Planning, Analysis And Design of A Trapezoidal Shaped Concert Hall In Dibra Bazar, Barhara Kothi, Purnia, Bihar

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Abstract- *In this Journal a detailed analysis is done about the layout, analysis and design of concert hall. It also covers some basic information about concert hall. It also gives a detailed description of the layout of concert and acoustic in concert hall. The layout of the concert hall is prepared using AUTO CAD 2019. Then analysis of the structure is done using STAAD.pro and structural components of concert hall is designed respectively.A concert hall is a place where concerts of musical performance and cultural events take place. and acoustic in concert hall. Grid slab is used in the concert hall, this gives attractive soffit appearance. All the components have been designed specially to act together as system for maximum efficiency and peak performance.*

Keywords- Concert Hall,Auto Cad 2019, Staad.pro, Structural Components, Grid Slab,Maximum Efficiency, Peak Performance.

I. INTRODUCTION

A concert hall is a place where concerts of musical performance and cultural events takes place. The hall where the concerts are held may have a “stage” and there will be an “auditorium” where the audience sits. The structural and acoustical aspects of this type of hall have a great variation with other types of halls.

The concert hall should be designed in such a way that it has a good sound quality. The sound quality of the classical concert hall is largely affected by its shape, interior design and finishing materials. Well-designed concert hall provides a sufficient amount of reverberation at all frequencies. It is noted that architectural acoustics in general and auditorium acoustics have two main principles. The first is to provide a good acoustic environment inside the room, known as sound absorption. The second is in between rooms and surrounding, which is known as sound isolation.

In most halls, walls, floors, and ceiling have little absorption. The audience is the largest source of sound absorption and at higher frequencies the air itself provides a large amount of absorption.

The sound quality of a classical concert hall is largely affected by its shape, interior design and finish materials.Halls which are trapezoidal shaped blocks the flutter echoes and deliver an equational acoustic energy by controlling the reflection and diffusion of sound. Using wooden cladding, marble and granite as a finishing material the acoustics of the hall can be maintained.

AIM OF STUDY

The aim of the research is to design a concert hall and also analyzed using Staad.pro in trapezoidal shaped in my own village Dibra Bazar, Barhara Kothi, District Purnia, Bihar.

OBJECTIVES

The following objectives were formulated to achieve the target of the project.

- To preparea concert hall to accommodate 1000 people with Auto CAD 2019.
- To analysethe structure with STAAD.Pro V8i. The analysis will give the moment, shear force and axial force which helps in designing the beam and column.
- To designthe structural components of the concert hall.

NECESSITY

- Easy accessibility to concert hall from all over the city.
- Improves economic status of the surrounding area.
- Constructing aesthetically pleasing building that will attract audience.

SCOPE

- The planning of the concert hall was done using Auto CAD.
- The analysis of concert hall was done using STAAD.Pro V8i.
- The design of concert hall was done.

II. THEORETICALBACKGROUND

MAJOR DESIGN EXPERIENCE

Experience in designing the following structural members

- Slab
- Grid slab
- Beam
- Column
- Foundation

REALISTIC DESIGN CONSTRAINTS

- **Environmental**

The building will experience earthquake load, wind load and live load. So, the building must withstand these loads.

- **Constructability**

As it is a concert hall the number of columns should be less so that it does not obstruct the audience. Usage of grid slab reduces the number of columns.

- **Social**

By constructing a concert hall in that area, the social status of the area gets improved.

REFERENCE TO CODES AND STANDARS

There are some codes and standards were refereed for this project and they are listed in the Table 1.1.

