Behaviour of Multi-Storey R.C.C Structure with Different Types of Bracing against Earthquake Forces

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Abstract - Nowadays, the construction of the high-rise multi-storey buildings has been increased due to the increasing population. Earthquake is one of the main phenomena causing damage to the structure .As the height of the structure increases ,it undergoes larger seismic forces .So, it is important to improve the resistance of multi-storey building to lateral loads. There are many structural systems which resist lateral loads by the addition of different structural systems. In this project work, Steel Bracing structural system is considered and compared to their results against lateral forces. Here, seven structural systems are considered in which one is Un braced framed structure and others are Braced frame structure. For the purpose G+15 storey multi-storey R.C.C structure with rectangular plan of dimension 30mx20m uniform throughout the height is considered and analyzed for gravity and lateral loads using ETABS 18 software. Its intention is to obtain the functioning characteristics like Storey displacements, Storey drift, Natural time period, and Base shear to evaluated and compare with unbraced frame structure. The use of Mega X-Bracing shows good performance in resisting lateral loads since Storey displacements and Storey drifts are found to be less than that of other bracing system

Key Words **: Bracing, Earthquake Force, Storey displacements, Storey drift, Natural time period, and Base shear, ETABS etc**

1. INTRODUCTION

Bracing is one of the most widely used lateral load resisting systems in multi-storied buildings. Bracing is a highly efficient and economical method of resisting horizontal force in a frame structure. Braced frame is a structural system ,which is designed primarily to resist wind loads and earthquake forces. Braced frames can be an effective system for seismic retrofit due to their high stiffness. Braced frames are almost always composed of steel members.

The beams and columns that form the frame carry vertical loads, and the bracing system carries the lateral loads. Braced frames reduce lateral displacement, as well as the bending moment in columns. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. It allows obtaining a great increase of lateral stiffness with a minimal Added weight, and so it is very effective for

existing structure for which the poor lateral stiffness is the main problem.

1.1 Different types of Bracings

Bracings are mostly a diagonal member which connects either beam-column junction or mid-point of beam or columns span length. On basis of that there are two types of bracing systems. First is **Eccentric** and another is **Concentric**.

- **Diagonal Bracing :** These are compression as well as tension type bracings .It consists of a single brace instead of two as in case of X-bracing.

- **V–Bracing :**Also called as chevron bracings. Here the braces intersect at the midpoint of the beam

- **Inverted V–Bracing:** These are also inverted chevron have the shape of alphabet V.

- **X–Bracing:** These are the commonly used bracing systems here diagonals intersect each to form alphabet X

- **K–Bracing :** K-braces connect to the columns at mid height .K-bracing is generally discouraged in seismic regions because of the potential for column failure if the compression brace buckles.

2. OBJECTIVE

In this project G+15 Storey R.C.C structure is analyzed to study the effect of lateral forces such as Earthquake forces for Zone III considering different bracing system.

Type of Structure Analyzed:

- RCC bare frame without bracing system.
- RCC Bare frame with bracing system. Types of bracing system used are as

follows:

- Diagonal Bracing
- V-Bracing
- X-Bracing
- Mega Diagonal bracing
- Mega V-Bracing
- Mega X-Bracing

The software to be used for the analysis is ETABS 18. The comparison of structural behavior is observed such as Storey Displacement of building, storey Drift, Natural Time Period,

Base shear and Conclusions are drawn based on the observations and better structural system is found out with this study.

3. METHODOLOGY

To achieve the above objective following step-by-step procedures are followed;

- Carried out literature study to find out the objective of the project work.
- In the present investigation a G+15 storied building is considered, having general arrangement measurement of 30m x20m along X and Y Direction with a bay size of 5 m in both the direction.
- Seven Structural systems is adopted in this work ie, One Un braced frame structure and others are Braced frame structure with different types of braces.
- Analyze all selected models using ETABS 18 software applying Design Loads as per IS 875.
- Evaluate the analysis results and verify the requirement of the geometrical limitations.

3.1 Problem Statement

Following types of structural arrangement is studied;

- Reinforced concrete multi-storey building want Bracing system.
- Reinforced concrete multi-storey building with Diagaonl Bracing, V–Bracing, X–Bracing, Mega Diagonal Bracing, Mega V-Bracing, and Mega X-Bracing.

Geometrical Data:

- No of Stories : G+15
- No.of Bay in X-Direction: 6
- No.of Bay in Y-Direction: 4
- Type of Building Use : Residential
- Plan Dimension : 30mX20m

- Typical Storey Height :3.0m
- Bottom Storey Height :3.0m
- Height of Structure :51m

Materials:

- Concrete Grade :M20,M25,M30
- Steel(Rebar) :Fe500
- Steel(Bracing) :Fe250

Member Properties:

- Thickness of Slab :150mm
- Column Size :600mmX600mm
- Beam Size :450mmX230mm
- Bracing :ISNB175H
-

Loads Considered:

- Dead Load :Auto
- Live Load :3kN/m^2
- Floor Finish :1.5kN/m^2
- Wall Load :13kN/m(9”Thick)
- Other Loads :Seismic Load

Seismic Load:

- Seismic design shall be done in accordance with IS: 1893:2016. The building is situated in earthquake zone III (Mangaluru). The parameters to be used for analysis and design are given below (As per IS: 1893:2016 (Part I)

- Zone III
- Zone Factor :0.16(IS1893(Part1)
- Importance factor :1.2
- Response Reduction :5.0SpecialRCMoment Facto Resisting Frame(SMRF)
- Structure Type :RC Frame Structure.

4 MODELING OF THE STRUCTURE

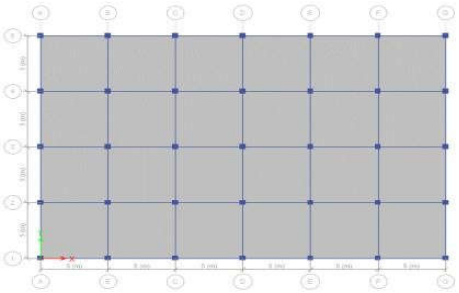


Fig-1 : Plan of the Models

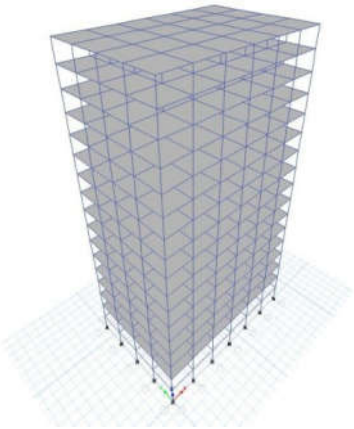


Fig-2 : Un braced Building (3DView)

