ANALYSIS AND DESIGN OF MULTISTOREY BUILDING BY USING STAAD PRO

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Abstract

In the last few decades tall or multi-storey buildings has gain very much importance, because in metro cities there is a rapid increase in population with limited land. Most of the people require good accommodations, aesthetic, comfort and safety. That's the reason for increase in construction of multi-storey buildings. Earthquake will cause more severe effect on tall buildings compare to small buildings. Due to earthquake asymmetrical buildings will damage more than symmetrical buildings. A review of the analysis and design of a multi-storey building with STAAD Pro is carried out. Planning is done by using AutoCAD and load calculations were done manually and then the structure was analysis using STAAD Pro. The dead load, imposed load and wind load with load combination are calculated and applied to the structure. Overall, the concepts and procedures of designing the essential components of a multistory building are described. STAAD Pro software also gives a detailed value of shear force, bending moment and torsion of each element of the structure which is within IS code limits..

KEYWORDS: Staad.pro, multi-storey building, shear force, bending moment.

INTRODUCTION

Human life is affected due to nature's forces like floods, hurricanes, tornadoes, earthquakes etc. The structural design for a building must ensure that the building is able to stand safely, to function without excessive deflections or movements which may cause fatigue of structural elements, cracking or failure of fixtures, fittings or partitions, or discomfort for occupants. It must account for movements and forces due to temperature, creep, cracking and imposed loads. It must also ensure that the design is practically buildable within acceptable manufacturing tolerances of the materials. It must allow the architecture to work, and the building services to fit within the building such that it is functional (air conditioning, ventilation, lighting etc.). The aim of this project work is to analyze a 5-storeyed hostel building for different load combinations using STAAD Pro software. Based on the analysis, design of the structure is done mainly in accordance with IS specifications.

DESIGN PHILOSOPHIES

The limit state method is adopted for the analysis and design of the structure. IS codes, SP-16 and SP-32 charts are also used as an aid for detailing and design purpose.

The major requirements of a properly designed building are:

(a) **GOOD STRUCTURAL CONFIGURATION**: Its size, shape and structural system carrying loads are such that they ensure a direct and smooth flow of inertia forces to the ground.

- **LATERAL STRENGTH**: The maximum lateral (horizontal) force that it can resist is such that the damage induced in it does not result in collapse.

- **ADEQUATE STIFFNESS**: Its lateral load resisting system is such that the earthquake-induced deformations in it do not damage its contents under low-to moderate shaking.

- **GOOD DUCTILITY**: Its capacity to undergo large deformations under severe earthquake shaking even after yielding is improved by favorable design and detailing strategies.

LITERATURE REVIEW

- Ibrahim, et.al (April 2019)1: Design and Analysis of Residential Building(G+4): After analyzing the G+4 story residential building structure, conducted that the structure is rate in loading like dead load, live load, wind load and seismic loads. Member dimensions (Beam, column, slab) are assigned by calculating the load type and its quantity applied on it. Auto CAD gives detailed information at the structure members

- length, height, depth, size and numbers, etc. STADD Pro. has a capability to calculate the program contains number of parameters which are designed as per IS 456: 2000. Beams were designed for flexure, shear and tension and it gives the detail number, position and spacing brief..

- Dunnala Lakshmi Anuja, et.al (2019)2: Planning, Analysis and Design of Residential Building(G+5) By using STAAD Pro:Frame analysis was by STAAD-Pro. Slab, Beams, Footing and stair-case were design as per the IS Code 456-2000 by LSM. The properties such as share Deflection torsion, development length is with the IS code provisions. Design of column and footing were done as per the IS 456-2000 along with the SP-16 design charts. The check like one-way shear or two-way shear within IS Code provision. Design of slab, beam, column, rectangular footing and staircase are done with limit state method. On comparison with drawing, manual design and the geometrical model using STADD Pro.

- Mr K. Prabin Kumar, et.al (2018):A Study on Design of Multi-Storey Residential Building: They used STADD Pro. to anal-ysis and designing all structure member and calculate quantity of reinforcement needed for concrete section. Various structure action is considered as members such as axial, flexure, shear and tension. Pillar are delineated for axial forces and biaxial ends at the ends. The building was planned as per IS: 456- 2000.

- Deevi Krishna Chaitanya, et.al (January, 2017)4: Analysis and Design of a (G+6) Multi-Storey Building Using STAAD Pro:They used static indeterminacy methods to calculate numbers of unknown forces. Dis-tributing known fixed and moments to satisfy the condition of compatibility by Iteration method. Kani's method was used to distribute moments at successive joints in frame and continues beam for stability of members of building structure. They used the designing software STADD Pro. which reduced lot of time in design, gives accuracy.
- R. D. Deshpande, et.al (June, 2017)5: Analysis, Design and Estimation of Basement+G+2 Residential Building: They found that check for Deflection was safe. They carried design and analysis of G+2 residential building by using E-Tabs software with the estimation of building by method of center line. They safely designed column using SP-16 checked with interaction formula.

MERCANTILE OR HOSTEL OCCUPANCY

Apartment means a part of a building intended for any type of independent use including one or more rooms or enclosed spaces located on one or more floors or parts thereof in a building, intended to be used for residential purposes and with a direct exit to a public street, road or highway or to a common area, leading to such street, road or highway. This word is synonymous with residential flat. No land development or redevelopment shall be made or no building shall be constructed on any plot on any part of which there is deposited refuse, excreta or other offensive matter which in the opinion of the Secretary is considered objectionable, until such refuse, excreta or other offensive matter has been removed there from and the plot has been prepared or left in a manner suitable for land development or building purpose for the satisfaction of the Secretary. The rear yard shall be not less than 1.5m depth. Parking building/parking plazas/parking towers shall have minimum 5m open space all around the building. Not more than 15% of the total floor area of the parking building shall be permitted for shop or restaurant or hotel or office purpose.

MINIMUM DISTANCE FROM THE ROAD

For buildings above 10m in height, in addition to the minimum front, rear and side open spaces required for height up to 10m, there shall be provided proportionate increase in such minimum open space at the rate of 0.5m per every 3m height exceeding 10m.

RESEARCH METHODOLOGY

DEAD LOAD

All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^2and25$kN=m^2$respectively:

IMPOSED LOAD

Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the

differential settlements to which the structure may undergo.

WIND LOAD

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term wind denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 meters above ground.

WORKING WITH STAADPRO

Types of structures

A structure can be defined as an assemblage of elements. STAAD is capable of analyzing and designing structures consisting of frame, plate/shell and solid elements. Almost any type of structure can be analyzed by STAAD. A SPACE structure, which is a three dimensional framed structure with loads applied in any plane, is the most general. A PLANE structure is bound by a global X-Y coordinate system with loads in the same plane. A TRUSS structure consists of truss members who can have only axial member forces and no bending in the members. A FLOOR structure is a two or three dimensional structure having no horizontal (global X or movement of the structure [FX, FZ MY are restrained at every joint]. The floor framing (in global X-Z plane) of a building is an ideal example of a FLOOR structure. Columns can also be modeled with the floor in a FLOOR structure as long as the structure has no horizontal loading. If there is any horizontal load, it must be analyzed as a SPACE structure.

Generation of the structure

The structure may be generated from the input or mentioning the co-ordinates in the GUI.

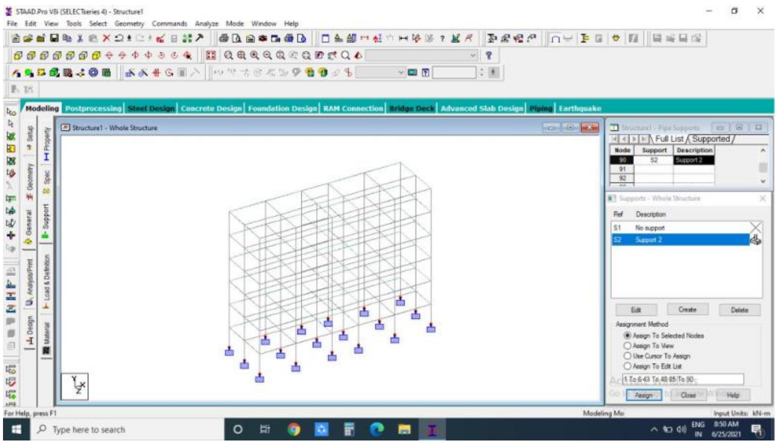


Figure 3.1: Generation of the structure

Material constants

The material constants are: modulus of elasticity (E); weight density (DEN); Poisson's ratio (POISS); coefficient of thermal expansion (ALPHA), Composite Damping Ratio, and beta angle (BETA) or coordinates for any reference (REF) point. E value for members must be provided or the analysis will not be performed. Weight density (DEN) is used only when self-weight of the structure is to be taken into account. Poisson's ratio (POISS) is used to calculate the shear modulus (commonly known as G) by the formula, G = 0.5 x E/ (1 + POISS) If Poisson's ratio is not provided, STAAD will assume a value for this quantity based on the value of E. Coefficient of thermal expansion (ALPHA) is used to calculate the expansion of the members if temperature loads are applied. The temperature unit for temperature load and ALPHA has to be the same.

