As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology
Volume 9, Issue 12, pages 10-44.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol9issue12.html
DOI: https://doi.org/10.46501/IJMTST0912003

A Study on the use of Different Bracings in RC Buildings and Functioning of A – Chevron Bracing using ETABS Software

Anadula Prasad[1] | K Jagan[2]

[1]PG Scholar, Department of Civil Engineering, Visakha Institute of Engineering and Technology, Visakhapatnam, India.
[2]Assistant Professor, Department of Civil Engineering, Visakha Institute of Engineering and Technology, Visakhapatnam, India.

To Cite this Article

Anadula Prasad and K Jagan. A Study on the use of Different Bracings in RC Buildings and Functioning of A – Chevron Bracing using ETABS Software, International Journal for Modern Trends in Science and Technology, 2023, 9(12), pages. 10-44.https://doi.org/10.46501/IJMTST0912003

Article Info

Received: 26November 2023; Accepted: 17 December 2023; Published: 26 December 2023.

ABSTRACT

Bracing Plays important role in design of Earthquake Resistant Structures, which reduces the response of the structure when they are subjected to lateral loads. There are many different types of bracers in use. In the present study various bracing are used to evaluate the response of reinforced concrete buildings. The main task of a structure is to bear the lateral loads and transfer them to the foundation. Since the lateral loads imposed on a structure are dynamic in nature, they cause vibrations in the structure. In order to have earthquake resistant structures, bracing have been used. Buildings having square and rectangular plans, with square and rectangular column cross- sections are analyzed, with and without Bracing. In the present study the software ETABS 2015 have been used. Using Time history analyses the response of the Reinforced concrete building considered in the present study is evaluated and compared with and without Bracing. It has been observed that buildings with Global bracing are performing well in terms of response of the structure when compared to various bracing system irrespective of the floor plan. In Time History analysis, up to 90% decrease in the time Period is obtained when global bracing are used. it reduced the Base Shear of the structures by 70%. Hence global bracing can be used in RC multi storey buildings to reduce the response effectively.

INTRODUCTION

GENERAL

The Bracing are the more applied tools for controlling responses of the structures. These tools are applied based on different construction technologies in order to decrease the structural responses to the seismic excitation. Though over the recent years heavy costs have been paid for accurate recognition of force of an earthquake in the research institutes of the world with the purpose of decreasing its damage, the increasing need for more research studies on the effects resulted from the earthquake is felt in the theoretical and laboratorial scales. Over the last fifty years, the earthquakes are categorized into two groups of near-field earthquakes and far-field earthquakes based on the distance of the place of recording the earthquake from the fault. Later, this definition was modified and other factors also influenced this categorization. Over the recent years, the research studies concentrated on the study of impacts of ground motion in the near-field earthquake on the structural performance. The devastative effects of the recent earthquakes such as Northridge earthquake (1994), Kobe earthquake (1995), and Taiwan earthquake (1999) on the buildings of the cities adjacent to fault, and with regard to the close location of many of the cities of India to the active faults indicate the significance of the research.

In last few years, many essential developments in seismic codes are turned up. Utmost of the modification in the seismic design area derive from greater awareness of actual poor buildings performances in contemporary earthquakes. Due to the renewed knowledge of the existing buildings behavior, retrofit of buildings is a paramount task in reducing seismic risk. New techniques for protecting buildings against earthquake have been developed with the aim of improving their capacity. Seismic isolation and energy dissipation are widely recognized as effective protection techniques for reaching the performance objectives of modern codes. However, many codes include design specifications for seismically isolated buildings, while there is still need of improved rules for energy dissipation protective systems. At the time of an earthquake, structure experience lots of vibration due to the energy released in earth's crust. The beams and columns which are simply connected with no resistance become unstable for lateral loads. This affects the structure, which is not desirable. Therefore, we have design the structure to resist lateral loads by providing appropriate lateral load resisting system. There are many alternatives available for lateral load resisting system depending on the structure, type of lateral load, seismic zone etc., following are some of the lateral load resisting systems that are commonly used in practice.

a) Moment Resisting Frames.
b) Braced Frames.
c) Shear walls.
d) Dual structural system.
e) Coupled shear wall.

BRACING

Bracing is an effective and economical method of resisting horizontal forces in a framed structure. These systems are utilized both in RC as well as in steel buildings. Normally, the structure comprises of column and beams whose basic purpose is to transfer gravity load when braces are fixed to it , the total set of members forms a vertical cantilever truss like structure to resist the horizontal forces. Bracing members are utilized in the building as a horizontal load resisting system to improve the stiffness of the frame for seismic forces. Braces can be connected with fixed ended or pin ended connection. In the case of pin ended connection, it will subjected to axial forces and it. Normally fails under compressive load by global buckling. Once the buckling occurs, its strength gets reduced in the succeeding cycles. But there will not be many changes in maximum tensile strength in subsequent cycles. The main advantage of using braces is that they dissipate the energy without damaging the building and also it can be replaced without any difficulty when it gets damaged.

HORIZONTAL BRACING: Bracing in every floor level gives a load path to transfer the horizontal forces to the planes of vertical bracing. It is needed at each floor level The floor systems that are provided by themselves act as braces to provide resistance.

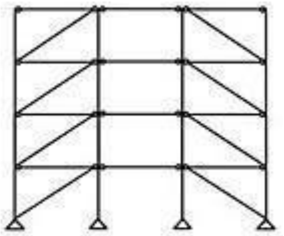
VERTICAL BRACING: Bracing in vertical planes(between lines of column) provides load path for transferring horizontal forces to ground level and provide a stiff resistance against overall sway.

TYPES OF BRACING

There are 4 types of bracing used in the structures for resisting the forces act onthe building structures.

Single diagonals

Single diagonals



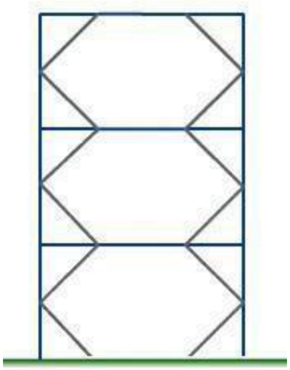
Trussing is formed by inserting diagonal structural members into rectangular areas of a structural frame, helping to stabilize the frame as shown in Figure 1.1. If a single brace is used, it must be sufficiently resistant to tension and compression.

X-bracing

Single X-Bracing

X-bracing uses two diagonal members crossing each other. These only need to be resistant to tension, one brace at a time acting to resist sideways forces, depending on the direction of loading as shown in Figure 1.2. As a result, steel cables can also be used for cross-bracing.

K-Bracing

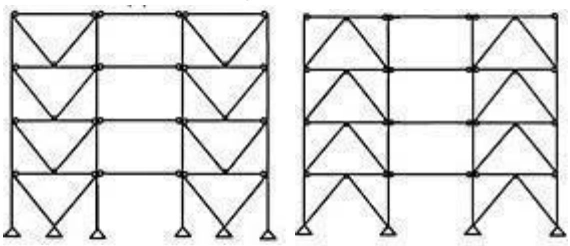


K-Bracing

K-braces connect to the columns at mid-height. this frame has more flexibility for the provision of openings in the facade and results in the least bending in floor beam as shown in Figure 1.3. K-bracing is generally discouraged in seismic regions because of the potential for column failure if the compression brace buckles.

V-bracing

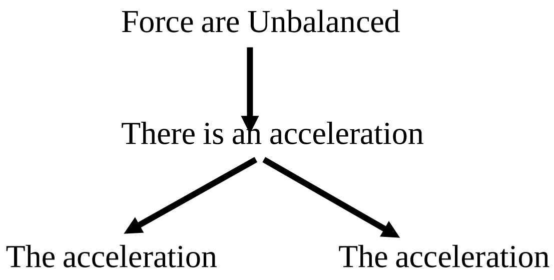
V-bracing



Two diagonal members forming a V-shape extend downwards from the top two corners of a horizontal member and meet at a center point on the lower horizontal member (left-hand diagram). Inverted V-bracing (right-hand diagram, also known as chevron bracing) involves the two members meeting at a center point on the upper horizontal member as shown in Figure 1.4.Both systems can significantly reduce the buckling capacity of the compression brace so that it is less than the tension yield capacity of the tension brace. This can mean that when the braces reach their resistance capacity, the load must instead be resisted in the bending of the horizontal member.

NEWTON'S SECOND LAW OF MOTION

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object as shown in Figure 1.5.



Depends directly	depends inversely
Upon the force	upon the object mass

Representation of Newton's second law of motion.

Acceleration is a change in velocity. As long as we know the mass of the object andthe net force acting on the object, we can determine acceleration. Let's look at the formula: a = f / m, where a = acceleration, f = force acting on the object, m = the mass of the object.

If we know the mass and acceleration of an object, we can calculate for force. Simply rearrange the equation to solve for force. $F = m * a$

STATEMENT OF THE PROBLEM

The term dynamic may be defined directly as time-varying; thus, a dynamic load is any load of which its magnitude, direction, and/or position varies with time. Equivalently, the structural response to a dynamic load, i.e., the resulting stresses and deflections, is also time varying, or dynamic. A tall building in an area of high seismic and high winds needs to be carefully designed to ensure the adequate balance and stiffness and strength is achieved. Conventional practice is to stiffen a building in order to reduce the dynamic response under wind loading. However, this has the effect of increasing the seismic base shear that is attracted. By adding supplementary bracing to the structure, it is possible to reduce the flexural stiffness of the building to minimize seismic base shear, and at the same time control the wind response.

OBJECTIVES

a) To compare the seismic response of buildings with and without bracing systems, with new bracing system called A-chevron bracing.
b) To determine displacements variations in the structure due to introduction of bracing system.
c) To find the reduction in base shear by using bracing in Reinforced concrete buildings.
d) To study the variations in time period for different structures with and without bracing.
e) To compare Time History analysis when using bracing in structures.

RESEARCH AIM

To reduce the response of the structure effectively using Bracing and proving it asmost efficient in the stability of the structure.

SCOPE AND LIMITATIONS

Braced framed structures are usually considered to resist the lateral forces and alsoearthquake loads. they provide due to their strength, stiffness to the structures. They provide more stiffness against the horizontal shear because the diagonal memberelements work in axial stress.

LITERATURE REVIEW

Chang.K.H (2009) Structural analysis is the judgment of the effects of loads on physical structures and their segments. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, vehicles, machinery, furniture, attire, soil lamina, prostheses and biological tissue. Structural analysis engages the range of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are exercised to check a structure's vigor for use, often preventing physical tests. Structural analysis is hence a key component of the engineering design of structures as described.

Zhao.Y.G and Ono.T (2001) mentioned about Moment methods for structural reliability in which they said, to perform an accurate analysis a structural engineer must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non- linear behavior.

Mario Paz (1985) further discussed about Structural dynamics in 1985 and the Structural analysis is mainly concerned with finding out the behavior of a physical structure when subjected to force. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. In essence all these loads are dynamic, including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. If a load is applied sufficiently slowly, the inertia forces (Newton's first law of motion) can be ignored, and the analysis can be simplified as static analysis. Structural dynamics, therefore, is a type of structural analysis which covers the behaviour of structures subjected to dynamic (actions having high acceleration) loading. Dynamic loads include people, wind, waves, traffic, earthquakes, and blasts. Any structure can be subjected to dynamic loading. Dynamic analysis can be used to find dynamic displacements, time history, and modal analysis.

