Design and Analysis of Residential Institute Building

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Abstract - *The project is about planning, designing and analyzing of an apartment building with floors of G+3. This design project is taken up with the objectives of understanding the behavior of the structure and to gain confidence in designing the structure, making use of the codal provisions. It is planned in such a way to meet all the facilities needed by the accommodator. In the residential building, all the floors are only for residential purpose and that are provided with living room, kitchen master- bed room, bath and toilets. In this project, the building is designed as a framed structure to construct houses on each floors. The load calculation for the analysis of the frame are carried out as per IS 875. The analysis of the frame is done using STAAD.PRO software. The structural elements such as slab, beam, column, footing and staircase, are designed by limit state method. Water tank and Septic tank are designed by Working Stress Method, using M25 concrete and Fe415 steel satisfying all codal provisions of IS-456: 2000 and SP-16.*

Key Words: (Size 10 & Bold) Key word1, Key word2, Key word3, etc (Minimum 5 to 8 key words)…

1. INTRODUCTION

The residential building (flats) include a building which consists of separated rooms for each and every action of a man involved in his day to day life. The different types of rooms in our residential building are as follows:

- Living room
- Kitchen
- Drawing room
- Bed rooms

Attached with bathrooms and toilets

The environment of our residential building is very pleasing and gives comfort to the people living in it and it is also located in the centre of the city so that the people comfort to go in and around the city for their basic needs.

1.1 LITERATURE REVIEW:

P.P. Chandurkar et. al. (2013): Study of G+9 building:

He had presented study of G+9 building having three meters height for each storey. The whole building design had carried out according to their IS code for seismic resistant design and the building had considered fixed at base. They design for Structural elements assumed as square or rectangular in section. They analyse whole building using ETAB software in that four different models were studied with different positioning of shear walls.

Mohit Sharma et.al. (2015): To study the dynamic analysis of multi- storeyed Building:

He considered a G+30 storied regular reinforced concrete framed building.Dynamic analysis of multi-storeyed. Building was carried out. These buildings have the plan area of 25m x 45m with a storey height 3.6m each and depth of foundation is 2.4 m. & total height of chosen building including depth of foundation is 114 m. The static and dynamic analysis has done on computer with the help of STAAD-Pro software using the parameters for the design as per the IS:1893-2002 Part-1 for the zones- 2 and 3. It was concluded that not much difference in the values of Axial Forces as obtained by static and dynamic analysis.

1.2 METHODOLOGY:

The systematic approach followed during the project considered of the following steps :

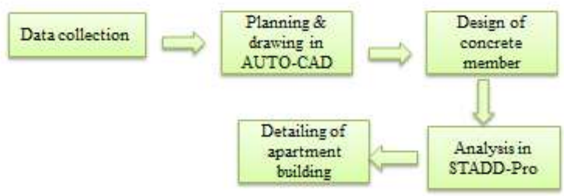

Fig -1: METHODOLOGY

2. WORK PROCESS

2.1 BASIC DATA

i. Type of building –apartment building
ii. No of storey- G+3
iii. Type of structure – reinforced concrete frame with a one way slab and beam floor system
iv. Bearing capacity of soil- 200KN/m

Note: Others required data assume using NBC **(**National building code for planning and IS:456-2000 for concrete design work

2.2 PLAN OF APARTMENT BUILDING

Fig -2: plan

2.3 **DESIGN OF BUILDING COMPONENTS**

DESIGN OF SLAB

Lx = 3.15 m

Ly = 8.75 m

f_{ck} = 25 N/mm^2

f_y = 415 N/mm^2

calculation of effective depth:

Overall depth, d = 0.126 mm

Effective cover = 20 mm

Provide an effective depth, d = 130 mm

Overall depth 'D' = 150 mm

calculation of effective span:

Effective span = Clear span + Effective span
= 3.28 m

Floor finish load = 1 kN/m

Total load = 8.75 kN/m

Factored load = 13.13 kN/m

type of slab:

Ly / Lx = 8.75 / 3.15

= 2.78 > 2

Hence, design as One – way slab.

calculation of load:

Dead Load = 3.75 kN/m^2

Live Load = 4 kN/m^2

Floor Finishes = 1 kN/m^2

Total Load = 8.75 kN/m^2

Factored Load = 8.75 x 1.5

W_u = 13.125 kN/m^2

calculation of bending moment:

M_u = 17.650 kNm

shear force:

V_u = 21.525 kN.

limiting moment of reinforcement:

$M_{u,lim}$ = 58.305 kNm .