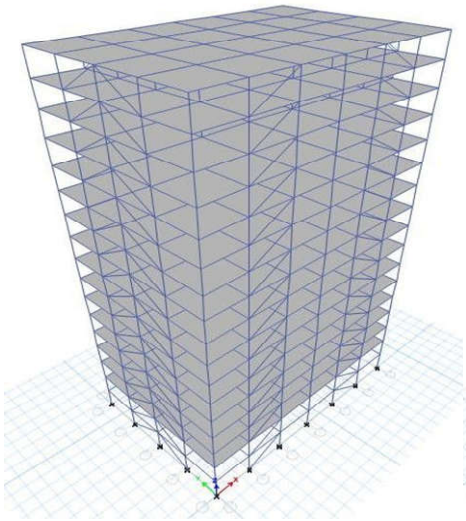


Fig -3: Diagonal Bracing

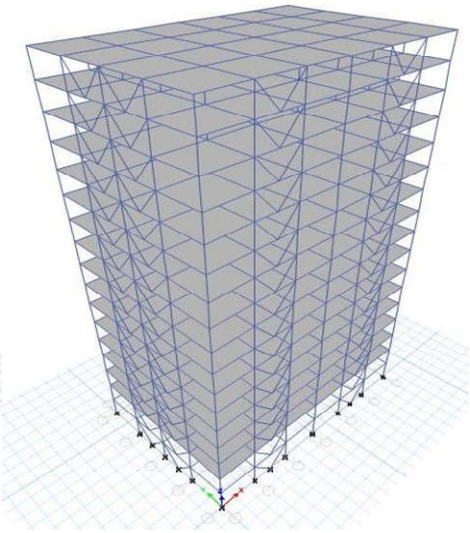
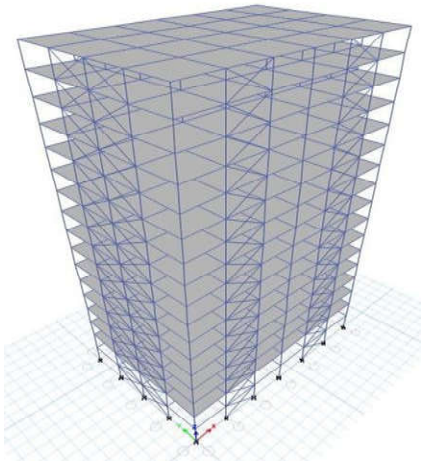


Fig-4: V-Bracing



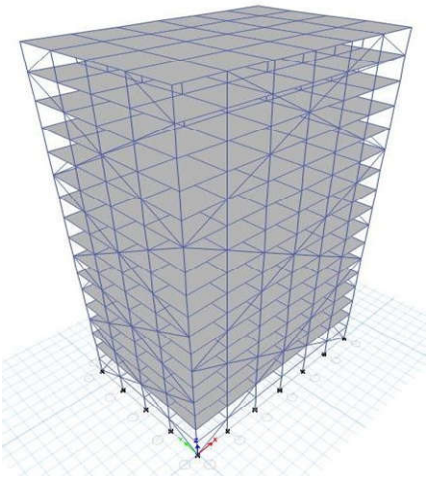
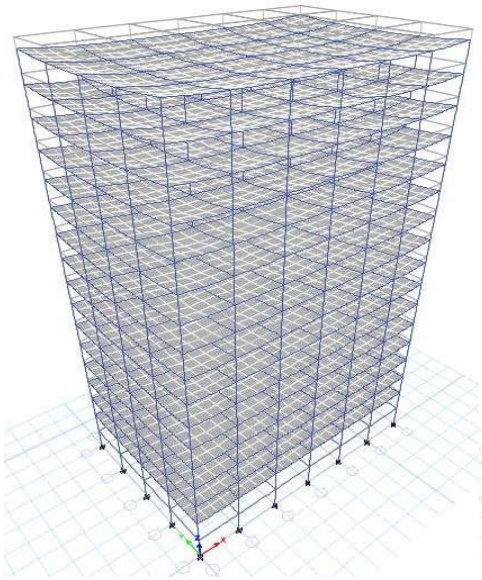


Fig -7: Mega V-Bracing

Fig-8: Mega X- Bracing



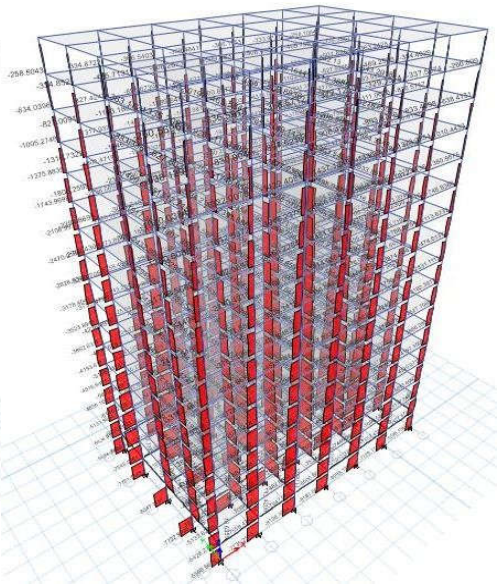
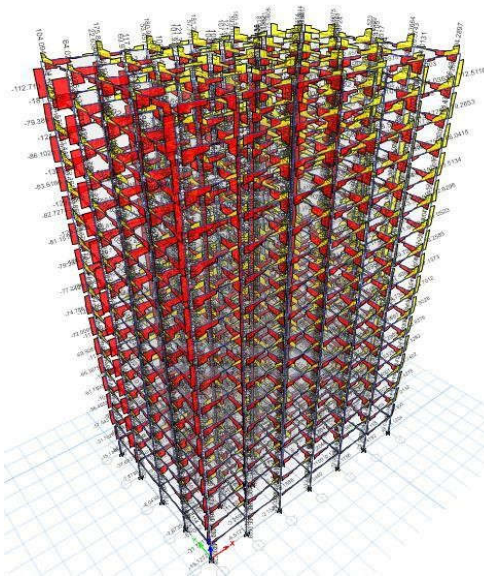


