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Analysis and Design of Sports Complex using ETABS

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ABSTRACT: The design process of structural planning and design requires not only imagination and conceptual thinking but also sound knowledge of science of structural engineering besides the knowledge of practical aspects. The purpose of standards is to ensure and enhance the safety, keeping careful balance between economy and safety. In the present study G+1 building is designed (Slabs, Beams, Columns and Footings) ETAB's software. In order to design them, it is important to first obtain the plan of the particular building that is, positioning of the particular rooms, that they serve their respective purpose and also suiting to the requirement and comfort of the users. Thereby depending on the suitability; plan layout of beams and the position of columns are fixed. Thereafter, the loads are calculated namely the dead loads, which depend on the unit weight of the materials used (concrete, brick) and the live loads, which according to the code IS:456-2000 and HYSD BARS Fe500 as per IS:875-1987 part II. Safe bearing capacity of soil is adopted as 140KN/m². Footings are designed based on the safe bearing capacity of soil. For designing of columns and beams, it is necessary to know the moments they are subjected to. Designing of slabs depends upon whether it is a one-way or a two-way slab, the end conditions and the loading. From the slabs, the loads are transferred to the beam. Thereafter, the loads (mainly shear) from the beams are taken by the columns. Finally, the sections must be checked for all the four components with regard to strength and serviceability.

KEYWORDS: ETABS Software, sports complex, strength, serviceability.

I. INTRODUCTION

A sports complex is a group of sports facilities. The sports facilities are of indoor kind for e.g. table tennis, carom, chess, gymnasium etc. sports are the integral part of the student life so it is the essential requirement of good educational institution. It makes institution reputation higher and also increases the financial status.

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Table 1 Composition of Sports Complex

Facility	Numbers
Table tennis room	1
Gymnasium	1
Chess room	1
Carom room	1
Office room	1
Rest room	4
Store room	1
Toilet	4

Table Tennis

The upper surface of the table, known as the playing surface, shall be rectangular, 2.74 m long and 1.525 m wide, and shall lie in a horizontal plane 76 cm above the floor. Fluorescent or luminescent colours shall not be used anywhere in the playing area.

Gymnasium

Bigger equipment's shall be kept close to the walls. The smaller ones can be placed near the centre of the room. The height of the room must also be taken into consideration. A low ceiling will make it difficult to install equipment. The entryway is another problem. Even if the room is spacious, a small doorway will make it impossible to put large equipment in the room.

Carom

The light shall be hung/fitted at a convenient height above the Carom Board so that when a conical or square shade, preferably of metal, is used, the light shall fall only on the Carom Board including the frame. The shade shall be one with the inner side completely snow-white in colour. The bulb used, preferably transparent white, shall be between 60 and 100 watts. However, the height of the light can be altered at the request of a player in such a manner that the naked light does not strike the eyes of the players.

Table 2 Room dimensions

Table tennis room	24000mm X 15000mm
Carom room	12000mm X 5600mm
Gymnasium	24000mm X 15000mm
Office room	12000mm X 5600mm
Store room	12000mm X 5600mm
Chess room	12000mm X 5600mm
Ladies restroom	4000mm X 7000mm
Ladies W/C	4000mm X 3000mm
Gents restroom	4000mm X 7000mm
Gents W/C	4000mm X 3000mm

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II. METHODOLOGY

It is combination of Working Stress Method and Ultimate Load Method, which makes use of optimum material strength and loads by increasing the same with partial safety factors removing the drawbacks of both of the methods but retaining their good points. It is also based on sound scientific principles and backed. By 25 years of research, the Limit State Method has proved to have edge over the Working Stress Method from the economic and strength point of view. Consequently we need not stick to Working Stress Method any more.

1. Limit State of Collapse which deals with strength, overturning, sliding, buckling, fatigue, failure etc.,
2. Limit State of Serviceability which deals with discomfort to occupancy and/or malfunction, caused by excessive, deflection, crack-width, vibration, leakage, etc. and also loss of durability.

Types of load used

Dead loads

The dead load comprises of the weight of wall partitions floor finishes, false ceiling, false floors and other permanent construction in the buildings. The dead loads may be calculated from the dimensions of various members and their unit weights. The unit weights of the plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24kN/m³ and 25kN/m³ respectively. (IS 456:2000)

Live loads

Live load is produced by the intended use or occupancy of a building including the weight of movable partition, distributed and concentrated loads, load due to impact and vibration and dust loads. Live loads do not include loads due to wind, seismic activity, snow, and dead load imposed due to temperature changes to which structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo. (IS 875:1987 part2).

