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Analysis and Design of (G+5) Residential Building Building by Using Staad Pro

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ABSTRACT :

The analysis and design of a (G+5) residential building by using STAAD PRO software. The project Focuses on the structural design of the building, ensuring it meets safety, stability, and functionality requirements While complying with local building codes and standards STAAD PRO is employed to model the structure,Perform dynamic and static load analyses, and generate detailed design outputs for structural elements likeBeams, columns, slabs, and foundations. The software's advanced capabilities, such as automated load Combinations and optimization features, streamline the design process, enhancing both accuracy and efficiency. The design is optimized for material usage, minimizing costs while maintaining safety and performance. The Study demonstrates the critical role of STAAD Pro in modern residential building design, offering a reliable, approach to ensuring the structural integrity of multi-story buildings in urban environments. The design Is made using software on structural analysis design STAAD pro. The load consists of dead load IS 875 part-1, Live load IS 875 part-2 and sesmic load as per IS 1893-2002. The building is designed as two-dimensional Vertical frame and Analyzed for the maximum and minimum bending moments and shear forces as per IS 456-2000, The help is taken by software available in institute and the Computations of loads, moments and shear forces and obtained from this software.

Keywords : STAAD Pro, Residential Building, IS Standards.

1. INTRODUCTION

The core aim of building planning is to arrange all units on all floors efficiently, considering their functional requirements and making optimal use of available space. The layout is influenced by factors such as climate, site location, accommodation needs, local by-laws, and surroundings. Despite these, certain universal planning principles guide all residential structures:

Key Planning Principles

1. Aspect
   Aspect refers to the placement of doors and windows to optimize sunlight, breeze, and views for comfort and hygiene. Preferred aspects:
   Kitchen – East €
   Dining Room – South (S)
   Living/Drawing Room – South or South-East (S or SE)
   Bedroom – South-West or West (SW or W)
   Verandah – SW or W (with shading)
   Reading rooms, stairs, studios, etc. – North (N)
2. Prospect
   The visual impression from outside. Proper door and window placement enhances appearance and hides undesirable views.
3. Privacy
   Internal – Achieved by grouping, door arrangement, lobbies, screens, etc.
   External – Achieved by entry planning, landscaping, and barriers like trees or trellises.
4. Grouping
   Logical arrangement of rooms based on function and proximity. E.g., kitchen near dining but away from the living room; services near bedrooms.

5. Roominess
   Maximum space utility with minimal dimensions, avoiding cramped designs while ensuring storage and functionality.
6. Furniture Requirements
   Planning must accommodate furniture and fixtures. Circulation space and door/window placement should allow flexible furniture arrangement.
7. Sanitation
   Light – Natural light is preferred. Min window area: 1/10 of floor (1/5 for schools, etc.).
   Ventilation – Natural or mechanical, ensures fresh air and prevents discomfort.
   Cleanliness & Conveniences – Dust prevention, easy-to-clean surfaces, proper slope and drainage. Sanitary facilities are mandatory.
8. Flexibility
   Spaces should be usable for multiple purposes, especially in budget-conscious or middle-class homes.
9. Circulation
   Horizontal – Corridors, halls, lobbies
   Vertical – Stairs, lifts, ramps
10. Elegance
    Aesthetic appearance through well-designed elevations that reflect the interior plan. Should be developed with the layout and be attractive within budget limits.
11. Economy
    Budget influences planning. While aspect and grouping must remain unaffected, minor compromises in prospect can be made. Economy should not compromise safety or utility.

2.LITERATURE REVIEW

1.Sreeshna K.S (2016) this paper deals with structural analysis and design of G+4 storied Apartment building. The work was completed in three stages. The first stage was three dimensional Models and scrutiny of building and the second stage was to design the structural elements and The final was to detail the structural elements. In this project STAAD.Pro software is used for Analysing the building. The IS:875 (Part 1) and (Part 2) were referred for dead load and live load. Design of structural elements like beam, column, slab, staircase, shear wall, retaining wall, pile Foundation is done according to IS Codes.