Fig -9: Displacement

Fig-10:AxialForceDiagram



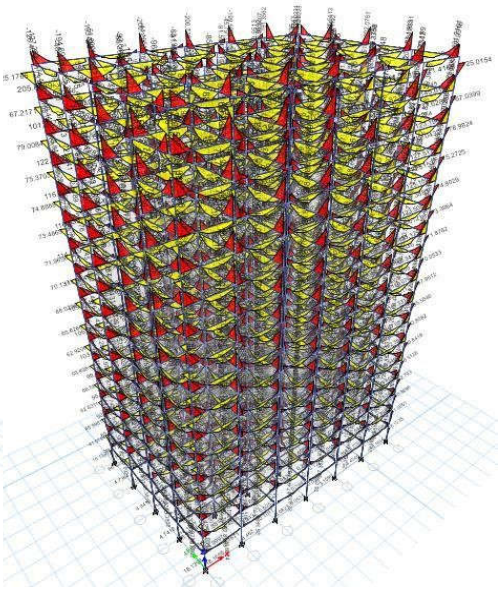


Fig -11: Shear Force

Fig-12:BendingMoment

RESULTSANDDISCUSSION

- Response Spectrum Analysis and Time History Analysis is carried out for Regular building without and with Bracing.
- The models are checked for Storey displacement ,Storey drift, Natural Time Period, and Base Shear.

Max. Storey Displacement

❖ It is total displacement of the Top Storey with respect to ground.

- **Diagonal Bracing:**

Floor Level	Diagonal Bracing	
	X-Direction	Y-Direction
15hFloor	82.693	82.768
14thFloor	81.214	81.192
13thFloor	79.076	78.994
12thFloor	76.268	76.147
11thFloor	72.842	72.698
10thFloor	68.86	68.708
9thFloor	64.388	64.242
8thFloor	59.488	59.358
7thFloor	54.214	54.106
6thFloor	48.609	48.529
5thFloor	42.717	42.664
4thFloor	36.574	36.549
3rdFloor	30.247	30.223
2ndFloor	23.794	23.775
1stFloor	17.172	17.18
Ground Floor	10.464	10.476
Plinth Level	4.3	4.33
Footing Level	0	0

Table-1: Max.Storey Displacement (mm) of Diagonally. Braced Building

12thFloor	74.001	73.39
11thFloor	70.44	69.765
10thFloor	66.349	65.632
9thFloor	61.779	61.06
8thFloor	56.794	56.232
7thFloor	51.576	51.088
6thFloor	46.12	45.669
5thFloor	40.408	40.016
4thFloor	34.484	34.171
3rdFloor	28.398	28.175
2ndFloor	22.204	22.072
1stFloor	15.959	15.907
Ground Floor	9.724	9.727
Plinth Level	4.077	4.203
Footing Level	0	0

Table-2: Max Storey Displacement (mm) of V-Braced Building.

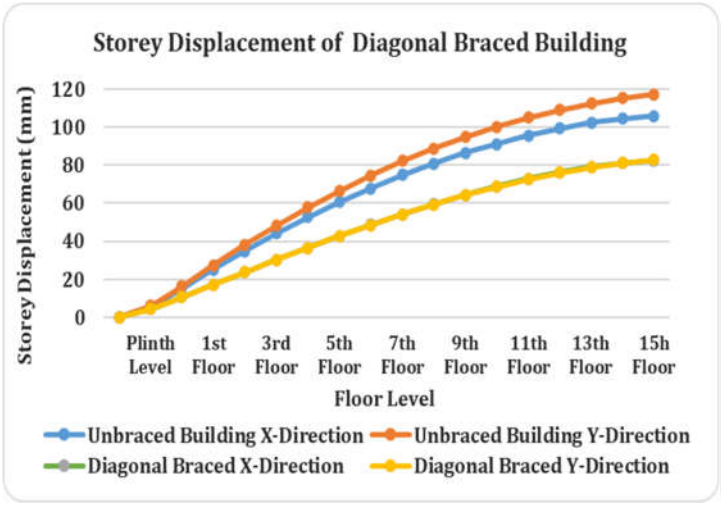


Fig-13: Max.Storey Displacement of Diagonally Braced Building.

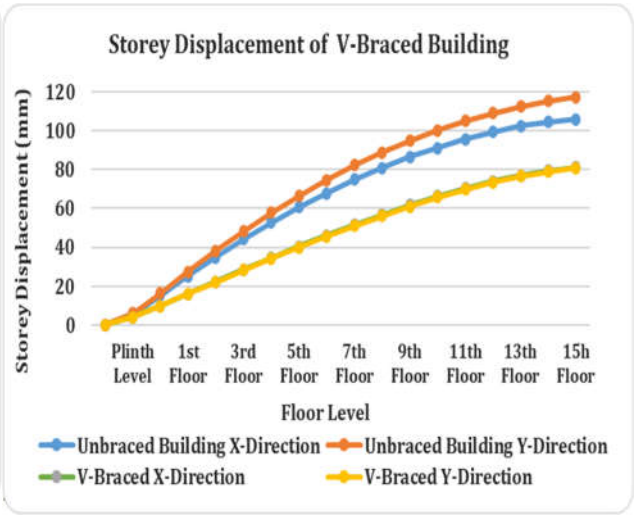


Fig-14: Max.Storey Displacement of V-. Braced Building.

- **V-Bracing:**

Floor Level	V-Braced Building	
	X-Direction	Y-Direction
15hFloor	81.14	80.829
14thFloor	79.377	78.943
13thFloor	76.99	76.459

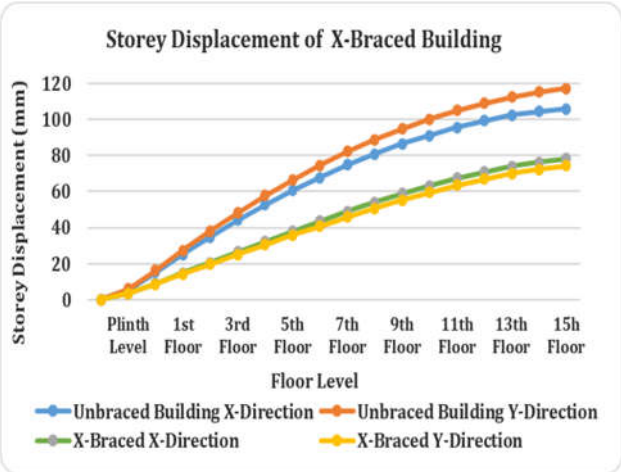


Fig-15: Max.StoreyDisplacementofX-BracedBuilding.

