COMPARATIVE STUDY OF STEEL FRAME WITH DIFFERENT TYPES OF BRACINGS USING RESPONSE SPECTRUM METHOD

[1]Ankit Vishwakarma, [2]Anjali Rai
[1] PG Student (M.Tech Structural Engineering), [2]Assistant Professor
[1][2] Structural Engineering, Department of Civil Engineering, Institute of Engineering & Technology, Lucknow

Abstract: In the structure of steel frame, there should be an appropriate lateral force resisting system which effect on the performance of the structure. It is necessary to design a structure to perform well under seismic loads. So this paper is aimed at investigating and comparing various types of bracings and without bracing systems and analysis of structure using ETAB software are done. During an earthquake , bracing element in the structural system plays a vital role in performance of steel frame . In this study two types of bracings are used Diagonal Forward Bracing and K- bracings in Zone III and analysis is carried out by Response Spectrum Method. Various parameters are considered such as Natural Time period, Base shear, Storey shear, Storey drift and Storey stiffness were studied. From this study it is concluded that, X-bracing are the best bracing system for reducing the storey drift. It is also observed that base shear is high in Diagonal Forward Bracing system because of the increased stiffness. In this work Comparison between the seismic parameters such as Natural Time period, base shear, Storey shear , storey drift and Storey stiffness for steel frame with different combination of bracing and without bracing are studied.

Index Term: ***Steel Frame Structure, ETAB Software, Diagonal Forward Bracing, K- bracing, Natural Time period, Base shear, Storey shear , Storey drift, Storey stiffness.***

I INTRODUCTION

In the present time, the construction industry of Steel structure plays an important role. Previous earthquakes in India show that not only non-engineered structures but engineered structures need to be designed in such a way that they perform well under seismic loading. Steel Frame structures are one of the most common appropriate choices for residential type of building constructions in the world. Among these buildings, there is a different types of braced frame structures are commonly the most favourite types, it is so because of requirement of less skill needed for welding and joints, and the lighter section for beams and braces. Structural response can be increased in Steel moment resisting frames by introducing steel bracings in the structural system. Bracing can be applied as concentric bracing or eccentric bracing. There is a categorization of braced frames into two different types, concentric and eccentric which gives a specific properties and design requirement. There are different types of bracings is to arrange steel bracings, such as cross bracing 'X', diagonal bracing 'D', 'V' type bracing, 'Inverted V' bracing, 'K'-bracing.

Steel moment resisting frames without bracing they shows the inelastic response failure that shows at beam and column connections or joints. Bracing resists lateral forces by flexure and shear in beams and columns i.e. by frame action. Ductile fracture at beams and columns connections under severe earthquake loading. Moment resisting frames have low elastic stiffness. P-Δ effect is an another problem associated with such structures in high rise Multi storey buildings. So, to increase the structure response to lateral loading and good ductility properties to perform well under seismic loading concentric bracings can be provided.

The present study will determine the advantage of concentrically braced steel frames over Steel moment resisting frames. A simple computer based modelling in ETAB Software is performed for Response spectrum analysis subjected to earthquake loading.

II OBJECTIVE OF STUDIES

The aim of this research is analysis of steel frame Multi storey building with different Bracing systems under gravity and seismic load.

1. To study the performance of steel frame building with different arrangement of bracing (Diagonal Forward and K) and without bracing systems.

2. To compare the parameters such as, Natural time period, Base shear, Storey shear, storey drift, stiffness on the performance of Multi storey buildings with different types of bracings i.e., (Diagonal Forward and K).

3. To find optimized bracing system under given loads.

III METHOD OF ANALYSIS

Response Spectrum Method: Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). The maximum response is plotted against the undamped natural period and for various damping values and can be notified in terms of maximum relative velocity or else maximum relative displacement.

1. Natural Period: Natural Period 'T_n'of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass 'm' and stiffness 'k'. These three quantities are related by:

$$T_n = 2\Pi\sqrt{(m/k)}$$

It's units is seconds (s).

2. Base shear: The design base shear along any principal direction of a building shall be designed by:

$$\mathbf{V_b = A_h \times W}$$

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{Sa}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where,

A_h = Design horizontal acceleration spectrum

W= Seismic weight of the building

Factors and Coefficients

Seismic Zone Factor, Z [IS 1893-2016 Table 2]

Response Reduction Factor, R [IS 1893-2016Table 7]

Importance Factor, I [IS 1893-2016 Table 6]

Soil Type [IS 1893-2016 Table 1]

3. Storey Drift: story drift can be defined as the displacement of one floor level of the building with respect to its adjacent level above or below the considered floor level.

