COMPARISON OF STATIC AND LINEAR DYNAMIC METHODS OF ANALYSIS IN CONTEXT OF IS1893:2016 AND EUROCODE 8.

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Submitted By
GATBEL BUONY
2K17/STE/022
Under the supervision of
Prof. ALOK VERMA

CIVIL ENGINEERING DEPARTMENT
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042
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DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, (GATBEL BUONY), Roll No.2K17/STE/22 student of M.Tech (Structural Engineering), hereby declare that project desertation titled “COMPARISON OF STATIC AND LINEAR DYNAMIC METHODS OF ANALYSIS IN CONTEXT OF IS1893:2016 AND EUROCODE 8” which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi, in partial fulfillment of the requirement for the award of degree of Master of Technology is original and not copied from any source without proper citation. This work has not been previously formed the basis for the award of any degree, Diploma Associateship, Fellowship or other similar title or recognition.

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Date …………………………..

CIVIL ENGINEERING DEPARTMENT
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled "COMPARISON OF STATIC AND LINEAR DYNAMIC METHODS OF ANALYSIS IN CONTEXT OF IS1893:2016 AND EUROCODE 8" which is submitted by GATBEL BUONY Roll No 2K17/STE/22 (Civil Engineering Department), Delhi Technological University, Delhi, in partial fulfillment of the requirement for the award of degree of Master of Technology is a record of project work carried out by student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any degree or diploma to this University or elsewhere.

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Place: Delhi Prof. ''SUPERVISOR'' ALOK VERMA
Date ………………………………………..

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Signature ………………………..
Place: Delhi GATBEL BUONY (M.TECH)

ABSTRACTS

Earthquake motion causes a vibration of the structure leading to inertia forces. Thus a structure must be able to safely transmit the horizontal and the vertical inertia forces generated in the superstructure through the foundation to the ground. In earthquake-resistant design, it is required that the response of the structures to induced seismic forces is within the acceptable limit. In Indian IS1893:2016 standard, the regulations are not intended that no structure shall suffer any damage during the earthquake of all magnitudes. It has been endeavored to ensure that, as far as possible, structures are able to respond, without structural damage, to shocks of 'moderate intensities and without total collapse to shocks of heavy intensities.

The analysis of earthquake resistant design of structure can be done either by a linear or non-linear method [1]. In this paperwork, a comparative study has been conducted on four different frames using linear static and linear dynamic methods of analysis. In each frame, the response quantities have been determined for the 3-an increment of story number started with the one of three up to twenty-seven story framed buildings. This means that for each frame, nine different building having the same materials and the same loading conditions but different height have been analyzed. The responses quantities for these buildings are determined by taking the application guidance provided in IS1893: 2016 and that of the EUROCODE 8.

In applying the Indian code of standard, IS1893:2016, it has been observed that as the number of story increases, the seismic weight keep increasing. The natural period for the first mode becomes longer as the number of the story increases. This

means that for 3 story frame, the natural periods can be shorter than that of 6 stories framed building for the first mode in each orthogonal direction. This has a tremendous effect on the values of shear forces. It has observed that when the Natural period is in the interval of (0-0.55) the shear values increase as the number of story increase, but when it is in the interval of (0.55-4) the shear values decrease as the number of story increases. This phenomenon has been observed for medium soil type. It has been observed that the linear dynamic method produce higher response values than that of the linear static method. Furthermore, the mode shapes have been determined for 9 stories framed building using both EXCEL and ETABS and the variation of the results is not that much.

In applying the Eurocode 8, the seismic weight and natural period, show the same pattern as observed in the Indian code of standard. The base shear values decrease as the number of story increase when the natural period is less than 4Tc or 2. It increases for both linear static and linear dynamic method as the number of story increase whenever the natural period is greater that 4Tc or 2. For a building with less story number, the linear dynamic methods of analysis procedure higher response values than that of the linear static method. As the number of story increase, the linear static method resulted in an excessive response value than that of the linear dynamic methods. The axial, shear and bending moment for a column of 3 stories and that of 27 stories has been determined. It turns out that, for 3 stories framed building, the linear dynamic analysis produces a higher response value. But for that of 27 stories framed building, the reverse is true. It has been observed that the two codes show different response patterns.

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V_B	Design seismic base shear
A_h	Design horizontal earthquake acceleration coefficien
W	Seismic weight of the building
Z	Seismic zone factor
I	Importance factor
T_a	Approximate fundamental period (in second)
$(\frac{Sa}{g})$	Design / Response acceleration coefficient for rock or soil sites as given by Fig. 2 and 6.4.2 based on appropriate natural period
Si	Lateral shear strength of storey i
R	Response reduction factor
Q_i	Lateral force at floor i
h_i	Height measured from the base of the building to floor i
n	Number of storeys or floor
m_k	Modal mass of mode k Number
p_k	Mode participation factor of mode k
w_i	Seismic weight of floor i
Φ_{ik}	Mode shape coefficient at floor i in mode k
Q_{ik}	Design lateral force at floor i in mode k
A_{hk}	Design horizontal earthquake acceleration spectrum value for mode k of oscillation
λ	Peak response (for example, member forces, displacements, storey forces, storey shears or base reactions) due to all modes considered
λ_k	Absolute value of maximum response in mode k
r	number of modes being considered
λ_i	response quantity in mode i (including sign)
λ_j	response quantity in mode j (including sign)
ρ_{ij}	Coefficient used in complete quadratic combination (CQC) method while combining responses of modes i and j
ζ	modal damping ratio

β	frequency ratio = ω_j/ω_i
ω_i	Circular frequency (in rad/s) in mode i
ω_j	circular frequency in j^{th} mode
Sd(T)	design spectrum (for elastic analysis). At T=0, the spectral acceleration given by this spectrum equals the design ground acceleration on type A ground multiplied by the soil factor S
F_i	*horizontal seismic force at storey i*
F_b	*base shear force*
T	vibration period of a linear single degree of freedom system
s_i	displacement of mass mi in the fundamental mode shape of a building
s_j	displacement of mass mj in the fundamental mode shape of a building
h_i	height of mass mi above the level of application of the seismic action
h_j	height of mass mj above the level of application of the seismic action
E_E	effect of the seismic action
E_{Ei}	is the value of this seismic action effect due to the vibration mode i
λ	is the correction factor, the value of which is equal to: λ = 0,85 if T1 < 2 TC and the building has more than two storeys, or λ = 1,0 otherwise
M	mass of th building
m_i	mass of storey i
m_j	mass of storey j
$\psi_{E,i}$	combination coefficient for a variable action i, to be used when determining the effects of the design seismic action
$\psi_{2,i}$	combination coefficient for the quasi-permanent value of a variable action i
$\mathrm{C_t}$	is 0,085 for moment resistant space steel frames, 0,075 for moment resistant space concrete frames and for eccentrically braced steel frames and 0,050 for all other structures
$\mathrm{a_g}$	design ground acceleration on type A ground
g	acceleration of gravity
α	ratio of the design ground acceleration to the acceleration of gravity

S	soil factor
T_B	is the lower limit of the period of the constant spectral acceleration branch
T_C	is the upper limit of the period of the constant spectral acceleration branch
T_D	is the value defining the beginning of the constant displacement response range of the spectrum
β_0	is the lower bound factor for the horizontal design spectrum.
q	behaviour factor
γ_1	importance factor

CHAPTER 1: INTRODUCTION

An earthquake force is generated on the building structure due to the release of energy from the seismic source under the surface layer of the earth which travel like a motion. This energy is released due to certain factors such as explosion which is being created by the human activities, volcanic eruptions in the location, dislocation of the segment of the earth crust. Among the others, dislocation of crust segment resulted in the most damaging quake[2]. When the earthquake strict a particular building, it creates an inertia force in the vertical and horizontal direction as well. These forces need to be transferred effectively from the superstructure part to the supporting soil. Therefore, in the earthquake resistant design, it is required to make sure that the structure will respond to a particular earthquake without total collapse. In this paper, two codes have been taken to investigate the variation of the magnitude of seismic base shear and also for Shear forces and bending moments for Exterior edge, Exterior middle, and Interior middle columns by applying linear static and dynamic methods of analysis. These standards are IS 1893:2016 and Eurocode 8.

In India, IS1893 is the standard which provides the principle guidance procedures through which the designers can determine the seismic forces on the structure. It must be brought into our understanding that the seismic response of the structures depends on the mass of the structure under investigation and the seismic coefficients such as zonal factor, the importance of the structure, stiffness of the load resistance components, soils types. E.t.c,. When we take a look at IS1893:2002, it deals with the determination of the seismic induced action on the various part of the structural component of the building structure.

The standard permit the use of either linear static or linear dynamic method of analysis based on the height of the structure to be design for seismic-resistant and the zonal location. To analysis the structure by linear dynamic method, one may use either time history dynamic method of analysis or respond spectrum. However, in either of these methods, the calculated design base shear (V_B) shall be compared with a base shear ($\bar{V}_B$)obtained using a fundamental periodT_a. Where V_B is less than ($\bar{V}_B$), the values of response quantities resulted need to be multiplied with the ratio of ($\bar{V}_B/V_B$)[3].

Bureau of Indian Standards has introduced the 6th revision of seismic code IS1893 as a draft in the year 2016 and finally as code in 2017[4]. This version has given different curves for spectral acceleration coefficient (Sa/g) for both static and dynamic methods separately. A new formula is provided for calculation of fundamental time-period of structures with shear walls. The code also limits the application of the linear static method of analysis to the regular building up to 15m height in Zone II[1].

EN1998 is applied to the design and construction of the building and civil engineering related works in the seismically vulnerable areas. The main purpose of the standard is to ensure that in the event of an earthquake, the human lives are protected, damages are limited and structures important for civil protection remain operational. This Eurocode 8 is further sub-divided into EN 1998-1 up to EN 1998-6 [5]. EN 1998-1 is subdivided into 10 Sections, some of which are specifically devoted to the design of buildings. Section-2 focused on the performance requirement and the compliance criteria's applicable to buildings and other civil Engineering structures, Section-3 give the representation of seismic action on the building and their combination with other loads. Section-4 is devoted to the general design rule which is specific to the building. Section-5-9 contain the various specific rule for the material and element for the building structures. Finally, Section 10 incorporates the important parameters with respect to base isolation of the building structures. They range from the fundamental requirements and safety-related issues which are specific to the base isolation[5].

For the two standards, the use of the linear static method of analysis is limited to the buildings with less height. In a view to exploring some of the reasons for which the codes restrict the method, this work has been done. In this project work, four different frames have been analyzed by considering the same loading condition. The first frame is five by six bays with a shear wall around the lift and the staircase being considered in the model. The second one is a frame of five by six bays where the beams and columns are only considered in the model. The thirds frame is a regular three by three bays. The last one is a frame of six by six bays of four meters width in each orthogonal directions. The base shear has been determined for different story number.

First, a frame having three story number has been considered. To investigate the effect of building height on base shear values, for each frame, the seismic effect has been determined for different story number. For three- an increment of story number, the values of seismic forces have been obtained for both linear methods of analysis. The base shear for three, six, nine, twelve and up to twenty-seven stories has been obtained and the values were compared in the excel sheet. To figure out the earthquake forces on different columns, the shear forces and bending moments for interior-middle, exterior edge, and exterior- middle columns were taken for the fourth frame. The shear and bending moments values have been compared for the two methods of analysis.

CHAPTER 2: BACKGROUND OF IS1893 AND THE METHODS OF ANALYSIS

2.1 Introduction

Natural ocurring disastrous events have influenced human existence in an immemorable period of time. Despite its impact on society, human has dealt with its negative influence and coexist with such phenome in vulnerable areas. Of all natural disaster, e.g., Earthquakes, floods, tornadoes, hurricanes, droughts, and volcanic eruptions, the least understood and the most destructive are Earthquakes. The earthquake force is an inertial force caused by the ground accelerations [2].To design the structure to resist the effect of earthquake forces, the first Indian standard(1893:1962) was published in the year 1962 by Bureau of Indian standard. The code has been revised in 1966, 1970, 1975, 1984 and 2002. With the rapid development in the area of earthquake engineering, enormous research works have been conducted. The committee decided to put different structures provision, for the fifth revision (IS1893:2002), into five separate parts. This resulted in [6];-

- Part 1 General provisions and buildings
- Part 2 Liquid retaining tanks - Elevated and ground supported
- Part 3 Bridges and retaining walls
- Part 4 Industrial structures including stack like structures
- Part 5 Dams and embankments

Though this part 1 contains the provisions which are specific to the buildings structures unless it is stated in a particular section, it should be used in conjunction with part 2 to 5[3]. It should be noted that in the Zoning map used to determine the Zone coefficient for the seismic base Shear determination, zone I and zone II have been merged and assigned as zone II in the fifth revision. The structural response to the earthquake action would be affected by the types of foundation system being used in addition to the underlying soil type. The standard provides the guidelines for which the designer can grasp the seismic coefficients based on the properties of the soil by considering the effect in a gross manner. It also offers general principles and design criteria and specifies seismic design lateral forces[6]. The Bureau of Indian Standards has introduced the 6th revision of seismic code IS1893 as a draft in the year 2016 and finally as code in 2017[4].

2.2 General principle of IS1893:2016

Clause 6.1 of IS1893 (part1):2016 provides the following aseismic design principles.

I) The earthquake motion can be resolved into each perpendicular direction to determine its effect. The most dominant one is that of the horizontal one.

II) Vertically generated inertia due to earthquake needs to be considered. This force may be ignored if it is not sufficient to be considered. Earthquake acceleration component in vertical direction needs to be considered for pre-stressed, slabs and cantilevered members. For overall stability of structure with large span, this component has to be taken into account.

III) The standard provides the specification for determination of the seismic action on structures which stand on the rocks, or hard soils which do not settle, slide or get liquefy due to the reduction of strength during ground vibration.

IV) The design approach adopted in this code is to ensure that structures possess at least a minimum strength to withstand a minor earthquake without damage, resist moderate earthquakes without significate structural damages and withstand a major earthquake without collapse.

V) Though the actual seismic loads are larger than the design force considered in the code, the ductility, over strength and detailing provide an extra safety margin

VI) In this standard, it is required that the design lateral force shall be taken in each orthogonal horizontal directions of the structure. The force shall be applied to each direction one at a time for the structure having resisting members in both orthogonal axes. A structure having lateral force resisting elements in a direction other than the two orthogonal directions, shall be analyzed considering the load combination in such a way that the full load will be applied on one direction plus 30 percent of the design earthquake load in other directions [1].

2.3 Assumptions in earthquake resistant design of structures

The following assumptions shall be made in the earthquake resistant design of structures:

a) The Earthquake caused a vibration of the structure is considered to last for a small duration so that the resonance which can be observed on Steady-state sinusoidal excitation will not occur as it will require time to reach such Amplitude of vibration.
b) The Simultaneous occurrent of an earthquake with the wind, maximum sea wave or other actions like flooding is considered un-probable.
c) The elastic modulus of materials to be used for application in a specific condition may be used as the same as that of static analysis unless otherwise stated (see IS 456, IS 1343 and IS 800)[1].

2.4 Method of Analysis

The response of buildings structure to earthquakes action is dynamic in nature which resulted in a complex, three dimensional, and nonlinear characteristic phenomena. Mos simplified procedures for the determination of the seismic effect where produced due to the limitation of the technology and lack of full understanding of the general nature of earthquake. These include non-linear Static procedure (NSP) which neglect the effect of dynamic nature of earthquake, Linear static method which neglects both dynamic and nonlinear nature of earthquake, Linear dynamic method which neglects the Nonlinear nature of it. In contrast, nonlinear dynamic method regards the nature of the earthquake without all the above mentioned simplified assumptions [7].

2.3.1 Linear Static Procedure (LSP) as per the Indian Code of standard

At any floor, the earthquake force is the product of the total mass of the floor and its acceleration. This force is transferred to the supporting elements. The amount by which different vertical elements share the force depends on the floor diaphragm actions, the lateral stiffness of the vertical elements and torsion in the building due to eccentricity. Therefore, the design of the lateral force shall first be computed for the whole building. This design lateral force shall then be distributed to the various floor levels of the building. The overall design seismic forces thus obtained at each floor levels, shall then be distributed to the various lateral load resisting elements depending on the floor diaphragm actions [6].

2.4.1.1 Design Seismic Base Shear

The design Total lateral force or the base shear produced by the seismic induced motion can be determined using the following expressing [1];

$V_B = A_h W$ …………………………………………...……… (2.1)

Where,

A_h= Design horizontal spectrum value obtaining using the fundamental natural period of vibration in the direction on consideration

W=Total seismic weight of the building structure

2.4.1.2 Parameters for the determination of seismic Coefficient A_h

A_h=($\frac{ZIS_{a/g}}{2R}$)……………………………………………. (2.2)

Where:- Z=Zone factor given from the table below

a) Zonal Factor

Table 2 1: Zone factor as given in (IS1893; Table 3)

Seismic zone	II	III	IV	V
Seismic Intensity	Low	Moderate	severe	Very severe
Z	0.10	0.16	0.24	0.36

b) Important Factor I

This is a parameter which depends on the function for which the particular structure was built. It is given in (IS-table 8). It is equal to 1 for all other types of building and is equal to 1.5 for service and community building such as school, hospital and emergency building like telephone exchange .etc. For residential building, it is equal to 1.2 [1].

c) Response reduction R

This is the factor which takes into account the energy dissipation capacity of the particular structural system used for the lateral load resistant. This factor depends on the perceived seismic damage performance of the structure during an earthquake, characterized by ductile or brittle deformations. It is given in (IS1893: 2016, table 9) for different lateral load resisting system. It should not be underestimated that the Code restricts the use of RC and Steel structure in Seismic Zone III, IV, V [1].

d) Spectral acceleration Coefficient Sa/g

It is a factor which depends on the characteristic of the underlying soil properties, Fundamental time period and damping of the structure. The value of this parameter can be determined by using one of the below formulas [1].

1) For use in the equivalent static method

$$=\left\{\begin{matrix} 2.5 & 0 < T < 0.40 \\ \frac{1.0}{T} & 0.40 < T < 4.00 \\ 0.25 & T > 4 \end{matrix}\right\}\text{..For rocky, or hard soil sites}$$

$$\left(\frac{Sa}{g}\right)= \quad =\left\{\begin{matrix} 2.5 & 0 < T < 0.55 \\ \frac{1.36}{T} & 0.55 < T < 4.00 \\ 0.34 & T > 4 \end{matrix}\right\}\text{ for medium soil sites... (2.3)}$$

$$=\left\{\begin{matrix} 2.5 & 0 < T < 0.67 \\ \frac{1.67}{T} & 0.67 < T < 4.00 \\ 0.42 & T > 4 \end{matrix}\right\}\text{for soft soil site}$$

2) For use in response spectrum method

$$=\left\{\begin{matrix} 1+15T & T < 0.10 \\ 2.5 & 0.10 < T < 0.40 \\ \frac{1.0}{T} & 0.40 < T < 4.00 \\ 0.25 & T > 4 \end{matrix}\right\}\text{..For rocky, or hard soil sites}$$

$$\left(\frac{Sa}{g}\right)= \quad =\left\{\begin{matrix} 1+15T & T < 0.10 \\ 2.5 & 0.10 < T < 0.55 \\ \frac{1.36}{T} & 0.55 < T < 4.00 \\ 0.34 & T > 4 \end{matrix}\right\}\text{ for medium soil sites.... (2.4)}$$

$$=\left\{\begin{matrix} 1+15T & T < 0.10 \\ 2.5 & 0.10 < T < 0.67 \\ \frac{1.67}{T} & 0.67 < T < 4.00 \\ 0.42 & T > 4 \end{matrix}\right\}\text{for soft soil}$$

e) Fundamental Natural Period

The fundamental natural period of the structure (Ta) can be estimated by the use of the given expressions below:

a) Bare MRF buildings (without any masonry infills):

$$T_a = \begin{cases} 0.075T^{0.75} & (for\ RC\ MRF\ buildings \\ 0.080T^{0.75} & (for\ RC - Steel\ composite\ MRF\ buildings \ldots\ldots\ldots\ldots\ldots \text{(2.5)} \\ 0.085T^{0.75} & (for\ Steel\ MRF\ building) \end{cases}$$

Where, h = Height of building, in m.

b) Buildings with RC structural walls:

$$T_a = \frac{0.075h^{0.75}}{\sqrt{A_w}} \geq \frac{0.09h}{\sqrt{d}} \quad \text{(2.6)}$$

Where: - A_w is the effective area (m^2) of walls in the first story of the building. And for other building (Ta) may be estimated by the empirical expression: Ta=($\frac{0.09}{\sqrt{d}}$), where b= is the horizontal distance measured at the plinth level in the required direction [1].

2.4.1.3 Seismic weight (W)

The seismic weight for each building floor is computed as the sum of full dead load plus the appropriate imposed load for the particular floor determined based on the code provisions. In determining the seismic weight of each floor, the weight of the columns and walls shall be equally distributed to the floors above and below each story[1].

2.4.1.4 Imposed load

The imposed loads to be considered for the determination of the seismic weight of the structures can be obtained by using the below guideline in the table values which are taken from the code. This load need not be considered for the roof of the structure [1].

Table 2 2: Percentage of the imposed load to be included in seismic load calculation (IS1893:table10)

Imposed Uniformly Distributed Floor Loads (KN/m2)	Percentage of Imposed Load
Up to and including 3.0	25
Above	50

2.4.1.5 Distribution of Design Force

The design base shear $\boldsymbol{V_B}$ shall be distributed at each floor level of the building as per the following expression:

$$\boldsymbol{Q_i = V_B * \frac{w_i h_i^2}{\sum_j^n w_j h_j 2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.7)}$$

Where;

Qi = Design lateral force at floor i; wi = Seismic weight of floor; hi = Height of floor i measured from the plinth level.

n = Number of stories in the building is the number of levels at which the masses are located.

2.4.2 Linear Dynamic procedure (LDP)

This is the most commonly used method of analysis for the design of the buildings that range from simple low rise to multi-story structures. Although not necessarily appropriate to be applied, design codes such as the New Zealand Loadings Code of standards for the seismic-resistant design of structure NZS4203:1992 tend to use this analysis method for all structural types, including irregular structures [7]. Indian Code of Standard recommend this method to be used for the following buildings:-

- It is applicable for regular buildings if the height is greater than 40m in Zones IV and V or greater than 90m in Zone II and III.
- Applicable for irregular buildings, if the height is more than 12m in Zones IV and V and more than 40m in Zones II and III. The model should adequately include the type of irregularity present in the building. For those with plan Irregularity defined in the code, the lumped mass model principle should not be used[3].
- For the Current code (IS1893:2016). The method is to be used for all structural system in all zone except regular frame in zone II having a height up to 15m in which Linear Static may be used[1].

The linear dynamic method of the analysis for the design of structures for seismic-resistant can be carried out by either response spectrum or by the use of a time history method. But, in either method being employed, the design base shear (V_B) shall be compared with a base shear $(\overline{V}_B)$ calculated using a fundamental period T_a obtained using one of the formulas given in the code. Where (V_B) is less than $(\overline{V}_B)$ all the response quantities of the structure shall be multiplied by $(\overline{V}_B/V_B)$. The number of modes to be considered is such that the sum of the model mass for all the modes must be at least 90 percent of the total seismic mass of the building [1].