2.Amar Hugar et al., (2016) has been discussed that the Computer Aided Design of Residential Building involves scrutiny of building using STAAD.Pro and a physical design of the Structure. Traditional way of study shows tedious calculations and such tests is a time-consuming Task. Analysis are made quickly by using software's. This project completely deals with scrutiny Of the building using the software STAAD.Pro. Finally, the results are compared with physical Calculations. The elements are created as per IS:456-2000.

3.SOFTWARES

STAAD Pro

- STAAD (Structural Analysis and Design) is a powerful software by Bentley Systems used for structural analysis and design.
- A structure Is any object that remains stable under load.
- Analysis Phase: Involves identifying loads on members and calculating shear forces and bending moments.
- Design Phase: Involves selecting materials and dimensions to resist the analyzed loads.
- Manual analysis of complex beams can take hours or days; buildings with many members may take weeks.
- STAAD Pro automates and accelerates this process, completing in hours what would normally take much longer.
- Especially useful for high-rise and complex structures.

AutoCAD

AutoCAD is a CAD software developed by Autodesk for 2D and 3D drafting and design. Before CAD, drafting was done manually using tools like drafting boards, compasses, and inking pens. Since its launch in 1982, AutoCAD has become the most widely used CAD software globally.

Key Features:

- 2D drafting and 3D modeling
- Free-form design tools
- Intelligent documentation
- 3D rendering and animations
- Autodesk also offers discipline-specific variants:
- AutoCAD Architecture, Civil 3D, Electrical, Map 3D, Mechanical, Plant 3D, MEP, P&ID, and AutoCAD

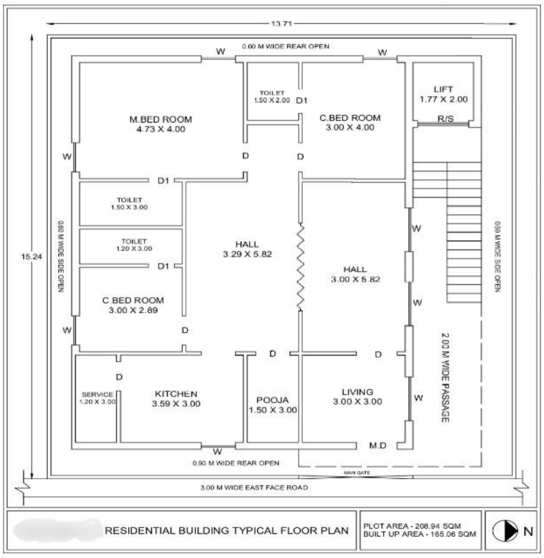
4.PLANANDELEVATION

Plan:

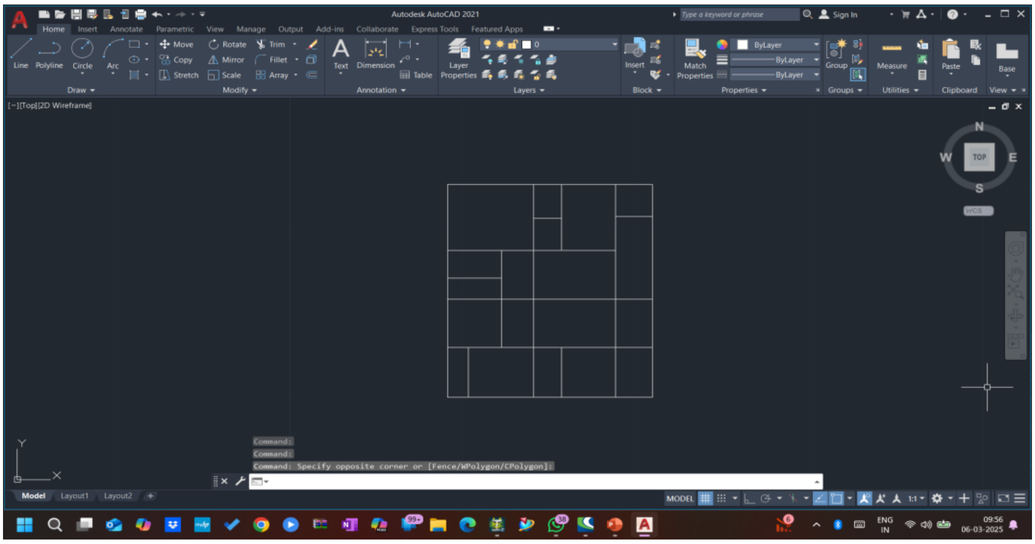
The AutoCAD Plot No.1 represents the plan of a G+5 apartment building located in Gachibowli, Hyderabad, an area surrounded by many other residential buildings. The plan shows a total of four blocks, each with a single three-bedroom flat per floor, making five flats per block. All flats follow a similar layout, clearly indicating the orientation and dimensions of each room such as bedrooms, bathrooms, kitchen, and hall. The total plan area is 208.94 square meters, with a built-up area of 165.06 square meters, and space around the building is reserved for car parking. The plan also includes furniture arrangements and the location of staircases, with one staircase provided per block, as detailed in AutoCAD Plot No.3. At the center of the building is a small structure containing four lifts, which is a mandatory feature for buildings above G+5 floors. This central area also includes a clubhouse for residents' recreational activities, and maintenance charges are collected monthly. Although the building is still under construction, it is a multi-storied structure designed for commercial use.

