To Study Analysis and Design of Multi-Storey building using STAAD-pro. and Comparing with Manual Calculations

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Abstract - *Structural planning is an art and science of designing with economical, serviceable and durable structural. This project is generally based on theoretical design and analysis of structural framed building. The entire process of structural planning and design required imaginations, sound knowledge and thinking. Analysis and design of G+4 story residential building structure by using IS Code method. Analysis and of entire structure have been complete by manually design and verifies by STADD Pro. Software. All the drafting and detailing was done by using Auto CAD, also serve as a base for transfer of the structure for analysis and design in STAAD Pro. In this project, the design of slab, beam, column, staircase, etc. is calculated by "Limit State Method" using IS: 456-2000 code book. Different load active on the member are consider according to IS: 875-1987 (part 1, part2, part3). Hence residential building is properly planed in accordance with National Building Code of India.*

***Key Words*: STAAD-pro, Residential, Economical, storey, AutoCAD**

1. INTRODUCTION

Now a days due to the over population in the urban cities and high cost of the land, there is a need to accommodate in multi-storey building. The determination of general shape, specific dimension and size is known as structure analysis, so that it will perform the function for it create and will safely withstand the influences which will act on throughout its useful life. The entire process of structural planning and designing requires not only imaginations and calculations, but also science knowledge of structural engineering decide knowledge of particle aspect, such bye-laws and design codes, backed by sample experience and judgment.

In this project, an effort made on planning, analysis and design of residential building. For analysis and design of building, the plan draft by AUTO-CAD software which plan import in STAAD Pro.

1.1 Literature Review

Ibrahim, et.al (April 2019): Design and Analysis of Residential Building(G+4):

After analyzing the G+4 story residential building structure, conducted that the structure is rate in loading like dead load, live load, wind load and seismic loads. Member dimensions (Beam, column, slab) are assigned by calculating the load type and its quantity applied on it. Auto CAD gives detailed information at the structure members length, height, depth, size and numbers, etc. STADD Pro. has a capability to calculate the program contains number of parameters which are designed as per IS 456: 2000. Beams were designed for flexure, shear and tension and it gives the detail number, position and spacing brief.

Dunnala Lakshmi Anuja, et.al (2019): Planning, Analysis and Design of Residential Building(G+5) By using STAAD Pro.:
Frame analysis was by STAAD-Pro. Slab, Beams, Footing and stair-case were design as per the IS Code 456-2000 by LSM. The properties such as share deflection torsion, development length is with the IS code provisions. Design of column and footing were done as per the IS 456-2000 along with the SP-16 design charts. The check like one-way shear or two-way shear within IS Code provision. Design of slab, beam, column, rectangular footing and staircase are done with limit state method. On comparison with drawing, manual design and the geometrical model using STADD Pro.

Mr K. Prabin Kumar, et.al (2018): A Study on Design of Multi-Storey Residential Building:

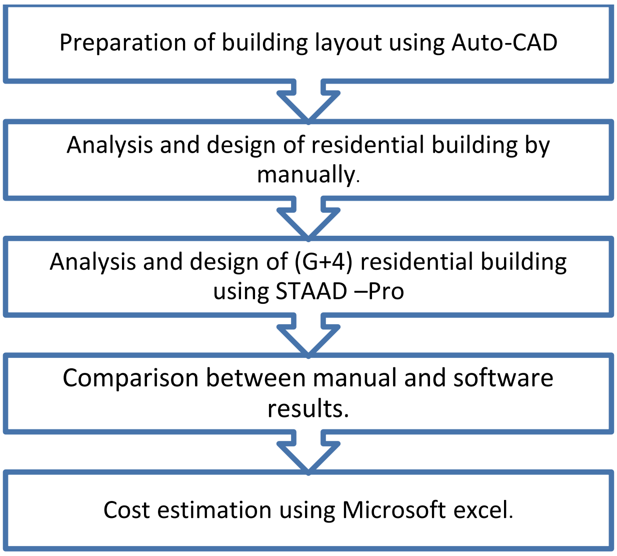
They used STADD Pro. to analysis and designing all structure member and calculate quantity of reinforcement needed for concrete section. Various structure action is considered as members such as axial, flexure, shear and tension. Pillar are delineated for axial forces and biaxial ends at the ends. The building was planned as per IS: 456-2000.

