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Design and Analysis of High-Rise Building using STAAD Pro

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Abstract
This project's principle objective is to analyze and design a multi-story building [G + 10 (3-dimensional frame)] using STAAD Pro. The Design involves load calculations and analyzing the whole structure by STAAD Pro. The design methods used in STAAD-Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. STAAD. Pro features a state-of-the-art user interface, visualization tools, powerful analysis, and design engines with advanced finite element and dynamic analysis capabilities. From model generation, analysis, and Design to visualization and result verification. The loads considered for designing the residential building are Gravity Load, which includes dead loads and live loads, and Lateral load, including only Wind Loads. The total height of a building is 30m, and the area of a residential building is around 9,048 sq. ft.

Keywords – *STAAD Pro, Limit State Design, Gravity Load, Lateral Load, High-Rise Building, Design, Analysis.*

I. INTRODUCTION

The design process of structural planning and Design requires imagination and conceptual thinking, and sound knowledge of structural engineering science besides the knowledge of practical aspects, such as recent design codes, goodbye laws, backed up by ample experience, intuition, and judgment. The purpose of standards is to ensure and enhance safety, keeping a careful balance between economy and safety. The process of Design commences with the planning of the structure, primarily to meet its functional requirements. Initially, the requirements proposed by the client are taken into consideration. They may be vague, ambiguous, or even unacceptable from an engineering point of view.

The Design of any structure is categorized into the following two main types:

1. Functional Design

2. Structural Design

The principle elements of an R.C.C building frame consist of:

- Slabs to cover a large area.
- Beams to support slabs and walls.
- Columns to support beams.
- Footings to distribute concentrated column loads over a large of the supporting soil such that soil bearing capacity is not exceeded.
- In a framed structure, the load is transferred from slab to beam, from beam to column, and then to the foundation and soil below it.

TABLE 1: Maximum Span of Slabs

Support Condition	*Cantilevers*	*Supported*	*Fixed/Continuous*
One-way Two-way	*One-way Two-way*	*One-way Two-way*	*One-way Two-way*
Maximum Recommended span of slabs	*1.5m 2.0m*	*3.5m 4.5m*	*4.5 6.0m*

TABLE 2: Maximum Spans of Beam Carrying Live Load

Beam type	*Cantilevers*	*Supported*	*Fixed/Continuous*
Rectangular	*3meters*	*6meters*	*8meters*
Flanged	*5meters*	*10meters*	*15meters*

II. LITERATURE SURVEY

Various research papers have been published in Designing and Analysis of High-rise building using STAAD Pro. The conclusions of all these research papers have been gathered and are as follows.

Babitha rani, Nagendra Babu (April 2018) designed and analyzed G + 4 Building using STAAD Pro. It was a 3- dimensional framed design that involved load calculations and analyzing the whole structure by STAAD Pro. The design methods used in STAAD-Pro analysis were Limit State Design conforming to the Indian Standard Code of Practice. The results proved to be very accurate.

B. Giresh Babu (June 2017) has done a seismic analysis and Design of G + 7 Residential Building using STAAD Pro. Earthquake, or Seismic analysis, to calculate the response of a structure subjected to earthquake excitation. He collected various necessary seismic data to carry out the seismic analysis of the structure. In this study, the structures' seismic response was investigated under earthquake excitation expressed in member forces, join displacement, support reaction, and story drift.

A. D. Bhosale, Archit Pradip Hatkhambar, Rupesh Vinayak Katkar (April 2018), Analysed and Designed a Multi-storey building using STAAD Pro V8i. After the analysis and design of their structure, they concluded that STAAD Pro could save a lot of time and is very accurate in design. They considered Dead load, live load, combination, and wind loads in the designing process.

Pabba Mounika, Maroju Navya, Syed Viqar Malik (Februrary 2016) has designed a Residential Building and analyzed it using STAAD Pro. In their design and analysis, the manual calculations were compared to STAAD Pro results. The results of both manual and software matched and were accurate.

