slight variation in time period in these frames. The K1 model exhibit lower time period as compared to other braced models. Table 5 shows The V1, V2, V3, V4 and V5 models have same reduction in time period at first (3.05%) and last modes (3.76%) as compared to bare frame. The V1 model exhibit lower time period at all modes as compared to other braced models. Thus, it can be said that K1 & V1 model has more flexibility and mass when compared to other models.

4.1.2 Frequency (cyc/sec)

By introducing the bracings in a frame, the natural frequency can be increased. Thus probability of collapse of a structure under dynamic loading can be minimized.

Table -6: Frequency of K-frames

MODES	K0	K1	K2	K3	K4	K5
1	0.763	0.783	0.783	0.783	0.783	0.783
2	0.912	0.999	0.996	0.993	0.992	0.992
3	0.976	1.045	1.041	1.035	1.033	1.033
4	2.327	2.391	2.391	2.391	2.391	2.391
5	2.764	2.993	3.015	3.007	3.004	3.005
6	2.985	3.149	3.174	3.16	3.155	3.154
7	4.045	4.169	4.169	4.169	4.169	4.169
8	4.712	5.095	5.13	5.125	5.124	5.124
9	5.191	5.448	5.503	5.49	5.488	5.49
10	5.753	5.93	5.93	5.93	5.929	5.93
11	6.724	7.242	7.297	7.292	7.29	7.291
12	7.506	7.753	7.752	7.752	7.751	7.752

Table -7: Frequency of V-frames

MODES	V0	V1	V2	V3	V4	V5
1	0.763	0.787	0.786	0.787	0.787	0.787
2	0.912	1.028	1.024	1.019	1.017	1.018
3	0.976	1.073	1.067	1.057	1.053	1.053
4	2.327	2.409	2.409	2.409	2.409	2.409
5	2.764	3.07	3.1	3.09	3.086	3.087
6	2.985	3.219	3.254	3.231	3.223	3.224
7	4.045	4.207	4.207	4.207	4.207	4.207
8	4.712	5.224	5.273	5.268	5.267	5.269
9	5.191	5.556	5.634	5.616	5.614	5.617
10	5.753	5.984	5.983	5.984	5.984	5.984
11	6.724	7.415	7.49	7.486	7.485	7.486
12	7.506	7.819	7.818	7.818	7.818	7.818

Table 6 shows that, in K1, K2, K3, K4 and K5 models the frequency has increased by 2.62% as compared to bare model at first mode. The K1 model shows slightly higher frequency value at all modes. Table 7 shows that, The V1, V2, V3, V4 and V5 models have same frequency at first and last modes. Frequency has increased by 3.15% as compared to bare model at first mode. Thus, K1 & V1 models show slightly higher frequency value at all modes and can be considered as stable frame among others.

4.1.3 Displacement (mm)

Mainly, the reduction of displacement in stories is due to increase of stiffness of structure as well as decrease of response of structure. Reduction in the displacement means that it is stable, comfort ability is better and structural strength diminishment is less.

Table-8: Displacement of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	8.72	8.25	8.21	8.27	8.29	8.30
STORY15	8.58	8.10	8.08	8.13	8.15	8.15
STORY14	8.35	7.88	7.87	7.91	7.93	7.93
STORY13	8.05	7.57	7.59	7.62	7.64	7.64
STORY12	7.67	7.19	7.23	7.26	7.27	7.27
STORY11	7.21	6.75	6.80	6.83	6.83	6.83
STORY10	6.69	6.24	6.31	6.33	6.33	6.33
STORY9	6.11	5.67	5.76	5.78	5.78	5.78
STORY8	5.47	5.06	5.16	5.17	5.17	5.17
STORY7	4.77	4.41	4.51	4.52	4.51	4.51
STORY6	4.04	3.72	3.82	3.82	3.82	3.82
STORY5	3.26	3.00	3.09	3.09	3.09	3.08
STORY4	2.46	2.26	2.33	2.33	2.33	2.33
STORY3	1.63	1.51	1.56	1.55	1.55	1.55
STORY2	0.81	0.77	0.79	0.79	0.78	0.78
STORY1	0.14	0.15	0.15	0.15	0.15	0.15

Table-9: Displacement of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	8.72	8.08	8.04	8.13	8.18	8.18
STORY15	8.58	7.93	7.91	7.99	8.03	8.03
STORY14	8.35	7.71	7.70	7.78	7.81	7.81
STORY13	8.05	7.40	7.42	7.49	7.51	7.51
STORY12	7.67	7.02	7.07	7.13	7.14	7.14
STORY11	7.21	6.58	6.65	6.70	6.71	6.71
STORY10	6.69	6.07	6.18	6.21	6.22	6.21
STORY9	6.11	5.51	5.64	5.67	5.67	5.67
STORY8	5.47	4.92	5.05	5.07	5.07	5.07
STORY7	4.77	4.28	4.42	4.43	4.43	4.42
STORY6	4.04	3.61	3.74	3.75	3.74	3.74
STORY5	3.26	2.91	3.03	3.03	3.03	3.03
STORY4	2.46	2.20	2.30	2.29	2.29	2.28
STORY3	1.63	1.47	1.54	1.53	1.53	1.53
STORY2	0.81	0.76	0.79	0.78	0.78	0.78
STORY1	0.14	0.16	0.16	0.16	0.15	0.16

Table 8 shows that, roof displacement is reduced by 5.39% in K1, 5.85% in K2, 5.16% in K3, 4.93% in K4, 4.82% in K5 as compared with bare frame. Maximum displacement reduction is in K2 model (5.85%). Due to increase in stiffness of the frame, lateral displacement has been drastically reduced. Maximum displacement is in K0 model. The displacement values have steadily increased over the height. Table 9 shows that, roof displacement is reduced by 7.34% in V1, 7.79% in V2, 6.77% in V3, 6.19% in V4, 6.19% in V5 as compared with bare frame. Maximum displacement reduction is in V2 model (7.79%). By creating the K2 & V2 model, the structural response can be reduced.

4.1.4 Story drift ratio

It is the difference of the displacements successive stories over the height of building. By decreasing the story drift of structure, its stability can be increased.

Table-10: Story drift ratio of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	0.000053	0.000052	0.000048	0.00005	0.000052	0.000052
STORY15	0.000082	0.000082	0.000072	0.000077	0.000079	0.000079
STORY14	0.00011211	0.0001115	0.00010347	0.0001057	0.00010714	0.00010732
STORY13	0.00013956	0.00013615	0.00012934	0.00013158	0.00013294	0.00013308
STORY12	0.00016393	0.00015927	0.00015231	0.00015452	0.00015577	0.00015587
STORY11	0.00018551	0.00018005	0.00017267	0.00017482	0.00017592	0.00017599
STORY10	0.00020457	0.00019753	0.00019084	0.00019288	0.00019382	0.00019383
STORY9	0.00022142	0.00020916	0.00020705	0.00020894	0.00020969	0.00020966
STORY8	0.00023641	0.00022197	0.00022138	0.00022308	0.00022363	0.00022356
STORY7	0.00024969	0.0002339	0.0002339	0.00023533	0.00023569	0.00023557
STORY6	0.00026115	0.00024318	0.00024464	0.00024574	0.00024589	0.00024575
STORY5	0.00027038	0.0002465	0.00025342	0.0002541	0.00025405	0.0002539
STORY4	0.00027597	0.00025028	0.00025906	0.00025921	0.00025898	0.00025884
STORY3	0.00027153	0.00024742	0.00025631	0.00025583	0.00025542	0.00025532
STORY2	0.00022897	0.00021549	0.00022178	0.00022074	0.00022026	0.00022023
STORY1	0.000092	0.00010017	0.0001004	0.0001	0.0001	0.00010071

