IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 3, March 2016.
www.ijiset.com
ISSN 2348 – 7968

Design of Apartment Building at Irinjalakuda, Thrissur

Athira -T J[1]
[1] Civil Engineering Department, SCMS School of Engineering and Technology,
Ernakulum, Kerala, India

Abstract
The training work includes analysis and design of an apartment building located at Irinjalakuda with G+12 storeys having a car parking facility provided at ground floor. The building comprises of a shear wall around lift pit and the foundation of the building is pile foundation. The work is conducted in three stages. First stage includes the modelling and analysis of the structure in STAAD.Pro V8i .Second stage is the manual design of different structural components like beam, column, slab, water tank, shear wall, staircase, pile foundation and pilecap Final stage includes their detailing using AUTOCAD 2014.In addition to the analysis and design, construction sites were visited as a part of the industrial training.
Keywords: *beam, column, slab, water tank, shear wall, staircase, pile foundation, pilecap.*

1. Introduction

Industrial training is an essential component in the development of the practical and professional skills required by an engineer. The objective of the industrial training is to achieve exposure on practical engineering fields. Through this exposure, one can achieve a better understanding of engineering practice in general and sense of frequent and possible problems that may arise during the construction.

In the design of reinforced concrete structure, the aim is to provide a safe, serviceable, durable, economical and aesthetically pleasing structure. For the structure to be safe, it must be able to resist the worst loading conditions. Under normal working conditions, the deformation and cracking must not be excessive for the structure to remain serviceable, durable and aesthetically pleasing during the expected design life. Furthermore, the structure should be economical with regard to both construction and maintenance cost.

The objectives of industrial training are:

- To get exposure to engineering experience and knowledge, which are required in the industry.
- To apply the engineering knowledge taught in the lecture rooms in real industrial situations.
- To share the experience gained from the "industrial training" in the discussion held in the lecture rooms.
- To get a feel of the work environment.
- To gain exposure on engineering procedural work flow management and implementation.
- To get responsibilities and ethics of engineers.

There are certain considerations that a sensible designer ought to bear in mind that is, economy and aesthetics. One can always design a massive structure, which has more than adequate stability strength and serviceability, but the ensuring cost of the structure may be exorbitant and the end product far from aesthetics. In the design of structures, the aim is to design the structure in such a way that it fulfills its intended purpose during its intended life time and be adequately safe in terms of strength, stability and structural rigidity and have adequate serviceability in terms of stiffness, durability etc. Safety requires the possibility of collapse of the structure (partial or total) is acceptably low not under normal expected loads (service loads), but also under less frequent loads (such as due to earthquakes or extreme winds) and accidental loads (blasts, impacts, etc.). Other two important considerations that a sensible designer ought to bear in mind are that the structure should be economical with regard to both construction and maintenance cost and aesthetically pleasing during the expected design life.

2. Training Information

The industrial training was done in Stuba Engineering Consultancy, Palarivattom under the guidance of Er. Abhilash Joy is one of the leading consultant in the field of analysis and design of civil engineering structure. They undertake wide range of structures, which include both reinforced concrete structures as well as steel structures. They have expertise in alternative technologies in construction industry with wide range of materials like Ferro cement, clay, bamboo, glass, gypsum and lightweight materials. They are serving as structural consultant to many leading builders all over the state.

Stuba offer the optimum solution for the design of R.C.C, steel and alternative materials. Their general service cover design, preparation of structural drawing and guidelines for construction. In addition to these services, they also do concrete mix design, structural supervision

ISSN 2348 – 7968

and proof checking of structural design. They also provide optimum foundation for structures based up on soil investigation studies. They approach each project by carefully analyzing the requirements and architectural design and various structural, engineering and cost effective alternatives for its implementation.

3. A Brief Description of Softwares used in Training

The training allowed acquaintance with a number of softwares. The most frequently softwares include:-

- STAAD.Pro V8i
- Auto CAD 2014

3.1 STAAD.Pro V8i

This analysis and design software provided to be worth its mettle and handled all the various challenges that have to be solved during the course of training. STAAD.Pro V8i is the most popular structural engineering software product for 3D model generation, analysis and multi-material design.it has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. The software is fully compatible with all windows operating system but is optimized for windows XP.

For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminum or timber buildings, transmission towers, stadiums or any other simple or complex structure, STAAD.pro has been the choice of design professionals around the world for their specific analysis needs. Once when the overall geometry of the structure has been specified, the section properties of the individual member elements are specified. Thereafter, loading on the members are specified. Following this, the support condition relevant to the structure are specified well. The input of the software can easily be inspected and modified with help of STAAD editor. Thereafter, the analysis can be performed. The analysis yields us the parameters required for performing the structural design of the structure. The required value can directly be read from the STAAD output file. The software also allows us to perform design as per specifications in various codes of practice.

3.2 Auto CAD 2014

Auto Cad is a CAD (Computer Aided Design or Computer Aided Drafting) software application for 2D and 3D design and drafting, developed and sold by Autodesk, Inc. It is a vector graphics drawing programme. It uses primitive entities- such as lines, polylines, circles, arcs and text as the foundation for the complex. Auto CAD's native file format, DWG, and to a lesser extent, its interchange file format, DXF has become the drawing and detailing works were done by making use of Auto CAD 2014.

4. Details of Project

It is a G+12 storied apartment building located at Irinjalakuda, Thrissur. Building consists of ground floor which is intended for parking and the rest of twelve floors are typical. Twelve floor consists of four units of residential area. The building is constructed on pile foundation. The building consists of lift, main stair, emergency stair and water tank .Small ramp is provided at ground floor. Shear walls are also provided around the lift wells.

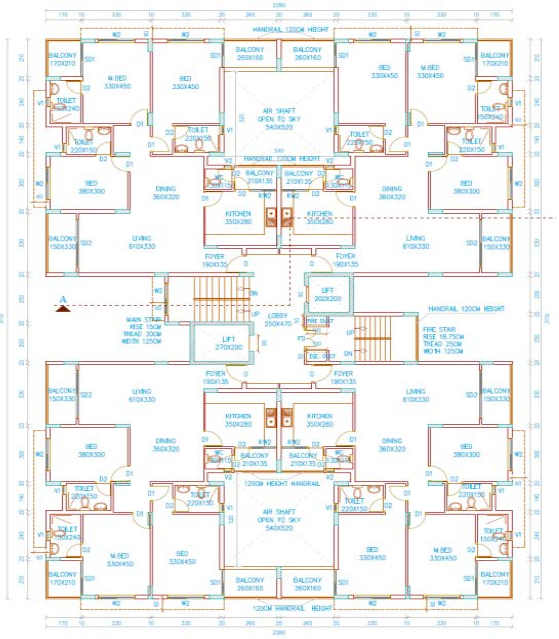

Fig. 1 Plan of the project

5. Soil Investigation Report

5.1 General

The soil investigation was carried out for this project at Irinjalakuda, Thrissur, in order to design the foundations for the proposed building. This report presents the details of soil investigation done, data obtained from various field and laboratory tests, their compilation and analysis.

ISSN 2348 – 7968

Recommendations are also made regarding the type of foundation to be adopted.

5.2 Purpose

The purpose of soil investigation including performing field tests with in the bore hole and collecting samples for laboratory tests was to accomplish the following:

- To determine the type and extend of subsurface material up to hard core level and 1 m hard core cutting.
- To provide engineering parameters and suitable type of foundation for the proposed building

5.3 Soil Profile

Proposed site consist of top layer of laterite clay with sand followed by laterite clay with sand and gravel followed by laterite clay followed by silty sand followed by hard rock. Observations are shown in the following table 1 and table 2.

Table 1: Soil investigation

Bore Hole No.1			
W.T = Not Met With			
Description of soil	***Classification***	***Depth in m***	***Standard Penetration Test Results No. of blows, N***
Laterite clay with sand (red)	CH	4.5	>50
Laterite clay with sand and gravel (red)	CH	6	19
Laterite clay(red)	CH	7.5	>50
Silty sand (brown)	SM	9	>100
Hard rock		10	

Table 2: Soil investigation

Bore Hole No.2			
W.T = Not Met With			
Description of soil	***classification***	***Depth in m***	***Standard Penetration Test Result (No. of blows, N)***
Laterite clay with sand and gravel(red)	CH	1.5	>50
Laterite clay with sand	CH	4.5	28
Clayey sand(red)-lateritic	SC	6	20
Lateritic clay with sand	CH	7.5	>50
Very fine silty sand	SM	11.6	>100
Hard Rock		12.6	

5.4 Recommendations

- At a depth of 1.5 m and a size of 2m × 2m footing, safe bearing capacity of 20T/m^{2}can be used in lateritic clay with sand with N value > 50.

- For high rise structures, bored cast in situ DMC piles resting in hard rock with sufficient embedment length can be provided with the following capacity.

Presence of hard rock to be tested by taking core samples.

6. Loads on the Building

6.1 Dead Loads

The dimensions of the cross section are to be assumed initially which enable to estimate the dead load from the known weights of the structure. The values of the unit weights of the structure. The values of the unit weight of the materials are specified in IS 875:1987(part-I).

6.2 Live Loads

They are also known as imposed loads and consist of all loads other than the dead loads of the structure. Commercial buildings will have comparatively higher values of the imposed loads than those of the residential buildings. The standard values are stipulated in IS875:1987 (part II).

ISSN 2348 – 7968

6.3 Earthquake Forces

Earthquakes generate waves which move from the origin of its location with velocities depending on the intensity and magnitude of the earthquake. The impact of earthquake on the structures depends on the stiffness of the structure, stiffness of the soil media, height and location of the structure, etc. the earthquake forces are prescribed in IS 1893:2002 (part-I).

Since the building is located in Kerala, it is included in the zone III. And the seismic base shear calculation and its distribution was done as per IS 1893:2002 (part-I).
The base shear or total design lateral force along any principle direction shall be determined by the following expression:

$$V_B = A_h \times W \quad (1)$$

Where,
V_B= Design base shear
A_h= Design horizontal seismic coefficient based on fundamental natural period, and type of soil
W = Seismic weight of the building

The design horizontal seismic coefficient,

$$A_h = \frac{ZIS_a}{2Rg} \quad (2)$$

Where,
Z = Zone factor given in table 2, for the maximum considered earthquake (MCE) and service life of the structure in a zone. The factor 2 in the denominator is used so as to reduce the MCE zone factor to the factor for design basic earthquake (DBE).
I = Importance factor, depending upon the functional use of structures, characterized by hazardous consequences of failure, post-earthquake functional needs, historical value or economic importance (Table 6 of IS 1893 (Part 1): 2002).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized.

by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0. The values for buildings are given in Table 7 of IS 1893 (Part 1): 2002

Sa/g = Average response acceleration coefficient.

Sa/g is determined on the basis of approximate fundamental natural period of vibration on both the directions.

Natural period of vibration,

$$Ta = \frac{(0.09 \times h)}{\sqrt{d}} \quad (3)$$

Distribution of design Force
The design base shear was distributed along the height of the building as per the following expression

$$Qi = V_B \frac{Wihi^2}{\sum_{j=1}^{n} wihj^2} \quad (4)$$

Where,
Wi= Seismic weight at floor i
hi = Height of floor i
n = Number of stories in the building (i.e. the number of levels at which the masses are located)

6.4 Load Combinations

Design of the structures would have become highly expensive in order to maintain either serviceability and safety if all types of forces would have acted on all structures at all times. Accordingly the concept of characteristics loads has been accepted to ensure at least 95 percent of the cases, the characteristic loads are to be calculated on the basis of average/mean load of some logical combinations of all loads mentioned above.

