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Static Analysis and Design of Multistorey (G+3) Residential Building using STAAD Pro

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Abstract: In this project, an attempt is made to analysis and design a multi-storey building (G+3, Residential Building) using STAAD Pro software. In the present scenario, huge numbers of structures have constructed in the world for numerous purposes. These structures have been designed from different techniques such as load bearing wall structures, framed structures, shell structures, composite structures, etc. In the present study has been focused on G+3 stories residential building for evaluate the static responses. The building has been constructed in symmetrical throughout with using framed structures. The study has been opted three steps: 1) Built geometrical and 3D model: the geometrical drawing and 3D model of the building has been done by Auto Cad and Staad Pro., 2) Performed static analysis: the building has been analyzed from Dead load, Live load, Wind load and their possible combinations using by IS codes. 3) Desing: Finally, building has been designed from M20 and M25 grade concrete for checking which structure is more stable and economical.
Keywords: Analysis, Design, STAAD PRO, (G+3) Residential building, Static Analysis.

I. INTRODUCTION

A building intended largely for home use is called a residential building. It include areas where people live, such as homes, apartments, and multistory structures. These structures are made of a variety of materials, including concrete, steel, brick, and wood, and are intended to offer comfort, safety, and functionality. Structural stability, ventilation, lighting, and adherence to regional building norms and laws are important considerations in the design of residential buildings.

In structural engineering, static analysis is a technique used to ascertain how structures react to static (non-moving) loads. These loads may consist of environmental loads (like snow or wind when presumed constant), live loads (temporary, like people and furniture), and dead loads (permanent, like the weight of structural components). In order to ensure that dynamic effects like damping or inertia are minimal, the analysis makes the assumption that the loads are delivered slowly and either stay constant or fluctuate extremely gently over time. In order to guarantee structural safety and serviceability, engineers use static analysis to evaluate internal forces, moments, stresses, and displacements.

Buildings with multiple stories are becoming more and more necessary due to the increasing demand for residential space and the fast pace of urbanization. For these structures to be safe, stable, and economically viable, structural analysis and design are essential. An effective platform for modeling, analyzing, and designing complex buildings in accordance with pertinent building rules and standards is provided by the widely used structural analysis and design program STAAD. Pro. The structural design and analysis of a G+3 (Ground + 3 Storey) residential structure utilizing STAAD. Pro is the main goal of this project. In accordance with Indian Standards (IS) standards, the structure is intended to be a reinforced concrete framed system that can safely withstand dead loads, live loads, and wind loads.

II. LITERATURE REVIEW

STAAD Pro has been used in numerous research to analyze and design multi-story buildings. The structural analysis and design of a multi-story building using STAAD Pro was the main emphasis of Adhiraj A. Wadekar and Ajay G. Dahake (2020). They evaluated static responses including bending moments, deformations, and support reactions before designing the building in accordance with Indian standard norms and guidelines. In order to assure structural safety, Gande Sharan Kumar et al. (2021) examined and constructed a G+8 residential building while taking seismic load concerns into account. In order to evaluate the structural behavior under various loading circumstances, Abhiyank Joshi and Rahul Sharma (2022) performed a comparative analysis of a G+4 multi-story structure utilizing different grades of concrete in STAAD Pro. The design of a G+11-story structure was examined more recently by Yeswanth Kumar (2024), who concentrated on the study and design of important structural components such as slabs, beams, columns, foundations, and seismic performance.

These studies demonstrate how well STAAD Pro works as an all-inclusive tool for assessing and creating intricate structures that adhere to contemporary building codes. On the basis of previous research, the major objectives: to use STAAD. Pro software to analyze and design a G+3 (Ground + 3 Storey) residential structure. To assess the building's performance and structural stability throughout the design phase by utilizing various concrete grades.