III. METHODOLOGY

A. Study of IS 875:1987

IS 875 deals with the various load cases that act upon a structure and ways to calculate them. Various parts of the code deal with load types such as dead load, live load, wind load, snow load, and various special loads and load combinations. As the building is considered to be situated in Hyderabad, which is not a seismic zone, seismic loads were not considered.

B. Preparation of Building Layout using AutoCAD

The layout of the building was prepared, discussed, and approved by an architect. The layout was then prepared using AutoCAD. The various layouts were prepared and then later discussed with the architect for error correction.

C. Analysis and Design Using STAAD Pro.

Once the architect's layout was approved by the architect, the layout was transferred from AutoCAD to STAAD Pro using a DXF file format. Once the layout was transferred, multiple stories were created using the Translational Repeat Tool in Staad Pro. After this, member properties were assigned. Next, the load cases were generated and applied to the structure. Once the loads were applied, the structure was analyzed and corrections were made to the structure for the various errors generated while the structure was being analyzed. After the analysis, we started designing the structure by entering the Design tab in STAAD Pro.

D. Limit State Method

The object of Design based on the limit state concept is to achieve acceptability that a structure will not become unserviceable in its lifetime for the use for which it is intended. i.e., it will not reach a limit state. In this limit state method, all relevant states must be considered in the design to ensure a degree of safety and serviceability. The acceptable limit for the safety and serviceability requirements before failure occurs is called a limit state.

E. Limit State of Serviceability

This state corresponds to the development of excessive deformation and is used to check members in which magnitude of deformations may limit the rise of the structure of its components.

i. Deflection
ii. Cracking
iii. Vibration

IV. ARCHITECTURAL LAYOUT

I. TABLE 3: Details of the Structure

Area of Plot	131'.6" x 72'.6"
Number of Floors	G + 10
Number of Units	80 (Ground floor parking)
Type Apartment	2BHK
Area of Each Apartment	Flat 1: 1104 S.ft Flat 2-4: 1094 S.ft Flat 5-7: 1163 S.ft Flat 8: 1173 S.ft

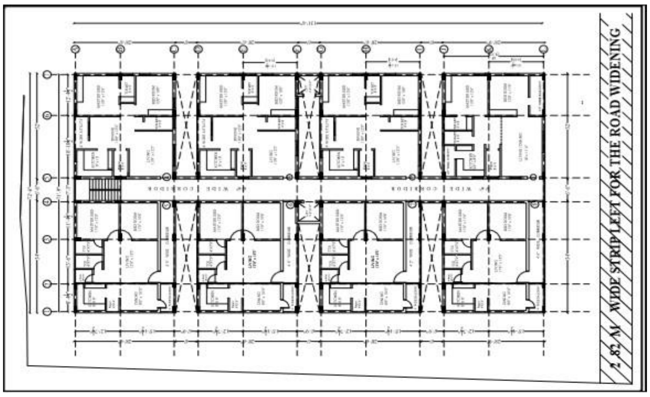


FIG 1: Floor Plan Layout of the Building

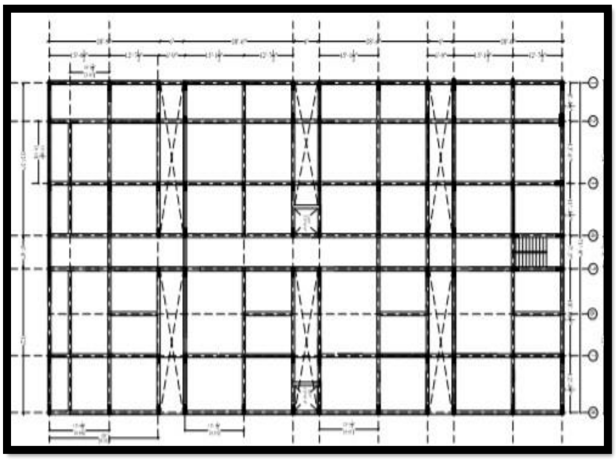


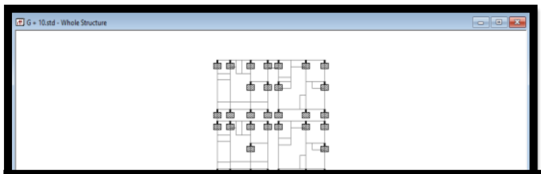
FIG 2: Typical Beam Layout

V. ANAYSIS OF HIGH-RISE BUILDING USING STAAD PRO

1. Modeling

The above figure shows the beam and column layout of the structure that is being modeled in the STAAD Pro. The total width of the building is 22.12 m while the lengths around 40.13 m. The figure also shows the X, Y, Z direction. Here Y direction is taken as the vertical component.