As per **IS 1893:2016**, the storey drift not be more **than 0.004H**, where H is the height of storey.

.

IV STRUCTURAL BUILDING DETAIL

The length and width is the dimensional plan of the building are 22.5m and 22.5m. The height of storey is 3m. The building is symmetrical to X and Y axis. The columns are assumed to be fixed at ground level. In this study, (G+19) storey steel building of 5 bays in X-direction and 5 bay in Y- direction have been considered for the investigation the effect of the different types of bracings. Below table shows details of the building that is used for the analysis of the building. Some identical steel section is used for all bracing pattern. The building has been analyzed using commercially available ETAB software.

Table 1: Description of the Building

S.No	Structural Part	Dimension
1.	Location	Lucknow (U.P)
2.	Type of Building	Residential Building (G+19)
3.	Plan Dimension	(22.5m×22.5m) =506.25 sq.m
4.	Type of structure	Steel structure
5.	Length in X-direction	22.5m
6.	Length in Y-direction	22.5m
7.	No of bays in X-direction	5No@4.5m
8.	No.of bays in Y-directions	5No@4.5m
9.	Floor to floor height	3m
10.	Total height of building	60m
11.	Slab thickness	127mm
12.	Column size	ISMB 600
13.	Beam size	ISMB 450
14.	Secondary Beam for slab	ISMB 400
15.	Diagonal Forward-Bracing	ISMB 350
16.	K-Bracing	ISMB 350

Table 2: Material Properties

S. No	Material	Grade
1.	Grade of steel	Fe250
2.	Rebar	HYSD 500
3.	Density of steel	7850 Kg/m3
4.	Young's Modulus E	$2.1\text{x}10^5 N/m^2$
5.	Shear Modulus	$80000 N/mm^2$
6.	Poisson's Ratio	0.3
7.	Concrete	M30

Table 3: SEISMIC DATA: As Per IS 1893:2016 (part 1)

1.	Earthquake Zone	III
2.	Zone Factor	Z = 0.16 (clause 6.4.2)
3.	Damping Ratio	5%
4.	Importance Factor	1.2 (clause 7.2.3)
5.	Type of soil	Medium soil (clause 6.4.2.1)
6.	Response Reduction Factor	5 (SMRF) (clause 7.2.6)

LOADINGS:

a) Live load 2 KN/m^2 as per IS 875 Part II
b) Dead Load of Building as per IS: 875- Part (I)
c) Earthquake load as per IS 1893:2016 Part (I)

V PROBLEM FORMULATION

Here we have considered the steel structure multi-storey building with different types of bracings subjected to under seismic loading as per IS 1893:2016 code provision. Seismic analysis of steel frame building with different bracings and without bracing system is carry out by using ETAB software.

- Model 1 -Steel Frame Building (G+19) without Bracing
- Model 2 -Steel Frame Building (G+19) with Diagonal Forward Bracing.
- Model 3 -Steel Frame Building (G+19) with K-Bracing.

- **Model 1 -Steel Frame Building (G+19) without Bracing**

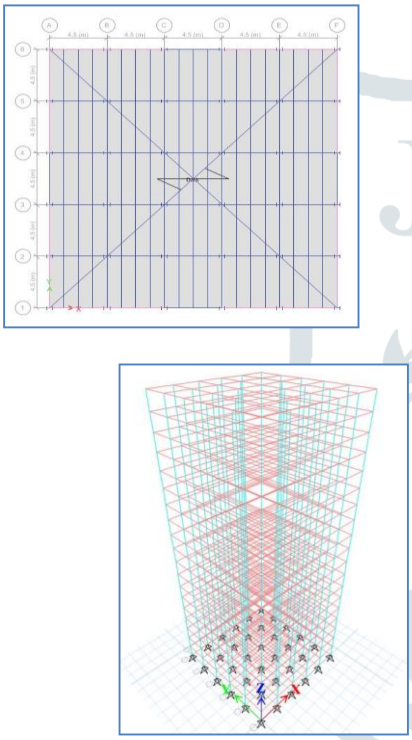
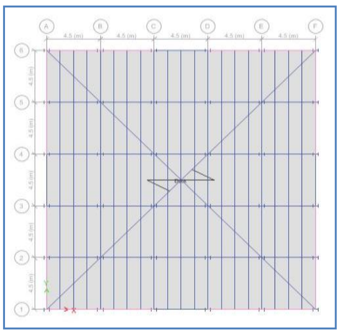


Figure 1: Plan and 3-D view

- **Model 2 -Steel Frame Building (G+19) with Diagonal Forward Bracing**.