III. METHODOLOGY

The study uses a methodical approach that is methodically displayed in a flow diagram shown in Fig. 1. A structured framework for the analysis and design of a G+3 residential building is offered by this methodology. Building layout preparation is the first step in the process, which is followed by the creation of intricate geometrical drawings using AutoCAD. After that, STAAD. Pro software is used to produce a 3D structural model. Applying static loads, such as dead, live, and wind loads, coupled with the proper load combinations in accordance with applicable standards, is how structural analysis is done. The construction is planned with concrete of grades M20 and M25 based on the analytical results. Both the analysis and design phases' results are carefully assessed and examined. Key findings are included in the study's conclusion, along with possible avenues for further investigation and advancement.

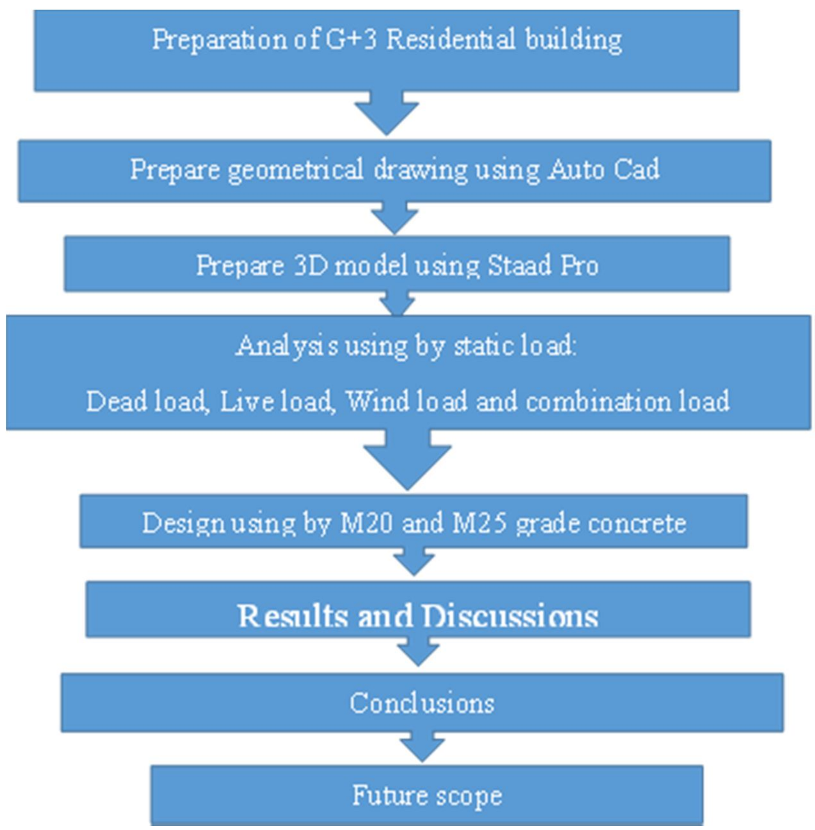

Fig. 1 Flow diagram opted analysis of residential building

IV. GEOMETRIC DIMENSIONS OF BUILDING AND STRUCTURAL ELEMENTS

The residential building's structural specifications include precise measurements and material characteristics that are necessary for analysis and design. To ensure sufficient load-carrying capacity, the columns are constructed with dimensions of 250 mm × 300 mm, while the beams are measured at 250 mm × 280 mm. The slab is appropriate for household floor loads because of its 125 mm thickness. Both the main and division walls are kept at a height of three meters, with a 1.2-meter parapet wall for safety and aesthetic reasons. The parapet and partition walls are 120 mm thick, while the main walls are 230 mm thick. The thickness of the floor finish is thought to be 50 mm. The following material unit weights are used: brick masonry at 20 kN/m³, cement mortar at 20 kN/m³, and concrete at 25 kN/m³. These characteristics are essential STAAD inputs. For precise load estimates, stability evaluation, and effective structural design, use pro analysis.

