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SeismicAnalysisofa Multi-Storey Building using Steel Braced Frames

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Abstract – *The main concern in the high rise building is their lateral stability i.e. they provide stability during seismic activity without any major destruction .Bracing is one of the horizontal force resisting system.An attempt is made to analyze the response of G+14 storied RC multi-storey building due to the application of different bracing system such as X, V, inverted V bracing and to find the best bracing system during earthquake. ETABs software is used for modeling and analyzing the building. The building is taken in Zone III and analyzed with Time History analysis method. Various parameters such as storey drift, storey displacement, fundamental time period and storey stiffness are studied. From the study it was concluded that building with bracing perform better during seismic activity as compared with building without bracing. Among all the different bracing, X bracing is the best bracing system to reduce the responses during seismic activity.*

KeyWords:*Time History Analysis, Storeydrift, Storey displacement, Time period, Storey stiffness.*

1. INTRODUCTION

Generally, it is recognized that seismic design of buildings should satisfy at least two fundamental requirements. First, the structure must behave elastically and protect relatively brittle non-structural components against minor earthquake ground shaking. Therefore, a structure should have sufficient strength and elastic stiffness to limit structural displacements, such as interstorey drift. Second, the structure must not collapse in a major earthquake. For this case, significant damage of the structure and non-structural components is acceptable. In order for a structure not to collapse and thereby minimize the loss of life, it must have large energy dissipation capacity during large inelastic deformations. In general, structural systems which exhibit stable hysteretic loops perform well under the large inelastic cyclic loadings characteristics of major earthquakes. Such stable hysteretic characteristics of a structure can be obtained provided that the structural members and joints are designed to possess sufficient ductility.

In Seismic Analysis, we come to know that earthquakes are the most volatile, disturbing and unpredictable of all natural disasters, in which it is very difficult to save life and engineering properties. Care has to take for each step of construction of a building from foundation part. When earthquakes take place, a building undergoes dynamic motion. Because of subjected to inertia forces that may act in the opposite direction to speeding up of earthquake excitations. These inertia forces normally called seismic loads dealt by assuming forces external to the building. To overcome these problems, we need to identify the seismic performance of multi-storey buildings during various horizontal force resisting systems. This is because to make sure that the high rise buildings withstand during earthquake events. Hence, can save as many lives as possible. During earthquake the performance of a structure depends on many factors such as stiffness, adequate lateral strength, simple and regular configurations etc.

2. OBJECTIVE

The objective of this research is focused on the technique which areused to study the seismic behaviour of R.C buildings with seismic zone III of India using bracing system. The whole design was carried out in ETABs which covers all aspects of structural engineering. More specifically, the salient objectives of this research are:

1) To perform a comparative study of the various seismic parameters.
2) Comparison among building with X, V bracing,inverted V bracing and without bracing on the basis of storey displacement, storey drift,storey stiffness & fundamental time period.
3) To propose the best suitable technique for seismic analysis.

In this paper, an RC multi-storey residential building isstudied for earthquake using Time history method in the ETABs software. This analysis is carried out by considering seismic zone III, and for this zone, the behaviour assesses by taking the medium soil. A different response for displacements, storey drift and other parameters are plotted for zone III for medium type of soil.

3. STRUCTURALMODELING

For the purpose of this study,a RC framed (G+14) multistory building having same floor plan with 6 bays of 3m each along longitudinal direction and along transverse direction as shown in figure 1. Four models with different types of bracings wereselectedinordertodetermine thebehaviourofstructuralsteelduringseismicactivity. The columns are fixed at the ground and are taken as restrains. The bottomstorey height is 3.5m and rest are of 3m. All the values of loads and dimensions are given in table no.1.The load cases considered in the seismic analysis are as per IS 1893:2002 (part 1). Figure 1 and 2 shows the geometrical configuration of the building. The model was prepared for bare frame and with differentbracingsystems.Table1givesthematerialproperti es ofthemembers.

