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Planning, Analysis and Design of Auditorium with One Way, Two Way and Grid Slabs

Dr. Sreelatha Vuggumudi

Associate Professor, NBKR Institute of Science & Technology, Vidyanagar, Andhra Pradesh, India 524413

***Abstract* - An auditorium offers immense potential to increase connections with community to a large extent. From the literature, it is observed that most of the auditoriums were designed for only two-way slab and by considering different types of footing. Analysis and designs were not available for auditoriums with different types of slabs. Comparative studies are also not available for the same and that necessitated this project. The main objective is to plan, analyse and design an auditorium with one-way, two-way and grid slab. The project involves the planning, analysis, and design of an auditorium with a seating capacity of 500 people as per the of (IS 2526-1963 [5]). The plans of an auditorium were developed using AutoCAD software. Analysis and design of an auditorium were carried out using STAAD Pro software. An auditorium with two-way slab is found to be economical compared to an auditorium with one way slab and grid slab based on the volume of concrete required. The critical elements of auditorium such as slabs, beams, columns and footings were manually designed for the forces and moments obtained from the analysis. From this project, it is concluded that the grid slab offers lesser thickness. However, by considering design an auditorium with two way slab was found to be more economical.**

Keywords: Auditorium, One way slab, Two-way slab, Grid slab, Analysis, Design.

I. INTRODUCTION

An auditorium is a room built to enable an audience to hear and watch performances at venues such as theatres. Auditorium can be found in entertainment venues, community halls, and theatres, and may be used for rehearsal, presentation, performing arts productions, or as a learning space. For movie theatres, the number of auditoriums is expressed as the number of screens.

Sullivan and Adler designed a tall structure in Chicago with load-bearing outer walls and the exterior appearance partly based on the design of H. H. Richardson's Marshall Fields Warehouse. In the center of the building an auditorium was designed with a seating capacity of 4300. The soil beneath the auditorium consists of soft blue clay to a depth of over 100 feet, which made conventional foundations impossible. Hence, the foundation was designed as a floating mat with crisscrossed railroad ties, topped with a double layer of steel rails embedded in concrete. Harish and Ramaprasad Reddy [2] designed a prayer hall as an auditorium using AutoCAD and STAAD-PRO softwares considering seismic load as the major load apart from the other loads. The research shows that long span structures are considerably cost effective than plane structures.

Dileep Kumar et.al [1] and Ramesh Bhaskar et.al [8] planned and designed an auditorium using IS 2526 – 1963 [5] and IS 456 – 2000 [3] specifications respectively. Due to low bearing capacity of the soil, considering the economy aspect they have adopted for grillage foundation. Vineeth Reddy et.al [9] analyzed and designed an auditorium manually using substitute frame method and moment distribution method. The slabs were designed as two-way rectangular slab and the columns for both uniaxial and biaxial loading. Isolated footing and dog-legged staircase were adopted in the design of auditorium. The results were verified by using STAAD-PRO and the design results were similar compared to the manual design.

The critical review of literature indicated that most of the auditoriums were designed are single storey and only with two-way slabs. Analysis and the design were not available for auditorium with one way and grid slabs. The main objective of this research is to plan, analyse and design an auditorium with one way slab, two way slab and grid slab to obtain the economical design.

II. PLANNING AND ANALYSIS OF AN AUDITORIUM

Specifications for planning of auditorium was taken from IS 2526-1963 and are tabulated in Table 1. An auditorium is planned for a seating capacity of 500 people.

Considering the area occupied by each person as 0.84 m^2, total area for seating is calculated as 420 m^2. A side passage of 3 m is allowed around the auditorium.

The plan and elevation of the proposed auditorium is drafted using AutoCAD software and is shown in Figs. 1 and 2 respectively.

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2.1 Loads

Dead loads such as floor load, load due to wall are considered from IS:875 (part-1) – 1987 as 5 kN/m^2 and 12 kN/m respectively. Live load acting on the roof is considered from IS:875 (part-2) – 1987 as 2 kN/m^2.

