ANALYSIS AND DESIGN OF 10 STOREY BUILDING SUBJECTED TO WIND AND SEISMIC LOADS USING STAAD. PRO

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ABSTRACT

The design and analysis of multi-storey reinforced concrete (RCC) buildings require accurate structural modelling and careful consideration of both gravity and lateral loads. This study presents the modelling, analysis, and design of a 10-storey RCC building using STAAD. Pro software to evaluate its structural performance under various loading conditions. The structure is modelled as a three-dimensional space frame incorporating beams, columns, slabs, and fixed supports, ensuring realistic simulation of structural behaviour. Loads were calculated in accordance with Indian Standard codes, including dead load, live load, wind load (IS 875 Part 3), and seismic load (IS 1893 Part 1). The analysis results showed that the maximum bending moment in beams was about 120 kNm, with shear forces up to 85 kN. Columns experienced axial loads up to 1800 kN with bending moments of 150 kNm. Slabs were subjected to an effective load of approximately 7.6 kN/m². Design of structural elements was carried out using the limit state method as per IS 456:2000. Beam reinforcement (Ast) was found to be in the range of 900–1400 mm², corresponding to a steel percentage of 0.8%–1.2%. Column reinforcement ranged between 1.2%–2.0% of gross cross-sectional area, with Ast values of approximately 1800–3200 mm². Slab reinforcement was relatively lower, with Ast values of 350–600 mm²/m width, corresponding to 0.3%–0.6% steel. The maximum storey displacement was about 38 mm, and inter-storey drift remained within permissible limits. The base shear was approximately 600 kN, highlighting the significance of lateral loads. The study concludes that STAAD.Pro ensures accurate analysis and efficient design, and proper reinforcement detailing is essential for achieving safe, durable, and economical multi-storey structures.

Keywords: STAAD.Pro, Structural Modelling, Multi-storey Building, Wind Load Analysis, Seismic Analysis, Structural Design, Load Combinations, Storey Drift, Limit State Design, IS Codes.

1. INTRODUCTION

The rapid pace of urbanization and industrial development has led to a growing demand for residential, commercial, and institutional buildings. Due to scarcity of land and increasing land costs in urban areas, vertical development in the form of multi-storey and high-rise buildings has become inevitable. While multi-storey buildings provide efficient land utilization and increased accommodation capacity, they also pose significant structural challenges, particularly due to lateral loads such as wind and earthquakes.

In low-rise buildings, gravity loads generally dominate the design. However, as the height of a building increases, lateral loads become critical and significantly influence structural behaviour. Wind loads can cause lateral sway, vibration, and discomfort to occupants, while earthquake loads can induce severe dynamic effects leading to cracking, structural damage, or collapse if not properly addressed. Therefore, accurate estimation and analysis of these loads are essential to ensure structural safety and serviceability.

Traditionally, structural analysis and design were performed using manual methods, which are time-consuming and prone to human error, especially for complex multi-storey structures. The advent of computer-aided analysis software has revolutionized structural engineering practice. Software such as AutoCAD and STAAD.Pro allows engineers to model real-life structures accurately, apply various loading conditions, and obtain reliable results within a short time.

This paper presents a detailed study on the structural modelling, wind and seismic analysis, and design of a 10-storey reinforced concrete building using AutoCAD and STAAD.Pro. The study aims to understand the behaviour of the structure under gravity and lateral loads and to demonstrate the effectiveness of software-based analysis in modern structural engineering.

2. LITERATURE REVIEW

Several researchers have studied the behaviour of multi-storey buildings under wind and seismic loads using advanced structural analysis software. Karve and Shah emphasized that computer-aided analysis significantly reduces manual errors and improves the reliability of reinforced concrete design. Punmia et al. highlighted the importance of the Limit State Method in achieving safe and economical designs for RCC structures.

Many studies have focused on the application of STAAD.Pro for analysing G+10 and G+15 buildings. Researchers observed that as the number of storeys increases, lateral displacement, storey drift, and base shear also increase, necessitating larger member sizes and higher reinforcement percentages. Studies comparing wind and seismic effects concluded that seismic loads often govern the design in earthquake-prone regions, whereas wind loads become critical for very tall and slender buildings.

Researchers such as Chopra and Agarwal emphasized that while equivalent static analysis is suitable for regular medium-rise buildings, dynamic methods such as response spectrum and time history analysis provide more realistic results for taller or irregular structures. However, for regular 10-storey buildings, equivalent static analysis is widely accepted and provides sufficiently accurate results.

