STRUCTURAL ANALYSIS AND DESIGN OF A G+3 RESIDENTIAL BUILDING

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ABSTRACT

In order to compete in the ever-growing competent market it is very important for a structural engineer to save time. As a sequel to this an attempt is made to analyze and design a multistoried residential building by using a software package STAAD.Pro. For analyzing a multi storied building one has to consider all the possible loadings and see that the structure is safe against all possible loading conditions. The present project deals with the analysis and design of a multi storied residential building of G+3. The dead load, live loads and wind loads are applied and the design for beams and columns is obtained STAAD.Pro with its new features surpassed its predecessors and compotators with its data sharing capabilities with other major software like AutoCAD.

Keywords: STAAD. Pro, dead load and live loads and wind loads, Multi-storey building, AutoCAD, Concrete mix.

1. INTRODUCTION

General

The importance of wind engineering is emerging in India ever since the need for taller and slender buildings is coming forth. Considering the ever-increasing population as well as limited space, horizontal expansion is no more a viable solution especially in metropolitan cities. There is enough technology to build super-tall buildings today, but in India we are yet to catch up with the technology which is already established in other parts of the world. Nowadays, Construction of high-rise building is a basic need because of scarcity of land. Conventional method of manual design of high-rise building is time consuming as well as possibility of human errors. So it is necessary to use some computer based software which gives more accurate results and reduce the time.

STAAD-PRO is the structural software is nowadays accepted by structural engineers which can solve typical problem like static analysis, wind analysis, using various load combination to confirm various codes. Many times, wind engineering is being misunderstood as wind energy in India. On the other hand, wind engineering is unique part of engineering where the impact of wind on structures and its environment being studied. More specifically related to buildings, wind loads on claddings are required for the selection of the cladding systems and wind loads on the structural frames are required for the design of beams,

columns, lateral bracing and foundations. Wind in general governs the design when buildings are above 150 m height. However the other force which effect most on high rise building are the lateral forces caused by earthquakes. When buildings grow taller, they become flexible and they are moving away from the high frequency earthquake waves. This paper describes wind and seismic analysis of high-rise building in various zones of Indian subcontinent. For the analysis purpose a twelve story reinforced concrete framed structure is selected. The wind loads are estimated by Indian code IS: 875 (Part-3)-1987.

2. LITRATURE REVIEW

K. Vishnu Haritha, Dr.I. Yamini Srivallie (2015) According to them wind effect is predominant on tall structures depending on location of the structure, height of the structure. Further they discussed their paper is equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carried out using STAAD PRO.

MVK. Satish et.al (2017) he examined and designed a G+3 hospital building and its facility arrangement reaction to seismic load were studied using STAAD.Pro and after were investigated through a 3Dnon linear reaction history examination and corrected with non-linear static working methodology (NSP), this study recommends utilization of modular NSP rather than first mode NSP as it gives better result while comparing building structures.

Safwanahmad et.al (2017) designed a G+2 hospital building using STAAD.Pro by applying suitable loads and sectional details to component within the main aim of this factor was to study the extent of credibility of using STAAD.Pro for analysis Dr. Ashokkumar et.al (2017) designed a G+3 hospital building using substitute frame method in STAAD.Pro the efficiency of analyzing using software over manual method was analyzed and a comparative analysis was carried out.

Adiyanto (2008), analyzed a 3-storey hospital building using STAAD Pro. Seismic loads were applied to the building. The dead loads and live loads were taken from BS6399:1997 and seismic loads intensity is based on equivalent static force procedure in UBC1994. Result showed that the building can withstand any intensity of earthquake. It means that the buildings were suitable to be built in any area located near the epicenter of the earthquake.

3. OBJECTIVE AND METHODOLOGY

3.1 Objective of the study

1. To design G+3 residential apartment building using Staad. Pro software to with stand the wind loads, dead loads and live loads.
2. Analysis using Staad pro on G+3 residential apartment building.
3. Design using Staad. Pro on G+3 residential apartment building.

3.2 Methodology

Step 1- With the help of co-ordinate system, firstly we provide the nodes and connect them by using the command "ADD BEAM" to make the plan.

Step 2- By selecting all the nodes, use of translation repeats with step spacing= -1.5m, and global direction as Y, No. of steps = 1.

