Seismic Performance of Soft Storey Behaviour in Irregular Steel Frames using Different Bracing Systems

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Abstract – *Nowadays, the earthquake and seismology is of utmost importance for structural engineers around the globe. Braced frames are popular ones to resist seismic excitation with less deformations in comparasion with gravity load resisting system as there is a formation of stiff system. This paper mainly presents innovative braced frames such as hexa and octa-braced frames to know the effect of soft storey in a steel frame. The steel frame used in this paper is (G+20) irregular frames. A comparison is made between symmetrically irregular and asymmetrically irregular frame. As there is no proper methods to know the time and intensity of earthquake, it is utmost important to have a proper infrastructure. In this paper, V, Hexa, Octa and Zipper braced frames are used. Dynamic analysis is performed for irregular frames and the parameters considered are Storey displacement, Storey drift and Storey shear. ETABS 2017 Software is used for analysis. From the analysis performed, results reveal that there is a better improvement in seisimic performance with the addition of bracings.*

Key Words: **Softstorey, Storey Displacement, Bracing configuration, ETABS 2017**

1.INTRODUCTION

Steel structures generally needs less construction time and larger span feasibility and has better seismic resistance than reinforced concrete structure, which are known facts and thereby popularity of steel is increasing nowadays. Braced frames are generaly classified into concentrically braced and eccentrically braced frames. Members of steel frames are made by using structural steel and thereby it works effectively intension and compression zone. Softstories may be located at top, bottom or intermediate points, so that the floor above or below may be stiffer compared to itself. Structures in seismically active areas are subjected to lateral earthquake forces, in addition to primary gravity loads. The intensity and properties of earthquake are generally detrmined by the performance of a building during earthquake. For the first time in a study, N.Mashhadiali and A.Kheyroddin[2] investigated the structural behaviour of hexagrid system, thereby the idea of hexa-braced frame is arisen which is used in this paper.

The simple parameters that are used to determine the stiffnes of frames are storey displacement, storey drift and Storey shear. Storey displacement is defined as the displacement of a storey with respect to the base of a structure. Storey drift is the lateral displacement of one level of multistoried building relative to the level below. The seismic force to be applied at each floor level is defined as Storey shear. Bracings are economical method to laterally stiffen the frame structures against wind and gravity loads. As the trend of constructing tall buildings is increasing, it is of utmost importance to find cost effective structural forms.

In this paper, four different types of bracings are analysed under dynamic analysis with same frame property. The analytical study is carried out by using ETABS 2017.

1.1 Scope and Objective of the Study

Various types of bracing are selected for the study. Work is restricted to irregular frames with geometric irregularity.

The main objective of the study are as follows:

- To investigate the performance of symmetrically irregular and asymmetrically irregular frames with and without bracings.
- To investigate the dynamic performance of V, Hexa, Octa and Zipper braces for symmetrically and asymmetrically irregular frames.

2. MODELLING AND ANALYSIS OF FRAMES

A 20-storey structure which is not actually constructed, but they meet with seismic code representing low, medium and high rise buildings which are designed for Los Angeles, California region is selected for the study.

2.1 Specifications

20 storey benchmark building which ois 30.48m by 36.58m in plan and 80.77m in elevation.

Bays are 6.1m on center with 5bays in North-South direction and 6-bays in East-West direction.

The building has two basement levels. The level directly below the ground level is first basement (B-1) and level below this is second basement (B-2).

Basement level height : 3.65m

Ground level height : 5.49m

1st – 19th level height : 3.96m

The interior and corner colums are same. Colums are box columns with ASTM A500 Column Splices, which are seismic or tension splices to carry bending and uplift forces.

Beams are of section W30x99 at B2-4th level & 11th-16th level. W30X108 at 5th-10th level, W27X84 at 17th-18th level, 19th and 20th level has beam sections W24X62 & W21X50.

The brace members are square hollow sections : HSS5X5X1/4; D.E Nassani.et.al[6]. The steel yield stress is fy = 250 and 345 MPa.

2.2 Modelling of frame

For the evaluation of seismic response of frames under seismic loading in case of time history analysis, frames were subjected to eartghquake ground acceleration of El-Centro 1940 NS earthquake.

As per the specificatons above, the bare frame is as given in fig1.