V. LOAD CALCULATIONS

Various loads are taken into account in structural design to guarantee stability and safety. The term "dead load" describes the constant static weight of structural components such as walls, slabs, beams, and finishes. The term "live load" refers to transient or mobile loads that change over time, such as people, furniture, and equipment. The lateral stresses that wind pressure exerts on a structure, particularly on tall or exposed buildings, are taken into consideration by wind load. By combining multiple loads (such as dead + living, dead + wind) in accordance with applicable construction rules, load combinations are used to examine real-life conditions and make sure the structure can safely withstand a range of potential loading scenarios.

1) *Dead load as per IS-875 (Part-1)*

   Self-weight of slab = slab thickness × unit wt. of RCC = 3.125 kN/m^2 Floor finish load = thickness of F.F. unit wt. of cement mortar = 1 kN/m^2 Total load = 3.125 + 1 = 4.125 kN/m^2 (apply on the floors)

   partition wall load = thickness of partition wall × height × unit wt. of brick masonry = 7.2 kN/m (apply on the beams)

   main wall load = thickness of main wall × height × unit wt. of brick masonry = 13.8 kN/m (apply on beams)

   parapet wall load = thickness of parapet wall × height × unit wt. of brick masonry = 2.88 kN/m (apply on beams)

2) *Live load:* live load is opted from IS:875 (Part-2) for numerous partitions of residential building as shown in Table-1.

Tabel 1: Live load for residential building

Occupancy	Loading
All rooms & kitchen	2 kN/m^2
Toilet & bathrooms	2 kN/m^2
Corridors, passages, & staircase	3 kN/m^2
Balconies	3 kN/m^2

3) *Wind load calculation* [$P_Z = 0.6 V_Z^2$] ………eq1

   P_Z = WIND SPEED

   V_Z = Design wind speed at any height [$V_Z = V_B \times K_1 \times K_2 \times K_3$] ………eq2

   V_B = Basic wind speed of the region = 47 K_1 = Probability factor (risk coefficient) = 1

   K_2 = Terrian, height & structure size factor = 1.05(at 10m) & 1.075(at 13m) K_3 = Topography factor = 1

   By putting all above values in eq1 & eq2 we get P_Z = 1.416 KN/m2 (at 10m)

   P_Z = 1.531 KN/m2 (at 13m)

4) *Load combinations*

   1.5 (DL + LL)
   1.2 (DL +LL+WL X)
   1.2 (DL +LL+WL Z)
   0.9 (DL +LL+WL X)
   0.9 (DL +LL+WL Z)

VI. ANALYSIS AND DESIGN

Static analysis in STAAD is used to analyze a G+3 residential structure. Pro entails assessing how the structure will behave structurally under different applied loads, including wind, live, and dead loads. STAAD is used to create a comprehensive 3D model of the reinforced concrete framed construction shown in Fig. 2. Pro according to the structural and architectural plans. The internal forces, bending moments, shear forces, and deflections in beams, columns, slabs, and foundations are then evaluated using static analysis. To guarantee compliance and safety, the loads and their combinations are applied in line with Indian Standard (IS) standards. Finding the crucial load-bearing components and confirming their functionality under various loading scenarios are made easier by the study. Structural components are developed for strength and serviceability based on the findings. Through this procedure, the building's structural soundness, economic viability, and ability to sustain all applied loads over the course of its service life are guaranteed.

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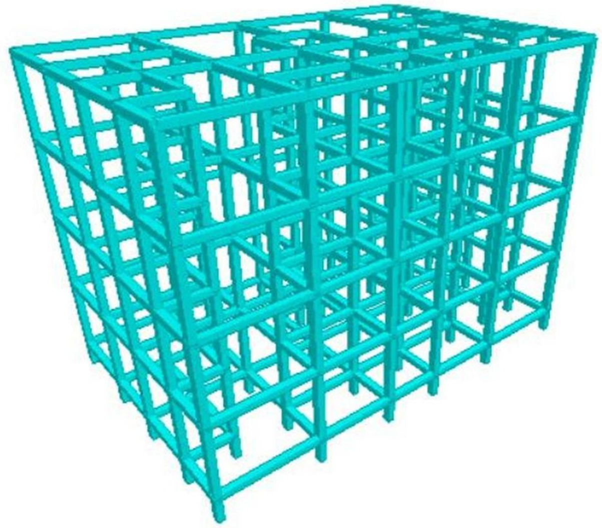

