Pushover Analysis of a Residential Building

A

Project Report

Submitted in partial fulfillment 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

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Waknaghat, Solan-173234, Himachal Pradesh

DECLARATION

I hereby declare that the work presented in the Project report entitled "**Pushover Analysis of a Residential Building**" submitted for partial fulfillment 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.Ashish Kumar) & (Mr. Chandra Pal Gautam) This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Rishabh Jaswal (181613)   Sushant (181616)

Department of Civil   Department of Civil
Engineering   Engineering

Jaypee University of   Jaypee   University of
Information Technology   Information Technology

Certificate

This is to certify that the work which is being presented in the project report titled "**Pushover Analysis of a Residential Building**" in partial fulfillment 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 Sushant (181616) and Rishabh Jaswal (181613) during a period from July 2021 to May , 2022 under the supervision of Mr. Chandra Pal Gautam (Assistant professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

Mr.Chandra Pal Gautam   Prof.(Dr.) Ashish Kumar

Assistant professor   Professor & Head of Department
of Civil Engineering   Department of Civil Engineering

JUIT , Waknaghat   JUIT , Waknaghat

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Abstract

In the world of Civil Engineering the buildings are the most common and important types they are shelter providers to the people out here and thus they need to be safe from earthquakes etc. In order to do so and see how building going to perform if they are pushed laterally by applying some gradual amount of forces we are performing this project which is titled " Pushover Analysis of a Residential building" to analyst different aspects of structural analysis and to have hands on experience on industry leading software like ETABS, STAADPRO , SAP etc. The Pushover Analysis is not the major criteria in determination of strength of the structure but for sure it could be a game changer in the civil industry as it can be used to laterally apply the increasing load on the structure before they are really on the site under those condition thus with the help of Pushover Analysis we can make necessary modification required in our structure or building to make them safe by any kind of lateral load which could be from earthquake or wind or due ot some other phenomenon.

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Chapter-1

Introduction

1.1 General

Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformations. Pushover analysis was carried out for the base-fixed superstructure to examine the yield displacements and succeeding inelastic behaviors. Pushover analysis is a static analysis used to investigate how far into the inelastic range a building can go before it is on the verge of a total or a partial collapse.

In this project we are going to design a building and then analyze different aspect of structural stability like pushover analysis, Bending Moment Diagram, Shear Force Diagram, Displacement etc.
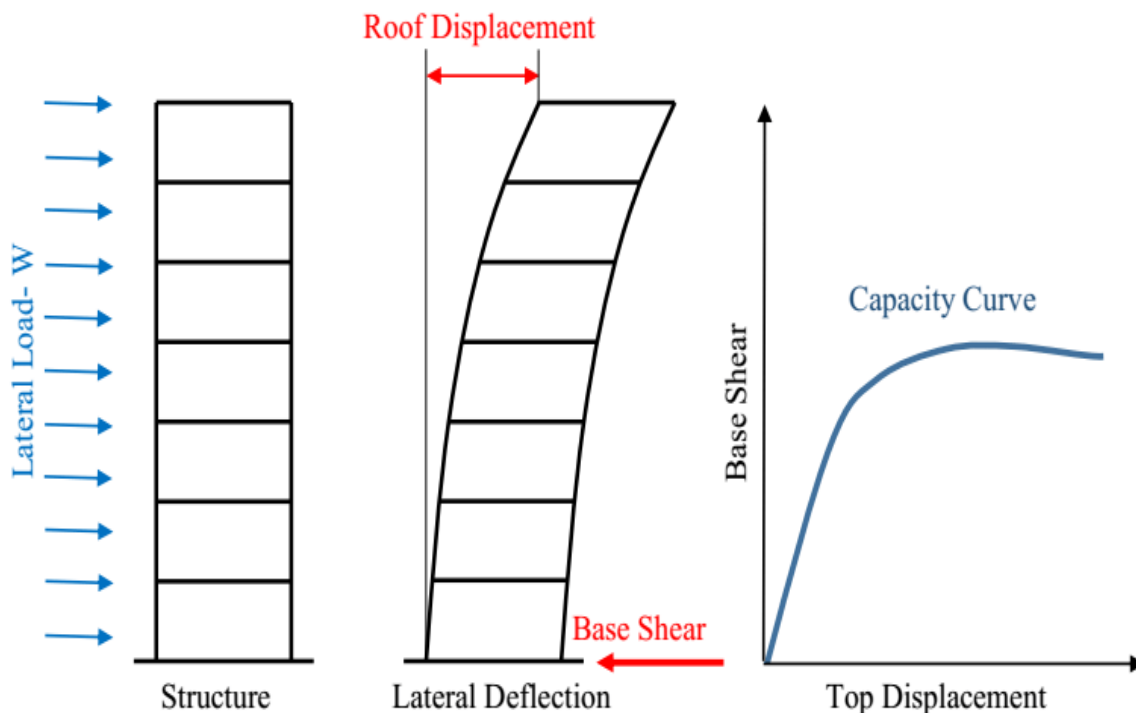

Fig 1.1

Structures withstand important distortion that is inelastic, a strong earthquake and powerful attributes from the build modification over time, so examining the performance of the build need inelastic strategies that are scientific in these dynamics.

methods are generally straightforward and consider Post conduct that is versatile. The method includes in any case certain Inelastic analytical methods comprehending the real conduct of frameworks by recognizing disappointment modes and also the possibility of dynamic breakdown. Inelastic review means fundamentally incorporating time history analysis that is inelastic and inelastic analysis that is static is otherwise known as pushover analysis. Inelastic analysis, that is static or pushover investigations, might be the chosen strategy for seismic delivery evaluation because of its effortlessness. Nonlinear analysis that is static or pushover research, is manufactured in the course of the past several years and keeps changed into the analysis that is favored for setting and execution that is seismic needs as the approximations and improvements that some measure of variety is actually constantly anticipated that will exist in seismic interest forecast of pushover analysis. Regardless of the fact that, in publishing, pushover investigations was appeared to catch crucial reaction that is auxiliary attributes under seismic activity, the exactness and also the unwavering top quality of weakling comparison in foreseeing around the globe and location seismic requests for the amount utter of just what architecture happen an interest of talk and enhanced weakling programs have-been proposed to beat the specific limits of mainstream pushover tips. In any case, the increased strategy tends to be when it comes to the part that is most computationally requesting and theoretically complex that utilization of these systems is unlikely in the engineering industry and requirements. As main-stream pushover comparison is normally utilized for configuration and execution that is seismic needs, its restrictions, flaws plus the exactness of its objectives in routine software ought to be known by considering the components influencing the pushover predictions. As it comprises, the materialness of pushover evaluation in anticipating seismic requests ought to be explored for low, middle and skyscraper tissues by recognize specific problems, for example, showing nonlinear part conduct, computational program associated with means, species in the forecasts.
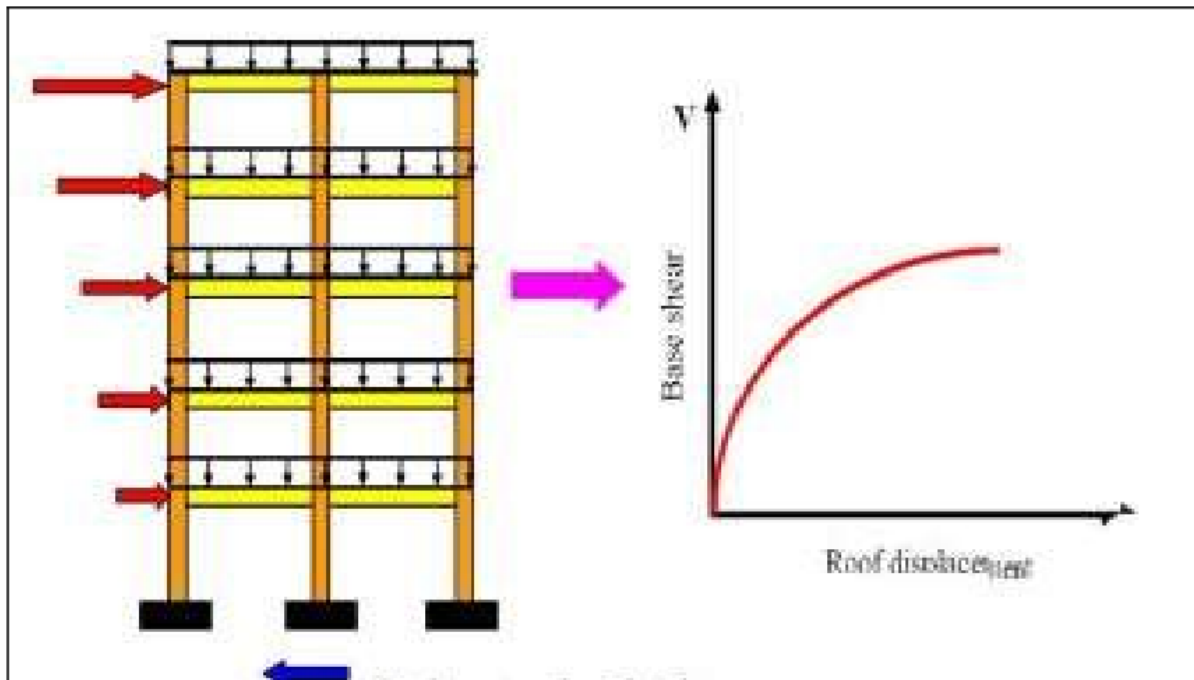
Fig 1.2

1.2 Importance of Pushover Analysis

The Pushover analysis can be used in many different realms of civil engineering, it can be used on structures to see how they are going to perform in real life scenarios they can give the idea of effect of the lateral loading on structure well before in advance at the time of design and analysis so the structure can be modified according to the needs and the safety standards of the conditions.

The pushover analysis can also sometimes be used to evaluate or check the seismic capacity of the structures that are already built and also appeared in several guidelines in the retrofit seismic design.

Pushover analysis also helps in improving the performance of the overall structure which is newly designed that depends on ductility and redundancies to the earthquake and its forces.
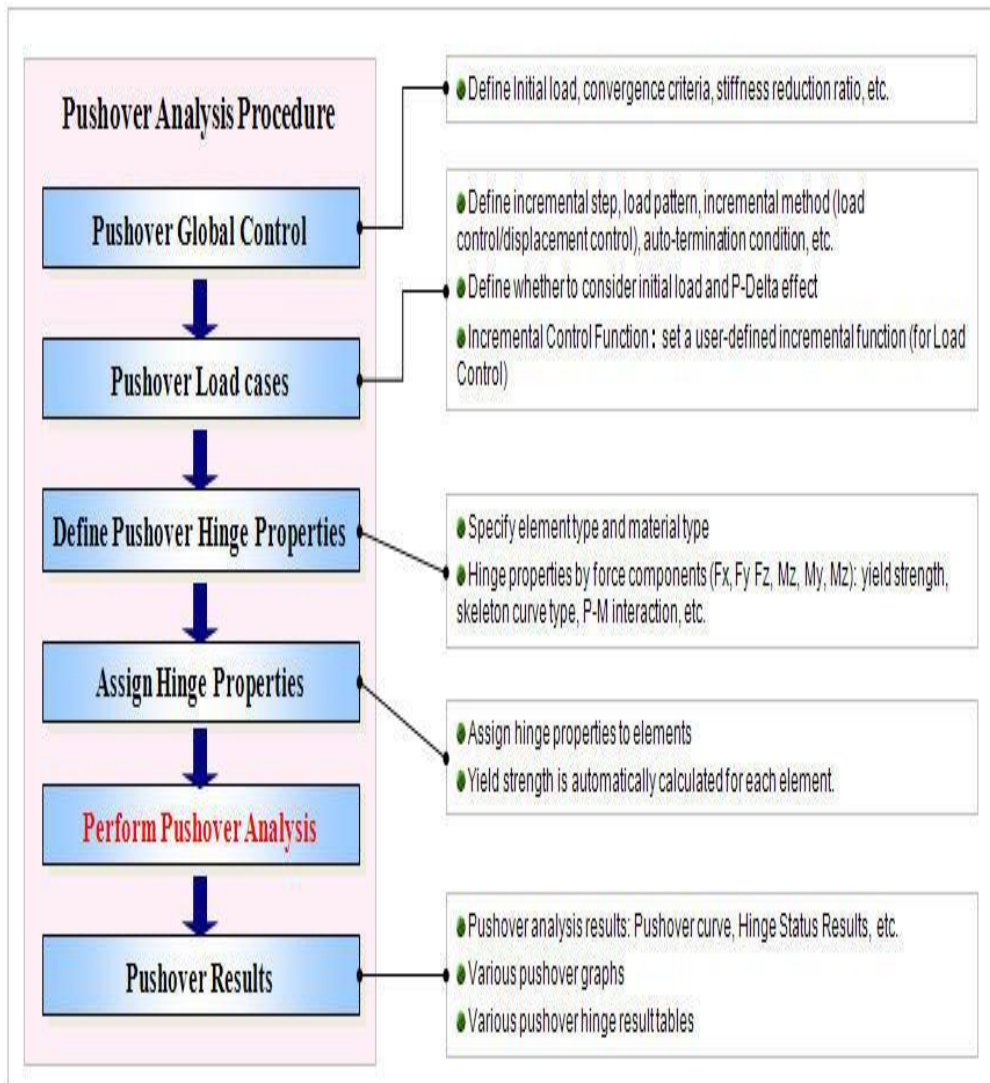
Fig 1.3

1.3 Pushover Analysis as the Non-linear static Procedure

Pushover Analysis can also be defined as the static procedure which is a kind of Nonlinear procedure.