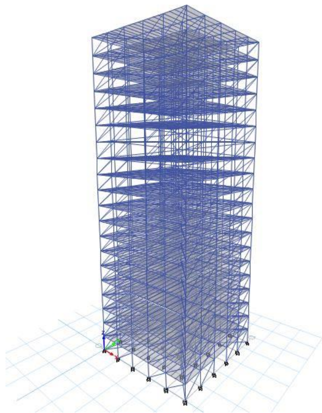


Figure 2: Plan and 3-D view

- **Model 3 -Steel Frame Building (G+19) with K-Bracing**

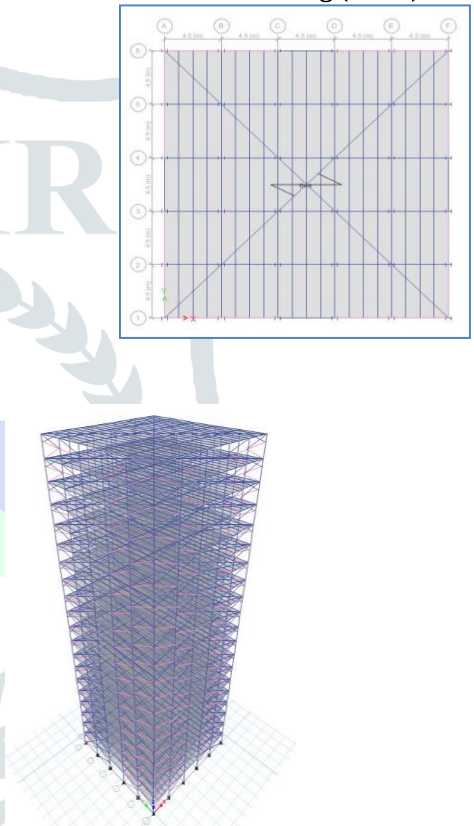


Figure 3: Plan and 3-D view

VI RESULT AND DISCUSSION

The parametric study of Natural Time period, Base shear, Storey shear, storey drift and storey stiffness of building in different stories by response spectrum analysis for (G+19) storeys is performed here. The results obtained from the analysis are compared by graphical representation:

A. Natural Time Period

Table 4: Natural Time Period

Mode	Without Bracing (sec)	Diagonal Forward Bracing (sec)	K-Bracing (sec)
Mode 1	8.407	2.837	5.99
Mode 2	4.059	2.451	3.879
Mode 3	3.65	1.465	3.477
Mode 4	2.799	0.833	1.988
Mode 5	1.662	0.722	1.274
Mode 6	1.329	0.46	1.167
Mode 7	1.189	0.43	1.125
Mode 8	1.182	0.375	0.833
Mode 9	0.927	0.291	0.738
Mode 10	0.765	0.253	0.648
Mode 11	0.762	0.248	0.634
Mode 12	0.667	0.219	0.533

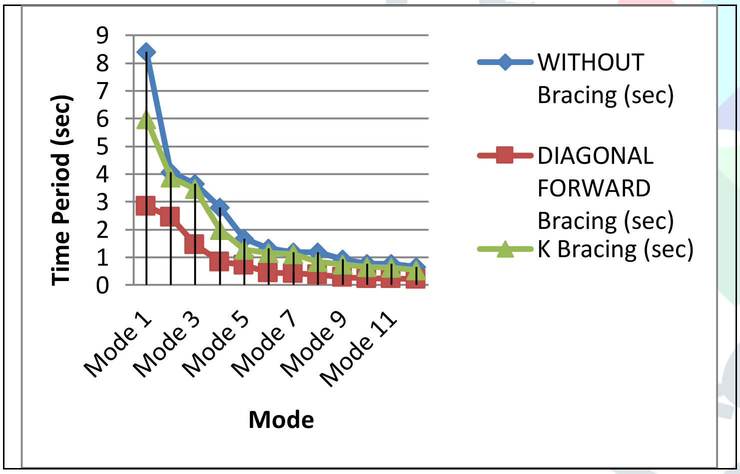


Figure 4: Comparison of Time period

From above graph and table of Natural time period, it is concluded that Diagonal Forward bracing is more efficient bracing as compared to without and K-bracing systems.