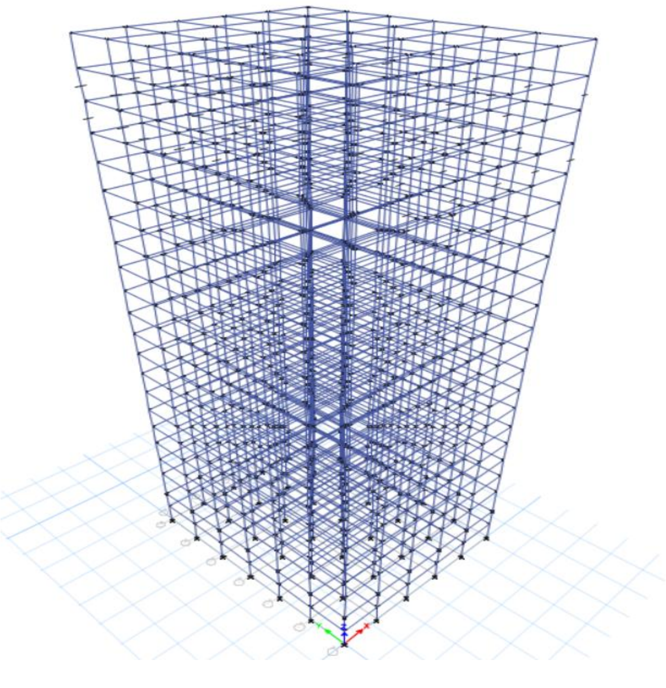

Fig-1 : 3-D View of Bare Frame

In this paper, symmetrically irregular and asymmetrically irregular frames were modelled. For modelling symmetrically irregular frames, 10 bays were removed from 20th to 15th storey and for modelling asymmetrically irregular frame, 10 bays were removed from 20th to 17th storey and 5 bays were removed from 16th to 13th storey. Thus a total of 60 bays were removed from each frame. Result analysis were as shown in Table1. For analysis purposes, braces were inserted into the middle frames and dynamic analysis were performed. Parameters considered are Storey Displacement, Storey Drift and Storey Shear. Elevation view of Asymmetrically irregular frame with different types of bracings are shown in fig4, fig5, fig6 and fig7.