Table-11: Story drift ratio of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	0.000053	0.000053	0.000047	0.000051	0.000053	0.000053
STORY15	0.000082	0.000082	0.000074	0.000077	0.000079	0.000079
STORY14	0.000112	0.0001114	0.000101	0.000104	0.000107	0.000107
STORY13	0.000140	0.0001351	0.000126	0.000129	0.000132	0.000132
STORY12	0.000164	0.0001578	0.000148	0.000152	0.000154	0.000154
STORY11	0.000186	0.00017819	0.000168	0.000172	0.000173	0.000173
STORY10	0.000205	0.00019454	0.000186	0.000189	0.000191	0.000191
STORY9	0.000221	0.00020441	0.000202	0.000205	0.000206	0.000206
STORY8	0.000236	0.00021659	0.000216	0.000219	0.000219	0.000219
STORY7	0.000250	0.00022801	0.000228	0.000230	0.000231	0.000231

STORY6	0.000261	0.00023598	0.000238	0.000240	0.000241	0.000240
STORY5	0.000270	0.00023747	0.000247	0.000248	0.000248	0.000248
STORY4	0.000276	0.00024088	0.000253	0.000253	0.000253	0.000253
STORY3	0.000272	0.00023912	0.000251	0.000251	0.000250	0.000250
STORY2	0.000229	0.00021258	0.000221	0.000219	0.000219	0.000219
STORY1	0.000092	0.00010144	0.000104	0.000102	0.000100	0.000101

Table 10 shows that, the maximum drift of K0 model is at the fourth story, is reduced by 9.31% in K1, 6.13% in K2, 6.07% in K3, 6.16% in K4, 6.21% in K5 model as compared to bare frame. There is a slight reduction in story drifts in braced models.Maximum reduction is observed in K5 (6.21%) model at fourth story. Also at, K2 model has least drift value middle stories. Table 11 shows that, the maximum drift of V0 model is at the fourth story, is reduced by 12.72% in V1, 8.33% in V2, 8.33% in V3, 8.33% in V4, 8.33% in V5 model as compared to bare frame. Maximum reduction is observed in V5 (8.33%) model at fourth story. Also at, V2 model has least drift value middle stories. The bare model has maximum story drift ratio.

4.1.5 Story shear (kN)

The maximum lateral load that has occurred at the base of a structure due to earthquake shaking is referred to as base shear. Base shear increases with the mass and lateral stiffness of a building. Bracings in a frame will increase the base shear considerably.

Table-12: Story shear of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	428.79	446.31	438.12	437.67	437.90	438.04
STORY15	1030.36	1082.65	1065.65	1063.49	1063.48	1063.79
STORY14	1565.43	1659.14	1638.28	1633.37	1632.63	1633.00
STORY13	2034.51	2167.57	2147.19	2138.67	2136.76	2137.10
STORY12	2450.43	2615.44	2596.97	2584.29	2580.89	2581.12
STORY11	2823.30	3015.71	2999.55	2982.53	2977.44	2977.50
STORY10	3157.98	3379.14	3365.84	3344.53	3337.72	3337.58
STORY9	3460.47	3710.83	3701.06	3675.75	3667.28	3666.93
STORY8	3738.50	4012.91	4006.31	3977.38	3967.44	3966.92
STORY7	3995.50	4286.62	4282.59	4250.56	4239.40	4238.75
STORY6	4229.24	4533.98	4532.13	4497.62	4485.53	4484.81
STORY5	4436.77	4754.68	4754.95	4718.60	4705.89	4705.15
STORY4	4614.39	4942.12	4944.04	4906.45	4893.38	4892.65
STORY3	4750.77	5081.76	5084.84	5046.48	5033.24	5032.53
STORY2	4827.63	5158.45	5161.99	5123.23	5109.91	5109.24
STORY1	4834.86	5165.89	5169.39	5130.58	5117.26	5116.60

Table-13: Story shear of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	428.79	457.52	446.14	445.45	445.68	445.97
STORY15	1030.36	1109.96	1086.42	1082.94	1082.69	1083.36
STORY14	1565.43	1701.27	1672.45	1664.55	1662.93	1663.94
STORY13	2034.51	2223.58	2195.31	2181.67	2177.95	2179.20
STORY12	2450.43	2684.98	2659.20	2639.05	2632.67	2634.05
STORY11	2823.30	3098.12	3075.51	3048.60	3039.24	3040.64
STORY10	3157.98	3473.25	3454.67	3421.17	3408.75	3410.09
STORY9	3460.47	3815.30	3801.66	3762.00	3746.65	3747.90
STORY8	3738.50	4126.61	4117.42	4072.20	4054.24	4055.40
STORY7	3995.50	4408.21	4402.74	4352.75	4332.61	4333.74
STORY6	4229.24	4661.83	4659.64	4605.78	4583.98	4585.14
STORY5	4436.77	4887.12	4888.05	4831.31	4808.38	4809.60
STORY4	4614.39	5077.91	5081.24	5022.52	4998.92	5000.23
STORY3	4750.77	5220.14	5225.07	5165.09	5141.15	5142.57
STORY2	4827.63	5298.86	5304.35	5243.70	5219.62	5221.11
STORY1	4834.86	5306.64	5312.07	5251.34	5227.24	5228.75

It can be seen from table 12 that, base shear is increased in K1 by 6.85%, K2 by 6.92%, K3 by 6.12%, K4 by 5.84% and K5 by 5.83%. By comparing all these, K2 model has greatest base shear (6.92%) and K0 has least value. It can be seen from table 13 that, base shear is increased in V1 by 9.76%, V2 by 9.87%, V3 by 8.61%, V4 by 8.11% and V5 by 8.15%. By comparing all these, V2 model has greatest base shear (9.87%) and V0 has least value. The story shear value steadily reduces over the height. In all models, the story shear at the base is more and at the top story shear is less.

4.2 Varying percentage of K- & V-bracings in a frame

4.2.1 Time period (sec)

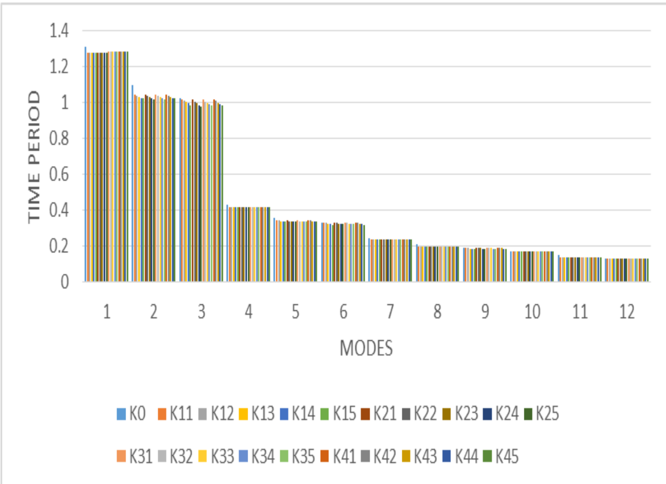

Chart-3: Comparison of time period of varying percentage of V-bracings in a frame

