Structural Stability Analysis Of Steel Structure With Different Bracing Systems

Arunkumar M.B[1], Dr. S.B. Vanakudre [2]
[1]P.G student, Dept. of Civil Engineering, SDM College of Engineering and technology Dharwad-580002.
[2]Principal, SDM College of Engineering and technology Dharwad-580002.

Abstract- *The steel structures require high structural stability because they have to sustain with earthquake and wind forces in the structure. This research is carried on linear static and non-linear static analysis (Pushover analysis) and compared both analyses. The steel structure of 23 storey is modelled with ETABS software. The structural analysis with pushover analysis effect, for this different bracings are used such as without, A, chevron, inverted V, K, V, X type bracing are used for the analysis. The structure is analysed for seismic forces. After the analysis results are arrived for axial force, maximum storey displacement, storey shear, maximum storey drifts, storey stiffness, weight and base shear. The seismic forces is as per IS 1893-2002 (Part-1) and steel structure is as per code IS 800-2007.*

Keywords- Steel framed structure, Bracing, linear static & pushover analysis, Seismic analysis.

I. INTRODUCTION

The steel structure is stable to carry the vertical loads, but in case of horizontal load, it can sustain only by the bracing and shear wall. Hence bracing system is to strengthen the structure laterally. The lateral forces like earthquake and wind forces to be restrain to reduce the displacement and all structural parameters. The structure transfers lateral loads through column to the foundation. Hence reduces the section of beams, columns by providing bracings in the structure

The structures are analysed with different bracing system by the analysis software ETABS. The present study is on linear and non-linear static analysis (Pushover) with different bracing system and comparison with both the analysis. The following are the different types of bracing systems used in the analysis.

1. A type bracing
2. Chevron bracing
3. Diagonal Bracing
4. Inverted V type bracing
5. V type bracing
6. K type bracing
7. X type bracing

II. LITERATURE REVIEW

1. **Mallikarjuna B.N, Ranjith A[(4)]:**In this paper, they analysed the 18 storey steel frame structure in the software STAAD .Pro 2007 and compared P-delta analysis with linear static analysis. They used different type of bracing systems such as X, Double X, single Diagonal, V and K type of bracings. In the comparison of continuous bracing system and Alternative bracing system by considering P-delta effects, the inter storey drifts reduced greatly. When the P-Delta analysis and static analysis are compared, the displacement increases from 70% to 75% and 85% to 95% for continuous type bracing and alternative type bracing respectively. Continuous type bracing system the axial force in P-Delta analysis increases to 22% in comparison with static analysis and increases twice for other type of bracings.
2. **Jagadish J. S, Tejas D. Doshi. [2013][(3)]:**In this study they adopt the structure with G+15 storey and different systems of bracing are used they are V, single Diagonal, X, Double X and K type of bracings. These models are analysed in the software STAAD. Pro V8i.For safety and design, a high frame structural stability is required for high-rise buildings. To reduce the displacements, bracings are good-enough.in the shape criteria i.e. irregularity shape the displacement is maximum for K and V-bracing. For the same type of structure, the weight and reactions are less in un-braced structure when compared with different type of braced the structure. For the structure with different bracing system, the valves of maximum storey displacement and maximum storey drift valves may increase or decrease.
3. **Neeraj Kulkarni, S.M.Maheswerappa, and Dr. J.K.Dattatraya[(2)]:**In this paper, they consider 40 storey steel structures with Earthquake load is considered for the analysis using SAP2000 software. They used different type of bracing systems such as Inverted v, single Diagonal, K and V type of bracings. They concluded that, when the P-delta and linear static analysis are compared, the displacement is 40% more and axial force increases 8% for un-braced structure. For linear and P-delta analysis, X-bracing has more strength, and displacement is decreased about 47.5% and 47.9% respectively.