Supports

Supports are specified as PINNED, FIFIXED, or FIFIXED with Different releases (known as FIFIXED BUT). A pinned support has restraints against all translational movement and none against rotational movement. In other words, a pinned support will have reactions for all forces but will resist no moments. A fixed support has restraints against all directions of movement. Translational and rotational springs can also be specified. The springs are represented in terms of their spring constants. A translational spring constant is defined as the force to displace a support joint one length unit in the specified global direction. Similarly, a rotational spring constant is defined as the force to rotate the support joint one degree around the specified global direction.

Loads

Loads in a structure can be specified as joint load, member load, temperature load and fixed-end member load. STAAD can also generate the self-weight of the structure and use it as uniformly distributed member loads in analysis. Any fraction of this self-weight can also be applied in any desired direction.

Joint loads

Joint loads, both forces and moments, may be applied to any free joint of a structure. These loads act in the global coordinates system of the structure. Positive forces act in the positive coordinate directions. Any number of loads may be applied on a single joint, in which case the loads will be additive on that joint.

Member loads

Three types of member loads may be applied directly to a member of a structure. These loads are uniformly distributed loads, concentrated loads, and linearly varying loads (including trapezoidal). Uniform loads act on the full or partial length of a member. Concentrated loads act at any intermediate, specified point. Linearly varying loads act over the full length of a member. Trapezoidal linearly varying loads act over the full or partial length of a member. Trapezoidal loads are converted into a uniform load and several concentrated loads. Any number of loads may be specified to act upon a member in any independent loading condition. Mmber loads can be specified in the member coordinates system or the global coordinates system.

Area/ floor load

Many times a floor (bound by X-Z plane) is subjected to a uniformly distributed load. It could require a lot of work to calculate the member load for individual members in that floor. However, with the AREA or FLOOR LOAD command, the user can specify the area loads (unit load per unit square area) for members. The program will calculate the tributary area for these members and provide the proper member loads. The Area Load is used for one way distributions and the Floor Load is used for two way distributions.

Fifixed end member load

Load effects on a member may also be specified in terms of its fixed end loads. These loads are given in terms of the member coordinates system and the directions are opposite to the actual load on the member. Each end of a member can have six forces: axial; shear y; shear z; torsion;

Load Generator Moving load, Wind Seismic

Load generation is the process of taking a load causing unit such as wind pressure, ground movement or a truck on a bridge, and converting it to a form such as member load or a joint load which can be then be used in the analysis.

Moving Load Generator

This feature enables the user to generate moving loads on members of a structure. Moving load system(s) consisting of concentrated loads at fixed specified distances in both directions on a plane can be defined by the user. A user specified number of primary load cases will be subsequently generated by the program and taken into consideration in analysis.

Seismic Load Generator

The STAAD seismic load generator follows the procedure of equivalent lateral load analysis. It is assumed that the lateral loads will be exerted in X and Z directions and Y will be the direction of the gravity loads. Thus, for a building model, Y axis will be perpendicular to the floors and point upward (all Y joint coordinates positive). For load generation per the codes, the user is required to provide seismic zone coefficients, importance factors, and soil characteristic parameters. Instead of using the approximate code based formulas to estimate the building period in a certain direction, the program calculates the period using

Raleigh quotient technique. This period is then utilized to calculate seismic coefficient C. After the base shear is calculated from the appropriate equation, it is distributed among the various levels and roof per the specifications. The distributed base shears are subsequently applied as lateral loads on the structure. These loads may then be utilized as normal load cases for analysis and design.

ANALYSIS OF G+5 RCC FRAMED BUILDING USING STAAD.PRO

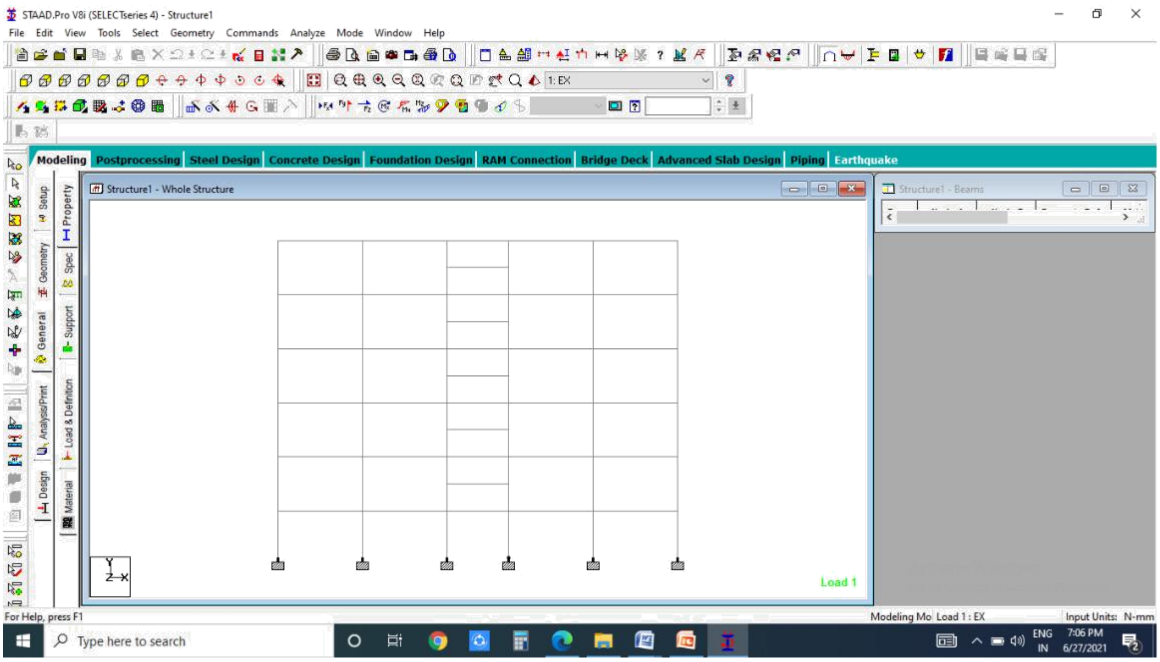


Figure 3.3: Plan of the G+5 story building

All columns = 0.40 * 0.60 m
All beams = 0.3 * 0.5 m
All slabs = 0.125 m thick

Physical parameters of building

Length = 4 bays @ 5.5m + 1 bay @ 4m =26m

Width = 2 bays @ 4 m =8.0m

Height = 3m + 5 storey @ 3.5m = 20.5m
Live load on the floors is 2kN/m2
Live load on the roof is 1.5kN/m2
Grade of concrete and steel used
Used M25 concrete and Fe 415 steel