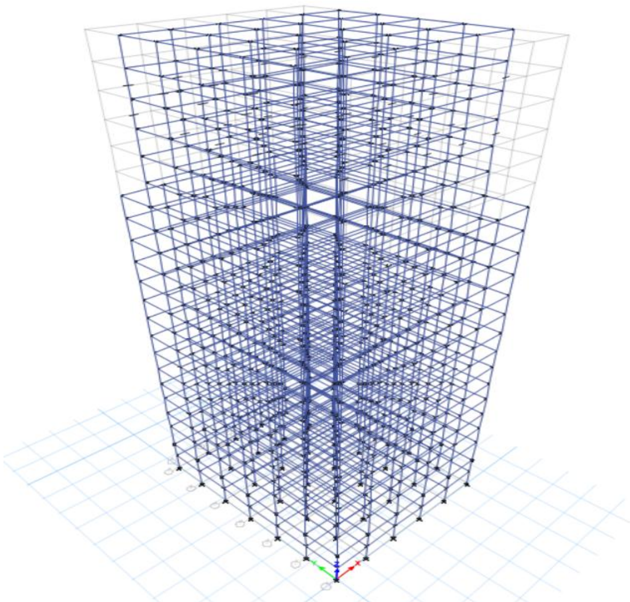

Fig -2: 3-D View of Symmetrically Irregular frame

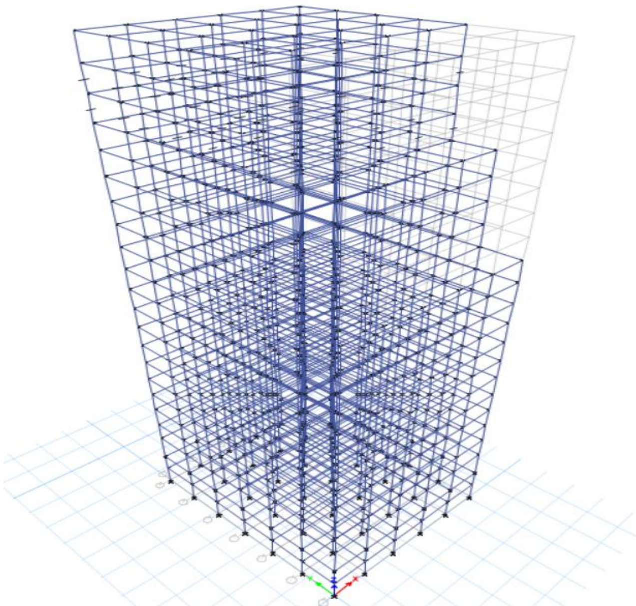

Fig -3: 3-D View of Asymmetrically Irregular frame

Table -1: Result Analysis of Irregular Frames

Model	Storey Displacement	Storey Drift	Storey shear
Symmetrically Irregular	155.939mm	0.006263	1522.22kN
Asymmetrically Iregular	192.19mm	0.007175	1521.371kN