Design codes

Basic codes used for design of structure are published by Indian Standard, New Delhi:

IS 456:2000-Plain and reinforced concrete- code of practice (fourth revision)

Loading standards-The loads to be considered for structural design are specified in the following loading standards:

IS 875(Parts 1-5):1987- code of practice for design loads (other than earthquake) for buildings and structures (second revision)

Part 1: Dead loads

Part 2: Live loads

Table 3 Soil Studies

Sl.no	Parameters	Unit	1	2	3
1	Specific gravity	-	2.24	2.34	2.40
2	Dry density	g/cm ³	1.63	1.79	1.93
3	Recommended SBC of soil	T/cm ²	14	14	14

PLAN DETAILS

BUILDING PARAMETERS

Length along x- direction	= 27.38 m	Support condition	= Fixed.
Length along y-direction	= 38.18 m	Each storey height	= 3.5 m
No of storey	= 2	Main beam	= (230×350) mm
Main column	= (230×375) mm	Wall thickness	= 230 mm
Slab thickness	= 150 mm.		

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MATERIALS PROPERTIES

1) STEEL

Modulus of elasticity E	= 200Gpa	Poisson's ratio μ	= 0.17
Steel density	= 77kN/m ³ (7850kg/m ³)	Ultimate yield strength of steel F _y	= 250Mpa
Yield strength of steel	F _u = 415Mpa		

CONCRETE

Density of concrete	= 25 kN/m ³
Characteristic strength of concrete	= 25 Mpa

Loads assigned

Dead Load	=2kN	Live Load	=4.0kN
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III.PLANNING, MODELS AND DESIGNING

