Seismic Performance Assessment of High-Rise Building

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Abstract: *From various studies, it is seen that the symmetric structure is more resistive to the wind and seismic load effects. A raft foundation can develop adequate resistance to horizontal and moment loadings and thus be suitable for buildings with moderate height. Story Shear (Drift) values are seen to be maximum at the base and gradually increase with Zone.*

ETABS is useful for large and complex models to analyze the nonlinear construction sequencing and time effect. ETABS provides every detail of the member and helps in reducing the workload and design time. Manual calculations match with software results that provide an extra edge over the reliability and efficiency of the software.

Regular structure with RC moment-resisting frame and masonry walls performs better under seismic load compared to re-entrant corner structure which performs worse than irregular structure. Structures with shear walls are more efficient than the structure without shear walls in resisting lateral forces acting on the structure. The shear structure is hence suitable in earthquake-prone areas due to its higher stiffness and less displacement. Building models compared on different effects such as moments, shear force, lateral loads, drift, and base shear helps to choose the optimized design. Drift is decreased in a shear wall structure than frame structure. Story acceleration is more in shear structure than frame structure. The story drift due to wind load mainly acts in the middle of the structure and as the height of the building increases the story drift reduces while the story shear is maximum at the base. The Response Spectrum Method provides a real-time representation of seismic loads in the form of static loads and also demonstrates the behavior of the structure under it.

Seismic retrofitting an existing building most often would be more challenging than designing a new one. Viscous Dampers and seismic resisting devices such as shear walls, dampers, rubber pads, and spring can be used in new structures. The new techniques within the seismic style of structures or retrofitting of the present buildings are supported by everchanging the dynamic characteristics of the system to receive less seismic force.

1. Introduction

1.1 Introduction for High Rise Building

High-Rise building is not a modern feature, ancient cities in Egypt and Rome had living accommodation up to 6 to 7 floors. As time passed through centuries, tall buildings were limited to religious and civic buildings. Even the commercial centers were not building high but instead use large plots of land. The general progress towards the high-rise building was seen with the industrial revolution and with the invention of lifts which help to build tall buildings with ease in reaching top floors and the subsequent population migration from rural to town and city living.

The first country to start constructing high-rise buildings in the 19th century in Chicago and soon in New York embarked on the development of high-rise buildings. But as the bricks were the major construction material, the general limit to the buildings was upmost 10 stories. As advances were made the quest for the true skyscraper was started in earnest. By the turn of the 19th-century, high-rise construction techniques had been all but perfected and with the adoption of the electrical Lift, high-rise living was a fact. The term "high-rise building" means any building having occupied floors located more than 75 feet above the lowest level of Fire Department vehicle access at that point of time under their national code of conduct.

As per the building code of India, tall buildings are one with more than four floors and high-rise is one with more than 15m in height. The BMC proposed a building with a height of 30m to be considered a high-rise building. But from the structural point of view, it can be defined as the building that its height will be affected by lateral forces resulting from earthquakes and wind forces to such an extent that such forces will play a major role in the process of design. In India, more than 2500 high-rise buildings, a majority of them are constructed in India's commercial capital, Mumbai. Also, more than a thousand mid-rises exist already in the city. Mumbai has seen a massive construction boom with buildings reaching heights of 100, 150, 200, and even 250m.

1.2 Seismic Effect

As we move forward and look for sustainable development and continue the growth of the cities, we need software to calculate many factors that will affect the building in the long term. The wind and earthquake factors were earlier not taken into consideration and if they were considered they were the same for the different shapes, sizes, and methods. Hence new codes were developed worldwide and adopted for high-rise buildings. In India, we have the Bureau of Indian Standards that came up with the 6th revision of seismic

code IS1893 which covers the Design Earthquake Resistant Structure for High Rise Structures.

Broadly, earthquake-resistant buildings can be divided into four categories:

1. Earthquake Resistant-Operational

2. Earthquake Resistant-Immediate Occupancy

3. Earthquake Resistant-Life Safety

4. Earthquake Resistant-Collapse Prevention.

High-rises in most parts of India adopt the last, which simply may prevent a collapse. Further, high-rises need a separate code because how an earthquake hits a 5-storey building is very different from the way it hits a 20-storey building.

1.3 IS Code

Loads that need to be taken into consideration when designing a building are vertical loads from self-weight, imposed loads, snow loads, and horizontal loads from both wind and unintended inclinations. The horizontal loading from wind is sometimes the design load for tall buildings, which produces an instant within the column. The vertical loads are the self-weights, finishing loads, and live loads, and that they are transferred to the muse through columns, load-bearing walls, or towers.

IS 875 Part 1

● **Dead Load:**

Dead load is because of the self-weight of the structural elements like beams, columns, slabs, interior, and exterior walls. Dead loads are the permanent loads that are always present. Dead loads depend on the unit weight of the building material. Dead loads include the self-weight of walls, floors, beams, columns, etc. The unit weight of commonly used building materials is given within the code.

IS 875 Part 2

● **Live Load:**

Live loads on floors and roofs accommodate all the load masses which are temporarily placed on the structure, for example, a stack-like load of people, furniture, machines, etc. Live loads keep on changing with time. Live loads are also called imposed loads.

IS 875 Part 3

● **Wind Load:**

The force exerted by the horizontal component of wind is to be considered within the design of the building. Wind loads rely on the rate of the wind, shape, and size of the building. The strategy of calculating wind loads on the structure is given in IS 875 (Part-3):1987.

IS 1893 (2002)

Criteria for Earthquake Resistant Design of Structures,

Part 1: General Provisions and Buildings

The guidelines are given by the Indian Standard Codes for Earthquake Resistant Structure. After observing Indian earthquakes for several years, the Bureau of Indian Standard has divided the country into five zones depending upon the severity of the earthquake. The factor Earthquake Resistant Design is the topmost priority for designing a structure.

Earthquake loads rely upon the zone and place where the building is located. As per code, India is classified into four seismic zones. Now, it's mandatory to follow these recommendations for the design of structures and recommends earthquake-resistant design of the structure.

IS 13920:2016

Ductile Design and Detailing of Reinforced Concrete Structure Subjected to Seismic Forces

It provides ductile detailing of varied members sort of a beam, columns, shear wall, etc. This will ensure the designated behavior of the RCC structure during cycling loads like an earthquake. These standard addresses lateral load resisting structural system of RC structure composed of:

a. RC moment-resisting frames

b. RC moment-resisting frames with unreinforced masonry infill walls

c. RC moment-resisting frames with RC structural walls

d. RC structural walls

This shall be adopted for all lateral loads systems and in several Seismic Zones like Seismic Zone III, IV, or V (Standard optional is Seismic Zone II). Further, the code covers the details and formula for Longitudinal Reinforcement, Transverse Reinforcement, Special Confining Reinforcement & Special Shear Walls.

2. Aim and Objective

Aim

- In this project, we will assess the sustainability and performance of high-rise stack-like buildings against Earthquake and Wind loads.
- Also, to calculate the Base Shear, Bending Moment, Drift, and Torsion.
- We are also going to check the reliability of the E-Tabs software.

Objective

- To know the effects of the seismic forces on the overall structure.
- To understand the effect of wind forces on different floors of a multi-rise structure.
- To determine the safety of the structure against all the external forces that can act on the structure.
- To learn the advantages of the software in the assessment of a high-rise structure.

3. Seismic Performance Assessment of High-Rise Building

1.   In this project, we are going to assess the sustainability and Performance of a High-Rise Building against Earthquake Loads.

2.   The Software that we are adopting for the design and analysis is ETABS.

3.   Also, we are Checking the Reliability of the software for design and analysis purposes by comparing it with Manual Calculations.

4.   The reliability of the software is checked by analyzing a G+6 structure manually and on ETABS.

5.   In our manual calculations, we have evaluated the stability of the structure by using Kani's Method and we have also designed a generalized Excel Sheet for load calculations and analysis of the structure.

6.   For analyzing the stability of the structure different methods such as *Moment Distribution Method, Stiffness Matrix Method, Kani's Method*, etc. can be used.