4. **Dr. (Mrs.). D. Brindha, Mr. Adarsh Paul.[2017]**[(1)]**:**In this paper, they adopted (G+5) steel building with different bracing system such as inverted bracings, diamond bracings, V bracings, K bracings, X bracings, reverse K bracings. The modelling and analysis of these buildings is carried out in ANSYS 14.5.The results compared are strain energy, lateral drift, and stresses in the structure. They conclude that V bracing has least deflection and X bracing reduces the lateral sway, K and reverse K bracing systems has less strain energy, and X bracing is preferred since strain energy dissipation is more in this system.

III. METHODOLOGY

The model is 23 storey steel building with the height of 67.8 m and the analysis done with the software ETABS by the method of linear static and Push over analysis. The steel structure requires stability along horizontal direction also the strength parameters taken into consideration for the lateral forces by providing the steel bracings. The model analysis with different bracing system like without bracing, with bracing A type, chevron, diagonal, inverted V, K, V, and X bracings. Results are compared with parameters like axial force, maximum storey displacement, maximum storey drift, storey shear, weight and base shear of the structure.

The details of the structural data that are considered for the analysis as shown in table 3.0

Table 3.0 Details of the Structural Data

Sl. No.	Parameters	Value
1.	Type of Building	Commercial Building
2.	Number of Storey	23 Stories
3.	Seismic Zone	IV
4.	Location	Delhi
5.	Floor Area	3747.98sqft
6.	Total Height of Building	67.8m
7.	Column Sectional Details	ISHB 450-2 Double
8.	Beam Sectional Details	ISMB-600
9.	Slab	150 mm
10.	Live Load[(7)]	4 kN/m^2
11.	Dead Load	As per Section
12.	Grade of Concrete	M30
13.	Grade of Steel	Fe345
14.	Zone factor Z from (Table-2)[(5)]	0.36
15.	Importance factor I, from (Table-6)[(5)]	1.00
16.	Response reduction factor R (Table-7)[(5)]	5.0
17.	Damping ratio	5%

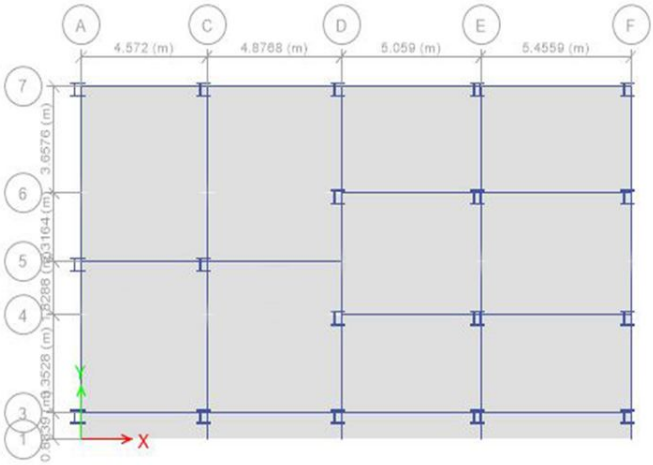

Fig. 3.0 Plan of the building in ETABS

3.1 Loads

The following loads are considered for the study are as follows.

Dead Load: The self-weight of the structure is calculated as per the codal provisions and is taken automatically by the software.

Live Load: 4kN/m^2 including roof as per IS 875(Part-2) 1987[(7)]

3.2 Load combinations

The Gravity Loads, Earthquake Loads are taken for the analysis, according to IS 800-2007 and IS:1893(Part-1)-2002, the following load combinations shall be accounted.

For Deflection

- (DL + S.Dead)
- (DL + LL + S.Dead)

For Strength

- 1.5 (DL + S.Dead)
- 1.5 (DL + LL + S.Dead)
- 1.2 (DL + LL + S.Dead + E-X)
- 1.2 (DL + LL + S.Dead - E-X)
- 1.2 (DL + LL + S.Dead + E-Y)
- 1.2 (DL + LL + S.Dead - E-Y)
- 1.5 (DL + S.Dead + E-X)
- 1.5 (DL + S.Dead - E-X)
- 1.5 (DL + S.Dead + E-Y)
- 1.5 (DL + S.Dead - E-Y)
- 0.9 (DL + S.Dead) + (1.5 E-X)

- 0.9 (DL + S.Dead) - (1.5 E-X)
- 0.9 (DL + S.Dead) + (1.5 E-Y)
- 0.9 (DL + S.Dead) - (1.5 E-Y)

The following are the elevations for different types of bracing systems.