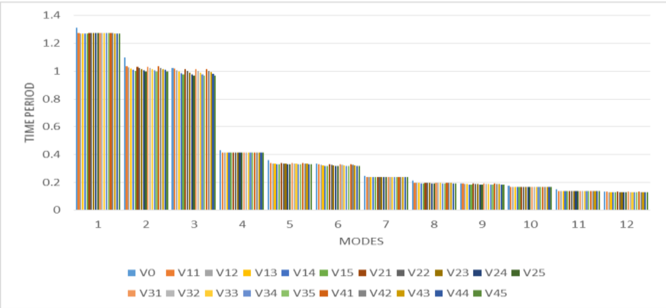

Chart-4: Comparison of time period of varying percentage of V-bracings in a frame

Chart-3 shows that, time period has been reduced in type 1 models by 2.59%, in type 2 models by 2.59%, in type 3 models by 2.05% and in type 4 models by 2.05% at first mode. The maximum reduction in time period is observed in type 1 and type 2 models. Further in these type 2 models exhibit slightly lower time period i.e. K25 model shows less time period (2.59% reduction) among others. The maximum time period is observed in K0 model. Chart-4 shows that, time period has been reduced in type 1 models by 3.05%, in type 2 models by 2.97%, in type 3 models by 2.97% and in type 4 models by 3.05% at first mode. The maximum reduction in time period is observed in type 2 and type 3 models. Comparing time periods at all modes, these models exhibit slightly lower time period i.e. V25, V35 models show less time period among others. The maximum time period is in V0 model. Due to increase of bracing members, the stiffness of a frame is increased and is the cause of reduction of time period.

4.2.2 Frequency (cyc/sec)

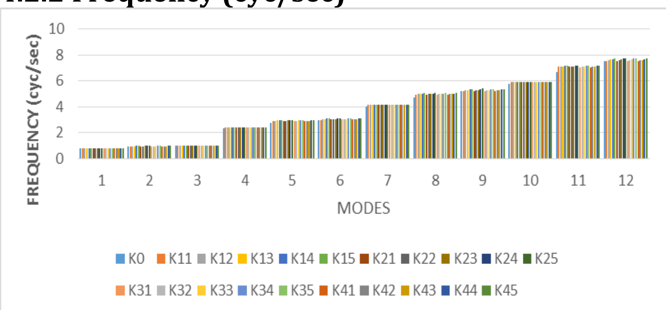

Chart-5: Comparison of frequency of varying percentage of K-bracings in a frame

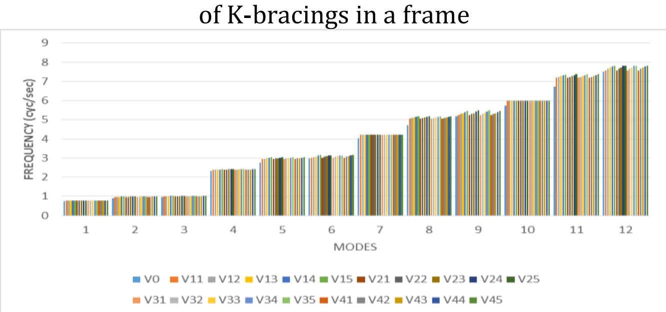

Chart-6: Comparison of frequency of varying percentage of V-bracings in a frame

Chart-5 shows that, the frequency value has been increased in type 1 models by 2.62%, in type 2 models by 2.62%, in type 3 models by 2.09% and in type 4 models by 2.09% at first mode. The maximum increment of frequency value is observed in type 2 models. Further in these type 2 models exhibit slightly greater time period i.e. K25 model shows higher frequency (increased by 2.62%) among others. The lowest frequency values are observed in bare model. The K25 model can be considered as stable among others. Chart-6 shows that, the frequency value has been increased in type 1 models by 3.15%, in type 2 models by 3.01%, in type 3 models by 3.01% and in type 4 models by 3.15% at first mode. The maximum increment of frequency value is observed in type 2 and type 4 models. Further in these type 2 models exhibit slightly greater time period i.e. V25and V45 model shows higher frequency (increased by 3.15%) among others. The lowest frequency values are observed in bare model. The V25 and V45 model can be considered as stable among others.

4.2.3 Displacement (mm)

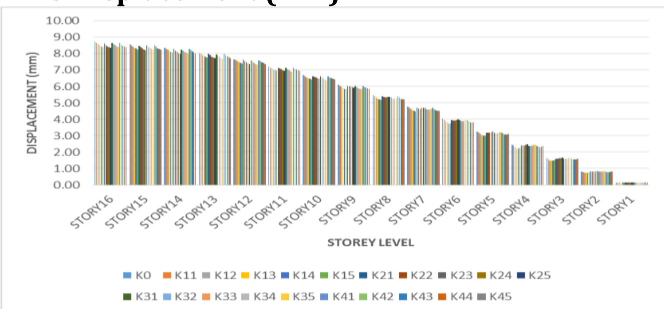

Chart-7: Comparison of displacement of varying percentage of V-bracings in a frame

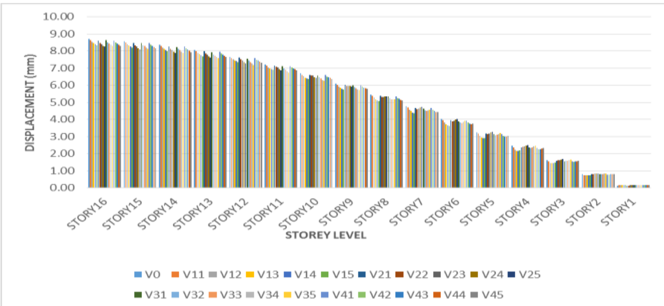

Chart-8: Comparison of displacement of varying percentage of V-bracings in a frame

Chart-7 shows that, roof displacements have lessened as there is an increase in percentage of bracings. In type 1 models displacement is reduced by 0.57% in K11, 1.38% in K12, 2.29% in K13, 2.98% in K14, 3.56% in K15 as compared to bare frame. Similarly, in type 2, type 3, type 4 models reduction varies as 1.03 to 4.13%, 0.69 to 3.56%, 0.8 to 3.67% respectively. Thus maximum reduction is observed in type 2 models i.e. in K25 model (4.13% reduction), has least story displacement among others. Chart-8 shows that, roof displacements have lessened as there is an increase in percentage of bracings. In type 1 models displacement is reduced by 0.8% in V11, 1.94% in V12, 2.98% in V13, 3.56% in V14, 4.47% in V15 as compared to bare frame. Similarly, in type 2, type 3, type 4 models reduction varies as 1.49 to 5.39%, 1.03 to 4.82%, 1.15 to 4.7% respectively. Thus maximum reduction is observed in type 2 models i.e. in V25 model (5.39% reduction), has least story displacement among others. Due to increase in stiffness of the frame, lateral displacement has been progressively reduced.

