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Analytical Investigation of Structural Behaviour of Conventional Slab and Flat Slab in Multi-storeyed RCC Framed Structure

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Abstract: ***Analysis and design of buildings must take earthquakes into account. Analyzing how a structure will react to a given set of loads is called structural analysis. Design is the process of determining the structure's proper parameters. It would take a long time to do structural analysis and design by hand. Any building may be easily analysed and designed with the help of software. The goal of this research and design study is to compare and contrast four common commercial building slab configurations—the conventional slab, the flat slab with drop panels, the grid/waffle slab, and the structure with a load bearing wall. At get to the results, a study was run in STAAD to analyse the impact of varying pressures on two different slab designs. The cutting edge of computer programming. The IS-1893:2002 standard mandates the incorporation of seismic forces. We used IS-456:2000 to determine how wide, tall, and deep to make the beams, columns, and slabs. IS-875:1987 (Parts 1 and 2) specifies the requirements for applying load combinations, dead loads, and imposed loads (Parts 3 and 5). (Part 5). Wind speeds of 55 metres per second and an earthquake zone of 5 will be employed as criteria in the next research. The results of a research comparing the displacements, moments, shear forces, and axial forces in two different slab pattern structures are shown using bar charts. Data is presented in the form of tables and bar charts. In general, the greater the number of stories, the greater the amount of movement between floors. Buildings using grid slabs performed better in the examination of the building's resistance to wind and seismic loads, and they were also shown to be more cost-effective.***
Keywords: We used Staad.Pro for the structural design and analysis of this commercial SLAB.

I. INTRODUCTION

Low-rise, mid-rise, and high-rise housing developments have all evolved in urban areas as a result of the space crunch. Conventional masonry composite (RC) and concrete flat slab (CS) body systems are used for these types of houses. To build a machine, engineers utilise a conventional slab, which is supported by a beam and, in turn, by a column. It's possible to call this the "Beam-Slab Load Transfer" technique, and it's widely used in practise across the globe. "flat slab" describes the alternative body form in which the slab lays flat on top of the column. Being that there may or may not be any beams on this body form, it is also known as a beam without a slab.

When a building serves more than one purpose, it is said to be multifunctional. Multipurpose buildings reflect the present trend toward effective space management. More and more individuals are finding work in the rapidly growing service industry, which is housed in multipurpose buildings. Today's metropolitan areas are distinguished by their very efficient land use. In order to meet the needs of a large number of clients at once, modern structures are becoming bigger and more multipurpose. A multi-storey building is one that rises above ground level more than once. This project involves the use of AutoCAD 2019, STAAD PRO, SketchUp, and manual designing in addition to other software packages for the study and design of a multi-story structure with three basements, five upper floors, and six upper penthouses. For the neighbourhood of Jagathy in Trivandrum, we suggest the following structure. Since here is where a lot of municipal and industrial garbage ends up.

Rapid urbanisation is a global phenomenon at the current time. The need for dwellings rises in step with urbanisation and population growth [1]. Building skyscrapers became a common response. Although increased urbanisation has many advantages, problems may develop when high-rise structures are poorly planned and executed [2]. High-rise structures should undergo seismic and wind load analysis prior to construction [3]. A house is a partition in the landscape [4] because it provides protection from the elements and separates people from one another. Many skyscrapers fall victim to seismic forces. When it comes to designing buildings to withstand earthquakes, the seismic zone is a key factor [5].

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A. Arrangement of the Slabs

The flat slab is made out of R.C.C. concrete and is held up by concrete caps and columns. Since beams are no longer required for support, a flat slab is often called a beam-much less slab. They rely on columns for assistance. Quickly, the loads are moved to the columns.

Different types of concrete Flat Slabs include:

1) A column without a column head and a slab without a drop.
2) Both the dip in the slab and the lack of a column capital in the column design are problematic.
3) Column with column head and drop-free slab.
4) Dropped slab and a column topped with a column head.

The plank looks like the one in the diagram below.

Figure 1: Flat slab

B. Conventional Slab

A typical slab is one that is supported by structural elements like beams and columns. Load is passed to the beams, which in turn carry it to the columns, since the slab is thin and the beam depth is deep. When compared to the flat slab, it requires more formwork.

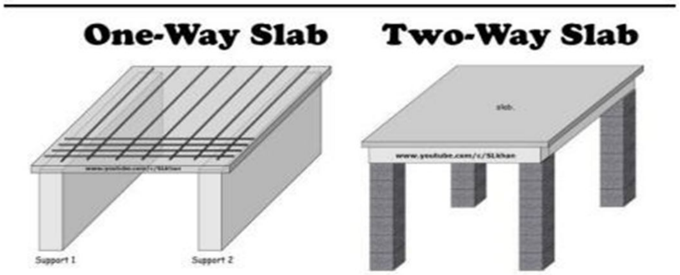

Figure 2: Conventional slabs

C. Waffle Slab

Waffle slabs, also known as grid slabs, are a kind of reinforced concrete roof or floor that have square grids with deep sides. Hotels, shopping centres, and restaurants often employ these slabs to greet guests with a picturesque scene.

The presence of numerous columns is avoided, making it ideal for venues like auditoriums and movie theatres.

Figure 3: Waffle slab

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Referring to the diagram below, the grid slab looks like this:,

Figure 4: Grid slab

II. LITERATURE REVIEW

Planning and Analysis of G+2 Residential Building Using Integrated Green Design Concept was published in 2016 by Prakriti Joshi, Bhawana Rana Manger, Prashika Tamang, Dinesh Nabkoty, Tshering Yangden Lachenpai, CCCT Polytechnic, Sikkim. In this article, we look at how to design a building's framework such that it may be used for its intended purpose for its whole expected lifespan while making little use of finite materials. Overall, the project yields a useful final result for the neighbourhood and the completion of an environmentally sustainable building.

In 2015, a study by Mahmad sabeer, D. Gouse Peera, JNTUA, Anantapura, titled "Comparison of RCC Building design using STAAD and ETABS Software," was released. The primary focus of this work is a comparison of the design outputs from STAAD Pro. and ETABS. The beam design findings led them to the conclusion that ETABS needed less steel surface area overall than STAAD Pro. While the column design results show that both programmes arrive at the same total quantity of steel, the other findings show that the two programmes are otherwise indistinguishable. As a consequence, it would be inappropriate to compare the outcomes of this instance to others.

The 2017 article "A Comparative Study of Structural Analysis and Design utilising STAAD Pro, SAP-2000, and ETABS Software" was written by Balwinder Lallotra and Dhirendra Singhal from the University of Science and Technology in Murthal, Haryana. The focus of this research is a comparison of STAAD Pro., SAP, and ETABS for structural analysis and design. STAAD Pro. clearly combines good provisions from many standards, leading to more precise findings. On the other hand, SAP and ETABS provide greater leeway when it comes to modelling the structures and the design particulars.

The 2017 article "Seismic Analysis & Design of Multi-storey Building Using Etabs" was written by Rinkesh R Bhandarkar, Utsav M Ratanpara, and Mohammed Qureshi from the Faculty of Engineering Technology and Research in Bardoli, Gujarat. Based on their research and design, they have determined that shear structures perform better than frame structures. The frame construction might end up being cheaper than the shear one. Due to its greater rigidity and reduced displacement, the shear structure is well-suited for use in earthquake-prone areas.

A. Durga, Y. Sai Swaroop, CH. Lokesh Nishanth, and Pavan Kumar Jogi, Chaitanya Kumar Jagarapu The main objective of this painting is to analyse and plan a commercial structure with unusual slab configurations. At least fifty percent of the building's gross floor area must be dedicated to business functions for it to be considered a commercial enterprise structure. Through the use of ETABS software, the effects of seismic and wind forces on houses with different slab preparations were evaluated. IS 456-2000 compliant analysis and design have been completed. Combinations of loads are considered in accordance with the IS 875 standard. According to IS 875, we treat live hundreds as if they were thousands.

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Storey displacement is greatest for Conventional slab and smallest for Load bearing wall sort & grows with rise in storey height, as concluded by their research and evaluation work. For all possible configurations of loads, the shear at the base is lowest for a flat slab and highest for a load-bearing wall. Load-bearing wall base shear is 44.5% higher than that of a flat slab base shear. In comparison to the bearing wall, the R.C. conventional slab is 92.6% thicker. The top floor is the fourth in any given building.

Authors: Latha M.S. and Pratibha K The ribs in a grid slab are often separated at the same C language intervals in the perpendicular directions, making the slab seem monolithic.

As a rule, these grid slabs are used in architecture for quite long spans. The gift-giving industry makes use of the rectangular blank sample. A symmetrical and uneven form for the ordinary, a plan abnormal and vertical abnormal shape for the classic slab, and a grid slab are all taken into account in the prevalent view.

