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Design and Analysis of Steel Structures Using Tekla and STAAD

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Abstract- The design and analysis of steel structures require accuracy, efficiency, and strict compliance with design codes to ensure safety and economy. Modern structural engineering practice increasingly relies on advanced software tools to handle complex geometries, load combinations, and detailing requirements. This study presents a comprehensive approach to the structural analysis and design of steel structures using STAAD for analysis and Tekla Structures for detailed modeling and fabrication-level detailing. Structural analysis is performed in STAAD to evaluate member forces, displacements, and stability under various loading conditions, including dead, live, wind, and seismic loads as per relevant design standards. The designed member sections are then transferred to Tekla Structures to generate precise three-dimensional models, connection details, shop drawings, and material take-offs. The integration of analysis and detailing platforms enhances design accuracy, minimizes errors, and improves constructability. The study demonstrates how coordinated use of STAAD and Tekla leads to optimized structural performance, reduced design conflicts, and efficient fabrication planning. The results confirm that software-based integrated workflows significantly improve the reliability and productivity of steel structure projects.

Keywords: Steel structures; Structural analysis; STAAD; Tekla Structures; Load combinations; Connection detailing; BIM; Structural design optimization.

I. INTRODUCTION

The basics needs of human existences are food, clothing's & shelter. From times immemorial man has been making efforts in improving their standard of living. The point of his efforts has been to provide an economic and efficient shelter. The possession of shelter besides being a basic, used, gives a feeling of security, responsibility and shown the social status of man.

Every human being has an inherent liking for a peaceful environment needed for his pleasant living, this object is achieved by having a place of living situated at the safe and convenient location, such a place for comfortable and pleasant living requires considered and kept in view.

- A Peaceful environment.
- Safety from all natural source & climate conditions
- General facilities for community of his residential area.

The engineer has to keep in mind the municipal conditions, building bye laws, environment, financial capacity, water supply, sewage arrangement, provision of future, aeration, ventilation etc., in suggestion a particular type of plan to any client.

Stages In Structural Planning

Once the type of structure is finalized and planned, design of structure involves the corresponding stages in the planning

1. Column position
2. Orientation of columns
3. Beam location
4. Spanning of slabs
5. Layout and planning of stairs

6. Type of footing

1. Column positioning:

The guiding principle, which help in deciding the positioning of columns are:

Columns should preferably locate at near the corner of building and at intersections of walls because basically the function of the column is to support beams which are normally placed under the walls to support them.

When the centre distance between the intersection of walls is large or where there are no cross walls, the spacing between the two columns is governed by limitations of the beam. As the span of the beam increases, therefore the spans of beam should be avoided for economy reason and from the considerations of controlling the deflection and cracking.

Column should be avoided inside a big hall as it mars the functional utility and the appearance and obstructs the clear view and usable space.

Large spacing of column not only increases the span and the beam but it increases the load on the column at each floor posing problem of stocky column in lower stories of multi-storied building.

2. Orientation of columns:

Normally columns provided in the building are rectangular with width of column not less than the width of supported beam for effective load transfer. The following guidelines can useful for deciding the orientation.

According to requirements of aesthetic and utility, projection of column outside the wall. In the room should avoided as they not only give bad appearance but also obstruct the usage of corners and create problem in placing furniture flush with the wall. The depth of column shall be in the plane of the wall to avoid such offsets.

When a column is rigidly connected to beam at rigid angles. It has required to carry moments in addition to axial load in such case, the column should be so oriented that the depth of column perpendicular to the major axis of building so as to get moment resisting capacity.

Also when effective length of the column in one plane is greater than that in other plane at right angles, the greater dimension shall be in the plane having large effective length. The size of columns which has been used for design of residential building is 230*330,230*400,230*450 and 230*600.

3. Position of beams:

Following are some of the guidelines for beams:

Beams shall normally be provided under the walls or below heavy concentrated loads directly into slabs.

Since beams are preliminarily provided to support slabs, its spacing shall be decided by the maximum spans of slabs.

4. Spanning of slab:

This is decided by the positions of supported beams or walls. When the supports are only opposite sides or only one direction, the slab act as a one-way supported slab. However the two-way action of slab does not depend only on the manner in which it is supported but also in the aspect ratio or reinforcement in two directions and boundary conditions.

II. DESIGN OF SLAB

INTRODUCTION OF SLABS

Slabs are plane structural members whose thickness is small as compared to its length and breadth. Slabs are most frequently used as roof covering and floors in various shapes such as square, rectangle, circular, triangular etc. in buildings.