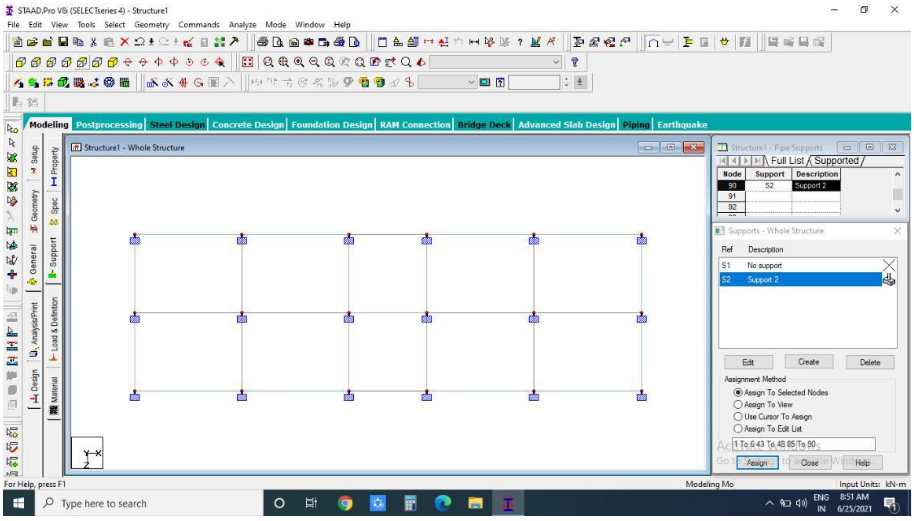


Figure 3.4: Elevation of the G+5 story building

Generation of member property

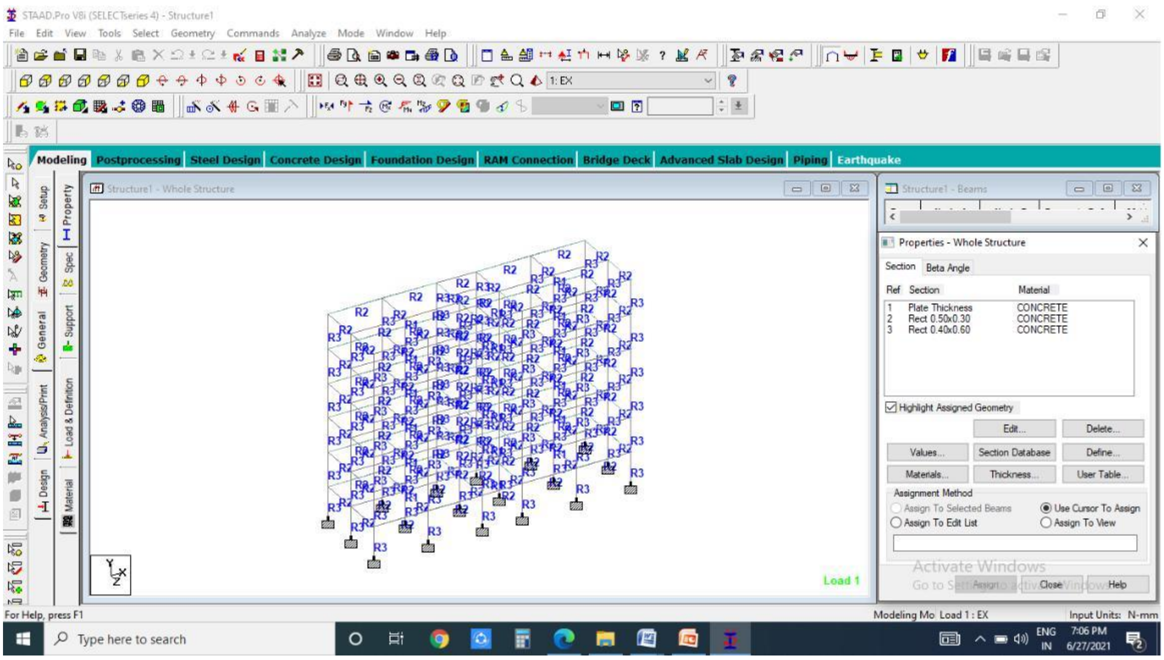


Figure 3.5: Generation of member property

Generation of member property can be done in STAAD.Pro by using the window as shown above. The member section is selected and the dimensions have been specified. The beams are having a dimension of 0.3*0.5 m and the columns are having a dimension of 0.4*0.6 m.

Supports

The base supports of the structure were assigned as fixed. The supports were generated using the STAAD. Pro support generator.

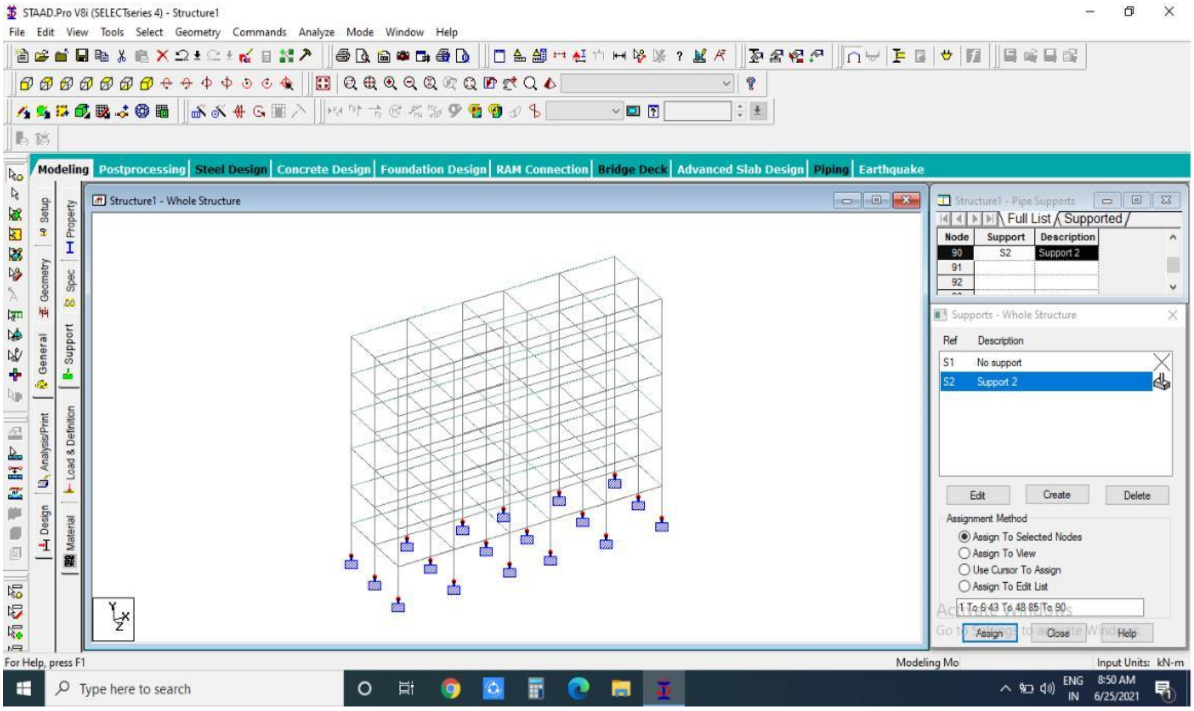


Figure 3.6: Fixing supports of the structures

Materials of the structure

The materials for the structure were specified as concrete with their various constants as per standard IS code of practice.

Loading

The loadings were calculated partially manually and rest was generated using STAAD.Pro load generator. The loading cases were categorized as

- Self-weight
- Dead load from slab
- Live load
- Wind load
- Seismic load
- Load combinations

Dead load from slab can also be generated by STAAD.Pro by specifying the floor thickness and the load on the floor per sqm. Calculation of the load per sq m was done considering the weight of beam, weight of column, weight of RCC slab, weight of terracing, external walls.

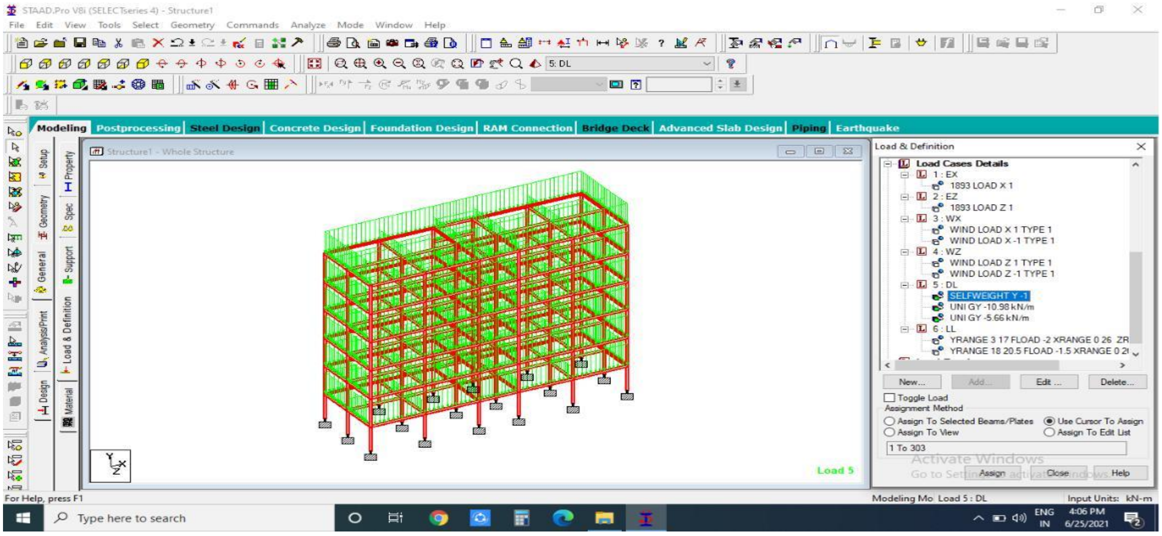


Figure 3.7: Dead load

Live load:

The live load considered in each floor was 2.0 KN/sq m and for the terrace level it was con-sidered to be 1.5 KN/sq m. The live loads were generated in a similar manner as done in the earlier case for dead load in each floor. This may be done from the member load button from the load case column.