The reviewed literature clearly indicates the importance of proper structural modelling, accurate load estimation, and software-based analysis in ensuring the safety and performance of multi-storey buildings.

3. BUILDING DESCRIPTION AND PLANNING

The building considered in this study is a 10-storey reinforced concrete framed structure intended for commercial/public use. The plan configuration is kept regular and symmetric to minimize torsional effects during wind and seismic action. A rectangular plan layout is adopted to ensure uniform distribution of mass and stiffness.

Architectural and structural planning is carried out using AutoCAD software. The planning stage considers functional requirements such as circulation, staircase and lift placement, ventilation, and accessibility. Structural planning focuses on the proper alignment of columns, beams, and slabs to ensure effective load transfer from superstructure to foundation.

The drawings provide accurate dimensions, storey heights, and member locations, which are essential inputs for structural modelling in STAAD.Pro. Proper planning at this stage reduces modelling errors and improves the accuracy of analysis results.

Table 1: General Building Details

Parameter	Description
Type of Structure	Reinforced Concrete Framed Structure
Number of Storeys	10
Usage	Commercial / Public Building
Structural System	Moment Resisting Frame
Analysis Software	STAAD.Pro
Drafting Software	AutoCAD

4. STRUCTURAL MODELLING IN STAAD.PRO

Based on the AutoCAD drawings, a three-dimensional space frame model of the building is developed in STAAD.Pro. The building is idealized using nodes and members, where columns are represented as vertical members and beams as horizontal members. Slab loads are transferred to beams using appropriate floor load assignments.

Table 2: Material Properties

Material	Grade	Property
Concrete	M25	fck = 25 MPa
Reinforcement Steel	Fe415	fy = 415 MPa

Material properties are defined as per Indian Standard codes. Concrete of grade M25 and steel of grade Fe415 are used. Fixed supports are assumed at the base to simulate rigid foundation conditions. Member properties are assigned based on preliminary design assumptions. The finite element method implemented in STAAD.Pro is used to analyse the structure. The software enables accurate computation of internal forces, displacements, and support reactions, which are essential for structural design.

5. LOAD CALCULATION AND MODEL ANALYSIS

Dead Load Calculation

Dead loads are permanent loads due to the self-weight of structural components such as slabs, beams, columns, walls, staircases, and fixed installations. These loads are calculated accurately using the unit weight of materials and member dimensions. For reinforced concrete, a unit weight of 25 kN/m³ is considered.

Live Load Calculation (IS 875 Part 2) : Live loads are variable loads arising from occupancy, furniture, and usage of the building. As per IS 875 (Part 2), standard recommended values are adopted since live loads cannot be predicted precisely. Typical floor live load is taken as 3 kN/m², staircase load as 3 kN/m², and roof load as 1.5 kN/m².

Wind Load Calculation (IS 875 Part 3) : Wind loads are lateral loads caused by wind pressure acting on the building and increase with height. The design wind speed is calculated using basic wind speed and terrain factors, and wind pressure is obtained using IS 875 provisions. The resulting wind force per floor is applied as lateral load in the analysis.

Earthquake Load Calculation (IS 1893):Earthquake loads are dynamic forces generated due to ground motion and depend on the seismic zone, building mass, and height. As per IS 1893, the design base shear is calculated using zone factor, importance factor, and response reduction factor. The base shear is distributed along the height, with higher storeys attracting greater forces..

Description:

This figure illustrates different load cases applied to the structure, including dead load, live load, wind load in X and Z directions, and seismic load in X and Z directions

Table3: Load Case Details

Load Case	Description
DL	Self-weight + walls
LL	Floor occupancy load
WL	Wind lateral load
EQ	Seismic lateral load