Table 2.1 Reference to codes and standards

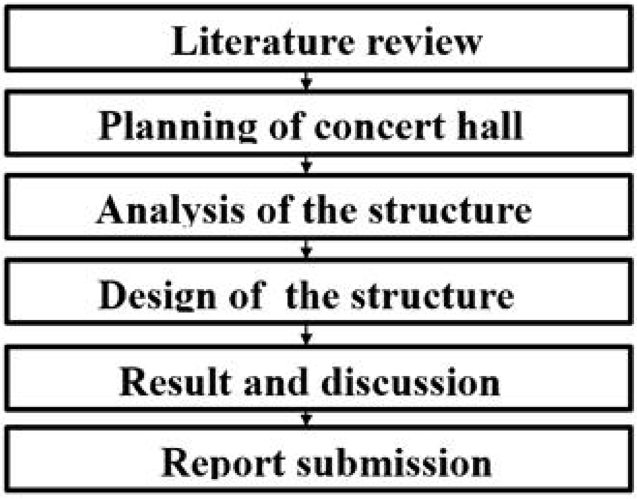
Codes and standards	**Context**
IS 456 :2000	For the design of RCC structural members
IS 800 :2007	Code of practice for general construction in steel.
IS 2526 - 1963	Code of practice for acoustical design of auditoriums and conference halls
IS 875 PART 1-(1987)	Code of practice for design loads for buildings and structures
IS 875 PART 2-(1987)	Code of practice for design loads for buildings and structures
IS 875 PART 3-(1987)	Code of practice for design loads for buildings and structures

SOFTWARE / EQUIPMENT USED

Software and equipment used in this project are listed as below:

- Auto CAD 2019 – Used for preparing the plan of the structure.
- STAAD.Pro V8i – Used for analyzing the structure.

III. METHODOLOGY



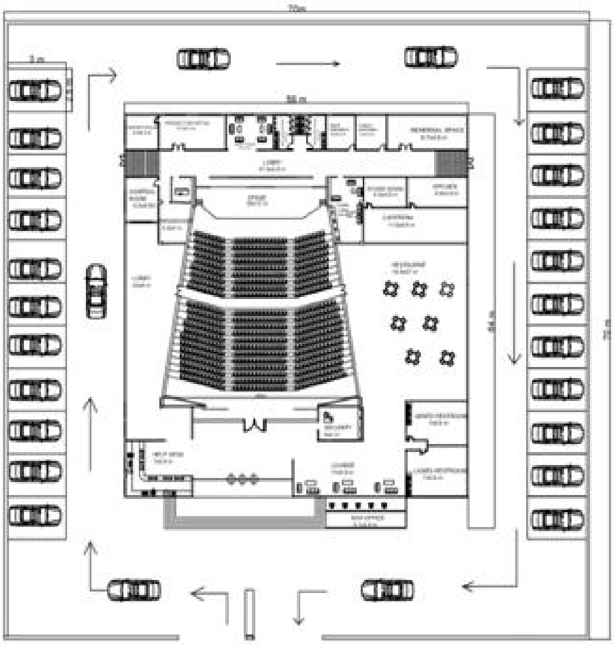
IV. RESULT AND DISSCUSSION

PLANNING

The layout of the concert hall is prepared using AUTOCAD 2019, as per the requirement.
Detail of the plan is given below