Slab carries transverse loads and transfers them to the beams by the bending action in one or more directions.

A slab is the cover provided over the two or four walls or beams of room in order to enclose it. A slab may be a roof or a floor depending on its location in the building.

In most cases slabs are analyzed as flexural members only. Usually slabs are horizontal except in the case of staircases and ramps. The design live load on the slab for floor is usually 2 KN/m2 in residential and 4KN/m2 for commercial building.

The various types of Slabs provided are:

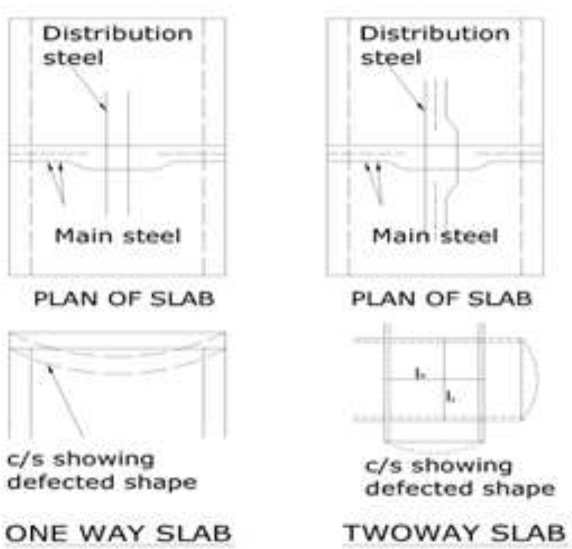
- Simply supported slabs spanning in one direction (one way slabs)
- Simply supported slabs spanning in two directions (two way slabs)
- Continuous slabs: These slabs may be one way or two way
- Cantilever slabs
- Flat slabs.

III. DESCRIPTION OF SLABS

ONE WAY SLAB

In one way slab the load will be transferred only in one direction i.e., onto the two beams in short span. The slabs are those in which the length is twice the breadth. The ratio of longer span to the shorter span (ly/lx) is greater than two then the slab is assumed to be designed as one way slab. Main reinforcement is designed along one direction (shorter span) and distribution reinforcement is designed along other direction (longer span).

TWO WAY SLAB



GENERAL REQUIREMENTS FOR SLABS AS PER (IS 456-2000)

When the slab load is transferred in two directions i.e., on to four beams in shorter and longer spans then the slab is said to be two way slabs. If the ratio of longer span to the shorter span is less than or equal to two, the slab is likely to bend along the two directions and such slabs has to be designed two way slabs. In case of two way slabs, the bending moments and deflections are less compared to one way slabs for similar loading and hence the thickness required will be less. The main reinforcements have to be designed in both directions in two way slabs.

1. Effective span:-

The effective span of a simply supported slab shall be taken as clear span plus effective depth of slab or centre to centre distance between the supports whichever is less.

The effective span of cantilever slab shall be taken as its length to the face of the supports plus half the effective depth except where it forms the end of a continuous slab where the length to the centre of support shall be taken.

2. Limiting stiffness:-

The stiffness of the slab is governed by the span to the depth ratio as per clause 23.2 of IS 456-2000 for spans not exceeding 10m, the span to the depth ratio should not exceed the limits given below

- Cantilever-7
- Simply supported-20
- Continuous-26

From the above conditions we will initially assumed the thickness of the slab. For slabs spanning into two directions, the shorter of the two spans should be used for calculating the span to effective depth ratios.

For two way slabs of shorter spans (up to 3.5m) with mild steel reinforcement, the span to over all depth ratios given below may generally be assumed to satisfy vertical deflection the limits for loading class up to 3kN/m2

- Simply supported slabs 35
- Continuous slabs 40

For high strength deformed bars of grade Fe415, the values given above should be multiplied by 0.8

3. Minimum Reinforcement: - The reinforcement in either directions of span shall not be less than 0.15% of gross cross sectional area if mild steel is used.

However this value is reduced to 0.12% for high strength deformed bars (HYSD).

4. Maximum diameter of bar: The diameter of the bar should not exceed 1/8th of total thickness of slab (clause 26.5.2.2 of IS 456-2000).

5. Spanning of main reinforcement:- The spanning of main reinforcement in slab shall not be more than 3times effective depth of solid slab or 300mm whichever is less (clause 26.3.3 of IS 456- 2000)

6. Distribution reinforcement: The area of distribution reinforcement shall not be less than 0.15% of gross cross sectional area if plain bars are used and 0.12% of high yield strength deformed bars are used. The spacing of distribution reinforcement in slabs shall not be more than five times the effective depth of slab or 450mm whichever is less.

