Study on the G+5 Building with Different Plan Irregularities by Staad Pro

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Abstract - This study explores the structural analysis, design, and material optimization of a G+5 residential building in Hyderabad, conforming to Indian Standard codes. Using STAAD.Pro, the analysis incorporates critical load conditions, including live, floor finish, wind, and seismic loads, following IS 875 and IS 1893 provisions. The foundation design employs isolated footings tailored to medium soil conditions, ensuring safe bearing capacity and structural stability.

Material optimization focuses on efficient use of M25 grade concrete and Fe 415 steel, providing cost-effective solutions while maintaining safety and serviceability. Key structural parameters, such as building height, column and beam dimensions, and slab and wall thicknesses, are accurately modeled to align with IS 456 standards. The design integrates modern structural engineering techniques to address static and dynamic loads, ensuring resilience against environmental stresses.

This study underscores the importance of combining advanced analysis tools with code-compliant design principles, contributing to sustainable, economical, and safe construction practices for urban infrastructure in challenging environments.

Keywords: STAAD.Pro, G+5 Residential Building, Structural Design, Material Optimization, Indian Standard Codes, IS 456, IS 875, IS 1893, Foundation Design, M25 Concrete, Fe 415 Steel, Sustainable Urban Development.

1.INTRODUCTION

STAAD.Pro, developed by Bentley Systems, is a leading software for structural analysis and design, offering advanced tools for analyzing and designing a variety of structures, such as buildings, bridges, towers, and industrial facilities. Known for its user-friendly interface and powerful analysis capabilities, STAAD.Pro supports a wide range of materials, including steel, concrete, aluminum, and timber, adhering to international design codes for safety and precision.

The software features robust finite element analysis (FEA) tools and dynamic analysis capabilities, making it ideal for addressing complex engineering challenges. Its integrated visualization tools enable engineers to build, analyze, and validate structural models efficiently. Additionally, STAAD.Pro facilitates seamless integration with STAAD.Foundation for foundation design, enhancing its utility in projects that demand diverse structural solutions.

Engineers benefit from its ability to model and analyze structures for various load conditions, such as dead loads, live loads, wind loads, and seismic effects. The software supports optimization and documentation, allowing for precise adjustments and improved designs. With features like international section profile libraries and integration with AutoCAD, STAAD.Pro offers flexibility for global design applications.

As the backbone of many civil engineering projects, STAAD.Pro ensures compliance with safety standards while reducing the time and effort required for manual calculations, making it indispensable for modern structural engineering tasks.

1.2SCOPE OF THE WORK

While STAAD.Pro is extensively utilized for designing G+5 buildings, certain critical areas warrant deeper investigation. Advanced dynamic analysis for seismic resilience, especially under medium soil conditions, remains insufficiently addressed. The optimization of material usage, crucial for cost-sensitive projects, requires further exploration, particularly concerning alternative wall materials like AAC blocks and traditional bricks under varied loading conditions.

Additionally, the structural performance of irregular plan layouts and non-uniform load distributions has not been comprehensively analyzed, limiting insights into complex designs. Sustainability metrics, including the reduction of carbon footprints and integration of environmentally friendly practices, such as precast construction methods, are minimally incorporated into current research. Finally, there is limited validation of design models against real-world scenarios, which is essential for bridging the gap between theoretical designs and practical applications. Addressing these gaps would enhance the versatility and reliability of STAAD.Pro for modern engineering challenges

1.3 OBJECTIVES

1.Structural Analysis and Design

Analyze and design a G+5 residential building in Hyderabad using STAAD.Pro software.

Incorporate live loads, floor finish loads, wind loads (as per IS 875:1987), and seismic loads (as per IS 1893:2002).

2.Foundation Design

Design isolated footings with a minimum thickness of 305 mm, ensuring compliance with Type II medium soil conditions.

Verify that the allowable bearing pressure of 200 kN/m² is not exceeded as per IS 1893:2002.

3.Material Optimization
Calculate and optimize the required quantities of M25 grade concrete and Fe 415 steel for structural elements.
Provide cost-effective and safe reinforcement solutions for columns, beams, slabs, and footings.
4.Code Compliance Validation
Ensure that the design complies with IS 456:2000, IS 875:1987, and IS 1893:2002 for structural stability, strength, and serviceability.
Verify the design under both static and dynamic loading conditions to meet prescribed safety standards.