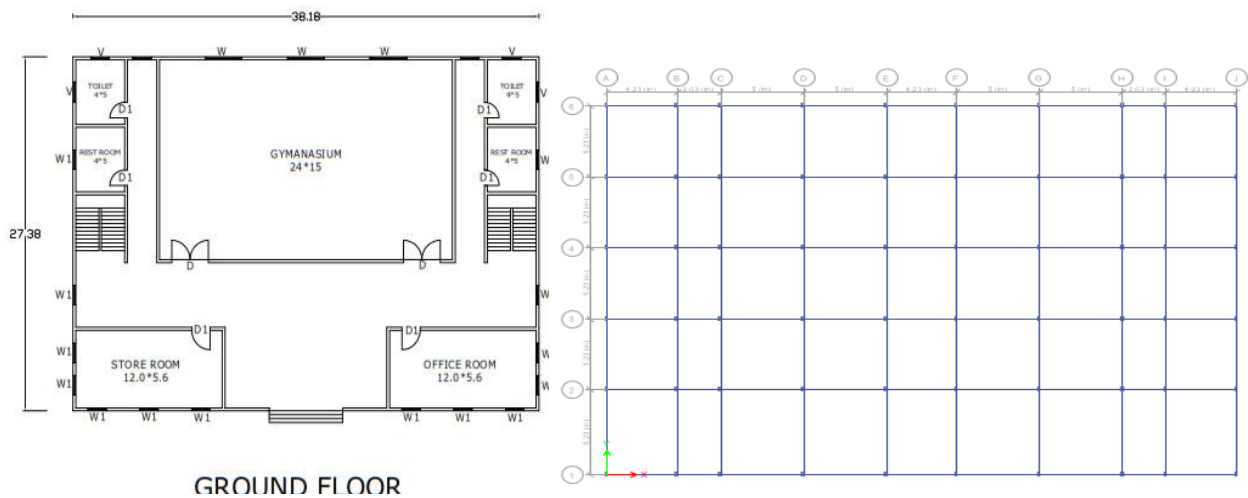


Figure 1 Beam-Column Layout of Plan

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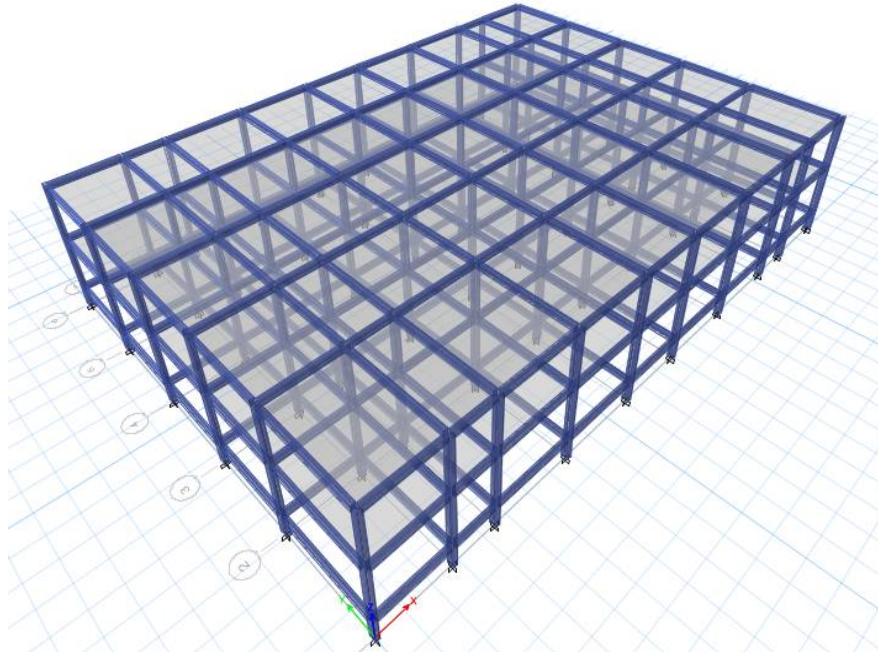