IS 456:2000, IS 875:1987 (Part-V) and IS 1893(part-I):2002 stipulates the combination of the loads to be considered in the design of the structures. The different combination used are:

1) 1.5(DL+LL)
2) 1.2 (DL + LL + ELx)
3) 1.2 (DL + LL + ELz)
4) 1.2 (DL + LL− ELx)
5) 1.2 (DL + LL – ELz)
6) 0.9 DL + 1.5 ELx
7) 0.9 DL + 1.5 ELz
8) 0.9 DL − 1.5 ELx
9) 0.9 DL − 1.5 ELz
10) 1.5 (DL + ELx)
11) 1.5 (DL + ELz)
12) 1.5 (DL − ELx)
13) 1.5 (DL – ELz)
14) 1.2 (DL + LL + WLx)
15) 1.2 (DL + LL + WLz)
16) 1.2 (DL + LL − WLx)
17) 1.2 (DL + LL – WLz)
18) 0.9 DL + 1.5 WLx
19) 0.9 DL + 1.5 WLz
20) 0.9s DL − 1.5 WLx
21) 0.9 DL − 1.5 WLz
22) 1.5 (DL + WLx)
23) 1.5 (DL + WLz)
24) 1.5 (DL − WLx)
25) 1.5 (DL – WLz)

ISSN 2348 – 7968

All these combinations are built in the STAAD.Pro. analysis results from the critical combinations are used for the design of structural member.

Note :
DL - Dead load
ELz - Earthquake load in z direction
LL - Live load
WLx - Wind load in x direction
ELx - Earthquake load in x direction
WLz - Wind load in z direction

7. Modeling

7.1 General

Structural analysis, which is an integral part of any engineering project, is the process of predicting the performance of a given structure under prescribed loading condition. The performance characteristics usually of interest in structural design are:

- Stress or stress resultant (axial forces, shears and bending moments)
- Deflections
- Support reactions

Thus the analysis of a structure typically involves the determination of these quantities caused by the given loads and / or the external effects. Since the building frame is three dimensional frame i.e. a space frame, manual analysis is tedious and time consuming. Hence the structure is analysed with STAAD.Pro .In order to analyse in STAAD.Pro, the first step was to generate model geometry, specify member properties, specify geometric constants and specify support and loads.

7.2 Generating Model Geometry

At first the position of beams and columns were fixed .The file was then imported to STAAD.Pro. The members were then connected along the nodes using the member incidence command.

7.3 Specifying Member Property

The next task is to assign cross section properties for the beams and columns, the member properties were given as Indian. The width ZD and depth YD were given for the sections .The fixed support conditions were given to the structure.

a) Slab

Thickness of slab = 120 mm

b) Beam

The beam dimensions are as follows:

B1 = 300 × 800 mm
B2 = 300 × 500 mm

c) Column

The column dimensions are as follows:

C1 = 300 × 800 mm
C2 = 300 × 500 mm

d) Staircase

The staircase is provided as an equivalent slab.

Rise = 150 mm
Tread =300 mm

7.4 Specifying supports

All supports were fixed supports.

7.5 Specifying Loads

a) Live load calculation

As per IS: 875 (part 2)-1987, the live loads considered are given in table 3.

Table 3: Live loads

Area	***Live load (kN/m^2)***
All rooms and kitchens	2
Toilet and bathrooms	2
Corridors,passages,staircases	3
Balconies	3
Parking	5

ISSN 2348 – 7968

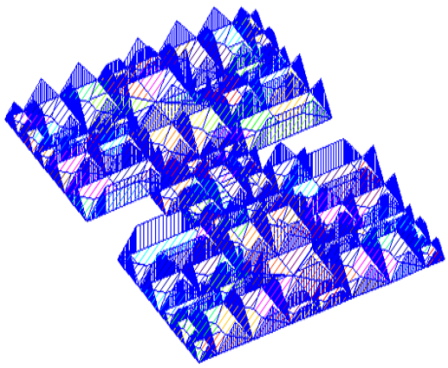

Fig. 2 Live load for first floor

b) Dead load calculation

As per IS: 875 (part 1) -1987 dead load includes self-weight of columns,beams,slabs, brick walls, floor finish etc.

- Unit weight of brick = 20 kN/m^3
- Unit weight of concrete = 25kN/m^3

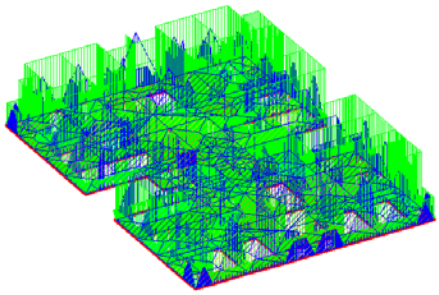

Fig.3 Dead load for first floor

Here sample calculation is done:

a)*Wall load*

Thickness of wall = 200 mm

Main wall load

= unit weight of brick×thickness of wall×(floor height –beam depth)

=20 ×0.20 × (3 -0.8)

= 8.8kN/m

=20×0.20 × (3-0.5) (with different beam size)

= 10 kN/ m

Partition wall load = 20 ×0 .10 × (3-.0.8)

=4.4kN/ m

= 20 ×0.10×(3-0.5)

(with different beam size)

= 5 kN/m

b) *Floor load*

Thickness of slab = 120 mm

Slab load = 0.12×25 = 3kN /m^2

Floor finish = 1.67kN/m^2 (as per IS 875 part 1)

Total floor load = 4.67kN/m^2

c) Wind loads

These loads depend on the velocity of the wind at the location of the structure, permeability of the structure, height of the structure etc. They may be horizontal or inclined forces depending on the angle of inclination of the roof for pitched roof structures. Wind loads are specified in IS 875:1987 (Part-III).

Basic wind speed in Kerala, Vb= 39 m/sec

Design wind speed, Vz

$= V_b \times k_1 \times k_2 \times k_3$ (5)

[Clause 5.3 of IS 875:1987 (Part-III)]
Category - 4, Class B

Where:
k_1 = Probability factor = 1
(Clause 5.3.1)
k_2 = Terrain, height and structure size factor = 1.15(Clause 5.3.2)
k_3 = Topography factor = 1
(Clause 5.3.3)
Basic wind pressure, Pz = 0.6 Vz^2 [Clause 5.4 of IS 875: 1987 (Part-III)] (6)

The wind loads are assigned as nodal forces on frames.

Wind force on each node, $F = Ae \times Pz$ (7)

ISSN 2348 – 7968

Where: *Ae* = Effective area on each node

Table 4: Wind Load Calculations

Height (m)	***V_b (m/sec)***	***k_1***	***k_2***	***k_3***	***V_z (m/s)***	***p_z (N/m^2)***
3	39	1	0.98	1	38.22	876.46
6	39	1	0.98	1	38.22	876.46
9	39	1	0.98	1	38.22	876.46
12	39	1	0.98	1	38.22	876.46
15	39	1	1.00	1	39.00	912.6
18	39	1	1.02	1	39.78	949.46
21	39	1	1.04	1	40.56	987.06
24	39	1	1.04	1	40.56	987.06
27	39	1	1.04	1	40.56	987.06
30	39	1	1.10	1	42.90	1104.24
33	39	1	1.12	1	43.68	1144.76
36	39	1	1.13	1	44.07	1165.29
39	39	1	1.14	1	44.46	1186.01

c) Earthquake load calculation

As per IS 1893:2002 (part-I) earthquake loads are calculated.

Height of building,h=39 m

STAAD.Pro has a seismic load generator in accordance with IS code mentioned

Description

The seismic load generator can be used to generate the lateral loads in X and Z directions only. Y is the direction of gravity loads. This facility has not been developed for cases where the Z axis is set to be the vertical direction using the " SET Z UP" command.

Methodology

The design base shear is computed by STAAD in accordance with the IS:1893(Part I)-2002,$V_b = A_h \times W$

Where the design seismic coefficient, $A_h = (ZISa)/(2Rg)$

STAAD utilizes the following procedure to generate the lateral seismic loads:

1) User provides seismic zone coefficient and desired "IS 1893(Part I)-2002" specifies through the DEFINE 1893 LOAD command.
2) Program calculates the structure period (T)
3) Program calculates Sa/g utilizing T.
4) Program calculates V_b from above equation. W is obtained from weight data provided by the user through the DEFINE 1893 LOAD command.
5) The total lateral seismic load (base shear) is then distributed by the program among different levels of structure as per IS:1893(Part I)-2002 procedure.

While defining the seismic load following parameters were used

i) Z = seismic zone coefficient
This building is located in Kerala (Zone III)
Z= 0.16 (IS 1893 (Part I):2002, clause 6.4.2 table 2)
ii) RF = Response reduction factor.
RF = 3(Clause 6.4.2, table 7)
iii) I = importance factor, depending upon the functional use of structures
I=1 (clause 6.4.2, table 6)
iv) SS =rock or soil site factor, For soft soil the value is 3
v) ST = optional value for type of structure
This building is of RC building ST = 1

ISSN 2348 – 7968

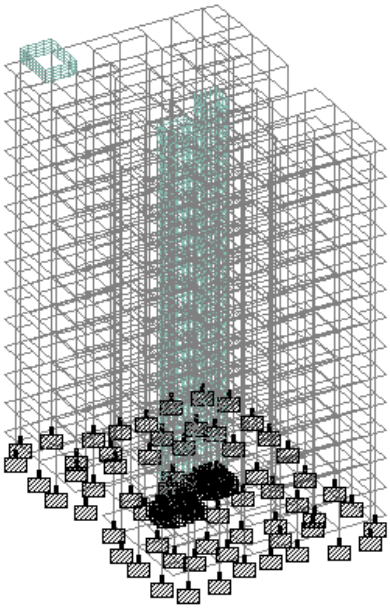

Fig .4 3D model in STAAD

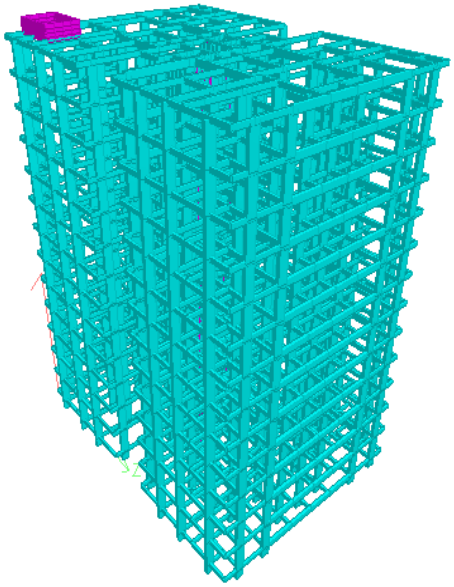

Fig. 5 3D rendered model in STAAD

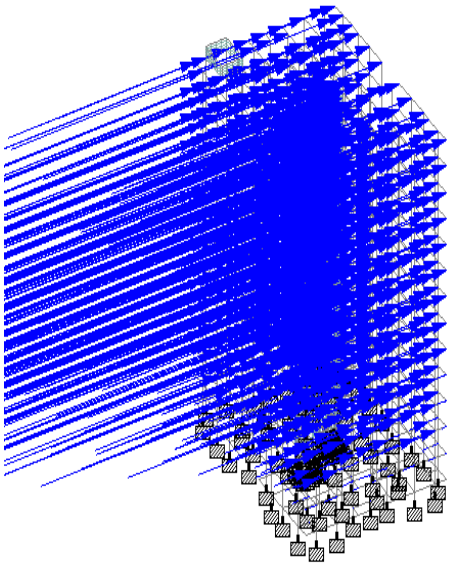

Fig. 6 Earthquake load in positive X-direction

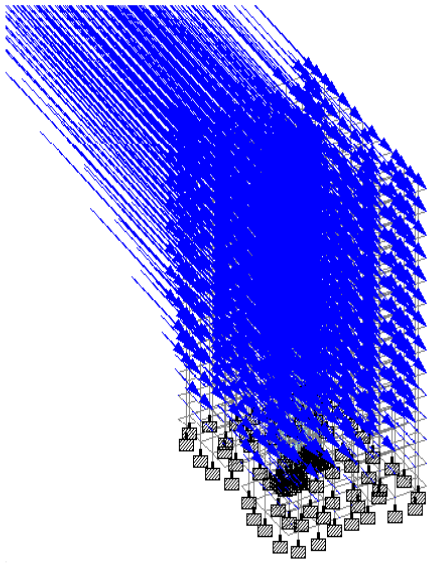

Fig.7 Earthquake in positive Z-direction

Utilizing the seismic load generator in STAAD.Pro, the seismic load was provided in X and Z directions as shown in following figures.

