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Planing Analysis and Design of Residential Building Using Staad Pro

G. Prema Swathi[1], Ch. Srinivas[2]

Gedela Sai Partha Saradhi[3], Allu Vamsi Krishna[4], Agraharapu Akhil Prasad[5],

Chukkala Sri Ram Govind[6]

[1]Assistant Professor , Department of Civil Engineering, Godavari Institute of Engineering & Technology(Autonomous), Rajahmundry.
[2] Head of the Department , Department of Civil Engineering,Godavari Institute of Engineering & Technology(Autonomous), Rajahmundry.
[3,4,5,6] B.Tech Student, Department of Civil Engineering, Godavari Institute of Engineering & Technology(Autonomous), Rajahmundry.

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Abstract - One of the major challenges the country faces is a rapid growing population, which creates a demand for more facilities and limited land availability. This issue can be partially addressed through the construction of residential buildings. A residential building is a building that contains separate living places where people can live or stay regularly. This buildings have the necessary facilities and utilities to meet the needs of the people living there. example of this buildings is individual houses, apartments, hotels, private dwelling etc.
This study provides an in-depth analysis of a residential building using STAAD PRO, a prominent structural analysis and design software. The process begins with defining the project scope, followed by the development of a detailed three-dimensional model that integrates architectural designs, material specification, and load conditions in accordance with relevant building codes. A variety of analysis, including linear static and dynamic evaluations, are performed to asses the structural performance under diverse loading scenarios. The results are meticulously reviewed to ensure adherence to safety standards, emphasizing the optimization of critical structural elements such as beams, columns, slabs. Additionally, the paper outlines a systematic approach to estimating costs, detailing material quantities and labor requirements to produce a comprehensive budget.

***Key Words*:** Residential building, STAAD PRO, Auto-cad, Analysis, Designing.

INTRODUCTION

The basic needs of human existence are food, clothing, and shelter. Throughout history, humanity has consistently worked to improve these aspects of living, striving for better standards of life. Shelter, in particular, plays a crucial role by providing a sense of security, responsibility, and social status. Every individual naturally desires a peaceful environment for a pleasant living experience, which is best achieved by having a home located in a safe and convenient area.

When planning and designing residential buildings, engineers must consider various factors such as municipal regulations, building byelaws, environmental conditions, financial constraints, water supply, sewage systems, future provisions, aeration, ventilation, and even traditional principles like Vastu. These considerations are essential for suggesting an appropriate plan. A well-designed residential building includes proper ventilation, sufficient doors, and windows to ensure comfort and functionality. Structural analysis is critical in this process, as it involves determining the general shape and specific dimensions of a structure to ensure it performs its intended function while safely withstanding the forces it will encounter throughout its lifespan.

The rapid growth of urban populations has led to an increased demand for housing in cities. However, with rising land costs and limited land availability, the construction of multistoried buildings has become a practical solution to accommodate this urban influx. These high-rise structures are now an integral part of modern urban living.

objectives

The specific objectives of the present investigation are listed below:

•To KNow various design aspects of planning, analysis and design of a residential building.

•To evaluate each and every activity involved in construction of a building.

•To manually analyze the problem frame, under vertical loading conditions.

•To perform the same analysis using standard analysis software Staad.Pro.

•Perform substitute frame analysis for the loading cases.

•Compare the accuracy of the substitute frame analysis with manual and Staad.Pro anal- ysis and check its validity in lateral loading cases.

Design the structural members of the residential buildings.