FIG 3: Plan of the G + 10 Structure



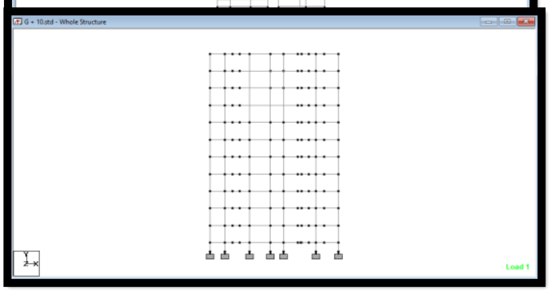


FIG 4: Elevation of the Structure

2. Creation of Supports

All the columns have been assigned fixed support using the STAAD pro Support creator and have been assigned accordingly. Fixed Supports have restricted movements in all directions as well there is restricted moment. This means FX FY FZ MX MZ MY all will have some values.

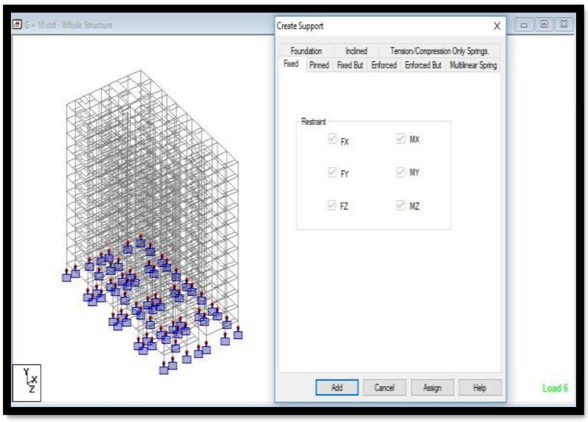


FIG 5: Support Generation for the Structure

3. Dead Load

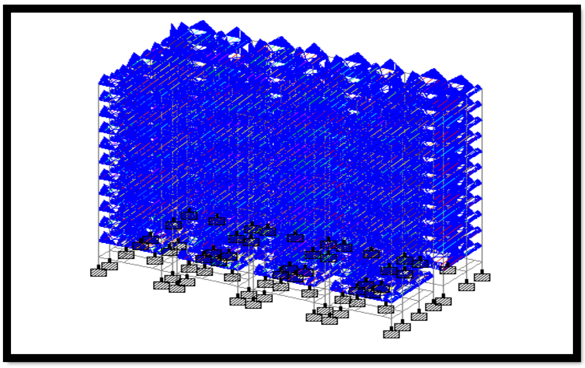
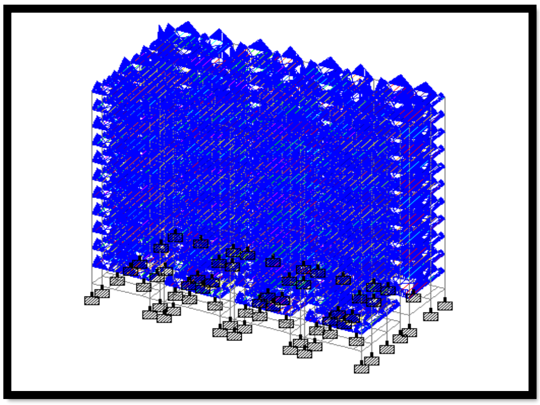


FIG 6: Dead Load from Slab and Walls

4. Live Load

FIG 7: Live Load acting on the Structure



The Live load acting on each floor is considered to be 4 Kn/m^3.

