PASSIVE COOLING DESIGN FEATURE FOR ENERGY EFFICIENT IN PERI AUDITORIUM

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Abstract - IES – Integrated Environmental Solution Passive design responds to local climate and site conditions in order to maximize the comfort and health of building users mean while minimizing energy use. The key to design a passive building is to take best advantage of the local climate. Passive cooling refers to any technologies or design features adopted to reduce the temperature of buildings without the need of power consumption. Energy reduction was achieved by both the harnessing of natural ventilation and minimizing heat gain in line with applying good shading devices alongside the use of double glazing. Additionally green roofing provide its potential by acting as an effective roof insulation. In this project, passive cooling building in "PERI INSTITUTE OF TECHNOLOGY" is designed. The auditorium is designed to provide good acoustic & cooling for many different types of performance specifically lectures, seminar hall, presentation, conference, dramas, etc., our auditorium is free from reverberation effect. The total area of auditorium is 1860Sq.m. with 3000 seats. The plan was done using AUTO CAD. The structural elements like slab, beams, columns and footing are manually designed using IS 456-2000 code book. IS 2526-1963 for auditorium

Keywords- passive cooling, energy reduction, ventilation, minimizing heat, shading device.

1. INTRODUCTION

Construction is a process that consist of the building or assembling of infrastructures. Structure design is an art and science of designing with economy, safe serviceable and durable structures. The entire process of structural planning and design does not require only imagination and conceptual thinking, but also the structural engineering knowledge of practical aspects such as relevant design codes, laws. Auditorium provides a pleasant environment to the college specially for conducting conference. An auditorium includes any room intendent for listening to music, including theatres, music halls, class room and meeting halls. The design of various, functional, technical, artistic and economical requirements, an auditorium often has to accommodate an unprecedentedly large audience.

Hearing conditions in an auditorium are considerably affected by purely architectural considerations like shape, dimensions, volume, and layout of boundary surfaces, seating arrangements, audience capacity, surface treatment and materials used for interior decoration. Seeing to the increasing use of auditorium in this present scenario, the study of acoustical concepts in "AUDITORIUM DESIGN" is a necessity. So now a day the acoustical concepts are the main considerations in any assembly buildings. By considering the acoustical concepts and control of reverberation defects, we designed "AN ACOUSTIC AUDITORIUM".

2.Slab Design

DATA

Span of the slab	=	6m×6m
Wall thickness	=	230mm
Grade of cement	=	M-20
Grade of steel	=	Fe-415 HYSD

CALCULATION

L_x	=	6m
L_y	=	6m
l_x/l_y	=	6/6
	=	1m<2

Since the ratio to long span to short span is less than 2, we are using two way slab.

TO FIND EFFECTIVE DEPTH

Depth	=	6000/26
Adopt effective depth(d)	=	240mm
Overall depth (D)	=	240+25
	=	265mm

TO FIND EFFECTIVE SPAN

Effective span	=	(clear span + effective depth)
	=	6.24m

LOAD

Self-weight of slab	=	6.625kN/m^2
Live load	=	4kN/m
Floor finish	=	1kN/m^2
Service load	=	11.6kN/m^2
Ultimate load	=	1.5×11.625
	=	17.43kN/m^2

ULTIMATE MOMENTS AND SHEAR FORCES

By referring (table no:26 of IS 456:2000) and read out the moment co-efficient

(ly/lx) = 1m
α_x = 0.047
α_y = 0.035

By interpolation method,

M_{ux} = $(\alpha_x W_u L_x^2)$
= 31.89 kN.m
M_{uy} = $(\alpha_y w_u l_x^2)$
= 23.712 kN.m
V_{ux} = $0.5 \times W_u \times L_x$
= 54.288 Kn

CHECK FOR DEPTH

M_{max} = $0.138 f_{ck} bd^2$
D = 107.49 mm < 240 mm

Effective depth selected is sufficient to resist the design ultimate moment

REINFORCEMENT

M_u $=0.87 f_y A_{st} d[1-(A_{st} f_y / bd f_{ck})]$
A_{st} = 380mm^2

Adopt 10mm diameter bars

Spacing = $(\pi/4)\times 10^2/380$
= 206~ 250mm
No.of.bars = $380/(\pi/4)\times 10^2$
= 4.85~ 6 nos

Check for shear stress

τ_v = v_u / bd
= 0.226 N/mm^2
P_t = $100A_{st}$ / bd
= 0.158

Table 19 0f IS456 – 2000 value is given as

$K.\tau_c$ = (1.125×0.32)
= 0.36 N/mm^2

$K.\tau_c > \tau_v$.