By this technique the structural deformations are noted of the structure that needed to be analyzed by the engineers. By the help of pushover analysis structure are capable of redesigning themselves during earthquake as in some case some components of the

structure fails then the important forces are shifted to the other components and in this manner the structure becomes structurally and laterally stable by the lateral forces of the environment throughout its life span as calculated by the engineers.

1.4 There are two types of Pushover Analysis:-

Displacement Coefficient Method of FEMA356 :-In this we push and fix the target displacement is fixed and we check how it behaves to target displacement.

Capacity Spectrum Method (CSM) OF ATC-40 :- In this load is placed and checked at each stage until the performance point condition is reached.

1.5 Hinges

Hinges are a thing from where failure occurs in pushover analysis we have chosen the hinges.In hinges one can expect yielding and cracking to occur and they are at both the ends of beam and column hinge represents how much is displacement for applied force at that point under the seismic load. We are taking 10% from the upward and downward of the column and both the ends of 10% of the beam . In pushover analysis pushover analysis is not taken but we can take specific terms and we are taking the American standard .

1.6 Building Performance level:-

Operational level:- Major cracking will occur in partition walls and ceilings as well as in structural elements .

Immediate occupancy:- It will gain its original strength and stiffness but it does not sustain any drift. Minor cracking in partition walls and structural elements. It is kind of safe if the structure is on IO level.

Life Safety Level:- In this building is safe but not economical repair is possible in life safety level a duct can fail.There is no larger damage is seen in this.
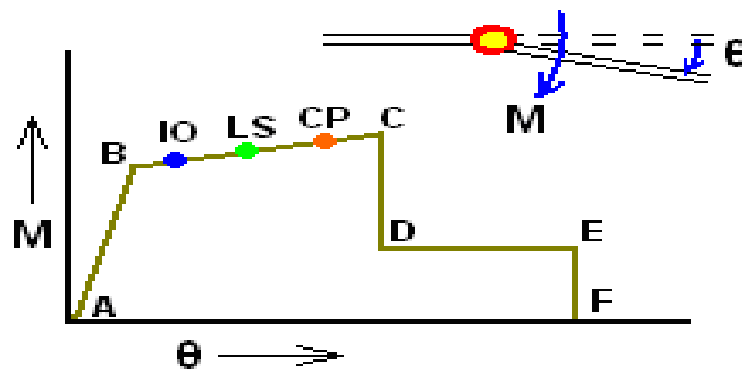
Fig 1.3

Collapse Prevention Level:- In this building remains in collapse level.

1.7 Limitation:

The single degree of freedom idealization

The single degree of freedom idealization means the structure is moving in a single direction which is not possible in real life . In this it assumes structure as a one mass which is fixed from bottom and free from top and it moves in a single degree of freedom which is not possible . In this we are ignoring there are numerous joints with different values of damping.

1.8 Where to use Pushover Analysis

1. When we are making a structure, we forget to add some seismic parameters and anything as related to that or we have not done or structure is deficient so there we can do pushover analysis and can check in structure which hinge fails first.

2.In this let's say we have made building in 1980 and seismic code get revised and in reversing some thing get changed and this we can do retrofitting and where we have to do retrofitting can bt told by the help of pushover analysis

1.9 Steps in Etabs:-

1. First we have to design and analyze any seismic force . Because pushover analysis is for only analysis purpose not for design purpose structure should be designed in any response
   spectrum .and we have to see if all members are passed or not.
2. Then we have to define things and we have to take dead load as nonlinear and we define pushover in X and Y direction.
3. Assign hinges properties in Column, Beam , Wall etc.

4. And we run analysis in Pushover in X and Y direction

5. And check hinges made in each step.

6. Check Shear force diagram & Bending moment diagram.

7. And pushover capacity curve.

1.10 Nonlinear Static Procedure

The ASCE/SEI 41-06 (2007) Nonlinear Static Procedure (NSP) applies a single invariant load pattern to the structure (based on the first mode form), while the desired displacement is estimated using an upgraded version of the displacement coefficient approach (DCM).

A monotonically increasing lateral load pattern (representing inertial forces developed during an earthquake) is applied to an inelastic model directly incorporating the nonlinear load-deformation behaviors of the individual components of the building until a target displacement is achieved at the control node (usually the roof). This target displacement is determined using the expression to indicate the maximum displacement predicted to occur during the design earthquake.

1.11 ETABS

ETABS stands for Extended Three-Dimensional Analysis of Building System. It is a sophisticated and suitable special purpose analysis & design program particularly developed for building systems.

ETABS is the software used for this project and all the work has been done on this.

There are different types of structural analysis procedure and they are

1.) Linear static procedure

2.) Linear dynamic Procedure

3.) Non-Linear static Procedure

4.) Non-Linear Dynamic Procedure

Chapter-2

Literature and Review

2.1Literature and Review

1. **Pushover Analysis of a CTV building by Daigoro Isobe: -**This work belongs to Daigoro Isobe in this project a CTV building was analyzed by the procedure of Pushover Analysis in order to check for the static responses difference the continuously increasing load from all the four directions were applied for example East ,West, South and north facing side was kept untouched by the load to see the effects of the loads on the north facing wall and it was also seen that the strength in all three cases were almost identical , it was also seen that the strength of west section was half of the strength of east section and it was all seen by the help of pushover analysis .

2. **Pushover Analysis by Peng Pan, Masayoshi Nakashima: -** In this Work Pushover analysis was carried out to check for the yield displacement the structure taken for this project was base fixed superstructure , the force pattern which is required in for the pushover to happen was taken in accordance Japanese seismic codes .The main objective of the project was to check for story drift of the building so that the overall damage could be better understood .The building story drift reading were like the building was drifting at angle of 0.005 rad .

3. **Pushover Analysis of fiber reinforced polymer by B. Ghiassi , G.P. Lignola: -** In this project an model for the fiber reinforced polymer structure was made the testing or checking was done with the help of monotonically increasing load on the structure the type of the analysis used in static nonlinear analysis and this the method most commonly used for the purpose of the evaluation of the nonlinear models or the thing that need to be carried out experimentally moreover it was

challenging work as testing the strength of these materials was difficult because of their heterogeneous nature , the work was more focused on how to improve the strength of walls and other members with these materials .

4. **Collapse Analysis by Mohamed A. El-Reedy :-**
The analysis of building was done in checking the collapse of a building by noting down its plasticity and deformations ,deflection , joint failure etc.This is done high riser guard building the data and the tolerance values are taken as usual ones after all that the plasticity was checked of the structure .

5.**Bridge Seismic Retrofit Methods for Seismic Events Mohiuddin Ali Khan:-**
In this the lateral spectral analysis of the structure was done it was done for the bridges of limited ductility capacity .The model for this project was structured on staad pro and was analyzed on two fronts , the comparisons were also made on the density of light weight or high weight concrete since the lateral forces were dependent on concrete.

6. **In-plane behavior of the un strengthened and textile-reinforced mortar-strengthened models: -** This project was about the analysis of subassemblies as the conventional pushover analysis was performed along with mass proportional load pattern.As the results the pushover curve and lateral displacements were shown.

7.**Earthquake Engineering by Robert V. Whitman :-** In this we learnt that the pushover analysis is the procedure which shows how far into inelastic range the structure can go before the verge of collapse or total failure .A model was prepared on computer providing all necessary resistance and after that small shocks of horizontal movement were given to mimic ground movements of earthquake and the deformations were calculated .

8.**The Pushover Analysis by Rahul Leslie:-** The pushover analysis was done on the 10 storey building which was supposed to be the shopping complex the software used for this purpose was SAP 2000 everything including the beams

,columns etc were created using frame elements as this analysis seems complete but there was some limitations like torsional effects for building faced because of the diagonal struts.

2.2 Brief Description of proposed project

Type of the Project	Pushover Analysis of a building
Building type	Residential building
No. of storey	4
Type of slab	1) Two-way slab 2) One way slab
Method of analysis	Non-linear static procedure
Design concept	Fe415
Reinforcement	
Seismic load	calculated as per IS 1893 (part I) 2002 using Seismic coefficient method
Soil type	Soft soil

2.3 METHODOLOGY

1. Firstly we have designed the building through Indian codes.

2. In software we have firstly defined the materials of concrete M30 and rebar HYSD Grade500.

3. And we have defined dimension of beam, column, slab material 4000Psi.

4.And we have defined the load patterns dead load, Live load, Earthquake in X direction and Earthquake in Y direction and lateral load from IS1893 2002.

5.For pushover analysis we have to define mass.WE have to check what is the mass of building.

6. Then we have to take pushover as non linear in PA-X and PA-Y

7. Then we have to take hinges in 10% from bottom of beam and 10% from up amd 10% from both the sides of beam.

8.Then we have to run the analysis .

9.And check bending moment digram and shear force digram.

2.4 Floor Plan of the building
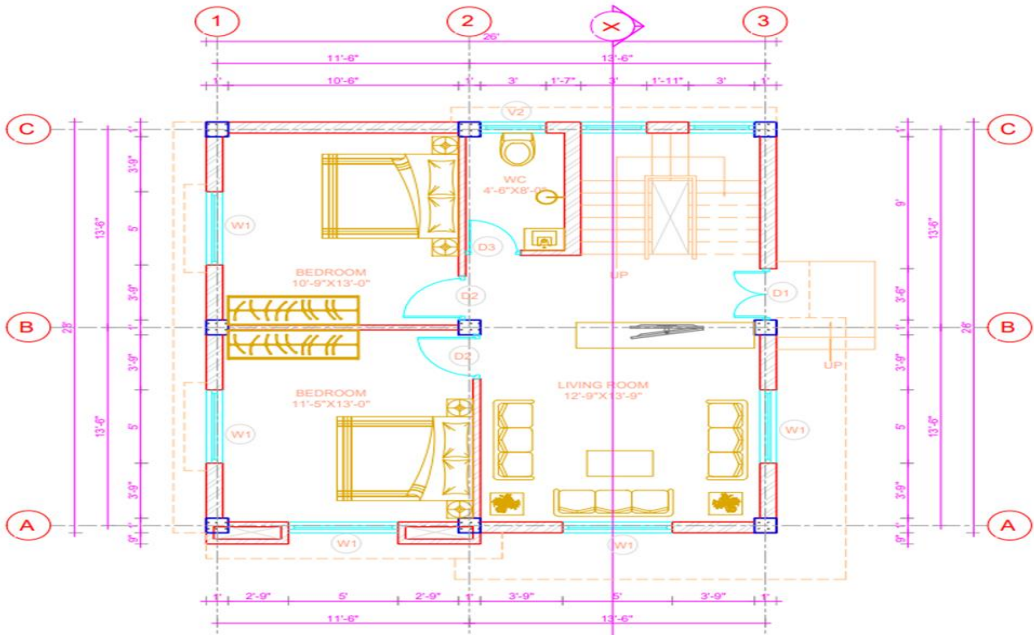
Fig 2.1
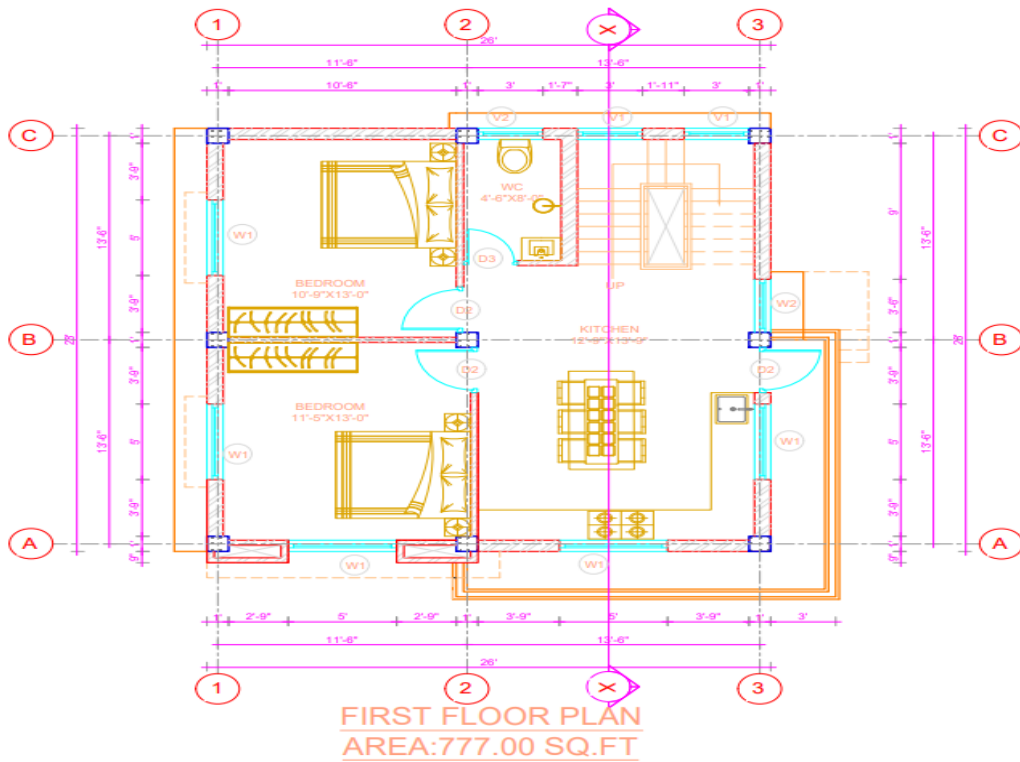
Fig 2.2

2.5 Preliminary Design

Dead load: - Loads are of two types that is dead load and live load and we got the live load alright so we got it load

So, we are going to calculate the dead load of the structure that will be further used for the purpose of the modeling.

columns and you can see that on this: the load comes from half of the slab and half of the slab and the load all comes from half of the slab and half of the slab and same thing goes for other columns as well but if you see in these column of the structure over the model the load comes from half of the slab half of the slab half of the slab and half of this left and there are some columns which bear a load higher than the rest of the columns that column will be known as the critical column.