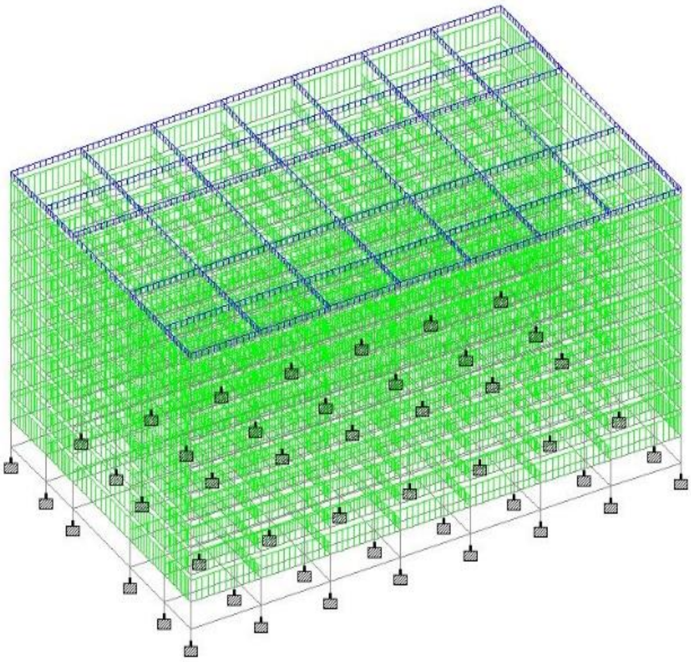

Fig .1: Dead Load

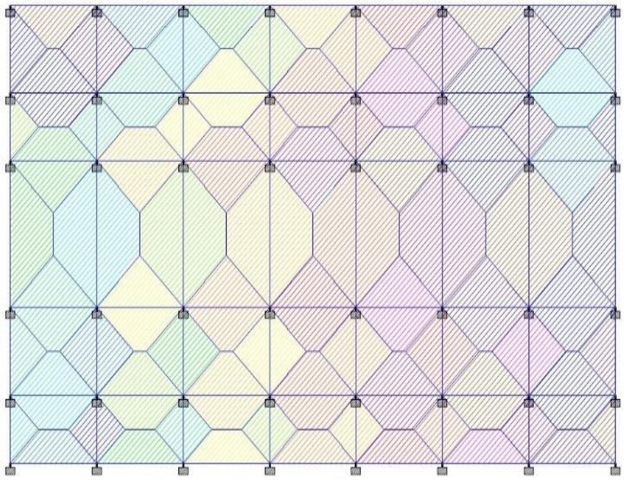

Fig .2: Floor Finish Load

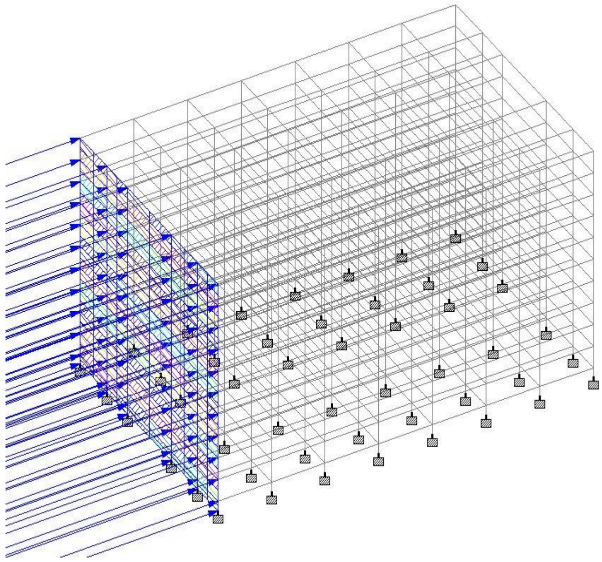

Fig .3: Wind Load

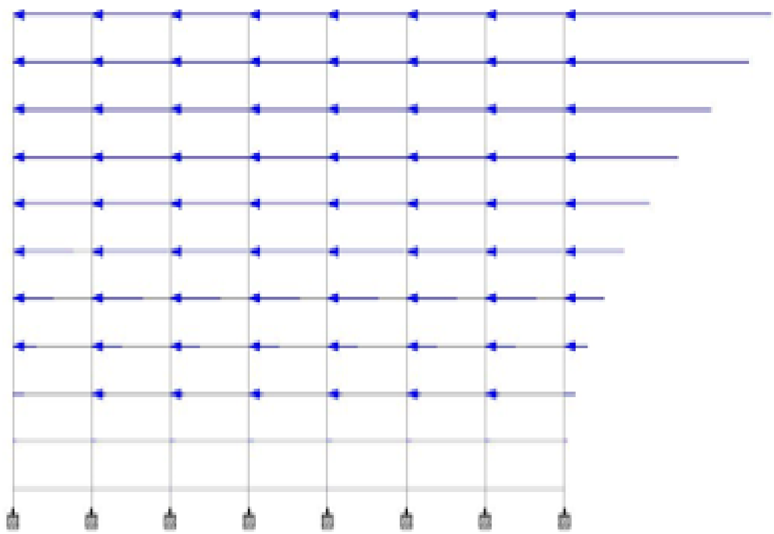

Fig .4: Earth Quake Load

Typical Combinations

- 1.5 (DL + LL)
- 1.5 (DL + WL)
- 1.5 (DL + EQ)
- 1.2 (DL + LL + WL)
- 0.9 DL ± 1.5 WL

Table 4: Sample Load Combinations

Combination No	Expression
LC1	1.5 DL
LC2	1.5 (DL + LL)
LC3	1.5 (DL + WL)
LC4	1.5 (DL + EQ)
LC5	1.2 (DL + LL + WL)