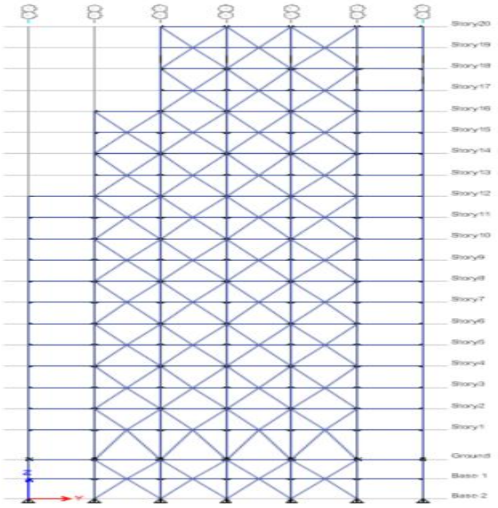

Fig -4: Elevation view of asymmetrically irregular frame with V-Bracing

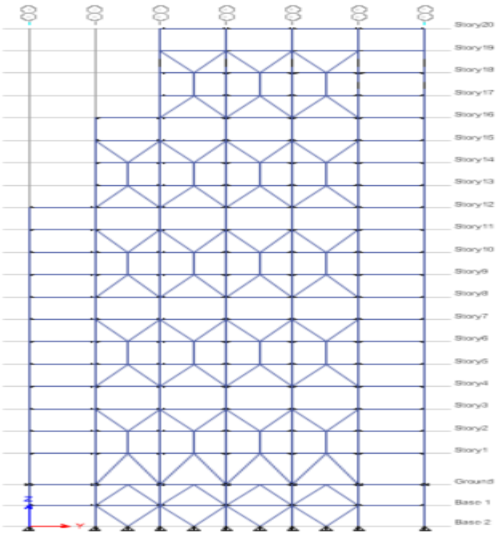

Fig -5: Hexa-Bracing

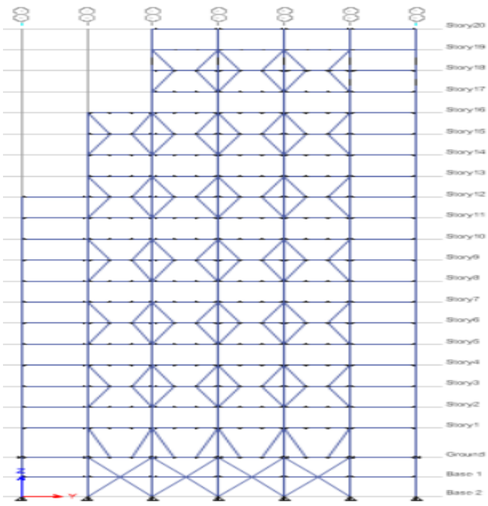

Fig -6: Octa-Bracing

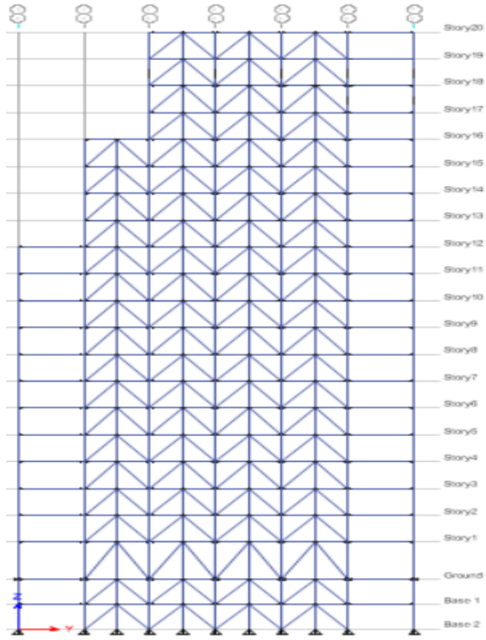

Fig -7: Zipper Brace

Braces were inserted from top to bottom and in case of V and Zipper bracing whereas in case of Hexa and Octa bracings, hexagonal and octagonal pattern of configuration is as shown in fig5 and fig6 with soft storey in between. Similar analysis is done for symmetrically irregular frames. Elevation view of Symmetrically irregular frame with different types of bracings are shown in fig8, fig9, fig10 and fig11.