7.   For the calculation of Seismic Loading, the Response Spectrum Method is used.

4. Methodology

Kani's Method

        Prof. Gasper Kani of Germany in 1947 first introduced Kani's method. The method is named after him. This is an indirect extension of the slope deflection method. This is an efficient method due to the simplicity of moment distribution. The method offers an iterative scheme for applying the slope deflection method of structural analysis. Whereas the moment distribution method reduces the number of linear simultaneous equations and such equations needed is equal to the number of translator displacements, the number of equations needed is zero in case of the Kani's method. Kani developed a method of iteration for statically indeterminate structures. It is an approximate method that can save a good amount of time compared to the moment distribution method, especially when considering structural floors with a couple of stories or more.

        This method may be considered as a further simplification of the moment distribution method wherein the problems involving sway were attempted in a tabular form thrice (for double story frames) and two shear coefficients had to be determined which when inserted in end moments gave us the end moments. All this effort can be cut short very considerably by using this method. Kani developed a method of iteration for statically indeterminate structures. It is an approximate method that can save a great deal of time compared to the moment distribution method, especially when considering structural floors with a couple of stories or more. If you know the sum of restrained moments at a joint and know all the rotation contributions of members meeting at that point, you can find the end rotation contributions. After systematically working through the frame, you can determine the moments in those members in the structural frame.

Advantages of Kani's method:

•All the computations are carried out in a single line diagram of the structure.

•The effects of joint rotations and sway are considered in each cycle of iteration. Henceforth, no need to derive and solve the simultaneous equations. This method thus becomes very effective and easy to use especially in the case of multistory building frames.

•The method is self-correcting, that is, the error, if any, in a cycle is corrected automatically in the subsequent cycles. The checking is easier as only the last cycle is required to be checked.

•The convergence is quick. It leads to the solutions in just a few cycles of iterations.

5. Software

        Various types of software that are commonly used nowadays are enlisted below. In the construction industry, the innovation of software has stood as a boon for the analysis of structures. Instead of manual calculations, the software gives us various kinds of

results with a single click. They also suggest some better structures in case of failure.

ETABS

ETABS is engineering software for designing and analysis of multi-story buildings. Unique features of this include modeling tools and templates, code-based load prescriptions, analysis methods, and solution techniques, all coordinated with the grid-like geometry. Basic, as well as advanced structures under static or dynamic conditions, may be evaluated using ETABS. It includes seismic performance, modal and direct-integration time-history analyses, P-Delta, and Large Displacement effects. Nonlinear links and concentrated PMM or fiber hinges may capture material nonlinearity under monotonic or hysteretic behavior. Intuitive and integrated features make applications of any complexity practical to implement.

Multi-story buildings typically consist of identical or similar floor plans that repeat in the vertical direction and this is what is fundamentally used in ETABS. Modeling features that highlight streamline analytical-model generation, and analysis of advanced seismic systems, are listed as follows:

- Templates for global-system and local-element modeling
- Customized section geometry and constitutive behavior
- Grouping of frame and shell objects
- Nonlinear hinge specification
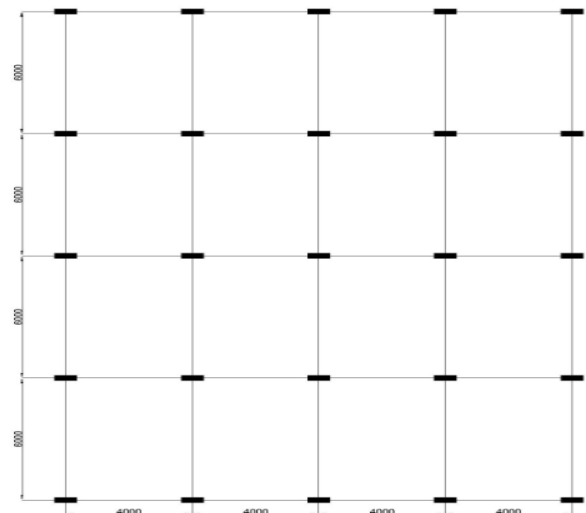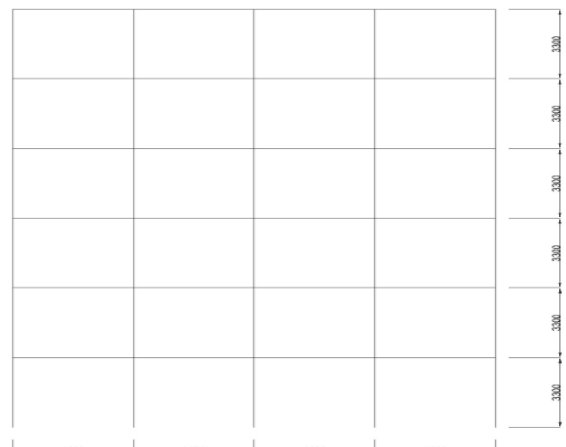- Automatic meshing with manual options
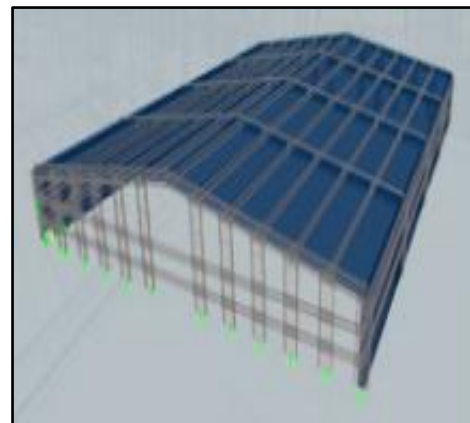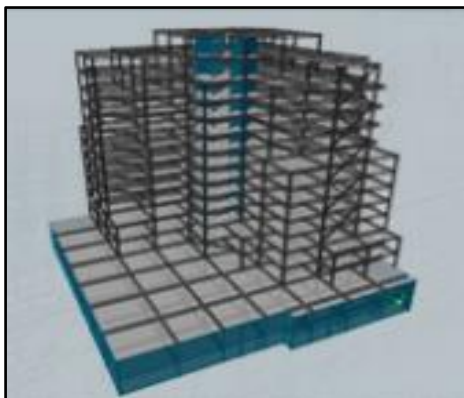
ETABS Interface View

6. KANI's Verification and Observation

Determination of Moments for Verification of ETABS Program using KANI'S method:

Typical Floor Plan of Frame

Top View of G+6 Model

Sectional Elevation C-C of G+6 Model

Member Size

Size of Column	= 700mmX250mm
Size of Beam	= 450mmX250mm
Slab Thickness	= 120mm
External Wall Thickness	= 250mm
Internal Wall Thickness	= 150mm

Design Data

Live Load	= 3 kN/m2
Floor Finish	= 1.5 kN/m2
Roof Finish	= 4.5 kN/m2
Density of Concrete	= 25 kN/m3
Density of Wall Masonry	= 20 kN/m3
Grade of Concrete	= M30
Grade of Steel	= 415

Fig 5.3 Slab Weight Distribution

Section C-C (From Top View)

Load Calculation

Weight on Roof:

I. Slab Weight	=Thickness X Density

=0.120X25.000

=3.000 kN/m2

Roof Finish	=4.500 kN/m2
Live Load	=3.000 kN/m2
Total	=10.500 kN/m2

Distributing this load on Beam, (Triangular) on frame of C-C Section

$$W = w.Lx/3$$

$$= \frac{10.500 \times 4.000}{3.00}$$

$$= 14.000 \ kN/m$$

II. Self Wt. Of Beam	=0.250X0.450X25.000
	= 2.813 kN/m

III. Self Wt. Of Wall	=3.300X0.150X20.000
	= 9.900 kN/m

Total UDL on Roof   =26.713   kN/m

Weight on Each Story:

I. Slab Weight	=Thickness X Density
	=0.120X25.000
	=3.000 kN/m2
Floor Finish	=1.500 kN/m2
Live Load	=3.000 kN/m2
Total	=7.500