2.4.3 Non-linear Static Procedure

This method finds a widespread in the estimation of inelastic structural response measures in performance-based design for the seismic analysis of the building. Nevertheless, the conventional nonlinear static method of analysis using lateral load patterns provided in FEMA-356 do not sufficiently represent the effects of varying dynamic pattern during seismic structural responses or the effect of higher modes[8].

2.4.4 Non-linear Dynamic Procedure

This method is very useful in verifying the performance of structures and the traditional limitations which prevent it from being implemented in structural analysis and design are all invalid [7]. Despite the improvement being done on the method, all the uncertainties which resulted from the modeling of the nonlinear characteristic of the building materials and the structural components still persist. Also, the response of the structure for two different ground excitations may differ with a significant amount even if they produce the same elastic structural response. Therefore, the responses of the structures need to be repeated for ground seismic excitations which is representative of the site in which the structure is to be constructed. Because of the above-mentioned problem, linear dynamic method is mostly used by the designer[9].

CHAPTER 3: COMPARISON OF STATIC AND LINEAR DYNAMIC METHOD BASED ON IS 1893:2016

3.1 Reviews from the past study

The study has been carried out on G+9 multi-storied building using static and dynamic (response spectrum) methods of analysis. By using STAAD-Pro as per the IS-1893-2002-Part-1, the values of the structural responses such as bending moments, axial forces, torsions, displacements, joint displacement, beams and column end forces of the seismic action were determined[10].

From the analysis results, the author concluded the following points:-

- ⇨ For bending moments, the values are 35 to 45 % higher for the response spectrum method than those by the method of linear static
- ⇨ For Torsion, the column values have a negative sign for Linear static while they are positive for the response spectrum method.
- ⇨ Nodal Displacements are 50% higher for linear dynamic (Response spectrum) method of analysis than the values determined by the static method.

A regular G+30 building has been taken to compare the analysis result for linear static and response spectrum method using IS1893-2002 Standard provision. The plan of the building is 25m*45m and the depth of the foundation below the ground surface is 2.4m. The story height for each floor to floor is 3.6m and the analysis is done by considering zone 2 and zone 3 based on the Indian code zonal category. The STAAD-PRO software is used for the analysis purpose and the total building height from the foundation to the top of the building become 114m[11].

From the analysis results, the author concluded the following points:-

- ⇨ For zone 2 and zone 3, the torsion for the column has a negative sign for linear static while they are positive for the response spectrum method.
- ⇨ Bending moments and displacements at different points in the beam was 10% to 15% and 17% to 28 % higher when using the linear dynamic method.

Another comparative study of linear static and linear dynamic method for seismic analysis of multi-storied RCC structure by ETAB has been taken on G+12 building. The response values such as displacement, Shear, moments and story drift were compared for the methods [12].

From the analysis results, the author concluded the following points:-

- In X-direction, the displacements values determined by the linear static method were less than those values obtained by linear dynamic (response spectrum) method of analysis for story 1 to 4 but the reverse is true for story 5 to 12.
- In Y-direction, the displacements values determined by the linear static method were less than those values obtained by linear dynamic (response spectrum) method of analysis.
- The difference of story moments for the two methods is higher in X-direction than in Y-direction. In both orthogonal directions, the difference of story drift was insignificant.

A G+15 residential building has been taken for the comparative study of both static and response spectrum method of the analysis. The framing system being used is special moment resisting frame and that of the ordinary moment resisting framing system. For the structures being supposed to be constructed in seismic zone II, a STTAD-PRO software package has been chosen for the analysis purpose[13].

From the analysis results for both OMRF and SMRF, the author concludes that:-

- The author observed that the special moment resisting frame is better when compared with that of the ordinary one.
- The resulted (Displacements) of static analysis in SMRF values were low when compared with those of OMRF.

ETABS and SAP 2000 v.15 have been used to model a 20 storied building for seismic zone V in India. Actual earthquakes, EL-CENTRO 1949 and CHI-CHI Taiwan 1999 have been investigated. Multi-story irregular buildings in which a story plan is changing on different floors is taken for analysis. The building has been analyzed by using the linear static, response spectrum and time history analysis based on IS codes provisions[14].

From the analysis results, the author concluded the following points:-

- The displacement keeps increasing from the first story to the last one as the height of building increases.
- The building responses values with severe irregularity produced more deformation than those with less irregularity in this high seismic zone. The overturning moments decreases as the building height increases.
- The story base shear for the regular building is highest when compared to irregularly shaped buildings.

Finally, an analysis is being done for G+9 Reinforced concrete building by computer software ETABS. A building with regular, C- shape, L- shape of plan irregularities has been taken for investigation. These RCC framed structures are analyzed both statically and dynamically and the results are compared for bending moment, shear force, deflection, story shear, story drift [15].

- The bending moment of continuous beams in regular, C- shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis.
- The shear forces of continuous beams in regular, C-shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis.
- The deflections of continuous beams in regular, C-shape, L- shape building are lower in magnitude for static than the linear dynamic method of analysis.
- The maximum bending moments of the column for regular, C-shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis.
- The maximum shear forces of the column for regular, C-shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis.
- The story drift and story shear of the building for regular, C-shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis and more in L-shape building(dynamic analysis).

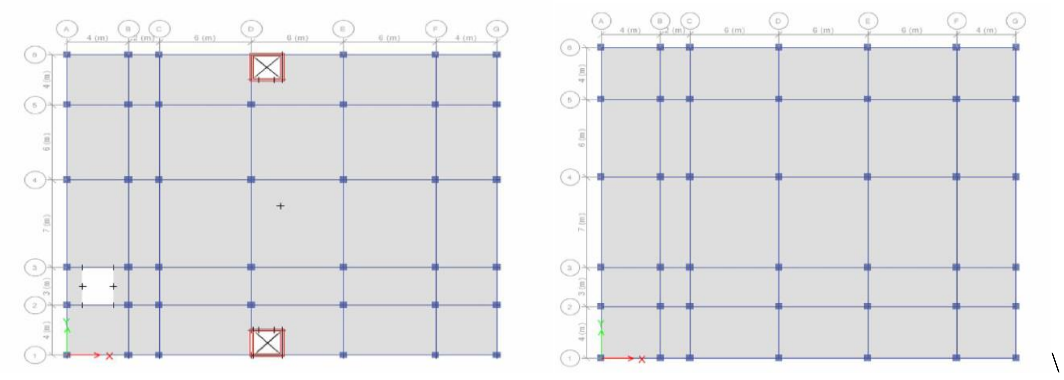
- The story wise maximum bending moment and story wise maximum shear force in beams of the building for regular, C-shape, L-shape building are lower in magnitude for static than the linear dynamic method of analysis.

3.2 Research gap

From the study being taken on different building structures, it has been observed that the values of story lateral displacement get increasing from bottom to top. Different frames with various irregularities, height, and different loading condition have been taken. However, two or more frames with the same loading, same shape, same materials but different story number are not been taken to investigate the seismic response quantities for both linear static and dynamic method of analysis. To depict this effect, four different frames are taken in this paperwork. In each frame, the response quantities for 3-increments of story number up to 27^{th} story are analyzed for both linear methods and the values are compared. This is done for two different standards.

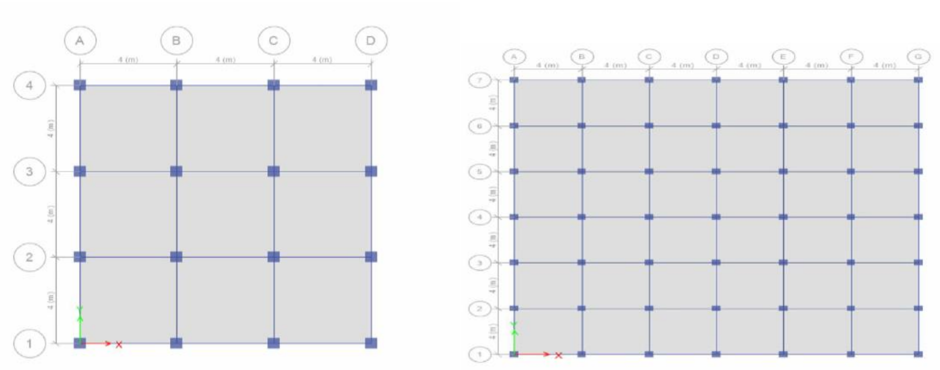
3.3 Problem statement

Consider reinforced concrete offices buildings shown below. The buildings are located in Seismic zone (II) in India and the same buildings are to be constructed in the Afar region in Ethiopia. The soil condition encountered is medium stiff. The reinforced cement concrete buildings are to be designed using a structural moment resisting framed system. The dead loads of the finishing materials and the imposed loads in each floor area are determined based on the code provisions. It is required to determine the seismic Base shear on the structure using linear Static and linear Dynamic method of Analysis by applying the application rules given in IS1893:2016 and Comparing the base shear as the number of story increase. The same Structures will be analyzed by EN1998 Codes. The same Loading will be applied to all frames. Note: The base shear is to be determined for each 3-increment of the building story numbers.



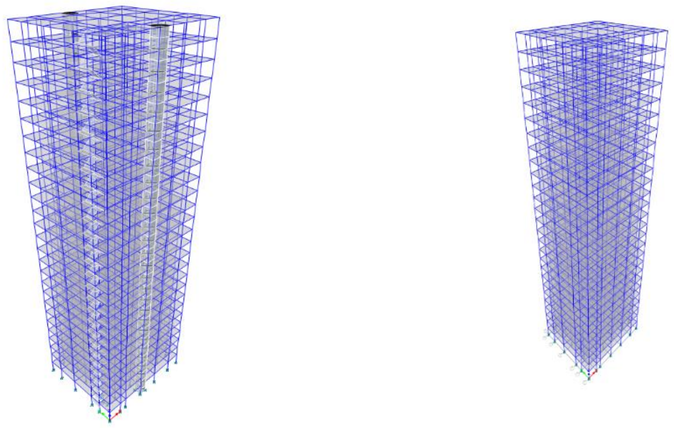
A B

Figure 3 1: Regular Frame with a shear wall around the lift and same without a shear wall, 6*5 bays floor plan



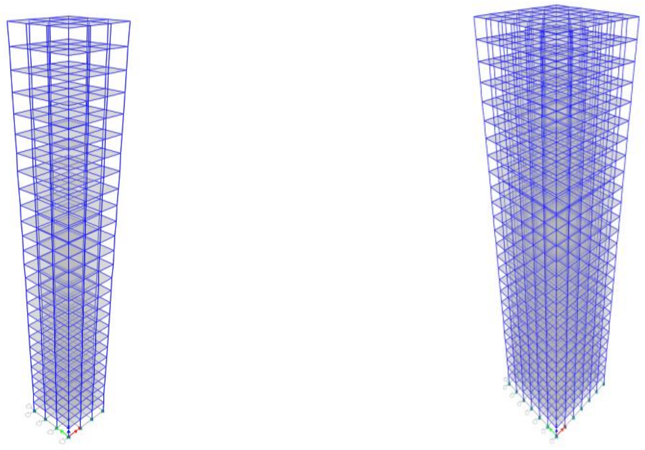
C D

Figure 3 2: 3*3 and 6*6 bays of 4m width regular frames floor plan



A B

Figure 3 3: Regular Frame with a shear wall around the lift and same without a shear wall, 6*5 bays of 27 story 3D



C D

Figure 3 4: 3*3 and 6*6 bays regular frames of 27 story 3D

Beams Cross-sectional Area= 400mm*350mm

Column Cross-sectional area=500mm*500mm

Slab thickness=200mm

Concrete Grade=M30 and E=5000$\sqrt{Fck}$ as per Indian Code of standard

Steel/Rebar= HYSD=Fe-415 will be used

3.4 Indian Code of Standards and EN Eurocodes to be used for the determination of loads for the Base Shear determination.

Table 3 1: List of standards to be used for the analysis of frames in Zone (II), India

Notation	Use
IS 1893: 2016 Part1	Earthquake Resistant Design of structures
IS 875: Part1-1987	Dead loads on the structures
IS 875: Part 2-1987	Imposed Loads on Structures
IS 456-2000	Plain and Reinforced concrete-code of practice
IS 800:2007	Steel Design Code
Eurocode 2-2004	Concrete Design code

Eurocode 3-2005	Steel design Code
Eurocode 8-2004	Earthquake Resistant Design of structure
ES EN 1998: 2015	Design of structures for earthquake resistant

3.5 Dead loads from walls and Flooring Materials

Table 3 2: Specification for materials to be used for dead load calculation [16].

Types	Description and section dimension	Weight/Area Load	Density
Partition wall	HCB(H*W*L)=200*150*400mm		1500kg/m^3
Exterior walls	HCB(H*W*L)=200*200*400mm		1500kg/m^3
Cement mortar	(10mm thick)	20.40KN/m^3	2080kg/m^3
Cement plaster	(5mm thick)	20.40KN/m^3	2080kg/m^3
Finishing material	Tile	0.013KN/m^2	

3.5.1 Dead load Calculation for partition wall

Story Height=3.6m. Therefore, the wall height=Story height-Depth pf the beam (400mm)

Partition wall loads on interior beam= (1500kg/m^3*10m/s^2*)*0.15*3.2m=7200N/m=**7.2kN/m**

Plastering on wall=2*(20.40KN/m^3*0.005*3.2m) =**0.6528KN/m**

Total Partition wall load on Beam=7.2kN/m+0.6528KN/m**=7.85KN/m**

3.5.2 Dead Loads Calculation for Exterior walls

Partition wall loads on interior beam=

(1500kg/m³*10m/s²*)*0.2*3.2m=9600N/m=**9.6kN/m**

Plastering on wall=2*(20.40KN/m³*0.005*3.2m) =**0.6528KN/m**

Total Exterior wall load on Beam=9.6kN/m+0.6528KN/m**=10.25KN/m**

3.5.3 Dead Load on floors

Cement mortar loads= 20.40KN/m³*0.01= **0.204kN/m²**

Cement Plastering loads=2*(20.40KN/m³*0.005) = **0.204kN/m²**

Therefore, the Total load on floors= 0.204KN/m²+0.204kN/m²**=0.408kN/m²**

3.6 Imposed Loads

These load values are defined based on the functional classification of each floor areas. However, the Imposed loads of magnitude 4KN/m² is to be used for all building rooms of this particular office building [17].

3.7 Base Shear determination based on IS1893:2016 standard

According to Indian new code of standard IS1893:2016, the linear dynamic method in the analysis of the seismic load on the structures have to be applied for all buildings other than regular structures lower than 15m in Seismic Zone II[1]. This method may be conducted by using either response spectrum or time history analysis. When either of the methods is used, the design base shear V_B estimated shall not be less than the design base shear $\overline{V}_B$calculated using a fundamental periodT_a. When V_B is less than $\overline{V}_B$, the force response quantities shall be multiplied by the ration of the base shear given as ($\overline{V}_B/V_B$)[1].

3.7.1 Seismic weight of the Building

Seismic weight of each floor is its full dead load plus the appropriate amount of imposed load as given in Table 10 for various loading classes specified in IS 875 Part 2. The same shall be used in the three- dimensional dynamic analysis of buildings also. While computing the seismic weight of each floor, the weight of columns and walls in any story shall be appropriately apportioned to the floors above and below the story[1].

3.7.2 Base Shear Determination for Frame (A)

For this frame, the linear Static and Linear Dynamic method of Analysis is used for the determination of the base shear at each building story category as it can be seen in the subsequent steps. The base shear for 3- story increments is determined.

3.7.2.1 Equivalent Method Result - IS1893 2016

For this method, the ETABS software is used for the analysis of the frame to obtain the seismic response of the structures. Though the IS1893:2016 have provided a different Spectral Acceleration Coefficient for each linear method of analysis, in this paper the same is used for both.

3.7.2.2 Seismic weight of the structure for each building story category

The seismic weight for the determination of base shear is calculated by considering the full dead load of the structure for each building story category and the

50% of the imposed loads as the load at each floor is 4kN/m² > 3kN/m². The result is as shown below calculated by ETABS Software and DATA presentation by Excel.

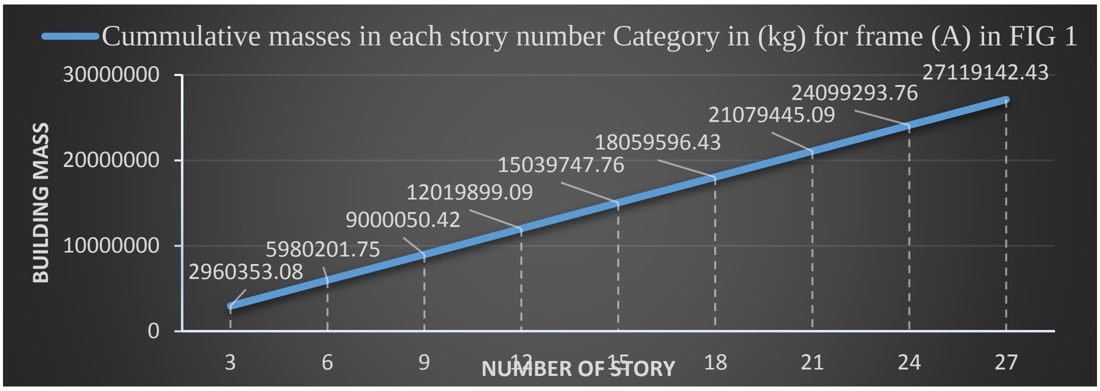


Figure 3 5*:* seismic weight for the frame (A) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

$$\text{(\%) Increase from 3 story frame to 27 stories} = \left(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}\right.{*}100$$

$$= ((27119142.43-2960353.08)/2960353.08)*100=\mathbf{816.077971\%}$$

3.7.2.3 Natural period for the first mode in each building story category for the frame (A)

The natural periods of the building to be used for the calculation of the base shear in linear static methods can be obtained by applying the appropriate equation. In this paper works, the ETABS software was used to get the periods in each story category and the presentation of DATA was done by excel.

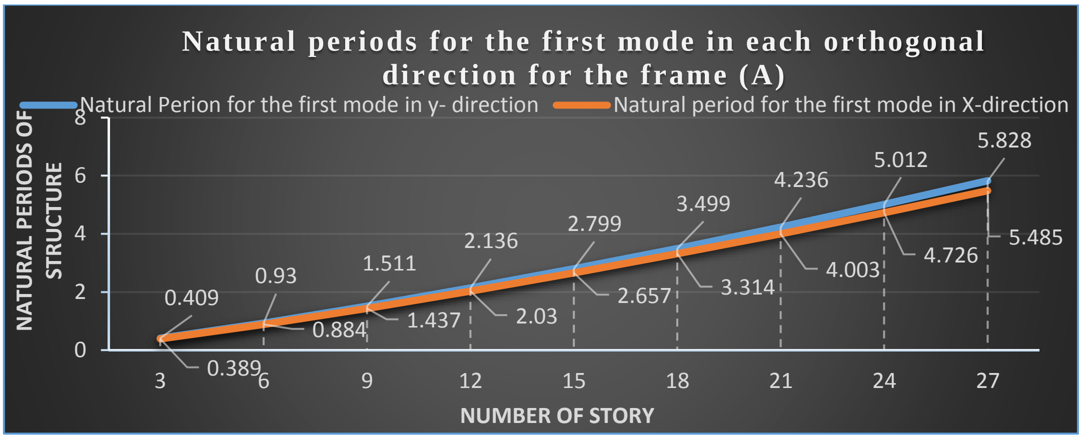


Figure 3 6: Natural periods for the first modes in each orthogonal direction for the frame (A).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section.

3.7.2.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to IS1893 2016, as calculated by ETABS.

a) Structural Period

Period Calculation Method = Program Calculated

Table 3 3: Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2]	Z = 0.1
Response Reduction Factor, R [IS Table 7]	R = 3
Importance Factor, I [IS Table 6]	I = 1
Site Type [IS Table 1] = II	

b) Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5]	$\frac{S_a}{g} = 0.34$	$\frac{S_a}{g} = 0.34$

c) Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]

$$A_h = \frac{ZI\frac{S_a}{g}}{2R}$$

Table 3 4: Calculated Base Shear in X- direction

Direction	Period Used (sec)	W (kN)	V_b (kN)
X	5.485	267017.5918	1513.0997

Table 3 5: Calculated Base Shear in Y- direction

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	5.828	267017.5918	1513.0997

3.7.2.5 Dynamic Analysis Method

IS1893:2016 allow the use of this method for the determination of the seismic base shear and its vertical distribution at each floor level of the building structure for most of the buildings other than regular buildings lower than 15m in Seismic Zone II where the linear static method can be used[1].

3.7.2.5.1 Modal Mass (m_k) and Modal Participation Factors (p_k)

The modal mass (*M*k) and modal participation factor (*Pk*) of mode *k* are given by the following expressions:

$$m_k = \frac{(w_i \Phi_{ik})^2}{g \sum w_i \Phi_{ik}^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

$p_k = \frac{\sum w_i \Phi_{ik}}{\sum w_i \Phi_{ik}^2}$……………………..... (3.2)

Where,

w_i……mass at the floor level i

Φ_{ik}…….response value at floor level i and mode k

3.7.2.5.2 Seismic base shear and lateral force at each story levels

The peak lateral force Q_{ik} at i^{th} floors in the k^{th} mode is;-

$Q_{ik} = A_{hk} \Phi_{ik} p_k W_i$……………………………………… (3.3)

3.7.2.5.3 Combination of modes

a) The square root of the sum of the squares (SRSS) method

$\lambda = \sqrt{\sum_{k=1}^{r} \lambda^2{}_k}$………………………………………… (3.4)

Where,

λ_k=Absolute value of the quantity in mode k

r=Number of modes being considered

b) Complete Quadratic Combination (CQC) method

$\lambda = \sqrt{\sum_{i=1}^{r} \sum_{j=1}^{r} \lambda_i \, \rho_{ij} \lambda_j}$………………………………… (3.5)

Where,

r = number of modes being considered

λ_i= response quantity in mode i (including sign)

λ_j= response quantity in mode j (including sign)

ρ_{ij}= cross-modal coefficient

$$\rho_{ij} = \frac{8\zeta^2(1+\beta)\beta^{1.5}}{(1-\beta^2)^2+4\zeta^2\beta(1+\beta)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.6)$$

Where,

ζ =modal damping ratio

β= frequency ratio = ω_j/ω_i

ω_i= circular frequency in i^{th} mode

ω_j= circular frequency in j^{th} mode

In this paper, the ETABS software is used to determine the base shear in Seismic Zone II and the square root of the sum of the squares (SRSS) method is used for the combination of the responses.

3.7.2.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 3 6: Base Shear calculated for each 3-increment of story number by two methods for the frame (A)

	Linear Static Methods		Response spectrum method	
No of story	x	y	x	y
3	(-) 1214.5832	(-) 1214.5832	5896.573	5088.1451
6	(-) 1510.009	(-) 1434.6227	7278.8356	6316.1293
9	(-) 1397.9834	(-) 1329.4271	7057.6135	6240.0965
12	(-) 1321.2956	(-) 1256.1233	7083.758	6340.3185
15	(-) 1263.3812	(-) 1199.2918	6854.0866	6182.047
18	(-) 1216.0931	(-) 1151.9644	6738.9798	6101.4762
21	(-) 1176.1206	(-) 1176.1206	6602.5736	6242.8772
24	(-) 1344.6101	(-) 1344.6101	7236.1117	6888.1375
27	(-) 1513.0997	(-) 1513.0997	7903.1601	7571.2479

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6,9 and up to 27 story frame Building. This is true for both orthogonal directions.