Kartik prashar, jagdeep singh gahir (2007) on Seismic behavior of RC framed structure with different types of bracing system says that- steel bracing system is an efficient and effective lateral load resisting system. Steel braced RC frame as lateral load resisting system for reinforced concrete structure is a effective technique. Structure with different types of bracing system reduce the storey drift and displacement of structure. Out of various arrangments of bracing X bracing system are more effective in increasing lateral load capacity of structure. Bracing system reduce bending moment and shear force in the column. Steel bracing transfer the lateral load through axial action. The performance of the steel cross bracing is better than other bracing system. Steel bracing can be used to retrofit the existing structure

SUMMARY

This literature review shows the published papers till now on the issue of Braces with reference to their authors. It is briefly discussed about response of Bracing system on structural model, the analysis done using Etabs and the Codal provisions used in this thesis. The next chapter deals with research methodology in which theoretical terms and methods could be applied to the issue.

MODELLING

DESIGN DATA

Material Properties:

M25 grade of concrete and Fe 500 grade of Steel are used for all slabs and beams of the building whereas M30 is used for columns with same grade of Steel. Elastic material properties of these materials are taken as per IS 456-2000. The short-term modulus of elasticity () of concrete is taken as: = **5**√ MPa

Where k =characteristic compressive strength of concrete cube

For the Steel rebar with stress and modulus of elasticity is taken as per IS 456-2000.

STRUCTURAL ELEMENTS

The different structural elements considered are columns, beams and slabs with variable sections are mentioned below. Also, the different shapes of building are considered while keeping the total area unchanged. The story data shown in the Table 4.1.

Description of Members used:-
Column Sizes:
1) Square Columns = 600mm*600mm.
2) Rectangular Columns = 1200mm*300mm.
Beam Sizes:
1) Interior Beams = 230mm*600mm.
2) Exterior Beams = 300mm*650mm.
Slab Sizes:
1) Panel Area = 6m*6m= 36
2) Thickness = 125mm.

Story Data:-

Storey Data

Name	Height Mm	Elevation Mm	Master Storey	Similar To	Splice Storey
Story 20	3000	60000	Yes	Story 20	No
Story 19	3000	57000	No	Story 20	No
Story 18	3000	54000	No	Story 20	No
Story 17	3000	51000	No	Story 20	No
Story 16	3000	48000	No	Story 20	No
Story 15	3000	45000	No	Story 20	No
Story 14	3000	42000	No	Story 20	No
Story 13	3000	39000	No	Story 20	No
Story 12	3000	36000	No	Story 20	No
Story 11	3000	33000	No	Story 20	No
Story10	3000	30000	No	Story 20	No
Story9	3000	27000	No	Story20	No
Story8	3000	24000	No	Story20	No
Story7	3000	21000	No	Story20	No
Story6	3000	18000	No	Story20	No
Story5	3000	15000	No	Story20	No
Story4	3000	12000	No	Story20	No
Story3	3000	9000	No	Story20	No
Story2	3000	6000	No	Story20	No
Story1	3000	3000	No	Story20	No
Base	0	0	No	None	No

Loads

While applying the loads to the structure we consider only the external loads which are actually acting on the members neglecting its self-weight because ETABS 2015 automatically takes the members self-weight.

Applied Loads:-

The Shell loads (on Slabs) acting in the Gravity direction are Dead=1.5kN/m^2 and Live=4kN/m^2. The Frame loads applied uniformly on the beams as Dead=5.25kN/m.

The Seismic loads EQ-x and EQ-y are given in Load patterns directly using Code IS1893:2002. Also the Wind loads wind-x and wind-y are given using Code IS875:1987. Which are shown in Table 4.2.

Load Patterns:- Load Patterns

Name	Type	Self-Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	0	
EQ-x	Seismic	0	IS1893 2002
EQ-y	Seismic	0	IS1893 2002
wind-x	Wind	0	Indian IS875:1987
wind-y	Wind	0	Indian IS875:1987

Functions:-

Time History Function:-

This Function is selected from the program; Time History of ELCENTRO is taken with step size of 0.02 seconds and 8 points per line. The table with values and time is shown in Table 4.3.

Load Cases:- Load Cases - Summary

Name	Type
Dead	Linear Static
Live	Linear Static
EQ-x	Linear Static
EQ-y	Linear Static
wind-x	Linear Static
wind-y	Linear Static
RS-x	Response Spectrum
RS-Y	Response Spectrum
Thx	Nonlinear Modal History (FNA)
Thy	Nonlinear Modal History (FNA)

Push-X	Nonlinear Static
Push-Y	Nonlinear Static

Buildings with Bare Frame

This is square shape building with 6 rows of Slab panels in both X; Y directions and square shaped Columns with 4m spanning connected beams as shown in Figure 4.1. It is elevated for ten floors with height of 3m between adjacent floors as shown in Figure 4.2. The 3D view with all connecting structural members is also shown in Figure 4.3.

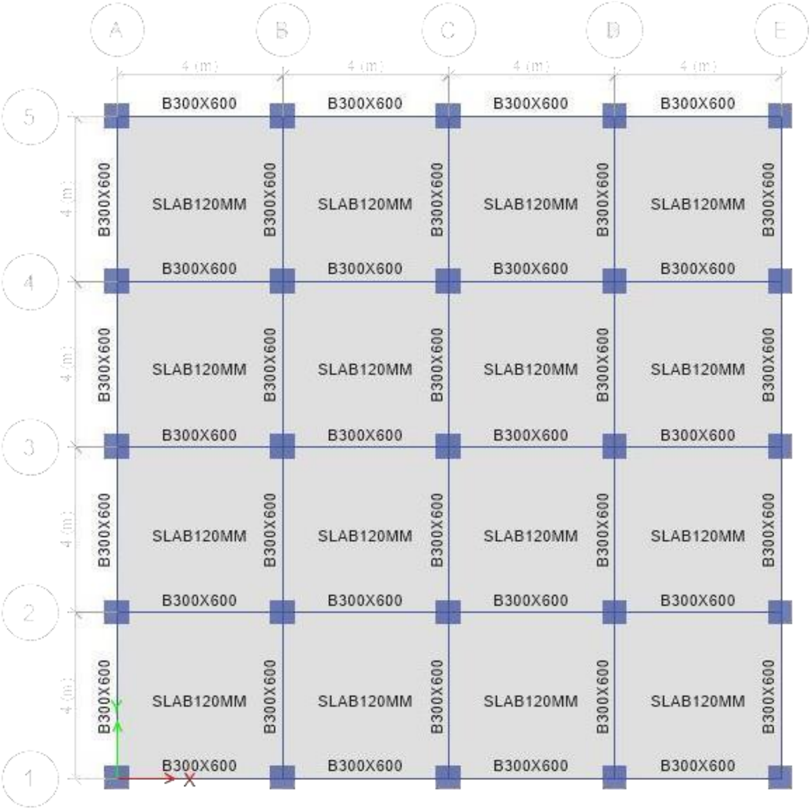
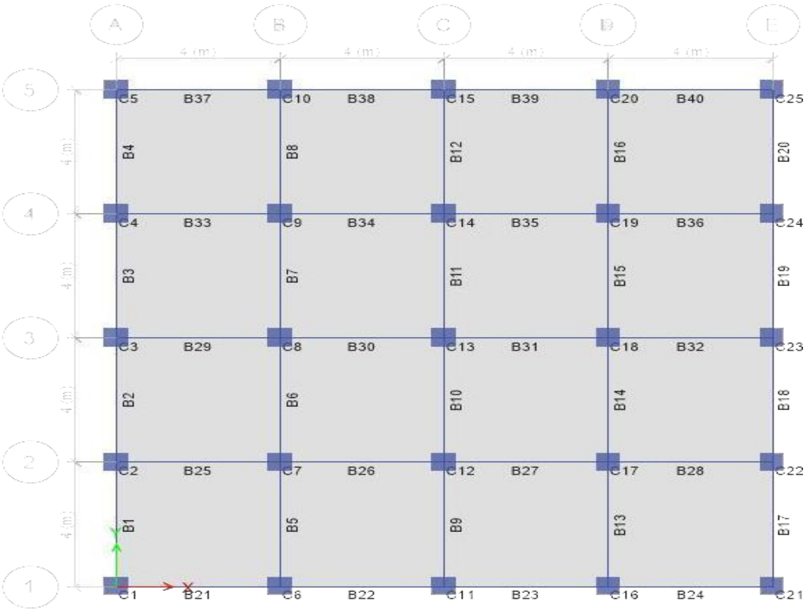


Figure 4.1: Plan of the frame.

Figure 4.2 : column layout



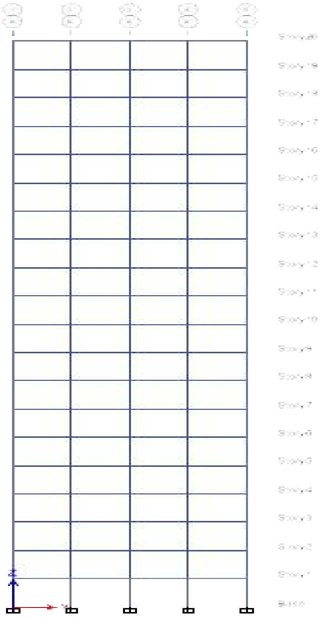


Figure 4.3 : Elevation of bare frame.

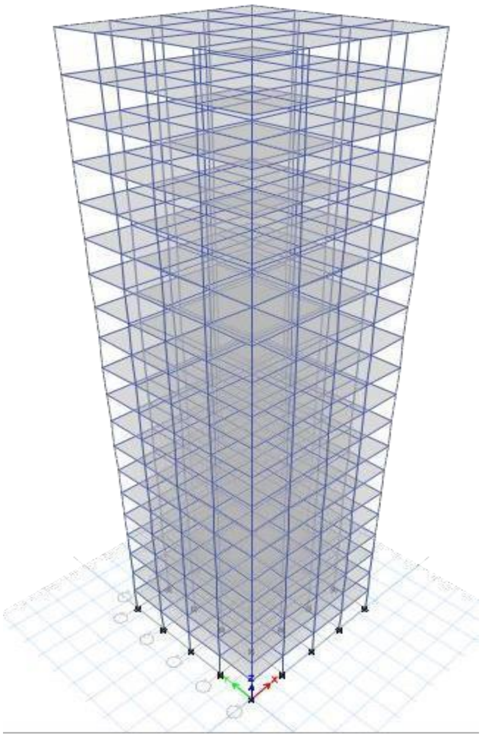
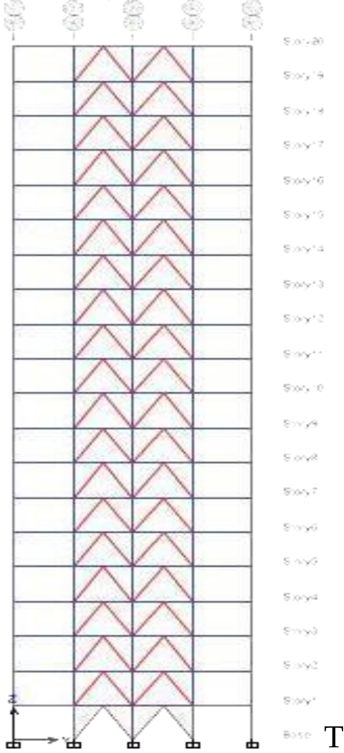


Figure 4.4: 3D view of bare frame.