The spreadsheet shows:

Cell reference box: 6R x 1C, formula bar: =1*I11

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
5		Dead Load Calulation														
6									Area of Slab							
7	Floor finish Load	22.91183							l	18.27	5.568424					
8	partition load	22.91183							b	13.5	4.114599					
9	slab self wt	57.27959														
10	beam self wt	11.39133							Area					26		8.166667
11	column self wt	5.60025							22.91183					7.924413		2.489079
12	wall load	41.211														
15														2.169694		

Fig 2.3

So, the calculated value for the dead load is shown above in the excel sheet of the project.

Live loads: - Live loads are the kind of the loads which are supposed to be mobile and do not constitute the normal and member weight of the structure like the weight of the beams, columns on the other hand live loads are like humans, chairs, tables.

The load intensity that we are using for this project is 2kn/m^2 and according to the clause 3.2.1 it says that for floor supporting structural members the specified reduction should be

used which means that in designing the columns and other structures carrying the slab the reduction factors should be applied as shown in the fig below

weight per metre run of finished partitions, subject to a minimum of 1 kN/m², provided total weight of partition walls per square metre of the wall area does not exceed 1·5 kN/m² and the total weight per metre length is not greater than 4·0 kN.

3.2 Reduction in Imposed Loads on Floors

3.2.1 For Floor Supporting Structural Members — Except as provided for in 3.2.1.1, the following reductions in assumed total imposed loads on floors may be made in designing columns, load bearing walls, piers, their supports and foundations.

Number of Floors (Including the Roof) to be Carried by Member under Consideration	Reduction in Total Distributed Imposed Load on all Floors to be Carried by the Member under Consideration (Percent)
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

The live load calculated of this structure is shown in the excel sheet given below: -

So, the calculated dimensions of the columns used by us in this project is 350*350 mm.

The spreadsheet content:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
13		161.3058												
14														
15														2.169694
16		Live Load Calculation												
17	live load intensity =2 kn/m2													
18														
19	GF	0												
20	FF	41.2413												
21	SF	36.65893												
22	Roof	34.36775												
23														
24														
25	Floor	Dead	Live	Total										
26	GF	161.3058	41.24130129	202.5471										
27	FF	161.3058	36.65893448	197.9648										
28	SF	161.3058	34.36775108	195.6736										
29				596.1855										
30														
31														
32			Factored Load	894.2782			Asc=4%of Ag								
33							Asc=0.04*Ag								
34				1162.562										
35														
36			Ultimate Load	1162562			Ag	52747.8							
37														
38							l=b	300						
39								350						
40														

Fig 2.5

Staircase load: - The calculation of the staircase load is an important part of the preliminary calculations of loads that are later on to be applied on the structure's model. So, the description of the staircase taken for this project is it has total length of 33.08 m and covers the area of 9.47m^2 and has thickness of 0.1m and volume of 0.947 m^3.

The view for the staircase is provided below for the reference purpose: -

Fig 2.6

The calculated loads are as the follows in given excel sheets: -

Fig 2.7

So, the total dead load of the staircase is calculated as the 40.88 kn.

This load will now be used along with other load combinations to provide the software with the real-life scenario so that structural analysis software can use these informative values to analyze the structure.

2.6 Calculation of the wall loads

After the calculation of above loads now it's time for the calculation of the wall load. Wall in simple terms is just the element that ultimately divides the spaces between each other and they are the integral and unalienable part of the building so they need to be in structure and loads need to be calculated as under the dead load category.

They also play the important role in keeping the privacy and safety of the building, they shouldn't be very heavy that they disturb the normal rigidness of the building and they shouldn't be very light either.

The wall load was found to be 10.87 kn and this will be used along the course of the project

2.6 Calculated Lateral Seismic loads

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

Direction and Eccentricity

Direction = X

Eccentricity Ratio = 0% for all diaphragms

Structural Period

Period Calculation Method = Program Calculated

Seismic Zone Factor, Z [IS Table 2]	Z=0.16
Response Reduction Factor, R [IS Table 7]	R=5
Importance Factor, I [IS Table 6]	I=1
Site Type [IS Table 1] = II	

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5] = (Sa/g) = 1.817482

Seismic Coefficient, A_h [IS 6.4.2] = $\square_h = \dfrac{\square\square\frac{\square_\square}{\square}}{2\square}$

Beam: - For beam preliminary design is done according to deflection criteria. According to IS 456: 2000 clause 23.2.1 for continuous beams Span/d min=26× modification factors but we will ignore this value because this is for simply supported section and our case is going to be fixed one. So, we take Span/depth= (13 to 15) and taking value 15.

Base Shear Calculation: - Base Shear Calculation According to IS 1893 (Part I): 2002 Cl. No. 6.4.2 the design horizontal seismic coefficient Ah for a structure shall be determined by the following expression: R g = (Z I S A /a h 2)

Where, Z = Zone factor given by IS 1893 (Part I): 2002 Table 2,

Here for Zone V, Z = 0.36 I = Importance Factor, I = 1.5 for commercial building, R = Response reduction factor given by IS 1893 (Part I): 2002 Table 7, R = 5.0 Sa/g = Average response acceleration coefficient which depends on Fundamental natural period of vibration (Ta). According to IS 1893 (Part I): 2002 Cl. No. 7.4.2 d 0.09h

Ta =0.09h/√d, Calculated Base shear is shown in below table

Direction	Period Used (sec)	W (kn)	Vb (kN)
X	0.748	4682.5503	136.1672

Design of column: - Columns are those elements of the structure that are mostly subjected under axial loads of the structure and their length should be more than the twice of the least length of the dimension in order to increase their strength they are reinforced with steel traversal or longitudinally .T he columns which are reinforced are majorly used to transfer the load to structure with the help of their longitudinal bars present in there so that it can resist the compression or bending and the other traverse steel bars are used resist

bursting of the member . The shape of columns of the structure can vary from square ,
circular, rectangular ,hexagonal to many other. The most important thing is that the
strength is the most important criteria and it depends upon the size of column , materials of
columns , cross-sectional area , length of coloum .The method used for the design of the
members are working state method and limit state design
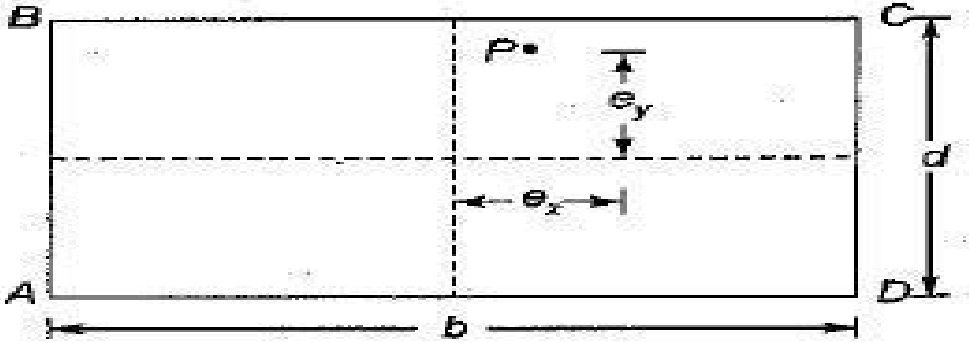
Fig 2.9

2.7 Modeling

Modeling the structure is one the most important parts of the project as this is the stage
after which the structure could really be analyzed by the software. Modeling simply means
creating the virtual structural building without creating the real one on the site after which
we see the modifications needed in the design.

The first steps involve the creation of the nodes and then those nodes will be connected by
the beams which will form the basic unitary structure of the building; the vertical beams
will be considered as the columns.
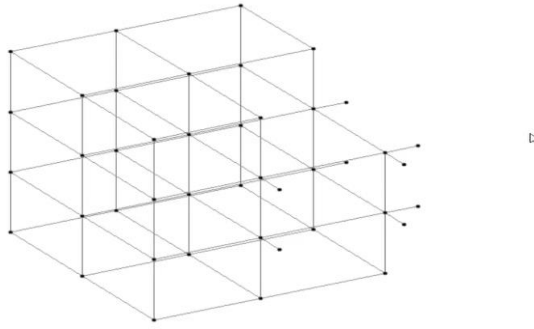
Fig 2.10

This is the unitary perspective view of the building as per the floor plans taken.

2.) The second step is to assign the section properties to the section the section that we have created with the combinations of beams and columns for them in order to behave as the real ones we need to assign some specific dimension height and width.
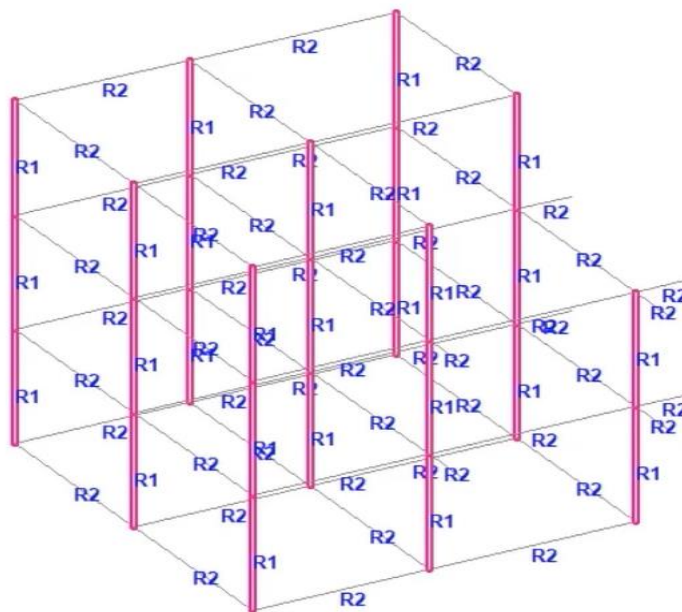
Fig 2.11

In the above figure the vertical sections are being assigned the dimensions and horizontal sections already assigned with section properties and are denoted by R1 and R2.

So now we can basically say that the unitary structure of the building is ready.

1.) The supports that are used in this project are fixed supports and all the columns are connected with fixed supports to restricts their movement in undesired direction throughout the life of the building.

2.) Seismic parameters refer to the estimated value for different seismic conditions and their effect on the building that can be used by the software itself for the purpose of calculations. The zone for this project 4 and the type of the soil taken is medium soil and importance factor taken is 1.0.
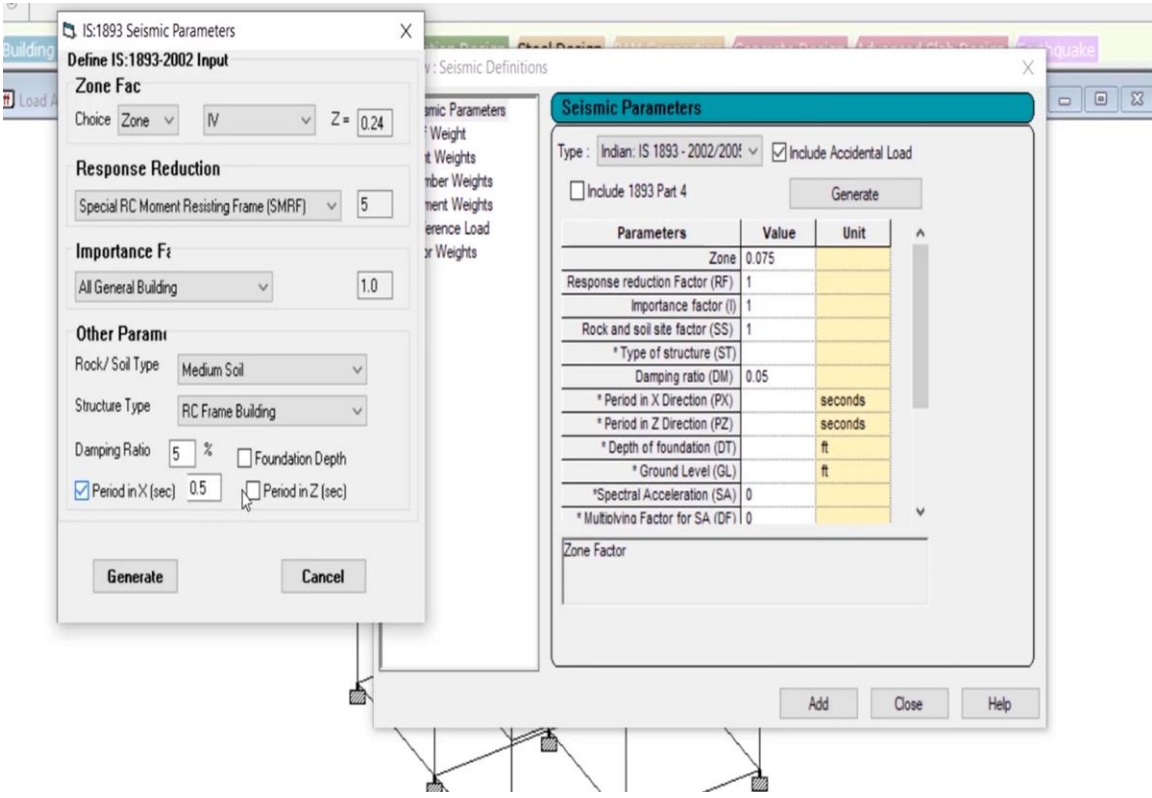
Fig 2.12

3. Next the load case details are defined before they can be used in a structure this is generally categorically differentiating between the different load case as they are consisting of earthquake load, dead load, live load along with some other loads.