Fig. 2 3D-Render view of structure

VII. RESULT AND DISCUSSION

The table shows the percentage distribution of structural reactions (axial forces, moments, or stresses) under various load combinations on different levels of a G+3 residential structure, as determined using STAAD Pro analysis. According to conventional load combinations, the results show how each floor responds to combined static and wind stresses.

Ground level: With values ranging from 24.19% to 24.23%, the ground level continuously bears the largest load contribution across all load combinations. Given that it supports the combined weight of all upper floors, this is to be expected. First Floor: A moderate load distribution is demonstrated by the first floor's contribution, which ranges from 10.34% to 10.48%. It transfers loads to the ground floor and supports the second and third stories. Second Floor: In line with usual structural behavior, the load contribution is comparatively lower here, ranging from 6.28% to 6.30%. This suggests a tendency of decreasing load intensity as we ascend up the structure. It's interesting to note that the third level displays negative percentages (-17.31% to -17.50%), which could indicate a tensile reaction or uplift brought on by wind load effects. This is especially noticeable when there are wind load combinations in both the X and Z directions. This means that the top floor is more vulnerable to lateral forces and may undergo a partial force direction reversal as a result of wind-induced suction.

We got the certain results from the above analysis, design and comparison for the grade of concrete. They are discussed for the load combinations for Table 3 to Table 5:

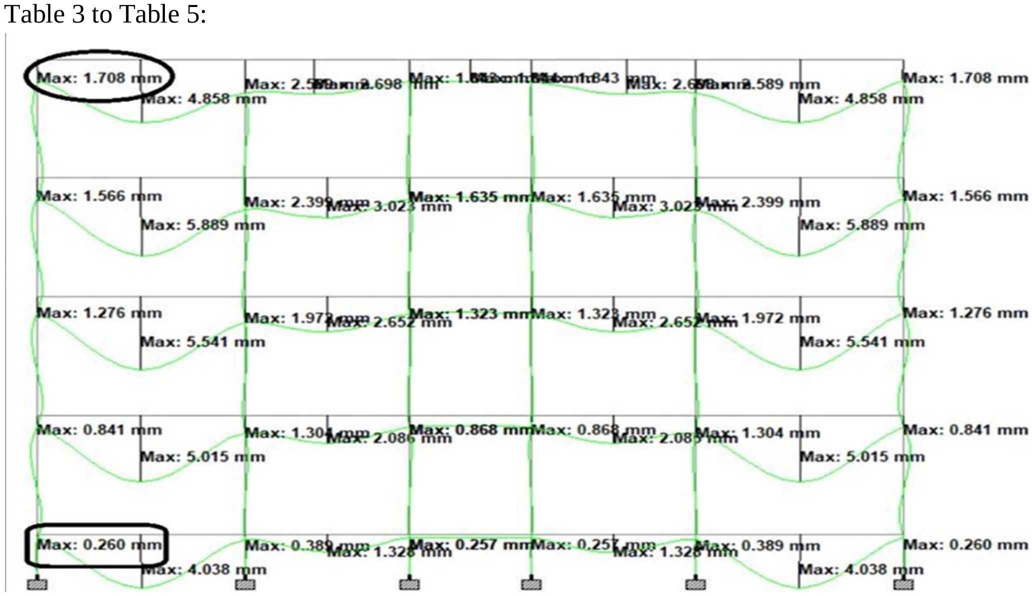

Fig. 3 Maximum deflection in x-direction

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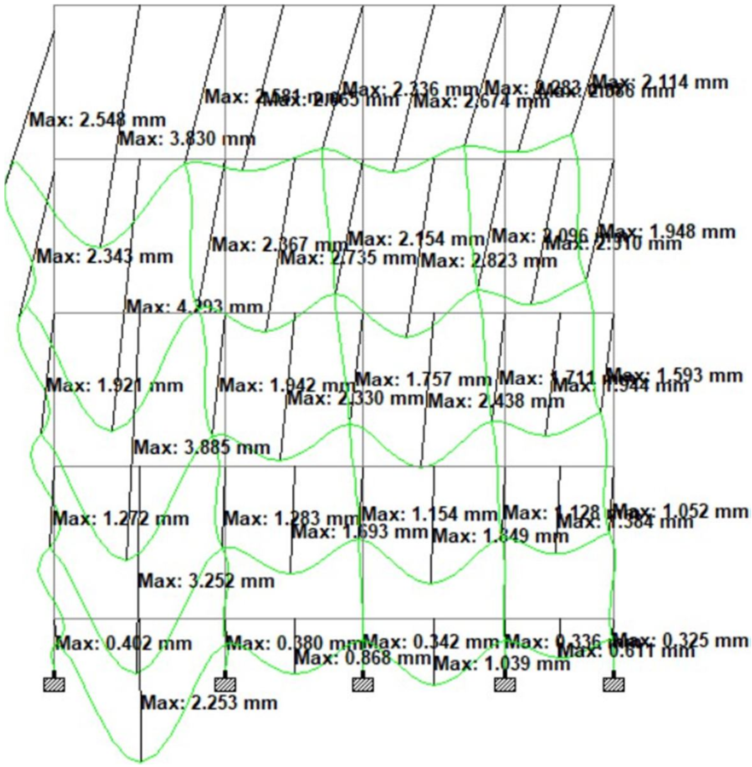

Fig. 4 Deflection response of in x-direction

Table 2: Deflection variation from floor to floor in the x-direction (for M25 & Fe415)

Load combination	Ground floor	First floor	Second floor	Third floor
1.5(DL+LL)	24.23%	10.34%	6.3%	-17.31%
1.2(DL+LL+WLX)	24.19%	10.48%	6.28%	-17.5%
1.2(DL+LL+WLZ)	24.19%	10.48%	6.28%	-17.5%
0.9(DL+LL+WLX)	24.20%	10.47%	6.28%	-17.48%
0.9(DL+LL+WLZ)	24.20%	10.47%	6.28%	-17.48%

Table 3: Deflection variation from floor to floor in the z-direction (for M25 & Fe415)

Load combination	Ground floor	First floor	Second floor	Third floor
1.5(DL+LL)	44.34%	19.46%	10.50%	-10.78%
1.2(DL+LL+WLX)	44.22%	19.46%	10.91%	-9.87%
1.2(DL+LL+WLZ)	44.22%	19.46%	10.91%	-9.87%
0.9(DL+LL+WLX)	44.26%	19.44%	10.91%	-9.83%
0.9(DL+LL+WLZ)	44.26%	19.44%	10.91%	-9.83%

Table 4: Deflection variation from floor to floor in the x-direction (for M20 & Fe415)

Load combination	Ground floor	First floor	Second floor	Third floor
1.5(DL+LL)	27.18%	11.99%	6.5%	-9.99%
1.2(DL+LL+WLX)	27.19%	12.03%	6.5%	-10.06%
1.2(DL+LL+WLZ)	27.19%	12.03%	6.5%	-10.06%
0.9(DL+LL+WLX)	27.19%	12.05%	6.5%	-10.07%
0.9(DL+LL+WLX)	27.19%	12.05%	6.5%	-10.07%

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Table 5: Deflection variation from floor to floor in the z-direction (for M20 & Fe415)