Step 3- By selecting all beams of plan, use of translation repeat with step spacing = 3m, global direction = Y, No. steps = 4.

Step 4- Assigning supports to the structure.

Step 5-Assigning properties to the structure i.e. giving dimension to the beam and column.

Step 6- Wind Load Definitions: In Wind Load Definitions we input the intensity details i.e., Wind intensities with respect to height.

Step 7- Load case details- • Dead Load (DL) • Live Load (LL) • Wind Load (WL-X and WL-Z)

Step 8- Assigning loads to the structure.

Step 9- Analysis

Step 10- Design

Note : Designing is done as per IS 456:2000

4. WORKING WITH STAAD.Pro

4.1 Auto Cadd Drawing (Plan)

Fig. 1: Auto cadd plan.

4.2 Building Specification

Table. 1: Description of the building data.

1	Details of the building	
i)	Structure	OMRF
ii)	Number of stories	G+3
iii)	Type of building	Regular and Symmetrical in plan
iv)	Flat area (l x b)	7.696 m X 19.318 m
iv)	Height of the building	12 m
v)	Support	Fixed
2	**Material properties**	
i)	Grade of concrete	M25
ii)	Grade of steel	Fe 415
iii)	Density of reinforced concrete	25 kN/m³
iv)	Young's modulus of M30 concrete, E_c	27386.13 kN/m²
vi)	Young's modulus steel, E_s	2×10^8 kN/m²
3	**Type of Loads & their intensities**	
i)	Floor finish + slab	4.75 kN/m²
ii)	Live load on floors	3 kN/m²
iii)	External wall load on beams + plastering	14 kN/m²
iv)	Internal wall load on beams + plastering	7.63 kN/ m²

4	Member Properties	No. of stories	Grade	Section sizes (mm)
i)	Column	ALL	M25	350 x 350
ii)	Beam	ALL	M25	230 x 300
iii)	Slab	ALL	M 25	150

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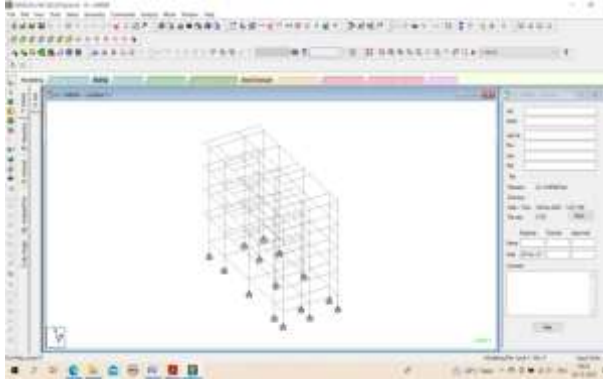## 5. ANALYSIS OF G+3 RCC BUILDING

5.1 G+3 Building

Fig. 2: G+3 storey building.

5.2 Generation of member property

Fig. 3: Generation of member property.

Generation of member property can be done in STAAD.Pro by using the window as shown above. The member selection is selected and the dimension have been specified. The beams having size of 0.23m x 0.30m and columns size of 0.35m x 0.35m.

5.3 Specification

Releasing end moments to the secondary beams both at starting and end of the beams.

5.4 Support

The base support of the structure was assigned as Fixed. The support was generated using the STAAD.Pro support generator.
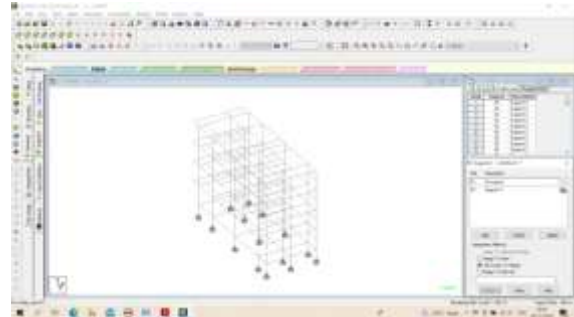
Fig. 4: 5 supports.

5.5 Materials for The Structre

The materials for the structure were specified as concrete with their various constant as per standard IS code of practice.

5.6 Loading

The loadings were calculated partially manually and rest was generated using STAAD.Pro generator.