METHODOLOGY

PLANING

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Planning in AutoCAD for a G+3 residential building involves several critical steps to ensure functionality, aesthetics, and structural stability. First, the site plan is created by marking property boundaries, road access, setbacks, and open spaces. Next, the floor plan is developed, allocating spaces for living rooms, bedrooms, kitchens, bathrooms, staircases, and balconies, ensuring proper circulation and ventilation. The structural layout, including column positions, beam arrangements, and slab details, is then designed based on load calculations and architectural requirements.Elevation and section views are essential to visualize the building's façade and interior heights. AutoCAD's layer management helps differentiate architectural, structural, and electrical components. Dimensions, annotations, and hatching enhance clarity. Window and door placements follow natural lighting and ventilation principles. Staircase planning ensures proper rise, tread, and headroom. Parking, landscaping, and service areas are integrated based on available space.Electrical layouts include power points, light fixtures, and panel locations, while plumbing layouts show water supply, drainage, and sanitary connections. AutoCAD blocks help insert furniture and fixtures for better visualization. A 3D model can be generated for realistic representation. The final drawings are checked for compliance with building codes, and detailed working drawings are prepared for execution on-site. Proper planning ensures safety, comfort, and efficiency in construction.Building plans are detailed graphical representations of a building's design, illustrating how it will appear upon completion. These plans serve as essential tools for builders and contractors to guide the construction of various types of structures. Additionally, building plans are crucial for estimating project costs and preparing accurate budgets.The process of creating building plans begins when a property owner or developer presents their vision for a new structure to an architect. Depending on the project's complexity and level of detail required, architects produce various types of drawings to ensure a clear understanding and facilitate a seamless construction process.

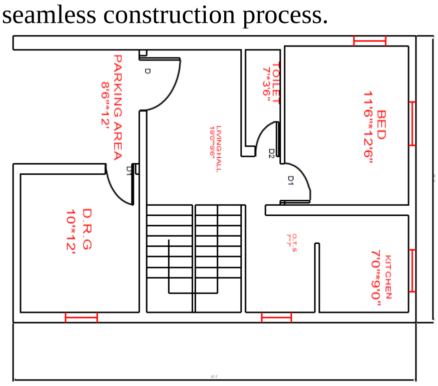


Fig: Suggested Plan

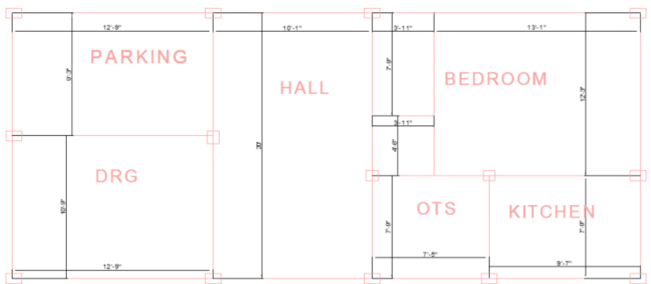


Fig: Grid View of Building

Advise of vasthu for building

A building is a multi-story structure designed for either commercial or residential use, such as a shopping complex or an apartment. Incorporating Vastu principles is essential to ensure the prosperity and harmony of those living or working within the building. Rooted in the ancient texts of the Vedas, Vastu Shastra provides guidelines to transform a plot into a "healthy building," promoting health, wealth, and well-being.

A Vastu-compliant building not only fosters success and prosperity but also reduces stress and negative energy, creating a positive environment for its occupants. By adhering to these principles, buildings are designed to align with natural energies, ensuring a balanced and fulfilling life. Whether the purpose of the building is residential or commercial, integrating Vastu principles has become a vital aspect of its construction.

vaasthu tips for building

1The plot chosen for a building should ideally be square or rectangular, as irregularly shaped plots are believed to bring misfortune to the occupants.

2Avoid extending the building in the South or West, and refrain from having cuts in the North or East, as these are considered inauspicious.

3Sample open spaces should be maintained towards the North, North-East, and East for features like lawns, parking areas, or gardens. These vital directional areas should remain uncluttered and free from construction.

4The main entrance or door should be positioned in the East and should be larger than other doors, especially the exit door, to attract positive energy.

5The building's height should be greater on the South and West sides to balance energy flow.

6Staircases should ideally be located in the South-West for optimal design alignment.

7The kitchen is best placed in the South-East corner to ensure harmony and health.

8Doors, windows, and ventilators should be in even numbers, avoiding numbers ending with zero.