4.2.4 Story drift ratio

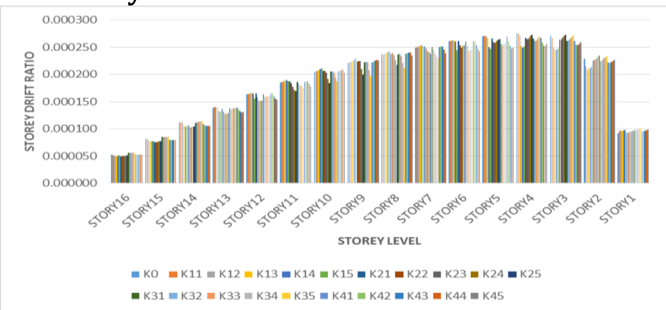

Chart-9: Comparison of story drift ratio of varying percentage of V-bracings in a frame

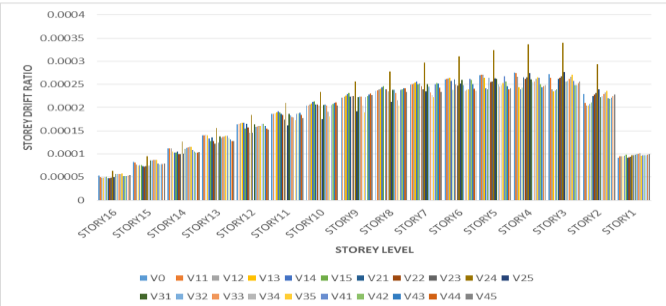

Chart-10: Comparison of story drift ratio of varying percentage of V-bracings in a frame

Chart-9 shows that, the story drift is reduced by 0% in K11, 1.81% in K12, 8.33% in K13, 9.42% in K14, 9.42% in K15, 2.89% in K21, 3.98% in K22, 3.26% in K23, 2.17% in K24, 1.09% in K25, 3.62% in K31, 5.15% in K32, 4.71% in K33, 3.62% in K34, 2.54% in K35, 2.89% in K41, 6.52% in K42, 8.69% in K43, 8.33% in K44, 7.25% in K45 as compared to bare frame. Comparing all these models, K25 (type 2) model has slightly less drift values at central stories. Chart-10 shows that, roof displacement has slightly reduced as there is a increase in percentage of bracings. The story drift is reduced by 1.79% in V11, 3.57% in V12, 14.28% in V13, 14.28% in V14, 14.28% in V15, 3.57% in V21, 7.14% in V22, 3.57% in V23, 3.57% in V24, 0% in V25, 7.14% in V31, 7.14% in V32, 8.21% in V33, 6.43% in V34, 3.57% in V35, 7.14% in V41, 10.71% in V42, 14.25% in V43, 10.71% in V44, 10.71% in V45 as compared to bare frame. Comparing all these models, V25 and V35 (type 2) model has slightly less drift values at middle stories. Further increase in the bracing members has resulted in gradual lessening of the drift ratio.

4.2.5 Story shear (kN)

The maximum lateral load that has occurred at the base of a structure due to earthquake shaking is referred to as base shear. Base shear increases with the mass and lateral stiffness of a building.

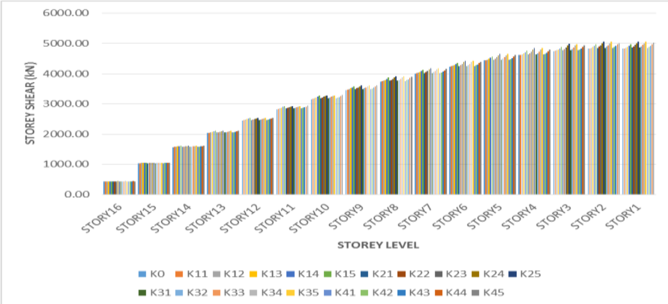

Chart-11: Comparison of story shear of varying percentage of V-bracings in a frame

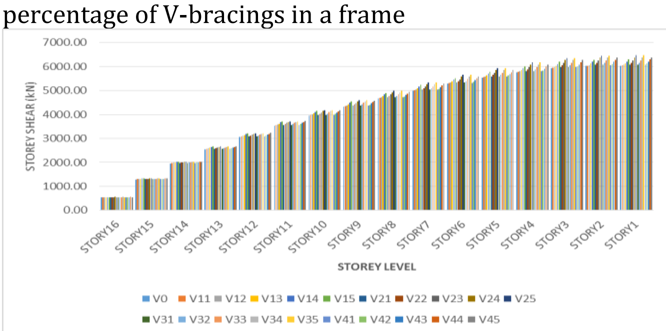

Chart-12: Comparison of story shear of varying percentage of V-bracings in a frame

Chart-11 shows that maximum story shear is at base and least at top story. Story shear value has increased in type 1 models by 0.11% in K11, 0.44% in K12, and 1.0% for K13, 1.88% in K14, 2.88% in K15. Similarly in type 2, type3, type 4 models, it varies as 0.55 to 4.78%, 0.55 to 4.75%, 0.43 to 3.92% respectively. It is observed that the base shear is maximum in type 2 model i.e. in K25 model (2.23% increment). Chart-12 shows that maximum story shear is at base and least at top story. Base shear value is increased in type 1 models by 0.13% in V11, 0.58% in V12, and 1.48% for V13, 2.85% in V14, 4.24% in V15. Similarly in type 2, type 3, type 4 models varies as 0.75 to 6.06%, 0.75 to 6.06%, 0.58 to 5.65% respectively. It is observed that, the base shear is maximum in V25 and V35, 6.06% is increased in both models as compared to steel frame without bracing.

For Time history method,

4.3 Eccentric K- & V-frames

4.3.1 Time period (sec)

Table-14: Time period of K-frames

MODES	K0	K1	K2	K3	K4	K5
1	1.311	1.277	1.277	1.277	1.277	1.277
2	1.096	1.001	1.004	1.007	1.008	1.008
3	1.024	0.957	0.961	0.967	0.968	0.968
4	0.43	0.418	0.418	0.418	0.418	0.418
5	0.362	0.334	0.332	0.333	0.333	0.333
6	0.335	0.318	0.315	0.317	0.317	0.317
7	0.247	0.24	0.24	0.24	0.24	0.24
8	0.212	0.196	0.195	0.195	0.195	0.195
9	0.193	0.184	0.182	0.182	0.182	0.182
10	0.174	0.169	0.169	0.169	0.169	0.169
11	0.149	0.138	0.137	0.137	0.137	0.137
12	0.133	0.129	0.129	0.129	0.129	0.129

Table-15: Time period of V-frames

MODES	V0	V1	V2	V3	V4	V5
1	1.311	1.271	1.271	1.271	1.271	1.271
2	1.096	0.973	0.977	0.981	0.983	0.982
3	1.024	0.932	0.937	0.946	0.95	0.949
4	0.43	0.415	0.415	0.415	0.415	0.415
5	0.362	0.326	0.323	0.324	0.324	0.324
6	0.335	0.311	0.307	0.309	0.31	0.31
7	0.247	0.238	0.238	0.238	0.238	0.238
8	0.212	0.191	0.19	0.19	0.19	0.19
9	0.193	0.18	0.177	0.178	0.178	0.178
10	0.174	0.167	0.167	0.167	0.167	0.167
11	0.149	0.135	0.134	0.134	0.134	0.134
12	0.133	0.128	0.128	0.128	0.128	0.128

Table 14 shows the maximum time period is in K0 model and least in K1 model as compared to other models. The K1, K2, K3, K4 and K5 models have same reduction in time period at first (2.59%) and last modes (3.0%) as compared to bare frame. There is a slight variation in time period in these frames. The K1 model exhibit lower time period at all modes as compared to other braced models. Table 15 shows the maximum time period is in V0 model and least in V1 model as compared to other models. The V1, V2, V3, V4 and V5 models have same reduction in time period at first (3.05%) and last modes (3.76%) as compared to bare frame. There is a slight variation in time period in these frames. The V1 model exhibit lower time period at all modes as compared to other braced models. Thus, it can be said that V1 model has more flexibility and mass when compared to other models.