5. Wind Load

The horizontal load caused by the wind is called wind loads. It depends upon the velocity of wind and the shape and size of the building. Complete details of calculating wind loads on structures are given in IS 875(part-3)- 1987. For low-rise buildings,s say up to four to five stories, the wind load is not critical because the moment of resistance provided by the continuity of floor system to column connection and walls provided between columns is sufficient to accommodate the effect of these forces.

Design Wind Speed Vz = Vb x K1 x K2 x K3

Where,

Vb- Design Wind Speed

K1- Probability factor

K2- Terrain factor

K3- Topography factor

The exposure factor is -1.0 (As per code)

The wind speed may be taken as a constant up to a height of 10m. However, pressures for buildings less than 10m high may be reduced by 20 % for stability and Design of the framing.

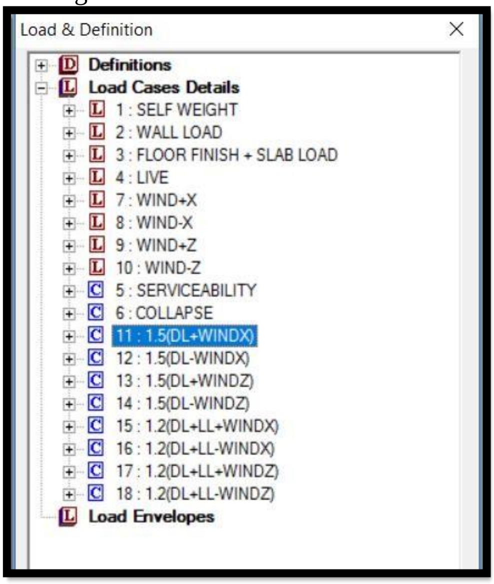


FIG 8: Combinations for Wind Load

6. Load Combinations

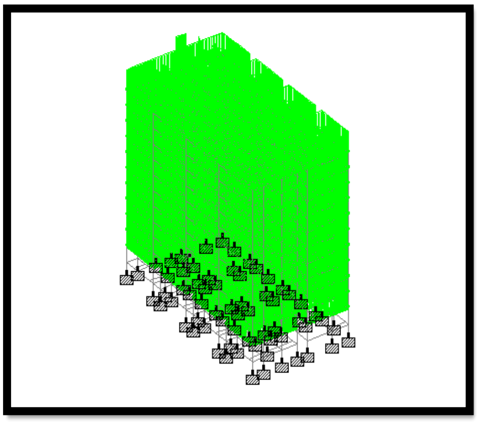


FIG 9: Load Combinations Acting on the Structure

The structure has to be analyzed for load combinations considering all the previous loads in the proper ratio. These combinations are generated by the inbuilt auto- load generator for various load combinations as per IS Codes.

VI. DESIGN OF HIGH-RISE BUILDING USING STAAD PRO

After the STAAD Pro has completed analyzing the whole structure, we can now proceed to the design part of the structure. STAAD Pro can design a structure for various types of materials like Steel, Concrete, Aluminum, and Timber. We will choose RCC or Reinforces Cement Concrete for designing our structure. After completion of the analysis, we go back to the modeling mode and click on the Design Tab, where we select concrete as the material. Once that is done, we select the Design Code, which is to be followed. We select IS 456.

Once that is done, we select the various members to be designed, such as columns, beams slabs, etc. After that, we specify the design parameters according to our wish. Otherwise, STAAD will carry out the Design as per the specified Design Code.