Building with Chevron Bracing



This is square shape building with 6 rows of Slab panels in both X; Y directions and square shaped Columns with 4m spanning connected beams as shown in Figure 4.5. It is elevated for ten floors with height of 3m between adjacent floors as shown in Figure. The 3Dview with all connecting structural members is also shown in Figure 4.6.

Figure 4.5: bracing with chevron bracing**.**

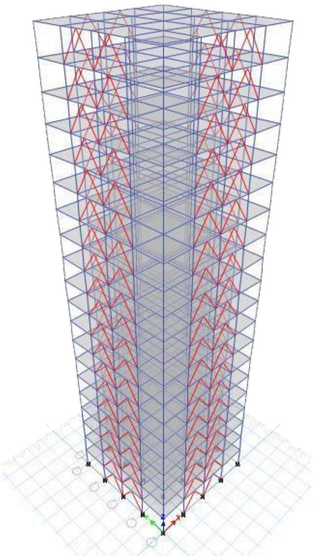


Figure 4.6: chevron bracing 3D-view.

Building with A Chevron Bracing

This is square shape building with 6 rows of Slab panels in both X: Y directions and square shaped Columns with 4m spanning connected beams as shown in Figure 4.7. It is elevated for ten floors with height of 3m between adjacent floors as shown in Figure 4.8. The3D view with all connecting structural members.

.

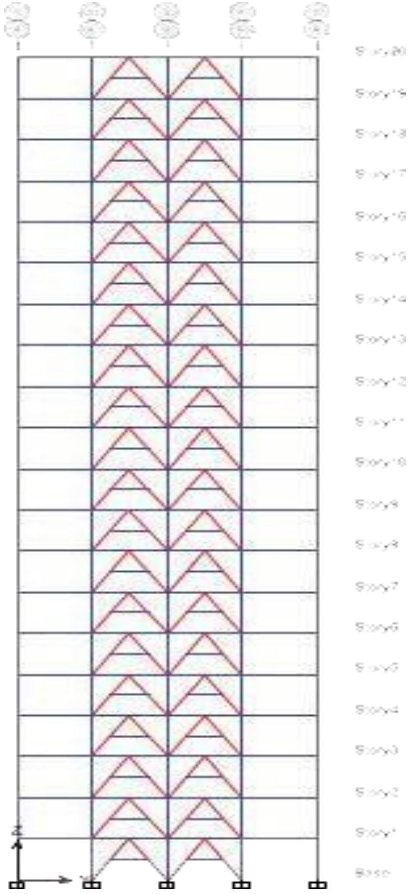


Figure 4.7: Elevation of A chevron bracing.

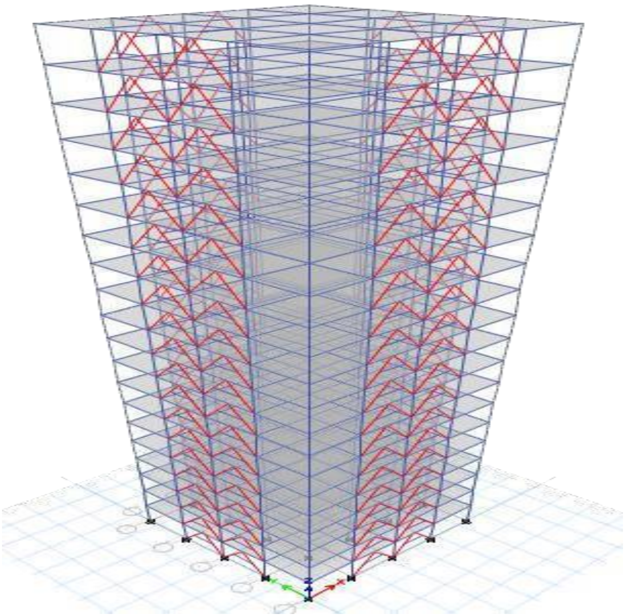


Figure 4.8: A chevron 3D-view.

Building with X Bracing

This is square shape building with 6 rows of Slab panels in both X: Y directions and square shaped Columns with 4m spanning connected beams as shown in figure 4.9. It is elevated for ten floors with height of 3m between adjacent floors as shown in figure 4.10. The 3D view with all connecting structural members.

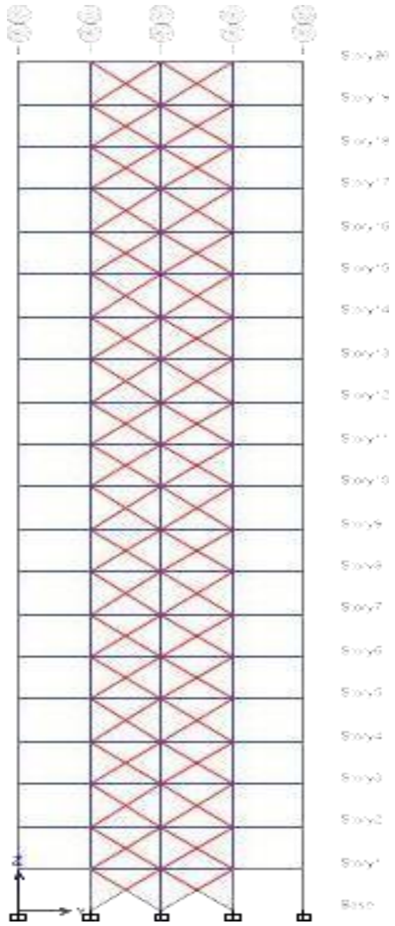


Figure 4.9 : X bracing Elevation YZ-plane.

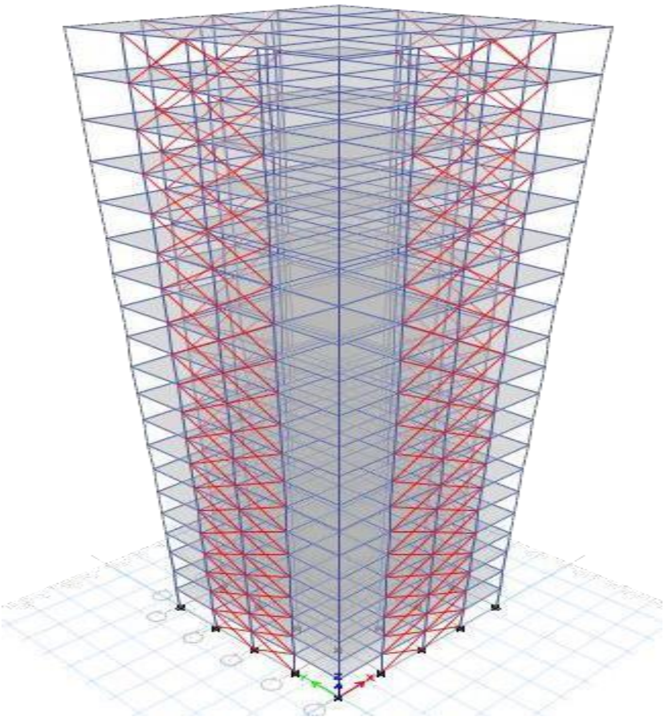


Figure 4.10 : X bracing 3D-view.

Building with Global Bracing

This is square shape building with 6 rows of Slab panels in both X: Y directions and square shaped Columns with 4m spanning connected beams as shown in Figure 4.11. It is elevated for ten floors with height of 3m between adjacent floors as shown in Figure 4.12. The 3D view with all connecting structural members.

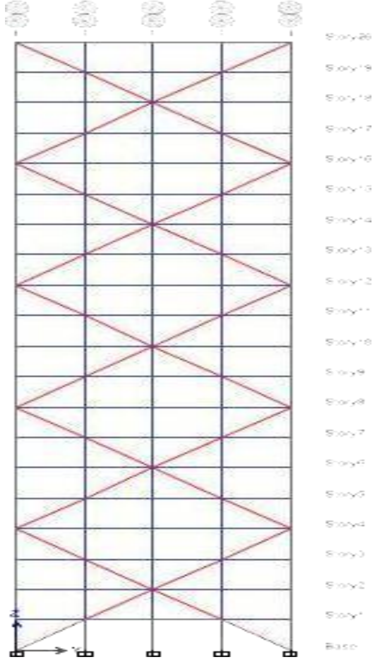


Figure 4.11 : Global Elevation YZ-plane.

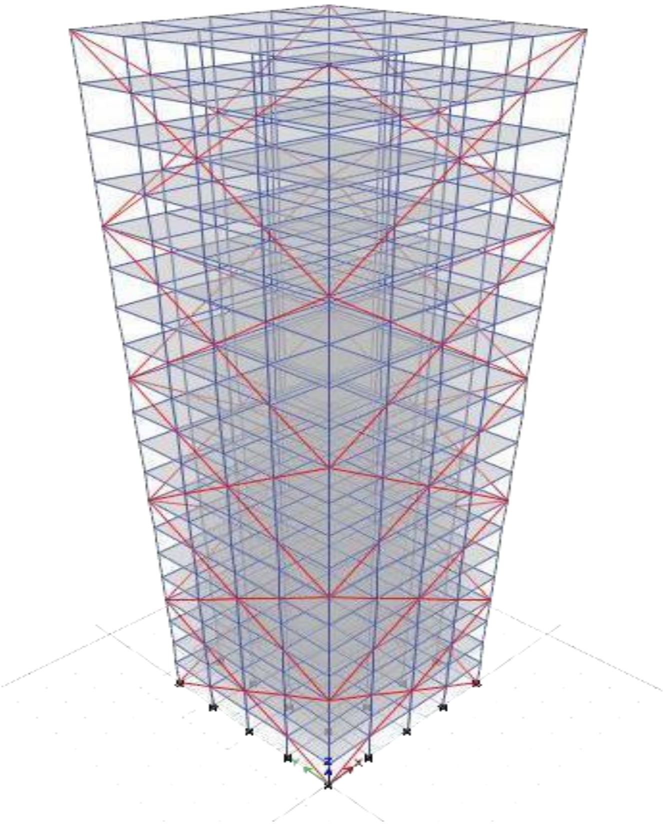


Figure 4.12: Global bracing 3D-view.

SUMMARY

The modelling, load and conditions are applied to the structure before analysis. Providing the design data to the modelling of structural elements. The next chapter deals with the analysis of these structures generated here. The results obtained have been shown in tabulated forms.

ANALYSIS & DISCUSSION OF RESULTS

ADOPTED METHODS FOR ANALYSIS

The method adopted for Time history Analysis are listed below. The results (Output) are calculated after the analysis is started. Then these methods are compared in discussions of results.

TIME HISTORY ANALYSIS:

Time Function

ETABS Software handles the initial conditions of a time function differently forlinear and nonlinear time-history load cases.