Deevi Krishna Chaitanya, et.al (January, 2017): Analysis and Design of a (G+6) Multi-Storey Building Using STAAD Pro.:
They used static indeterminacy methods to calculate numbers of unknown forces. Distributing known fixed and moments to satis$_{fy}$ the condition of compatibility by Iteration method. Kani's method was used to distribute moments at sucessire joints in frame and continues beam for stability of members of building structure. They used the designing software STADD Pro. which reduced lot of time in design, gives accuracy

R. D. Deshpande, et.al (June, 2017): Analysis, Design and Estimation of Basement+G+2 Residential Building:

They found that check for deflection was safe. They carried design and analysis of G+2 residential building by using E-Tabs software with the estimation of building by method of center line. They safely designed column using SP-16 checked with interaction formula.

1.2 METHODOLOGY



2. WORK PROGRESS

2.1 BASIC DATA

Type of building – Residential building.
Type of structure –multi storey Rcc framed structure
No. of storey – 5 (G+4)
Floor to floor height – 3.0m.
External walls – 230 mm including plaster
Internal walls – 115 mm including plaster
Height of plinth – 0.6 m.
Depth of Footing – 2.4 m.

2.2 PLAN OF RESIDENTIAL BUILDING

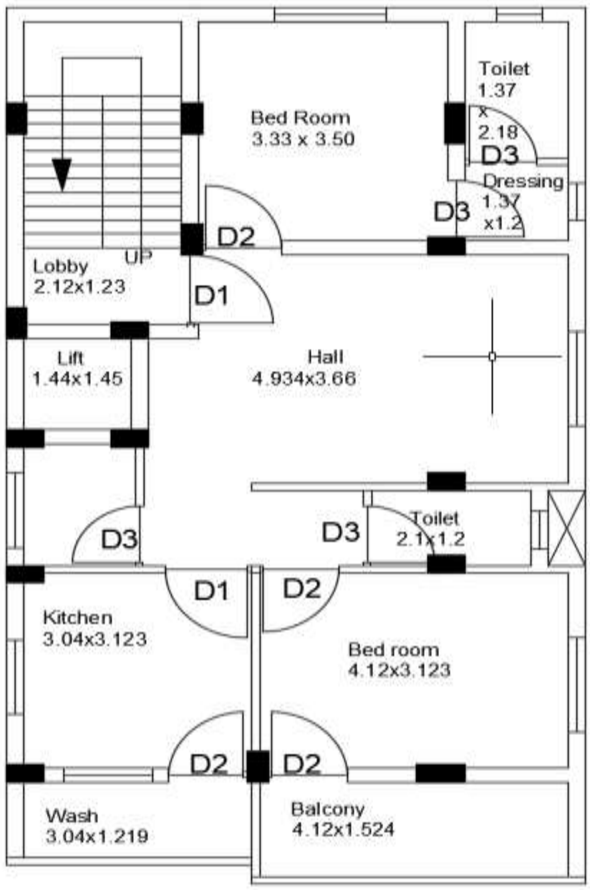


Fig1: Plan of Residential Building

2.3 DESIGN OF BUILDING COMPONENTS

Design of Slab

Step1.

L_x = 3.295m L_y = 6.064m

L_y/L_x = 1.840 < 2. hence it is two-way slab.

