

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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## Design of an Auditorium Building

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**ABSTRACT:** This project deals with the analysis and design of the Auditorium with special emphasis on Slabs, Beams, Columns, Footing and Staircase. Analysis is carried out using Substitute Frame Analysis and preliminary analysis of Beams is carried out using Moment Distribution method. Concrete mix used for the RCC members is M20 and steel used is high yield strength deformed bars of grade Fe415. Limit State Method is adopted for the design of all structural members in the building. Safe bearing capacity of soil is taken as 200kN/m<sup>2</sup>. Footing is designed as Isolated type. Plan and detailing of reinforcement are enclosed in this report. Area and other specifications are taken from IS 2526:1963 (Code of practice for acoustical design of Auditorium and conference halls) and NBC (National Building Code). The limit state method of collapse using IS: 456-2000, and SP16 have been adopted for the design of structural components like slabs, beams, columns and foundations. Design and analysis is done manually and the results are verified using STAAD Pro. We have used the AUTO CAD.

**KEYWORDS:** Acoustic, Beam, Column, Footing, Analysis, Slab, Auto Cad, Staad Pro, etc

### I. INTRODUCTION

An auditorium is a room built to enable an audience to hear and watch performances such as theatres. Auditorium, Conference hall, Library and Indoor Games are necessary for an Engineering college. In Kuppam College of Engineering, Library, Conference hall are located at different locations and also there is no special building for Auditorium. This project reports on the analysis and design of Auditorium, Library and Indoor Games hall in one separate block. All structural components for the building such as beams, columns, slabs, staircase etc are analysed and designed. Isolated footing is adopted for all columns. Safe bearing capacity is taken as 200kN/m<sup>2</sup>. The structure is designed by using limit state method, adopting M20 concrete and Fe415 HYSD bars. Site plan, plan showing various floors, section of plan, elevation of plan and detailing of reinforcements for Beam, Column, Slab, Staircase and Footing are also enclosed

#### 1.1. ACOUSTICAL REQUIREMENTS

- **Halls Used for Speech** - The clarity of speech is most important in this case. Optimum clarity depends on:
  - 1 correct reverberation time,
  - 2 absence of echo,
  - 3 correct loudness level at all parts of hall.
- **Halls for music** - Adequate reverberation is important to lend proper blending and fullness of music. The reverberation time is required to be higher than for halls meant for speech only.
- **General Purpose Halls Used for Both speech and music** - The reverberation time should be in-between that provided for in halls for music and speech.
- **Cinemas (Sound Picture halls)** - In view of the fact that a certain amount of reverberation is already present in the recorded sound, the reverberation time required in this case is lower than that required.
- **Open-Air Auditoriums and Conference halls** - While the general acoustical requirements are similar to those specified for halls additional requirements which arise are dealt with in 10-

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## 1.2. GENERAL PRINCIPLES OF DESIGN

### 1.2. 1. Seats

Seats should be staggered sideways in relation to those in front so that a listener in any row is not looking directly over the head of- the person in front of him .This is particularly important for halls where the audience provides the major part of the required sound absorption

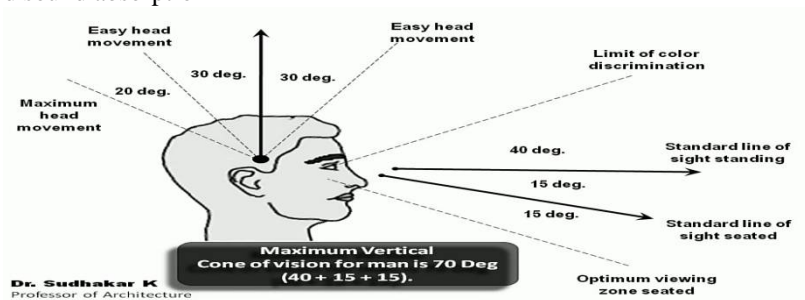


Figure. 1.Cone of vision

### 1.2.2. Seating arrangement

Seating arrangements in an auditorium seating layout (or assembly space) will either be identified as “multiple-aisle” or “continental