A description is as follows:

1. Linear cases always start from zero, therefore the corresponding time function must also start from zero.

Nonlinear cases may either start from zero or may continue from a previous case. When starting from zero, the time function is simply defined to start with a zero value. When analysis continues from a previous case, it is assumed that the time function also continues relative to its starting value. A long record may be broken into multiple sequential analyses which use a single function with arrival times. This prevents the need to create multiple modified functions.

Fast Nonlinear Analysis

Fast Nonlinear Analysis is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems. Because of its computationally efficient formulation, it is well-suited for time-history analysis and often recommended over direct-integration applications. During dynamic-nonlinear FNA application, analytical models should:

a) Be primarily linear elastic.

b) Have a limited number of predefined nonlinear members.

c) Lump nonlinear behaviour within link objects.

In addition to nonlinear material force-deformation relationships, these link objects may simulate concentrated damping devices, isolators, and other energy-dissipating technologies. If fuse mechanisms are not integral to the design intention, an initial elastic analysis may reveal locations where inelasticity is likely to occur. However, it is always best to predefine inelastic mechanisms such that their design may provide for sufficient ductility, while elastic systems are ensured sufficient strength. Capacity Design provides for a more reliable model and a better-performing structure.

Fast Nonlinear Analysis may be implemented within ETABS2015 using the process outlined as follows:

Model. Create the analytical model.

Mass. Define the mass source through Define > Mass Source. Mass must be present within joint locations to enable formulation.

Modal load case. Modify the existing modal load case to use Ritz Vectors, which capture response more effectively when compared with the same number of Eigen Vectors, by selecting Define > Load Cases > Modal > Modify/Show Load Case > Ritz.

On the same form, under Loads Applied, select a Load Type and orientation which is suitable for the given model and investigation. For example, Accel and UX would be suitable for the lateral analysis of a 2D portal frame. Maximum Cycles and Participation Ratios may remain on default settings.

During analysis, data from the modal load case will then coordinate with the time history load case.

Time function. Define the time function through Define > Functions > Time History. The existing ramp and uniform functions may be modified, or a function may be added from the various types available, including from the file of a time-history record.

Time-history load case. Add a new load case for the time-history analysis by selecting Define > Load Cases > Add New Load Case.

- Name the time-history load case.
- Select Load Case Type > Time History, Analysis Type > Nonlinear, TimeHistory Type > Modal.

- Under Loads Applied, select Load Type > Accel, Load Name > U1, then select the time function previously defined. If conversion from gravity units to distance units is necessary, enter the appropriate scale factor.

- Enter an Output Time Step of $^1/10$ the fundamental period of vibration. A preliminary modal analysis may be run to compute this value. This time step will likely be finer than the default value and provide more detail in the output.

- Enter a quantity of time steps which coordinates the time-step size with the duration of loading.

Analysis. Run analysis with both the modal and time-history load cases.
Output. Various options are available for reviewing output, including:

a) Graphically display member forces per time step by selecting Display > Show Forces/Stresses > Frames/Cables/Tendons. Next, specify the time-history load case, the time step, and the response quantity to review. Use the arrows at the bottom of the window to scroll through the range of dynamic response.
b) Deflection data and tabular output formats are also available.

Base Reactions

Base shear is an estimate of the maximum expected lateral force that will occur due toseismic ground motion at the base of a structure. Calculations of base shear (**V**) depend on:

a) Soil conditions at the site

b) Proximity to potential sources of seismic activity

c) Probability of significant seismic ground motion

d) The level of ductility and over-strength associated with various structural configurations and the total weight of the structure

e) The fundamental (natural) period of vibration of the structure when subjected to dynamic loading.

Earthquake shaking is random and time variant. Indian Standard Code represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear (VB)

Comparison of Base Shear

The base shear was found increasing from moment resisting structural system to Global bracing frame system. The percentage increase from MRF to Chevron bracing system is 57%, for A-Chevron bracing system is 58%, X-bracing structural system is 58% and Global bracing structural system is 81%. It is well known that if mass, increases the base shear increases. The base shear is same for the both x and y ground motions, since the plan is symmetric

Moment Resisting Frame (Bare Frame)

Design Base Shear obtained by Performing Static Analysis

The base shear is evaluated by using fundamental translation naturalperiod (Ta)

Design Base Shear (VB) : 2286.74 kN

Design Base Shear obtained by Performing Response Spectrum Analysis

Design Base Shear (Vb) : 684.18 kN

Scaled Design Base Shear : 11886.98 kN

The value of base shear obtained from response spectrum analysis is observed to be lesser when compared to value of base shear obtained from static analysis, according to this situation IS 1893 (part 1): 2002 under clause 7.8.2 Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method. However, in either method, the design base shear (Vb) shall be compared with a base shear (VB) calculated using a fundamental period T, where the dynamic base shear is less than the static base shear at all the response quantities (for example member forces, displacements, storey forces, story shears and base reactions) must be multiplied by VB/Vb.

2286.74/684.18 = 3.34 (scale factor)
684.18 x 3.34 = 2285.16 kN
Similarly, the same procedure has been carried out for other structuralsystems and the results obtained are presented in Table 5.1.

Table 5.1: Base Shear

Base Shear (kN)					
Values	Bareframe	Chevron	A-Chevron	X-bracing	Global
Static	2286.74	4117.39	4151.66	4158.83	5430.63
Dynamic	684.18	1265.38	1279.27	1277.61	1539.41
Scaled Dynamic	2285.17	4226.36	4272.75	4267.22	5141.64

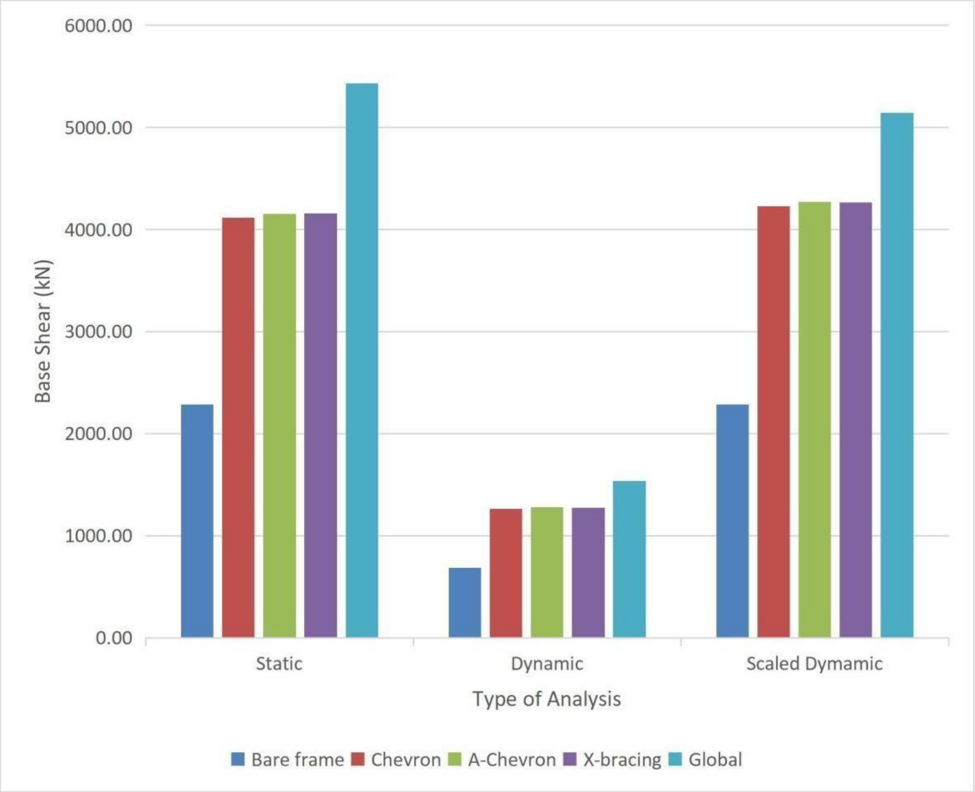


Figure 5.1: Comparison of base shear

From the comparison values in Figure 5.1, it can be clearly found that due to introduction of Braces in the structures the base shears for bare frame to chevron bracing system is 57%, for A-chevron bracing system is 58%, X-bracing structural system is 58% and global bracing system is 81%. It is well known that if mass increases the base shear increases. The base shear is same for both x and y ground motions, since the plane is symmetric.

Story Maximum and Average Lateral Displacements

ETABS provides a simple table in the summary output with "Story Maximum and Average Lateral Displacements". This provides indication of maximum to average ratio to check torsional irregularity. The Maximum Displacements due to Push-X in X-direction are shown in Table 5.2.

Table 5.2: Storey Displacement

EQ					
Displacement (mm)					
Story	Bareframe	Chevron	A-Chevron	X-bracing	Global
Story20	116.47	82.18	82.86	83.52	58.34
Story19	114.41	78.27	78.92	79.37	55.83

Story18	111.68	74.09	74.70	75.01	53.39
Story17	108.23	69.73	70.30	70.50	50.78
Story16	104.10	65.17	65.71	65.83	47.59
Story15	99.35	60.43	60.94	61.02	44.22
Story14	94.05	55.55	56.01	56.08	41.21
Story13	88.26	50.54	50.97	51.03	38.16
Story12	82.05	45.46	45.84	45.93	34.50
Story11	75.49	40.34	40.68	40.79	30.69
Story10	68.62	35.24	35.54	35.68	27.52
Story9	61.51	30.21	30.46	30.64	24.47
Story8	54.20	25.31	25.52	25.74	20.88
Story7	46.76	20.60	20.78	21.03	17.14
Story6	39.21	16.17	16.31	16.58	14.21
Story5	31.61	12.08	12.18	12.46	11.57
Story4	24.02	8.41	8.48	8.76	8.63
Story3	16.52	5.26	5.30	5.56	5.52
Story2	9.35	2.72	2.75	2.95	3.18
Story1	3.17	0.90	0.91	1.03	1.26