The loading cases were categorized as:

- Self-weight
- Dead load
- Live load
- Wind load
- Seismic load
- Load combinations

5.6.1 Self-Weight

The self weight of the structure can be generated by STAAD. Pro itself with the self weight command in the load case column.
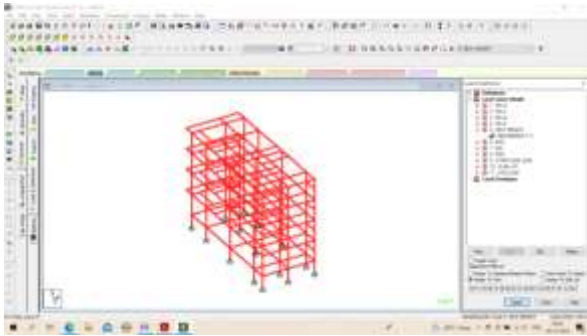
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Fig. 5: Self weight.

5.6.2 DEAD LOAD

Wall weight

External wall thickness of brick=230mm (9")

Internal wall thickness of AAC block=115mm (4")

Parapet wall thickness of AAC block=115mm (4") Ext. & Int.

Wall Height=3m-0.3m=2.7m

Parapet wall height=1m

External plaster : outer and internal plaster = 15mm & 12mm = total 27mm

Internal plaster: outer and internal plaster = 12mm & 12mm = total 24mm

External wall weight = (0.23 x 2.7 x 20) + (0.027 x 2.7 x 22) = 12.42 + 1.6038 = 14KN/m

Internal wall weight = (0.115 x 2.7 x 20) + (0.024 x 2.7 x 22) = 6.21 + 1.4256 = 7.6356KN/m

Parapet wall weight = (0.115 x 1 x 20) + (0.027 x 1 x 22) = 2.3 + 0.594 = 3 KN/m

Slab + floor finish weight

Slab thickness = 150mm

Floor finish = 50mm

Density of concrete = 25KN/m^3

Density of floor finish = 20KN/m^3

Floor weight = (0.150 x 25) + (0.050 x 20) = 4.75KN/m2

Stair case weight

The stair case weight = 20KN/m
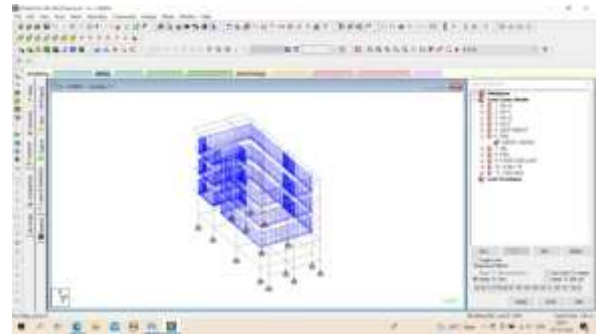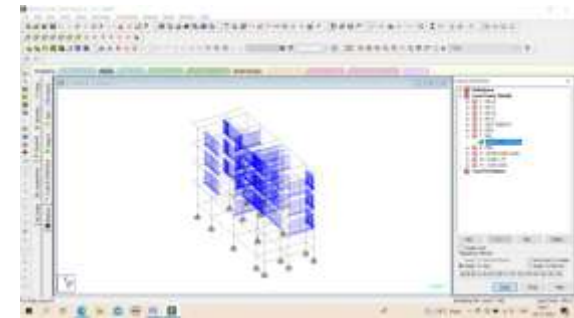