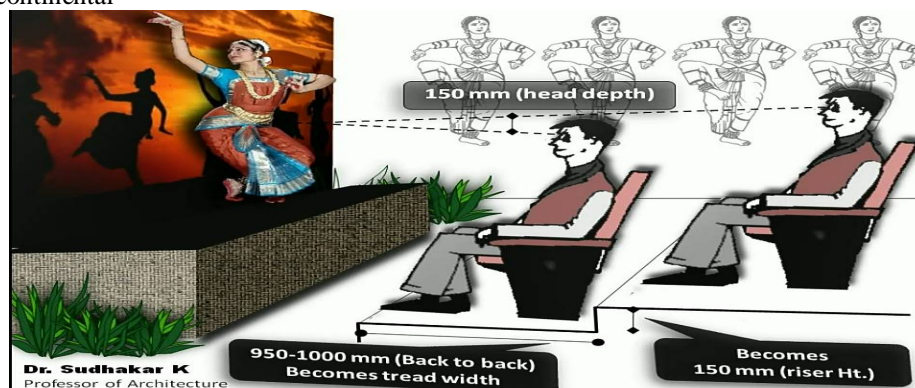


Figure.2. Seating arrangement

### 1.2.3. Seating Dimensions

The average seat width has grown from 450 mm to 650 mm, a grow of 12.7% that is related to a growing human size as “Theatre Projects Consultants”

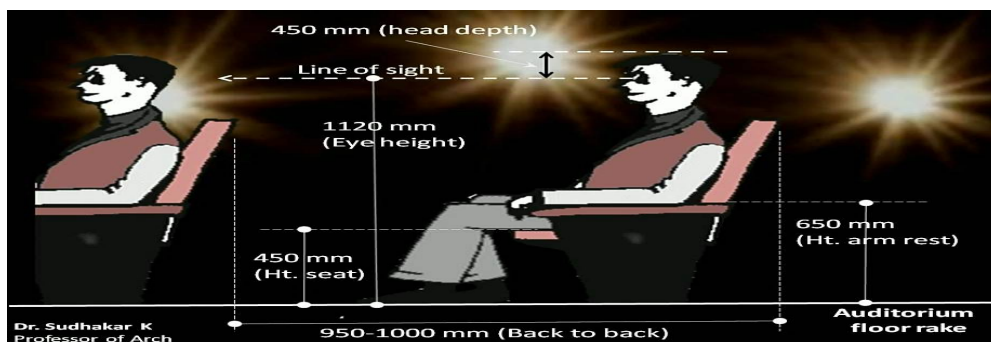


Figure3.Seating dimensions

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## II.LITERATURE SURVEY

### *Howard G. Latham, The signal to noise ratio for speech intelligibility – An Auditorium Acoustics design index*

The Signal-to-Noise Ratio devised by Lochner and Burger contributed an objective design index for predicting speech intelligibility. Their index provided a measure of useful and detrimental reflected speech energy according to the integration and masking characteristics of hearing, and enabled predictions to be made from impulse measurements in models. However, it was necessary to extend the Signal-to-Noise Ratio theory to account for the effect of fluctuating ambient background noise on speech intelligibility.

### *Howard G. Latham, The Measurement of Quality in Auditorium Acoustics by Subjective Scaling Methods - A Review of Developments in Theory and Practice*

The effects of reflections: The terms 'reflection' and 'echo' have sometimes been confused, in that any perceptible reflection was called an 'echo'. It could be useful to identify three types of reflection by their subjective effects in complex sound fields: • Imperceptible but contributing towards sound impression. • Perceptible but not disturbing, and not perceived as an echo or new source. • Perceptible and disturbing. The threshold of perceptibility has been defined as the level at which 50 per cent of subjects noticed a difference in the sound field. The critical level of a reflection was determined when 50 per cent of listeners were disturbed.

### *Chan H. Haan & Fergus R. Fricke, Statistical Investigation of Geometrical Parameters for the Acoustic Design of Auditorium*

Volume/seat: Sabine la showed that the reverberation time of an auditorium is directly proportional to the room volume and inversely proportional to the total absorption in the auditorium. As the total absorption is largely dependent on the number of seats in the auditorium the reverberation time will be dependent on the volume/seat ratio.

## III.ANALYSIS

A multi-storeyed frame is a complicated statically indeterminate structure. The analysis by moment distribution method is very lengthy and difficult. Hence substitute frame analysis is adopted for better and easier calculation.

## IV. DESIGN

### 4.1. DESIGN OF SLAB

#### Dimensions

$L_x$	=	3.2	
$L_y$	=	5.5	
Span ratio	=	5.5 / 3.2	
	=	1.1 < 2	i.e., Two way slab

Assume,

Overall depth	=	150-20
D	=	130mm

#### Torsion reinforcement at corner

Area of torsion steel at each of the corners in 4 layers is computed as	=	$0.75 * A_{st}$ along shorter span
	=	$0.75 * 523.59$
	=	$393 \text{mm}^2$

Length cover which torsion steel is provided

	=	$1/5 * \text{shorter span}$
	=	$1/5 * 3200$
	=	640mm Using 6mm dia bars
Spacing	=	$1000ast / A_{st}$
	=	$(1000 * \pi * 62 / 4) / 393$
	=	71.9mm

