FORCE BASE v/s DISPLACEMENT BASE SEISMIC ANALYSIS OF A 5-STOREY RC BUILDING

A

PROJECT REPORT

Submitted in partial fulfilment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

Month: May – Year: 2022

STUDENT'S DECLARATION

We hereby declare that the work presented in the Project report entitled **“Force base Vs Displacement base Seismic analysis of a 5-storey RC building”** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Tanmay Gupta** This work has not been submitted elsewhere for the reward of another degree/diploma. I am fully responsible for the contents of my project report.

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Rohit Lakhera (181619)
Department of Civil Engineering
Jaypee University of Information Technology, Waknaghat, India
May 2022

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **“Force base Vs Displacement base Seismic analysis of a 5 storey RC building”** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Aniket (181608), Rohit Lakhera (181619)** during a period from August, 2021 to May, 2022 under the supervision of **Dr. Tanmay Gupta** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: 14th May 2022

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ABSTRACT

Force Based Design (FBD) methods which is used in many places is getting older and obsolete while Displacement based design (DBD) methods are emerging as a viable alternative. As we can see in FBD method we have to starts with an estimation of base shear force, which is calculated based on the fundamental period and ductility capacity of the structure. Then This base shear force which is calculated individually for x and y direction and distributed to the various floor levels based on the fundamental mode shape, and the structure to be analysed is designed for these lateral loads. On the other hand, DBD method explicit consideration of displacements is required. If we look at it, DBD calculate base shear capacity according to the demand of target displacement which is determined in the starting. In this method, an assumed inelastic displacement profile determine the lateral loads at various floor levels. A Case study of 5 Storey Building is taken and application of displacement base design and force base design is done using Revit and SAP 2000 to compare them. Then building is analysed through force based method and displacement based method various values like time period, base shear, effective stiffness and displacements are calculated and compared with each other in which we found out that force method is more calculation intensive and resource heavy.

Keywords: Force based design method, Direct displacement-based design method, 5 storey building, revit, sap 2000

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LIST OF ABBREVIATION

FBD- Force Based Design

DBD- Displacement Based Design

DDBD- Direct Displacement Based Design

CHAPTER 1: INTRODUCTION

1.1 Background

We have been using Force based design method since quite some time but it has its limitation due to which other method were discovered like performance-based design method displacement based design method and direct displacement-based design method but since they are new there all the flaws are not visible which means they need further experimentation to increase the trust in them. In this thesis we have compared force-based design method and displacement-based design method to see the difference between them and see how calculation is done for both of these methods.

In 1990, the concept of response spectrum was created, which involves plotting a spectrum of responses for a large number of single degree of freedom periods. Following the calculation of the structural periods, these spectrum graphs are used to determine the structure's expected response to earthquakes.

The base shear force is an estimate of the maximum total lateral force that will occur at the bottom of a building due to seismic ground motion. The base shear (V) is calculated using a number of variables, including the soil conditions at the construction site, the epicentral distance, the chance of an earthquake, and the basic (natural) period of vibration of the structure.

1.2 Force-Based Design, (FBD)

The FBD approach is based on computing the bottom shear force resulting from earthquake dynamic motion that use the acceleration response spectrum and, as a result, the building's projected elastic period. Static loads are imposed to a structure in this process, with magnitudes and directions that closely resemble the effects of dynamic loading generated by earthquakes.

Due to dynamic loading at each story of the building, mass is usually concentrated around concentrated lateral forces. Additionally, concentrated lateral forces usually follow the structure's elemental mode shape during construction, i.e., they are bigger at higher altitudes. As a result, the finest lateral displacements and thus the largest lateral forces frequently occur at the structure's highest level. These effects are modelled in most design codes' comparable static lateral force methods by applying a force at each story-level in the structure that is proportional to the height. [1]

1.3 Displacement-Based Design, (DBD):

The displacement-response spectrum is used to calculate the base shear force in this method. It also depends on examining the structure in its inelasticvphase. This paper explains the fundamentals of Direct Displacement-Based Design, a revolutionary seismic design method (DDBD). It is regarded as one of the only design methodologies for multi-degree of freedom structure analysis.

The shape is described on this technique via way of means of the secant stiffness and equal damping of an equal single degree of freedom shape. This layout is primarily based totally on attaining a distinct displacement limit state, which may be described via way of means of material stress limits or non-structural drift limits acquired from design codes on the design stage seismic-intensity. The use of the substitute structure to characterise the structure avoids many of the problems inherent in force-based design (FBD), where initial stiffness is used to calculate an elastic period, which is a drawback that is present in most building codes. [1]

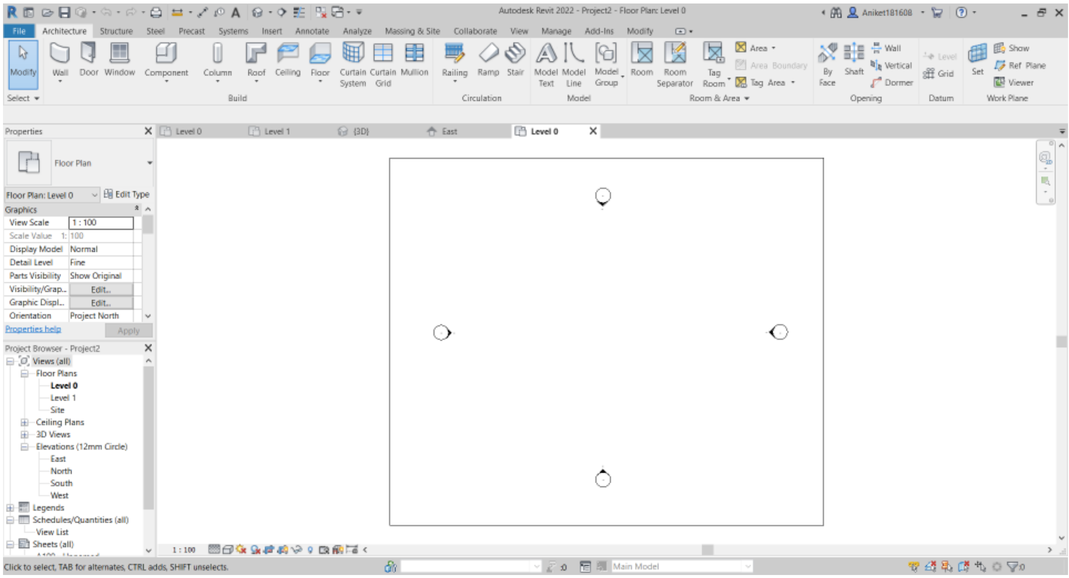
1.4 Software used:

In the process of working on this project we used Revit for modelling of the multistorey building and sap2000 for analysis of the building:

a) Revit

Autodesk's Revit architecture is a powerful architecture design and documentation software application for architects and building professionals. Revit architecture is intended to help with building information modelling (BIM) projects. Revit architecture can support information in application, models, and the accurate drawing of complex building structures.

Rivet architecture's user interface is similar to that of other software. They also provided products such as Autodesk 3ds Max. It is also comparable to window-based applications such as Microsoft Word.



View Scale	1 : 100
Scale Value 1:	100
Display Model	Normal
Detail Level	Fine
Parts Visibility	Show Original
Visibility/Grap...	Edit...
Graphic Displ...	Edit...
Orientation	Project North

Click to select, TAB for alternates, CTRL adds, SHIFT unselects.

Fig 1. 1 Revit Graphical user Interface

b) SAP 2000

SAP 2000 analysis employs Limit State Design methods that adhere to the Indian Standard Code of Practice. SAP 2000 has a cutting-edge interface, visualisation tools, and powerful analysis and style engines with advanced finite element and dynamic analysis capabilities. SAP 2000 is the professional's choice for model generation, analysis, and style, as well as visualisation and result verification.

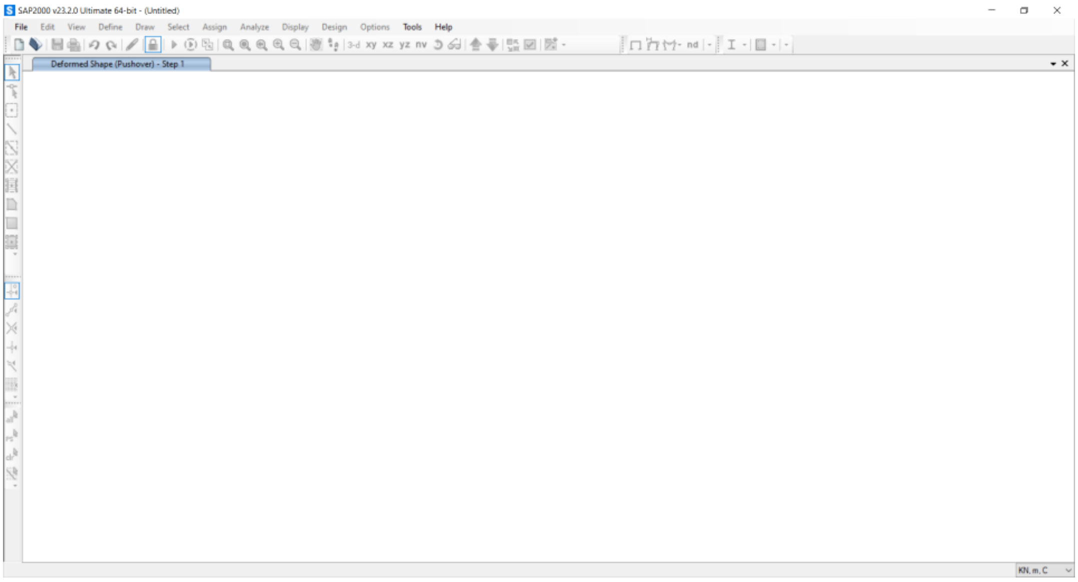


Fig 1. 2 SAP 2000 Graphical User Interface

1.5 Organization of the thesis

This dissertation shows how much beneficial or what is the main difference between a house or a multistorey building is when designed to be earthquake resistant using Force-Based design method and Direct-Displacement based design method. The organization of this thesis is as follows.

Chapter 1 is basically introduction to our project report in which we have briefly explained the two main methods by which we are going to design and analyse the building model after that we have given the description of two main building design modelling software which are Revit and sap 2000.

Chapter 2 which is literature review is explanation of theory behind force based design and direct displacement based method. Then explanation of force and displacement design method followed by terms used in the calculation of the methods like seismic base shear, ductility, design limit states and in the end objectives and summary of the literature review.

Chapter 3 starts with case study of the 5 storey building information model that we considered its building plan using revit general details of it main loads considered in it and last design data to be used in software and calculation

Chapter 4 It is finally the analysis of the building using the help of sap 2000 then results are compared by calculating the values in force based design method and displacement based design method then last but not the least we have results and discussions where both of the results are compared and difference is seen between them.

CHAPTER 2: LITERATURE REVIEW

2.1 Basic methods for Elastic analysis

When structure systems experience only small deformation and are composed of linearly elastic material they are known as linear structural systems. The principle of superposition is usually applicable for such structures using two of the main methods as shown below:

2.1.1 Force method

When we are analysing a structural system using the force method first we have to determine degree of statistical indeterminacy which is same as the number of redundant reactions. Then those redundant reactions are removed to obtain a statistical determinate structure which can also be called as the primary or released structure. Once structure is artificially reduced to statistical determinacy it is possible to find any desired displacement.

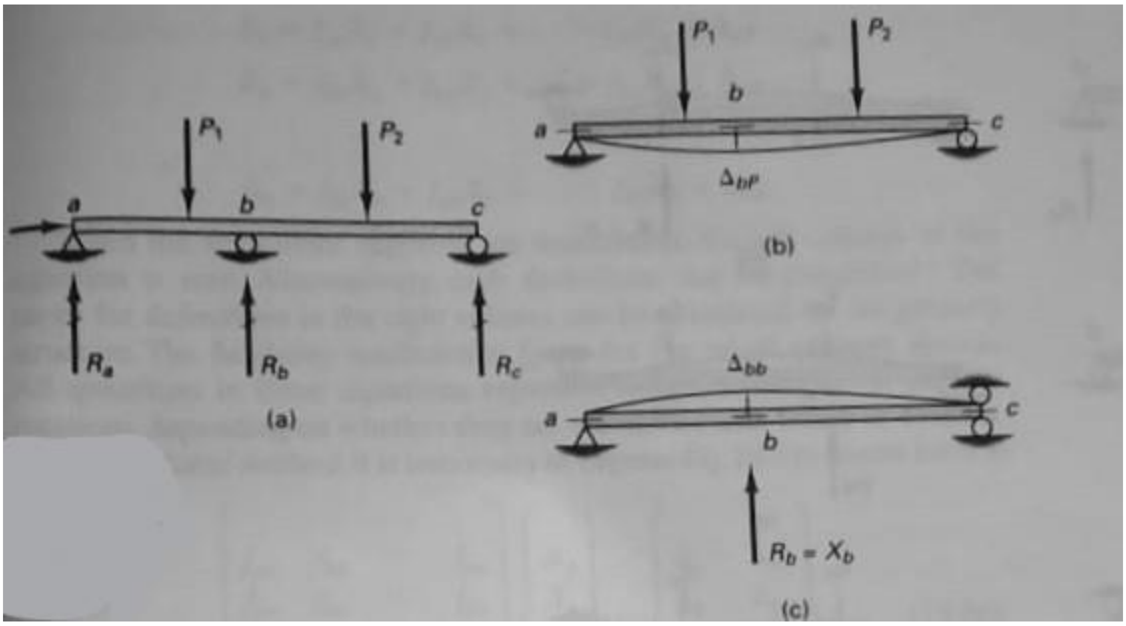


Fig 2. 1 Super position in force method

2.1.2 Displacement method

The force method assumed redundant forces to be unknown, whereas the displacement method assumes the displacement – both linear and/or angular – of the joints or nodal points to be unknown. So, first and foremost, we must prevent these joint displacements, also known as kinematic indeterminants or degrees of freedom. As a result, a modified system is formed, consisting of a series of members whose endpoints are restricted from translation and rotation. Then, easily calculate reactions at these artificially restrained ends due to externally applied loads..

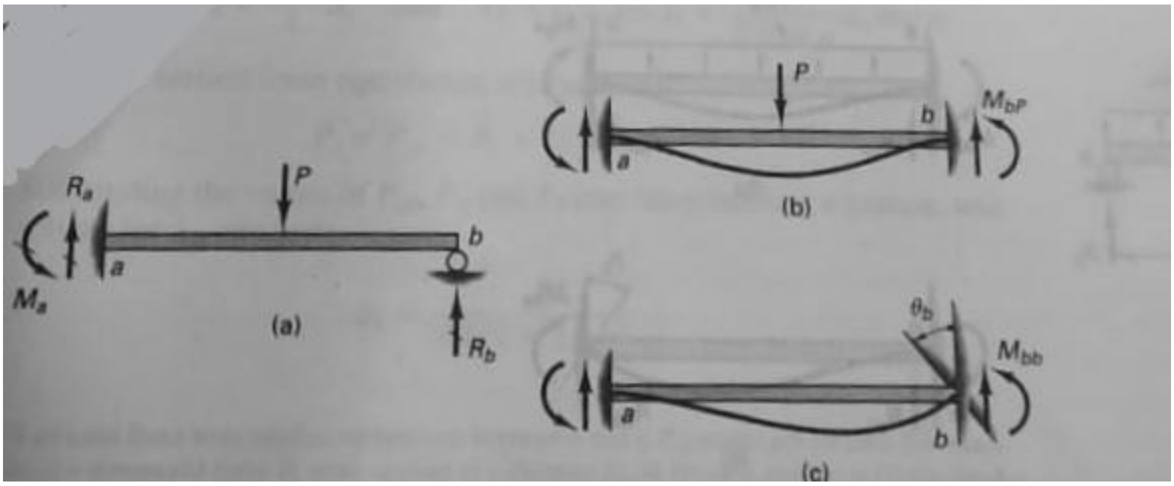


Fig 2. 2 Superposition of displacement method

2.2 Force-Based Design method (FBD):

The FBD procedure evaluates the base shear force deriving from the earthquake dynamic motion using the acceleration response spectrum and the building's expected elastic period. In this approach, static loads with magnitudes and orientations that closely resemble the impacts of dynamic loading induced by earthquakes are applied to a structure. Dynamic loading tends to concentrate lateral forces on each floor of a building where there has been a concentration of mass. Furthermore, concentrated lateral forces tend to follow the fundamental mode shape of the building, which means that they are greater at higher elevations in a structure. As a result, the greatest lateral displacements and forces frequently occur at the top level of a structure. The comparable static lateral force techniques in most design codes replicate these effects by introducing a force at each floor levels in the building that is directly proportional to the height. [1]

Prior to the 1980s, seismic design recognised that ductility was more important than strength. A ductile structure that can deform inelastically in response to an earthquake without losing strength, despite being designed with a lower design strength. As a result, the reduced design force level is frequently used in the FBD procedure. In the 1990s, some issues with the application of FBD were discovered, primarily due to the interdependence between strength and stiffness. Member sizes should be determined early in the design process, and forces should be distributed among members in proportion to their assumed stiffness. If the member sizes are changed, the calculated design forces are no longer valid, and the design process must be recalculated.[2]

Priestley et al[5] discover at least three major flaws in FBD. To begin, FBD assumes initial stiffness to determine the structural period and the allocation of design forces among different structural elements. Because stiffness is determined by the strength of the elements, this cannot be determined until the design process is completed. Second, allocating seismic force among elements based on initial stiffness is illogical in many structures because it incorrectly assumes that all elements can be forced to yield at the same time. Finally, no single force-reduction factor (based on ductility capacity) exists for a given structural type and material.

2.3 Displacement-Based Design method, (DBD)

The displacement response spectrum is used as the basis for calculating the base shear force in this method. It is also necessary to investigate the structure while it is in its inelastic phase. The fundamentals of the new seismic design method known as Direct Displacement-Based Design are presented in this paper (DDBD). It is regarded as one of the most basic design approaches for analysing multi-degree-of-freedom structures. The shape is described on this technique via way of means of the secant stiffness and equal damping of an equal single degree of freedom shape. This layout is primarily based totally on attaining a distinct displacement limit state, which may be described via way of means of material stress limits or non-structural drift limits acquired from design codes on the design stage seismic intensity. The use of a replacement structure to characterise a structure avoids many of the drawbacks of force-based design (FBD), which uses beginning stiffness to estimate an elastic period, which is a flaw found in most building codes. [6]

DDBD calculates the strength required at designated plastic hinge locations to achieve the desired design in terms of defined displacement objectives. It must then be paired with capacity design processes to ensure that plastic hinges only appear where they are intended and that non-ductile inelastic deformation modes do not develop. These capacity design procedures must be adjusted to the DDBD approach. [1]

2.4 Direct Displacement Based Design, DDBD Method:

To begin performing DDBD, the building's design drift, d, is determined based on the type of building and its performance level. The drift slope is defined by the equation below. [1]

$$\theta_d = \frac{Inter-story\ displacement}{Stroy\ height} \tag{2.1}$$

In this method, the structure is defined by its secant stiffness and damping at maximal displacement. The structure is subjected to the estimated base shear, and the assumed amount of damping is verified; if necessary, the design forces are changed. Adjusting the forces is usually unnecessary because the changes are insignificant. When performing DDBD, the secant stiffness, K_e, at maximum displacement, Δ_{max}, at the level of equivalent viscous damping is used. FBD, on the other hand, employs elastic stiffness and elastic damping (=5%).