Distributing this load on Beam, (Triangular) on frame of C-C Section
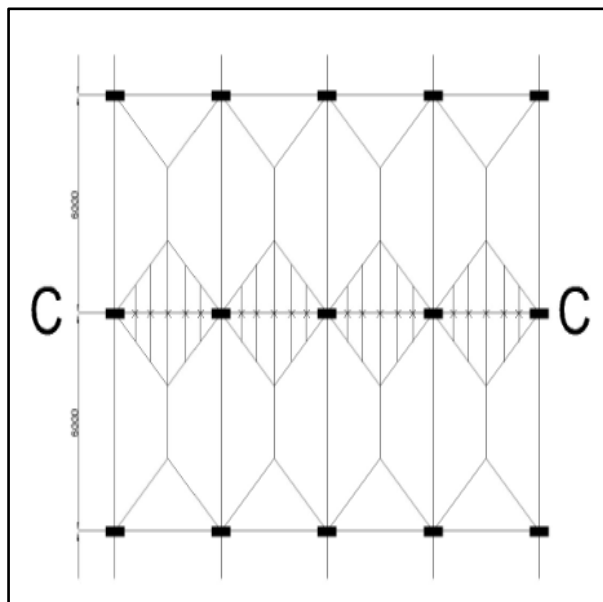
$$W = w.Lx/3$$

=	7.500X4.000		
	3.000		
=	10.000	kN/m	

II. Self Wt. Of Beam   =0.250X0.450X25.000

= 2.813 kN/m

III. Self Wt. Of Wall   =3.300X0.150X20.000
= 9.900 kN/m

Total UDL on Floors   =   22.713 kN/m
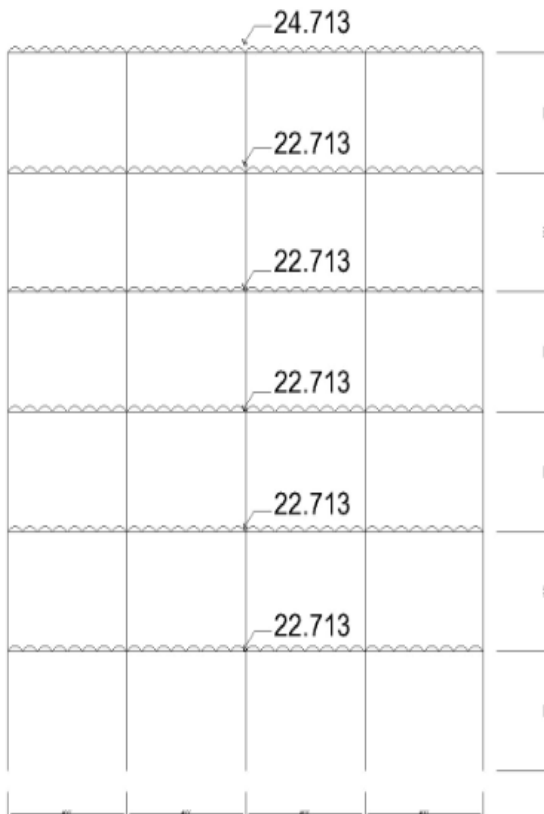
Uniform Distributed Load on the G+6 Frame

(C-C Elevation Section)

Earthquake Load Calculation (Manual)

Weight on Roof Level:

I. Slab Weight   =16X24X0.12X25.00

= 1152 kN

II. Floor Weight   =16X6X1.50

= 144 kN

III. Beam Self Weight=0.25X0.45X25.00X16+24

=0.25X0.45X25.00X40

= 112.5 kN

IV. Col Self Weight=0.25X0.75X25.00X1.65X25

= 193.36 kN

V. Wall Internal =1.425X0.15X20.00X48+72

=1.425X0.15X20.00X120

= 513 kN

Wall External =1.425X0.25X20.00X80

= 570 kN

Total Load   =   5855.86 kN   (for roof)

Weight on Each Floor:

I. Slab Weight   =16X24X0.12X25.00

= 1152 kN

II. Floor Weight   =   16X24X1.50

= 576 kN

III. Beam Self Weight   =0.25X0.45X25X16+30

=0.25X0.45X25X46

= 129.375 kN

IV. Col Self Weight   =0.25X.75X25X3.30X25

= 386.719 kN

V. Wall Internal   =3.30X0.15X20X48+72

=3.30X0.15X20X120

= 1188 kN

Wall External	=3.30X0.25X20X80
	= 1320 kN

VI. Live Load	=16X6X 3.00
	= 288 kN

Total Load	**=**	**5040.094 kN**
(for typical floor)		

Earthquake Lateral Load Calculation

Manual Calculation

Floor	Wi	hi	hi2	Wihi2	Factor	Manual Storey Shear	Base Shear Vb	From ETABS Storey Shear	%Diff
Roof(6)	5855.86	19.80	392.04	2295731.35	0.41	1426.06	1426.06	1410.07	1.13%
5	5473.22	16.50	272.25	1490084.15	0.27	925.61	2351.66	912.30	1.46%
4	5473.22	13.20	174.24	953653.85	0.17	592.39	2944.05	583.87	1.46%
3	5473.22	9.90	98.01	536430.29	0.10	333.22	3277.27	328.43	1.46%
2	5473.22	6.60	43.56	238413.46	0.04	148.10	3425.37	145.95	1.47%
1	5473.22	3.30	10.89	59603.37	0.01	37.02	**3462.39**	36.49	1.46%
	33221.96			5573916.47		3462.39		3417.12	

Z	Z/2	I	R	I/R	Sa/g	Ah	W	Vb
0.36	0.18	1.50	5.00	0.30	1.93	0.104	33221.96	3462.39

Manual Calculation	3462.39
ETABS Program	3417.12
% Difference=	1.32%

Manual Calculation

ETABS Calculation
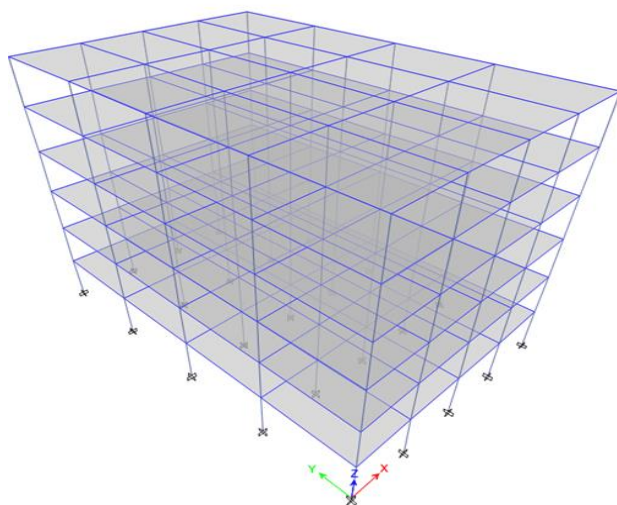
ETABS G+6 Model View

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern EQ X according to IS1893 2002, as calculated by ETABS.

Direction and Eccentricity

Direction = X

Eccentricity Ratio = 0% for all diaphragms

Structural Period

Period Calculation Method = Approximate

Structure Height Above Base, h_n

Coefficient, C_t [IS 7.6.1]

Approximate Fundamental Period, T_a [IS 7.6.1]

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2]   Z=.36
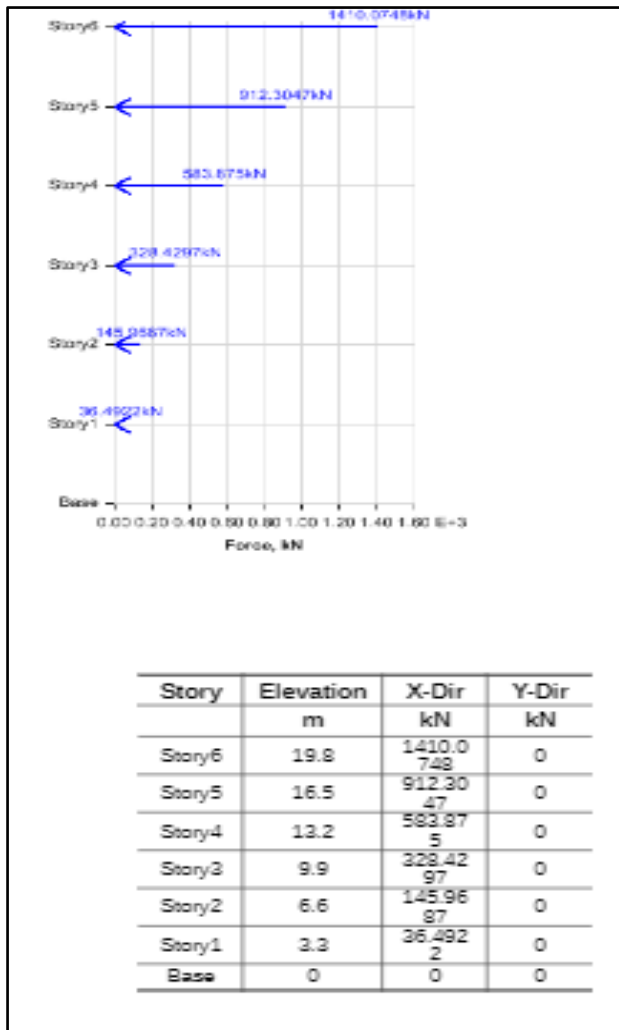
Response Reduction Factor, R [IS Table 7]   R=5