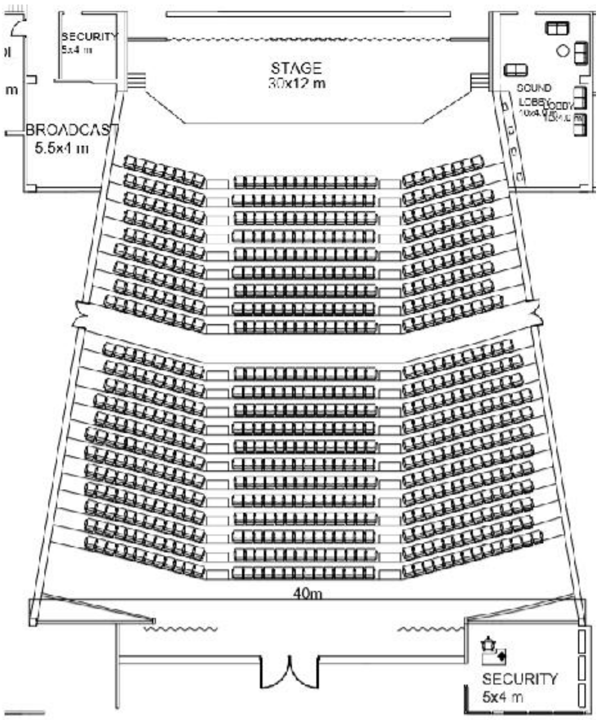
Table 3.1 Description of plan

S.NO	Description	Area
1	Total area	4900 m^2
2	Built up area	3712 m^2
3	Auditorium area	1546 m^2
4	Stage area	360 m^2
5	Seating capacity	1000
6	Lounge	100 m^2
7	Box office	44.6 m^2
8	Lobby	380 m^2
9	Help desk	41.3 m^2
10	Restaurant	445 m^2
11	Cafeteria	56 m^2
12	Store room	26 m^2
13	Broadcast	22 m^2
14	Control room	26 m^2
15	Server room	24 m^2
16	Production office	47 m^2
17	Guest lounge	26 m^2
18	Male dressing room	24 m^2
19	Female dressing room	24 m^2
20	Rehearsal room	47 m^2



All dimensions are in meter Scale 1:400

Figure 3.1 Layout of concert hall



All dimensions are in meter Scale 1:400

Figure 3.2 Plan of auditorium

ANALYSIS

The design of structural components values was taken from the result of STAAD.pro. A frame of length 60 m, breadth 58 m and height 6 m are created using structure wizard. The spacing between the column is given as 11.6 m.

The size of column is given as 0.7×0.65 m and size of the beam is given as 0.45×0.55 m. A live load of 4 kNm is given as per IS 875.The load combinations which is used in theSTAAD.pro analysis is 1.5(Dead load +Live load). Then run analysis and go to post modelling. The critical load for the beam and column is obtained.

Input data

- Length of building = 60 m
- Breadth of building = 58 m
- Height of building = 6 m
- Applied live load = 4 kNm

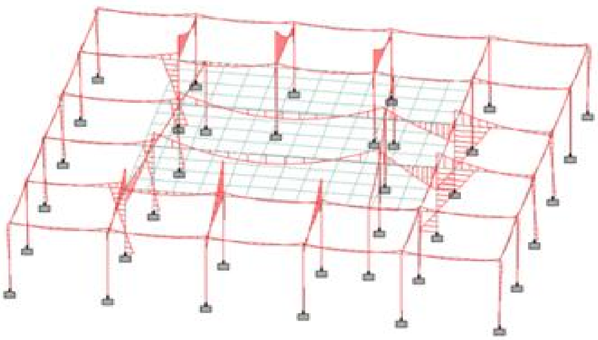


Figure 3.3 Bending moment in Z-axis

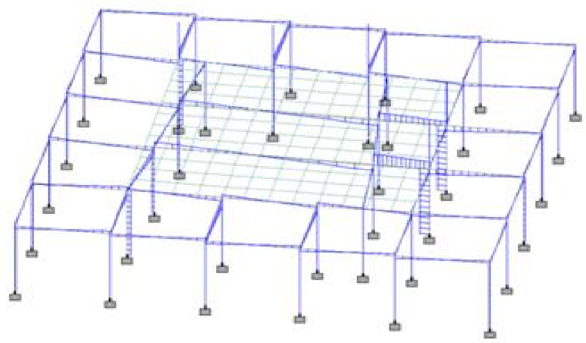


Figure 3.4 Shear force in Y-axis

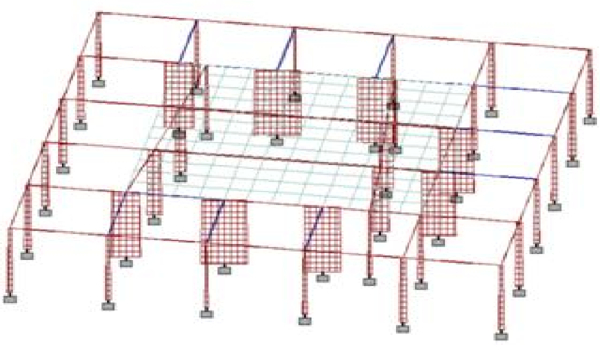


Figure 3.5 Axial force

Table 3.3 Abstract of the result for beam (SF)

