Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

Seismic Performance of Different Types of Braced Steel Frame Buildings

Abhishek Maharjan [a], Gokarna Bahadur Motra [b], Thaman Bahadur Khadka [c]

[a, b, c] *Department of Civil Engineering, Pulchowk Campus, IOE, TU*
[a] 076Msste001.abhishek@pcampus.edu.np, [b] gmotra@ioe.edu.np, [c] thamankhadka@pcampus.edu.np

Abstract
The popularity of steel structure is increasing in Nepal which carries the importance of our study.This paper represents the comparative study of analyzing different bracing systems in steel structure of 5 storied steel building excluding staircase cover by static and response spectrum method.Different type of bracings like cross bracing, diagonal bracing, inverted V bracing, and K bracing have been used to observe the impacts on displacements, story drifts, time periods and base shear.Bracing have been provided at edge and mid location of the structure.Parameters such as section properties, vertical loads, design parameters, support condition were taken constant.IS 1893:2016 and NBC 105:2020 codal provisions were followed in this study.Finally it is found that cross bracing system at mid location using IS code showed better effectiveness related to seismic performance in terms of displacement, drift and time period.

Keywords
Steel structure, bracing system,linear analysis,bracing location, IS 1893:2016,NBC 105:2020

1. Introduction

One of the important issues to consider for the design of steel structures is reducing the damage caused by earthquakes.A braced frame is a structural system which helps to resist wind and earthquake forces. Members in a braced frame are not allowed to sway laterally (which can be done using shear wall or a diagonal steel sections, similar to a truss).For this, analysis of braced and unbraced steel structures is an effective solution for designing the most economic and safe structure which can reduce the damage to a desirable outcome.Steel braced frame is one of the structural systems used to withstand lateral loads in multistoried buildings.Concentrically braced frames usually increase the lateral stiffness of the frame and usually decrease the lateral drift.However, increase in the stiffness may induce a larger inertia force due to earthquake.Eccentrically bracings decreases the lateral stiffness of the system and improve the energy dissipation capacity.Bracing increases the energy absorption of structures and/or decrease the demand imposed by earthquake loads and structures with augmented energy dissipation may safely resist forces and deformations caused by strong ground motions[1].

This research will help the civil engineers a scenario on the effectiveness of bracing system under lateral loading. Bracing members used to provide lateral load resistance for a building might also be called upon to carry tension under some conditions and compression under others[2].They too would need to be designed to resist both loads[2].Bracing for simpler steel buildings that contain beam continuous over columns, with rolled section purlins or open web joists framing between, usually consists of bridging between joists to stiffen the roof system and knee braces or moment resistant beam to column connections[3].The members of a braced frame act as a truss system and are subjected primarily to axial stress[4].Depending on the diagonal force, length, required stiffness and clearances,the diagonal members can be made of double angles, channels ,tees, tubes or even wide flange shapes[4].Four types of bracing system is used i.e. crossed bracing , K bracing, inverted V bracing and diagonal bracing system.Although steel buildings with dual seismic load resisting systems composed of inverted V braces and moment resisting frames have been widely used there is still insufficient information on how to design the system effectively[5]. This is due to the lack of knowledge on the interaction between the brace and the surrounding moment frames, and in particular, the beam in the braced bay[5].

2. Objective

The main objective of this research is to evaluate the seismic performance as displacement, drift, time period and base shear of the steel frame building with different types of bracing such as cross bracing, K bracing , inverted V bracing and diagonal bracing for which the following sub-objectives are set:

- To evaluate the response of structure with bracing at different location(edge and mid).
- To evaluate the response of structure using IS 1893:2016 part I and NBC 105:2020 codal provision.

3. Methodology

General type of steel building is selected which are constructed widely in Kathmandu valley nowadays.A finite element analytical model of the 5 storey building excluding staircase cover has been prepared in etabs17.Four types of bracing has been applied in the building: crossed bracing, K bracing, inverted V bracing and diagonal bracing system.Different model is prepared by providing bracing at different location: mid and edge for all types of bracing system.Although location is changed base shear is made alomost same.IS 1893:2016 part 1 and NBC 105:2020 codal provisions were followed in this study separately.Parameters such as section properties, vertical loads, design parameters, support condition were taken constant. Its' beams and columns is modeled as the frame element having rigid joint.Bracing joint is considered as pin joint.Then the model is analyzed and results are obtained for seismic responses for all buildings.These results are compared with each other using graphs.