Importance Factor, I [IS Table 6]   I=1.5

Site Type [IS Table 1] = II

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5]

| Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story6	19.8	1410.0748	0
Story5	16.5	912.3047	0
Story4	13.2	583.875	0
Story3	9.9	328.4297	0
Story2	6.6	145.9687	0
Story1	3.3	36.4922	0
Base	0	0	0

Lateral Load on G+6 ETABS Model

The value from the manual working and the values from ETABS Program have been compared ahead between:
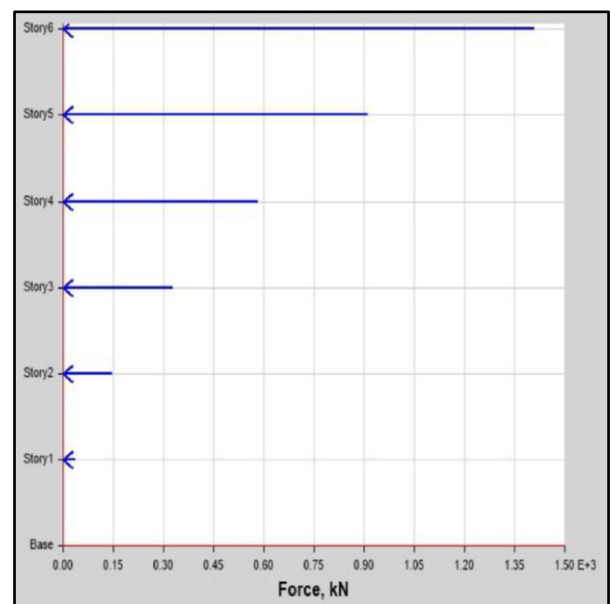
1. Lateral Load

2. Base Shear

3. Bending Moment

7. Comparison Between Manual and ETABS Program Values:
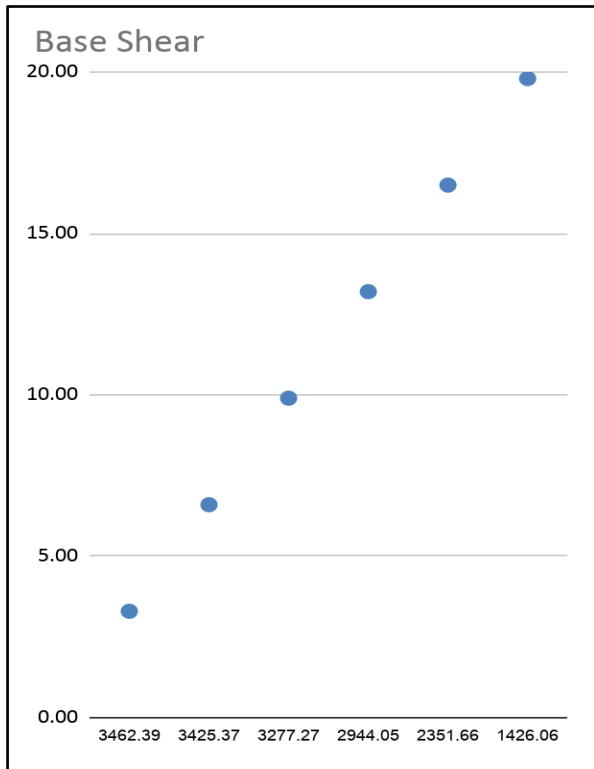
Lateral Load
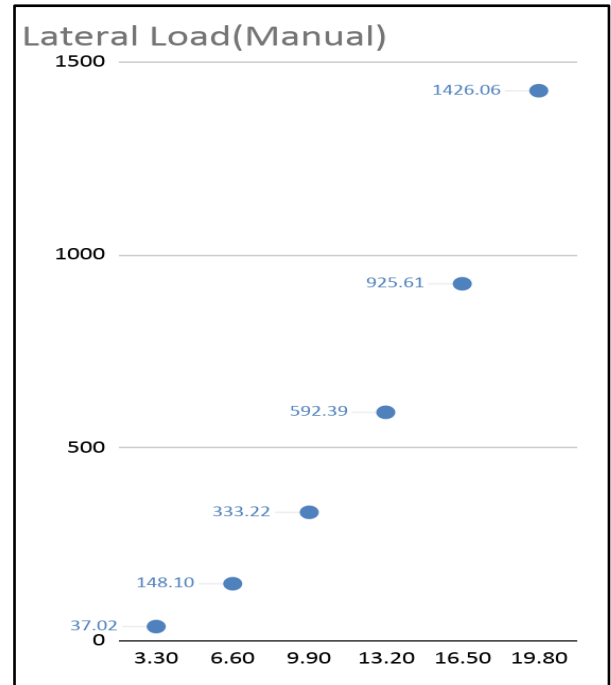
Forces are in X10^3

Lateral load from our Manual Calculation done on excel for Earthquake Force.
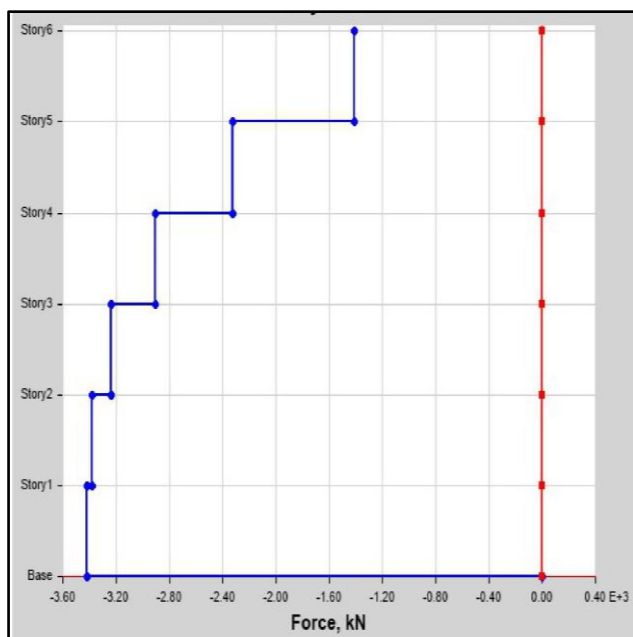

Forces are in X10^3

Lateral load from ETABS Program for Earthquake Force.

Base Shear

Forces are in X10^3

Base Shear from our Manual Calculation done on excel for Earthquake Force.
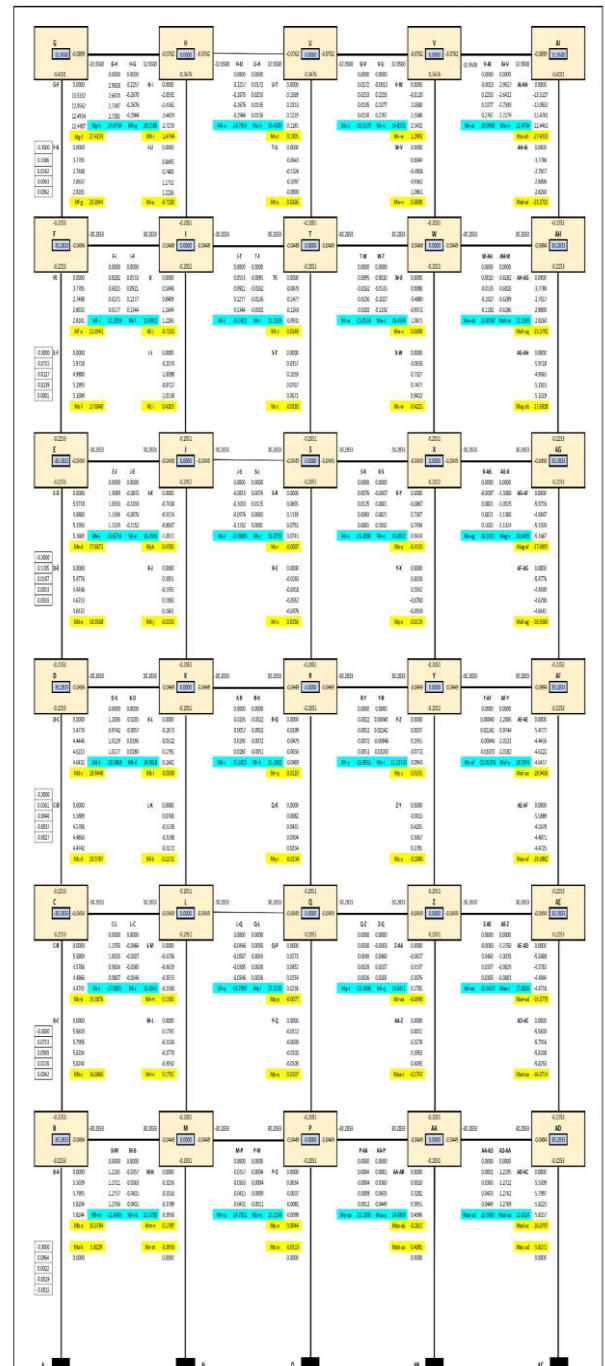