Direction of Shear force	Maximum positive SF (kN)	Maximum negative SF (kN)	Load condition
F_y	678.78	200.78	1.5(D. L+L.L)
F_z	176.27	217.28	1.5(D. L+L.L)

Table 3.4 Abstract of the result for column (BM)

Direction of bending moment	Maximum positive BM (kNm)	Maximum negative BM (kNm)	Load condition
M_z	1688	798.84	1.5(D. L+L.L)
M_y	3656.43	3568.88	1.5(D. L+L.L)

Table 3.5 Abstract of the result for column (SF)

Direction of Shear force	Maximum positive SF (kN)	Maximum negative SF (kN)	Load condition
F_y	107.43	247.24	1.5(D. L+L.L)
F_z	545.32	529.73	1.5(D. L+L.L)

DESIGN

DESIGN OF GRID SLAB

Step 1: Data

Size of grid = 10.8 m by 11 m

Spacing of ribs = 2 m

f_{ck} = 25 N/mm²

f_{y} = 415 N/mm²

Live load = 4 kN/m

Step 2: Dimensions

Adopt thickness of slab as 100 m

Depth of rib = $\frac{Span}{20} = \frac{10800}{20}$ = 540 mm

Width of rib = 200 mm

Adopt overall depth of rib as 600 mm

Step 3: Calculation of loads

Weight of slab = 0.1×25 =2.5 kN/m²

Total load of slab=2.5×10.8 ×11=297 kN

Weight of rib=0.2×0.5×25=2.5 kN/m

Total weight of beams (x-direction) = 7×2.5×10.8 = 189 kN

Total weight of beams (y-direction) = 5×2.5×11 = 138 kN

Total live load = 4 ×10.8 ×11 = 475 kNm

Total dead and live load = (297+189+138+475) = 1099 kN

Load per m² = $\frac{1099}{10.8\times 11}$ = 9 kN/m²

Step 4: Calculation of moments

If q_1 and q_2 are the loads shared in x and y direction

$q_1 = q(\frac{b_y^4}{a_x^4 + b_y^4}) = 9(\frac{11^4}{10.8^4+11^4})$ = 4.6 kN/m²

$q_2 = q(\frac{a_x^4}{a_x^4 + b_y^4}) = 9(\frac{10.8^4}{10.8^4+11^4})$ = 3.5 kN/m²

$M_x = \frac{q_1 b_1 a^2}{8} = \frac{4.6\times 2\times 10.8^2}{8}$ = 134 kNm

$M_y = \frac{q_2 a_1 b^2}{8} = \frac{3.5\times 2\times 11^2}{8}$ = 105 kNm

$Q_x = \frac{4.6\times 2\times 10.8}{2}$ = 50 kN

$Q_y = \frac{3.5\times 2\times 11}{2}$ = 38 kN

Step 5: Design of reinforcement

Maximum working moment M_w=134 kNm

Moment resisted in rib x-direction over 2 m= 268 kNm

$M_{uf} = 0.36 f_{ck} b_f D_f (d-0.42D_f)$

$= 0.36 \times 25 \times 2000 \times 100(500-0.42 \times 100)$

= 914 kNm

$M_u < M_{uf}$

$M_{ux} = 0.87 f_y A_{st} d\ [1- \frac{A_{st} f_y}{b d f_{ck}}]$

$402\times 10^6 = 0.87\times 415\times A_{st}\times 50[1- \frac{A_{st}\times 415}{2000\times 500\times 25}]$