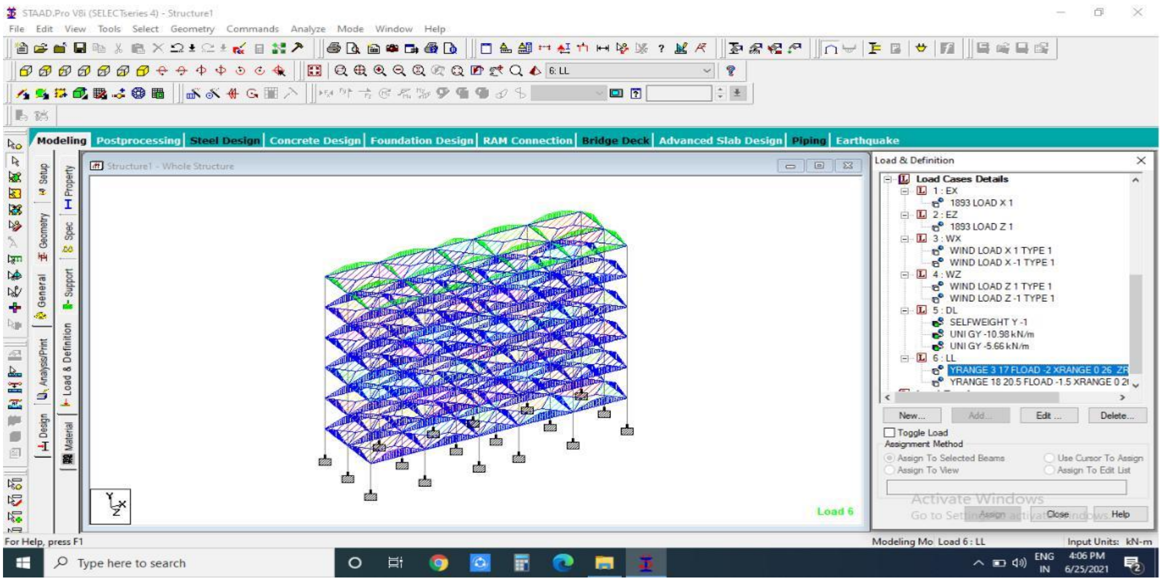


Figure 3.8: Live load

Wind load:

The wind load values were generated by the software itself in accordance with IS 875.Under the de ne load command section, in the wind load category; the definition of wind load was supplied. The wind intensities at various heights were calculated manually and feed to the software. Based on those values it generates the wind load at Different floors.

Table 3.1: Design wind pressure at various heights

Height [h]	Design Wind speed[V]	Design wind pressure[P]
Up to 10 m	36.379 m/s	0.793 KN/sq m
15 m	38.85 m/s	0.905 KN/sq m
20 m	40.51 m/s	0.984 KN/sq m
30 m	42.58 m/s	1.087 KN/sq m

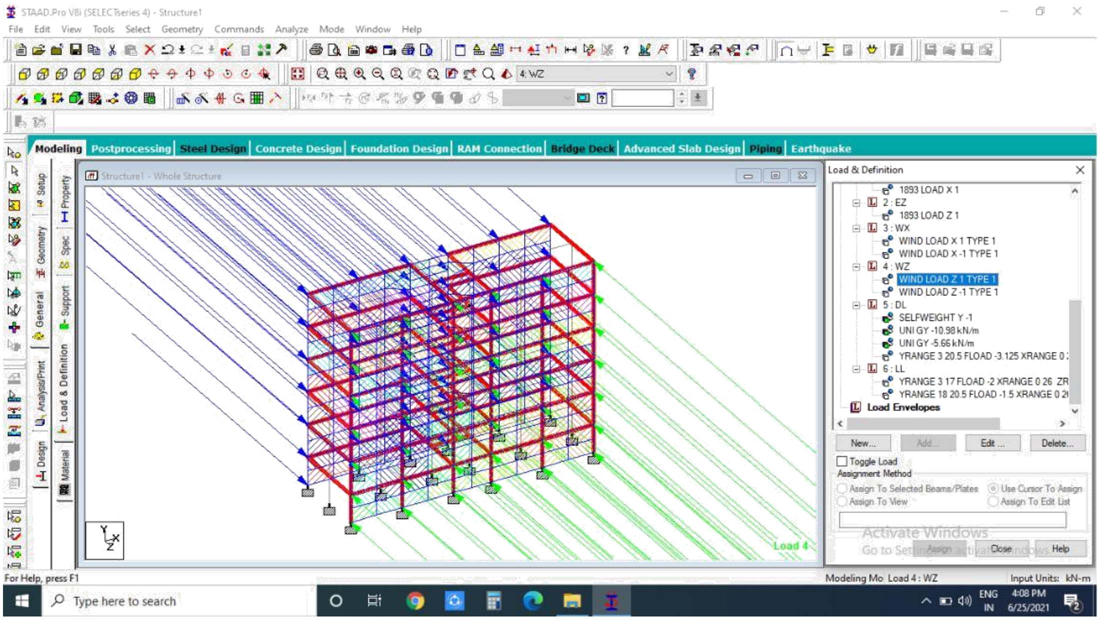


Figure 3.9: Wind load effect on structure

Seismic load

The seismic load values were calculated as per IS 1893-2002. STAAD.Pro has a seismic load generator in accordance with the IS code mentioned.

General format

DEFINE 1893 LOAD

ZONE f1 1893-spec

SELFWEIGHT

JOINT WEIGHT

Joint-list WEIGHT w 1893-Spec= RF f2, I f3, SS f4, (ST f5), DM f6, (PX f7), (PZ f8), (DT f9)

Where,

- Zone f1 = Seismic zone coefficient.
- RF f2 = Response reduction factor.

- I f3 = Importance factor depending upon the functional use. of the structures, character-ized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.

- SS f4 = Rock or soil sites factor (=1 for hard soil, 2 for medium soil, 3 for soft soil). Depending on type of soil, average response acceleration coefficient Sa/g is calculated Corresponding to 5

- ST f5 = Optional value for type of structure (=1 for RC frame building, 2 for steel frame building, 3 for all other buildings).

- DM f6 = Damping ratio to obtain multiplying factor for calculating Sa/g for Different damping. If no damping is specified 5% damping (default value 0.05) will be considered corresponding to which multiplying factor is 1.0.

- PX f7 = Optional period of structure (in sec) in X direction. If this is defined this value will be used to calculate Sa/g for generation of seismic load along X direction.

- PZ f8 = Optional period of structure (in sec) in direction. If this is defined this value will be used to calculate Sa/g for generation of seismic load along Z direction.

- DT f9 = Depth of foundation below ground level. It should be defined in current unit. If the depth of foundation is 30 m or below, the value of Ah is taken as half the value obtained. If the foundation is placed between then ground level and 30 m depth, this value is linearly interpolated between Ah and 0.5Ah.