X-Bracing:

Floor Level	X-Braced Building	
	X-Direction	Y-Direction
15hFloor	78.229	74.236
14thFloor	76.397	72.376
13thFloor	73.949	69.951
12thFloor	70.925	66.992
11thFloor	67.366	63.541
10thFloor	63.323	59.65
9thFloor	58.853	55.378
8thFloor	54.017	50.784
7thFloor	48.873	45.925
6thFloor	43.477	40.852
5thFloor	37.883	35.803
4thFloor	32.198	30.578
3rdFloor	26.471	25.198
2ndFloor	20.638	19.713
1stFloor	14.774	14.178
Ground Floor	8.969	8.649
Plinth Level	3.597	3.575
Footing Level	0	0

Table-3 : Max Storey Displacement(mm) of X-Braced Building

- **Mega Diagonal Bracing:**

Floor Level	Mega Diagonal Bracing	
	X-Direction	Y-Direction
15hFloor	80.235	82.667
14thFloor	79.16	81.022
13thFloor	77.507	78.81
12thFloor	75.153	76.098
11thFloor	72.043	72.774
10thFloor	68.471	68.743
9thFloor	64.347	64.223
8thFloor	59.889	59.447
7thFloor	55.06	54.307
6thFloor	49.813	48.67
5thFloor	44.102	42.719
4thFloor	37.887	36.695
3rdFloor	31.351	30.556
2ndFloor	24.711	24.039
1stFloor	17.917	17.278
GroundFloor	10.977	10.504
Plinth Level	4.38	4.217
Footing Level	0	0

Table-4: Max.StoreyDisplacement(mm)ofMega Diagonally Braced Building.

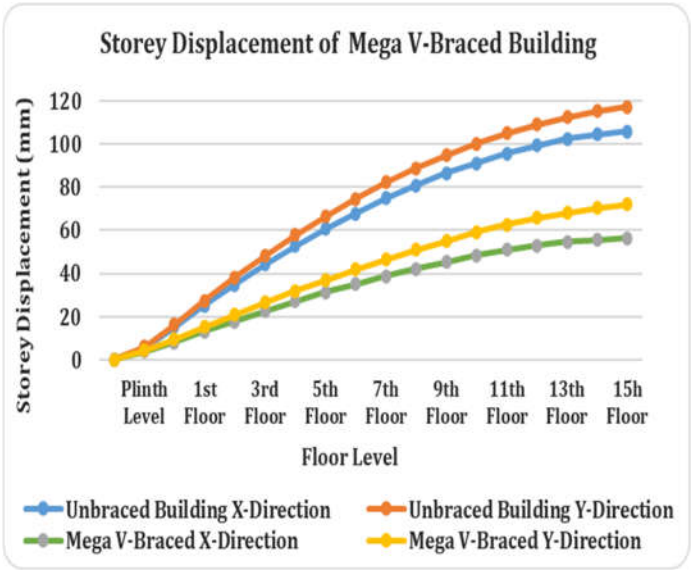


Fig-17: Max.Storey Displacement of Mega V-Braced Building.

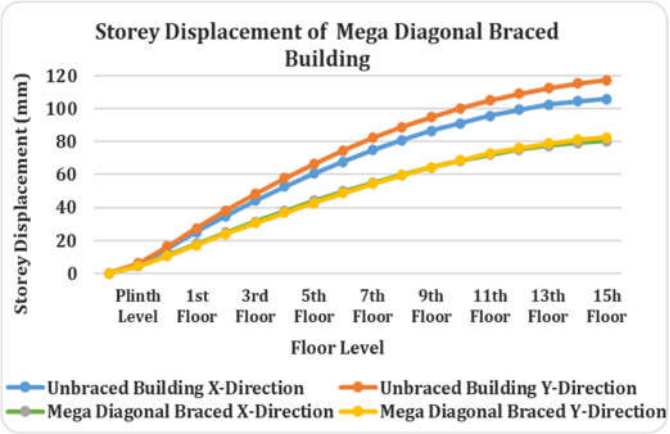


Fig 16 : Max. Storey Displacement of Megs . Diagonally Braced Building

- **Mega V-Bracing:**

FloorLevel	MegaV-BracedBuilding	
	X-Direction	Y-Direction
15hFloor	56.352	71.894
14thFloor	55.622	70.261
13thFloor	54.563	68.157
12thFloor	53.064	65.701
11thFloor	51.03	62.737
10thFloor	48.397	59.116
9thFloor	45.386	55.1
8thFloor	42.222	50.958
7thFloor	38.844	46.516
6thFloor	35.183	41.823
5thFloor	31.27	36.831
4thFloor	26.984	31.795
3rdFloor	22.439	26.538
2ndFloor	17.832	20.898
1stFloor	13.094	15.113
Ground Floor	8.176	9.346
Plinth Level	3.686	4.357
Footing Level	0	0

Table-5: Max Storey Displacement Mega V- Braced Building.

- **Mega X-Bracing:**

Floor Level	Mega X- Braced Building	
	X-Direction	Y-Direction
15hFloor	49.854	59.275
14thFloor	49.155	57.922
13thFloor	48.142	56.215
12thFloor	46.763	54.268
11thFloor	45.138	51.922
10thFloor	42.971	49.015
9thFloor	40.454	45.772
8thFloor	37.791	42.431
7thFloor	34.906	38.818
6thFloor	31.728	34.743
5thFloor	28.187	30.463
4thFloor	24.218	26.272
3rdFloor	20.057	21.983
2ndFloor	15.902	17.335
1stFloor	11.664	12.552
Ground Floor	7.299	7.784
Plinth Level	3.305	3.718
Footing Level	0	0

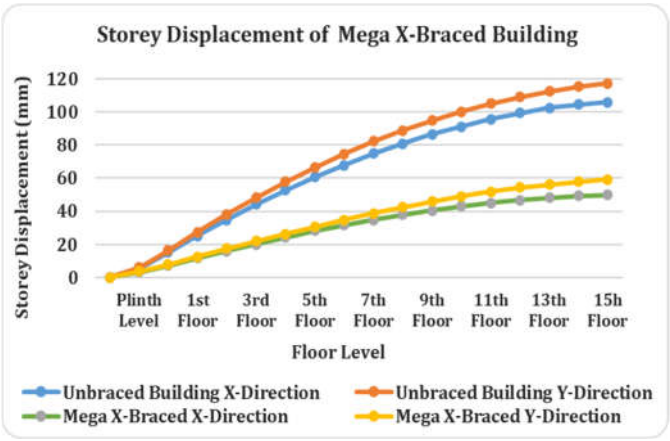


Fig-18: Max.Storey Displacement of Mega X-Braced Building.