$A_{st,x}$ = 2400 mm²

Provide 2 bars of 32 mm dia and 2 bars of 25 mm dia

$A_{st\ provided}$=2588 mm²

$M_{uy}=0.87 f_y A_{st} d\ [1- \frac{A_{st} f_y}{b d f_{ck}}]$

$300\times 10^6=0.87\times 415\times A_{st}\times 50[1- \frac{A_{st}\times 415}{2000\times 500\times 25}]$

$A_{st,y}$ =1800 mm²

Provide 4 bars of 25 mm dia

$A_{st\ provided}$=1962 mm²

Mesh reinforcement consisting of 10 mm dia bars @ 200 mm c/c are provide in the slab

Step 6: Check for shear

$\tau_v = \frac{V_u}{bd} = \frac{32.4}{1000\times 410}$

=0.32 N/mm²

$k\tau_c$=1.27×0.3

=0.38

$k\tau_c > \tau_v$

$S_v = \frac{A_{sv} f_y}{0.4b} = \frac{2\times 28\times 415}{0.4\times 200}$ =290 mm

Provide 6mm dia stirrups @ 250 mm c/c @ supports and gradually increase to 400mm towards the centre.

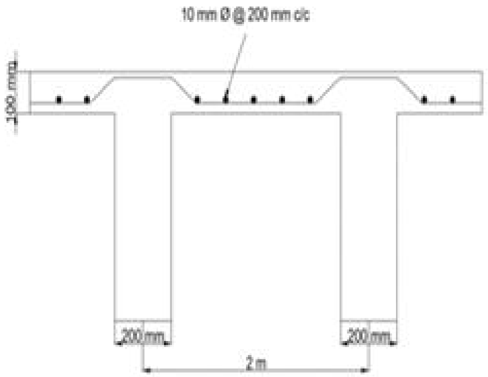


Figure 4. 6 Grid slab reinforcement

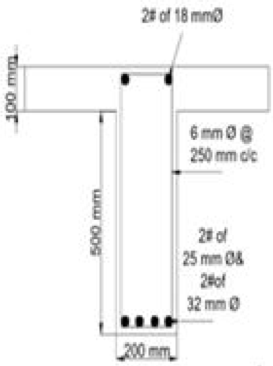


Figure 4.7 Ribs in x-direction

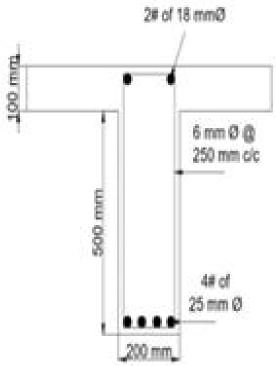


Figure 4.8 Ribs in y-direction

DESIGN OF SLAB

Step 1: Data

Length along y-direction(l_y) = 11 m

Length along x-direction(l_x) = 10.8 m

Live load=4 kN/m

f_{ck}=25 N/mm^2

f_y=415 N/mm^2

Step 2: Calculation of depth of slab

$\frac{l_y}{l_x} = \frac{11}{10.8} = 1.02 < 2$

Hence it is a two-way slab

$d = \frac{span}{25} = \frac{10800}{25} = 400$ mm

Assume cover of 20 mm

D = 420 mm

$L_{eff} = l_x + 400$

= 10.8 + .4 = 11.2 m

Step 3: Load calculation

Self weight of slab = 0.42×25=10 kN/m

Live load = 4 kN/m

Total load = 14 kN/m

Ultimate load = 1.5×14

= 21 kN/m

Step 4: Calculation of moment

$\alpha_x = 0.064$

$\alpha_x = 0.064$

$M_x = \alpha_x w l_x^2 = 0.064\times21\times11^2 = 185.8$ kNm

$M_y = \alpha_y w l_y^2 = 0.061\times21\times10.8^2 = 170.7$ kNm

Step 5: check for depth

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

$185.8\times10^6 = 0.138\times25\times1000\times d^2$

d = 232 mm < 400 mm

Step 6: Design of reinforcement

$\frac{L}{d} = 27 < 32$

Hence safe in deflection.