Balconies should be situated in the East or North to enhance ventilation and access to sunlight.

ANALYSIS

The analysis of a residential building involves studying various aspects such as structural stability, architectural functionality, material selection, and compliance with building codes. Structural analysis ensures the building can withstand loads, including dead loads, live loads, wind loads, and seismic forces. Engineers use software like STAAD.Pro, ETABS, or manual calculations to determine the strength of beams, columns, slabs, and foundations. Soil testing is conducted to choose the appropriate foundation type, whether shallow or deep, based on bearing capacity.

Architectural analysis focuses on space utilization, ventilation, lighting, and aesthetics. Floor plans are examined for efficient room layout, circulation space, and furniture placement. Elevations and sections are analyzed to enhance building appearance while ensuring practical design elements like balconies and windows. The building's orientation is checked for energy efficiency, maximizing natural light and minimizing heat gain.

Material analysis includes selecting high-quality concrete, steel, bricks, and finishing materials to ensure durability and cost-effectiveness. Plumbing and electrical layouts are examined for proper water supply, drainage, wiring, and fixture placements. Fire safety, emergency exits, and earthquake-resistant design are also considered.

Economic feasibility is analyzed by estimating construction costs, labor expenses, and maintenance costs. Environmental impact is assessed by integrating sustainable practices like rainwater harvesting, solar panels, and green spaces. Compliance with local building regulations and obtaining necessary approvals are crucial. A well- analyzed building ensures safety, functionality, efficiency, and long-term sustainability.

LOAD ANALYSIS

Load Analysis is the process of determining forces in each element in a structure. Gravity load include "dead", or permanent load, which is the weight of the structure, including walls, floors, fnishes and mechanical systems and "live", or temporary load, which is the weight of structure's contents and occupants.

TYPES OF LOADS

The types of loads acting on a building can be classified into several categories:

1.Dead Load (DL): Permanent loads due to the weight of the structure itself, including walls, floors, roofs, and fixed components like finishes and mechanical systems.

2.Live Load (LL): Temporary or movable loads caused by occupants, furniture, equipment, or stored materials within the building.

3.Wind Load (WL): Forces exerted by wind pressure acting horizontally or vertically on the structure, critical for tall or lightweight buildings.

4.Earthquake Load (EL): Dynamic forces caused by ground motion during an earthquake, requiring consideration of seismic activity in the design.

5.Snow Load (SL): The weight of accumulated snow or ice on roofs, especially in regions with heavy snowfall.

6.Rain Load: Water accumulation on flat or low-slope roofs, leading to additional weight if drainage systems are inadequate.

7.Thermal Load: Expansion or contraction due to temperature variations, impacting structural components like beams and walls.

8.Impact Load: Sudden forces from moving objects like elevators, vehicles, or machinery, often transient in nature.

9.Settlement Load: Stresses caused by uneven settling of the building foundation, potentially leading to structural damage.

Dynamic Load: Loads varying with time, such as vibrations from machinery, vehicles, or crowd movements

TYPES OF STRUCTURAL ANALYSIS

Structural analysis is the process of determining the forces, moments, stresses, and deformations in a structure to ensure its stability and safety. It helps engineers design buildings, bridges, and other structures to withstand applied loads. The main types of structural analysis include:

1.Static Analysis

Used when loads do not change with time or change gradually.

Assesses the structure under constant forces such as dead load and live load.

Divided into:

oLinear Static Analysis: Assumes material behavior is linear and deformation is small.

oNon-Linear Static Analysis: Considers large deformations, material non- linearity, and structural instability.

2.Dynamic Analysis

Used when loads vary with time, such as wind, earthquakes, or moving vehicles.

Important for earthquake-resistant and high-rise building design.

Types include:

Response Spectrum Analysis: Evaluates peak response under seismic forces.

Time History Analysis: Uses recorded earthquake data for simulation.

Modal Analysis: Determines natural vibration modes of the structure..Linear and Non-Linear Analysis

Linear Analysis: Assumes small deformations and proportional stress-strain behavior.