Hence the shear stress are within safe permissible limit

3.Beam Design

DATA

Span = 6000mm
Width of support= 230mm
Loads = 11.625 kN/m

M-20 grade of concrete
Fe-415 grade of steel

DIMENSION OF BEAM

Provide 230mm width

Span = 6m
d = 550mm
D = 600mm
B = 300mm

LOAD CALCULATION

Self-weight of beam g = 22.5 kN/m
Slab self weight = 59.6 kN
Parapet wall = 1.14kN/m
Total load = 127 kN/m
Design ultimate load W_u = 190.5 kN/m

ULTIMATE MOMENT AND SHEAR FORCE

M_u = $W_u L^2/8$
= 111.04 kNm
V_u = $0.5 W_u L$
= 74.01 kN
$M_{u\,lim}$ = $0.138 f_{ck} bd^2$
= 167.67 kNm

$M_u < M_{u\,lim}$ section is under reinforced

AREA OF STEEL REINFORCEMENT

M_u = $0.87 f_y A_{st} d[(1- A_{st} f_y)/(bd f_{ck})]$
A_{st} = 775.64 mm^2

Assume 12mm dia bars

No of bars = A_{st}/a_{st}
= 3.85~ 4 nos
Spacing = 145.81~ 200mm

CHECK FOR SHEAR STRESS

V_u = 74.01 kN
τ_v = V_u/bd
= 0.54 N/mm^2
P_t = 100 A_{st}/bd
= 0.57N/mm^2

Refer table 19 IS 456:2000

τ_c = 0.42 N/mm^2

$\tau_c > \tau_v$

Hence beam is safe against shear stress.

CHECK FOR DEFLECTION CONTROL

P_t = 0.57
K_t = 1.1
K_c = 1
K_f = 1

$(L/d)_{max}$ = $(L/d)_{basic} \times K_t \times K_c \times K_f$
= 22
$(L/d)_{actual}$ = 6000/550
= 20<22
Hence safe

4. COLUMN DESIGN

Column size = 230 × 230mm
P_u = 240.725 kN
M_{ux} = 15.945 kNm
M_{uy} = 11.856 kNm
f_{ck} = 20 N/mm²
Assume d^1/D = 0.10
b = 230mm
D = 230mm

EQUIVALENT MOMENT

Reinforcement in the section is designed for the axial compressive load P_u and the equivalent moment and finally reduced for safety.

M_u = $1.15\sqrt{M_{ux}^2+M_{uy}^2}$
= 22.85kNm

NON DIMENSIONAL PARAMETERS

$(P_u/f_{ck}\,bD)$ = 0.22

REINFORCEMENT

Since the column is under biaxial bending, equivalent reinforcement should be provided on all four sides. Hence using

Chart 44 of sp-16(f_y 415 N/mm2)
Assume d'/D = 0.10
$(P_u/f_{ck}\,bD)$ = 0.22
$(M_u/f_{ck}\,b\,D^2)$ = 0.09
(P/f_{ck}) = 0.04
= $0.04 \times f_{ck}$
= 0.8%
A_{sc} = (PbD)/100
= 423.2 mm²
A_{sc} = 2% A_g
= 1058 mm²
No of bars = A_{st}/a_{st}
= 3.37~ 4 bars

Provide 4 bars of 20mm diameter and 4bars of 16mm diameter (A_{sc}=190.03) distributed on all faces with 4 bars on each faces