- The base shear increased for 3 story frame to 6 story framed building in which the first natural period is in the interval of 0.10 to 0.55 and then decreased for 6 stories to 21 framed building in which the natural period is in the interval from (0.55 to 4). When the natural period for the first mode is more than 4 cycle/second, the base shear value gets increased excessively especially for a linear static method.
- It is observed that the base shear value for 21 stories framed building is decreased by 28.389% and 10.243% than the value for 6 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- It is observed that the base shear value for 6 stories framed building is increased by 24.323% and 23.442% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

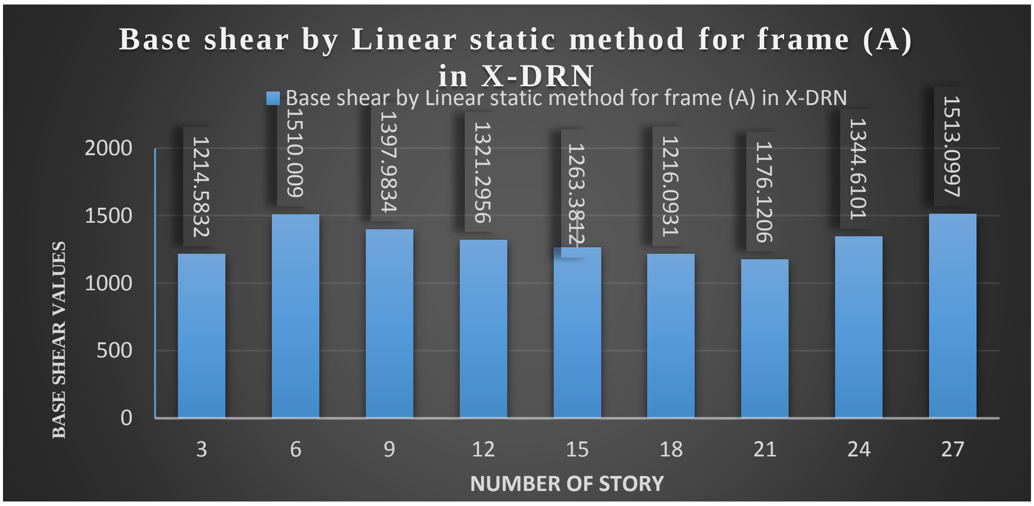


Figure 3 7: Base shear in X-direction for each 3-increment of Story number for the frame (A) by linear static method

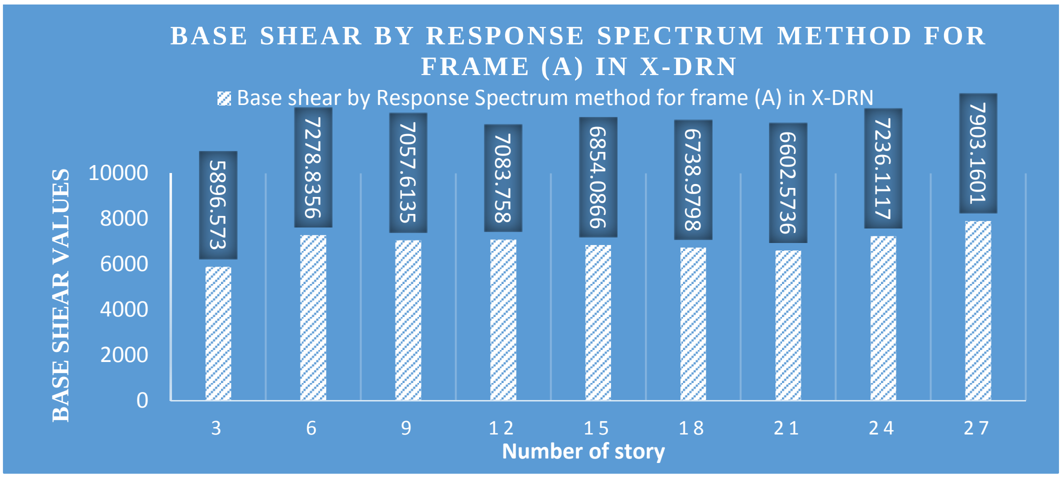


Figure 3 8: Base shear in X-direction for each 3-increment of Story number for the frame (A) by Response spectrum methods

3.7.3 Base Shear Determination for Frame (B)

For this frame, the linear Static and Linear Dynamic method of Analysis is used for the determination of the base shear at each building story category as it can be seen in the subsequent steps. The base shear for 3- story increments is determined.

3.7.3.1 Equivalent Method Result - IS1893 2016

The Base shear is determined by the software by using the same procedure as provided in the IS1893:2016.

3.7.3.2 Seismic weight of the structure for each building story category

The seismic dead load of the structure plus 50% of the imposed load based on the condition provided in the code is used to obtain the whole weight of the structure at the base level. This is done for all story number category at each 3- an increment of story. The Excel was used to represent the DATA in such a way that it could be easy to understand how the weight gets increasing as the number of story increase.

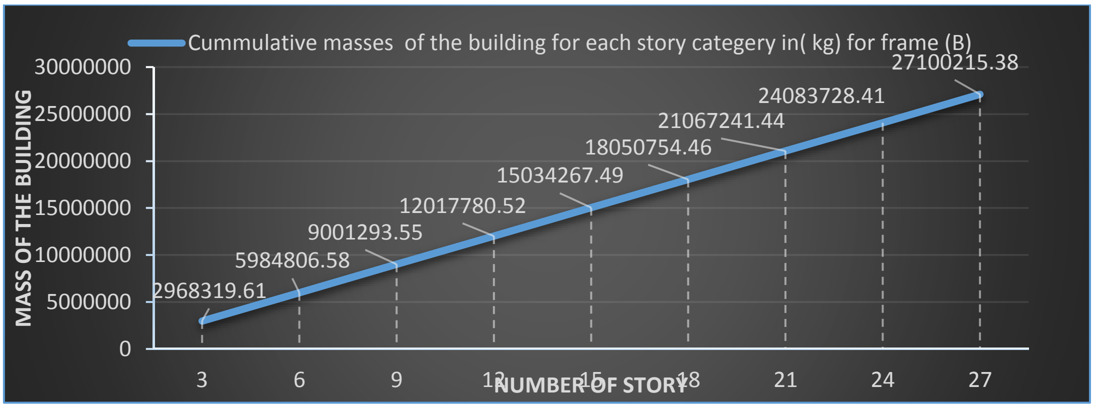


Figure 3 9: seismic weight for the frame (B) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$\left(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}*100\right.$$

= ((27100215.38-2968319.61)/ 2968319.61)*100=**812.981718%**

3.7.3.3 Natural period for the first mode in each building story category for the frame (B)

The building natural periods determined by the software for each story number category is shown below. Excel is used for the presentation of data.

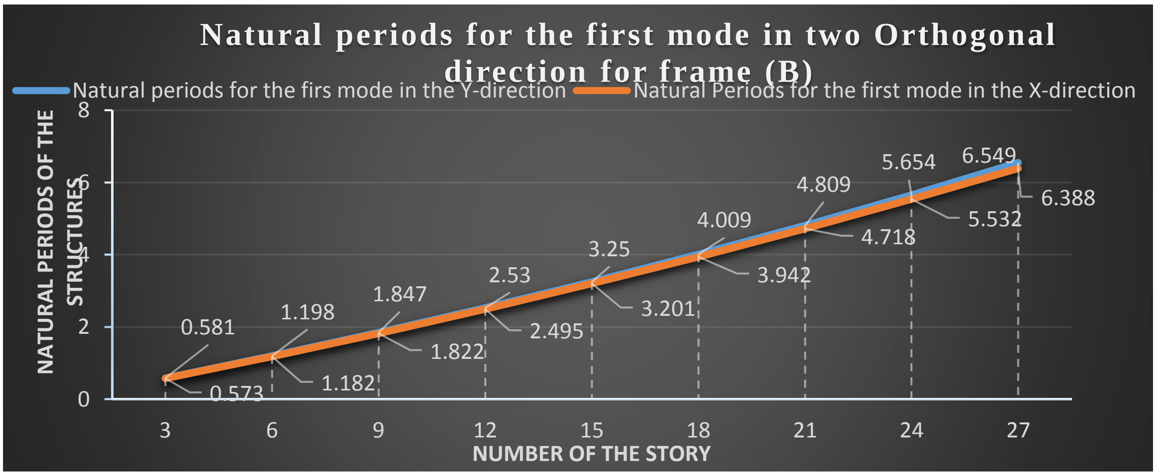


Figure 3 10: Natural periods for the first modes in each orthogonal direction for the frame (B).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section.

3.7.3.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to IS1893 2016, as calculated by ETABS-2016.

Table 3 7: Calculated Base Shear in X- direction

Direction	**Period Used (sec)**	**W (kN)**	**V_b (kN)**
X	6.388	265762.3325	1505.9866

Table 3 8: Calculated Base Shear in Y- direction

Direction	**Period Used (sec)**	**W (kN)**	**V_b (kN)**
Y	6.549	265762.3325	1505.9866

3.7.3.5 Dynamic Analysis Method

Linear dynamic analysis is done by following the procedure given in the code. The method being employed is response spectrum Analysis and the square root of the sum of the squares is used to get the response combination of different modes of the structures for each building story number category[1].

3.7.3.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 3 9: Base Shear calculated for each 3-increment of story number by two methods for the frame (B)

	Linear Static Method		Response Spectrum Method	
No of story	X	Y	X	Y
3	(-) 1151.9479	(-)1135.069	6042.3238	5907.2986
6	(-)1125.8222	(-)1110.5252	5776.1595	5639.2559
9	(-)1097.9783	(-)1083.4042	5851.0319	5725.0014
12	(-)1070.6198	(-)1055.8148	5741.5264	5619.3057
15	(-)1043.9268	(-)1028.211	5708.4898	5583.4775
18	(-)1017.9569	(-)1003.0988	5613.5485	5489.0418
21	(-)1170.728	(-)1170.728	6250.4255	6185.3191
24	(-)1338.3573	(-)1338.3573	1328.0148	1324.911
27	(-)1505.9866	(-)1505.9866	7683.3182	7606.8488

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6,9 and up to 27 story frame Building. This is true for both orthogonal directions.
- The base shear values decreased for 3 stories to 18 framed building in which the natural period is in the interval from (0.55 to 4). When the natural period for the first mode is more than 4 cycle/second, the base shear value gets increased excessively especially for a linear static method.
- It is observed that the base shear value for 18 stories framed building is decreased by 13.163% and 7.638% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

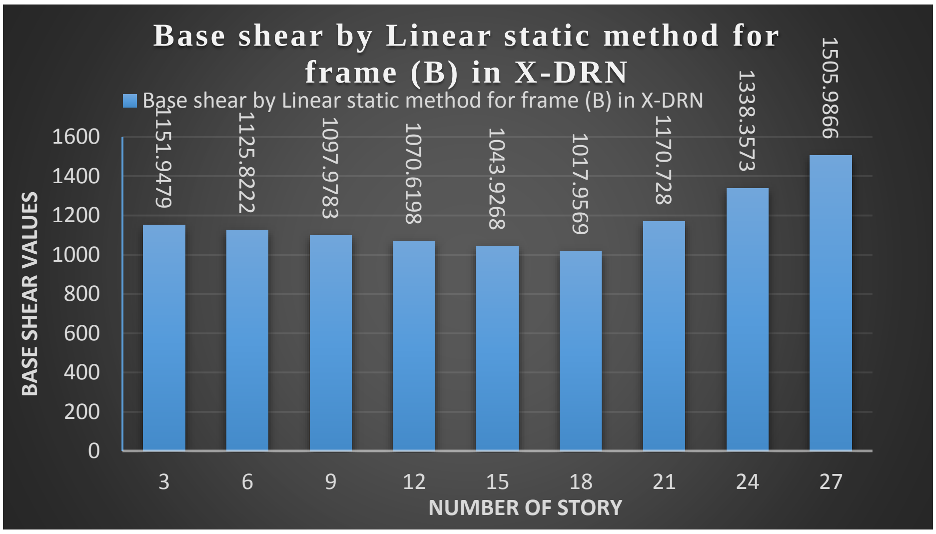


Figure 3 11: Base shear in X-direction for each 3-increment of Story number for the frame (B) by linear static

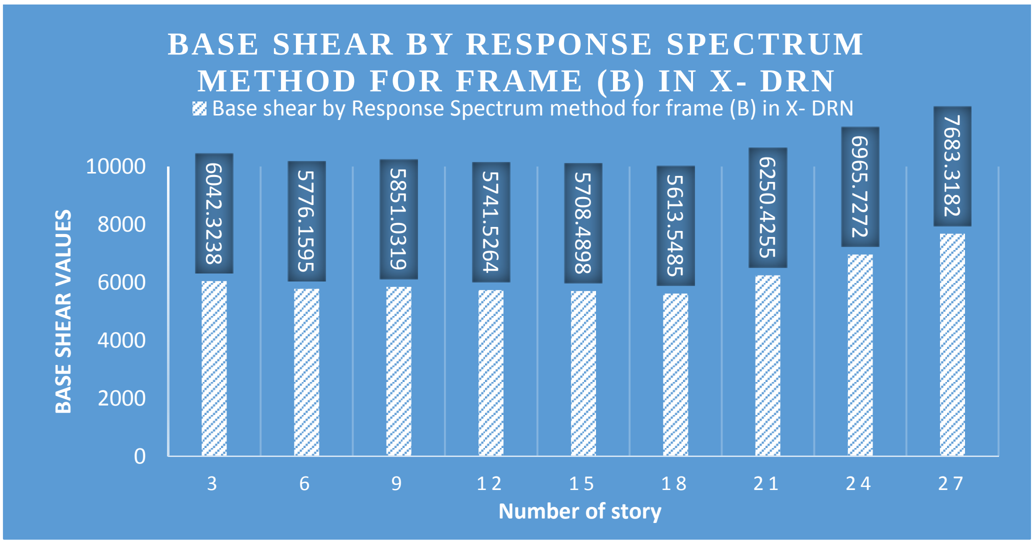


Figure 3 12: Base shear in X-direction for each 3-increment of Story number for the frame (B) by Response Spectrum

3.7.4 Base Shear Determination for Frame (C)

For this frame, the linear Static and Linear Dynamic method of Analysis is used for the determination of the base shear at each building story category as it can be seen in the subsequent steps. The base shear for 3- story increments is determined.

3.7.4.1 Equivalent Method Result - IS1893:2016

The Base shear is determined by the software by using the same procedure as provided in the IS1893:2016. This is done for each story number category.

3.6.4.2 Seismic weight of the structure for each building story category

The seismic dead load of the structure plus 50% of the imposed load based on the condition provided in the code is used to obtain the whole weight of the structure at the base level. This is done for all story number category at each 3- an increment of story. The Excel was used to represent the DATA in such a way that it could be easy to understand how the weight gets increasing as the number of floor increase.

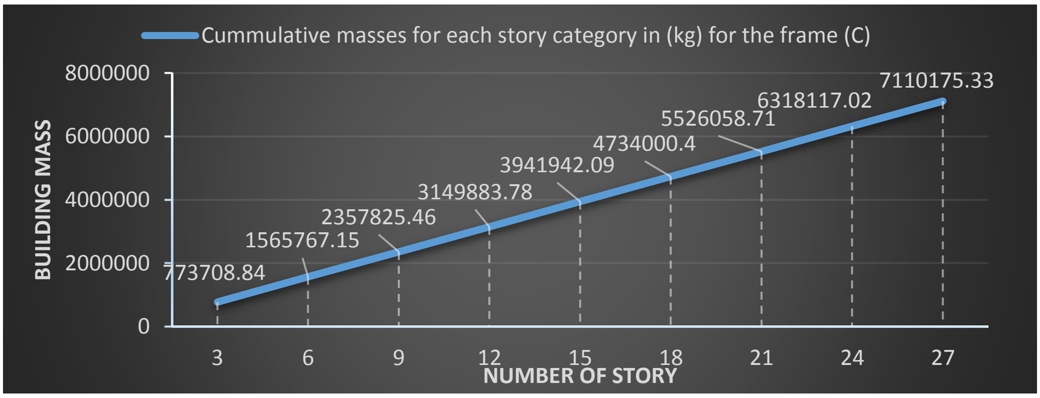


Figure 3 13: seismic weight for the frame (C) for each 3- an increment of story *number*

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame} * 100$$

= ((7110175.33-773708.84)/ 773708.84)*100=**818.9729989%**

3.7.4.3 Natural period for the first mode in each building story category for the frame (C)

The building natural periods determined by the software for each story number category is shown below. Excel is used for the presentation of data.

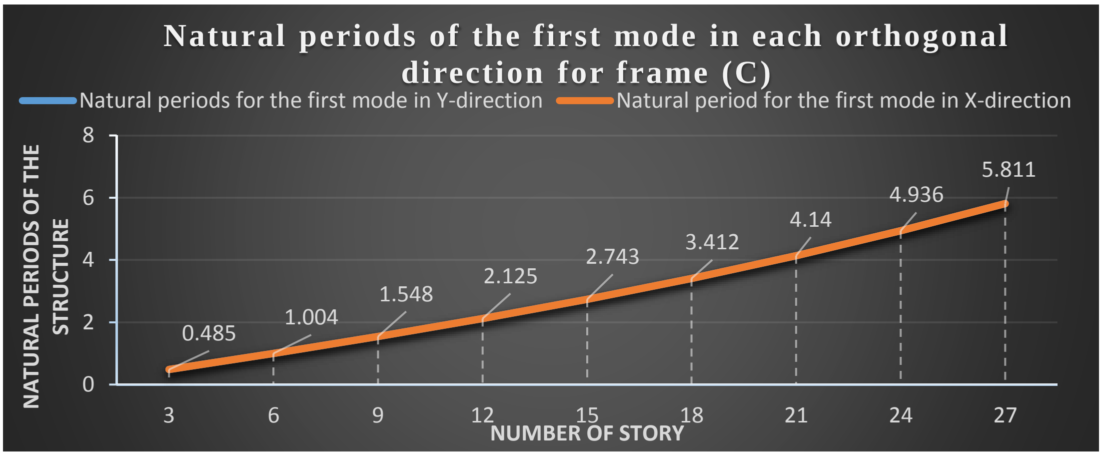


Figure 3 14: Natural periods for the first modes in each orthogonal direction for the frame (C).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section.

3.7.4.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to IS1893 2016, as calculated by ETABS-2016.

Table 3 10: Calculated Base Shear in X- direction

Direction	Period Used (sec)	W (kN)	V_B (kN)
X	5.811	69727.0024	395.1197

Table 3 11: Calculated Base Shear in Y- direction

Direction	Period Used (sec)	W (kN)	V_B (kN)
Y	5.811	69727.0024	395.1197

3.7.4.5 Dynamic Analysis Method

Linear dynamic analysis is done by following the procedure given in the code. The method being employed is response spectrum Analysis and the square root of the sum of the squares is used to get the response combination of different modes of the structures for each building story number category[1].

3.7.4.6 The calculation is done for each 3-increment of the story for both Linear Static and Linear Dynamic Method and the base shear obtained

Table 3 12: Base Shear calculated for each 3-increment of story number by two methods for the frame (C)

	Linear Static Method		Response Spectrum Method	
No of story	**X**	**Y**	**X**	**Y**
3	(-)316.1455	(-)316.1455	1630.3536	1630.3536
6	(-)346.8274	(-)346.8274	1765.9757	1765.9757
9	(-)338.5885	(-)338.5885	1781.2983	1781.2983
12	(-)329.4867	(-)329.4867	1784.2623	1784.2623
15	(-)319.3947	(-)319.3947	1744.8216	1744.8217
18	(-)308.4168	(-)308.4168	1707.855	1707.8551
21	(-)307.0887	(-)307.0887	1706.6963	1706.6967
24	(-)351.1042	(-)351.1042	1883.7925	1883.7929
27	(-)395.1197	(-)395.1197	2058.9636	2058.9636

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.

- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6,9 and up to 27 story frame Building. This is true for both orthogonal directions.
- The base shear increased for 3 story frame to 6 story framed building in which the first natural period is in the interval of 0.10 to 0.55 and then decreased for 6 stories to 21 framed building in which the natural period is in the interval from (0.55 to 4). When the natural period for the first mode is more than 4 cycle/second, the base shear value gets increased excessively especially for a linear static method.
- It is observed that the base shear value for 21 stories framed building is decreased by 12.940% and 3.473% than the value for 6 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- It is observed that the base shear value for 6 stories framed building is increased by 9.705% and 8.319% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

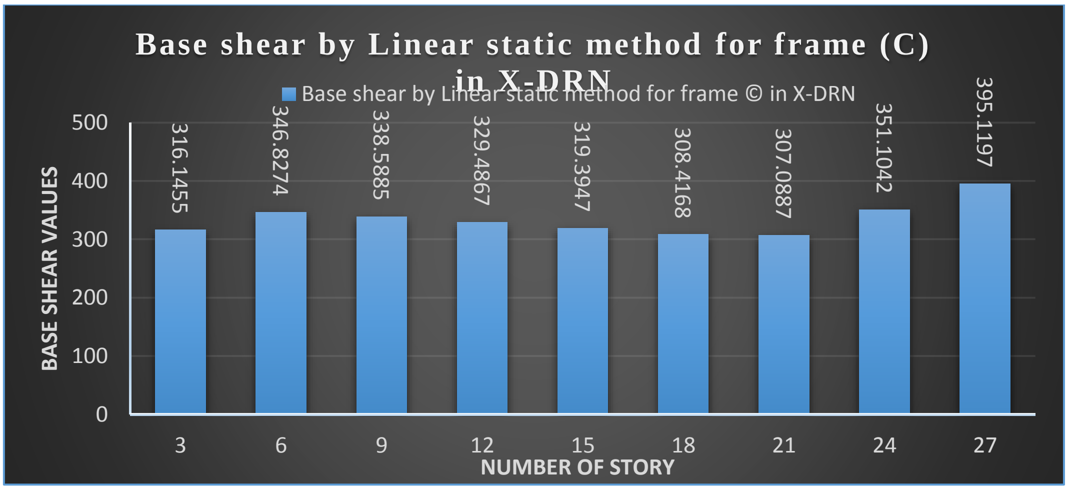


Figure 3 15: Base shear in X-direction for each 3-increment of Story number for the frame (C) by Linear static

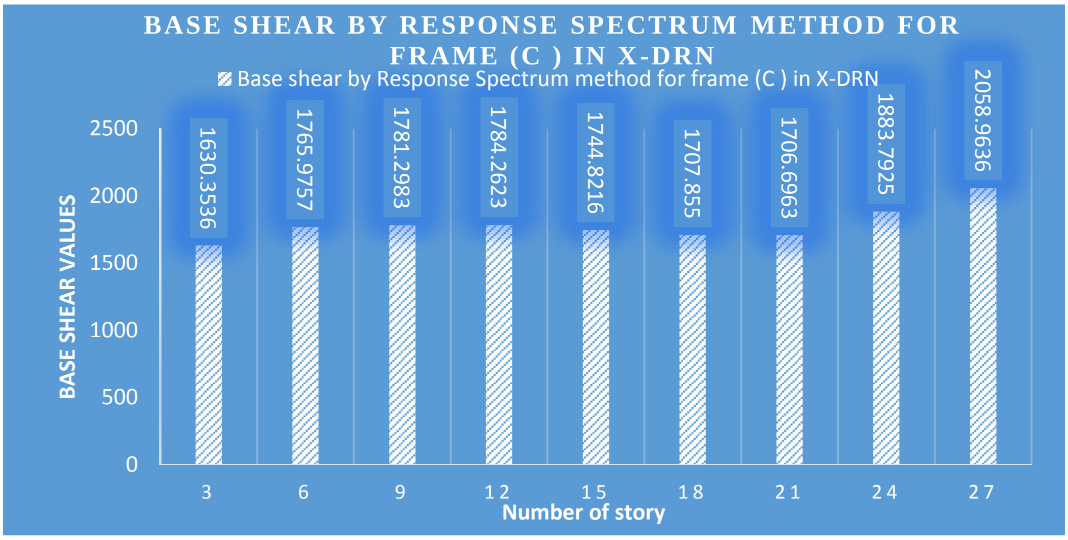


Figure 3 16: Base shear in X-direction for each 3-increment of Story number for the frame (C) by Response Spectrum

3.7.5 Base Shear Determination for Frame (D)

For this frame, the linear Static and Linear Dynamic method of Analysis is used for the determination of the base shear at each building story category as it can be seen in the subsequent steps. The base shear for 3- story increments is determined.