4. The next step in modelling the structure is to apply the loads that we have calculated till now as we are going to apply the wall loading in building. After the application of wall load the the view of the building is as follows.
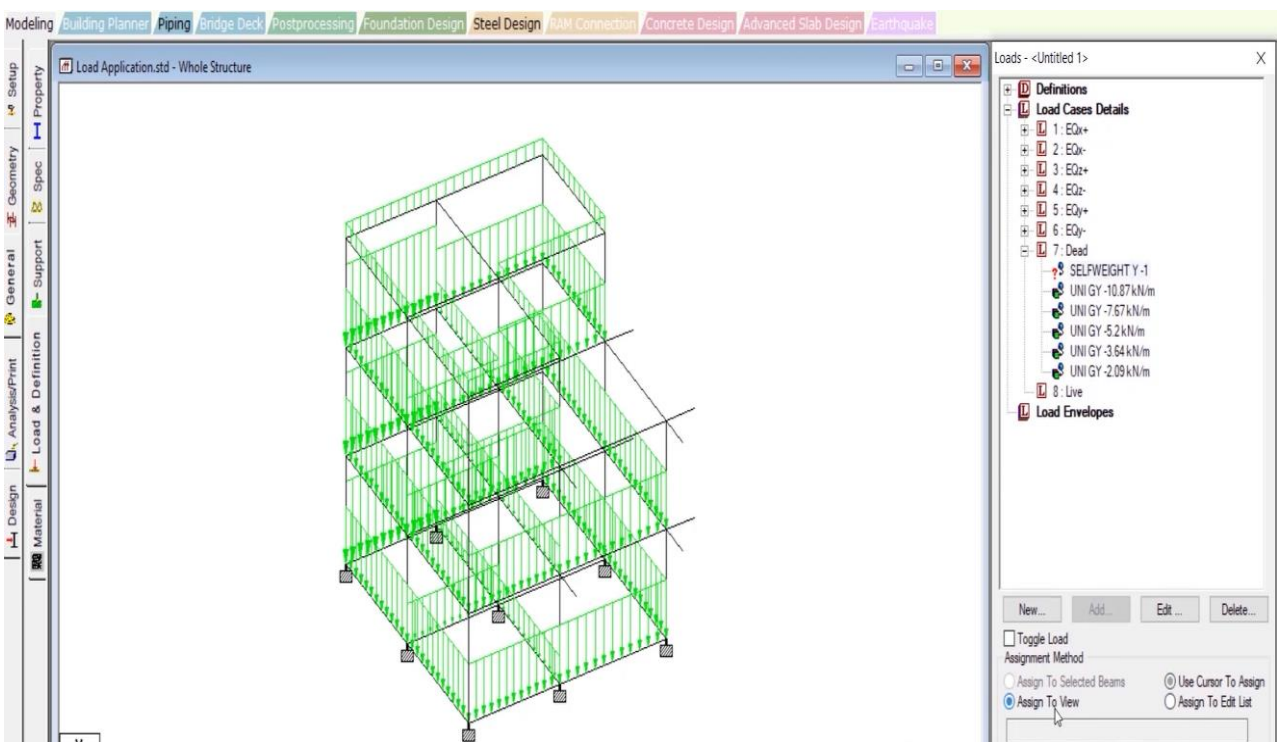
Fig 2.13

The green arrows facing downwards represents the wall load acting downwards.

5.After all these steps now its time for application of self-weight of the slab for example defining the pressure on the structure like for in this case it is 2kn/m^2, specifying the direction of the loading, signs of the loading (positive or negative) according to the situation. The fig representing the above discussion is as below: -
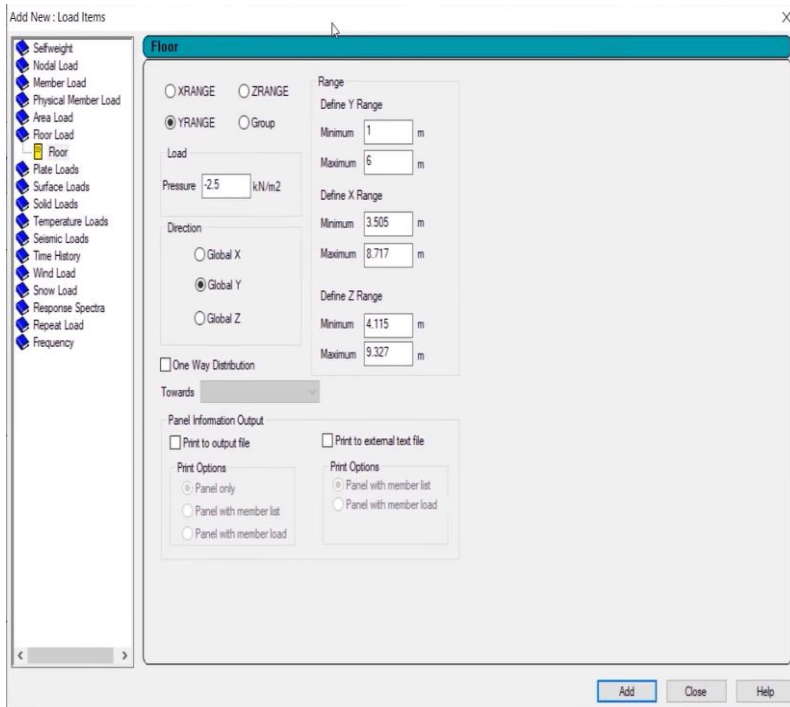
6.Live loading also needs to be added to the building live consist of the load which is not

structural part of the building and also not stationary. They are accessed from the tab shown in fig and the second shows the view after the application of loading.
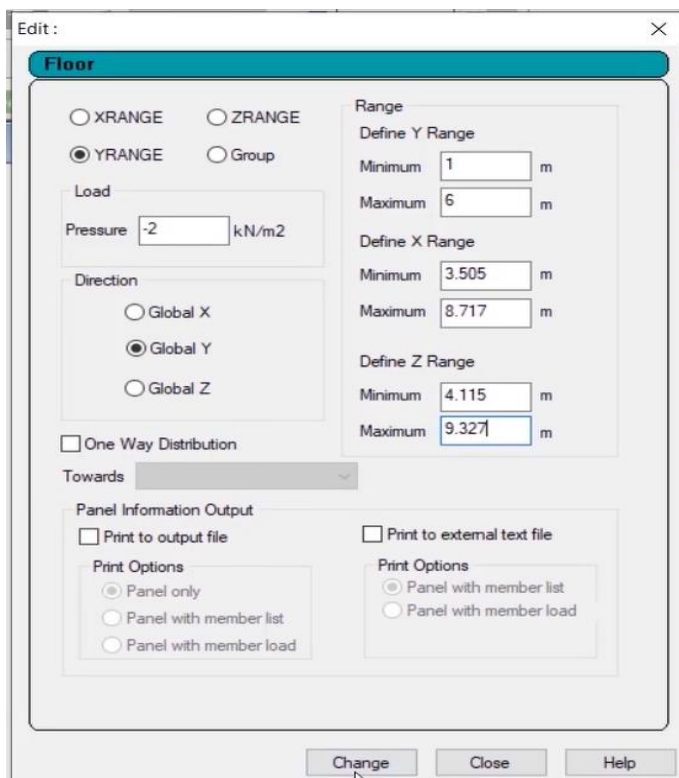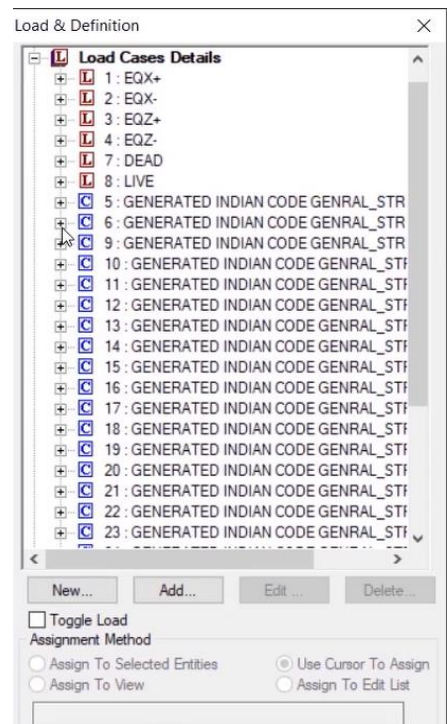
fig 2.14   fig 2.15
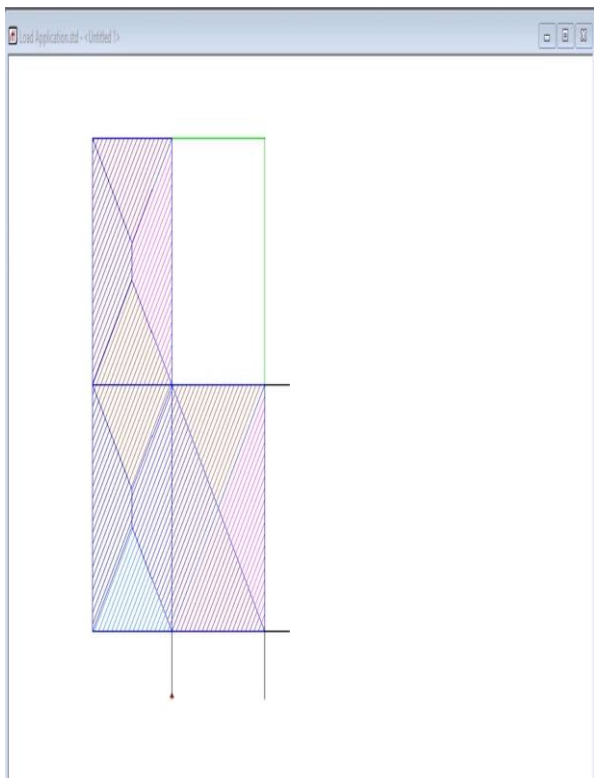
Fig 2.16
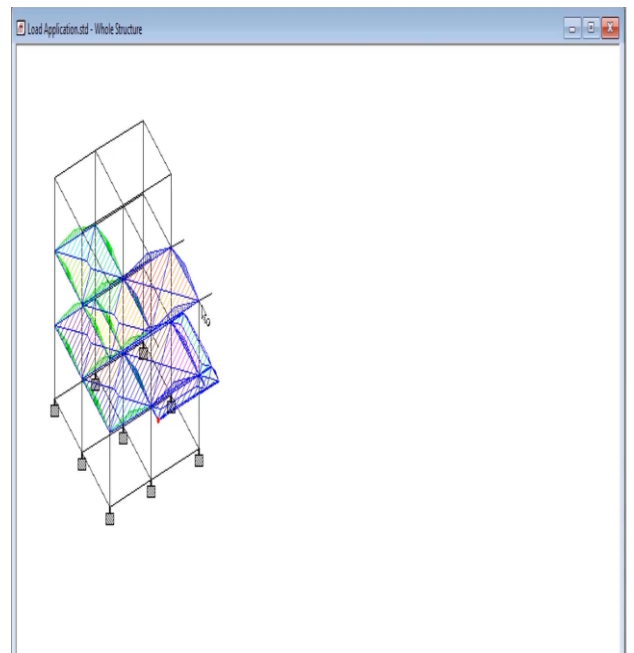
Fig 2.17