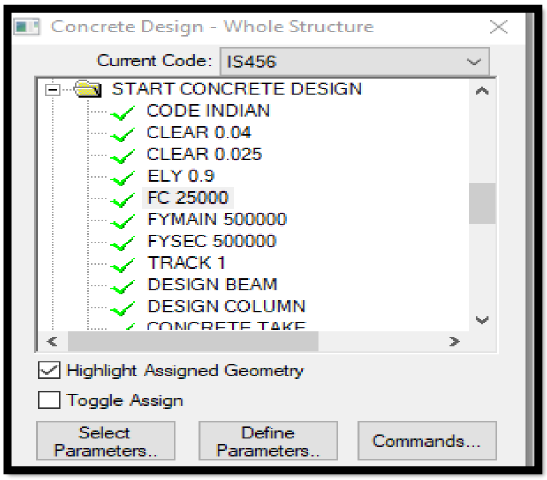


FIG 10: Assigning Design Parameter to the Structure

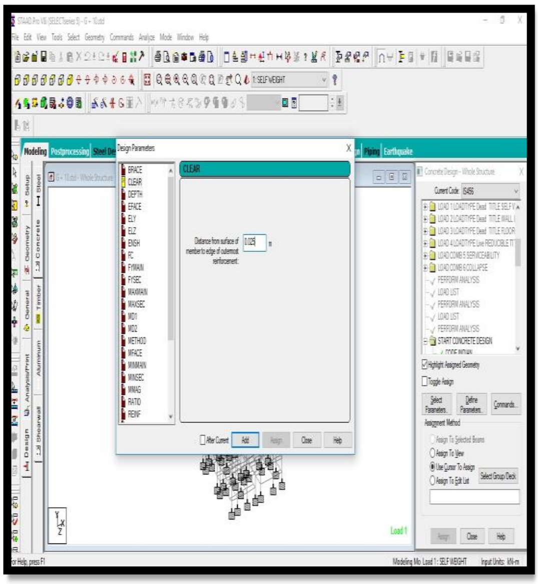


FIG 11: Input of Design Parameters in STAAD Pro.

Various Design parameters can be entered as per the user's command. These include the cover, reinforcement grade, maximum and minimum bar size, Design for torsion, eccentricity, etc. If not entered, the values will be taken as default by the STAAD engine as per the Codal Provisions.