Table 1: Specifications of an Auditorium

Particulars	Specifications
Height of the roof	6 m to 7.5 m
Farthest seat from the curtain line	23 m
Rise of each step for effective sight and listening	8 cm to 12 cm
Width of each seat	0.45 m to 0.56 m
Back-to-back distance of a seat	0.85 m to 1.06 m
Floor area excluding stage	0.6 m2 to 0.9 m2 per person
Foyer area	Not less than 20% of seating area
Lobby area and Lounge	Not less than 10% of seating area
Front row distance from stage	3.6 m to 4.5 m

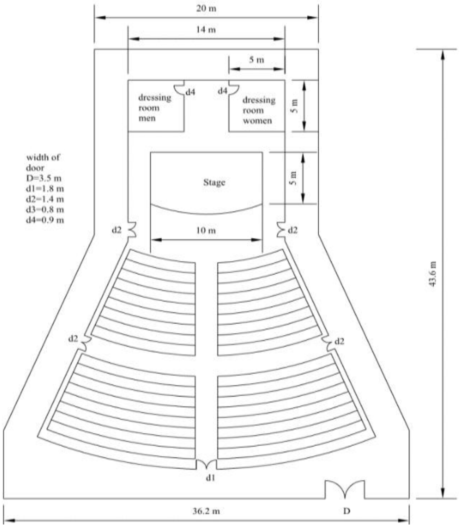

Figure 1: Plan of the proposed Auditorium

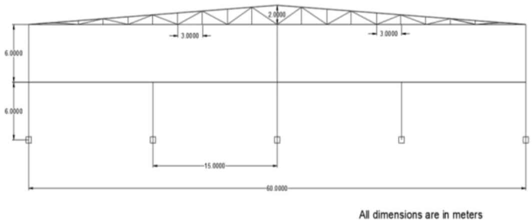

Figure 2: Elevation of the proposed industrial warehouse

2.2 Analysis

The analysis of slab was done by using STAAD RC-DC software and the analysis of beams and columns were done by using STAAD-Pro software by adopting a special reinforced concrete moment resisting frames.

2.2.1 Analysis of an auditorium with one-way slab

The slab was designed in such a way that the loads acting on it will have a one-way distribution in every plate. The maximum thickness of slab obtained by the STAAD RC-DC software is 400 mm. Fig. 3 shows a 3D model of an Auditorium with one-way slab.

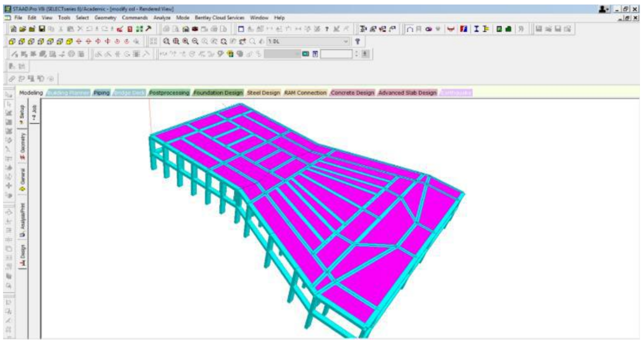

Figure 3: 3D model of an auditorium with one-way slab

From STAAD RC-DC software the total volume of concrete required for one way slab is calculated as 453.2 m3. From STAAD-Pro software the total volume of concrete required for other structural elements is obtained as 357.9 m3. Therefore, the total volume of concrete required for an auditorium with one way slab is 811.1 m3.

2.2.2 Analysis of an auditorium with two-way slab

The slab was designed in such a way that the loads acting on it will have a two-way distribution in every plate. The maximum thickness obtained for two-way slab is 230 mm. Fig. 4 shows a 3D model of an auditorium with two-way slab.