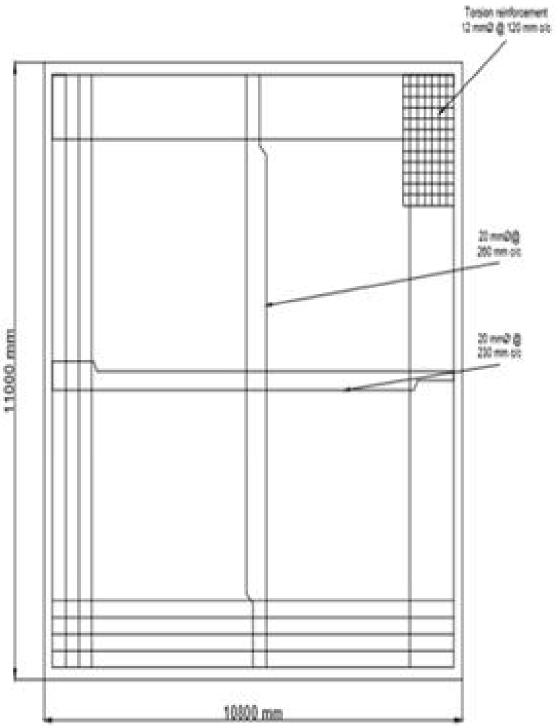


Figure 4.9 Slab reinforcement

DESIGN OF BEAM

Step 1: Data

b = 0.45 m

Overall depth of beam = 0.55 m

Provide a cover of 30mm

Effective depth = 550-30 = 520 mm

Effective span = 11.5 m

f_{ck} = 25 N/mm²

f_y = 415 N/mm²

M_u = 768 kNm

V_u = 312 kN

Step 2: Limiting moment of resistance

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

$= 0.138 \times 25 \times 450 \times 550^2$

$= 469$ kNm

$M_u > M_{u\,lim}$ hence design as a doubly reinforced section

Step 3: Design of compression reinforcement

$M_u - M_{u\,lim} = f_{sc} A_{sc} (d-d')$

$f_{sc} = \frac{0.0035(x_{umax}-d')\,Es}{x_{umax}}$

$= 537 \frac{N}{mm^2}$

$f_{sc} \ngtr 0.87 f_y = 361$ N/mm²

Adopt f_{sc} as 361 N/mm²

$A_{sc} = \frac{Mu - Mu\,lim}{fsc\,[d-d']}$

$= 1656$ mm²

Provide 25 mm diameter bars

No of bars $= \frac{A_{sc}}{\pi/4 \times 25^2}$

$= 3.4 \approx 4$

A_{sc} provided $= \frac{\pi}{4} \times 25^2 \times 4$

$= 1962.5$ mm²

Step 4: Design of tension reinforcement

$A_{st2} = \frac{f_{sc} A_{sc}}{0.87 f_y}$

$= 1656$ mm²

$A_{st1} = \frac{0.36 fck b d x_u}{0.87 f_y d}$

$= 2961$ mm²

$A_{st} = A_{st1} + A_{st2}$

$= 4617$ mm²

Provide 32 mm diameter bar

No of bars $= \frac{A_{st}}{\text{area of one bar}}$

$= 6$

A_{st} provided $= \frac{\pi}{4} \times 32^2 \times 6$

$= 4825\ mm^2$

Step 6: Design of shear reinforcement

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

$= 1.2\ N/mm^2$

$P_t = \frac{100A_{st}}{bd}$

$= 1.94$

$\tau_c = 0.81\ N/mm^2$

$\tau_v > \tau_c$

Hence provide nominal shear reinforcement