ISSN 2348 – 7968

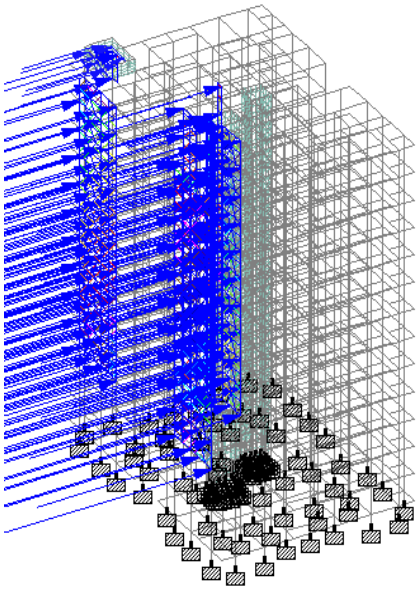

Fig.8 Wind load in positive X –direction

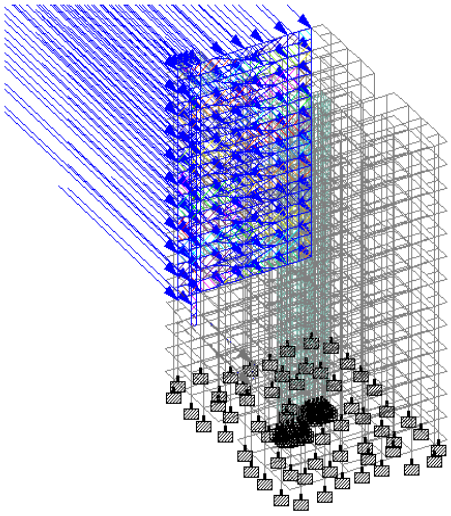

Fig.9 Wind load in positive Z –direction

8. Design of RC Building

8.1 General

The design of a structure must satisfy three basic requirements:

- Stability - To prevent overturning, sliding or buckling of the structure, or part of it, under the action of loads.
- Strength - To resist safely the stresses induced by the loads in the various structural members.
- Serviceability - To ensure satisfactory performance under service load conditions which implies providing adequate stiffness and reinforcement to contain deflections, crack widths and vibrations within acceptable limits, and also providing impermeability and durability.

The aim of structural design is to achieve an acceptable probability that the structure being designed will perform the function for which it is created and will safely withstand the influence that will act on it throughout its useful life. These influences are primarily the loads and the other forces to which it will be subjected. The effects of temperature fluctuations, foundation settlements etc. should be also considered.

The design methods used for the design of reinforced concrete structures are working stress method, ultimate load method and limit state method. Here we have adopted the limit state method of design for slabs, beams, columns, stairs and foundations.

In the limit state method, the structure is designed to withstand safely all loads liable to act on it through its life and also to satisfy the serviceability requirements, such as limitation to deflection and cracking. The acceptable limit of safety and serviceability requirements before failure is called limit state. All the relevant limit states should be considered in the design to ensure adequate degrees of safety and serviceability. The structure should be designed on the basis of most critical state and then checked for other limit states.

8.2 Design of Beam

A beam is a structural member subjected to a system of external forces at right angles to the axis. Beams are usually provided for supporting slabs and walls or secondary beams. The beam in which steel reinforcement is provided in the tensile zone only is known as singly reinforced beam. In the case of doubly reinforced beam, reinforcement is provided in compression zone also to carry compressive stresses. Design of beams were done using IS 456:2000 and SP 16:1980.

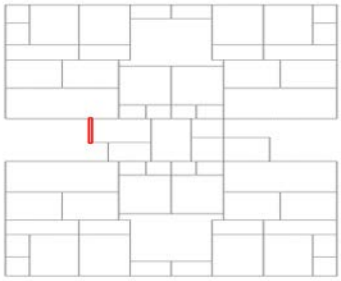

Fig. 10 Beam layout-STAAD model

Step 1: Material constants

ISSN 2348 – 7968

Characteristic strength of concrete, f_{ck} = 25 N/mm^2
Characteristic strength of steel, f_y = 500 N/mm^2

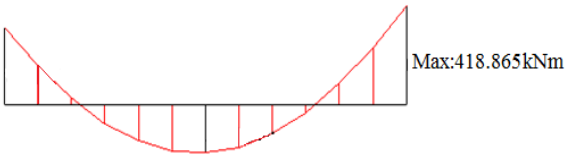

Fig. 11 Bending Moment Diagram (kNm)

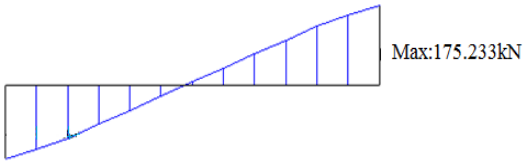

Fig. 12 Shear Force Diagram (kN)

Step 2: Dimensioning

Size of the beam = 300 mm × 500 mm
Assume clear cover of 25 mm and
25 mm diameter bar
Effective depth, d = 500 – 25 – $\frac{25}{2}$ = 462.5 m
As per Table 3 of SP-16,

Moment of Resistance, $M_{u,lim}$ = 0.134 $f_{ck} bd^2$
= 0.134× 25 × 300×462.5^2
= 214.97kNm

Step 3: Design for maximum mid span moment

Mid span moment, M_u = 418.865kNm (from STAAD)
Here, $M_u > M_{u,lim}$
Hence, the beam is to be designed as a doubly reinforced beam.

Step 4: Calculation of area of steel at mid span

($M_u - M_{u,lim}$) = (418.865-214.97) =203.895kNm

Stress in compression steel, $f_{sc} = \left\{\frac{0.0035\,(xu\,max - d')}{xu\,max}\right\} E_s$

$x_{u\ max}$ = limiting value of neutral axis depth

= 0.48 d = 0.48 ×462.5= 222 mm

d' =clear cover + $\frac{diameter}{2}$ = 25 +$\frac{25}{2}$ =37.5 mm

$f_{sc} = \left\{\frac{0.0035\,(222-37.5)}{222}\right\} \times 2 \times 10^5$

= 581.75 N/mm^2

But, f_{sc} should not be greater than 0.87 f_y = 0.87 × 500 = 435 N/mm^2

Therefore, $A_{sc} = \left\{\frac{Mu - M_{u,lim}}{f_{sc}\,(d-d')}\right\}$

$= \frac{203.895 \times 10^6}{435\,(425)} = 1102.88$ mm^2

Provide 3 bars of 25 mm dia bars (A_{sc} = 1472.62 mm^2)

$A_{st\,2} = \frac{A_{sc} f_{sc}}{0.87 f_y} = \frac{1124.03 \times 435}{0.87 \times 500} = 1124.03$ mm^2

$A_{st\,1} = \left\{\frac{0.36 f_{ck}\, b\, xu\ max}{0.87 f_y}\right\} = 1377$ mm^2

Total tension reinforcement = $A_{st} = A_{st\,1} + A_{st\,2}$

= 1124.03+ 1377 = 2501.038mm^2

Provide 6 bars of 25 mm dia bars.(2945.24 mm^2)

Step 5: Check for shear reinforcements

V_u =175.233kN (From STAAD)

$\tau_v = \frac{V_u}{bd}$

$= \frac{175.233 \times 10^3}{300 \times 462.5} = 1.41$ N/mm^2

$p_t = \frac{100 A_{st}}{bd} = 1.77$

As per IS 456-2000, table 19

τ_c = 0.79 N/mm^2

$\tau_v > \tau_c$, So shear reinforcement is required
Strength of shear reinforcement,

V_{us} = (V_u - τ_c bd)
= 175.233× 10^3-(0.79×300×462.5) = 65.38kN

From Clause.40.4 (a) of IS 456:2000
Spacing of stirrups, $S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$

$= \frac{0.87 \times 500 \times 2 \times \frac{\pi}{4} \times 8^2 \times 462.5}{65.38 \times 10^3}$

ISSN 2348 – 7968

=309.35 mm

Provide 8 mm diameter 2-L stirrups

According to IS 456:2000, Clause 26.5.1.5, the spacing of stirrups in beams should not exceed the least of:

i. 0.75d = 0.75 × 470 = 352.5mm or
ii. 300mm

Hence provide 8 mm diameter 2 legged stirrups @ 200mm c/c gradually increasing to 300 mm towards the centre.

Step 6: Check for deflection

As per IS 456 Cl: 23.2.1

$\frac{l}{d} = 20 \times K_t$

$f_s = 0.58\, f_y \times \frac{Area\ of\ cross-section\ of\ steel\ required}{Area\ of\ cross\ section\ of\ steel\ provided}$

$= 0.58 \times 500 \times \frac{2501.038}{2945.24}$

$= 246.305 N/mm^2$

Percentage of tension reinforcement

$= \frac{100Ast}{bd}$

$= \frac{100 \times 2945.24}{300 \times 462.5}$

$= 2.12$

As per IS 456:2000 (fig.4, page 38)

$K_t = 0.9$

Permissible $\frac{l}{d}$ $= 20 \times 0.9$

$= 18$

Actual $\frac{l}{d}$ $= \frac{2600}{462.5}$

$= 5.83$

Since actual $\frac{l}{d}$ is less than permissible $\frac{l}{d}$.

So it is safe under deflection.

Reinforcement detail is provided in Appendix C.

8.3 Design of Continuous Beam

A beam is a structural member subjected to a system of external forces at right angles to the axis. Beams are usually provided for supporting slabs and walls or secondary beams. The beam in which the steel reinforcement is provided only in tensile zone is known as singly reinforced beam. In case of doubly reinforced beam, reinforcement is provided in compression zone also to carry compressive forces. Design of beams was done using IS: 456: 2000 and SP 16: 1980.M20 Concrete and Fe 500 steel are adopted for beam design. Beam with cross section 300 ×500 mm which is found critical among other beams are selected for design. The bending moments and shear forces are found from the analysis results are used for the design.