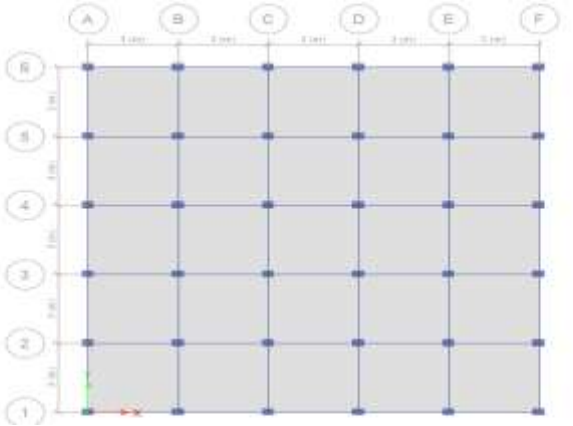


Figure 1: Plan of Building without Bracing.

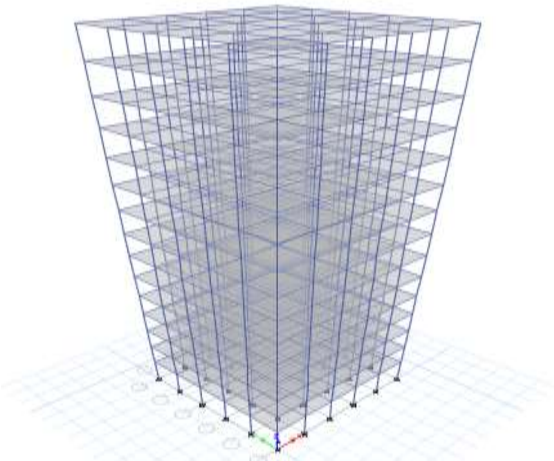


Figure 2: A 3D View of Building without Bracing.

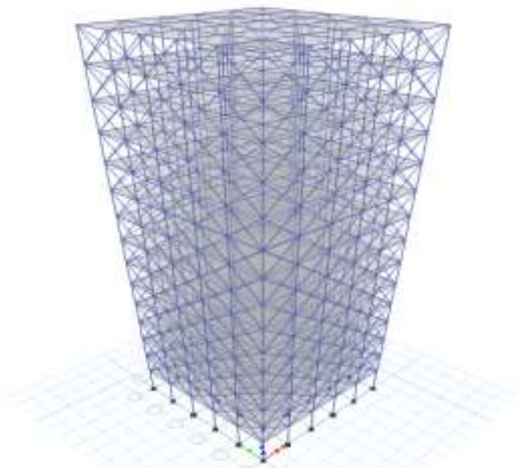


Figure 3:- 3D View of Building with X- Bracing.

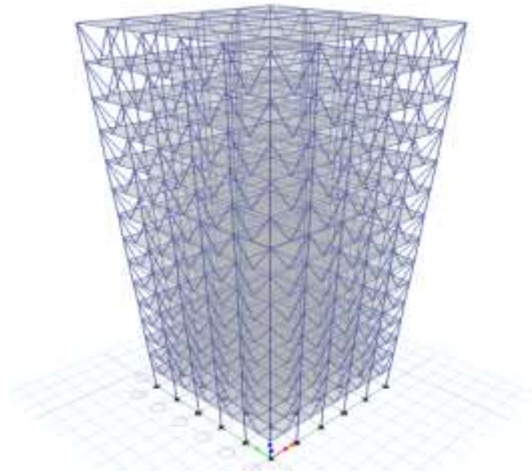


Figure 4:- 3D View of Building with V- Bracing

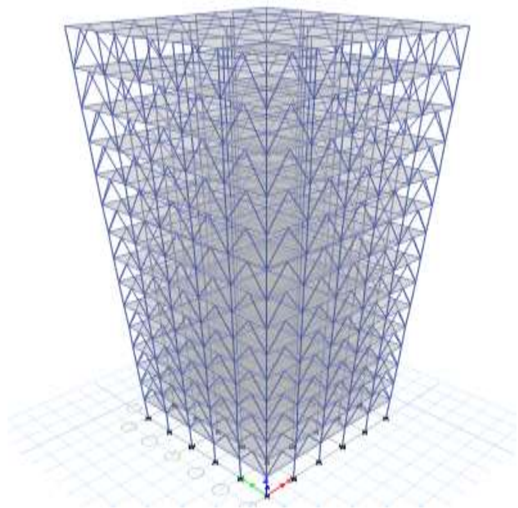


Figure 5:- 3D View of Building with Inverted V- Bracing.