$M_u < M_{u,lim}$

section is under reinforcement.

reinforcement :

$M_u = 0.87 f_y A_{st} d [1- (f_y A_{st} / f_{ck} b d)]$

$58.305 \times 10^6 = 0.87 \times 415 \times A_{st} \times 130 [1- 276 \times 10^{-4} A_{st}]$ = 1548 mm^2

Using 12 mm dia bars,

$a_{st} = \pi/4 \times 12^2$

= 200.96 mm^2

Spacing = $(a_{st} / A_{st}) \times 1000$ = 150 mm

spacing limit :

i) 3d = 3 x 130 = 390 mm

ii) 300 mm

Adopt a spacing of 150 mm & alternate bars are at bent up @ supports.

Distribution Reinforcement:

A_{st} = 0.12 % b D

= (0.12 x 1000 x 150) /100

= 180 mm^2

Using 10 mm dia bars,

$a_{st} = \pi/4 \times 10^2$

= 78.54 mm^2

Spacing = $(a_{st} / A_{st}) \times 1000$ = 436 mm

Spacing Limit :

i) 5d = 5x130 = 650 mm

ii) 450 mm

Provide 10 mm dia bars at 300 mm spacing.

Check For Shear Stress :

Considering the shorter span and unit widen of slab

$\tau_v = V_u / b d$

$= (21.525 \times 10^3) / (1000 \times 130)$

= 0.165 N/ mm^2

P_t = 100 x A_{st} (pro) / b d

= (100 x 1548) / (1000 x 130)

= 1.19

(Refer table 19 of IS: 456 : 2000)

τ_c = 0.685 N/ mm^2

K x τ_c = 1.3 x 0.685

= 0.89 N/ mm^2

$\tau_v < \tau_c$

Hence , the shear stresses are within safe permissible limits.

DESIGN OF TWO WAY SLAB :

lx = 3.2m

ly = 3.3m

fck = 25N/mm^2

fy = 415N/mm^2

Type Of Slab:

Ly / Lx = 3.3 / 3.2

1.03 < 2

Hence, design as two-way slab

Depth Of Slab:

Span/overall depth=35x0.8

= 3.2 x 10^3 / 35 x 0.8

= 120mm

d = 120 – (16 / 2) -20

= 92mm (or) 100mm

Effective Span:

Effective span = (clear span + eff depth)

= (3.2 x 10^3) + 100

= 3300mm

= 3.3m

c/c of support = 3430mm

Load Calculation

Self wt of slab = (1 x0.12 x 25)

= 3kN/m^2

Live load = 2kN/m^2

Floor finish load = 1 kN/m^2

Total load = 6kN/m^2

Design load Wu = 9 kN/m^2

Ultimate Design Moments

And Shear Force:

Refer table 27 of IS456-2000,

αx = 0.062

αy = 0.062

Mux = αx Wu lx^2

= 5.71kNm

Muy = αy Wu ly^2

= 6.08kNm

Vux = 0.5 Wul

= 14.85kN

Check Of Depth:

Mmax = 0.138 fckbd^2

6.08 x 10^6 = 0.138 x 25 x1000 xd^2

d = 41.98mm < 100mm

Hence safe.

Reinforcement Calculations:

M u = 0.87 fy Ast d [1- (fy Ast /fck b d)]

Ast = 173.38 mm^2

Adopt 10mm dia bar,

ast = π/4 x 10^2= 78.5mm^2

Spacing limit, As per IS 456-200

1. 3d = 3 x 100= 300mm

2. 300mm

Ast min = 0.12%bd= 144mm^2

No.of bars = Ast / ast

= 2.2

Spacing of main reinforcement,

S = 1000 x ast / Ast

= 452.76mm (or) 450mm

Provide 10mm dia @ 250mm c/c

Distribution Reinforcement:

Spacing of distribution rod,

S = 1000 x ast / Ast

= 50.265/ 144 x 1000= 349mm

So provide 8mm dia @ 300mm c/c.