Provide 6mm bars at 100mm c/c for length and 640mm at all corners in 4 layers

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## Reinforcement in end strips

$$A_{st} = 0.12\% \text{ of c/s}$$

$$= 180\text{mm}^2$$

Assume 10mm dia bars

$$\text{Spacing} = \frac{(1000 * \pi / 4 * 10^2)}{180}$$

$$= 436 > 300$$

As per code spacing should not exceed 300mm

Provide 10mm dia bars at 300mm c/c

$$A_{st} = \frac{(1000 * \pi / 4 * 10^2)}{300}$$

$$= 262\text{mm}^2$$

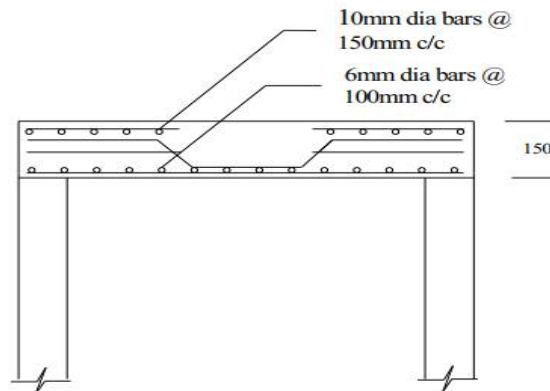


Figure4 -Reinforcement details of two way slab-section

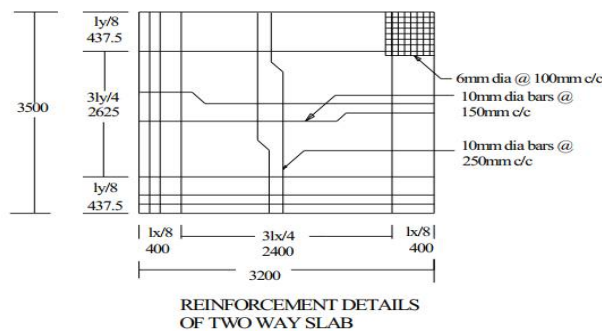


Figure 5-Reinforcement details of two way slab- plan

## 4.2.DESIGN OF BEAMS

### 4.2.1. DESIGN OF L-BEAMS

#### Dimensions

c/c of support =  $3.2 + (0.3/2) + (0.3/2)$   
= 3.5m

Thickness of slabs = 150 mm

$F_y$  = 20 N/mm<sup>2</sup>

$F_{ck}$  = 415 N/mm<sup>2</sup>

Width of beam = 300 mm

Overall depth = 300 mm

Effective cover = 25 mm

Effective depth = 300-25-10  
= 265mm

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## Reinforcement

### Shear reinforcement

$$\begin{aligned} \tau_{ve} &= V_e / b_w * d \\ &= 1.45 \text{ N/mm}^2 \\ P_t &= (100 * A_{st}) / (b_w * d) \\ &= 0.79 \text{ Ref table 19 of IS456 2000} \\ \tau_c &= 0.56 \text{ N/mm}^2 \end{aligned}$$

Hence shear reinforcement are required

using 10mm dia 2 legged stirrups with side cover 25mm top+ bottom cover of 25mm

$$b_l = 300 - 25 - 25 = 250 \text{ mm}$$

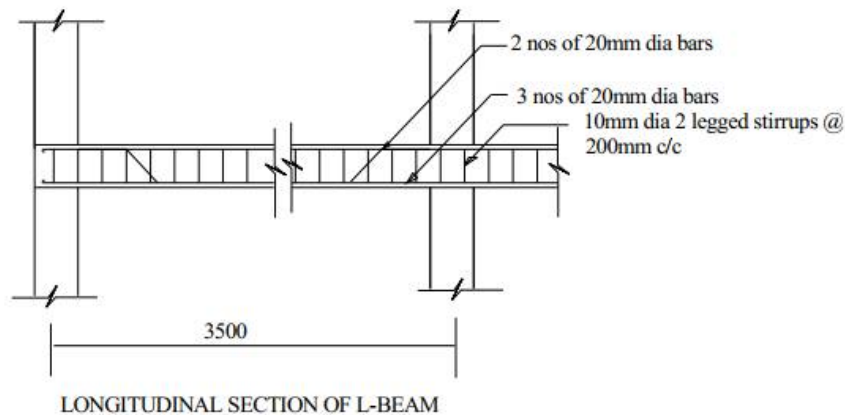
$$d_l = 300 - 25 - 25 = 250 \text{ mm}$$