Non-Linear Analysis: Considers large deformations, material yielding, and geometric changes affecting structure behavior.

4.Elastic and Plastic Analysis

Elastic Analysis: Assumes the structure returns to its original shape after load removal. Used for serviceability checks.

Plastic Analysis: Studies load-carrying capacity beyond the elastic limit until failure, useful for optimizing material usage.

5.Stability Analysis

Examines buckling behavior in slender structures under compressive forces.

Used in designing columns, beams, and trusses to prevent sudden collapse.

6.Matrix Method of Structural Analysis

Uses mathematical matrix formulations to analyze indeterminate structures.

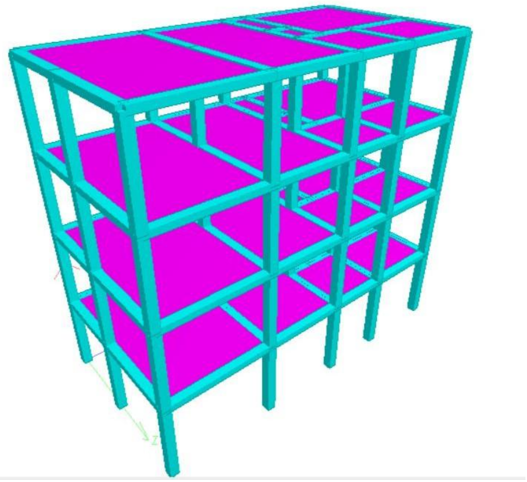
Includes methods like Stiffness Matrix and Flexibility Matrix analysis, widely used in computer-aided designs (e.g., STAAD.Pro, ETABS)

BUILDING DATA FOR ANALYSIS

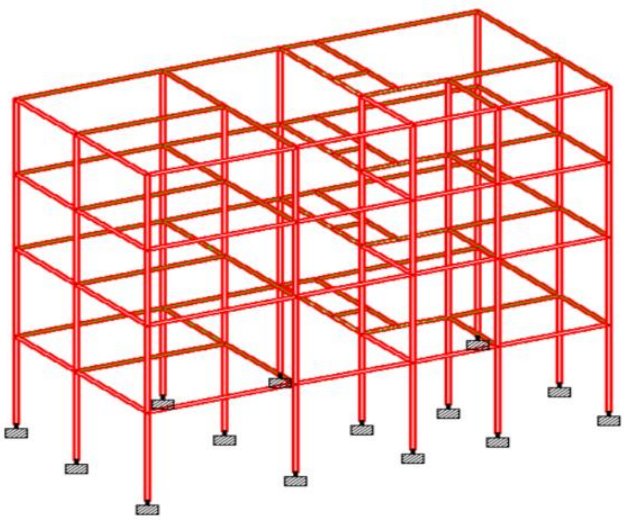
Table: Building Data For Analysis

1	Type of building	Residential building(G+3)
2	No.of stories	G+3
3	Floor height Ground floor Remaining floor	3.5m 3.0m
4	material	Concrete m20 and reinforcement of steel fe415
5	Size of beam	0.23x0.30m
6	Size of column	0.3x0.3