Table 5: Load Details

Load Type	Value
Live Load	As per IS 875 (Part 2)
Floor Finish Load	1.0–1.5 kN/m²
Wall Load	As per wall thickness
Wind Load	IS 875 (Part 3)
Seismic Load	IS 1893 (Part 1):2016

6. ANALYSIS OF 10-STOREY BUILDING

The structural analysis of the 10-storey reinforced concrete building was carried out using STAAD.Pro to evaluate its performance under gravity and lateral loads. The building was modeled as a three-dimensional space frame, and linear static analysis was performed considering dead load, live load, wind load (IS 875 Part 3), and seismic load (IS 1893). The finite element method was used to determine internal forces, displacements, and support reactions.

Linear Static Analysis

The analysis involved defining load cases, generating load combinations, and executing the solver to obtain bending moments, shear forces, axial forces, and nodal displacements. The results formed the basis for strength and serviceability checks.

Wind and Seismic Behaviour

Wind loads caused gradual lateral displacement increasing from base to top, with maximum displacement at the roof level. Seismic analysis using the equivalent static method showed a similar displacement pattern but generated comparatively higher base shear.

- Maximum top displacement ≈ 22 mm (within permissible limits)
- Wind base shear ≈ 450 kN

- Seismic base shear ≈ 600 kN

Seismic forces were found to govern the design.

Storey Displacement and Drift

Storey displacement increased linearly with height. Maximum displacement occurred at the top storey and remained within allowable limits.

Storey drift values were well below the permissible limit of (h/500) as per IS 1893, indicating adequate lateral stiffness and serviceability performance.

Table 6: Storey Displacement (Sample Values)

Storey	Height (m)	Displacement (mm)
10	30	22
9	27	20
8	24	18
7	21	16
6	18	13
5	15	10
4	12	8
3	9	6
2	6	3
1	3	1

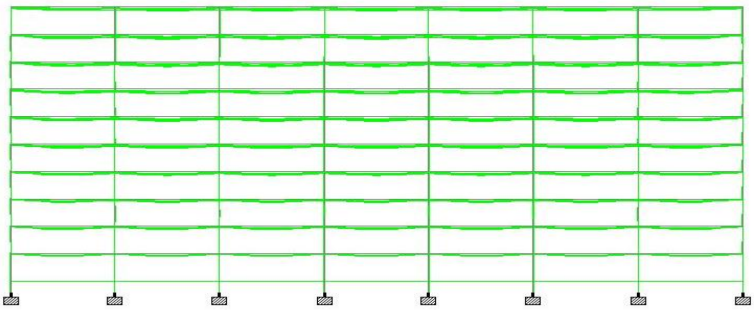

Fig .5: Story Displacement

Internal Force Behaviour:

Bending Moment Diagram

Bending moments develop in beams and columns due to applied loads. These moments determine reinforcement requirements.

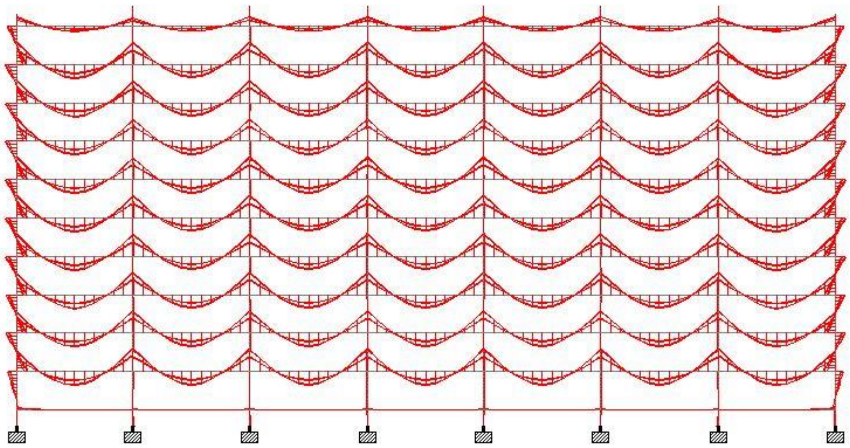

Fig .6: Bending Moment Diagram

Shear Force Diagram

Shear forces develop due to transverse loads and are highest near supports. Shear failure is brittle; hence, proper shear design is essential.