A complete description of the steps needed for making use of the DDBD approach withinside the layout of reinforced concrete moment resisting frame structure follows [7]:

Step1 Determine Displacement shapes Δ_i: The following equation which is presented by Calvi and Sullivan [7] is used to estimate the inelastic displaced shape of the structure as shown:

$$\Delta_i = \omega_\theta \theta_d h_i \frac{(4H_n - h_i)}{(4H_n - h_1)} \tag{2.2}$$

where: Δ_i: Displacement at level i

ω_θ : Drift reduction factor to include allowance for higher mode amplification of drift by reducing the design floor displacement

H_n, hi: ; are the total building height, and height of floor i.

Step 2 Determine the design displacement, Δ_d : Design displacement for the substitute structure can be calculated by

$$\Delta_d = \frac{\Sigma m_i {\Delta_i}^2}{\Sigma m_i \Delta_i} \tag{2.3}$$

where: m_i , Δ_i Mass and displacement at significant mass locations

Step 3 Calculate the effective height as shown in the equation below

$$H_e = \frac{\Sigma m_i \Delta_i H_i}{\Sigma m_i \Delta_i} \tag{2.4}$$

Step 4 Calculate yield drift slope θ_y with the formula :

$$\theta_y = 0.5\varepsilon_y \frac{l_b}{h_b} \tag{2.5}$$

where l_b is the beam span between column centre line

h_b is the overall beam depth

ε_y is the yield strain of flexure reinforcement

Step 5 Calculate yield displacement, Δ_y which can be seen as:

$$\Delta_y = \theta_y . H_e \tag{2.6}$$

$$\Delta_y = 0.5\varepsilon_y \frac{l_b}{h_b} H_e \tag{2.7}$$

Step 6 Calculate the displacement ductility, μ as shown:

$$\mu = \frac{\Delta_d}{\Delta_y} \tag{2.8}$$

Step 7 Estimate the equivalent viscous damping: The equivalent viscous damping formula is derived from the best fittings of various experiments. Through this study, the following formula was adopted.

$$\xi = 0.05 + 0.565 \frac{(\mu - 1)}{\mu\pi} \tag{2.9}$$

Step 8 Plot the elastic displacement response spectrum for (ξ=0.05) Firstly, the acceleration response spectrum is plotted from the code (according to type of soil and peak ground acceleration), then the displacement response spectrum is deduced using the following formula.

$$\Delta_{T,5} = \frac{T^2}{4\pi^2} a_{T,5} \tag{2.10}$$

where: , $\Delta_{T,5}$: Response displacement at ξ= 0.05 (5%)

$\alpha_{T,5}$: Response acceleration at ξ= 0.05 (5%)

Step 9 Plot the displacement response spectrum for ($\xi=\xi_d$) A damping modifier R_ξ is applied to the displacement spectrum obtained in the previous step to obtain the displacement spectrum at different levels of damping. The following equation is the damping modifier R_ξ

$$R_\xi = \left(\frac{0.10}{0.05+\xi}\right)^{0.5} \tag{2.11}$$

Fig. 2.3 depicts typical shapes for the displacement response spectrum at various damping ratios. This figure shows that as damping increases, so do the corresponding displacements.

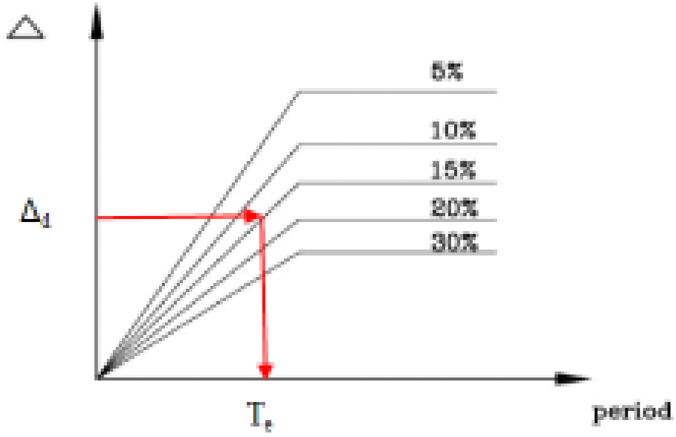


Fig 2. 3 Displacement response spectrums for different effective damping ratio [1]

Step 10 Calculate the effective period, T_e: The effective period can be obtained from the displacement response spectrum (using the design displacement) (calculated from step 2)

Step 11 Calculate the effective mass, m_e as shown:

$$m_e = \frac{\Sigma m_i \Delta_i}{\Delta_D} = \frac{\Sigma m_i {\Delta_i}^2}{\Sigma m_i \Delta_i^2} \tag{2.12}$$

Step 12 Calculate the effective stiffness of the building, k_e as shown:

$$k_e = \frac{4\pi^2 m_e}{T_e^2} \tag{2.13}$$

Step 13 Calculate the design base shear force with formula:

$$V_b = k_e.\Delta_d \tag{2.14}$$

2.4 Response Spectra

The response spectrum is a report favoured by earthquake engineers that was made popular by Housner and represents the interaction between ground acceleration and structural systems. It typically informs us about the frequency content amplitude of ground motion and the effect of subsequent structure-based filtering. The response spectrum in the spectrum The acceleration spectrum is a plot of the natural period of vibration of a single degree of freedom (SDOF) oscillator with a given damping value versus the peak absolute acceleration of the oscillator mass when subjected to base acceleration equal to the earthquake accelerogram. For a highly flexible structure, the relative displacement response spectrum approaches maximum ground displacement asymptotically.

2.4.1 Design Response Spectrum:

The design response spectrum could be a smooth response spectrum that specifies the level of seismic resistance required for a design. The planning spectrum must be specified for seismic analysis. A design acceleration spectrum or base shear coefficients as a function of natural period is required by IS 1893 (Part 1): 2002. These coefficients are ordinates of the acceleration spectrum divided by gravity acceleration. In SDOF systems, this relationship works well. The spectral ordinates are used to calculate inertia forces. [4]

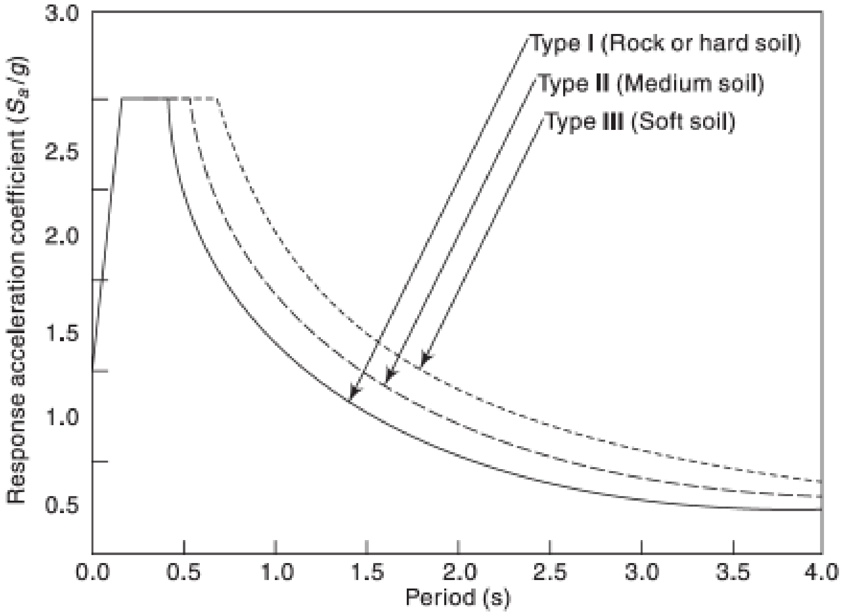


Fig 2. 4 Design Response Spectrum rock and soil sites for 5% damping

2.5 Seismic Base Shear

The total design lateral force or design seismic base shear (V_b) along any principal direction is determined [IS 1893 (Part 1): 2002, clause 7.5.3] by

$$V_b = A_h W \qquad (2.16)$$

where A_h is the design horizontal acceleration spectrum value, using the fundamental natural period T in the considered direction of vibration and W is the seismic weight of the building. The design horizontal seismic coefficient Ah for a structure is determined by the expression [IS 1893 (Part 1): 2002, clause 6.4.2]

$$A_h = \frac{ZIS_a}{2Rg} \qquad (2.17)$$

Where

Z is zone factor

I is Importance factor

R is response reduction factor

S_a/g is response acceleration coefficient for 5% damping

2.6 Ductility

As per IS 1893(part 1): 2002, Clause 6.1.3, “Actual forces that appear on structure during an earthquake are much higher than the design forces specified in the code”.

Which means complete protection on strength-based design criteria is not enough for an earthquake-resistant building so our basic approach for building design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage but no collapse. The Code IS 13920:1993 entitled, “Ductile detailing of reinforced Concrete structure subjected to seismic Force-Code of practice” is based on this approach. This standard addresses the requirement for lateral strength designing and detailing of monolithic reinforced concrete buildings in order to provide adequate toughness and ductility to withstand severe earthquake shock without collapsing. As a result, we can see that ductility is one of the most important factors influencing a structure's seismic performance, and it has been clearly observed that a well-designed structure performs significantly better than others during an earthquake.

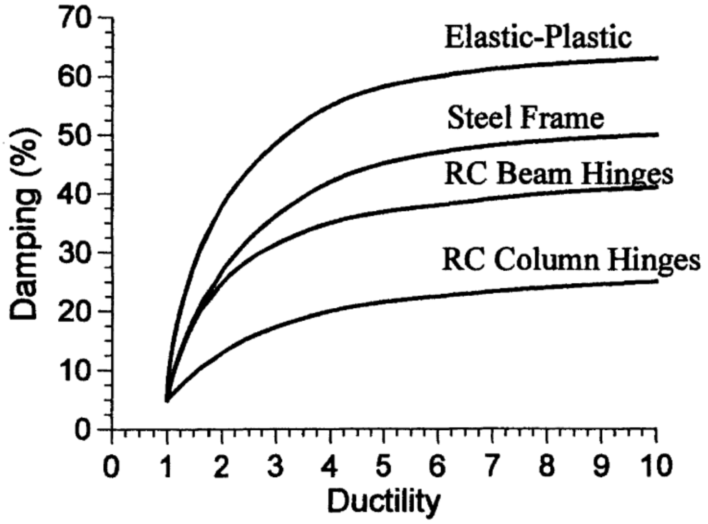


Fig 2. 5 Equivalent damping vs. ductility

2.7 Design Limit States

There are two limit states:-

1)The serviceability limit state

Serviceability limit can be explained as conservative and uneven protection against a level of damage that may require a repair and in which displacement ductility $\mu_\Delta = 1$. Eg. Crushing of concrete and a residual crack with unacceptable width. Main definition is a little less obvious since non-structural damage is dependent on design detail

2)Damage control limit state

Damage control limit state can be defined as material strain limit and by design drift limits, intended to restrict non-structural damage.

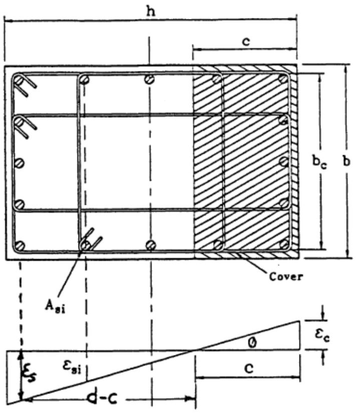


Fig 2. 6 Strain profile of a rectangular section

2.8 Summary of literature review

Literature review gives a brief review on force based method and displacement method and how we apply them in designing a earthquake resistant building. And various terms related to it which will be used during analysis of a multistory earthquake resistant building. In the force method redundant forces are assumed to be unknown, while in the displacement method we take the displacement – both linear and/or angular -of the joints or nodal points are taken as unknowns. To calculate the displacement.

2.9 OBJECTIVES

- Draw a 3D Building Information Model of a multi-story building in Revit of G+5
- Analysis of the G+5 multistorey buildings using SAP200 based on force-based design method.
- To analyse the seismic response of G+5 multistorey building using the following methods with the help of software SAP 2000
    - Force-based design method
    - Direct displacement-based design method
- Comparing the results obtained for above mentioned two methods

CHAPTER 3: CASE STUDY OF EARTHQUAKE RESISTANT BUILDING

MODELLING OF THE 5 STOREY RC BUILDING

3.1 Residential building plan:

Following building plan has been drawn in Revit with 2 bedroom 1 living room 1 kitchen 1 bathroom, which will be 5 story building. Building is designed with 1 main door for each floor 4 sub doors 2 for bed room and 1 each for bathroom and 1 for kitchen. Each floor comes with 11 windows 6 for 2 bed room 3 each, 1 for living room, 1 small window for bathroom and 2 windows 1 big and 1 small for kitchen with last window equipped at stairs. Building has a total of 25 doors and 55 windows in total. For the construction of building M25 concrete and Fe415 steel rebars were used

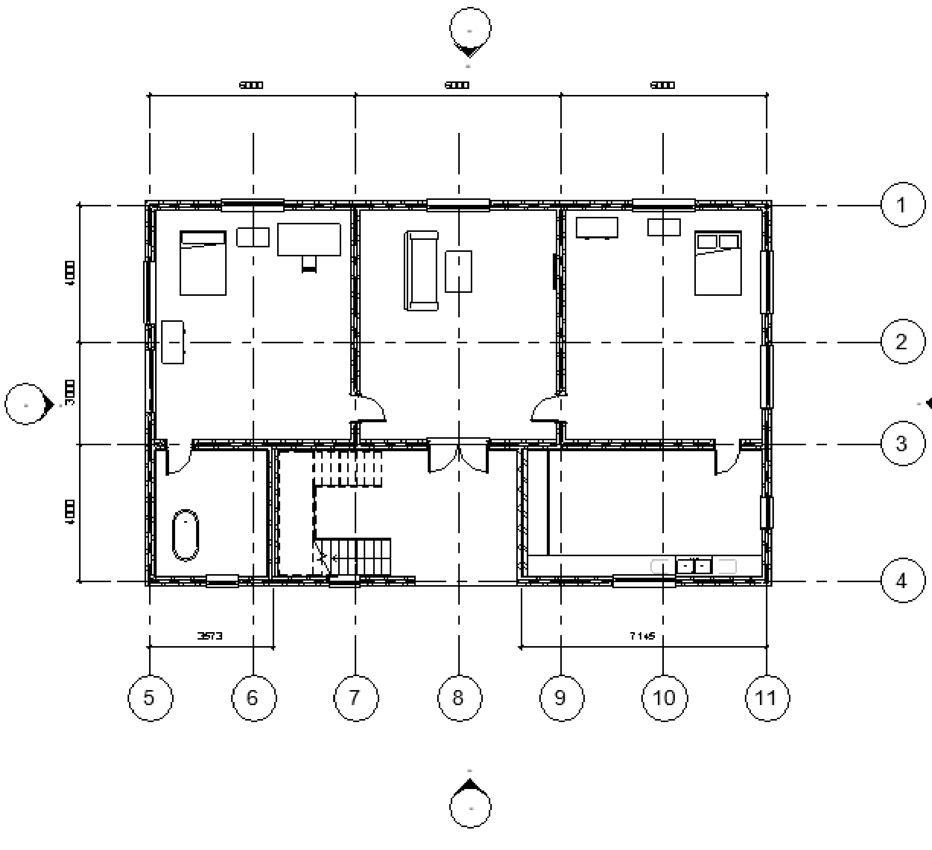


Fig 3. 1 Floor Plan of the Building

Dimensions of rooms

Bedroom*2 = (7*7) m^2

Bathroom = (4*3.573) m^2

Kitchen = (4*7.145) m^2

Height of each floor=3.1m

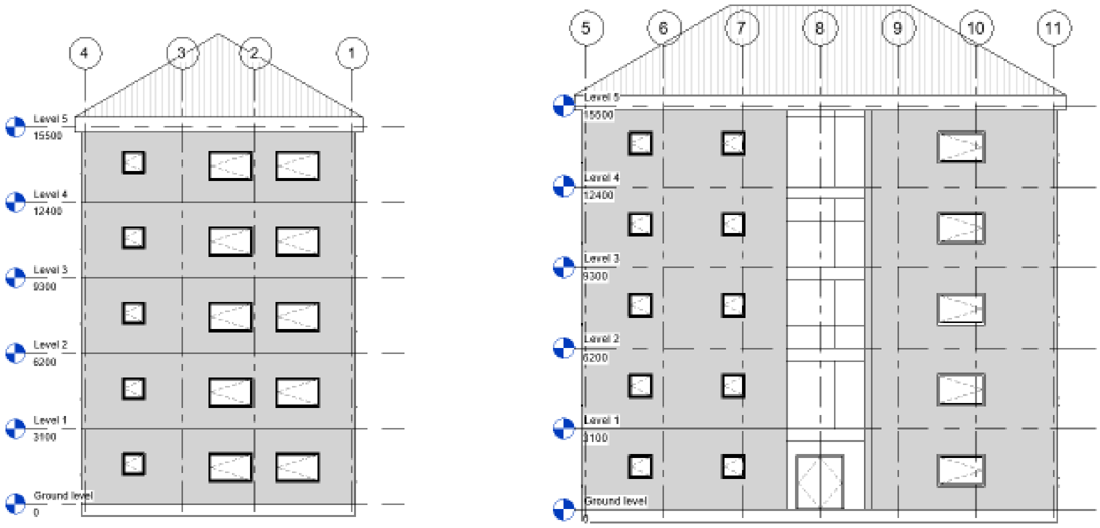


Fig 3. 2 East Elevation and South Elevation view of the building

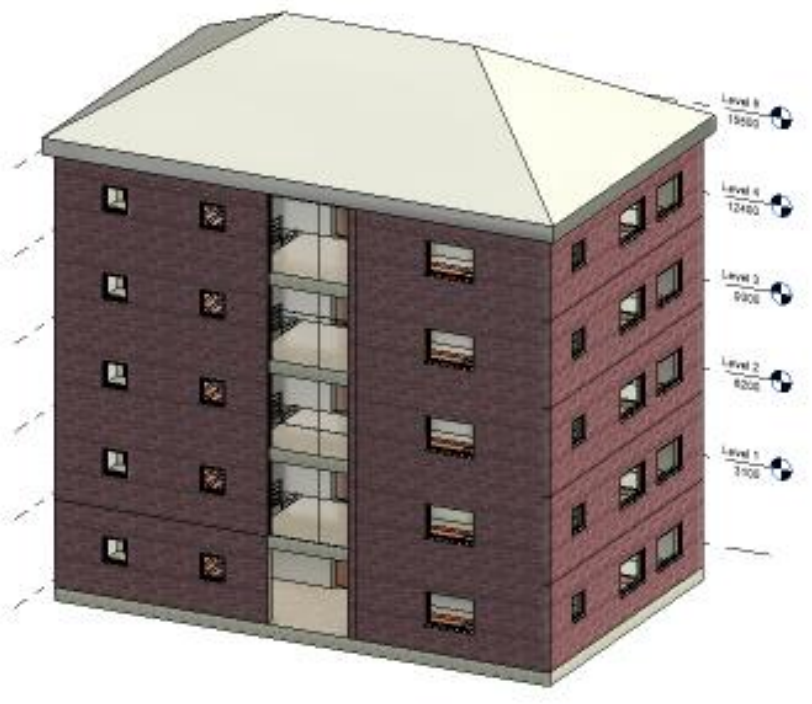


Fig 3. 3 3-D View of the G+5 Building

3.2 Details for Analysis of building

3.2.1 General details

A three-dimensional RCC (Reinforced Cement Concrete) frame with an area containment of 18m x 11m in the XZ plane and a y direction consisting of 5 storey is chosen for a multistory residential building. Buildings serve several collective needs, the most important of which are shelter from weather, safety/security, living space, privacy/space to yourself, storage of property, and the ability to live and work comfortably. A structure that serves as a shelter represents a physical division of the human being (a place for comfort and safety).