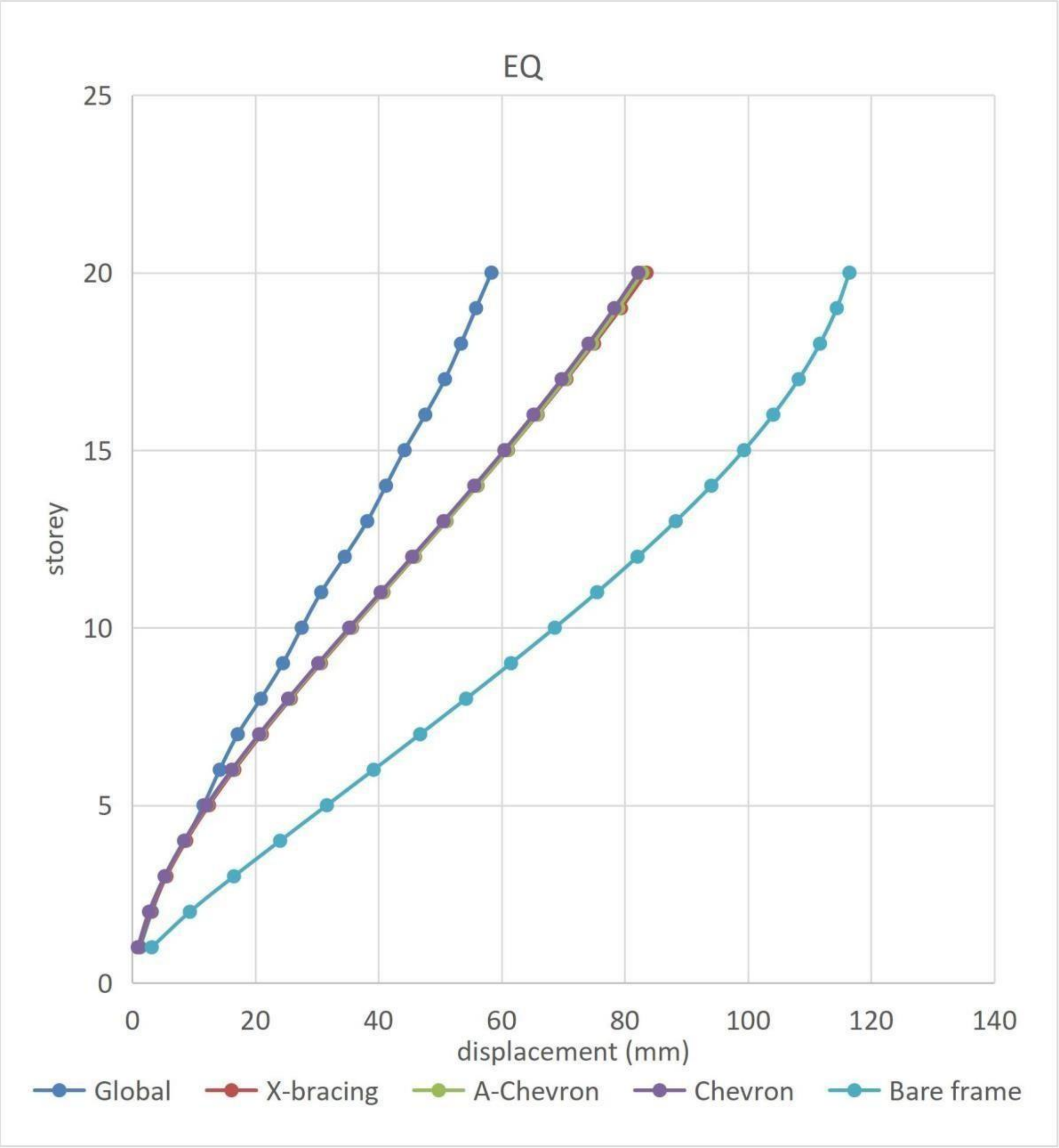


Figure 5.1: Displacement curve of bracing systems

Table 5.3: Scaled RS

Scaled RS					
Displacement (mm)					
Story	Bare frame	Chevron	A-Chevron	X-bracing	Global
Story20	89.30	58.18	58.61	59.10	42.78
Story19	87.90	55.44	55.84	56.19	41.01
Story18	86.09	52.52	52.91	53.16	39.30
Story17	83.83	49.51	49.87	50.04	37.48
Story16	81.14	46.38	46.72	46.83	35.28
Story15	78.04	43.17	43.49	43.55	32.96
Story14	74.56	39.87	40.17	40.20	30.90

Story13	70.73	36.52	36.79	36.80	28.80
Story12	66.54	33.11	33.36	33.35	26.27
Story11	62.03	29.68	29.90	29.88	23.64
Story10	57.21	26.23	26.44	26.41	21.44
Story9	52.08	22.80	22.98	22.95	19.29
Story8	46.67	19.42	19.57	19.53	16.70
Story7	40.98	16.10	16.24	16.20	13.98
Story6	35.02	12.91	13.02	12.99	11.82
Story5	28.79	9.88	9.97	9.95	9.79
Story4	22.30	7.09	7.15	7.14	7.42
Story3	15.63	4.60	4.64	4.65	4.92
Story2	8.99	2.51	2.53	2.55	2.95
Story1	3.08	0.90	0.91	0.93	1.22

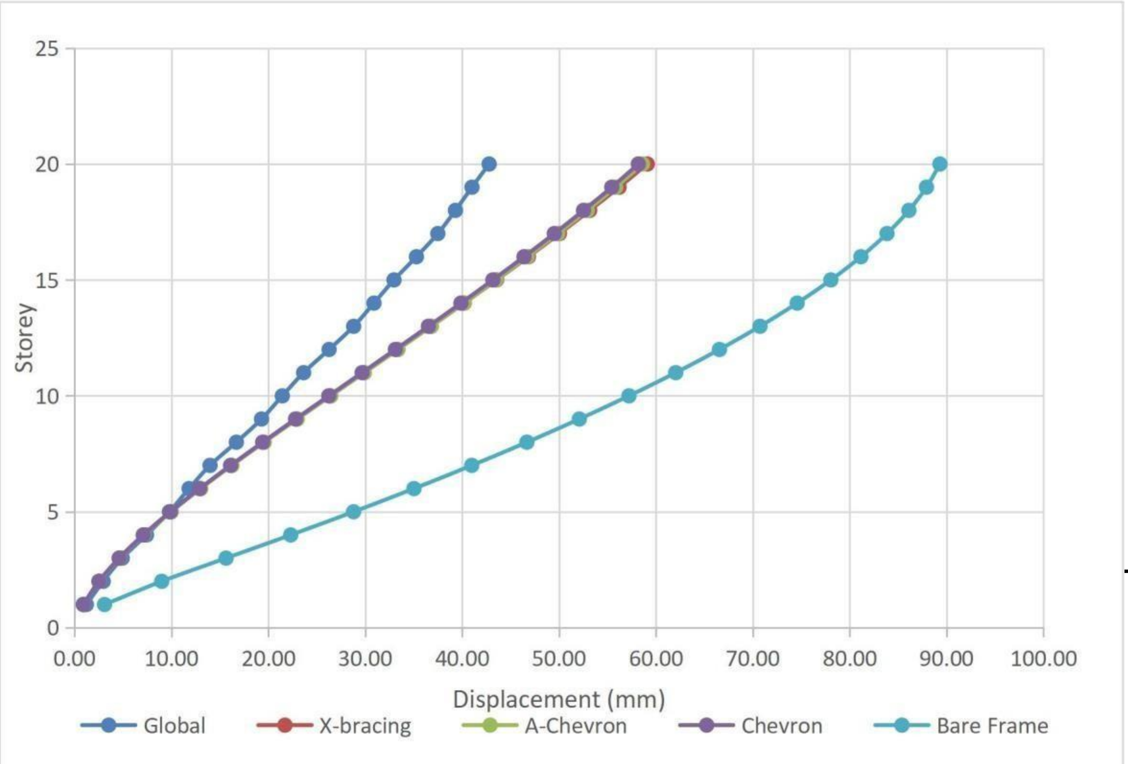
Figure 5.3: Displacement curve for braces

Storey Drift

Drift is a very complex topic in structural engineering. It involves too many factors to arrive at a suitable decision. It involves engineering judgment, The phenomenon fresh engineers might not feel. story is the lateral displacement of one level relative to the level above or below**.** Story drift ratio is the story drift divided by the story height.

Table 5.4 : EQ

EQ					
Drift (mm)					
Story	Bareframe	Chevron	A-Chevron	X-bracing	Global
Story20	2.06	3.91	3.94	4.15	2.50
Story19	2.73	4.18	4.21	4.36	2.45



Story18	3.45	4.37	4.40	4.51	2.61
Story17	4.13	4.56	4.60	4.67	3.19
Story16	4.75	4.73	4.77	4.81	3.37
Story15	5.30	4.89	4.92	4.94	3.01
Story14	5.79	5.00	5.04	5.04	3.05
Story13	6.21	5.08	5.13	5.11	3.66
Story12	6.57	5.12	5.16	5.13	3.82
Story11	6.87	5.10	5.15	5.11	3.17
Story10	7.11	5.03	5.07	5.04	3.05
Story9	7.31	4.90	4.94	4.91	3.59
Story8	7.45	4.70	4.74	4.71	3.75
Story7	7.55	4.44	4.47	4.45	2.93
Story6	7.60	4.09	4.13	4.12	2.64
Story5	7.59	3.67	3.70	3.70	2.94
Story4	7.49	3.15	3.18	3.20	3.11
Story3	7.17	2.54	2.56	2.61	2.34
Story2	6.18	1.83	1.84	1.92	1.92
Story1	3.17	0.90	0.91	1.03	1.26

