Planning, Design and Acoustical Control of Auditorium

PROJECT REPORT

Submitted by

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CONTENTS

SYNOPSIS

This project work deals with the planning, design, drawing, acoustics & estimation of an auditorium. It is a multipurpose auditorium, which is designed for speech, music, cultural activities etc.

It deals with structural elements.

1) Analysis of Frames
2) Design of Footing
3) Design of Columns
4) Design of Beams
5) Design of Slabs
6) Design of Truss
7) Design of Staircase

The slabs, beams, columns, footing, staircase have been designed by Limit state method using **IS :456-1978** and Design aids conforming to **IS:456-1978.**
Frames have been analysed by computer program in Fortran-77.
M15 and Steel Fe415 have been used for the design of slabs and beams. Concrete M20 and Steel Fe415 have been used for the design of columns, footings.

The drawing showing the reinforcement details for the members are given.

A detailed estimation of the multipurpose auditorium is also made.

INTRODUCTION

Auditorium design is based on the hard facts and is rarely a matter of inventing new forms of auditorium. The engineering works within a large number of constraints, some of which are self-imposed, and if inventiveness comes into it at all it is in the way that theory is put into practice.

These words by the architect Peter Moro referred to auditorium design. A designer must have greeted the prospect of a new auditorium with ideas of creating a totally new form or of returning to the purity of classical models, only to find his options becoming progressively more limited, with consultants from other disciplines criticizing one feature after another. As with all buildings, structural needs can limit freedom and architectural style is a balance between respect for precedents and current fashion. But for auditorium, there are the additional constraints: In planning for good visual conditions and sightliness, of meeting certain social demands in regard to layout of seating and not least providing good acoustic conditions. The designer has to remain continually aware of the relationship he is creating between performer and audience, striving to make it as intimate as possible. Designing auditorium is a complex, elaborate but highly constrained exercise.

All auditorium rely on both visual and acoustic stimulation. At the scale of concert halls acoustic reflections are no less significant in creating a sense of space, but the ear does not perceive as discrete events or echoes the thousands of reflections it receives. It blends them into a total experience. Only certain aspects of the sound are used to establish the size and character of the enclosed space.

TYPES OF AUDITORIUM

The types of auditorium mainly varies according to the kind of activities and differ for concerts, ballet, opera, plays, etc. The size and shape of auditorium is Designed according to visual and acoustical limits. In this we have discussed about different types of auditorium which are convenient for all types of performances.

Auditorium is classified as:
1. Open stage
2. Picture-frame stage

Open stage:

The open stage are of different shapes depending upon the degree of encirclement

1. 360' Encirclement:

The acting area is surrounded on all sides by audience. This form is also called centre stage or island stage. Entrances are made through the audience or from under the stage. There is no scenic background to the acting area and no problem of horizontal sight lines.

2. 210'-220' Encirclement:

Entrances to the acting area can be made from a vertical wall or platform on the open side, but the principal acting area is at the focus of the seating.

3. 180' Encirclement:

In this type emphasis has been made towards the back wall which form the boundary of the acting area. Extreme sight lines exclude any action behind the back wall.

4. 90' Encirclement:

This arrangement allows most of the action to be seen against stage walls or a scenic background rather than against members of the audience. It is a form with many possible variations allowing more extensive use of scenery than on thrust stages but still limited by the extreme sight lines.

5. Zero encirclement:

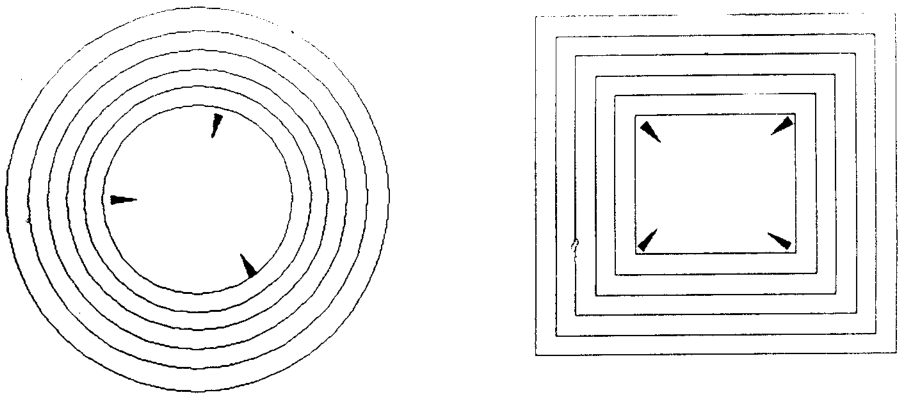
It consists of an open stage in as much as the acting area and the audience are within the same space. It is not sight lines which limit the use of scenery but the physical limitations of the structure. It is also called as end stage. The end stage conditions comes because of the restrictions imposed by an existing shell or by a consciously chosen structure.

6. Space stage:

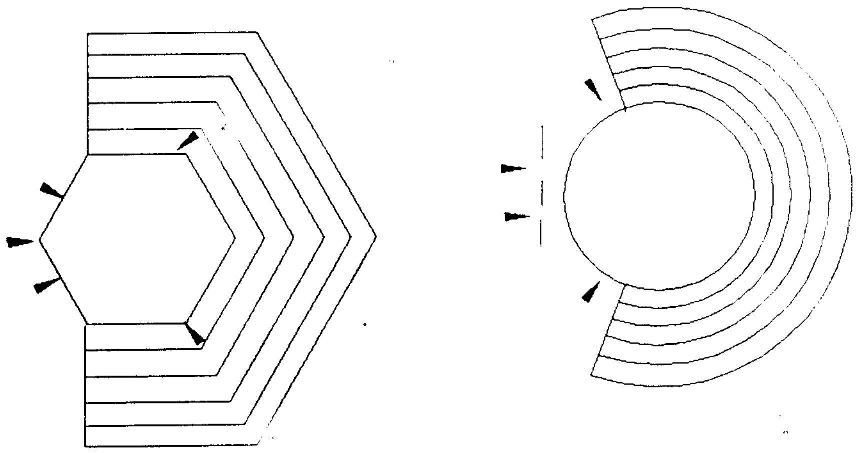
The term used when the stage is carried partly round the audience. The useful acting area is not really enlarged and the sides of the stage are not clearly defined but merges with the auditorium. Extreme side stages cannot have ideal sight lines from all seats.

Picture frame stage:

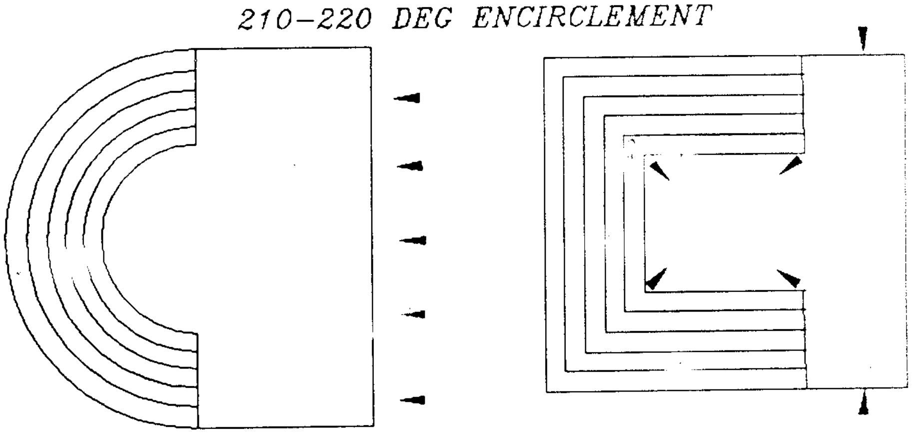
In this type there is an actual picture frame all round the proscenium opening. Here the action takes place within a room from which the fourth wall has been removed for the convenience of an audience of voyeurs. Its main advantage is its ability to contrive elaborate scenic effects and transformations the mechanics of which can be concealed from the audience. Because of the geometry of sight lines it is difficult to arrange large audience close to a picture-frame stage as the width of the proscenium opening. If the opening is made very large the expense of filling it with scenery becomes a burden. If the sight lines are designed for the wide opening, masking the sides in will interfere with the view from side seats.



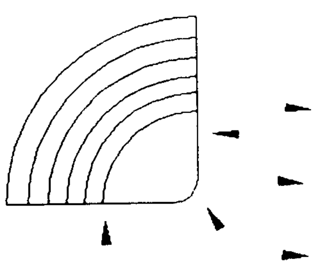
360 DEG. ENCIRCLEMENT



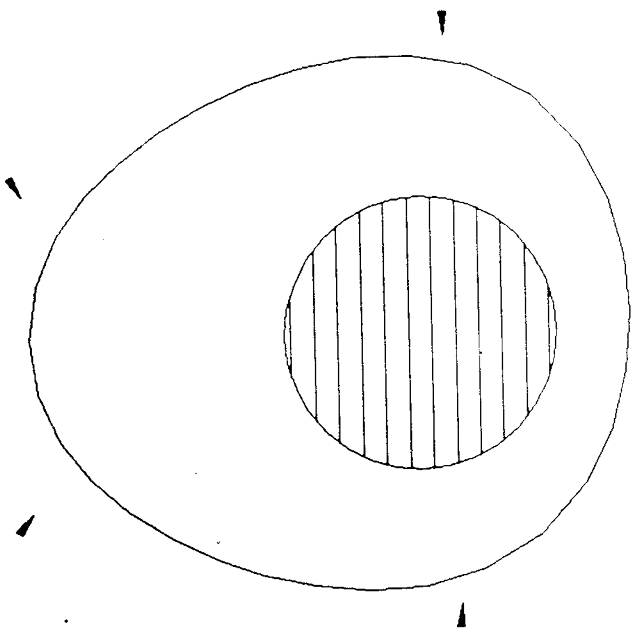
210–220 DEG ENCIRCLEMENT



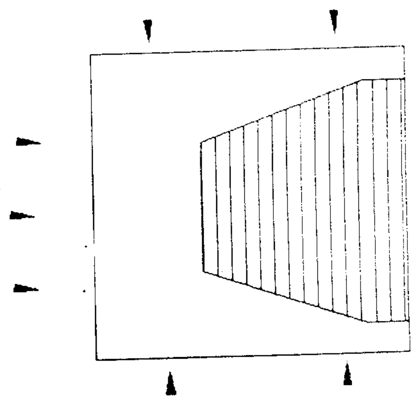
180 DEG. ENCIRCLEMENT



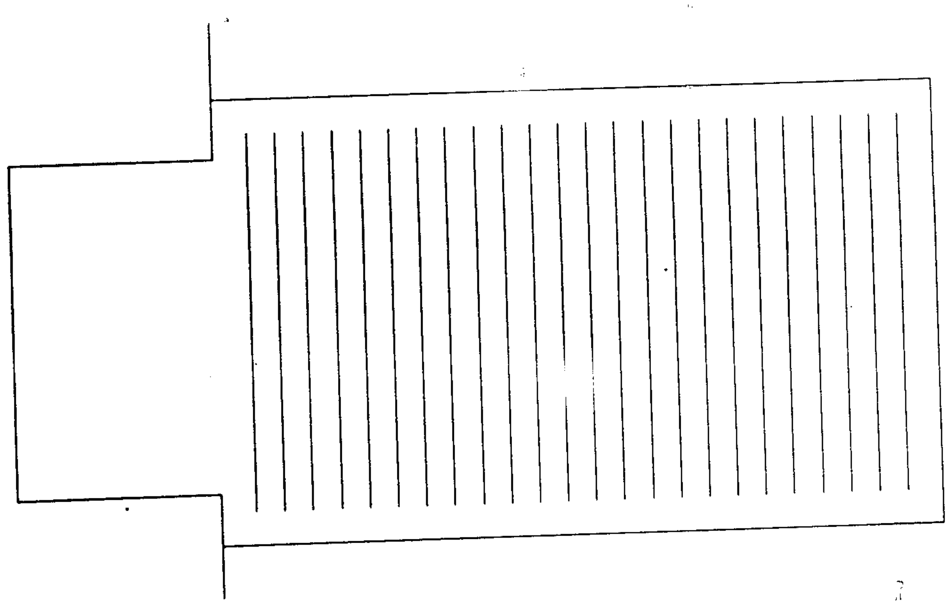
90 DEG. ENCIRCLEMENT



SPACE STAGE



SPACE STAGE



PICTURE FRAME STAGE

PLANNING OF AUDITORIUM

The size of auditorium mainly depends on the seating capacity, size of stage, production facilities to support it, public area provided etc.

Based upon seating capacity auditorium are classified as below:

1. Very large 1500 or more seats.
2. Large 900-1500 seats.
3. Medium 500-900 seats.
4. Small under 500 seats.

Factors to be considered while arriving seating capacity:

The capital cost of a auditorium does not depend mainly upon the number of seats. but also the many different standards of space, technical equipment and amenity which different buildings required for this purpose. Also every form of audience to stage relationship should be aimed. The capacity should be derived from the visual and acoustic limits for a particular kind of performance and the form of auditorium to stage relationship. The seating capacity should be related to the size of the town or catchment area in which the auditorium is to be situated.

Seating arrangements

The selection of seats is generally made from standard specifications. The choice largely depends on relative comforts, functional utility and authentic design. Some special or purposely designed furniture are used to its importance. The seating arrangement is also done considering the future replacements.

Viewing criteria

In addition to the requirements of good acoustic, the auditorium design must ensure that each person has a good view or any projections, screens and other visual aids which may be used. The viewing angle is defined as the angle described in the centre of the screen by the viewers' sight- line and the production axis for good quality viewing, it is better to take the extreme edge of the image rather than the center in order to minimise distortion towards the far edge. The maximum viewing angle is usually taken as 45°, giving an image distortion ratio between line and perceived image.

Type of production

There is a wide range of production which may have to be provided for in a auditorium. They are as follows:

Drama:

The average straight play seldom has a cast of more than 12, but it can be from 2 to 20.

Grand opera, full-scale ballet, musicals, pantomime:

These activities involve singers, dancers and chorus. The style of production and scenery is usually spectacular and generally implies a proscenium stage form.

Chamber opera, chamber ballet, music hall and variety, cabaret, plays with music:

The cast is not likely to be more numerous than for straight drama, but proper arrangements must be made for musicians.