- **Comparison of Max. Storey Displacement:**

% Reduction in Max. Storey Displacement				
Floor Level	Storey Displacement		% Reductionin Max. Storey Displacement	
	X-Dir.	Y-Dir.	X-Dir.	Y-Dir.
Un braced Building	105.92	117.17	-	-
Diagonal Bracing	82.69	82.77	21.93	29.36
V-Bracing	81.14	80.83	23.40	31.01
X-Bracing	78.23	74.24	26.14	36.64
Mega Diagonal Bracing	80.24	82.67	24.25	29.44
Mega V-Bracing	56.35	71.89	46.80	38.64
Mega X-Bracing	49.85	59.28	52.93	49.41

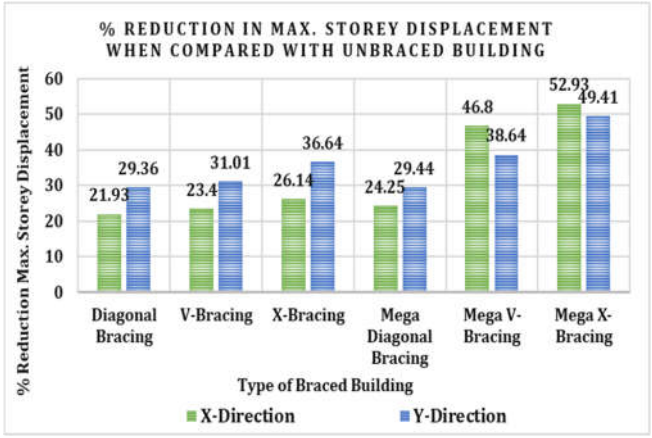


Fig-19: % Reduction in Max. Storey Displacement.

Table- 7: % Reduction in Max Story displacement

- **Max .Storey Drift**
- **Diagonal Bracing** **V -Bracing**

Floor Level	Diagonal Bracing	
	X-Direction	Y-Direction
15hFloor	0.000495	0.000527
14thFloor	0.000714	0.000734
13thFloor	0.000936	0.00095
12thFloor	0.001142	0.001159
11thFloor	0.001327	0.001351
10thFloor	0.001491	0.001521
9thFloor	0.001638	0.001668
8thFloor	0.001769	0.00179
7thFloor	0.001878	0.001891
6thFloor	0.001966	0.001972
5thFloor	0.002047	0.002038
4thFloor	0.002117	0.002109
3rdFloor	0.002173	0.002166
2ndFloor	0.002212	0.002209
1stFloor	0.002236	0.002235
Ground Floor	0.002212	0.002218
Plinth Level	0.001433	0.001443
Footing Level	0	0

Table-8: Max.Storey Drift of Diagonally

Floor Level	V-Braced Building	
	X-Direction	Y-Direction
15hFloor	0.000589	0.000631
14thFloor	0.000796	0.000829
13thFloor	0.000996	0.001023
12thFloor	0.001187	0.001208
11thFloor	0.001364	0.001378
10thFloor	0.001523	0.001529
9thFloor	0.001662	0.001658
8thFloor	0.001778	0.001766
7thFloor	0.001871	0.001851
6thFloor	0.001944	0.001916
5thFloor	0.001997	0.001963
4thFloor	0.002032	0.001999
3rdFloor	0.002065	0.002034
2ndFloor	0.002082	0.002055
1stFloor	0.002078	0.002063
Ground Floor	0.002056	0.002057
Plinth Level	0.001284	0.001318
Footing Level	0	0

Table-9: Max.Storey Drift of V-Braced Building.

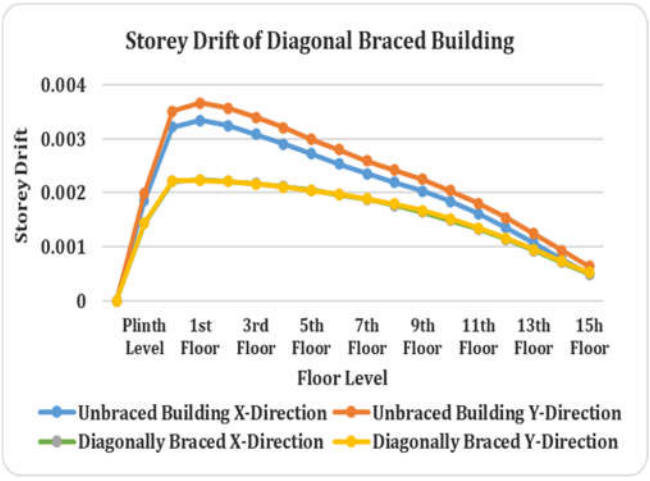


Fig-20: Max.Storey Drift of Diagonally Braced Building.

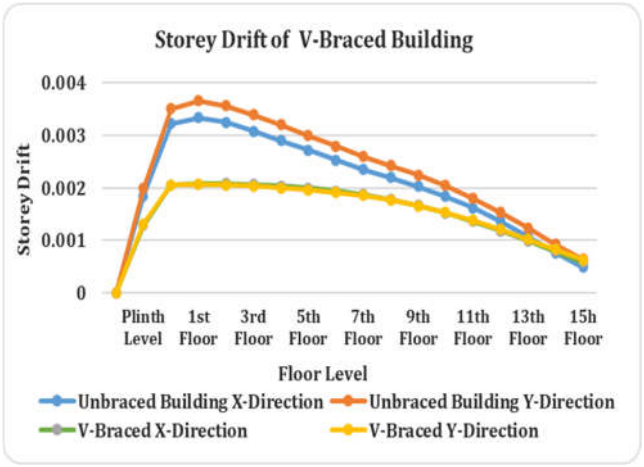


Fig-21: Max.StoreyDriftofV-BracedBuilding

- **X-Bracing**

Floor Level	X-Braced Building	
	X-Direction	Y-Direction
15hFloor	0.000612	0.000622
14thFloor	0.000817	0.000809
13thFloor	0.001008	0.000986
12thFloor	0.001186	0.00115
11thFloor	0.001348	0.001297
10thFloor	0.00149	0.001424
9thFloor	0.001612	0.001531
8thFloor	0.001715	0.00162
7thFloor	0.001799	0.001691
6thFloor	0.001865	0.001746
5thFloor	0.001914	0.001787
4thFloor	0.001945	0.001814
3rdFloor	0.001958	0.001828
2ndFloor	0.001954	0.001845
1stFloor	0.001935	0.001843
Ground Floor	0.001898	0.001831
Plinth Level	0.001199	0.001192
Footing Level	0	0

Table-10: Max .Storey Drift of X-Braced Building

Mega Diagonal Bracing:

Floor Level	Mega Diagonal Bracing	
	X-Direction	Y-Direction
15hFloor	0.000358	0.000548
14thFloor	0.000551	0.000738
13thFloor	0.000785	0.000904
12thFloor	0.001037	0.001108
11thFloor	0.001294	0.001344
10thFloor	0.001468	0.001507
9thFloor	0.001557	0.001595
8thFloor	0.001656	0.001719
7thFloor	0.001771	0.001881
6thFloor	0.001904	0.001984
5thFloor	0.002072	0.002012
4thFloor	0.002178	0.00208
3rdFloor	0.002214	0.002188
2ndFloor	0.002265	0.002254
1stFloor	0.002314	0.002258
Ground Floor	0.002317	0.002226
Plinth Level	0.00146	0.001406
Footing Level	0	0

Table-11: Max.Storey Displacement(mm)of Mega Diagonally Braced Building.