$S_v = V_u - V_c$

$= V_u - (\tau_c \times bd)$

$= 112\ KN$

$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$

$= 270\ mm$

$S_v \ngtr 0.75d = 410\ mm$

Adopt spacing as 300 mm

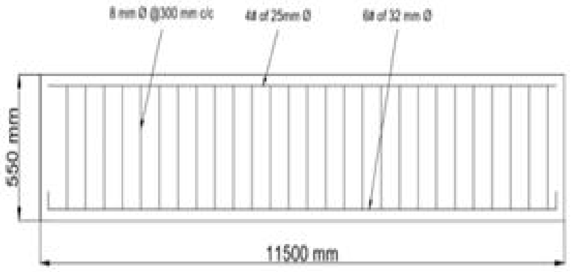


Figure 4.10 Beam reinforcement

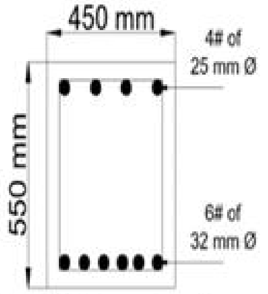


Figure 4.11 Cross section of beam

DESIGN OF COLUMN

STEP 1: Data

Factored Load = 2400 kN

Dimension = 700×650 mm

Provide a cover of 40 mm

$F_{ck} = 25\ N/mm^2$

$F_y = 415\ N/mm^2$

STEP 2: Slenderness ratio

$S = \frac{L}{Dx}$

$= \frac{6000}{700}$

$= 8.6 < 12$

$S = \frac{L}{Dy}$

$= \frac{6000}{650} = 9.2 < 12$

Hence, design a short column

STEP 3: Minimum eccentricity

$E_{x\,min} = (\frac{6000}{500}) + (\frac{700}{30})$

$= 34.3\ mm$

$E_{y\,min} = (\frac{6000}{500}) + (\frac{650}{30})$

$= 32\ mm$

Min eccentricity should not exceed

$0.05D_x = 0.05 \times 700 = 35 > E_{x\,min}$

$0.05D_y = 0.05 \times 650 = 32.5 > E_{y\,min}$

STEP 4: Design of longitudinal reinforcement

$p_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$A_c = A_g - A_{sc}$

$2400 \times 10^3 = 0.4 \times 25(650 \times 700 - A_{sc}) + 0.67 \times 415 \times A_{sc}$

$= 455000 - 10A_{sc} + 278A_{sc}$

$1945000 = 268A_{sc}$

$A_{sc} = 7257\ mm^2$

Provide 6 Nos of 32 mm diameter bars

Area of bars = $6\times\frac{\pi}{4}\times32^2$

$= 6430\ mm^2$

Provide 4 Nos of 18 mm diameter bars

Area of bars=$4\times\frac{\pi}{4}\times(18)^2$

$=1101\ mm^2$

A_{sc} provided=7531 mm^2

STEP 5: Minimum reinforcement

$\frac{0.8}{100}\times700\times650 = 3640\ mm^2$

Hence ok.