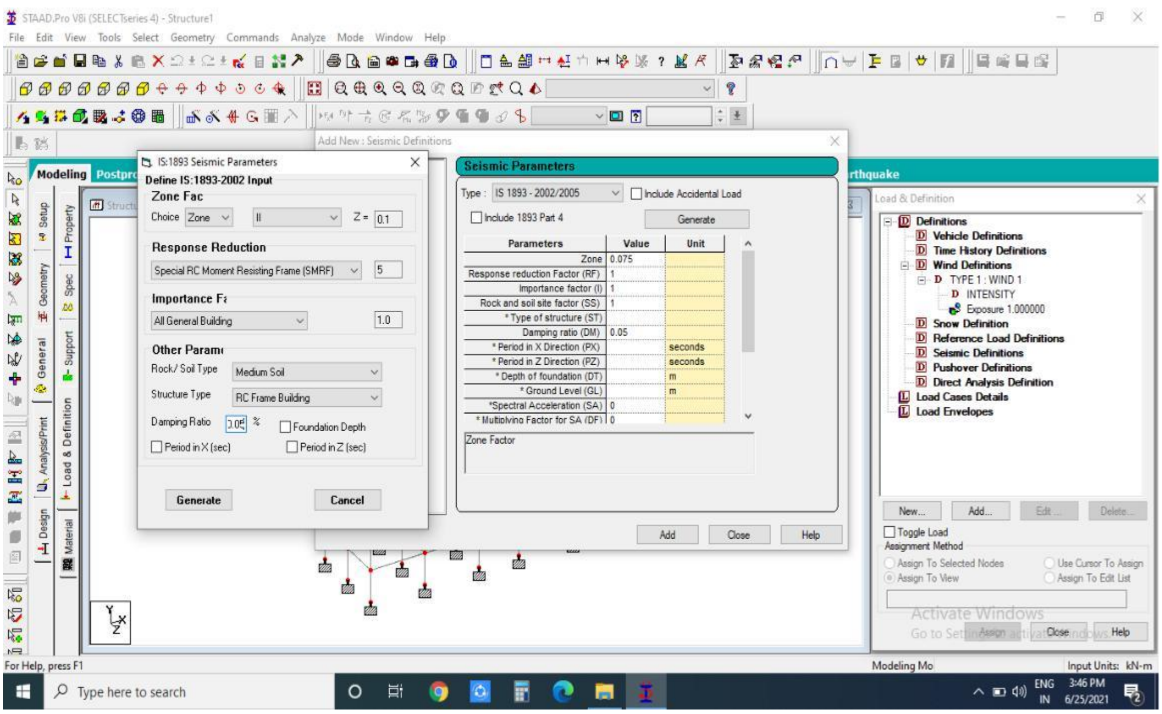


Figure 3.10: Seismic load de nation

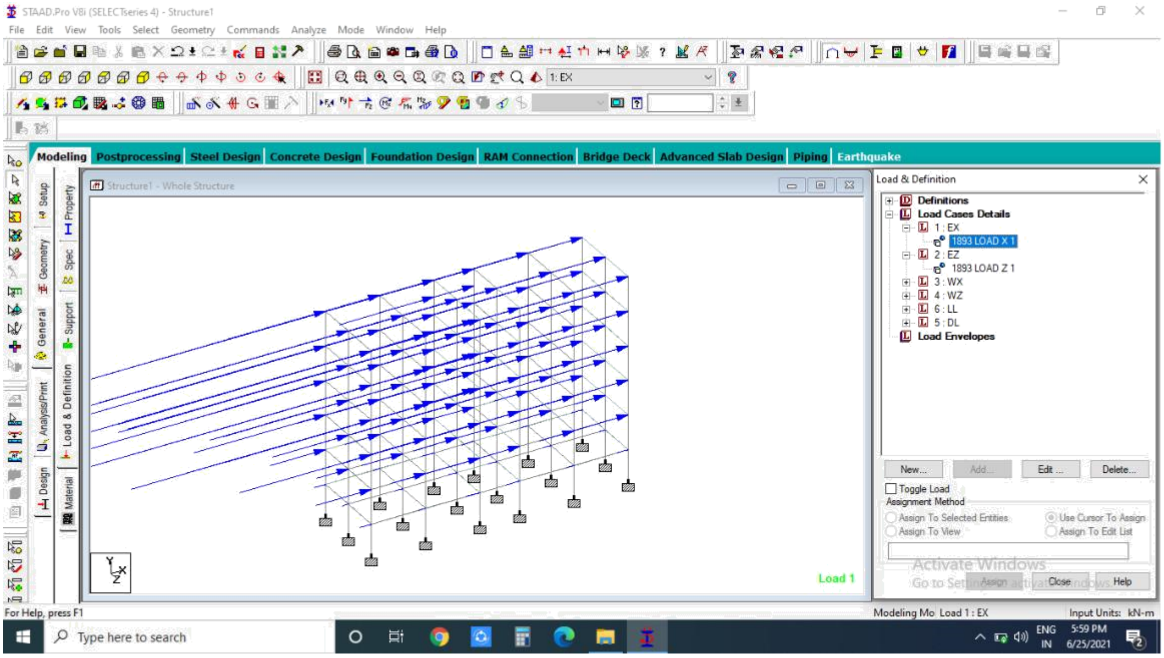


Figure 3.11: Structure under seismic load

Load combination

The structure has been analyzed for load combinations considering all the previous loads in proper ratio. In the first case a combination of self-weight, dead load, live load and wind load was taken in to consideration. In the second combination case instead of wind load seismic load was taken into consideration.