The maximum permissible spacing of distribution reinforcement shall not be more than 3times the effective depth of slab or 30cm, whichever is smaller.

7. Cover to reinforcement: Reinforcement shall have concrete cover of thickness as follows:

At each end of reinforcement bar not less than 25mm nor less than twice the diameter of such bar.

The bottom cover or reinforcement shall not be less than 20mm nor less than diameter of such bars.

IV. DESIGN OF BEAM

INTRODUCTION OF BEAMS:-

A reinforced concrete beam should be able to resist tensile, compressive and shear stresses induced in it by the loads on the beam coming from slab. Concrete is fairly strong in compression but very weak in tension, whereas steel is very strong in tension. Thus, the tensile weakness of concrete is overcome by the provision of reinforcing steel in the tension zone around the concrete to make a reinforced concrete beam ductile member.

There are three types of beams.

- Singly reinforced beams
- Doubly reinforced beams
- Flanged beams

DESCRIPTION OF BEAMS:-

In general, all the doubly Reinforced beams are used. In our project we considered the beams as doubly reinforced beam.

SINGLY REINFORCED BEAMS:-

In the singly reinforced simply supported beams reinforcing steel bars are paced near the bottom of the where they are most effective in resisting the tensile bending stresses. In singly reinforced cantilever beams reinforcing bars are placed near the top of beam.

The minimum percentage of steel required is 0.2.

DOUBLY REINFORCED BEAMS:-

A doubly reinforced beam is reinforced both in compression and tension regions. The section of the beam may be a rectangular, T or L sections. The necessity of use in steel at compression zone arises due to two main reasons as follows:

- When the depth of the beam is restricted the strength available from a singly reinforced beam is inadequate at support of continuous beam where bending moment changes sign.
- The minimum percentage of steel required is 0.4.

POSITIONING OF BEAMS:-

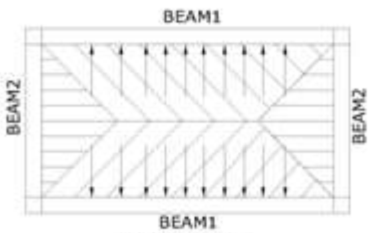
Some the guiding principles for the positioning of the beams are as follows:

- Beams are generally provided under the walls or below heavy concentrated loads to avoid these loads directly coming on slabs.
- The spacing of the beams is governed by the maximum spans of the slabs
- For designing the cantilever slabs, availability adequate anchorage should be checked.
- For larger spans and heavier loads the two ways action is advantageous, as the steel required is minimum.

Dispersion of load of slab on beam:-

As stated earlier the load of the slab is dispersed on the supporting in beam in accordance with the clause 24.5 of IS 456 which states that the on beams supporting solid spans, spanning in two directions at right angles and supporting uniformly distributed loads, may be assumed in accordance.

In the following pages we are determining the load on the supporting beam by adopting simplified formula. Since the loaded area is trapezoidal and triangular in section the calculation of load is rather cumbersome, that is why some simplified formula as to be adopted. Equivalent uniformly distributed load bending moments are calculated by using following for longer span beam which produces the same bending moment of trapezoidal load for longer span beam.



TWO WAY SLAB
AREA OF LOAD TRANSFERED TO BEAMS B1&B2

AREA OF LOAD TRANSFERED TO BEAMS B1&B2

For one way slab which are resting over two opposite supports, the load carried by each supporting beam is given as load on support i.e. Ws =326.07 KN-m

Check for the depth required:-

dreq= $\sqrt{\frac{Mu}{0.138*fck*beq}}$

beq=b+1/8(B-b)

=330+1/8(2100-330)

=551.25 mm

=414.06 mm

Take dreq=500 mm

$d_{edge} = 0.2\text{d} = 0.2 * 500 = 100\ mm$

D=500+50+$\frac{20}{2}$

D=560 mm

Dedge=100+50+20/2=160 mm>150 mm----------(OK)

Depth due to one way shear:-

Force:-

Vu=qu*Area

Vu=310.55*0.5*2.1

Vu=326.07 KN

Resistance:-

$V_{uc} = T_c * B_1 * d_1$

d1=500-$\left(\frac{500-100}{1000}\right)$*500

d1=300 mm

Take Xu=0.45d

Xu=0.45*500=225 mm

Therefore take B1=2100 mm

Take Vuc=350 KN

350=(Tc)*0.3*2.1

(Tc)=555.55 KN/m^2 =0.55 N/mm^2

Depth due to two way shear:-

Force:-

Vu=qu*Area

Vu=310.55*[(2.3*2.1)-(1.05*0.83)]