Fig. 6: External wall load.
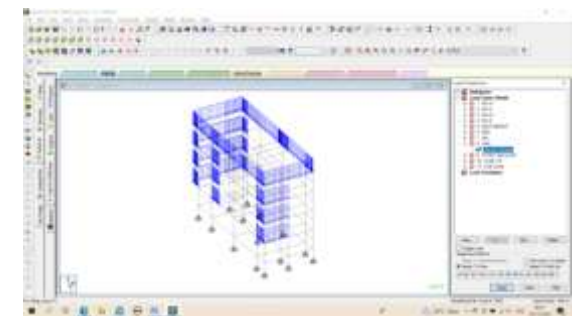

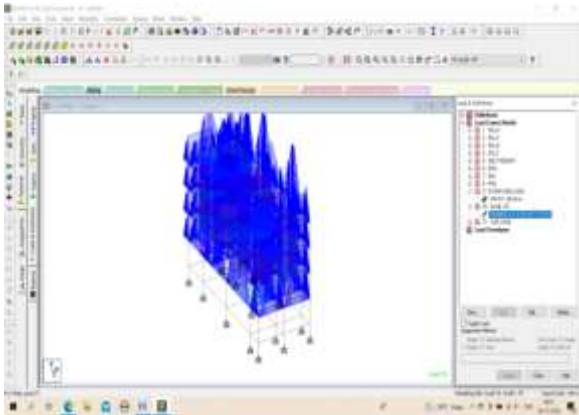Fig. 7: Internal wall load.

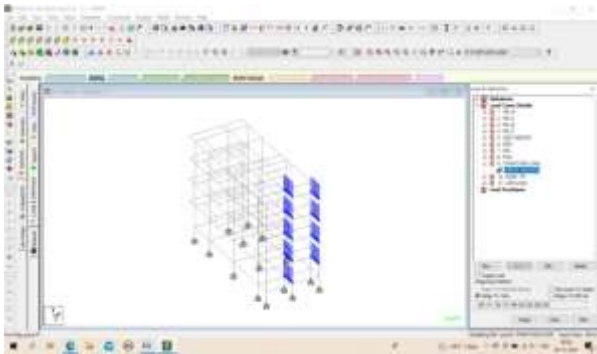Fig. 8: Parapet wall load.

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Fig. 9: Slab + ff load.

Fig. 10: Staircase load.

5.6.3 Live Load

The live load considered in each floor & terrace was 2.5 kN/m^2. The live loads were generated in similar manners as done in the earlier case dead load in floor. This may be done from the member load button from the load case column.
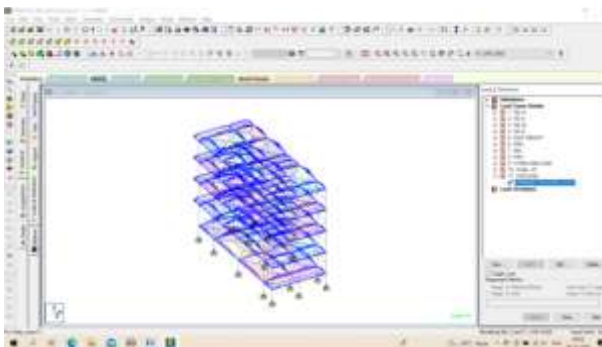

Fig. 11: Live load.

5.6.4 Wind Load

The wind load values were generated by the software itself in accordance withIS 875.Under the define load command section, in the wind load category , the definition of wind load was supplied. The wind intensities at various heights were calculated manually and feed to the software. Based on those values it generates the wind load at different floors.

Wind pressure $P_z = 0.6 * V_z^2$

$$V_z = V_b * k_1 * k_2 * k_3 * k_4$$

V_z = Design wind speed at any height z meters,

V_b = Basic wind speed in m/s = 44 m/s [clause 5.2 - from IS:875(PART 3) -1987]

k_1 = Probability factor (risk coefficient) =1 [Table 1 - from IS:875(PART 3) -1987]

k_2 = Terrain, height and structure size factor = 0.964 (below from table : 7.1)

k_3 = Topography factor Basic wind speed =1 (as per IS:875(PART 3) -1987)

k_4 = important factor = 1 (general constructions as per IS:875(PART 3) -1987)

Terrain, height and structure size factor (k2) [from table 2 from IS:875(PART 3) -1987] [for Category 3]

Table. 2: Terrain, height and structure size factor (k2).