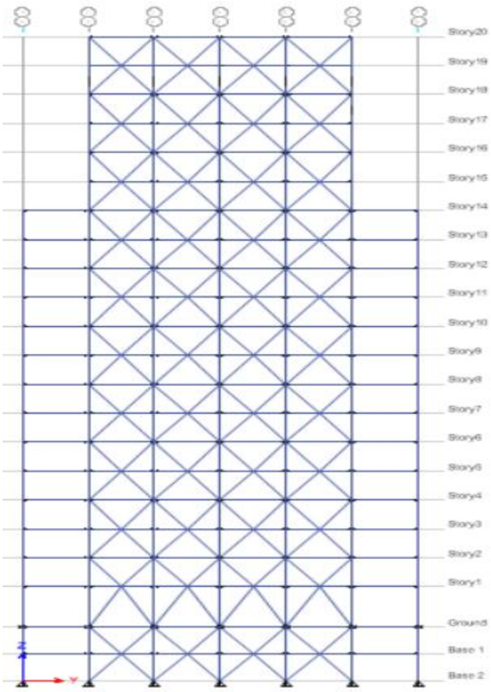

Fig -8: Elevation view of symmetrically irregular frame with V-Bracing

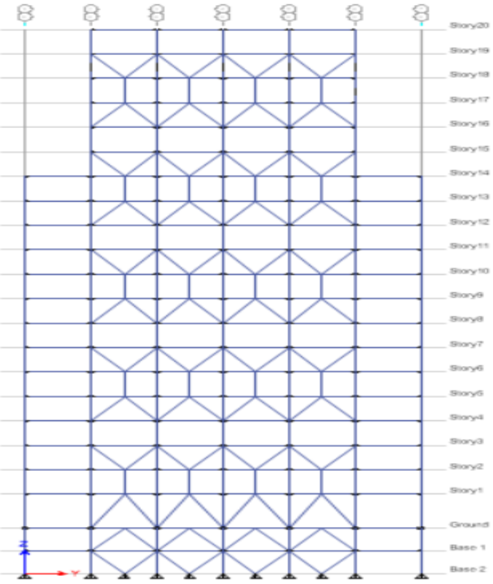

Fig -9: Hexa-Bracing

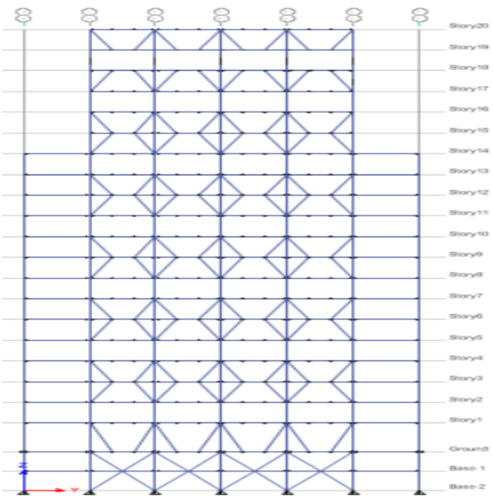

Fig -10: Octa-Bracing

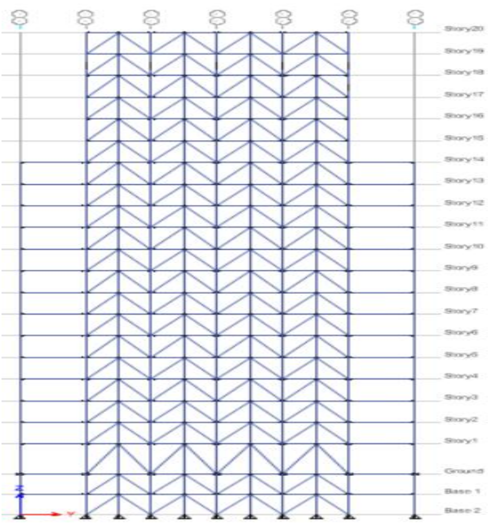

Fig -11: Zipper-Bracing

Table -2: Model Description

MODELS NAME	MODELS DETAIL
S	Symmetrically irregular frame
S_V	Symmetrically irregular frame with V-bracing
S_HEXA	Symmetrically irregular frame with V-bracing
S_OCTA	Symmetrically irregular frame with Octa-bracing
S_ZIPPER	Symmetrically irregular frame with Zipper-bracing
AS	Asymmetrically irregular frame
AS_V	Asymmetrically irregular frame with V-bracing
AS_HEXA	Asymmetrically irregular frame with V-bracing
AS_OCTA	Asymmetrically irregular frame with Octa-bracing
AS_ZIPPER	Asymmetrically irregular frame with Zipper-bracing

3. RESULTS AND DISCUSSIONS

Analysis is doneby using ETABS 2017. Comparison of irregular frames with and without bracings are done.Result analysis of Braces are shown in Table3 and Table4 and respective graphs are shown in graph 1&2.

Table -3: Result analysis of symmetrically irregular frame with and without bracings

Models name	Storey Displacement (mm)	Storey Drift
S	155.939	0.00626
S_V	131.465	0.00468
S_HEXA	121.588	0.00355
S_OCTA	120.326	0.00369
S_ZIPPER	133.842	0.00367

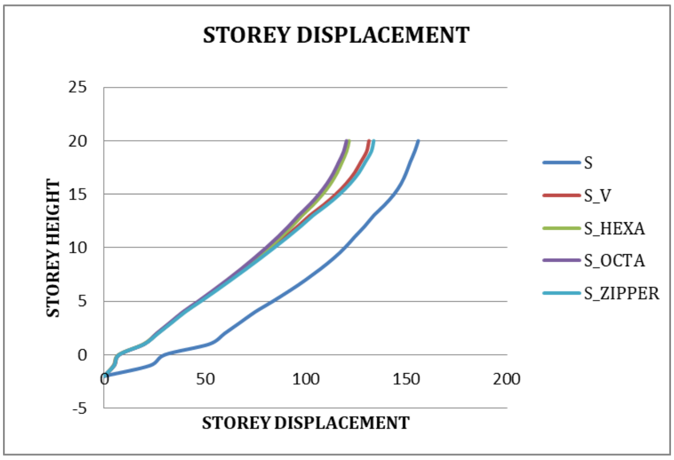

Chart -1: Graph showing storey displacement of symmetrically irregular frame

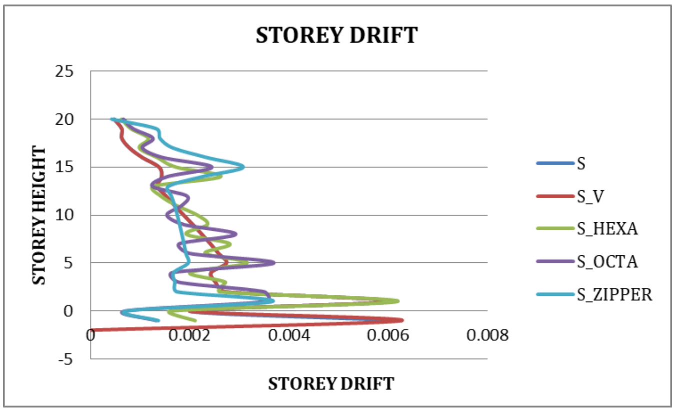

Chart -2: Graph showing storey drift of symmetrically irregular frame

The maximum storey displacement occurred at 20th storey. The maximum storey displacement of symmetrically irregular building at 20th storey without bracing is 155.939 mm. From Table 3, it is clear that storey displacement is reduced in case of octa bracing and has a storey displacement of 120.326mm. So, this bracing has more stiffness compared to others. The maximum storey drift of symmetrically irregular building at base 1 storey without bracing is 0.006263. Storey drift is reduced in case of hexa bracing and has a storey drift of 0.00355.