B. Comparison of Base Shear

Table 5: Base Shear

BRACING TYPE	BASE SHEAR V_B (kN)
WITHOUT BRACING	1051.6747
DIAGONAL FORWARD BRACING	1596.2764
V-BRACING	1120.1049

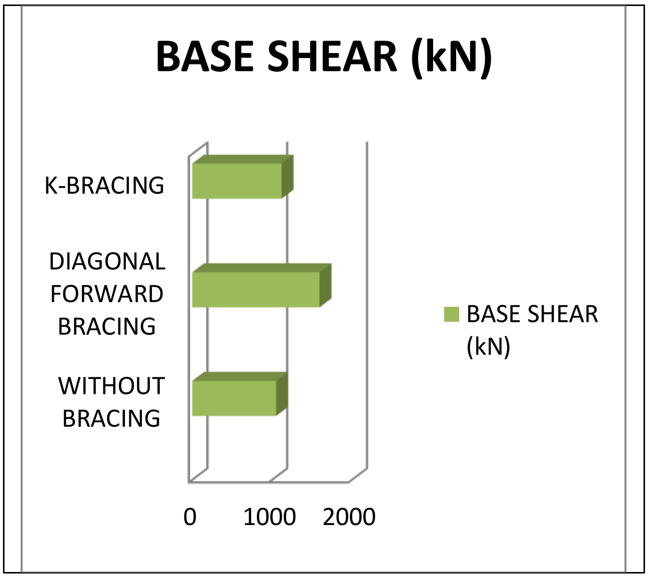


Figure 5: Comparison of Base Shear

From above graph and table of Base shear, it is concluded that Diagonal Forward bracing is more efficient bracing as compared to without and K-bracing systems.

C. Storey shear

Table 6: Storey shear of structure in (kN)

Storey	WITHOUT	DIAGONAL FORWARD	K
	Bracing (kN)	Bracing (kN)	Bracing (kN)
Storey 20	145.4596	219.3767	154.2695
Storey 19	132.4468	201.2392	141.1606
Storey 18	118.8719	180.6136	126.6926
Storey 17	106.0308	161.1028	113.0066
Storey 16	93.9235	142.707	100.1028
Storey 15	82.55	125.4261	87.981
Storey 14	71.9102	109.2601	76.6412
Storey 13	62.0042	94.2089	66.0835
Storey 12	52.832	80.2727	56.3078
Storey 11	44.3935	67.4514	47.3142
Storey 10	36.6889	55.7449	39.1026
Storey 9	29.718	45.1534	31.6731
Storey 8	23.4809	35.6768	25.0257
Storey 7	17.9775	27.315	19.1603
Storey 6	13.208	20.0682	14.077
Storey 5	9.1722	13.9362	9.7757
Storey 4	5.8702	8.9192	6.2564
Storey 3	3.302	5.017	3.5192
Storey 2	1.4676	2.2298	1.5641
Storey 1	0.3669	0.5575	0.391

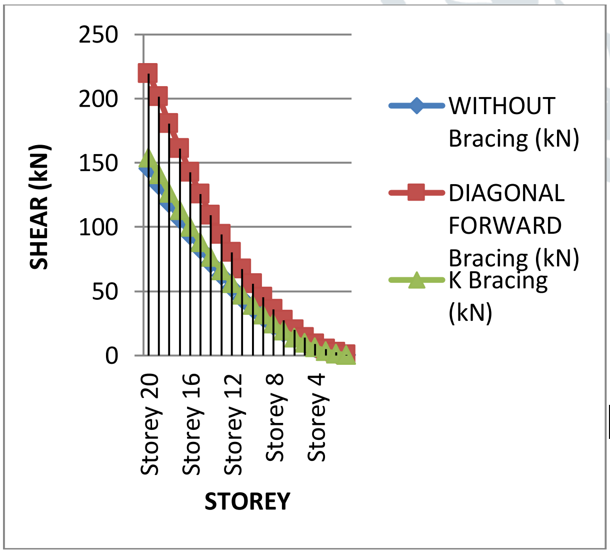


Figure 6: Shear V/S Storey

From above graph and table of Storey shear, it is concluded that Diagonal Forward bracing is more efficient bracing as compared to without and K-bracing systems.