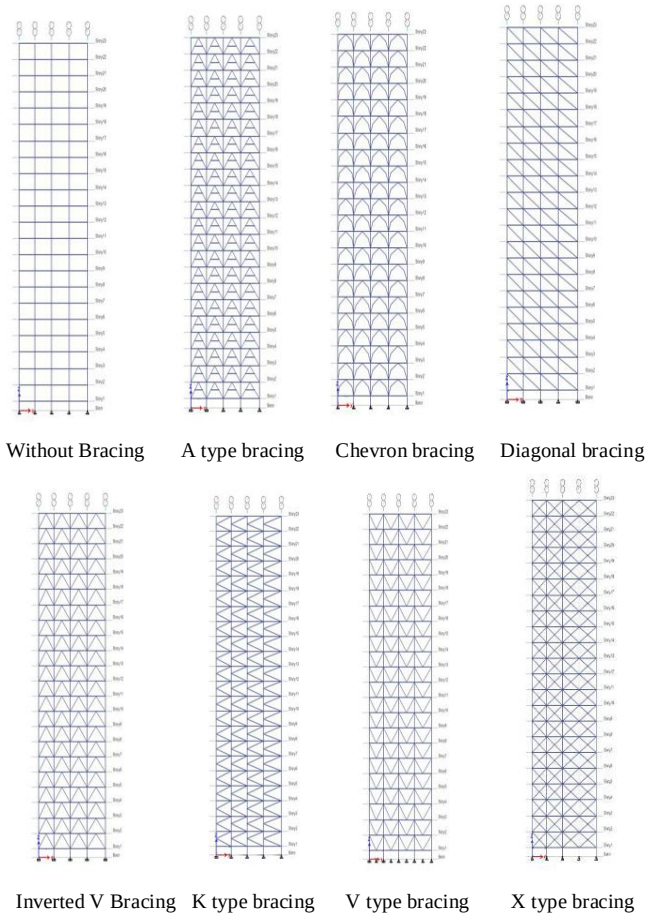

Fig. 3.1 Type of bracing of modelled in ETABS

IV. RESULTS AND DISCUSSION

4.1 LINEAR STATIC ANALYSIS:

4.1.1 Axial force:

Table 4.0 Percentage change in axial force for different bracing system

Type of bracing	Axial force (kN)	% Change	Remarks
Without Bracing	6602.653		
A Bracing	10004.2002	+34.00%	Increases
Chevron Bracing	6903.9444	+4.36%	Increases
Diagonal Bracing	8166.9382	+19.15%	Increases
Inverted V bracing	8543.9867	+22.72%	Increases
K Bracing	8200.111	+19.48%	Increases
V Bracing	5471.0702	-17.13%	Decreases
X Bracing	8404.6191	+21.44%	Increases

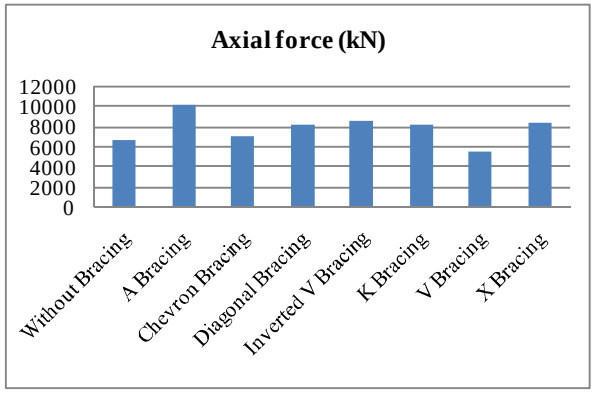

Fig. 4.0 Graphical representation of Axial force for different bracing system along X-direction

Discussion: From the fig. 4.0 and table 4.0, observed that the percentage reduction of axial force for V bracing is 17.13%.