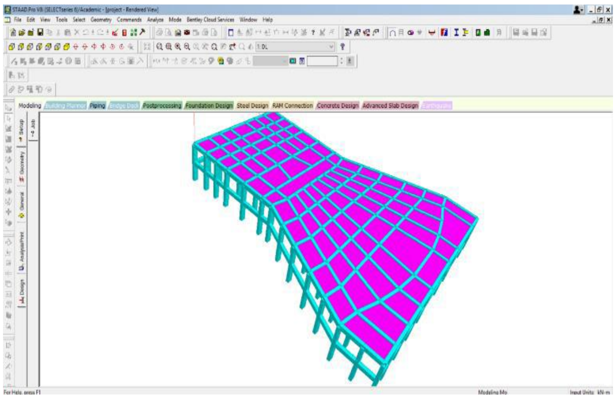

Figure 4: 3D model of an auditorium with two-way slab

The total volume of concrete required for two-way slab is calculated as 260.59 m^3. The total volume of concrete required for structural elements other than slab is obtained as 407.04 m^3. Therefore, the total volume of concrete required for an auditorium with two-way slab is 667.63 m^3.

2.2.3 Analysis of an auditorium with grid slab

The slab was designed with grids of equal sizes 4 m×3 m. The maximum thickness obtained for grid slab is 110 mm. Fig. 5 shows a 3D model of an auditorium with grid slab.

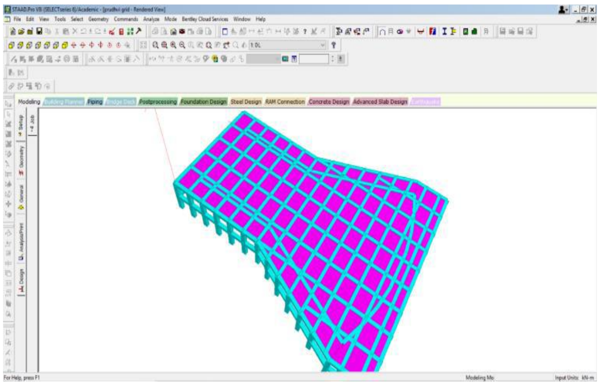

Figure 5: 3D model of an auditorium with grid slab

From STAAD RC-DC software the total volume of concrete required for grid slab is calculated as 124.63 m^3. From STAAD-Pro software the total volume of concrete required for other structural elements is obtained as 607 m^3. Therefore, the total volume of concrete required for an auditorium with grid slab is 731.63 m^3.

The total volume of concrete required for an auditorium with one-way slab, two-way slab and grid slabs were compared and the auditorium with two-way slab was found to be the most economical design.

The location of critical beam, critical column and graphs showing the moments and shear forces on critical beam and column are shown in Figs. 6 and 7 respectively.

