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Structural Analysis and Design of a G+21 Residential Apartment Using STAAD Pro: A Performance-Based Approach

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ABSTRACT

The growing demand for high-rise residential buildings necessitates advanced structural analysis and design techniques to ensure safety, efficiency, and sustainability. This study focuses on the analysis and design of a G+21 multi-storeyed residential apartment using STAAD Pro, a widely used structural analysis software. The primary objective is to assess the structural integrity of the building under various loading conditions, including dead loads, live loads, wind loads, and seismic forces, in compliance with the Indian Standard (IS) codes through Limit State Design (LSD) principles.

The project begins with a manual calculation of loads to verify the accuracy of STAAD Pro's computational model. Initially, a 2D frame analysis was conducted to compare manual calculations with software-generated results, ensuring precision and reliability. Following this validation, the complete G+21 structure was modeled and analyzed for different load combinations, simulating real-world conditions to evaluate its structural behavior. The software's interactive interface allows for efficient model generation, assignment of material properties, and application of various loads, streamlining the design process.

STAAD Pro's advanced finite element analysis (FEA) capabilities facilitate the design of reinforced concrete (RCC) structural components, including beams, columns, slabs, and foundations, while ensuring compliance with IS 456:2000, IS 875 (Part 1 & 2), and IS 1893:2016. The software also provides detailed reinforcement detailing and optimization, reducing material wastage and improving cost efficiency. The seismic analysis performed in the study adheres to earthquake-resistant design principles, ensuring that the building remains stable under lateral forces.

Compared to traditional manual design methods, STAAD Pro significantly enhances accuracy, efficiency, and time management in analyzing complex high-rise structures. The study concludes that automated structural analysis and design tools improve safety, reduce human errors, and optimize material usage, making them indispensable in modern construction practices. Future research can explore performance-based seismic design, wind tunnel testing simulations, and integration with Building Information Modeling (BIM) to further enhance the accuracy and efficiency of high-rise structural design.

This research highlights the importance of structural analysis software in modern high-rise construction and provides valuable insights into efficient design methodologies for sustainable urban infrastructure development.

Keywords: STAAD Pro, Load Combinations, Live Load, Dead Load, User Interface.

1. INTRODUCTION

Building construction is the branch of civil engineering which deals with the construction of building such as residential building, bungalows, row houses etc. Human beings needs three basic things an enclose space by walls with roof (house), food, cloth. In the early times humans beings lived in caves, over or under trees, to protect themselves etc. as the times passed as humans being started living in cottage made of pieces of timber. The condition of those cottage are converted into beautiful houses today. Rich people live in more facilitate houses like bungalows. Social progress of the county is denoted by buildings of that country. Now a days the house building is major work of the social progress of the county.

The STAAD Pro Graphical User Interface: It is used to generate the model, which can then be analysed using the STAAD engine. After analysis and design is completed, the GUI can also be used to view the results graphically. The STAAD analysis and design engine: It is a general-purpose calculation engine for structural analysis and integrated Steel, Concrete, Timber and Aluminium design. To start with we have solved some sample problems using STAAD Pro and checked the accuracy of the results with manual calculations. The results were to satisfaction and were accurate.

2. LITRATURE REVIEW

For high rise buildings, more reinforcement is required to be calculated for the top beam, hence greater region of steel is required in static analysis than dynamic analysis. As examine to static analysis deflection and shear bending is more in dynamic analysis. More steel is required in the lower beam of the structure in the dynamic evaluation as in contrast to static analysis. From the evaluation of columns, the vicinity and percentage of steel is discovered greater for dynamic load aggregate in contrast to static load combination [1].

Analysis and design on “The storey shear force.” Was found that the loaded irregular building longer and larger base shear than same regular building structure.[2]. The load was maximum when applied in the x-direction (parallel to shorter span) and the deflection get increased as the height of the building increases and the base shear was 5% more in the case of STAAD Pro as compared to manually calculation [3].

The wind load is more critical for the higher structures as compared the earthquake loads and the deflection is higher in wind load than the structures without wind load. The steel quantity was increased by 1.517% related to conventional design [4]. The reports are prepared on the effect of the wind velocity on the structure and structural response of the structure on the sloped ground. For this project work various frame geometries, a combination of static load and wind load is taken into consideration and many cases of the different wind zone are examined for this combination. Analysing the results for different heights in terms of axial force, displacement, moment, storey drift and shear force by using STAAD PRO software [5].