live load = 2 KN/M^2

modification factor = 1.4

basic value = 20

f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2

b(width) = 1000 mm

Step2. Estimations of slab thickness

As l_x>3.5, and steel is Fe415

L/d = 20 x M.F. =117.68 mm

say d = 175 mm

Assuming covers = 15mm

and 10mm ϕ main

D=d + cover + $\frac{\Phi}{2}$ = 195 mm

Step3. Effective span

l_{ex} = 3.47 m l_{ey} = 6.239 m

Step4. Loads calculation

Self-weight of slab = 1x0.195x25 = 4.875 KN/M

floor finish = 1 kN/M live load = 2 KN/M

total load(w) =7.875 KN/M

factor load (w_d) =1.5x7.875 = 11.8125 KN/m

Step5. Factors of bending moments

for X-direction

Mx = α_x x wd x l_{ex}^2

l_y/l_x = 1.8404

interpolation method

l_y/l_x α_x

1.75 0.113

1.84 x = α_x

2 0.118

x = 0.115

Mx = 16.328 KN-M …….1st equation

for Y-direction

My = α_y x wd x l_{ex}^2

l_y/l_x = 1.840

interpolation method

l_y/l_x α_y

1.75 0.037

1.84 y = α_y

2 0.029

y = 0.0341

My = 4.85 kN-M……2nd equation

Step6. Effective depth of slab

M_{xd} = Mu_{limit}

$d_{required}$ = 76.916 mm

$d_{required}$ < $d_{available}$, hence OK

Step7. Area and Spacing of Steel

At X-Direction

$$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$$

Ast_x = 267.009 mm

Ast_{min} =0.15% x b x D = 292.5 mm

Ast_x > Ast_{min}, hence provided Ast_x.

spacing of 8 mm ϕ bar

spacing = $\frac{ast\ x\ b}{Ast}$= 188.278 mm

say as spacing = 185 mm …….1st equation

S=3d = 540 mm ……...2nd equation

S=300 mm……...3rd equation

provide minimum value.

At Y-Direction

d' = d- ϕ = 165 mm

$$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$$

Ast_y = 82.356 mm

Ast_y < Ast_{min}, hence provided Ast_{min}

spacing of 8 ϕ mm

spacing = $\frac{ast\ x\ b}{Astmin}$ = 171.87 mm

say spacing = 170mm

S=3d' = 495 mm

S=300mm

provided minimum value

Step8. check for Shear

maximum shear force in either direction.

1. Vu= $\frac{wd \ x \ lex}{2}$ = 20.494 KN

2. τ_v= $\frac{Vu}{b \ x \ d}$ = 0.117 N/mm2

3. τ_{cmax}=2.8 N/mm2

$\tau_v < \tau_{cmax}$.

4. $Ast_p = \frac{ast \ x \ b}{sx}$ = 271.7405405 mm^2

5. $pt_p = \frac{Astp}{b \ x \ d} \ x100$ = 0.155%

interpolation method.

pt τ_c

0.15 0.28

0.155 x = τ_c

0.25 0.36

X = 0.284 N/mm^2

Design shear strength in slab

$\tau_c' = k \ x \ \tau_c$ = 0.3692

Thus, $\tau_v < \tau_c'$

Hence OK

Design of Beam

Span(le) = 1.392m

Effective Depth (d) = 410 mm

Depth (D) = 460 mm Width (b) = 230 mm

Flange thickness (Df) = 195 mm

Thickness of Support (t) = 230 mm

f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2

Equivalent udl

Step1. Total Service Load

(W_d) = 21.105 KN/M

Step2. Moment of Resistance

Md= $\frac{W \ x \ l^2}{2}$ = 20.447 KN-M

Step3. Limiting Moment of Resistance

Md1=0.138$f_{ck}bd^2$ = 106.709 KN/M

Step4. Comparison of Md and Md1

Md < Md1

Hence Singly Reinforced

Step5. Main Steel

$$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$$

Ast = 42.677 mm^2

Diameter 8 mm ϕ bar

Area of bars = 50.240 mm^2

Number of bars = 2.840

Bars Provided = 3 NOS

Ast Provided =150.720 mm^2

Step6. Design of Shear

a) Shear Force,

Vu=W x le = 29.378 KN

b) Nominal Shear Stress

τ_v= $\frac{Vu}{b \ x \ d}$= 0.312

c) τ_{cmax}=2.8 N/mm2 2.800

$\tau_v < \tau_{cmax}$, OK

d) Shear strength of concrete, τ_c

Pt= $\frac{Ast}{b \ x \ d} \ x100$ = 0.160%

0.150 0.280

0.250 0.360

τ_c = 0.288 N/mm^2

e) As $\tau_v > \tau_c$

Shear Reinforcement is Required.