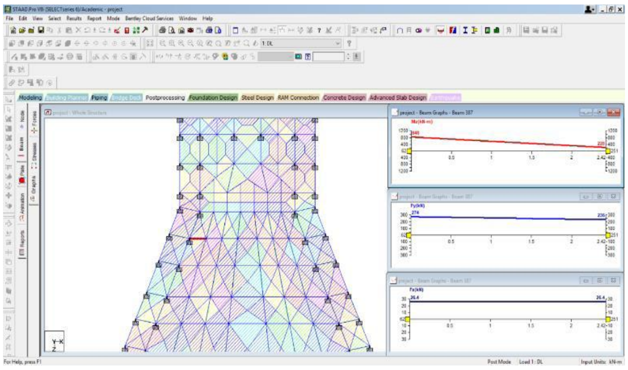

Figure 6: Location, shear force and bending moment diagrams of critical beam

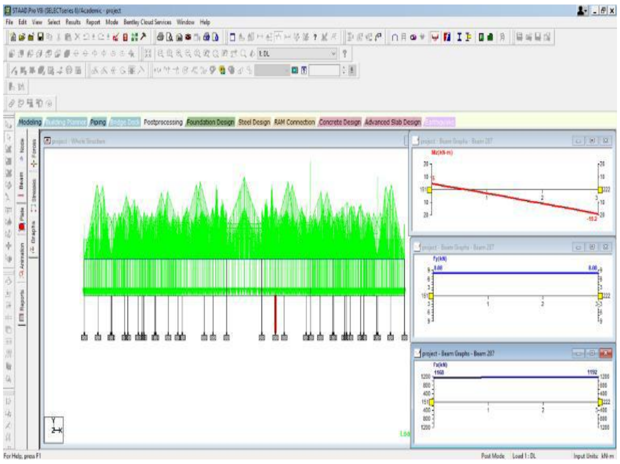

Figure 7: Location, shear force and bending moment diagrams of critical column

III. DESIGN OF AN AUDITORIUM

The critical elements (which carries maximum shear force and bending moment) such as slab, beam, column and footing were obtained from analysis. The elements were designed manually using limit state method with M25 grade concrete and Fe415 steel.

3.1 Design of Slab

The thickness of critical slab element is 230 mm. The detailed design of slab is given below.

Clear cover = 20 mm

Long span, L_Y = 7.62 m

Short span, L_x =5.92 m

Imposed load = 3 kN/m^2

Live load = 2 kN/m^2

Slab thickness = 230 mm

Effective depth along L_X, dx = 205 mm

Effective depth along L_Y, dy = 195 mm

Self-weight = 5.75 kN/m^2

Total load, TL = 10.75 kN/m^2

Boundary condition = One edge discontinuous and three edges continuous.

Design Moments:

Short span positive moment at mid span -

Moment coefficient, α_x = 0.080

Bending moment, BM = 30.14 kN-m

Mu = 1.5 x BM = 45.21 kN-m

Area of reinforcement required = 644.632 mm^2 /m

Reinforcement provided = T10 @ 120 c/c

= 654.000 mm2 /m

Long span positive moment at mid span -

Moment coefficient, α_y = 0.056

BM = 21.098 kN-m

Mu = 1.5 BM = 31.647 kN-m

Area of reinforcement required = 468.259 mm^2/m

Reinforcement provided = T8 @ 105 c/c

= 479.000 mm^2/m

Distribution reinforcement @ 0.12% of gross c/s area

Area of reinforcement required = 246.000 mm^2/m

Reinforcement provided = T8 @ 200 C/C

= 251.000 mm^2/m

Shear Check:

Along short span

Shear coefficient, SF1= 0.407

V = SF1 x TL x Lx = 25.929 kN

Vu = 1.5 x V = 38.894 kN

Shear stress, τ_v = 0.190 N/ mm^2

Nominal Shear Stress, τ_c = 0.403 N/ mm^2

Modification Factor 'K' = 1.140

K x τ_c = 0.459 N/ mm^2

> 0.190 N/ mm^2

Hence, the slab is safe in shear.

Along long span

Shear coefficient, SF2 = 0.330

V = SF2 x TL x LY = 21.001 kN

Vu = 1.5 x V = 31.502 kN

Shear stress, τ^v = 0.162 N/ mm^2

Nominal shear stress, τ^c = 0.351 N/ mm^2

Modification Factor 'K' = 1.140

K x τ_c= 0.4 N/ mm^2 > 0.162 N/ mm^2

Hence, the slab is safe in shear.

Deflection Check:

$$\left(\frac{l}{d}\right)_{req} = \left(\frac{l}{d}\right)_{basic} \times k_t \times k_c \times k_f$$

Basic span to depth ratio=20

Span correction factor=1.000

Tensile steel factor, k_t=1.474

Compression steel factor, k_c=1.000

Flange correction factor,k_f=1.000

Max span to depth ratio=20.00 x 1.00 x 1.47 x 1.00 x 1.00

=29.478

L_x/d=28.878<29.478

Hence, the slab is safe in deflection.

The reinforcement details of slab element are shown in Fig. 8.