2.Auto CAD Building plan

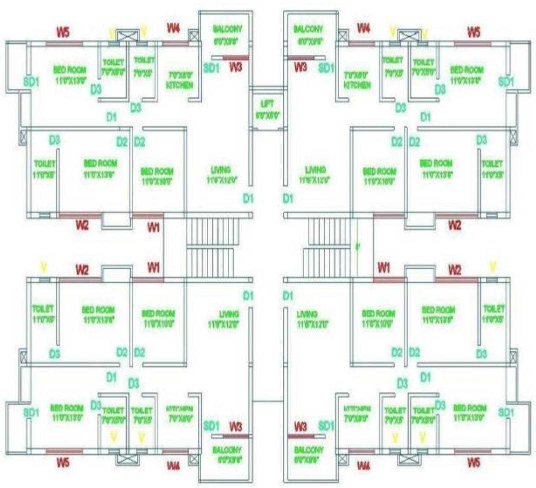

Fig.1Auto CAD building plan

3.METHODOLOGY

Structural loads in design encompass a variety of forces acting on a building or infrastructure, ensuring safety and functionality. These include:

Dead Loads

Permanent components like walls, floors, and ceilings form dead loads. Calculated based on unit weights (e.g., concrete: 24-25 kN/m³), they remain constant throughout the structure's lifespan.

Imposed Loads

Imposed loads arise from building occupancy and use, including movable partitions, furniture, and equipment. These exclude dynamic factors like wind or seismic forces.

Wind Loads

Wind loads involve air motion, primarily horizontal, acting on structures. They depend on design wind speed (V), calculated as $V=V_b \cdot k_1 \cdot k_2 \cdot k_3$ $V = V_b\ k_1\ x k_2\ x k_3$, accounting for risk, terrain, and topography. Wind pressure calculations involve external and internal coefficients.

Seismic Loads

These result from earthquakes, introducing lateral forces and deformations. Design involves seismic base shear ($V_b=A_h \cdot W$ $V_b = A_h..W$), natural vibration periods, and dynamic analysis using methods like Time History or Response Spectrum.

Structural Design Using STAAD

STAAD enables analysis and design of space, plane, or truss structures. It incorporates wind, seismic, and moving load generators, facilitating beam and column design per IS standards (e.g., IS 13920 for ductility). Features like deflection checks, code compliance, and post-processing enhance precision.

Advanced tools ensure structures withstand environmental, dynamic, and operational stresses while adhering to safety codes.

4. Statement of the project

Live load = 3 KN/m^2 (all over slabs)
Floor finish load = 1 KN/m^2 (all over slabs)
Location= Hyderabad
Wind load = As per IS875-1987
Earthquake load =As per IS-1893(part-1) – 2002
Depth of foundation below ground = 1.5 m
Type of soil = Type II, Medium as per IS:1893
Allowable bearing pressure = 200KN/m^2
Minimum thickness of footing = 0.305 m, Assume Isolated footing
Height of building
=GF:3+5storied@3m+lift&stairheight (3m)=21m
Length in x-axis = 30.78m
Length in z-axis = 19.35m
External Wall thickness of Brick = 0.23 m Internal wall thickness of AAC Block = 0.15 m Parapet wall thickness of AAC Block = 0.15m parapet wall Height = 1m
Columns =0.225 x 0.450 m & 0.225 x 0.525m
Beams = 0.225 x 0.225 m, 0.300 x 0.225m & 0.375 x 0.225m
All slabs= 0.120m thick
Terracing = 0.120m thick avg.
Grade of concrete= Used M25
Concrete Gade of steel = Used Fe 415 steel

5.Result and discussion

The structure was designed using concrete in accordance with relevant IS codes. Key parameters such as clear cover, yield strength of reinforcement (Fy), and concrete strength (Fc) were defined during the design process. To initiate the design, the specific members—beams and columns—needed to be identified within the software input window. This allowed for

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the specification of which structural components would be analyzed and designed as beams, which are primarily responsible for bending, and which would function as columns, bearing vertical loads. The design process ensures that the structural elements are tailored for their specific roles, complying with safety and performance requirements outlined in the IS code.