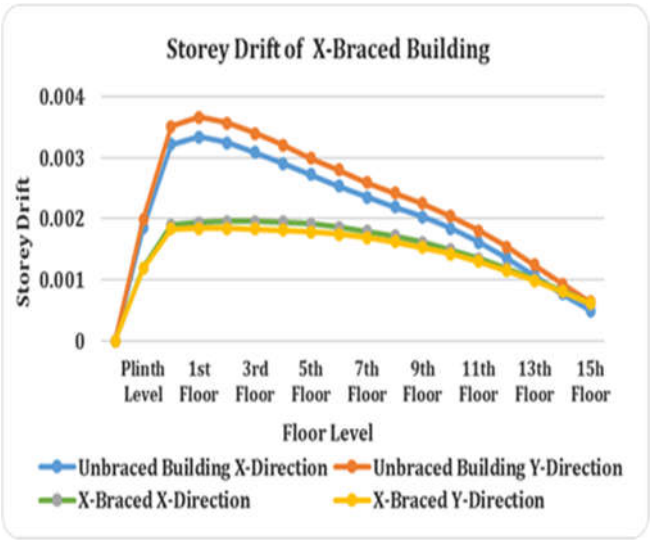


Fig-22: Max.Storey Drift of X-Braced Building.

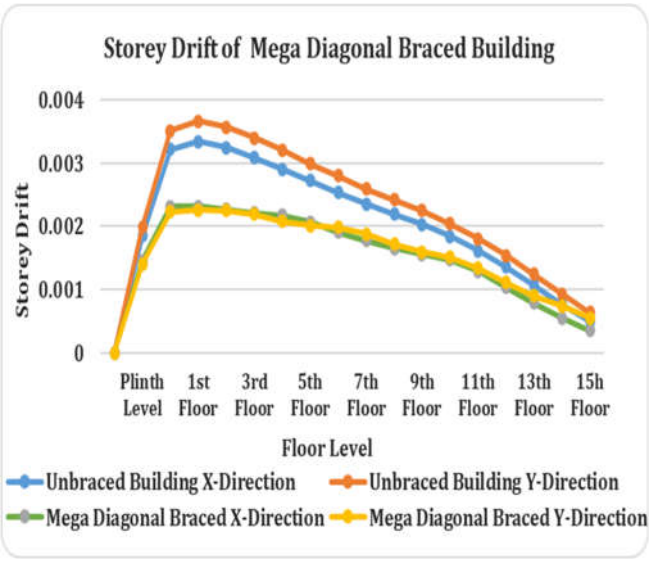


Fig-23: Max Storey Drift of Mega Diagonally Braced Building

Mega V-Bracing:

Floor Level	Mega V-Braced Building	
	X-Direction	Y-Direction
15hFloor	0.000257	0.000544
14thFloor	0.00038	0.000702
13thFloor	0.000537	0.000819
12thFloor	0.000717	0.000988
11thFloor	0.000912	0.001207
10thFloor	0.001026	0.001339
9thFloor	0.001062	0.001381
8thFloor	0.001126	0.001481
7thFloor	0.00122	0.001645
6thFloor	0.001338	0.001718
5thFloor	0.001477	0.001704
4thFloor	0.001539	0.001756
3rdFloor	0.001536	0.00188
2ndFloor	0.00158	0.001928
1stFloor	0.001639	0.001922
Ground Floor	0.001723	0.00197
Plinth Level	0.001193	0.001432
Footing Level	0	0

Table-12: Max. Storey Drift of Mega V-Braced Building

Mega X-Bracing

Floor Level	Mega X-Braced Building	
	X-Direction	Y-Direction
15hFloor	0.000233	0.000464
14thFloor	0.000338	0.000591
13thFloor	0.000476	0.000678
12thFloor	0.000642	0.000816
11thFloor	0.000828	0.001006
10thFloor	0.000932	0.001114
9thFloor	0.000956	0.001137
8thFloor	0.001002	0.001216
7thFloor	0.001074	0.001359
6thFloor	0.00118	0.001427
5thFloor	0.001323	0.001413
4thFloor	0.001387	0.00146
3rdFloor	0.001385	0.001564
2ndFloor	0.001413	0.001595
1stFloor	0.001458	0.001589
Ground Floor	0.001539	0.001639
Plinth Level	0.001102	0.001239
Footing Level	0	0

Table-13: Max. Storey Drift of Mega X-Braced Building

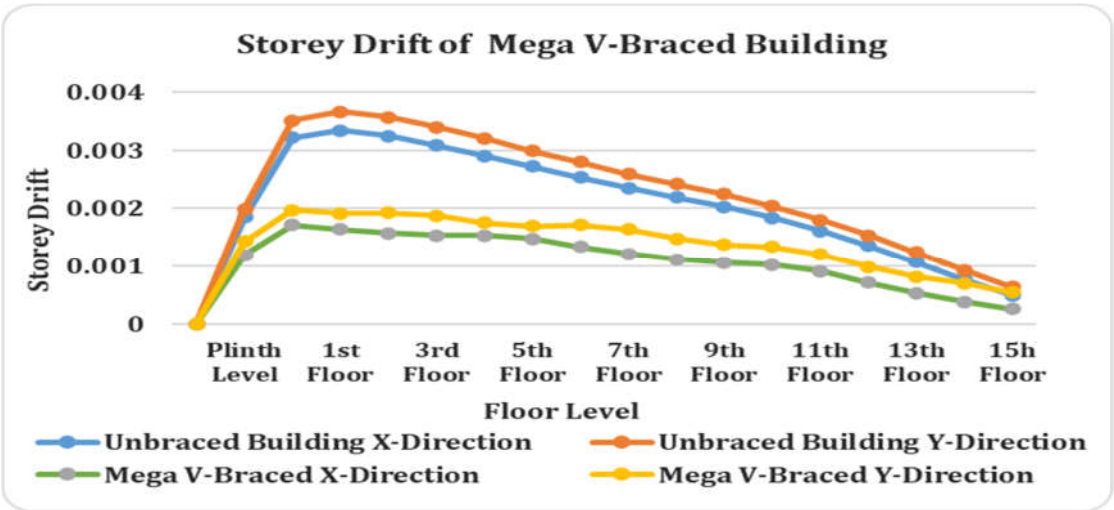


Fig-24: Max.Storey Drift of Mega V-Braced Building.