They conclude their research and critical thinking by Most common in conventional use is the deflection of a flat, rectangular slab. More so than in normal systems, grid slab deflection is particularly pronounced in abnormal ones. For both regular and irregular forms, the story is displaced more in the grid slab device than in the traditional slab. Story shear is greatest in the traditional slab device and lowest in the grid slab device for both regular and non-standard shapes. In the end, it was determined that grid slab costs more money and is hence more expensive than traditional slab.

P. Manjunath and Yogeendra R. Holebsgilu The buildings are found in sloping floor are very distinct from the ones in undeniable floor, in sloping floor the Buildings are very abnormal and unsymmetrical in horizontal and vertical planes. The homes in sloping floor reasons extra harm all through earthquake, due to the fact in sloping floor the shape is built with distinct column heights. In this look at 3-d analytical version of 10-storied constructing, the plan of every configuration consists of four bays in Y path and 6 bays in X path, that is stored identical for all configurations of constructing frame, the slope selected in among zero to 30 degrees. The constructing is placed on seismic sector V, with distinct soil type; the fashions are analyzed and designed via way of means of ETABS 2015 software.

After their studies and evaluation work, they finish the slope of the bottom increases. It outcomes in lower in seismic weight. Base shear may be very much less in sloping floor as compared to that on degree floor. Storey flow is extra in on the apparent floor as compared to that at the sloping floor that is because of boom in fixity and decreases in variety of stories. Effect of soil is extra essential at the earthquake overall performance of shape. The look at additionally possesses that during static linear technique and reaction spectrum evaluation the overall performance of the constructing on sloping floor has extra threat to earthquake than that of constructing found in undeniable floor.

Sahana T.S., and Navyashree K. Space constraints in urban areas have prompted the development of low-upward push, medium-upward push, and tall dwellings. Homes like that often make use of framed systems. Both vertical and lateral masses are applied to them. More weight is placed on the sides than the top and bottom, since lateral masses from wind and earthquakes are the primary designers' constraints.

Buildings that are only capable of supporting a vertical load will collapse under the weight of lateral loads. Body motion acquired only by the interaction of slabs, beams, and columns is insufficient as a pure inflexible body device. For buildings with a height greater than 15 to 20 (50m to 60m), the body alone is unable to provide the required lateral rigidity.

Having completed the necessary research and assessment, they focus on the second stage, which is the most important of the three to complete.

Soon after the end of the second level. Flat plate construction has much lower base shear than conventional R.C.C construction. The difference between the two is on the order of 8–13%. Earthquake forces are disproportionately significant.

III. METHODOLOGY

The below figure shows the flow of the proposed methodology and figure 6 shows the plan of the building proposed in the the STAD pro.

We Had designed the different slabs for G+6 storey building and the building has the shape of a C and measures 48 metres on a side when seen from the exterior. Its overall dimensions are 40 metres by 48 metres. Each room is comprised of square footage that is 4 metres by 4 metres.

At its widest point, the tunnel spans a distance of eight metres. A empty region of 384 square metres in total will be located in the middle of the structure. In addition to having a front door, this structure has a total gross area of 1440 square metres and is equipped with one.

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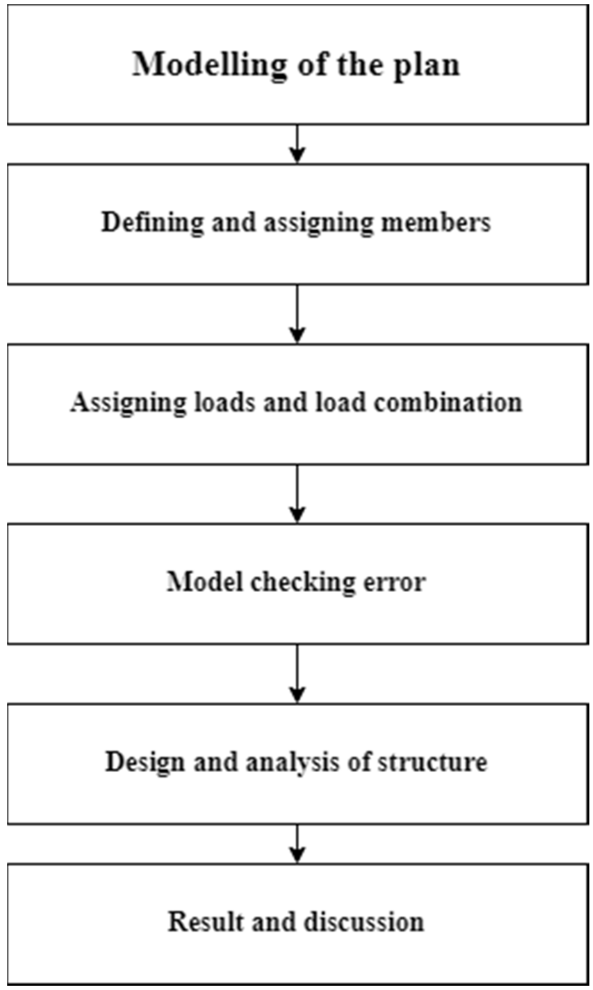

Figure 5: Flow of the proposed model.

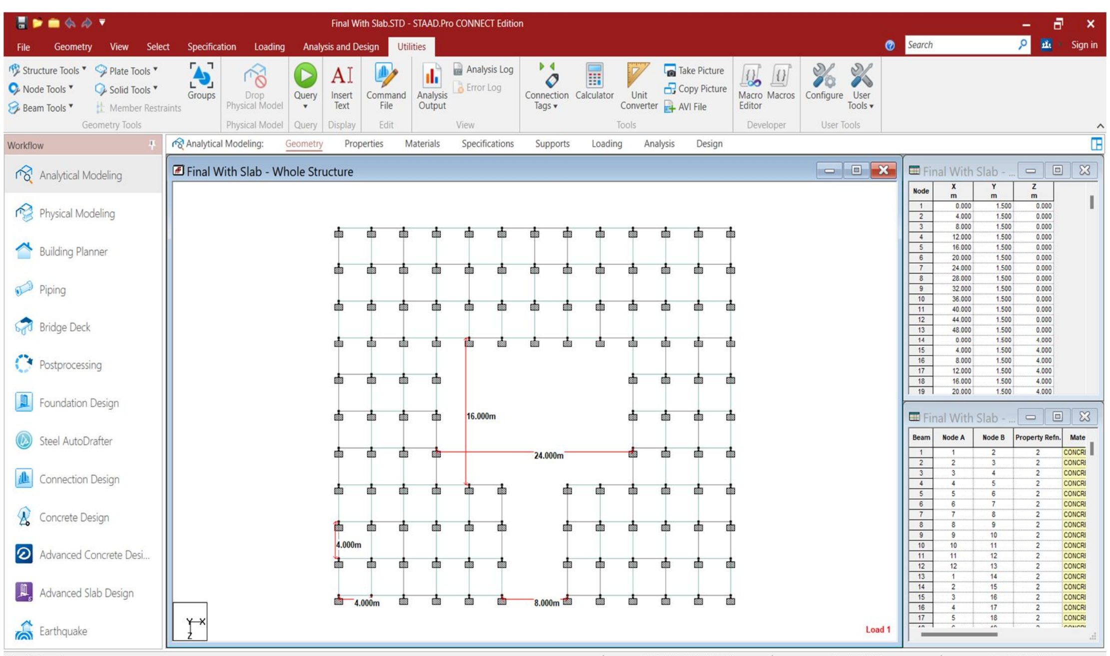

Figure 6: Plan for the building Dimensions of the beams, columns and slabs are provided in the below subsection.

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A. Beam

A beam resists loads perpendicular to its longitudinal axis. Because of the beam's longitudinal axis. Most loads deflect a beam by bending it. Even if the weight doesn't deflect the beam, this is true. The beam's point of support is where reaction forces are generated. When all forces acting on a beam are analysed, its shear and bending moments may be calculated. The beam's forces cause internal stresses, strains, and deflections. Bending and shear forces cause this. Beams can be identified by their length, material, and cross-section. IS-456:2000 is used throughout the calculation to determine beam starting dimensions.