3.2.2 Loads Considered

- **Dead Loads**: Dead loads are stationary or permanent loads that are transferred to a structure for the duration of its life. It consists primarily of the weight of rooftops, walls, beams, and columns sections, and so on, which are generally the continuous parts of the structure. IS 875 (Part 1) – 1987 can be used to calculate dead load.
- **Imposed Loads**: IS 875 (Part 2)– 1987 specifies the minimum live load values to be expected. The projected use or occupancy of a structure, as well as the heaviness of portable segments, conveyed and targeted burdens, load due to effect and vibration, and residue loads, all contribute to the live load. These heaps are assumed to have been supplied by the structure's anticipated usage or occupancy, which includes loads of moveable furniture and other items.
- **Seismic Loads**: Seismic loads are calculated in a similar fashion to gravity loads. The weight of sections and dividers in any level will be transmitted to the floors above and below it in a similar way. For the examination of live loads, the following reduced level is employed (as per IS: 1893 (part 1): 2002): terrace 0%, and floor 50%.
    - Design Lateral Force: Calculated for the entire structure and then distributed to various floor levels, segmented seismic force is generated from individual lateral load resisting elements based on floor diaphragm action.
    - Design Seismic Base Shear: Design Seismic Base Shear: The entire design lateral force (V_b) along any principal direction shall be derived using the following expression $V_b = A_hW$. Where V_b is the base shear A_h is design horizontal acceleration value and W is seismic weight.
- **Time history analysis:** A direct/linear time history study overcomes the limitations of a model response range analysis model of response spectrum analysis by excluding non-linear behaviour. For determining the reaction at discrete periods, the technique necessitates more significant computational efforts. One noteworthy advantage of this strategy is that it displays the general indication of response quantities in the response history. This is necessary because the effects of collaboration are taken into account in the structure of stress resultants. Go for a 5% dynamic response of the plane edge show with infills to a predetermined time history to IS code. Using the superposition technique, the damping proportion of disagreeable hard soil was determined.

  The time history data taken for time history analysis.

  - (El Centro) The 1940 El Centro earthquake (or 1940 Imperial Valley earthquake) struck the Imperial Valley in south-eastern Southern California near the international boundary of the United States and Mexico at 21:35 Pacific Standard Time on May 18 (05:35 UTC on May 19). It had a magnitude of 6.9 at the time. It was the first time a strong-motion seismograph near a fault ruptured recorded a significant earthquake. The quake was classified as a moderate-sized damaging event with a complicated energy release characteristic. It was the most powerful earthquake ever to strike the Imperial Valley, causing severe damage to irrigation infrastructure and nine deaths.

3.2.3 Design data considered

Live load or Imposed Load = 4.0 KN/m^2

Roof load to considered = 1.0 KN/m^2

Floor finish load = 1.0 KN/m^2

Beam Load to be used = 4.0 KN/m^2

Hypothetical Location = Jalandhar

Wind load = According to IS: 875, it is not intended for wind loads because earthquake loads are the only ones that are considered. According to IS-1893 (Part 1) – 2002

Damping ratio for building = 5%

Type of soil = Type II Medium soil, as per IS:1893

Storey height = 3100 mm

Thickness of slab = 180mm

Size of beam = 250mm×400mm

Size of column = 300mm×400mm

Walls = 230 mm thick brick masonry walls

Zone = IV

Importance Factor = 1

Property of Materials

Use M25 concrete and Fe415 steel.

CHAPTER 4: SEISMIC ANALYSIS OF 5 STOREY BUILDING

After analysis of 5 storey building is done in SAP 2000 with following properties:

Number of modes considered = 12

Frequency (cycle/sec) = 1/T

Circular frequency, ω (rad/sec) = $2\pi/T$

Eigen value to be considered = ω^2

Flow chart for steps and results calculated in Sap 2000

Start the Sap 2000 software

∨

Setting up 3d frame and structure of the building

∨

Assign the values for dimension

∨

Then assign the properties of material

∨

Define the properties of slab

∨

Assigning live load

∨

Assigning Earthquake load in X and Y direction

∨

Define mass source for seismic weight

∨

Assign the mesh on slabs to make it easy for program to analyse the structure

∨

Assign IS code for design of frames to make it easy to assign load combination

∨

Renaming load combination assigned by the software for easy resemblance

∨

Analyse the structure and display Shear diagram, moment diagram and deformed shape

∨

Define Gravity load for pushover analysis

V

Define pushover load in X and Y direction

V

Define hinges to see the displacement

V

Run analysis to get various results for base shear story drift and joint displacement

V

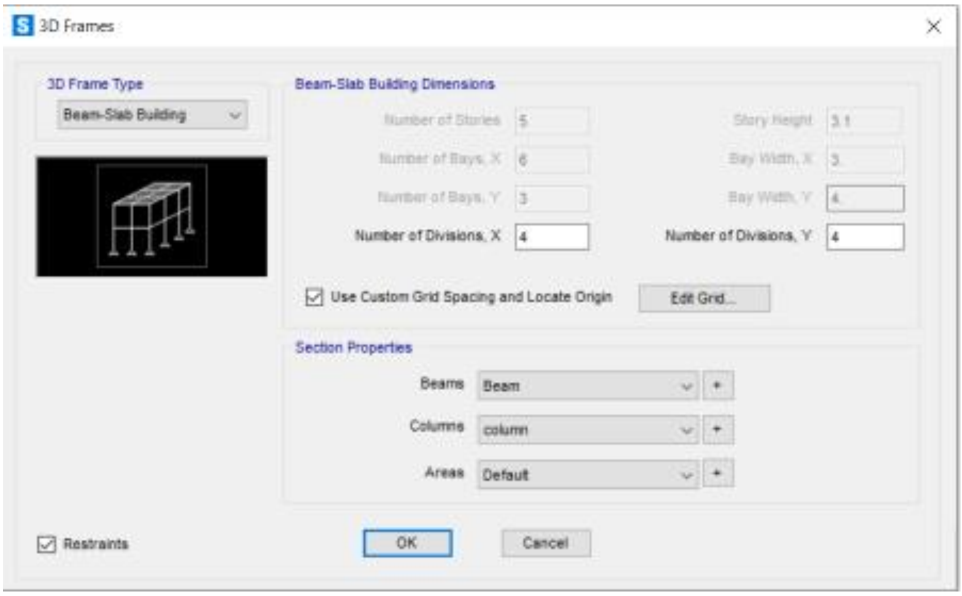
We can get base shear X dir which can be seen as 531 kN and in Y dir to be 424 kN

V

Table gives the values of joint displacement in tabular form which is extracted from SAP 2000

V

Response Spectrum Curve is extracted from software as shown



3D Frames

3D Frame Type: Beam-Slab Building

Beam-Slab Building Dimensions

Number of Stories: 5
Story Height: 3.1
Number of Bays, X: 6
Bay Width, X: 3
Number of Bays, Y: 3
Bay Width, Y: 4
Number of Divisions, X: 4
Number of Divisions, Y: 4

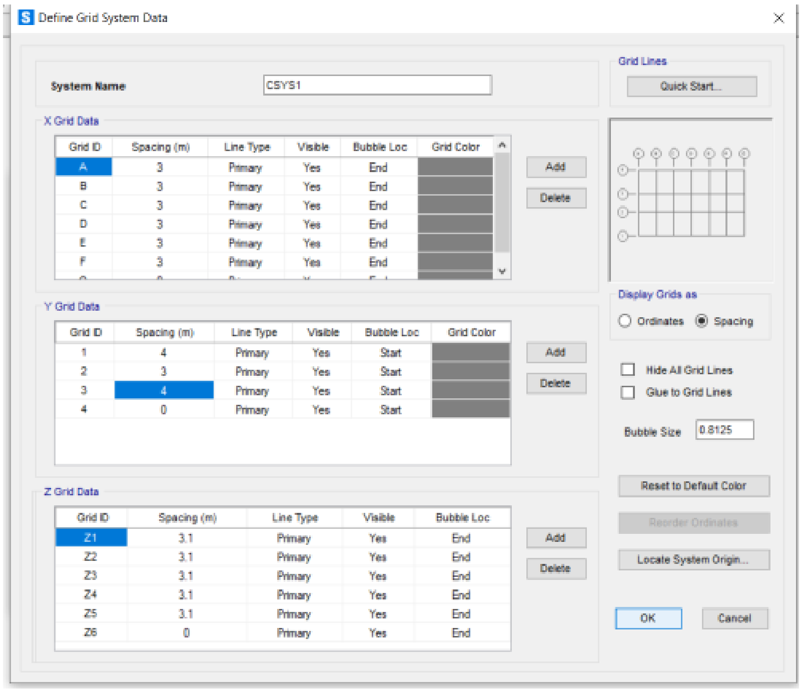
☑ Use Custom Grid Spacing and Locate Origin

Section Properties

Beams: Beam
Columns: column
Areas: Default

☑ Restraints

Figure 4. 1 Setting up 3d frame of the building



System Name: CSYS1

X Grid Data

Grid ID	Spacing (m)	Line Type	Visible	Bubble Loc	Grid Color
A	3	Primary	Yes	End	▨
B	3	Primary	Yes	End	▨
C	3	Primary	Yes	End	▨
D	3	Primary	Yes	End	▨
E	3	Primary	Yes	End	▨
F	3	Primary	Yes	End	▨

Y Grid Data

Grid ID	Spacing (m)	Line Type	Visible	Bubble Loc	Grid Color
1	4	Primary	Yes	Start	▨
2	3	Primary	Yes	Start	▨
3	4	Primary	Yes	Start	▨
4	0	Primary	Yes	Start	▨

Z Grid Data

Grid ID	Spacing (m)	Line Type	Visible	Bubble Loc
Z1	3.1	Primary	Yes	End
Z2	3.1	Primary	Yes	End
Z3	3.1	Primary	Yes	End
Z4	3.1	Primary	Yes	End
Z5	3.1	Primary	Yes	End
Z6	0	Primary	Yes	End

Display Grids as: ○ Ordinates ● Spacing

☐ Hide All Grid Lines

☐ Glue to Grid Lines

Bubble Size: 0.8125

Figure 4. 2 Putting values of distance between each frame

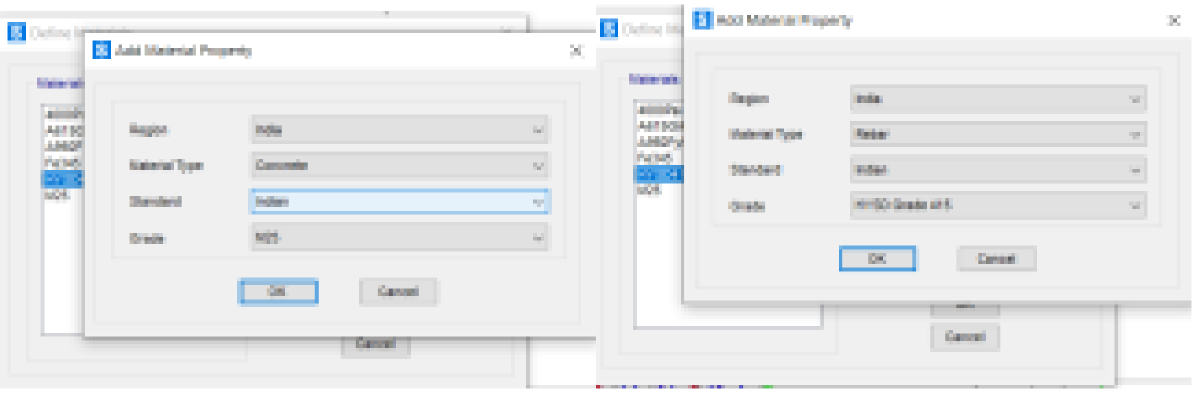
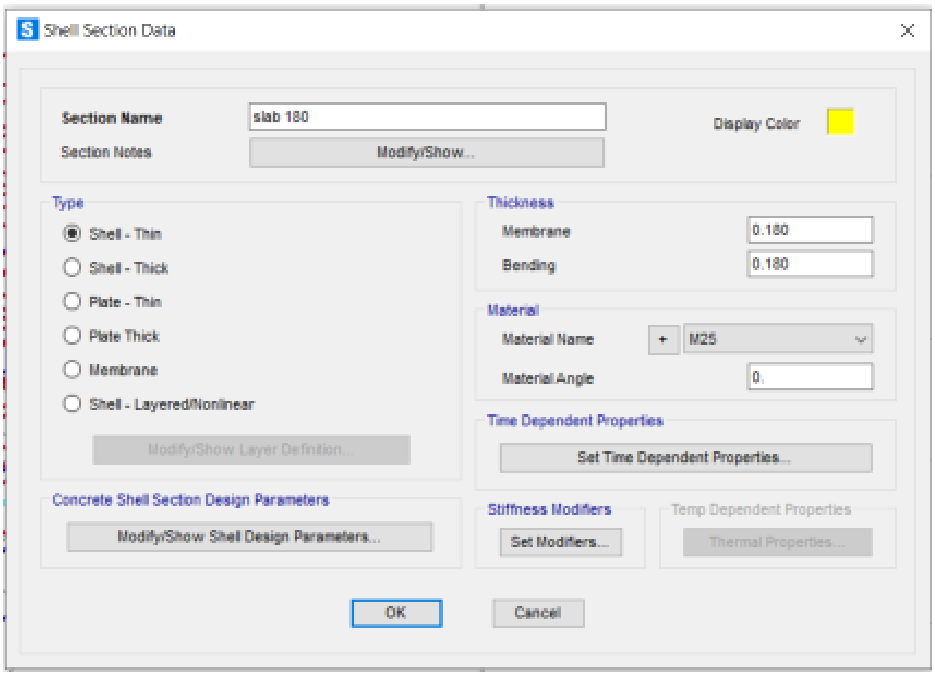


Figure 4. 3Setting the material of concrete and rebar



Shell Section Data

Section Name: slab 180

Section Notes: Modify/Show...

Display Color: 🟨

Type

● Shell - Thin

○ Shell - Thick

○ Plate - Thin

○ Plate Thick

○ Membrane

○ Shell - Layered/Nonlinear

Modify/Show Layer Definition...

Thickness

Membrane: 0.180

Bending: 0.180

Material

Material Name: + M25

Material Angle: 0.

Time Dependent Properties

Set Time Dependent Properties...

Concrete Shell Section Design Parameters

Modify/Show Shell Design Parameters...

Stiffness Modifiers

Set Modifiers...

Temp Dependent Properties

Thermal Properties...

OK Cancel

Figure 4. 4 Defining properties of slab

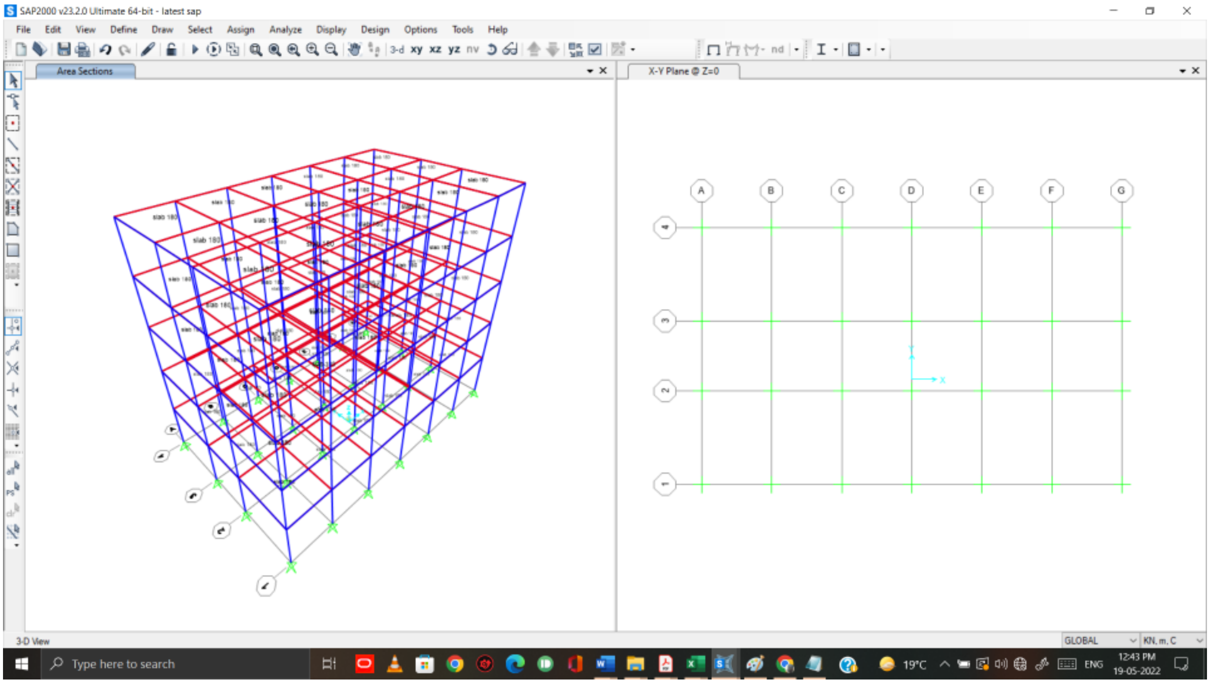


Figure 4. 5 3d and xy plane view of structure after setting the material and properties