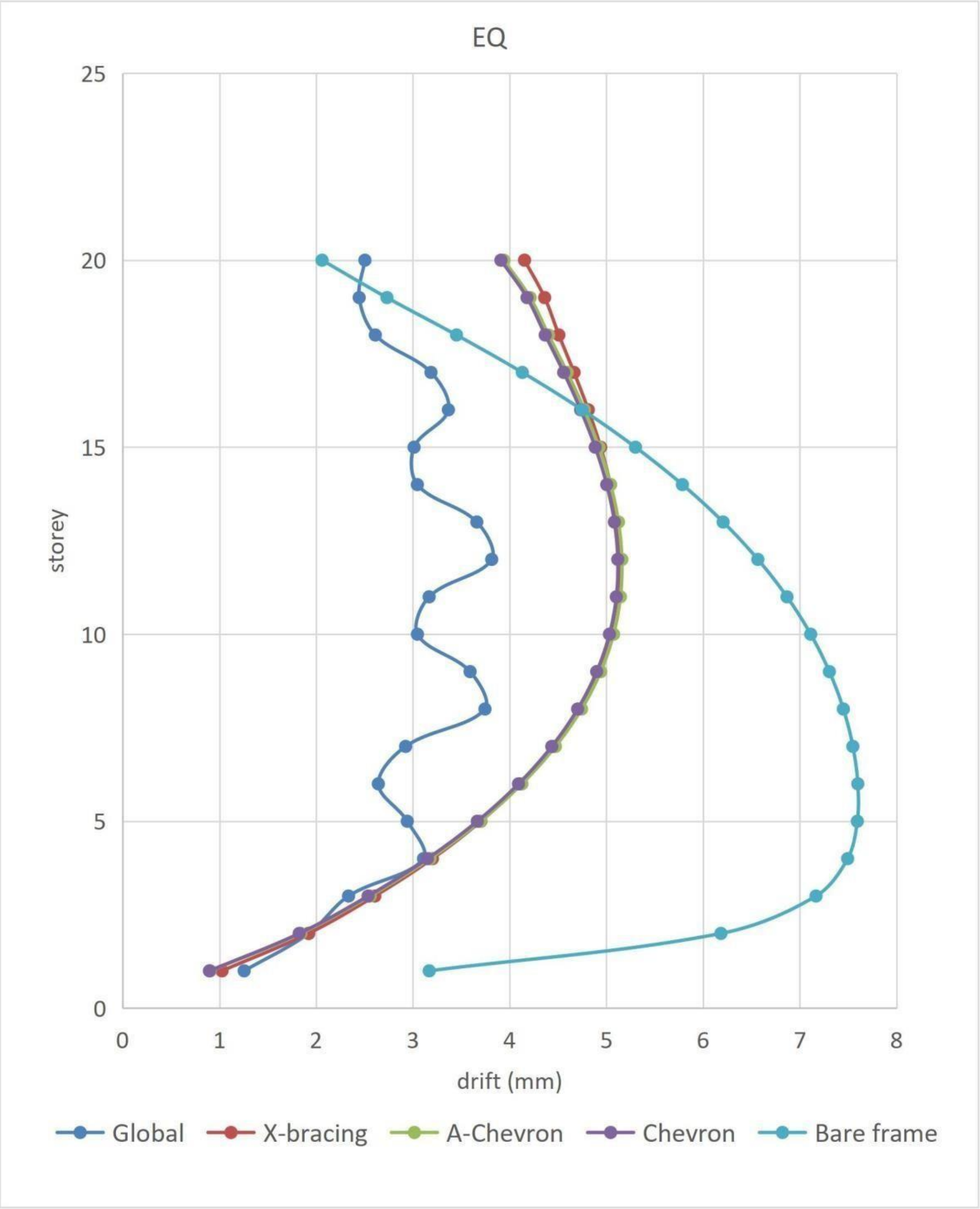


Figure 5.4 : Story drift curve

Table 5.5 : Scaled RS

	Scaled RS				
	Drift (mm)				
Story	Bare frame	Chevron	A-Chevron	X-bracing	Global
Story20	1.73	2.90	2.92	3.06	1.82
Story19	2.35	3.12	3.14	3.22	1.79
Story18	2.96	3.26	3.29	3.33	1.92
Story17	3.48	3.39	3.42	3.44	2.35
Story16	3.90	3.50	3.53	3.53	2.49
Story15	4.26	3.58	3.61	3.59	2.22
Story14	4.58	3.63	3.66	3.64	2.24
Story13	4.86	3.66	3.69	3.66	2.70
Story12	5.13	3.66	3.69	3.66	2.81
Story11	5.39	3.64	3.66	3.63	2.33
Story10	5.63	3.59	3.62	3.59	2.25
Story9	5.86	3.52	3.54	3.51	2.69
Story8	6.06	3.41	3.44	3.41	2.81
Story7	6.25	3.27	3.30	3.27	2.23
Story6	6.43	3.08	3.11	3.08	2.07
Story5	6.61	2.83	2.86	2.83	2.38
Story4	6.73	2.51	2.54	2.51	2.53
Story3	6.65	2.11	2.13	2.11	1.98
Story2	5.91	1.62	1.63	1.62	1.74
Story1	3.09	0.90	0.91	0.93	1.22

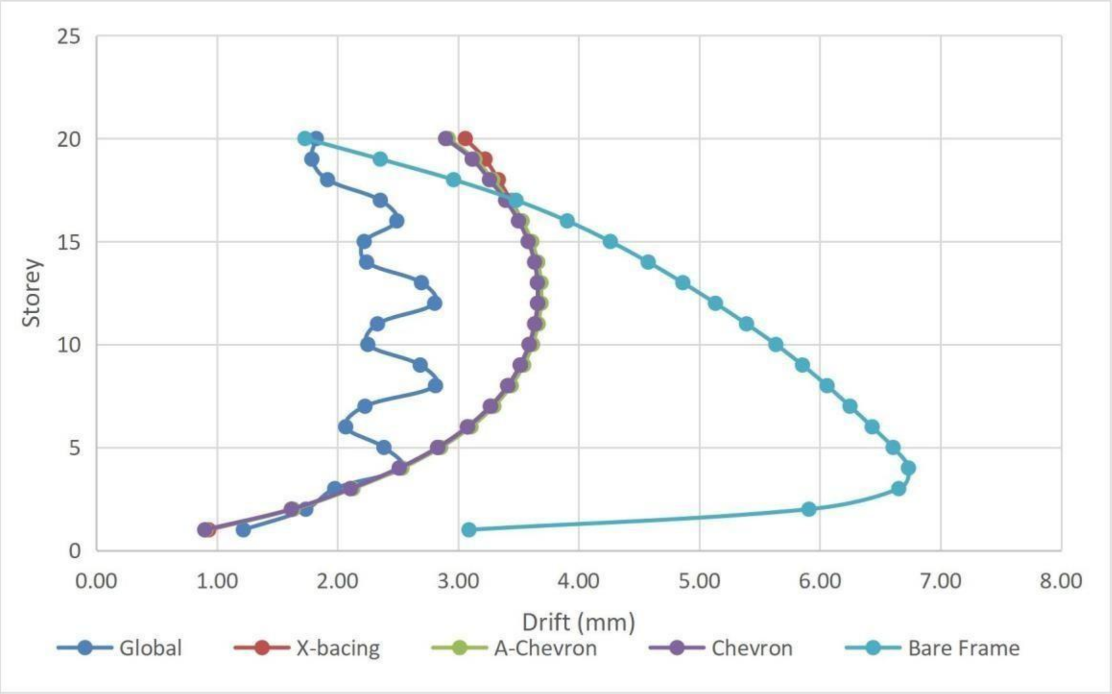


Figure 5.5 : Story drift curve

Natural Period

Natural Period Tn 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 its units are seconds (s).

Table 5.6 : Time Period

Mode	**Time Period (Sec)**				
	Bare frame	Chevron	A-Chevron	X-bracing	Global
1	3.01	1.77	1.78	1.79	1.32
2	3.01	1.77	1.78	1.79	1.32
3	2.48	1.12	1.13	1.14	0.64
4	0.97	0.48	0.48	0.46	0.40
5	0.97	0.48	0.48	0.46	0.40
6	0.81	0.31	0.31	0.30	0.21
7	0.55	0.23	0.23	0.21	0.21
8	0.55	0.23	0.23	0.21	0.21
9	0.47	0.15	0.16	0.14	0.15
10	0.38	0.15	0.15	0.13	0.15
11	0.38	0.15	0.15	0.13	0.13
12	0.33	0.11	0.11	0.10	0.11
13	0.28	0.11	0.11	0.10	0.11
14	0.28	0.09	0.09	0.08	0.09
15	0.24	0.09	0.09	0.07	0.09
16	0.22	0.07	0.07	0.07	0.08
17	0.22	0.07	0.07	0.06	0.08
18	0.17	0.06	0.06	0.06	0.08
19	0.17	0.06	0.06	0.05	0.08
20	0.14	0.05	0.05	0.05	0.07
21	0.14	0.05	0.05	0.05	0.07
22	0.12	0.05	0.05	0.05	0.06
23	0.12	0.05	0.05	0.04	0.06
24	0.10	0.04	0.04	0.04	0.06
25	0.10	0.04	0.04	0.04	0.06
26	0.09	0.04	0.04	0.04	0.05
27	0.09	0.04	0.04	0.03	0.05
28	0.08	0.04	0.04	0.03	0.04
29	0.08	0.04	0.04	0.03	0.04
30	0.07	0.04	0.03	0.03	0.04
31	0.066	0.034	0.034	0.029	0.039
32	0.059	0.034	0.032	0.029	0.036
33	0.059	0.032	0.031	0.027	0.036

34	0.054	0.032	0.029	0.027	0.034
35	0.052	0.03	0.028	0.026	0.033
36	0.049	0.03	0.027	0.026	0.032
37	0.046	0.028	0.027	0.025	0.031
38	0.045	0.028	0.018	0.025	0.03
39	0.042	0.027	0.015	0.024	0.03
40	0.042	0.027	0.015	0.024	0.03

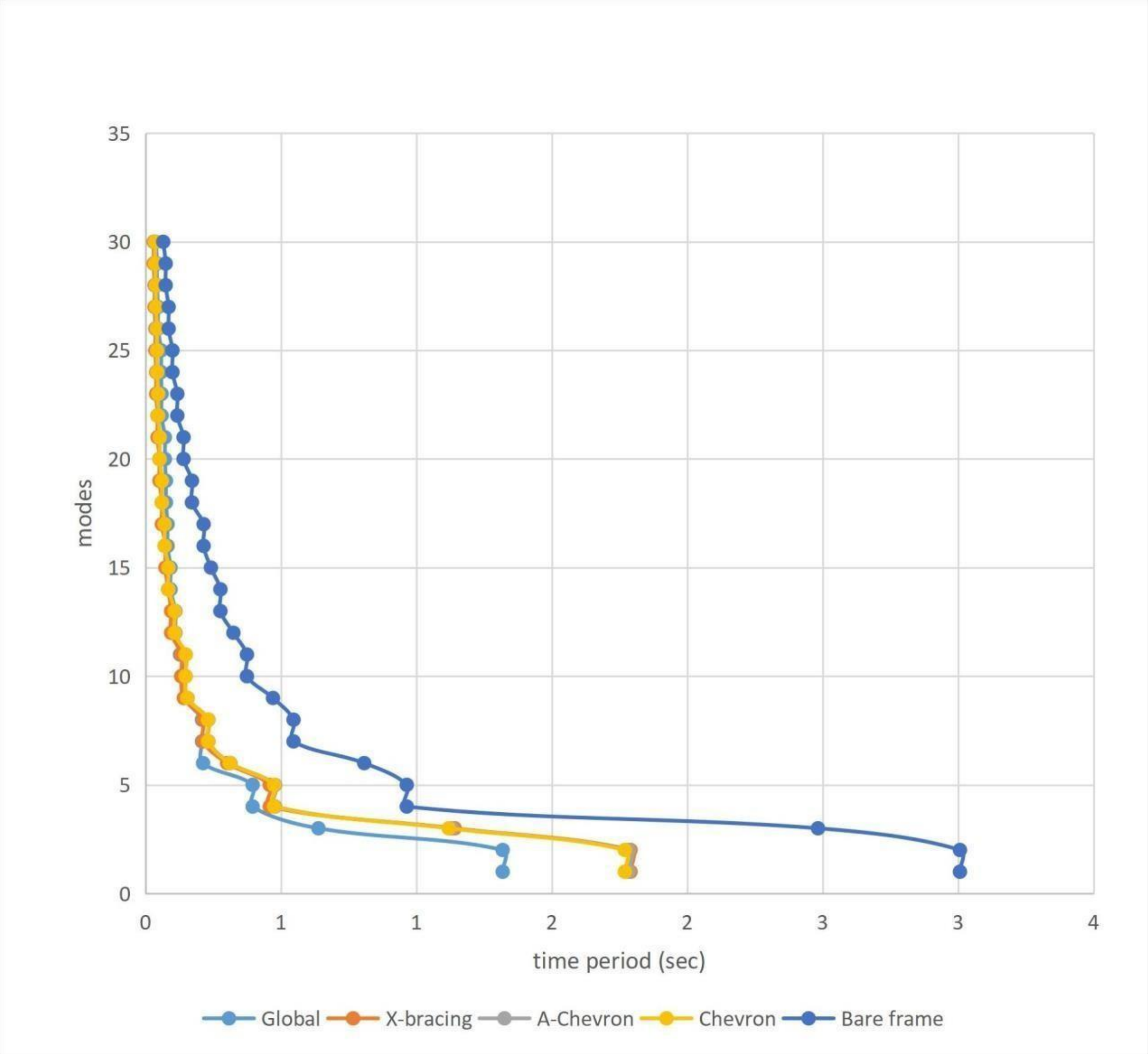
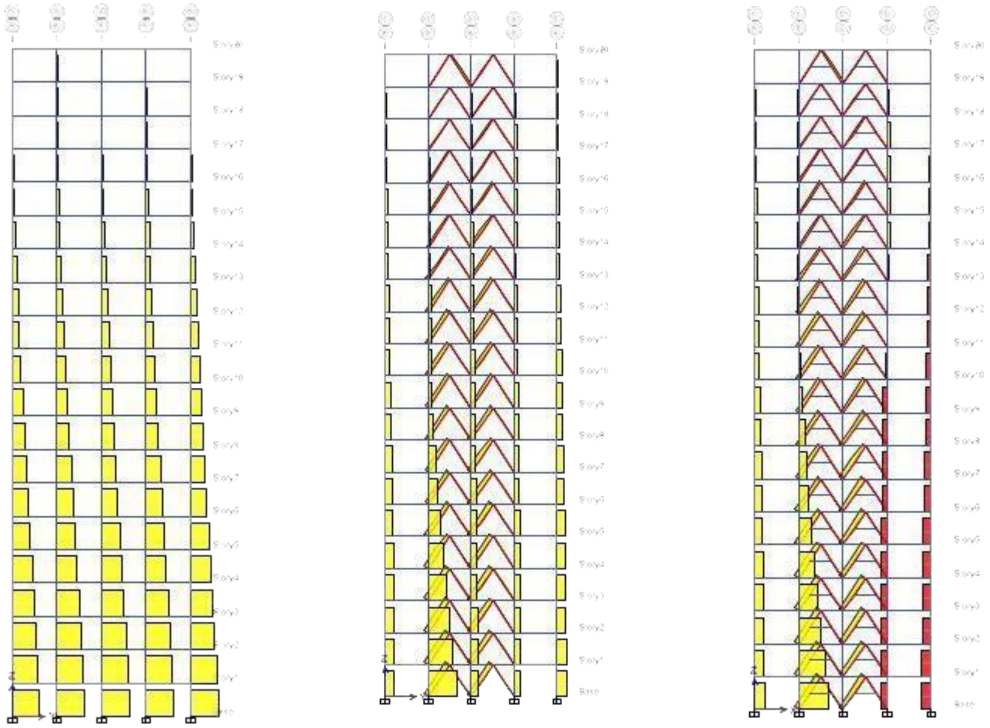