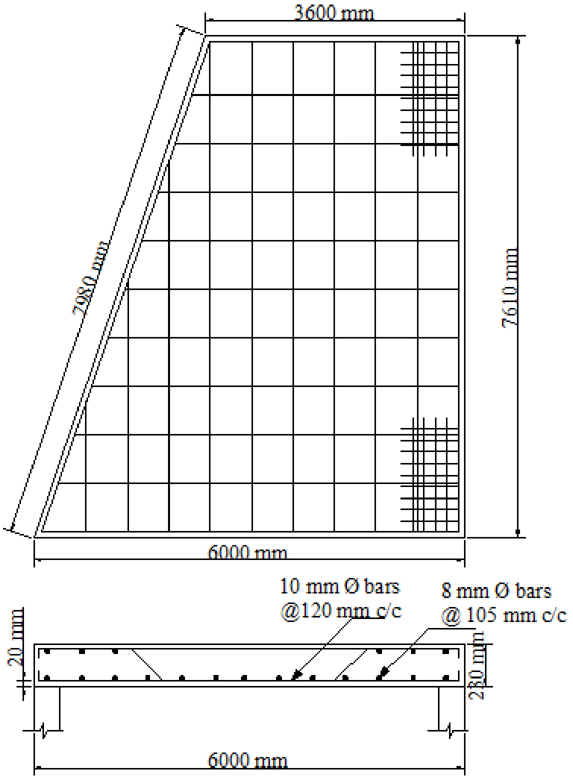

Figure 8: Plan and Sectional reinforcement of critical slab element

3.2 Design of Beam:

Span of the beam (l_o) = 2.42m.

Maximum ultimate moment (M_{umax}) = 845.669kN-m

$b_f = \frac{0.7\, l_0}{6} + b_w + 6 \times D_f$(for continuous beam l_0 is taken as 0.7 l_0)

Where,

b_f = effective width of flange

b_w=breadth of web = 0.45 m

D_f = Thickness of flange = 0.23 m

$b_f = \frac{0.7 \times 2.42}{6} + 0.45 + 6 \times 0.23$

=2.112 m

M_{umax} = 845.669 kN-m

Moment of resistance

$M_r = 0.36 \times f_{ck} \times b_f \times D_f\ (d - 0.42 D_f)$

= 0.36×25×2112×230 (575-0.42×230) = 2091.488 kN-m

$M_{umax} < M_r$

Hence it is safe.

Main Reinforcement:

$$A_{st} = 0.5 \times \frac{f_{ck}}{f_y}\left(1 - \sqrt{1 - \frac{4.6 M_{umax}}{f_{ck}\, b d^2}}\right) b_f \times D_f$$

$$A_{st} = 0.5 \times \frac{25}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 845.669 \times 10^6}{25 \times 450 \times 750^2}}\right] \times 2112 \times 230$$

= 5549.62 mm^2

Minimum Reinforcement $A_{stmin} = \frac{0.85 \times b \times d}{fy}$

$= \frac{0.85\times450\times575}{415} = 529.969\ \text{mm}^2$

Hence, Provide 7 bars of 32mm dia. as main reinforcement.

Design of Shear Reinforcement:

From the analysis, $V_u = 274.049$ kN

$\tau_v = \frac{V_{umax}}{b\times d} = 1.015\ \text{N/mm}^2$

$P_t = 2.49\%$

$\tau_c = 0.88\ \text{N/mm}^2$

Therefore, $\tau_v > \tau_c$, $\tau_v < \tau_{cmax.}$

so, shear reinforcement is required.

$V_{us} = V_u - \tau_c bd = 46350$ N

use 8-mm diameter 2-legged stirrups

$A_{sv} = 2\times\frac{\pi}{4}\times 8\times 8 = 100.48\ \text{mm}^2$

Spacing $= \frac{0.87\times f_y\times A_{sv}\times d}{V_{umax}} = \frac{0.87\times415\times100.48\times575}{46350} = 450.054$ mm

Adopt 8mm diameter 2-legged stirrups with 300 mm c/c spacing.