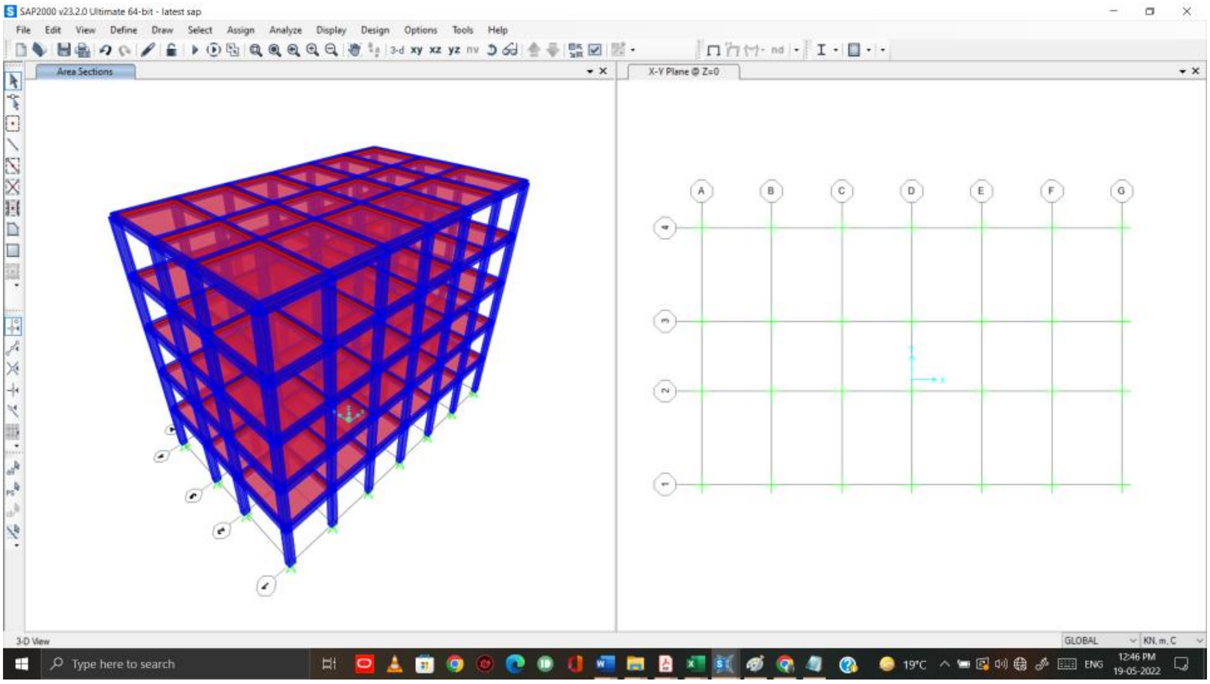
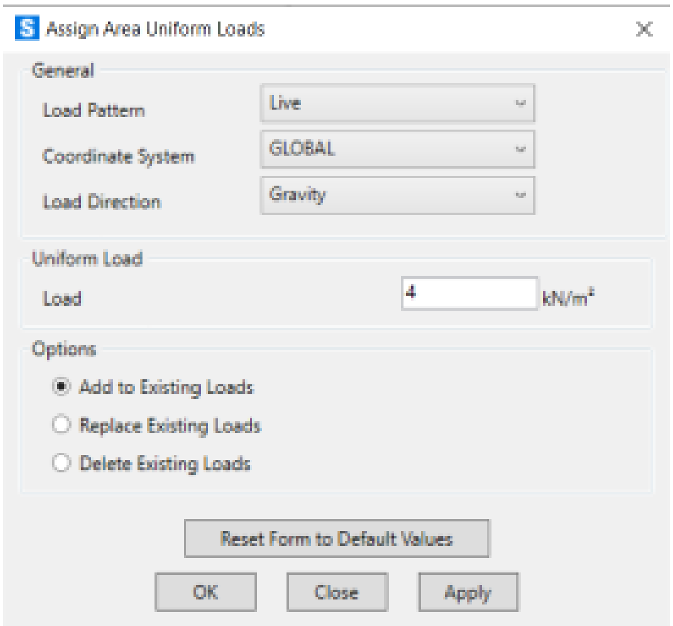


Figure 4. 6 3d thickened view for better visibility



General

Load Pattern: Live

Coordinate System: GLOBAL

Load Direction: Gravity

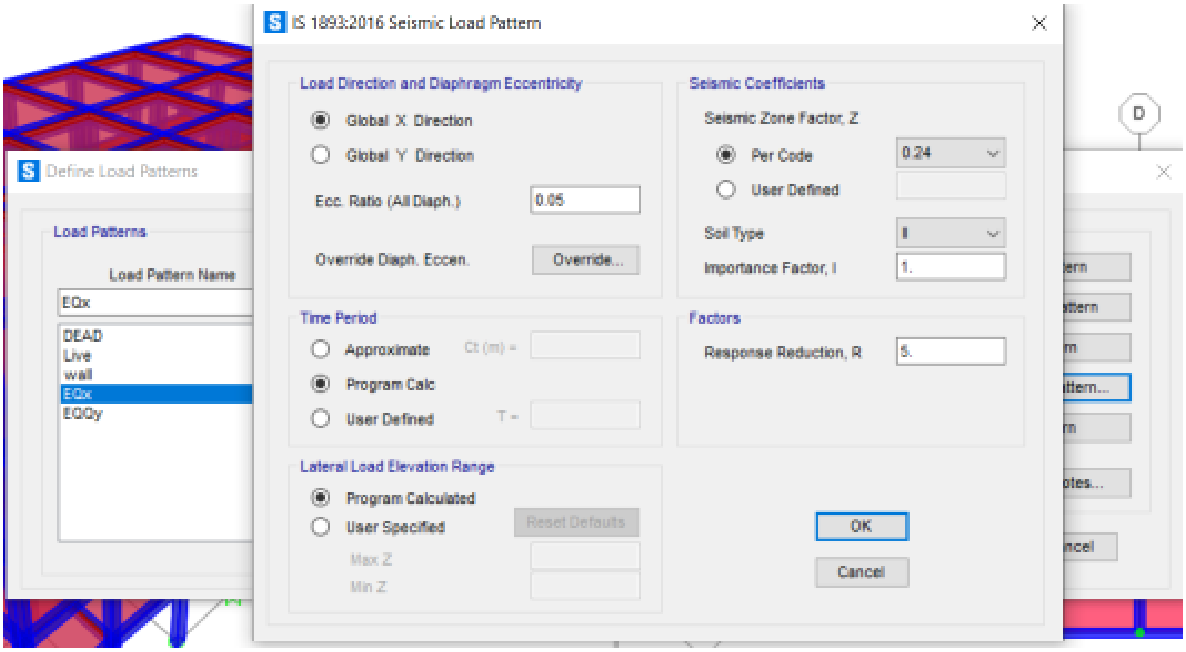
Uniform Load

Load: 4 kN/m²

Options

● Add to Existing Loads
○ Replace Existing Loads
○ Delete Existing Loads

Figure 4. 7Assigning of Live load


IS 1893:2016 Seismic Load Pattern

Load Direction and Diaphragm Eccentricity

● Global X Direction

○ Global Y Direction

Ecc. Ratio (All Diaph.) 0.05

Override Diaph. Eccen.

Time Period

○ Approximate Ct (m) =

● Program Calc

○ User Defined T =

Lateral Load Elevation Range

● Program Calculated

○ User Specified

Seismic Coefficients

Seismic Zone Factor, Z

● Per Code 0.24

○ User Defined

Soil Type II

Importance Factor, I 1.

Factors

Response Reduction, R 5.

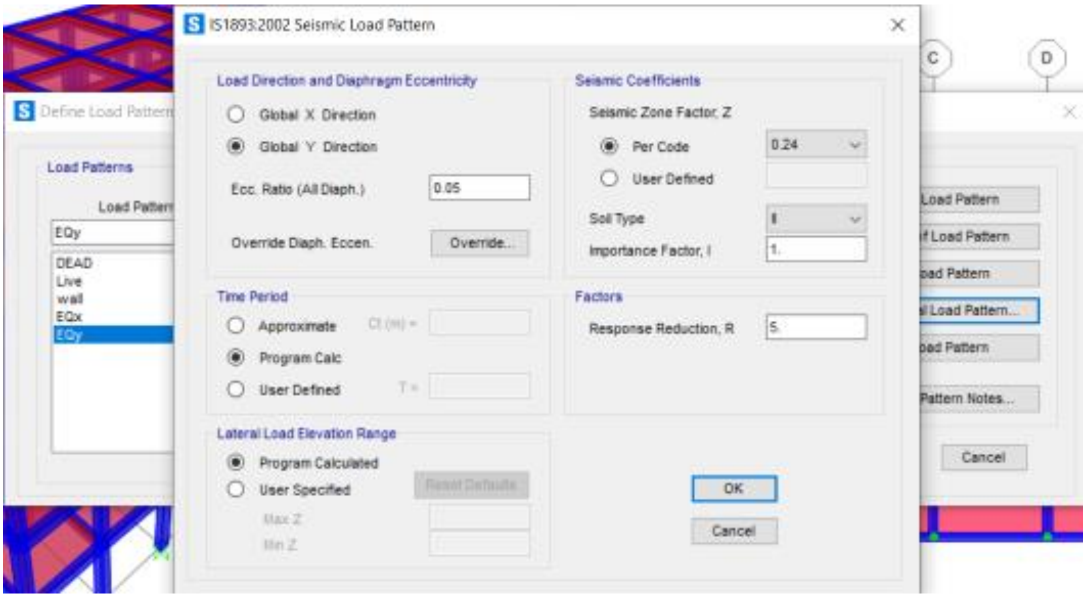
Define Load Patterns

Load Patterns

Load Pattern Name EQx

DEAD
Live
wall
EQx
EQQy

Figure 4. 8 Assigning earthquake load in X direction


IS1893:2002 Seismic Load Pattern

Load Direction and Diaphragm Eccentricity

○ Global X Direction

● Global Y Direction

Ecc. Ratio (All Diaph.) 0.05

Override Diaph. Eccen.

Time Period

○ Approximate Ct (m) =

● Program Calc

○ User Defined T =

Lateral Load Elevation Range

● Program Calculated

○ User Specified

Seismic Coefficients

Seismic Zone Factor, Z

● Per Code 0.24

○ User Defined

Soil Type II

Importance Factor, I 1.

Factors

Response Reduction, R 5.

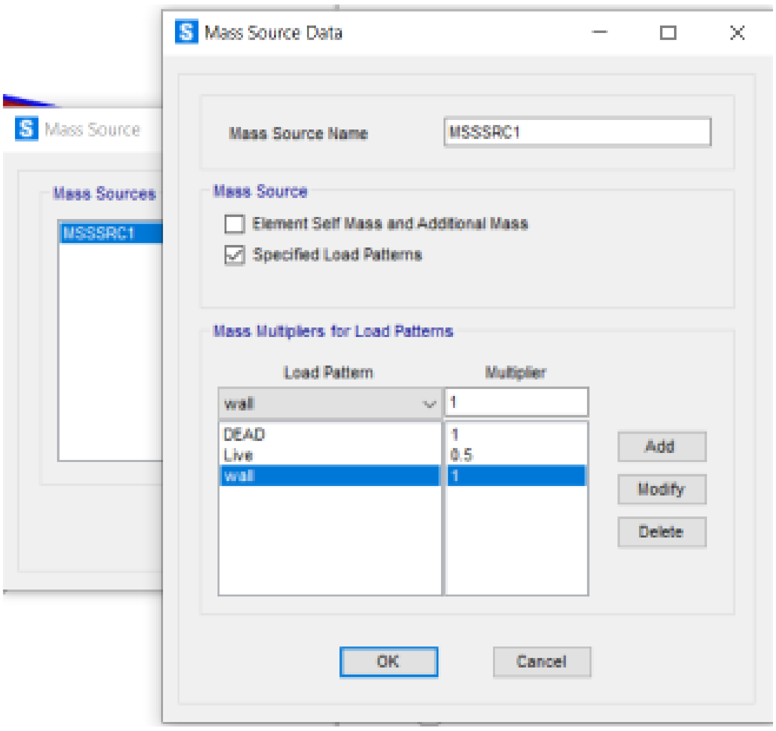
Define Load Patterns

Load Patterns

Load Pattern Name EQy

DEAD
Live
wall
EQx
EQy

Figure 4. 9Assigning Earthquake load EQy in Y direction



Mass Source Data

Mass Source Name: MSSSRC1

Mass Source

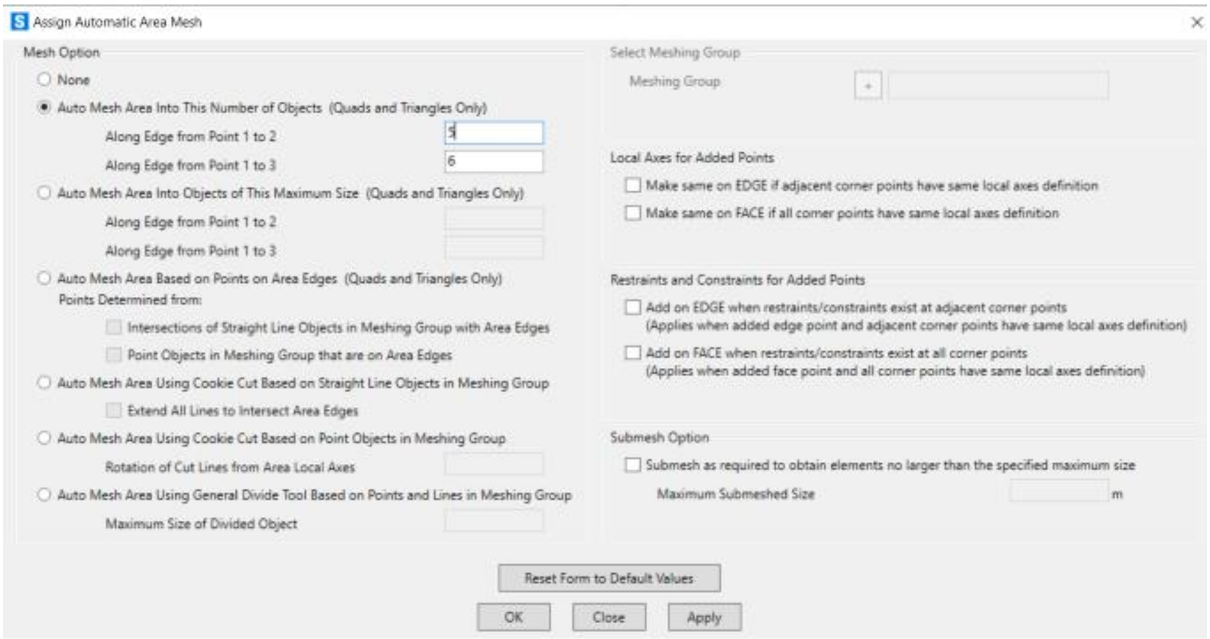
☐ Element Self Mass and Additional Mass

☑ Specified Load Patterns

Mass Multipliers for Load Patterns

Load Pattern	Multiplier
wall	1
DEAD	1
Live	0.5
wall	1

Figure 4. 10 Assigning Mass Source to calculate seismic weight of the building



Assign Automatic Area Mesh

Mesh Option

○ None

● Auto Mesh Area Into This Number of Objects (Quads and Triangles Only)

Along Edge from Point 1 to 2: 5

Along Edge from Point 1 to 3: 6

○ Auto Mesh Area Into Objects of This Maximum Size (Quads and Triangles Only)

Along Edge from Point 1 to 2

Along Edge from Point 1 to 3

○ Auto Mesh Area Based on Points on Area Edges (Quads and Triangles Only)

Points Determined from:

☐ Intersections of Straight Line Objects in Meshing Group with Area Edges

☐ Point Objects in Meshing Group that are on Area Edges

○ Auto Mesh Area Using Cookie Cut Based on Straight Line Objects in Meshing Group

☐ Extend All Lines to Intersect Area Edges

○ Auto Mesh Area Using Cookie Cut Based on Point Objects in Meshing Group

Rotation of Cut Lines from Area Local Axes

○ Auto Mesh Area Using General Divide Tool Based on Points and Lines in Meshing Group

Maximum Size of Divided Object

Select Meshing Group

Meshing Group

Local Axes for Added Points

☐ Make same on EDGE if adjacent corner points have same local axes definition

☐ Make same on FACE if all corner points have same local axes definition

Restraints and Constraints for Added Points

☐ Add on EDGE when restraints/constraints exist at adjacent corner points (Applies when added edge point and adjacent corner points have same local axes definition)

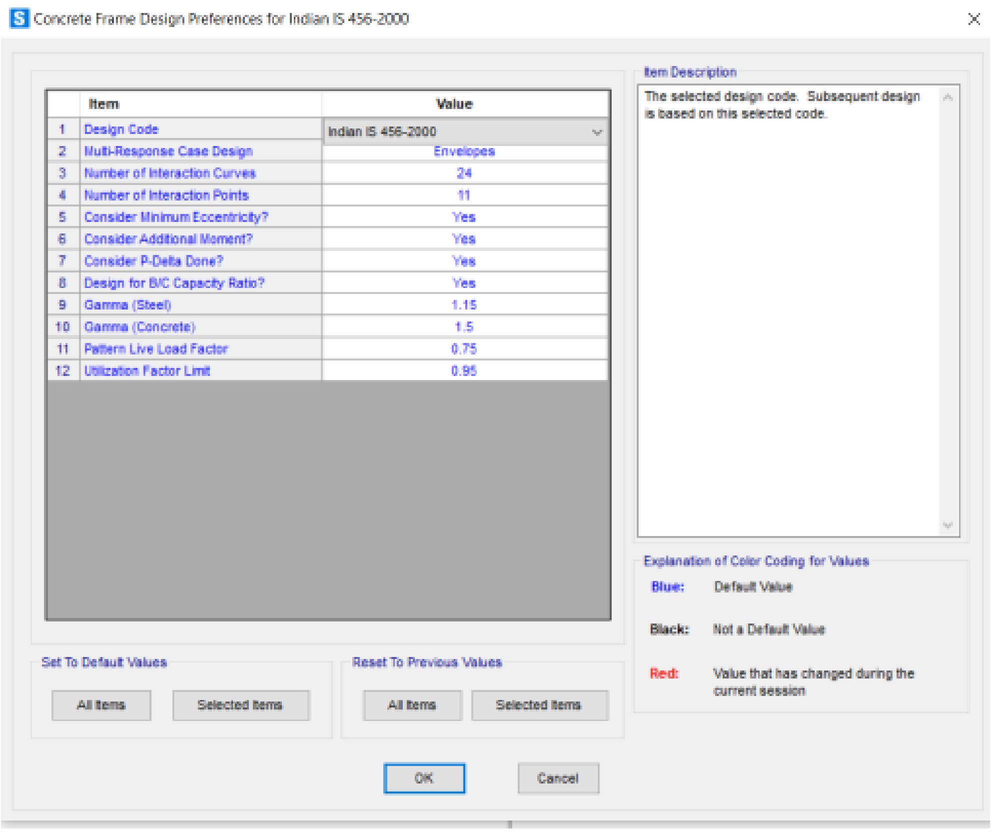
☐ Add on FACE when restraints/constraints exist at all corner points (Applies when added face point and all corner points have same local axes definition)

Submesh Option

☐ Submesh as required to obtain elements no larger than the specified maximum size

Maximum Submeshed Size m

Figure 4. 11 Meshing of salbs for analysis



Concrete Frame Design Preferences for Indian IS 456-2000

	Item	Value
1	Design Code	Indian IS 456-2000
2	Multi-Response Case Design	Envelopes
3	Number of Interaction Curves	24
4	Number of Interaction Points	11
5	Consider Minimum Eccentricity?	Yes
6	Consider Additional Moment?	Yes
7	Consider P-Delta Done?	Yes
8	Design for B/C Capacity Ratio?	Yes
9	Gamma (Steel)	1.15
10	Gamma (Concrete)	1.5
11	Pattern Live Load Factor	0.75
12	Utilization Factor Limit	0.95

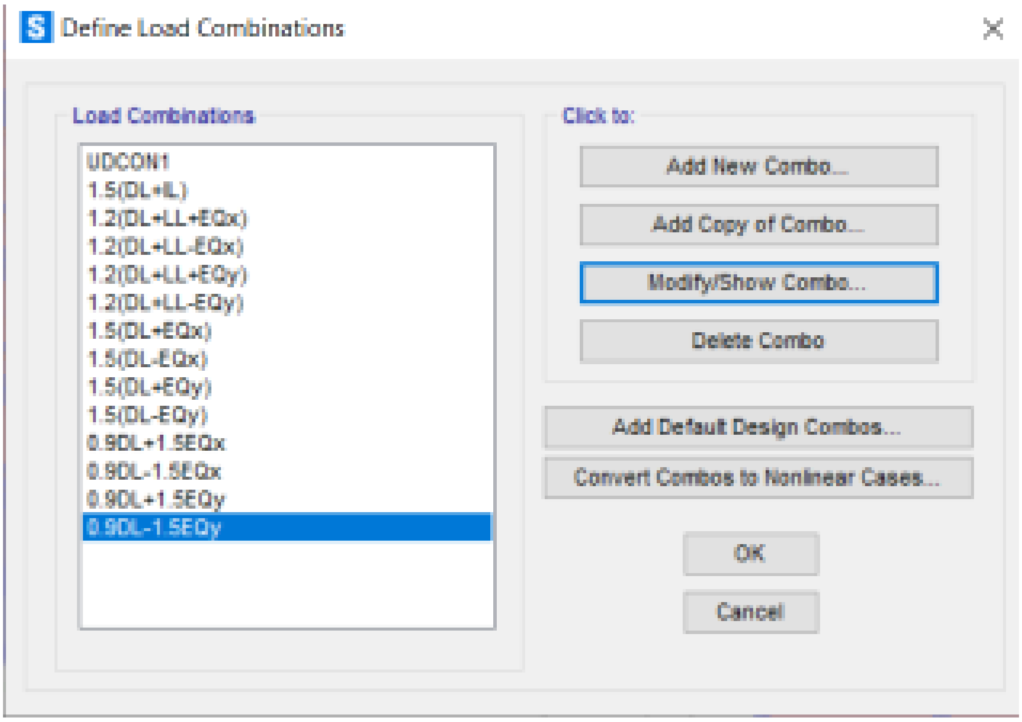
Item Description

The selected design code. Subsequent design is based on this selected code.