Table 1: Material and Section Properties

1.	Building Type	Residential building
2.	No. of storeys	G+14
3.	Bottom storey height	3.5m
4.	Total height	45.5m
5.	Floor height	3m
6.	Size of column	300mm*400mm
7.	Size of beam	230mm*300mm
8.	Thickness of slab	150mm
9.	Masonry wall thickness	250mm
10.	Seismic zone	III
11.	Grade of concrete	M20
12.	Grade of steel	Fe250
13.	Unit weight of concrete	$25KN/m^3$
14.	Unit weight of PCC	$24\ KN/m^3$
15.	Unit weight of brick	$20\ KN/m^3$
16.	Unit weight of plaster	$21\ KN/m^3$
17.	Wall load	13.5 KN/m

18.	Parapet wall load	7KN/m
19.	Live load	3 KN/m^2
20.	Roof load	2.5 KN/m^2
21.	IS Code for concrete	IS 456:2000
22.	IS Code for earthquake	IS 1893:2002 (part I)

Building is analalyzed on the basis of Various load combinations in the limit state of design for reinforced concrete structures as per IS 1893:2000(part1).

3.1 ETABs Overview

ETABs is used for seismic analysis and to study the behaviour of multistorey building with and without bracing are compared with different parametres of analysis.Complete analysis including structural modeling is performed in this software.

The analysis has been done by using ETABs software which involves following steps:-

1. Defining dimensions of the plan
2. Defining the members and material properties
3. Assigning loads and load combinations
4. Run and check model to find errors
5. Run analysis
6. Extract results and discuss

4. METHOD OFANALYSIS

4.1 Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed. In linear dynamic method, the structures is modeled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled utilizing time history analysis, the displacements and internal forces are found using linear elastic analysis. The playing point of linear dynamic procedure as for linear static procedure is that higher modes could be taken into account.

In order to study the seismic behaviour of RC multi-storey building under lateral forces with or without bracing, dynamic analysis is required. The ETABs software is used to perform linear time history analysis.

4.2Parameters considered for analysis

1. Storey drift
2. Storey displacement
3. Fundamental time period
4. Storey stifness

The seismic data is taken according to the IS 1893:2002 for the Zone III.

Table 2:Seismic Data

Serial No	Model Description	
1	Zone	III
2	Zone Factor	0.16
3	Type of building	Residential
4	Importance Factor	1
5	Soil Type	II
6	Soil Condition	Medium
7	Damping Ratio	5%
8	Response Reduction Factors	5

5. RESULTS

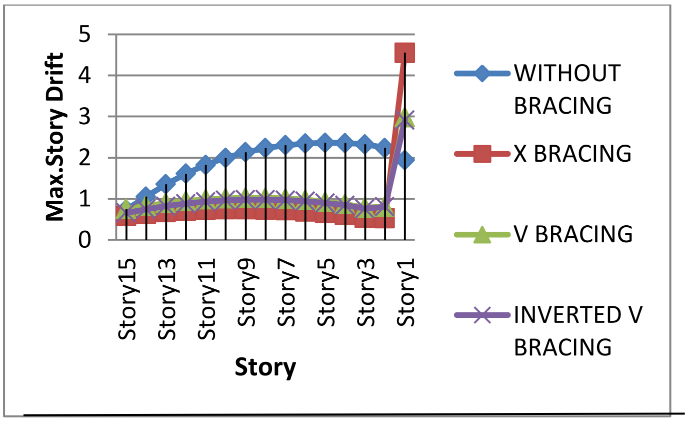
5.1 Storey drift

It is the relative displacement of one level relative to other level above or below. According to IS 1893:2002 (part 1),thestoreydrift should not exceed 0.004 times of relative storey height.

5.1.1Max. Storeydrift(mm) comparison in X direction the table and the graph below shows the comparison of various bracing with bare frame in terms of storey drift in X direction.

No of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.734	0.584	0.751	0.659
Story14	1.051	0.632	0.826	0.745
Story13	1.351	0.673	0.892	0.82
Story12	1.608	0.706	0.945	0.882
Story11	1.822	0.729	0.985	0.929
Story10	1.995	0.743	1.011	0.961
Story9	2.131	0.746	1.023	0.977
Story8	2.232	0.738	1.021	0.979
Story7	2.302	0.72	1.004	0.966
Story6	2.343	0.691	0.973	0.938
Story5	2.359	0.652	0.928	0.896
Story4	2.352	0.603	0.87	0.84
Story3	2.321	0.536	0.784	0.755
Story2	2.238	0.528	0.81	0.806
Story1	1.94	4.55	2.981	2.91