f) Shear Force

Vus= vu-(τ_c.bd) = 2232.560 KN

Vusv=Vus

Provided 6 mm ϕ two legged M.S. Vertical Stirrups

g) Spacing

Sv = $\frac{0.87fy.Ast.d}{Vusv}$ = 2257.575 mm

Check,

01) Minimum Spacing

Sv ≤ $\frac{0.87fy.Ast}{0.4b}$ = 133.621 mm

02) Maximum Spacing

0.75d or 300 mm

Provided Spacing 300 mm

Step8. Check for Development length

$Ld_{required}$ = $\frac{0.87fy\Phi}{4\tau_{bd}}$ = 169.922 mm

$Ld_{available}$ = t+(8 ϕ -d') = 253 mm

Step9. Check for Serviceability

Pt required = 0.160

Modification factor = 1.380

Basic L/d (rb) = 7

Allowable L/d (ra) = 9.660

Required d=L/d (ra) = 144.09

Design of column

Step1. Axial Load = 2349.92 KN

Step2. Size of column

L = 3000 mm b = 230 mm

Step3. Percentage of steel (Asc)

Pt > 0.8%Pt < 6%

Assuming percentage (%) = 2.0

Asc = 2%Ag = 0.02

Ac=0.02Ag = 0.98

Step4. Depth Required

Pu=0.4fckAc+0.67fyAsc

Ag = 175354.08 mm2

D=Ag/b = 762.41 mm

Provided D =770.00 mm

Provided Ag = 177100.00 mm^2

Step5.Check for Eccentricity and Slenderness ratio

Le/D = 3.9 Le/D<12 OK

e_{min}= $\frac{L}{50}+\frac{D}{30}$ = 31.67 mm

e_{min} > 20 mm

e_{max} = 0.05D = 38.50 mm

e_{min} < e_{max} OK

Step6. Area of Steel and Percentage Steel

Asc required = 3542 mm^2

Bar used 25 mm ϕ

Area of bar = 490.63 mm^2

No. of bars Required = 7.22

No. of bars Provided = 8

Ast Provided = 3925 mm^2

Pt of steel provided = 2.22

Pt>0.8%Pt<6%OK

Step7. Design of transverse steel

a) Diameter of links

= $\frac{1}{4}$ x ϕ and 6 mm

Greater is 6.25 mm

Say 8 mm dia. of link

b) Spacing

i)least lateral dimension = 770 mm

ii)16ϕ = 400 mm

iii)300 mm

Provided Spacing = 300 mm

Reinforcement Details 8 No.-25mm at 300 mm c/c.

Design of Footing

Load on Column = 2400.70 KN

Column size, b =230 mm

D = 770 mm SBC = 200.00 KN/M^2

fck = 20 N/mm^2 fy = 415 N/mm^2

Step1. Design Constants

Xu_{max} = 369.60 mm

Mu_{limit}=0.138fckbd2 = 376.37 KN-M

UBC = 1.5 x SBC = 300 KN/M^2

Step2. Size of Footing

Factored Load = 3601.05 KN

Assuming 5% as Self weight

Area of footing, A = 12.60 m

Assuming Square footing

Length of one side is 3.55 m

Adopted Length of one side is 3.60 m

Step3. Upward Soil Pressure

Soil Pressure= $\frac{Wu}{L\ x\ B}$ = 277.86 KN/m^2

Step4.Depth of Footing (For shear)

ks=0.5+Ratio of long side to short side = 0.80

ks >1

$\tau_c = 0.25\sqrt{fck}$ = 1.12 N/mm^2

A) Case I: One-way action

m=B - $\frac{b}{2}$ = 1.42 m

n=B - $\frac{d}{2}$ = 1.69 m

i)Shear Force Vu=B(Projection-d) x Soil pressure

= 1000.29KN

ii)Shear Resisted by Concrete = 4024.92 KN

From Equating,

Required d = 281.66 mm

B) Case II: Two-way Action

Required depth = 330 mm

C)Bending Moment

mx=m x Soil Pressure x m/2 = 278.17 KN-M

my=n x Soil pressure x n/2 = 394.45 KN-M

Effective Depth Required = 317.47 mm

Maximum from A, B and C is 330 mm

Adopted depth of footing = 330 mm

Effective cover, dc = 80 mm

D = 410 mm

Step5. Main steel

$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$ = 2844.66 mm^2

Bar Adopted 10 mm ϕ bar

Area of bar = 78.50 mm^2

Spacing of bars = 27.60 mm

Provide Spacing = 240 mm

Step6. Development length,

Ld = 470.12 mm

Step7. Reinforcement details

12mmϕ- 140mm c/c.