Explanation of Color Coding for Values

Blue:	Default Value
Black:	Not a Default Value
Red:	Value that has changed during the current session

Figure 4. 12 Assigning of prefrence for frame design Code

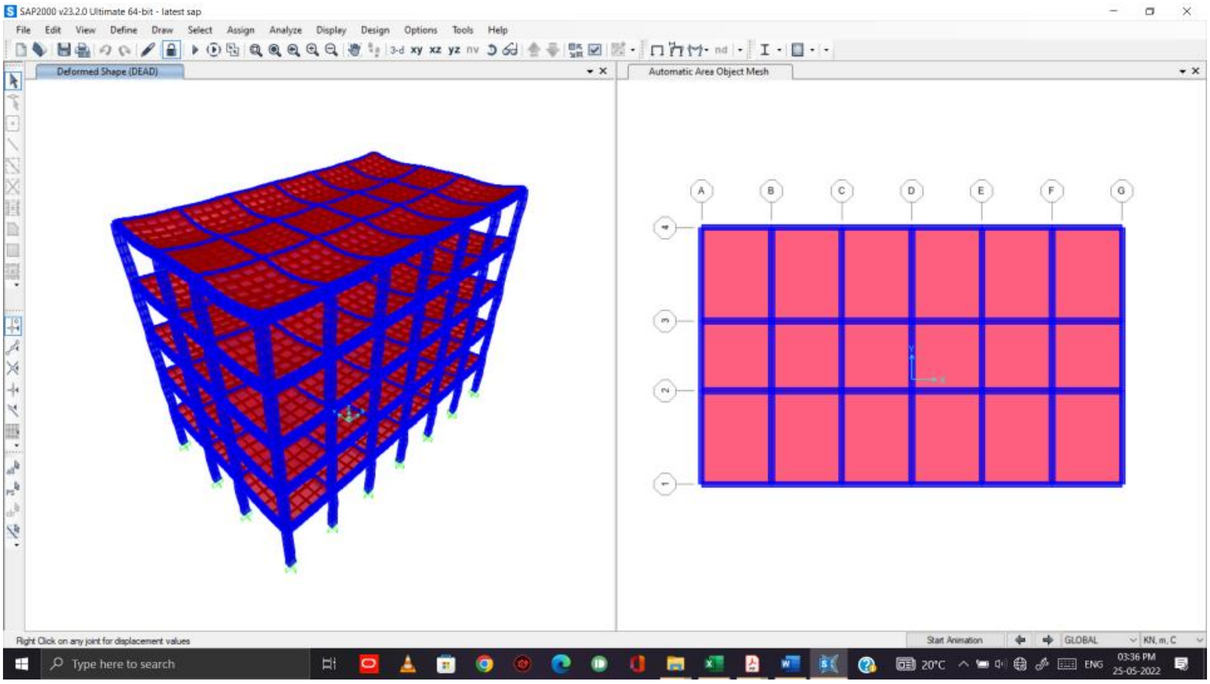


Define Load Combinations

Load Combinations

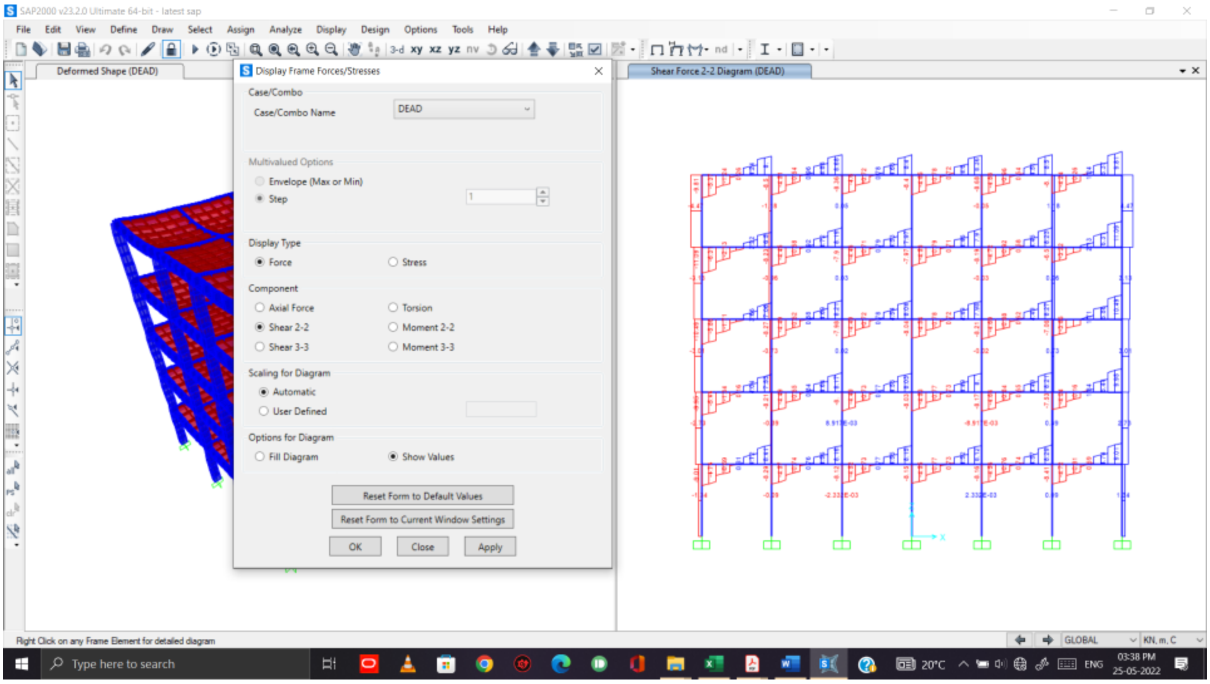
UDCON1
1.5(DL+IL)
1.2(DL+LL+EQx)
1.2(DL+LL-EQx)
1.2(DL+LL+EQy)
1.2(DL+LL-EQy)
1.5(DL+EQx)
1.5(DL-EQx)
1.5(DL+EQy)
1.5(DL-EQy)
0.9DL+1.5EQx
0.9DL-1.5EQx
0.9DL+1.5EQy
0.9DL-1.5EQy

Figure 4. 13 Assignment of Load Combination according to IS Code



Right Click on any joint for displacement values

Figure 4. 14 Deformed Shape after Analysis of the byilding



Display Frame Forces/Stresses

Case/Combo

Case/Combo Name: DEAD

Multivalued Options

○ Envelope (Max or Min)

● Step 1

Display Type

● Force ○ Stress

Component

○ Axial Force ○ Torsion

● Shear 2-2 ○ Moment 2-2

○ Shear 3-3 ○ Moment 3-3

Scaling for Diagram

● Automatic

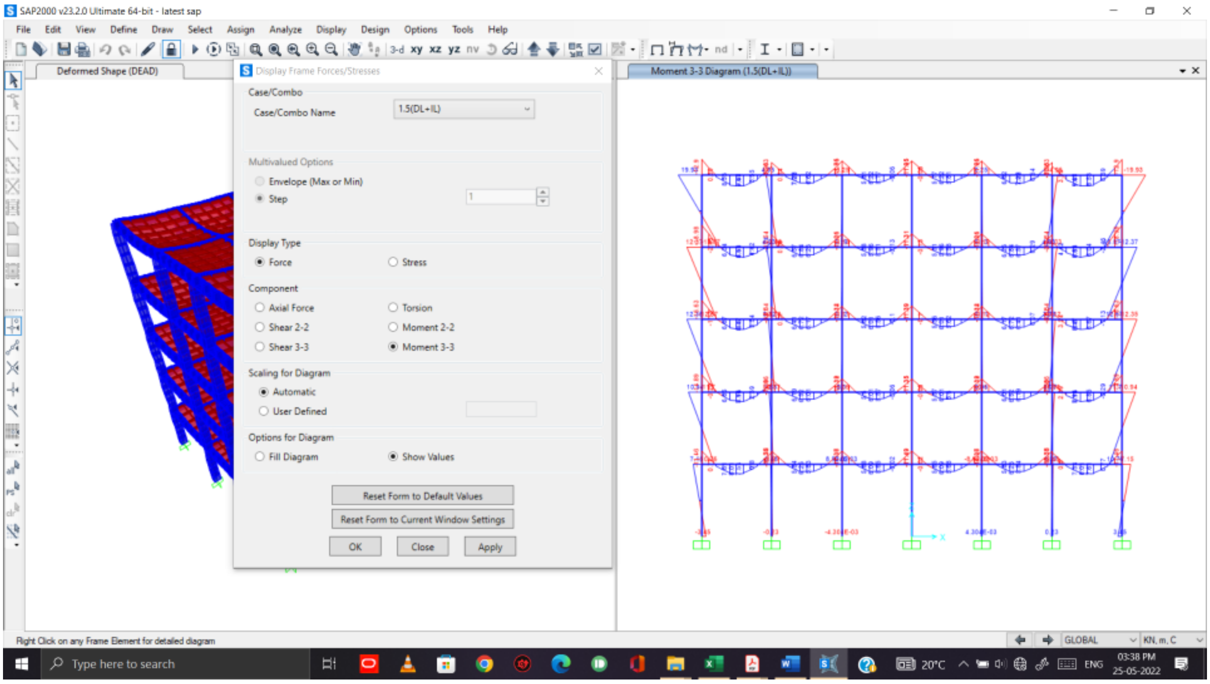
○ User Defined

Options for Diagram

○ Fill Diagram ● Show Values

Right Click on any Frame Element for detailed diagram

Figure 4. 15Shear values After Analysis



Display Frame Forces/Stresses

Case/Combo

Case/Combo Name: 1.5(DL+IL)

Multivalued Options

○ Envelope (Max or Min)
● Step: 1

Display Type

● Force ○ Stress

Component

○ Axial Force ○ Torsion
○ Shear 2-2 ○ Moment 2-2
○ Shear 3-3 ● Moment 3-3

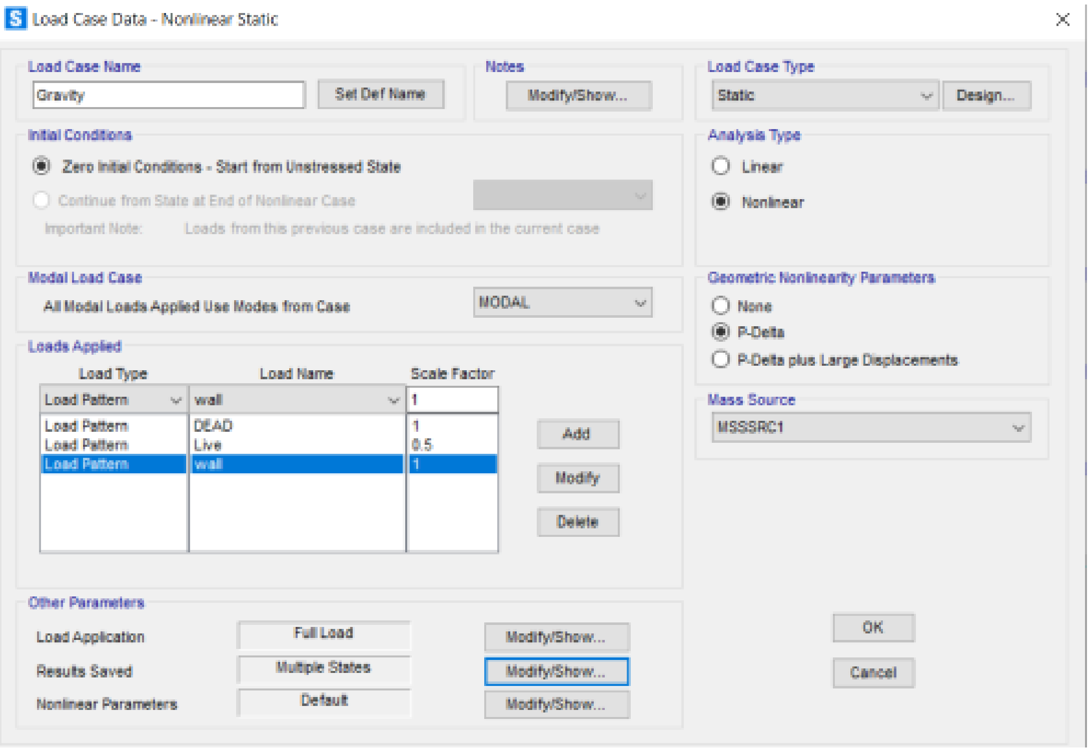
Scaling for Diagram

● Automatic
○ User Defined

Options for Diagram

○ Fill Diagram ● Show Values

Figure 4. 16Moment Values after analysis



Load Case Data - Nonlinear Static

Load Case Name: Gravity

Notes

Load Case Type: Static

Initial Conditions

● Zero Initial Conditions - Start from Unstressed State
○ Continue from State at End of Nonlinear Case

Important Note: Loads from this previous case are included in the current case

Analysis Type

○ Linear
● Nonlinear

Modal Load Case

All Modal Loads Applied Use Modes from Case: MODAL

Geometric Nonlinearity Parameters

○ None
● P-Delta
○ P-Delta plus Large Displacements

Loads Applied

Load Type	Load Name	Scale Factor
Load Pattern	wall	1
Load Pattern	DEAD	1
Load Pattern	Live	0.5
Load Pattern	wall	1

Mass Source: MSSSRC1

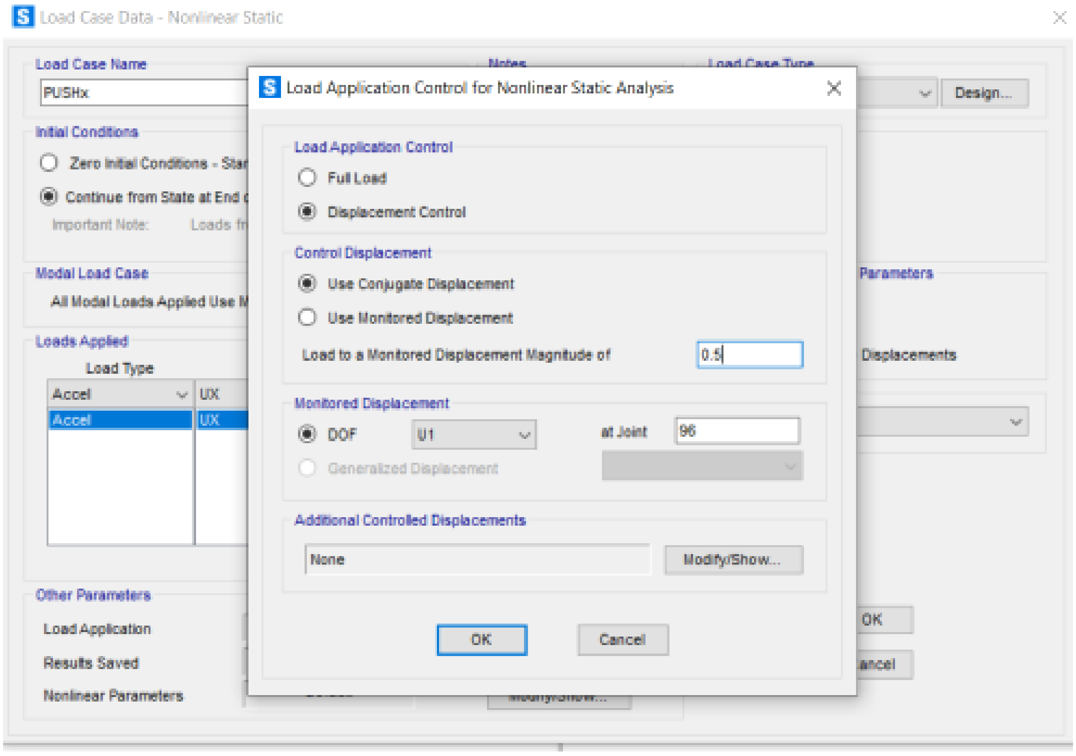
Other Parameters

Load Application: Full Load

Results Saved: Multiple States

Nonlinear Parameters: Default

Figure 4. 17 Setting Gravity load for Pushover analysis



Load Case Data - Nonlinear Static

Load Case Name: PUSHx

Initial Conditions: ● Continue from State at End of Nonlinear Case

Load Type: Accel, UX

Load Application Control for Nonlinear Static Analysis

Load Application Control

○ Full Load

● Displacement Control

Control Displacement

● Use Conjugate Displacement

○ Use Monitored Displacement

Load to a Monitored Displacement Magnitude of: 0.5

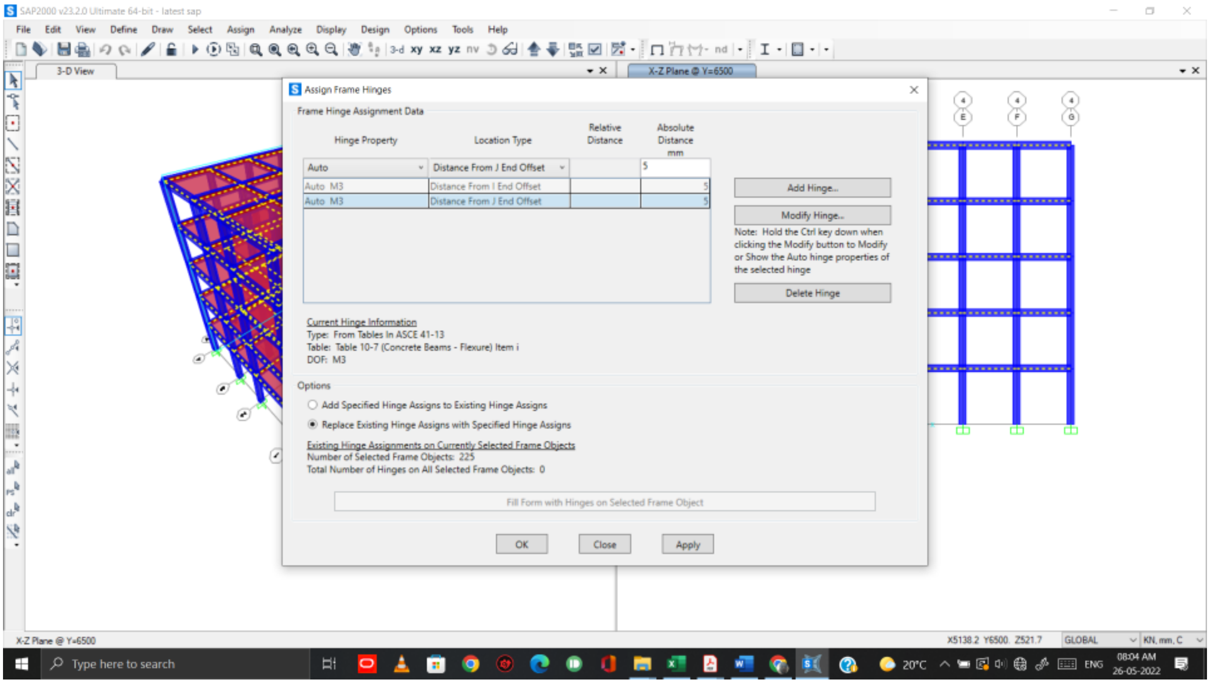
Monitored Displacement

● DOF: U1 at Joint: 96

○ Generalized Displacement

Additional Controlled Displacements: None

Figure 4. 18 Defining Pushover load in x direction



Assign Frame Hinges

Frame Hinge Assignment Data

Hinge Property	Location Type	Relative Distance	Absolute Distance mm
Auto	Distance From J End Offset		5
Auto M3	Distance From I End Offset		5
Auto M3	Distance From J End Offset		5