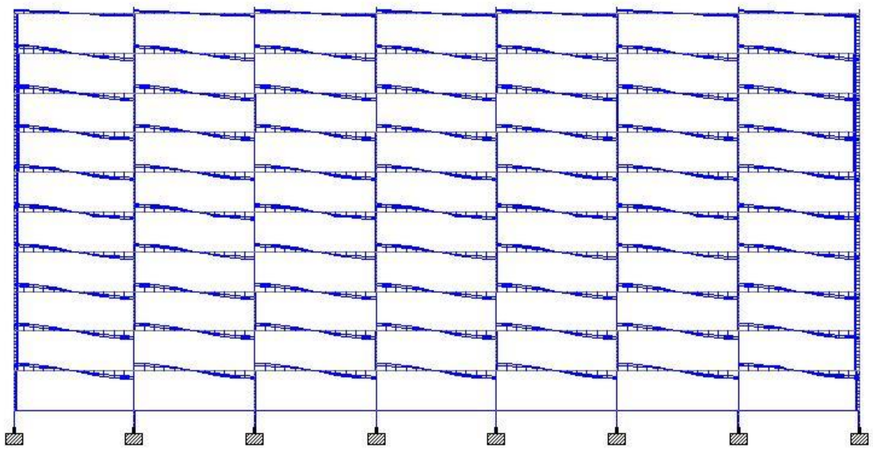

Fig.7: Shear Forse

AXIAL FORCE

Axial forces are primarily compressive in columns due to gravity loads. Columns at lower floors carry higher axial loads.

Maximum axial force ≈ **1500 kN**

These values are used for column design

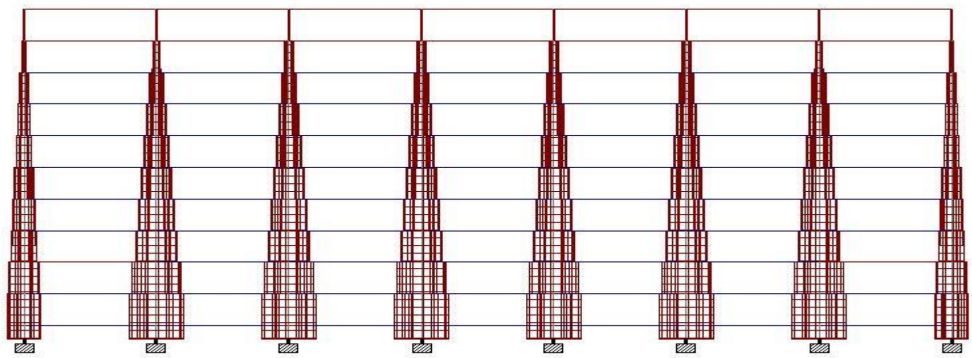

Fig .8: Axial Load

The analysis confirms that the 10-storey building satisfies both strength and serviceability requirements under gravity and lateral loads. Displacements and drifts are within permissible limits, and seismic effects govern the structural design. The selected structural configuration demonstrates adequate stiffness, stability, and safety, making the building structurally efficient and suitable for design implementation.

7. RESULTS AND DISCUSSION

The analysis results indicate that storey displacement increases gradually with height, with maximum displacement occurring at the roof level. Storey drift values are found to be within permissible limits specified by IS 1893, indicating adequate lateral stiffness.

Table 9: Seismic Parameters

Parameter	Value
Seismic Zone	As per project location
Zone Factor (Z)	As per IS 1893
Importance Factor (I)	1.0
Response Reduction Factor (R)	3 / 5 (as applicable)
Soil Type	Medium Soil

Base shear obtained from seismic analysis is higher than that from wind analysis, indicating that earthquake loads govern the design for the selected seismic zone. Bending moments and shear forces are maximum in lower storeys due to cumulative loading effects. Columns at ground and lower floors experience higher axial forces and require larger cross-sections and higher reinforcement.