4.1.2. Maximum storey displacement:

Table 4.1 Percentage change in maximum storey displacement for different bracing system

Type of bracing	Maximum storey displacement at top (mm)	% Change	Remarks
Without Bracing	73.499		
A Bracing	65.488	-10.89%	Decreases
Chevron Bracing	57.342	-21.98%	Decreases
Diagonal Bracing	95.466	+23.01%	Increases
Inverted V Bracing	57.041	-22.39%	Decreases
K Bracing	163.407	+55.02%	Increases
V Bracing	58.162	-20.86%	Decreases
X Bracing	36.78	-49.95%	Decreases

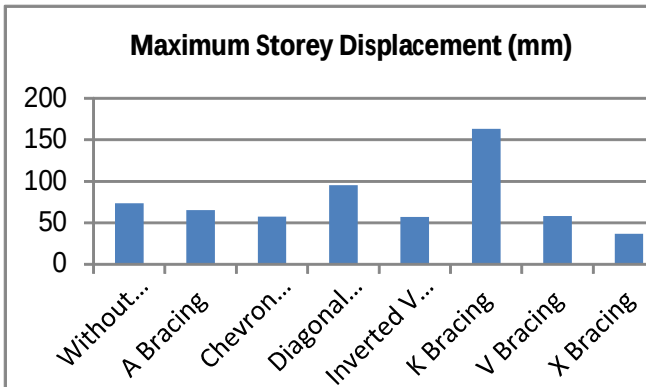

Fig. 4.1 Graphical representation of maximum storey displacement for different bracing system along X-direction

Discussion: From the fig. 4.1 and table 4.1, observed that the percentage reduction of maximum storey displacement for X bracing is 49.95%.

4.1.3 Maximum storey drift:

Table 4.2 Percentage change in maximum storey drift for different bracing system

Type of bracing	Maximum storey drift (mm)	% Change	Remarks
Without Bracing	0.001164		
A Bracing	0.004336	+73.15%	Increases
Chevron Bracing	0.002121	+45.12%	Increases
Diagonal Bracing	0.001544	+24.61%	Increases
Inverted V Bracing	0.001744	+33.25%	Increases
K Bracing	0.006664	+82.53%	Increases
V Bracing	0.000696	-40.20%	Decreases
X Bracing	0.001057	-9.19%	Decreases

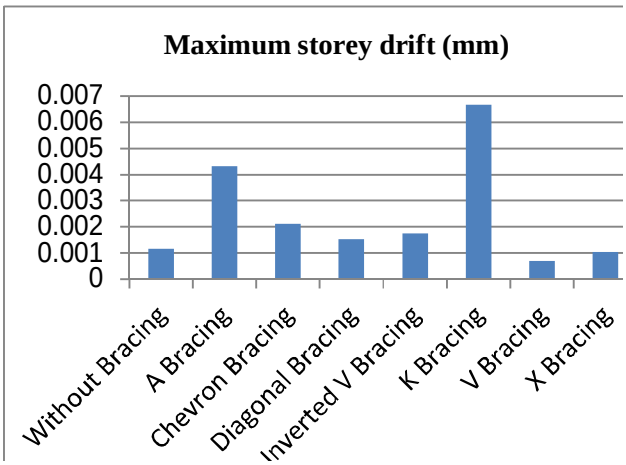

Fig. 4.2 Graphical representation of maximum storey drift for different bracing system along X-direction

Discussion: From the above fig 4.2 and table 4.2, observed that the percentage reduction of maximum storey drift for V & X bracing is 40.20% and 9.19% respectively.