Centerlineplan:

The centerline diagram of our building in STAAD Pro. Each support indicates the location of a column in the structure. Using the "Translational Repeat" and "Link Steps" tools, this layout is extended to form the full structural model. The resulting skeletal structure, shown below, is used for analysis under various loading conditions in STAAD Pro. While not the actual building, this model outlines the structural framework. A mesh is automatically generated for the analysis.



AUTO CAD PLAN



Centerline plan layout

5.LOAD CONSIDERATIONS

DEAD LOAD:

Dead loads are the permanent loads from construction materials such as roofs, floors, walls, foundations, claddings, finishes, and fixed equipment. These loads, which do not change over time, include components like steel columns, concrete floors, bricks, and roofing materials. In STAAD Pro, dead loads are assigned automatically using the member properties. By selecting the "Self-Weight" option in the load case, the software calculates the weight based on material density. Once applied, the skeletal structure appears red.

Dead load is calculated using the formula:

Dead Load = Volume of Member x Unit Weight of Material

These calculations follow IS 875 Part 1 standards.

IMPOSED LOAD:

Live loads are generated by the use and occupancy of a building. These include loads from people, furniture, movable equipment, storage, and activities like construction or maintenance. They are typically defined as uniform area loads, concentrated loads, or uniform line loads. Note that uniform and concentrated live loads should not be applied simultaneously during structural evaluation. Concentrated loads must be applied over small areas to simulate real-world usage, such as a 300-pound stair load applied at the center of a stair tread.

In STAAD Pro, live loads are applied as Uniformly Distributed Loads (U.D.L). A load case must be created, and the relevant beams are selected to carry this load. After assignment, the structure reflects the applied live load visually. For our structure, a live load of 25 N/mm is considered for design, following IS 875 Part 2 standards.

SEISMIC LOAD:

The design lateral force is first calculated for the entire building and then distributed to each floor level. At every floor, this force is further distributed to individual lateral load-resisting elements, assuming the presence of a rigid floor diaphragm.

Design Seismic Base Shear (Vb):

The total design lateral force (base shear) along any principal direction is calculated using IS 1893:2002. STAAD.Pro provides a seismic load generator aligned with this code.

Step-by-Step Procedure for Seismic Load Calculation:

1. Calculate Weights: Determine the weight of each floor and the total weight of the structure.
2. Fundamental Time Period (T):

Use: T = 0.075h^0.75 (as per IS 1893:2002, Clause 7.6.1),

Where h = height of the building in meters.

3. Determine Parameters:

Zone factor (Z), Importance factor (I), Response reduction factor ®, and damping ratio.

4. Horizontal Seismic Coefficient (Ah):

Calculated using the formula provided in the IS code.

5. Base Shear (Vb):

Vb = Ah × W, where W is the total seismic weight of the structure.

6. Lateral Force Distribution:

Distribute the base shear to each floor based on mass and height.

7. Member-Wise Distribution:

Distribute lateral forces to members using their relative stiffness.

Design Considerations:

The building is located in Seismic Zone II, so Zone Factor (Z) = 0.1.

Importance Factor (I) = 1.0 (Institutional Building).