Design Parameter for Fck = 25000 kN/m^2

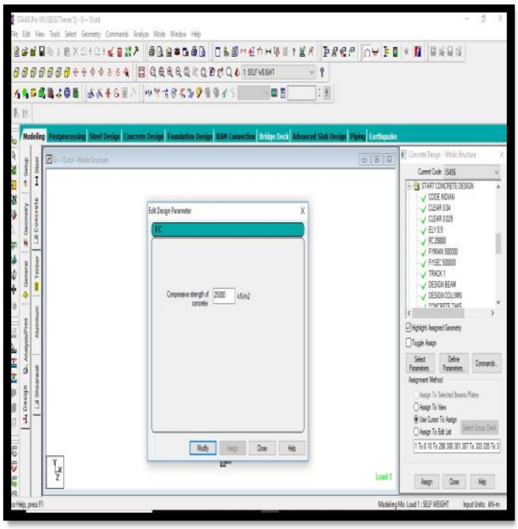


FIG 12: Designing Parameter for Fck

Design Parameter for Fy Main = 500000 kN/m^2

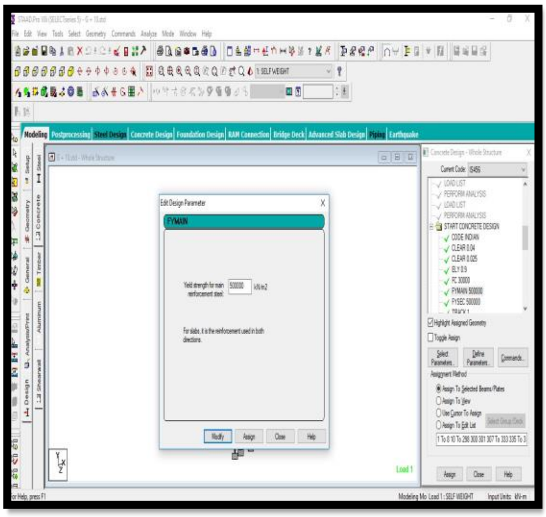


FIG 13: Input of Design Parameter for Fy MAIN

Design Parameter for Fy Sec = 500000 kN/m^2

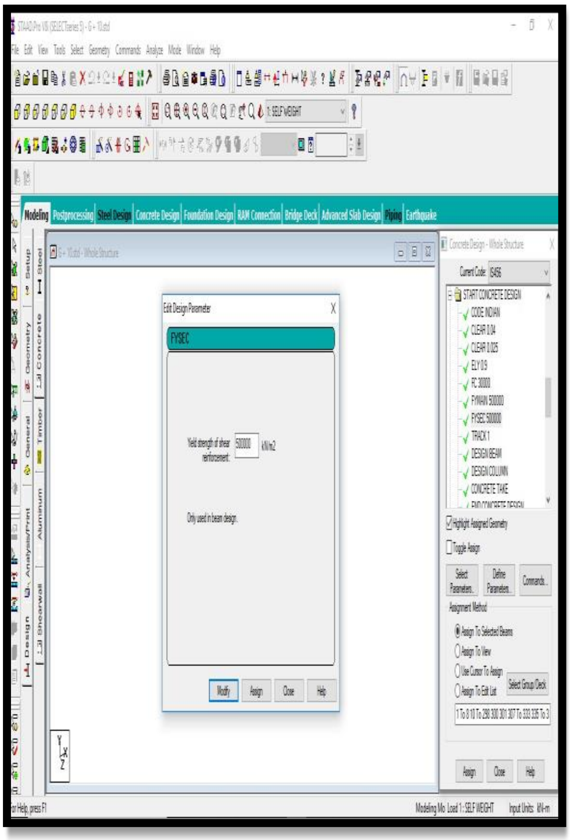


FIG 14: Input of Design Parameter for Fy SEC

VII. RESULTS

TABLE 4: Results for sample Beams

Beam no.	Size in m	Main Reinforcement	Shear Reinforcement
937	0.53 x 0.38	4 – 20 dia	2 Legged 12i @ 190 mm c/c
1560	0.53 x 0.38	10 - 20 dia	2 Legged 12i @ 190 mm c/c
4043	0.53 x 0.38	4 – 12 dia	2 Legged 12i @ 190 mm c/c

TABLE 5: Results for sample Columns

Column no.	Size in m	Main Reinforcement	Shear Reinforcement
814	0.45 x 0.75	20 – 12 dia	8 mm dia @ 190 mm c/c
1475	0.45 x 0.75	28 - 12 dia	8 mm dia @ 190 mm c/c
2122	0.45 x 0.75	12 - 12 dia	8 mm dia @ 190 mm c/c

Table 6: Results for Slab and Isolated Footing

Type	Thickness in m	Main Reinforcement	Distribution Reinf.
Slab	0.14	10 mm dia @ 300 mm c/c	10 mm dia @ 300 mm c/c
Isolated Footing	1.5 x 1.9	12 mm dia @ 150 mm c/c	12 mm dia @ 150 c/c

VIII. CONCLUSION

1) This project is mainly concentrated on the analysis and Design of multi-storied residential buildings with all possible cases of the loadings using STAAD. Pro Meeting the design challenges are described in a conceptual way.
2) We may also check the deflection of various members under the given loading combinations.
3) Further, in the case of rectification, it is simple to change the values at the place where the error occurred, and the obtained results are generated in the output.
4) Very less space is required for the storage of the data.
5) STAAD Pro V8i advanced software, which provides us a fast, efficient, easy to use, and accurate platform for analyzing and designing structures.
6) Shear reinforcement is calculated to resist both shear forces and torsional moments. The shear capacity calculation at different sections without the shear reinforcement is based on the actual tensile reinforcement provided by the STAAD program. Two-legged stirrups are provided to take care of the balance shear forces acting on these sections.
7) Maximum sagging (creating tensile stress at the bottom face of the beam) and hogging (creating tensile stress at the top face) moments are calculated for all active load cases at each of the above-

mentioned sections. Each of these sections is designed to resist both of these critical sagging and hogging moments. Where ever the rectangular section is inadequate as a singly reinforced section, a doubly reinforced section is tried.

8) The default design output of the beam contains flexural and shear reinforcement provided along the length of the beam.
9) Columns are designed for axial forces and biaxial moments at the ends. All active load cases are tested to calculate reinforcement. The loading which yields maximum reinforcement is called the critical load. The column design is done for the square section. Square columns are designed with reinforcement distributed on each side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under a uni-axial moment. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456 have been taken care of in the column design of STAAD.

IX. REFERENCES

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