Fig.2 Fixing support to the structure

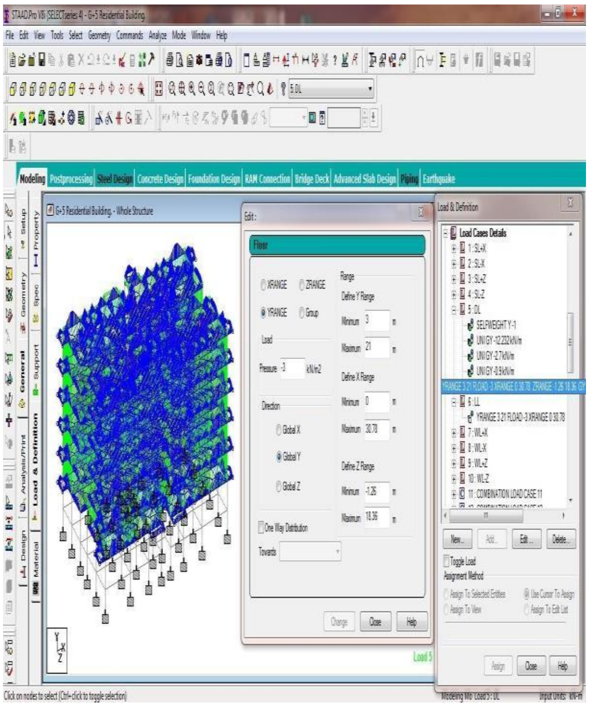


Fig.3 Input window of floor load generator

The structural analysis incorporated live, wind, and seismic loads, ensuring compliance with IS standards. The live load of 3 kN/m² was applied to each floor and terrace using STAAD's "member load" tool. Wind loads were computed per IS 875, with wind speed and pressure calculated manually based on height, terrain, and other factors. For example, at 10 m, the design wind speed (VzV_z) was 50 m/s, yielding a pressure (PzP_z) of 1.5 kN/m². Values were determined similarly for other heights, accounting for risk and terrain factors.

Seismic loads followed IS 1893:2002, with STAAD's seismic load generator distributing column and wall weights across floors. Two primary load combinations were analyzed: one integrating self-weight, dead load, live load, and wind load; and another substituting seismic load for wind. This approach ensured a robust design, addressing lateral forces from wind and seismic activity alongside vertical loads, guaranteeing structural integrity and compliance with safety standards.

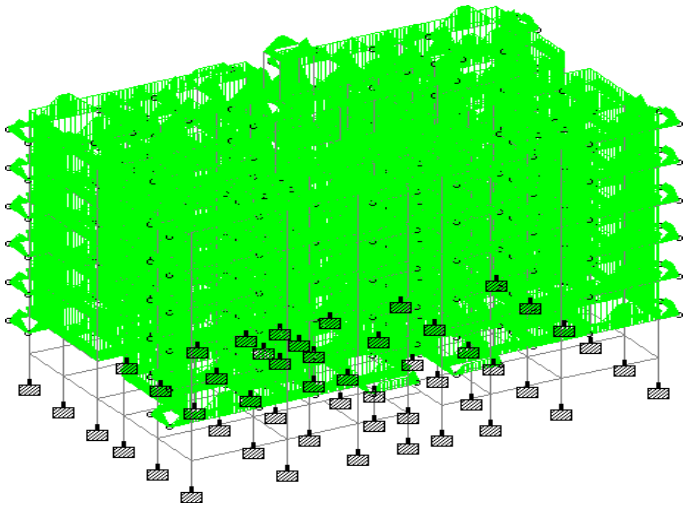
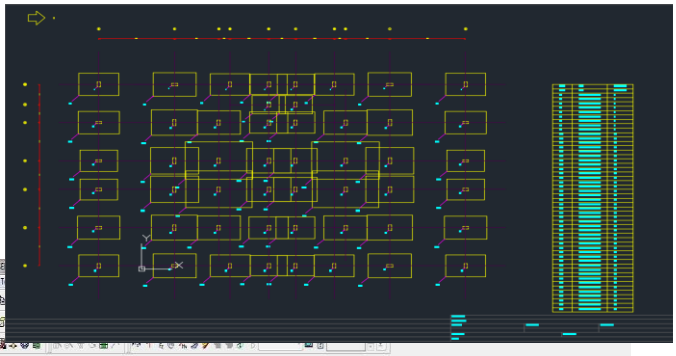


Fig.4 Input window for design purpose

Fig.5.Graph for shear force and bending moment for a beam

5.1 Analysis and Design Results of Staad Foundation



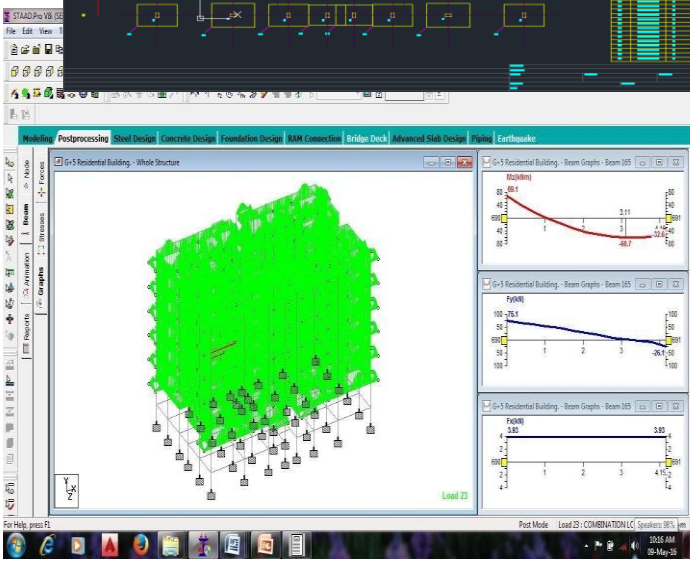


Fig.6.Layout geometry of footings

The provided table outlines the axial loads, shear forces, and moments across various levels (L.C) of the structure. These results are vital for analyzing the structural behavior under different load conditions, as they determine how the structure will react to forces and moments at each level. The axial loads are given in kilonewtons (kN) and indicate the compressive or tensile forces acting along the structure's axis. Shear forces in both the X and Z directions are also provided, showing how the load is distributed and the internal resistance at each level. Bending moments in the X and Z directions highlight the rotational forces acting on the structure.