4.1.4 Story shear:

Table 4.3 Percentage change in Storey shear for different bracing system

Type of bracing	Storey shear (kN)	% change	Remarks
Without Bracing	826.4538		
A Bracing	2583.6126	+68.01%	Increases
Chevron Bracing	983.0563	+15.93%	Increases
Diagonal Bracing	2121.0922	+61.03%	Increases
Inverted V Bracing	2545.0683	+66.33%	Increases
K Bracing	965.0975	+14.36%	Increases
V Bracing	2458.4074	+66.38%	Increases
X Bracing	1902.0929	+56.55%	Increases

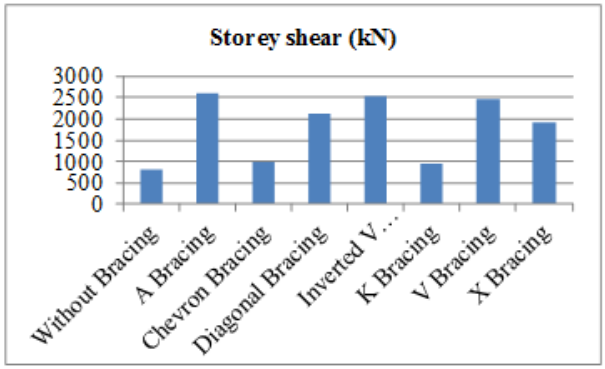

Fig. 4.3 Graphical representation of storey shear for different bracing system along X-direction

Discussion: From the above fig 4.3 and table 4.3, observed that there is no reduction in storey shear for every bracing system.

4.1.5 Storey Stiffness:

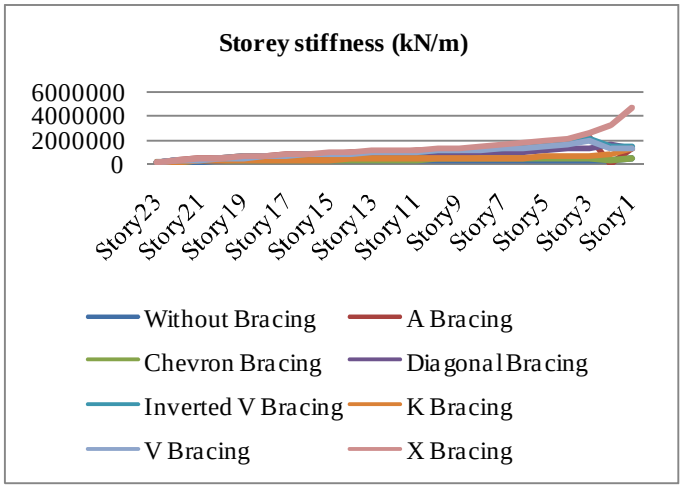

Fig. 4.4 Graphical representation of storey stiffness for different bracing system

Discussion: From the above fig. 4.4 the X bracing system has higher the stiffness at 1st storey and stiffness value is increasing order as compared to the other bracing system.

4.1.6 Weight and Base shear:

Table 4.5 Percentage change in weight and base shear for different bracing system

Sl. No.	Type of Bracing	Weight of the Building (kN)	Base shear in X-dir (kN)
1.	Without Bracing	25217.606	497.1933
2.	A Bracing	27706.2965	1722.4107
3.	Chevron Bracing	27183.2218	655.3724
4.	Diagonal Bracing	26593.9702	1414.0615
5.	Inverted V Bracing	27273.3927	1696.7122
6.	K Bracing	27353.5635	643.3983
7.	V Bracing	27274.4928	1638.9383
8.	X Bracing	27992.9918	1268.3953