(P/f_{ck}) = 0.04

Again using chart 44 0f SP-16, for
(P/f_{ck}) = 0.04
$(P_u/f_{ck}\,bD)$ = 0.22
$(M_u/f_{ck}\,b\,D^2)$ = 0.09
M_{ux1} = 21.90 kNm

Because of symmetry
M_{ux1} = M_{uy1} = 21.9 kNm
P_{uz} = 466.59 kN
P_u/P_{uz} = 0.515
From SP16, P_u/P_{uz} = 0.515
α_n is read as 1.5

Check for safety under biaxial bending
$=[(M_{ux}/M_{ux1})^{\alpha n} + (M_{uy}/M_{uy1})^{\alpha n}] \leq 1$
= $0.6+0.3 \leq 1$
= $0.9 \leq 1$

Hence the section is safe against biaxial bending

5. Footing Design

Total load = 240.725kN
Bearing capacity = 185kN/m²
Grade of concrete = M-20
Grade of steel = Fe-415
Column size = 230×230mm

SIZE OF FOOTING

Load of column = 240.7Kn
Self weight of footing(10%) = 24.07kN
Total factored load W_u = 264.77 kN
Footing area = 1m²

Proportion the footing area in the same proportion as the sides of the columns

Hence,
(2.3x)×(2.3x) = 1m
X = 0.43
Side of footing = 1m

Adopt a square footing of size 1m by 1m
Factored soil pressure at base is completed as:

P_u = 240.7kN/m²
< 277.5 kN/m²

Hence the footing area is adequate since the soil pressure developed at the base is less than the factored bearing capacity of soil.

FACTORED BENDING MOMENT

Cantilever projection from the side face of the column
= 0.5(1-0.23)
= 0.385m

Bending moment at side face is $(0.5\,P_u\,L^2)$
= 17.84 kNm

DEPTH OF FOOTING

a) Moment considerations :

M_u = $0.138 f_{ck} bd^2$
D = 80.39~ 100mm

b) From shear stress considerations we have the critical section for one way shear is located at a distance d from the face of the column

c)
V_{ul} = 250(1250 – d)N
Assuming the shear strength τ_c = 0.36 N/mm²
For M-20 grade % of reinforcements
P_t = 0.25

Design of reinforcement concrete structures

τ_c = 0.36
Hence adopt effective depth d = 520mm
Overall depth D = 550mm

REINFORCEMENT IN FOOTING

M_u = $[(0.87 f_y A_{st} d) (1- A_{st} f_y / bd f_{ck})]$
A_{st} = 558.92mm²
Spacing = 360
Adopt 16mm diameter bars at 360mm centers
Provide 12 mm dia bars,
No. of.bars = 2.77~ 4

CHECK FOR SHEAR

The critical section for one way shear is located at a distance d from the face of the columns

Ultimate shear force per metre width in the direction

V_u = 175 kN
100 A_{st}/ bd] = 0.35

Refer table 19 of IS 456 – 2000 and read the permissible shear stress
= $K_s \tau_c$
= 0.42 N/mm²

Nominal shear stress
τ_v = v_u/ bd
= 0.33 N/mm²

Since $\tau_v < K_s \tau_c$

Hence safe.