D. Storey Drift

Table 7: Maximum Storey drift

Storey	WITHOUT	DIAGONAL FORWARD	K	AS PER I.S CODE
	Bracing (mm)	Bracing (mm)	Bracing (mm)	(mm)
Storey 1	18.032	4.258	9.38	12
Storey 2	19.78	4.583	10.549	12
Storey 3	19.906	4.786	10.792	12
Storey 4	19.971	4.944	10.937	12
Storey 5	19.975	5.056	11.029	12
Storey 6	19.905	5.127	11.071	12
Storey 7	19.749	5.157	11.058	12
Storey 8	19.493	5.15	10.985	12
Storey 9	19.124	5.106	10.846	12
Storey 10	18.628	5.027	10.633	12
Storey 11	17.993	4.914	10.342	12
Storey 12	17.206	4.768	9.966	12
Storey 13	16.253	4.591	9.499	12
Storey 14	15.122	4.384	8.934	12
Storey 15	13.799	4.149	8.265	12
Storey 16	12.272	3.89	7.263	12
Storey 17	10.529	3.409	6.596	12
Storey 18	8.557	3.31	5.586	12
Storey 19	6.343	3	4.456	12
Storey 20	3.899	2.673	3.253	12

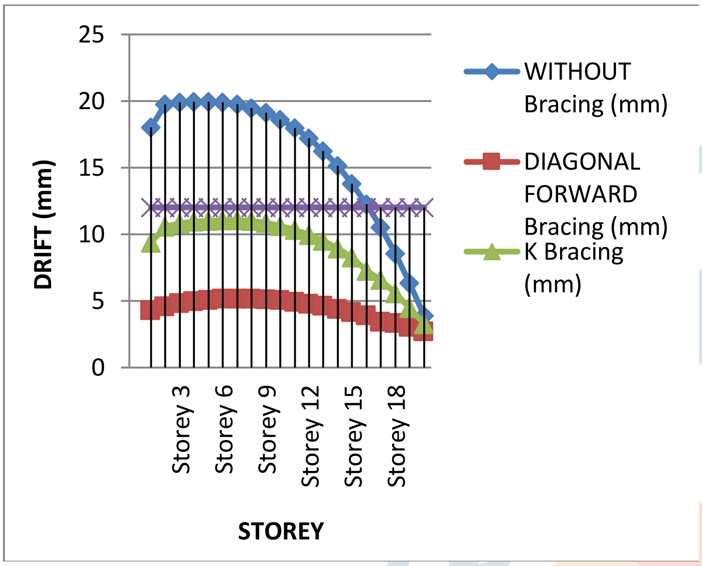


Figure 7 Drift V/S Storey

From above graph and table of Storey Drift, it is concluded that Diagonal Forward bracing is more efficient bracing as compared to without and K-bracing systems.

E. Storey Stiffness

Table 8: Maximum Storey Stiffness

Storey	WITHOUT Bracing (KN/m)	DIAGONAL FORWARD Bracing (KN/m)	K-Bracing (KN/m)
Storey 1	828576.163	2223956.901	903091.883
Storey 2	462378.906	1477395.077	554829.181
Storey 3	406630.113	1285231.243	460896.549
Storey 4	387360.193	1145614.752	434876.844
Storey 5	376428.412	1035270.372	420225.027
Storey 6	368355.619	946204.912	410355.849
Storey 7	361994.549	873769.39	402661.969
Storey 8	356705.306	814536.897	396042.442
Storey 9	351629.836	766252.436	387903.026
Storey 10	345981.169	727609.482	379505.439
Storey 11	339494.136	697359.426	371529.874
Storey 12	332681.87	673671.013	364119.97
Storey 13	326679.101	654390.558	357408.543
Storey 14	322475.621	637481.107	351120.881
Storey 15	319888.488	620460.226	344172.399
Storey 16	317147.563	598769.956	334761.022
Storey 17	311132.897	564236.752	320536.016
Storey 18	296886.937	504494.757	297768.342
Storey 19	263948.866	403296.754	257405.895
Storey 20	182980.19	242758.49	177301.336