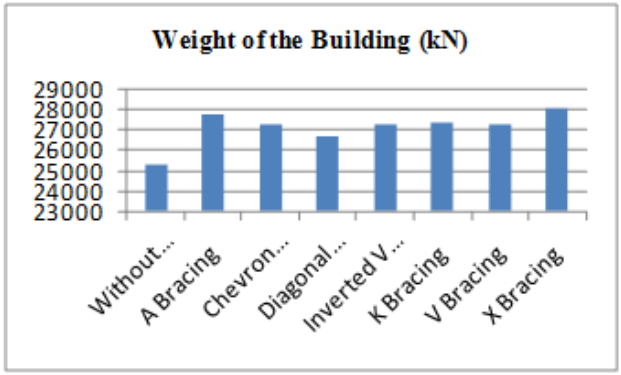

Fig. 4.5 Graphical representation of weight for different bracing system

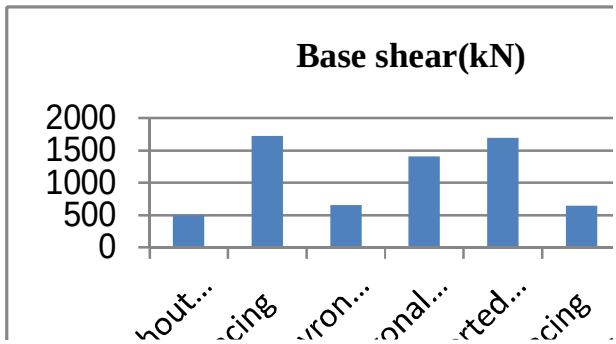

Fig. 4.6 Graphical representation of base shear for different bracing system

Discussion: From the above fig 4.5 and table 4.5, observed that there is maximum weight of the building for X type bracing system and from the fig. 4.6, table 4.5 K and V type bracing has less base shear compared to the other type bracing system.

4.2 PUSH OVER ANALYSIS

4.2.1 Axial force:

Table 4.7 Percentage change in Axial force for different bracing system

Type of bracing	Axial Force (kN)	% Change	Remarks
Without Bracing	6608.5588		
A Bracing	10073.8232	+34.39%	Increases
Chevron Bracing	6906.8638	+4.31%	Increases
Diagonal Bracing	8186.5904	+19.27%	Increases
Inverted V Bracing	8614.3239	+23.28%	Increases
K Bracing	8206.2044	+19.46%	Increases
V Bracing	5586.5858	-15.46%	Decreases
X Bracing	8411.0828	+21.43%	Increases

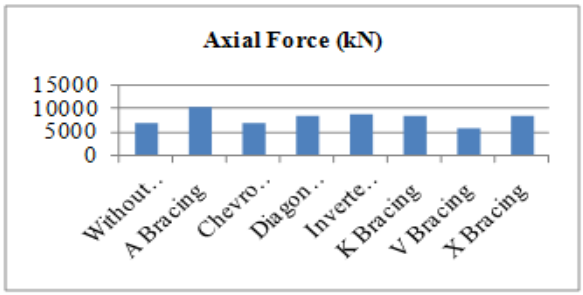

Fig. 4.7 Graphical representation of Axial force for different bracing system along X-direction

Discussion: From the fig. 4.7 and table 4.7, observed that the percentage reduction of axial force for V bracing is 15.46%.

4.2.2 Maximum Storey displacement:

Table 4.8 Percentage change in maximum storey displacement for different bracing system

Type of Bracing	Max storey displacement (mm)	% Change	Remarks
Without Bracing	73.891		
A Bracing	65.955	-10.74%	Decreases
Chevron Bracing	65.106	-11.88%	Decreases
Diagonal Bracing	95.574	+22.68%	Increases
Inverted V Bracing	57.417	-22.29%	Decreases
K Bracing	163.852	+54.90%	Increases
V Bracing	58.944	-20.22%	Decreases
X Bracing	36.793	-50.20%	Increases

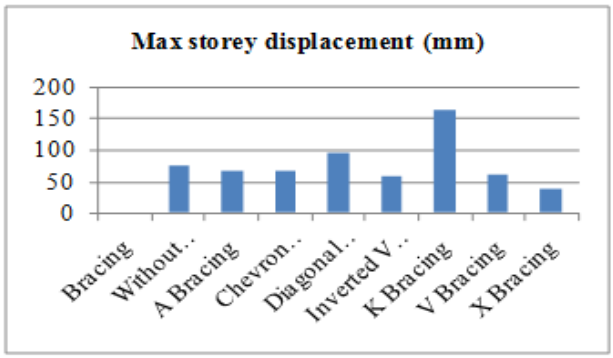

Fig. 4.8 Graphical representation of maximum storey displacement for different bracing system along X-direction

Discussion: From the above fig. 4.8 and table 4.8, observed that the percentage reduction of maximum storey displacement for X bracing is 50.20%.