$$A_{sv} = 157 \text{ mm}^2$$

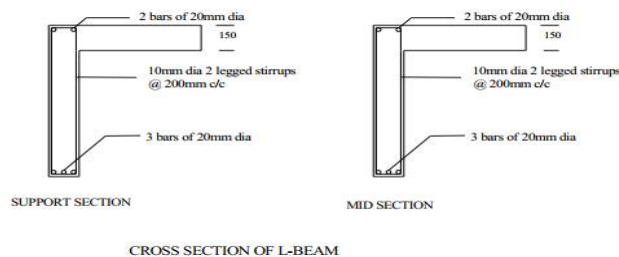
$$\sigma_c = A_{sv} * 0.87 * f_y / (\tau_y - \tau_c) * b$$

$$= 214.6$$

Provide 10mm dia 2 legged stirrups @ 200mm spacing



**Figure.6 -Reinforcement details of L-beams- longitudinal section**



**Figure.7 - Reinforcement details of L-beams- cross section**

## 4.2.2. DESIGN OF T- BEAM

### Dimensions

$$\text{Slab thickness} = 150 \text{ mm}$$

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$$\begin{aligned}
 \text{c/c of support} &= 3.2+(0.3/2)+(0.3/2) \\
 &= 3.5\text{m} \\
 f_y &= 20\text{N/mm}^2 \\
 f_{ck} &= 415\text{N/mm}^2
 \end{aligned}$$

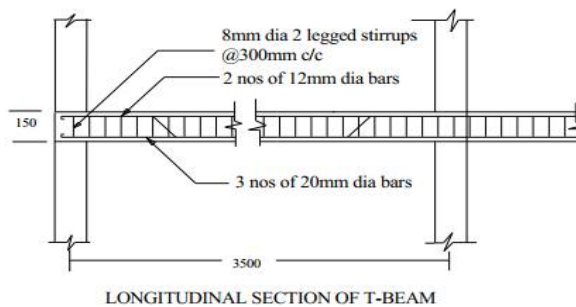
### Design of shear reinforcement

$$\begin{aligned}
 A_{sv}/b S_v &= 0.4/0.87*f_y \\
 S_v &= 302.47\text{mm}
 \end{aligned}$$

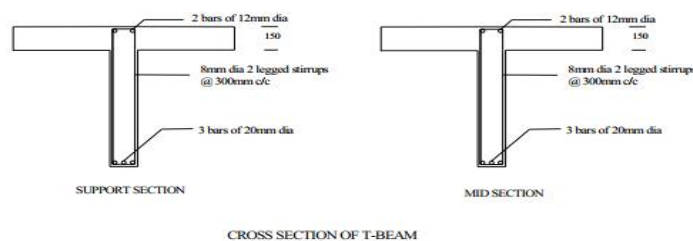
The spacing should not exceed 300mm

$$S_v = 300\text{mm}$$

Provide 8mm dia bars 2 legged stirrups at 300mm/c.



**Figure.8 -Reinforcement details of T-beam-longitudinal design**



**Figure.9. - Cross section of T-beam**

### 4.3. DESIGN OF DOG-LEGGED STAIRCASE

#### Dimensions

$$\begin{aligned}
 \text{Room size} &= 6.4*3.6\text{m} \\
 \text{Height of room} &= 4\text{m} \\
 \text{Live load} &= 5\text{kN/m}^2 \\
 f_y &= 415\text{N/mm}^2 \\
 f_{ck} &= 20\text{N/mm}^2 \\
 \text{Assume} \\
 \text{Tread} &= 300\text{mm} \\
 \text{Riser} &= 125\text{mm}
 \end{aligned}$$

#### Main reinforcement

$$\begin{aligned}
 M_u &= 0.87f_y A_{st} * d [1 - f_y A_{st} / bdf_{ck}] \\
 76.699*106 &= 0.87*415*A_{st} * 180 * [1 - (415*A_{st} / 1000*20*180)] \\
 A_{st} &= 1408.9\text{mm}^2 \\
 \text{Spacing with 10mm dia bars} &
 \end{aligned}$$

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$$S_v = \frac{(1000 \cdot \sqrt{4 \cdot 102})}{1408.9}$$

$$S_v = 55.75 \text{ mm}$$

Provide 10mm dia bars 100mm c/c

## Distributor Reinforcement

Provide

$$A_{st \text{ min}} = 0.12\% \text{ of cs area and assume 8mm dia bars}$$

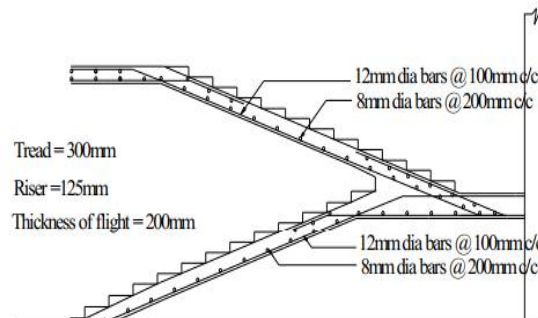
$$A_{st \text{ min}} = \frac{0.12}{100} \cdot 1000 \cdot 200$$