Infill walls with large openings are accounted for by assuming solid wall behavior in calculations.

6.DESIGN OF RESIDENCIAL BUILDING

DESIGN OF BEAMS:

Beams transfer loads from slabs to columns and are primarily designed to resist bending. In STAAD Pro, beams are assigned geometry and perimeter properties similar to columns. After defining the design parameters and running the analysis, reinforcement details are obtained.

Types of Reinforced Concrete Beams:

1. **Singly Reinforced Beams:**

Used in simply supported beams, where steel bars are placed at the bottom to resist tensile bending stresses. For cantilever beams, the reinforcement is placed at the top for the same reason.

2. **Doubly Reinforced Beams:**

Reinforcement is provided in both tension and compression zones. This type is used when:

- Beam depth is restricted.
- Singly reinforced section is insufficient to carry the load.
- In continuous beams where bending moments change signs or for special shapes like circular beams.

Design Process:

- Assign beam geometry.
- Use the Design Beam command in STAAD Pro.
- Analyze the structure.
- Extract reinforcement details manually or from the software.
- Figures accompanying this explanation may include:
- Reinforcement detailing at different sections.
- Beam deflection diagrams.
- Bending moment distribution.

DESIGN OF COLUMN:

A column (or strut) is a vertical compression member primarily designed to support axial loads. It must have a height at least three times its least lateral dimension. A reinforced concrete (RC) column is considered axially loaded when the resultant thrust aligns with the column's longitudinal centroid.

Columns may come in various shapes depending on architectural and structural needs—commonly square, rectangular, circular, hexagonal, or octagonal. L- and T-shaped columns may also be used in multi-story buildings.

Columns are vertical compression members critical for load transfer. The failure of a column can lead to structural collapse. Classification is based on:

Shape: Rectangular, Circular, Polygonal

Slenderness: Short (Leff/D < 12), Long (Leff/D > 12)

Loading: Axial, Uniaxial, Biaxial

Reinforcement Type: Tied or Spiral

IS Code Provisions:

Minimum eccentricity: e > (l/500 + D/30) or 20 mm

Longitudinal Steel: 0.8%–6% of gross area, minimum 12 mm dia, spacing ≤ 300 mm

Lateral Ties: Dia ≥ 6 mm or $1/4^{th}$ of largest longitudinal bar; pitch ≤ least lateral dimension or 16 × dia of smallest longitudinal bar or 300 mm

DESIGN OF SLABS:

Slabs are plate elements forming the floors and roofs of buildings, primarily carrying distributed loads by flexure. They are classified into two types:

1. One-Way Slab
2. Two-Way Slab

One-Way Slab

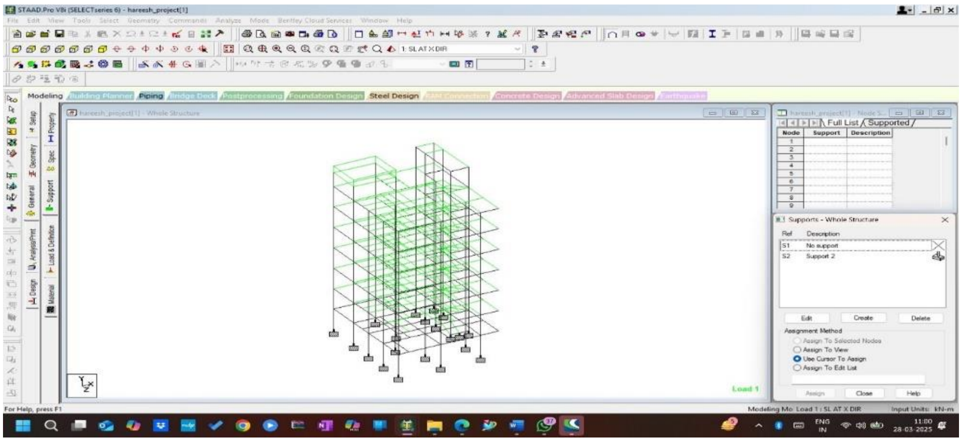
- ✓ Supported on two opposite sides.
- ✓ Load is carried in one direction only.
- ✓ Designed as one-way when ly/lx > 2.
- ✓ Main reinforcement is placed along the shorter span (direction of load).
- ✓ Secondary reinforcement is added transversely for temperature, shrinkage, and load distribution.