4. Building Configuration

A 5 storey steel building excluding staircase cover with 4 bays in both directions is taken for the study.In X direction spacing of 3.048 m for each bay is taken.In Y direction spacing of 3.65m, 3.35 m, 3.81m, and 3.96 m is taken.The storey height is kept 2.74 m for all floors.ISMB 300 is taken as size of beam.Column is made by joining two ISMC 400 section.ISA 200*200*18 mm is taken as size of bracing. Live load Wall load exterior Wall load interior Finish load Parapet load Stair dead Stair live is taken as 2 KN/m2, 5.04 KN/m, 1 KN/m, 1 KN/m, 2.65KN/m, 3.4KN/m and 5.5KN/m respectively.Support at the base of the column are assumed to be fixed.

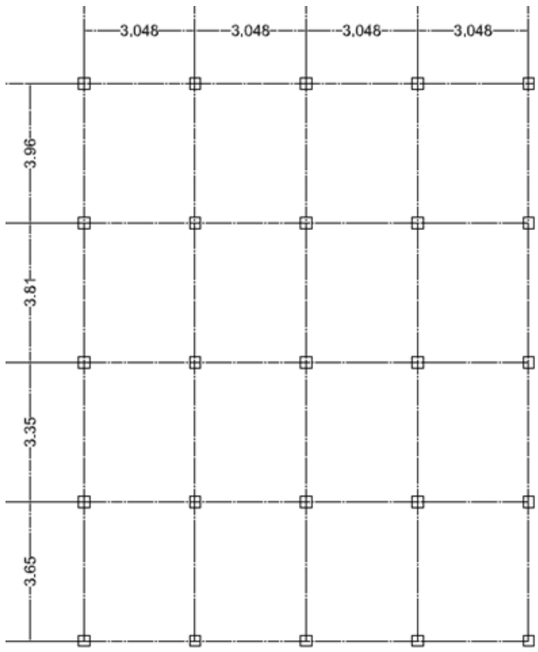


Figure 1: Plan of the building

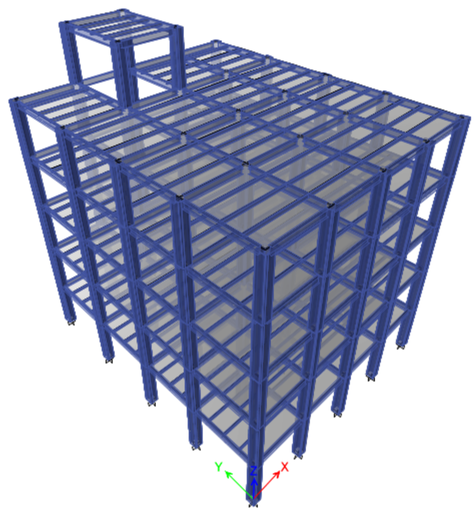
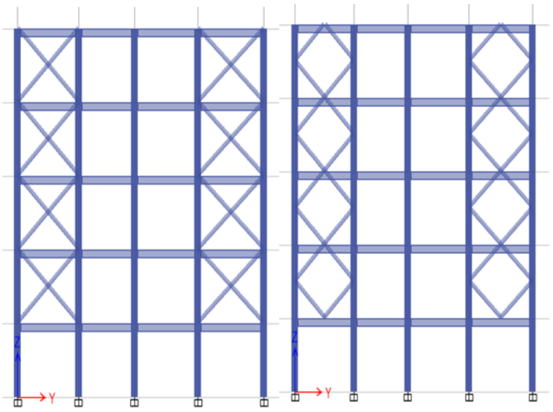
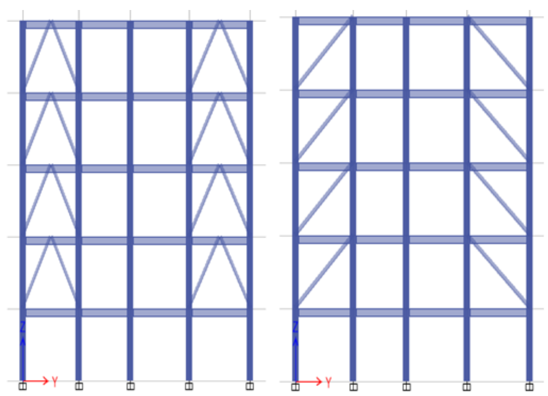