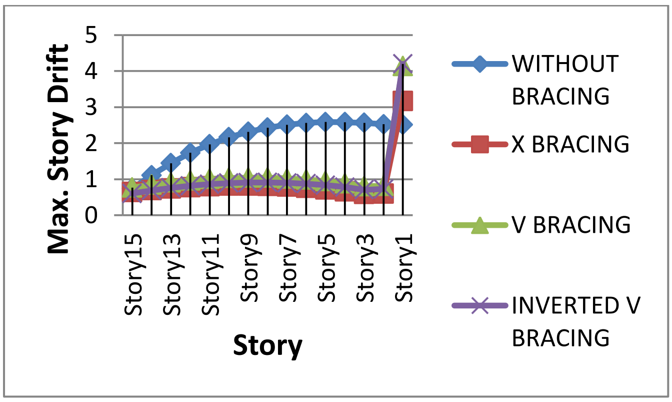
Max. Storey drift(mm) comparison in X direction-



5.1.2Max. Storeydrift(mm) comparison in Y direction-the table and graph below shows the comparison of different bracing system with bare frame in terms of storey drift in Y direction.

No.of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.743	0.649	0.771	0.606
Story14	1.109	0.701	0.849	0.687
Story13	1.445	0.747	0.917	0.758
Story12	1.731	0.783	0.97	0.816
Story11	1.969	0.808	1.01	0.861
Story10	2.163	0.822	1.035	0.891
Story9	2.316	0.825	1.045	0.908
Story8	2.431	0.817	1.042	0.91
Story7	2.511	0.797	1.024	0.899
Story6	2.561	0.765	0.992	0.874
Story5	2.584	0.721	0.946	0.835
Story4	2.583	0.667	0.888	0.783
Story3	2.562	0.589	0.807	0.707
Story2	2.523	0.6	0.815	0.731
Story1	2.512	3.17	4.14	4.199

Max. Storeydrift(mm) comparison in Y-direction-



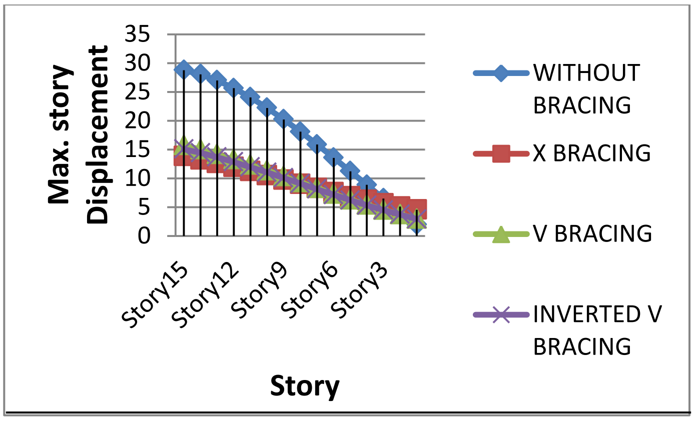
5.2 Storey Displacement

It is the diplacement of each storey with respect to ground level. According to IS 1893 (part1) :2002 the max value of diplacement is 1/250 times of storey height with respet to ground.

5.2.1 Max.Storey displacement (mm) comparison in x direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey displacement in X direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	28.779	13.832	15.751	15.063
Story14	28.045	13.247	15	14.404
Story13	26.993	12.615	14.174	13.659
Story12	25.643	11.942	13.283	12.838
Story11	24.035	11.236	12.338	11.957
Story10	22.213	10.506	11.353	11.028
Story9	20.218	9.764	10.341	10.068
Story8	18.086	9.018	9.318	9.09
Story7	15.854	8.28	8.297	8.111
Story6	13.552	7.56	7.293	7.145
Story5	11.21	6.869	6.319	6.206
Story4	8.851	6.217	5.391	5.31
Story3	6.499	5.613	4.521	4.47
Story2	4.178	5.078	3.737	3.715
Story1	1.94	4.55	2.981	2.91

Max. Storey displacement (mm) comparison in x direction-

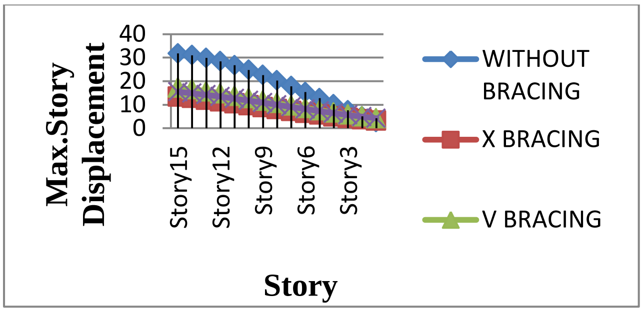


5.2.2Max.Storey displacement (mm) comparison in Y direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey displacement in Y direction.