WE have assigned dead load to the structure now this is the time to assign live load load the total intensity of the live load was 2.30 kn/m and after doing the necessary calculations we applied the live loading as shown below: -
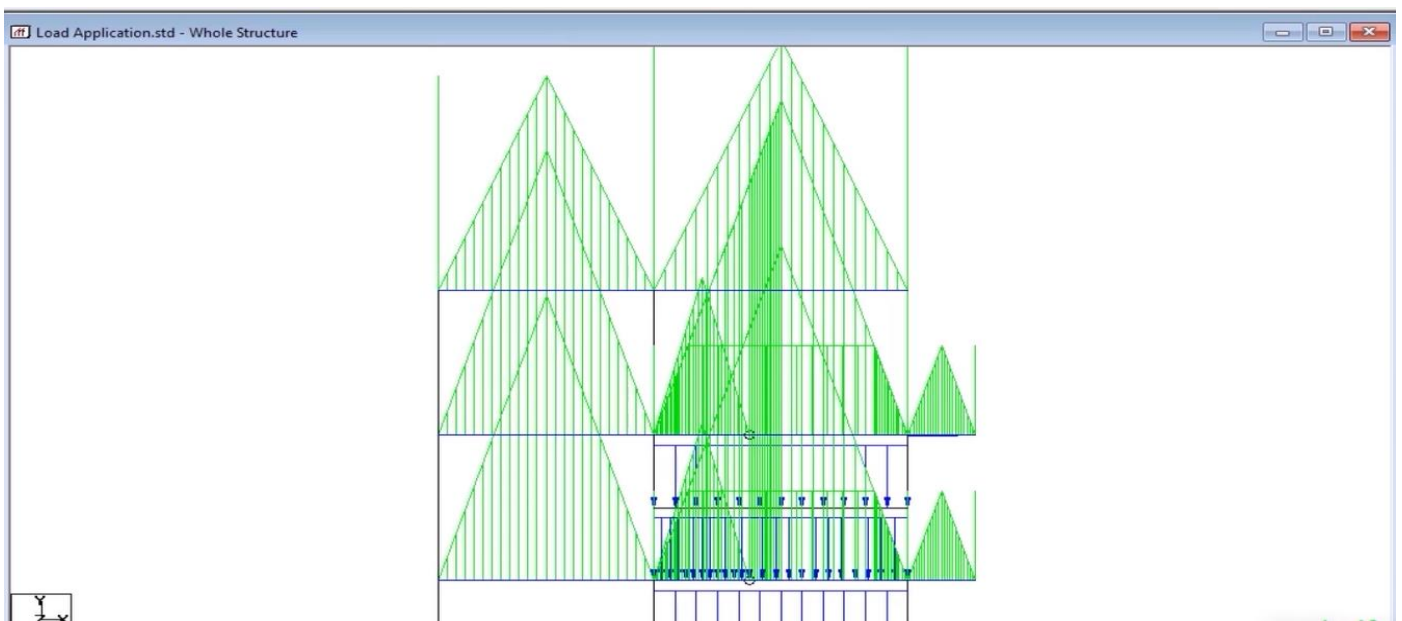
Fig 2.18

The various load combinations has been added in accordance with the nationality and Indian standard codes as they set the boundary for safety criteria of the structure.

Now we have given all the parameters for design and now we need to tell the software to consider them as beam and column as it only considers them as the members so we going to give design commands and then go to the design beam and column tab, then we just need to select the selected beams and assign them with results.
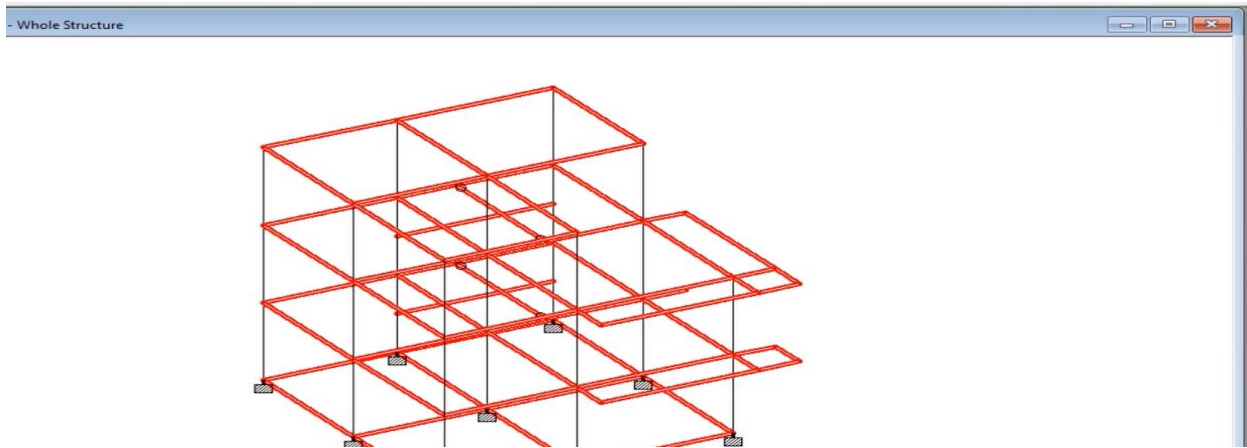
Fig 2.19

If we look at the design results for some specific positions it can be assessed in the tab for example in the fig below it has shown the shear bending at specific point and displacement at specific point .
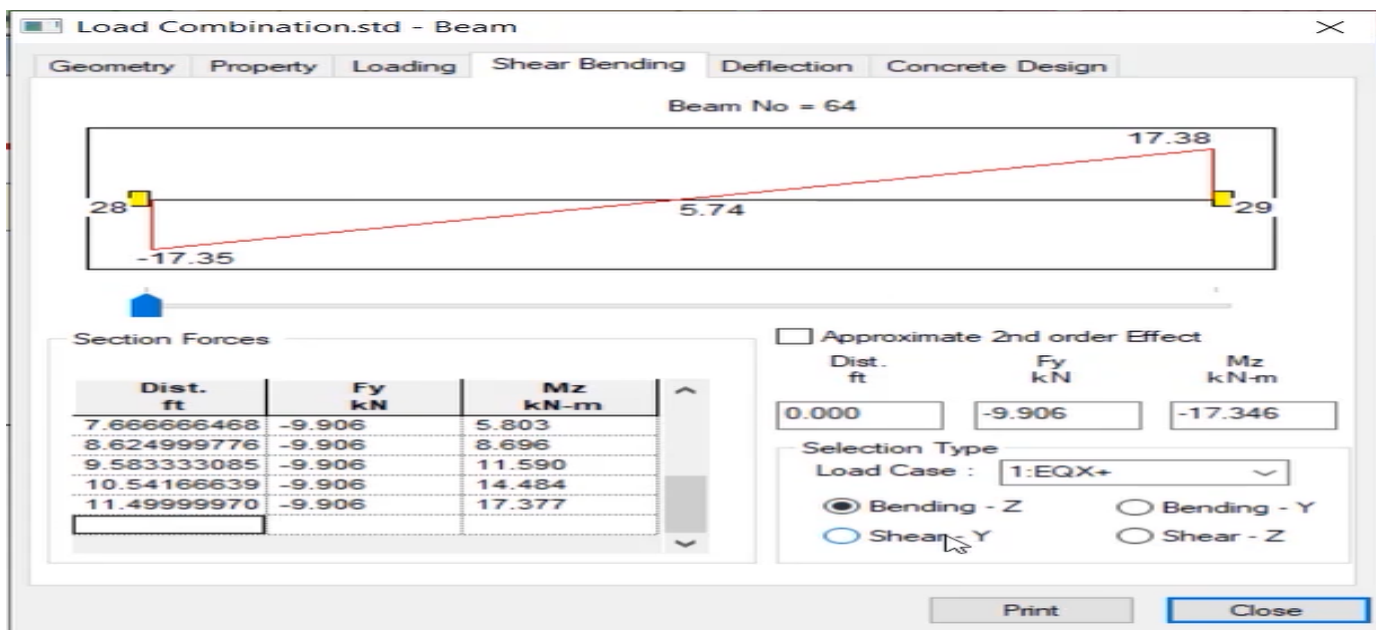
Fig 2.20

The above fig shows the reinforcement in the structure at some specific point.

Lateral Load

As the Pushover Analysis is simply pushing the building laterally with a gradual amount of force so the report generated by our structure can be seen in the figure below.

Fig 2.22

Chapter 3
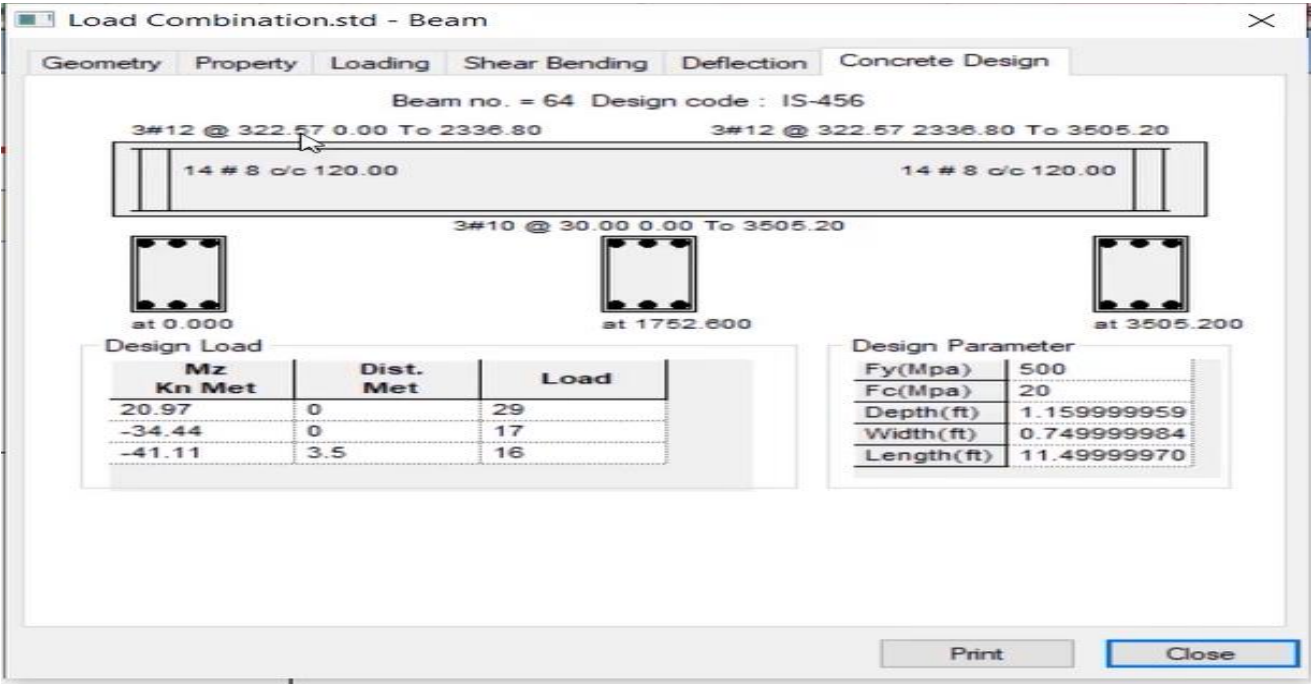
Results

The Bending Moment Diagram of the building is shown in fig 3 below: -

3.1Bending moment diagram of building:- The bending moment diagram of the building is show in fig below these are the results that we have got after doing the analysis of the building
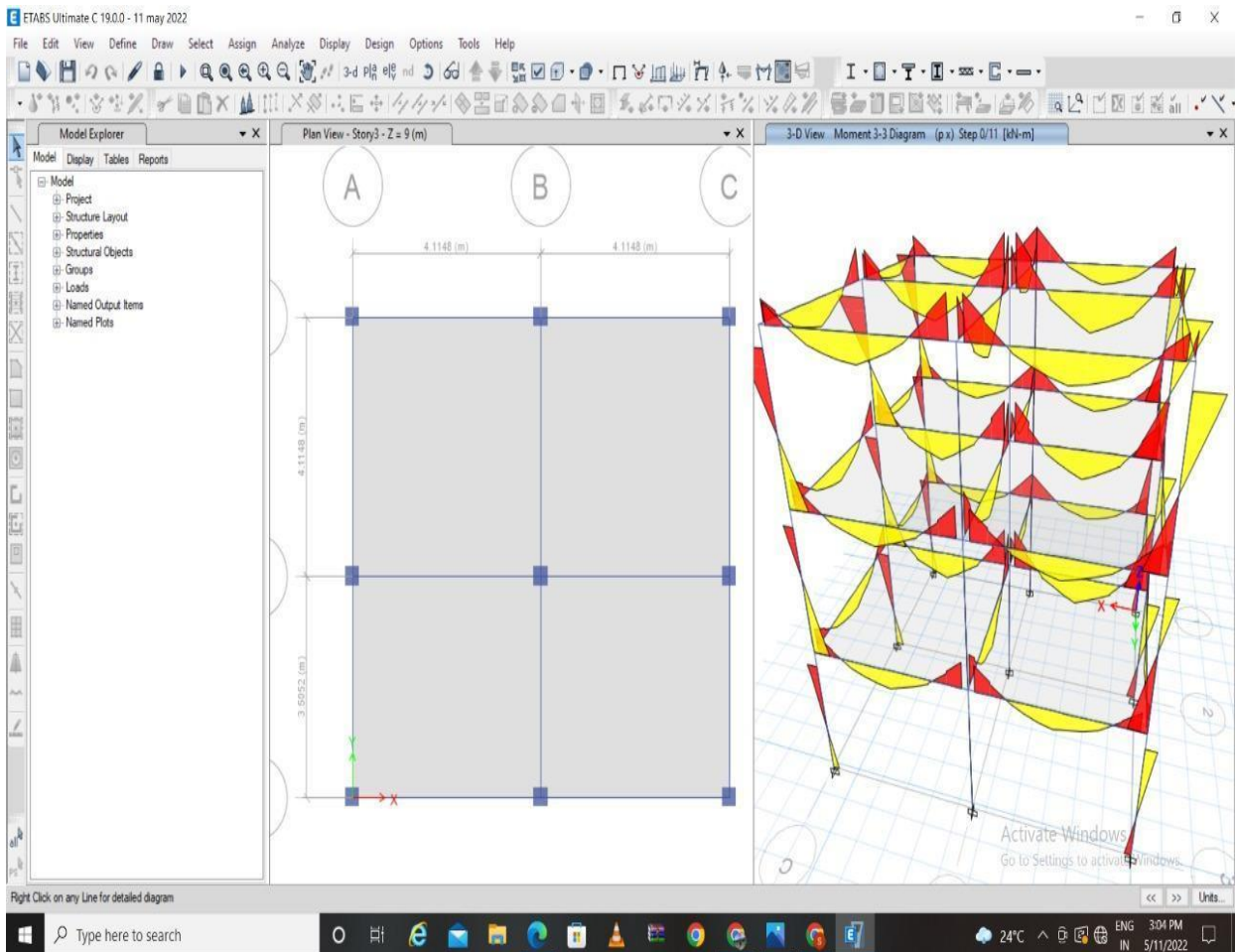
Fig 3.1