4.2.3 Maximum storey drift:

Table 4.9 Percentage change in maximum storey drift for different bracing system

Type of bracing	Max storey drift (mm)	Percentage change	Remarks
Without Bracing	0.001162		
A Bracing	0.004267	+72.76%	Increases
Chevron Bracing	0.002123	+45.26%	Increases
Diagonal Bracing	0.001539	+24.49%	Increases
Inverted V Bracing	0.00187	+37.86%	Increases
K Bracing	0.006664	+82.56%	Increases
V Bracing	0.000694	-40.27%	Decreases
X Bracing	0.001061	-8.69%	Decreases

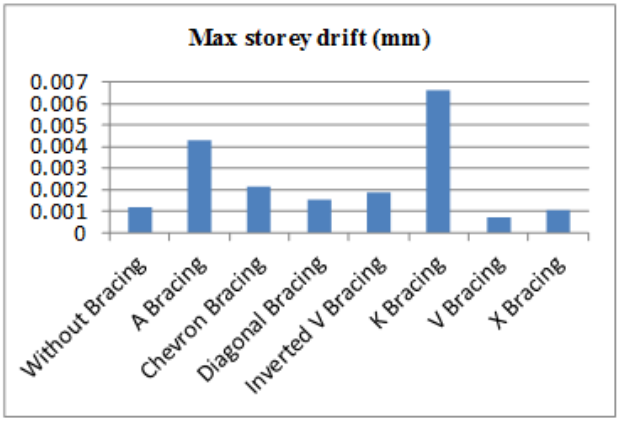

Fig. 4.9 Graphical representation of maximum storey drift for different bracing system along X-direction

Discussion: From the above fig 4.9 and table 4.9, observed that the percentage reduction of maximum storey drift for X & V bracing is 40.27% and 8.69% respectively.

4.2.4 Storey shear:

Table 4.10. Percentage change in storey shear for different bracing system

Type of bracing	storey shear(kN)	% change	Remarks
Without Bracing	745.7898		
A Bracing	2591.7693	+71.12%	Increases
Chevron Bracing	882.6764	+15.50%	Increases
Diagonal Bracing	2122.3748	+64.86%	Increases
Inverted V Bracing	2553.5883	+70.79%	Increases
K Bracing	2166.2239	+65.57%	Increases
V Bracing	2474.2883	+69.85%	Increases
X Bracing	2051.1032	+63.63%	Increases

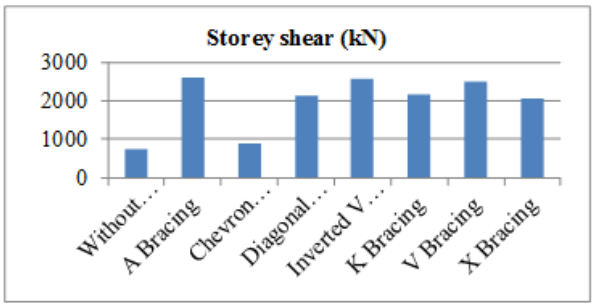

Fig. 4.10 Graphical representation of storey shear for different bracing system along X-direction

Discussion: From the above fig 4.10 and table 4.10, observed that there is no reduction in storey shear for every bracing system.

4.2.5 Storey stiffness:

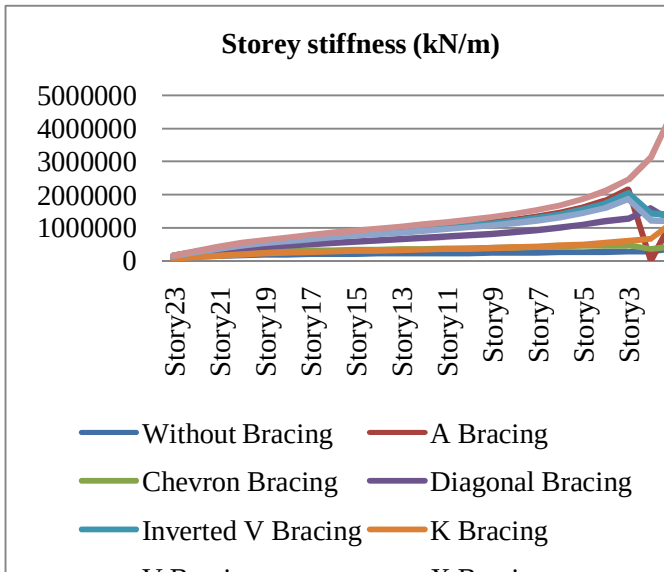

Fig. 4.11 Graphical representation of storey stiffness for different bracing system

Discussion: From the above fig. 4.11 the X bracing system has higher the stiffness at 1st storey and stiffness value is increasing order as compared to the other bracing system.