Check For Shear Stress:

τv = Vu / bd

=(14.85 x 103)/(1000x 100)

= 0.148N/mm^2

%Ast = 100 Ast / bd

= 0.173N/mm^2

Refer table 19 of IS456- 2000

K = 1.3

τc = 0.306N/mm^2

Design strength

= K x τc=1.3 x 0.306

= 0.398N/mm^2

τv <K τc

Hence safe in shear.

Check For Deflection:

(L/d)act = (3.3 x 103 / 100) act

= 3.3

Modification factor= 1.4 (IS456-2000, fig 4)

(L/d)max`= 1.4 x 28= 39.2

(L/d)max >(L/d)act

Hence safe in deflection.

DESIGN OF BEAM:

Clear span = 8.75 m

Width of support = 230 mm

Service load = 8.75 KN/m

M_{25} grade concrete& Fe_{415} grade steel.

calculation of size of beam:

Overall effective depth = L / 15= 8.75 / 15

= 500 mm

Provide overall depth of 500 mm

Depth of web = 500 + 50

= 550 mm

Width of web = D / 2

= 275 mm

Effective Span Of Beam:

Effective span = clear span + effective depth

= 9.25 m

c/c support = 8.75 + 0.23

= 8.98 m

Hence, effective span l = 8.98 m

Calculation Of Load :

Self weight = 0.23 x 0.55 x 25

= 3.162 KN/m

Live load = 8.75 kN/m

Total load , W = 11.912 kN/m

Factored load , W_u= 1.5 x total load

= 1.5 x 11.912

= 17.868 kN/m

Ultimate Design Moment & Shear Force:

B.M = $W_u l^2 / 8$

= 171 kNm

V_u = WL / 2

= 78.17 kN

Check For Effective Depth Required:

D = $(M_u / 0.138 f_{ck} b)^{0.5}$

= 222.6 < 500 mm

Hence the required effective depth is safe

Tension Reinforcement:

$M_{u,lim}$ = $0.138 f_{ck} b d^2$

= 198.97 x 10^6 Nmm

$M_u < M_{u,lim}$

the beam is designed as under reinforced section.

Main Reinforcement:

Calculation of Ast:

M_u = $0.87 f_y A_{st} d [1- (f_y A_{st} / f_{ck} b d)]$

A_{st} = 979.04 mm^2

Use 16 mm dia bars as a main reinforcement

Number of bars = 949.04 / 201.06

= 5 no's

Hence provide 5 no's of 16 mm dia bars as
a main reinforcement

Distibution Reinforcement Bars:

From IS 456:2000, clause 26.5.2.1

$A_{st,min}$ = 0.12% of b D

= (0.12 / 100) x 230 x 550

= 151.8 mm^2

Use 12 mm dia bar as a distribution reinforcement

Number of bars = 151.8 / 113.09

= 1.34 = 2 no's

Hence provide 2 no's of 12 mm dia
bars as a distribution reinforcement.

Check For Shear:

Normal shear stress, τ_v= V_u / b d

= $(78.17x10^3)$ / (230x500)

= 0.68 N/mm²

P_t = 100 x A_{st} (pro) / b d

= (100 x 979.04) / (230 x 500)

= 0.85

(Refer table 19 of IS: 456 : 2000)

τ_c = 0.598 N/ mm²

Hence shear reinforcement as provided in vertical stirrups.

Design For Shear Reinforcement:

From IS 456:2000 , clause 40.4

Shear carrying capacity of steel

V_u = $V_u - (\tau_c b d)$

= 9.4 kN

Use 10 mm dia bars of 2 legged verical stirrups.

Spacing:

Least as follows,

i) V_{us} = $(0.87 f_y A_{sv} d) / S_v$

A_{sv} = $2 x \pi/4 x 10^2$

= 157.08 mm²

V_{us} = $(0.87 x 415 x 157.08 x 500) / (9.4x10^3)$

= 3016.69 mm

ii) 0.75d= 0.75 x 500= 375 mm

iii)300mm

Hence provide 10 mm dia bars

2 legged vertical stirrups @

300 mm c/c distance as a shear reinforcement.