Concerts:

A symphony orchestra averages about 90 players, but may be 120 or more. Chamber concerts including jazz, pop and folk music will normally be limited to ten to twelve musicians but occasionally they may number forty or fifty.

Recitals are the smallest scale of musical performance with not more than four or five performers.

Choral concerts may require space for 200-400 singers, or even more on special occasions, in addition to a large orchestra.

Size of orchestra:

Most auditorium should make provision for a small orchestra of about ten to twelve players, though when the principal use is for drama, there will seldom be more than two or three musicians.

A medium orchestra would be up to about forty players which would be sufficient for most operas and ballets. A full orchestra may number 120 for some operas.

STRUCTURAL DESIGN

In accordance with the present trend in the field we have chosen Limit State Method for the design of structural members.

An introduction to the limit state method is given below.

The main object of limit state method is to achieve an acceptable probability that a structure will not become unservicable in its life time that is, it will not reach a limit state. A structure with appropriate degree of reliability should be able to withstand safely all loads that are liable to act on it throughout its life and it should also satisfy the servicability requirements, such as limitations on deflection and cracking.

In the limit state design, the loads, permissible stress and factor of safety are determined based on observation taken over a period of time. In this method stress as an element are obtained from the design loads including the load factors and compared with the design strength including the safety factors. This method is based on physical parameters. The partial safety factors are based on statistical and probilistic grounds and can be controlled. thus it is a more scientific approach for the design of reinforced concrete structures.

FRAME ANALYSIS
FRAME 1

MEMBER	NODE	AXIAL FORCE	SHEAR FORCE	BENDING MOMENT
1	1	83.5140	-9.5697	-0.3840
	9	-83.5140	9.5697	9.9538
2	2	351.0029	-8.9881	0.0779
	10	-351.0029	8.9881	8.9103
3	3	333.5942	5.2044	-2.7306
	11	-333.5942	-5.2044	-2.4738
4	4	324.8578	1.1550	-0.6723
	12	-324.8578	-1.1550	-0.4827
5	5	324.8768	-1.0931	0.6395
	13	-324.8768	1.0931	0.4536
6	6	333.0789	-5.0384	2.6548
	14	-333.0789	5.0384	2.3836
7	7	351.7470	8.8999	-0.0419
	15	-351.7470	-8.8999	-8.8580
8	8	83.1830	9.4302	0.3881
	16	-83.1830	-9.4302	-9.8183
9	9	53.2070	-3.8836	8.3878
	17	-53.2070	3.8836	9.0883
10	10	260.2246	-3.5309	7.4733
	18	-260.2246	3.5309	8.4159
11	11	223.1334	0.1226	-0.0445
	19	-223.1334	-0.1226	-0.5072
12	12	215.5647	-0.0936	0.2116
	20	-215.5647	0.0936	0.2096
13	13	215.5814	0.0852	-0.1855
	21	-215.5814	-0.0852	-0.1977
14	14	222.7253	-0.1217	0.0527
	22	-222.7253	0.1217	0.4949

15	15	260.5417	3.5514	-7.4874
	23	-260.5417	-3.5514	-8.4937
16	16	53.1969	3.8708	-8.3234
	24	-53.1969	-3.8708	-9.0952
17	17	21.5047	-7.1605	12.0150
	25	-21.5047	7.1605	13.7629
18	18	171.4084	-4.0568	8.2680
	26	-171.4084	4.0568	6.3365
19	19	111.7800	0.7510	-1.5047
	27	-111.7800	-0.7510	-1.1989
20	20	106.5864	0.0104	0.0244
	28	-106.5864	-0.0104	-0.0620
21	21	106.5987	-0.0607	0.0733
	29	-106.5987	0.0607	0.1453
22	22	111.5041	-0.7850	1.5703
	30	-111.5041	0.7850	1.2557
23	23	171.5057	4.1076	-8.3296
	31	-171.5057	-4.1076	-6.4576
24	24	21.6083	7.1942	-12.0380
	32	-21.6083	-7.1942	-13.8609
25	26	115.9145	-5.4669	8.1332
	33	-115.9145	5.4669	10.7276
26	27	40.2182	1.0539	-1.3680
	34	-40.2182	-1.0539	-2.2681
27	28	36.6284	-0.1693	0.1948
	35	-36.6284	0.1693	0.3892
28	29	36.6416	0.1029	-0.0879
	36	-36.6416	-0.1029	-0.2672
29	30	40.0333	-1.0873	1.4303
	37	-40.0333	1.0873	2.3210
30	31	116.0638	5.5667	-8.3058
	38	-116.0638	-5.5667	-10.8992

31	9	5.6862	30.3071	-18.3416
	10	-5.6862	37.5329	31.5178
32	10	11.1434	53.2453	-48.2013
	11	-11.1434	55.9547	54.7037
33	11	6.0616	54.5063	-52.1854
	12	-6.0616	54.6937	52.6353
34	12	4.8130	54.5994	-52.3642
	13	-4.8130	54.6006	52.3673
35	13	5.9912	54.6949	-52.6354
	14	-5.9912	54.5051	52.1800
36	14	10.9079	55.8485	-54.6163
	15	-10.9079	53.3515	48.3737
37	15	5.5594	37.8539	-32.0283
	16	-5.5594	29.9861	18.1417
38	17	-3.2770	31.7024	-21.1033
	18	3.2770	36.1376	29.3751
39	18	-3.8028	52.6790	-46.0589
	19	3.8028	56.5210	55.2798
40	19	-3.1744	54.8326	-53.2679
	20	3.1744	54.3674	52.1516
41	20	-3.0703	54.6110	-52.3856
	21	3.0703	54.5890	52.3327
42	21	-3.2162	54.3939	-52.2084
	22	3.2162	54.8061	53.1977
43	22	-3.8795	56.4153	-55.2628
	23	3.8795	52.7847	46.1865
44	23	-3.3233	36.2514	-29.3631
	24	3.3233	31.5886	21.1332
45	25	7.1605	21.5047	-13.7629
	26	-7.1605	21.9953	14.6780
46	26	5.7504	33.4994	-29.1477
	27	-5.7504	36.5006	36.3508

47	27	6.0533	35.0617	-33.7839
	28	-6.0533	34.9383	33.4876
48	28	5.8736	35.0205	-33.6205
	29	-5.8736	34.9795	33.5223
49	29	6.0373	34.9781	-33.5796
	30	-6.0373	35.0219	33.6846
50	30	5.7350	36.4492	-36.3706
	31	-5.7350	33.5508	29.1244
51	31	7.1941	21.8917	-14.3610
	32	-7.1941	21.6083	13.8609
52	33	5.4669	15.9145	-10.7276
	34	-5.4669	21.1855	23.3778
53	34	4.4129	19.0327	-21.1097
	35	-4.4129	18.0673	18.7927
54	35	4.5822	18.5611	-19.1819
	36	-4.5822	18.5389	19.1287
55	36	4.4793	18.1026	-18.8615
	37	-4.4793	18.9974	21.0089
56	37	5.5666	21.0361	-23.3298
	38	-5.5666	16.0639	10.8992

FRAME 2

MEMBER	NODE	AXIAL FORCE	SHEAR FORCE	BENDING MOMENT
1	1	240.3894	-30.4704	4.3217
	7	-240.3894	30.4704	26.1488
2	2	317.1349	11.1994	-5.6347
	8	-317.1349	-11.1994	-5.5647
3	3	304.8328	2.0708	-1.2364
	9	-304.8328	-2.0708	-0.8343
4	4	304.8328	-2.0708	1.2364
	10	-304.8328	2.0708	0.8343
5	5	317.1355	-11.1994	5.6347
	11	-317.1355	11.1994	5.5647
6	6	240.3898	30.4705	-4.3217
	12	-240.3898	-30.4705	-26.1488
7	7	188.8078	-7.4228	16.5545
	13	-188.8078	7.4228	16.8481
8	8	205.0203	-0.2503	0.5917
	14	-205.0203	0.2503	0.5344
9	9	195.5291	-0.1808	0.4213
	15	-195.5291	0.1808	0.3926
10	10	195.5291	0.1809	-0.4213
	16	-195.5291	-0.1809	-0.3926
11	11	205.0208	0.2503	-0.5918
	17	-205.0208	-0.2503	-0.5345
12	12	188.8083	7.4228	-16.5545
	18	-188.8083	-7.4228	-16.8481
13	13	137.3222	-27.3385	25.4385
	19	-137.3222	27.3385	21.0370
14	14	92.8049	6.9832	-5.5167
	20	-92.8049	-6.9832	-6.3547

15	15	86.2314	0.8311	-0.7734
	21	-86.2314	-0.8311	-0.6395
16	16	86.2313	-0.8313	0.7735
	22	-86.2313	0.8313	0.6397
17	17	92.8054	-6.9835	5.5169
	23	-92.8054	6.9835	6.3550
18	18	137.3223	27.3390	-25.4386
	24	-137.3223	-27.3390	-21.0377
19	19	99.9993	0.0000	0.0000
	25	-99.9993	0.0000	0.0000
20	24	99.9996	0.0000	0.0000
	26	-99.9996	0.0000	0.0000
21	25	99.9999	0.0000	0.0000
	27	-99.9999	0.0000	0.0000
22	26	100.0000	0.0000	0.0000
	28	-100.0000	0.0000	0.0000
23	7	23.0476	51.5815	-42.7033
	8	-23.0476	57.6185	57.1919
24	8	11.5980	54.4963	-52.2190
	9	-11.5980	54.7037	52.7169
25	9	9.3464	54.6000	-52.3039
	10	-9.3464	54.6000	52.3039
26	10	11.5980	54.7037	-52.7169
	11	-11.5980	54.4963	52.2190
27	11	23.0477	57.6185	-57.1919
	12	-23.0477	51.5815	42.7033
28	13	-19.9157	51.4861	-42.2867
	14	19.9157	57.7139	57.2334
29	14	-12.6823	54.5019	-52.2511
	15	12.6823	54.6981	52.7220
30	15	-11.6703	54.6000	-52.3412
	16	11.6703	54.6000	52.3412

31	16	-12.6824	54.6981	-52.7221
	17	12.6824	54.5019	52.2510
32	17	-19.9162	57.7139	-57.2334
	18	19.9162	51.4861	42.2867
33	19	27.3385	37.3238	-21.0371
	20	-27.3385	49.2202	49.5883
34	20	20.3553	43.5847	-43.2336
	21	-20.3553	42.9593	41.7327
35	21	19.5241	43.2720	-41.0932
	22	-19.5241	43.2720	41.0931
36	22	20.3554	42.9593	-41.7328
	23	-20.3554	43.5847	43.2338
37	23	27.3389	49.2206	-49.5888
	24	-27.3389	37.3234	21.0377

FRAME 3

MEMBER	NODE	AXIAL FORCE	SHEAR FORCE	BENDING MOMENT
1	1	134.6205	-88.3271	10.2062
	5	-134.6205	88.3271	78.1209
2	2	244.6305	104.5486	-62.0859
	6	-244.6305	-104.5486	-42.4627
3	3	205.4016	48.8310	-40.2877
	7	-205.4016	-48.8310	-8.5432
4	4	200.0666	44.1287	-44.6100
	8	-200.0666	-44.1287	0.4813
5	5	55.6433	12.2953	-17.5108
	9	-55.6433	-12.2953	-37.8182
6	6	100.4637	37.0462	-86.7207
	10	-100.4637	-37.0462	-79.9869
7	7	100.2175	20.4771	-54.9409
	11	-100.2175	-20.4771	-37.2058
8	8	127.9948	39.3626	-88.6776
	12	-127.9948	-39.3626	-88.4543
9	10	26.1922	-2.2018	15.6007
	13	-26.1922	2.2018	-11.8577
10	11	83.6430	36.1019	0.5327
	14	-83.6430	-36.1019	-61.9059
11	14	22.9504	-23.7457	11.6336
	15	-22.9504	23.7457	9.7378
12	12	35.3694	23.7422	-27.1544
	16	-35.3694	-23.7422	-34.5754
13	5	100.6225	78.9772	-60.6101
	6	-100.6225	103.0228	156.7922
14	6	33.1200	41.1439	-27.6087
	7	-33.1200	68.0561	81.6129
15	7	4.7661	37.1281	-18.1288

	8	-4.7661	72.0719	88.1963
16	9	-12.2949	55.6433	37.8183
	10	12.2949	52.7567	95.1756
17	10	21.5150	51.5472	-30.7896
	13	-21.5150	57.6528	36.1593
18	11	15.6230	16.5746	36.6730
	12	-15.6230	92.6254	115.6087
19	13	59.8545	47.7073	-24.3019
	14	-59.8545	60.6927	50.2727
20	15	23.7437	22.9506	-9.7377
	16	-23.7437	35.3694	34.5755

DESIGN OF FOOTINGS

FOOTING FOR COLUMN D9:

Concrete grade M20, steel Fe415
Load on column = 193.06 KN
Size of column = 300 x 400
Bearing capacity of soil = 200 KN/m^2
Self weight of column = 10 %
= 19.31
Total load = 212.37
Area of footing = 1.5 x 212.37 / 200 = 1.59 m^2

Provide 1.2 m x 1.5 m wide footing.

Bearing pressure, q_o = 1.5 x 212.37 / (1.2 x 1.5)
= 176.98 KN/m^2

BM, Mxx = q_o x (2L + a) (B - b)^2 / 24
= 176.98 x (2 x 1.5 + 0.4) (1.2 - 0.3)^2 / 24
= 20.31 KN-m

BM, Myy = q_o x (2B + b) (L - a)^2 / 24
= 176.98 x (2 x 1.2 + 0.3) (1.5 - 0.4)^2 / 24
= 24.09 KN-m

Depth,
d_{xx} = M/(Q x a) = (20.31 x 10^6 /(0.9 x 400)
= 238 mm
d_{yy} = M/(Q x b) = (24.09 x 10^6 /(0.9 x 300)
= 299 mm.

Depth of punching shear = $\frac{170.64 \times (1.2 \times 1.5 - 0.3 \times 0.4)}{2 \times (0.3 + 0.4)}$

Overall depth = 650 mm
Effective depth = 575 mm
Depth at end = 300 mm

Ast_{xx} = Mxx /(σst x j d) = 20.31 x 10 6 / (230 x 0.9 x 575)
= 170.64 mm^2
Ast_{yy} = Myy /(σst x j d) = 24.09 x 10 6 / (230 x 0.9 x 575)
= 202.4 mm^2

Provide 10 Nos of 12 mm dia RTS bars in long direction.