Table 10: Design Summary of Structural Members

Member	Governing Force	Design Status
Beams	Bending & Shear	Safe
Columns	Axial Load + Moment	Safe
Slabs	Flexure	Safe
Footings	Bearing Pressure	Safe

Description:
This figure shows the storey drift values for each floor level. The drift values are within permissible limits specified by IS 1893, indicating adequate lateral stiffness.

Description:
The bending moment diagram obtained from STAAD.Pro for a typical beam under critical load combinations is presented.

8. DESIGN OF STRUCTURAL COMPONENTS

Structural components are designed using the Limit State Method as per IS 456:2000. Beams are designed for bending moment and shear forces, columns are designed for combined axial load and bending, and slabs are designed for flexure and deflection control. Foundations are designed based on column reactions obtained from analysis.

Column Design: Columns are vertical members designed to carry axial loads combined with bending moments. Lower storey columns are provided with larger dimensions and reinforcement to resist higher axial loads due to the cumulative weight of upper floors. The reinforcement consists of main longitudinal bars and ties, spaced as per code requirements. Concrete grade M25 and steel grade Fe415 are used. The design ensures that columns are safe under combined loading, and deflections remain within permissible limits.

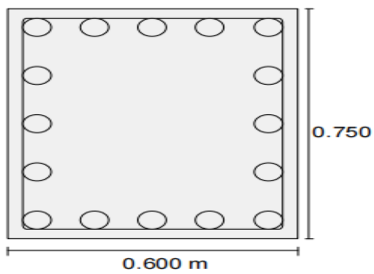

Fig .9: Column Design

Beam Design: Beams are horizontal members that transfer floor loads to columns and resist bending and shear forces. Each beam is designed with sufficient longitudinal reinforcement and distribution bars to satisfy bending and shear requirements. Beam sections are optimized for strength and serviceability, taking into account dead, live, wind, and seismic loads. Concrete grade M25 and steel grade Fe500 are used.

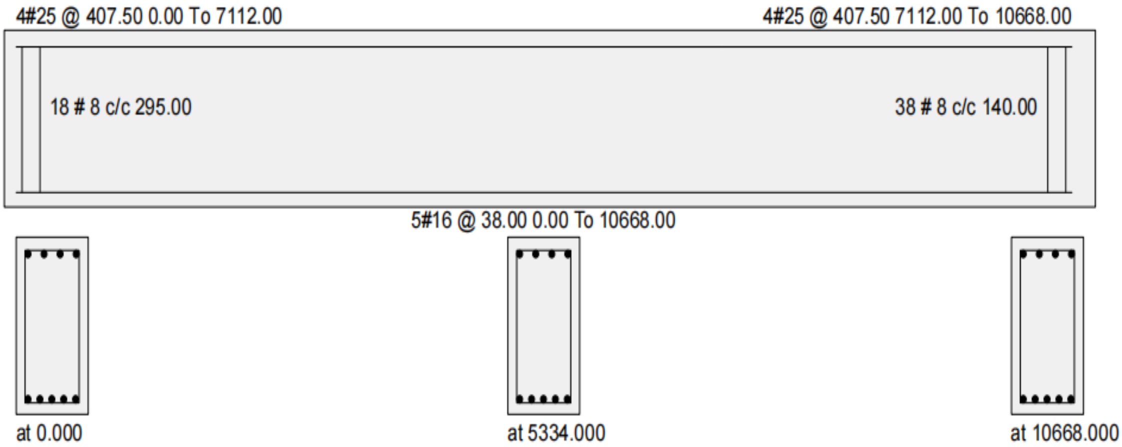

Fig .10:Beam Design

STAAD.Pro is used to obtain reinforcement details for beams and columns. Serviceability checks such as deflection and storey drift are also verified to ensure acceptable performance under normal usage.

The results demonstrate that proper modelling and accurate load application are essential for realistic analysis and safe design of multi-storey buildings.

9. CONCLUSIONS

This paper presents a comprehensive study on the structural modelling, wind and seismic analysis, and design of a 10-storey reinforced concrete building using AutoCAD and STAAD.Pro. The integration of AutoCAD planning with STAAD.Pro analysis proved effective in achieving accurate modelling and reliable results. The structure analysed satisfies all codal requirements for strength and serviceability. The study confirms that software-based analysis significantly improves efficiency and accuracy compared to traditional manual methods. The methodology adopted can be effectively applied to the design of similar multi-storey buildings in wind- and earthquake-prone regions.

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