7	Size of wall	Inner wall =0.125m and,outer wall=0.23m



3 DIMENSIONAL RENDERED VIEW OF THE BUILDING FROM STAAD PRO



3 DIMENSIONAL RENDERED VIEW OF STRUCTURE FROM STAAD PRO

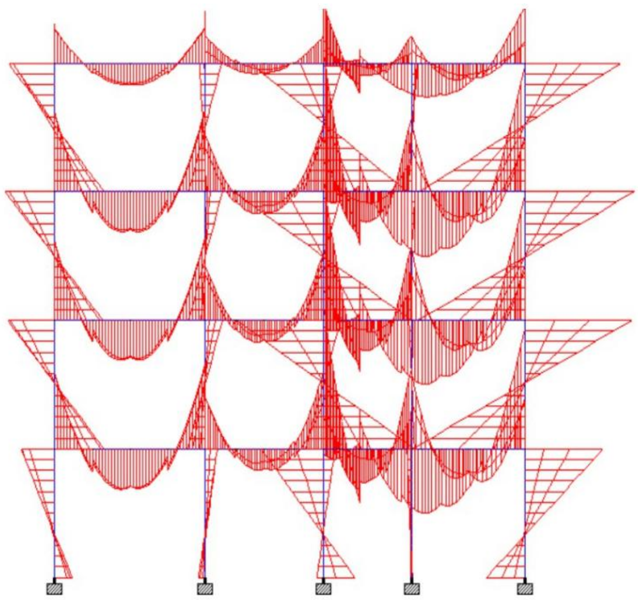


Fig: Bending Moment of the Structure

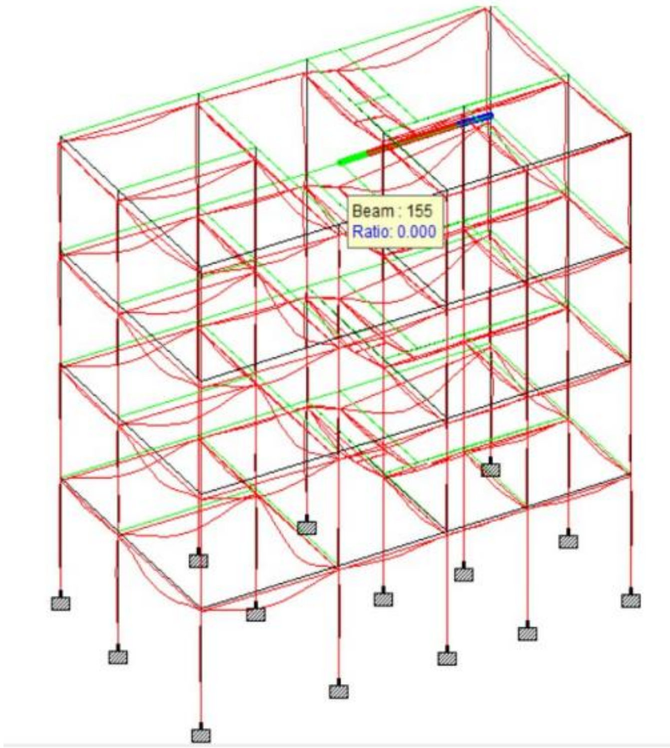


Fig:Deflection of the members

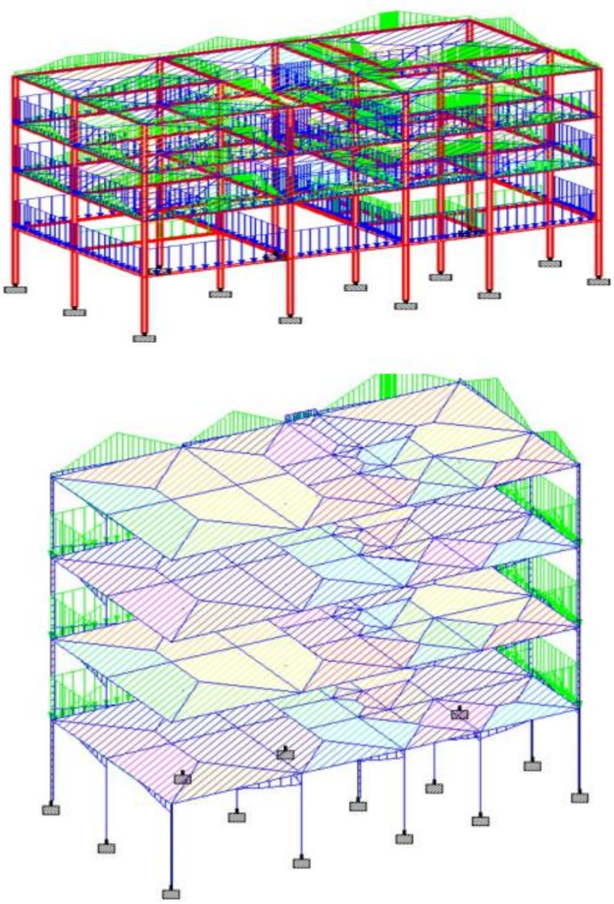


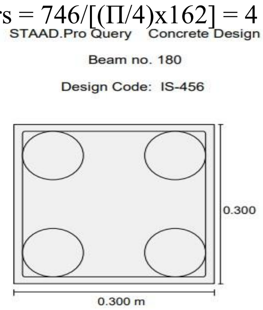
Fig: Loads acting on Structures

RESULTS:

Design of Column:

Size of column = 300mm x 300mm Length of column = 3000mm

Effective length = 0.65 x l = 0.65 x 3000 = 1950mm Slenderness ratio =l/b = 1950/230 = 8.47 < 12 Hence, it may be designed as short column.
Minimum eccentricity, e = l/500 + D/30 = 3000/500 + 300/30 = 16 Hence, Emin = 16mm
Load = 12.5KN
Factored load (Pu) = 1.5 x12.5 = 18.75KN Gross area Ag = 300 x 300
=90000mm2
Ac = Ag - Asc
Pu = 0.4 x fck x (Ag - Asc) + 0.6 x fy x Asc
18.75x 106= 0.4 x 25 x (90000 - Asc) + 0.6 x 415 x Asc
Asc = 746 mm2
Minimum reinforcement = 0.8/100 x 300 x 300 = 720 mm2 Hence, provide minimum reinforcement = 746 mm2 Provide 16mm dia of bars
No.of bars = 746/[(Π/4)x162] = 4 no's



Design Load

Load	4
Location	End 1
Pu(Kns)	-0.720000
Mz(Kns-Mt)	0.380000
My(Kns-Mt)	0.330000

Design Results

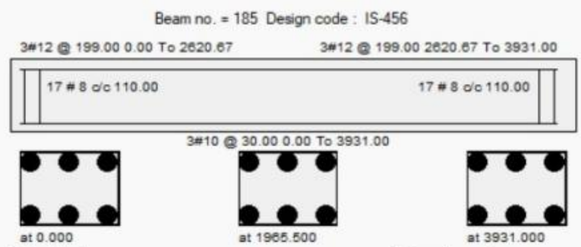
Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm²)	720.000000
As (%)	0.894000
Bar Size	16
Bar No	4