4.3.2 Frequency (cyc/sec)

Table-16: Frequency of K-frames

MODES	K0	K1	K2	K3	K4	K5
1	0.763	0.783	0.783	0.783	0.783	0.783
2	0.912	0.999	0.996	0.993	0.992	0.992
3	0.976	1.045	1.041	1.035	1.033	1.033
4	2.327	2.391	2.391	2.391	2.391	2.391
5	2.764	2.993	3.015	3.007	3.004	3.005
6	2.985	3.149	3.174	3.16	3.155	3.154
7	4.045	4.169	4.169	4.169	4.169	4.169
8	4.712	5.095	5.13	5.125	5.124	5.124
9	5.191	5.448	5.503	5.49	5.488	5.49
10	5.753	5.93	5.93	5.93	5.929	5.93
11	6.724	7.242	7.297	7.292	7.29	7.291
12	7.506	7.753	7.752	7.752	7.751	7.752

Table-17: Frequency of V-frames

MODES	V0	V1	V2	V3	V4	V5
1	0.763	0.787	0.786	0.787	0.787	0.787
2	0.912	1.028	1.024	1.019	1.017	1.018
3	0.976	1.073	1.067	1.057	1.053	1.053
4	2.327	2.409	2.409	2.409	2.409	2.409
5	2.764	3.07	3.1	3.09	3.086	3.087
6	2.985	3.219	3.254	3.231	3.223	3.224
7	4.045	4.207	4.207	4.207	4.207	4.207
8	4.712	5.224	5.273	5.268	5.267	5.269
9	5.191	5.556	5.634	5.616	5.614	5.617
10	5.753	5.984	5.983	5.984	5.984	5.984
11	6.724	7.415	7.49	7.486	7.485	7.486
12	7.506	7.819	7.818	7.818	7.818	7.818

Table 16 shows that, The K1, K2, K3, K4 and K5 models have same frequency at first and last modes. Frequency has increased by 2.62% as compared to bare model at first mode. The K1 model shows slightly higher frequency value at all modes and can be considered as stable frame among others. Table 17 shows that, The V1, V2, V3, V4 and V5 models have same time period at first and last modes. Frequency has increased by 3.15% as compared to bare model at first mode. The V1 model shows slightly higher frequency value at all modes and can be considered as stable frame among others.

4.3.3 Displacement (mm)

Table-18: Displacement of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	226.85	203.90	203.23	205.14	206.30	206.41
STORY15	223.12	200.67	200.19	201.59	202.64	202.72
STORY14	217.46	195.79	195.63	196.23	197.16	197.21
STORY13	209.66	189.10	189.35	189.85	190.00	190.01

STORY12	199.74	180.77	181.37	181.78	181.86	181.85
STORY11	187.84	170.73	171.71	172.04	172.07	172.04
STORY10	174.08	158.99	160.42	160.67	160.65	160.61
STORY9	158.65	145.66	147.53	147.70	147.64	147.60
STORY8	141.73	131.04	133.09	133.17	133.08	133.04
STORY7	123.51	115.01	117.14	117.15	117.04	117.00
STORY6	104.17	97.59	99.80	99.73	99.61	99.58
STORY5	83.91	79.01	81.19	81.07	80.95	80.93
STORY4	63.07	59.81	61.54	61.38	61.28	61.26
STORY3	42.06	40.06	41.19	41.03	40.95	40.94
STORY2	21.10	20.39	20.90	20.79	20.75	20.74
STORY1	3.51	3.90	3.96	3.91	3.83	3.84

Table-19: Displacement of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	226.85	201.35	200.77	202.58	203.43	203.50
STORY15	223.12	198.00	197.68	199.29	200.00	200.03
STORY14	217.46	192.92	193.03	194.45	195.01	195.01
STORY13	209.66	186.01	186.66	187.91	188.33	188.30
STORY12	199.74	177.48	178.59	179.68	179.98	179.92
STORY11	187.84	167.25	168.88	169.82	170.01	169.93
STORY10	174.08	155.36	157.59	158.37	158.48	158.38
STORY9	158.65	141.99	144.77	145.40	145.43	145.32
STORY8	141.73	127.51	130.47	130.95	130.92	130.81
STORY7	123.51	111.71	114.77	115.09	115.01	114.92
STORY6	104.17	94.63	97.76	97.94	97.82	97.74
STORY5	83.91	76.56	79.58	79.62	79.49	79.43
STORY4	63.07	58.05	60.41	60.35	60.23	60.19
STORY3	42.06	39.06	40.58	40.47	40.37	40.35
STORY2	21.10	20.09	20.76	20.66	20.60	20.59
STORY1	3.51	4.12	4.21	4.13	4.01	4.05

It can be seen from Table 18 that, roof displacement is reduced by 10.12% in K1, 10.41% in K2, 9.57% in K3, 9.06% in K4, 9.01% in K5 as compared with bare frame. Maximum displacement reduction is in K2 model (10.41%). Due to increase in stiffness of the frame, lateral displacement has been drastically reduced. Maximum displacement is in K0 model. Thus by creating the K2 model, the structural response can be reduced. Table 19 shows that, roof displacement is reduced by 11.24% in V1, 11.49% in V2, 10.69% in V3, 10.32% in V4, 10.29% in V5 as compared with bare frame. Maximum displacement reduction is in V2 model (11.49%). Due to increase in stiffness of the frame, lateral displacement has been drastically reduced. Maximum displacement is in V0 model. Thus by creating the V2 model, the structural response can be reduced. Also, it is observed that displacement value is lowest in bottom stories, very high at the upper stories.

4.3.4 Story drift ratio

Table-20: Story drift ratio of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	0.001242	0.001202	0.001128	0.001185	0.001220	0.001229
STORY15	0.001886	0.001849	0.001723	0.001789	0.001828	0.001836
STORY14	0.002602	0.002537	0.002375	0.002447	0.002486	0.002494
STORY13	0.003304	0.003137	0.003003	0.003080	0.003118	0.003125
STORY12	0.003969	0.003724	0.003587	0.003669	0.003706	0.003711
STORY11	0.004585	0.004266	0.004121	0.004206	0.004241	0.004245
STORY10	0.005143	0.004727	0.004600	0.004688	0.004721	0.004723
STORY9	0.005640	0.005039	0.005024	0.005113	0.005143	0.005144
STORY8	0.006075	0.005367	0.005391	0.005480	0.005507	0.005507
STORY7	0.006447	0.005807	0.005782	0.005806	0.005810	0.005809
STORY6	0.006754	0.006193	0.006202	0.006221	0.006221	0.006218
STORY5	0.006986	0.006400	0.006551	0.006562	0.006558	0.006555
STORY4	0.007105	0.006583	0.006784	0.006784	0.006776	0.006773
STORY3	0.006986	0.006555	0.006762	0.006746	0.006734	0.006732
STORY2	0.005883	0.005678	0.005821	0.005792	0.005779	0.005778
STORY1	0.002343	0.002599	0.002641	0.002606	0.002555	0.002558