For example, at L.C 11, the axial force is 1042.04 kN with shear forces of 1.160 kN in the X-direction and 0.475 kN in the Z-direction. Similarly, moments are recorded at each level, such as -0.097 kNm in the X-direction and -0.908 kNm in the Z-direction at L.C 11. These forces and moments vary across levels, reflecting the structural responses to different loading scenarios. The detailed data helps engineers optimize the design, ensuring that each member of the structure can safely bear the expected loads and perform effectively under dynamic conditions like wind or seismic forces.

L C	Axial (kN)	Shear X (kN)	Shear Z (kN)	Moment X (kNm)	Moment Z (kNm)
11	1042.047	1.160	0.475	-0.097	-0.908
12	736.812	20.519	-0.188	0.962	-29.405
13	956.534	-19.596	0.526	-1.403	28.603
14	692.362	0.082	28.408	60.768	0.192
15	1000.984	0.841	-28.069	-61.209	-0.994
16	881.613	-7.197	0.587	-0.305	10.677
17	884.011	-6.651	1.766	0.228	9.871
18	948.909	1.378	-10.067	-36.033	-1.734
19	900.936	0.164	-25.277	-40.923	0.004
20	745.749	16.974	0.095	0.868	-23.930
21	921.526	-15.118	0.666	-1.023	22.476
22	710.189	0.625	22.971	48.713	-0.253
23	957.086	1.232	-22.211	-48.869	-1.201
24	861.590	-5.199	0.714	-0.146	8.135
25	863.508	-4.761	1.657	0.281	7.491
26	915.426	1.662	-7.809	-28.728	-1.793
27	877.048	0.690	-19.977	-32.640	-0.403
28	694.698	0.774	0.317	-0.065	-0.606
29	491.208	13.679	-0.125	0.641	-19.603
30	637.689	-13.064	0.351	-0.935	19.068
31	461.575	0.055	18.938	40.512	0.128
32	667.322	0.561	-18.713	-40.806	-0.663
33	587.742	-4.798	0.391	-0.204	7.118
34	589.341	-4.434	1.177	0.152	6.581
35	632.606	0.919	-6.711	-24.022	-1.156
36	600.624	0.110	-16.852	-27.282	0.003
37	621.457	14.145	0.079	0.724	-19.942
38	767.939	-12.598	0.555	-0.853	18.730
39	591.824	0.521	19.142	40.594	-0.210
40	797.572	1.027	-18.509	-40.724	-1.001
41	717.991	-4.332	0.595	-0.121	6.780
42	719.590	-3.968	1.381	0.234	6.243
43	762.855	1.385	-6.507	-23.940	-1.494

Table.1 showing shear, axial load and bending moment

6.Conclusion

The analysis and design of the G+5 residential building using STAAD.Pro showcase the software's capability to manage complex structural designs efficiently. For Beam No. 156 at the roof level of the 1st floor, the design results reveal that the top reinforcement varies from 1224.03 mm² at the support to 157.69 mm² at mid-span, while the bottom reinforcement ranges from 351.18 mm² to 568.18 mm². Shear reinforcement includes 2-legged 8 mm stirrups spaced at 120 mm center-to-center. The beam's dimensions are 225 mm x 375 mm, with M25 concrete and Fe415 steel, ensuring stability under applied loads. Reinforcement provided includes 4-20 mm bars at the top and 2-16 mm to 3-16 mm bars at the bottom for effective load resistance. These results confirm STAAD.Pro's precision in designing safe and reliable structural components. Additionally, STAAD.Foundation complements STAAD.Pro by supporting the seamless design of isolated footings, pile caps, and mat foundations, ensuring these components can withstand varying load conditions.

6.1 Further Studies

Future research can explore the advanced features of STAAD.Pro and STAAD. Foundation, with a focus on optimizing structural and foundation designs for more complex geometries and dynamic loading conditions. Sustainability could be integrated by assessing the carbon footprints of materials, while earthquake resilience in designs could be enhanced. Further exploration into integrating STAAD tools with Building Information Modeling (BIM) software could improve workflow efficiency and collaboration. The application of artificial intelligence for automating designs and predictive maintenance in structures designed using STAAD tools presents a promising research direction. Additionally, a comparison of STAAD's cost-effectiveness and performance with other structural analysis software could provide insights for improving its practical applications.

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