Table -4: Result analysis of asymmetrically irregular frame with and without bracings

Models name	Storey Displacement (mm)	Storey Drift
AS	192.19	0.00718
AS_V	90.038	0.00277
AS_HEXA	125.093	0.004215
AS_OCTA	123.054	0.00432
AS_ZIPPER	104.679	0.003055

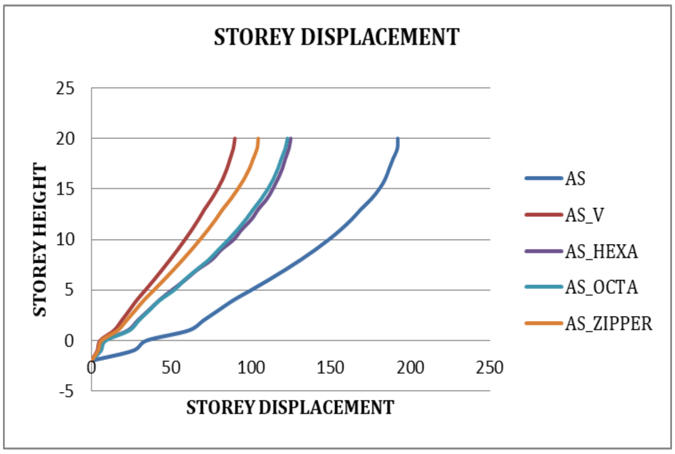

Chart -3: Graph showing storey displacement of asymmetrically irregular frame

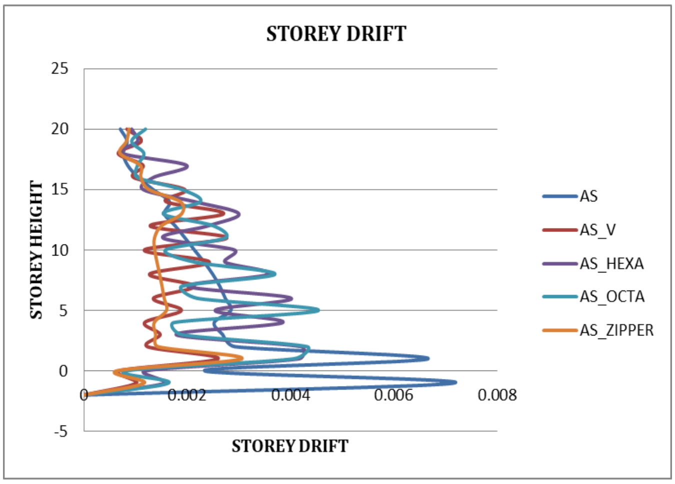

Chart -4: Graph showing storey drift of asymmetrically irregular frame

The maximum storey displacement occurred at 20th storey. The maximum storey displacement of symmetrically irregular building at 20th storey without bracing is 192.19 mm. From Table 4, it is clear that storey displacement is reduced in case of V-bracing and has a storey displacement of 90.038mm. So, asymmetrically irregular V-bracing has more stiffness compared to all other bracings. The maximum storey drift of asymmetrically irregular building at base 1 storey without bracing is 0.007175. Storey drift is reduced in case of V-bracing and has a storey drift of 0.00277.

Table -5: Storey shear(kN) of irregular frame

Models name	Symmetricallly irregular	Asymmetricallly irregular
IRREGULAR	1522.22 kN	1521.37 kN
V	1639.19 kN	1171.34 kN
HEXA	1591.19 Kn	1676.32 kN
OCTA	1606.28 kN	1701.15 kN
ZIPPER	2123.33 kN	1214.57 kN

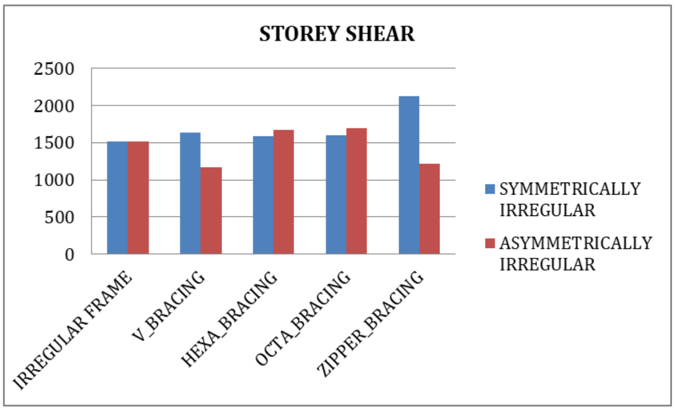

Chart -5: Graph showing Storey shear of irregular frame

With the introduction of bracings, Storey shear is gradually increasing. Symmetrically irregular octa bracing has maximum storey shear and asymmetrically irregular zipper bracing has maximum storey shear.