Fig 2 3D Model

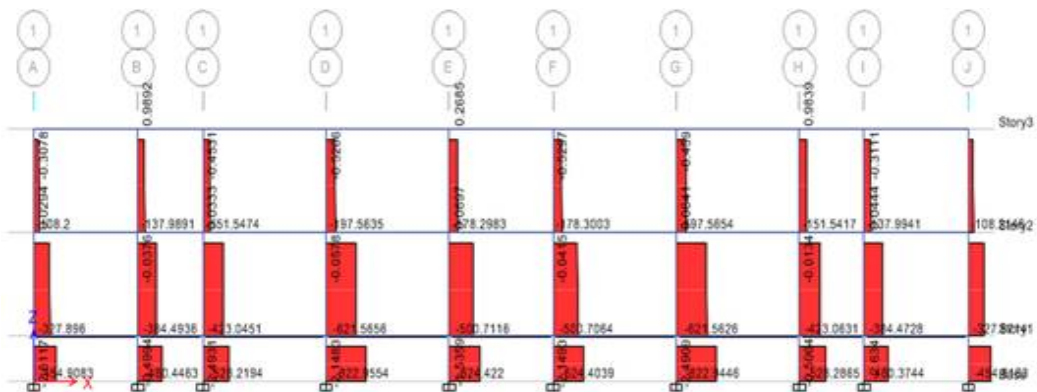


Fig 3 Axial force diagram

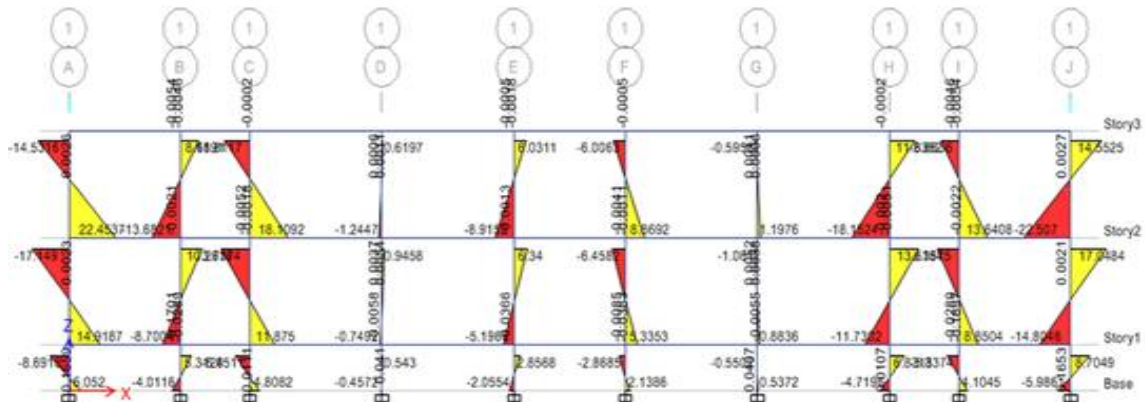


Fig 4 Moments in x direction

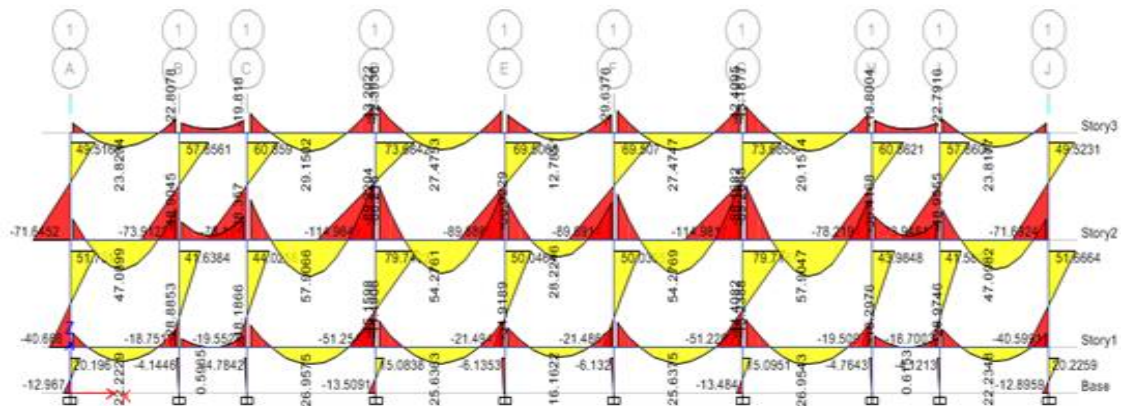


Fig 5 Moment in y direction

Design of slab

1. Data

Effective length $L_x = 4.23m$

$L_y = 5.23m$

$D = 150mm$ $d' = 20mm$

$d = D - d' = 130mm$

$L_y/L_x = 1.23 < 2$

Hence design 2 way slab.

2.

Design moment & shear

Self weight = $3.75 kN/m^2$

Floor finishing = $1.5 kN/m^2$

Live load = $3 kN/m^2$

Total load = $8.25 kN/m^2$

Factored load = $W_u = 12.37 kN/m^2$

Slab is simply supported on all four sides. Corners are held down by providing torsional reinforcement.

Moment coefficients are obtained from IS456 Table No.27 Pg.No.91.

$\alpha_x = 0.086$ $\alpha_y = 0.057$

$M_u = \alpha_x W_u l_x^2 = 19.30 kN/m^2$

$M_y = \alpha_y W_u l_x^2 = 12.61 kN/m^2$

$V_u = W_u * (r^4 / (1+r^4)) * (l_x/2) = 18.20 kN$

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3. Design of main reinforcement
 $M_{ulim} = 0.133 * f_{ck} * b * d^2 = 56.19 \text{ kN-m} > M_u$
 Hence section is under reinforced.
 - a. Reinforcement in x- direction
 Calculation of A_{st}
 $M_u = 0.87 * f_y * A_{st} * d [1 - (A_{st} * f_y) / (f_{ck} * b * d)]$
 $A_{st} = 356.02 \text{ mm}^2$
 Using 10 mm bars
 $\text{Spacing} = \{ [(3.142 * d^2) / 4] / A_{st} \} * 1000 = 200 \text{ mm}$
 Hence provide 10mm bars at 200mm c/c.
 - b. Reinforcement in y-direction
 $d = 120 \text{ mm}$
 $M_u = 0.87 * f_y * A_{st} * d [1 - (A_{st} * f_y) / (f_{ck} * b * d)]$
 $A_{st} = 252.16 \text{ mm}^2$
 Using 10mm bars
 $\text{Spacing} = 200 \text{ mm}$
 Hence provide 10mm bars at 200mm c/c.
4. Check for shear
 $\tau_v = V_u / (b * d)$
 $= 0.14 \text{ N/mm}^2$
 $P_t = (A_{st} * 100) / (b * d)$
 $= 0.30$
 From IS456-2000 Pg.No.73 Table No19.
 $\tau_c = 0.38 > \tau_v$
 Hence shear reinforcement is not required.
5. Check for deflection
 $L/d \text{ provided} = 32.53$
 Form IS456:2000 Pg.No.40
 Basic $L/d = 32$, $P_t = 0.30$
 $f_s = 0.58 * f_y (A_{st} \text{ required} / A_{st} \text{ provided})$
 $= 262.33 \text{ N/mm}^2$
 From IS456:2000 Pg.No.38 fig.no.4 modification factor for tension reinforcement.
 $F_1 = 1.4$
 $L/d \text{ max} = 32 * 1.4 = 44.8$
 Thus $L/d \text{ provided} < L/d \text{ max}$
 Therefore deflection control is satisfactory.
6. Torsional reinforcement at corners
 Size of the mesh = $l_x / 5 = 0.846 \text{ m}$
 Therefore provide mesh size = 846mm
 Area of torsional reinforcement = $0.75 * A_{st} = 267.01 \text{ mm}^2$
 Using 8mm bars
 $\text{Spacing} = 188.25 \text{ mm}$
 Therefore provide 8mm mesh of 180mm c/c.