Figure 2: 3D of the building

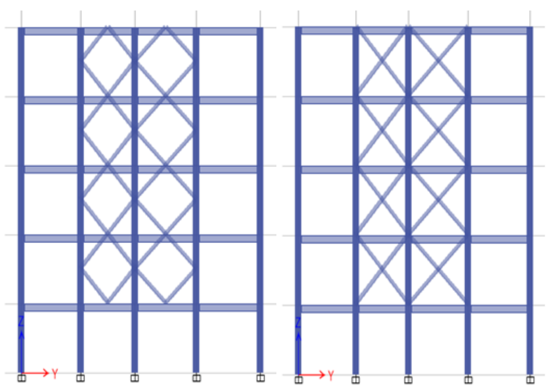


X Bracing K Bracing

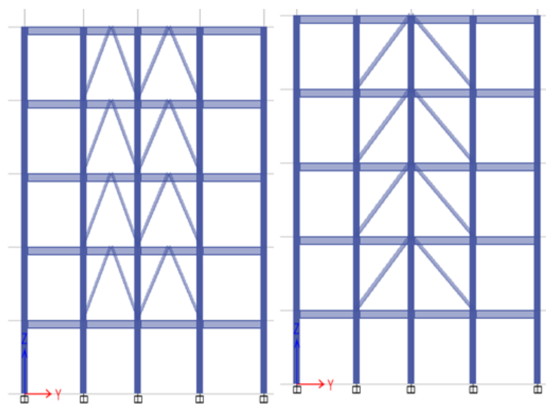


Inverted V Bracing Diagonal Bracing

Figure 3: Different types of bracing at edge



X Bracing K Bracing



Inverted V Bracing Diagonal Bracing

Figure 4: Different types of bracing at mid

5. Result and Discussion

Linear response spectrum analysis is performed using IS 1893:2016 and NBC 105:2020 codal provisions.Results obtained in terms of displacement, drift, time period and base shear for cross bracing, diagonal bracing, inverted V bracing, and K bracing at both location: mid and edge were interpreted and showed graphically as shown.

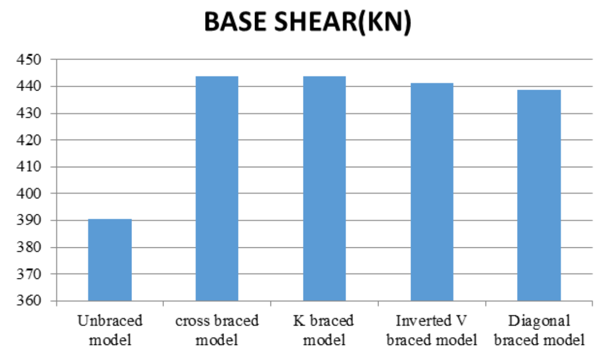


Figure 5: Base Shear (KN) for different models for bracing at edge using IS code

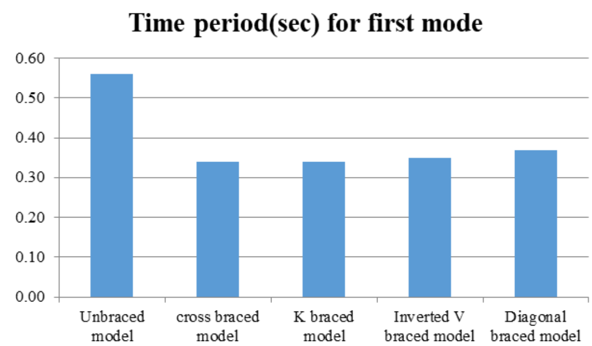


Figure 6: Time period (sec) of first mode for different models bracing at edge using IS code