Vu=1229.31 KN

Resistance:-

Vuc=Tc'*Resisting Area

Resisting Area= [1.05+0.83]*d_2

d_2=500-$\left(\frac{500-100}{1000}\right)$*200

d_2 = 420 mm

Resisting Area=2(1.05+0.83)*0.42

R.A=1.57 m^2

$T_c' = K_s * 0.25\sqrt{f_{ck}}$

Ks=0.5+βc

$K_s = 0.5 + \frac{0.33}{0.55} = 1.1$

Ks > 1; therefore Take Ks =1

$T_c' = 1 * 0.25\sqrt{25} = 1.25\text{mPa} = 1250\ \text{kN/m}^2$

$V_{uc} = 1250 * 1.57 = 1962.5\text{KN} > V_u \rightarrow (\text{OK})$

Cal of reinforcement:-

Mu=326.07 KN-m

Ast= $\frac{0.5*fck}{fy}\left(1 - \sqrt{1 - \frac{4.6*Mu}{fck*b*d^2}}\right) * b * d$

Ast= $\frac{0.5*25}{415}\left(1 - \sqrt{1 - \frac{4.6*326.07*10^6}{25*21000*500^2}}\right) * 2100 * 500$

Ast= 1861.94 mm^2 ≅1862 mm²

(Ast)min= $\frac{0.12\times2100\times500}{100}$

(Ast)min=1411.2 mm^2 < (Ast)cal-----------(OK)

(Pt) = $\frac{100\times1862}{2100\times500}$ = 0.17 < 1%

Therefore Take Pt= 1%

Ast=$\frac{\text{Pt}*\text{b}*\text{d}}{100} = \frac{1\times2100\times500}{100}$

Ast=10500 mm^2

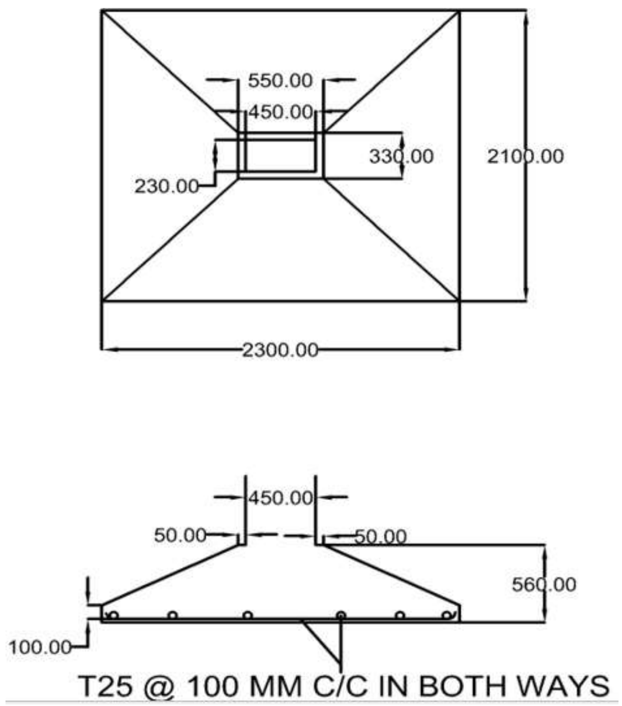
Taking T25

S=ast*width/Ast

S=491*2100/10500

S=98.2 mm ≅100 mm

Hence Provide T25 @ 100 mm both ways



Reinforcement Details Of Footing

V. DESIGN OF STAIR CASE

Introduction Of Stair Case:-

Stairs provide access for the various floors of the building. The stair consists of series of steps with landings at appropriate intervals. The stretch between the two landings is called flight. The room or space where stairs are provided is called stair case.

The width of stair depends upon the type of building in which it is provided. Generally in residential buildings, the width of stair is kept as 1m and is case of public building it may be up to 2m. To allow free flow of users, the width of landings should be at least equal to the width of stairs.