3.7.5.1 Equivalent Method Result - IS1893:2016

The Base shear is determined by the software by using the same procedure as provided in the IS1893:2016. This is done for each story number category.

3.6.5.2 Seismic weight of the structure for each building story category

The seismic dead load of the structure plus 50% of the imposed load based on the condition provided in the code is used to obtain the whole weight of the structure at the base level. This is done for all story number category at each 3- an increment of story. The Excel was used to represent the DATA in such a way that it could be easy to understand how the weight gets increasing as the number of floor increase.

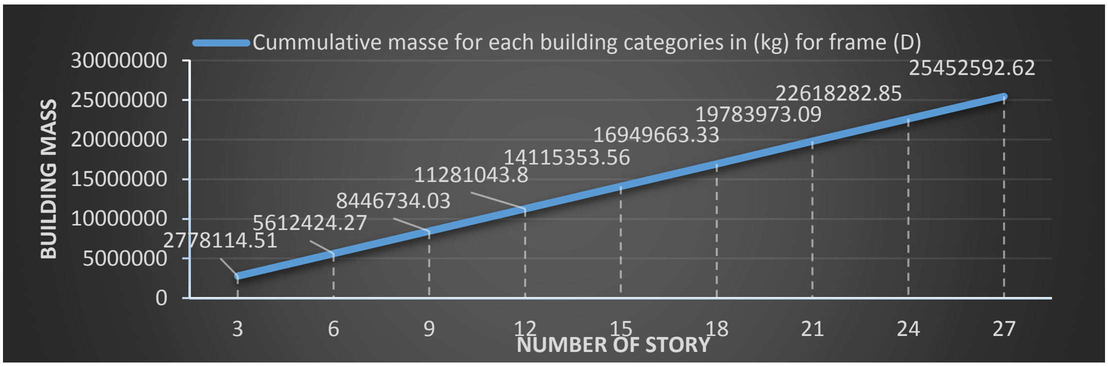


Figure 3 17: *seismic weight for the frame (D) for each 3- an increment of story number*

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =
$(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}*100$

= ((25452592.62-2778114.51)/2778114.51)*100=**816.1822714%**

3.7.5.3 Natural period for the first mode in each building story category for the frame (D)

The building natural periods determined by the software for each story number category is shown below. Excel is used for the presentation of data.

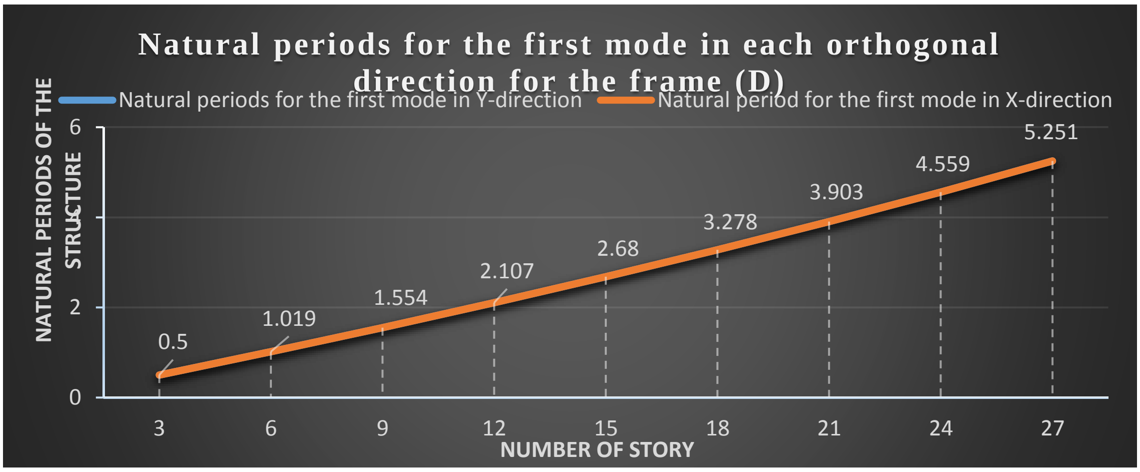


Figure 3 18: Natural periods for the first modes in each orthogonal direction for the frame (D).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section.

3.7.5.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to IS1893 2016, as calculated by ETABS-2016.

Table 3 13: Calculated Base Shear in X- direction

Direction	**Period Used (sec)**	**W (kN)**	**V_b (kN)**
X	5.251	249604.6725	1414.4265

Table 3 14: Calculated Base Shear in Y-direction

Direction	**Period Used (sec)**	**W (kN)**	**V_b (kN)**
Y	5.251	249604.6725	1414.4265

3.7.5.5 Dynamic Analysis Method

Linear dynamic analysis is done by following the procedure given in the code. The method being employed is response spectrum Analysis and the square root of sum of the squares is used to get the response combination of different modes of the structures for each building story number category[1].

3.7.5.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 3 15: Base Shear calculated for each 3-increment of story number by two methods for the frame (D)

	Linear Static Method		Response Spectrum Method	
No of story	X	Y	X	Y
3	(-)1135.1665	(-)1135.1665	5894.7097	5894.7097
6	(-)1223.7953	(-)1223.7953	6284.9318	6284.9318
9	(-)1208.0029	(-)1208.0029	6374.0538	6374.0538
12	(-)1190.1637	(-)1190.1637	6426.9534	6426.9535
15	(-)1170.5703	(-)1170.5703	6356.6086	6356.6082
18	(-)1149.3916	(-)1149.3916	6299.0124	6299.0127
21	(-)1126.7529	(-)1126.7529	6212.294	6212.2939
24	(-)1256.921	(-)1256.921	6759.2456	6759.2447
27	(-)1414.4265	(-)1414.4265	7437.2963	7437.2966

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6,9 and up to 27 story frame Building. This is true for both orthogonal directions.
- The base shear increased for 3 story frame to 6 story framed building in which the first natural period is in the interval of 0.10 to 0.55 and then decreased for

6 stories to 21 framed building in which the natural period is in the interval from (0.55 to 4). When the natural period for the first mode is more than 4 cycle/second, the base shear value gets increased excessively especially for a linear static method.

- ⇨ It is observed that the base shear value for 21 stories framed building is decreased by 8.613% and 1.169% than the value for 6 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- ⇨ It is observed that the base shear value for 6 stories framed building is increased by 7.808% and 6.620% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

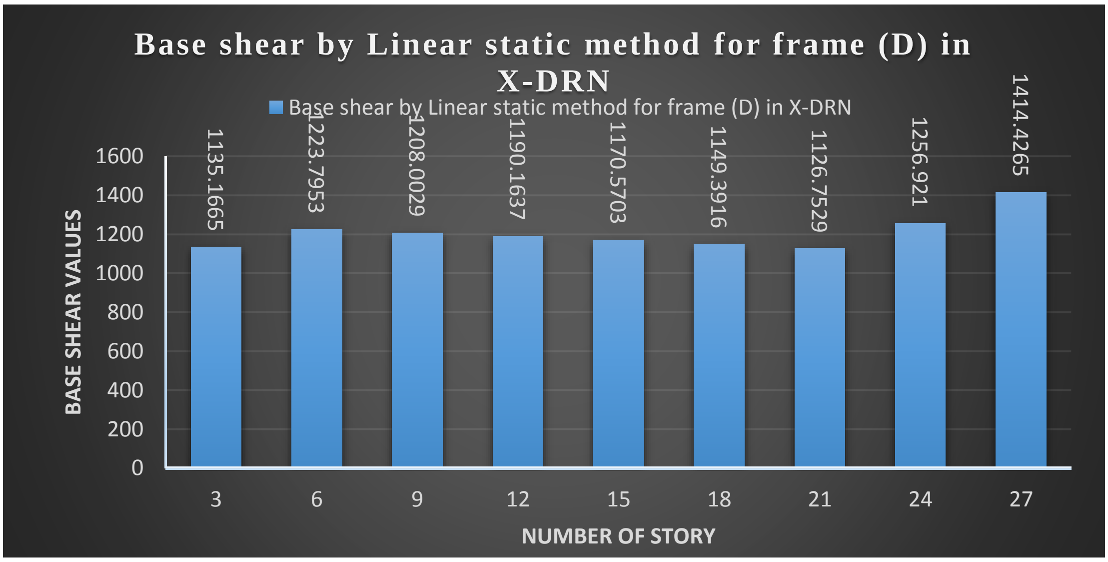


Figure 3 19: Base shear in X-direction for each 3-increment of Story number for frame by linear static (D)

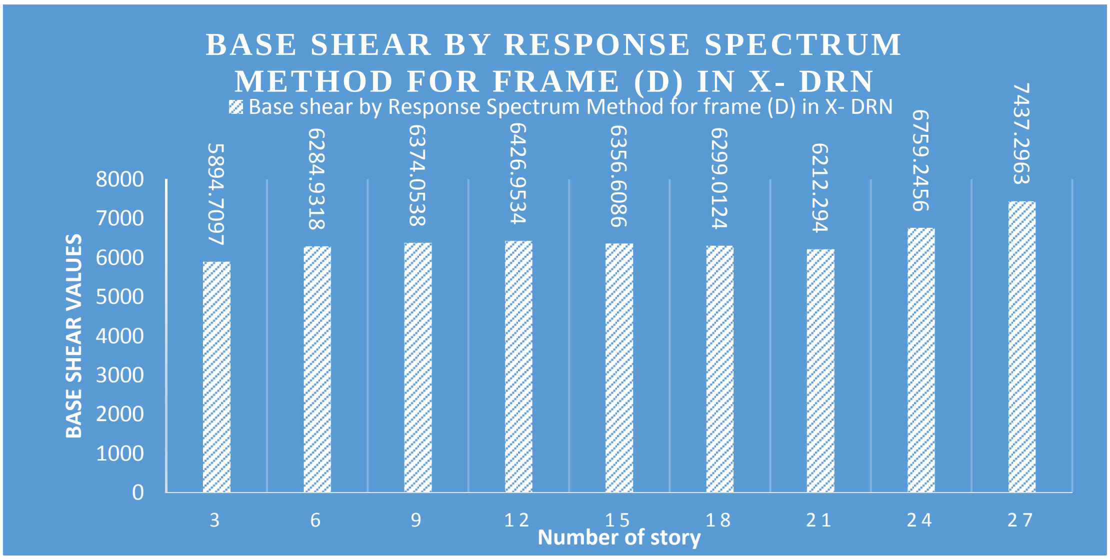


Figure 3 20: Base shear in X-direction for each 3-increment of Story number for frame by Response Spectrum (D)

3.7.6 Mode shape determination by excel and ETABS for Frame (D) of 9 story

The peak lateral force Q_{ik} at i^{th} floors in the k^{th} mode is given as:-

$$Q_{ik} = A_{hk} \Phi_{ik} p_k W_i$$

The values p_k and W_i can be calculated as per equation (3.2) and (3.1) respectively. Design horizontal acceleration spectrum value (A_{hk}) can be obtained using the period of structure Tk being determined for each modes based on dynamic analysis[1]. The stiffness and mass at each floor levels is calculated and shown below.

Table 3 16: Stiffness and mass at each story levels

Story Number	Stiffness (N/m)	mass (kg)
9	468552941	888574.67
8	512882466	944769.92
7	517271977	944769.92
6	518475013	944769.92
5	520397900	944769.92
4	524371409	944769.92
3	533144346	944769.92
2	566385279	944769.92
1	886590042	944769.92

The calculation for mode shapes has been done on 9 stories framed building using Excel and ETABS. The comparison based on the variation of the values obtained for the two methods has been conducted.

Table 3 17: Mode shapes values determined by Excel and ETABS

	MODE 1		MODE 2		MODE 3		MODE 4		MODE 5	
Frequency (rad/sec)	4.1229	4.0425	12.133	12.5543	19.665	21.9214	26.553	32.123	32.67	43.2528
MODE SHAPE	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**
ϕ_{9n}	0.015	0.015	-0.014	-0.014	-0.014	-0.014	-0.012	-0.012	-0.01	-0.01
ϕ_{8n}	0.0145	0.014	-0.0101	-0.01	-0.0037	-0.004	0.004	0.004	0.01	0.01
ϕ_{7n}	0.0136	0.013	-0.0038	-0.004	0.0083	0.008	0.0134	0.014	0.009	0.01
ϕ_{6n}	0.0123	0.012	0.0035	0.004	0.0144	0.014	0.0055	0.007	-0.01	-0.009
ϕ_{5n}	0.0106	0.01	0.0098	0.01	0.0103	0.011	-0.0095	-0.009	-0.009	-0.011
ϕ_{4n}	0.0086	0.008	0.0135	0.014	-0.001	-0.001	-0.0123	-0.013	0.009	0.008
ϕ_{3n}	-0.006	0.006	-0.0136	0.014	0.0115	-0.011	-0.0006	-0.001	-0.01	0.011
ϕ_{2n}	-0.004	0.004	-0.0101	0.011	0.014	-0.014	-0.0125	0.013	0.008	-0.007
ϕ_{1n}	-0.002	0.002	-0.0043	0.005	0.0073	-0.008	-0.009	0.011	0.01	-0.013

	MODE 6		MODE 7		MODE 8		MODE 9	
Frequency (rad/sec)	37.898	54.8865	42.113	66.2112	45.156	75.9246	46.981	82.553
MODE SHAPE	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**	**EXCEL**	**ETABS**
ϕ_{9n}	0.008	0.008	-0.005	-0.005	-0.004	-0.004	-0.002	-0.002
ϕ_{8n}	-0.014	-0.013	0.0118	0.01	0.0115	0.011	0.0064	0.005
ϕ_{7n}	0.0028	0.000241	-0.011	-0.008	-0.0175	-0.015	-0.0119	-0.007
ϕ_{6n}	0.0119	0.013	0.0025	-0.001	0.0189	0.012	0.0179	0.01
ϕ_{5n}	-0.01	-0.008	0.0083	0.009	-0.015	-0.005	-0.0244	-0.011
ϕ_{4n}	-0.006	-0.009	-0.013	-0.009	0.0068	-0.004	0.0313	0.011
ϕ_{3n}	-0.013	0.013	-0.007	0.001	-0.0035	0.012	0.0378	-0.01
ϕ_{2n}	0.002	0.002	-0.004	0.008	0.0123	-0.015	-0.0421	0.008
ϕ_{1n}	0.0118	-0.014	0.011	-0.011	-0.0148	0.012	0.0377	-0.005

From the mode shapes result for the two methods, the following things are observed:-

- ⇨ The frequencies are identical for the first few modes for both methods and then the results for ETABS become higher than that of Excel results for a higher mode of vibration.
- ⇨ The variation of the sign is observed in mode shape values for floor level 1 to floor level 3 but remain the same for both methods, this will not affect the base shear results as the response quantities are added by squaring them.
- ⇨ For mode 1 to mode 6 the mode shape values are almost identical. But for higher modes, the mode shapes by excel are large than that of ETABS in respective floor levels.

3.7.7 Shear forces and Bending Moments For frame (D) for 3 stories aimed at the selected columns

After the analysis is being carried out using the appropriate method, the load to be used for the design need to be determined. The magnitude of the load to be considered in the design is influenced by the method of the design being selected. It can be noticed that when using working stress design method, the design load will be taken as equal to the characteristic load values while it is a characteristic load with an appropriate safety factor in the limit state design method[18]. In this paperwork, the limits state design method has been selected to explore the magnitude of the shear forces and bending moments for the selected columns from the analysis results of linear static and linear dynamic methods. The axial, shear forces and the bending moments for Exterior Edge, Exterior middle, and Interior middle columns have been determined for the 3 stories framed building.

Table 3 18: Axials, shear forces, and bending moments for the exterior edge column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story 3	Exterior Edge	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-118.011	-7.6246	-15.1302
Story 3	Exterior Edge	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-94.0184	-7.6246	9.2685
Story 3	Exterior Edge	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-139.738	-26.4484	-35.7454
Story 3	Exterior Edge	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-115.745	-26.4484	48.8893
Story 3	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-66.1131	19.2824	12.7504
Story 3	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-42.1202	19.2824	111.0327

Story 3	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-191.637	-53.3554	-63.6261
Story 3	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-167.644	-53.3554	-52.8749
Story 3	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-66.1131	19.2824	12.7504
Story 3	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-42.1202	19.2824	111.0327
Story 3	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-191.637	-53.3554	-63.6261
Story 3	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-167.644	-53.3554	-52.8749
Story 2	Exterior Edge	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-232.279	4.6758	4.3932
Story 2	Exterior Edge	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-208.286	4.6758	-10.5695
Story 2	Exterior Edge	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-293.582	-27.4271	-48.6306
Story 2	Exterior Edge	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-269.589	-27.4271	39.136
Story 2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-77.3975	63.6648	94.5559
Story 2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-53.4045	63.6648	139.0081
Story 2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-448.464	-86.416	-138.7934
Story 2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-424.471	-86.416	-110.4416
Story 2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-77.3975	63.6648	94.5559
Story 2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-53.4045	63.6648	139.0081

Story 2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-448.464	-86.416	-138.7934
Story 2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-424.471	-86.416	-110.4416
story1	Exterior Edge	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-340.329	15.3575	51.3087
story1	Exterior Edge	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-316.336	15.3575	2.1649
story1	Exterior Edge	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-446.211	-29.3267	-67.6062
story1	Exterior Edge	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-422.218	-29.3267	26.2392
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-56.0165	110.6486	296.6304
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-32.0235	110.6486	86.8992
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-730.523	-124.618	-312.9278
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-706.53	-124.618	-58.4951
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-56.0165	110.6486	296.6304
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-32.0235	110.6486	86.8992
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-730.523	-124.618	-312.9278
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-706.53	-124.618	-58.4951

Table 3 19: Axials, shear forces, and bending moments for an exterior middle column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3

				m	kN	kN	kN-m
Story 3	Exterior middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-201.051	17.7928	25.3061
Story 3	Exterior middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-177.058	17.7928	-31.6308
Story 3	Exterior middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-201.051	-17.7928	-25.3061
Story 3	Exterior middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-177.058	-17.7928	31.6308
Story 3	Exterior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-149.349	71.0018	97.3803
Story 3	Exterior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-125.357	71.0018	130.6222
Story 3	Exterior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-252.753	-71.0018	-97.3803
Story 3	Exterior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-228.76	-71.0018	-130.6222
Story 3	Exterior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-149.349	71.0018	97.3803
Story 3	Exterior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-125.357	71.0018	130.6222
Story 3	Exterior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-252.753	-71.0018	-97.3803
Story 3	Exterior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-228.76	-71.0018	-130.6222
Story 2	Exterior middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-406.536	25.9307	45.3305
Story 2	Exterior middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-382.543	25.9307	-37.6476
Story 2	Exterior middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-406.536	-25.9307	-45.3305
Story 2	Exterior middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-382.543	-25.9307	37.6476

Story 2	Exterior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-249.68	120.9699	205.1847
Story 2	Exterior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-225.687	120.9699	182.3785
Story 2	Exterior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-563.392	-120.97	-205.1847
Story 2	Exterior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-539.4	-120.97	-182.3785
Story 2	Exterior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-249.68	120.9699	205.1847
Story 2	Exterior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-225.687	120.9699	182.3785
Story 2	Exterior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-563.392	-120.97	-205.1847
Story 2	Exterior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-539.4	-120.97	-182.3785
story1	Exterior middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-608.629	28.0996	66.1746
story1	Exterior middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-584.636	28.0996	-23.7441
story1	Exterior middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-608.629	-28.0996	-66.1746
story1	Exterior middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-584.636	-28.0996	23.7441
story1	Exterior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-322.284	145.7877	337.7098
story1	Exterior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-298.291	145.7877	129.0996
story1	Exterior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-894.974	-145.788	-337.7098
story1	Exterior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-870.981	-145.788	-129.0996

story1	Exterior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-322.284	145.7877	337.7098
story1	Exterior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-298.291	145.7877	129.0996
story1	Exterior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-894.974	-145.788	-337.7098
story1	Exterior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-870.981	-145.788	-129.0996

Table 3 20: Axials, shear forces and bending moments for interior middle column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story 3	Interior middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-312.381	20.8667	31.1461
Story 3	Interior middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-288.388	20.8667	-35.6275
Story 3	Interior middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-312.381	-20.8667	-31.1461
Story 3	Interior middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-288.388	-20.8667	35.6275
Story 3	Interior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-312.381	83.9121	121.83
Story 3	Interior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-288.388	83.9121	147.1916
Story 3	Interior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-312.381	-83.9121	-121.83
Story 3	Interior middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-288.388	-83.9121	-147.1916
Story 3	Interior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-312.381	83.9121	121.83

Story 3	Interior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-288.388	83.9121	147.1916
Story 3	Interior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-312.381	-83.9121	-121.83
Story 3	Interior middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-288.388	-83.9121	-147.1916
Story 2	Interior middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-624.364	29.9281	52.804
Story 2	Interior middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-600.371	29.9281	-42.9661
Story 2	Interior middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-624.364	-29.9281	-52.804
Story 2	Interior middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-600.371	-29.9281	42.9661
Story 2	Interior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-624.364	139.539	240.4734
Story 2	Interior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-600.371	139.539	206.3703
Story 2	Interior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-624.364	-139.539	-240.4734
Story 2	Interior middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-600.371	-139.539	-206.3703
Story 2	Interior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-624.364	139.539	240.4734
Story 2	Interior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-600.371	139.539	206.3703
Story 2	Interior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-624.364	-139.539	-240.4734
Story 2	Interior middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-600.371	-139.539	-206.3703
story1	Interior middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-936.864	30.3178	68.7625

story1	Interior middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-912.872	30.3178	-28.2546
story1	Interior middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-936.864	-30.3178	-68.7625
story1	Interior middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-912.872	-30.3178	28.2546
story1	Interior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-936.864	156.6247	350.371
story1	Interior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-912.872	156.6247	151.0203
story1	Interior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-936.864	-156.625	-350.371
story1	Interior middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-912.872	-156.625	-151.0203
story1	Interior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-936.864	156.6247	350.371
story1	Interior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-912.872	156.6247	151.0203
story1	Interior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-936.864	-156.625	-350.371
story1	Interior middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-912.872	-156.625	-151.0203

3.7.8 Shear forces and Bending Moments For frame (D for 27 stories aimed at the selected columns

The axial, shear forces and the bending moments for Exterior Edge, Exterior middle, and Interior middle columns have been determined for the 27 stories framed building.