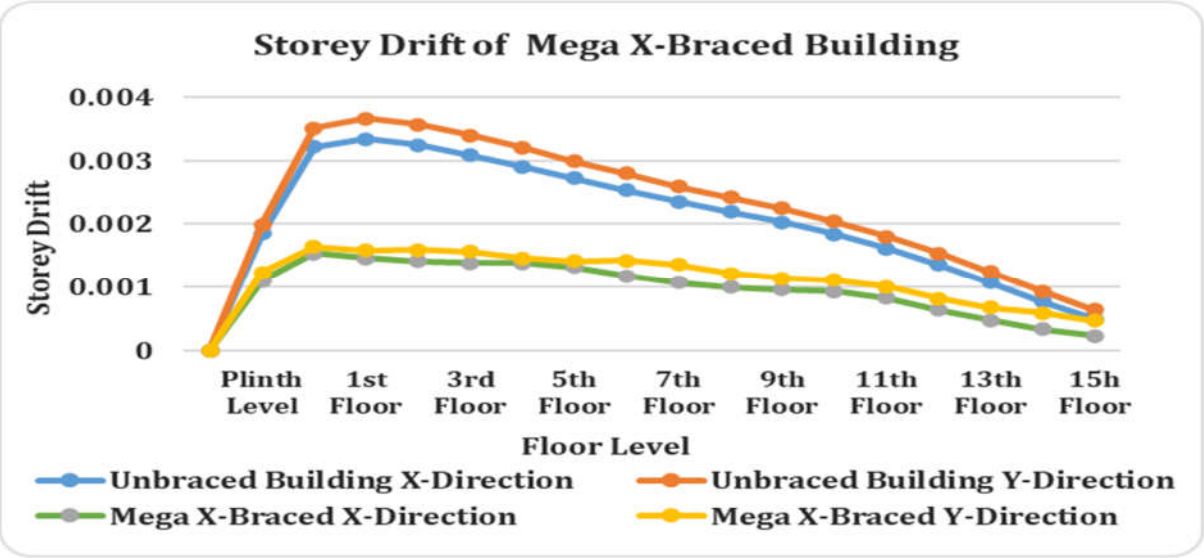


Fig-25: Max.Storey Drift of Mega X-Braced Building

- **Comparison of Max. Storey Drift:**

%Reduction in Max. Storey Drift				
Floor Level	**Storey Drift**		**%Reduction in Max. Storey Drift**	
	X-Dir.	**Y-Dir.**	**X-Dir.**	**Y-Dir.**
Un braced Building	0.0033	0.0037	-	-
Diagonal Bracing	0.0022	0.0022	32.99	38.95
V-Bracing	0.0021	0.0021	37.61	43.65
X-Bracing	0.0020	0.0018	41.32	49.60
Mega Diagonal Bracing	0.0023	0.0023	30.57	38.32
Mega V-Bracing	0.0017	0.0020	48.37	46.19
Mega X-Bracing	0.0015	0.0016	53.88	55.23

Table-14: % Reduction in Max .Storey Drift.

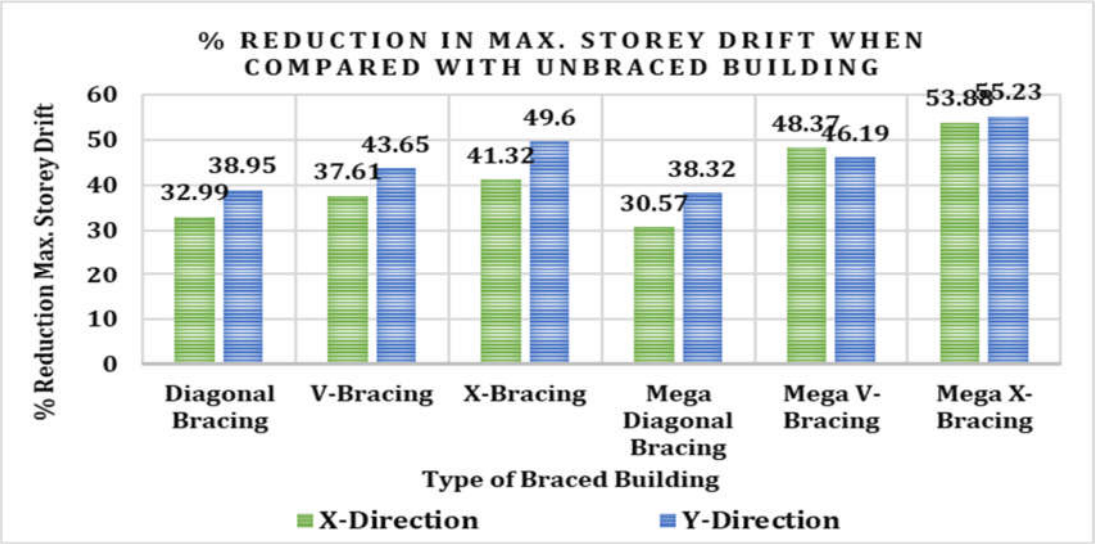


Fig-26: % Reduction in Max. Storey Drift.

❖ Natural Time Period:

❖ The Natural time periods are the important factors, which affect the seismic behaviour of the structure.

❖ So, study has been made and it shows, the variation in fundamental time period for different braced structure as shown in figure.

Peak Time Period(Sec.)	
Different Braced Buildings	**Time Period (Sec.)**
Un braced Building	2.94
Diagonal Bracing	2.46
V-Bracing	2.35
X-Bracing	2.28
Mega Diagonal Bracing	2.43
Mega V-Bracing	2.25
Mega X-Bracing	2.16

Table-15: Peak Time Period for different Braced Building.