Each step has one tread (going) and one riser. Riser and tread are proportioned so as to provide convenient and easy access. The riser may vary from 150mm to 200mm. the tread is in between 250mm to 300mm. As per IS: 456, the slope or pitch of the stairs should be in between 250 to 400

Given data:-

Fck = 25 N/mm^2

Fy = 415 N/mm^2

Assume floor finish = 1 KN/m^2

Live load = 3 KN/m^2

(1)Assume Tread and Riser dimensions:-

Riser=150 mm

Tread=270 mm

No. of Risers=floor height/Risers

=3000/150

=20 no's

No. Risers per flight=20/2

=10 no's

No. of treads in 1 flight = Riser-1 = 9

Horizontal length of going=9*0.27

=2.43 m

Both landings=1.25 m

Effective span between supports:-

$$=\frac{0.23}{2}+1.25+2.43+1.25+\frac{0.23}{2}$$

=5.16 m

(2)Assume waist slab thickness:-

D = 150 mm

d = 150-20-(10/2) = 125 mm

(3)Loads on going (per 'm' width):-

(a)Self weight of waist slab (Inclined)

=0.150*25

=3.75 KN/m^2

Self weight of slab on projected plan

$$= \frac{w\sqrt{R^2+T^2}}{T}$$

$$= \frac{3.75\sqrt{0.15^2+0.27^2}}{0.27}$$

= 4.3 KN/m^2

(b) Weight at 1 step
=0.5*0.27*0.15*1*25
=0.50 KN

Step of weight for 1m width = 0.27-0.50
1m = 0.50/0.27
1m = 1.85 KN/m

(c)Floor Finish = 1 KN/m
Live Load = 3 KN/m
Total Load (w) = 4.3+1.85+1+3
= 10.15 KN/m

Factored Load=10.15*1.5=15.225 KN/m

(4)Loads on landing (per 'm' width):-

Self weight=0.150*25 = 3.75
Floor Finish = 1
Live Load = 3
TL=7.75 KN/m^2

Wu = 7.75*1.5
= 11.625 KN/m

(5)Calculation of Bending:-

RA+RB = 66 KN
RA=RB = 33 KN

Mu = $\frac{Wu*L^2}{8}$

= $\frac{11.625*5.16^2}{8}$

= 38.69 KN-m

(6)Computation of effective depth (per 'm' width):-

dreq= $\sqrt{\frac{Mu}{0.138*fck*b}}$

= $\sqrt{\frac{38.69*10^6}{0.138*25*1000}}$

=105.89 mm < 125 mm---------- (OK)

(7)Computation of Steel Reinforcement:-

Ast= $\frac{0.5*fck}{fy}\left(1-\sqrt{1-\frac{4.6*Mu}{fck*b*d^2}}\right)*b*d$

Ast= $\frac{0.5*25}{415}\left(1-\sqrt{1-\frac{4.6*38.69*10^6}{25*1000*125^2}}\right)*1000*125$

Ast= 987.10 mm^2

Check for (Ast)min = 0.12*b*D/100
= 0.12*1000*150/100
= 180 mm^2 < 987.10 mm^2 ---(OK)

Spacing:-

Taking T12

S = $\frac{ast*width}{Ast}$

S=113*1000/987.10

S=114.47 mm

Hence provide T12 @ 100 mm centre to centre (Main Steel)

Distribution Steel:-

(Ast)min=0.12*b*D/100
=0.12*1000*150/100
=180 mm^2

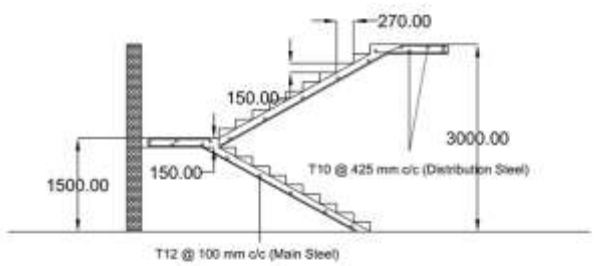
Taking T10

S = $\frac{ast*width}{(Ast)min}$

S=78.5*1000/180

S = 436.11 mm

Hence provide T10 @ 425 mm centre to centre (Distribution Steel)



Reinforcement Details Of Staircase

VI. CONCLUSIONS

Using the software staad.pro reduces lot of time in analyzing work. Moreover we use the staad.pro for analyzing the whole structure of beams and columns according to it.

- We conclude that the staad.pro analyze different load combinations at a time.
- Slabs, beams, columns, footings, staircases must be designed completely in manual calculations.
- The drawings of plan is developed using AUTO CAD Software
- Design of all the members as per IS 456-2000 and SP 16 table.

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- Reinforced Concrete Structures by Arun Kumar Jain.

IS CODES USED

- IS 456-2000 Plain and Reinforced Concrete – code of practice.
- SP 16-1980 Design aids for reinforced concrete.
- IS 875 part 1 (Dead Loads)
- IS 875 part 2 (Live Loads)

SOFTWARES

- AUTO CAD 2013
- STAAD.PRO V8i 20.07.04.12
- MS OFFICE 2007