NO OF STORYS	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	31.742	13.461	17.25	15.465
Story14	30.999	12.811	16.48	14.859
Story13	29.89	12.11	15.63	14.171
Story12	28.445	11.363	14.714	13.413
Story11	26.715	10.581	13.743	12.597
Story10	24.745	9.773	12.733	11.737
Story9	22.582	8.95	11.698	10.846
Story8	20.267	8.125	10.653	9.938
Story7	17.836	7.308	9.611	9.028
Story6	15.325	6.512	8.588	8.129

Story5	12.764	5.747	7.596	7.256
Story4	10.18	5.026	6.65	6.421
Story3	7.597	4.359	5.762	5.638
Story2	5.035	3.77	4.955	4.93
Story1	2.512	3.17	4.14	4.199

Max. Storey displacement (mm) comparison in Y direction-



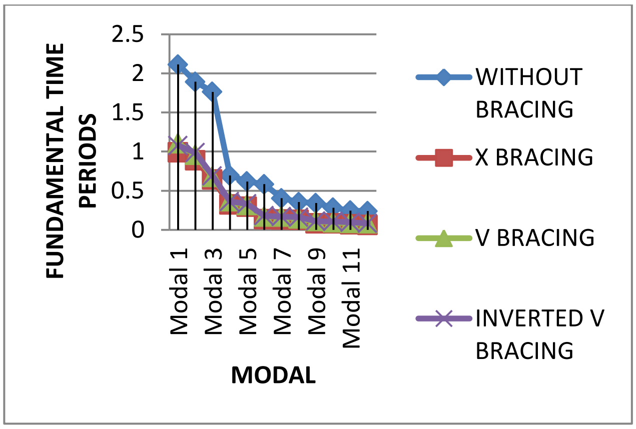
5.3 Fundamental time periods-

According to IS 1893:2002 it is the first(longest) modal time period of vibration.

5.3.1Fundamental time period (S) comparison-The table and the graph below shows the comparison of various bracing system with bare frame in terms of fundamental time period.

MODAL	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Modal 1	2.113	0.993	1.104	1.079
Modal 2	1.891	0.89	0.959	0.986
Modal 3	1.764	0.644	0.675	0.691
Modal 4	0.697	0.326	0.366	0.362
Modal 5	0.619	0.297	0.316	0.332
Modal 6	0.583	0.139	0.17	0.182
Modal 7	0.404	0.134	0.169	0.169
Modal 8	0.355	0.13	0.145	0.162
Modal 9	0.343	0.085	0.112	0.111
Modal 10	0.284	0.084	0.095	0.108
Modal 11	0.247	0.073	0.086	0.098
Modal 12	0.24	0.063	0.083	0.083

Fundamental time period (S) comparison



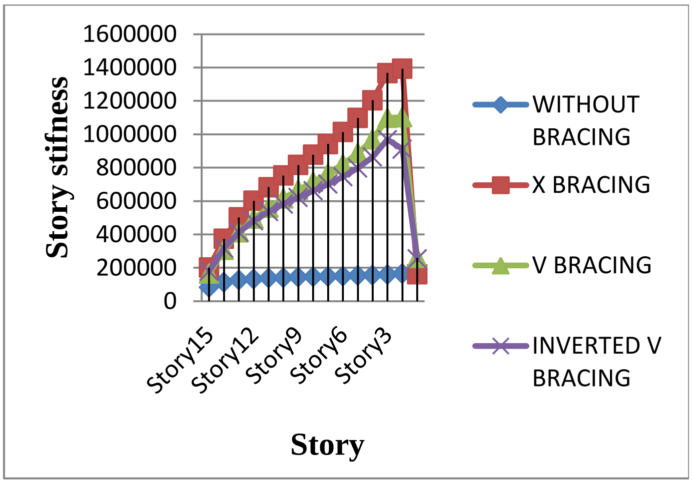
5.4 Storey stiffness

As per IS 1893:2002 the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of average lateral stiffness of the three storey above.