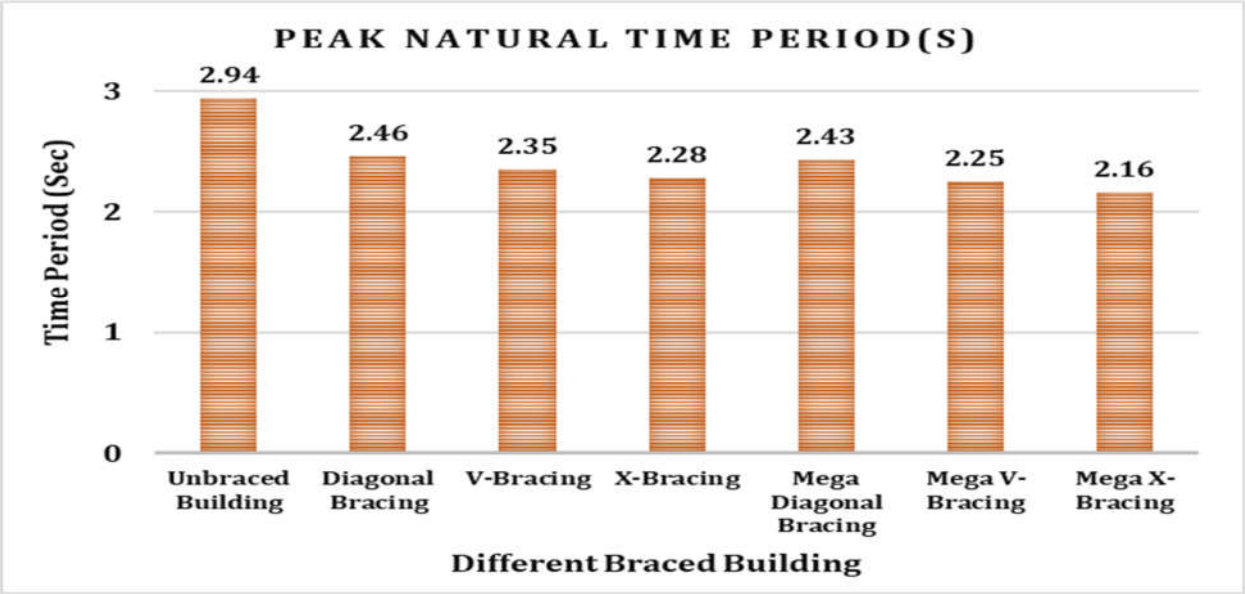


Fig-27: Peak Time Period for different Braced Building.

❖ Seismic Base Shear:

❖ Seismic Base Shear reflects the seismic lateral vulnerability an disconsidered as one of the primary input for seismic design.The variation in Base shear for structure resting different type of soil is as shown in figure.

Seismic Base Shear		
Different Braced Buildings	**Base Shear (kN)**	
	X-Dir.	**Y-Dir.**
Un braced Building	3225.14	3100.57
Diagonal Bracing	3319.63	3292.81
V-Bracing	3452.48	3466.25
X-Bracing	3546.64	3580.87
Mega Diagonal Bracing	3474.58	3331.25
Mega V-Bracing	3781.83	3598.46
Mega X-Bracing	3948.42	3750.44

Table-16: SeismicBaseShearfordifferentBraced Building.

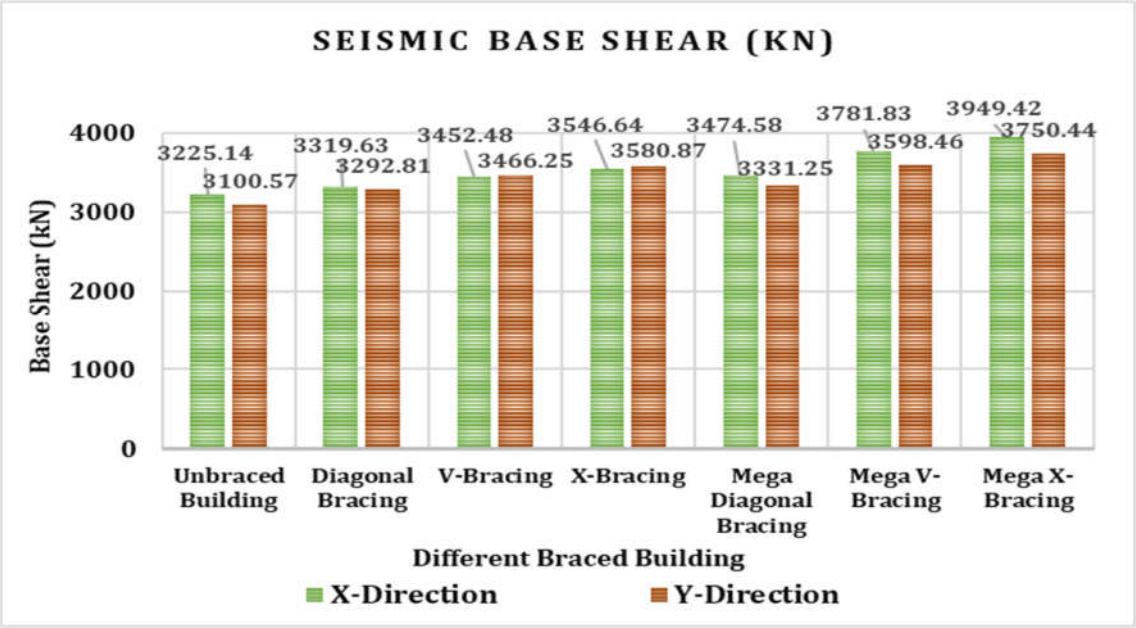


Fig-28: Seismic Base Shear for different Braced Building.

❖ CONCLUSIONS

❖ **From the results discussed with respect to the building models considered, leads to the following conclusions;**

❖ After the analysis of the structure with different type of Bracing, it has been concluded that the Storey Displacement and Storey Drift and Natural Time Period of the structure decreases after the application of bracing system.

❖ The maximum reduction in the storey displacement occurs after the application of Mega X-Bracing system.

❖ The displacement of the structure is reduced by52.93%inX direction and 49.41% in Y direction with the use of Mega X-bracing when compared with Un braced Building.

❖ The drift of the structure is reduced by53.88% inX direction and 55.23% in Y direction with the use of Mega X-bracing when compared with Un braced Building.

❖ Bracing increases the Seismic Base Shear of the building compared with Un braced Building along X and Y-Direction respectively.

❖ Building with bracing leads to minmum Displacement, maximum Base Shear and minimum Storey Drift compared to building without bracing.

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