Note: Hold the Ctrl key down when clicking the Modify button to Modify or Show the Auto hinge properties of the selected hinge

Current Hinge Information
Type: From Tables In ASCE 41-13
Table: Table 10-7 (Concrete Beams - Flexure) Item i
DOF: M3

Options

○ Add Specified Hinge Assigns to Existing Hinge Assigns

● Replace Existing Hinge Assigns with Specified Hinge Assigns

Existing Hinge Assignments on Currently Selected Frame Objects
Number of Selected Frame Objects: 225
Total Number of Hinges on All Selected Frame Objects: 0

Figure 4. 19 Assigning Hinges to the structure to identify displacement

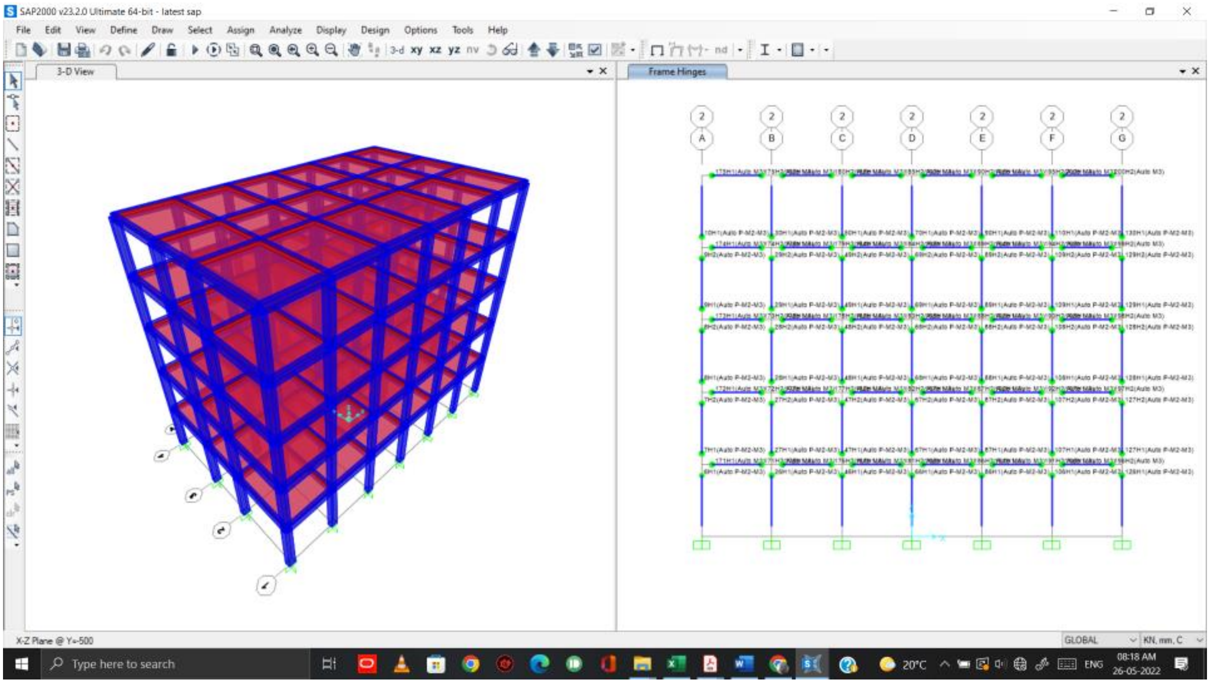


Figure 4. 20 Display of hinges after assignment

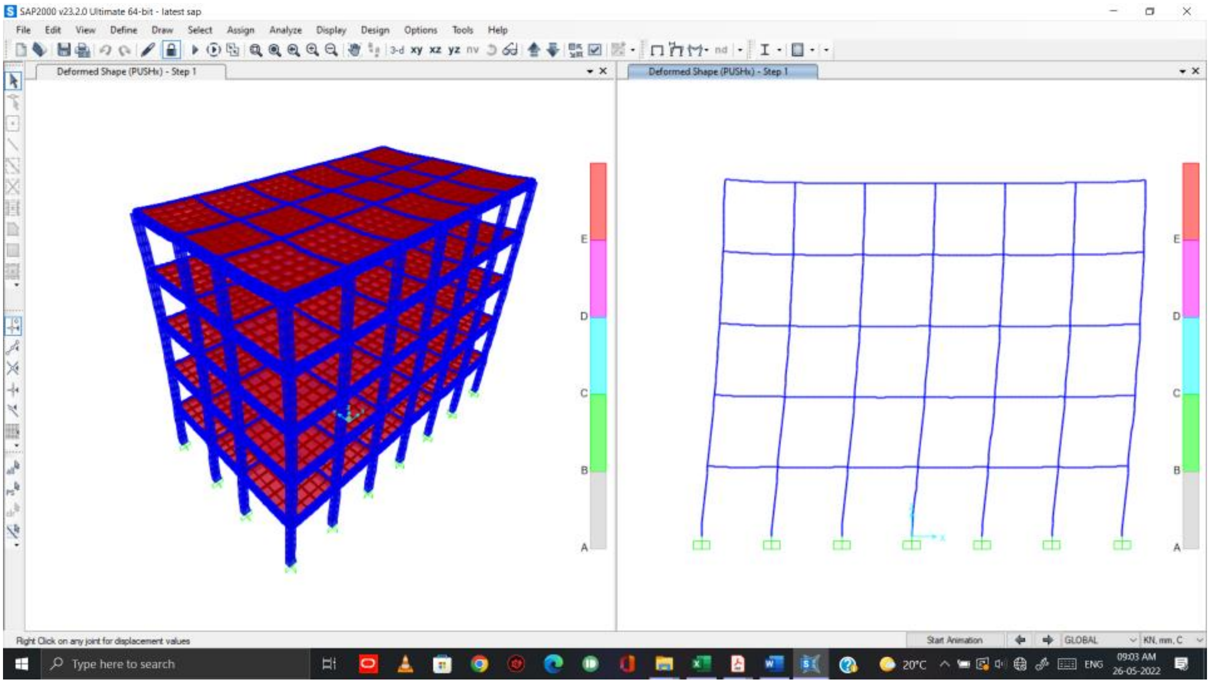
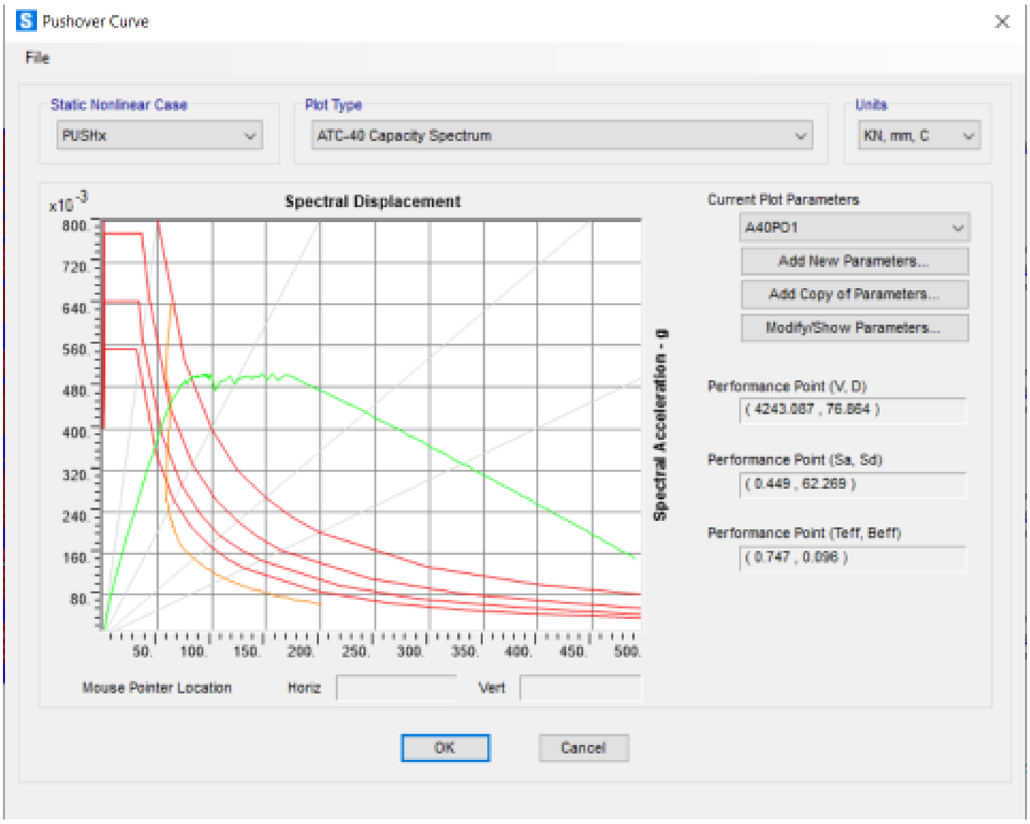


Figure 4. 21 Deformed shape during pushover Analysis



Static Nonlinear Case: PUSHx

Plot Type: ATC-40 Capacity Spectrum

Units: KN, mm, C

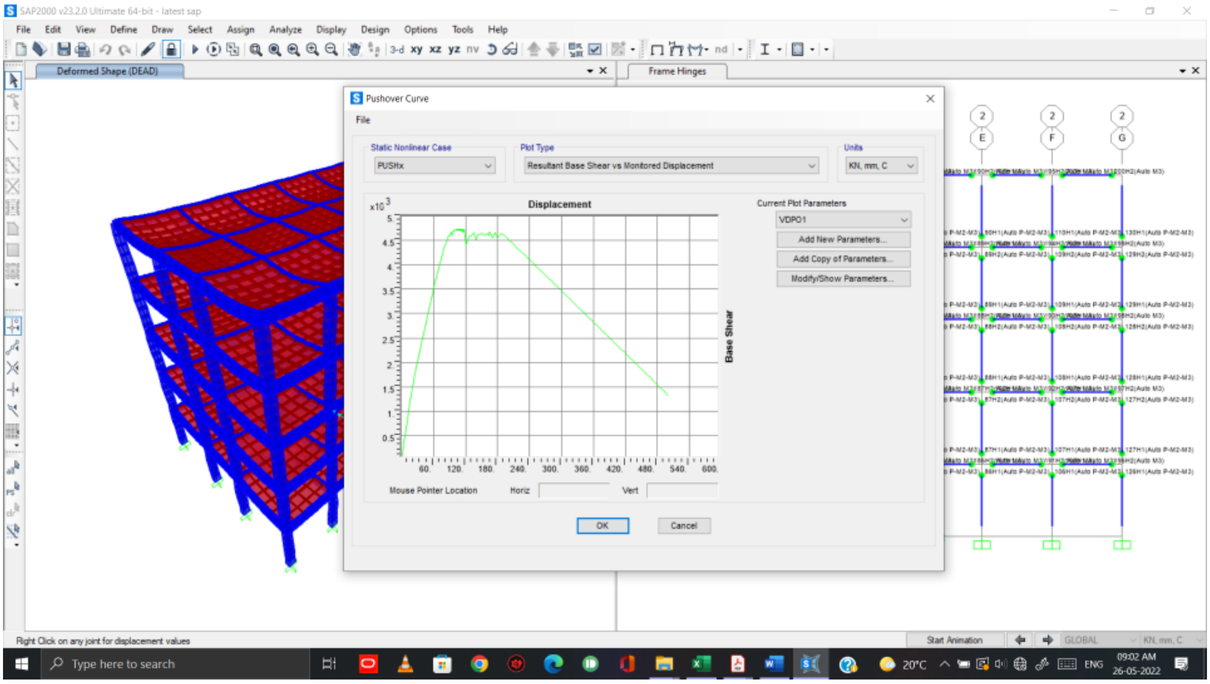
Current Plot Parameters: A40PO1

Performance Point (V, D)
(4243.087 , 76.864)

Performance Point (Sa, Sd)
(0.449 , 62.269)

Performance Point (Teff, Beff)
(0.747 , 0.096)

Figure 4. 22 Graph of specral displacement Vs Spectral accerelation



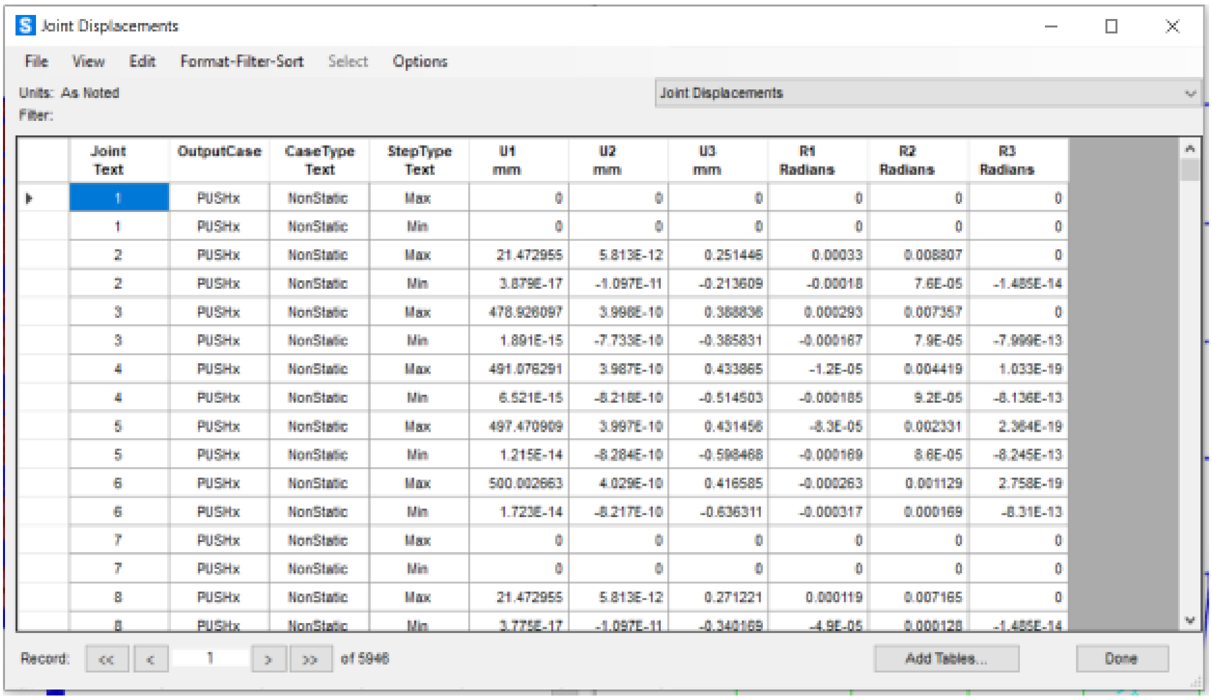
Static Nonlinear Case: PUSHx

Plot Type: Resultant Base Shear vs Monitored Displacement

Units: KN, mm, C

Current Plot Parameters: VDPO1

Figure 4. 23 Displacement Vs Base shear



Units: As Noted

Filter:

Joint Displacements

Joint Text	OutputCase	CaseType Text	StepType Text	U1 mm	U2 mm	U3 mm	R1 Radians	R2 Radians	R3 Radians
1	PUSHx	NonStatic	Max	0	0	0	0	0	0
1	PUSHx	NonStatic	Min	0	0	0	0	0	0
2	PUSHx	NonStatic	Max	21.472955	5.813E-12	0.251446	0.00033	0.008807	0
2	PUSHx	NonStatic	Min	3.879E-17	-1.097E-11	-0.213609	-0.00018	7.6E-05	-1.485E-14
3	PUSHx	NonStatic	Max	478.926097	3.998E-10	0.388836	0.000293	0.007357	0
3	PUSHx	NonStatic	Min	1.891E-15	-7.733E-10	-0.385831	-0.000167	7.9E-05	-7.999E-13
4	PUSHx	NonStatic	Max	491.076291	3.987E-10	0.433865	-1.2E-05	0.004419	1.033E-19
4	PUSHx	NonStatic	Min	6.521E-15	-8.218E-10	-0.514503	-0.000185	9.2E-05	-8.136E-13
5	PUSHx	NonStatic	Max	497.470909	3.997E-10	0.431456	-8.3E-05	0.002331	2.364E-19
5	PUSHx	NonStatic	Min	1.215E-14	-8.284E-10	-0.598468	-0.000169	8.6E-05	-8.245E-13
6	PUSHx	NonStatic	Max	500.002663	4.029E-10	0.416585	-0.000263	0.001129	2.758E-19
6	PUSHx	NonStatic	Min	1.723E-14	-8.217E-10	-0.636311	-0.000317	0.000169	-8.31E-13
7	PUSHx	NonStatic	Max	0	0	0	0	0	0
7	PUSHx	NonStatic	Min	0	0	0	0	0	0
8	PUSHx	NonStatic	Max	21.472955	5.813E-12	0.271221	0.000119	0.007165	0
8	PUSHx	NonStatic	Min	3.775E-17	-1.097E-11	-0.340169	-4.9E-05	0.000128	-1.485E-14