ß = b / a = 0.4 / 0.3 = 0.33
Reinforcement or central band = 2 x Ast_{xx} / (1 + ß)
= 2 x 170.64 / (1 + 1.33)
= 146.5 mm^2
Balance steel = 170.64 - 146.5 = 24.2 mm^2

Provide 8 nos of 12 mm dia RTS in central band for a distance of 1.2m
Provide balance steel 8 mm dia RTS 1 Nos. on each side of central band.

Check for shear:

V = qo (L x B - (a + b) (b + d))
= 176.98 (1.2 x 1.5 - (0.4 +0.575)(0.3 + 0.575))
= 167.58 KN

Tc = V / (2 (a + d) + (b + d)) dcc
= 167.58 x 10 3 / (2 (0.4 + 0.575) + (0.3 + 0.575)) 392
= 0.115

Permissible shear stress,
Tc = Ks x Tc
= (0.5 + (300/400)) x 0.16 sqrt(20)
= 0.894 N/mm^2

Hence no shear reinforcement is necessary.

FOOTING FOR COLUMN D13:

Concrete grade M20 steel Fe415	
Load on column	= 360.3 KN
Size of column	= 300 x 400
Bearing capacity of soil	= 200 KN/m^2
Self weight of column	= 10 %
	= 36
Total load	= 396.3 KN
Area of footing	= 1.5 x 396.3 / 200 = 2.97 m^2

Provide 1.2 m x 1.5 m wide footing.

Bearing pressure, q_o = 1.5 x 396.37 / (2 x 1.5)
= 198.15 KN/m^2

Bending Moment,
Mxx = qo x (2L + a) (B - b)^2 / 24
= 198.15 x (2 x 2 + 0.4) (1.5 - 0.3)^2 / 24
= 52.31 KN-m
Myy = q_o x (2B + b) (L - a)^2 / 24
= 198.15 x (2 x 1.5 + 0.3) (2 - 0.4)^2 / 24
= 71.86 KN-m

Depth,
d_{xx} = (M/(Q x a) = (52.31 x 10^6 /(0.9 x 400)
= 381 mm
d_{yy} = (M/(Q x b) = (72.86 x 10^6 /(0.9 x 300)
= 516 mm

Depth of punching shear = $\frac{198.15 \times (1.5 \times 2.0 - 0.3 \times 0.4)}{2 \times (0.3 + 0.4)}$

= 407.6 mm

Overall depth = 600 mm
Effective depth = 525 mm

Depth at end = 300 mm

Ast_{xx} = Mxx /(σst x j d) = 52.31 x 10 6 / (230 x 0.9 x 525)
= 481 mm^2

Ast_{yy} = Myy /(σst x j d) = 71.86 x 10 6 / (230 x 0.9 x 525)
= 661 mm^2

Provide 10 Nos of 10 mm dia RTS bars in long direction.

ß = b / a = 0.4 / 0.3 = 1.33

Reinforcement or central band = 2 x Ast_{xx} / (1 + ß)
= 2 x 481 / (1 + 1.33)
= 413 mm^2

balance steel = 481 - 413 = 68 mm^2

Provide 6 nos of 10 mm dia RTS in central band for a distance of 1.2m
Provide balance steel 10 mm dia RTS 1 nos on each side of central band.

Check for shear:

V = qo (L x B - (a + b) (b + d))
= 198.15 (1.5 x 2 - (0.4 +0.525)(0.3 + 0.525))
= 247.69 KN

Tc = V / (2 (a + d) + (b + d)) dcc
= 247.69 x 10 3 / (2 (0.4 + 0.525) + (0.3 + 0.525)) 382
= 0.185 N/mm^2

Permissible shear stress,

Tc = Ks x Tc
= (0.5 + (300/400)) x 0.16 sqrt(20)
= 0.894 N/mm^2

Hence no shear reinforcement is necessary.

FOOTING FOR COLUMN H12:

Concrete grade M20 steel Fe415

Load on column	= 158 KN
Size of column	= 300 x 400
Bearing capacity of soil	= 200 KN/m^2
Self weight of column	= 10 %
	= 15.8 KN
Total load	= 173.6 KN

Area of footing = 1.5 x 173.6 / 200 = 1.3 m^2

Provide 1.2 m x 1.5 m wide footing.
Provide same design as for the footing D9.

FOOTING FOR COLUMN A2:

Concrete grade M20 steel Fe415
Load on column = 582.6 KN
Size of column = 300 x 400
Bearing capacity of soil = 200 KN/m^2
Self weight of column = 10 %
= 58.3

Total load = 640.9 KN

Area of footing = 1.5 x 640.9 / 200 = 4.81 m^2

Provide 2 m x 2.5 m wide footing.

Bearing pressure, q_o = 1.5 x 640.9 / (2 x 2.5)
= 192.27 KN/m^2

Bending Moment,

Mxx = qo x (2L + a)(B - b$)^2$ / 24
= 192.27 x (2 x 2.5 +0.4) (2 - 0.3$)^2$ / 24
= 125.02 KN-m

Myy = q_o x (2B + b) (L - a$)^2$ / 24
= 192.27 x (2 x 2 + 0.3) (2.5 - 0.4$)^2$ / 24
= 151.92 KN-m

Depth,

d_{xx} = M/(Q x a) = (125.02 x 10^6 /(0.9 x 400)
= 650 mm

d_{yy} = M/(Q x b) = (151.92 x 10^6 /(0.9 x 300)
= 750 mm

Depth of punching shear = $\frac{192.27 \times (2.5 \times 2.0 - 0.3 \times 0.4)}{2 \times (0.3 + 0.4)}$

= 670.2 mm

Overall depth = 850 mm
Effective depth = 675 mm
Depth at end = 400 mm

Ast_{xx} = Mxx /(σst x j d) = 125.02 x 10 6 / (230 x 0.9 x 675)
= 895 mm^2

Ast_{yy} = Myy /(σst x j d) = 151.92 x 10 6 / (230 x 0.9 x 675)
= 1087.3 mm^2

Provide 10 Nos of 12 mm dia RTS bars in long direction.

ß = b / a = 0.4 / 0.3 = 1.33
Reinforcement or central band = 2 x Ast_{xx} / (1 + ß)
= 2 x 875 / (1 + 1.33)
= 768 mm^2

balance steel = 895 - 768 = 127 mm^2

Provide 10 Nos of 10 mm dia RTS in central band for a distance of 2m
Provide balance steel 10 mm dia RTS 2 nos on each side of central band.

Check for shear:

V = qo (L x B - (a + b) (b + d))
= 192.27 (2.5 x 2 - (0.4 +0.675)(0.3 + 0.675))
= 567.2 KN

Tc = V / (2 (a + d) + (b + d)) dcc
= 567.2 x 10 3 / (2 (0.4 + 0.675) + (0.3 + 0.675)) 6.53
= 0.261 N/mm²

Permissible shear stress,
Tc = Ks x Tc
= (0.5 + (300/400)) x 0.16 sqrt(20)
= 0.894 N/mm²

Hence no shear reinforcement is necessary.

FOOTING FOR COLUMN D11:

Concrete grade M20 steel Fe415

Load on column	= 955.8 KN
Size of column	= 400 dia
Bearing capacity of soil	= 200 KN/m²
Self weight of column	= 10 %
	= 96 KN
Total load	= 1052 KN
Area of footing	= 1.5 x 1052 / 200 = 7.9 m²

Provide 3 m wide square footing.

Bearing pressure, q_o = 1.5 x 1052 / (3 x 3)
= 175.3 KN/m²

Side of inscribed square = 0.4 / sqrt (2)
= 0.283 m

Maximum bending moment = q_o x B (B - G ²) / 8
= 175.33 x 3 (3 - 0.283 ²) / 8
= 4.85 x 10 5 N-m

Depth = sqrt(4.85 x 10 8 / (0.9 x 500))
= 1038.2 mm

Provide D = 1110 mm
d = 1035 mm

Depth at edge = 500 mm

Ast required = 4.85 x 10 8 / (230 x 0.9 x 1035)
= 2264 mm²

Provide 16 mm dia RTS bars of 12 Nos on both ways

Check for shear

V = 175 38 (3 x 3 - (1035+0.283)+(0.1035+ 0.285)
= 1442.85

Tv = 1442.85 / (2 (.3865 + 0.3865) x 0.803
= 1.01 N/mm²

Permissible shear stress ,
= Ks x Tc
= 0.16 x sqrt(20) x (0.5 + (0.4/0.4)
= 1.07 N/mm²

Hence safe for shear.

DESIGN OF COLUMNS

COLUMN D 9

Concrete grade M20, steel Fe415
Size of column = 300 x 400 mm
Load on column = 193.06 KN
Moment = 106.75 KN-m
Unsupported length = 3.6 m.
e_{min} = l / 500 + D /30 = 17 mm < 20 mm
l / D = 3.6 x 10 ³ / 300 = 12
Hence design as short column.

$$\frac{d'}{d} = \frac{40 + 12.5}{400} = 0.13 = 0.15$$

Pu / (Fck x b x D) = 1.5 x 106.75 / (20 x 300 x 400) = 0.7
Mu / (Fck x b x D²) = 1.5 x 106.75 / (20 x 300 x 400²) = 0.2
Using chart 33, l/Fck = 0,
p = 0.8%
Ast = 0.8 x 300 x 400 / 100 = 960 mm².

Provide 6 Nos of 12 mm dia RTS bars and 2 Nos of 16 mm dia bars.

Lateral ties:

1) 16 / 4 4 mm
2) 5 mm

Provide 6 mm dia ties.

Pitch:

1) 300 mm
2) 16 x 12 = 192 mm
3) 48 x 6 = 288 mm

Provide 6 mm dia lateral ties @ 190 mm c/c.

COLUMN D13:

Concrete grade M20, steel Fe415
Size of column = 300 x 400 mm
Load on column = 360.3 KN
Moment = 43.28 KN-m
Unsupported length = 3.6 m.

e_{min} = l / 500 + D /30 = 17 mm < 20 mm

l / D = 3.6 x 10 ³ / 300 = 12

Hence design as short column.

$$\frac{d'}{d} = \frac{40 + 12.5}{400} = 0.13 = 0.15$$

Pu / (Fck x b x D) = 1.5 x 360.3 / (20 x 300 x 400) = 0.23
Mu / (Fck x b x D^2) = 1.5 x 43.28 / (20 x 300 x 400^2) = 0.07
Using chart 33, 1/Fck = 0,
p = 1.0%
Ast = 1.0 x 300 x 400 / 100 = 1200 mm^2.

Provide 6 Nos of 16 mm dia RTS bars

Lateral ties:

1) 16 / 4 = 4 mm
2) 5 mm

Provide 6 mm dia ties.

Pitch:

1) 300 mm
2) 16 x 16 = 256 mm
3) 48 x 6 = 288 mm

Provide 6 mm dia lateral ties @ 250 mm c/c.

COLUMN H12:

Concrete grade M20, steel Fe415

Size of column	= 300 x 400 mm
Load on column	= 158.00 KN
Moment	= 9.8 KN-m
Unsupported length	= 3.6 m.

e_{min} = l / 500 + D /30 = 17 mm < 20 mm

l / D = 3.6 x 10^3 / 300 = 12

Hence design as short column.

$$\frac{d'}{d} = \frac{40 + 12.5}{400} = 0.13 = 0.15$$

Pu / (Fck x b x D) = 1.5 x 150.00 / (20 x 300 x 400) = 0.09
Mu / (Fck x b x D^2) = 1.5 x 9.8 / (20 x 300 x 400^2) = 0.02
Using chart 33, 1/Fck = 0,
p = 0.8%
Ast = 0.8 x 300 x 400 / 100 = 960 mm^2.

Provide 6 Nos of 12 mm dia RTS bars and 2 Nos of 16 mm dia bars.

Lateral ties:

1) 16 / 4 = 4 mm
2) 5 mm

Provide 6 mm dia ties.

Pitch:

1) 300 mm
2) 16 x 16 = 192 mm
3) 48 x 6 = 288 mm

Provide 6 mm dia lateral ties @ 190 mm c/c.

COLUMN A2:

Concrete grade M20, steel Fe415
Size of column = 300 x 400 mm
Load on column = 582.6 KN
Moment = 8.9 KN-m
Unsupported length = 3.6 m.

e_{min} = l / 500 + D /30 = 17 mm < 20 mm

l / D = 3.6 x 10 ³ / 300 = 12

Hence design as short column.

$$\frac{d'}{d} = \frac{40 + 12.5}{400} = 0.13 = 0.15$$

Pu / (Fck x b x D) = 1.5 x 582.6 / (20 x 300 x 400) = 0.36
Mu / (Fck x b x D^2) = 1.5 x 8.9 / (20 x 300 x 400^2) = 0.01
Using chart 33, 1/Fck = 0,
p = 0.8%
Ast = 0.8 x 300 x 400 / 100 = 960 mm^2.

Provide 6 Nos of 12 mm dia RTS bars and 2 Nos of 16 mm dia bars.

Lateral Ties

1) 16 / 4 = 4 mm
2) 5 mm

Provide 6 mm dia ties.

Pitch

1) 300 mm
2) 16 x 12 = 192 mm
3) 48 x 6 = 288 mm

Provide 6 mm dia lateral ties @ 190 mm c/c.

COLUMN D11:

Concrete grade M20, steel Fe415
Size of column = 400 mm dia
Load on column = 955.8 KN
Moment, Mxx = 57.87 KN-m, Myy = 1.24 KN-m
Unsupported length = 3.6 m.

e_{min} = l / 500 + D /30 = 17 mm < 20 mm

l / D = 3.6 x 10^3 / 300 = 12

Hence design as short column.