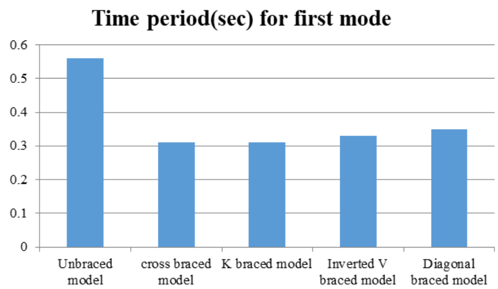


Figure 7: Time period (sec) of first mode for different models bracing at mid using IS code

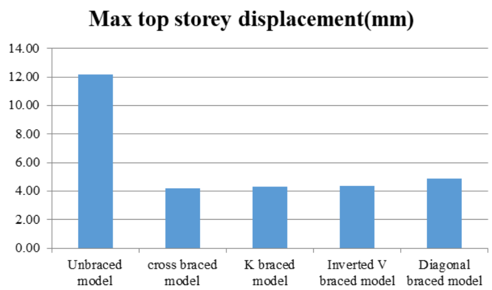


Figure 8: Top story displacement for different models by Response spectrum method in x-direction bracing at edge using IS code

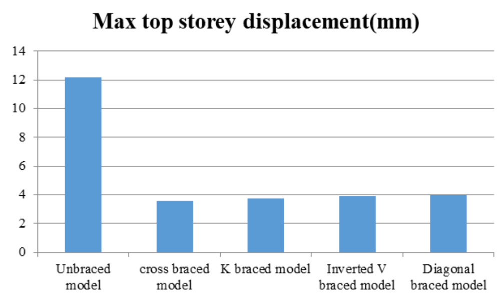


Figure 9: Top story displacement for different models by Response spectrum method in x-direction bracing at mid using IS code

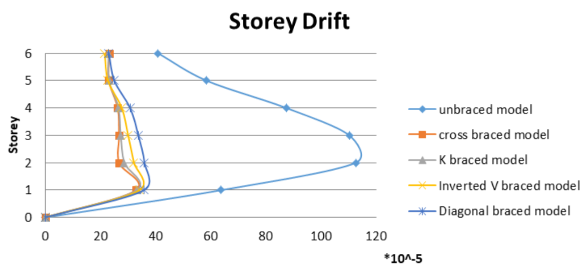


Figure 10: Story drift for different models by response spectrum along X direction for bracing at edge using IS code

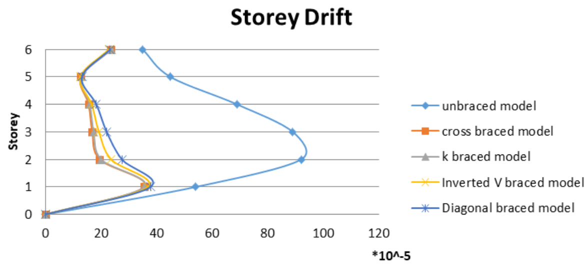


Figure 11: Story drift for different models by response spectrum along Y direction for bracing at mid using IS code

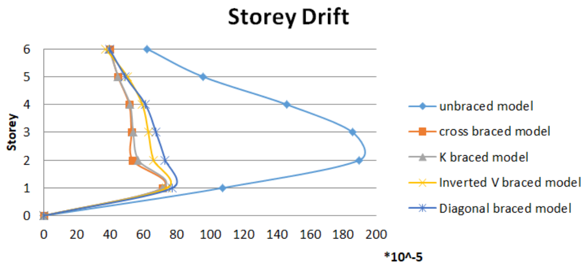


Figure 12: Story drift for different models by response spectrum along X direction for bracing at edge using NBC code

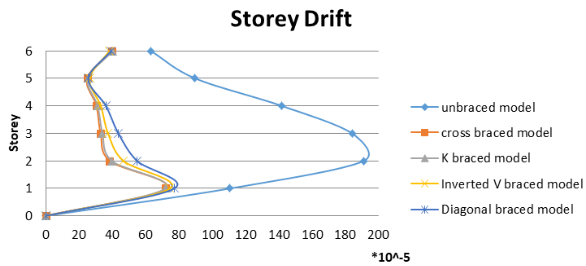


Figure 13: Story drift for different models by response spectrum along Y direction for bracing at mid using NBC code