Forces are in X10^3

Fig 5.9 Base Shear from ETABS Program for Earthquake Force.
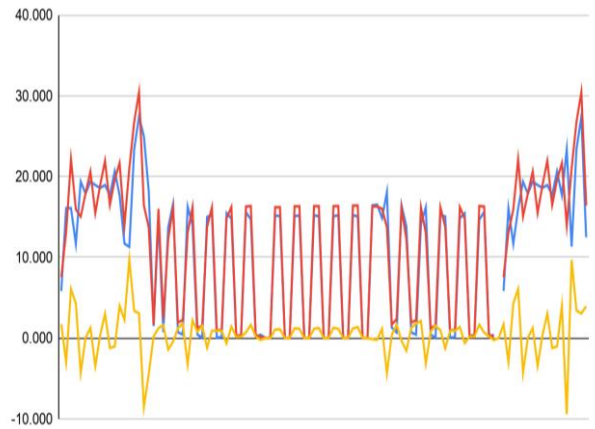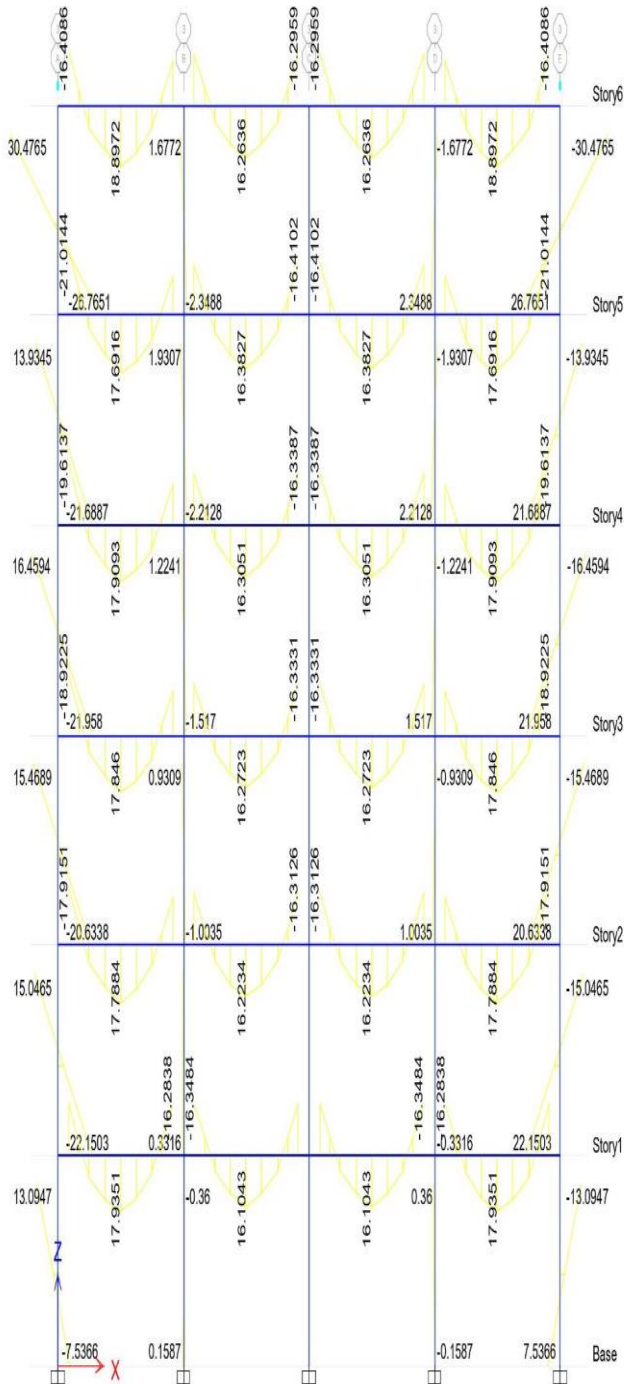
Moment (DL+LL)

Manual Calculation

Moment on Frame Manual Calculation

(C-C of Elevation of G+6 Floor Frame)

ETABS Program

Moment on Frame ETABS Program

(C-C of Elevation of G+6 Floor Frame)

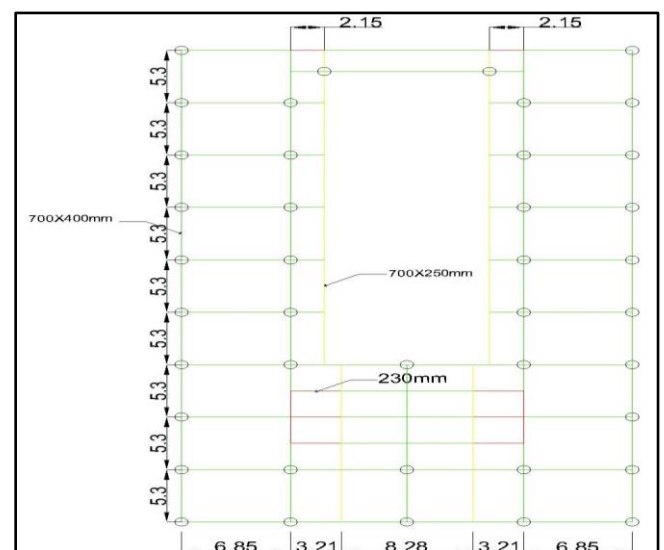## Graphical Representation of Moment Values

Graphical Representation of Moment Values

The variation between Manual and ETABS values is shown in the above table and it is shown in graphical representation which shows that Manual InDesign and ETABS value are very close and, in our verification, we got just 4 values more than ±5 kNm (If consider symmetrical structure it is just 2 values that exceed the range).

With this, we can say that the ETABS Program is reliable as it has similar values as manual calculation such as the KANI'S Method, that we used to find the above moment value.

High-Rise Building Dimension and Load

Typical Floor Plan:

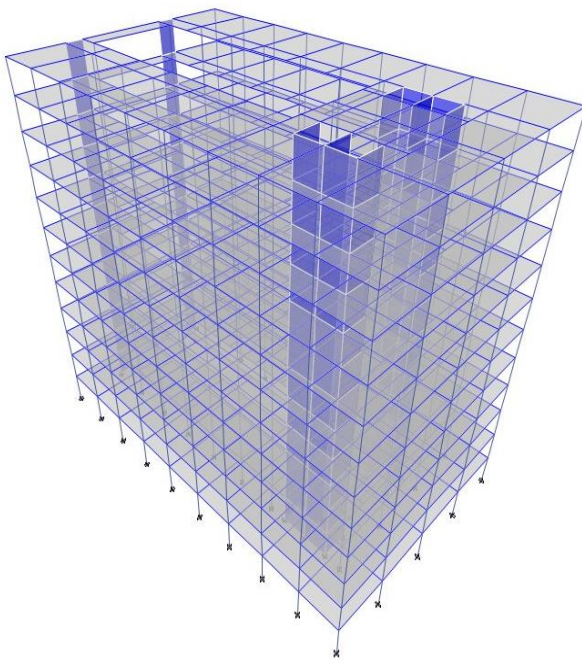

Member Size:

Floor to Floor Height= 3.75m

Beam Dimension 1= 700X400 mm (Rectangular)