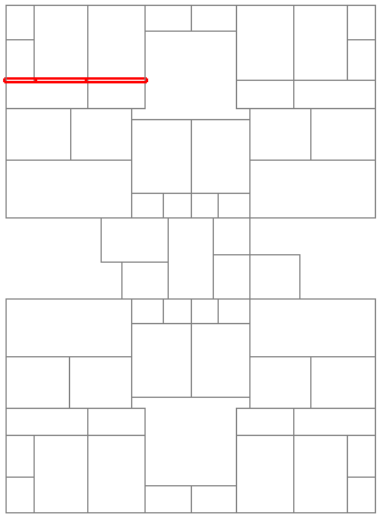

Fig.13 Beam layout - STAAD model

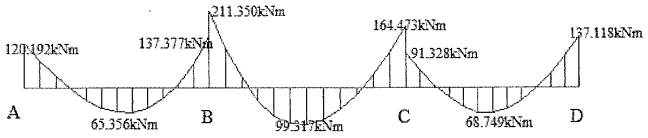

Fig.14 Bending moment diagram (kNm)

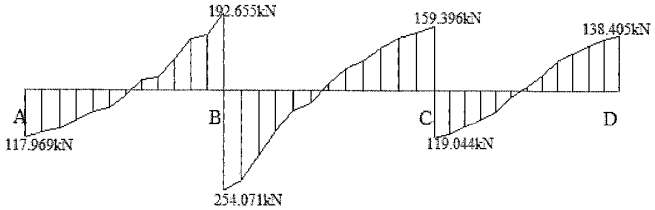

Fig. 15 Shear force diagram (kN)

Step 1: Material constants

Use M25 concrete and Fe500 steel bars

ISSN 2348 – 7968

f_{ck}= 25 N/mm^2

f_y = 500 N/mm^2

Step 2: Preliminary dimensioning

Width of beam ,b= 300 mm

Depth of beam D = 500 mm

Assume 25mm cover and 25 mm Φ bars

Effective depth = 500 – 25 – 12.5 = 462.5 mm

Step 3: Ultimate bending moment

Maximum positive bending moment,

Mu = 99.317kNm (From STAAD)

Maximum negative bending moment, *Mu*=211.35kNm(From STAAD)

Step 4:Limiting moment of resistance

(M_u)lim = 0.134×f_{ck}×b × d^2

= 0.134× 25×300 ×462.5^2 = 214.9kNm

Mu <(M_u)lim, Hence singly reinforced section

Design for positive moment

$\frac{M_u}{b \times d^2} = \frac{99.32 \times 10^6}{300 \times 462.5^2}$ =1.54

From table 3 of SP 16:1980

Pt = 0.387

Ast $= \frac{Ptbd}{100} = \frac{0.387 \times 300 \times 462.5}{100}$ = 536mm^2

Hence provide 2-20 mm Φ bars (Ast =629 mm^2)

Design for negative moment

$\frac{M_u}{b \times d^2} = \frac{211.35 \times 10^6}{300 \times 462.5^2}$ =3.29

From table 3 of SP 16: 1980

Pt = 0.935

Ast $= \frac{Ptbd}{100} = \frac{0.935 \times 300 \times 462.5}{100}$ = 1256.3mm^2

Hence provide 4-20 mm Φbars(Ast=1570.79mm^2)

Step 5:Check for shear stress

Maximum shear force,*Vu*=254.071kN (From STAAD)

$\tau_v = \frac{Vu}{b \times d} = \frac{254.071 \times 10^3}{300 \times 462.5}$= 1.83 N/mm^2

From table 19 of IS 456

pt = $\frac{100\ Ast}{b \times D} = \frac{100 \times 629}{300 \times 462.5}$=0.45

τ_c = 0.49N/mm^2 (IS 456:2000 table 19)

$\tau_v > \tau_c$, ∴ shear reinforcement should be provided.

As per IS 456:2000 clause 40.4

Strength of shear reinforcement = V_{us}= V_u – (τ_c× b ×d)

= 254.071×10^3 – (0.49 ×300 × 457.5)

=186.81 kN

Assuming 8 mm Φ 2 legged stirrups are used

According to IS 456:2000, clause 26.5.1.5,

The spacing of stirrups in beams should not exceed the least of

a)0.75d = 0.75 × 457.5 = 343.125 mm

b)300 mm

Maximum spacing of 300 mm

Therefore provide 8 mm Φ 2 legged stirrups @ 100 mm c/c up to a distance of 0.25 L_{eff} from the face of the support and provide 8 mm Φ 2 legged stirrups @ 300 mm c/c in all other places.

Step 6: Main reinforcement

Table. 5: Reinforcement details of beam AB

ISSN 2348 – 7968

Beam AB	***B= 300mm D= 500mm***		
	Left	***centre***	***Right***
	Negative	Positive	Negative
Bending Moment,Mu(kNm)	120.192	65.356	137.38
$\frac{M_u}{b \times d^2}$	1.87	1.01	2.14
Pt,(from SP16:1980)	0.484	0.255	0.557
Ast(required) $=\frac{Ptbd}{100}$ (mm^2)	1234	353.81	772.83
Ast(provided)mm^2	(#4-20mmΦ)	(#2-20mmΦ)	(#4-20mmΦ)
Factored shear force,*Vu*(kN)	192.655		
Shear force,τ_v(N/mm^2)	1.38		
Shear reinforcement	8 mm Φ, 2-legged stirrups @ 100 mm c/c		

Table. 6: Reinforcement details of beam BD

Beam BC	***B= 300mm D= 500mm***		
	Left	***centre***	***Right***
	Negative	Positive	Negative
Bending Moment ,*Mu*(kNm)	211.35	99.317	164.47
$\frac{M_u}{b \times d^2}$	3.29	1.54	2.56
pt,(from SP16:1980)	0.935	0.387	0.680
Ast(required) $=\frac{Ptbd}{100}$ (mm^2)	1297.3	536.96	943.5
Ast(provided)mm^2	(#4-20mmΦ)	(#2-20mmΦ)	(#4-20mmΦ)
Factored shear force,*Vu*(kN)	254.071		
Shear force,τ_v(N/mm^2)	1.83		
Permissible shear stress, τ_c (N/mm^2)	0.48		
Shear reinforcement	8 mm Φ, 2-legged stirrups @ 100 mm c/c		

Table. 7: Reinforcement details of beam BD

ISSN 2348 – 7968

Beam CD	***B= 300mm D= 500mm***		
	Left	***centre***	***Right***
	Negative	Positive	Negative
Bending Moment ,*Mu*(kNm)	91.328	68.749	137.118
$\frac{M_u}{b \times d^2}$	1.42	1.07	2.13
pt,(from SP16:1980)	0.359	0.267	0.557
Ast(required) $=\frac{Ptbd}{100}$ (mm^2)	498.11	370	732.8
Ast(provided)mm^2	(#4-20mmΦ)	(#2-20mmΦ)	(#3-20mmΦ)
Factored shear force,*Vu*(kN)	138.405		
Shear force,τ_v (N/mm^2)	0.99		
Permissible shear stress, τ_c, (N/mm^2)	0.64		
Shear reinforcement	8 mm Φ, 2-legged stirrups @ 100 mm c/c		

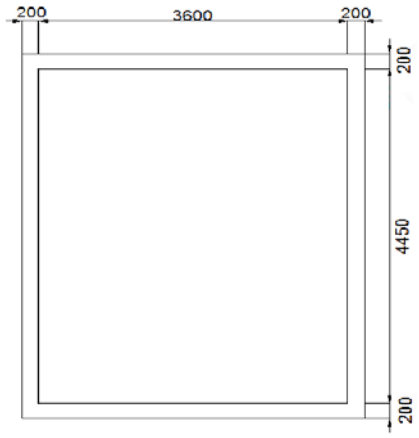

Fig. 16 Plan of two-way slab (All dimensions are in mm)

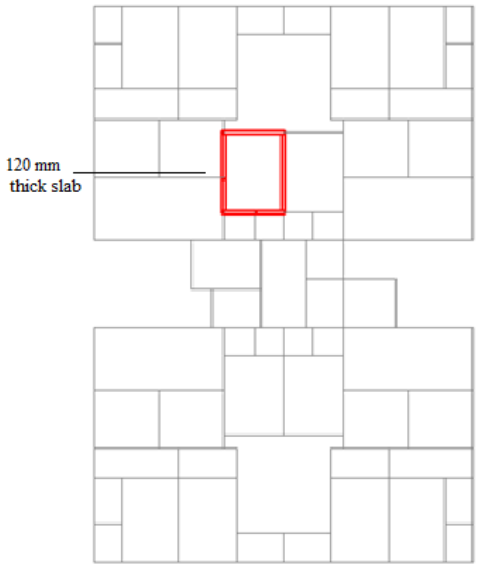

Fig.17 Slab layout-STAAD model

8.4 Design of Two-Way Slab

Slabs are plate elements having their depth much smaller than other two dimensions. They usually carry a uniformly distributed load from the floors and roof of the building. Design of reinforced concrete slab was done using IS 456:2000. Slabs of thickness 120 mm is used in the building and designed as two-way slab. Grade of concrete M25 is assumed for slab design.

Step 1: Material constants

Concrete, f_{ck} = 25 N/mm²
Steel, f_y = 500 N/mm²

Step 2: Dimensioning

Clear span distance in shorter direction, ℓ_x= 3.6 m
Clear span distance in longer direction, ℓ_y = 4.45 m
As per IS 456:2000, Clause 24.1,
Thickness of slab = ℓ_x /32 =3600/32 = 113 mm~ 120 mm
Assume 20mm cover and 10mm diameter bars
Effective depth,d = 120 – 20 – $\frac{10}{2}$= 95mm

Step 3: Effective span

ISSN 2348 – 7968

As per IS 456: 2000 clause 22.2

Effective Span along short and long spans are computed as:

L_{ex1} = centre to centre of support = 3.8 m
L_{ex2} = clear span + eff.depth = 3 +.095= 3.695m
L_{ey1} = centre to centre of support= 4.65 m
L_{ey2} = clear span + eff.depth= 4.45 + .095 = 4.545m
Effective span along short span, L_{ex} = 3.695m
Effective span along long span, L_{ey}= 4.545m

Step 4: Load calculation

Dead Load on Slab	= 0.12×25 = 3kN/m²
Live Load on Slab	= 3kN/m²
Floor Finish	= 1.67kN/m²(As per IS 875:Part 1,Table 2)
Total load	= 7.67kN/m²
Factored load	= 1.5 × 7.67=11.5 kN/m²

Step 5: Type of slab

Effective span along short span, L_{ex} = 3.695 m
Effective span along long span, L_{ey} = 4.545m

$\frac{L_{ey}}{L_{ex}}$= 4.545/3.695 = 1.2 < 2.
Hence, design as two-way slab.

Step 6: Ultimate design moment

As per IS 456:2000 table 26, take the moment coefficients for

$\frac{L_{ey}}{L_{ex}}$ = 4.545/3.695 = 1.2

Short span moment coefficients (interior panel)
Negative moment coefficient, α_x = 0.043
Positive moment coefficient, α_x = 0.032
Long span moment coefficients:
Negative moment coefficient, α_y = 0.032
Positive moment coefficient, α_y = 0.024

Step 7: Design moments

M_x(-ve) = αx W l_x^2 = 0.043 ×11.5×3.695² = 6.75kNm
M_x(+ve) = α_x W l_x^2 = 0.032 ×11.5×3.695² = 5.02kNm
M_y(-ve) = α_y W l_x^2 = 0.032 ×11.5× 3.695² = 5.02kNm
M_y(+ve) = α_y W l_x^2 = 0.024 ×11.5×3.695² = 3.76kNm

Step 8: Check for depth

M_u = 0.134f_{ck} bd²

$$d_{req} = \sqrt{\frac{(M_u)_{lim}}{0.134 \times f_{ck} \times b}} = \sqrt{\frac{6.75 \times 10^6}{0.134 \times 25 \times 1000}}$$

= 44.88 mm < 95 mm
Hence the effective depth selected is sufficient to resist the design ultimate moment.