Two-Way Slab

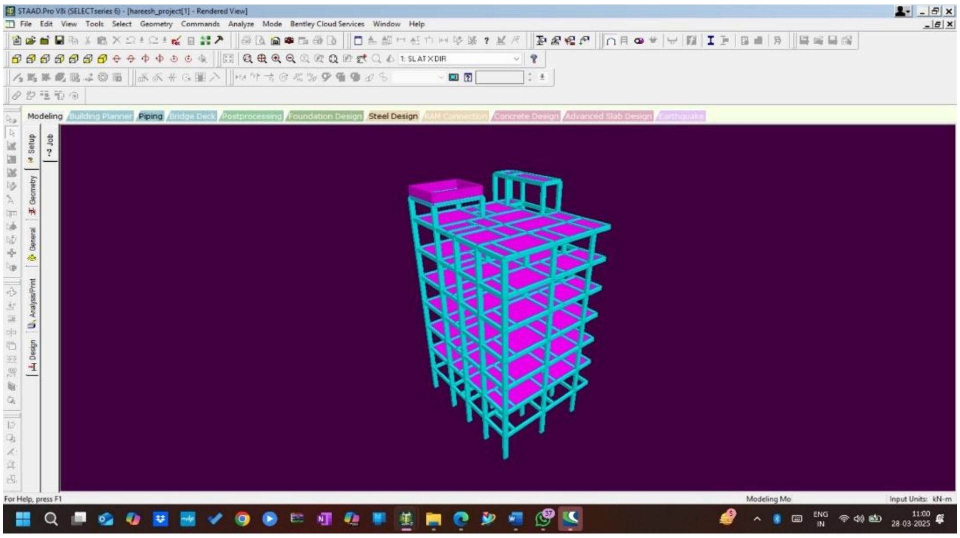
- ✓ Supported on all four sides.
- ✓ Load is carried in both directions (two-way action).
- ✓ Reduces deflections and bending moments compared to one-way slabs.

DESIGNPARAMETERS

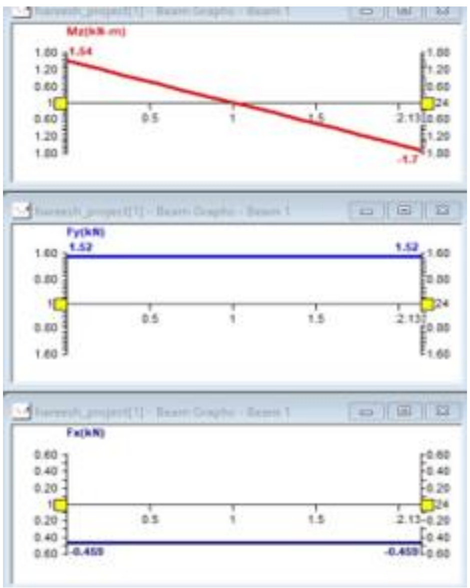
- Concrete Design IS Grade of Concrete(fc) :- M 25
- Grade of primary Steel (fy main) :- Fe 500
- Grade of Secondary Steel(fy sec) :- Fe415
- Maximum Diameter of Main Bars (max main) :- 25MM
- Minimum Diameter of Main Bars (min main):- 10MM
- Maximum Diameter of Secondary Bars (max sec) :- 12MM
- Minimum Diameter of Secondary Bars (min sec):- 8MM