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Heigh(t)	Terrain Category 3
10	0.88
15	0.94
12	0.904 (by interpolation)

Calculation of Vz

For 12m (3+3(3)=12),

$Vz = Vb * k1 * k2* k3 = 44 * 1 * 0.904 * 1 * 1 = 39.776$

Calculation of Pz

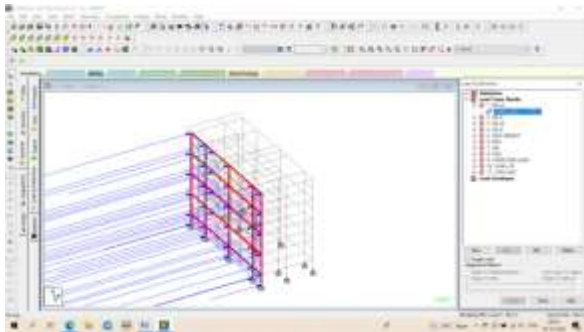$Pz = 0.6 \times Vz^2 = 0.6 \times (39.776)^2 = 949.27$ N/m^2 = 0.95 kN/m^2

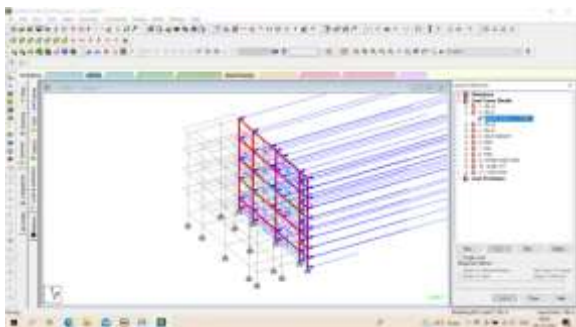Fig. 12: Assigning wind load in WL+X direction.

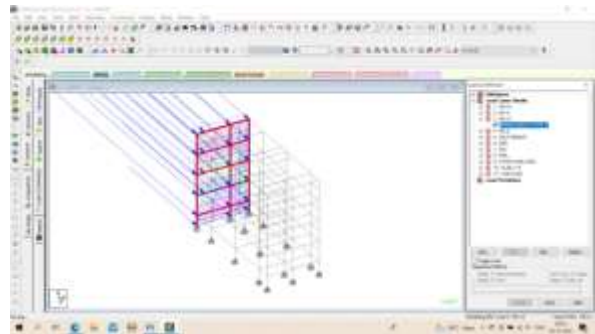Fig. 13: Assigning wind load in WL - X direction.
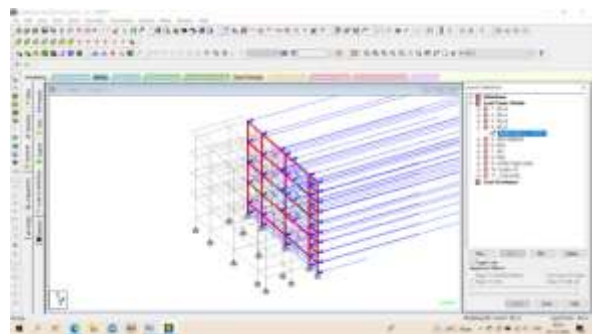

Fig. 14: Assigning wind load in WL + Z direction.

Fig. 15: Assigning wind load in WL - Z direction.

5.6.5 LOAD COMBINATION

The structure has been analyzed for load combinations considering all the previous loads in proper ratio. In the first case a combination of self-weight, dead load, live load and wind load was taken in to consideration. In the second combination case instead of wind load seismic load was taken into consideration.

The load combinations are (as per IS 875 PART 3);

Serviceability combinations:

1(DL+LL)

1(DL)+0.8(LL)+0.8(WL+X)

1(DL)+0.8(LL)+0.8(WL-X)

1(DL)+0.8(LL)+0.8(WL+Z)

1(DL)+0.8(LL)+0.8(WL-Z)

Collapse combinations:

1.5(DL+LL)

1.5(DL+(WL+X))

1.5(DL+(WL-X))

1.5(DL+(WL+Z))

1.5(DL+(WL-Z))

1.2(DL+LL+(WL+X))

1.2(DL+LL+(WL-X))

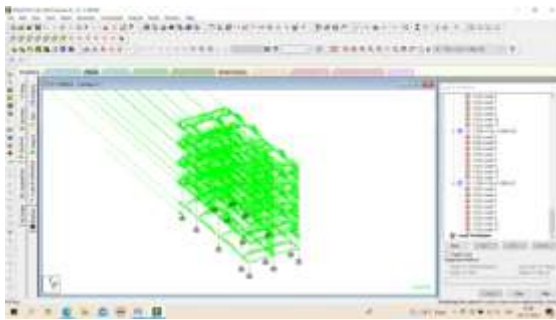1.2(DL+LL+(WL+Z))