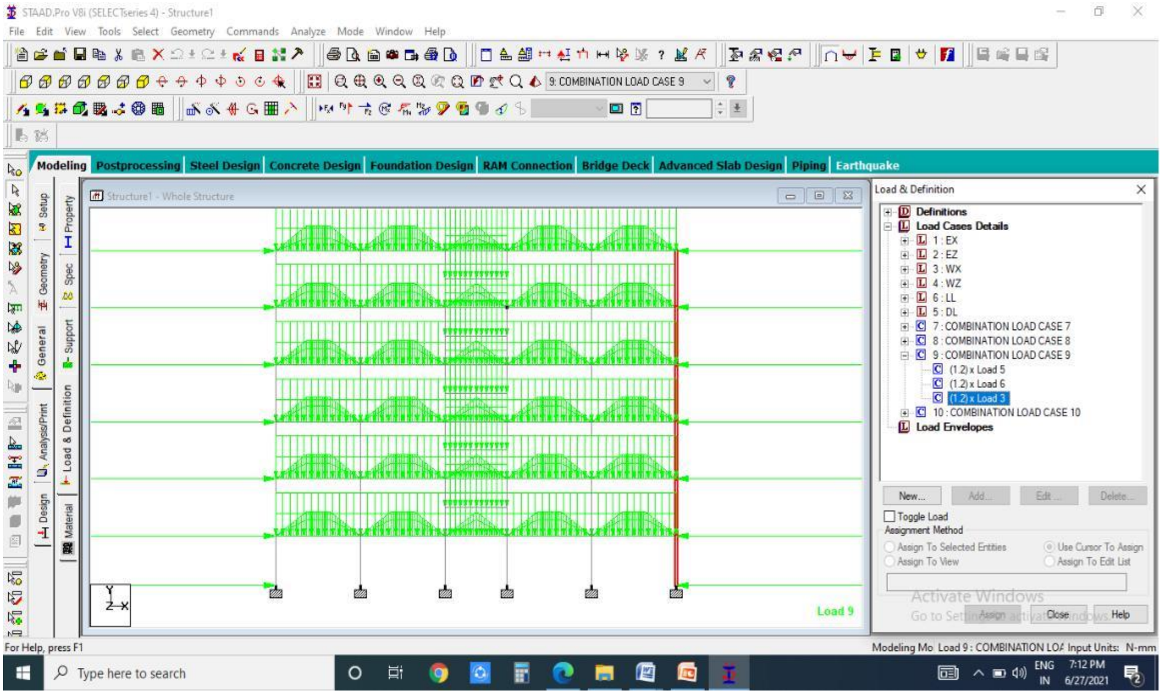


Figure 3.12: Combination under wind load

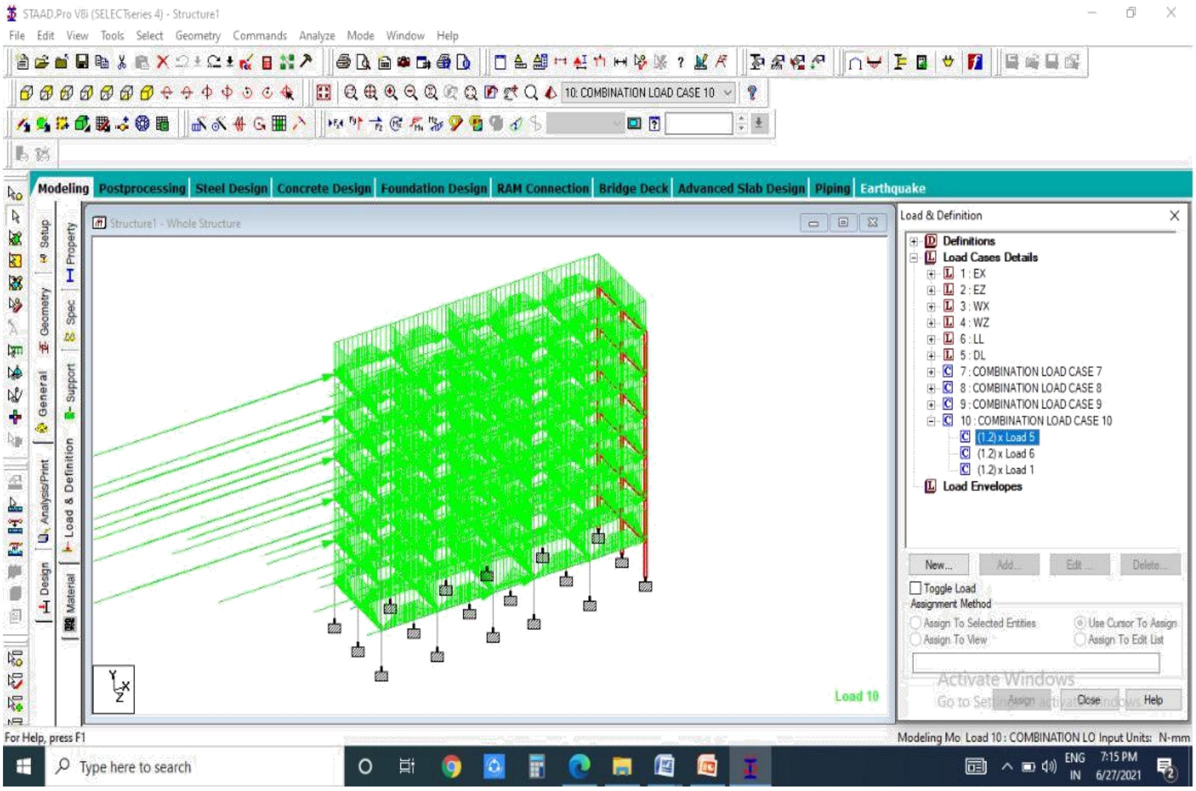


Figure 3.13: Combination under seismic load

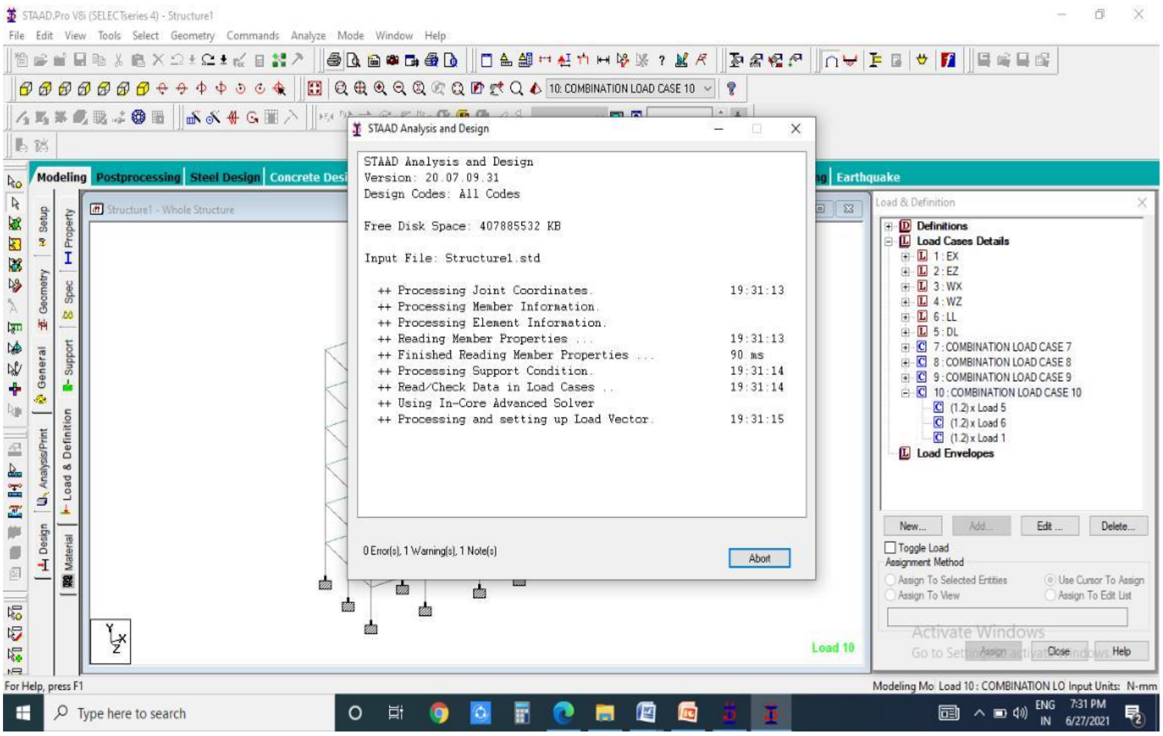


Figure 3.14: showing the analyzing window

Design of G+5 RCC Bulding
Beam Design

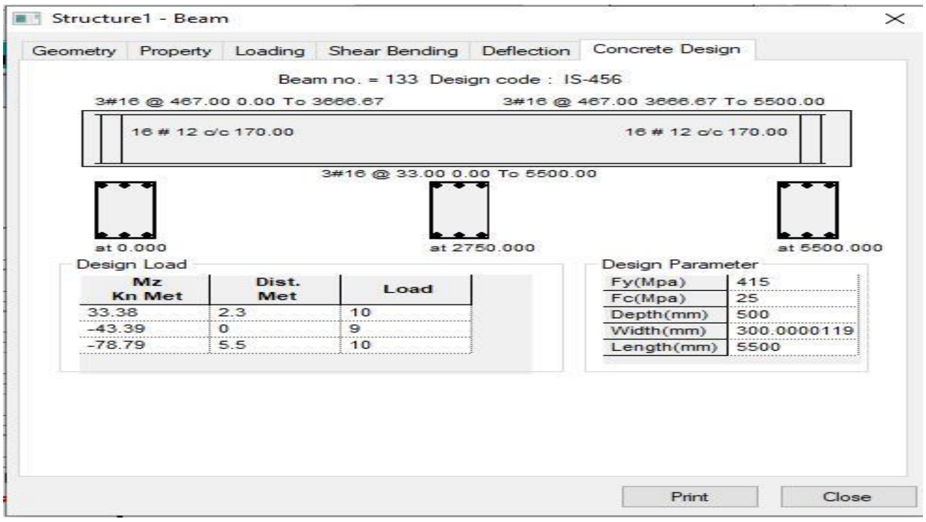
The beam is designed in Staad.pro software by using IS code 475

There are two types of reinforced concrete beams

1. Single reinforced beams 2. Double reinforced beams.

1. Single reinforced beams: In singly reinforced simply supported beams steel bars are placed near the bottom of the beam where they are effective in resisting in the tensile bending stress.

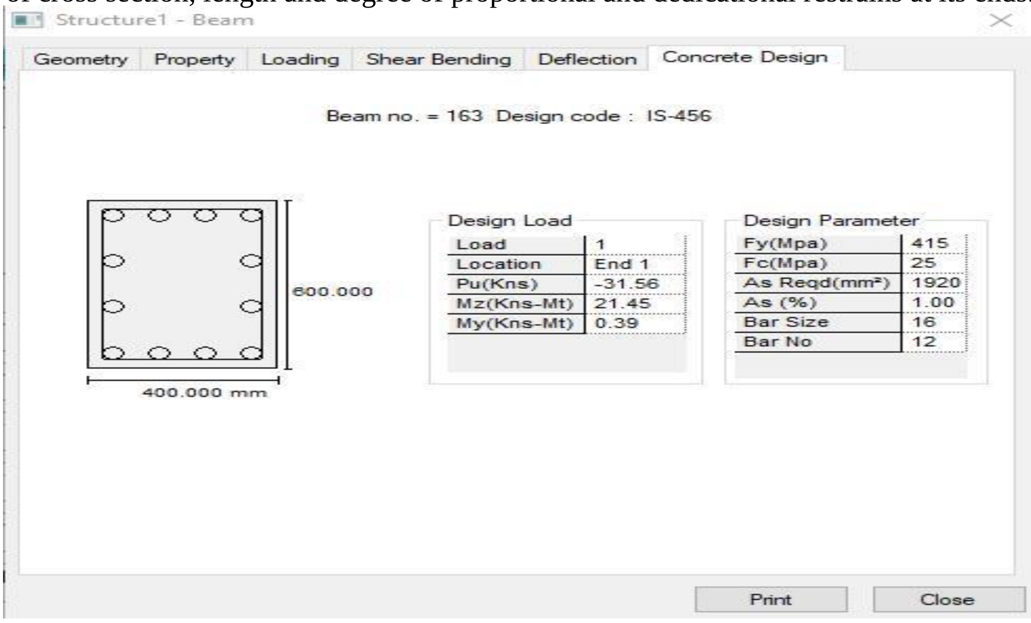
2. Double reinforced beams: It is reinforced under compression tension regions. The necessities of steel of compression region arise due to two reasons. When depth of beam is restricted. The strength availability singly reinforced beam is in adequate.



Mz Kn Met	Dist. Met	Load
33.38	2.3	10
-43.39	0	9
-78.79	5.5	10

Fy(Mpa)	415
Fc(Mpa)	25
Depth(mm)	500
Width(mm)	300.0000119
Length(mm)	5500

Column Design
A column may be defined as an element used primarily to support axial compressive loads and with a height of a least three times its lateral dimension. The strength of column depends upon the strength of materials, shape and size of cross section, length and degree of proportional and dedicational restrains at its ends.