Design of Staircase

Type of slab = Waist slab

Riser =150 mm Tread = 230 mm

Height =3 m

Width of landing between beams = 400 mm

fck =20 N/mm^2 fy = 415 N/mm2

Step1. Effective Span

Effective span

= Going + half of support + half of support

$=3.5+\frac{0.4}{2}+\frac{0.4}{2}$ = 3.9 m

Step2. Depth of waist of slab

Basic Value = 20

M.F. = 1.4

d = $\frac{Span}{20\ x\ MF}$ = 162.5 mm

Assume d = 180 mm

D = d + $\frac{\phi}{2}$ + clear cover

D = 205 mm

Step3. Load calculation

Dead Load

i. Load of waist slab = 25 x D x $\frac{\sqrt{R^2+T^2}}{T}$
= 6.12 KN/M

ii. Load of one Step = $\frac{\frac{1}{2} x\ R\ x\ T}{T}$
= 0.075 KN/M

Total dead load = 6.12 KN/M

Floor Finish = 1 KN/M

Live Load = 5 KN/M

Total load (W_d) = 12.195 x 1.5 = 18.29 KN/M

Step4. Bending Moment

BM = 0.125 x W_d x lex^2

= 34.8 KN/M

Step5. Check for Depth

M_u = 0.36fck.Xu_{max}.b.(d-0.42 Xu_{max})