Table 3 21: Axials, shear forces and bending moments for exterior edge column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story27	Exterior Edge	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-200.842	-57.5832	-90.4549
Story27	Exterior Edge	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-176.849	-57.5832	93.8114
Story27	Exterior Edge	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-196.961	-51.6596	-77.8176
Story27	Exterior Edge	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-172.968	-51.6596	87.4931
Story27	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-181.254	-40.3114	-57.4188
Story27	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-157.262	-40.3114	112.824
Story27	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-216.548	-68.9314	-110.8537
Story27	Exterior Edge	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-192.555	-68.9314	68.4805
Story27	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-181.254	-40.3114	-57.4188
Story27	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-157.262	-40.3114	112.824
Story27	Exterior Edge	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-216.548	-68.9314	-110.8537
Story27	Exterior Edgee	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-192.555	-68.9314	68.4805
Story2	Exterior Edge	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-4607.14	6.7603	16.5358

Story2	Exterior Edge	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-4583.15	6.7603	-5.0973
Story2	Exterior Edge	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-5763.63	-37.862	-72.4831
Story2	Exterior Edge	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-5739.64	-37.862	48.6755
Story2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-1801.57	98.6525	195.7382
Story2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-1777.58	98.6525	164.5247
Story2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-8569.2	-129.754	-251.6856
Story2	Exterior Edge	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-8545.21	-129.754	-120.9465
Story2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-1801.57	98.6525	195.7382
Story2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-1777.58	98.6525	164.5247
Story2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-8569.2	-129.754	-251.6856
Story2	Exterior Edge	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-8545.21	-129.754	-120.9465
story1	Exterior Edge	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-4711.33	23.3728	77.2842

story1	Exterior Edge	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-4687.34	23.3728	2.4912
story1	Exterior Edge	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-5934.13	-38.8955	-95.3939
story1	Exterior Edge	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-5910.14	-38.8955	29.0715
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-1721.62	152.2627	430.5962
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-1697.62	152.2627	89.4366
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-8923.85	-167.785	-448.706
story1	Exterior Edge	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-8899.86	-167.785	-57.8739
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-1721.62	152.2627	430.5962
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-1697.62	152.2627	89.4366
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-8923.85	-167.785	-448.706
story1	Exterior Edge	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-8899.86	-167.785	-57.8739

Table 3 22: Axials, shear forces and bending moments for exterior middle column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story27	Exterior Middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-239.79	11.1189	16.4663
Story27	Exterior Middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-215.797	11.1189	-19.1143

Story27	Exterior Middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-239.79	-11.1189	-16.4663
Story27	Exterior Middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-215.797	-11.1189	19.1143
Story27	Exterior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-220.638	46.3485	67.9365
Story27	Exterior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-196.645	46.3485	80.4919
Story27	Exterior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-258.942	-46.3485	-67.9365
Story27	Exterior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-234.949	-46.3485	-80.4919
Story27	Exterior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-220.638	46.3485	67.9365
Story27	Exterior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-196.645	46.3485	80.4919
Story27	Exterior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-258.942	-46.3485	-67.9365
Story27	Exterior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-234.949	-46.3485	-80.4919
Story2	Exterior Middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-6315.97	40.6989	77.3655
Story2	Exterior Middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-6291.97	40.6989	-52.871
Story2	Exterior Middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-6315.97	-40.6989	-77.3655
Story2	Exterior Middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-6291.97	-40.6989	52.871
Story2	Exterior Middle	Next to	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-3700.41	204.4628	385.8169

		Bottom					
Story2	Exterior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-3676.41	204.4628	268.7889
Story2	Exterior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-8931.53	-204.463	-385.8169
Story2	Exterior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-8907.53	-204.463	-268.7889
Story2	Exterior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-3700.41	204.4628	385.8169
Story2	Exterior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-3676.41	204.4628	268.7889
Story2	Exterior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-8931.53	-204.463	-385.8169
Story2	Exterior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-8907.53	-204.463	-268.7889
story1	Exterior Middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-6522.36	40.1371	96.8425
story1	Exterior Middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-6498.37	40.1371	-31.5961
story1	Exterior Middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-6522.36	-40.1371	-96.8425
story1	Exterior Middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-6498.37	-40.1371	31.5961
story1	Exterior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-3722.35	204.9137	492.1008
story1	Exterior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-3698.36	204.9137	163.8394

story1	Exterior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-9322.38	-204.914	-492.1008
story1	Exterior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-9298.39	-204.914	-163.8394
story1	Exterior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-3722.35	204.9137	492.1008
story1	Exterior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-3698.36	204.9137	163.8394
story1	Exterior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-9322.38	-204.914	-492.1008
story1	Exterior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-9298.39	-204.914	-163.8394

Table 3 23: Axials, shear forces and bending moments for the interior middle column of the building

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story27	Interior Middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-294.856	12.2705	18.7668
Story27	Interior Middle	Top	Comb1 (1.2dead+1.2 live+1.2E+X	End	-270.863	12.2705	-20.4989
Story27	Interior Middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-294.856	-12.2705	-18.7668
Story27	Interior Middle	Top	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-270.863	-12.2705	20.4989
Story27	Interior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-294.856	51.6551	78.3581
Story27	Interior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-270.863	51.6551	87.0092
Story27	Interior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-294.856	-51.6551	-78.3581

Story27	Interior Middle	Top	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-270.863	-51.6551	-87.0092
Story27	Interior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-294.856	51.6551	78.3581
Story27	Interior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-270.863	51.6551	87.0092
Story27	Interior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-294.856	-51.6551	-78.3581
Story27	Interior Middle	Top	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-270.863	-51.6551	-87.0092
Story2	Interior Middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-7645.84	47.5205	89.5621
Story2	Interior Middle	Next to Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-7621.85	47.5205	-62.5035
Story2	Interior Middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-7645.84	-47.5205	-89.5621
Story2	Interior Middle	Next to Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-7621.85	-47.5205	62.5035
Story2	Interior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-7645.84	238.6361	447.0849
Story2	Interior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-7621.85	238.6361	316.7798
Story2	Interior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-7645.84	-238.636	-447.0849
Story2	Interior Middle	Next to Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-7621.85	-238.636	-316.7798
Story2	Interior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-7645.84	238.6361	447.0849
Story2	Interior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-7621.85	238.6361	316.7798
Story2	Interior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-7645.84	-238.636	-447.0849

Story2	Interior Middle	Next to Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-7621.85	-238.636	-316.7798
story1	Interior Middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	Start	-7956.85	43.4829	100.746
story1	Interior Middle	Bottom	Comb1 (1.2dead+1.2 live+1.2E+X	End	-7932.86	43.4829	-38.3994
story1	Interior Middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	Start	-7956.85	-43.4829	-100.746
story1	Interior Middle	Bottom	Comb2 (1.2dead+ 1.2 live-1.2 E+X	End	-7932.86	-43.4829	38.3994
story1	Interior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	Start	-7956.85	221.8247	511.8406
story1	Interior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Max	End	-7932.86	221.8247	198.141
story1	Interior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	Start	-7956.85	-221.825	-511.8406
story1	Interior Middle	Bottom	Comb3 (1.2 dead+1.2live+1.2 RS Min	End	-7932.86	-221.825	-198.141
story1	Interior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	Start	-7956.85	221.8247	511.8406
story1	Interior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Max	End	-7932.86	221.8247	198.141
story1	Interior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	Start	-7956.85	-221.825	-511.8406
story1	Interior Middle	Bottom	Comb4 (1.2 dead+1.2 live-1.2 RS) Min	End	-7932.86	-221.825	-198.141

The following analysis results were observed from both linear methods:-

- ⇨ Linear Dynamic method has higher results for axial forces, shear and bending moments for both 3 stories framed building and that of 27 stories.
- ⇨ Axial forces values for both methods decreases from bottom to top columns, a shear force for linear static method change in a sign for topmost column and the

same is true for moments. The shear for linear dynamic method decrease from bottom to top columns.

- The magnitude of axial forces and bending moments for the interior middle column is higher than others for the selected load's combination which produced the maximum response. Comparing the magnitude of shear force values for interior middle column (bottom story) and Exterior middle (bottom story) for both methods of analysis, it is observed that the interior column has a 7% to 8.336% higher values than that of the exterior middle column. This is true for both 3 stories and 27 stories framed building.
- Finally, the magnitude of axial, shear forces and bending moments get increased for 27 stories than that of 3 stories framed building.

CHAPTER 4: BACKGROUND OF EUROCODE 8 AND THE METHODS OF ANALYSIS

In the year 1975, Eurocode was started by the decision being made by the commission of the European community. The commission decides to lay down the regulations in the field of construction based on article 95 of the treaty of Rome which was conducted in 1957. The program was done in order to eliminate the technical challenges which happen in the field of construction and the harmonization of the technical specification by providing technical rules which, in the initial period, would serve as a second option to the national specifications in the force in member states, and ultimately would replace them.

In 1984- The first Eurocodes was published by the commission with the help of a steering committee containing representatives of Member State and in the year 1990 to 1998, the Conversion, by CEN, of the first Eurocodes into provisional European standards (ENVs) was carried out. This was followed by the conversion of the provisional European standards (ENVs) into European Standards (EN) which was initiated in 1998. The year 2002 was regarded as the rebirth of Eurocode and in 2003 the Commission Recommendation on the implementation and use of Eurocodes was issued.

The publication of this En Eurocode was completed in the year 2007. At this time, the standard was parallelly implemented with the national standard in which both standards co-exist. In general, En Eurocodes can be defined as the set of European standards which were prepared in a view to lay down the common rules for the engineer to design the construction related works and to check the strength and the stability condition of the structure when it is subjected to the extreme fires or earthquakes. After the publication of the total 58 Eurocodes in the year 2007, the use and implementation of the standards were extending to all European countries and there is a firm plan for these standards to be used internationally [19].

In December 11, 2003, the commission stressed the importance of the training to be provided to the engineers on the use of Eurocodes. It also mentioned that the standard needs to be provided at a continuous basis in engineering schools at national and international level as well. It is recommended to undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge [20].

The Structural Eurocode program comprises the following standards which consist of different parts in each standard Category:

- EN 1990 Eurocode: Basis of structural design
- EN 1991 Eurocode 1: Actions on structures
- EN 1992 Eurocode 2: Design of concrete structures
- EN 1993 Eurocode 3: Design of steel structures
- EN 1994 Eurocode 4: Design of composite steel and concrete structures
- EN 1995 Eurocode 5: Design of timber structures
- EN 1996 Eurocode 6: Design of masonry structures
- EN 1997 Eurocode 7: Geotechnical design
- EN 1998 Eurocode 8: Design of structures for earthquake resistance
- EN 1999 Eurocode 9: Design of aluminum structures

4.1 Further part of EN 1998

EN1998 is applied to the design and construction of the building and civil engineering related works in the seismically vulnerable areas. The main purpose of the standard is to ensure that in the event of an earthquake, the human lives are protected, damages are limited and structures important for civil protection remain operational. This Eurocode 8 is further sub-divided into a different separate part which includes[5]:-

- EN 1998-1 applies to the design of buildings and civil engineering works in seismic regions.
- EN 1998-2 contains specific provisions relevant to bridges
- EN 1998-3 contains provisions for the seismic assessment and retrofitting of existing buildings
- EN 1998-4 contains specific provisions relevant to silos, tanks, and pipelines

- EN 1998-5 contains specific provisions relevant to foundations, retaining structures and geotechnical aspects
- EN 1998-6 contains specific provisions relevant to towers, masts, and chimneys

EN 1998-1 is subdivided into 10 Sections, some of which are specifically devoted to the design of buildings. Section-2 focused on the performance requirement and the compliance criteria's applicable to buildings and other civil Engineering structures, Section-3 give the representation of seismic action on the building and their combination with other loads. Section-4 is devoted to the general design rule which is specific to the building. Section-5-9 contain the various specific rule for the material and element for the building structures. Finally, Section 10 contains the fundamental requirements and other relevant aspects of design and safety related to base isolation of structures and specifically to base isolation of buildings[5].

4.2 Assumptions in Eurocodes.

The design which employs the Principles and Application Rules is deemed to meet the requirements provided the assumptions given in EN 1990 to EN 1999 are satisfied[21].

- The design of the structure in the selection of the structural system is assumed to be carried out by the well professional and experienced engineer.
- The construction execution is being assumed as will be carried out by well skilled and experienced personnel
- It is assumed that the supervision and the quality control related work is carried out in an effective manner for all construction stages started from the design office up to on-site works.
- The materials for the constructions are being selected and use as per the specifications provided in the EN1990 or as given in the EN1991 to EN1999. Or the materials are being used by referring to the execution standard or reference materials or the production specification provided.
- The maintenance of the structure will be carried out

- ⇨ The use of the structure will be based on the assumption being taken in the design process.
- ⇨ It should be bear in mind that no change is expected to be made during the construction phase of the structure and even in the subsequent life of the structure. This is also true even if such change will enable the structures to have more resistant to the action of the loads expected [5].

NOTE: there may be cases when the above assumptions need to be supplemented[21].

4.3 Methods of Analysis

Depending on the structural characteristics of the building, one of the following two types of linear-elastic analysis or Non-linear methods that follow may be used:

1) lateral force method of analysis
2) modal response spectrum analysis
3) Non-linear static (pushover) analysis
4) Non-linear time-history analysis

4.3.1 Requirements for application of Lateral force method of analysis

This method of analysis may be applied to the building's structure whose response is not affected by the contribution of the higher mode other than the fundamental one in each principle horizontal direction [5].

The criteria required to satisfy the above conditions is that the fundamental period of structure limit and the Regularity in Elevation must be meet:-

⇨ $$\boldsymbol{T} \leq \begin{cases} \boldsymbol{4Tc} \\ \boldsymbol{2.0\ s} \end{cases}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

  - Where: - Tc is given in Table 3.2 or Table 3.3 EN 1998-1.

- ⇨ The load's resisting structural elements are required to run from the foundation level up to the top of the structures. These may include, columns, cores, shearwalls, and other elements. If the setback is there in a structural framing system, these elements should run up to the level of the setback. The setback limitation given in the code must be satisfied in this regard.
- ⇨ The mass of the structure at each story levels and the lateral stiffness of the building shall remain constant from the bottom of the structural foundation to the topmost part of the building. If there is a change to be expected for the above parameters, they must not abruptly changes but gradually.
- ⇨ For the building with the structural framed system, the ratio of the actual resistance of the structure and that required by the analysis should not varied at each adjacent story disproportionally.

4.3.2 Seismic base Shear determination using lateral force method

The earthquake-induced Base shear force Fb, for each horizontal direction in which the building is analyzed, shall be determined using the following expression:

$F_b = S_d(T_1) * m * \lambda$…………………………………………….. (4.2)

Where: - $S_d(T_1)$ Is the ordinate of the design spectrum at (T).

The selection of appropriate spectral type is based on the magnitude of the seismic action based on the assessment of the quake that contributed to most of the seismic destruction defined in a probabilistic term. If the earthquake surface-wave magnitude, Ms, not greater than 5.5, it is recommended that the Type 2 spectrum is adopted. The corresponding ground types are given in Table 3.1-EN1998-1. T_1= is the fundamental period of the building structure in the considered direction. It can be determined by using athe ppropriate formula given in structural dynamic.

For a building up to 40m Height, It can be determined by:- $T_1 = C_t * H^{3/4}$ where C_t depends on the structural system being used.

λ=is the correction factor, the value of which is equal to: λ = 0,85 if T1 < 2 TC and the building has more than two story, or λ = 1,0 otherwise. This is to account for the fact that the modal mass of the building of at least three story will be less than the total building mass.

m= Total mass of the building above the Foundation or above the top of the rigid basemen floor. This is calculated as:-

m=$\sum G_{k,j} + \sum \psi_{E,i}\, Q_{k,i}$,

Where, $\psi_{E,i}$ is the combination coefficient for variable action given as follow:-

$\psi_{E,i} = \varphi\psi_{2,i}$, Where φ is given in table 4.2-EN1998-1 based on story activities in each category[5]. $\psi_{2,i}$, is given in the tableA1.1-EN1990:2002 based on the building category[21].

4.3.3 Distribution of the horizontal seismic forces

The seismic action on the structure and the structural responses are determined by applying lateral loads $\boldsymbol{F_i}$ to all storeys at each level given as:-

$\boldsymbol{F_i = F_b \frac{m_i s_i}{\sum m_j s_j}}$, where: - s_i, s_j are the displacements at each story levels.

When the fundamental mode shape is approximated by horizontal displacements increasing linearly from the bottom to top of the structure, the horizontal forces Fi should be taken as being given by:

$\boldsymbol{F_i = F_b \frac{m_i h_i}{\sum m_j h_j}}$, where $h_{i,} h_j$are the height of masses at each levels above the levels of application of seismic base shear.

The horizontal forces $\boldsymbol{F_i}$ determined shall be distributed to the lateral load resisting system assuming the floors are rigid in their plane. The accidental torsional effect may be taken into account by multiplying the seismic action with some factor determining using the formula provided in the code [5].

4.3.4 Modal response spectrum analysis

This method is to be used for the analysis of the building structure which failed to satisfy the condition for the Vertical regularity requirements provided in the code. It should be noted that the responses of all the modes which actually contribute to the global structural response need to be considered. The need to consider all the modes of structural response shall be fulfilled if the following conditions are met.

- The sum of the modal masses of the modes to be considered should amount to at least 90% of the resulted total seismic weight of the structure.
- The modes with the effective modal masses which can be 5% of the total mass of the structures need to be taken in to under consideration

The above conditions need to observed in each orthogonal direction when using a spatial structural model.

4.3.5 Combination of modal responses

After the independent determination of the seismic responses of the building for different modes of the vibration, the combined effect of the earthquake action $\boldsymbol{E_E}$ is obtained by using the following expressioon

$\boldsymbol{E_E} = \sqrt{\sum \boldsymbol{E_{EI^2}}}$, Where: - (E_E) is the combined seismic effect of the response being taken in to consideration such as displacemen or forces. $(\boldsymbol{E_{Ei}})$ is the seismic responses of the structures for the particular i mode of the vibration.

The designer may decide to use a more accurate method as a mean of combining the values of the response such as "Complete Quadratic Combination" [5]. The accidental torsional effect may be taken into account depending on whether the model is spatial or planar as per the standard provisions.

4.3.6 Non-linear methods

When exploring the response of the structure for earthquake resistant, the model used for elastic analysis method can be extended to the one that can incorporate the strength of the structural framed component and their characteristic in the post-elastic stage. This can be done by the use of the non-linear method.

4.3.6.1 Non-linear static (pushover) analysis

Among the others, the non-linear static method is a mean of structural analysis through which the designer can determine the structural response subjected to seismic action. The method is actually carried out by applying a monotonically increasing horizontal load under a constant gravity loading on the structure. One of the reasons by which the engineer may use this method can be for the verification of the performance of the new structure to be constructed or the investigation of existing building condition.

- The method can be used for the verification or revision of the over-strength ratio value given as (αu/α1).
- This can be employed to have an understanding of the damage distribution over the structural frame and the overview of the plastic deformation expected to take place.
- To investigate the condition of the already existing building for the purpose of retrofitting its components as required by the EN 1998-3.
- This can be used as an alternative method in the analysis of the structure for the seismic resistant design over linear elastic method.
- For a building which does not satisfy the plan and special regularity requirements given in the code, we can use a spatial model of our structure.
- It can be used to obtain a curve called ‘’Capacity Curve’’ which is curve defining the relationship between the structural base shear and the controlled displacement.

a) Lateral load

For the purpose of this method, at least two different vertically distributed loading condition should be applying on the structure for the analysis.

- Loading which is proportional to the mass of the building with a uniform pattern should be applied on the structure without regarding the elevation configuration.
- loading with a modal pattern which is actually proportional to the lateral loading distribution determined using one of the linear elastic methods of the analysis.

4.3.6.2 Non-linear time-history analysis

When the equation of the motion based on the recorded/simulated accelerogram or an artificial one is solved using the method of numerical integration, the time-dependent structural response can be obtained on solving the differential equation. The structural element models should incorporate the bilinear force-deformation relationship at the element level and the mean value of the material property need to be taken. zero-post yield stiffness may be assumed. This should be supported by providing the rule through which the complaint of the element in the post-elastic condition when it is unloaded and then reloaded again can be effectively understood. This rules should explain all expected element behavior including the energy dissipation characteristic. The average of the response quantity should be taken for several time history response values of the analysis[5].

CHAPTER 5: COMPARISON OF STATIC AND LINEAR DYNAMIC METHOD BASED ON EUROCODE 8

5.1 Base Shear determination based on EN1998 standard

ETABS: 2016 Software is used to determine the frame response to seismic loading for this paperwork.

5.2 Base Shear Determination for Frame (A)

For this frame, the base shear has been determined using the two linear methods of analysis. The loading applied on the structure constitutes the dead load plus the percentage of imposed load obtained based on the code provisions. The moment resisting frame having Medium capacity dissipation behavior (DCM) is used as a structural system. For this, the behavioral factor of 4 is used.

5.2.1 Equivalent Static Method of Analysis

This is one of the methods in the linear elastic analysis of the structures for the purpose of seismic resistant design. It can be used for the building structures whose response value cannot be significantly influenced by the contribution of the other higher modes of vibration than that of the first natural period of oscillation.

- ⇨ The fundamental period of the structure in two principle direction should be less than the following values/.

$$\boldsymbol{T} \leq \begin{cases} \boldsymbol{4} * \boldsymbol{T_C} \\ \boldsymbol{2.0\ s} \end{cases} \qquad (5.1)$$

Where Tc is defined in the code.

⇨ The building meets the criteria given for regularity in elevation

5.2.2 Seismic weight of the structure for each building story category

The inertia forces which are generated due to the action of the seismic can be determined by taking into consideration the building masse associated with each difference loading on the structure by the use of the equation given below.

$$\boldsymbol{M} = \sum \boldsymbol{G}_{k,j} + \sum \boldsymbol{\psi}_{E,i} * \boldsymbol{Q}_{k,i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.2)}$$

Where: - $\boldsymbol{\psi}_{E,i}$is the combination coefficient for variables actions.