Beam Dimension 2= 700X250 mm (Rectangular)

Column Dimension= 900 mm (Circular)

Slab Dimension= 150 mm

Exterior Wall Dimension= 250 mm

Interior Wall Dimension= 150 mm

Shear Wall Dimension= 230 mm

Grade of Concrete M30

Grade of Steel Fy415

Design Data:

Density of Concrete= 25

Density of Masonry= 20

Live Load= 3 kN/m2

Floor Finish= 1.5 kN/m2

Roof Finish= 4.5 kN/m2

Wind Load is applied on Diaphragm

Earthquake Load= 1.5 kN/m2 (Half of Live Load)

Mass Source:

Dead Load 100%

Live Load 25%

Floor Finish 25%

Roof Finish 25%

ETABS Model Data:

Typical floor plan of High-Rise Building

ETABS Plan

12-Story High-Rise Building
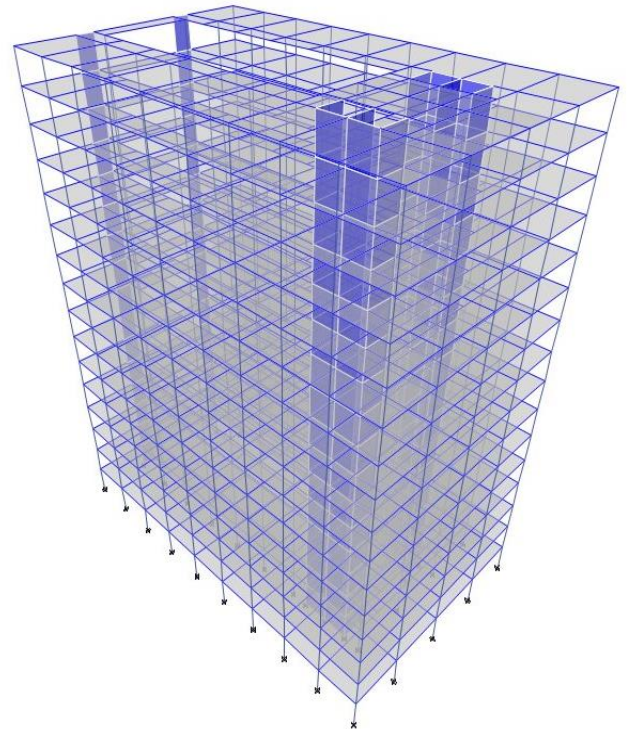
16-Story High-Rise Building

Story Data

Name	Height mm	Elevation mm	Master Story	Similar To	Splice Story
Story12	3750	45000	Yes	None	No
Story11	3750	41250	No	Story1	No
Story10	3750	37500	No	Story1	No
Story9	3750	33750	No	Story1	No
Story8	3750	30000	No	Story1	No
Story7	3750	26250	No	Story1	No
Story6	3750	22500	No	Story1	No
Story5	3750	18750	No	Story1	No
Story4	3750	15000	No	Story1	No
Story3	3750	11250	No	Story1	No
Story2	3750	7500	No	Story1	No
Story1	3750	3750	Yes	None	No
Base	0	0	No	None	No

12-Story Data

Story Data

Name	Height mm	Elevation mm	Master Story	Similar To	Splice Story
Story16	3750	60000	Yes	None	No
Story15	3750	56250	No	Story1	No
Story14	3750	52500	No	Story1	No
Story13	3750	48750	No	Story1	No
Story12	3750	45000	No	Story1	No
Story11	3750	41250	No	Story1	No
Story10	3750	37500	No	Story1	No
Story9	3750	33750	No	Story1	No
Story8	3750	30000	No	Story1	No
Story7	3750	26250	No	Story1	No
Story6	3750	22500	No	Story1	No
Story5	3750	18750	No	Story1	No
Story4	3750	15000	No	Story1	No
Story3	3750	11250	No	Story1	No
Story2	3750	7500	No	Story1	No
Story1	3750	3750	Yes	None	No
Base	0	0	No	None	No

16-Story Data

20-Story High-Rise Building

Story Data

Name	Height mm	Elevation mm	Master Story	Similar To	Splice Story
Story20	3750	75000	Yes	None	No
Story19	3750	71250	No	Story1	No
Story18	3750	67500	No	Story1	No
Story17	3750	63750	No	Story1	No
Story16	3750	60000	No	Story1	No
Story15	3750	56250	No	Story1	No
Story14	3750	52500	No	Story1	No
Story13	3750	48750	No	Story1	No
Story12	3750	45000	No	Story1	No
Story11	3750	41250	No	Story1	No
Story10	3750	37500	No	Story1	No
Story9	3750	33750	No	Story1	No
Story8	3750	30000	No	Story1	No
Story7	3750	26250	No	Story1	No
Story6	3750	22500	No	Story1	No
Story5	3750	18750	No	Story1	No
Story4	3750	15000	No	Story1	No
Story3	3750	11250	No	Story1	No
Story2	3750	7500	No	Story1	No
Story1	3750	3750	Yes	None	No
Base	0	0	No	None	No
Story20	3750	75000	Yes	None	No
Story19	3750	71250	No	Story1	No
Story18	3750	67500	No	Story1	No
Story17	3750	63750	No	Story1	No
Story16	3750	60000	No	Story1	No
Story15	3750	56250	No	Story1	No
Story14	3750	52500	No	Story1	No
Story13	3750	48750	No	Story1	No
Story12	3750	45000	No	Story1	No
Story11	3750	41250	No	Story1	No
Story10	3750	37500	No	Story1	No
Story9	3750	33750	No	Story1	No
Story8	3750	30000	No	Story1	No
Story7	3750	26250	No	Story1	No
Story6	3750	22500	No	Story1	No
Story5	3750	18750	No	Story1	No
Story4	3750	15000	No	Story1	No
Story3	3750	11250	No	Story1	No
Story2	3750	7500	No	Story1	No
Story1	3750	3750	Yes	None	No
Base	0	0	No	None	No

20-Story Data

Comparison between 20-16-12 Floor High-Rise Building Due to Earthquake Force:
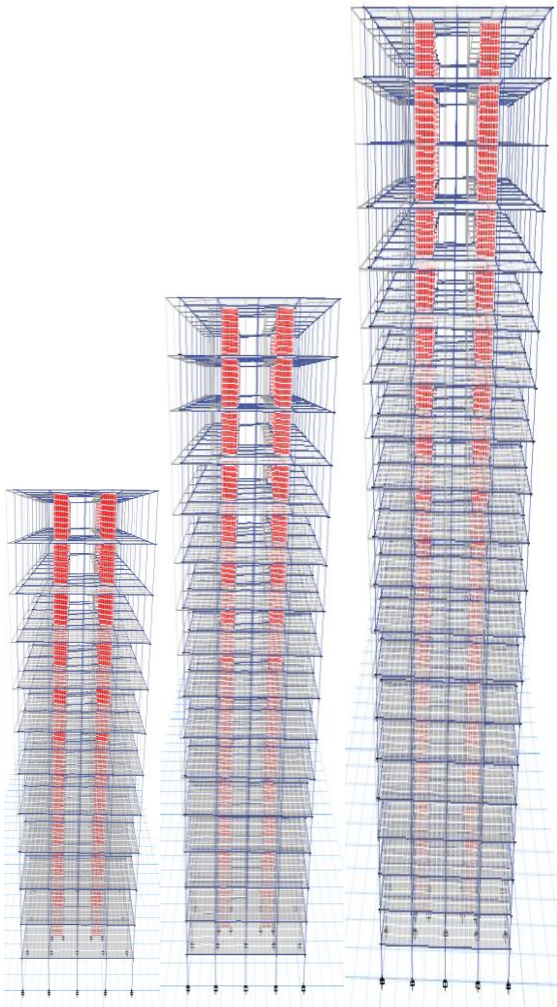
Axial Force
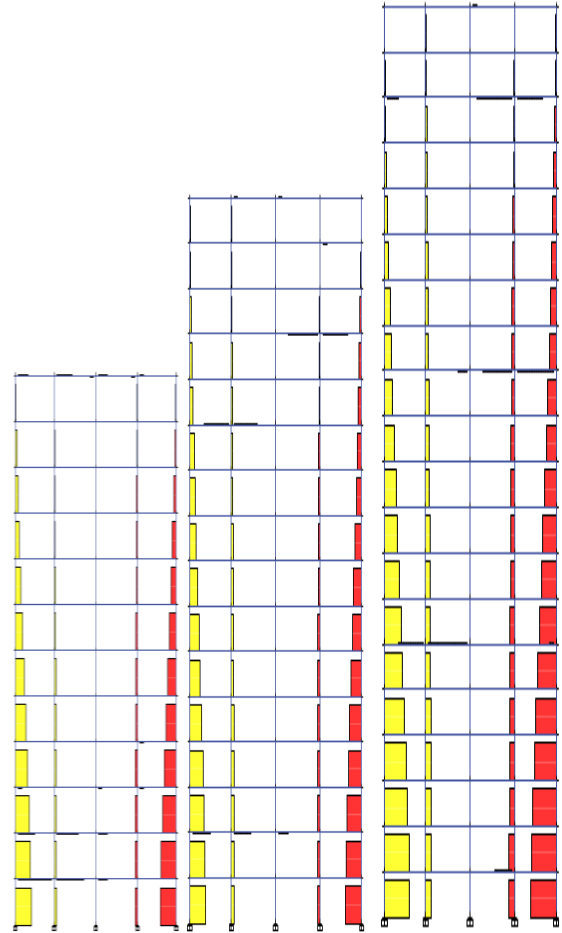
As we can see the axial force goes on increasing from top to bottom and with each story added to the structure.