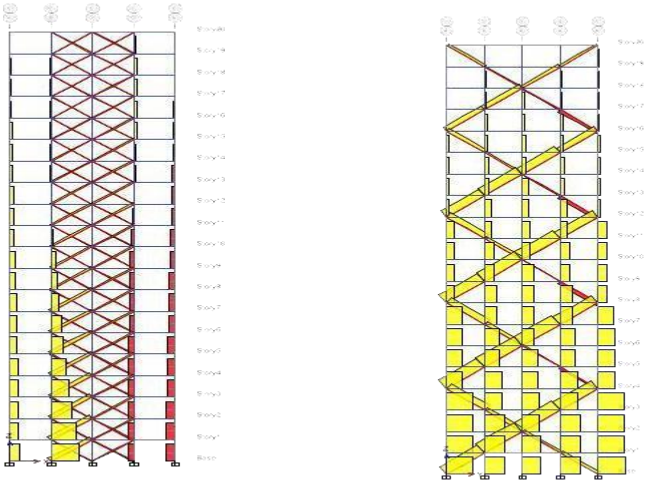
Figure 5.6 : Time period curve

Axial Force : Axial force is the compression or tension force acting in a member. If the axial force acts through the centroid of the member it is called concentric loading. If the force is not acting through the centroid it's called eccentric loading.

Figure 5.7 : Axial force for bracing system



Bare Chevron A-Chevron

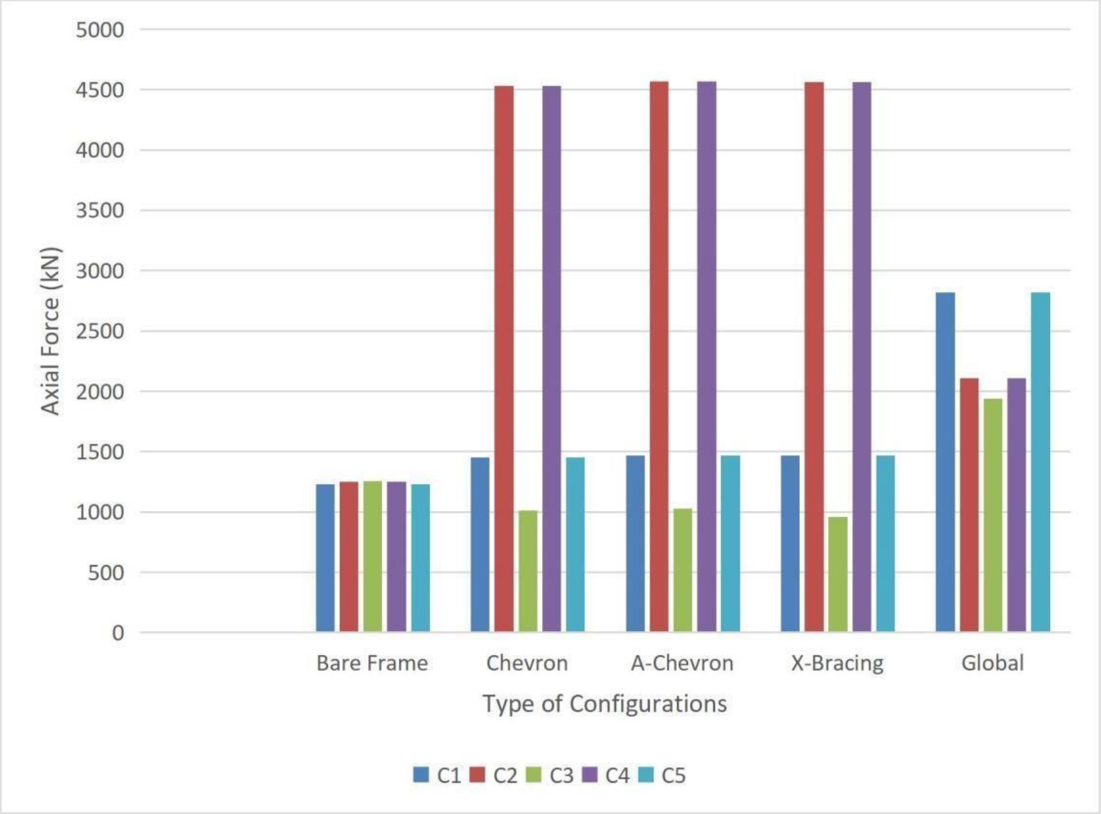


X Global

Axial Force (kN)					
Type of Structure	C1	C2	C3	C4	C5
Bare Frame	1227.34	1251.11	1253.51	1251.11	1227.34
Chevron	1454.29	4532	1012.09	4532.25	1454.29
A-Chevron	1466.18	4570.8	1027	4570.8	1466.18
X-Bracing	1467.24	4564.32	961.17	4564.32	1467.24
Global	2817.05	2108.17	1938.36	2108.17	2817.05

Table 5.7 : Axial Force

Figure 5.8 : Bending Moment



Bending Moment

Bending moment is the reaction induced in a structural element when an external force or moment is applied to the element, causing the element to bend. The most common or simplest structural element subjected to bending moments is the beam.

Table 5.8 : Bending Moment

	Bending Moment (kNm)			
Type of Structural System	B1	B2	B3	B4
Bare Frame	7.22	27.48	25.64	4.93
Chevron	98.24	23.77	4.32	101.24
A-Chevron	98.97	23.96	4.37	101.99
X-Bracing	106.18	18.73	8.01	108.51
Global	2.89	9.63	9.07	2.16