Table-21: Story drift ratio of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	0.001242	0.001159	0.001060	0.001158	0.001218	0.001227
STORY15	0.001886	0.001781	0.001618	0.001728	0.001795	0.001804
STORY14	0.002602	0.002430	0.002225	0.002346	0.002414	0.002422
STORY13	0.003304	0.002982	0.002810	0.002940	0.003009	0.003015
STORY12	0.003969	0.003534	0.003355	0.003494	0.003562	0.003566
STORY11	0.004585	0.004041	0.003854	0.004000	0.004066	0.004068
STORY10	0.005143	0.004457	0.004304	0.004455	0.004518	0.004517
STORY9	0.005640	0.004827	0.004764	0.004854	0.004914	0.004910
STORY8	0.006075	0.005266	0.005233	0.005285	0.005300	0.005298
STORY7	0.006447	0.005693	0.005670	0.005720	0.005730	0.005726
STORY6	0.006754	0.006026	0.006062	0.006106	0.006111	0.006105
STORY5	0.006986	0.006169	0.006388	0.006421	0.006420	0.006413
STORY4	0.007105	0.006330	0.006610	0.006627	0.006620	0.006614
STORY3	0.006986	0.006324	0.006608	0.006604	0.006590	0.006585
STORY2	0.005883	0.005587	0.005777	0.005751	0.005733	0.005732
STORY1	0.002343	0.002684	0.002742	0.002698	0.002625	0.002630

Table 21 shows that, the maximum drift of V0 model is at the fourth story, is reduced by 10.9% in V1, 6.97% in V2, 6.72% in V3, 6.83% in V4, 6.91% in V5 model as compared to bare frame. There is a slight reduction in story drifts in braced models. Maximum reduction is observed in V1 (10.9%) model at fourth story. Also V2 model has least drift value middle stories. The bare model has maximum story drift ratio. Table 20 shows that, the maximum drift of K0 model is at the fourth story, is reduced by 7.34% in K1, 4.51% in K2, 4.52% in K3, 4.63% in K4, 4.67% in K5 model as compared to bare frame. There is a slight reduction in story drifts in braced models.Maximum reduction is observed in K1 (7.34%) model at fourth story. Also, K2 model has least drift value middle stories.

4.3.5 Story shear (kN)

The maximum lateral load that has occurred at the base of a structure due to earthquake shaking is referred to as base shear. Base shear increases with the mass and lateral stiffness of a building. Bracings in a frame will increase the base shear considerably.

Table-22: Story shear of K-frames

LEVEL	K0	K1	K2	K3	K4	K5
STORY16	9094.04	8866.04	8820.85	8948.32	8992.27	8997.87
STORY15	22496.26	22002.36	21917.09	22221.56	22324.08	22335.39
STORY14	35353.75	34700.80	34621.63	35083.62	35235.57	35250.05
STORY13	47513.37	46769.55	46757.70	47355.14	47546.51	47562.49
STORY12	58878.85	58010.90	58126.24	58835.74	59056.77	59072.80
STORY11	69382.65	68749.56	68572.97	69318.32	69559.80	69574.79
STORY10	78945.46	79006.35	78756.17	78611.41	78865.08	78878.17
STORY9	87451.44	88377.86	88064.80	86903.50	86825.45	86835.93
STORY8	94756.62	96765.64	96396.17	95185.98	94758.38	94736.71
STORY7	100730.99	104071.54	103661.26	102417.68	101972.67	101948.71
STORY6	105315.28	110214.43	109787.53	108521.19	108063.83	108038.60
STORY5	108563.50	115140.16	114720.40	113437.91	112972.05	112946.40
STORY4	110646.64	118835.20	118423.88	117129.14	116657.61	116632.08
STORY3	111810.85	121291.12	120883.15	119579.01	119103.90	119078.88
STORY2	112311.26	122534.65	122124.31	120814.25	120337.29	120312.85
STORY1	112352.06	122651.09	122239.22	120928.45	120451.28	120426.90

It can be seen from table 22 that, base shear is increased in K1 by 9.17%, K2 by 8.8%, K3 by 7.63%, K4 by 7.21% and K5 by 7.03%. By comparing all these, K1 model has greatest base shear (9.17%) and K0 has least value.

Table-23: Story shear of V-frames

LEVEL	V0	V1	V2	V3	V4	V5
STORY16	9094.04	9203.93	9191.11	9055.16	9006.17	9017.94
STORY15	22496.26	22871.96	22848.79	22505.03	22376.77	22403.54
STORY14	35353.75	36143.61	36119.41	35575.03	35365.54	35404.03
STORY13	47513.37	48874.32	48856.31	48127.94	47839.30	47886.03
STORY12	58878.85	60936.34	60920.55	60032.14	59669.94	59721.43
STORY11	69382.65	72198.45	72185.96	71166.06	70738.46	70791.51
STORY10	78945.46	82541.57	82541.97	81420.78	80937.52	80989.35
STORY9	87451.44	91871.90	91895.42	90702.02	90173.37	90221.83
STORY8	94756.62	100133.15	100171.52	98931.46	98367.38	98410.99
STORY7	100730.99	107262.94	107313.78	106047.42	105456.80	105494.86
STORY6	105315.28	113212.03	113283.17	112004.75	111394.99	111427.52
STORY5	108563.50	117956.83	118056.43	116774.07	116150.92	116178.59
STORY4	110646.64	121510.56	121624.13	120340.84	119708.59	119732.52
STORY3	111810.85	123878.01	123991.04	122706.63	122068.45	122090.05
STORY2	112311.26	125087.12	125191.31	123905.04	123263.67	123284.30
STORY1	112352.06	125202.43	125303.96	124017.20	123375.45	123396.00

It can be seen from table 23 that, base shear is increased in V1 by 11.44%, V2 by 11.53%, V3 by 10.38%, V4 by 8.11% and V5 by 9.81%. By comparing all these, V2 model has slightly high base shear (11.53%) and V0 has least value. shows that the story shear value steadily reduces over the height. In all models, the story shear at the base is more and at the top story shear is less.

4.4 Varying percentage of K- & V-bracings in a frame

4.4.1 Time period (sec)

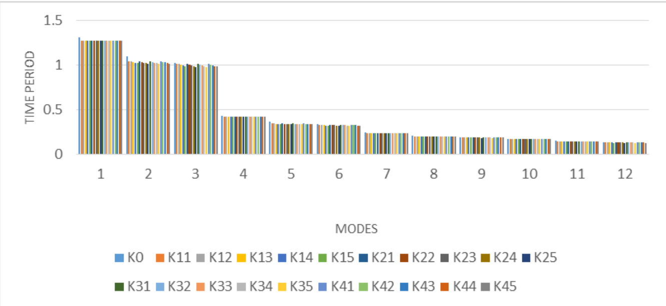

Chart-13: Comparison of time period of varying percentage of K-bracings in a frame

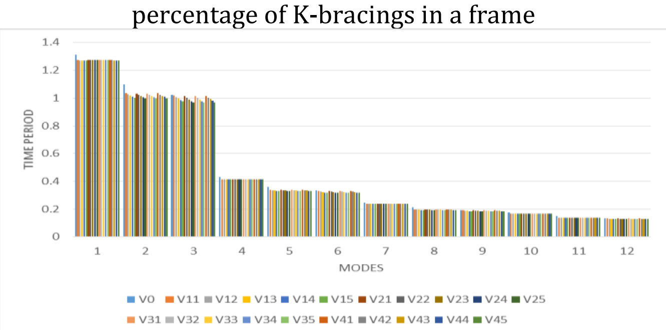

Chart-14: Comparison of time period of varying percentage of V-bracings in a frame