1.2(DL+LL+(WL-Z))
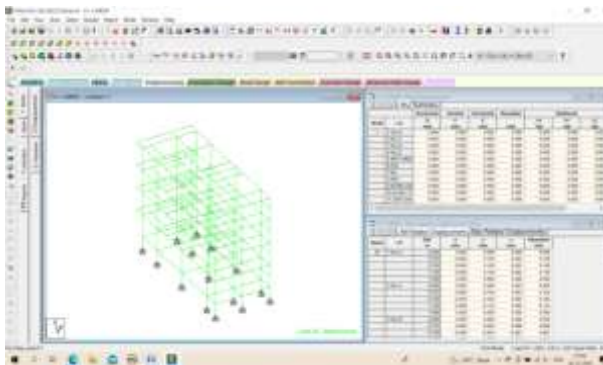

Fig. 16: Load combinations.

Fig. 17: Displacement.
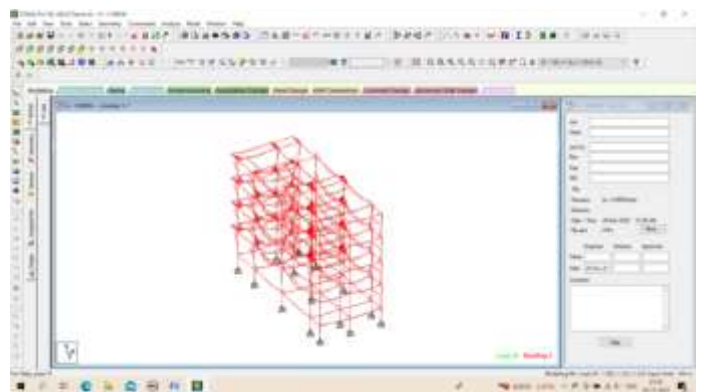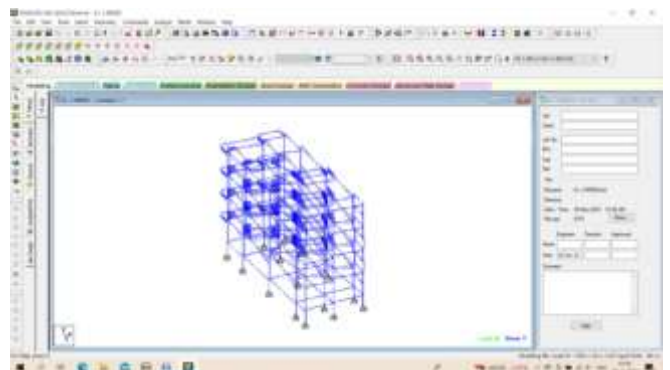

Fig. 18: Base reactions.

Fig. 19: BMD.

Fig. 20: SFD.

5.7 DESIGN OF G+3 RCC FRAMED BUILDING

The structure was designed for concrete in accordance with IS code. The parameters such as Clear cover, F_y, F_c, etc were specified. The window shown below is the input window for the design purpose. Then it has to be specified which members are to

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be designed as beams and Which member are to be designed as columns.

Some of the sample analysis and design results have been shown below for Beam number 177 which is at the roof level of 3rd floor.

Fig. 21: Shear bending.

Fig. 22: Property.

Fig. 23: Deflection.

Fig. 24: Concrete design.

6. RESULTS

Fig. 25: Stadd output quantities.

7. 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.

Design for Flexure: 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 are designed to resist both of these critical sagging and hogging moments. Where ever the rectangular section is

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inadequate as singly reinforced section, doubly reinforced section is tried.

Design for Shear: Shear reinforcement is calculated to resist both shear forces and tensional moments. Shear capacity calculation at different sections without the shear reinforcement is based on the actual tensile reinforcement provided by STAAD program. Two-legged stirrups are provided to take care of the balance shear forces acting on these sections.

Beam Design Output: The default design output of the beam contains flexural and shear reinforcement provided along the length of the beam.

Column Design: Columns are designed for axial forces and biaxial moments at the ends. All active load cases are tested to calculate reinforcement. The loading which yield maximum reinforcement is called the critical load. Column design is done for rectangular section. Rectangle columns are designed with reinforcement distributed on each two side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under bi-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 STTAD.

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