3.2 Story Drifts data is shown in below table: -

Story	Output Case	Case Type	Step Type	Direction	Max Drift mm	Avg Drift mm	Ratio
Story4	~StaticResponse Spectrum	LinStatic		X	1.002	1.002	1
Story4	~StaticResponse Spectrum	LinStatic		Y	1.002	1.002	1
Story3	~StaticResponse Spectrum	LinStatic		X	1.71	1.71	1
Story3	~StaticResponse Spectrum	LinStatic		Y	1.71	1.71	1
Story2	~StaticResponse Spectrum	LinStatic		X	2.163	2.162	1
Story2	~StaticResponse Spectrum	LinStatic		Y	2.163	2.162	1
Story1	~StaticResponse Spectrum	LinStatic		X	1.691	1.69	1.001
Story1	~StaticResponse Spectrum	LinStatic		Y	1.691	1.69	1.001

Fig 3.2
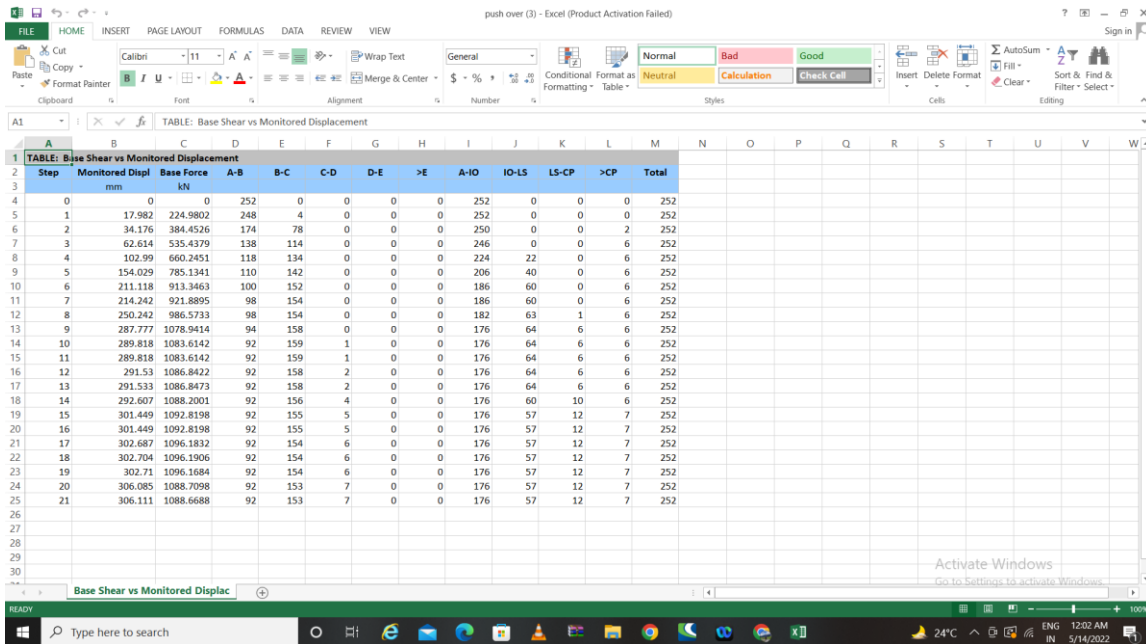
Fig 3.3

3.3 Shear force diagram

38
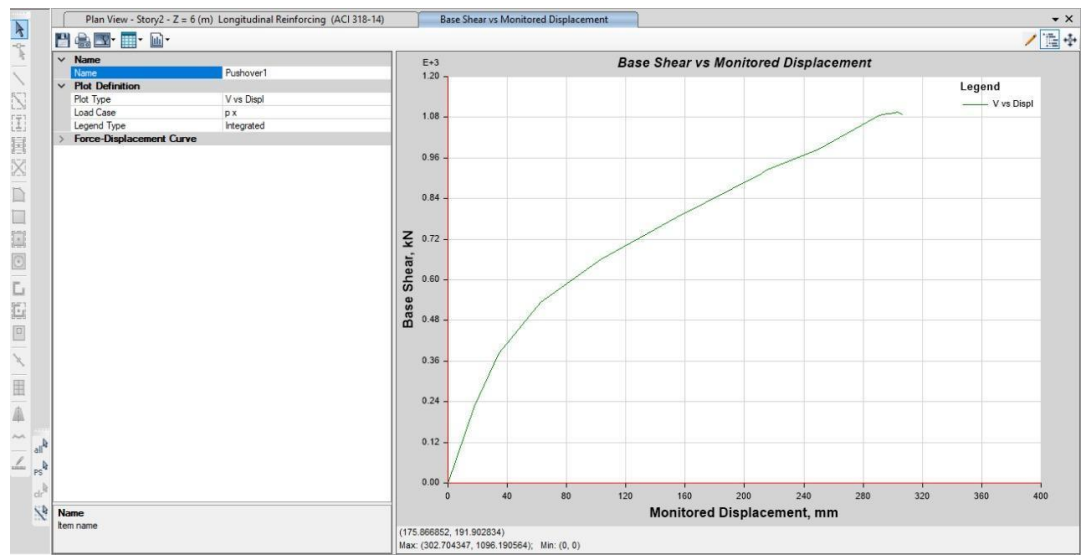
Fig 3.4

3.4 The hinge response of the building is shown in fig 5 below: -
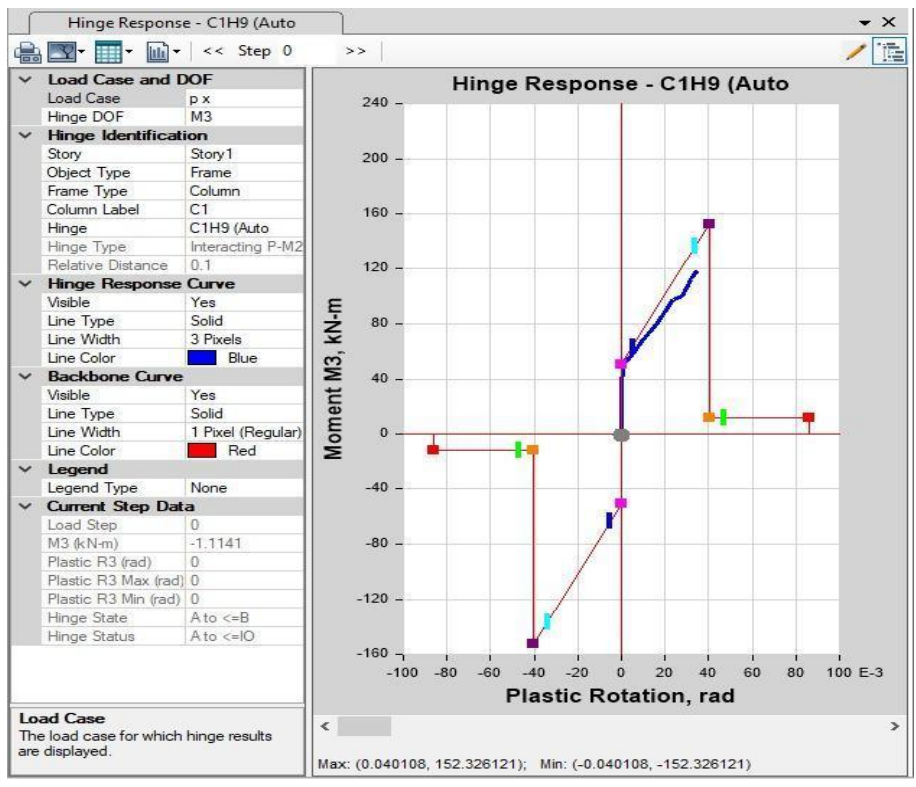
Fig 3.5

3.5 FEMA440 graph is shown in fig below: -
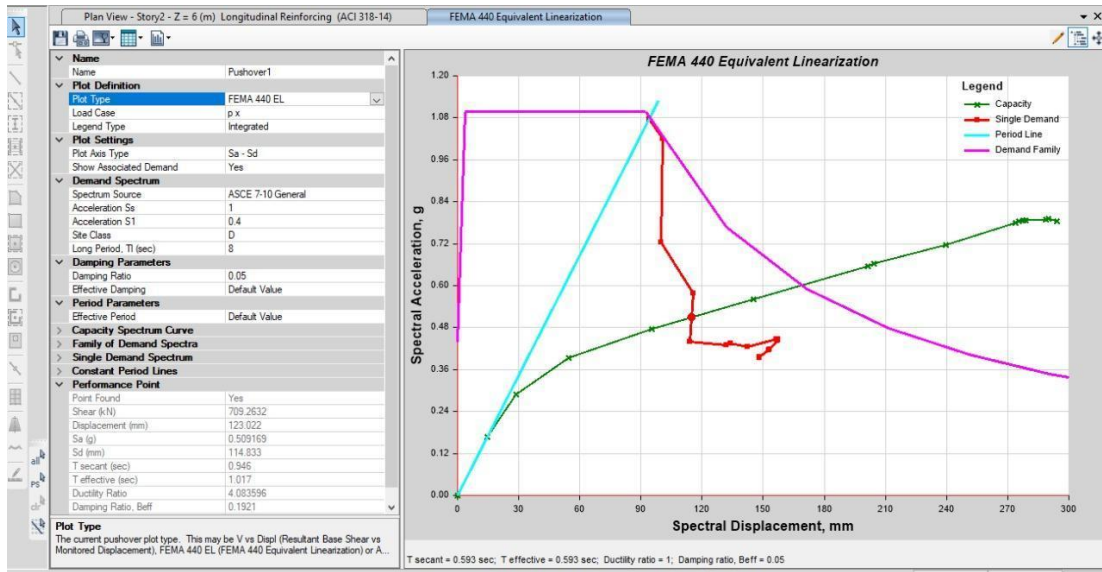
Fig 3.6

3.6 Hinges showing in picture :-
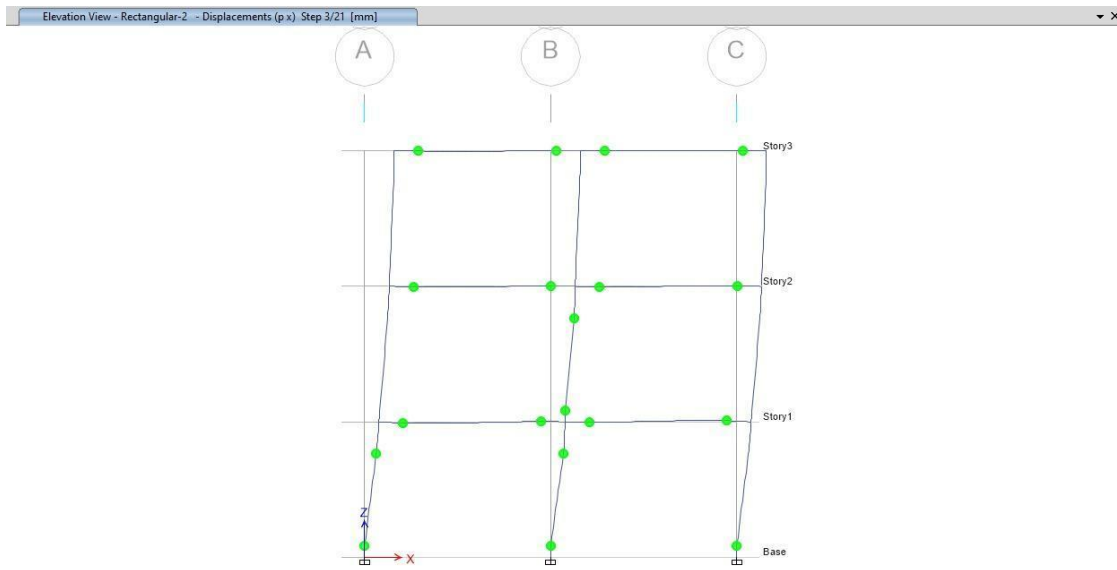
Fig 3.7

Green Hinges showing in building after pushing the building which means which means there is no major damage when hinges become red which means we have to work on that point. Pushover is a very useful analysis it helps in retrofitting of building and we can also check from that which joint of building is weak.