Chart-13 shows that, time period has been reduced in type 1 models by 2.59%, in type 2 models by 2.59%, in type 3 models by 2.59% and in type 4 models by 2.59% at first mode. The maximum reduction in time period is observed in type 2 and type 3 models. Comparing time periods at all modes, these models exhibit slightly lower time period i.e. K25, K35 models show less time period among others. The maximum time period is in bare model. Chart-14 shows that, time period has been reduced in type 1 models by 2.59%, in type 2 models by 2.59%, in type 3 models by 2.59% and in type 4 models by 2.59% at first mode. The maximum reduction in time period is observed in type 2 and type 3 models. Comparing time periods at all modes, these models exhibit slightly lower time period i.e. V25, V35 models show less time period among others. The maximum time period is in bare model. Due to increase of bracing members, the stiffness of a frame is increased and is the cause of reduction of time period.

4.4.2 Frequency (cyc/sec)

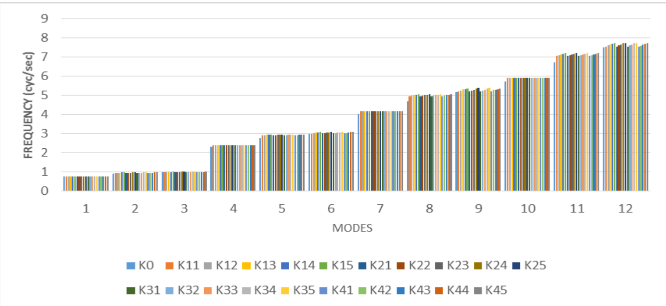

Chart-15: Comparison of frequency of varying percentage of K-bracings in a frame

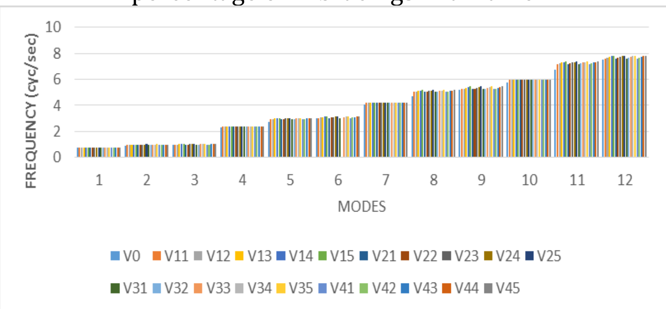

Chart-16: Comparison of frequency of varying percentage of V-bracings in a frame

Chart-15 shows that, the frequency value has been increased in type 1 models by 2.62%, in type 2 models by 2.62%, in type 3 models by 2.62% and in type 4 models by 2.62% at first mode. The maximum increment of frequency value is observed in type 2 and type 4 models. Further in these type 2 models exhibit slightly greater time period i.e. K25and K45 model shows higher frequency (increased by 2.62%) among others. The lowest frequency values are observed in bare model. The K25 and V45 model can be considered as stable among others. Chart-16 shows that, the frequency value has been increased in type 1 models by 3.01%, in type 2 models by 3.01%, in type 3 models by 3.01% and in type 4 models by 3.15% at first mode. The maximum increment of frequency value is observed in type 2 and type 4 models. Further in these type 2 models exhibit slightly greater time period i.e. V25and V45 models show slightly higher frequency among others. The lowest frequency values are observed in bare model. The V25 and V45 model can be considered as stable among others.

4.4.3 Displacement (mm)

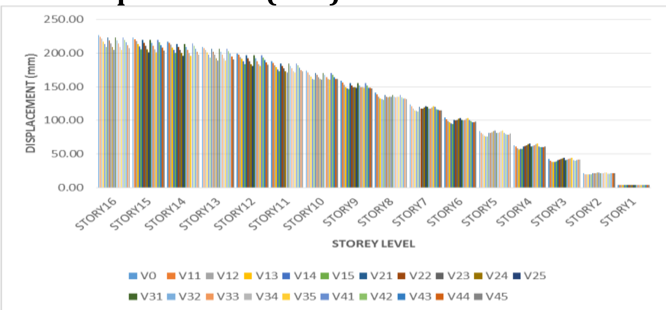

Chart-17: Comparison of displacement of varying percentage of K-bracings in a frame

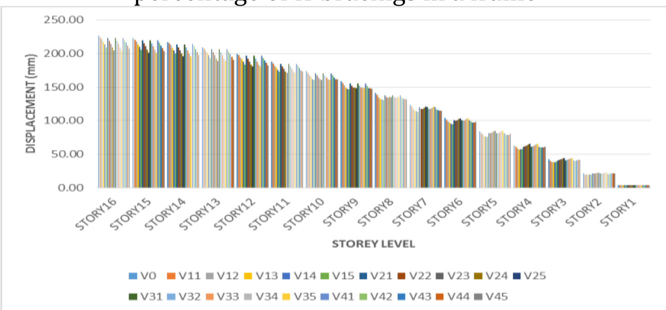

Chart-18: Comparison of displacement of varying percentage of V-bracings in a frame

Chart-17 shows that, roof displacements have lessened as there is an increase in percentage of bracings. In type 1 models displacement is reduced by 0.71% in K11, 1.74% in K12, 2.89% in K13, 4.13% in K14, 5.42% in K15 as compared to bare frame. Similarly, in type 2, type 3, type 4 models reduction varies as 1.08 to 6.45%, 1.08 to 6.45%, 1.01 to 5.96% respectively. Thus maximum reduction is observed in type 2 and type 3 models i.e. in K25 and K35 models (6.45% reduction), has least story displacement among others. Chart-18 shows that, roof displacement have lessened as there is an increase in percentage of bracings. In type 1 models displacement is reduced by 0.98% in V11, 2.41% in V12, 4.04% in V13, 5.83% in V14, 7.74% in V15 as compared to bare frame. Similarly, in type 2, type 3, type 4 models reduction varies as 1.51 to 9.54%, 1.51 to 9.54%, 1.43 to 8.56% respectively. Thus maximum reduction is observed in type 2 and type 3 models i.e. in V25, V35 model (4.13% reduction), has least story displacement among others. Due to increase in stiffness of the frame, lateral displacement has been drastically reduced.