The 20-floor high-rise building shows high axial load compared to 16 and 12-floor high rise buildings due to earthquake forces, also we can say that 16 floor high rise will be a proper structure with the same dimension as it will be safe when compared to 20 floors but economical than 12-floor high rise building.

Deformed Shape

Buildings become laterally flexible as their height increases. Flexural type behavior is exhibited only near the lower stories where the axial deformation in the columns could be significant, particularly in tall buildings. However, at higher floor levels, the response changes to shear type as the axial load level lowers.

**Fundamental Natural Period of Buildings**
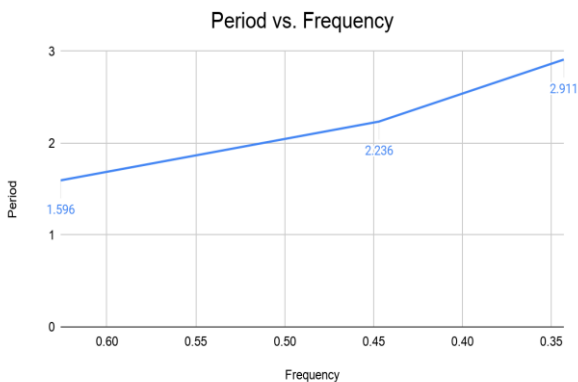
Period v/s Frequency

Building Floor	Period	Frequency
12	1.596	0.626
16	2.236	0.447
20	2.911	0.343

As the height of the building increases, its mass increases but its overall stiffness decreases. Hence, the natural period of a building increases with an increase in height. Buildings with 12, 16, and 20 floors have the same plan but are of different heights. Taller buildings have larger fundamental natural period than shorter ones.
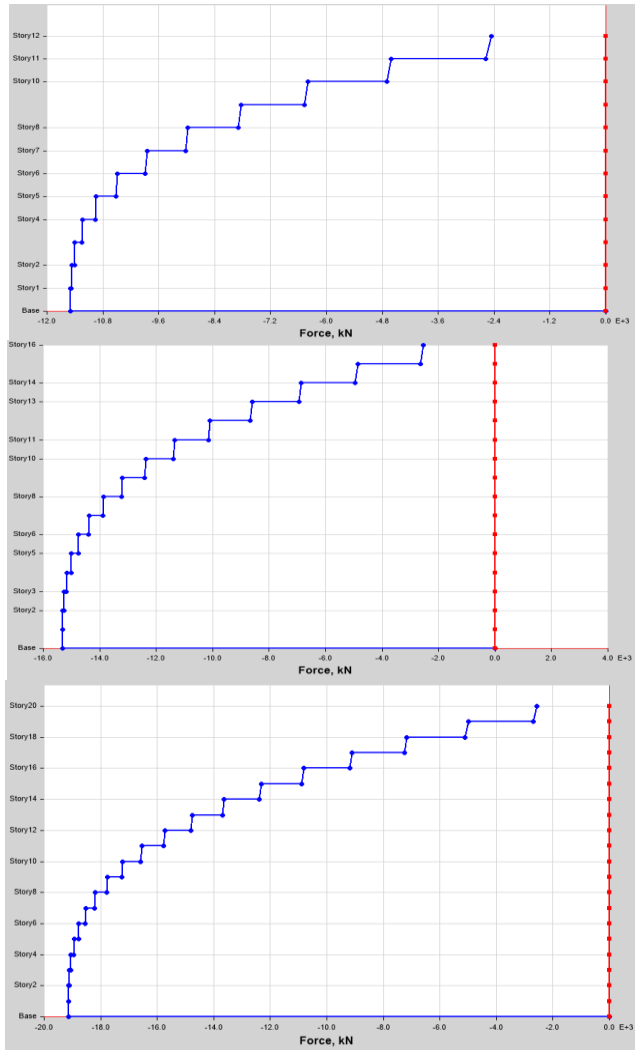
Lateral Load
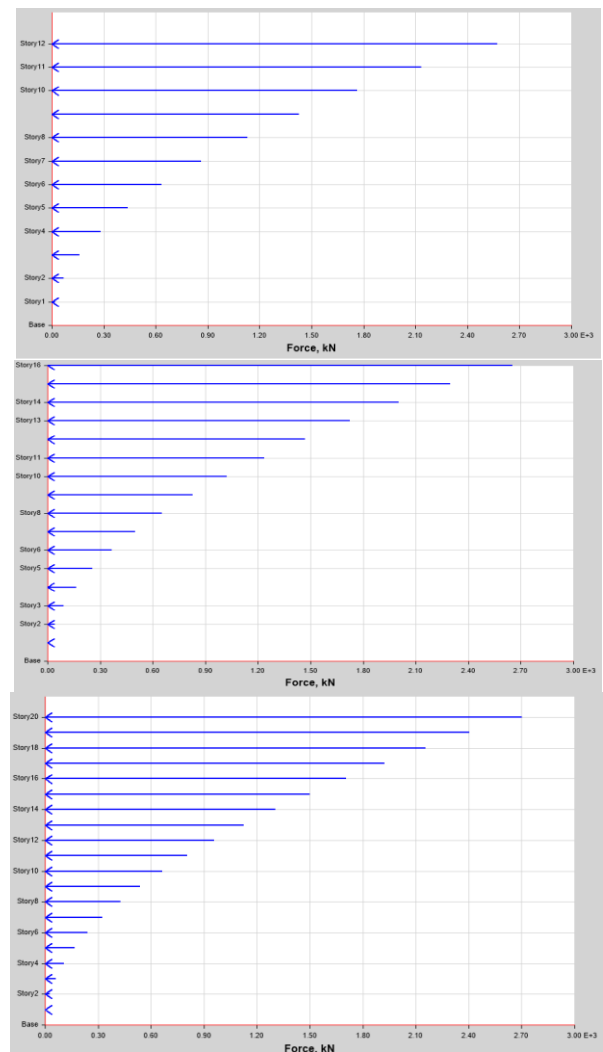
These loads can cause a structure to shear or bend along the direction of the forces. Lateral loads also