Load combination	Ground floor	First floor	Second floor	Third floor
1.5(DL+LL)	50%	21.57%	10.8%	-4.8%
1.2(DL+LL+WLX)	49.95%	21.56%	10.96%	-4.5%
1.2(DL+LL+WLZ)	49.95%	21.56%	10.96%	-4.5%
0.9(DL+LL+WLX)	49.77%	21.5%	10.95%	-4.5%
0.9(DL+LL+WLX)	49.77%	21.5%	10.95%	-4.5%

The findings show that multi-story buildings exhibit realistic structural behavior, with wind- sensitive behavior at the top and maximum load transfer at the bottom. Stable model integrity is implied by the consistency across combinations. The third floor should get extra consideration for uplift mitigation, such as enhanced stiffness or anchorage, particularly under lateral stresses.

The displacement summary is displayed in the table you supplied. Pro for different nodes and load combinations (L/C) in a G+3 residential building's structural model. Along with the resulting displacement values, the table displays the maximum and minimum displacements in the X, Y, and Z directions as well as the rotational directions (rX, rY, and rZ).

The highest resultant displacement at Node 204 under Load Case 5 (1.5 DL + LL) is 4.914 mm, with a vertical displacement (Y) of -4.829 mm and a horizontal displacement in Z of - 0.907 mm. According to IS 456:2000, which permits vertical deflection ≤ Span/250 for beams and floors, this value falls within acceptable bounds for serviceability. The predominance of vertical displacement demonstrates that the largest contributor to total deformation is gravity loads (DL + LL).

Impact of Wind Loads: The greatest X-direction displacement of Node 183 under WL X is 0.434 mm, whereas Node 189 with combined DL + LL + WL yields 0.788 mm. The structural design appears to have good lateral stiffness, as evidenced by the wind-induced lateral deflection being well below critical drift limits.

Displacements in Rotation: Since all of the rotational displacements (rX, rY, and rZ) fall between -0.001 and +0.001 radians, the structure is not significantly unstable in either torsional or rotational directions. Max rZ = 0.001 rad is displayed by Nodes 215 and 204, which is negligible and appropriate. ***Consistency and Symmetry:*** Model stability and symmetry in load distribution are indicated by displacements in opposite directions (Max X = +0.788 mm at Node 189 and Min X = -0.788 mm at Node 200, for example).

- Both the structures are safe and can be constructed.
- Reactions summary for M25 & Fe415

All Summary

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	189	6 1.2(DL+LL+	0.788	-1.971	-0.563	2.196	-0.000	-0.000	-0.001
Min X	200	6 1.2(DL+LL+	-0.788	-1.971	-0.563	2.196	-0.000	0.000	0.001
Max Y	183	1 WL X	0.434	0.007	-0.044	0.436	-0.000	-0.000	-0.000
Min Y	204	5 DL+LL(1.5)	-0.000	-4.829	-0.907	4.914	0.001	0.000	-0.000
Max Z	47	5 DL+LL(1.5)	0.125	-0.379	0.042	0.402	0.000	-0.000	-0.001
Min Z	215	5 DL+LL(1.5)	-0.005	-2.115	-0.972	2.328	-0.001	-0.000	-0.000
Max rX	204	5 DL+LL(1.5)	-0.000	-4.829	-0.907	4.914	0.001	0.000	-0.000
Min rX	203	5 DL+LL(1.5)	-0.000	-2.951	-0.943	3.098	-0.002	0.000	0.000
Max rY	216	6 1.2(DL+LL+	-0.087	-1.604	-0.581	1.708	-0.000	0.000	0.001
Min rY	205	6 1.2(DL+LL+	0.087	-1.604	-0.581	1.708	-0.000	-0.000	-0.001
Max rZ	199	5 DL+LL(1.5)	-0.109	-2.428	-0.611	2.507	0.001	-0.000	0.001
Min rZ	191	5 DL+LL(1.5)	0.109	-2.428	-0.611	2.507	0.001	0.000	-0.001
Max Rs	204	5 DL+LL(1.5)	-0.000	-4.829	-0.907	4.914	0.001	0.000	-0.000