DESIGN OF COLUMN

Length = 3 m

Grade = M_{25}

Steel = Fe_{415}

Assume column size= 300 mm x 230 mm

load calculation:

load from beam B1= (3.15 x 15.713) / 2

= 24.75 kN

load from beam B2 = (8.75 x 17.868) / 2

= 78.17 kN

self weight of column = 3 x 0.3 x 0.23 x 25

= 5.175 kN

Total load , W = 108.095 kN

Factored load , W_u = 108.09 x 1.5

= 162.1425 kN

Size Of Column:

Assume 1 % of steel reinforcement

A_{sc} = 1% A_g= 0.01 A_g

A_c = A_g – 0.01 A_g **=** 0.99A_g

From IS 456:2000, clause 39.3

P_u = $(0.45 f_{ck} A_c) + (0.67 f_y A_{sc})$

= 13.92 A_g

A_g = 11648.17 mm²

A_g = b x d

d = 50.64 mm say 50 mm

Check For Slenderness:

From IS 456 : 2000, column 25.12

Effective length of column= 0.85 x L

= 0.85 x 3000

= 2550 mm

Assume least lateral dimension of column,

B = 230 mm

Slenderness ratio = (Effective Length / LL Dimension)

Where, LL Dimension= Least Lateral Dimension

= (2550 / 230)

= 11.09 < 12

Therefore column is short column

To Find A_{SC} :

A_{sc} = 0.01 A_g

= 0.01(230 x 300)= 690 mm²

Use 12 mm diameter bars,

Spacing = (a_{st} / A_{st}) x 1000= 150 mm

Number of bars = $(690) / (\pi/4x12^2)$

= 6.1

Hence provide 6 numbers of 12 mm dia bars

@ 150 mm c/c

Clear Cover:

From IS 456:2000, clause 26.4.1, greater of as follows,

Diameter of longitudinal reinforcement= 12 mm

Clear cover = 40 mm

Transverse Reinforcement:

From IS 456:2000, clause 26.5.3.2(c)

a) Maximum diameter of reinforcement

Greater of as follows,

1) 1/4 x diameter of

largest longitudinal reinforcement= 1/4 x 12

= 3 mm

2) 6 mm (Say 8 mm)Diameter of transverse reinforcement= 8 mm

b) Pitch

Least of as follows,

1) b = 230 mm

2) 16 x dia of smallest

longitudinal reinforcement= 16 x 12

= 192 mm

3) 300 mm

Hence provide 8 mm diameter bar

@ spacing of 200 mm c/c

distance of transverse reinforcement.

DESIGN OF FOOTING:

Load from column= 2000 kN

Size of column = 300 mm x 230 mm

SBC = 200 kN/m²

f_{ck} = 25 N/mm²

f_y = 415 N/mm²

SIZE OF FOOTING:

Assume self-weight of footing as 10% of column load

Self-weight of footing = 200 kN

Total load on soil = 2200 kN

Factored load = 2200 x 1.5

= 3300 kN

SBC of soil = 200 kN/m²

Area of footing required = 3300 / 250 x 1.5

= 8.8 m²

Assume Side ratio= 1.3

L x B = 1.3 B m²

1.3B x B = 8.8 m²

B = 3 m

L = 4 m

We take length and width as 3 x 4 m for each footing

Check = 3300 / (3 x 4) kN/m²

= 275 kN/m²

Hence the footing is adequate since

the soil pressure developed at

the base is less than the bearing capacity of soil.