5.4.1Max.Storey stifness (kN/m) comparison in x direction- the table and graph below shows the comparison of various bracing system with bare frame in terms of storey stiffness in X direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	82225.893	201749.63	165111.89	179165.8
Story14	113846.64	373293.98	306364.7	316707.3
Story13	126534.47	501809.39	412105.18	411757.6
Story12	133531.57	601861.5	494022.47	481678
Story11	138074.29	683217.72	560090.31	536175.6
Story10	141383.28	752901	616125.72	581487.3
Story9	144031.15	816253.48	666559.5	621892.3
Story8	146339.62	877773.32	715104.71	660695.7
Story7	148514.22	941771.95	765284.54	700841.2
Story6	150703.98	1013015.1	820943.82	745401.4
Story5	153036.45	1097900.6	887210.06	798351.3
Story4	155659.05	1203792.2	969674.53	863782
Story3	159033.88	1366816.7	1098192.5	968549.9
Story2	165553.96	1392896.2	1102921.2	911152.3
Story1	191139.93	161702.39	259663.03	252550.7

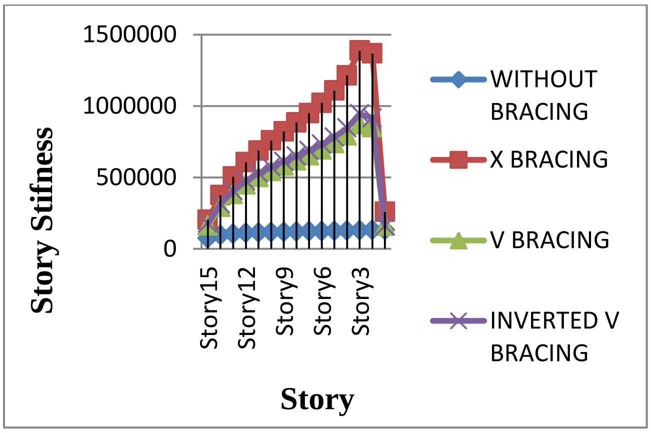
Max.Storey stifness (kN/m) comparison in x direction-



5.4.2Max.Storey stifness (kN/m) comparison in Y direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey stiffness in Y direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	72684.213	202627.23	163480.93	177941.84
Story14	96586.265	375344.8	291989.22	313435.62
Story13	105880.63	504836.59	382069.79	406758.85
Story12	111006.47	605800.18	448897.84	475112.96
Story11	114314.96	687972.52	501129.39	528233.64
Story10	116709.24	758416.06	544362.17	572292.24
Story9	118614.25	822505.88	582445.61	611505.59
Story8	120267.07	884780.63	618311.46	649109.94
Story7	121817.56	949601.85	654481.54	687972.12
Story6	123372.44	1021775.5	693444.68	731076.42
Story5	125018.23	1107918.2	738182.25	782244.12
Story4	126826.98	1214374.3	791565.06	845682.99
Story3	128924.25	1386994.3	870299.17	944067.29
Story2	131374.3	1366867.2	850370.28	916639.61
Story1	132134.35	258920.79	161354.81	159764.65

Max.Storey stifness (kN/m) comparison in Y direction-



6. CONCLUSION

From the above study and results several conclusions can be drawn such as:

1) Building with bracing is more earthquake resistance than building without bracing.
2) Steel bracing can be used to strengthen or retrofit the existing structures.
3) Displacements and Drifts are reduced in Building with bracing as compared to building without bracing.
4) X bracing is more effective as compared with other bracing for storey drift in x as well as y directions.
5) X bracing is also more effective in x and y direction as compared to other bracing for storey displacement.
6) The fundamental time period can be also reduced with bracing. Again the X bracing performed better in terms of fundamental time period it gives the lesser value of time period as compared with other bracing.
7) For storey stiffness X bracing is more effective in both x and y direction as compared with other bracing system.
8) Hence, in comparison to X, V and inverted V bracing, X bracing is the most effective bracing system of all.

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BIOGRAPHY

Mr. MohdAtif khan was born in 1996 in Bareilly city. He received his Bachelor of Technology degree in civil engineering from BabuBanarasi Das University, Lucknow in 2017. Now He is pursuing his Master of Technology in Structural Engineering from BabuBanarasi Das University, Lucknow