6. Reinforcement diagrams

6.1 Slab

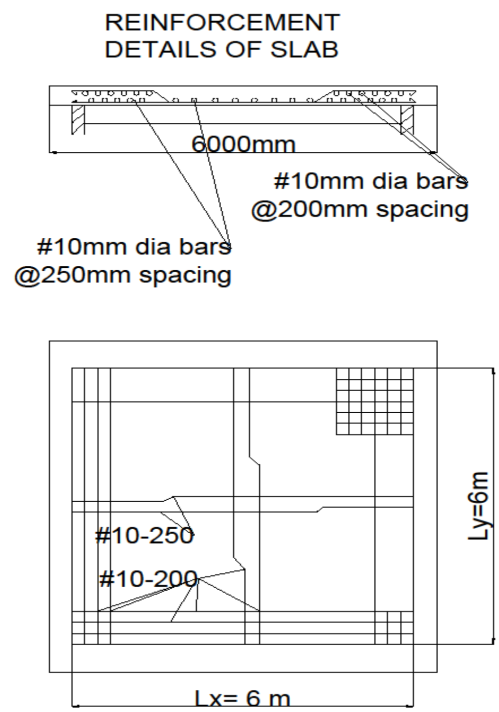

Fig. 1: Reinforcement detail of Slab

6.2 Beam

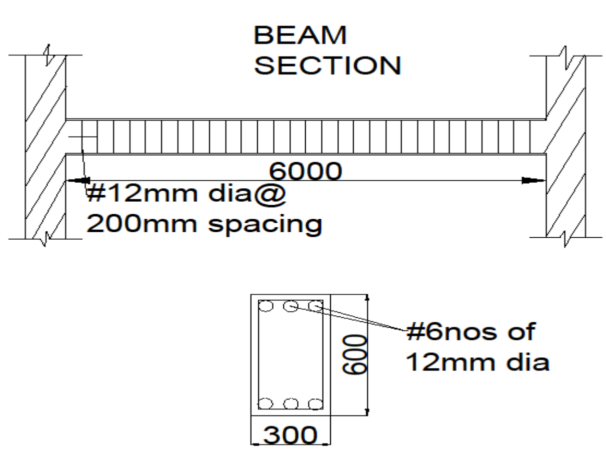

Fig. 2: Reinforcement detail of Beam

6.3 Plan Of Auditorium & layout

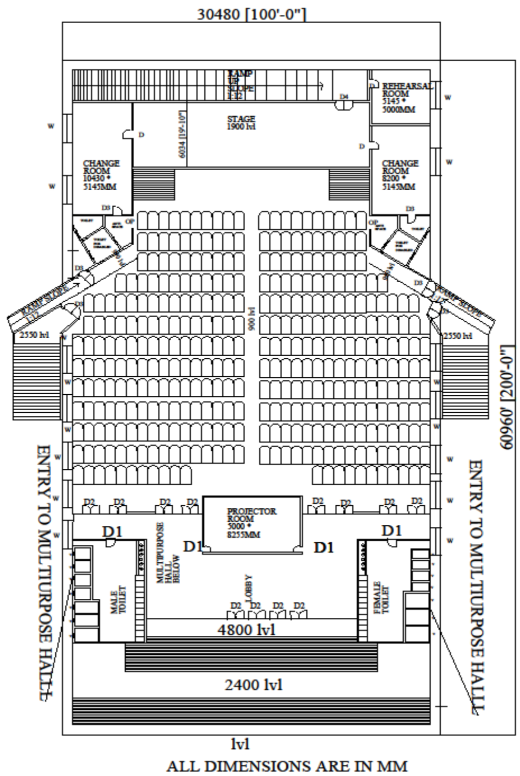

Fig. 3: Plan of an Auditorium

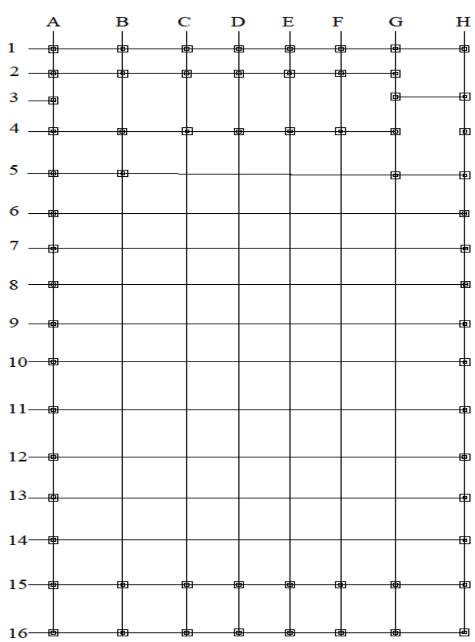

Fig. 4: Column Layout of the Auditorium

6.4 Column

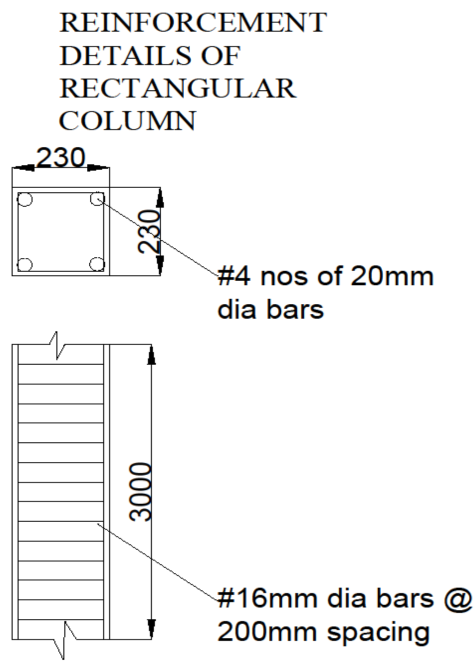

Fig. 5: Reinforcement detail of Column

6.5 Footing

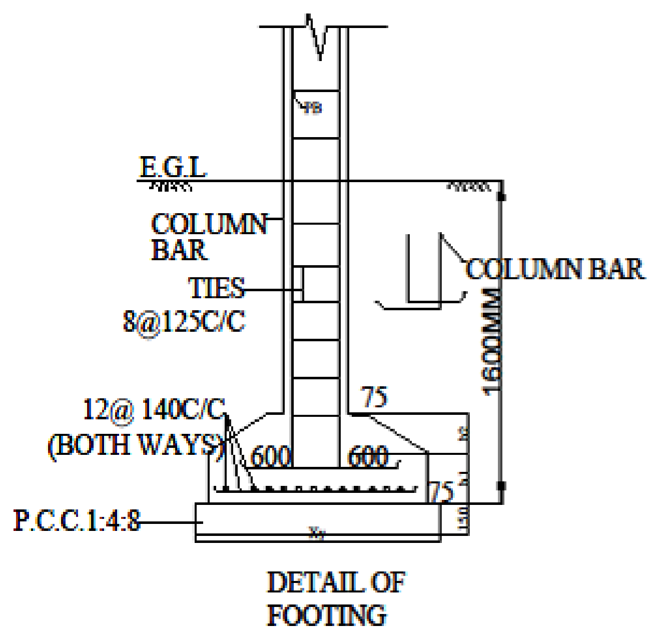

Fig. 6: Reinforcement detail of Footing

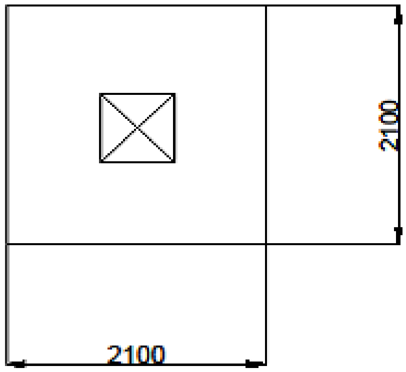

Fig. 7: Layout of Footing

7. Result

Table 1: Details of Structural Members

S. NO	ELEMENT	DESIGN PROVIDED
1	SLAB	**Depth** = 240m **Main reinforcement:** 6 nos of 10mm diameter at 200mm spacing
2	BEAM	**Depth** = 300mm **Main reinforcement:** 4 nos of 16mm diameter and 12mm diameter at 200mm spacing
3	COLUMN	**Diameter:**230mm **Main reinforcement:**4 nos of 20mm dia and 16mm dia at 250 mm spacing
4	FOOTING	**Depth:**100mm **Main reinforcement:** 4 nos of 16mm diameter and 16mm diameter at 360mm spacing

8. CONCLUSION

Planning and design of auditorium can be considered under an enthusiastic project. The specimen design for structural components like slab, beam, column, and footing are manually done and enclosed with the report. This make the building to give decent finishing without any disturbances and noises. This project implies interest in immense application of various factors involved in the building so this was the main reason for under taking this project. This design reduces the heat transmission from outside through passive cooling and thereby reducing the usage of the cooling loads and future bills accordingly. Calculations have been done for loads on slabs, beams, columns and after calculating the loads accordingly followed by the footing design.

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