The elevation for the building planned is as shown in the below figure,

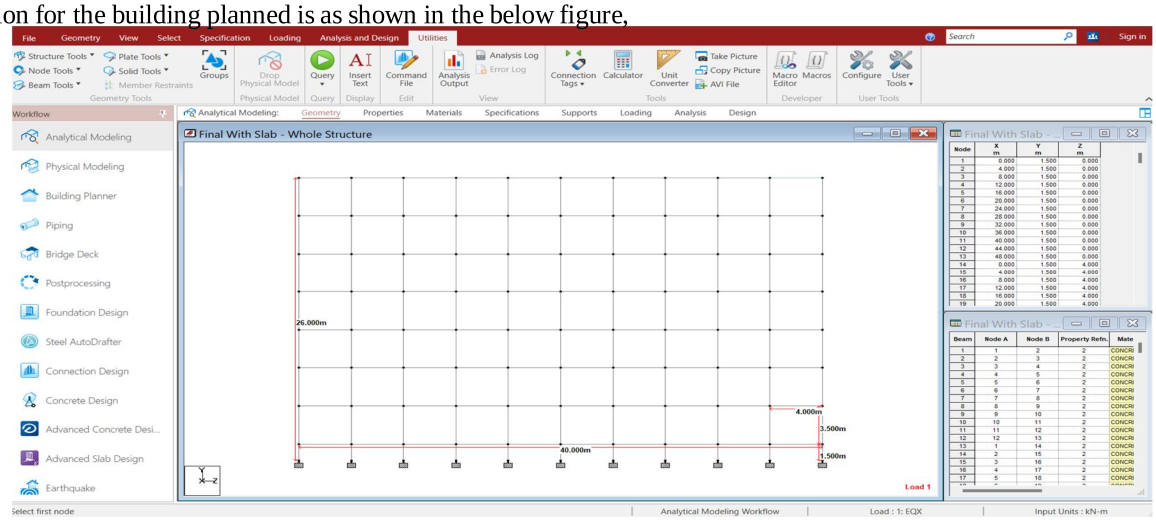

Figure 7: Building elevation

Let L be the beam length; it's 4 metres.

Clause 23.2.1 of IS-456:2000 allows a maximum L/D of 26. That's the limit. L/D ratio must be at least 26. Cost-effective span-to-depth ratios for basic and continuous aided beams are 10 to 16. As per the assumptions L/D is considered as 16 and the D is given by 4/16 hence the value for D is 0.250 m.

As a general rule, the ratio of the overall width to the depth of rectangular beam sections has to fall somewhere in the range of 0.5 to 1. Hence considering b/D = 1 on simplifications the value of b becomes 0.250 meters. From the above calculations it is clear that the width of the beam is 250 mm.

B. Columns

A compressive load on a building column is transmitted by a vertical axial component. In traditional slab construction, columns support the beams; in flat slab construction, columns support the slab. A column transfers slab and beam weight to the foundation. This makes the column self-supporting. When constructing a building, the columns must be robust enough to support the structure's weight for its whole life. If not, the collapse of a single column could be devastating for the entire structure.

In multi-story buildings, a column's side must be at least 400 millimetres wide. The column is 500 mm by 500 mm and 500 mm tall.

C. Slabs

It is a part of the framework that contains surfaces that are parallel to one another or nearly parallel on both the top and bottom of the piece. It may also be said that these surfaces are parallel to one another. As a component of the structure, it is often employed to provide a level, usable surface that can be applied in a broad range of settings. This function may be carried out in a number of different ways. The thickness of the concrete slab is just a few inches at most, which is a rather little amount considering its length. In order to assess whether or not a slab is one-way or two-way, the ratio of the length of the larger span to the length of the shorter span is used. This was accomplished with the help of the STAAD application. Since it is not possible to install the pro slab without first using plates that have the necessary thickness, the pro slab must be applied using these plates.

Conventional slabs

IS-456:2000, item 24.1, specifies two-way reinforcement of mild steel slabs.

Total depth (D) should be less than 40 for a continuous slab. This value is 0.8 for high-strength deformed Fe415 bars. For a continuous slab, the maximum span-to-depth ratio is 32 (0.8x40).
The analysis assumes the slab's length is 4000 mm. L/D = 32, therefore 4000 divided by D = 2.
D is 125mm, hence the maximum slab depth is 125mm.

Flat slabs
Flat slabs have no beams. Since the slab sits directly on the columns, drop panels are required. IS-456:2000 requires flat slabs to be 125mm thick. The slab's thickness is 150 millimetres in this case. Drop panels are also available. IS-456:2000 clause 31.2.2 requires drop panels where needed. A drop is a decrease in panel length of 33.33 percent or more. Outside panel drop heights should be similar to or higher than inside panels.
The drop or column strip on the interior panel must be 1333.33 millimetres wide. Minimum width. The resulting column strip is 1 350 millimetres wide.
1350 divided by 2 equals 675 millimetres for column strip width. Outer panel drop is measured in millimetres. Conventional slab IS-456:2000, item 24.1, specifies two-way reinforcement of mild steel slabs.
Total depth (D) should be less than 40 for a continuous slab. This value is 0.8 for high-strength deformed Fe415 bars. For a continuous slab, the maximum span-to-depth ratio is 32 (0.8x40).
The analysis assumes the slab's length is 4000 mm. L/D = 32, therefore 4000 divided by D = 2.
D is 125mm, hence the maximum slab depth is 125mm.

D. Load withstanding calculation Load bearing capacity of the structure is the essential part while designing the structure of the building.
Dead load
IS-875:1987 specifies how to calculate structural dead loads (Part 1). STAAD. You can utilise the floor thickness or kg/m2 to generate dead loads in Pro. Both are choices. The following calculation shows how the load per metre for a typical slab was calculated by include the weight of the walls and parapet. Next paragraph shows the result.
Multiply the parapet wall's height by its thickness by the brick wall's unit weight. This equals 1.0 times 0.18 times 23.55, or 4.6 kN/m.

With the help of IS-875:1987, we were able to make an educated guess as to the unit weight of the substance (Part 1). To calculate the load bearing capacity of a brick wall, multiply the wall's height by its thickness by the brick's weight.
= 3.5 x 0.18 x 23.55 =14.72 KN/m

Parapet wall's weight is calculated -> 4.6 / 0.18 which gives 25.56 KN/m^2 Load imposed on the wall -> 14.72/0.18 which gives 64 KN/m^2
From the above calculations the load of the floor is considered as 1.0 KN/m^2 Live load calculation
IS-875:1987 (Part 2) recommends 4.5 KN/m2 for the ground level and 1.5 KN/m2 for the terrace. In the previous scenario, the dead and live loads on each level were estimated. This load is spread across the same modules throughout traditional slab and flat slab construction.

Seismic load
The value of the STF is two if the soil is general and if it is the rock soil the value is one and 3 for the sand soil.
The value of the concrete DR will be considered as 0.05. For the employed method to predict the impact of seismic waves the values of Zone V is considered.
By considering the clause of 6.4.2 and by table number 7, the value of the RRF is five. By considering the clause of 6.4.2 and by table number 7, the value of the I is one.
By considering the clause of 6.4.2 and IS 1893, the value of the Zone is 0.36 (Zone V). The load imposed from the wind on the building structure is tabulated and shown below

Table 1: Wind load on building

Height (m)	Terrain and height multiplier (k_2)	1.180 k_2^2	1.270 k_2^2	P_D = Max {1.180k_2^2, 1.270 k_2^2} KN/m^2
10	1	1.18	1.27	1.271
15	1.05	1.30	1.40	1.401
20	1.07	1.35	1.45	1.455
26	1.1	1.42	1.53	1.537

The pressure co-efficient of the walls which has been designed in the STAAD pro is given by the letter F, Cpi and Cpo represents the pressure of the building inside and outside the building and the equation and constant is provided below,

$$F = C_{pe} - C_{pi}$$

Table 2: Pressure of wall co-efficient.

	Windward side	Leeward side	Remaining two sides
C_{pe}	0.7	-0.25	-0.6
C_{pi}	-0.5	-0.5	-0.5
F= C_{pe}-C_{pi}	1.2	0.25	-0.1

Procedure for designing the storey building in STAAD pro is provided below, Step 1: Drafting in software tool
The floow plan which is presented in the above figure is desgined in the software. Step2: Geometry
The structure of the building is as shown in the below figure,

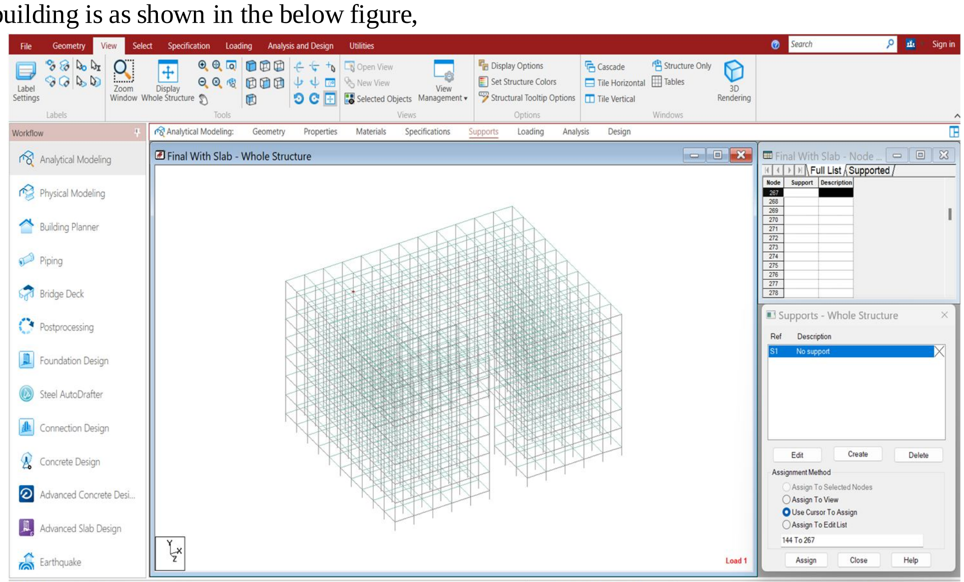

Figure 8: Structure of the building frame.