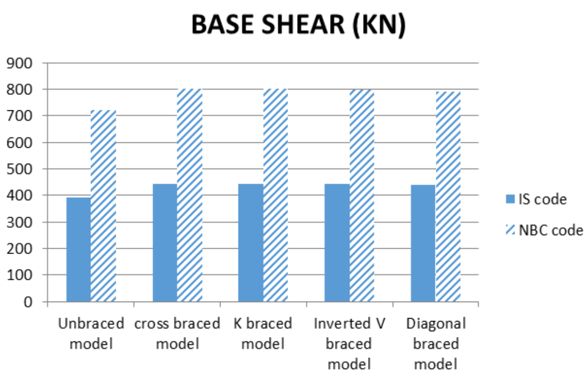


Figure 14: Base Shear (KN) for different models for bracing at edge using different code

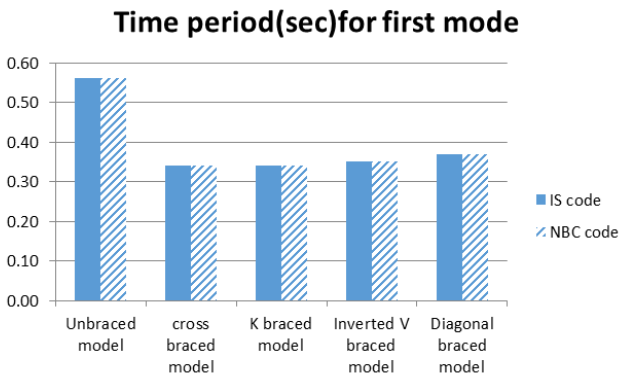


Figure 15: Time period (sec) of first mode for different models for bracing at edge using different code

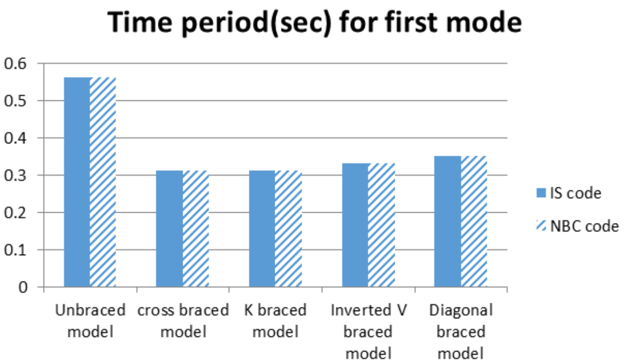


Figure 16: Time period (sec) of first mode for different models for bracing at mid using different code

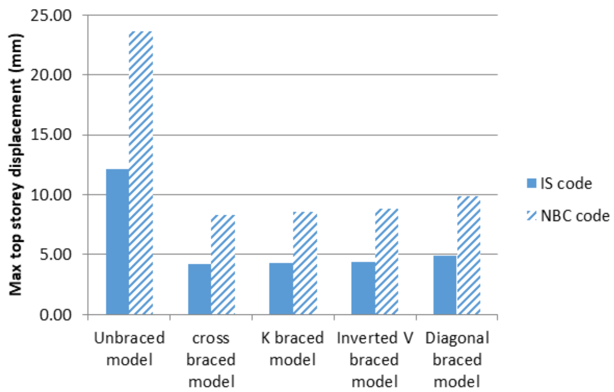


Figure 17: Top story displacement for different models by Response spectrum method in x-direction bracing at edge using different code

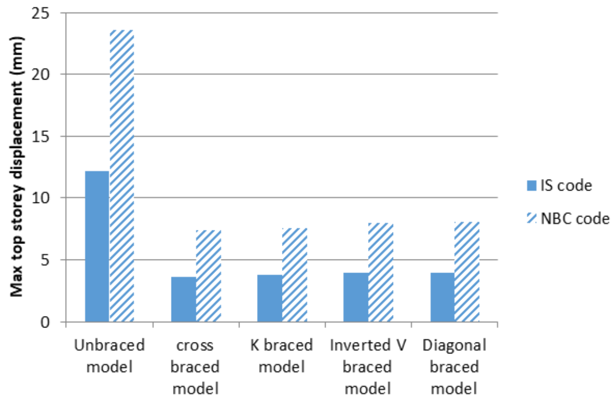


Figure 18: Top story displacement for different models by Response spectrum method in x-direction bracing at mid using different code