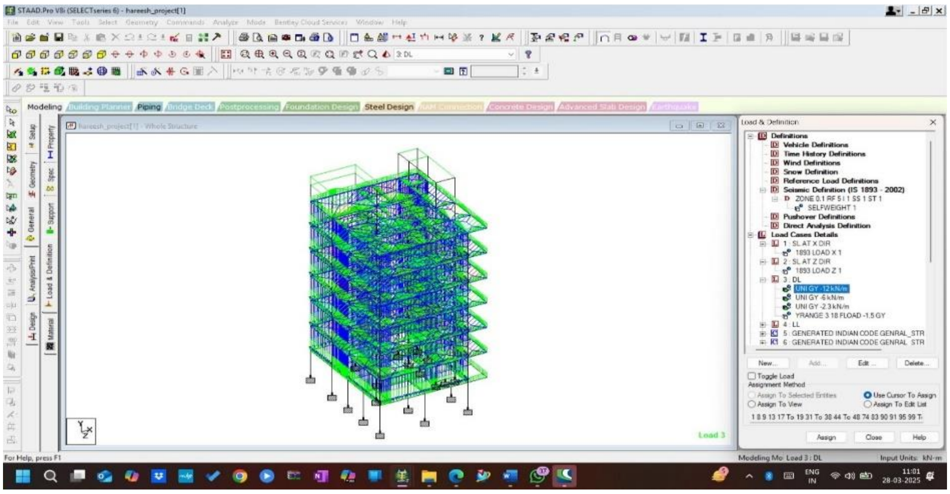
3D Modeling with fixed supports



3D Rendering of the structure



Shear Bending of beam



Dead load is applied

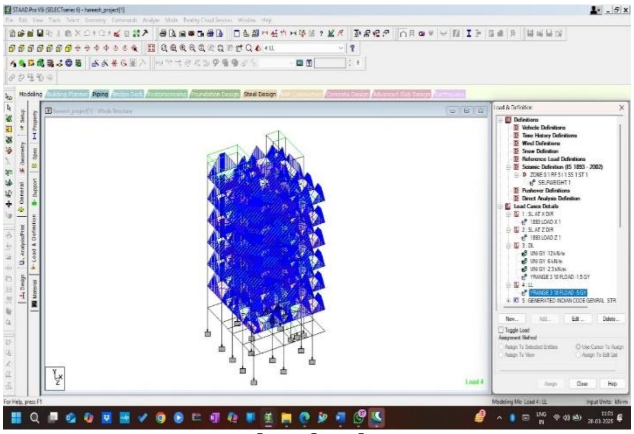
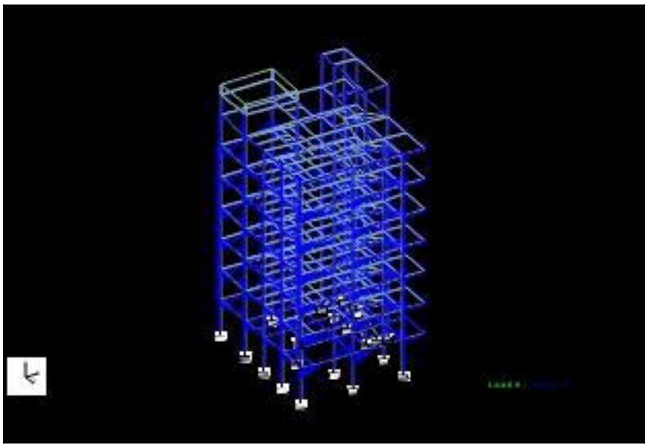
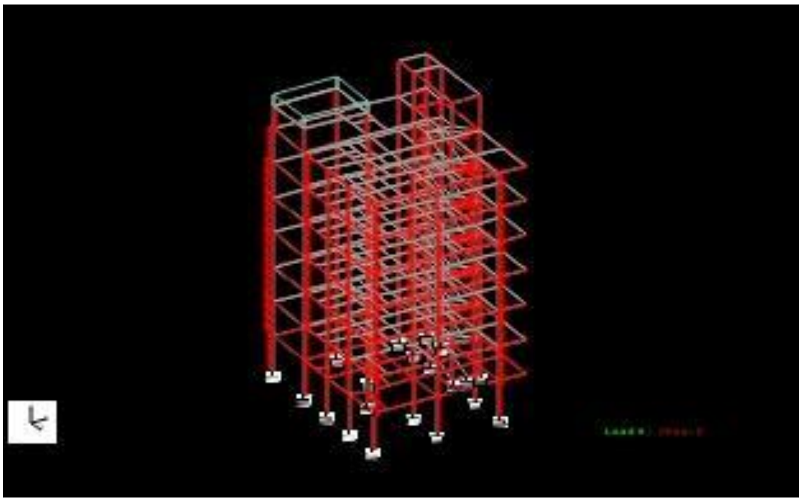