4. CONCLUSIONS

In this paper, different type of bracings are used in irregular frames and dynamic analysis are performed. Storey drift and storey displacement are compared.

- Storey displacement is greatly reduced in asymmetrically irregular frame with V-bracing.
- In case of soft-storey mechanism, storey displacement is reduced in symmetrically irregular frame with octa-bracing and has a percentage reduction of 41.087% in comparison with symmetrically irregular frame without bracing.
- Storey displacement has a percentage reduction of 53.15% with the introduction of V-bracings in asymmetrically irregular frames. So, asymmetrically irregular V-bracing has more stiffness.
- Storey drift is also reduced in presence of bracing system. V-bracing has a percentage reduction of 61% in comparison with asymmetrically irregular frame without bracing.
- In case of soft-storey, drift is reduced in case of symmetrically irregular hexa-bracing, and has a percentage reduction of 43.221% in comparison with symmetrically irregular frame without bracing.
- Storey Shear is increasing with the addition of bracings.

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REFERENCES

[1] M.Suneel Kumar, R.Senthilkumar, L.Sourabha, (2019), " Seismic Performance of Special Concentric Steel Braced Frames", Journal of structures, Volume 20, Page No. 166-175.

[2] Niloufar Mashhadiali & Ali Kheyroddin, (2018), "Seismic Performance Of Concentrically Braced Frame With Hexagonal Pattern Of Braces to Mitigate Soft Story Behavior" , Engineerng Structures, Volume 175, Page No. 27-40.

[3] Ali Kheyroddin & Niloufar Mashhadiali, (2018), "Response Modification Factor of Concentrically Braced Frames With Hexagonal Pattern of Braces", Journal of Constructional Steel Research, Volume 148, Page No. 658–668.

[4] Yasaman Balazadeh-Minouei, Robert Temblay & Sanda Koboevic, (2018), "Seismic Retrofit of an Existing 10-Story Chevron-Braced Steel Frame", Journal of Structural Engineering, Volume 144, Page No. 1-14.

[5] K.K Wijesundara, R.Nascimbene, G.A. Rassati, (2018), "Evaluation Of The Seismic Performance of Suspended Zipper Column Concentrically Braced Steel Frames," Journal of Constructional Steel Research, volume, Volume 150, Page No. 452-461.

[6] Dia Eddin Nasssani, Ali Khalid Hussein, Abbas Haraj Mohammed, (2017), "Comparative Assessment of Steel Frames With Different Bracing Systems Under Seismic Effect," Structures, Volume 11, Page No. 229-242.

[7] Elnaz Nobahar, Mojtaba Farahi, Massood Mofid, (2016), "Quantification of Seismic Performance Factors of the Buildings Consisting of Disposable Knee Bracing Frames", Journal of Constructional Steel Research, Volume 124, Page No. 132-141.

[8] Tenchini, A., D'Aniello, M.,Rebelo, C., Landolfo, R., da Silva, L.S., & Lima, L., (2016), "High Strength Steel in Chevron Concentrically Brace Frames Designed according to Eurocode 8", Engineering Structures, Volume 124, Page No. 167-185.

[9] Yigit Ozcelik, Afsin Saritas, Patricia M. Clayton, (2016), "Comparison of Chevron an Suspended-Zipper Braced Steel Frame," Journal of Constructional Steel Research, Volume 119, Page No. 169-175.

[10] K.S.K Karthik Reddy, Sai Kala Kondepudi & Harsha Kaviti, (2015), "A Comparative Study on Behavior of Multistoried Building with Diffferent Types and Arrangements of Bracing Systems", International Journal of Science Technology & Engineering, Volume 2, Page No. 135-150.

[11] Sutat Leelataviwat, Bunyarit Suksan, Jarun Srechai and Pennung Warnitchai, (2011), "Behavior of Ductile Knee-Braced Moment Frames," Journal of Structural Engineering, Volume 137, Page No. 579-588.