3.7 Earthquake Torsion in X direction:-
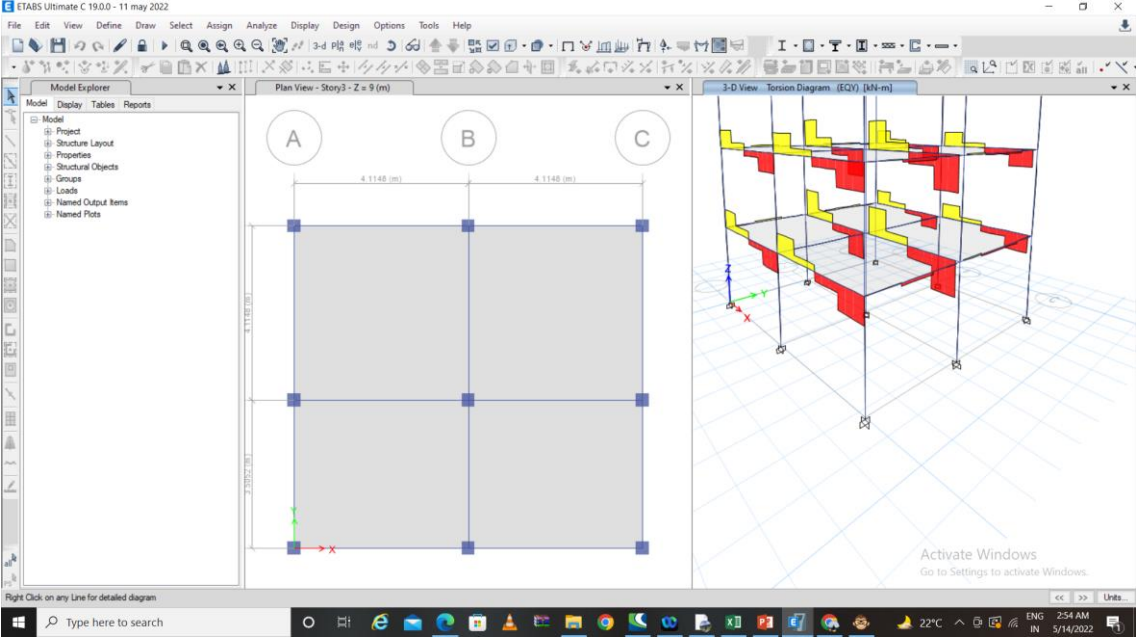
Fig 3.8

3.8Earthquake Torsion in Y Direction:-
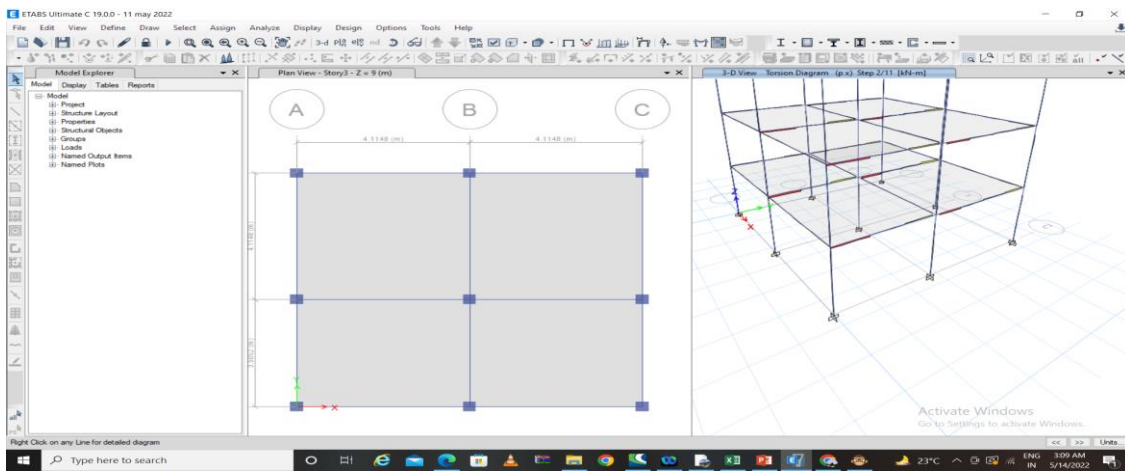
Fig 3.9

3.9 Axial Force in Y Direction :-
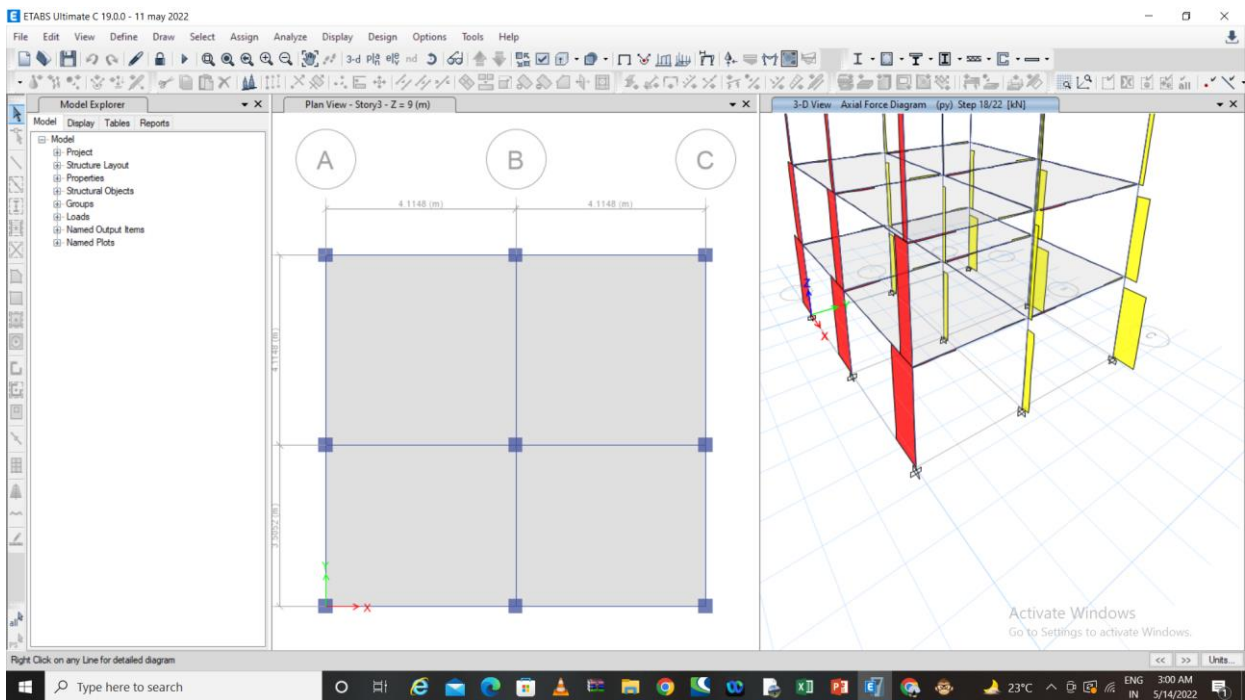
Fig 3.11

Axial Force in X Direction :-
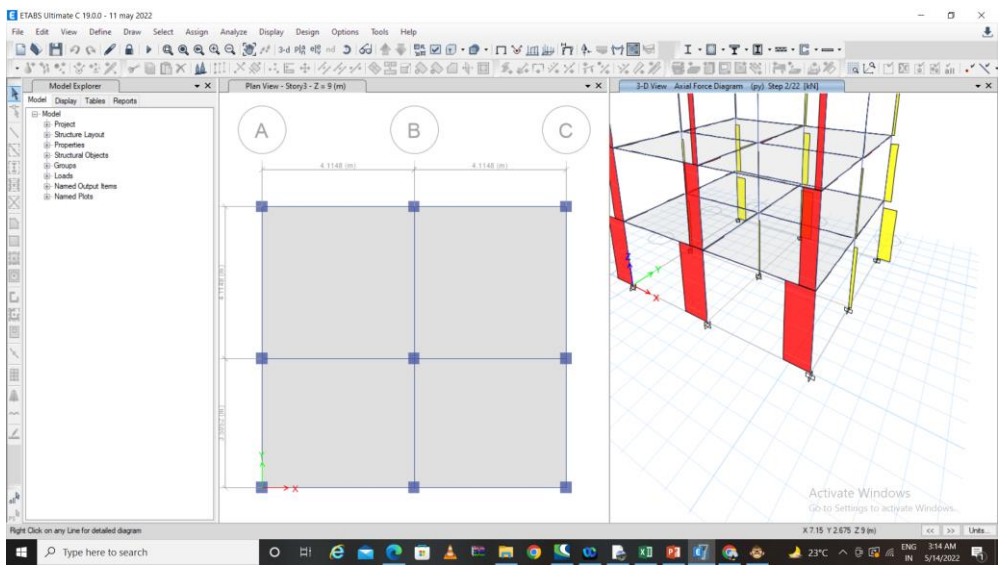
Fig 3.12

3.9 Shear force digram Pushover in Y Direction:-
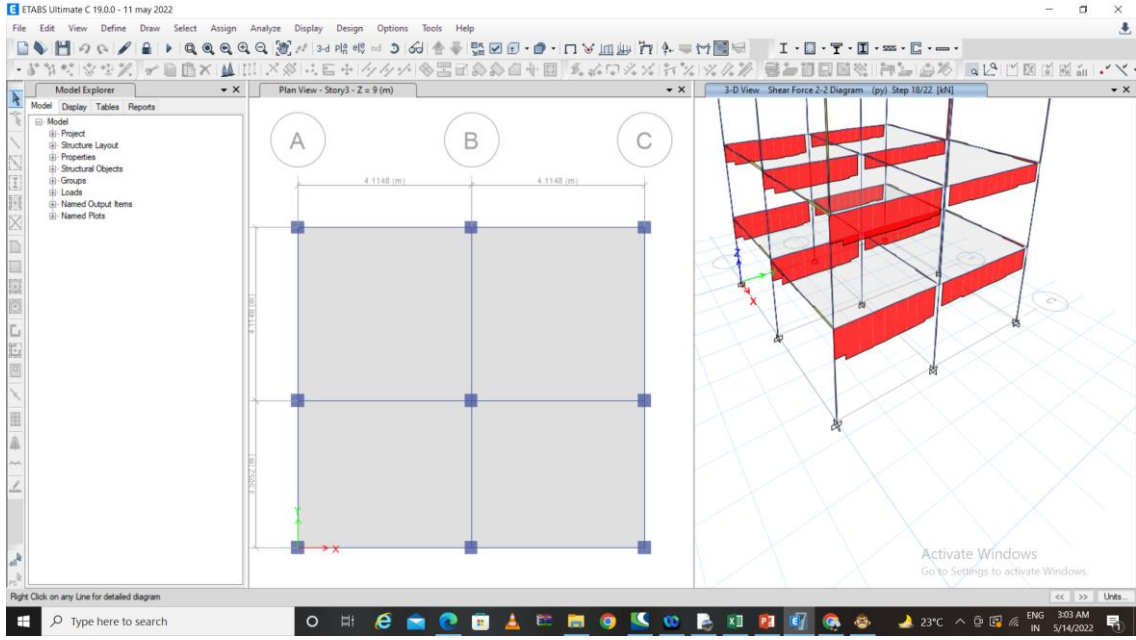
Fig 3 .13
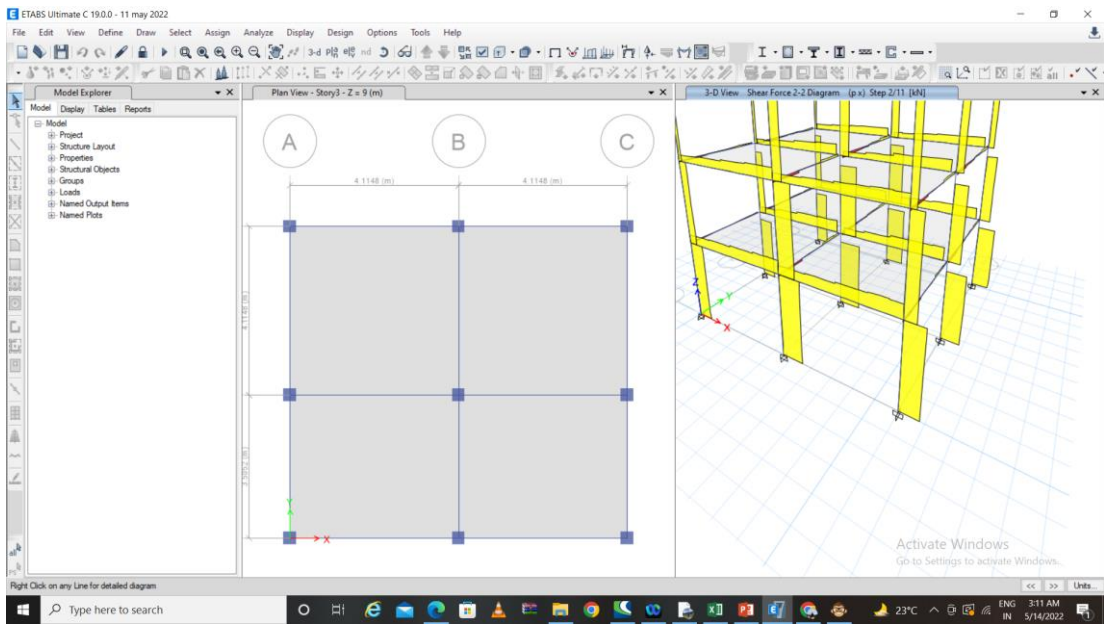
3.10 Shear force digram Pushover in X Direction:-