$$= 240 \text{ mm}^2$$

$$\text{Spacing} = \frac{1000(\pi/4) \cdot 8^2}{240}$$

$$= 209.44 \text{ mm}$$

Provide 8mm dia bars @ 200mm c/c



DETAILING OF DOG LEGGED STAIRCASE

Figure .10-Reinforcement details of doglegged staircase

## 4.4. DESIGN OF COLUMN

### 4.4.1. DESIGN OF AXIALLY LOADED COLUMN

#### Dimensions

$$\text{Factored load} = 1200 \text{ kN}$$

$$\text{Concrete grade} = \text{M20}$$

$$\text{Characteristic strength of reinforcement} = 415 \text{ N/mm}^2$$

$$\text{Unsupported length of column} = 3.55 \text{ m}$$

$$\text{Cross sectional area of column} = 400 \cdot 300$$

#### Longitudinal reinforcement

$$P_u = [0.4f_{ck} A_c + 0.67f_y - 0.4f_{ck}] A_{st}$$

$$1200 \cdot 103 = [(0.4 \cdot 20 \cdot 400 \cdot 300) + [(0.67 \cdot 415) - (0.4 \cdot 20)] A_{sc}]$$

$$A_{sc} = 888.7 \text{ mm}^2$$

$$\text{Minimum reinforcement provided} = 0.008 \cdot 400 \cdot 300$$

$$= 960 \text{ mm}^2$$

ie, Provide 6 nos of 20 mm dia bars of longitudinal reinforcement

#### Lateral ties

$$\text{Tie diameter} > 6 \text{ mm}$$

$$< 16 \text{ mm}$$

Provide 8mm diameter ties

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Tie spacing > 16\*20  
= 320mm  
ie, provide 8mm dia ties @ 300mm c/c

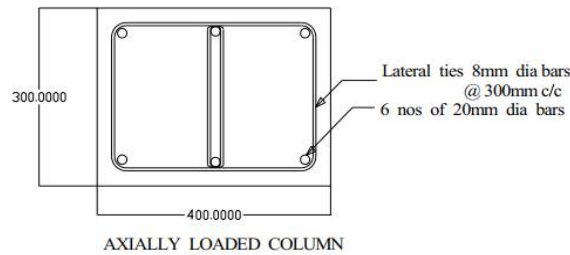


Figure 11.-Reinforcement details of axially loaded column

## 4.4.2. DESIGN OF UNIAXIALLY LOADED COLUMN

### Design of lateral ties

Dia of lateral ties not less than 6mm and not greater than 16mm

Take 8mm dia ties

Spacing should not be greater than 300mm

Or

$$16\phi = 16*20 = 320\text{mm}$$

Hence provide 8mm  $\phi$  bars @ 250mm c/c

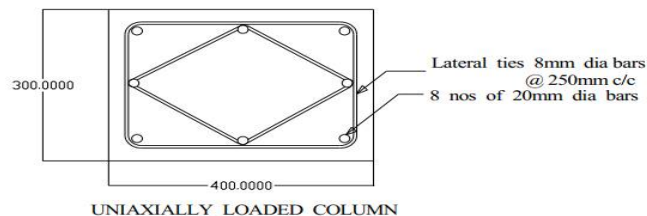


Figure12 -Reinforcement details of uniaxially loaded column

## 4.4.3. DESIGN OF BI AXIALLY LOADED COLUMN

### Design of lateral ties

According to IS456:2000,

Dia of lateral ties not less than 6mm and not greater than 16mm

Take 8mm dia ties

Spacing should not be greater than 300mm

or

$$16\phi = 16*20 = 320\text{mm}$$

Hence provide 8mm  $\phi$  bars @ 300mm c/c

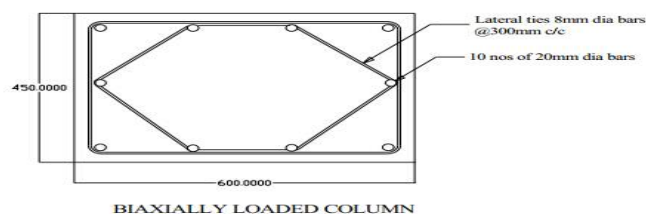


Figure13. -Reinforcement details of bi axially loaded columns



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## 4.5.DESIGN OF FOOTING

### Dimension

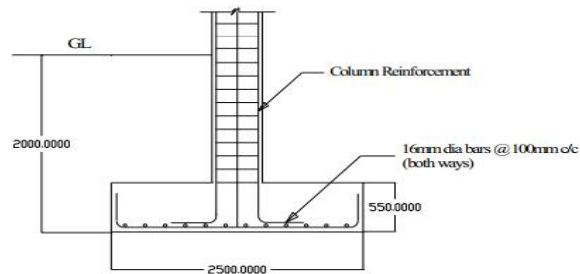
Factored load, $P_u$	=	1200 kN
Size of column	=	400 × 300 mm
SBC of soil	=	200 kN/m <sup>2</sup>
$F_{ck}$	=	20 N/mm <sup>2</sup>
$F_y$	=	415 N/mm <sup>2</sup>