Step 9: Reinforcements along Short and long span directions

As per IS: 456 2000 Annex G Clause. G.1
The area of reinforcement is calculated using the relation:

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

Short span direction:
M_x(-ve) = 6.75kNm

$$6.75 \times 10^6 = 0.87 \times 500 \times A_{st} \times 95 \left[1 - \frac{A_{st} \times 500}{1000 \times 95 \times 25}\right]$$

A_{st}= 143.45 mm²
M_x(+ve) = 4.58kNm

$$5.02 \times 10^6 = 0.87 \times 500 \times A_{st} \times 95 \left[1 - \frac{A_{st} \times 500}{1000 \times 95 \times 25}\right]$$

A_{st}= 108.365 mm²
Long span direction:
M_y(-ve) = 5.02kNm

$$5.02 \times 10^6 = 0.87 \times 500 \times A_{st} \times 95 \left[1 - \frac{A_{st} \times 500}{1000 \times 95 \times 25}\right]$$

A_{st}= 108.365 mm²
M_y(+ve) = 3.76kNm

$$3.76 \times 10^6 = 0.87 \times 500 \times A_{st} \times 95 \left[1 - \frac{A_{st} \times 500}{1000 \times 95 \times 25}\right]$$

A_{st}= 81.89 mm²

Reinforcement provided
Short span: Provide 10mm diameter bars @ 280mm c/c ($A_{st\ prov}$ = 144 mm²)
Long span: Provide 10mm diameter bars @ 280mm c/c ($A_{st\ prov}$ = 144 mm²)

Step 10: Check for spacing

As per IS 456:2000 Clause. 26.3.3(b)
Maximum spacing = 3d or 300mm, whichever is less
= 3 × 95 = 285mm (or) 300mm (take lesser value)
= 285 mm

Provide spacing of 280 mm
$spacing_{prov} < spacing_{max}$

Step 11: Check for area of steel

As per IS 456 clause 26.5.2.1 pg 48

ISSN 2348 – 7968

$A_{st_{min}}$ = 0.12 % of bD= $\frac{0.12\times1000\times120}{100}$
= 144 mm²
We give a min amount of reinforcement of 144 mm²

Step 12: Check for shear

As per IS 456:2000, Table13

Shear force, V_u= $\frac{W\times lx}{2}$= $\frac{11.5\times3.695}{2}$=21.24kN

As per IS 456:2000 Clause 40.1
Nominal shear stress, τ_v =$\frac{V_u}{bd}$
= 21.24× 10^3/1000 × 95= 0.22 N/mm²
Percentage of steel, p_t= 100 A_s/bd
= (100 × 144)/ (1000 × 95) = 0.15

As per IS 456:2000, Table 19
Permissible shear stress, τ_c = 0.29 N/mm²
As per IS 456:2000 Clause 40.2,
Design shear strength of concrete = kτ_c
= 1.3× 0.29 = 0.377 N/mm²
As per IS 456:2000 Table 20
Maximum shear stress, $\tau_{c\,max}$= 3.1 N /mm²
τ_v<$k\tau_c$ < $\tau_{c\,max}$,
So shear reinforcement is not required.

Step 13: Check for deflection

$A_{st_{prov}}$ =144 mm²
$A_{st_{req}}$ =143.45 mm²

As per IS 456 :2000 fig. 4 ,page 38
f_s= $\frac{0.58 f_y A_{st_{req}}}{A_{st_{prov}}}$
=$\frac{0.58\times500\times143.35}{144}$ = 288.69 N/mm²
p_t = 100 A_s/bd
=(100 × 144)/ (1000 ×95)
= 0.151
As per IS 456:2000, Fig 4
Modification factor = 1.3
Permissible l/d ratio = 32 × 1.3 = 41.6
Actual l/d= (3695/95) = 38.89 < 41.6
Therefore, deflection is safe with provided depth.

Step: 14 Check for cracking

(As per IS 456:2000, Clause 43.1)

1. Steel provided is more than 0.12%
2. Spacing of main steel < 3d = 3 ×95 = 285mm
3. Diameter of reinforcement < $\frac{D}{8}$= 120/8= 15mm
Hence it is safe against cracking.
Reinforcement details is provided in appendix c.

8.5 Design of Column

Column size = 300 mm× 500 mm

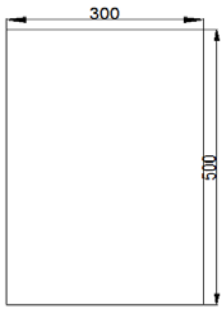

Fig.18 Plan of column

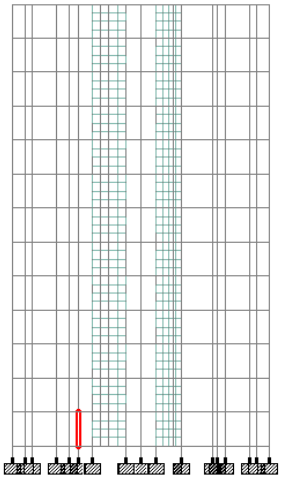

Fig.19 Column layout –STAAD model

Step 1: Material Constants

Concrete, fck = 30 N/mm²

Steel,f_y = 500 N/mm²

Step 2: Dimensioning

Depth of column, D = 500 mm
Breadth of column,b = 300 mm
Unsupported length of column, l = 3000 - 500 = 2500 mm
Support condition: - both ends hinged
As per Table 28 of IS 456:2000
Multiplication factor for effective length = 1

ISSN 2348 – 7968

Effective length of column, l_{eff} = $1 \times l$ = 2.5m
Factored axial Load, P_u = 2946kN
Factored Moment in X-dir, M_{ux} = 90.260kNm
Factored Moment in Y-dir, M_{uy} = 15.781 kNm
Type of Column:
l_{eff}/ D = 2.5/0.5 = 5< 12
l_{eff}/ b = 2.5/0.3 = 8.3< 12
So design as a short column with biaxial bending

Step 3: Calculation of eccentricity

(Ref: Clause.25.4 of IS 456:2000)

Eccentricity in Y direction, $e_y = \frac{l}{500} + \frac{b}{30}$
= 15 < 20 mm
Eccentricity in X direction, $e_x = \frac{l}{500} + \frac{D}{30}$
= 21.6 >20 mm

Step 4: Moments due to minimum eccentricity

$M_{ux} = Pu \times e_x = 2946 \times 0.021 = 61.866$kNm

$M_{uy} = Pu \times e_y = 2946 \times 0.02 = 58.92$kNm
Hence we choose M_{ux}= 90.260kNm and M_{uy}=58.92 kNm

Step 5: Longitudinal reinforcement

Assume percentage of steel, p_t = 2.5 % ;
$\frac{p}{f_{ck}} = \frac{2.5}{30} = 0.08$
(0.8% - 6% is the range of minimum steel area of column as per IS 456: 2000)
Assume 40 mm clear cover and 25 mm diameter bars,
$d' = 40 + (25/2) = 52.5$mm
Uniaxial moment capacity of the sections
$\frac{d'}{D}$ = 52.5/500 = 0.105 (About X axis)
$\frac{d'}{D}$ = 52.5/300 = 0.175 (About Y axis)
$\frac{P_u}{bdf_{ck}}$ = 0.65
$\frac{M_{ux1}}{fck\ b\ D^2}$ = 0.07(From chart 48 of SP 16)
M_{ux1} =157.5kNm
$\frac{M_{uy1}}{fck\ b\ D^2}$ =0.07(From chart 48 of SP 16)
M_{uy1}= 94.5kNm
For 2.5% steel, Fe 500 and M30 concrete,
$\frac{P_{uz}}{A_g}$ = 22.5N/mm² (From chart 63 of SP16)
A_g = 300×500 = 150000 mm²
P_{uz} = 3375kN
$\frac{P_u}{P_{uz}}$ = 2946/3375 = 0.872
$\frac{M_{ux}}{M_{ux1}}$ = 90.260/157.5= 0.573
$\frac{M_{uy}}{M_{uy1}}$ = 58.92/94.5= 0.62

For $\frac{M_{uy}}{M_{uy1}}$ = 0.62 and $\frac{P_u}{P_{uz}}$ = 0.872,
we get $\frac{M_{ux}}{M_{ux1}}$=0.8 (Refer chart 64, SP- 16)
As Permissible value of $\frac{M_{ux}}{M_{ux1}}$= 1.0, which is greater than the actual value of $\frac{M_{ux}}{M_{ux1}}$
So the assumed reinforcement of 2.5% is satisfactory.
$A_{st} = \frac{p \times b \times D}{100}$ = (2.5×300×500)/100 = 3750 mm²
So provide 8 numbers of 25 mm diameter bars.

Step 6: Lateral ties(from IS 456: 2000 clause 26.5.3.2)

Diameter

1. The diameter of lateral ties shall not be less than one- fourth of the largest longitudinal bar = $\frac{1}{4} \times 25 = 6.25$ mm
2. It should not be less than 6 mm

Provide 8 mm diameter lateral ties

Pitch
Pitch of the transverse reinforcement shall not be more than the least of the following distances.

1. Least lateral dimension of compression member = 300 mm
2. 16 times the smallest diameter of the longitudinal reinforcement bar to be tied= 16× 25= 400 mm
3. 300 mm

Provide 8mm diameter lateral ties at 300mm c/c.

8.6 Design of Staircase (Emergency stair)

ISSN 2348 – 7968

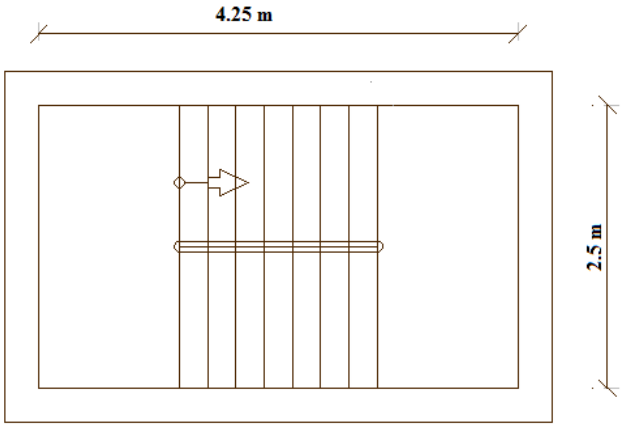

Fig. 20 Top view of staircase

Step 1: Material Constants

Concrete, f_{ck} = 25 N/mm²

Steel, f_y = 500 N/mm²

Step 2: Preliminary dimensioning

Rise of stair,R = 150mm
Tread of stair,T = 300mm
Effective span = 4.25+0.20=4.45m
(As per IS 456:2000, Clause 33.1)
Thickness of waist slab = $\frac{l_{eff}}{32}=\frac{4450}{32}$=139.06 mm
Provide an overall depth D = 180 mm
Assume 16 mm diameter bars and a clear cover of 25 mm
Effective depth = 180 – 25 – 8 = 147 mm

Step 3: Load calculation

Dead load of waist slab = Thickness of waist slab

$$\times 25 \times \frac{\sqrt{R^2+T^2}}{T}$$

$$= 0.18 \times 25 \times \frac{\sqrt{0.15^2+0.3^2}}{0.3} = 5.03 \text{kN/m}$$

The self-weight of the steps is calculated by treating the step to be equivalent horizontal slab of thickness equal to half the rise $\frac{R}{2}$
Self-weight of step= 0.5×0.15×25 = 1.875kN/m²
Floor finish = 1.67kN/m² (As per IS 875: Part 1,Table 2)
Live load = 3kN/m²

Total service load= 9.81kN/m²
Consider 1m width of waist slab
Total load /m run = 9.81kN/m
Total ultimate load = W_u = 1.5×9.81= 14.715 kN/m

Step 4: Ultimate design moment

Maximum bending moment at the centre of the span is given by,

$$Mu = \frac{W u \times ls^2}{8}$$

$$= \frac{14.715 \times 4.45^2}{8} = 36.42 \text{kNm}$$

Step 5: Check for the depth of waist slab

$$d_{required} = \sqrt{\frac{Mu}{0.138 \times fck \times b}}$$

$$= \sqrt{\frac{36.42 \times 10^6}{0.138 \times 25 \times 1000}}$$

= 108.72 mm

$d_{provided} > d_{required}$
Hence the effective depth selected is sufficient to resist the ultimate moment.