Reinforcement in edge strip
 $A_{st} = (0.12 * b * D) * 100 = 180 \text{ mm}^2$
 Using 8 mm bars
 $\text{Spacing} = 279.25 \text{ mm}$
 Provide 8mm dia bars at 200mm c/c.

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Design of beam

1. Data

Breadth of beam $b = 230\text{mm}$
Effective depth of beam $d = 320\text{mm}$
Over all depth of beam $D = 350\text{mm}$
Effective span $= 4.23\text{m}$
Width at supports $= 230\text{mm}$
Live load $= 3\text{kN/m}$
 $f_y = 500\text{N/mm}^2$
 $f_{ck} = 25\text{N/mm}^2$

2. Design moment and shear force

$M_u = 46.76\text{kN-m}$
 $V_u = 79.36\text{kN}$
 $M_{u\text{limt}} = 0.133 * f_{ck} * b * d^2$
 $= 78.3\text{kN-m} < M_u$
Hence design singly reinforced rectangular section.

3. Calculation of area of steel

$M_u = 0.87 * f_y * A_{st} * d [1 - (A_{st} * f_y) / (f_{ck} * b * d)]$
 $A_{st} = 373.9\text{mm}^2$
Provide 6no's of 14mm dia bars $= 461.8\text{mm}^2$.

4. Shear reinforcement

$\tau_v = V_u / (b * d)$
 $= 1.07\text{N/mm}^2$
 $P_t = [A_{st} / (b * d)] * 100$
 $= 0.627$
From IS 456:2000 Pg.No. 73, Table No. 19
 $\tau_c = 0.53 < \tau_v$
Hence shear reinforcement is to be designed.
Shear to be taken by steel reinforcement,
 $V_u = 79.36\text{kN}$
Shear resisted by concrete $V_c = \tau_c * b * d$
 $= 39.008\text{kN}$

Shear to be resisted by reinforcements.

$V_{us} = V_u - V_c$
 $= 40.36\text{kN}$

Using 8mm dia 2 legged stirrups

$V_{us} = (0.87 * f_y * A_{sv} * d) / S_v$
 $S_v = 346.72\text{mm}$

But maximum spacing permitted is

- $0.75 * d = 240\text{mm}$
- 300mm

Hence provide 2 legged 8mm stirrups at 200mm c/c

5. Check for deflection criteria

From IS456:2000 Pg.No.37, Clause:23.2.1
Basic $= L/d = 26$
 $P_t = 0.785$
 $f_s = 0.58 * f_y * (A_{st\text{ required}} / A_{st\text{ provided}})$
 $= 234.8\text{N/mm}^2$

From fig.4 in IS456:2000, modification factor for providing tensile steel

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$$F_1 = 1.3$$

From fig.5 in IS456:2000, modification factor for providing steel

No compressive steel, $F_2 = 1.00$

Since this is not flanged section.

$$F_3 = 1.00$$

$$\begin{aligned} \text{Maximum L/d permitted} &= F_1 * F_2 * F_3 * \text{Basic L/d} \\ &= 33.8 \end{aligned}$$

$$\text{L/d provided} = 13.21 < 33.8$$

Thus L/d provide < Max L/d permitted.

Hence deflection control is satisfactory.