### Size footing

Load on column	=	1200 kN
Weight of footing and backfill at 10%	=	120 kN
Area of footing	=	$(1200+120)/(1.5*200)$
	=	4.4 m <sup>2</sup>

$A_{st}$	=	1970.4mm <sup>2</sup>
$P_t$	=	$100 A_{st}/bd$
	=	$(100*1970.4)/(1000*450)$
	=	0.43 > 0.25 Assuming 60mm dia bars,
Spacing	=	$1000a_{st}/A_{st}$
	=	$1000*\pi*16^2/(4*1970.4)$
	=	105mm

Hence, provide 16mm dia bars @ 100mm c/c in both directions.



FOOTING FOR AXIALLY LOADED COLUMN

Figure 14-Reinforcement details of axially loaded column

## V. STAAD REPORT

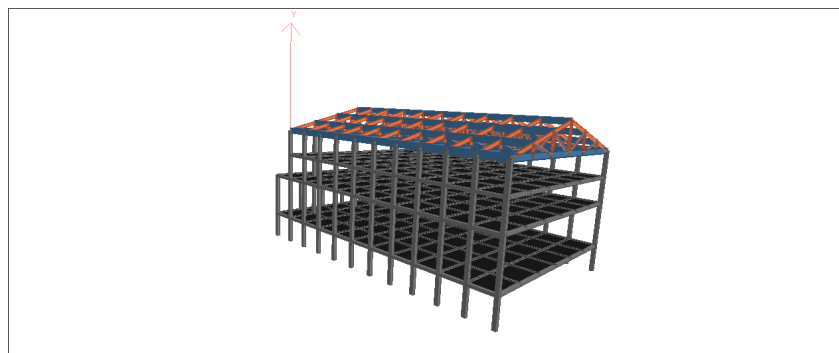


Figure 15-3D Rendered View –AUDITORIUM BUILDING

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### Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

	Beam	Node	L/C	Shear			Bending		
				Axial Fx (kN)	Fy (kN)	Fz (kN)	Torsion Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	11	12	1:DEAD LOAD	1.49E+3	-6.961	0.794	-2.807	1.112	-5.096
Min Fx	4	4	1:DEAD LOAD	-1.12E+3	3.042	0.989	-0.704	-1.837	-5.631
Max Fy	455	193	1:DEAD LOAD	298.344	210.660	12.044	0.013	-19.519	317.050
Min Fy	451	189	1:DEAD LOAD	298.344	-210.660	12.044	-0.013	-19.519	-317.050
Max Fz	733	229	2:LIVE LOAD	394.419	-0.000	91.711	0.000	-151.253	-0.000
Min Fz	733	229	1:DEAD LOAD	-551.043	0.000	-121.584	0.000	196.592	0.000
Max Mx	865	242	1:DEAD LOAD	3.576	5.636	-0.077	22.973	0.105	16.464
Min Mx	869	246	1:DEAD LOAD	3.576	5.636	-0.077	-22.972	-0.105	16.463
Max My	733	229	1:DEAD LOAD	-551.043	0.000	-121.584	0.000	196.592	0.000
Min My	733	234	1:DEAD LOAD	-542.561	0.000	-121.584	0.000	-168.160	-0.000
Max Mz	455	193	1:DEAD LOAD	298.344	210.660	12.044	0.013	-19.519	317.050
Min Mz	451	189	1:DEAD LOAD	298.344	-210.660	12.044	-0.013	-19.519	-317.050