4.4.4 Story drift ratio

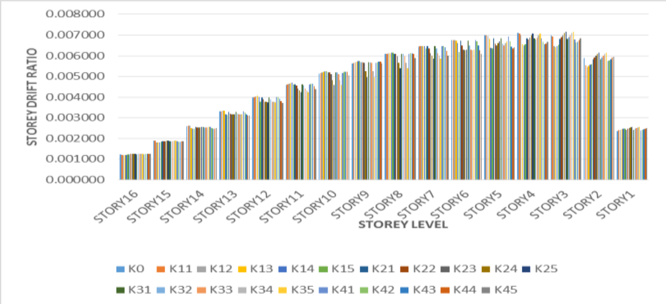

Chart-19: Comparison of story drift ratio of varying percentage of K-bracings in a frame

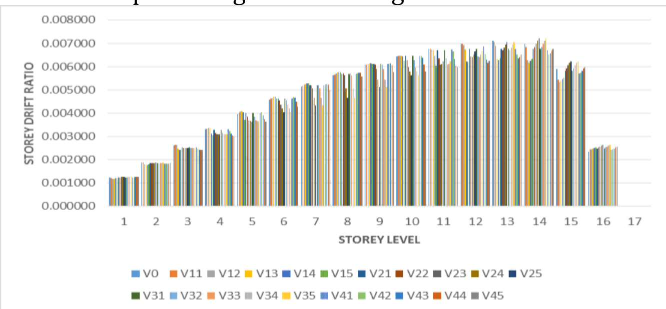

Chart-20: Comparison of story drift ratio of varying percentage of V-bracings in a frame

Chart-19 shows that, the story drift is reduced by 0.45% in K11, 1.83% in K12, 7.83% in K13, 8.66% in K14, 7.67% in K15, 3.79% in K21, 4.33% in K22, 3.35% in K23, 4.38% in K24, 0.51% in K25, 3.79% in K31, 4.33% in K32, 3.35% in K33, 1.84% in K34, 0.51% in K35, 3.53% in K41, 6.22% in K42, 7.91% in K43, 10.8% in K44, 6.09% in K45 as compared to bare frame. Comparing all these models, K25 and K35 models have slightly lower drift values at middle stories. Chart-20 shows that, roof displacement has slightly reduced as there is a increase in percentage of bracings. The story drift is reduced by 0.77% in V11, 2.91% in V12, 10.81% in V13, 11.75% in V14, 10.51% in V15, 4.94% in V21, 5.5% in V22, 4.2% in V23, 2.21% in V24, 0.61% in V25, 4.94% in V31, 5.5% in V32, 4.2% in V33, 2.21% in V34, 6.4% in V35, 4.77% in V41, 8.37% in V42, 10.47% in V43, 13.31% in V44, 8.18% in V45 as compared to bare frame. Comparing all these models, V25 and V35 models has slightly less drift values at middle stories. Further increase in the bracing members has resulted in gradual reduction of the drift ratio.

4.4.5 Story shear (kN)

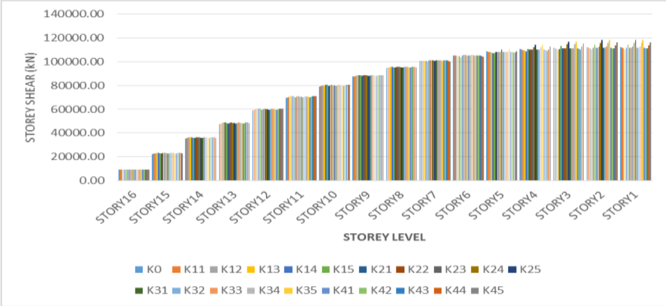

Chart-21: Comparison of story shear of varying percentage of K-bracings in a frame

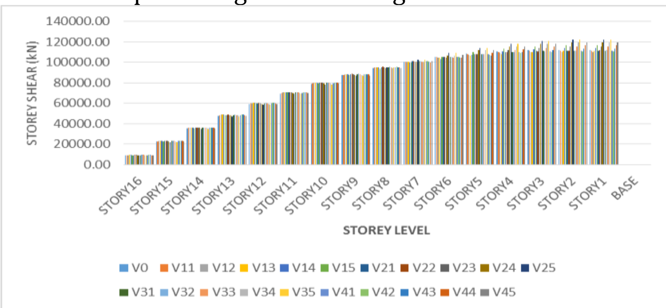

Chart-22: Comparison of story shear of varying percentage of V-bracings in a frame

Chart-22 shows that maximum story shear is at base and least at top story in all models. Story shear value has decreased in type 1 models by 1.77% in V12, 0.97% in V13, and increased by 0.21% for V11, 1.58% in V14 and increased by 4.18% in V15. Similarly in type 2, type3, type 4 models, it varies as 9.08%, 9.08% and 6.54% respectively. It is observed that the base shear is increased in type 2 model i.e. in V25 model by 5.43% as compared to bare frame. Chart-21 shows that maximum story shear is at base and least at top story in all models. Story shear value has decreased in type 1 models by 0.42% in K11, 1.13% in K12, and 1.81% for K13, 0.37% in K14 and increased by 1.89% in K15. Similarly in type 2, type3, type 4 models, it varies as 5.43%, 5.15% and 3.72% respectively. It is observed that the base shear is maximum in type 2 model i.e. in K25 model (5.43% increment).

4.1 CONCLUSION

The following conclusions are drawn from the analysis results,

For response spectrum analysis

1. It is observed that, the time period has been reduced by 2.6% in K1, 2.6% in K25, 3.05% in V1, 2.97% in V25 and V35 models at first mode as compared to bare model. These models have lowest modal time period among others models.

2. The frequency value has increased due to addition of bracings in a system and in K1, K25, V1, V25 and V45 models the frequency is increased by 2.62%, 2.62%, 3.15%, 3.15% and 3.15%s respectively in first mode as compared to bare frame. Further, these have slightly higher values at all modes.
3. It can be observed that, maximum reduction in story displacement has occurred in K2 by 5.85%, K25 by 4.15%, and V2 by 7.8%, and V25 by 5.39% at roof level as compared to frame without bracing. With increase in the stiffness, the structural response got reduced.
4. Maximum story drift is in bare model at fourth story, got reduced by 6.13% in K2, 9.42% in K15, 12.61% in V1 and 14.28% in V15 model. Also, it is noted that V2, V25 and V35 models have low drift value at middle stories.
5. The base shear is increased in K2 by 5.5%, K25 by 2.23%, V2 by 9.87%, V25 and V35 models by 5.2% as compared to bare model. Due to increase of lateral stiffness in a frame base shear has been increased.

For time history analysis,

1. Maximum reduction in time period is seen in K1 by 2.59%, K25 & K45 by 2.59%, V2 by 5.31%, V25 & V45 by 3.05% in first mode as compared to unbraced model.
2. The natural frequency has increased in K1, K25, K45, V1, V25 and V45 models by 2.62%, 2.62%, 2.62%, 3.15%, 3.01% and 3.01% respectively at first mode and these have slightly higher frequency values at all modes.
3. The story displacement is reduced in K2 by 10.41%, K25 by 6.45%, and V2 by 11.5%, V25 and V35 models by 9.54% at roof level as contrasted with bare model.
4. It is noted that, maximum story drift is in bare model at fourth story and is reduced by 7.35% in K2, 8.66% in K14, 10.9% in V1 and 11.75% in V14 model. Also, it is observed that K2, K25, K35, V2, V25 and V35 models have lower drift values at middle stories.
5. The base shear is increased in K1 by 9.17%, K25 and K35 by 5.43%, V2 by 11.51%, V25 and V35 models by 9.08% as compared to bare model.

By performing dynamic analysis, we have assessed the exact performance of K- and V-bracing models. It can be said that, the K2, V2, K25 and V25 models defined in the present work can be considered as optimum when compared to other types of models. By comparing the response parameters, it is found that eccentric V-bracing system yields the effective results than eccentric K-bracing system, thus will give better performance against earthquake forces.

6.2 Recommendations for further work

It is recommended that further research be undertaken in following areas,

1. Investigating the seismic performance of the tall building by optimizing columns and beams.
2. Evaluating the optimum earthquake response of tall building by doing pushover analysis to assess the member's ductility of K- and V- models.

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