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The below figure shows the support for the building which has been designed in the software tool.

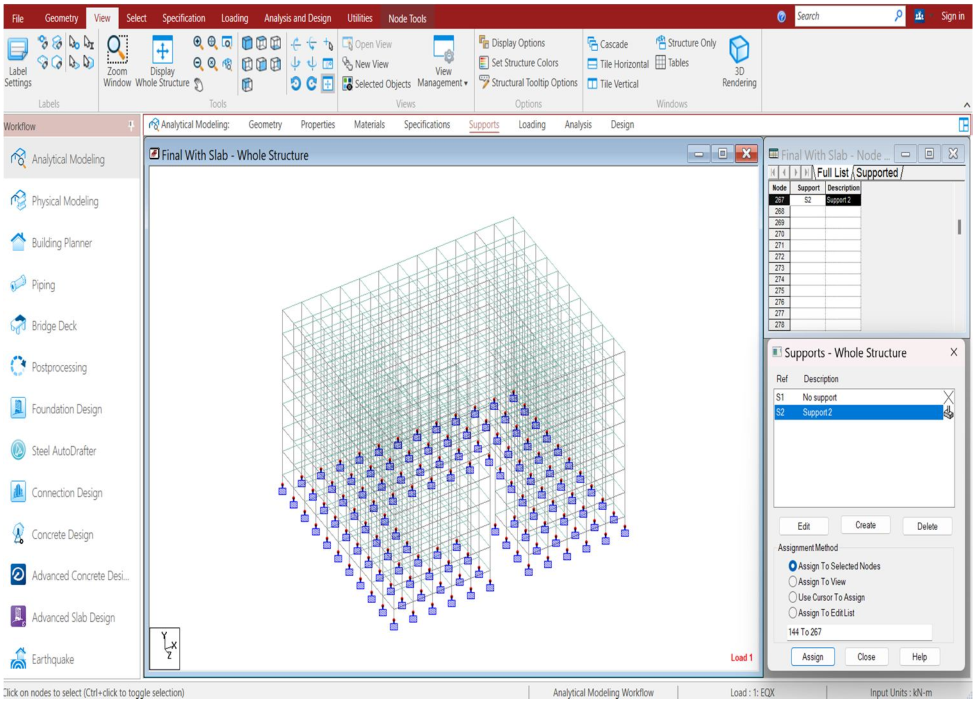


Figure 9: Support design for the building

3D rendering of a simulated building frame. Right-click the STAAD.Pro window and select Render in menu to have the figure as shown below

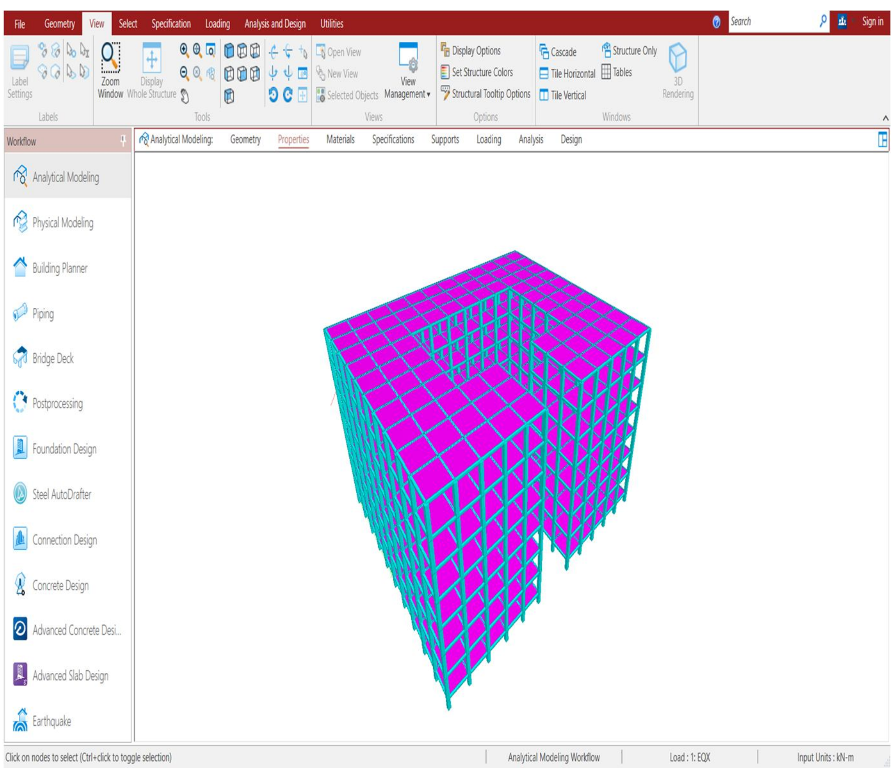
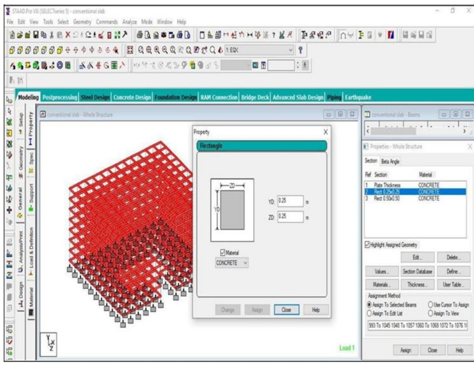
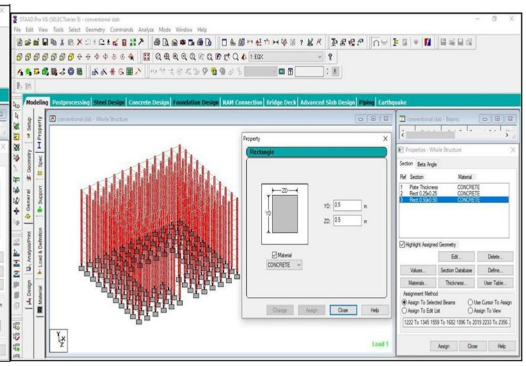
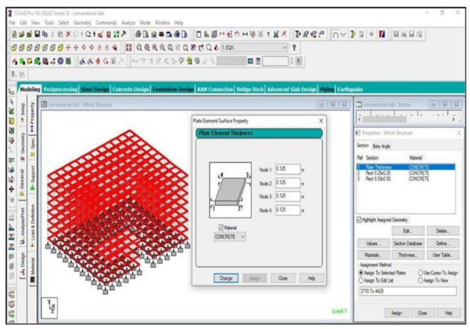


Figure 10: 3D render of the building generated in tool.

The material's property selection and the prismatic can be defined in three axes such as x,y and Z with rectangular section given by 250 mm.

a) b)



c)

Figure 11: Building material selection properties shown in a) x-axis b) y-axis c) z-axis.

Simulating the forces such as wind, earthquake (seismic) which affects, dead , live load etc and these are listed below,
The tool allows to select the seismic forces in the software and the different zones of it is provided we had selected the IS-1893:2002 with the values calculated earlier, the illustration is as shown in the below figure.

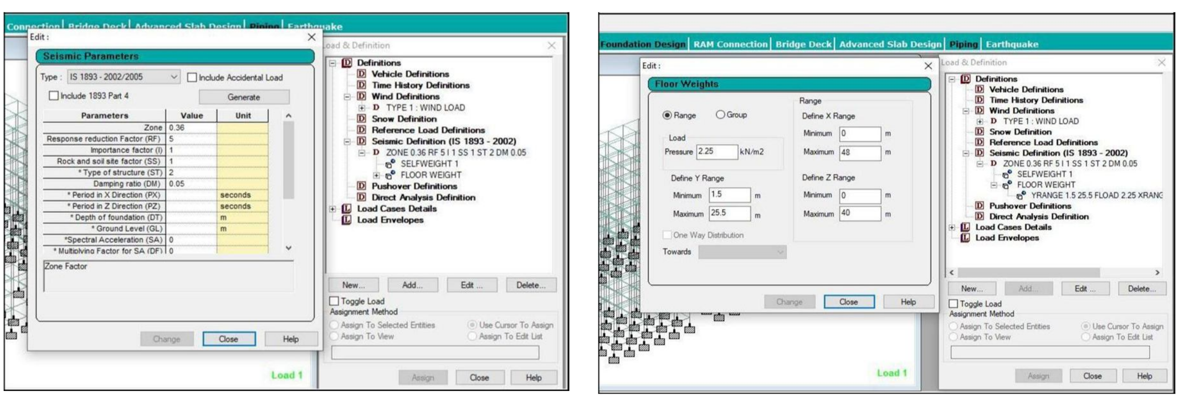


Figure 12: Simulating the Seismic zones to effect top floors.