D = 120 mm < 180 mm OK

Step6. Calculate Main Steel

$$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$$

Ast = 573.68 mm^2

Provide 10 mm ϕ bar

Area of bar = 78.54 mm^2

Spacing = $\frac{A\phi}{Ast}x1000$

= 136.90 mm, say 140 mm c/c

Provide 10mm ϕ bar @ 140 mm c/c

Step7. Area of distribution Steel

Astd = 0.15%of b.D

= 307.50 mm^2

Provide 8 mm ϕ bars

Area of bar = 50.26 mm^2

Spacing =$\frac{A\phi}{Astd}x1000$

= 163.45, say165 mm

Provide 8 mm ϕ bar @ 165 c/c

STADD PRO. OUTPUT

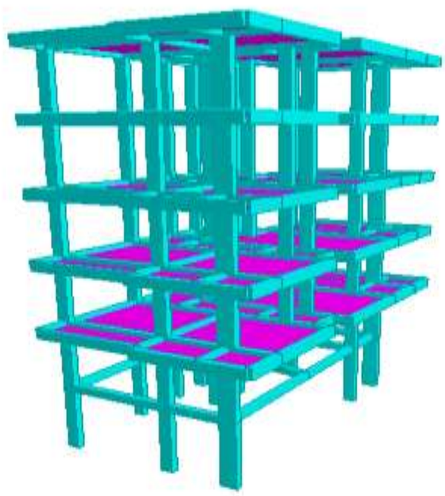


Fig2: 3D rendering model of building plan

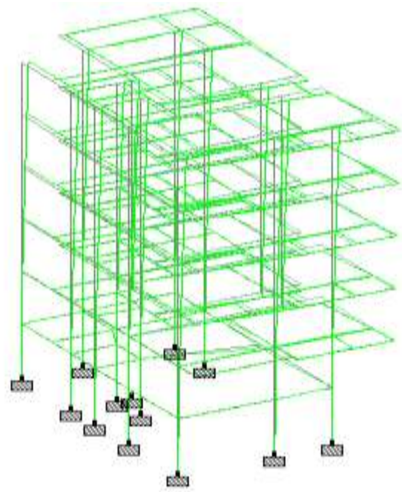


Fig3: Displacement on member

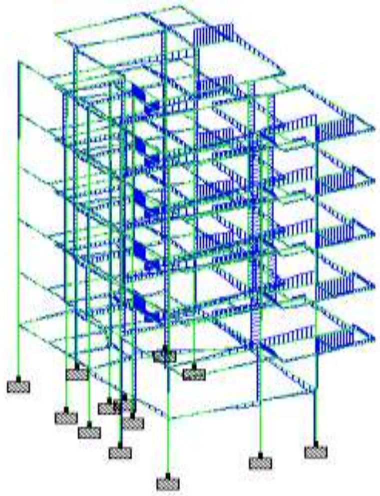


Fig4: Shear force on member

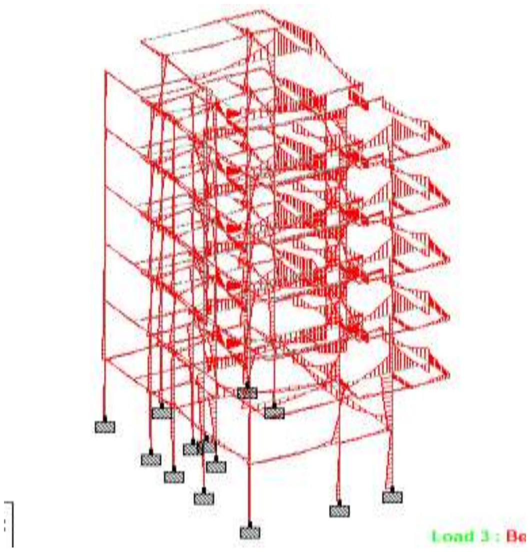


Fig5: Bending moment on member

RESULT AND CONCLUSION

From the work carried out in SADD Pro. can conclude that,

1. Comparison between manual calculation and STADD Pro. Software analysis and design, conclude that the analysis is same but design is some different.
2. Using STADD Pro., analysis and design of multi-storey building has completed much quickly and easier than the manual calculation.
3. Building plan was develop and draft in Auto- CAD with required dimension.
4. During designing G+4 storey residential building structure is capable to sustain all loads acting on building.
5. The design of slab, beam, column, rectangular footing and staircase is done with IS 456-2000 as limit state method.

REFERENCES

1. Shaikh Ibrahim, Md Arifuzzaman, Jisan Ali Mondal, Md Taukir Alam, Sanuwar Biswas, Sagar Biswas, Design and Analysis of Residential Building, International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 04 | Apr 2019.
2. Dunnala Lakshmi Anuja, V.S.Nagasai , Planning, Analysis and Design of Residential Building(G+5) By using STAAD Pro., International Journal of Engineering Development and Research(IJEDR), Volume 7, Issue 3 | ISSN: 2321-9939.
3. Mr. K. Prabin Kumar , R. Sanjaynath , A Study On Design Of Multi Storey Residential Building -A Review, International Journal of Pure and Applied Mathematics(IJPAM), Volume 119 No. 17 2018, 2797-2802 ISSN: 1314-3395.
4. Deevi Krishna Chaitanya, L. Santhosh Kumar, Analysis And Design Of A (G + 6) Multi Storey Residential Building Using STAAD Pro., Anveshana's International Journal Of Research In Engineering And Applied Sciences (AIJREAS), Volume 2, Issue 1 (2017, Jan), (Issn-2455-6300)
5. R. D. Deshpande, Manoj N. Pai, N. Pawan, Aashish P. Pednekar, Analysis, Design And Estimation Of Basement+g+2 Residential Building, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 | June -2017 .
6. Imam Usman Shekh, Udaysinh Redekar, Kartar Rathod, Sagar Sabale, Sachin Ghatule, Pranay Khare, N. L. Shelke, Analysis, Design and Estimation of G +7 Storey Building Structure by using IS Code Methods and by Software's, International Journal of Engineering and Management Research (IJEMR), Volume-7, Issue-2, March-April 2017, Page Number: 522-528.
7. Design of Reinforced concrete structure by S. Ramamrutham.
8. IS CODE 456-2000.
9. IS CODE 875-1987 (Part 1,2 and 3).
10. Design of R.C.C. Structures by Nirali Prakashan.