Assume p = 3%
p / Fck = 0.15
Uniaxial moment capacity of section about xx axis

$$\frac{d'}{d} = \frac{52.5}{400} = 0.13 = 0.15$$

Refer chart 57,

Pu / (Fck x D^2) = 955.8 x 1.5 / (20 x 400^2) = 0.45
Mu / (Fck x D^3) = 0.78
Mux1 = 0.78 x 20 x 400^3 = 998.4 KN-m
Muy1 = 998.4 KN-m
Referring chart 63, corresponding to p= 3, Fy = 415, Fck = 20,
Puz / Ag = 18
Puz = 2262 KN.
Pu / Puz = 995.8 x 1.5 / 2262 = 0.66
Mux / Mux1 = 55.87 / 998.4 = 0.084
Muy / Muy1 = 1.24 / 998.4 = 0.002
Refer chart 64,
Mux / Mux1 = 0.99
Ast = 3 x (354 x 354) / 100 = 3764 mm^2

Provide 12 Nos of 20 mm dia RTS bars.

Lateral ties:

1) 16 / 4 = 4 mm
2) 8 mm

Provide 6 mm dia ties.

Pitch:

1) 300 mm
2) 16 x 12 = 192 mm
3) 48 x 8 = 288 mm

Provide 8 mm dia lateral ties @ 190 mm c/c.

COLUMN D12:

Concrete grade M20, steel Fe415
Size of column = 400 mm dia
Load on column = 1098 KN
Moment, Mxx = 38.7 KN-m, Myy = 0.7 KN-m
Unsupported length = 3.6 m.

e_{min} = l / 500 + D /30 = 17 mm < 20 mm

$l / D = 3.6 \times 10^3 / 300 = 12$

Hence design as short column.

Assume p = 3%
p / Fck = 0.15
Uniaxial moment capacity of section about xx axis

$$\frac{d'}{d} = \frac{52.5}{400} = 0.13 = 0.15$$

Refer chart 57,

$Pu / (Fck \times D^2) = 1098 \times 1.5 / (20 \times 400^2) = 0.52$
$Mu / (Fck \times D^3) = 0.065$
$Mux1 = 0.065 \times 20 \times 400^3 = 83.2$ KN-m
$Muy1 = 83.2$ KN-m
Referring chart 63, corresponding to p= 3, Fy = 415, Fck = 20.
Puz / Ag = 18
Puz = 2262 KN.
Pu / Puz = 1098 x 1.5 / 2262 = 0.73
Mux / Mux1 = 38.7 / 83.2 = 0.47
Muy / Muy1 = 1.24 / 83.2 = 0.02
Refer chart 64,
Mux / Mux1 = 0.98
Ast = 3 x (354 x 354) / 100 = 3764 mm^2

Provide 12 Nos of 20 mm dia RTS bars.

Lateral ties:

1) 16 / 4 = 4 mm
2) 8 mm

Provide 8 mm dia ties.

Pitch:

1) 400 mm
2) 16 x 12 = 192 mm
3) 48 x 8 = 384 mm

Provide 8 mm dia lateral ties @ 190 mm c/c.

COLUMN D2:

Concrete grade M20, steel Fe415
Size of column = 400 mm dia
Load on column = 200 KN
Moment, Mxx = 43.68 KN-m, Myy = 30.33 KN-m
Unsupported length = 3.6 m.

$e_{min} = l / 500 + D / 30 = 17$ mm < 20 mm

$l / D = 3.6 \times 10^3 / 300 = 12$

Hence design as short column.

Assume p = 1%

p / Fck = 0.04

Uniaxial moment capacity of section about xx axis

$$\frac{d'}{d} = \frac{52.5}{400} = 0.13 = 0.15$$

Refer chart 57,

Pu / (Fck x D^2) = 200 x 1.5 / (20 x 400^2) = 0.09

Mu / (Fck x D^3) = 0.113

Mux1 = 0.053 x 20 x 400^3 = 144.64 KN-m

Muy1 = 144.64 KN-m

Referring chart 63, corresponding to p= 3, Fy = 415, Fck = 20,

Puz / Ag	= 12
Puz	= 1508 KN.
Pu / Puz	= 200 x 1.5 / 1508 = 0.21
Mux / Mux1	= 43.68 / 144.64 = 0.45
Muy / Muy1	= 30.33 / 144.64 = 0.31

Refer chart 64,

Mux / Mux1 = 0.8

Ast = 1 x 283x283 / 100 = 801 mm^2

Provide 8 Nos of 12 mm dia RTS bars.

Lateral ties:

1) 16 / 4 = 4 mm
2) 8 mm

Provide 8 mm dia ties.

Pitch:

1) 300 mm
2) 16 x 12 = 192 mm
3) 48 x 8 = 384 mm

Provide 8 mm dia lateral ties @ 190 mm c/c.

SCHEDULE OF COLUMNS

COLUMN NO	SIZE (mm)	TOTAL BARS No of Bars-Dia	LATERAL TIES Dia- Spacing
D9	300x400	6 - 12mm 2 - 16mm	6-190mm c/c
D13	300x400	6 - 16mm	6-250mm c/c
H12	300x400	6 - 12mm 2 - 16mm	6-190mm c/c
A2	300x400	6 - 12mm 2 - 16mm	6-190mm c/c
D11	400 dia	12 - 20mm	8-190mm c/c
D12	400 dia	12 - 20mm	8-190mm c/c
D2	400 dia	8 - 12mm	8-190mm c/c

DESIGN OF BEAMS

BEAM B1:

Concrete Grade M15, Steel Fe415

Span = 4.8 m

Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	=	0.23 x 0.45 x 25	= 2.59
Load from side corridor	=	6.25 x 5.56 / 4.8	= 7.24
Load from brick wall	=	3.3 x 0.23 x 20	= 13.8
Total Load			= 23.64 KN/m

Factored BM $= \frac{1.5 \times 24 \times 4.8^2}{12} = 69.12$ KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as singly reinforced beam

$\frac{Mu}{bd^2} = \frac{69.12 \times 10^6}{230 \times) / 8} = 1.74 KN/mm^2$

$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$

Ref Table 1

$P_t = 0.576$

$A_{st} = \frac{0.576 \times 230 \times 415}{100} = 549.8 mm^2$

$A_{sc} = \frac{0.016 \times 230 \times 415}{100} = 16 mm^2$

Provide 3 numbers of 16 mm dia rts at bottom.
Provide 2 numbers of 10 mm dia rts at top.

SHEAR

Maximum Shear Force = 24 x 4.8 = 57.6 KN

Vu = 1.5 x 57.6 = 86.4 KN

Shear stress $= \frac{86.4 \times 10^3}{230 \times 415} = 0.905 < T_c$

Ref Table 33, For $P_t = 0.576$, $T_c = 0.490$

Shear to be carried by stirrups $= 86.4 - \frac{0.49 \times 230 \times 415}{1000}$

$= 39.63$ KN

$$\frac{V}{d} = \frac{39.63}{41.5} = 0.955 \text{ KN/cm}$$

From Table 62

Provide 6 mm dia rts bars at 200 mm c/c.

BEAM B2 :

Concrete Grade M15, Steel Fe415

Span = 4.0 m

Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	=	0.23 x 0.45 x 25	= 2.59
Parapet wall	=	0.23 x 1 x 20	= 4.60
Load from side corridor	=	9.75 x 3.98 / 4.0	= 9.70
Load from sunshade	=	0.75 x 0.075 x 25	= 1.41
Total Load			= 18.30 = 19 KN/m
Factored BM	=	$\frac{1.5 \times 19 \times 4^2}{12}$	= 38 KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as singly reinforced beam

$$\frac{Mu}{bd^2} = \frac{38 \times 10^6}{230 \times 415^2} = 0.9593 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 \approx 0.1$$

From Table 1, $P_t = 0.288$

$$A_{st} = \frac{0.288 \times 230 \times 415}{100} = 218.29 \text{ mm}^2$$

Provide 3 numbers of 10 mm dia rts at bottom.

Provide 2 numbers of 10 mm dia rts at top.

SHEAR

Maximum Shear Force = 19 x 4 / 2 = 38 KN

V_u = 1.5 x 38 = 57 KN

Shear stress = $\frac{57.0 \times 10^3}{230 \times 415}$ = 0.597 < T_c max

Ref Table 61, For $P_t = 0.288$, $T_c = 0.373$

Shear to be carried by stirrups = $57 - \frac{0.373 \times 230 \times 415}{1000}$

= 21.38 KN

$$\frac{V_{us}}{d} = \frac{21.380}{41.5} = 0.515 \text{ KN/cm}$$

From Table 62

Provide 6 mm dia rts bars at 200 mm c/c.

BEAM B3 :

Concrete Grade M15, Steel Fe415
Span = 4.0 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Parapet wall	= 0.23 x 1 x 20	= 4.60
Load from side corridor	= 6.25 x 3.98 / 4.0	= 6.22
Load from sunshade	= 0.75 x 0.075 x 25	= 1.41
Total Load		= 14.82 KN/m
		= 15 KN/m

Factored BM $= \frac{1.5 \times 15 \times 4^2}{12} = 30$ KN m

Adopt same design as for B2

BEAM B4:

Concrete Grade M15, Steel Fe415
Span = 4.8 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Load from mezzanine floor	= 9.625 x 5.6/4 x 2	= 26.95
Total Load		= 29.54 =30 KN/m

Factored BM $= \frac{1.5 \times 30 \times 4.8^2}{12} = 86.4$ KN m

$Mu_{lim} = 2.07 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as doubly reinforced beam

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as singly reinforced beam

$$\frac{Mu}{bd^2} = \frac{86.4 \times 10^6}{230 \times 415^2} = 2.18 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$$

From Table 1, P_t = 0.726

A_{st} = $\frac{0.751 \times 230 \times 415}{100}$ = 716.64 mm^2

A_{sc} = $\frac{0.034 \times 230 \times 415}{100}$ = 33.02 mm^2

Provide 4 numbers of 16 mm dia rts at bottom.
Provide 2 numbers of 12 mm dia rts at top.

SHEAR

Maximum Shear Force = 30 x 4.8 / 2 = 72 KN

V_u = 1.5 x 72 = 108 KN

Shear stress = $\frac{108 \times 10^3}{230 \times 415}$ = 1.13 < T_c max

Ref Table 61, For P_t = 0.751, T_c = 0.54

Shear to be carried by stirrups = 108 - $\frac{0.54 \times 230 \times 415}{1000}$

= 56.46 KN

$\frac{V_{us}}{d}$ = $\frac{49.83}{41.5}$ = 1.20 KN/cm

From Table 62

Provide 6 mm dia rts bars at 160 mm c/c.

BEAM B5:

Concrete Grade M15, Steel Fe415
Span = 4.8 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Load from brick wall	= 0.23 x 3 x 20	= 13.80
Load from side corridor	= 9.625 x 5.56 / 4.8	= 11.15
Total Load		= 27.54 =28 KN/m
Factored BM	= $\frac{1.5 \times 28 \times 4^2}{12}$	= 80.64 KN m

Adopt same design as for B4

BEAM B6:

Concrete Grade M15, Steel Fe415
Span = 4 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59	
Load from mezzanine floor	= 9.625 x 5.6 /4.8	= 11.23	
Load from side corridor	= 9.75 x 3.98 / 4	= 9.70	
Total Load		= 23.52	= 24 KN/m

Factored BM $= \frac{1.5 \times 24 \times 4^2}{12} = 48$ KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as singly reinforced beam

$\frac{Mu}{bd^2} = \frac{48 \times 10^6}{230 \times 415^2} = 1.21$ KN/mm²

$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$

From Table 1, $P_t = 0.371$

$A_{st} = \frac{0.371 \times 230 \times 415}{100} = 354.12$ mm²

Provide 4 numbers of 12 mm dia rts at bottom.
Provide 2 numbers of 12 mm dia rts at top.

SHEAR

Maximum Shear Force $= 24 \times 4 / 2 = 48$ KN

$V_u = 1.5 \times 48 = 72$ KN

Shear stress $= \frac{72 \times 10^3}{230 \times 415} = 0.754 < T_c$ max

Ref Table 61, For $P_t = 0.371$, $T_c = 0.43$

Shear to be carried by stirrups $= 72 - 0.43 \times \frac{230 \times 415}{1000}$

$= 30.96$ KN

$\frac{V_{us}}{d} = \frac{30.96}{41.5} = 0.746$ N/cm

From Table 62
Provide 6 mm dia rts bars at 250 mm c/c.

BEAM B7:

Concrete Grade M15, Steel Fe415
Span = 4.8 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Load from brick wall	= 0.23 x 1 x 20	= 4.6
Load from mezzanine floor	= 9.625 x 5.6 / 4.8	= 11.15
Total Load		= 18.42 = 19 KN/m

$$\text{Factored BM} = \frac{1.5 \times 19 \times 4.8^2}{12} = 54.92 \text{ KN m}$$

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 =$ 82 KN m

Hence design as singly reinforced beam

$$\frac{Mu}{bd^2} = \frac{54.92 \times 10^6}{230 \times 415^2} = 1.38 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$$

From Table 1, $P_t = 0.435$

$$A_{st} = \frac{0.435 \times 230 \times 415}{100} = 415.21 \text{ mm}^2$$

Provide 3 numbers of 16 mm dia rts at bottom.
Provide 2 numbers of 12 mm dia rts at top.

SHEAR

Maximum Shear Force = 19 x 4.8 / 2 = 45.6 KN
V_u = 1.5 x 45.6 = 68.4 KN

$$\text{Shear stress} = \frac{68.4 \times 10^3}{230 \times 415} = 0.72 < T_c \max$$

Ref Table 61, For $P_t = 0.435$, $T_c = 0.4405$
Shear to be carried by stirrups $= 68.4 - \frac{0.440 \times 230 \times 415}{1000}$

= 26.35 KN

$$\frac{V_{us}}{d} = \frac{49.83}{41.5} = 0.64 \text{ KN/cm}$$

From Table 62
Provide 6 mm dia rts bars at 250 mm c/c.

BEAM B8:

Concrete Grade M15, Steel Fe415
Span = 4.8 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.590
Load from brick wall	= 0.23 x 3 x 20	= 13.800
Load from mezzanine floor	= 9.625 x 5.56 / 4.8	= 13.670
Load from portico	= 6.25 x 5.68 / 4	= 8.034
Total Load		= 38.094 = 39 KN/m
Factored BM	$= \frac{1.5 \times 39 \times 4.8^2}{12}$	= 112.32 KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as doubly reinforced beam

$$\frac{Mu}{bd^2} = \frac{112.32 \times 10^6}{230 \times 415^2} = 2.83 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$$

From Table 1, $P_t = 0.9503$, $P_c = 0.244$

$$A_{st} = \frac{0.9503 \times 230 \times 415}{100} = 907.06 \text{ mm}^2$$

$$A_{sc} = \frac{0.244 \times 230 \times 415}{100} = 232.9$$

Provide 3 numbers of 20 mm dia rts at bottom.
Provide 2 numbers of 16 mm dia rts at top.