The next simulation is to add the wind into the structured model by choosing add in the menu and the values were entered as per the calculations.

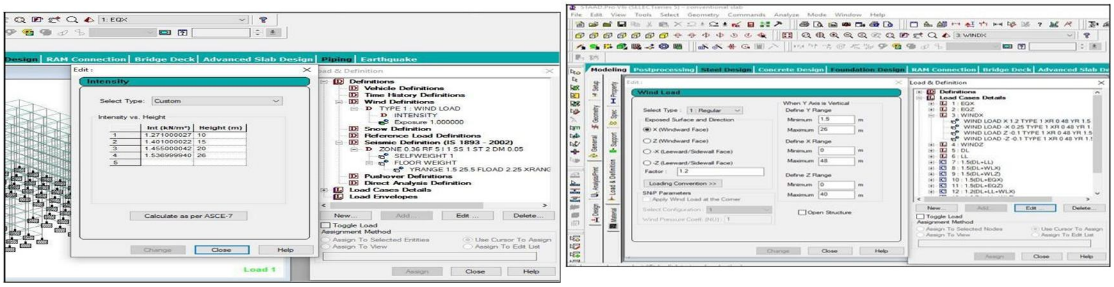
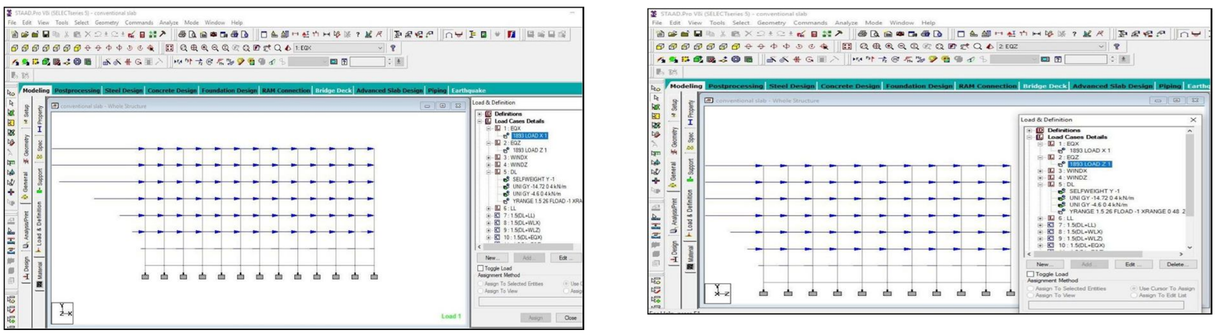


Figure 13: Simulating the Wind loading

The loading on the building due to earthquake along the x and Z direction on the structure of designed building using the software is as shown in the below figure,



a) b)

Figure 14: a)earthquake along X direction b) simulation of the earthquake in x direction on loads

The load from the dead wall is simulated in the software and it is provided by 14.72 kN/m which is as shown in the below figure.

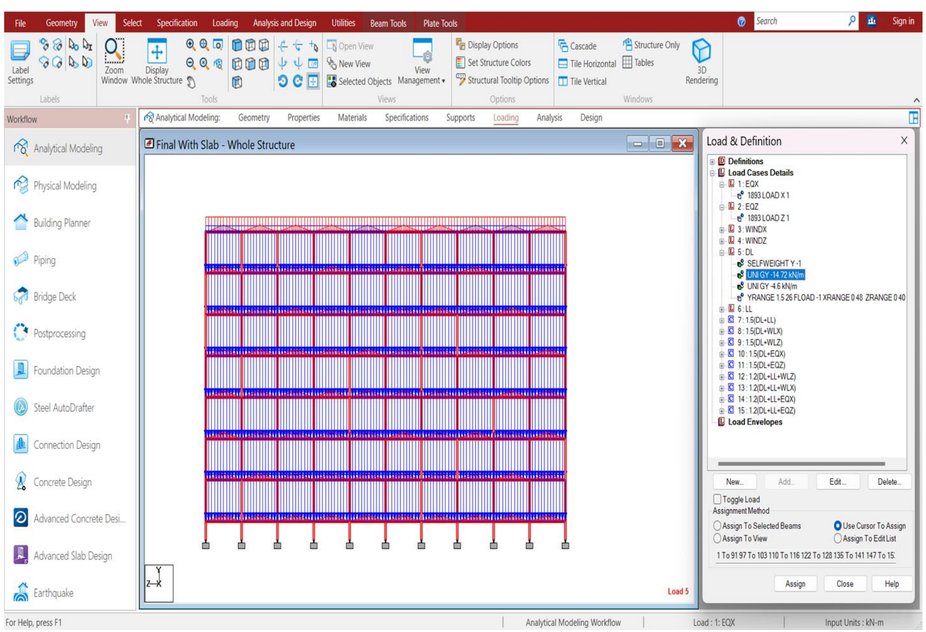


Figure 15: Dead load on structure from wall.

The load of 4.6 kN/m is the dead load occurred from the parapet wall if normal slab is constructed and the simulation shows it.

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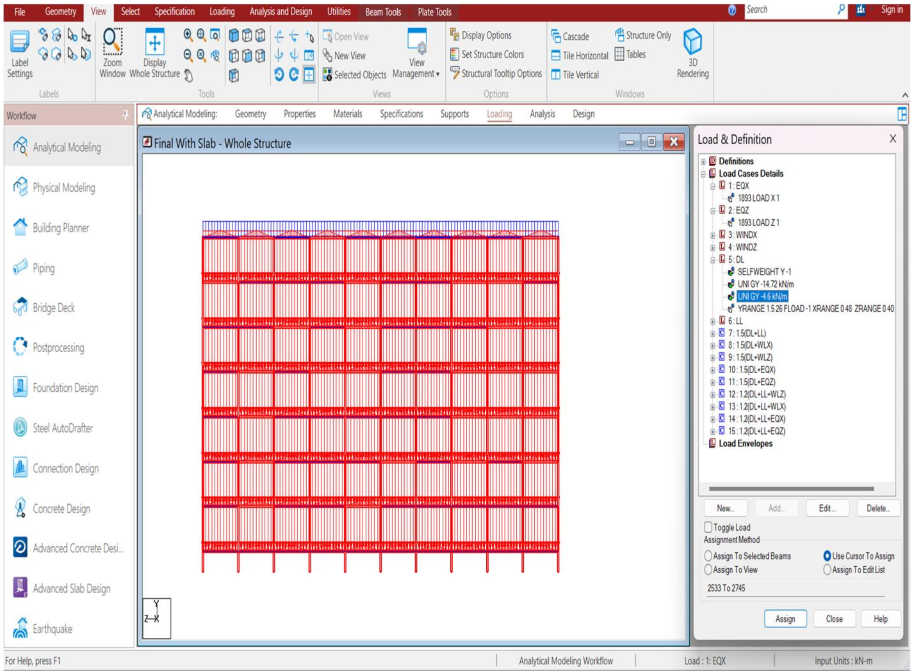

Figure 16: Load from parapet wall

The below figure shows the dead floor load imposed on the building and the below figure shows it.

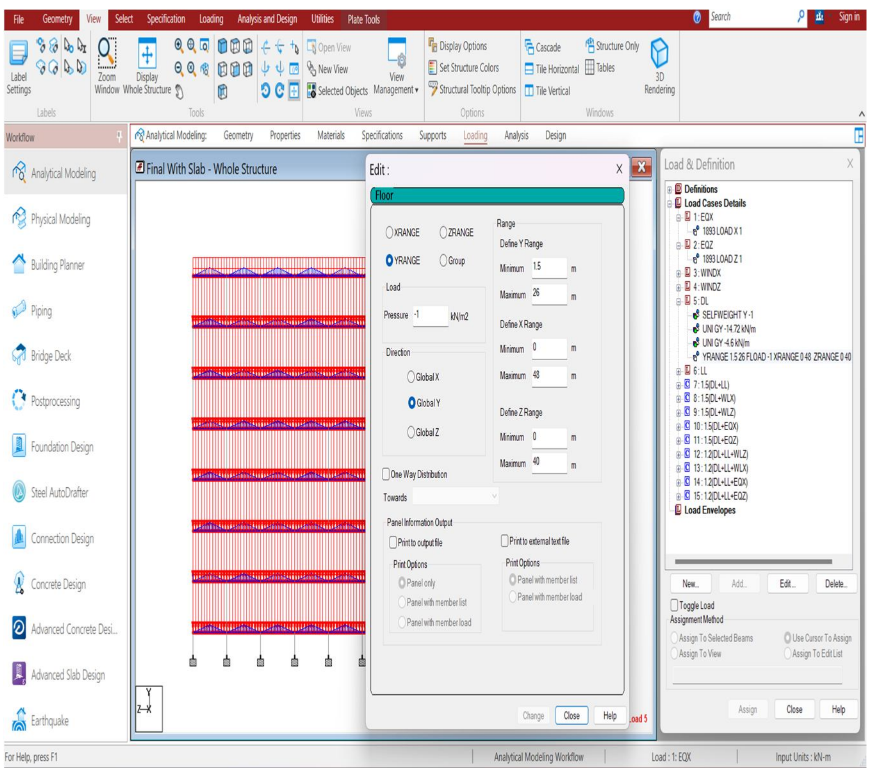

Figure 17: Load distribution all over the building.