Design of column

1. Data

Size of column (230mm X 375mm)

Axial load $P_u = 444.67\text{kN}$

Factored moment, $M_{ux} = 16.301\text{kN-m}$

$$M_{uy} = 48.41\text{kN-m}$$

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

$$f_y = 500\text{N/mm}^2$$

2. Reinforcement calculation

$$P_u / (f_{ck} * b * D) = 0.206$$

$$\begin{aligned} \text{Uniaxial, } M_u &= 1.15(M_{ux2} + M_{uy2})^{0.5} \\ &= 58.74\text{kN-m} \end{aligned}$$

$$M_u / (f_{ck} * b * D^2) = 0.072$$

$$d'/D = 0.11$$

Referring to chart.no.48 in SP:16

$$P/f_{ck} = 0.02$$

$$P = 0.5$$

$$\begin{aligned} A_{sc} &= (P/100) * b * D \\ &= 431.25\text{mm}^2 \end{aligned}$$

Provide 4no's of 16mm dia

$$\text{Area provided} = 804\text{mm}^2$$

$$\begin{aligned} \text{Actual P} &= [\text{Area provided} / (b * D)] * 100 \\ &= 0.93 \end{aligned}$$

$$P/f_{ck} = 0.037$$

3. To find M_{ux1}

$$P/f_{ck} = 0.037$$

$$P_u / (f_{ck} * b * D) = 0.206$$

$$d'/D = 0.11$$

From chart.no.48 in SP:16

$$M_{ux1} / (f_{ck} * b * D^2) = 0.09$$

$$M_{ux1} = 72.77\text{kN-m}$$

4. To find M_{uy1}

Since P/f_{ck} , $P_u / (f_{ck} * b * D)$ and $M_u / (f_{ck} * b * D^2)$ are same

Hence $M_{uy} = 72.77\text{kN-m}$

5. $P_{uz} = (0.45 * f_{ck} * A_c) + (0.75 * f_y * A_{sc})$

$$\begin{aligned} A_c &= (D * b) - \text{area provided} \\ &= 85446\text{mm}^2 \end{aligned}$$

$$A_{sc} = 804.25\text{mm}^2$$

$$P_{uz} = 1265.76\text{kN}$$

6. To find α_n

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$$P_u/P_{uz} = 0.351$$

This is between 0.2 to 0.8

$$\alpha_n = 1 + \{[(P_u/P_{uz}) - 0.2] / 0.6\} = 1.251$$

7. Checking interaction formula

$$(M_{ux}/M_{ux1})^{\alpha_n} + (M_{uy}/M_{uy1})^{\alpha_n} = 0.75 < 1$$

8. Design of lateral ties

Dia of lateral ties, $\phi/4 = 4\text{mm}$

Use 8mm dia ties

Maximum spacing

a. Least lateral dimension = 230mm

b. $16 * \phi = 256\text{mm}$

c. 300mm

Provide 8mm dia at 200mm c/c.

IV. EXPERIMENTAL RESULTS

Table 4 Analysis results of column

Table 5 Analysis results of footing

Sl No.	Column Name	Numbers of column	P _u (kN)	M _{ux} kN-m	M _{uy} kN-m
1	C1	6	464.36	-13.06	-68.16
2	C2	8	575.71	16.45	62.04
3	C3	22	696.43	-21.72	-16.51
4	C4	12	754.10	26.51	24.60
5	C5	12	1022.22	-11.16	51.68

Sl No.	Footing Name	P _u (kN)	M _{ux} kN-m	M _{uy} kN-m
1.	F1	464.36	5.45	-2.90
2.	F2	575.71	-6.67	-12.17
3.	F3	693.43	6.83	13.44
4.	F4	754.10	-7.36	-1.38
5.	F5	1022.22	9.72	-16.41

V. CONCLUSIONS

In this present work ETABS is used to analyse the RC moment resting frame structure of G+1 considering the gravity loads. The following conclusion is drawn from the present work,

1. G+1 sports complex plan has been drawn in Auto CAD Software and analysed using ETABS software.
2. The results obtained from ETABS software are validated manually by using code book IS456:2000.
3. Manual design has been done for different structural elements (Beam, slabs, columns, footing, and staircase) as per IS456:2000.
4. By designing a sports complex for the Jain Institute of technology it will help in overall development of the institution.

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