This coefficient represents the probability in which the action $\boldsymbol{Q}_{k,i}$ may not be present over the entire structure during earan thquake. It may also present the reduction of the participation of the masses in the motion of structure due to the non-rigidity of their connection.[22]

$$\boldsymbol{\psi}_{E,i} = \boldsymbol{\varphi} * \boldsymbol{\psi}_{2,i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.3)}$$

Where $\boldsymbol{\varphi}$=0.8 table 4.2-EN 1998-1 (Correlated occupancy)

$\boldsymbol{\psi}_{2,i}$=Table A1.1-EN 1990:2002. 0ffice building=0.3[21]

The imposed load on structure is 4kN/m² and the calculation have been done for all building story number category as it can be shown in the below figure.

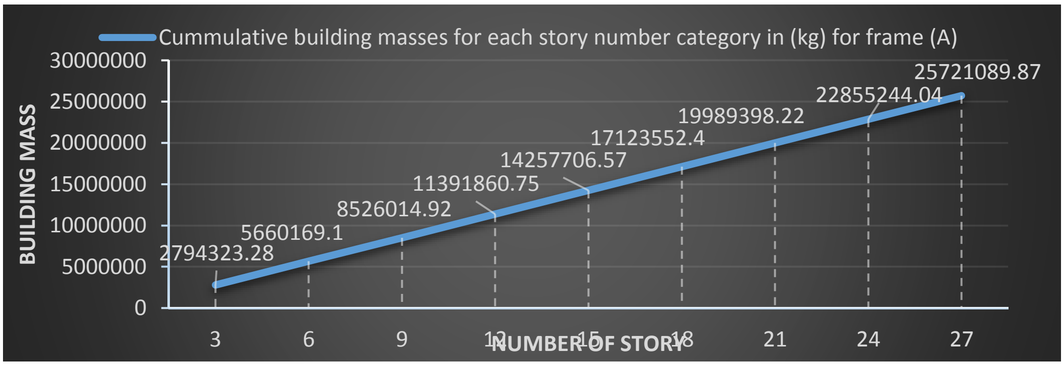


Figure 5 1: seismic weight for the frame (A) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$(\frac{weight\ of\ 27\ story\ frame-weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}*100$$

= ((25721089.87-2794323.28)/ 2794323.28)*100=820.4765266%

5.2.3 Natural period for the first mode in each building story category for the frame (A)

The fundamental period of the structure for the two principle direction is obtained with the help of ETABS software. The first two modes period is presented by the use of Excel and it can be seen below.

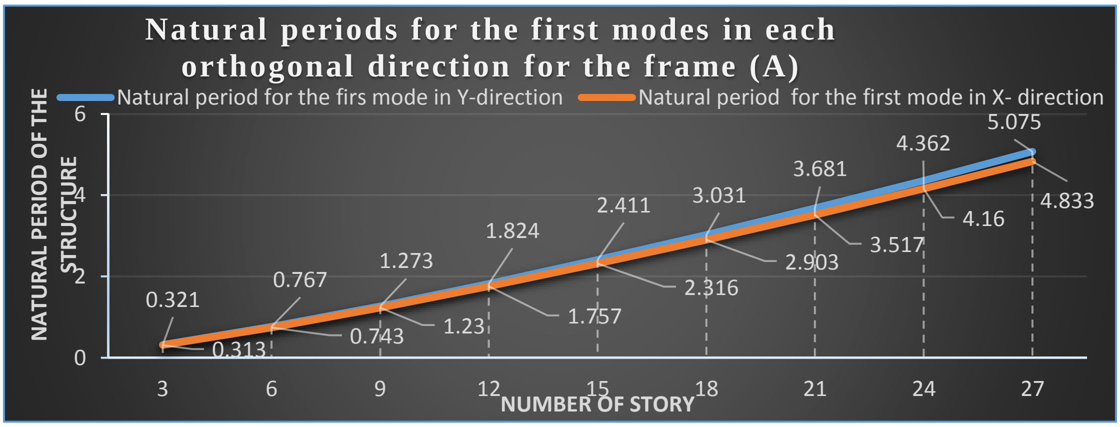


Figure 5 2: Natural periods for the first modes in each orthogonal direction for the frame (A).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section.

5.2.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to EUROCODE8 2004, as calculated by ETABS.

5.2.4.1 Base Shear in X- Direction

a) Structural Period

Period Calculation Method = Program Calculated

Coefficient, C_t [EC 4.3.3.2.2]	$C_t = 0.075\text{m}$
Structure Height Above Base, H	$H = 97.2 \text{ m}$

b) Factors and Coefficients

Country = **Ethiopia**, Afar Region.

Design Ground Acceleration, a_g	$a_g = 0.2g$

Ground Type [EC Table 3.1] = B

Soil Factor, S [EC Table 3.3]	$S = 1.35$
Constant Acceleration Period Limit, T_B [EC Table 3.3]	$T_B = 0.05 \text{ sec}$
Constant Acceleration Period Limit, T_C [EC Table 3.3]	$T_C = 0.25 \text{ sec}$
Constant Displacement Period Limit, T_D [EC Table 3.3]	$T_D = 1.2 \text{ sec}$
Lower Bound Factor, β [EC 3.2.2.5(4)]	$\beta_0 = 0.2$
Behavior Factor, q [EC 3.2.2.5(3)]	$q = 4$

c) Seismic Response

Spectral Response Acceleration, Sd(T1) [EC 3.2.2.5(4) Eq. 3.13]

$$S_d(T_1) = a_g S[\frac{2}{3} + \frac{T}{T_B}(\frac{2.5}{q} - \frac{2}{3})] \text{ for } T \leq T_B$$

$$= a_g S \frac{2.5}{q} \text{ for } T_B \leq T \leq T_C \text{......eqn(14)}$$

$$= a_g S \frac{2.5}{q}[\frac{T_C}{T}] \geq \beta a_g \text{ for} T_C \leq T \leq T_D$$

$$= a_g S \frac{2.5}{q}\left[\frac{T_C T_D}{T^2}\right] \geq \beta a_g \text{ for} T_D \leq T$$

d) Equivalent Lateral Forces

Seismic Base Shear Coefficient $V_{coeff} = S_d(T_1)\lambda$

Table 5 1: Calculated Base Shear in X-direction

Direction	**Period Used (sec)**	**W (kN)**	**F_b (kN)**
X	4.833	253258.0812	8610.7748

5.2.4.2 Vertical laterally distributed shear at each floor levels.

$$\boldsymbol{F_i = F_B * \frac{S_i * m_i}{\sum S_j * m_j}} \text{.. (5.4)}$$

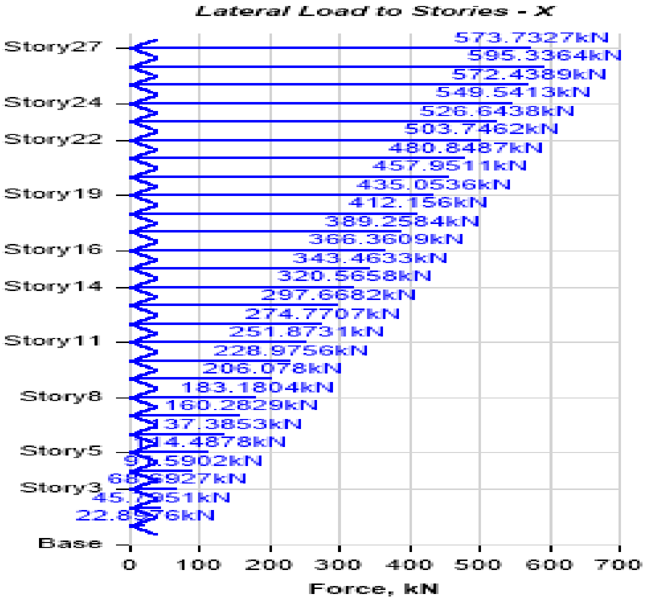


Figure 5 3: distributed Lateral load at each story level in the x-direction for the frame (A)

5.2.4.3 Base Shear in Y- Direction

a) Equivalent Lateral Forces

Seismic Base Shear Coefficient $V_{coeff} = S_d(T_1)\lambda............ (5.5)$

Table 5 2: Calculated Base Shear in Y-direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
Y	5.075	253258.0812	8610.7748

5.2.4.4 Vertical Lateral distributed shear at each floor levels.

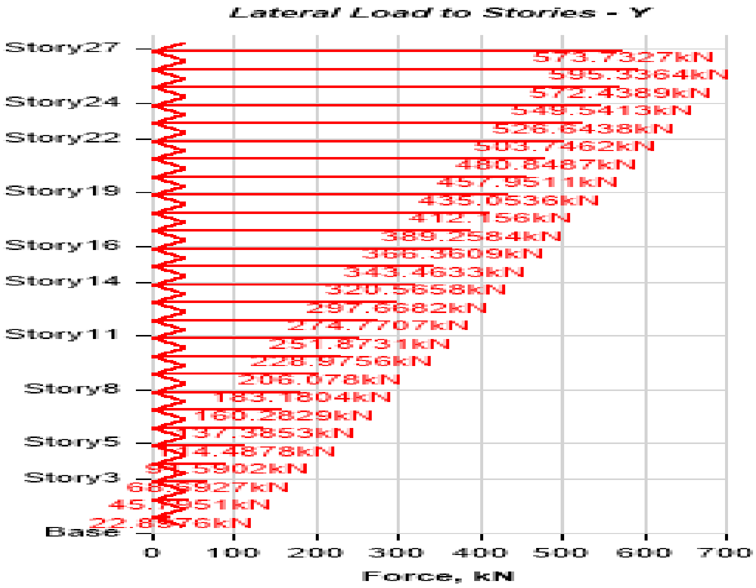


Figure 5 4: distributed Lateral load at each story level in Y-direction for the frame (A)

5.2.5 Response Spectrum Analysis.

This is a type of linear dynamic analysis which can be used for the building that does not satisfy the requirements given in the code for Equivalent static methods. It should be considered in the analysis that the sum of the effective masse for all the modes taken must be 90% of the total masses of the building under study. For this paperwork, the ETABS: 2016 is used for the base shear determination as per the code and the response quantities are combined using Square root of the sum of squares (SRSS) method.

5.2.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 5 3: Base Shear calculated for each 3-increment of story number for two methods for the frame (A)

	Linear Static method		Response Spectrum Method	
Number of The story	x	y	x	y

3	(-)3154.9544	(-)3071.8795	3182.9701	2925.6123
6	(-)2690.7504	(-)2605.1114	2844.3335	2640.3305
9	(-)2854.913	(-)2854.9133	3053.4417	2882.1482
12	(-)3814.2229	(-)3814.2235	3754.1659	3568.1784
15	(-)4773.5324	(-)4773.5338	4499.3085	4304.2295
18	(-)5732.8413	(-)5732.8441	5280.3782	5079.6869
21	(-)6692.1491	(-)6692.1543	6084.1585	5883.7589
24	(-)7651.4571	(-)7651.4646	6918.5431	6718.7298
27	(-)8610.7639	(-)8610.775	7762.7772	7563.5177
Note: The positive Values of base shear for Linear static method has been taken				

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6 and 9 story framed building. But for a frame of 12 stories, 15 and up to 27 story buildings, the base shear by linear static method becomes higher than that of the linear dynamic method.
- The base shear decreased for 3 story frame to 6 story framed building in which the first natural period is in the interval of (4TC or 2) and then increased excessively for 6 stories to 27 framed building in which the first natural period is greater than (4Tc) for both methods.

- It is observed that the base shear value for 6 stories framed building is decreased by 17.252% and 11.906% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- It is observed that the base shear value for 27 stories framed building is increased by 220.013% and 172.921% than the value for 6 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

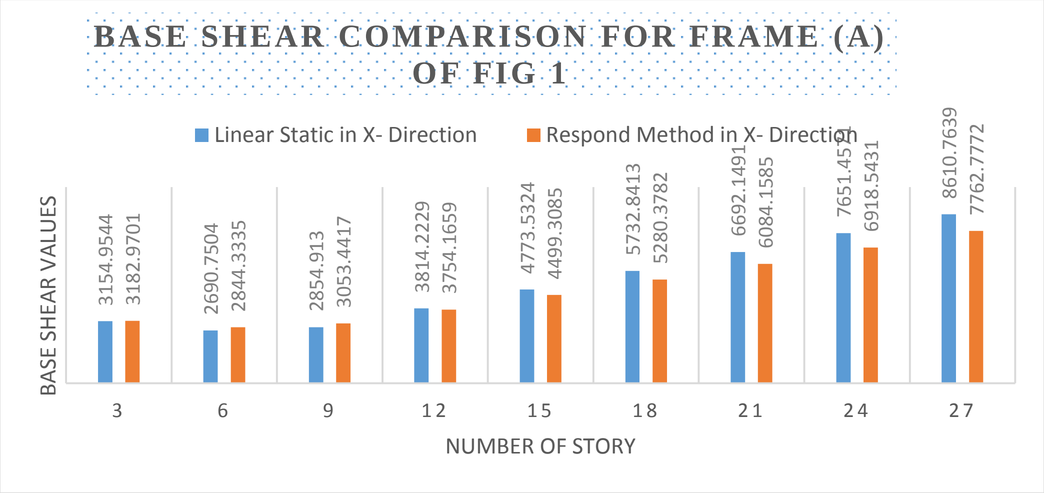


Figure 5 5: Base shear in X-direction for each 3-increment of Story number for the frame (A)

5.3 Base Shear Determination for Frame (B)

For this frame, the base shear has been determined using the two linear methods of analysis. The loading applied on the structure constitutes the dead load plus the percentage of imposed load obtained based on the code provisions. The moment resisting frame having Medium capacity dissipation behavior (DCM) is used as a structural system. For this, the behavioral factor of 4 is used.

5.3.1 Equivalent Static Method of Analysis

This is one of the methods in the linear elastic analysis of the structures for the purpose of seismic resistant design. It can be used for the building structures whose response value cannot be significantly influenced by the contribution of the other higher modes of vibration than that of the first natural period of oscillation.

- ⇨ The fundamental period of the structure in two principle direction should be less than the following values.

$$\boldsymbol{T \leq \begin{cases} 4 * T_C \\ 2.0\ s \end{cases}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.6)}$$

Where Tc is defined in the code.

⇨ The building meets the criteria given for regularity in elevation

5.3.2 Seismic weight of the structure for each building story category

The inertia forces which are generated due to the action of the seismic can be determined by taking into consideration the building masse associated with each difference loading on the structure by the use of the equation given below.

$\boldsymbol{M} = \sum \boldsymbol{G}_{\boldsymbol{k},\boldsymbol{j}} + \sum \boldsymbol{\psi}_{\boldsymbol{E},\boldsymbol{i}} * \boldsymbol{Q}_{\boldsymbol{k},\boldsymbol{i}}$ …………………………….. (5.7)

Where: - $\boldsymbol{\psi}_{\boldsymbol{E},\boldsymbol{i}}$is the combination coefficient for variables actions.

This coefficient represents the probability in which the action $\boldsymbol{Q}_{\boldsymbol{k},\boldsymbol{i}}$ may not be present over the entire structure during earan thquake. It may also present the reduction of the participation of the masses in the motion of structure due to the non-rigidity of their connection.[22]

$\boldsymbol{\psi}_{\boldsymbol{E},\boldsymbol{i}} = \boldsymbol{\varphi} * \boldsymbol{\psi}_{\boldsymbol{2},\boldsymbol{i}}$ …………………………………...... (5.8)

Where $\boldsymbol{\varphi}$=0.8 table 4.2-EN 1998-1 (Correlated occupancy)

$\boldsymbol{\psi}_{\boldsymbol{2},\boldsymbol{i}}$=Table A1.1-EN 1990:2002. 0ffice building=0.3[21]

The imposed load on structure is 4kN/m² and the calculation have been done for all building story number category as it can be shown in the below figure.

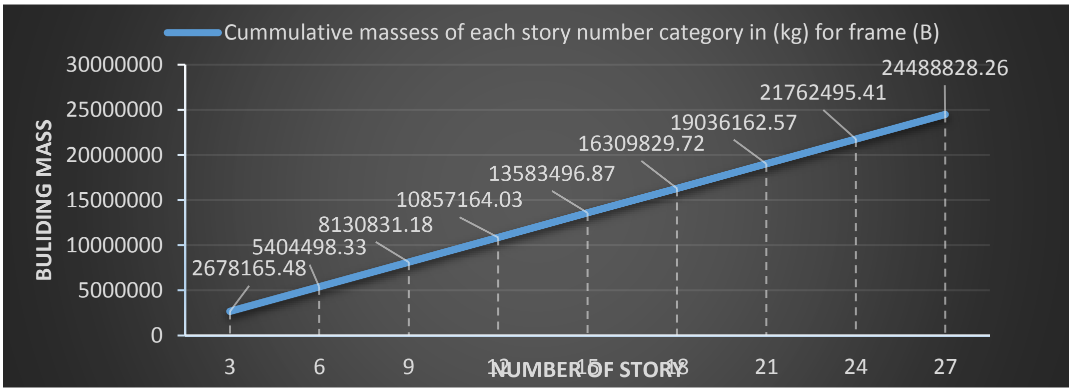


Figure 5 6: seismic weight for the frame (B) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$\left(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}\right.*100$$

= ((24488828.26- 2678165.48)/ 2678165.48)*100= 814.3881677%

5.3.3 Natural period for the first mode in each building story category for the frame (B)

The fundamental period of the structure for the two principle direction is obtained with the help of ETABS software. The first two modes period is presented by the use of Excel and it can be seen below.

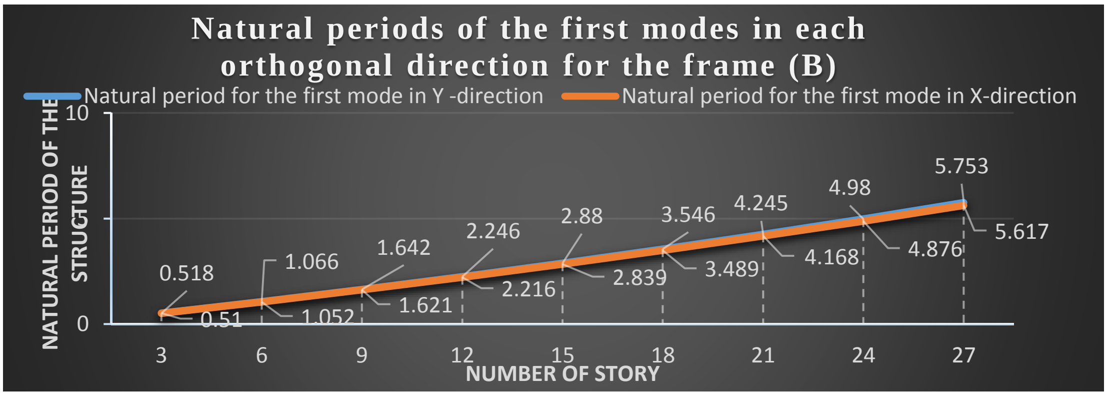


Figure 5 7: Natural periods for the first modes in each orthogonal direction for the frame (B).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section

5.3.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X and E+Y according to EUROCODE 8 2004, as calculated by ETABS.

5.3.4.1 Equivalent Lateral Forces

Seismic Base Shear Coefficient $V_{\mathrm{coeff}} = S_{\mathrm{d}}(T_1)\lambda$ …………. (5.9)

Table 5 4: calculated Base Shear in X-direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
X	5.617	240153.3725	8165.2147

Table 5 5: Calculated Base Shear in Y-direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
Y	5.753	240153.3725	8165.2147

5.3.5 Response Spectrum Analysis

This is a type of linear dynamic analysis which can be used for the building that does not satisfy the requirements given in the code for Equivalent static methods. It should be considered in the analysis that the sum of the effective masse for all the modes taken must be 90% of the total masses of the building under study. For this paperwork, the ETABS: 2016 is used for a base shear determination as per the code and the response quantities are combined using Square root of the sum of squares (SRSS) method.

5.3.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 5 6: Base Shear calculated for each 3-increment of story number by two methods for the frame (B)

	linear Static method		Response spectrum method	
Number of stories	x	y	x	y
3	(-)1845.1036	(-)1819.1489	1960.2174	1913.8839
6	(-)1805.8469	(-)1802.0008	1958.2157	1932.3842
9	(-)2711.0314	(-)2711.0314	2728.6149	2698.4379
12	(-)3620.0619	(-)3620.0619	3527.1323	3490.9227
15	(-)4529.0925	(-)4529.0925	4335.238	4292.9729
18	(-)5438.123	(-)5438.123	5147.3136	5098.9073
21	(-)6347.1536	(-)6347.1536	5971.3249	5915.4069
24	(-)7256.1841	(-)7256.1841	6794.1343	6730.6673
27	(-)8165.2147	(-)8165.2147	7614.5596	7543.2638

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3 stories, 6 and 9 story framed building. But for a frame of 12 stories, 15 and up to 27 story buildings, the base shear by linear static method becomes higher than that of the linear dynamic method.
- The base shear decreased for 3 story frame to 6 story framed building in which the first natural period is in the interval of (4TC or 2) and then increased excessively for 6 stories to 27 framed building in which the first natural period is greater than (4Tc) for both methods.

- It is observed that the base shear value for 6 stories framed building is decreased by 2.174% and 0.102% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- It is observed that the base shear value for 27 stories framed building is increased by 352.154% and 288.852% than the value for 6 stories framed

building using Linear Static and Linear dynamic method in X-direction respectively.

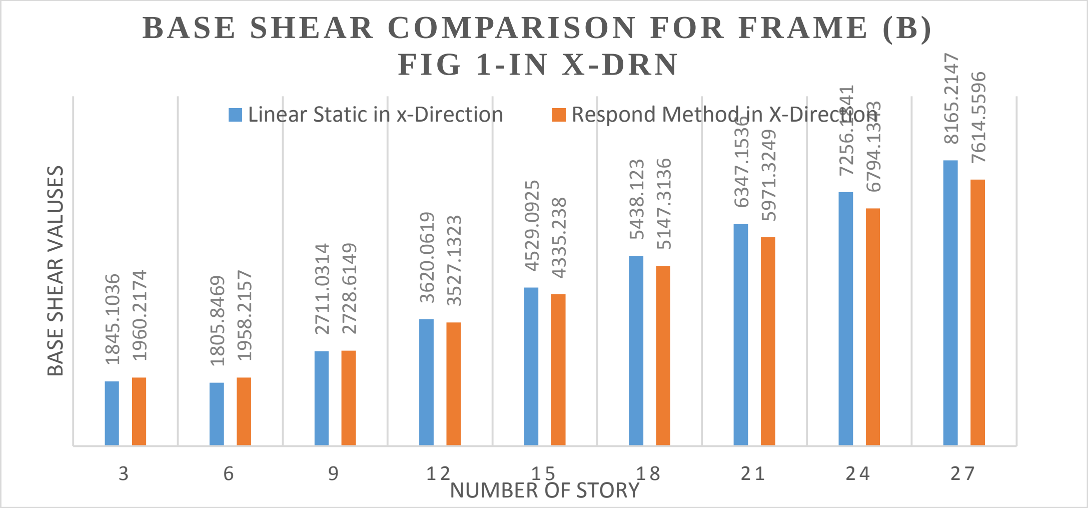


Figure 5 8: Base shear in X-direction for each 3-increment of Story number for the frame (B)

5.4 Base Shear Determination for Frame (C)

For this frame, the base shear has been determined using the two linear methods of analysis. The loading applied on the structure constitutes the dead load plus the percentage of imposed load obtained based on the code provisions. The moment resisting frame having Medium capacity dissipation behavior (DCM) is used as a structural system. For this, the behavioral factor of 4 is used.