Step 6: Reinforcements

$$\frac{M_u}{bd^2} = \frac{36.42 \times 10^6}{1000 \times 147^2} = 1.68$$

From table :3 of SP 16 : 1980, P_t = 0.498

$$\frac{100\ Ast}{bd} = 0.498$$

$A_{st}=\frac{0.498 \times 1000 \times 147}{100}$ = 732.06 mm²
Maximum spacing for 16 mm ☐ bars

Spacing $=\frac{1000 \times A_{\emptyset}}{A_{st}}$

$$=\frac{1000 \times \frac{\pi}{4} \times 16^2}{732.06}$$

= 274.65 mm
Provide 16 mm dia bars @ 250 mm c/c spacing

Step 7: Check for spacing of main steel

As per IS 456:2000 Cl: 26.3.3 (b)

Max spacing $= \left\{ \begin{matrix} 3d \\ or \\ 300\ mm \end{matrix} \right\}$,whichever is less

$$= \left\{ \begin{matrix} 3 \times 147 = 441\ mm \\ or \\ 300\ mm \end{matrix} \right\}$$,whichever is less

= 300 mm
Spacing provided < spacing maximum

Hence Safe

Step 8: Check for area of steel

ISSN 2348 – 7968

As per IS 456:2000, Cl: 26.5.2.1,
Ast min = 0.12% cross sectional area
$= \frac{0.12\times1000\times180}{100}$ = 216 mm^2
$Ast_{provided} > Ast_{minimum}$
Hence ok.

Step 9: Distribution reinforcement

0.12% cross sectional area
$= \frac{0.12\times1000\times180}{100}$
= 216 mm^2
Use 8mm dia bars
Spacing $_{required} = \frac{1000\times\frac{\pi\times8^2}{4}}{216}$ = 232.71 mm
Provide 8 mm dia bars at 200 mm c/c

Step 10: Check for spacing of distribution steel

As per IS 456:2000 Cl: 26.3.3 (b)
Max spacing $= \left\{\begin{matrix} 5d \\ or \\ 450\ mm \end{matrix}\right\}$,whichever is less
$= \left\{\begin{matrix} 5\times147 = 735\ mm \\ or \\ 450\ mm \end{matrix}\right\}$,whichever is less
= 450 mm
Spacing $_{provided}$ < spacing $_{maximum}$

Hence Safe

Step 11: Check for shear

(As per IS 456:2000, Clause 40)

Shear, $V_u = \frac{W_u \times l_e}{2}$

$= \frac{14.715\times4.45}{2}$

= 32.74kN

As per IS 456:2000, Clause 40.1
Nominal shear stress, $\tau_v = \frac{V_u}{bd} = \frac{32.74\times10^3}{1000\times147}$ = 0.222N/ mm²

$pt = \frac{100\ Ast}{bd}$

$= \frac{100\times732.06}{1000\times147}$ = 0.498
As per IS 456: 2000,Table 19
τ_c = 0.49N/ mm²
As per IS 456: 2000,Cl:40.2
Design shear strength of concrete, k×τ_c
= 1.24 ×0.49 = 0.607 N/ mm²
As per IS 456: 2000,Table 20
Max. value of shear stress, $\tau_{c\,max}$ = 3.1 N/ mm²
$\tau_v < \tau_c < \tau_{c\,max}$
So shear reinforcement is not required.

8.7 Design of Water Tank

Step 1: Material constants

Steel, f_y = 500 N/mm^2
Concrete, f_{ck} = 25 N/mm²

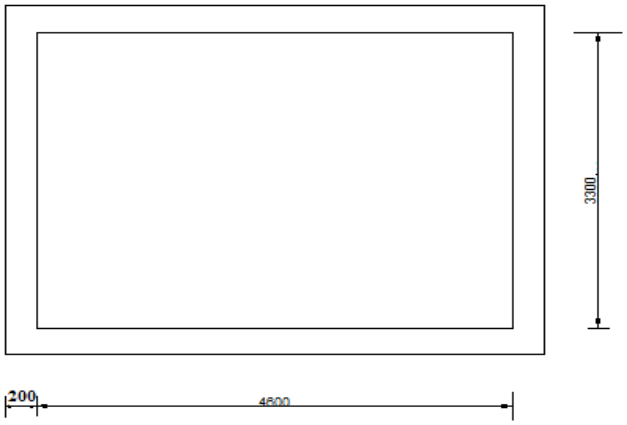

Fig.21 Dimensions of water tank(in mm)

Step 2: Dimensions of water tank

Length of wall = 4.60 m
Width of wall = 3.3 m
Height of wall = 1.5 m

Step 3: Design constants

(As per working stress method)
As per IS 456:2000, table 21
Permissible stress in concrete, σ_{cbc} = 8.5 N/mm^2
As per IS 456:2000, table 22
Permissible stress in steel, σ_{st}= 0.55×f_y
=0.55×500
=275 N/mm^2

$m = \frac{280}{3\sigma_{cbc}}$ = 10.98
$k = \frac{1}{1+\frac{\sigma_{st}}{m\,\sigma_{cbc}}}$ =0.253
$j = 1 - \frac{k}{3}$ = 0.916

Step 4: Design of side walls

Height of wall, a = 1.5 m
Width of wall, b = 3.3 m
Density of liquid, w = 9.81 kN/m^3

ISSN 2348 – 7968

$\frac{b}{a}=\frac{3.3}{1.5}=2.2$
$\frac{l}{a}=\frac{4.60}{1.5}=3.06$
Moment coefficient for individual wall panel, top and bottom hinged, vertical edges fixed from IS 3370 (Part IV)-1967, (Table 1)
$M_y = 0.059$
As per IS: 3370 (Part II)-1967, (Clause 3.3.2 Table 1),
Maximum horizontal moment, M = $M_y \times w \times a^3$
$=0.059\times9.81\times1.5^3 = 1.95$kNm
Using 12 mm diameter bars and 25 mm clear cover
Overall depth, D = 200 mm
Provide 200 mm thick wall
Effective depth provided, d= 200-25-6
=169mm

Step 5: Check for effective depth

$$M_u = 0.134\, f_{ck}\, b\, d^2$$
$$d_{req} = \sqrt{\frac{M_u}{0.134\, f_{ck}\, b}} = \sqrt{\frac{1.95\times10^6}{0.134\times25\times1000}} = 25.16 < 169$$
Hence the effective depth selected is sufficient to resist design ultimate moment.

Step 6: Reinforcement required in horizontal direction

Area of steel required, $A_{st} = \frac{M}{\sigma_{st} j\, d}$

Area of steel, $A_{st}=\frac{1.95\times10^6}{275\times0.916\times169} = 45.805$ mm^2

As per IS : 3370 (Part II)-1967 Cl:7.1.1 The minimum reinforcement in walls, floors and roofs in each of two directions at right angles shall have an area of 0.3 % of the concrete section in that direction for sections up to 100 mm thick. For sections of thickness greater than 100 mm and less than 450 mm the minimum reinforcement in each of the two directions shall be linearly reduced from 0.3 % for 100 mm thick section to 0.2 % for 450 mm thick section. For sections of thickness greater than 450 mm, minimum reinforcement in each of the two directions shall be kept at 0.2 %. In concrete sections of thickness 225 mm or greater, two layers of reinforcing steel shall be placed one near each face of the section to make up the minimum reinforcement specified in Cl:7.1.1.Since t > 150 mm, reinforcement should be provided in two layers.

Minimum reinforcement required,
$A_{st\,min}$ = 0.242 % of concrete section
$=\frac{0.242\times1000\times200}{100}$
= 484 mm^2
Spacing required = 233.672 mm
Provide 12mm diameter bars @ 150 mm c/c in horizontal direction

Step 7: Reinforcement required in vertical direction

Moment coefficient, M_x = 0.012
Maximum vertical moment, M = $M_x \times w \times a^3$
= 0.405kNm
Area of steel required, $A_{st} = \frac{M}{\sigma_{st} j\, d}$

$A_{st} = \frac{0.405\times10^6}{275\times0.916\times269} = 5.97$mm^2
Minimum reinforcement required,
$A_{st,min}$= 0.242 % of concrete section
$=\frac{0.242\times1000\times200}{100} = 484$ mm^2
Spacing required =233.67 mm
Provide 12 mm diameter bars @ 150 mm c/c in vertical direction

Step 8: Design of top slab

Let the thickness of top slab be 120 mm.
Use 10 mm diameter bars and 20 mm clear cover.
Effective depth, d=95 mm.

Loads on the slab
Dead load = 0.12 × 25 = 3 kN/m^2
Live load = 1.5kN/m^2
Finish load = 1.67kN/m^2 (As per IS 875:Part 1,Table 2)
Total load, w = 6.17kN/m^2
Factored load =6.17×1.5=9.255kN/m^2
$\frac{l_y}{l_x}=\frac{4.6}{3.3}=1.4<2$
Hence, design as a two way slab. All edges are discontinuous.

Step 9: Area of reinforcement in shorter span

Moment coefficient, α_x= 0.085
Moment, $M_{ux} = \alpha_x\, w\, l_x^2 = 0.085\times 9.25\times 3.3^2$
= 8.56kNm
Area of steel required, $A_{st} = \frac{M}{\sigma_{st} j\, d}$
$= \frac{8.56\times10^6}{275\times0.916\times95} = 357.70$ mm^2
For 10 mm diameter bars
Spacing required =219.56 mm
Provide 10 mm diameter bars @ 200 mm c/c as main reinforcement.

Step 10: Area of reinforcement in longer span

Moment coefficient, α_y= 0.056

ISSN 2348 – 7968

Moment, M_{ux}= $\alpha_y\ wl_x^2$= 0.056 × 9.25× 3.3^2
= 5.64kNm
Area of steel required, A_{st} = $\frac{M}{\sigma st j d}$ = $\frac{5.64\times10^6}{275\times0.916\times95}$=235.68$mm^2$
For 10 mm diameter bars
Spacing required =333.65 mm
Provide 10 mm diameter bars @ 250 mm c/c

Step 11: Check for effective depth

$$M_u = 0.134\ f_{ck}\ b\ d^2$$

$$d_{req} = \sqrt{\frac{M_u}{0.134\ f_{ck}\ b}} = \sqrt{\frac{8.56\times10^6}{0.134\times25\times1000}} = 50.54 < 95$$

Hence the effective depth selected is sufficient to resist design ultimate moment.

Step 12: Design of base slab

Let the thickness of base slab be 200 mm.
Use 12 mm diameter bars and 20 mm clear cover.
Effective depth, d= 174 mm.

Step 13: Loads on the slab

Dead load= 0.2× 25 = 5 kN/m^2
Load due to water=(1.5-0.3)× 9.81(Assume 300 mm free board)
= 11.772kN/m^2
Finish load = 1.67kN/m^2 (As per IS 875:Part 1,Table 2)
Total load, w = 18.442kN/m^2
Factored load = 27.663kN/m^2
$\frac{l_y}{l_x} = \frac{4.6}{3.3} = 1.4 < 2$
Hence, design as a two way slab. All edges are discontinuous.

Step 14: Area of reinforcement in shorter span

Moment coefficient, α_x = 0.085
Moment, M_{ux} = $\alpha_x\ wl_x^2$
= 0.085 × 27.663× 3.3^2 = 25.606kNm
Area of steel required, A_{st} = $\frac{M}{\sigma st j d}$
= $\frac{25.606\times10^6}{275\times0.916\times174}$=584.203$mm^2$
For 12 mm diameter bars
Spacing required =198.6 mm
Provide 12 mm diameter bars @ 150mm c/c as main reinforcement.