Simulating the live load imposed by expecting the top floor and the setting in tool is as shown below

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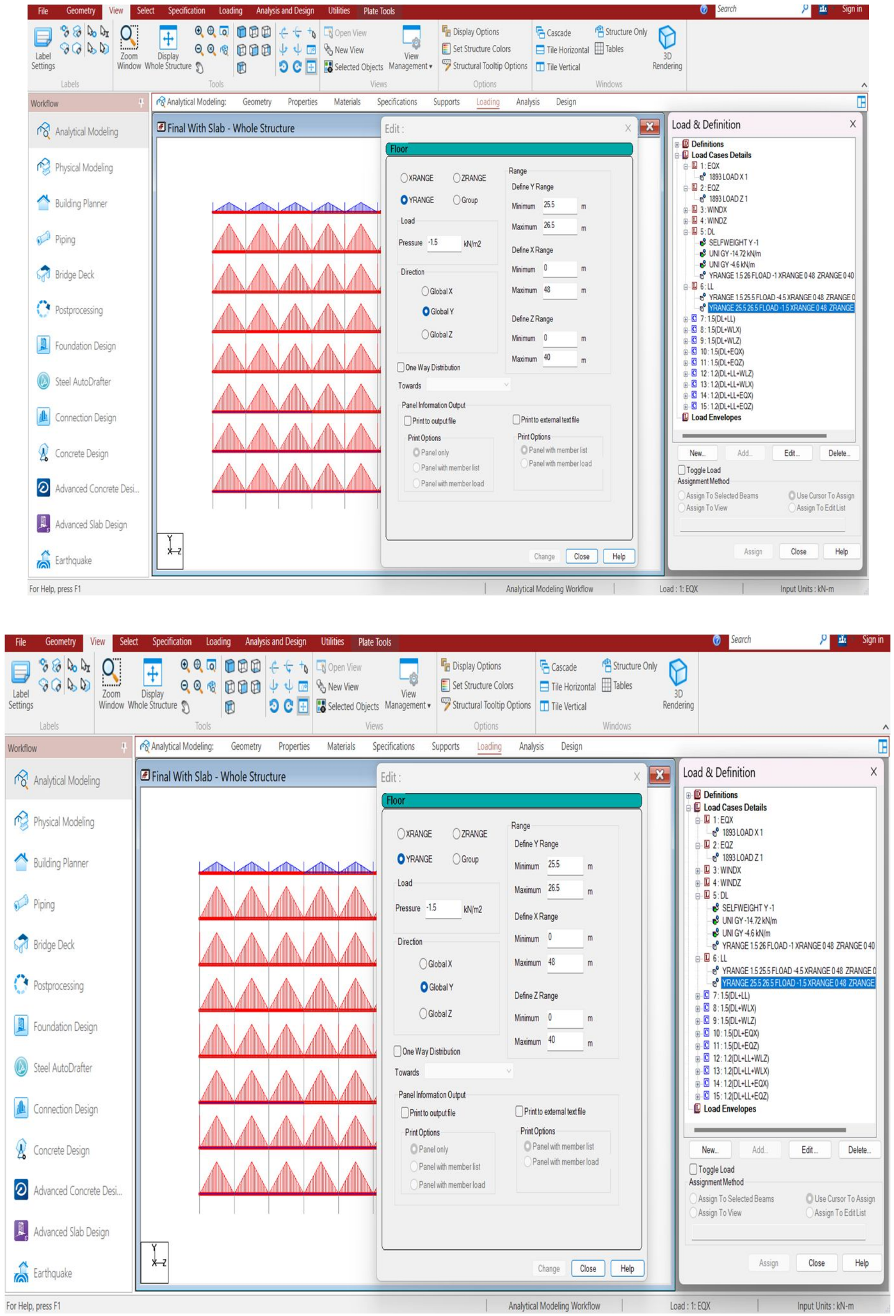

Figure 18: Load imposed on the structure expect top floor.

For the analysis had added all the loads stated above and allowed the tool to impose all the loads on building plan to analyse the structural strength of it and results are discussed in the next section.

IV. RESULT AND DISCUSSION

This section of the research details the results and interpretations. STAAD models and analyses G+6 multistory buildings. After the examination is complete, conventional and flat slab structures are compared using the same way. Six types of loads were examined, according to the report. Following DL are LLX, WLX, WLZ, and EQX/EQZ. The programme uses master-slave to accomplish tasks on a single node. At each node point on each level's master slaves, the outputs of both structures are compared. Every step becomes a master slave. All discoveries on each level may be accessible from a single node using a master slave. Distributed hash tables enable this.

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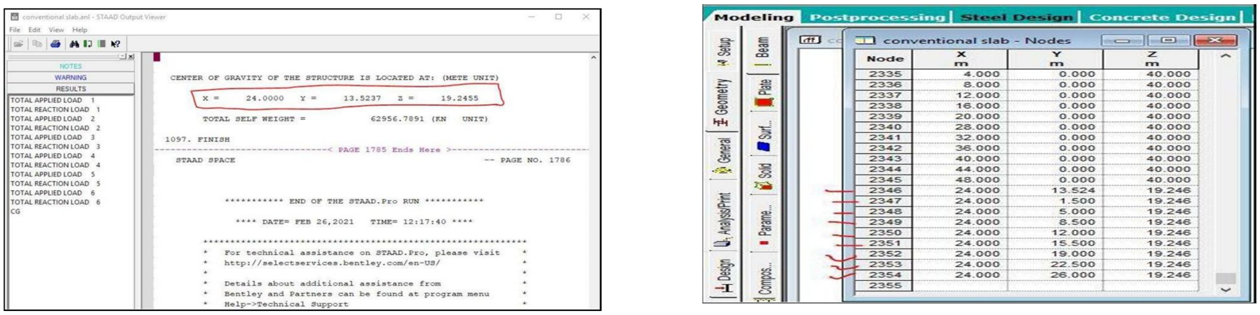
The structure centroid is calculated by pressing the CG button in the tool and it is as shown in the below figure,

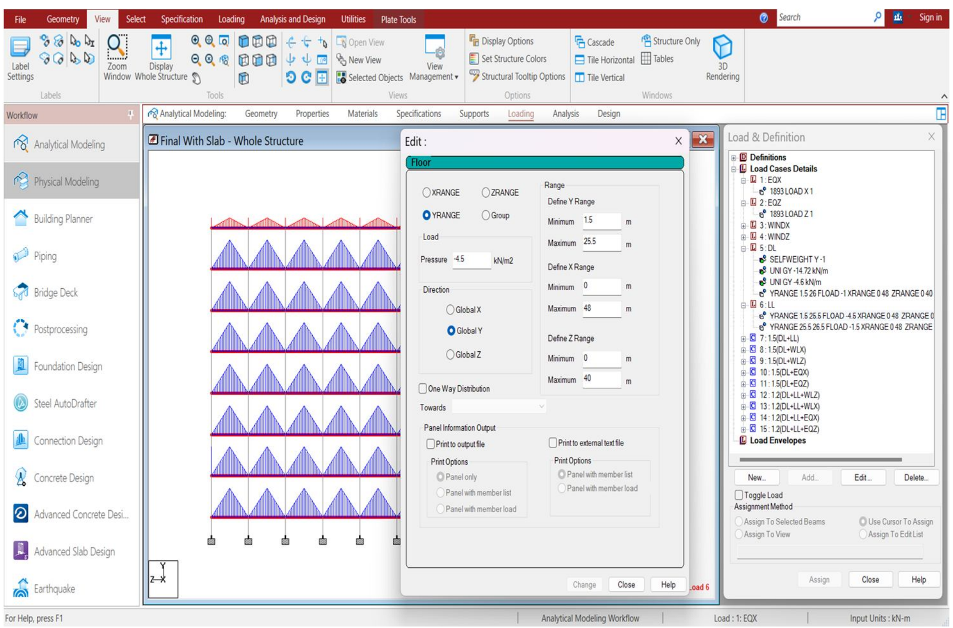


a) b)

Figure 19: a) Centroid calculation of the building b) centroid for the every floors of building.

A. *Comparison of the displacements for the 1.5 and 1.2 in X and Z directions considering the load*

In both groupings of structures, the master and slave levels see the most activity. Both building groupings are affected. To generate these results, load combinations in the x and z axes at each floor level are analysed. Changing the weight carried by each load arrangement is one way to show height variation. Example: bar graphs. In x and z, we test DL+WLX, 1.5 (DL+EQX), 1.2 (DL+LL+WLX), and 1.2 (DL+LL+EQZ). Due to the little amount of data in the remaining load combinations, bar graphs are not provided.