STEP 6: Design of lateral tie

Tie bars = $\frac{1}{4}$ of 32

$= 8\ mm < 16\ mm$

Provide 8 mm diameter bars

STEP 7: Spacing of lateral tie

=16 times of longitudinal reinforcement

$=16\times20$

=320mm which is greater than 300 mm

So, provide 8 mm dia bars @ 300 mm spacing

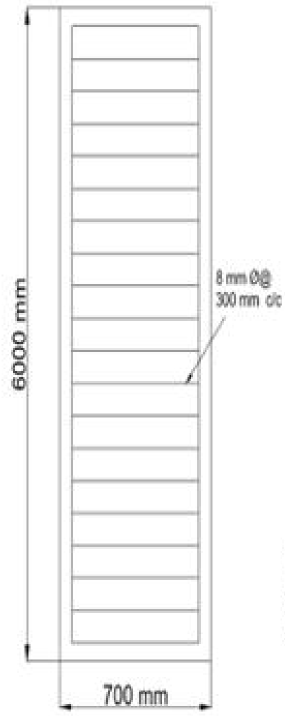


Figure 4.12 Column reinforcement

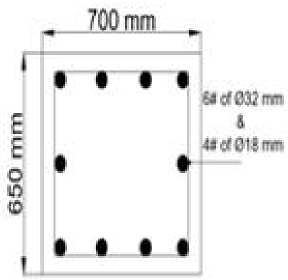


Figure 4.13 Cross section of column

DESIGN OF FOOTING

Step 1: Data

Size of column = 700x650 mm

Load on column = 2400 KN

f_{ck} = 25 N/mm^2

f_y = 415 N/mm^2

Soil bearing capacity [SBC] = 300 kN/mm^2

Step 2: Size of footing

Area of footing = $\frac{\text{Load on column}}{\text{SBC}}$

$= \frac{2400}{300}$

$= 8\ m^2$

$3x\times4x = 8$

$x = 0.66$

Provide length and width of footing as 2.5 m and 3.2 m

p_{max} = 238 kN/m^2 < 300kN/m^2

Factored upward pressure of soil

$P_{u\,max}$ = 357 kN/m^2

$P_{u\,min}$ = 210 kN/m^2

Factored load p_u = 3200 kN

Step 2: Two-way shear

Adopt thickness of footing=500 mm

Assuming 16 mm dia bars

Effective depth d = 500-50-8

= 452 mm

Punching area of footing = (a + d) × (b + d)

= (0.65+0.442) × (0.5+.442)

= 1.03 m^2

Punching shear force = 3200-(283×1.03)

= 2908 KN

Perimeter along critical section = 2(a + d) ×2(b + d)

= 4068 mm

Punching shear stress = $\frac{2908\times1000}{4068\times442}$

= 1.6 N/mm^2

Allowable shear stress = $k_s\tau_c$

$k_s = \frac{0.5+0.65}{0.05}$

= 1.8

$k_s\ \tau_c$ =2.25

Step 3: Design of flexure

M_u = 180 kN/m^2

$\frac{M_u}{bd^2}$ = 0.92

From SP16, percentage of reinforcement can be found for M25 concrete

Pt = 0.265%

A_{st} = pt×b×d

A_{st} = 2120 mm^2

Provide 16 mm dia bars at 150 mm c/c

No of bars = $\frac{A_{st}}{16^2\times\pi/4}$

= 12

Step 4: Check for development length

L_d = 47×dia of bars

= 752 mm

Provide 60 mm side cover

Total length available for critical section =0.5×(L-a)-60

=840>L_d

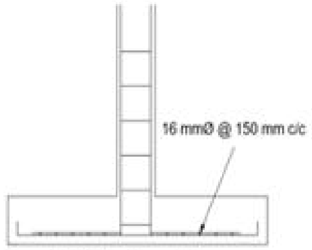


Figure 4.14 Footing reinforcement

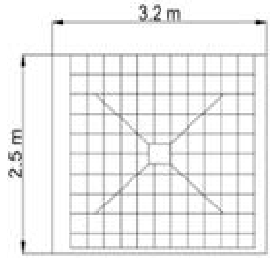


Figure 4.15 Footing reinforcement

V. CONCLUSIONS

In this project the methodology, layout, analysis and design of the concert hall was presented.The layout oof the concert hall is prepared using AUTO CAD 2019. The important components of the concert hall are analyzed using STAAD.pro V8i. The uniqueness of the project was the use of grid slab and trapezoidal shaped hall. Halls with trapezoidal shaped plan make it possible to accommodate a large audience while providing good visibility and acoustics. The use of grid slab eliminates placement of column inside the hall. The use of grid slab reduces the number of columns. The usage of grid slab gives attractive soffit appearance. The completion of concert hall will ensure safety of the building. Thus, the objective is achieved and the building is designed.

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