Step 15: Area of reinforcement in longer span

Moment coefficient, α_y = 0.056
Moment, M_{ux} = $\alpha_y\ wl_x^2$
= 0.056 × 30.408× 3.3^2 = 18.54kNm
Area of steel required, A_{st} = $\frac{M}{\sigma st j d}$
= $\frac{18.54\times10^6}{275\times0.916\times174}$=422.99$mm^2$
For 12 mm diameter bars
Spacing required =267.375mm
Provide 12 mm diameter bars @ 150 mm c/c

Step 16: Check for effective depth

$$M_u = 0.134\ f_{ck}\ b\ d^2$$

$$d_{req} = \sqrt{\frac{M_u}{0.134\ f_{ck}\ b}} = \sqrt{\frac{25.606\times10^6}{0.134\times25\times1000}} = 87.42 < 174$$

Hence the effective depth selected is sufficient to resist design ultimate moment.

8.8 Design of Shear wall

Step 1: Material constants

Use M_{30}Concrete and steel bars of grade Fe 500
For M_{30} concrete, f_{ck} = 30 N/mm^2
For Fe $_{500}$ steel, f_y= 500 N/mm^2

Step 2: Preliminary dimensions

Horizontal length of wall,l_w= 2900 mm
Thickness of wall t_w= 200 mm
As per IS 13920: 1993, clause 9.1.2, thickness of wall should not be less than 150 mm.
∴ Provided thickness of web is ok.

Step 3: Results from STAAD

Factored axial load, P_u = 2858 kN
Factored shear force V_u =213.51 kN
Factored moment, M_u= 42.6kNm

Step 4: Check for boundary elements

As per IS 13920:1993,clause 9.4.1,where the extreme fibre compressive stress in the wall due to fa4tored gravity load plus factored earthquake forces exceed 0.2 f_{ck} boundary elements shall be provided along the vertical boundaries of wall.

Extreme fibre compressive stress, $f_c = \frac{Pu}{Ag} \pm \frac{Mu\times l_w}{2I_y}$
Area of cross section = Ag = 2900 × 200 = 580000mm^2
Moment of inertia of the section, $I_y = \frac{t_w\times l^3}{12}$

$$= \frac{200 \times 2900^3}{12} = 4.06 \times 10^{11} \text{ mm}^4$$

Extreme fibre compressive stress,

$$f_c = \frac{2858 \times 10^3}{580000} \pm \frac{42.6 \times 10^6 \times 2900}{2 \times 3.253 \times 10^{11}}$$

5.117 N/mm^{2}and 4.737N/mm^2

Limiting value of stress = 0.2 f_{ck}= 0.2 × 30 = 6 N/mm^2

As extreme stresses are less than the limiting value, boundary elements are not required.

Step 5: Checking whether two layers of steel are required

As per IS 13920:1993, clause 9.1.5, if the factored shear stress in the wall exceeds $0.25\sqrt{f_{ck}}$ Or if the wall thickness exceeds 200 mm, reinforcement shall be provided in two curtains, each having bars running in the longitudinal and transverse directions in the plane of the wall.

Factored shear force, *Vu* = 213.51 kN

As per IS 13920:1993, clause 9.2.1,

Nominal shear stress, $\tau_v = \frac{V_u}{b \times d_w}$

Effective depth of wall, $d_w = 0.8 \times l_w$
$= 0.8 \times 2900$
$= 2320$ mm

$$\tau_v = \frac{V_u}{b \times d_w}$$

$$= \frac{213.51 \times 10^3}{200 \times 2320} = 0.46 \text{N/mm}^2 < 0.25 \times \sqrt{30} = 1.369 \text{ N/mm}^2$$

So two layers of steel is not required

Step 6: Check for maximum shear stress

As per 13920:1993, clause 9.2.3 the nominal shear stress in the wall,τ_v shall not exceed τ_{cmax}, as per Table 20 of IS 456:2000

τ_v=1.369 N/mm2

Maximum shear stress = τ_{cmax} = 3.5 N/mm^2

$\tau_{cmax} > \tau_v$, Hence safe.

Step 7: Calculation of shear reinforcement

As per IS 13920:1993 clause 9.2.1, the minimum reinforcement ratio shall be 0.0025 of the gross area in each direction.

Assume 0.5% steel in vertical direction

A_{st}= 0.5% × 200 × 1000
= 1000 mm^2

Provide 12mm Φ bars at 180 mm c/c

As per IS 13920:1993, clause 9.1.5,

Maximum spacing is lesser of

i. $\frac{l_w}{5}$
ii. $3t_w$
iii. 450 mm

Spacing provided < maximum spacing
∴ safe

Factored shear force,*Vu* = 213.51kN

As per IS 13920 Cl.9.2.1

$$\tau_v = \frac{V_u}{b \times d_w} = \frac{213.51 \times 10^3}{200 \times 2320} = 0.46 \text{N/mm}^2$$

Assuming minimum reinforcement ratio in the horizontal direction

pt = 0.25% (IS 13920 ,Cl.9.1.4)

As per IS 456.Table 19 and 20

Design shear stress ,τ_c = 0.37 N/mm^2

$\tau_{c\,max}$= 3.5N/mm^2

$\tau_v > \tau_c$

So shear reinforcement is required

$$Pt = \frac{100\,As}{bd}$$

$$= \frac{0.25 \times 200 \times 1000}{100} = 500 \text{ mm}^2$$

Provide 10 mm ☐ bars @ reinforcement (628 mm^2)

Step 9: Calculation of moment of resistance of rectangular shear wall section

As per IS 13920:1993, Annex- A

$x_u/l_w < x_u^*/l_w$

$$\frac{M_{uv}}{f_{ck} \times t_w \times lw^2}$$

$$= \Phi[(1+\lambda/\Phi)(\frac{1}{2} - 0.416\frac{x_u}{l_w}) - (\frac{x_u}{l_w}^2)(0.168 + \frac{\beta^2}{3})]$$

$$\Phi = \frac{0.87 f_y \rho}{\frac{f_{ck}}{0.87 f_y}} = 0.03$$

$$\beta = \frac{}{0.0035 E_S} = 0.62$$

$$\lambda = \frac{p_u}{f_{ck} \times t_w \times l_w} = 0.02$$

$$\frac{x_u}{l_w} = [(\Phi+\lambda)/(2\Phi+0.36)] = 0.2$$

$$\frac{x^*_u}{l_w} = \frac{0.0035}{0.0035 + 0.87\frac{f_y}{E_S}} = 0.616$$

$x_u/l_w < x_u^*/l_w$

M_{uv}= 4183 kNm

$M_u < M_{uv}$

∴ Section is safe in flexure and we can avoid the separate boundary element with confining reinforcement

8.9 Design of Pile

Step 1: Material constants

For M_{25} Concrete, f_{ck} = 25 N/mm^2
For Fe_{500} Steel, f_y = 500 N/mm^2

ISSN 2348 – 7968

Step 2: Pile Capacities

Depending upon the load coming on the column, single or group piles were provided. From the soil report the load carrying capacity of piles are as follows.

Table. 8: Pile Capacities

Sl No.	*Pile diameter (cm)*	*Pile capacity (kN)*
1	50	770
2	60	1070
3	70	1420

Step 3: Design of 700mm diameter pile

Factored column reaction = 2946kN
Safe pile capacity = 1420kN
Number of piles = $\frac{2946}{1420}$ = 2
Load on each pile = $\frac{2946}{2}$ =1473 kN
Ultimate load on each pile,Pu =1.5×1473=2209.5kN
Horizontal force,H =56.872kN(from STAAD)
Horizontal force on one pile,H =$\frac{56.872}{2}$=28.436kN
Depth of pile = 12.6 m

Step 4: Determination of depth of fixity

As per IS: 2911 (Part-1 / Section-2) – 1979-Appendix C Table 2
Value of soil parameter ,K_1= 1.8 kg/cm^2 (for N>50)
As per IS: 2911 (Part-1 / Section-2) – 1979-Appendix C Fig:2

Fixity depth= 6✕ diameter of pile
=6✕ 0.7
= 4.2 m
Moment due to horizontal force, M_u =28.43✕4.2
= 119.406kNm
Axial load on pile, P_u =2209.5kN

$\frac{P_u}{f_{ck}\times D^2}$ =$\frac{2209.5\times10^3}{25\times700^2}$ = 0.18

$\frac{M_u}{f_{ck}\times D^3}$ =$\frac{119.406\times10^6}{25\times700^3}$= 0.013

Assuming 25 mm diameter bars and 50 mm clear cover
d'= cover + $\frac{\emptyset}{2}$= 50 +$\frac{25}{2}$= 62.5mm

$\frac{d'}{D}$=$\frac{62.5}{700}$=0.089~ 0.1

As per chart 60 of SP 16:1980
$\frac{p}{f_{ck}}$= 0 .08
As per IS 456:2000, Clause 26.5.3.1
But, p_{min}=0.8% total c/s area
Area of longitudinal steel,A_s= 3078.76 mm^2
Hence provide 10 numbers of 25 mm diameter bars as longitudinal reinforcement.
Provide 8 mm diameter circular links at 180 mm c/c
This is to be provided up to fixity depth 6D = 4.2m
For depth after 4.2m, provide minimum longitudinal reinforcement as per As per IS: 2911(Part 1/Sec 1)-1979, Clause 5.11.1, p_{min}= 0.4%
Area of longitudinal steel, $A_s = \frac{P_{min}\times\pi\times D^2}{4\times100} = \frac{0.4\times\pi\times700^2}{4\times100}$
= 1539.38 mm^2
Hence provide 4 numbers of 25 mm diameter bars as longitudinal reinforcement.

Step 5: Lateral reinforcement

From IS: 2911(Part 1/Sec 1)-1979 [clause 5.11.3]
The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same is chosen to impart adequate rigidity of the reinforcing cage during its handling and installations. The minimum diameter of the links or spirals shall be 6 mm and the spacing of the links or spirals shall not be less than 150 mm. So provide 8 mm diameter circular links at 180 mm c/c.

Reinforcement details is provided in Appendix C.

8.10 Design of Pile Cap

700mm Diameter – 2 pile group

Step 1: Material constants

For M25 Concrete, f_{ck} = 25 N/mm^2
For Fe415 Steel, f_y = 500 N/mm^2

Step 2: Dimensioning

As per IS 2911(Part 1-Sec 1)-1979, Clause 5.6,
Spacing between 2 piles = 2✕diameter of pile = 1400 mm
As per IS: 2911 (Part-1 / Sec 1) – 1979 Clause 5.12.5, the clear overhang of the pile cap beyond the outermost pile in the group shall normally be 100 to 150mm.