BENDING MOMENT DUE TO PRESSURE:

Bending moment for shorter side

Mu = $P_u \times l_x^2 / 2$

= 261.855 kNm

Mu = $P_u \times l_y^2 / 2$

= 470.59 kNm

DEPTH OF FOOTING :

i) From moment consideration

Mu (limit) = $0.138 \times f_{ck} \times b \times d^2$

= 369.33 mm

ii) From shear stress consideration

V_{ul} = $P_u (l - d)$

τ_c = 0.36 N/mm²

P_t = 0.25%

τ_c = V_{ul} / bd

assume shear strength as 0.36 N/mm²

for M25 grade concrete

0.36 = 275 (1.85- d)/d

d = 800 mm

Take D = 800+6+40

= 846 mm

To Find Area Of Steel

Longer span:

M_u= $0.87 \times f_y \times A_{st} \times d \, [1 - f_y \times A_{st} / f_{ck} \times b \times d]$

A_{st}= 1688.36 mm²

Shorter span:

M_u= $0.87 \times f_y \times A_{st} \times d \, [1 - f_y \times A_{st} / f_{ck} \times b \times d]$

A_{st}= 924.29 mm²

Use 16 mm dia bars,

Spacing (longer span) = 150 mm

Use 10 mm dia bars,

Spacing (shorter span) = 200 mm

r/f in central bar with of 3 m= (2/B+1)

A_s t= $(78.54/200)x10^3$

= 392.5

= (2/1.3+1) x 392.5

= 341.30 mm^2

$A_{st\ min}$ = 0.12%bd

= 0.12/100 x 1000 x 800

= 960 mm^2

provide 12 mm dia bars

spacing = 113/960 x 1000

= 117.70 mm c/c

Provide 12 mm dia @ 100mm c/c

CHECK FOR SHEAR STRESS:

M_u= 0.87 x f_y x A_{st} x d [1 - f_y x A_{st}/f_{ck} x b x d]

A_{st} = 961.83 mm^2

provide 16 mm dia bar,

spacing = ast/Ast x 1000

= 200 mm

CHECK FOR PUNCHING SHEAR:

Punching shear stress across the section

V_z = P_U (A-a)

= 183.33 (3.00 X 2.00 – 0.885 x 0.665)

= 992.1 kN

τ_{vz} = Vz/bd

= 0.56 N/mm^2

$\tau_{vz} < K_S \tau_C$

τ_C = $0.25(f_{ck})^{0.5}$ = 1.1 N/mm^2

k_S = 1

τ_C = 1.1 N/mm^2

Hence safe.

DESIGN OF SUNSHADE:

Specification :

Projection of sunshade = 600 mm

Assume uniform thickness = 50 mm

Load Calculation :

Consider on meter length of sunshade

Total self-weight of sunshade = 1 x 0.6 x 0.05 x 0.5 x 25000

= 750 kN

Total imposed load = 1 x 0.6 x 0.75

= 450 kN

Total load = 1200 kN

Therefore design load = 1800 kN

Bending Moment :

Wu = 1800 x 0.6 / 2

= 540 kNm

Depth Required :

Effective depth required ,d = (Mu/Qu x b)1/2

= 13.98 mm

Eff depth available = 32 mm

32mm >13.98mm

Hence ok

Ast = 482 mm^2

Minimum area of steel provided= 60 mm^2

Assume 6mm dia bars

Maximum permitted spacing= 3 x d

= 3 x 32

= 90 mm

Provide 6mm dia Fe_{415} bars @ 90mm c/c

Distribution Bars :

0.12% of steel = 60 mm^2

= 36 mm^2

Assume 6mm dia bars

Maximum permitted spacing= 180 mm

Provide 4 no.s of 6mm dia bars

Check For Shear :

Nominal shear stress= Vu / bd

= 0.06 N/mm^2

τ_C = 0.28 N/mm^2

Hence the slab is safe against shear

Development Length :

Ld = (6x0.87x415)/ (4x1.2x1.6)

= 280 mm

Result :

Thickness of sunshade= 60 mm

Main R/F: 8mm dia Fe_{415} bars @ 200mm c/c

Distribution R/F: 8mm dia Fe_{415} bars @ 200mm

DESIGN OF STAIRCASE

Data:

Thread = 300 mm

Rise = 150 mm

Width of landing beam = 1.32 m

Imposed load = 5 kN/m^2

Floor finish load = 1 kN/m^2

f_{ck} = 25 N/mm^2

f_y = 145 N/mm^2

Dimensions:

Height of each flight = 3.00 / 2 = 1.5 m

Number of risers required = 1.5 / 0.15= 10 NoS

Number of treads in each flight= 9 NoS

Space occupied by treads = 9 x 0.3= 2.7 m

Bearing of landing slab = 230 mm

Thickness of waist slab D = 200 mm

Effective span = 4.43 m

Load Calculation:

$W = W_S (R^2 + T^2)^{1/2} / T$

=5.59 kN/m^2

Dead load on one step =0.75 kN/m^2

Total load =12.34 kN/m^2

Bending Moment & Shear Force:

Maximum bending moment at centre of span

$M = 0.125\ W_U\ L^2$

= 45.40 kNm

Check For Depth Of Waist Slab:

$M_u = 0.138 \times f_{ck} \times b \times d^2$

=120mm

Hence safe

Main Reinforcement:

$M_u = 0.87 \times f_y \times A_{st} \times d\ [1 - f_y \times A_{st} / f_{ck} \times b \times d]$

A_{st} =936.47mm^2

Provide 12mm dia bars

Spacing $= A_{st}/a_{st}$

Provide 12mm dia bars at 150mm c/c spacing

Distribution Reinforcement:

= 0.12% bD

=0.12/100 x 1000 x 200

=240mm^2

Provide 10mm dia bars

Spacing =373.9 =370mm

Provide 10mm dia bars at 300mm c/c spacing

2.4 STAAD.Pro OUTPUT ANALYSIS

in our project we consider G+3 apartment building for planning, design and analysis,the each floor contain 4 no's of 2BHK flat.

STAAD.Pro RESULT

STAAD.Pro V8i SELECTseries4

Version 20.07.09.31

Proprietary Program of

Bentley Systems, Inc.

Date= OCT 19, 2016

Time= 12:11:52

TOTAL REACTION

FORCE-X = 0.00

FORCE-Y = 75387.87

FORCE-Z = 0.00

B E A M . 232

LENGTH : 3980.0 mm

SIZE : 230.0 mm X 500.0 mm

COVER : 30.0 mm

SECTION 0.0 mm 995.0 mm 1990.0 mm 2985.0 mm 3980.0 mm

TOP 218.58 0.00 0.00 218.58 218.58

BOTTOM 218.58 218.58 218.58 218.58 0.00

C O L U M N . 291

LENGTH: 3000.0 mm

CROSS SECTION: 230.0 mm x 300.0 mm

COVER : 40.0 mm

LOAD CASE : 2 (Z) /(Y)

STEEL AREA : 1269.60 Sq.mm.

REQD. CONCRETE AREA: 67730.41 Sq.mm.

MAIN REINFORCEMENT : Provide 12 - 12 dia.(equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED

TOTAL VOLUME OF CONCRETE = 144.4 CU.METER

BAR DIA	WEIGHT (in mm)
8	39347
10	12960
12	28229
16	30698
20	12225
TOTAL	123460

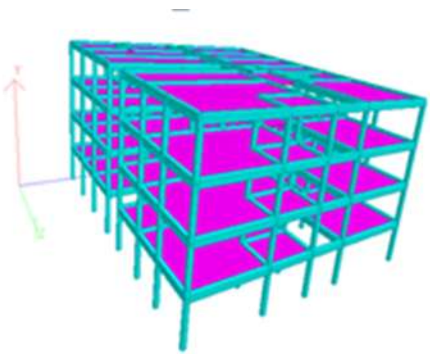

Fig -1: 3D VIEW

3. CONCLUSION

In this project, we have successfully made an attempt of Planning, Analyzing and Designing of an Apartment building. The design has been made accordingly satisfy all practical needs. The structural members are designed manually and analyzed by using STAAD.PRO software. The two way slab, singly reinforced beams, columns, isolated footings and dog legged staircase are designed for M25 grade concrete and Fe415 steel by Limit State Method and Water tank and septic tank by Working Stress method using IS-456: 2000 and SP-16.By choosing this project, we had an opportunity to learn about the requirements of planning and designing of a residential building.During this design project, we learned various methodologies and necessary design concepts used in the today's construction world.

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