Fig. 9 shows the longitudinal and sectional reinforcement of the beam.

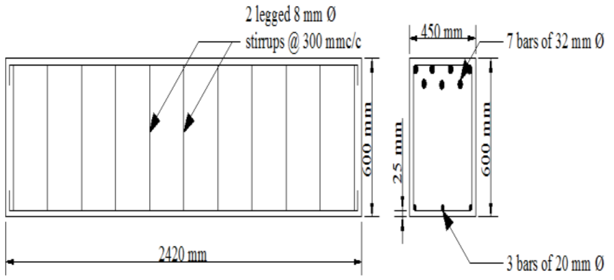

Figure 9: Longitudinal and sectional reinforcement of critical beam

3.3 Design of Column:

From the analysis,

Ultimate axial load, $P_u = 1191.78$ kN

$M_{ux} = -2.569$ kN-m

$M_{uy} = 124.171$ kN-m

Let us assume the cover d′= 50 mm

Equivalent Moment:

The reinforcement in section is designed for axial compressive load P_u and equivalent moment. The equivalent momentis given by relation

$M_u = 1.15\sqrt{{M_{ux}}^2 + {M_{uy}}^2} = 142.83$ KN-m

Non – Dimensional Parameter:

$\frac{P_u}{f_{ck}\,bD} = \frac{1191.78X\,10^3}{25X450X750} = 0.141$

$\frac{M_u}{f_{ck}\,bd^2} = \frac{142.83X10^6}{25X450X750^2} = 0.0225$

$\frac{d'}{D} = 0.067$

Longitudinal Reinforcement:

$\frac{p}{f_{ck}} = 0.00$ (chart no 32 of ISI hand book SP-16 for $\frac{P_u}{f_{ck}\,bD} = 0.141$)

So, provide minimum reinforcement

Provide 4 bars of 12mm diameter and 4 bars of 10 mm diameter distributed equally all phases with 3 bars on each phase.

Least lateral dimension = 450mm

a) 16 x diameter = 16 x 12 = 192mm
b) 300mm

Hence, provide 8mm diameter bars as lateral ties with a spacing of 192mm c/c.

Fig. 10 shows the longitudinal and sectional reinforcement of the column.

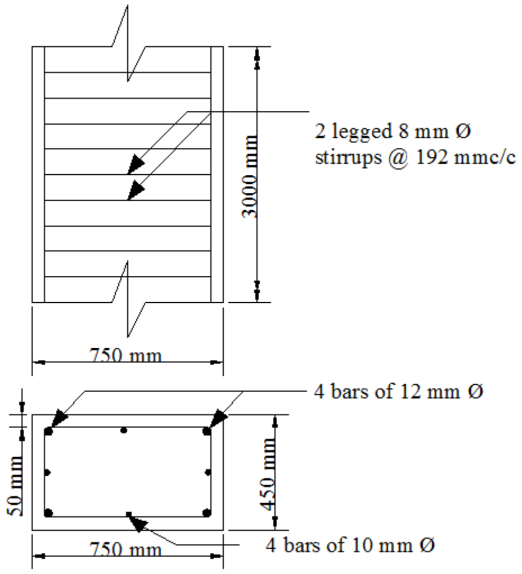

Figure 10: Longitudinal and sectional reinforcement of critical column

3.4 Design of an Isolated Footing:

The column section is of width 450mm and depth 750 mm.

Design load $P_u = 1191.78$ kN

Bearing capacity of soil = 200 kN/m^2

Size of Footing:

Load from column $P_u = 1191.78$ kN

Self-weight of column footing = 10% of column load

$= \frac{10}{100} \times 1191.78 = 119.2$ kN

Total load = 1191.78+ 119.2= 1311kN

Therefore, Area of footing = 6.555 m^2

Provide 3.3 × 2.0 m footing of rectangular cross section.

Therefore, Net upward soil pressure (q) $= \frac{1311}{3.3\times2} = 198.636$ kN/m^2.