Figure 16-Beam forces in Staad Pro

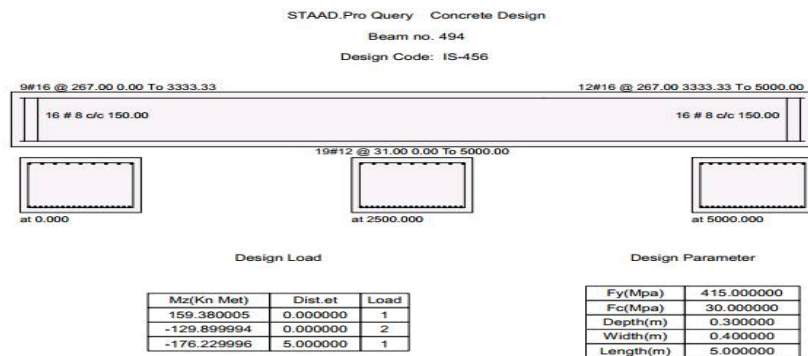


Figure 17-Beam design

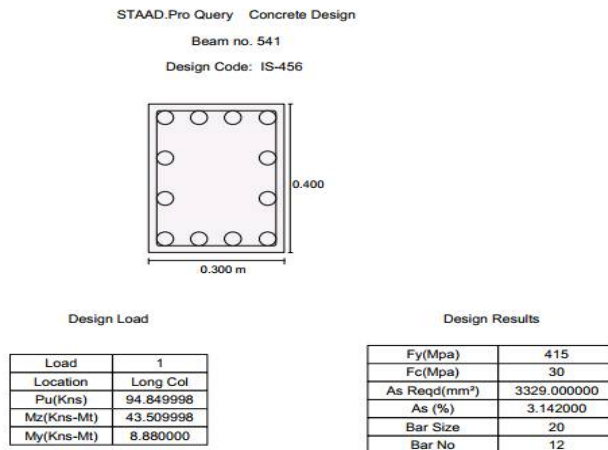


Figure 18-Column design

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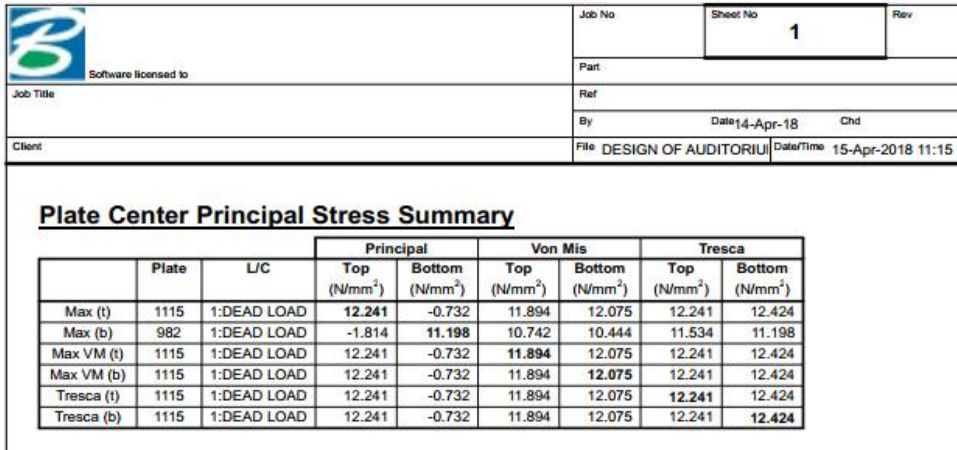