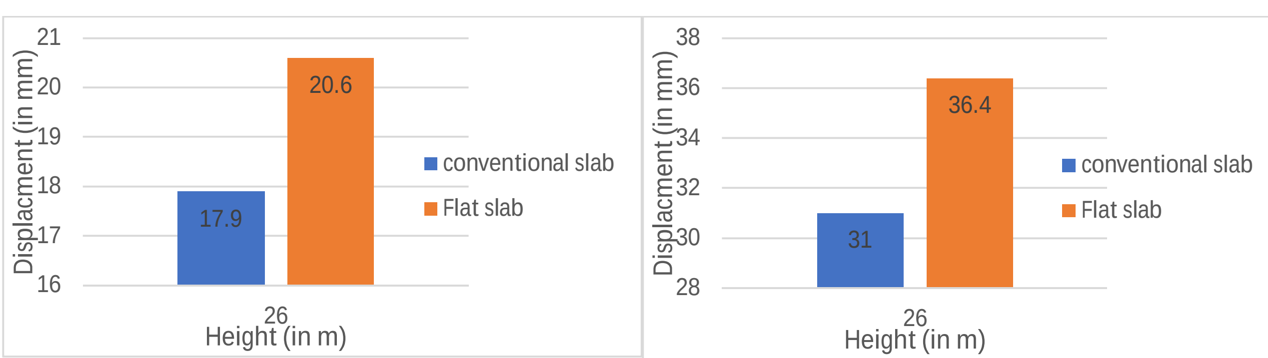


Figure 20: Displacements in X direction for 1.5 (DL + WLX and EQX)

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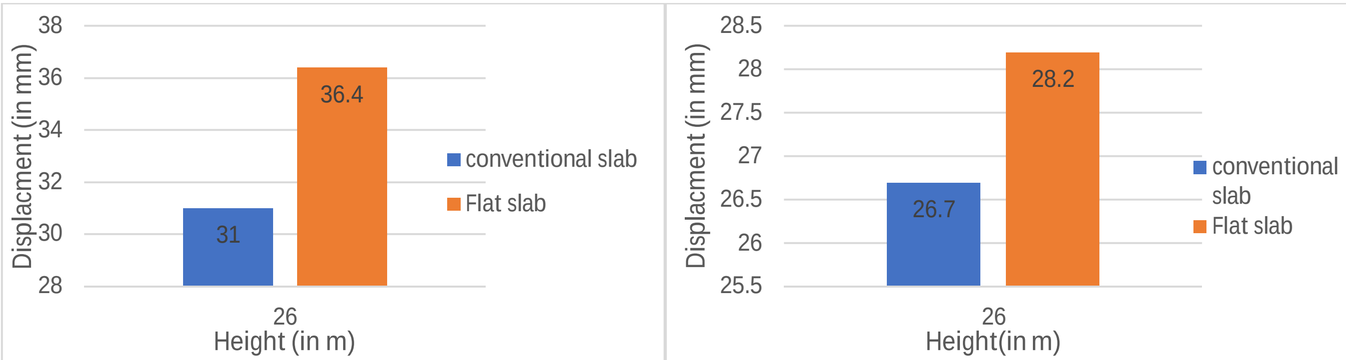


Figure 21: Displacement in direction X direction for 1.2 (DL+LL+EQX +WLX)

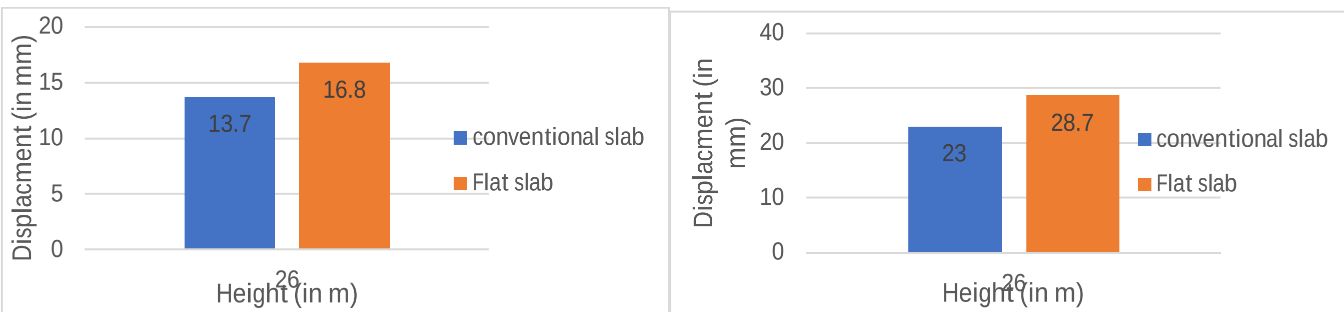


Figure 22: Displacement in Z direction for the values 1.2 (DL+LL+ EQZ)

B. Comparison of Base Shear

The column's base must be considered when evaluating shear values. For the column sample, shear values are estimated for various x and z load combinations. Each load combination is checked. The example column helped establish these values. This column has several interconnected nodes. Except for the tallest and lowest nodes, every node is linked to a column on both sides. Only the top and bottom nodes break this restriction. Valid computation requires assigning a value to each shear node. If the column is above or below it, the shear values will change. This impacts outcomes. Since there is no column below or above, the shear force at that node must be computed algebraically. Only this method can determine this value. This is the only choice since no other column may be utilised for comparison are as shown in the below figure.