Net ultimate soil pressure acting upwards $(q_u) = 1.5\times q$

$= 1.5\times198.636 = 297.954\ \text{kN/m}^2$.

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Depth of Footing from Bending Moment Considerations:

The critical section for BM will be the face of column in length and width directions.

The projections of the footing from the face of the column in the length and width directions are $C_x = \frac{3.3-0.75}{2} = 1.275$m and $C_y = \frac{2-0.45}{2} = 0.775$m

The portion of the footing from the edge to the face of the column acts as a cantilever portion.

Bending moment at the face of the column

Along length direction, (M_X) = 11.322 kN-m (per m strip)

Along width direction, (M_y) = 89.48 kN-m (per m strip)

For a balanced design $M_{ulimit} = 0.36\times (f_{ck}) \times b\times x_{umax}\times (d-0.42\times x_{umax})$

$89.48\times10^6 = 0.36\times25\times1000\times0.48\times d\times (d - 0.42\times0.48\times d)$

d = 161.07mm

Assume effective cover = 60mm.

Overall depth = 161.07+60 = 221.07 (say 450mm)

Therefore, effective depth provided, d = 450-60 = 390mm.

Check for One way Shear:

The critical section for one way shear occurs at a distance of ‘d’ from the face of the column

$V_x = q_u\times (1.275-0.39) = 263.69$ kN (per m strip)

$V_y = q_u\times (0.775-0.39) = 114.71$ kN (per m strip)

Nominal shear stress $= \frac{V_u}{Bd} = \frac{263.69\times1000}{3300\times390} = 0.204$ N/m^2

For a balanced design,

$0.36\times f_{ck}\times b\times x_{umax} = 0.87\times f_y\times A_{st}$

$p_t = 100\times (A_{st}/bd) = 1.2$ %

$\tau_{c} = 0.69$ N/mm^2

Therefore, $\tau_v<\tau_c$, $\tau_v<\tau_{cmax}$

Hence safe against one-way shear.

Check for Two-way shear or punching shear:

$B_1 = b + d = 450 + 390 = 840$mm

$L_1 = l + d = 750 + 390 = 1140$mm

Perimeter $(P_o) = 2\times (B_1 + L_1) = 2\times (840+ 1140) = 3960$mm

Shear force at critical section $(V_u) = q_u[L\times B-L_1\times B_1]$

$= 1513.42$kN

Nominal shear stress $(\tau_v) = \frac{V_u}{Pd} = \frac{1877.11\times1000}{3960\times390}$

$= 1.21$ N/mm^2

$k_s = (0.5+\beta c)$ should not be greater than 1.

$$\beta c = \frac{short\ side\ of\ column}{long\ side\ of\ column} = \frac{0.45}{0.75} = 0.6$$

$k_s = 0.5+0.6 = 1.1$

Therefore, $k_s = 1$.

$\tau_c= 0.25\times\sqrt{fck}$

$= 0.25\times\sqrt{25} = 0.25\times5 = 1.25$ N/mm^2

$\tau'_c = K_s\times \tau_c = 1\times1.25 = 1.25$ N/mm^2

$\tau_v< \tau'_c$.

Hence safe against two-way shear.

Reinforcement Calculations:

For bending parallel to width

$M_u = 0.87\times f_y\times A_{st}\times d\ (1- \frac{f_y Ast}{fck\ Bd})$

$A_{st} = 644.303$mm^2

Assume 12 mm dia bars, no. of bars $= \frac{644.303}{\frac{\pi}{4}\times\emptyset^2} = 5.69 = 6$ bars

For a length of 3.3 m, no. of bars = 3.3×6 = 20 bars.

Spacing (s)$= \frac{a_{st}}{A_{st}}\times 1000 = 83.33mm \approx 85\ mm.$

For bending parallel to length

$M_u = 0.87\times f_y\times A_{st}\times d(1- \frac{f_y Ast}{fck\ Bd})$

$A_{st} = 80.54$mm^2

Assume 12 mm dia bars, no. of bars $= \frac{80.54}{\frac{\pi}{4}\times\emptyset^2} = 1.60 = 2$ bar

For a width of 2 m, no. of bars = 2×2 = 4 bars.