Load	1
Location	End 1
Pu(Kns)	-31.56
Mz(Kns-Mt)	21.45
My(Kns-Mt)	0.39

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm²)	1920
As (%)	1.00
Bar Size	16
Bar No	12

Figure 3.16: Column Design

ANALYSIS RESULTS

Some of the sample analysis results have been shown below for beam number 64 which is at the roof level of 1st floor

Figure 4.1: Geometry of beam no.133

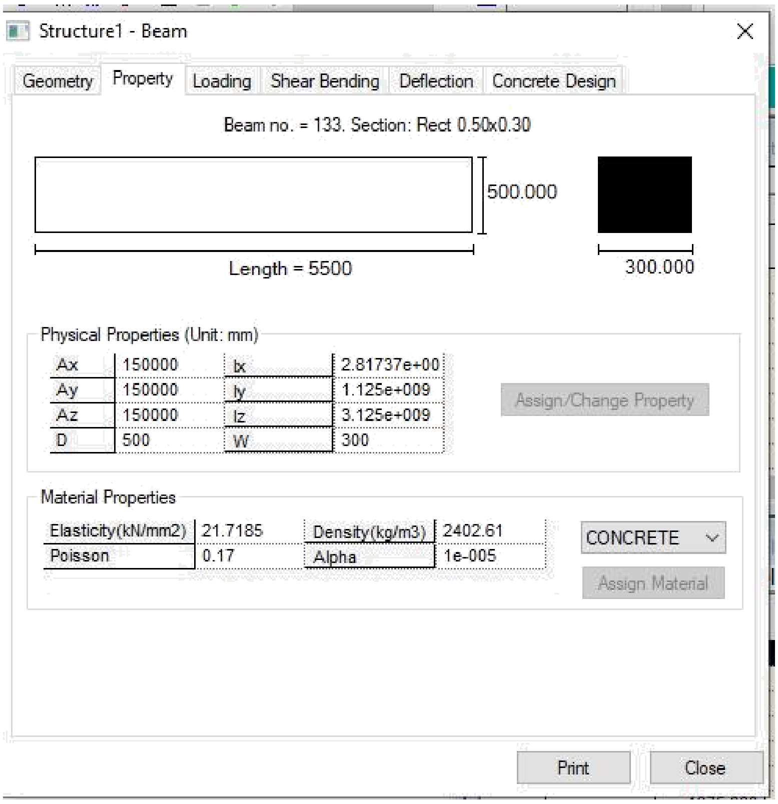


Figure 4.2: Property of beam no.133

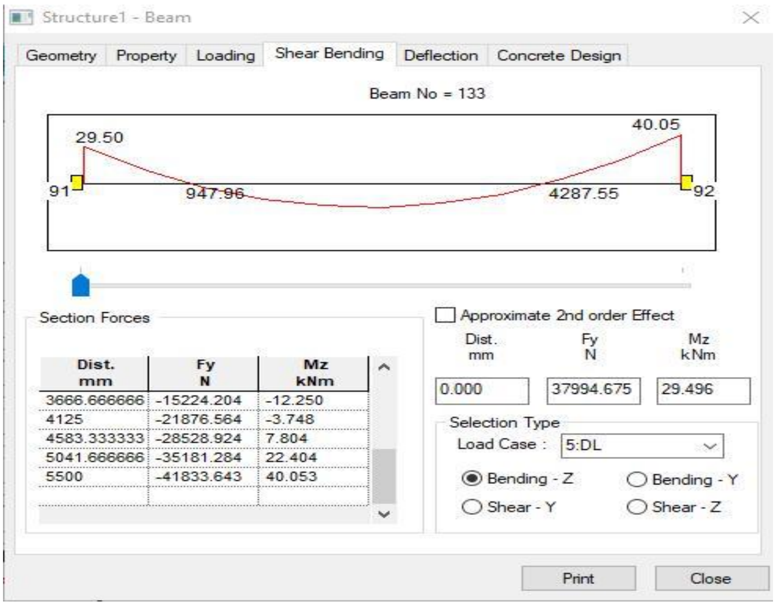


Figure 4.3: Shear bending of beam no.133

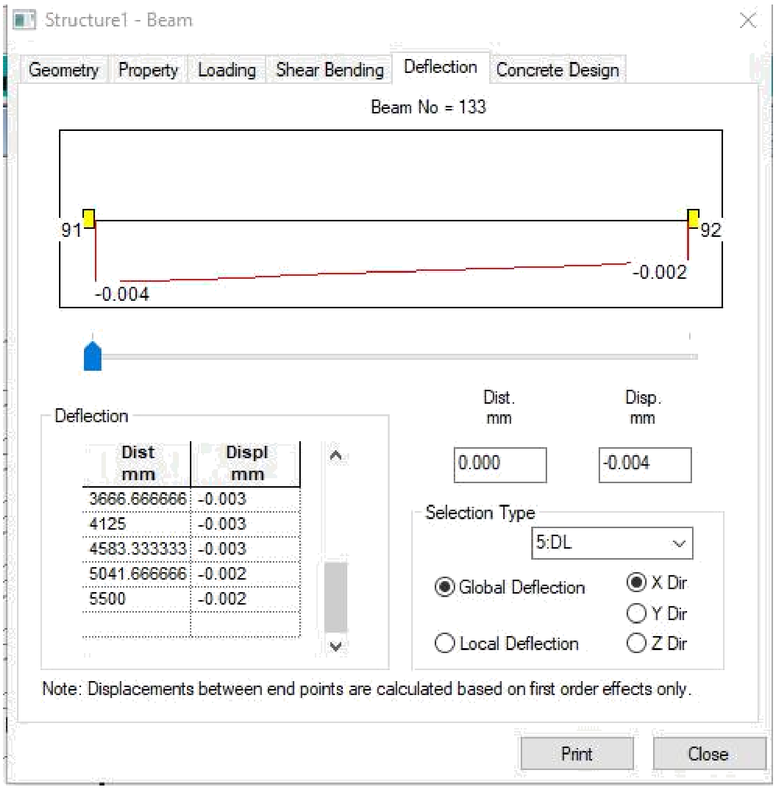


Figure 4.7: Shear bending of column no.163

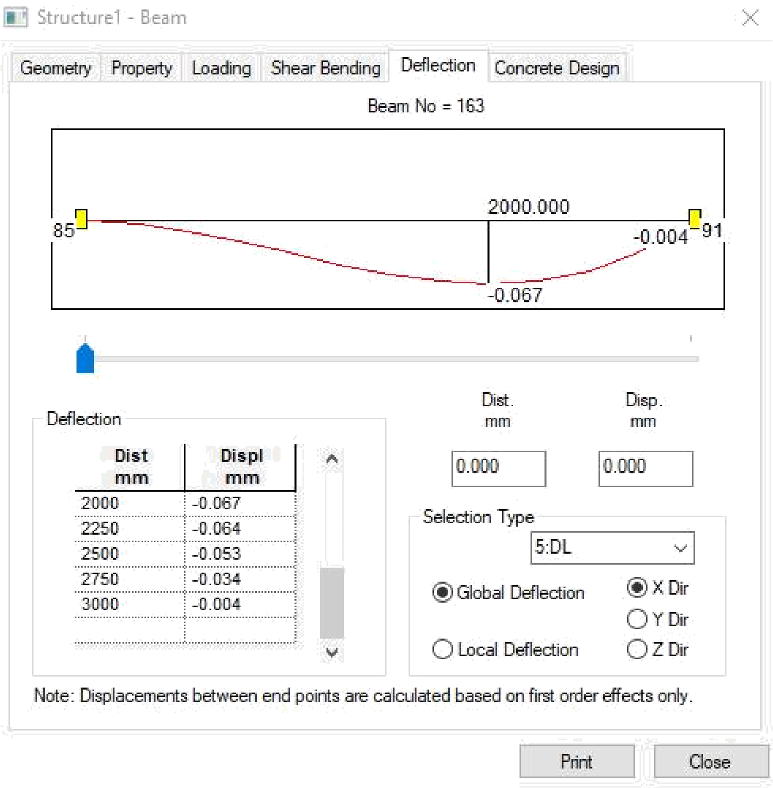


Figure 4.8: Deflection of column no.163

POST PROCESSING MODE

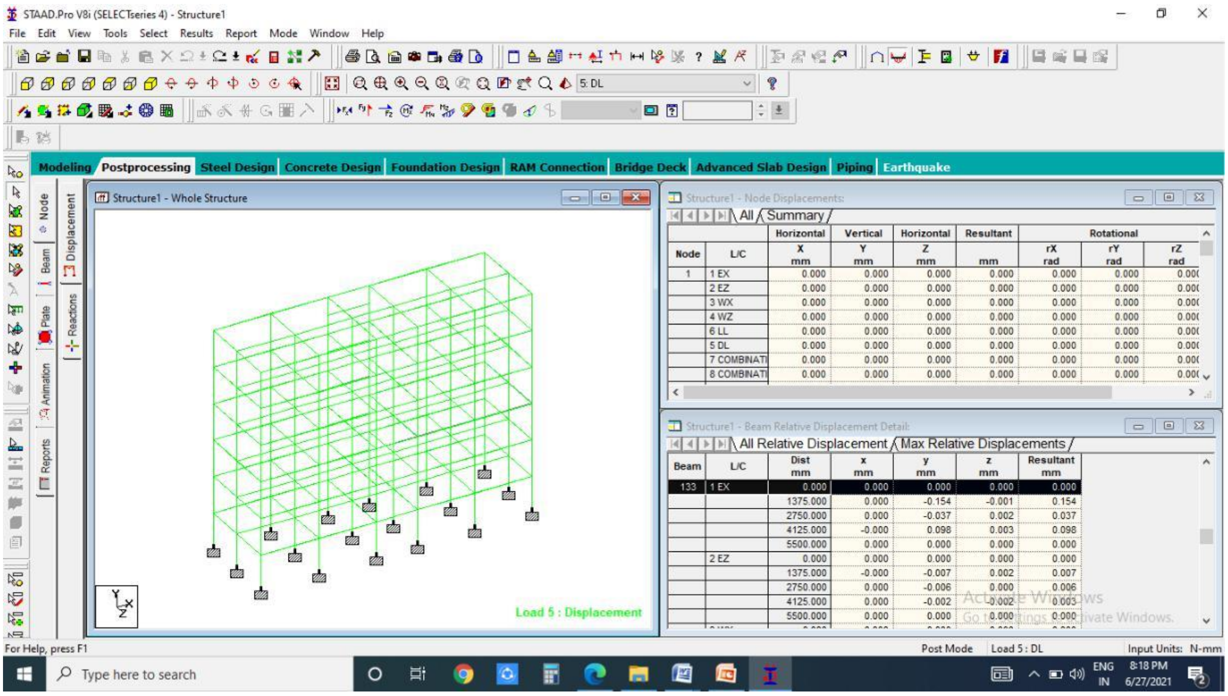


Figure 4.9: Post processing mode in STAAD.pro

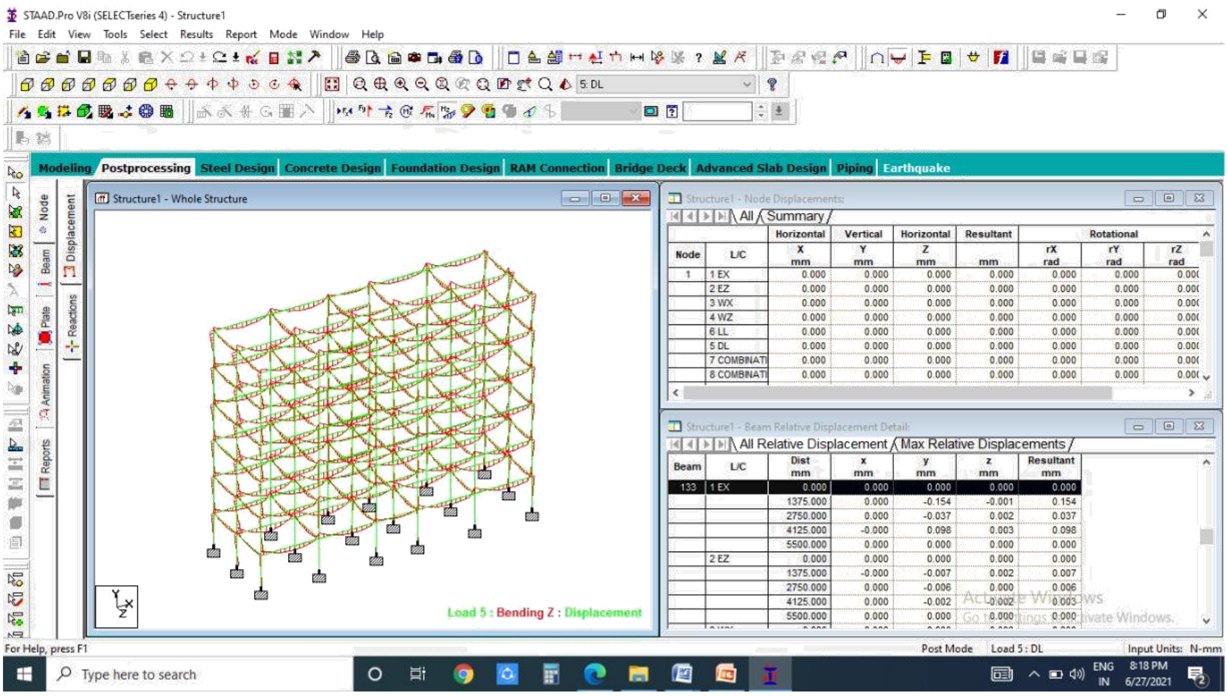


Figure 4.10: Bending in Z

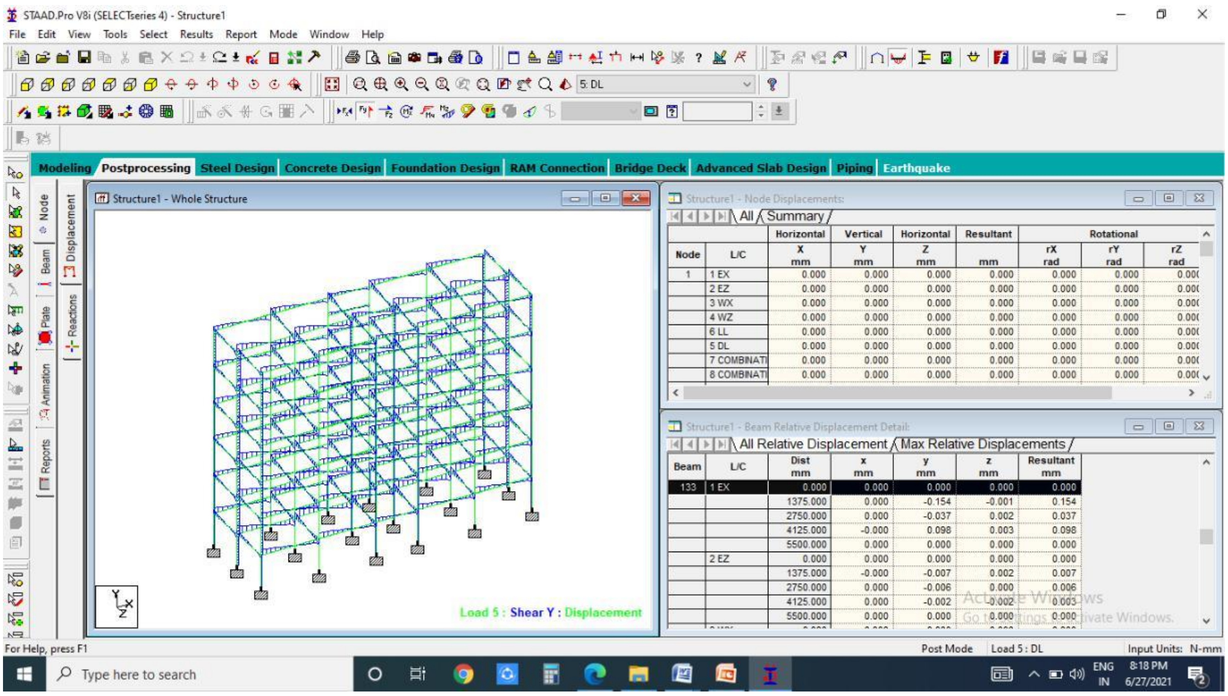


Figure 4.11: Shear force in Y

CONCLUSIONS

By Using STADD Pro., analysis and design of multistory building is easier and quick process than manual process. Proposed size of the beam and column can be safely used in the structure. The structure is safe in shear bending and Deflection. There is no hazardous effect on the structure due to wind load and seismic load on the structure. The structure we taken is stable and structurally defined using various loads and combination. The Deflection value is more in WL (Wind Load) combination than the SL (Seismic Load) combination. To know the behavior of the structure by applying various loads like dead load, live load, wind load and seismic load by using staad.pro. And also find out the Shear forces, displacement, bending and reactions of structure. By using staad.pro ,we performed dynamic analysis. So that, the results obtained in staad.pro is more effective as compared to analysis and design performed by theoretical method.

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6. IS 456-2000, Design of RCC elements

7. IS 1893(part 1):2002 - for earthquake design