Record: 1 of 5946

Table of Joint displacement during pushover analysis

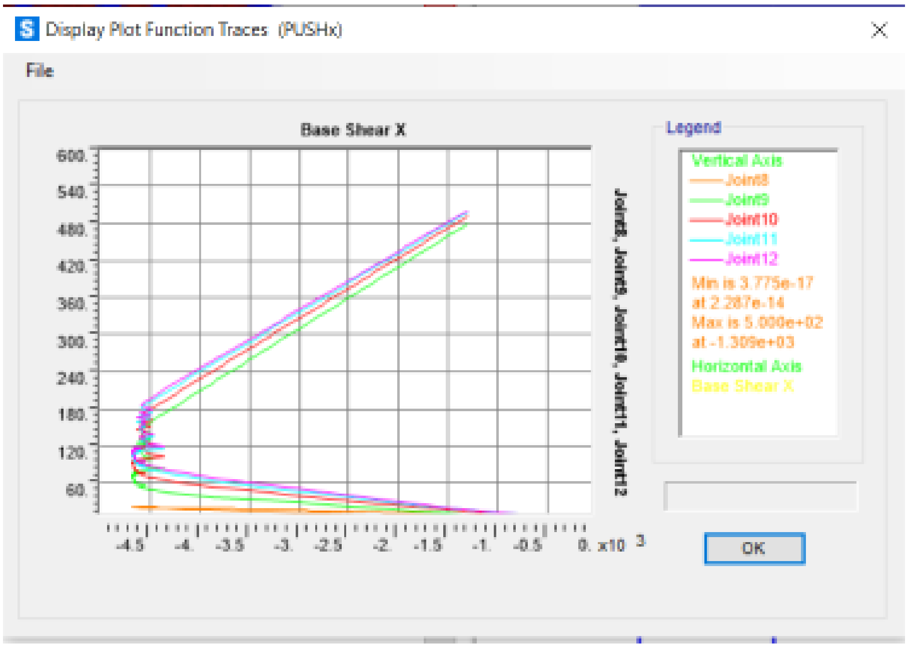
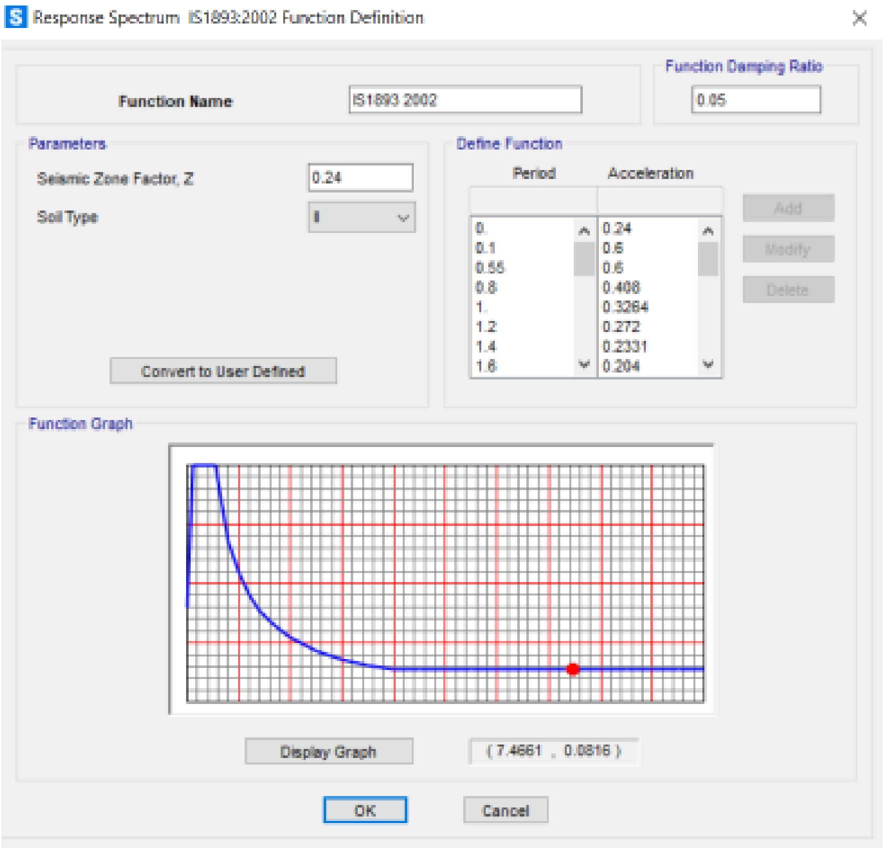


Figure 4. 24 Graph beetween base shear and joints on each floor



Response Spectrum IS1893:2002 Function Definition

Function Name: IS1893 2002

Function Damping Ratio: 0.05

Parameters

Seismic Zone Factor, Z: 0.24

Soil Type: II

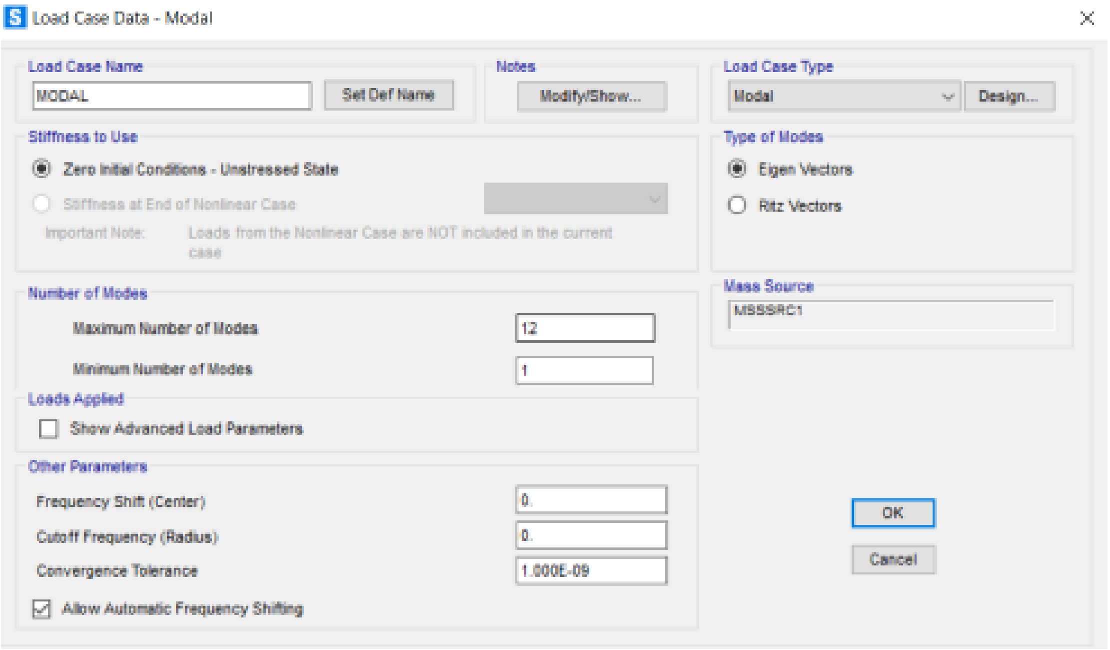
Define Function

Period	Acceleration
0.	0.24
0.1	0.6
0.55	0.6
0.8	0.408
1.	0.3264
1.2	0.272
1.4	0.2331
1.6	0.204

Function Graph

(7.4661 , 0.0816)

Figure 4. 25 Values for response spectrum



Load Case Data - Modal

Load Case Name: MODAL

Load Case Type: Modal

Stiffness to Use

● Zero Initial Conditions - Unstressed State

○ Stiffness at End of Nonlinear Case

Important Note: Loads from the Nonlinear Case are NOT included in the current case

Type of Modes

● Eigen Vectors

○ Ritz Vectors

Mass Source: MSSSRC1

Number of Modes

Maximum Number of Modes: 12

Minimum Number of Modes: 1

Loads Applied

☐ Show Advanced Load Parameters

Other Parameters

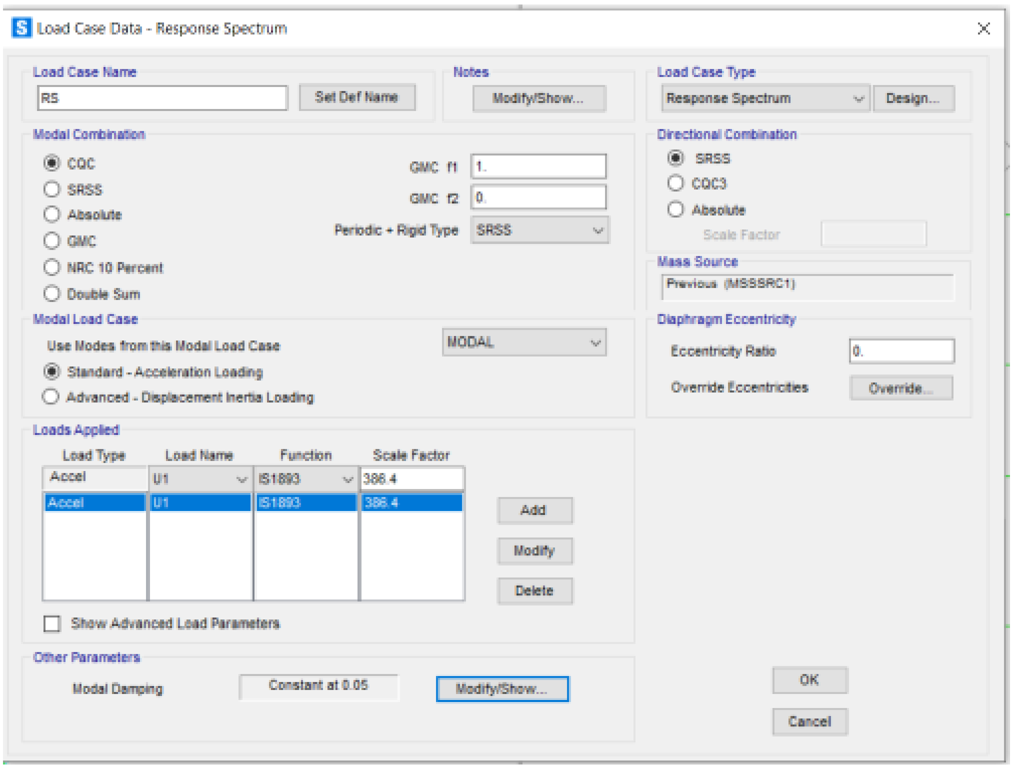
Frequency Shift (Center): 0.

Cutoff Frequency (Radius): 0.

Convergence Tolerance: 1.000E-09

☑ Allow Automatic Frequency Shifting

Figure 4. 26 Load case data and modes considered



Load Case Name: RS

Notes

Load Case Type: Response Spectrum

Modal Combination
- ● CQC
- ○ SRSS
- ○ Absolute
- ○ GMC
- ○ NRC 10 Percent
- ○ Double Sum

GMC f1: 1.

GMC f2: 0.

Periodic + Rigid Type: SRSS

Directional Combination
- ● SRSS
- ○ CQC3
- ○ Absolute

Scale Factor

Mass Source: Previous (MSSSRC1)

Modal Load Case

Use Modes from this Modal Load Case: MODAL
- ● Standard - Acceleration Loading
- ○ Advanced - Displacement Inertia Loading

Diaphragm Eccentricity

Eccentricity Ratio: 0.

Override Eccentricities

Loads Applied

Load Type	Load Name	Function	Scale Factor
Accel	U1	IS1893	386.4
Accel	U1	IS1893	386.4

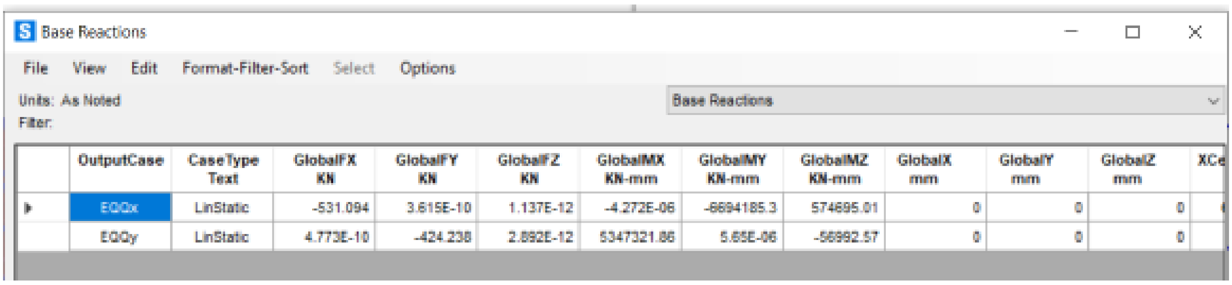
☐ Show Advanced Load Parameters

Other Parameters

Modal Damping: Constant at 0.05

Figure 4. 27 Load case data for response spectrum

Table 4.1. 1 Base Shear value



Units: As Noted

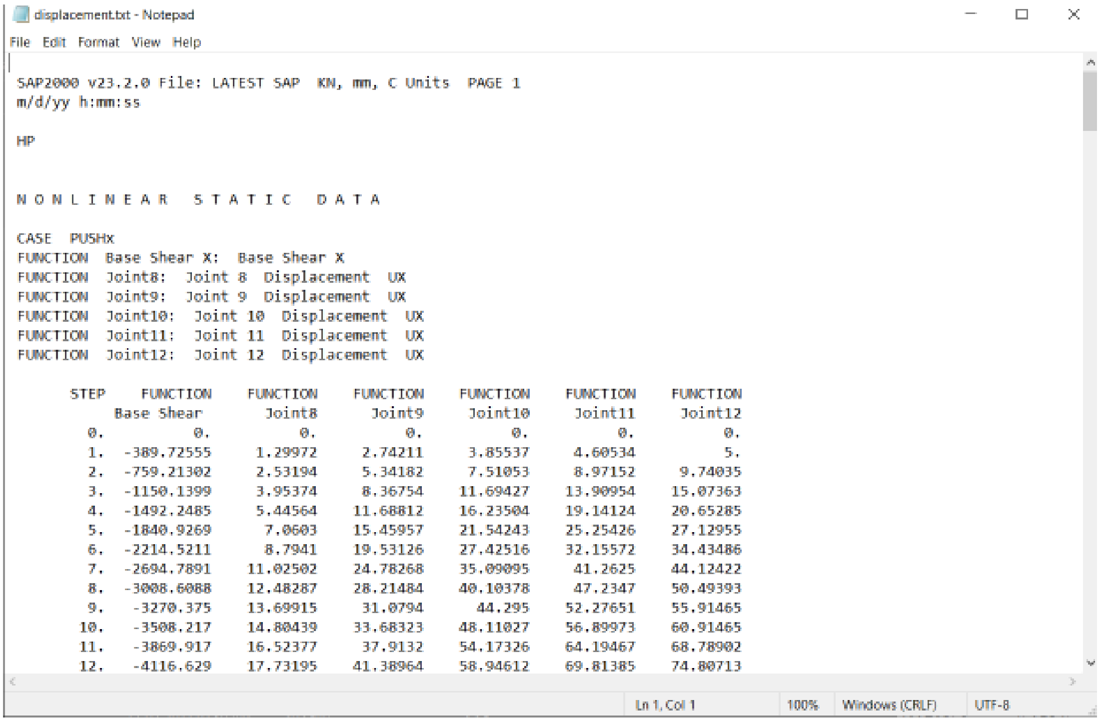
Filter:

Base Reactions

OutputCase	CaseType Text	GlobalFX KN	GlobalFY KN	GlobalFZ KN	GlobalMX KN-mm	GlobalMY KN-mm	GlobalMZ KN-mm	GlobalX mm	GlobalY mm	GlobalZ mm	XCe
EQQx	LinStatic	-531.094	3.615E-10	1.137E-12	-4.272E-06	-6694185.3	574695.01	0	0	0	
EQQy	LinStatic	4.773E-10	-424.238	2.892E-12	5347321.86	5.65E-06	-56992.57	0	0	0	

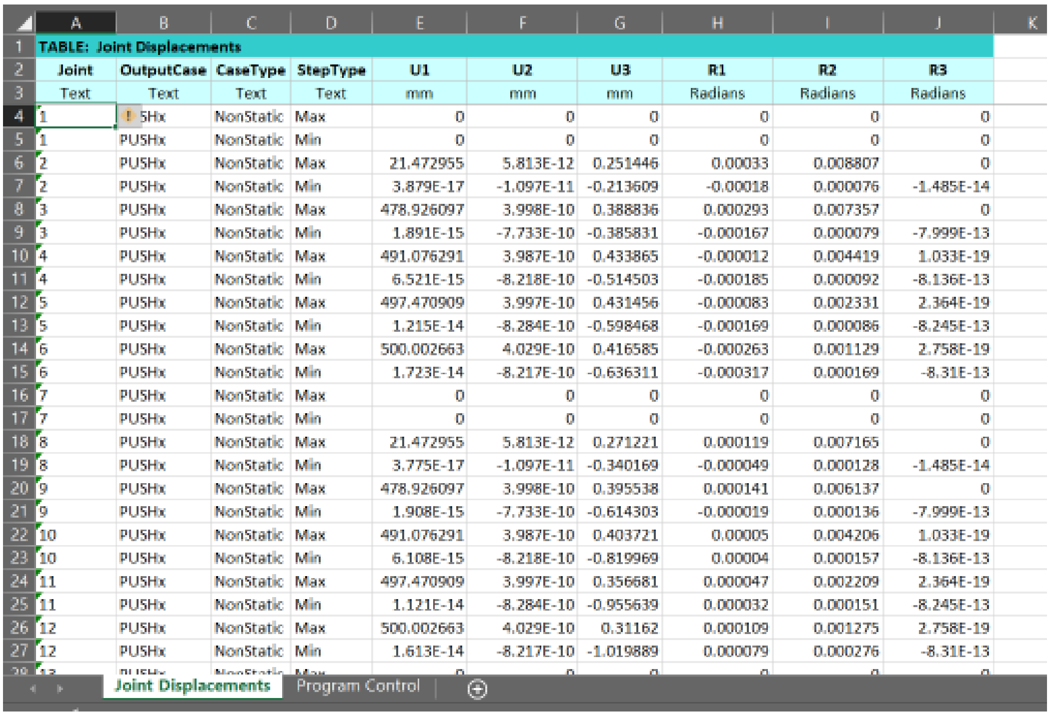
In this table Global Fx in EQx is the base shear in x direction while Global Fy in EQy is base shear in y direction