SHEAR

Maximum Shear Force	= 39 x 4.8 / 2	= 93.6 KN
$-V_u$	= 1.5 x 93.6	= 140.4 KN
Shear stress	$= \frac{140.4 \times 10^3}{230 \times 415}$	$= 1.479 < T_c$ max

Ref Table 61, For $P_t = 0.9503, T_c = 0.585$
Shear to be carried by stirrups $= 140.4 - \frac{0.585 \times 230 \times 415}{1000}$

= 84.56 KN

$$\frac{V_{us}}{d} = \frac{84.56}{41.5} = 2.04 \text{ KN/cm}$$

From Table 62
Provide 8 mm dia rts bars at 180 mm c/c.

BEAM B9:

Concrete Grade M15, Steel Fe415
Span = 4 m
Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Load from portico	= 6.25 x 5.68 / 4	= 8.88
Total Load		= 11.47 = 12 KN/m

Factored BM $= \frac{1.5 \times 12 \times 4^2}{12} = 144$ KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as doubly reinforced beam

$$\frac{Mu}{bd^2} = \frac{144 \times 10^6}{230 \times 415^2} = 3.64 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$$

From Table 1, $P_t = 1.2$, $P_c = 0.505$

$$A_{st} = \frac{1.2 \times 230 \times 415}{100} = 1145.4 \text{ mm}^2$$

$$A_{sc} = \frac{0.505 \times 230 \times 415}{100} = 482 \text{ mm}$$

Provide 4 numbers of 12 mm dia rts at bottom.
Provide 4 numbers of 20 mm dia rts at top.

SHEAR

Maximum Shear Force = 1228 x 4 / 2 = 24 KN
V_u = 1.5 x 24 = 36 KN

$$\text{Shear stress} = \frac{36 \times 10^3}{230 \times 415} = 0.377 < T_c \max$$

Ref Table 61, For $P_t = 1.2$, $T_c = 0.63$
Shear to be carried by stirrups $= \frac{0.63 \times 230 \times 415}{1000}$
$= 60.13 \text{ KN} > V_u$

From Table 62
Provide 8 mm dia rts bars at 200 mm c/c.

BEAM B10:

Concrete Grade M15, Steel Fe415

Span = 4.8 m

Adopt thickness of beam as 0.23 x 0.45 m

LOADING:

Self weight of beam	= 0.23 x 0.45 x 25	= 2.59
Load from balcony slab	= 8.5 x 2.5 / 4.8	= 3.81
Load from cantilever slab	= 8.5 x 3.8 / 4.8	= 6.73
Total Load		= 13.13 = 14 KN/m
Factored BM	= $\frac{1.5 \times 14 \times 4.8^2}{12}$	= 40.32 KN m

$Mu_{lim} = 2.03 \times 10^6 \times 0.23 \times 0.415^2 = 82$ KN m

Hence design as singly reinforced beam

$$\frac{Mu}{bd^2} = \frac{40.32 \times 10^6}{230 \times 415^2} = 1.02 \text{ KN/mm}^2$$

$$\frac{d'}{d} = \frac{35}{415} = 0.084 = 0.1$$

From Table 1, $P_t = 0.303$

$$A_{st} = \frac{0.303 \times 230 \times 415}{100} = 289.21 \text{ mm}^2$$

Provide 3 numbers of 12 mm dia rts at bottom.
Provide 2 numbers of 12 mm dia rts at top.

SHEAR

Maximum Shear Force = 14 x 4.8 / 2 = 33.6 KN

V_u = 1.5 x 33.6 = 50.4 KN

$$\text{Shear stress} = \frac{50.4 \times 10^3}{230 \times 415} = 0.528 < T_c \max$$

Ref Table 61, For $P_t = 0.303$, $T_c = 0.38$

Shear to be carried by stirrups $= 50.4 - \frac{0.303 \times 230 \times 415}{1000}$

= 14.13 KN

$$\frac{V_{us}}{d} = \frac{14.13}{41.5} = 0.34 \text{ KN/cm}$$

From Table 62

Provide 6 mm dia rts bars at 250 mm c/c.

BEAM B11 (Balcony secondary beam)

Concrete mix M15, Steel Fe415

Span = 4.8m.

Size of beam = 230 x 450 mm

LOADING:

Self weight of beam = 0.23 x 0.45 x 25 = 2.6

Load from slab = wl/2 = 8.5 x 4.8 / 2 = 21.0

Total load = 23.6 KN/m

Factored BM,

$Mu = wl^2/10 = 1.5 \times 23.6 \times 4.8^2/10 = 81.56$ KN-m

Assume clear cover = 25mm, d = 425mm

From table d, Fy = 415N/mm², Fck = 15 N/mm²

$$\frac{Mu_{lim}}{bd^2} = 2.07 \text{ N/mm}^2 = 2.07 \times 10^3 \text{ KN/m}^2$$

$$Mu_{lim} = 2.07 \times 10^3 \times bd^2$$
$$= 2.07 \times 10^3 \times 0.23 \times 0.425^2 = 86 \text{ KN} > Mu.$$

Hence design as singly reinforced beam.

$$\frac{Mu}{b} = 81.56 / 0.23 = 354.61 \text{ KN-m} = 355 \text{ KN-m}.$$

Refer chart5 corresponding to Mu/b = 355 KN-m.

d = 0.425 = 42.5 cm

Percentage of steel:

pt = 100 As / (b x d²) = 0.67

As = 0.67 x b x d / 100 = 655 mm²

Provide 4 Nos of 12 mm dia RTS bars at bottom.

Provide 2 Nos of 12 mm dia bars at top.

SHEAR

Maximum Shear Force = 23.6 x 4.8 / 2 = 56.64 KN

V_u = 1.5 x 56.64 = 84.96 KN

$$\text{Shear stress} = \frac{84.96 \times 10^3}{230 \times 415} = 0.87 < T_c \text{ max}$$

Ref Table 61, For $P_t = 0.67$, $T_c = 0.52$

Shear to be carried by stirrups $= 86.96 - \frac{0.52 \times 230 \times 425}{1000}$

= 34.03 KN

$$\frac{V_{us}}{d} = \frac{34.03}{42.5} = 0.8 \text{ KN/cm}$$

From Table 62

Provide 6 mm dia RTS bars at 150 mm c/c.

BEAM B12 (Balcony main beam)

Concrete mix M15, Steel Fe415
Size of beam = 300 x 600 mm

LOADING:

Self weight of beam = 0.30 x 0.60 x 25 = 4.5 KN/m²
in slanting length

Self weight in plan length = 4.5 x 1.044 = 4.7 KN/m²

Load from slab = 23.6 x 4.8 = 113.3
Total load on slab = 7 x 113.3 = 793.1 KN/m
Load on slab per meter length = 793.1 / 8 = 103.8 KN/m
Factored BM,

$Mu = wl^2/10 = 1.5 \times 103.8 \times 4.8^2/10 = 358.7 = 370$ KN-m

Assume clear cover = 30 mm, d = 570 mm
From table d, Fy = 415N/mm², Fck = 15 N/mm²

$$\frac{Mu_{lim}}{bd^2} = 2.07 \text{ N/mm}^2 = 2.07 \times 10^3 \text{ KN/m}^2$$

$$Mu_{lim} = 2.07 \times 10^3 \times bd^2$$
$$= 2.07 \times 10^3 \times 0.3 \times 0.55^2 = 187.8 \text{ KN} < Mu.$$

Hence design as doubly reinforced beam.

$$\frac{Mu}{bd^2} = \frac{360 \times 10^6}{300 \times 562.5^2} = 3.97 \text{ N/mm}^2$$

$$\frac{d'}{d} = \frac{50}{550} = 0.09 = 0.1$$

Refer chart 49,

pt = 1.302, pc = 0.611

$$Ast = \frac{1.302 \times 300 \times 550}{100} = 2148.3 \text{ mm}^2$$

$$Asc = \frac{0.611 \times 300 \times 550}{100} = 1008.2 \text{ mm}^2$$

Provide 7 Nos of 20 mm dia RTS bars at bottom.
Provide 3 Nos of 20 mm dia bars at top.

SHEAR

Maximum Shear Force = 103.8 x 4.8 / 2 = 249.12 KN
V_u = 1.5 x 249.12 = 373.7 KN

$$\text{Shear stress} = \frac{373.7 \times 10^3}{300 \times 550} = 2.27 < T_c \max$$

Ref Table 61, For P_t = 1.302, T_c = 0.6504

Shear to be carried by stirrups $= 373.7 - \frac{0.6504 \times 300 \times 550}{1000}$

$= 266.38$ KN

$$\frac{V_{us}}{d} = \frac{266.38}{55} = 4.84 \text{ KN/cm}$$

From Table 62

Provide 10 mm dia RTS bars at 110 mm c/c.

SCHEDULE OF BEAMS

BEAM NO.	SPAN (m)	SECTION (mm)	BOTTOM BARS St Bent Dia	TOP BARS No-Dia	STIRRUPS No-Spacin
B1	4.8	230x450	2-1-16mm	2-10mm	6-200mm
B2,B3	4.0	230x450	2-1-10mm	2-10mm	6-200mm
B4,B5	4.8	230x450	2-2-16mm	2-12mm	6-150mm
B6	4.0	230x450	2-2-12mm	2-12mm	6-250mm
B7	4.8	230x450	2-1-16mm	2-12mm	6-250mm
B8	4.8	230x450	2-1-20mm	2-16mm	8-180mm
B9	4.0	230x450	4-0-12mm	4-20mm	8-200mm
B10	4.8	230x450	2-1-12mm	2-12mm	6-250mm
B11	4.8	230x450	2-2-16mm	2-12mm	6-150mm
B12	8.0	300x600	7-3-20mm	3-20mm	10-110mm

SLAB DESIGN

SLAB S1:(side foyer)
Concrete grade M15, steel Fe415
Span = 3.73 m
Panel size = 3.73 x 12

$$\frac{Ly}{Lx} = \frac{12.0}{3.73} = 3.22 > 2$$

Hence design as one way slab.
Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.15	= 3.75
Floor finish		= 1.00
Live load		= 1.50
Total load		= 6.25 KN/m²

Max BM = $wl^2 / 10$ = $\frac{6.25 \times 3.73^2}{10}$ = 8.70 KN-m.

Factored BM = 1.5 x 8.70 = 13.04 KN-m.
For concrete grade M15, steel Fe 415, t= 135mm
Refer table T 18 & T 19

Provide 8 mm dia RTS bars @ 140 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 150 x 1000 = 180 mm²
Spacing of distribution bars = (50/180) x 1000 = 278 mm²

Provide 8 mm dia RTS @ 250mm c/c

SLAB S2: (Green Room slab)
Concrete grade M15, steel Fe415
Span = 3.73 m
Panel size = 3.73 x 8

$$\frac{Ly}{Lx} = \frac{8.00}{3.73} = 2.14 > 2$$

Hence design as one way slab.
Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.15	= 3.75
Floor finish		= 1.00
Live load		= 1.50
Total load		= 6.25 KN/m

Max BM = $wl^2 / 10$ = $\frac{6.25 \times 3.73^2}{10}$ = 8.70 KN-m.

Factored BM = 1.5 x 8.70 = 13.04 KN-m.
Adopt same design as S1

SLAB S3: (Front foyer)
Concrete grade M15, steel Fe415
Span = 4.00 m
Panel size = 4.00 x 14.4
$\frac{Ly}{Lx} = \frac{14.4}{4.00} = 3.6 > 2$

Hence design as one way slab.
Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab = 25 x 0.15		= 3.75
Floor finish		= 1.00
Live load		= 1.50
Total load		= 6.25 KN/m
Factored BM	= $wl^2 / 12$	= $\frac{6.25 \times 3.73^2}{12}$ = 12.5 KN-m.

For concrete grade M15, steel Fe 415, t= 135mm
Refer table T18 & T19

Provide 8 mm dia RTS bars @ 150 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 150 x 1000= 180 mm²
Spacing of distribution bars = (50/180) x 1000 = 278 mm²

Provide 8 mm dia RTS @ 250mm c/c

SLAB S4: (Balcony slab)
Concrete grade M15, steel Fe415
Span = 1.00 m
Panel size = 4.8 x 1.00
$\frac{Ly}{Lx} = \frac{4.80}{1.00} = 4.80 > 2$

Hence design as one way slab.
Adopt 100 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.10	= 2.50
Floor finish		= 1.00
Live load		= 5.00
Total load		= 8.50 KN/m

Factored BM = $1.5\ wl^2 / 10 = \frac{1.5 \times 8.5 \times 1^2}{10} = 1.35$ KN-m

For concrete grade M15, steel Fe 415, t= 135mm

$A_{st} = \frac{1.35 \times 10^6}{230 \times 0.904 \times 80} = 81.2\ N/mm^2$

Provide 6 mm dia RTS bars @ 180 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 100 x 1000 = 120 mm^2
Spacing of distribution bars = (28/120) x 1000 = 233 mm^2

Provide 6 mm dia RTS @ 220 mm c/c

SLAB S5 : (Balcony projection slab)
Concrete grade M15, steel Fe415
Span = 2.0 m
Panel size = 4.80 x 2.0

$\frac{Ly}{Lx} = \frac{4.8}{2} = 2.4 > 2$

Hence design as one way slab.
Adopt 100 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.10	= 2.50
Floor finish		= 1.00
Live load		= 1.50
Total load		= 8.50 KN/m

Factored BM = $1.5\ wl^2 / 10 = \frac{1.5 \times 8.5 \times 2^2}{10} = 5.1$ KN-m.

$A_{st} = \frac{5.10 \times 10^6}{230 \times 0.904 \times 80} = 306.6\ N/mm^2$

Provide 8 mm dia RTS bars @ 160 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 100 x 1000= 120 mm^2
Spacing of distribution bars = (28/120) x 1000 = 233 mm^2
Provide 6 mm dia RTS @ 220 mm c/c

SLAB S6: (Ground floor side foyer roof)
Concrete grade M15, steel Fe415
Span = 3.73 m
Panel size = 3.73 x 12

$\frac{Ly}{Lx} = \frac{12.0}{3.73} = 3.22 > 2$

Hence design as one way slab.
Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab = 25 x 0.15	=	3.75
Floor finish	=	1.00
Live load	=	5.00
Total load	=	9.75 KN/m

Factored BM = 1.5 wl²/ 10 = $\frac{9.75 \times 3.73^2}{10}$ = 20.35 KN-m.