5.4.1 Equivalent Static Method of Analysis

This is one of the methods in the linear elastic analysis of the structures for the purpose of seismic resistant design. It can be used for the building structures whose response value cannot be significantly influenced by the contribution of the other higher modes of vibration than that of the first natural period of oscillation.

- ⇨ The fundamental period of the structure in two principle direction should be less than the following values.

$$\boldsymbol{T} \leq \begin{cases} \boldsymbol{4 * T_C} \\ \boldsymbol{2.0\ s} \end{cases} \text{……………………………………………………….. (5.10)}$$

Where Tc is defined in the code.

- ⇨ The building meets the criteria given for regularity in elevation

5.4.2 Seismic weight of the structure for each building story category

The inertia forces which are generated due to the action of the seismic can be determined by taking into consideration the building masse associated with each difference loading on the structure by the use of the equation given below.

$$\boldsymbol{M = \sum G_{k,j} + \sum \psi_{E,i} * Q_{k,i}} \text{ …………………………………………… (5.11)}$$

Where: - $\boldsymbol{\psi_{E,i}}$is the combination coefficient for variables actions.

This coefficient represents the probability in which the action $\boldsymbol{Q_{k,i}}$ may not be present over the entire structure during an earthquake. It may also present the reduction of the participation of the masses in the motion of structure due to the non-rigidity of their connection.[22]

$$\boldsymbol{\psi_{E,i} = \varphi * \psi_{2,i}} \text{ ……………………………………………………….. (5.12)}$$

Where $\boldsymbol{\varphi}$=0.8 table 4.2-EN 1998-1 (Correlated occupancy)

$\boldsymbol{\psi_{2,i}}$=Table A1.1-EN 1990:2002. 0ffice building=0.3[21]

The imposed load on structure is 4kN/m² and the calculation have been done for all building story number category as it can be shown in the below figure.

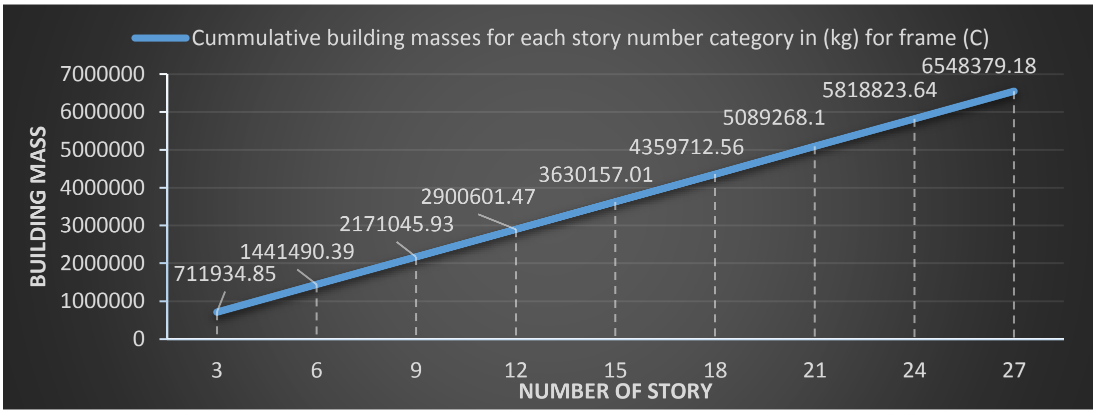


Figure 5 9: seismic weight for the frame (C) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame} * 100$$

= ((6548379.18- 711934.85)/ 711934.85)*100= 819.8003413%

5.4.3 Natural period for the first mode in each building story category for the frame (C)

The fundamental period of the structure for the two principle direction is obtained with the help of ETABS software. The first two modes period is presented by the use of Excel and it can be seen below

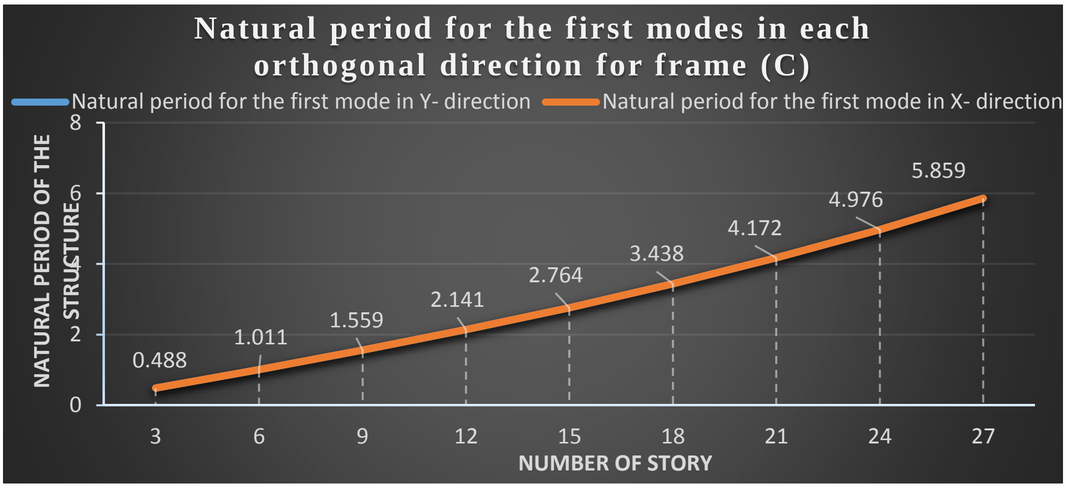


Figure 5 10: Natural periods for the first modes in each orthogonal direction for the frame (C).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section**.**

5.4.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X according to EUROCODE8 2004, as calculated by ETABS.

5.4.4.1 Equivalent Lateral Forces

Seismic Base Shear Coefficient $V_{coeff} = S_d(T_1)\lambda$………………… (5.13)

Table 5 7: Calculated Base Shear in X-direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
X	5.859	64217.664	2183.4006

Table 5 8: Calculated Base Shear in Y-direction

Direction	**Period Used (sec)**	**W (kN)**	**F_b (kN)**
Y	5.859	64217.664	2183.4006

5.4.5 Response Spectrum Analysis

This is a type of linear dynamic analysis which can be used for the building that does not satisfy the requirements given in the code for Equivalent static methods. The sum of the effective modal masses for the modes taken in to account amount to at least 90% of the total mass of the structure. For this paperwork, the ETABS: 2016 is used for a base shear determination as per the code and the response quantities are combined using Square root of the sum of squares (SRSS) method.

5.4.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 5 9: Base Shear calculated for each 3-increment of story number by two methods for the frame (C).

	Linear Static Method		Response Spectrum Method	
Number of Story	x	y	x	y
3	(-)512.5666	(-)512.5666	546.837	546.837
6	(-)501.6231	(-)501.6231	543.4955	543.4955
9	(-)723.8834	(-)723.8834	736.1718	736.1718
12	(-)967.1363	(-)967.1363	950.0324	950.0324
15	(-)1210.3891	(-)1210.3891	1162.8386	1162.8388
18	(-)1453.642	(-)1453.642	1372.8732	1372.8733
21	(-)1696.8948	(-)1696.8948	1583.858	1583.8581
24	(-)1940.1477	(-)1940.1477	1790.8893	1790.8893
27	(-)2183.4006	(-)2183.4006	1994.2826	1994.2826

From the base shear results, the following things are observed:-

- For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.

- The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3, 6 and 9 story framed building. But for a frame of 12 stories, 15 and up to 27 story buildings, the base shear by linear static method becomes higher than that of the linear dynamic method.
- The base shear decreased for 3 story frame to 6 story framed building in which the first natural period is in the interval of (4TC or 2) and then increased excessively for 6 stories to 27 framed building in which the first natural period is greater than (4Tc) for both methods.
- It is observed that the base shear value for 6 stories framed building is decreased by 2.182% and 0.615% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.
- It is observed that the base shear value for 27 stories framed building is increased by 335.267% and 266.936% than the value for 6 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

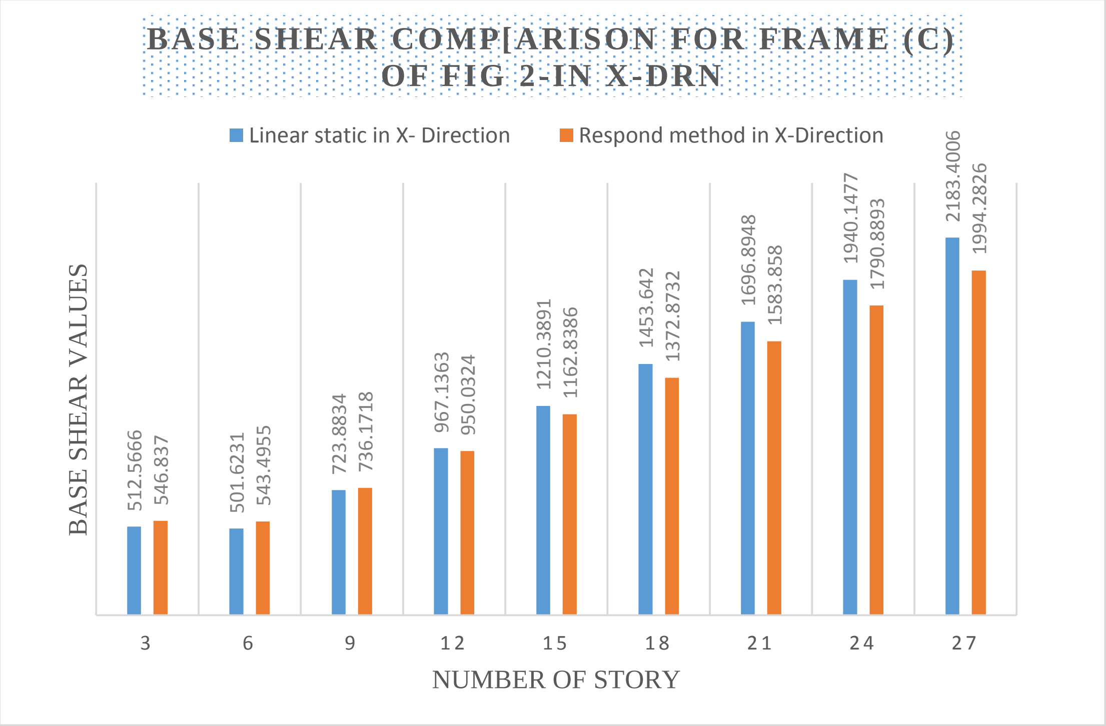


Figure 5 11: *Base shear in X-direction for each 3-increment of Story number for the frame (C)*

5.5 Base Shear Determination for Frame (D)

For this frame, the base shear has been determined using the two linear methods of analysis. The loading applied on the structure constitutes the dead load plus the percentage of imposed load obtained based on the code provisions. The moment resisting frame having Medium capacity dissipation behavior (DCM) is used as a structural system. For this, the behavioral factor of 4 is used.

5.5.1 Equivalent Static Method of Analysis

This is one of the methods in the linear elastic analysis of the structures for the purpose of seismic resistant design. It can be used for the building structures whose response value cannot be significantly influenced by the contribution of the other higher modes of vibration than that of the first natural period of oscillation.

- ⇨ The fundamental period of the structure in two principle direction should be less than the following values/.

$$\boldsymbol{T \leq \begin{cases} 4 * T_C \\ 2.0\ s \end{cases}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.14)}$$

Where Tc is defined in the code.

- ⇨ The building meets the criteria given for regularity in elevation

5.5.2 Seismic weight of the structure for each building story category=

The inertia forces which are generated due to the action of the seismic can be determined by taking into consideration the building masse associated with each difference loading on the structure by the use of the equation given below.

$\boldsymbol{M} = \sum \boldsymbol{G_{k,j}} + \sum \boldsymbol{\psi_{E,i}} * \boldsymbol{Q_{k,i}}$ …………………………………….. (5.15)

Where: - $\boldsymbol{\psi_{E,i}}$is the combination coefficient for variables actions.

This coefficient represents the probability in which the action $\boldsymbol{Q_{k,i}}$ may not be present over the entire structure during earan thquake. It may also present the reduction of the participation of the masses in the motion of structure due to the non-rigidity of their connection.[22]

$\boldsymbol{\psi_{E,i}} = \boldsymbol{\varphi} * \boldsymbol{\psi_{2,i}}$ ……………………………………………….. (5.16)

Where $\boldsymbol{\varphi}$=0.8 table 4.2-EN 1998-1 (Correlated occupancy)

$\boldsymbol{\psi_{2,i}}$=Table A1.1-EN 1990:2002. 0ffice building=0.3[21]

The imposed load on structure is 4kN/m² and the calculation have been done for all building story number category as it can be shown in the below figure.

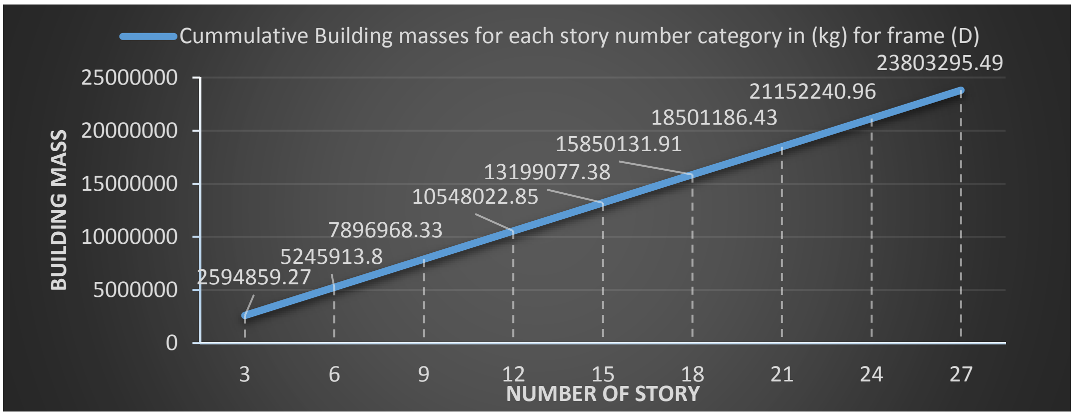


Figure 5 12: seismic weight for the frame (D) for each 3- an increment of story number

It can be observed that as the building story number increase, the seismic weight also increase. The percentage increase in seismic weight for 3 story frame from that of 27 story frame can be calculated as below:-

(%) Increase from 3 story frame to 27 stories =

$$\left(\frac{weight\ of\ 27\ story\ frame - weight\ of\ 3\ story\ frame)}{weight\ of\ 3\ story\ frame}\right.*100$$

= ((23803295.49- 2594859.27)/ 2594859.27)*100= 817.3251037%

5.5.3 Natural period for the first mode in each building story category for the frame (D)

The fundamental period of the structure for the two principle direction is obtained with the help of ETABS software. The first two modes period is presented by the use of Excel and it can be seen below.

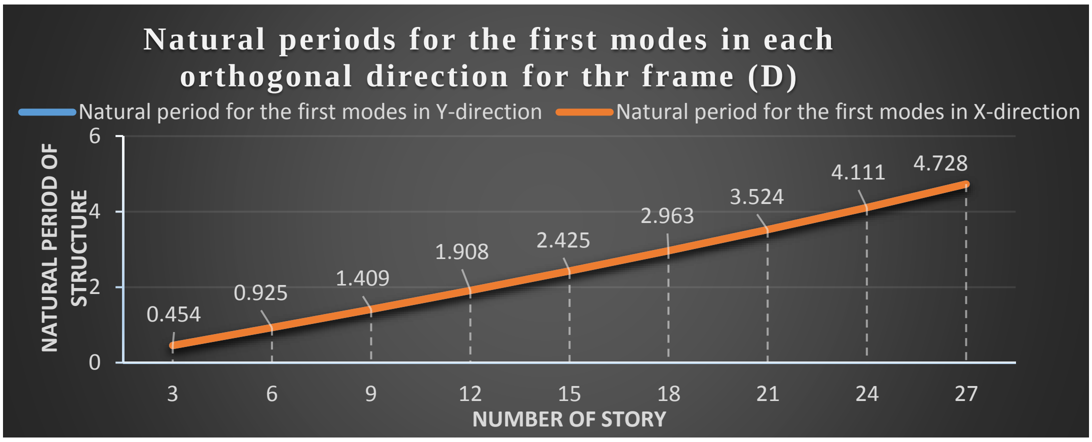


Figure 5 13: Natural periods for the first modes in each orthogonal direction for the frame (D).

From the above results of the first natural period of the structure for each story number categories, it can be seen that the period become longer in each successive increment of story number. These phenomena have a great influent on the seismic base shear values which can be perceived in the subsequent section**.**

5.5.4 Base shear in each orthogonal direction for 27 story

This calculation presents the lateral seismic loads for load pattern E+X according to EUROCODE8 2004, as calculated by ETABS.

5.5.4.1 Equivalent Lateral Forces

Seismic Base Shear Coefficient $V_{coeff} = S_d(T_1)\lambda$……………….. (5.17)

Table 5 10: Calculated Base Shear in X-direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
X	4.728	233430.5925	7936.6401

Table 5 11: Calculated Base Shear in Y- direction

Direction	Period Used (sec)	W (kN)	F_b (kN)
Y	4.728	233430.5925	7936.6401

5.5.5 Response Spectrum Analysis

This is a type of linear dynamic analysis which can be used for the building that does not satisfy the requirements given in the code for Equivalent static methods. It should be considered in the analysis that the sum of the effective masse for all the modes taken must be 90% of the total masses of the building under study. For this paperwork, the ETABS: 2016 is used for a base shear determination as per the code and the response quantities are combined using Square root of the sum of squares (SRSS) method.

5.5.6 The calculation is done for each 3 story increment for both Linear Static and Linear Dynamic Method and the base shear obtained is plotted

Table 5 12: Base Shear calculated for each 3-increment of story number by two methods for the frame (D).

	Linear static method		Response Spectrum Method	
No of Story	**x**	**y**	**x**	**y**
3	(-)2009.79	(-)2009.7904	2134.8241	2134.8241
6	(-)1995.132	(-)1995.1324	2149.9477	2149.9477
9	(-)2633.055	(-)2633.0554	2709.4383	2709.4383
12	(-)3516.986	(-)3516.9862	3504.9263	3504.9263
15	(-)4400.917	(-)4400.917	4301.8261	4301.8265
18	(-)5284.848	(-)5284.8478	5097.55	5097.5502
21	(-)6168.779	(-)6168.7786	5896.0452	5896.0452
24	(-)7052.709	(-)7052.7094	6695.5508	6695.5506
27	(-)7936.64	(-)7936.6401	7488.3047	7488.3047

From the base shear results, the following things are observed:-

- ⇨ For linear Static method of analysis, the base shear is negative in both orthogonal directions.
- ⇨ For linear dynamic analysis method, the base shear values are positive in both orthogonal directions.
- ⇨ The seismic base shear values calculated by the Linear dynamic method are greater than that obtained by the linear static method for 3, 6 and 9 story framed building. But for a frame of 12 stories, 15 and up to 27 story buildings, the base shear by linear static method becomes higher than that of the linear dynamic method.
- ⇨ The base shear decreased for 3 story frame to 6 story framed building in which the first natural period is in the interval of (4TC or 2) and then increased excessively for 6 stories to 27 framed building in which the first natural period is greater than (4Tc) for a linear static method.
- ⇨ It is observed that the base shear value for 6 stories framed building is decreased by 0.735% than the value for 3 stories framed building using Linear Static method in X-direction.
- ⇨ It is observed that the base shear value for 27 stories framed building is increased by 294.899% and 250.769% than the value for 3 stories framed building using Linear Static and Linear dynamic method in X-direction respectively.

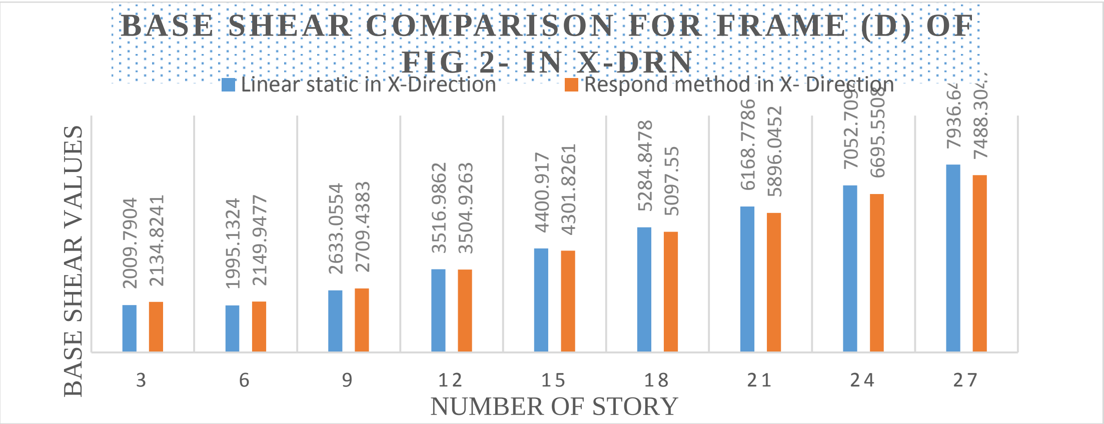


Figure 5 14: Base shear in X-direction for each 3-increment of Story number for the frame (D)

5.5 Shear forces and Bending Moments For frame D for 3 stories aimed at the selected columns.

In designing a particular structure, difference loading such as dead loads imposed loads, and so forth, can be subjected to the building at the same time. Due to this reason, the designers have to consider the effects of these loading in combination. In view of this, the standard gives a format through which these actions can be combined. The general format given by the Eurocode is in the form of the following formula[21].

$$E_d = E\left\{G_{K,J}; P;\ A_{Ed};\ \psi_{2,i}Q_{K,J}\right\}\ j \geq 1; i \geq 1 \text{.............................}(5.18)$$

The combinations in the brackets above can also be expressed by using the following formula.

$$\sum_{J\geq 1} G_{K,j}\,'' + ''p'' + ''\,A_{Ed}'' + ''\sum_{i\geq 1} \psi_{2,i} Q_{K,j} \text{..........................}(5.19)$$

The partial factors for actions and combination of actions can be obtained in EN1991and from ANNEX A. The combinations has been used to determine the effect of dead loads, imposed and Seismic loads on structures. These are done for a structure having 3 stories and also for 27 stories framed building as well. The axial forces, shears and a bending moment of Exterior edge, Exterior middle, and interior middle columns have been determined and the values were compared for linear static and linear dynamic methods of analysis. The analysis results can be seen as provided in the subsequent sections.