Fig 3.14

Story data

Tower	Name	Height m	Master Story	Similar To	Splice Story	Color
T1	Story3	3	No	None	No	Cyan
T1	Story2	3	No	None	No	Magenta
T1	Story1	3	No	None	No	Gray8Dark

Grid data

Tower	Name	Type	Ux m	Uy m	Rz deg	Story Range	Bubble Size mm	Color
T1	G1	Cartesian	0	0	0	Default	1250	Gray6
T1	Rectangular	Cartesian	0	0	0	Default	1250	Gray6

Name	Grid Line Type	ID	Ordinatem	Bubble Location	Visible
Rectangular	X (Cartesian)	A	0	End	Yes
Rectangular	X (Cartesian)	B	4.1148	End	Yes
Rectangular	X (Cartesian)	C	8.2296	End	Yes
Rectangular	Y (Cartesian)	1	0	Start	Yes
Rectangular	Y (Cartesian)	2	3.5052	Start	Yes

Rectangular	Y (Cartesian)	3	7.62	Start	Yes

Point Coordinates

Label	Is Auto Point	X m	Y m	DZBelowm
1	No	0	7.62	0
2	No	4.1148	7.62	0
3	No	8.2296	7.62	0
4	No	8.2296	3.5052	0
5	No	4.1148	3.5052	0
6	No	0	3.5052	0
7	No	4.1148	0.0052	0
8	No	8.2296	0.0052	0

9	No	0	0.0052	0
10	No	0	0	0
11	No	4.1148	0	0
12	No	8.2296	0	0
13	Yes	4.1145	3.6433	0
14	Yes	4.1146	3.655	0
15	Yes	4.1146	3.655	0
16	Yes	4.1148	3.7101	0

Line Connectivity

Column Bays :-

Label	PointBayI	PointBayJ	IEndStory
C1	1	1	Below
C2	2	2	Below
C3	3	3	Below
C4	4	4	Below
C5	5	5	Below

C6	6	6	Below
C7	7	7	Below
C8	8	8	Below
C9	9	9	Below

Beam Bays :-

Label	PointBayI	PointBayJ
B1	10	11
B2	11	12
B3	5	4
B4	6	5
B5	6	1
B6	5	2
B7	1	2

B8	2	3	
B9	4	3	
B10	12	4	
B11	11	5	
B12	10	6	

Area Connectivity

Label	NumPoints	PointNumber	PointBay
F1	4	1	6
F1		2	5
F1		3	2
F1		4	1
F2	4	1	10

F2		2	11
F2		3	5
F2		4	6
F3	4	1	5
F3		2	4
F3		3	3
F3		4	2
F4	4	1	11
F4		2	12
F4		3	4
F4		4	5

Properties :-

Materials

Material	Type	SymType	Grade	Color	Notes
3000Psi	Concrete	Isotropic	f'c 3000 psi	Yellow	

4000Psi	Concrete	Isotropic	f'c 4000 psi	Gray8Dark
A416Gr270	Tendon	Uniaxial	Grade 270	Red
A615Gr60	Rebar	Uniaxial	Grade 60	Green
A992Fy50	Steel	Isotropic	Grade 50	Magenta
Rebar grade 60	Rebar	Uniaxial	Grade 60	Blue

Reinforcement Sizes

Name	Diameter	Area
	mm	cm2
6	6	0.3
8	8	0.5
10	10	0.8

12	12	1.1
14	14	1.5
16	16	2
18	18	2.5
20	20	3.1
22	22	3.8
25	25	4.9
26	26	5.3
28	28	6.2
32	32	8
36	36	10.2
40	40	12.6
50	50	19.6

IS1893 2002 Auto Seismic Load Calculation

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

Direction and Eccentricity

Direction = X

Eccentricity Ratio = 0% for all diaphragms

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2]

Response Reduction Factor, R [IS Table 7]

Importance Factor, I [IS Table 6]

Site Type [IS Table 1] = II

Seismic Response

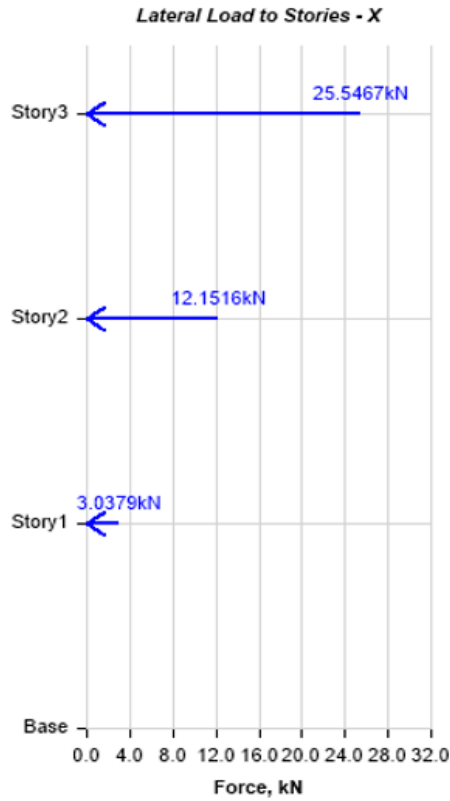Spectral Acceleration Coefficient, S_a/g [IS 6.4.5]

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]

Calculated Base Shear

Direction	Period Used (sec)	W (kN)	V_b (kN)

X	0.706	1321.3013	40.7362

Applied Story Forces

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story3	9	25.5467	0
Story2	6	12.1516	0
Story1	3	3.0379	0
Base	0	0	0

Fig 3.14

IS1893 2002 Auto Seismic Load Calculation

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

Direction and Eccentricity

Direction = Y

Eccentricity Ratio = 0% for all diaphragms

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2]

Response Reduction Factor, R [IS Table 7]

Importance Factor, I [IS Table 6]

Site Type [IS Table 1] = II

Seismic Response

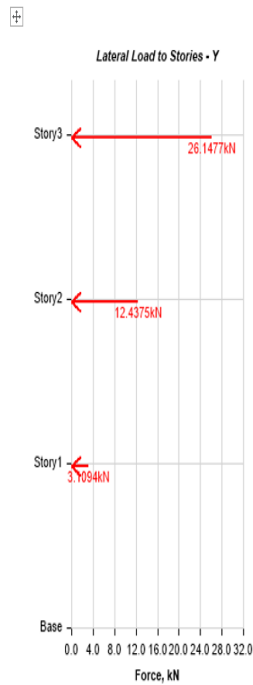Spectral Acceleration Coefficient, S_a /g [IS 6.4.5]

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2]

Calculated Base Shear

Direction	Period Used (sec)	W (kN)	V_b (kN)
Y	0.69	1321.3013	41.6946

Applied Story Forces

Lateral Load to Stories - Y

Story	Elevation	X-Dir	Y-Dir
	m	kN	kN
Story3	9	0	26.1477
Story2	6	0	12.4375
Story1	3	0	3.1094
Base	0	0	0

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Fig 3.15

Model results

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	0.706	1.417	8.9023	79.2501
Modal	2	0.69	1.45	9.1117	83.023
Modal	3	0.519	1.927	12.106	146.5562
Modal	4	0.212	4.707	29.5751	874.6877
Modal	5	0.209	4.778	30.0191	901.1457
Modal	6	0.161	6.211	39.0233	1522.8152
Modal	7	0.117	8.524	53.5577	2868.427
Modal	8	0.117	8.558	53.7735	2891.5853
Modal	9	0.092	10.885	68.3914	4677.3778
Modal	10	0.006	164.287	1032.2475	1065534.8492

Case	Mode	Period					
Modal	11	0.006	164.293	1032.2816	1065605.3714		
Modal	12	0.006	164.464	1033.3605	1067833.9247		

Case	Mode	Period sec	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumR
Modal	1	0.706	0.846	0	0	0.846	0	0	0	0.1915	0.0003	0
Modal	2	0.69	0	0.8491	0	0.846	0.8491	0	0.1885	0	0	0.188
Modal	3	0.519	0.0003	0	0	0.8463	0.8491	0	0	0.0001	0.8543	0.188
Modal	4	0.212	0.1197	0	0	0.966	0.8491	0	0	0.7083	4.698E-05	0.188
Modal	5	0.209	0	0.118	0	0.966	0.9671	0	0.7149	0	0	0.9034
Modal	6	0.161	0.0001	0	0	0.9661	0.9671	0	2.28E-06	0.0003	0.1138	0.9034
Modal	7	0.117	0.0339	0	0	1	0.9671	0	0	0.0997	1.777E-05	0.9034
Modal	8	0.117	0	0.0329	0	1	1	0	0.0966	0	0	1

Modal	9	0.092	2.517E-05	0	0	1	1	0	0	0.0001	0.0315	1
Modal	10	0.006	0	0	0	1	1	0	0	0	0	1
Modal	11	0.006	0	0	0	1	1	0	0	0	0	1
Modal	12	0.006	0	0	0	1	1	0	0	0	0	1

Modal Load Participation Ratios

Case	ItemType	Item	Static %	Dynamic %
Modal	Acceleration	UX	100	100
Modal	Acceleration	UY	100	100
Modal	Acceleration	UZ	0	0

Case	Mode	Period sec	UX	UY	UZ	RZ	UX*	UY*	UZ*	RZ*
Modal	1	0.706	1	0	0	0	1	0	0	0
Modal	2	0.69	0	1	0	0	0	1	0	0
Modal	3	0.519	0	0	0	1	0	0	0	1

Modal	4	0.212	1	0	0	0	1	0	0	0
Modal	5	0.209	0	1	0	0	0	1	0	0
Modal	6	0.161	0	0	0	1	0	0	0	1
Modal	7	0.117	0.999	0	0	0.001	0.999	0	0	0.001
Modal	8	0.117	0	1	0	0	0	1	0	0
Modal	9	0.092	0.001	0	0	0.999	0.001	0	0	0.999
Modal	10	0.006	0	0	0	1	0.451	0	0	0.549
Modal	11	0.006	0	0	0	1	0.473	0	0	0.527
Modal	12	0.006	0	0	0	1	0.495	0	0	0.505

TABLE: Base Shear vs Monitored Displacement

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total

	mm	kN										
0	0	0	252	0	0	0	0	252	0	0	0	252
1	17.982	224.9802	248	4	0	0	0	252	0	0	0	252
2	34.176	384.4526	174	78	0	0	0	250	0	0	2	252
3	62.614	535.4379	138	114	0	0	0	246	0	0	6	252
4	102.99	660.2451	118	134	0	0	0	224	22	0	6	252
5	154.029	785.1341	110	142	0	0	0	206	40	0	6	252
6	211.118	913.3463	100	152	0	0	0	186	60	0	6	252
7	214.242	921.8895	98	154	0	0	0	186	60	0	6	252
8	250.242	986.5733	98	154	0	0	0	182	63	1	6	252
9	287.777	1078.9414	94	158	0	0	0	176	64	6	6	252
10	289.818	1083.6142	92	159	1	0	0	176	64	6	6	252
11	289.818	1083.6142	92	159	1	0	0	176	64	6	6	252
12	291.53	1086.8422	92	158	2	0	0	176	64	6	6	252
13	291.533	1086.8473	92	158	2	0	0	176	64	6	6	252
14	292.607	1088.2001	92	156	4	0	0	176	60	10	6	252
15	301.449	1092.8198	92	155	5	0	0	176	57	12	7	252
16	301.449	1092.8198	92	155	5	0	0	176	57	12	7	252
17	302.687	1096.1	92	154	6	0	0	176	57	12	7	252

		832										
18	302.704	1096.1906	92	154	6	0	0	176	57	12	7	252
19	302.71	1096.1684	92	154	6	0	0	176	57	12	7	252
20	306.085	1088.7098	92	153	7	0	0	176	57	12	7	252
21	306.111	1088.6688	92	153	7	0	0	176	57	12	7	252

Conclusion

After completing the whole project, we analyzed the structure with different checks like displacements, capacity curve, bending moment diagram and shear force diagram and in pushover analysis simply the building is pushed with lateral force and displacements were recorded and we learned how different lateral forces have effect on building and if building is forced beyond certain limits its sections will be completely deformed and the structure will collapse.

1.) The lateral increasing force was applied on the structure, the force was lowest on the lower storey's and was the highest on top floors so that drift could be recorded and it was seen that the residential building was in the safe limit otherwise in case of failure some modification would be needed and that's the purpose of doing the pushover analysis.

2.) After seeing the displacement, and storey drift of the building in respect to lateral force building the structure was in safe range and could bear the lateral force up to that magnitude in real life scenario.

Future scope

After performing the Pushover Analysis it can be said that it is powerful analyzing method for determine the strength of the structure by mimicking the intensity of lateral loads on the structure and could become the future of strength determination when it's about facing challenge up against the earthquake or wind load or load due some external calamities . So Pushover Analysis was a technique which was worth learning in the realm of the civil engineering and for the purpose of the structural Analysis .

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