Figure 19-Plate principal stresses in Staad Pro

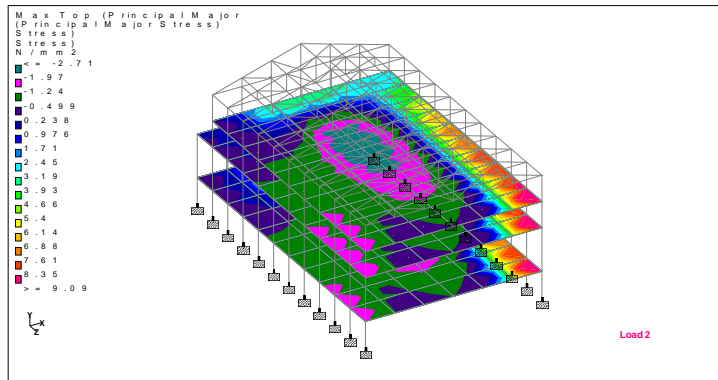


Figure20- MAXIMUM PRINCIPAL STRESSES

## VI. AUTOCAD LAYOUTS

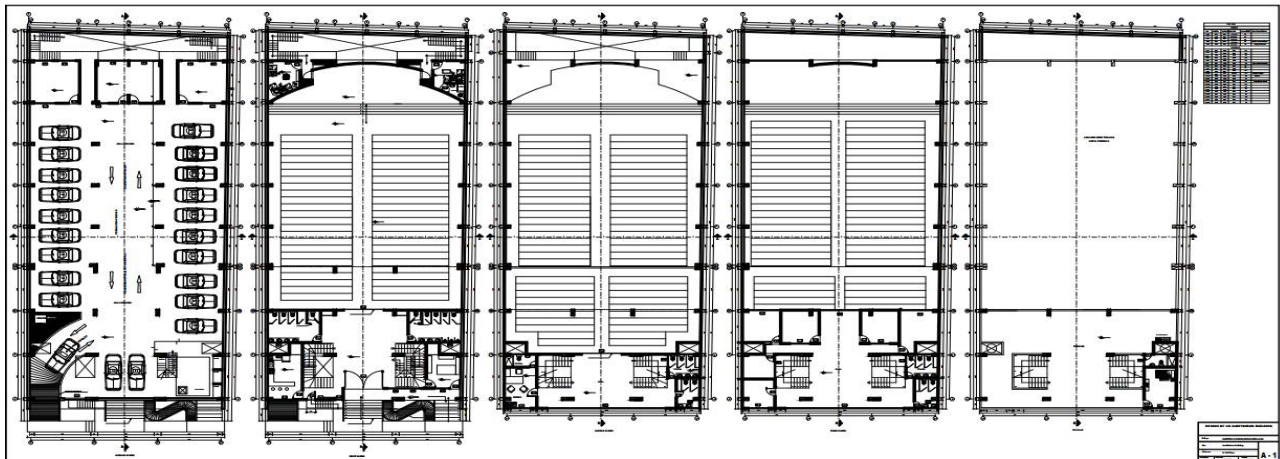
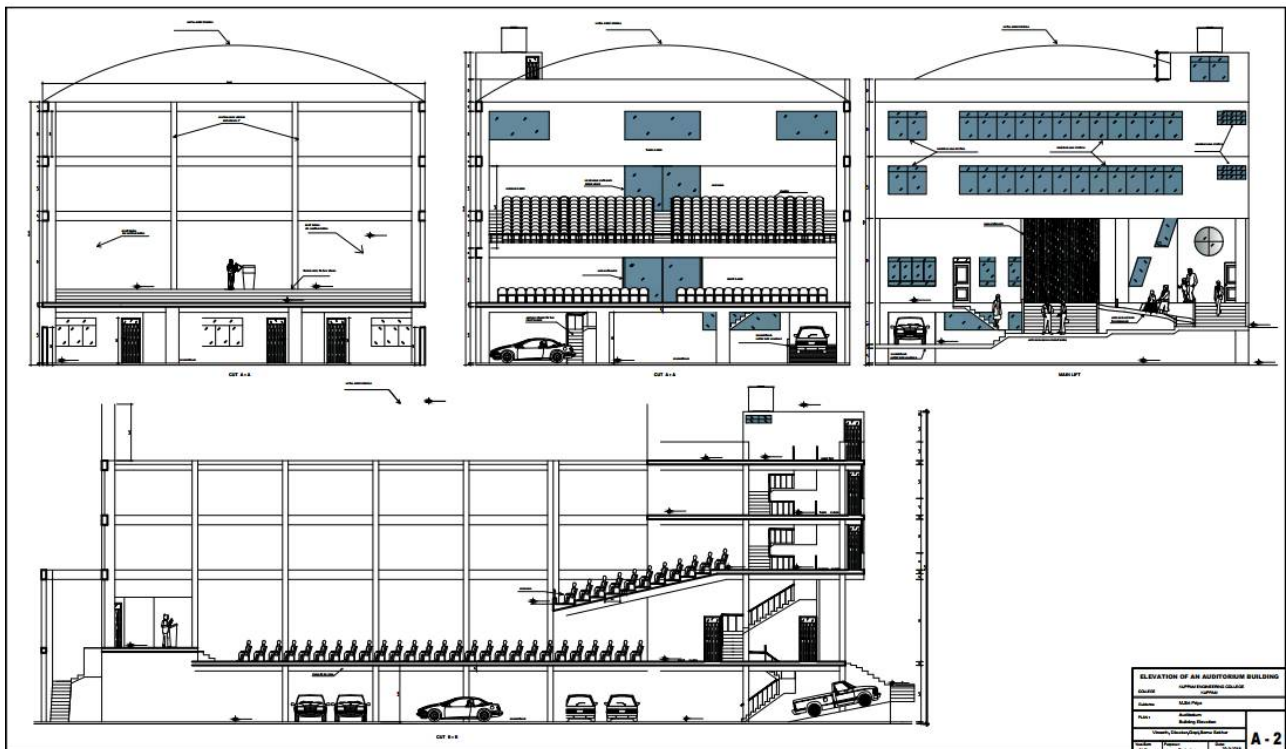


Figure21: Floor Plan of Auditorium building using AutoCAD



**Figure22: Elevation of Auditorium building using AutoCAD**

## VII. CONCLUSION

The analysis and design of the structural components of the college auditorium envisaged planning for each floor of the building with detailed analyses of Beams, Columns, Slabs and Stairs. Isolated footings for Columns were considered. This project concerns the feasibility of construction of an auditorium with good acoustic properties. It involves the application of earlier coursework to carry out the analysis and design of components of structure. It was analysed using STAAD.Pro using generic loading. The construction of auditorium presents a solution for many cultural programmes being held. This project can be directly implanted

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