The structure is inspected against the base shear and roof displacement and they are in permissible limits. An RCC high rise building stories combined seismic load and wind loads. In the top beam of the structure requires more reinforcement required for static analysis as compare to dynamic analysis. Deflection and shear bending are less in static analysis compare to dynamic analysis. In column area of steel is always less for static load compared to dynamic load [6].
Structural loads, assist conditions, and intensive properties should be determined to perform a precise analysis. The results of such analysis usually grab support responses, stresses, and displacements. Under normal working conditions, the damage and splitting must not be larger for the structure. A maximum factor of safety should be considered in load combinations so the structure won't fail during natural hazards or because of overloading [7].

The effects in terms of bending moment, aid reaction, shear force, axial pressure is analysed. Due to the impact of wind load on the structure, the story wise variation of the result with respect to specific parameters are compared and the reinforcement is additionally calculated which will make sure the structural safety of the building [8].

This study a comparison was done between two 30-storey buildings. After the basic work is done. Then it was made with two different load combination.1st 30-storey building was made with the combination of seismic load, live load and dead load. And 2nd 30- storey building was made with the combination of wind load, live load and dead load. The analysing and designing was done for the comparison between two 30-storey building taking same beam and column size using different load combination it was clearly visible that the top beams of a building in seismic load combination required more reinforcement than the building under wind load combination. But the deflection and shear bending is more in wind load combination compare to seismic. But in lower beams more reinforcement is required for wind load combination. For column the area of steel and percentage of steel always greater required for wind load combination than the seismic load combination [9].

This study was focused on to develop, design and analysis model of skyscraper building in Staad.pro. In this research the plan depended on IS 875-part1 for dead load, IS 875-part2 for live load IS 875-part3 for wind load IS code 1893-2002 for earthquake load resistant criteria which stated the separate analysis criteria based on Zone of area IS 456-2000 for concrete design in this work or research the analyst found that the earthquake load take place in x-direction acting on the building, in this study were found that the deflection and height of the building are direct proportion as height grows the deflection also grows [10].

This study a 30-storey structure was designed and analysed for two load case combinations; 1st case is a load combination of seismic+ live load+ dead load whereas 2nd case is load combination of wind load+ live load+ dead load. After completing the design and analysing the structure, it was found that The top beam of the structure requires more reinforcement in 1 st case compared to 2 nd case. Hence it reveals that more reinforcement is required in static analysis than dynamic analysis. Deflection and shear bending is more in dynamic analysis compare static analysis. In lower beams more reinforcement is required for dynamic loads compared to static loads. For columns, area of steel and percentage of steel is always greater for dynamic load combination compared to static load combination [11].

3 PROPOSED SYSTEM

3.1 Objective of the study

Computer aided analysis and design of residential building by using STAAD PRO Includes:
1. Generation of structural framing plan
2. Creation of model of structure in STAAD PRO
3. Application of various load combinations on the member.
4. Analysis and design of G+21 building

3.2 Methodology

Step 1: To model the residential building using the STAAD Pro software and analyse the same structure using STAAD Pro.
Step 2: To analyse the residential building and structural elements like beams, stairs, columns, slabs.
Step 3: To design the residential building using STAD Pro - To design the structural elements like beams, columns using software.

3.3 BUILDING DETAILS

3.3.1 AutoCAD plan

The building which we considered for the project is a G+21-storeyed Residencial building located at Hyderabad. The plan area is 300m^2, two 2BHK Flats per each floor and the ground floor is for free for parking and its open storey. The building details are mentioned below:

Table 3.3.1 Description of the Building data

1	**Details of the building**			
i)	Structure		OMRF	
ii)	Number of stories		G+21	
iii)	Type of building		Regular and Symmetrical in plan	
iv)	Flat area (l x b)		12.27 m X 16.95 m	
iv)	Height of the building		66 m	
v)	Support		Fixed	
2	**Material properties**			
i)	Grade of concrete		M30	
ii)	Grade of steel		Fe 415	
iii)	Density of reinforced concrete		25 kN/m^3	
iv)	Young's modulus of M30 concrete, E_c		27386.13 kN/m^2	
vi)	Young's modulus steel, E_s		2 x 10^8 kN/m^2	
4	**Member Properties**	**No. of stories**	**Grade**	**Section sizes (mm)**
i)	Column	ALL	M30	900 x 600
ii)	Beam	ALL	M30	600 x 380
iii)	Plinth beam	Ground	M30	600 X 430
iv)	Slab	ALL	M 30	125

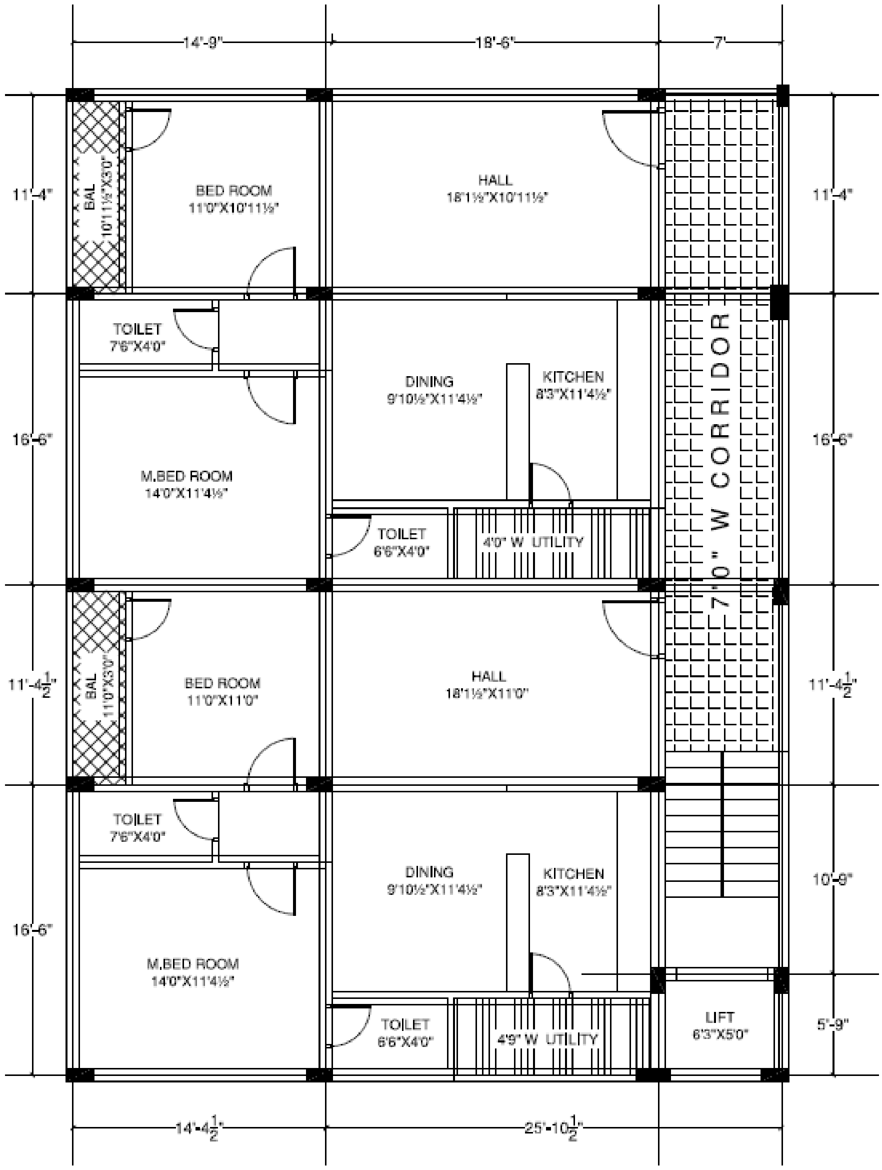

Fig 3.1: STAAD input file (AutoCAD plan)

4. RESULTS AND DISCUSSIONS

Loads can usually be considered to be primary or secondary. Secondary loads are those loads due to temperature changes, construction eccentricities, shrinkage of structural materials, settlement of foundations, or other such loads. Despite the fact that each and every load and loading combination should be considered in order to reduce the chance of structural failure, the determination of the loading remains a statistical exercise. Each and every load cannot be foreseen; thus, it is critical to determine the worst case that is reasonable to assume to act upon the structure. The sources of primary loading include the materials from which the structure was built, the occupants, their furniture, and various weather conditions, as well as unique loading conditions experienced during construction, extreme weather and natural catastrophes.