For concrete grade M15, steel Fe 415, t= 135mm
Refer table T18 & T19

Provide 10 mm dia RTS bars @ 130 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 150 x 1000 = 180 mm²
Spacing of distribution bars = (50/180) x 1000 = 278 mm²

Provide 8 mm dia RTS @ 250mm c/c

SLAB S7:(Green room roof slab)
Concrete grade M15, steel Fe415
Span = 3.73 m
Panel size = 3.73 x 8

$\frac{Ly}{Lx} = \frac{8.00}{3.73} = 2.14 > 2$

Hence design as one way slab.
Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.15	=	3.75
Floor finish		=	1.00
Live load		=	5.00
Total load		=	9.75 KN/m

Factored BM = 1.5 wl²/ 12 = $\frac{9.75 \times 3.73^2}{12}$ = 19.96 KN-m.

For concrete grade M15, steel Fe 415, t= 135mm
Refer table

Provide 10 mm dia RTS bars @ 130 mm c/c

Distribution reinforcement :
For Fe415 steel,
Distribution steel = 0.12 % x 150 x 1000 = 180 mm²

Spacing of distribution bars = (50/180) x 1000 = 278 mm^2

Provide 8 mm dia RTS @ 250mm c/c

SLAB S8: (Mezzanine floor slab first floor))

Concrete grade M15, steel Fe415

Span = 4.8 m

Panel size = 4.8 x 4

$$\frac{Ly}{Lx} = \frac{4.80}{4.00} = 1.2 < 2$$

Hence design as two way slab.

Adopt 125 mm thick slab, effective depth, d = 110 mm

LOADING

Self weight of slab	= 25 x 0.125	= 3.125
Floor finish		= 1.50
Live load		= 5.00
Total load		= 9.625 KN/m

Short span :

Max BM = 0.152 x 9.625 x 4 ^{2} = 8.1 KN-m

Refer table 1,

Provide 10 mm dia RTS bars @ 180 mm c/c

Long span:

Max BM	= 0.037 x 9.625 x 4^2	= 5.7KN-m
Factored BM	= 1.5 x 5.7	= 8.55 KN-m

Provide 8 mm dia RTS bars @ 130 mm c/c

Provide same design for the stage floor of same dimension.

SLAB S9: (Portico slab)

Concrete grade M15, steel Fe415

Span = 4.00 m

Panel size = 24.00 x 4

$$\frac{Ly}{Lx} = \frac{24.00}{4.00} = 6.00 > 2$$

Hence design as one way slab.

Adopt 150 mm thick slab, effective depth, d = 135mm.

LOADING

Self weight of slab	= 25 x 0.15	= 3.75
Floor finish		= 1.00
Live load		= 1.50
Total load		= 6.25 KN/m

Factored BM = $1.5\, wl^2/12 = \frac{1.5 \times 6.25 \times 4^2}{12}$ = 18.75 KN-m.

For concrete grade M15, steel Fe 415, t= 130mm
Refer table

Provide 10 mm dia RTS bars @ 150 mm c/c

Distribution reinforcement :
For Fe415 steel,

Distribution steel	= 0.12 % x 150 x 1000	= 180 mm^2
Spacing of distribution bars	= (50/180) x 1000	= 278 mm^2

Provide 8 mm dia RTS @ 250mm c/c

SCHEDULE OF SLAB

SLAB NO.	DEPTH (mm)	SHORT SPAN STEEL Dia-spacing	LONG SPAN STEEL Dia-spacing	REMARKS
S1	150	8mm @ 140mm c/c	8mm @ 250mm c/c	One-way
S2	150	8mm @ 250mm c/c	8mm @ 250mm c/c	One-way
S3	150	8mm @ 150mm c/c	8mm @ 250mm c/c	One-way
S4	100	6mm @ 180mm c/c	6mm @ 220mm c/c	One-way
S5	100	8mm @ 160mm c/c	6mm @ 220mm c/c	One-way
S6	150	10mm @ 130mm c/c	8mm @ 250mm c/c	One-way
S7	150	10mm @ 130mm c/c	8mm @ 250mm c/c	One-way
S8	125	10mm @ 180mm c/c	8mm @ 170mm c/c	Two-way
S9	150	10mm @ 150mm c/c	8mm @ 250mm c/c	One-way

DESIGN OF TRUSS

Dead load and Live load		
Weight of roofing material	= $15\ Kg/m^2$	
Self weight of purlin	= $10\ Kg/m^2$	
Live load	= 75 x 6.26 x 1	
	= 68.7	
	= $69\ Kg/m^2$	
Self weight of truss	= (l/3) + 5	
	= 13	
	≈ $15\ Kg/m^2$	
False ceiling	= $75\ Kg/m^2$	
Total	= $184\ Kg/m^2$	
Total dead load	= 184 x 24 x 4	
	= 17664	
Load on each end panel	= W/2	
	= 17664/16	= 1104 Kg
Load	≈ 1110 Kg	

WIND LOAD

Basic wind pressure = $150\ N/m^2$

For	16.26°	-0.512p	-0.5p
	0.2p	-0.712p	-0.7p
	-0.2p	-0.312p	-0.3p

Load each panel	= 0.712 x 150 x 1.56
	= $166.6\ Kg/m^2$
	≈ $170\ Kg/m^2$
Load on panel (leeward)	= 0.7 x 150 x 1.56
	= $163.8\ Kg/m^2$
	≈ $170\ Kg/m^2$

ANALYSIS OF TRUSS

No	Member	Dead load + Live load		wind load		Design force	
		Comp.	Tens	Comp.	Tens	Comp.	Tens
1	U1U2	29447			4372	29447	4372
2	U2U3	30963			4080	30963	4080
3.	U3U4	30963			4080	30963	4080
4.	U4U5	26996			3497	26996	3497
5.	U5U6	26996			3497	26996	3497
6.	U6U7	30341			4080	30341	4080
7	U7U8	30030			4080	30030	4080
8	U8U9	29719			4372	29719	4372
9	U9U10	29719			4372	29719	4372
10	U10U11	30030			4080	30030	4080
11.	U11U12	30341			4080	30341	4080
12.	U12U13	26996			3497	26996	3497
13.	U13U14	26996			3497	26996	3497
14.	U14U15	30963			4080	30963	4080
15.	U15U16	30963			4080	30963	4080
16.	U16U17	29447			4372	29447	4372
17.	U1L1		28269	4173		4173	28269
18.	L1L2		28269	4173		4173	28269
19.	L2L3		24485	3565		3565	24485
20.	L3L4		24485	3565		3565	24485
21	L4L5		14960	2046		2046	14960
22	L5L6		14960	2046		2046	14960
23.	L6L7		24485	3565		3565	24485
24.	L7L8		24485	3565		3565	24485
25.	L8L9		28269	4173		4173	28269
26.	L9U17		28269	4173		4173	28269
27	U2L1	0			0	0	0
28.	U2L2	2115			338	2115	338
29	U3L2	1066	1		170	1066	170
30	U4L2		2115	338		338	2115
31.	U4L3		0	0		0	0
32.	U4L4	2808			448	2808	448
33.	U5L4	1066			148	1066	148
34.	U6L4	2808			448	2808	448
35.	M1L4		9525	1520		1520	9525
36.	U6M1		0	0		0	0
37.	U6M2		2115	338		338	2115
38.	M1M2		9525	1520		1520	9525
39.	U7M2		1066	170		1066	170
40.	U8M2	2115			338	2115	338
41.	M3M2		13331	2032		2032	13331
42.	U8M3		0	0		0	0
43.	U9M3		13331	2032		2032	13331
44.	U9M4		13331	2032		2032	13331
45.	U10M4		0	0		0	0
46.	M4M5		13331	2032		2032	13331
47.	U10M5	2115			338	2115	338
48.	U11M5	1066			170	1066	170
49.	U12M5		2115	338		338	2115
50.	U12M6		0	0		0	0
51.	U12L6	2808			448	2808	448
52.	U13L6	1066			170	1066	170
53.	U14L6	2808			448	2808	448
54.	U14L7		0	0		0	0
55.	U14L8		2115	338		338	2115
56	U15L8	1066			170	1066	170
57.	U16L8	2115			338	2115	338
58.	U16L9	0			0	0	0
59.	M5M6		9525	1520		1520	9525
60.	M6L6		9525	1520		1520	9525
61.	U9L5	0			0	0	0

Design of members

Top chord members

length	= 1.563 m	
Max comp force	= 30963 Kg	
Try 2L 75 x 75 x 10 mm		
Area of section	= 28.04 cm^2	
Effective length	= 0.85 l	
	= 0.85 x 156.25	= 132.81 cm
r_{xx}	= 2.26 cm	
S.R.	= 132.8 / 2.26	= 58.77
Allowable stress according IS tables	= 1232.3 Kg/cm^2	
Safe load	= 1232.3 x 28.04	= 34554 Kg
Bottom chord members		
Max tension	= 4080	
Check as tension member		
Dia of rivet	= 16	
Dia of rivet hole	= 17.5	
allowing for two rivet holes		
net area	= 28.04 cm^2 - 2 x 1.75 x 0.1 = 27.69 cm^2	
Safe tension	= 27.69 x 1500 = 41535 Kg	

But max tensile load in member is only 4372 Kg

Bottom chord members

Max tension	= 28269 Kg	
Try 2L 75 x 75 x 10 mm		
Dia of rivets	= 17.5 mm	
Net area	= 19.52 - 2 x 1.75 x 0.08	
	= 9.24	
Safe tension	= 19.24 x 1500	= 28860 Kg
Check for comp		
Max comp	= 4173 Kg	
Length of Member	= 1.625 m	
Effective length	= 0.85 x 162.5	= 138.12
r_{xx}	= 1.96	
S.R.	= 138.13 /1.96	= 70.47
safe load	= 1114.8 19.24	= 21449 Kg
Hence safe		
Member L4L5,L5L6		
Length of Member	= 5.5 m	
Max tension	= 14960 Kg	
Try L 75 x 75 x 10 mm		
Area of section	= 14.02 cm^2, r_{xx}	= 1.94 cm
S.R.	= 550 / 2.26	= 243.36 < 350
Dia of rivet hole	= 1.75 cm	
Net area	= a + bk	
a	= (7.5 - 0.5) x 1 - 1.75 x 1	= 5.25 cm^2

b	= (7.5 - 0.5) x 1	= 7 cm^2
k	$= \frac{1}{1 + 0.35\,(b/a)}$	
	$= \frac{1}{1 + 0.35\,(7 / 5.25)}$	= 0.681
Net area	= 5.25 + 0.681 x 7	= 10.02 cm^2
safe tensile load	= 10.02 x 1500	= 15034 Kg

But maximum is 14960 Kg.

check for comp.

Max comp	= 2046	
S.R.	= 243.36	
Safe comp stress	= 193.28 x 14.02	= 2710 Kg

Hence safe.

Design of struts

Member U5 L4

Max comp	= 1066	
Length of member	= 1.820 m	= 182 cm
Try 50x50x4		
Area of section	= 3.689 cms^2	
r_{xx}	= 1.53	
S.R.	= 0.85 x 182 /1.53	= 101.11
Comp stress	= 791.2	
Safe comp load	= 791.2 x 3.68	= 2911 Kg

Check for tension

Max tension	= 170 Kg	
a	= (5-0.2) x 0.4 - 1.75 x 0.4	= 1.22
b	= 1.92	
k	$= \frac{1}{1 + 0.35(1.92/1.22)}$	= 0.645
Net area	= 1.22 + 0.645 x 1.92	= 2.46 cm
Safe tensile load	= 2.46 x 1500	= 3687 Kg

Hence safe.

Member U2 L1

Max comp.	= 4173	
Length of member	= 0.455	
S.R.	= 0.85 x 0.4455/1.53	= 25.28
Comp stress	= 1464.2	
Safe comp load	= 1464.2 x 25.28	= 37012 Kg

Hence safe.

Member U4 L4

Max comp.	= 1066
Length	= 2.75 m

S.R.	= 275 x 0.85/1.53	= 152.78
Safe Comp stress	= 438.88 Kg/cm	
Safe comp load	= 438.88 x 3.68	= 1615 Kg
Hence safe.		

Check for tension

Max tension	= 170	
Net area	= 2.46 cm	
Safe tensile load	= 2.46 x 1500	= 3887 Kg
Hence safe.		

Member L4M1,M2M3,M3M4

Max comp.	= 2032 Kg	
Try 75x75x10		
Length	= 1.625 m	
S.R.	= 0.85 X1.625/2.26	= 61.12
Safe comp stress	= 1208.8	
Safe comp load	= 1208.8 x 14.02	= 16947 Kg
Hence safe.		
Check for tension		
Max tension	= 13331 Kg	
Try 75x75x10		
Area	= 14.02cm²	
a	= (7.5 -0.5) x1-1.75x 1	= 5.25cm²
b	= (7.5 -0.5) x 1	= 7cm²
k	$= \frac{1}{1 + 0.35(7/5.25)}$	= 0.681
Net area	= 5.25 + 0.681 x 7	= 10.02cm²
Safe tensile load	= 10.02 x 1500	= 15034Kg

DESIGN OF STAIR CASE

STAIR CASE 1

Concrete mix M15, Steel Fe415
Adopt 150 mm overall thickness
d = 150 mm
Effective span = 4.5 m

LOADING

Self weight of waist slab = 0.15 x 25 = 3.75
Hand rails = 0.25
Total load = 4 KN/m
Load on horizontal plane = 4 x .33/ 0.3 = 4.48
Brick steps = 1 x 0.3 x (0.15 /2) x 20 x 1.12
= 0.5
Live load = 5
Total load = 9.99 KN/m

Max BM = 10 x 4.5^2/10 = 20.25 KN/m
Mu = 30.38 KN-m

Refer table 20

Provide 12 mm dia RTS at 140 mm c/c
Provide 6 mm dia RTS at 150 mm c/c

STAIR CASE 2

Concrete mix M15, Steel Fe415
Adopt 150 mm overall thickness
d = 150 mm
Effective span = 4.8 m

Flight A

LOADING

Self weight of waist slab = 0.15 x 25 = 3.75
Hand rails = 0.25
Brick steps = (.15 x 0.3 / 2) x 20= 0.45 KN/m
Total load = 4.45 KN/m

Loading on horizontal plane = 4.45 x 1.12 = 4.98 KN/m
Load of landing = 0.15 x 25 = 3.75
Total load = 8.73 KN/m
Max BM = 8.8 x 4.8^2/10 = 20.28 KN/m
Mu = 30.41 KN-m

Provide 12 mm dia RTS at 140 mm c/c
Provide 6 mm dia RTS at 150 mm c/c

Flight B

span = 4.1 m
Max BM = $8.8 \times 4.1^2 / 10$ = 14.8 KN-m
Factored BM = 22.19 KN-m

Provide reinforcement as for flight A.