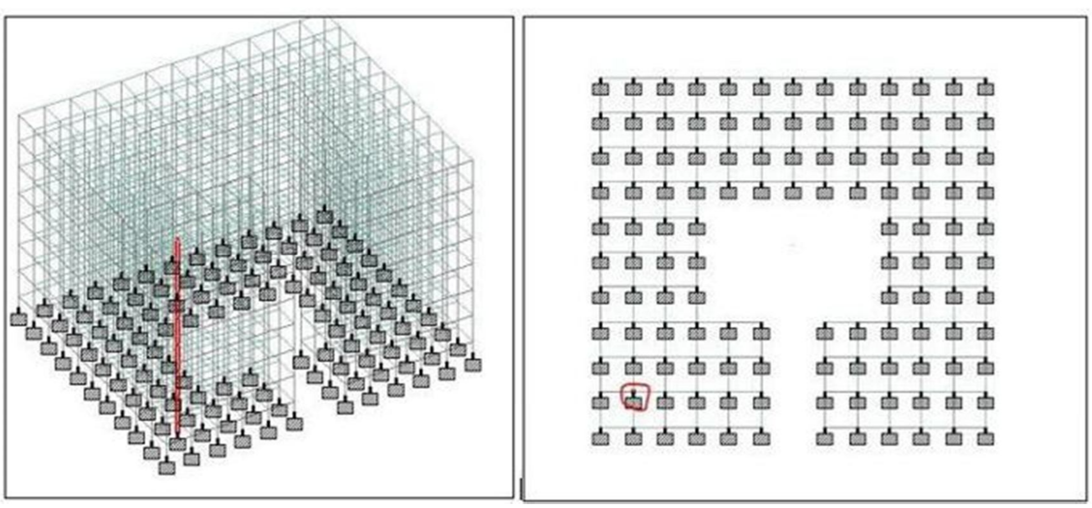


Figure 23: Plan of the building in 3D

The base shears on the X and Z directions is as shown in the below figure,

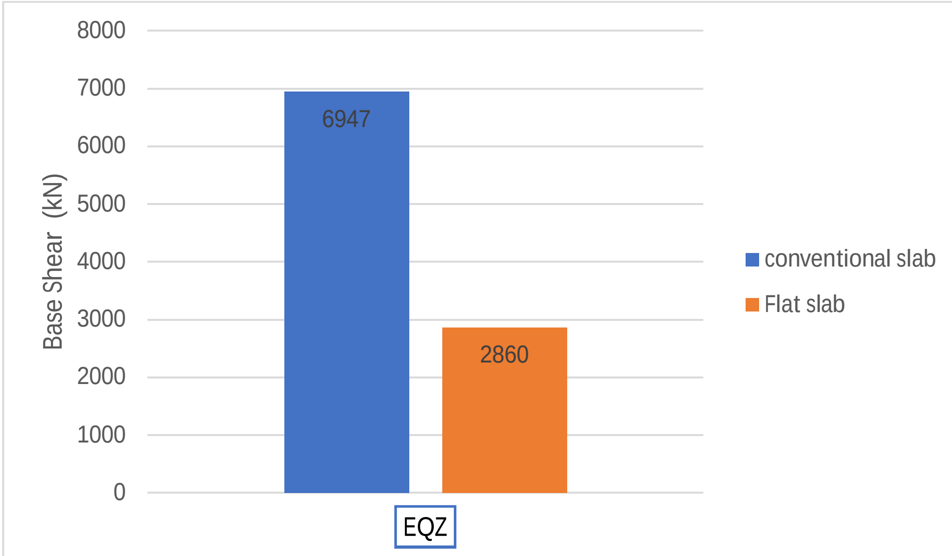
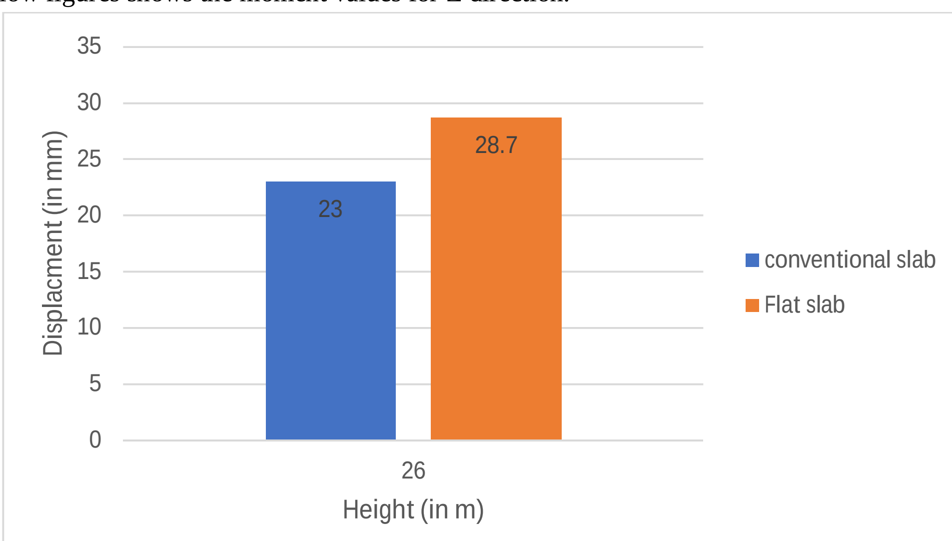


Figure 24: Base shear is negative along 'Z' direction

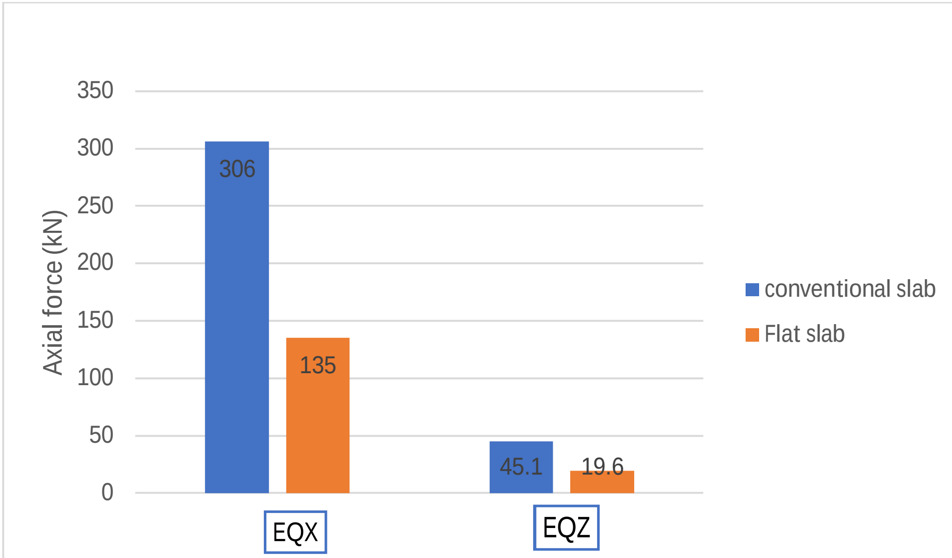
C. *Comparison of Moment Values*

Each column's beginning computes moments. Sample columns are used to calculate moment values for y- and z-axis load arrangements. This column has several nodes. Only the top and lowest floors break this restriction. A node needs two immediate values. New information will change both the column above and below it. To compute the instant at a node, add both values algebraically. The below figures shows the moment values for Z direction.



D. Axial force

Calculating axial force uses the column's base. Many load combinations are evaluated while computing column moment values. This column has several nodes. Figure a three-dimensional viewpoint, and Figure building design. Below are both figures. Both graphs show each highlighted number clearly. The axial force exerted by the column was determined using a number of different load configurations. There are four different load combinations that may be used: 1.2 (DL+LL+WLX), 1.5 (DL+WLX), and 1.5 (DL+EQX). As can be seen in the figures, the moment values associated with any further load combinations are far lower than those now under consideration, therefore they may be safely ignored.



V. CONCLUSION

Axial force is determined by measuring the weight of the column at its footing. When determining column moments, a large number of load permutations are considered. There are numerous hubs in this column. Take a look at the building from all angles, and see it from a third-person perspective. Each number is shown below. Each of the highlighted numbers is shown clearly in both graphs.

Multiple load combinations were used to calculate the axial force imparted by the column. Loads include DL+WL+EQX, 1.2(DL+LL+WLX), 1.5(DL+WLX), and 1.5(DL+EQX). You can see from the numbers that there is no need to look at any other load combinations as their moment values are so much less than the ones being looked into.

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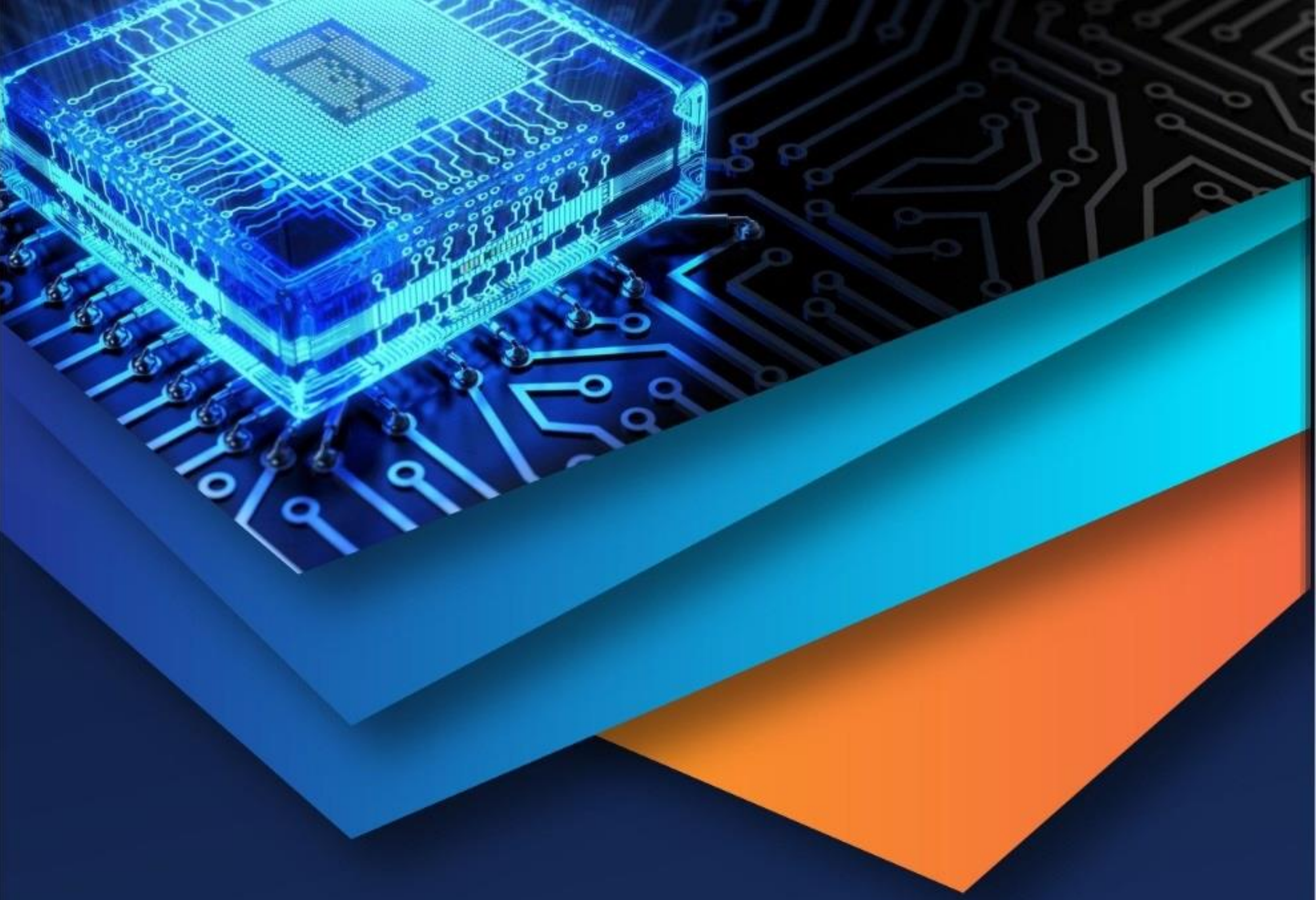

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