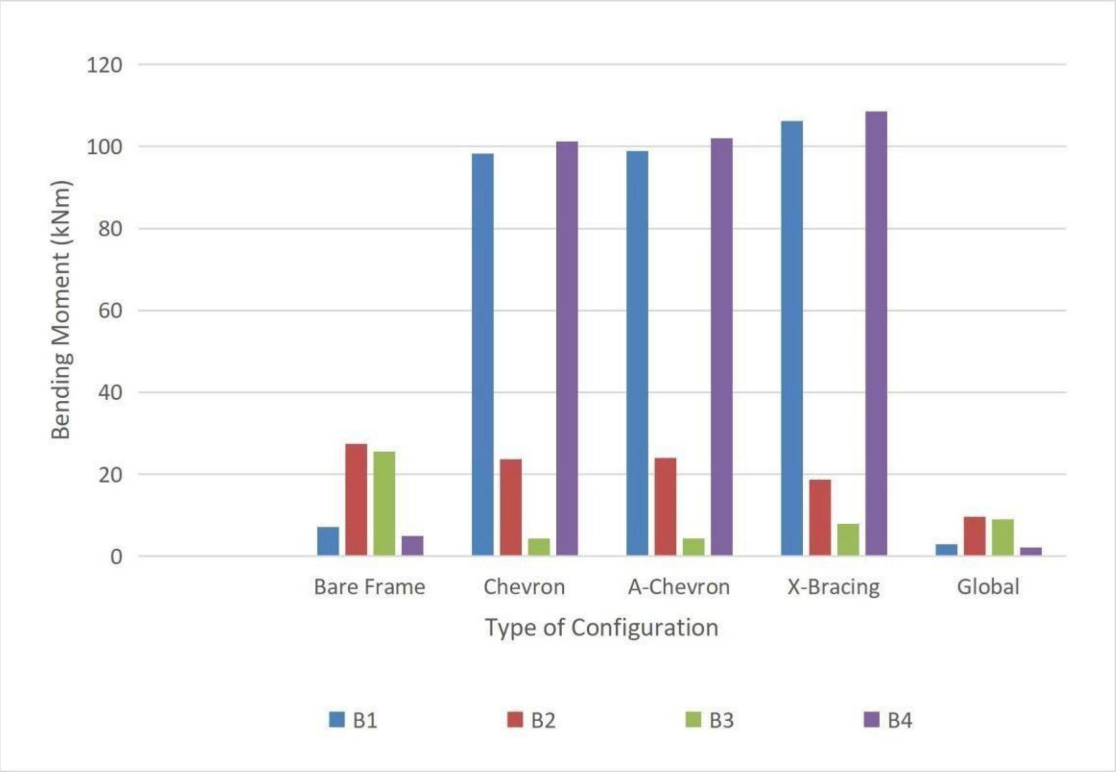
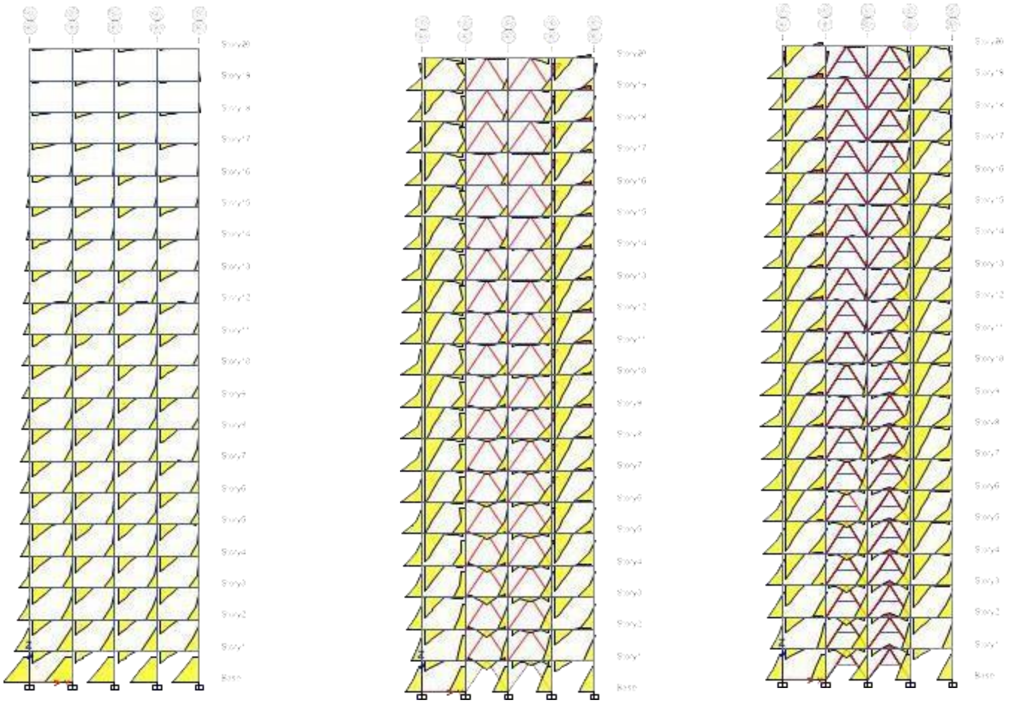
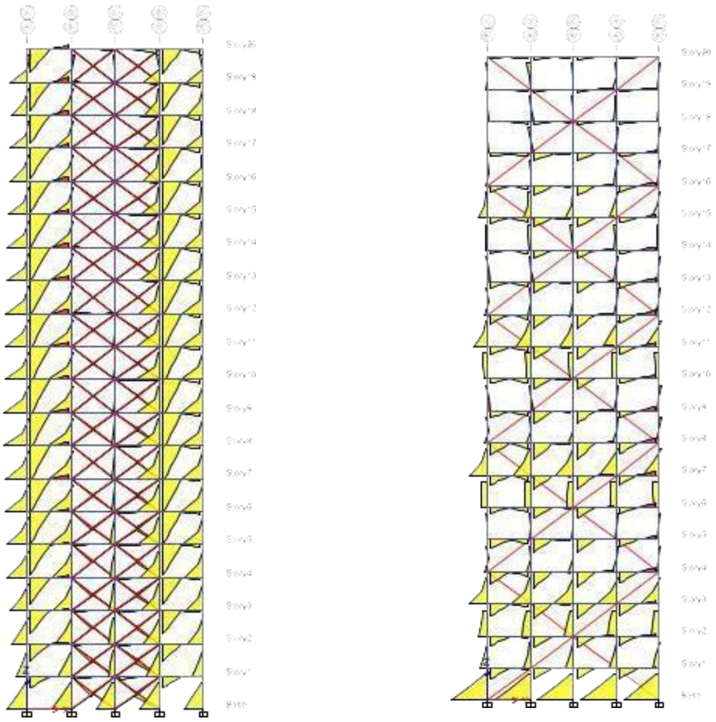


Figure 5.9 : Shear force



Bare Frame Chevron A-Chevron

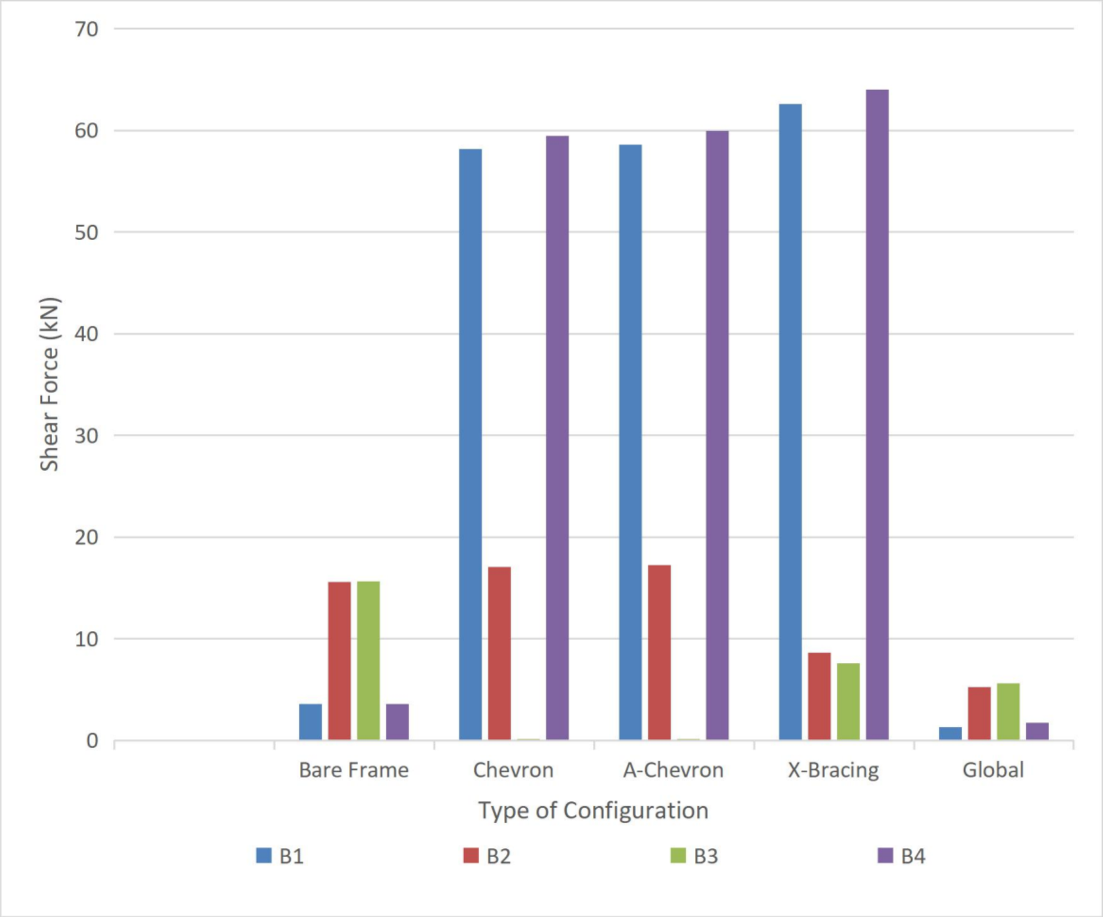


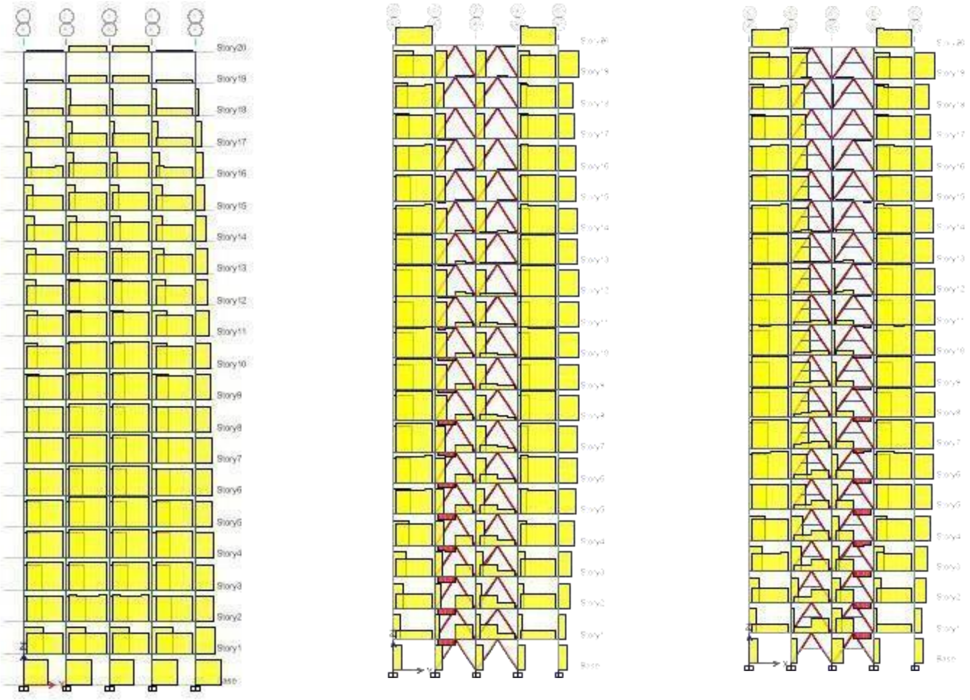
X Global

Figure 5.10 : Bending moment

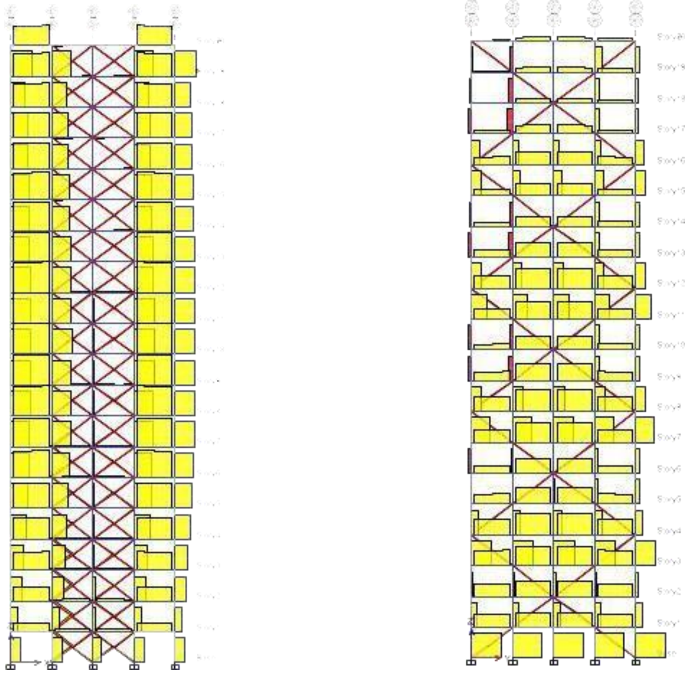
Table 5.9 : Shear Force

Shear Force (kN)				
Type of Structural System	B1	B2	B3	B4
Bare Frame	3.57	15.61	15.64	3.6
Chevron	58.18	17.08	0.11	59.49
A-Chevron	58.61	17.22	0.11	59.94
X-Bracing	62.59	8.63	7.56	64.02
Global	1.33	5.26	5.6	1.74





Bare Frame Chevron A-Chevron



X Global

Figure 5.11 : Shear force