Table 1: Stiffness for different models by earthquake along X direction for bracing at edge using IS code

	Stiffness (KN)			
Storey	**Cross braced frame model**	**K braced model**	**Inverted V braced model**	**Diagonal braced frame model**
5	244560	231333	225141	224489
4	398728	389968	380360	336869
3	507193	507012	455529	403414
2	599708	570572	505835	446158
1	435998	429535	420540	409112

Table 2: Stiffness for different models by earthquake along X direction for bracing at mid using IS code

	Stiffness (KN)			
Storey	**Cross braced frame model**	**K braced model**	**Inverted V braced model**	**Diagonal braced frame model**
5	353182	328991	324113	320615
4	549856	528743	485894	482535
3	679598	669748	555429	550806
2	747981	715279	576794	565515
1	454816	447286	433647	431929

From above results, it is seen that structure with bracing system gave better performance.By the use of bracing system, stiffness of the structure became high.Cross bracing system showed better effectiveness related to seismic performance in terms of displacement, drift and time period.From the stiffness table, it is observed that the structure with cross bracing has higher stiffness value than the structure with K bracing, inverted V bracing and diagonal bracing.Cross bracing supports compression and tension at a same time as one brace will be sunbjected to tension while orther brace will be subjected to compression. As we know time period and displacement is inversely proportional to stiffness.Time period , displacement and drift for structure with cross bracing system is less than structure with other bracing systems. From above results, it is observed that structure with bracing at mid showed better seismic performance than structure with bracing at edge for every bracing system.From table of stiffness we can see that stiffness for structure with bracing at mid is greater than structure with bracing at edge. The structure were designed using both IS and NBC code.From results it is found that Structure designed by IS code gave good performance than NBC code for Kathmandu valley.While calculating fundamental time period , only NBC code uses amplication factor.Response reduction factor and zone factor is different for these two codes.That's why base shear coefficient using NBC code is higher than base shear coefficient using IS code.Mass source taken in NBC code is higher than IS code.Due to increase in base shear, the responses are greater using NBC code.

6. Conclusion

On the basis of the results obtained from the analysis, we can conclude that bracing system at mid location using IS code has showed better effectiveness related to seismic performance in terms of displacement, drift and time period.Following conclusions are drawn:

- Among different types of bracing structures, cross bracing structure has showed significant decrease in displacement.Cross bracing structure has reduced displacement upto 70% whereas K bracing, inverted V bracing and diagonal bracing structure has reduced displacement upto 69%, 67% and 67% respectively.Displacement is increased upto 93% ,104%, 103%, 103% and 102% for unbraced , Cross bracing ,K bracing, inverted V bracing and diagonal bracing structure using NBC code in comparision to using IS code.
- Base shear is increased upto 13% ,13%, 12%, and 12% for Cross bracing ,K bracing, inverted V bracing and diagonal bracing structure respectively. Base shear is increased by 84% and 80% for unbraced structure and all type of bracing structure respectively using NBC code in comparision to using IS code.
- Cross bracing structure has reduced drift upto 80% whereas K bracing, inverted V bracing and diagonal bracing structure has reduced drift upto 78%, 74% and 74% respectively. Drift is increased upto 51% and 50% for unbraced structure and all type of bracing structure respectively using NBC code in comparision to using IS code.
- Time period is decreased upto 44% ,44%, 42%, and 40% for Cross bracing ,K bracing, inverted V bracing and diagonal bracing structure respectively.
- Sections in braced frame structure can be decreased.

References

[1] L. Di Sarno and A.S. Elnashai. Bracing systems for seismic retrofitting of steel frames. *Journal of Constructional Steel Research*, 65(2):452–465, 2004.

[2] L.F. Geschwindner. *Unified Design of Steel Structures*. Wiley, 2011.

[3] E.H. Gaylord and C.N. Gaylord. *Design of Steel Structures*. McGraw-Hill Civil Engineering Series. McGraw-Hill, 1972.

[4] N. Subramanian. *Design of Steel Structures*. OUP India, 2008.

[5] Toshibumi Fukuta, Isao Nishiyama, Hiroyuki Yamanouchi, and Ben Kato. Seismic performance of steel frames with inverted v braces. *Journal of Structural Engineering*, 115(8):2016–2028, 1989.