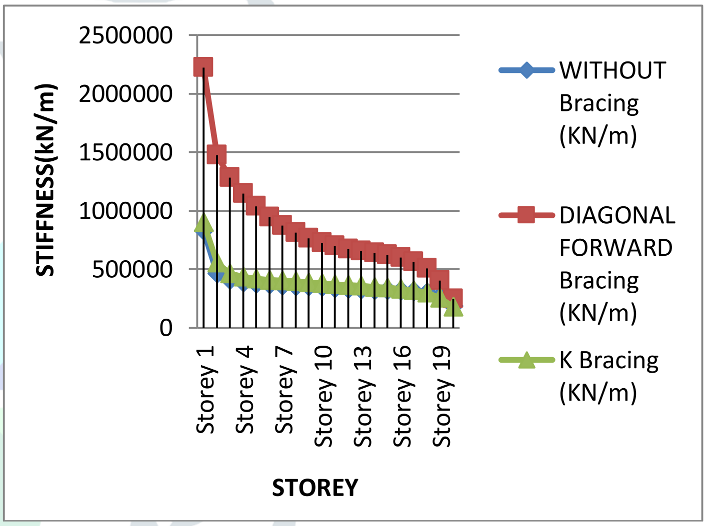


Figure 8 Stiffness V/S Storey

From above graph and table of Storey Drift, it is concluded that Diagonal Forward bracing is more efficient bracing as compared to without and K-bracing systems.

VII CONCLUSIONS

From the above work the following conclusion are given below:

1. Natural Time period

i. From above **graph 4** and **table 4** it is concluded that Diagonal Forward bracing is 61.37% efficient as compared to without bracing systems model.

ii. From above **graph 4** and **table 4** it is concluded that Diagonal Forward bracing is 18.65% efficient as compared to K- bracing systems model.

2. Base shear

i. From above **graph 5** and **table 5** it is concluded that Diagonal Forward bracing is

ii. 34.11% efficient as compared to without bracing systems model.

iii. From above **graph 5** and **table 5** it is concluded that Diagonal Forward bracing is 29.83% efficient as compared to K- bracing systems model.

3. Storey Drift

i. From above **graph 7** and **table 7** it is concluded that Diagonal Forward bracing is 72.11% efficient as compared to without bracing systems model.

ii. From above **graph 7** and **table 7** it is concluded that Diagonal Forward bracing is 42.67% efficient as compared to K- bracing systems model.

4. Storey Stiffness

i. From above **graph 8** and **table 8** it is concluded that Diagonal Forward bracing is 57.02% efficient as compared to without bracing systems model.

ii. From above **graph 8** and **table 8** it is concluded that Diagonal Forward bracing is 8.42% efficient as compared to K- bracing systems model.

REFERENCES

[1] Safvana P (2018)"Seismic Analysis Of Braced Rcc and Steel Structures Using Etabs Software", IJRSFP (USA), Vol. 9, Issue, 4(C), pp 25689-25691

[2] Suyog Sudhakar Shinde (2017) **,"**Evaluating Seismic Efficiency of Combination of Bracing for Steel Building" ,(IJARIIT), (Volume3, Issue5) ,pp 46-55

[3] Muhammed Tahir Khaleel (2016),"Seismic Analysis of Steel Frames with Different Bracings using ETSBS Software",(IRJET), Volume: 03 Issue: 08 ,pp 2081-2087.

[4] Adithya. M, Swathi rani K.S, Shruthi H K, Dr. Ramesh B.R (2015) " Study on Effective Bracing Systems for High Rise Steel Structures", (SSRG-IJCE) – volume 2 Issue 2, pp 19-23.

[5] Pratik Bawankar (2015) "Seismic Analysis of High-Rise Building using Response Spectrum Method", IJSRD Vol. 3, Issue 06, pp 172-178

[6] Mr. Sandesh N. Suryawanshi, Prof. S. B. Kadam, Dr. S. N. Tande (2014) "Torsional Behaviour of Asymmetrical Buildings in Plan under Seismic Forces" IJEERT, ISSN 2349-4395 (Print) & ISSN 2349-4409, Volume 2, Issue 4, July 2014, pp 170-176.

[7] Krishnaraj R. Chavan, H.S.Jadhav (2014) "Seismic Response of R C Building with Different Arrangement of Steel Bracing System", ISSN: 2248-9622, Vol. 4, Issue 7(Version 3), pp.218-222.

[8] K.K.Sangle, K.M.Bajoria V.Mhalungkar (2012) "Seismic Analysis of High Rise Steel Frame Building with and without Bracing" (WCEE), pp 1-10.

[9] Shahrzad Eghtesadi, Danesh Nourzadeh, Khosrow Bargi (2011) "Comparative Study on Different Types ofBracing Systems in Steel Structures"(WASET),pp 1863-1867.

[10] IS: 1893(Part 1): 2016 "Criteria for Earthquake Resistant Design of Structures".

[11] IS: 875(Part 2)-1987 "Code of Practice for design loads for buildings and structures".

[12] IS 800:2007 "Code of Practice for General Construction in steel".