There are various loads acting on a structure. Our project study constitutes the analysis of the following loads.

- Self Weight
- Gravity Load

- Wind Load
- Seismic Load

The loads are applied on the structure as gravity loads (Dead and live loads), Joint loads (Seismic loads). After the application of different loads, combination of loads has to be specified as mentioned in IS 456:2000.

Calculation: The loads taken for analysis are dead load, live load, wind load and seismic load. Since the structure will be erected in zone-2, seismic design should also be done. The loading standards ensure structural safety and eliminate wastage that may be caused due to unnecessary heavy loading without proper assessment.

Loading details:

Height of external or internal wall = 3 – 0.3 = 2.7m
Height of parapet wall = 1m
Thickness of slab = 125mm = 0.125m
Thickness of Floor finish = 50mm = 0.05m
Thickness of external wall (9inch) = 0.23 m
Thickness of internal wall (4 ½ inch) = 0.115m
Thickness of parapet wall (4 ½ inch) = 0.115m
Density of brick work = 20 KN/m^3
Density of plaster = 22 KN/m^3
Density of concrete = 25 KN/m^3

External wall load	(0.23 x 2.7 x 20) = 12.42KN/m
Internal wall load	(0.115 x 2.7 x 20) = 6.21 KN/m
Parapet wall load	(0.23 x 1 x 20) = 4.6 KN/m
Slab + Floor finish load	(0.125 x 25) + (1.2) = 4.32 KN/m^2
Stair case load	20 KN/m