Fig: STAAD Results of an Column

Design of Beam:

fck = 25 N/mm2 fy = 415 N/mm2
Support width = 300mm
Length = 3931mm
1.Depth of beam:
Selecting depth in range of (1/12) to (1/15) based on stiffness
d = 3931/15 = 250mm
D = 300mm (cover 50mm), Width (b) = 230mm
Effective span = It is the least of c/c of supports = 4.44 + 0.23/2 + 0.23/2 = 4.67
2.Loads:
Self-weight of beam = 0.23 x 0.30x 1 x 25 = 1.725 KN/m2
Imposed load = 6.75 KN/m2 Total load = 8.475 KN/m2
Factored load = 1.5 x 8.475= 12.7125 KN/m2
Factored bending moment (Mu) = [(wu x l2)/8] =24.55 KN-m
3Depth required:
Minimum depth required (Mu) = 24.55 x 106 = 0.138 x 25 x 230 x x2
= 175.89mm <250mm
d = 250mm D=300mm
Hence, provide depth is adequate
4Tension reinforcement:
Mu lim = 0.87fyAstd (1- fyAst/fckbd)
24.55 x 106 = 0.87 x 415 x Ast x 300 (1-415xAst/25x230x300)
Ast= 240.57 mm2
Provide 12mm Φ of bars and 10 mm dia of bars
No of bars on top= 240.57/[(Π/4)x122] = 3 no's No of bars on bottom= 3no,s

Provide top reinforcement is 3no's @12mm bars Provide bottom reinforcement 3no's @10mm bars Stirupps= 8mm bars@110mmc/c
5Check for deflection (stiffness):
For SSB basic value of l/d=20 Modification factor for tension steel = 1.14
Stress in steel under service or working loads fs = 193.76 N/mm2 From fig of IS456-2000 Modification factor = 1.15
Maximum permitted = l/d = 1.15 x 20 = 23 l/d provided ratio = 3931/300 = 13.33<23
Hence deflection is safe.