4.2.6 Weight and Base shear

Table 4.12 Percentage change in weight and base shear for different bracing system

Sl. No.	Type of Bracing	Weight of the Building (kN)	Base shear in X-dir kN
1.	Without Bracing	25217.606	498.6128
2.	A Bracing	27706.2965	1727.8486
3.	Chevron Bracing	27183.2218	656.1811
4.	Diagonal Bracing	26593.9702	1414.9165
5.	Inverted V Bracing	27273.3927	1702.3922
6.	K Bracing	27353.5635	644.8845
7.	V Bracing	27274.4928	1649.5255
8.	X Bracing	27992.9918	1268.3953

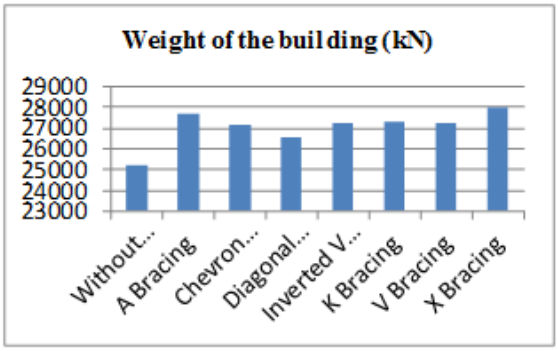

Fig. 4.13 Graphical representation of base shear for different bracing system

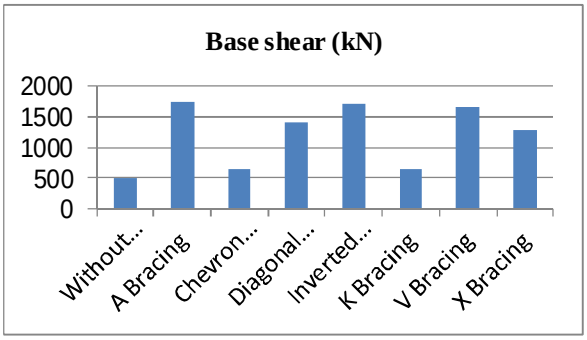

Fig. 4.14 Graphical representation of base shear for different bracing system

Discussion: From the above fig 4.13 and table 4.12, observed that there is maximum weight of the building for X type bracing system and from the fig. 4.14, table 4.12 K and V type bracing has less base shear compared to the other type bracing system.

V. CONCLUSIONS

LINEAR STATIC ANALYSIS

1. The reduction of axial force for the V bracing is 17.13% with respect to the without bracing system.
2. The maximum percentage reduction in storey displacement occurs in X bracing i.e., 49.95% compared to all types of bracing system.
3. The maximum percentage reduction of storey drift for V bracing is 40.20% and minimum percentage reduction is 9.19% for X type
4. There is no reduction in the storey shear values and maximum shear occurs at first storey for all type of bracing.
5. The maximum stiffness is in the X bracing system.
6. The weight of the building varies with the different type of bracing system.
7. The base shear value reduced in K and chevron bracing system.

PUSH OVER ANALYSIS

1. The percentage reduction of axial force is 15.26% for V bracing.
2. The maximum percentage reduction in storey displacement occurs in X bracing i.e., 50.20%.
3. The maximum percentage reduction in storey drift for V bracing is 40.27% and that of X bracing is 8.69%
4. The maximum stiffness found in the X bracing system.
5. The weight of the building varies for all type of bracing system.
6. Here also base shear value reduced in K and chevron bracing system.

VI. ACKNOWLEDGEMENT

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