Spacing (s)= 620mm.

Hence, adopt the footing size as 3.3m×2m and an effective depth of 390mm with a clear cover of 60mm. Fig. 11 shows the longitudinal and sectional reinforcement of the isolated footing.

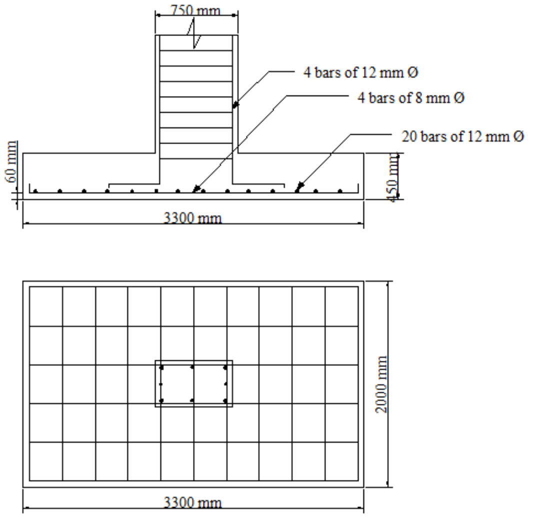

Figure 11: Longitudinal and sectional reinforcement of isolated footing

IV. CONCLUDING REMARKS

The following are the major conclusions drawn from the planning, analysis and design of an auditorium with one way, two way and grid slabs.

i. The grid slab is found to be more economical compared to one way and two-way slab considering design of slab.
ii. The auditorium with two-way slab found to be more economical compared to auditorium with one way and grid slabs.

iii. The volume of concrete required for an auditorium with two-way slab is 17.68% lesser compared to volume of concrete required for an auditorium with one way slab.
iv. The volume of concrete required for two-way slab is 8.74% lesser compared to the volume of concrete required for an auditorium with grid slab.

REFERENCES

[1] Dileep kumar, R., Kaleel, J., Vidyalakshmi, M., and Rajesh gunna, R., "Design of steel grillage foundation for an auditorium." *International Journal of Research in Science, Engineering and Technology (IJIRSET)*, Vol. 04, No. 11, 2017.

[2] Harish, S., and Ramaprasad Reddy, L., "Design and analysis of auditorium by using STAAD Pro." *International Journal of Research in Science, Engineering and Technology (IJIRSET)*, Vol. 06, No. 7, 2017.

[3] BIS 456, 2000. "Indian Standard plain and reinforced concrete – code of practice (Fourth Revision)" *Bureau of Indian Standards, New Delhi*, India.

[4] BIS 800, 2007. "Indian Standard construction in steel - code of practice." *Bureau of Indian Standards, New Delhi*, India.

[5] BIS 2526, 1963. "Acoustical design of auditorium and conference halls." *Bureau of Indian Standards, New Delhi*, India.

[6] BIS 875 (PART - 1), 1987. "Indian Standard code of practice for design loads (other than earthquake) for buildings and structures part 1 dead loads – unit weights of building materials and stored materials." *Bureau of Indian Standards, New Delhi*, India.

[7] BIS 875 (PART-2), 1987. "Indian Standard code of practice for design loads (other than earthquake) for buildings and structures part-2 imposed loads." *Bureau of Indian Standards, New Delhi*, India.

[8] Ramesh Bhaskar, Manoj Nallanathel and Pavan Kumar, B.V. "Analysis & Design of auditorium By Using STAAD Pro Software."

[9] Vineeth Reddy, Diwakar Reddy, Gopi and Soma Sekhar. "Design of an Auditorium Building." *International Journal of Research in Science, Engineering and Technology (IJIRSET)*, Vol.7, No. 4, 2018.

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