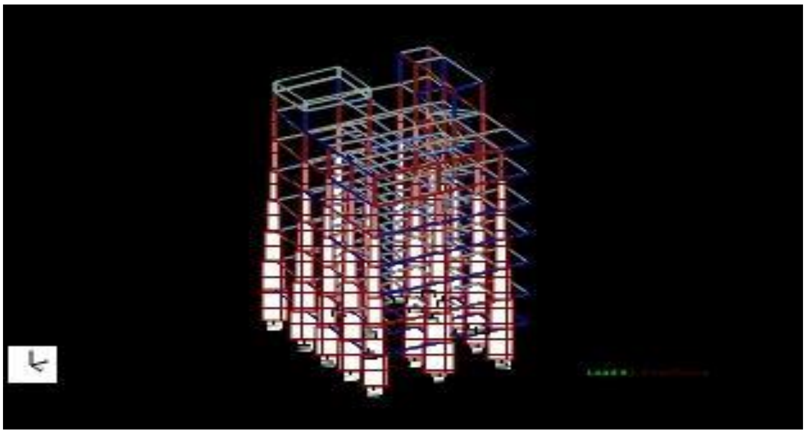
Plate load



shear force in Y Direction



shear force in Z Direction

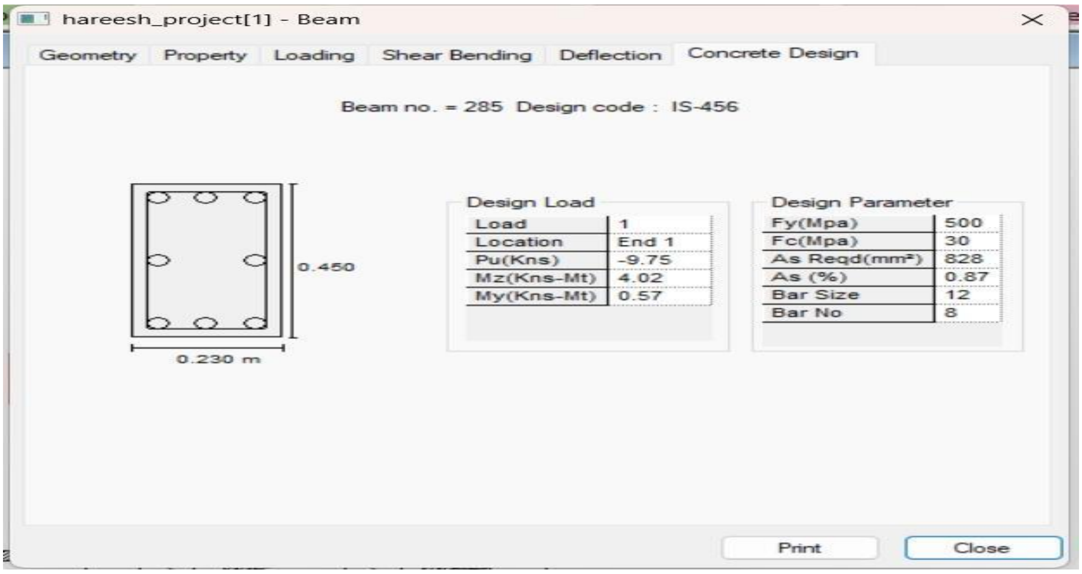


Displacement structure

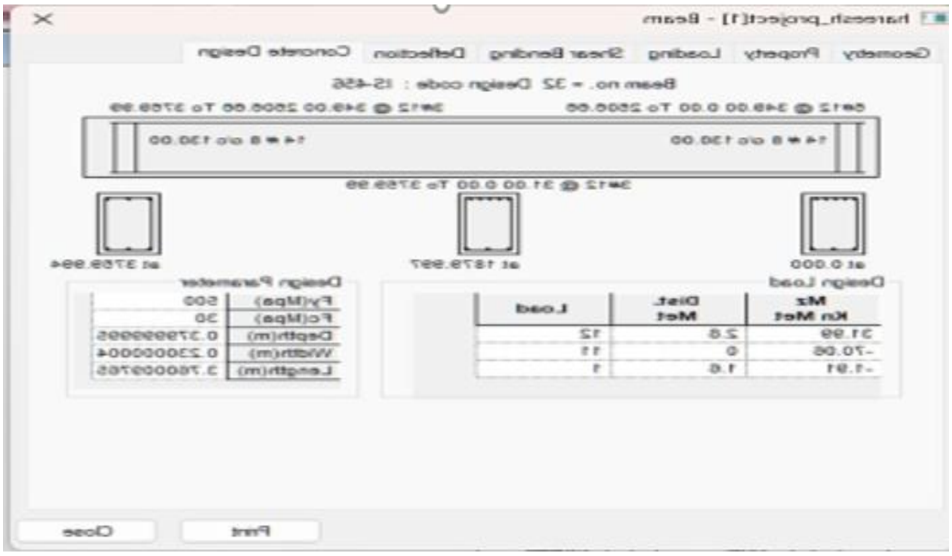
RESULTS

	Plate	L/C	Shear		Membrane			Bending Moment		
			SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kN-m/m	My kN-m/m	Mxy kN-m/m
Max Qx	534	12 GENERAT	0.080	0.000	-0.016	0.000	0.010	-2.857	-0.885	0.406
Min Qx	534	18 GENERAT	-0.072	0.007	-0.007	-0.028	-0.007	2.264	0.482	-0.189
Max Qy	587	13 GENERAT	-0.007	0.062	0.000	0.002	-0.001	-0.160	-2.918	0.416
Min Qy	571	11 GENERAT	-0.005	-0.040	0.000	-0.002	0.003	0.659	0.486	-0.268
Max Sx	536	16 GENERAT	-0.018	0.004	0.239	0.012	0.018	0.360	-0.334	-0.981
Min Sx	82	14 GENERAT	0.006	-0.001	-0.252	-0.017	0.000	-0.419	-0.053	1.422
Max Sy	535	18 GENERAT	-0.001	-0.023	0.003	0.227	0.002	0.113	-0.332	1.228
Min Sy	81	12 GENERAT	-0.009	0.022	-0.016	-0.289	-0.034	-0.425	-0.054	-0.709
Max Sx	563	12 GENERAT	0.017	0.002	0.007	0.001	0.037	1.777	-0.794	-0.347
Min Sx	81	12 GENERAT	-0.009	0.022	-0.016	-0.289	-0.034	-0.425	-0.054	-0.709
Max Mx	534	18 GENERAT	-0.072	0.007	-0.007	-0.028	-0.007	2.264	0.482	-0.189
Min Mx	534	12 GENERAT	0.080	0.000	-0.016	0.000	0.010	-2.857	-0.885	0.406
Max My	599	12 GENERAT	-0.012	0.059	-0.001	0.004	0.003	0.132	2.777	0.022