- Reactions summary for M20 & Fe415

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	189	6 COMBINATI	0.639	-2.890	-0.229	2.968	-0.000	-0.000	-0.000
Min X	200	6 COMBINATI	-0.639	-2.890	-0.229	2.968	-0.000	0.000	0.000
Max Y	183	1 WL X	0.434	0.007	-0.044	0.436	-0.000	-0.000	-0.000
Min Y	204	5 COMBINATI	-0.000	-6.374	-0.384	6.386	0.001	0.000	-0.000
Max Z	192	3 DL	0.037	-3.165	0.073	3.166	0.000	0.000	-0.000
Min Z	203	5 COMBINATI	-0.000	-3.348	-0.417	3.374	-0.002	0.000	0.000
Max rX	204	5 COMBINATI	-0.000	-6.374	-0.384	6.386	0.001	0.000	-0.000
Min rX	203	5 COMBINATI	-0.000	-3.348	-0.417	3.374	-0.002	0.000	0.000
Max rY	216	1 WL X	-0.026	0.002	-0.044	0.051	0.000	0.000	0.000
Min rY	205	1 WL X	0.026	0.002	-0.044	0.051	0.000	-0.000	-0.000
Max rZ	199	5 COMBINATI	-0.136	-3.805	-0.187	3.812	0.001	-0.000	0.002
Min rZ	191	5 COMBINATI	0.136	-3.805	-0.187	3.812	0.001	0.000	-0.002
Max Rs	204	5 COMBINATI	-0.000	-6.374	-0.384	6.386	0.001	0.000	-0.000

Table 6: The below table describe the warnings given for M20 and Fe415:

No. of beams and column under warning	Warning given
61, 66, 74, 76, 82, 84, 85, 89, 163, 173	Unable to accommodate required reinforcement.
67, 70, 73, 79, 83, 157, 160, 169,	Reinforcement approx. 5% to 10% exceeds maximum limits

- M25 concrete grade is better than M20 concrete grade for construction work because the permissible deflection is less in M25 concrete grade as compare to M20 concrete grade.
- Our structure is more stable when we use M25 grade of concrete instead of M20. Additionally, structure is economical.

The G+3 residential building modeled in STAAD Pro exhibits sufficient strength, stiffness, and serviceability, as confirmed by the design and analysis results. According to normal design requirements, the structure can bear lateral loads and gravity. Additionally, there are very few maximum rotations and deflections, guaranteeing occupant comfort and safety.

VIII. CONCLUSION

The residential building has been constructed from load bearing and framed structures in nowadays. Present study has been focused on the G+3 storey residential building constructed in Meerut. Primarily, the geometrical drawing and 3D model has been developed on Auto CAD and Staad Pro. The building has been analyzed with entire possible conditions idealized for construction and finishing materials, boundary conditions, beam and columns elements, walls (load bearing, partition and compound walls), etc. After the modelling the building has been analyze from dead, live, wind, and combinations load. The idealized first combination load, the building has been observed top of the deformation 4.858mm in longitudinal direction and

3.83mm in transverse direction respectively. The building has been performed very well during all load combination, the static responses of deformation, bending moment, shear forces have observed within the permissible limits. The building has been performed better conditions. Finally, this study concludes that the structure designed using the above data is safe, whether M20 or M25 grade concrete is used. The analysis and design are easier when using STAAD Pro software, which also saves time.

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[7] Abhiyank Joshi & Rahul Sharma (2022): the study compares the design and analysis of a G+4 multi-storey building using STAAD Pro with different grades of concrete, assessing structural behavior under various load conditions.
[8] Yeswanth Kumar (2024) A Review on Design of G+11 Storied Building Using STAAD-Pro. the study presents the analysis and design of a building elements as slab, beam, column, and foundation design, as well as seismic analysis.