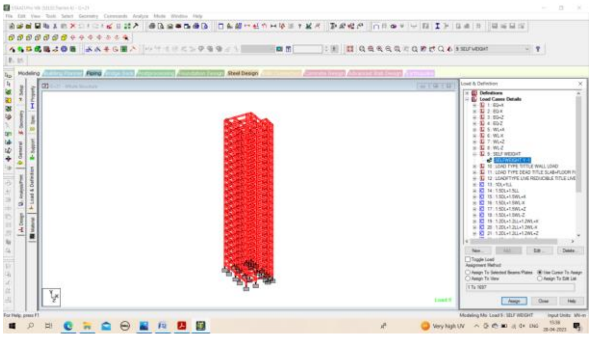

Fig 4.1: Self weight

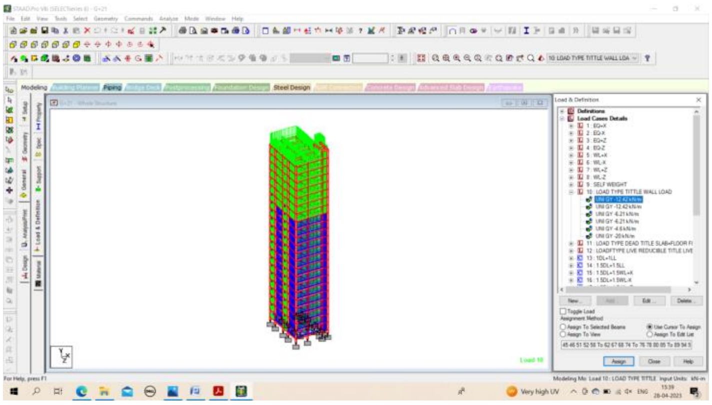

Fig 4.2 External wall load

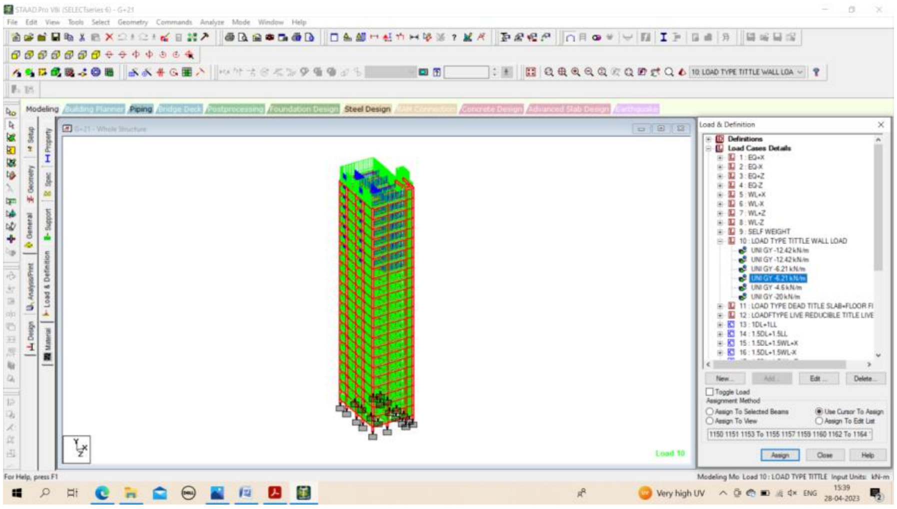

Fig 4.3: Internal wall load

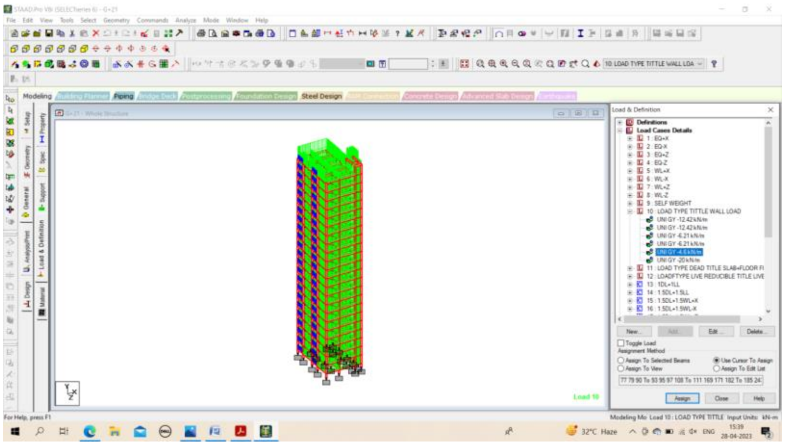

Fig 4.4: Parapet wall load

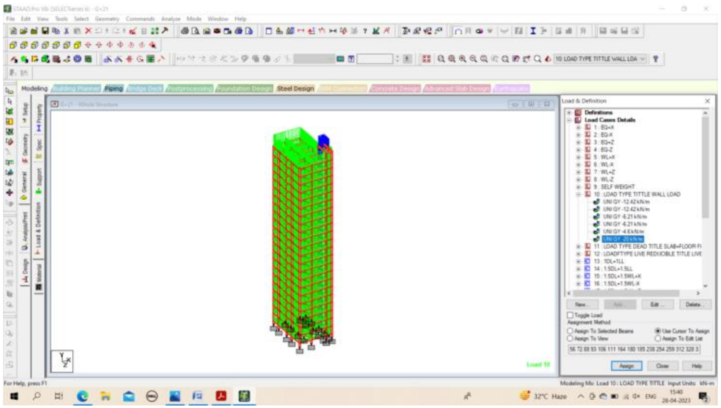

Fig 4.5: Stair case load

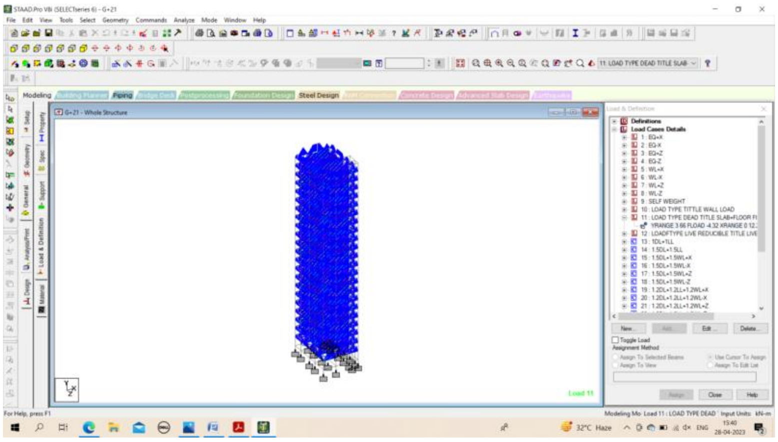

Fig 4.6: Slab + FF load

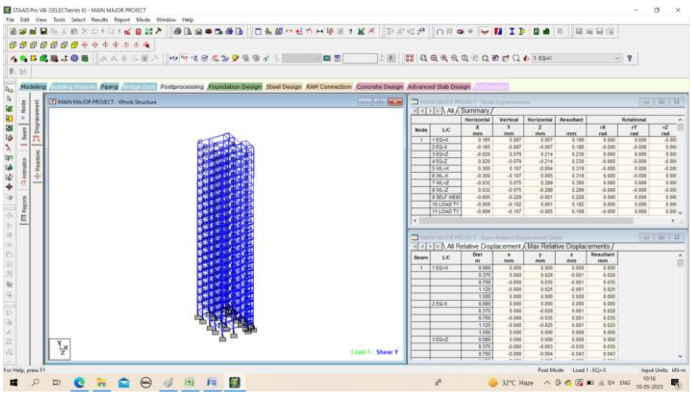

Fig 4.7: SFD

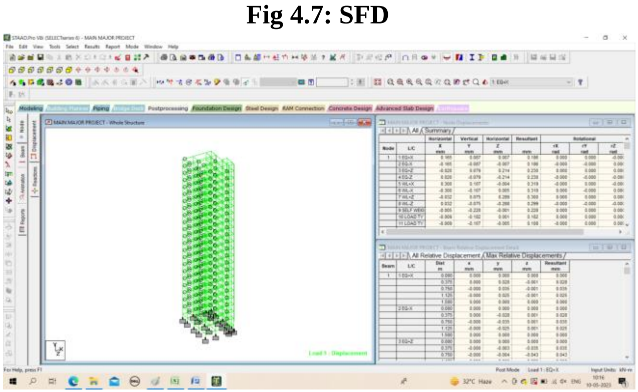

Fig 4.8 : Deflections

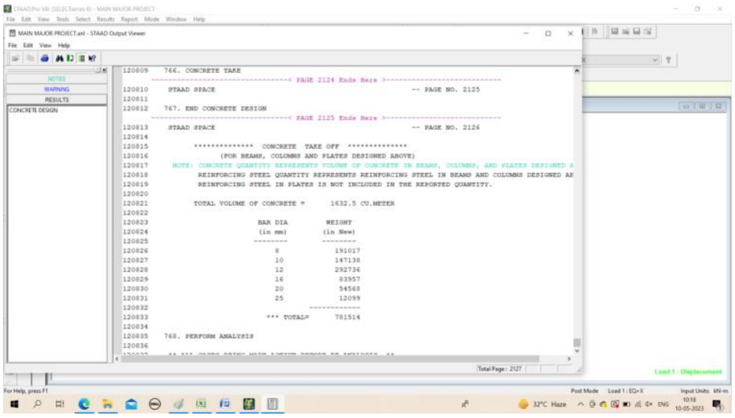

Fig 4.9 Output

5. CONCLUSIONS

STAAD PRO has the capability to calculate the reinforcement needed for any concrete section. The program contains a number of parameters which are designed as per IS: 456(2000). Beams are designed for flexure, shear and torsion This analysis various studies carried out over designing and analysing a structure with the help of different software. All the studies considered above gives a suggestion of adopting STAAD.Pro over other software for analysing a building structure. Due to its flexibility and its provision for economic sections both in terms of steel and concrete, STAAD.Pro is adopted for further analysis procedure. The analysis and design are done for residential building and various results of bending moment, shear force etc, are discussed. The analysis and design were done according to standard specifications using STAAD.Pro for static and dynamic loads. The dimensions of structural members are specified and the loads such as dead load, live load, seismic load and wind load are applied. Deflection and shear tests are checked for beams, columns and slabs. The tests proved to be safe. Both theoretical and practical work has been done. Hence, I conclude that we can gain more knowledge in practical work when compared to theoretical work.

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