ACOUSTICS

This section should help the building designer understand the basic principles of architectural acoustics and help him to design buildings in which later corrections will be unnecessary. The proper acoustics for any kind of activity in a building can be determined in advance and necessary provisions can be made during the design.

Often acoustic problem are not recognised explicitly by the designer. Each element of design and construction of a building has some influence on its acoustical characteristics and unless all the factors involved are clearly understood and properly incorporated during the design of the building, satisfactory results will be seldom achieved. Acoustics should not only influence the choice of finish materials in halls, but also the basic disposition of elements of the building.

The basic purpose of architectural acoustics is to provide a satisfactory acoustic environment for whatever the space uses be intended.

Terms dealing with sound:

Sound power:

Sound power in watts describes the energy of the sound source. This power may be (I) total power radiated by the source over its entire frequency range. (ii) the power radiated in limited frequency range (iii) the power radiated in each of a series of frequency band.

Sound intensity:

The sound intensity is the power radiated in specific direction through unit area normal to this direction.
E.g.: watts per sq.cm.

Sound pressure (p):

The sound pressure is the variation from normal atmospheric pressure caused by the flow of sound energy as to and fro motion of molecules in air. Its unit is n/m^2

Decibels:

The decibel is a dimensionless unit for expressing the ratio of two numeric values on a logarithmic scale. It is convenient to use decibels in dealing with sound power, sound intensity and sound pressure.

Noise reduction:

Noise reduction is difference in decibels of the sound pressure level or sound intensity levels at two points along a sound path.

Sound absorption coefficient:

The absorption coefficient is the fraction of incident sound energy that is absorbed by a sound surface. Random incidence of the impinging sound is assumed unless or otherwise specified.

Absorption unit (a):

Absorption units are usually expressed in sabins and equal the area of a surface 's' times its absorption coefficient ( ).

Noise reduction coefficient:

Noise absorption coefficient for a sound absorption material is arithmetic average of the absorption coefficient at 250,500, 1000 & 2000 Hz, rounded off to the nearest multiple of 0.05.

Dead room:

A dead room is one characterised by large amount of absorption.

Live room:

Live room is one characterised by very small amount of absorption.

Reverberation:

Reverberation is the persistence of sound after the source of sound has stopped. It is due to them repeated reflection of the sound remaining between the enclosing surface.

Reverberation time (t):

Reverberation time of a room is by definition that time required for sound level to decrease 60-db after the source has stopped. The reverberation time given by the following expression.

T = (0.165 x V)/A where

V = Volume in m3

A = Total room absorption in metric sabins

Diffusion:

Ideally a diffused sound field is one in which the sound level is everywhere the same. Diffusion is a desirable characteristic for many listening spaces.

Echo:

An echo is a sound wave reflected or otherwise returned with sufficient magnitude and delay so as to be perceived as a sound distinct from the directly transmitted sound.

Flutter echo:

Flutter echo is a rapid succession of reflected sound waves resulting from a single initial sound pulse. This effect often occurs with the sound source between two hard parallel walls and sometime confused with reverberation.

Creep:

Creep is the reflection of sound along a curved surface. It occurs when a sound source is located close to surfaces such as domes, vaults, etc so that the reflected sound energy is conserved and can be heard distinctly at some point further along the surface.

Essential features of good acoustics:

The sound heard must be sufficiently loud in every part of the hall and no echo should be present.

The total quality of speech and music must be unchanged.

There should be no overlapping of signals.

The reverberation should be quite long enough to give proper blending of sound and yet be short enough so that there is no excessive overlapping and confusions

There should be no concentration of sound in any part of the hall.

The boundaries should be sufficiently sound proof to exclude extraneous noise.

Factors affecting architectural acoustics & their remedy:

1. Reverberation
2. Adequate loudness
3. Focussing due to walls and ceilings.
4. Absence of echoes.
5. Echelon effect.
6. Extraneous noise.

Reverberation: .

If reverberation is large there is overlapping of successive sounds which results in loss of clarity in hearing. If the reverberation is very small the loudness is inadequate. Thus for a hall should neither be too large nor too small. It must have a definite value which may be satisfactory both to the speaker as well as to the audience. This preferred value of the time of reverberation is called the optimum reverberation time.

Reverberation can be controlled by the following factor:

By providing windows ventilators which can be opened and closed to make the value of the time of reverberation optimum.

Using heavy curtains with folds.

The walls are lined with absorbent material such as felt, celotex, fibre board, glass wool etc.

Having full capacity of audience.

By covering the floor with carpets.

By providing acoustic tiles.

Adequate loudness

If the reverberation time is very small it will minimise the chances of confusion between the different syllables but the intensity of sound is weakened such that it may go below the level of intelligibility of hearing.

Loudness may be increased by:

Using large sounding boards behind the speaker facing the audience.
Low ceiling helps in reflecting the sound energy towards the audience.

Focussing effect due to walls and ceilings.

If there are focussing surfaces on the walls or ceilings or the floor of the hall they produce concentration of sound into particular regions while in some other parts no sound reaches at all. In this way there will be regions of silence or of poor audibility while there should be uniform distribution of sound in the hall. If there are extensive reflective surfaces the reflected and direct sound waves may form stationary wave system thus making the sound intensity distribution bad and uneven.

Favorable conditions for uniform distribution of sound energy:

There should be no curved surfaces, if present must be treated with absorbent material.

Ceiling should be low.

A paraboloidal reflected surface arranged with the speaker at the focus helps in sending a uniform reflected beam of sound in the hall.

Absence of echoes:

An echo is heard when direct and reflected sound waves coming from the source reaches the listener with a short interval of 1/7th second. The reflected sound coming earlier than this help in raising the loudness while those arriving later produce echoes and cause confusion. This should be avoided or weakened as far as possible by absorption. Echoes may be avoided by covering the long distant walls and high ceiling with absorbent material

Echelon effect:

A set of railings or any regular spacing of reflected surfaces may produce a musical note during the regular succession of echoes of the original sound to the listener, it makes original sound unintelligible. Hence this type of surfaces should be avoided.

Extraneous noises:

In a good hall literally no noise should reach from outside. Generally there are three types of noises. They are

Airborne noise :

Noises which reach through open windows, doors, ventilators and other openings from outside are termed as airborne noises.

Airborne noise can be minimised by:

By allotting proper places for doors and windows.

By concealing openings for pipes, vents, ducts etc

Using double doors and windows with separate frames with insulating material between them.

By making arrangements for perfectly shunting the doors and windows.

Structure borne noises:

The noises which are conveyed through the structure of the building are known as structural noises.

These noises can be minimised by:

Breaking the continuity by interposing layers of some acoustical insulators.

Using double walls with air space between them.

Inside noises:

The noises which are conveyed from inside the structure are known as structural noises.

Any machinery inside the hall should be fitted on the floor with a layer of wood, felt or anti-vibration mounting between them.

Sound - conditioning or noise reduction with acoustical treatment :

Airborne noise, structure-borne noises can be controlled and reduced within the hall with acoustical treatment. The sound treatment is employed for noise reduction to alleviate the discomfort and annoyance caused by excessive sound reflection. This is known as sound-conditioning. It controls the reverberation of the hall to make it satisfactory of hearing conditions of speech and music. This is referred to as acoustic correction

Acoustic perfuming:

Spaces that are too quiet and hence require acoustic perfuming. It can be fulfilled by planting of trees with rustling leaves, splashing fountains, gurgling sounds in courtyard etc. It is done by sound tone of 20-dB.

Sound quietening:

Sound quietening is required in spaces having excessive noise, generated from inside or outside. Outside noise can be quietened by sound insulation constructions. Inside noise can be quietened to some extent by incorporating absorptive surfaces and elements. Porous absorbers can be provided for high frequency sounds.

SOUND -ABSORPTIVE MATERIALS

The rate at which sound is absorbed in a room is a prime factor in reducing noise and controlling reverberation. All materials used in the construction of buildings absorb some sound, but proper acoustical control requires the use of materials namely sound absorbers. These materials are known as "acoustical materials".

Sound absorption

Sound is absorbed by a mechanism which converts the sound into other forms of energy ultimately into heat. Many materials depend upon their porosity. E.g.: mineral wool, pads and blankets. The sound waves readily propagate themselves into these interstices, where a portion of the sound energy is converted into heat by frictional and viscous resistance within the pores and by vibration of the small fibres of the material. If the material is sufficiently porous, and of appropriate thickness, about 95% of the incident sound wave may be absorbed.

Sound absorptive materials:

Absorption by porous materials normally is higher at high frequencies and small at low frequencies. Absorption by panel vibration is small at high frequencies by may be large at low frequencies. By using them in proper proportions, it is possible to control the absorption of sound throughout the audible range of frequencies.

Rating of acoustical absorptivity of materials:

The absorption coefficients depend not only on the nature of the material, thickness on the way in which it is mounted and on the depth of the air space behind it.

Type of acoustical materials:

Some of the common available acoustical materials are:

1. Prefabricated units:

These include acoustical tile; mechanically perforated units backed with absorbent materials; and certain wall boards, tile boards, and absorbent sheets.

2. Acoustical plaster and sprayed-on materials:

These materials comprise plastic and porous materials applied with a trowel; and fibrous materials, combined with binder agents, which are applied with an air gun.

3. Acoustical blankets:

Blankets are made up chiefly of mineral or wood wool, glass fibers, kapok batts, and hair felt.

TABLES OF ABSORPTION COEFFICIENTS:

Tables of sound- absorption coefficients of acoustical materials are in table:

Absorption Coefficients (Hz)

Materials	125	250	500	1000	2000	4000
Brick:						
Unglazed	0.03	0.03	0.03	0.04	0.05	0.07
unglazed. Painted	0.01	0.01	0.02	0.02	0.02	0.03
Carpet heavy on concrete	0.02	0.06	0.15	0.35	0.60	0.70
Same on 40 oz. hairfelt or foam rubber	0.10	0.25	0.55	0.70	0.70	0.70
same with impermeable latex backing on 40 oz. hair felt or foam rubber	0.10	0.25	0.40	0.40	0.50	0.60
Fabrics:						
Light velour, 10 oz. per yd2 hung straight, in contact with wall	0.03	0.04	0.11	0.17	0.25	0.35
Medium velour, 14 oz. per yd2 draped to half area	0.07	0.30	0.50	0.65	0.70	0.70
Heavy velour, 10 oz. per yd2 draped to half area	0.14	0.35	0.55	0.70	0.75	0.80
Heavy cotton flannel, 14 oz. per yd2 hung flat 6" away from wall	0.25	0.55	0.65	0.60	0.75	0.90
Floor:						
Concrete, terrazzo, marble or ceramic tile	0.01	0.01	0.02	0.02	0.02	0.02
Linoleum, Aspalt, Rubber, vinyl, or cork tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02
Wood on joists	0.15	0.11	0.01	0.07	0.06	0.07
Wood parquet in asphalt on concrete	0.04	0.04	0.07	0.06	0.06	0.07
Glass:						
Large panes of heavy plate glass	0.15	0.06	0.04	0.03	0.02	0.02
Ordinary window glass	0.25	0.15	0.10	0.07	0.05	0.03
Gypsum board, 1/2 in.	0.30	0.10	0.05	0.04	0.07	0.09

Openings:

Proscenium, average, curtain open	0.30	0.35	0.40	0.45	0.50	0.55
Under-Balcony, upholstered seats	0.35	0.45	0.60	0.70	0.70	0.65
Plaster, gypsum or lime on tile or brick	0.02	0.02	0.02	0.03	0.04	0.04
on lath	0.14	0.10	0.06	0.05	0.04	0.04
suspended	0.20	0.12	0.08	0.05	0.04	0.04
Plywood panelling, 3/8 in.	0.28	0.22	0.17	0.09	0.10	0.11
Air at 50% R.H. metric sabins per 100m³	0.00	0.00	0.00	0.29	0.96	2.44

Absorption Coefficients for audience and Seating (Hz)

	125	250	500	1000	2000	4000
Audience, seated upholstered seats	0.39	0.57	0.80	0.94	0.92	0.87
Unoccupied cloth-covered upholstered seats	0.19	0.37	0.56	0.67	0.61	0.59
Unoccupied plastic-covered upholstered seats	0.35	0.45	0.50	0.55	0.50	0.40
Unoccupied wooden pews with cushions	0.20	0.25	0.30	0.45	0.45	0.45
Unoccupied metal or wood seats, or pews	0.04	0.04	0.05	0.07	0.07	0.07

ACOUSTICAL CALCULATION

Total volume of Auditorium = 9720 m^3

Material	Area	α125Hz	α500Hz	α2000Hz	Sα125Hz	Sα500Hz	Sα2000Hz
Ceiling	864.0	0.1	0.1	0.1	86.4	86.4	86.4
Windows	59.2	0.25	0.1	0.05	14.8	5.92	2.96
Doors	40.0	0.28	0.17	0.1	11.2	6.8	4.0
Walls	1001.2	0.01	0.02	0.02	10.02	20.04	20.04
Seats	669.4	0.35	0.5	0.5	234.3	334.7	334.7
Audience	1338.8	0.39	0.57	0.92	522.1	763.1	1231.7
Total area at unoccupied condition					356.71	453.86	448.1
Total area with audience					644.55	882.27	1345.1

For 125Hz:

1. Empty Hall condition:
   Total absorption area =356.71m^2
   Reverberation time = 0.165 V = $\frac{0.165 \times 9720}{356.71}$
   = 4.49 Sec
2. Occupied hall condition:
   Total absorption area = 644.552
   reverberation time = (0.165 x 9720)/ 644.552 = 2.488 sec

Extra area to be provide
(Assuming critical reverberation time = 1.8 sec)
A = (0.165 x 9720)/ 1.8 = 891 m^2
Extra area = 891m^2 - 356.71 m^2 = 534.29 m^2

Material	Area	α	αs
Gypsum Board False Ceiling	864.0	0.3	259.3
Curtains (windows& doors)	99.2	0.25	24.8
Plaster (grade A)	1001.8	0.3	300.54
			584.64 m^2

For 500Hz:

1. Empty Hall condition:
   Total absorption area = $453.86m^2$
   Reverberation time = $0.165\ V = \frac{0.165 \times 9720}{453.86}$
   = 3.53 Sec

2. Occupied hall condition:
   Total absorption area = 887.276
   Reverberation time = (0.165 x 9720)/ 887.276 = 1.807 sec

Extra area to be provide
(Assuming critical reverberation time = 1.8 sec)
A =(0.165 x 9720)/ 1.8 = 891 m^2

Extra area = $891m^2 - 453.86\ m^2 = 437.14\ m^2$

Material	Area	α	αs
Gypsum Board False Ceiling	864.0	0.05	43.2
Curtains (windows& doors)	99.2	0.65	64.48
Plaster (grade A)	1001.8	0.6	601.08
			708.76 m^2

For 2000Hz:

1. Empty Hall condition:
   Total absorption area = $448.1m^2$
   Reverberation time = $0.165\ V = \frac{0.165 \times 9720}{448.1}$
   = 3.6 Sec

2. Occupied hall condition:
   Total absorption area = 1345.1
   Reverberation time = (0.165 x 9720)/ 1345.1 = 1.19 sec

Extra area to be provide
(Assuming critical reverberation time = 1.8 sec)
A =(0.165 x 9720)/ 1.8 = 891 m^2

Extra area = $891m^2 - 448.1\ m^2 = 442.9\ m^2$

Material	Area	α	αs
Gypsum Board False Ceiling	864.0	0.07	60.48
Curtains (windows& doors)	99.2	0.75	74.4
Plaster (grade A)	1001.8	0.3	300.54
			435.42 m^2

SOUND SYSTEMS

Purpose and scope:

It must be kept in mind that a sound amplification or distribution system is not a cure for hostile acoustical environment. Sound system is an information transferal device, whereby information from a source transferred to an audience who hears the message. It is of vital importance, therefore the system be designed and constructed so that this machine is fulfilled, not only that the words of the source be heard by the listeners but also that the listener be able to understand the message transmitted. The performance of sound system, even with a best of electronic components can fail if the acoustical environment is unfavorable or if the designer failed to understand the problems of associated with poor acoustical properties and designed accordingly.

Acoustic gain:

The acoustic gain of a sound reinforcement is the improvement in loudness which is achieved by having a sound system. Specifically it is defined as the ratio of sound level at a listener's ears with the sound system operating at to the sound level at the same location without any amplification.

Loudspeaker locations:

There are two and only two types of loudspeaker locations which have been found satisfactory and recommended for system design. These are:

1 Central cluster of loudspeaker located in the centre and at the upper portion of the front of an auditorium.

2. A distributed system consisting of numerous loudspeakers located in the ceiling of the room and firing sound vertically downwards.

Central system:

This type is preferred in most situations in which the loudspeaker is located directly above the actual source of sound. Only loudspeaker position is used in this sort, and it is capable of giving maximum realism. The listener with its two ears is readily able to localize the direction of source of sound, and if the amplified comes from the same direction as the original sound, he gets and impression merrily of increased loudness or clarity but not of artificial amplified sound.

When the listener are far away from the central loudspeaker cluster, or if they do not have line of sight to the cluster, auxiliary loudspeaker can be placed nearby overhead locations

In this type high directive, narrow beam horns are used for long throw into the rear of the room with the central line or axis directed at the rear row of seats. Wider angled Horns with horizontal angle of 60 & 90 deg are used for the short throw coverage of the front of the room.

Sound is transmitted directly from the source to the listener follows the inverse square relationship. Sound which has been reflected one or more times from room boundaries is called reverberant times.

The critical distance travel of sound is calculated from the following formula:

Dc =0.141sqrt (qxr)

Where, q = directive factor of sound source

R = room constant in sq.ft = sa/(1-a)

Distributed system:

In this type, loudspeaker units are generally placed in the ceiling, facing down and sounding the rough appropriate grillage. Each loudspeaker unit covers between 60 and 90 deg depending upon the type selected. In a large auditorium in additional to central cluster, it is better to cover a balcony area from auxiliary overhead units rather than depending on the central loudspeaker. This reduces the size of the central unit and gives better control of distribution.

This type of system is used in any situation where the ceiling height is inadequate to use a central system or where all listeners cannot have line of sight on a central loudspeaker. The spacing of the speakers is based upon the fact that one of the objectives is uniformity of coverage in the listeners area. Since the coverage area is a function of the height of the ceiling, this is the parameter which governs the spacing.

Loudspeaker spacing for a 90 deg coverage angle

D = 2x(h - 4) ft.

Loudspeaker spacing for a 60 deg coverage angle

D = 1.15x(h - 4) ft.

Where, h = floor to ceiling height in feet.

Position of loudspeaker:

Several common types of loudspeaker locations must be avoided as they never work well and can cause problems with acoustic response and sound quality. They are.

1. Never place a loudspeaker on each side of a wide stage. Such installations produce an area of confusion in the middle of the room while the listeners on the sides have a very ragged acoustical response due to wave cancellation and addition.

2. Never place loudspeakers on both side walls of a room with each loudspeaker firing into the center of the room. A system of this type can be made to operate well if the loudspeaker faces the rear of the room.

3. Never place loudspeaker at the corners of a room or on the rear wall firing forward

ENVIRONMENTAL SERVICES

LIGHTNING

Exterior lighting:

Flood lighting, and other forms of exterior lighting, are important in promoting awareness and demonstrating the character and architectural form of the buildings.

The main application of exterior lighting are:

1 Upward illumination to emphasize vertical features (structural towers and columns). Contrasting bands of brightness, starting from different levels. 1000w tungsten halogen lamps are generally used

2 Concealed illumination under arches, in window recesses and penetrating spaces.

3. Floodlighting of external facades. The intensity will depend upon the type of surface and surroundings, ranging from about 50 lux for imitation stone in well-lit surroundings, to 150 lux for dark stone or red bricks. Sodium or mercury halide lamps enhance the colour and gives a contrast with other lighting in the vicinity.

Symmetrical lightning of walks, balconies, terraces
Entrances drives using pillar or column lamps
Downlighting below canopies, entrance lobbies, etc to distinguish entrances.

Interior lighting:

Lighting is use for both decorative and functional purposes, although the distinction between these roles is tending to reduce as a aesthetics are translated into precise technical standards of designed appearance lighting.

The level of luminosity and its pattern are important in setting the 'mood' of the interior and of directing attention to appropriate feature. If the range of luminosity is small, the scene lacks attraction or focus and appears dull; if in addition the level is low, it will appear gloomy. The bright features should be those of most significance to the users: the darker ones those from which attention may need to be distracted. By varying the relative luminance architectural features may be emphasize or visual faults in the space corrected. Directional effects in lighting influence three-dimensional objects, producing different contrasts in light and shadow.

Auditorium lighting

Lighting design for auditorium must satisfy a number of requirements:

The spatial illumination must be at a sufficient level to avoid strong contrasts. It also must be capable of being dimmed (projection) and increase (discussions, intervals, social events, etc)

Possible glare from luminaries, windows and high reflectance from surfaces must be avoided.

A balance must be maintained between the relative brightness of surfaces in view and also colour harmonization.

Seperate emergency lighting must be provided, giving a hall illumination of at least 0.5 lux

Provision should be made for energy reclaim from light fittings.

Luminaries

Direct luminaries

Lighting installed in the ceiling of a large auditorium is mainly direct with a general direction of about 10' to the vertical from slightly behind and over the shoulder of the audience. The light fittings may be concealed in the stepped recesses formed in the ceiling construction. Spotlights and other stage lighting equipment may also be housed in the ceiling voids. For uniform illumination as well as a sense of order and orientation, a large number of luminaries must be used, arranged in regular patterns.

Indirect luminaries

This from of lighting is often used for perimeter lighting, either as washes or wedges of light over specific areas. Perimeter lighting reduces strong contrasts as well as providing a brighter and relaxing environment but it must not be pronounced as to create visual distraction from the stage of speaker. The illumination must be uniform and regular it must not produce small patches, edge scalloping nor 'haloes' from too close proximity of luminaries. A visual cutoff angle of at least 45' is required.

ESTIMATION

No.	Description	Quantity	Rate	Unit	Amount
1	Earthwork excavation in ordinary soil with initial lead and lift.	994.60	11	m^3	10941
2	Providing PCC 1:4:8 for levelling coarse	238.70	430	m^3	102641
3	Providing RCC footing 1:2:4 mix using 20 mm size metal.	514.68	1500	m^3	772020
4.	Plinth beam in RCC 1:2:4 mix using 20mm size metal	43.57	2100	m^3	91497
5	Providing RCC 1:2:4 mix using 20mm size metal upto roof level	98.01	2300	m^3	225412
	Providing RCC 1:2:4 mix using 20mm size metal upto first floor level.	34.33	2200	m^3	2592808
6	Providing RCC 1:2:4 mix using 20mm size metal upto second level.	109.36	2200	m^3	240592
7	Providing RCC 1:2:4 mix using 20mm size metal including centering, ceiling, finishing with CM 1:3 for sunshades.	16.53	140	m^2	2314
8.	Brickwork in CM 1:3 using first class bricks for all floors	318.55	600	m^3	509680
9	Filling the basement with pallam sand	675.77	50	m^3	33789
10	Providing concrete floor in 1:4:8 mix 100mm				

	thick and with ellispattern finish in the top	42.60	75	m^2	3195
11.	Providing RCC 1:2:4 mix using 20mm size metal including cost of reinforcement,centering, ceiling complete for roof slab.	229.51	2200	m^3	504,922
12.	Providing balcony beams and cantilever beams in RCC 1:2:4 mix using 20mm size metal	43.41	2300	m^3	99,843
13.	Providing balcony slab in RCC 1:2:4 mix using 20mm size metal	34.56	2200	m^3	76,032
14.	Supplying and fixing country wood doors including necessary fittings	103.50	900	m^2	93,150
15.	Supplying and fixing country wood windows including necessary fittings	200.00	850	m^2	170,000
16.	Supplying and fixing ventilators including necessary fittings	37.55	800	m^2	30,040
17.	Plastering in CM 1:5 for walls.				
	i) Inside 8mm thick	378.79	50	m^2	18,940
	ii) Outside 8mm thick	462.22	50	m^2	23,111
	iii) Ceiling 6mm thick	490.04	60	m^2	29,400
18.	Weathering coarse with one coarse of machine pressed flat tiles in CM 1:3 with an admixture overa surki concrete in lime 1:2	433.84	130	m^2	56,399

19.	Supplying and fixing steel trusses 24m span including necessary fittings.	12Nos	15000	-	180,000
20.	Supplying and fixing channels ISMC100 including necessary fittings.	18 Nos	5000	-	90,000
21.	Supplying and fixing corrugated AC sheets with necessary fittings.	1104.40	20	m^2	22,092
22.	Colour washing with 3 coats of approved cement paint for walls and sunshades and ceilings.	866.53	35	m^2	30,329
23.	Painting for doors, windows, truss with best quality enamel paint.	224.48	50	-	11224
24.	Seats with good upholsery.	1300 Nos	400/seat	-	5,20,000
25.	False Ceiling	826.48	150	m^2	1,23,972
26.	Steps with handrails (three stairs)				28,000
			Grand Total		62,20,020

Add 7.5% for water supply	4,66,502
Add 7.5% for sanitary works	4,66,502
Add 10% for unforseen items and contingencies	6,22,002
Add 7.5% for electrification works4,	66,502
Add 3% for work charged establishment	1,86,601
	84,28,129

CONCLUSION

Generally a auditorium depends upon two factors namely viewing criteria and sound clarity. Viewing may be affected by poor arrangement of seats. We have adopted a graphical method which provides obstruction free view form both auditorium and balcony. The planning of auditorium has been strictly adhered to the rules and regulations. Eg. For passages, foyer and arrangement of seats.

Generally planners fail to concentrate on sound system and their modifications to suit the environment. We have studied in depth the acoustical behaviour and necessary corrections were made. Suitable materials were chosen for the necessary correction. By providing the acoustic treatment a noise reduction of 4dB were achieved. The cost of treatment varies between 1-2% of the total cost.

Since it is not a major cost affecting factor, we suggest that importance should be given in with acoustical design of auditorium.

FUTURE SCOPE

Acoustics occupies a curious place in the reputation of an auditorium. Mainly because of the complexities of the problems which had to be addressed, the science of acoustics has taken a while to attain some maturity. Of course much more remains to be discovered, but the present conceptual framework looks a sufficiently robust base on which to build further advances. Meanwhile the design of a good auditorium remains no less an art, which demands diverse talents. In the 2000-year history of auditorium, there has been much conservative copying of precedent. With a scientific basis to acoustic design, the fundamental requirements of auditorium can be reassessed and innovation can be applied to a design problem which, by its nature, will always be bounded by considerable constraints.

BIBLIOGRAPHY

1 IS 456- 1978- Indian Standard Code of Practice for Plain and Reinforced Structures

2 Syal I C and Goel A K -
Reinforced Concrete Structures

3 Vazirani V N and Ratwani N M
Concrete Structures - Analysis, Design and Details of Structures

4 Design Aids to IS 456-1978, Indian Standard Institution.

5 Ramachandra
'Design of Steel Structures'

6 Arya & Ajmani
'Design of Steel Structures'

7 Rnderick Ham Aadipt Riba
Theatre Planning

8 Paul Dunham
Sound Control & Thermal Insulation

9 Kundeen & Harris
'Acoustics Designing in Architecture

10 Swenson
'Principles of Modern Acoustics'

11 R L Suri
'Acoustics Design & Practice'

12 T Smith
'Building Acoustics'