Table 4.1. 2 Values of base shear and displacement at each floor in tabular form



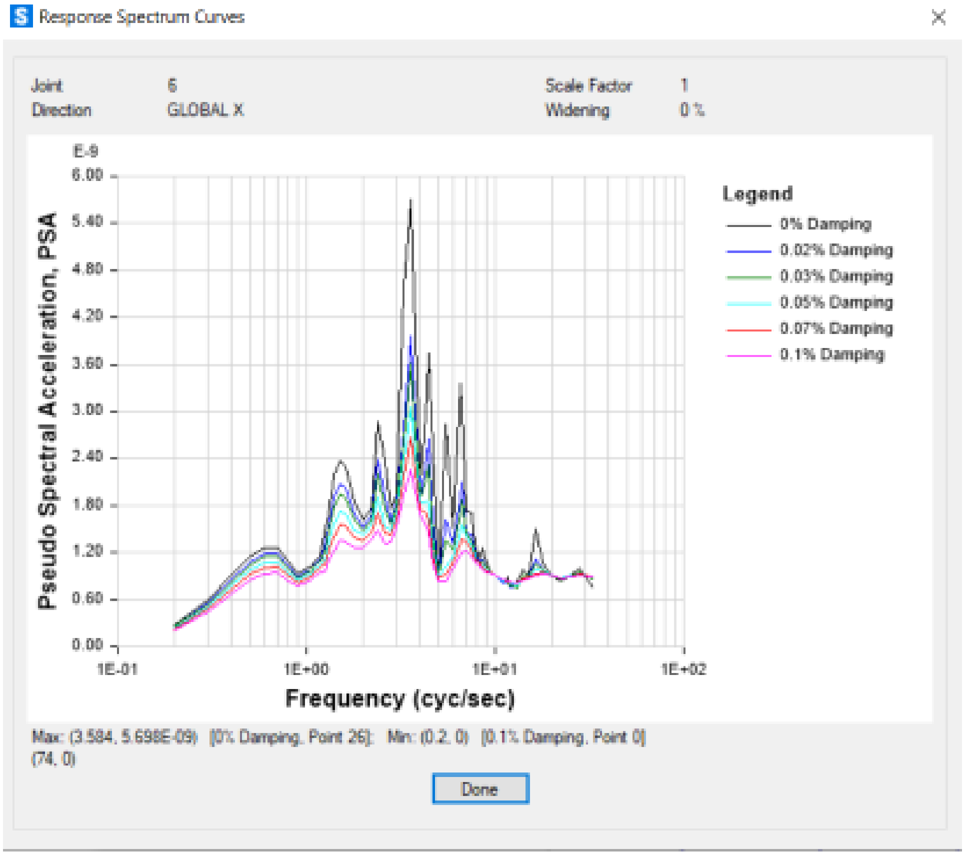
```
SAP2000 v23.2.0 File: LATEST SAP  KN, mm, C Units  PAGE 1
m/d/yy h:mm:ss

HP


N O N L I N E A R   S T A T I C   D A T A

CASE  PUSHx
FUNCTION  Base Shear X:  Base Shear X
FUNCTION  Joint8:  Joint 8  Displacement  UX
FUNCTION  Joint9:  Joint 9  Displacement  UX
FUNCTION  Joint10:  Joint 10  Displacement  UX
FUNCTION  Joint11:  Joint 11  Displacement  UX
FUNCTION  Joint12:  Joint 12  Displacement  UX

      STEP     FUNCTION     FUNCTION     FUNCTION     FUNCTION     FUNCTION     FUNCTION
             Base Shear       Joint8       Joint9      Joint10      Joint11      Joint12
        0.           0.           0.           0.           0.           0.           0.
        1.   -389.72555      1.29972      2.74211      3.85537      4.60534           5.
        2.   -759.21302      2.53194      5.34182      7.51053      8.97152      9.74035
        3.   -1150.1399      3.95374      8.36754     11.69427     13.90954     15.07363
        4.   -1492.2485      5.44564     11.68812     16.23504     19.14124     20.65285
        5.   -1840.9269       7.0603     15.45957     21.54243     25.25426     27.12955
        6.   -2214.5211       8.7941     19.53126     27.42516     32.15572     34.43486
        7.   -2694.7891     11.02502     24.78268     35.09095      41.2625     44.12422
        8.   -3008.6088     12.48287     28.21484     40.10378      47.2347     50.49393
        9.    -3270.375     13.69915      31.0794       44.295     52.27651     55.91465
       10.    -3508.217     14.80439     33.68323     48.11027     56.89973     60.91465
       11.    -3869.917     16.52377      37.9132     54.17326     64.19467     68.78902
       12.    -4116.629     17.73195     41.38964     58.94612     69.81385     74.80713
```

Table 4.1. 3 Joint Displacement in excel



	A	B	C	D	E	F	G	H	I	J
1	TABLE: Joint Displacements									
2	Joint	OutputCase	CaseType	StepType	U1	U2	U3	R1	R2	R3
3	Text	Text	Text	Text	mm	mm	mm	Radians	Radians	Radians
4	1	5Hx	NonStatic	Max	0	0	0	0	0	0
5	1	PUSHx	NonStatic	Min	0	0	0	0	0	0
6	2	PUSHx	NonStatic	Max	21.472955	5.813E-12	0.251446	0.00033	0.008807	0
7	2	PUSHx	NonStatic	Min	3.879E-17	-1.097E-11	-0.213609	-0.00018	0.000076	-1.485E-14
8	3	PUSHx	NonStatic	Max	478.926097	3.998E-10	0.388836	0.000293	0.007357	0
9	3	PUSHx	NonStatic	Min	1.891E-15	-7.733E-10	-0.385831	-0.000167	0.000079	-7.999E-13
10	4	PUSHx	NonStatic	Max	491.076291	3.987E-10	0.433865	-0.000012	0.004419	1.033E-19
11	4	PUSHx	NonStatic	Min	6.521E-15	-8.218E-10	-0.514503	-0.000185	0.000092	-8.136E-13
12	5	PUSHx	NonStatic	Max	497.470909	3.997E-10	0.431456	-0.000083	0.002331	2.364E-19
13	5	PUSHx	NonStatic	Min	1.215E-14	-8.284E-10	-0.598468	-0.000169	0.000086	-8.245E-13
14	6	PUSHx	NonStatic	Max	500.002663	4.029E-10	0.416585	-0.000263	0.001129	2.758E-19
15	6	PUSHx	NonStatic	Min	1.723E-14	-8.217E-10	-0.636311	-0.000317	0.000169	-8.31E-13
16	7	PUSHx	NonStatic	Max	0	0	0	0	0	0
17	7	PUSHx	NonStatic	Min	0	0	0	0	0	0
18	8	PUSHx	NonStatic	Max	21.472955	5.813E-12	0.271221	0.000119	0.007165	0
19	8	PUSHx	NonStatic	Min	3.775E-17	-1.097E-11	-0.340169	-0.000049	0.000128	-1.485E-14
20	9	PUSHx	NonStatic	Max	478.926097	3.998E-10	0.395538	0.000141	0.006137	0
21	9	PUSHx	NonStatic	Min	1.908E-15	-7.733E-10	-0.614303	-0.000019	0.000136	-7.999E-13
22	10	PUSHx	NonStatic	Max	491.076291	3.987E-10	0.403721	0.00005	0.004206	1.033E-19
23	10	PUSHx	NonStatic	Min	6.108E-15	-8.218E-10	-0.819969	0.00004	0.000157	-8.136E-13
24	11	PUSHx	NonStatic	Max	497.470909	3.997E-10	0.356681	0.000047	0.002209	2.364E-19
25	11	PUSHx	NonStatic	Min	1.121E-14	-8.284E-10	-0.955639	0.000032	0.000151	-8.245E-13
26	12	PUSHx	NonStatic	Max	500.002663	4.029E-10	0.31162	0.000109	0.001275	2.758E-19
27	12	PUSHx	NonStatic	Min	1.613E-14	-8.217E-10	-1.019889	0.000079	0.000276	-8.31E-13

In given table for joint displacements we have taken joint from 8 to 12 to compare the joint displacement



Joint 6

Direction GLOBAL X

Scale Factor 1

Widening 0 %

Max: (3.584, 5.698E-09) [0% Damping, Point 26]; Min: (0.2, 0) [0.1% Damping, Point 0]
(74, 0)

Figure 4. 28 Response spectrum Curve

4.1 Building design analysis by Force Based design Method (FBD Method)

Design parameter

For seismic zone 4 the zone factor z is 0.24 (Table 2 of IS: 1893). Importance factor of 1.o (Table 6 of IS: 1893). Building is required to be provided with moment resisting frames detailed as per IS:1320-1993. Hence the response reduction factor, R, is 5.

Design weight:

Floor area is 11×18=198 sq. m since live load is 4 kN/sq.m only 50% of live load is lumped at floors. At roof, no live load is to be lumped. Hence the total seismic weight on the floors and the roof is:

Floors:

M_1=M_2= M_3= M_4=198×(1+4+4×0.5)

=1386 kN

Roof:

M_5=198×(1+4)=990kN

Seismic weight of building:

$$\Sigma M_i = (1386 + 31.284) \times 4 + (990 + 10.416)$$

=6669.552 kN=680.104 Ton

Fundamental Period:-

Lateral load resistance is provided by moment resisting frames. Hence approximate fundamental natural time period can be seen as:

EL in X-direction:

$$T = 0.09h/\sqrt{d}$$

$$= \frac{0.09(15.5)}{\sqrt{18}}$$

=0.32 sec

The building is located on Type 2 (medium soil) from fig 2 of IS 1893, for T=0.32 sec S_a/g=2.5

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

$$= \frac{0.24}{2}.\frac{1}{5} \times 2.5$$

=0.06

Design Base shear

$$V_b = A_h W$$

=0.06×6669.552

=400.17 kN

EL in Y-direction:

$$T = 0.09h/\sqrt{d}$$

$$= \frac{0.09(15.5)}{\sqrt{11}}$$

=0.420 sec

The building is located on Type 2 (medium soil) from fig 2 of IS 1893, for T=0.32 sec S_a/g=2.5

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

$$= \frac{0.24}{2}.\frac{1}{5} \times 2.5$$

=0.06

Design Base shear

$$V_b = A_h W$$

=0.06×6669.552

=400.17 kN

EL in Z-direction:

$$T = 0.09h/\sqrt{d}$$

$$= \frac{0.09(15.5)}{\sqrt{15.5}}$$

=0.354 sec

The building is located on Type 2 (medium soil) from fig 2 of IS 1893, for T=0.32 sec S_a/g=2.5

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

$$= \frac{0.24}{2}.\frac{1}{5} \times 2.5$$

=0.06

Design Base shear

$$V_b = A_h W$$

=0.06×6669.552

=400.17 kN

Therefore, seismic force for the building is same in X and Y direction

Force distribution with Building height:

The Base shear for building is distributed with height as per c;lause7.7.1 Table gives the calculation as show in the table given below:

Table 4. 1 Base shear values in each floor

storey level	W_i	h_i	$W_ih_i^2$	Q	lateral force	
					x-dir	y-dir
5	990.416	15.5	237947.444	0.368026	147.2731	147.2731
4	1417.282	12.4	217921.3418	0.337053	134.8783	134.8783
3	1417.282	9.3	122580.7548	0.189592	75.86906	75.86906
2	1417.282	6.2	54480.33546	0.084263	33.71958	33.71958
1	1417.282	3.1	13620.08386	0.021066	8.429896	8.429896
Total			646549.9599	1	400.17	400.17

Design Displacement

$$\Delta_d = \frac{\sum m_i {\Delta_i}^2}{\sum m_i \Delta_i}$$

Table 4. 2 Mass and displacement at each floor

storey	Δ_i	m_i	$m_i{\Delta_i}^2$	$m_i\Delta_i$
1st	0.0214	1417.282	0.649059	30.32984
2nd	0.478	1417.282	323.8264	677.461
3rd	0.491	1417.282	341.6799	695.8857
4th	0.497	1417.282	350.0815	704.3894
5th	0.5	990.416	247.604	495.208
		sum	1263.841	2603.274

$$\Delta_d = \frac{1263.841}{2603.74}$$

=0.4855m

Elastic lateral stiffness

The gross moment of inertia

$$I = \frac{1}{12} bh^3$$

$=1.66*10^{15}$

and hence the first guess of the effective moment of inertia is:

$$I_{eff}=40\%I_g$$

$$=6.655*10^{14}$$

The initial elastic lateral stiffness of each floor is then defined using the following equation

$$K_{el}=\frac{3(E_cI)eff}{H^3}$$

Table 4. 3 lateral stiffness of each floor

storey	Hi	K_{el}
5	15.5	1.78712E+11
4	12.4	3.49046E+11
3	9.3	8.27369E+11
2	6.2	2.79237E+12
1	3.1	2.2339E+13
		2.64865E+13

Fundamental period

Total mass of structure can be written as: -

W=6669.52kN

4.2 Building design analysis by Direct displacement Based design method (DDBD method)

To start performing DDBD, the design drift of the building, is determined according to the type of the building and its performance level

$$\theta_d = \frac{\text{Inter} - \text{storey displacement}}{\text{Storey height}}$$

Step1 Determine Displacement shapes as shown:

$$\Delta_i = \omega_\theta \theta_d h_i \frac{(4H_i - h_i)}{(4H_i - h_1)}$$

Table 4. 4 Displacement at each floor

storey	**1st**	**2nd**	**3rd**	**4th**	**5th**
Displacement	0.0214	0.478	0.491	0.497	0.5

Step 2 Determine the design displacement as shown:

$$\Delta_d = \frac{\sum m_i {\Delta_i}^2}{\sum m_i \Delta_i}$$

Table 4. 5 Mass and displacement at each floor

storey	Δ_i	m_i	$m_i {\Delta_i}^2$	$m_i \Delta_i$
1st	0.0214	1417.282	0.649059	30.32984
2nd	0.478	1417.282	323.8264	677.461
3rd	0.491	1417.282	341.6799	695.8857
4th	0.497	1417.282	350.0815	704.3894
5th	0.5	990.416	247.604	495.208
		sum	1263.841	2603.274

$$\Delta_d = \frac{1263.841}{2603.74}$$

=0.4855m

Step 3 Calculate the effective height by :

$$H_e = \frac{\Sigma m_i \Delta_i H_i}{\Sigma m_i \Delta_i}$$

Table 4. 6 Effective height of each floor

storey	H_i	H_e
1st	3.1	1.50505
2nd	6.2	3.0101
3rd	9.3	4.51515
4th	12.4	6.0202
5th	15.5	7.52525

Step 4 Calculate yield drift slope as shown:

$$\theta_y = 0.5\varepsilon_y \frac{l_b}{h_b}$$

$$\theta_y = 0.193$$

Step 5 Calculate yield displacement, Δ_y as shown:

$$\Delta_y = \theta_y . H_e$$

$$\Delta_y = 0.5\varepsilon_y \frac{l_b}{h_b} H_e$$

Table 4. 7 Yield displacement at each floor

Storey	H_i	H_e	Δ_y
1st	3.1	1.50505	0.145237
2nd	6.2	3.0101	0.290475
3rd	9.3	4.51515	0.435712
4th	12.4	6.0202	0.580949
5th	15.5	7.52525	0.726187

Step 6 Calculate the displacement ductility, μ with formula:

$$\mu = \frac{\Delta_d}{\Delta_y}$$

Table 4. 8 Displacement ductility at each floor

storey	Δ_y	μ
1st	0.145237	3.342805
2nd	0.290475	1.671402

3rd	0.435712	1.114268
4th	0.580949	0.835701
5th	0.726187	0.668561

Step 7 Estimate the equivalent viscous damping: The formula of the equivalent viscous damping is deduced from best fittings of certain experiments. Through this study, the following formula was adopted.

$$\xi = 0.05 + 0.565\frac{(\mu - 1)}{\mu\pi}$$

Table 4. 9 Viscous damping at each floor

Storey	Viscous damping (ξ)
1st	0.176
2nd	0.122
3rd	0.0684
4th	0.0146
5th	-0.0393

Step 8 Plot the elastic displacement response spectrum for (ξ=0.05) Firstly, the acceleration response spectrum is plotted from the IS code (according to type of soil and peak ground acceleration), then the displacement response spectrum is deduced using the following formula.

$$\Delta_{T,5} = \frac{T^2}{4\pi^2} a_{T,5}$$

$$\Delta_{T,5} = 0.496m$$

Step 9 Displacement response spectrum for (ξ=ξ_d) A damping modifier R_ξ is applied to the displacement spectrum obtained in the previous step to obtain the displacement spectrum at different levels of damping. The following equation is the damping modifier R_ξ

$$R_\xi = \left(\frac{0.10}{0.05 + \xi}\right)^{0.5}$$

$$R_\xi = 0.6651$$

Corresponding damped displacement

$$\Delta_{d,\xi} = \Delta_{T,5} R_\xi = 0.3298$$

Step 10 Calculate the effective period, T_e: The effective period can be obtained from the displacement response spectrum (using the design displacement) (calculated from step 2)

$$T_e = T_c \frac{\Delta_d}{\Delta_{d,\xi}}$$

$$T_e = 0.120$$

Step 11 Calculate the effective mass, m_e :

$$m_e = \frac{\Sigma m_i \Delta_i}{\Delta_D} = \frac{\Sigma m_i {\Delta_i}^2}{\Sigma m_i \Delta_i^2}$$

$$m_e = 2604.12\ tonns$$

Step 12 Calculate the effective stiffness of the building:

$$k_e = \frac{4\pi^2 m_e}{T_e^2}$$

$$k_e = 7.0 * 10^8 = 700 \text{ kN/m}$$

Step 13 Base shear can be calculated by:

$$V_b = k_e . \Delta_d$$

$$V_b = 700 \times 0.485$$

$$= 339 \text{kN}$$

4.3 Comparison of Results

From all the values that we have calculated we can compare in a tabular as show in table below

Table 4. 10 Comparison of different values of force based and direct displacement-based design

	FBD	DDBD
K_{el}	$2.6*10^{13}$	
K_{eff}		$7.0*10^{8}$
$T(s)/T_{eff}$	0.32	0.120
q factor	3.5	
μ		3.342
V_{base}	400kN	339kN

From result we can infer that :-

- Time period in force based design method is more than direct displacement based design method.
- Stiffness in force based design method is more than direct displacement based method
- V_{base} in Force Based method is more than displacement based method
- Damping in force based design is more and can change compared to constant value in direct displacement based displacement method

5. CONCLUSION

The project is started by selecting a 5 storey Building located in Jalandhar (Zone IV). Having learned Revit and a basic 3-D Modelling of the building is done.

SAP-2000 is further utilized to analyse the building under seismic loads to calculate base shear, response spectrum graph. To compare the building designed using force-based design method and direct displacement design method comparable of values are calculated like time period, effective stiffness, base shear and other values. During this project we concluded that force based method is more calculation intensive while assuming some values which can lead to more time spent in checking different iteration of it to get accurate value while direct displacement based is established with steps to follow albite new it makes many steps needed to be followed clear, but since this method is new it still needs to be further studied and experimented to find flaws in it. But since Force method is a old method so we already know its flaws which makes it rather reliable.

5.1 Future Scope of Project

This project is conducted because we still see the use of Force based method in many places so to make it aware about displacement based method which was developed in 2000, by M.J .N. Priestley and M.J. Kowalsky[5] in this project we compare These two method Force based and displacement based design method used on a Five storey building. This project was made perfect by also analysing it on Sap 2000 software while modelled in revit software to properly visualise. In this project major milestones were literature review when searching for what other people have done on this project to get the general outline of the project and should I do to further advance it next mile was to model and then analyse it many works before have only calculated the values or modelled the building in software so to better my project we decided to do modelling of the building in the revit program and analysed using SAP 2000 to compare values with Manual calculation that we did after it we saw that direct displacement based method calculation yielded values were less than Force based method which tells us that it is less resource intensive with more importance on ductility compared to Force based method with strength of the structure. This project can be further expanded by doing comparison on different structure like towers power plant or more structures like this which are susceptible to earthquake.

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