exert constant and instantaneous forces and vary with the shape and height of the building. Hence, we see that a 20-floor high-rise building faces high lateral force and deforms mode than the other two.
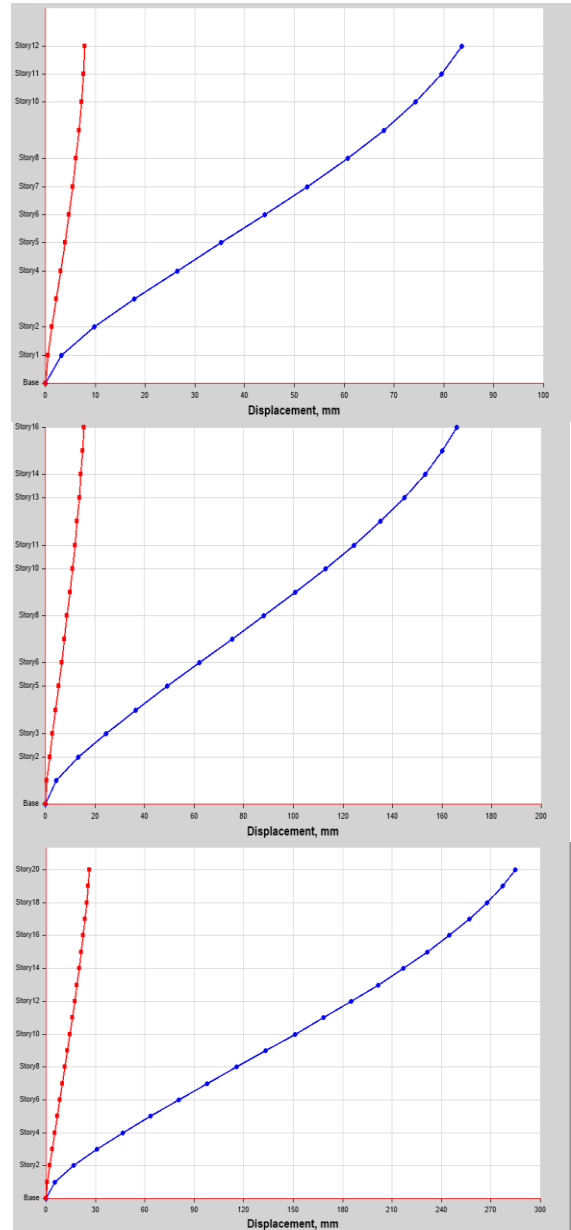
Base Shear

These graphs show the trend of base shear as the height of the structure increases. It gives the value of total lateral force at the base of the structure.

Base Shear also increases with weight, stiffness, and location of the building near/far from the fault line.

Maximum Story Displacement

These graphs show the variation of maximum displacement of the structure as the height of the structure increases. It shows the displacement at any height of the structure concerning the ground. Lateral displacement is least in buildings with global braces, while it is maximum in (bare) moment frame buildings.

Maximum Story Drift
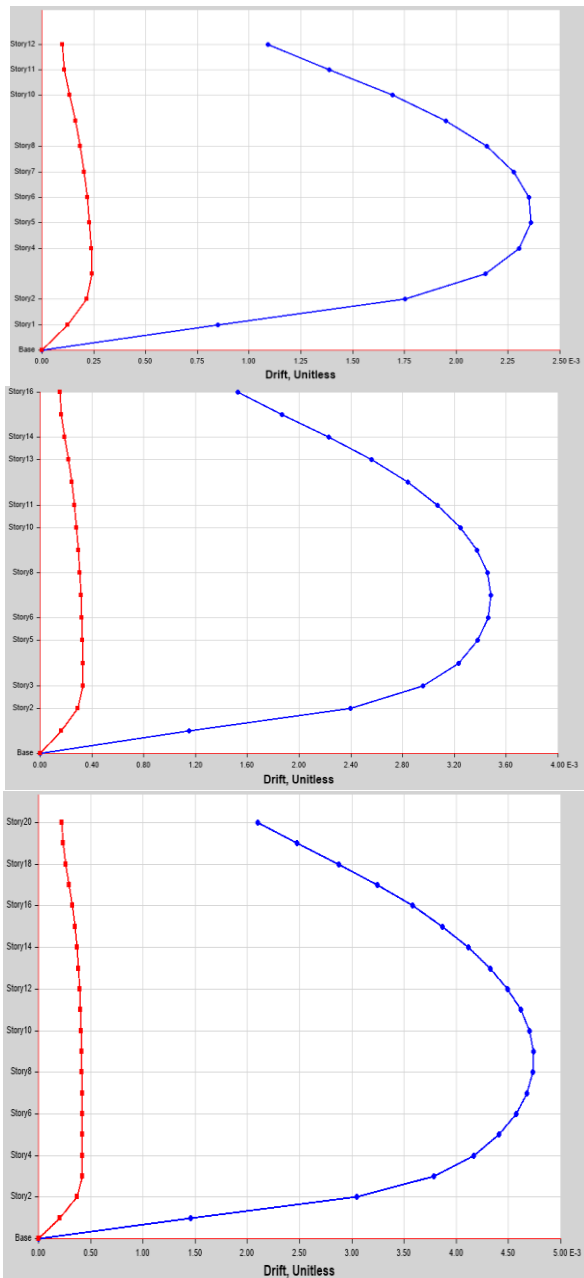
These graphs show the variation of storey drift as per changing height of the structure. It generally gives the ratio of two consecutive floors to the height of the floor.

8. SUMMARY

ETABS software proves to be very convenient and reliable for analysis of multistoried structures with consideration of earthquake forces. The software also provides the values of various factors in graphical form, which can be used to compare and trends the structure. The structure can be viewed from multiple angles and automatically generate the reports and graphs after the design is performed.

For manual calculation of the moments acting on the structure, Kani's method can be used conveniently. This method involves the calculation of unknown FEM of the structural members acting on their adjacent joints such that they satisfy the conditions of continuity of slope and displacement.

After manual calculation of a sample structure using Kani's method and designing the same structure on the ETABS, the values of the final moments showed many similarities. There was a slight variation in the values of final moments at some joints due to a difference in the number of iterations on software and excel. The graph attached in the comparison report shows the trend of the final moment values and proves there is much similarity in the values obtained.

After designing the same structure for 3 different numbers of floors (i.e., 20 floors, 16 floors, 12 floors) we analyzed the trend of different values such as story drift, base shear, overturning moment, etc. The graphs of each of these different factors can be used for comparing the trend in which these values differ from each other as the number of floors is changed.

This comparison can help in deciding the best design of the structure so that it can be designed and constructed with maximum safety and minimum flaws.

The graphs can also provide values at any floor of the structure and the design can be modified accordingly.

9. CONCLUSIONS

After comparing the final moment values by KANI'S Method and ETABS it can be concluded that the values are quite similar but there are slight variations at some joints owing to the limitations of iterations in the manual calculation. The calculation of seismic lateral force by manual method and by ETABS showed almost similar value. Hence, ETABS is reliable and convenient for the seismic design of the multistoried structure and provides a detailed report and analysis of the designed structure.

The ETABS software is very convenient for seismic calculations and provides detailed reports, drawings, tables, and graphs, which can be used in analysis and design. The conclusion can be made that as the story goes on, the Earthquake Force acting on top of the story increases and thus increases the various factors acting on the structure.

10. REFERENCES

1. https://theconstructor.org/earthquake/i-s-codes-earthquake-resistant-building-design/6427/#:~:text=The%20list%20of%20In

dian%20standard,%2C%20IS%3A%2013935%E2%80%931993

2. https://www.iitk.ac.in/nicee/skj/Research_Papers/Review-IndianSeismicCodeIS1893(Part1)2002.pdf

3. https://civilengineering.blog/2017/11/04/dead-loads-live-loads-wind-loads/#:~:text=Dead%20loads%20includes%2C%20the%20self,(part%2DI)%2D1987

History

http://ijetch.org/papers/671-EA1012.pdf

Precaution

1. https://www.nbmcw.com/tech-articles/tall-construction/36266-india-s-towering-aspirations-a-reality-now.html

2. https://rahat.up.nic.in/sdmplan/Earthquake/AnnexureI-V/AnnexureI_Bldg.%20Earthquake.pdf

Methodology

Approximate method

1. https://nptel.ac.in/content/storage2/courses/105105109/pdf/m6l36.

2. https://www.nitsri.ac.in/Department/Civil%20Engineering/Civil_401_Chapter_9.pdf

KANI'S Method

1. http://www.sietk.org/downloads/QB/B.Tech/Civil/III%20B.Tech/STRUCTURAL%20ANALYSIS%20-II/UNIT-III.pdf

2. http://ethesis.nitrkl.ac.in/2395/1/STUDY_OF_SUBSTITUTE_FRAME_METHOD_OF_ANALYSIS_FOR_LATERAL_LOADING_CONDITIONS.pdf

Software

1. https://wiki.csiamerica.com/display/etabs/Home

2. https://wiki.csiamerica.com/pages/viewpage.action?pageId=9896206

Earthquake Behavior of Structure

(Graph and Explanation)

https://www.iitk.ac.in/nicee/IITK-GSDMA/EBB_001_30May2013.pdf