Table 5 13: Axial, shear forces, and bending moments for exterior edge column

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story 3	Exterior Edge	Top	Comb1 (1*dead+0.3*live+1*E +X)	Start	-84.6062	-1.7336	-8.715

Story 3	Exterior Edge	Top	Comb1 (1*dead+0.3*live+1*E+X)	End	-64.6121	-1.7336	-3.1674
Story 3	Exterior Edge	Top	Comb2 (1*dead+0.3*live-1*E+X)	start	-109.9859	-22.0264	-26.7873
Story 3	Exterior Edge	Top	Comb2 (1*dead+0.3*live-1*E+X)	End	-89.9918	-22.0264	43.6972
Story 3	Exterior Edge	Top	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-77.8805	0.2101	-1.8889
Story 3	Exterior Edge	Top	Comb3 (1*dead+0.3*live+1*RS) Max	End	-57.8864	0.2101	45.3985
Story 3	Exterior Edge	Top	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-116.7115	-23.9701	-33.6133
Story 3	Exterior Edge	Top	Comb3 (1*dead+0.3*live+1*RS) Min	End	-96.7174	-23.9701	-4.8687
Story 3	Exterior Edge	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-77.8805	0.2101	-1.8889
Story 3	Exterior Edge	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-57.8864	0.2101	45.3985
Story 3	Exterior Edge	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-116.7115	-23.9701	-33.6133
Story 3	Exterior Edge	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-96.7174	-23.9701	-4.8687
Story 2	Exterior Edge	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-160.6342	13.0516	16.9131
Story 2	Exterior Edge	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-140.6401	13.0516	-24.8522
Story 2	Exterior Edge	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-235.807	-28.966	-47.8557
Story 2	Exterior Edge	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-215.8129	-28.966	44.8354

Story 2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-142.4396	14.4037	20.0546
Story 2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-122.4455	14.4037	47.1763
Story 2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-254.0015	-30.3181	-50.9972
Story 2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-234.0074	-30.3181	-27.1931
Story 2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-142.4396	14.4037	20.0546
Story 2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-122.4455	14.4037	47.1763
Story 2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-254.0015	-30.3181	-50.9972
Story 2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-234.0074	-30.3181	-27.1931
story 1	Exterior Edge	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-228.1564	28.4322	80.8956
story 1	Exterior Edge	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-208.1623	28.4322	-10.0874
story 1	Exterior Edge	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-364.9873	-38.2026	-92.2945
story 1	Exterior Edge	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-344.9932	-38.2026	29.954
story 1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-196.757	30.7624	85.7381

story 1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-176.7629	30.7624	33.4109
story 1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-396.3867	-40.5328	-97.137
story 1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-376.3926	-40.5328	-13.5443
story 1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-196.757	30.7624	85.7381
story 1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-176.7629	30.7624	33.4109
story 1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-396.3867	-40.5328	-97.137
story 1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-376.3926	-40.5328	-13.5443

Table 5 14: Axial, shear forces, and bending moments for the exterior middle column

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story 3	Exterior middle	Top	Comb1 (1*dead+0.3*live+1*E+X)	Start	-146.3115	20.2034	27.2563
Story 3	Exterior middle	Top	Comb1 (1*dead+0.3*live+1*E+X)	End	-126.3174	20.2034	-37.3946
Story 3	Exterior middle	Top	Comb2 (1*dead+0.3*live-1*E+X)	start	-146.3115	-20.2034	-27.2563
Story 3	Exterior middle	Top	Comb2 (1*dead+0.3*live-1*E+X)	End	-126.3174	-20.2034	37.3946
Story 3	Exterior middle	Top	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-130.3109	22.4654	32.4264
Story 3	Exterior middle	Top	Comb3 (1*dead+0.3*live+1*RS) Max	End	-110.3168	22.4654	40.0732

Story 3	Exterior middle	Top	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-162.3121	-22.4654	-32.4264
Story 3	Exterior middle	Top	Comb3 (1*dead+0.3*live+1*RS) Min	End	-142.318	-22.4654	-40.0732
Story 3	Exterior middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-130.3109	22.4654	32.4264
Story 3	Exterior middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-110.3168	22.4654	40.0732
Story 3	Exterior middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-162.3121	-22.4654	-32.4264
Story 3	Exterior middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-142.318	-22.4654	-40.0732
Story 2	Exterior middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-295.5006	34.1772	57.9407
Story 2	Exterior middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-275.5065	34.1772	-51.4265
Story 2	Exterior middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-295.5006	-34.1772	-57.9407
Story 2	Exterior middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-275.5065	-34.1772	51.4265
Story 2	Exterior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-248.3565	35.8618	61.129
Story 2	Exterior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-228.3624	35.8618	54.0558
Story 2	Exterior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-342.6448	-35.8618	-61.129
Story 2	Exterior middle	Next to	Comb3 (1*dead+0.3*live+1*RS) Min	End	-322.6507	-35.8618	-54.0558

		bottom					
Story 2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-248.3565	35.8618	61.129
Story 2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-228.3624	35.8618	54.0558
Story 2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-342.6448	-35.8618	-61.129
Story 2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-322.6507	-35.8618	-54.0558
story 1	Exterior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-442.5377	41.3646	95.9834
story 1	Exterior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-422.5436	41.3646	-36.3832
story 1	Exterior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-442.5377	-41.3646	-95.9834
story 1	Exterior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-422.5436	-41.3646	36.3832
story 1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-357.7982	43.922	101.1586
story 1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-337.8041	43.922	39.65
story 1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-527.2772	-43.922	-101.1586
story 1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-507.2831	-43.922	-39.65
story 1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-357.7982	43.922	101.1586
story 1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-337.8041	43.922	39.65

story 1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-527.2772	-43.922	-101.1586
story 1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-507.2831	-43.922	-39.65

Table 5 15: Axial, shear forces, and bending moments for Interior Middle Column

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story 3	Interior Middle	Top	Comb1 (1*dead+0.3*live+1*E+X)	Start	-215.5252	23.9187	34.4024
Story 3	Interior Middle	Top	Comb1 (1*dead+0.3*live+1*E+X)	End	-195.5311	23.9187	-42.1373
Story 3	Interior Middle	Top	Comb2 (1*dead+0.3*live-1*E+X)	start	-215.5252	-23.9187	-34.4024
Story 3	Interior Middle	Top	Comb2 (1*dead+0.3*live-1*E+X)	End	-195.5311	-23.9187	42.1373
Story 3	Interior Middle	Top	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-215.5252	26.3372	39.5324
Story 3	Interior Middle	Top	Comb3 (1*dead+0.3*live+1*RS) Max	End	-195.5311	26.3372	45.1431
Story 3	Interior Middle	Top	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-215.5252	-26.3372	-39.5324
Story 3	Interior Middle	Top	Comb3 (1*dead+0.3*live+1*RS) Min	End	-195.5311	-26.3372	-45.1431
Story 3	Interior Middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-215.5252	26.3372	39.5324

Story 3	Interior Middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-195.5311	26.3372	45.1431
Story 3	Interior Middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-215.5252	-26.3372	-39.5324
Story 3	Interior Middle	Top	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-195.5311	-26.3372	-45.1431
Story 2	Interior Middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-430.78	39.49	68.0567
Story 2	Interior Middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-410.7859	39.49	-58.3113
Story 2	Interior Middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-430.78	-39.49	-68.0567
Story 2	Interior Middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-410.7859	-39.49	58.3113
Story 2	Interior Middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-430.78	41.3309	71.4513
Story 2	Interior Middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-410.7859	41.3309	61.1045
Story 2	Interior Middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-430.78	-41.3309	-71.4513
Story 2	Interior Middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-410.7859	-41.3309	-61.1045
Story 2	Interior Middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-430.78	41.3309	71.4513

Story 2	Interior Middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-410.7859	41.3309	61.1045
Story 2	Interior Middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-430.78	-41.3309	-71.4513
Story 2	Interior Middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-410.7859	-41.3309	-61.1045
story 1	Interior Middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-646.3708	44.4576	99.592
story 1	Interior Middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-626.3767	44.4576	-42.6724
story 1	Interior Middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-646.3708	-44.4576	-99.592
story 1	Interior Middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-626.3767	-44.4576	42.6724
story 1	Interior Middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-646.3708	47.1105	104.8949
story 1	Interior Middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-626.3767	47.1105	46.0316
story 1	Interior Middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-646.3708	-47.1105	-104.8949
story 1	Interior Middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-626.3767	-47.1105	-46.0316
story 1	Interior Middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-646.3708	47.1105	104.8949

story 1	Interior Middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-626.3767	47.1105	46.0316
story 1	Interior Middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-646.3708	-47.1105	-104.8949
story 1	Interior Middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-626.3767	-47.1105	-46.0316

5.6 Shear forces and Bending Moments For frame (D for 27 story building aimed at the selected columns

The same procedures have been followed for the determination of axial, shear and bending moment for the selected columns. The analysis results can be seen in the subsequence tables.

Table 5 16: Axial, shear forces, and bending moments for exterior edge column

Story	**Column**	**Unique Name**	**Load Case/Combo**	**Station**	**P**	**V2**	**M3**
				m	kN	kN	kN-m
Story27	Exterior Edge	Top col	Comb1 (1*dead+0.3*live+1*E+X)	Start	-152.0434	-48.6073	-80.6141
Story27	Exterior Edge	Top col	Comb1 (1*dead+0.3*live+1*E+X)	End	-132.0493	-48.6073	74.9292
Story27	Exterior Edge	Top col	Comb2 (1*dead+0.3*live-1*E+X)	Start	-134.5324	-24.1782	-31.4781
Story27	Exterior Edge	Top col	Comb2 (1*dead+0.3*live-1*E+X)	End	-114.5383	-24.1782	45.892
Story27	Exterior Edge	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-130.8101	-24.7014	-33.3304
Story27	Exterior Edge	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	End	-110.816	-24.7014	75.5703

Story27	Exterior Edge	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-155.7657	-48.084	-78.7618
Story27	Exterior Edge	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	End	-135.7716	-48.084	45.2509
Story27	Exterior Edge	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-130.8101	-24.7014	-33.3304
Story27	Exterior Edge	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-110.816	-24.7014	75.5703
Story27	Exterior Edge	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-155.7657	-48.084	-78.7618
Story27	Exterior Edge	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-135.7716	-48.084	45.2509
Story2	Exterior Edge	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-1378.086	90.4087	181.4719
Story2	Exterior Edge	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-1358.092	90.4087	-107.8358
Story2	Exterior Edge	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-6099.772	-111.8686	-220.1449
Story2	Exterior Edge	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-6079.778	-111.8686	137.8345
Story2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-697.3816	84.571	169.4335
Story2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-677.3875	84.571	131.4357
Story2	Exterior Edge	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-6780.477	-106.0309	-208.1065
Story2	Exterior Edge	Next to	Comb3 (1*dead+0.3*live+1*RS) Min	End	-6760.483	-106.0309	-101.437

		bottom					
Story2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-697.3816	84.571	169.4335
Story2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-677.3875	84.571	131.4357
Story2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-6780.477	-106.0309	-208.1065
Story2	Exterior Edge	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-6760.483	-106.0309	-101.437
story1	Exterior Edge	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-1330.866	135.7047	384.1575
story1	Exterior Edge	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-1310.872	135.7047	-50.0974
story1	Exterior Edge	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-6352.928	-146.4703	-396.7174
story1	Exterior Edge	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-6332.934	-146.4703	71.9875
story1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-603.8192	127.4246	360.592
story1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-583.8251	127.4246	69.5777
story1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-7079.975	-138.1902	-373.1519
story1	Exterior Edge	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-7059.98	-138.1902	-47.6876
story1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-603.8192	127.4246	360.592
story1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-583.8251	127.4246	69.5777

story1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-7079.975	-138.1902	-373.1519
story1	Exterior Edge	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-7059.98	-138.1902	-47.6876

Table 5 17: Axial, shear forces, and bending moments for the exterior middle column

Story	**Column**	**Unique Name**	**Load Case/Combo**	**Station**	**P**	**V2**	**M3**
				m	kN	kN	kN-m
Story27	Exterior middle	Top col	Comb1 (1*dead+0.3*live+1*E+X)	Start	-170.2603	39.9233	59.5478
Story27	Exterior middle	Top col	Comb1 (1*dead+0.3*live+1*E+X)	End	-150.2662	39.9233	-68.2066
Story27	Exterior middle	Top col	Comb2 (1*dead+0.3*live-1*E+X)	Start	-170.2603	-39.9233	-59.5478
Story27	Exterior middle	Top col	Comb2 (1*dead+0.3*live-1*E+X)	End	-150.2662	-39.9233	68.2066
Story27	Exterior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-154.6879	35.8903	53.5319
Story27	Exterior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	End	-134.6938	35.8903	61.3367
Story27	Exterior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-185.8327	-35.8903	-53.5319
Story27	Exterior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	End	-165.8386	-35.8903	-61.3367
Story27	Exterior middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-154.6879	35.8903	53.5319

Story27	Exterior or middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-134.6938	35.8903	61.3367
Story27	Exterior or middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-185.8327	-35.8903	-53.5319
Story27	Exterior or middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-165.8386	-35.8903	-61.3367
Story2	Exterior or middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-4479.835	183.5584	348.2738
Story2	Exterior or middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-4459.841	183.5584	-239.113
Story2	Exterior or middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-4479.835	-183.5584	-348.2738
Story2	Exterior or middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-4459.841	-183.5584	239.113
Story2	Exterior or middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-2128.031	172.1767	326.4053
Story2	Exterior or middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-2108.037	172.1767	224.6368
Story2	Exterior or middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-6831.639	-172.1767	-326.4053
Story2	Exterior or middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-6811.645	-172.1767	-224.6368
Story2	Exterior or middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-2128.031	172.1767	326.4053

Story2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-2108.037	172.1767	224.6368
Story2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-6831.639	-172.1767	-326.4053
Story2	Exterior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-6811.645	-172.1767	-224.6368
story1	Exterior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-4629.538	181.5946	437.6957
story1	Exterior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-4609.544	181.5946	-143.407
story1	Exterior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-4629.538	-181.5946	-437.6957
story1	Exterior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-4609.544	-181.5946	143.407
story1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-2111.596	170.7089	411.1276
story1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-2091.602	170.7089	135.2053
story1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-7147.48	-170.7089	-411.1276
story1	Exterior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-7127.486	-170.7089	-135.2053
story1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-2111.596	170.7089	411.1276

story1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-2091.602	170.7089	135.2053
story1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-7147.48	-170.7089	-411.1276
story1	Exterior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-7127.486	-170.7089	-135.2053

Table 5 18: Axial, shear forces, and bending moments for the interior middle column

Story	Column	Unique Name	Load Case/Combo	Station	P	V2	M3
				m	kN	kN	kN-m
Story27	Interior middle	Top col	Comb1 (1*dead+0.3*live+1*E+X)	Start	-204.5986	43.7774	67.3006
Story27	Interior middle	Top col	Comb1 (1*dead+0.3*live+1*E+X)	End	-184.6045	43.7774	-72.7871
Story27	Interior middle	Top col	Comb2 (1*dead+0.3*live-1*E+X)	Start	-204.5986	-43.7774	-67.3006
Story27	Interior middle	Top col	Comb2 (1*dead+0.3*live-1*E+X)	End	-184.6045	-43.7774	72.7871
Story27	Interior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-204.5986	39.3898	60.5477
Story27	Interior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Max	End	-184.6045	39.3898	65.5127
Story27	Interior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-204.5986	-39.3898	-60.5477

Story27	Interior middle	Top col	Comb3 (1*dead+0.3*live+1*RS) Min	End	-184.6045	-39.3898	-65.5127
Story27	Interior middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-204.5986	39.3898	60.5477
Story27	Interior middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-184.6045	39.3898	65.5127
Story27	Interior middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-204.5986	-39.3898	-60.5477
Story27	Interior middle	Top col	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-184.6045	-39.3898	-65.5127
Story2	Interior middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-5306.602	214.3279	403.3225
Story2	Interior middle	Next to bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-5286.608	214.3279	-282.5268
Story2	Interior middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-5306.602	-214.3279	-403.3225
Story2	Interior middle	Next to bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-5286.608	-214.3279	282.5268
Story2	Interior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-5306.602	201.0248	378.026
Story2	Interior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-5286.608	201.0248	265.3069
Story2	Interior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-5306.602	-201.0248	-378.026

Story2	Interior middle	Next to bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-5286.608	-201.0248	-265.3069
Story2	Interior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-5306.602	201.0248	378.026
Story2	Interior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-5286.608	201.0248	265.3069
Story2	Interior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-5306.602	-201.0248	-378.026
Story2	Interior middle	Next to bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-5286.608	-201.0248	-265.3069
story1	Interior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	Start	-5521.267	196.7137	455.3347
story1	Interior middle	Bottom	Comb1 (1*dead+0.3*live+1*E+X)	End	-5501.273	196.7137	-174.1491
story1	Interior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	Start	-5521.267	-196.7137	-455.3347
story1	Interior middle	Bottom	Comb2 (1*dead+0.3*live-1*E+X)	End	-5501.273	-196.7137	174.1491
story1	Interior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	Start	-5521.267	184.896	427.6824
story1	Interior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Max	End	-5501.273	184.896	164.0267
story1	Interior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	Start	-5521.267	-184.896	-427.6824

story1	Interior middle	Bottom	Comb3 (1*dead+0.3*live+1*RS) Min	End	-5501.273	-184.896	-164.0267
story1	Interior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	Start	-5521.267	184.896	427.6824
story1	Interior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Max	End	-5501.273	184.896	164.0267
story1	Interior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	Start	-5521.267	-184.896	-427.6824
story1	Interior middle	Bottom	Comb 4 (1*dead+0.3*live-1*RS) Min	End	-5501.273	-184.896	-164.0267

The following analysis results were observed from both linear methods:-

- For 3 story framed building, the axial, shear forces, and bending moments values for Exterior edge columns and exterior middle columns are higher for linear dynamic than using linear static method of analysis.
- For the same 3 story framed buildings, the values of the axial forces are the same in the interior middle column by both linear static and linear dynamic method of analysis. But the Shear and bending moment values for this column are higher when using the linear dynamic method.
- For 27 story framed building, the values of the axial forces are the same in the interior middle column by both linear static and linear dynamic method of analysis. But the Shear and bending moment values for this column are higher when using the linear static method.
- For 27 story framed building, the shear forces and bending moments are higher in linear static analysis than linear dynamic method.
- For both 3 story and 27 framed buildings, axial forces, shear and bending moment are decreasing from bottom to topmost story. This is true for the selected column based on the combination which produced the maximum response among the other.

- For 27 framed building, comparing the magnitude of shear force values for interior middle (bottom column) column and Exterior middle (bottom column) for both methods of analysis, it is observed that the interior column has an 8.3% higher values than that of the exterior middle column.
- When comparing the magnitude of shear force values for interior middle and Exterior middle column for 3 stories framed building for the bottom story, it turns out that the interior middle column is 7.477% and 7.260 higher than exterior middle column using static and linear dynamic method respectively.
- Finally, the magnitude of axial, shear forces and bending moments get increased for 27 stories than that of 3 stories framed building

CHAPTER 6: CONCLUSION

In this paperwork, a comparative study has been conducted on four different frames using linear static and linear dynamic methods of analysis. In each frame, the response quantities have been determined for the 3-an increment of story number started with the one of three up to twenty-seven story framed buildings. This means that for each frame, nine different building having the same materials and the same loading conditions but different height have been analyzed. Therefore, the total number of analysis of the building by each subsequent two standards is 36. The responses quantities for these buildings are determined by taking the application guidance provided in IS1893: 2016 and that of the EUROCODE 8.

In applying the Indian code of standard, IS1893:2016, it has been observed that as the number of stories increases, the seismic weight keep increasing. The natural period for the first mode becomes longer as the number of the story increases. This means that for 3 story frame, the natural periods can be shorter than that of 6 stories framed building for the first mode in each orthogonal direction. This has a tremendous effect on the values of shear forces. It has observed that when the Natural period is in the interval of (0-0.55) the shear values increase as the number of story increase, but when it is in the interval of (0.55-4) the shear values decrease as the number of story increases. This phenomenon has been observed for medium soil type. It has been observed that the linear dynamic method produce higher response values than that of the linear static method. Furthermore, the mode shapes have been determined for 9 stories framed building using both EXCEL and ETABS and the variation of the results is not that much.

In applying the Eurocode 8, the seismic weight and natural period, show the same pattern as observed in the Indian code of standard. The base shear values decrease as the number of story increase when the natural period is less than 4Tc or 2. It increases for both linear static and linear dynamic method as the number of story increase whenever the natural period is greater that 4Tc or 2. For a building with less story number, the linear dynamic methods of analysis produce higher response values than that of the linear static method. As the number of story increase, the linear static method resulted in an excessive response value than that of the linear dynamic methods. The axial, shear and bending moment for a column of 3 stories and that of 27 stories has been determined. It turns out that, for 3 stories framed building, the linear dynamic analysis produces a higher response value. But for that of 27 stories framed building, the reverse is true.

From the observation of the response values determined using the above two different standards, it has been observed that the two codes show different response patterns.

7 APPENDICES

A7.1 Details information for the frame (A)

This frame is five by six bays. The widths of the bays in X-direction are 4m, 2m, 6m, 6m, 6m, and 4m. In Y-direction, the bays widths are 4m, 3m, 7m, 6m, and 4m. In this frame, the Shear walls around the lifts and the stairs case are modeled. The thickness of the shear wall in both lifts is 200mm and the c/c spacing in each orthogonal directions are 2m. The area coverage of the staircase is 2m*3m and the width of the landing is 1m. This frame is sub-divided into nine different building categories which have the same materials properties and the same loading condition but having different story number. These are 3, 6, 9, 12, 15, 18, 21, 24, and 27 story framed buildings. The analysis for the response of these buildings to seismic loads have been taken and the comparative study has been taken.

A7.2 Details information for the frame (B)

This frame has the same plan arrangement as a frame (A) except that the staircase and the Shear walls around the lifts were not modeled. This frame is sub-divided into nine different building categories which have the same materials properties and the same loading condition but having different story number. These are 3, 6, 9, 12, 15, 18, 21, 24, and 27 story framed buildings. The analysis for the response of this building to seismic loads have been taken and the comparative study has been taken.

A7.3 Details information for the frame (C)

This frame is three by three bays. The widths of the bays are equal in both X-direction and Y-direction which is 4m. Staircase and shear wall was not modeled in the frame. This frame is sub-divided into nine different building categories which have the same materials properties and the same loading condition but having different story number. These are 3, 6, 9, 12, 15, 18, 21, 24, and 27 story framed buildings. The analysis for the response of this building to seismic loads have been taken and the comparative study has been taken.

A7.4 Details information for the frame (D)

This frame is six by six bays. The widths of the bays are equal in both X-direction and Y-direction which is 4m. Staircase and shear wall was not modeled in the frame. This frame is sub-divided into nine different building categories which have the same materials properties and the same loading condition but having different story number. These are 3, 6, 9, 12, 15, 18, 21, 24, and 27 story framed buildings. The analysis for the response of these buildings to seismic loads have been conducted and the comparative study has been taken. For the 9 story building of this framed category, the mode shape has been determined using Excel and ETABS. Again, the comparative study for the axial, shear forces, and bending moments for the exterior edge, exterior middle, and interior middle column has been considered for 3 stories and 27 story building of this frame category.

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