Min My	602	13 GENERAT	0.003	0.056	0.000	-0.000	0.000	-0.007	-3.771	1.056
Max Mx	82	14 GENERAT	0.006	-0.001	-0.252	-0.017	0.000	-0.419	-0.053	1.422
Min Mx	535	12 GENERAT	0.004	0.018	-0.018	-0.275	0.000	-0.199	0.770	-1.533

Member End Forces



Reinforcement Details of column



Reinforcement Details of beam

7.CONCLUSION

- Modeling: G+5 building structure modeled in STAAD Pro with accurate geometry and member properties.
- Load Application: Applied dead load, live load, wind load, and seismic load as per IS codes.
- Code Compliance: Design performed in accordance with IS 456:2000, IS 875, and IS 1893:2016.
- Structural Analysis: STAAD Pro conducted automatic analysis for moments, shear forces, axial forces, and deflections.
- Design of Members: Efficient and safe design of beams, columns, slabs, and footings.
- Optimization: Structural components were optimized for strength, stability, and economy.
- Deflection & Serviceability: Deflections were within permissible limits; structure meets serviceability criteria.
- Reinforcement Detailing: Provided as per design requirements and code recommendations.
- Software Efficiency: STAAD Pro increased design accuracy, reduced manual work, and saved time.
- Result: Safe, economical, and code-compliant design of the G+5 residential building.

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