ISSN 2348 – 7968

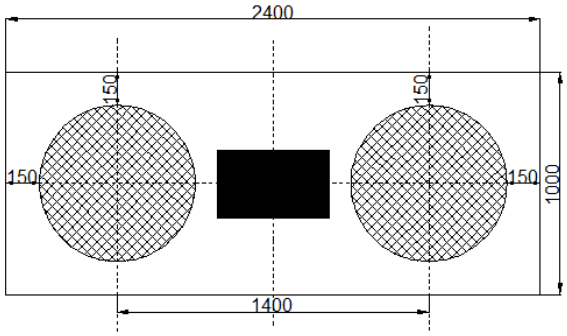

Fig.22 Dimensions of the pile cap (All dimensions are in mm)

Length of pile cap
= (spacing between the piles + Diameter of pile + 2 × 150 mm overhang)
= 1400+700+300 = 2400mm
Breadth of pile cap
= diameter of pile + (2× 150 mm overhang)
= 700 + (2 × 150) = 1000mm
Provide a breadth of 1000mm
Depth of pile cap
= Development length of column bar + Cover

For 25 mm diameter bars, development length,
L_d= 1214 mm
(From Table 66 of SP 16)Assume a clear cover of 75mm (As per IS 2911 (Part 1/ Section 1), and 20m Diameter bars Clause 5.12.6, the clear cover for main reinforcement in the cap slab shall not be less than 60mm)

Depth of pile cap = 1214 + 75 = 1289mm
Provide a depth of 1290mm
Size of Pile Cap: 2.4× 1.0 × 1.29m
Double pile cap was designed as simply supported beam.
Effective depth, d = 1290 – 75 – $\frac{25}{2}$= 1205 mm
Breadth, b = 1000mm
Factored axial load on column = 2209.5kN
Factored axial load on pile, P_u = 2209.5kN

Step 3: Main reinforcement

Ultimate moment, M_u= $\frac{WL}{4}$= $\frac{2209.5\times2.4}{4}$= 1325.7kNm

$\frac{M_u}{bd^2}$= $\frac{1325.7\times10^6}{1000\times1205^2}$= 0.916

p_t= 0.216 (From Table - 3 of SP 16)

A_{st}=$\frac{p_t bd}{100}$= $\frac{0.216\times1000\times1205}{100}$ =2597.4 mm^2

Hence, provide 9 numbers of 20 mm diameter bars.
Area of steel provided = 2827.433 mm^2
Top Reinforcement
Nominal steel to be provided
Area of steel required A_{st} =$\frac{0.87\times b\times d}{f_y}$
=$\frac{0.87\times1000\times1205}{500}$=2092.35 mm^2
Provide 19 numbers of 12mm diameter bars.

Step 4: Check for shear reinforcement

Maximum shear in pile cap= 3071kN

τ_v = $\frac{V_u}{bd}$
= $\frac{3071\times10^3}{1000\times1205}$=2.55N/mm^2

Ast = 2092.35 mm^2

$\frac{100\times Ast}{bd}$ =$\frac{100\times2092.35}{1000\times1205}$ = 0.174

From Table 19 of IS 456, corresponding to M25 concrete,
τ_c = 0.304N/mm^2
Since, τ_v> τ_c, shear reinforcement needs to be provided
V_{us} = (V_u - τ_c bd)
= 3071 × 10^3 - (0.34 × 1000 × 1205) = 2662.15kN
Assume 10 mm ☐ 4 legged bars
Area of shear reinforcement effective in shear = 314.159 mm^2

Spacing ,s_v = $\frac{0.87\times f_y\times A_{sv}\times d}{0.4\times b}$
= $\frac{0.87\times500\times314.159\times1205}{2662.15\times10^3}$
= 61.729mm
Provide 4 legged 10mm diameter stirrups @ 60 mm c/c.

Step 5: Side face reinforcement

As per IS 456:2000, Clause 26.5.1.3, since depth of pile cap is greater than 750mm side reinforcement need to be provided.
Side face reinforcement = 0.1% Web area
= $\frac{0.1}{100}$ × 1000 × 1290 = 1290mm^2
Side face reinforcement on one face = $\frac{1290}{2}$= 645mm^2
Providing 12mm diameter bars,
Spacing = $\frac{\pi\times12^2\times1000}{4\times645}$= 175.344mm
Hence, provide 12mm diameter bars @ 170 mm c/c on each side face.

9. Site Visits

9.1 Site Visit 1: Transasia Shipping Company, Kakkanad.

A site visit was conducted to the construction site of Transasia shipping company, Kakkanad got an opportunity

ISSN 2348 – 7968

to observe the construction techniques adopted for boring and concreting of DMC pile from this site. There are about 286 piles whose casting is under progress. The hard rock is available at a depth of 17 m.Rotary drilling is carried out till hard strata.

A DMC pile driving equipment consists of a tripod, DMC rods, tremmiepipes, electric motor or diesel engine, generator, pump sets and hose pipes.

Fig.23 Rotary drilling

Fig.24 DMC piling arrangement

The pile points are marked during the setting out process. Tripod is placed such that the chisel (cutting tool) is suspended exactly at the centre of the pile point.A casing is provided at the pile point which prevents the shift of the point. The diameter of the chisel is equal to the diameter of the pile. The chisel used for the piling in this work is shown in figure.

The chisel which is connected to the DMC rods is dropped from a height of nearly 1.5 m to 2m.A sump tank filled with Bentonite solution of density 1.12 is excavated near to the bore hole. The Bentonite solution is continuously pumped and circulated through the DMC rods and chisel. While the chisel hits the ground, the debris and soil is flushed along with Bentonite solution.

Fig.25 Chisel

Fig.26 Bentonite solution

As the depth of the rod is reached, another DMC rod is attached to the previous one and the process is carried until the required depth is reached .The material on which the pile rests is collected and examined. The DMC rods are removed after boring and the carefully placed in the bore hole .The pile cage reinforcement is shown in figure.

ISSN 2348 – 7968

Fig.27 Pile cage reinforcement

Tremmie pipes are inserted into the bore hole one by one successively to the depth. Flushing is carried out for nearly one hour. Concrete of M_{25} grade is mixed in a mixer machine and placed into the bore hole via funnel .Firstly the mix is poured by closing funnel by a lid called dunken.Then allowing the whole concrete mix to pour all on a sudden. Fig below shows the procedure.

Fig.28 Concreting of pile foundation

The portion of concrete above cut off level is removed, since the concrete in this region will be of poor quality due to excess mud at the surroundings.

9.2 Site Visit 2: Commercial Building, Ernakulam.

A site visit was conducted to the construction site of commericialbuilding,Ernakulam.The foundation provided is pile foundation at a maximum depth of 30 m.The building is having two basements and it's a 10 storied building.M_{25} grade concrete is used. Size of the largest column is 1.2 m×0.9 m .The floor height varies as 3.7 m, 4.2 m, 5.2 m etc. The thickness of slab used is 24.5 cm.The thickness of slab drop is 20.5 cm.

Fig.29 Flat slab with slab drop

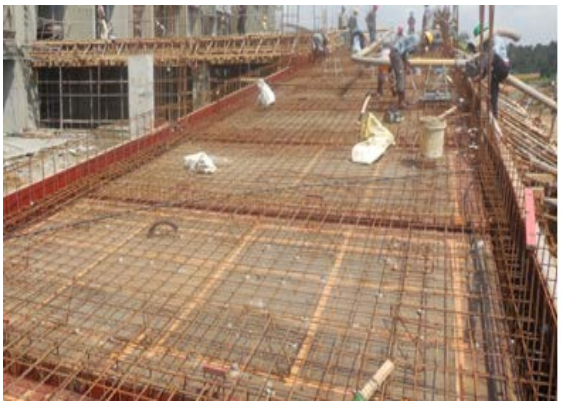

Fig.30 Ramp reinforcement

Ramp is having 1 in 10 slope and 4 m width. Diameter of bars provided are 12 mm at 100 mm c/c spacing.

ISSN 2348 – 7968

Fig.31 Reinforcement of shear wall

16 mm diameter bars are provided at 120 mm c/c vertically and horizontal reinforcement of diameter 12 mm c/c provided at 100 mm c/c.

Fig.32 Reinforcement of column

Dimension of the column (Fig.30) is 300 × 1200 mm.The reinforcement provided is 25 mm diameter bars and 12 mm diameter stirrups are provided at 150 mm c/c

Fig.33 Reinforcement of beam

Beam dimension is 200 × 900 mm .The compression reinforcement provided is 30 mm diameter bars and 12 mm diameter stirrups.

Fig.34 Reinforcement of two –way slab

The two-way slab is provided with 12 mm diameter bars at 100 mm c/c.

ISSN 2348 – 7968

9.3 Site Visit 3: Confident Elite Apartment Building, Thrissur

Confident elite apartment building is having G+15 floors. Ground floor is for car parking. Ground floor is having floor height of 3.9 m and the rest of the floor height is 2.9 m for other floors. The dimension of column is 200× 700 mm, 200×900 mm and that of beam is 200×500 mm and 200×600 mm size .M $_{25}$ is the grade used for beams and slabs and
M $_{30}$ is grade used for columns. Pile foundation is provided at a depth of 28 m.Total of 146 piles were used of diameters 600 mm,700mm and 800 mm respectively.

Fig.35 Sunken slab

Sunken slab is the slab provided in toilets and bathrooms in order to conceal all the pipelines below the floor. The thickness of the sunken slab provided is 100 mm.

Fig.36 Reinforcement of sunken slab

Sunken slab is provided with reinforcement of diameter 8 mm at a spacing of 250 mm c/c.

Fig.37 Reinforcement of column

Fig.37 shows the reinforcement of column. The size of the column is 200 ×700 mm.The reinforcement provide is 25 mm diameter bars at a spacing of 180 mm and special confining reinforcement is provided at 80 mm c/c.

Fig.38 Reinforcement of slab

The diameter of slab reinforcement is 10 mm at a spacing of 200 mm c/c.

10. Conclusions

The analysis and design of the apartment Building located at Irinjalakuda, Thrissur was done as a part of the industrial training. It was a G + 12 storied building with parking facilities in the ground floor. The analysis was done using the software package STAAD Pro.V8i.All the structural components were designed manually and detailed using AutoCAD 2014. The analysis and design were done according to standard specifications. The slab, column, beam and pile cap layouts were prepared. The site visits gave me knowledge regarding the execution of design into a structure. The industrial training provided an opportunity to identify, observe and practice how

ISSN 2348 – 7968

engineering is applicable in the real industry. As well as getting experience on technical practice, it was also possible to learn the importance of punctuality, commitment and team spirit.

Acknowledgement

Thanks are extended to all staffs and friends of SCMS school of science and technology and Stuba Engineering Consultancy for assistance in completing the work.

References

[1] B.C.Punmia. and A.K Jain, Reinforced Concrete Design, New Delhi: Laxmi publications Private Limited.
[2] N Krishna Raju, Advanced Reinforced Concrete Design, New Delhi: C.B.S Publishers and Distributers.
[3] P S Unnikrishnan and D.Menon, Reinforced Concrete Design, New Delhi: Tata McGraw-Hill Publishing Company Limited.
[4] S Ramamruthum., Design of Reinforced Concrete Structures, New Delhi: Dhanpat Rai Publishing Company (P) Ltd.
[5] IS 2911(Part1/Sec 2):1979, Code of Practice for the design and construction of piled foundations, Bureau of Indian Standards, New Delhi, 1979.
[6] SP 16: 1980, Design Aids for Reinforced Concrete to IS: 456-1978, Bureau of Indian Standards, New Delhi, 1980.
[7] IS: 875 (Part 1)-1987, Indian Standard Code of Practice for Design Loads (Other than earthquake) for Building and Structures, Bureau of Indian Standards, New Delhi, 1987.
[8] IS: 875 (Part 2)-1987, Indian Standard Code of Practice for Design Loads (Other than earthquake) for Building and Structures, Bureau of Indian Standards, New Delhi, 1987.
[9] IS: 875 (Part 3)-1987, Indian Standard Code of Practice for Design Loads (Other than earthquake) for Building and Structures, Bureau of Indian Standards, New Delhi, 1987.
[10] SP 34: 1987, Hand Book on Concrete Reinforcement and Detailing, Bureau of Indian Standards, New Delhi, 1987.
[11] IS: 13920:1993, Ductile detailing of reinforced concrete structures subjected to seismic forces, Bureau of Indian Standards, New Delhi.
[12] IS 456:2000, Indian standard Plain and reinforced concrete – Code of Practice, Bureau of Indian standard, New Delhi, 2000.
[13] IS: 1893 (Part 1) :2002- Indian Standard Criteria for earthquake resistant design of structures, Bureau of Indian Standards, New Delhi, 2002.