Design Load

Mz Kn Met	Dist. Met	Load
13.47	2	5
-20.92	0	5
-20.71	3.9	5

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
Depth(m)	0.230000004
Width(m)	0.300000011
Length(m)	3.930999994

Fig:STAAD Results of a Beam

DESIGN OF SLAB :
1.Length to breadth ratio:
Length of longer span of slab (Ly) = 3.322mm Length of shorter span of slab (Lx) = 3.931 mm
(Ly/Lx) = 0.84 < 2 = two way slab (from IS456-2000 ANNEX D 1.11)
2.Effective depth:
Span to effective depth ratio's for span upto 10m, continuous slab is 26 as per
IS 456-2000 , clause23.2.1
Longer span in slab (Ly) = 3.322 mm (deff) = (span/26) = 123.92 mm Assume 10mm dia of bar with 15 mm cover
d = (deff + bar dia + cover) = 148.8=150 mm
3.Effective span:
In Y-direction Ly(eff) =3372mm (Ly+d) In X-direction Lx(eff) = 4081mm (Lx+d)
4.Calculations of loads:
Dead load = 1 x 0.15 x 25 = 3.75 KN/m2 Live load = 2KN/m2
Total load = 5.75KN/m2
Factored load = 1.5 x 5.75 = 8.625 KN/m2
5.Design bending moment (BM) and Shear force (SF): Maximum moment in both direction
Mx = αx x wl2 , My = αy x wl2
For edge strip αx = 0.055 , αy = 0.037 For mid span αx = 0.041 , αy = 0.028 Maximum Bending Moments at edge strip in the both directions For shorter span = Mx = 0.055 x 8.65 x (3931/1000)2 =7.51KN/m
For longer span = My = 0.037 x 8.65 x (3322/1000)2 =3.53KN/m
Maximum Bending Moments at mid span in the both directions For shorter span
Mx = 0.041 x 8.65 x (3931/1000)2=5.48KN/m
For longer span = My = 0.028 x 8.65 x (3322/1000)2=2.67KN/m
6Area of reinforcement:

Take fe415 grade of steel for reinforcement In X-direction:
Mx = 0.87 x fy Ast d (1- fyAst /fck x b x d) = 786534 mm2
Minimum reinforcement required is 0.12% = 943.84 mm2
Cross sectional area of a 8mm dia of bar = 50.26 mm2 No.of bars = 20 No's, Spacing = 200 mm
Hence, use 20 no's of bars of 8mm dia @ 200mm spacing In Y-direction:
My = 0.87 x fy Ast d (1- fy Ast /fck x b x d) = 421500 mm2
Minimum reinforcement required is 0.12% = 505.8 mm2
Cross sectional area of a 8mm dia of bar = 50.26 mm2 No.of bars = 11 No's Spacing = 280 mm
Hence, use 11 no's of bars of 8mm dia @ 280mm spacing

CONCLUSIONS

1This project involved the planning, analysis, and designing of a residential building.
2Our team learned to plan buildings in accordance with the National Building Code of India (NBC) - 2005 and developed drafting skills using AutoCAD.
3Gravity load analysis was performed manually as per IS codes, determining bending moments.
4Structural analysis was carried out using STAAD Pro, ensuring design safety as per IS codes.
5A comparison between manual and software results showed approximately equal values, validating accuracy.
6Slab, beam, and column designs were done using the limit state method, ensuring deflection control and overall safety.
7The structure is designed to safely withstand all loads throughout its lifetime while meeting serviceability requirements.

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