Comparative Analysis and Design of Public Building Using Manual Method and STAAD.Pro Software

(IJCSNT) International Journal of Communication Systems and Network Technologies
ISSN Number: 2053-6283
Volume 12, Issue No. 3, 173–192
©The Author(s) 2023
https://journals.mirlabs.in/index.php/ijcsnt
DOI-10.18486/ijcsnt/12.3.169
IJCSNT

Parashuram Lokre[1], Manoj Kumar[2], Umashankar Y[3], Vivekanand A[4]

Abstract

Analysis and design of a any building needs basic knowledge of structural analysis, so in this project considering basic idealization how the structure is to analyze and design is to be carry out is covered by considering some ongoing projects. In the project tried to cover all the necessary analysis data consideration for different loads and load combination is considered manually and results are compared with software readings by considering same and design data loads and load combination. In detailed detailing is also tried to cover as per the IS code provisions.

Keywords

Structural Analysis, STAAD.Pro, Manual Design, Load Calculation, IS 456:2000, Reinforced Concrete

Received: 05 August 2023; **Revised:** 14 November 2023; **Accepted:** 06 December 2023; **Published:** 31 December 2023;

[1, 2, 3, 4]Department of Civil Engineering, Guru Nanak Dev Engineering College, Bidar, Karnataka, India.

Corresponding author:
Email: manoj2999@gmail.com

Introduction

About the Projects

We started our project through inspection of drawings of function hall building which is proposed to locate at K.R.Nagar[1]. The project work deals with the structural analysis and design of a proposed multipurpose hall located at K.R.Nagar, Having C+G+1 floors. Architectural plans were provided. With the given plan, beam column layout was plotted, with the help of which slabs were identified as one way, two way. Loads were worked out using IS:875-1987. Here the analysis of the structure is carried out using the software STAAD[2]. Pro V8i. 3D Model were considered and are analyzed for Dead loads and Live loads. The design is carried out as according to IS: 456:2000. Design aids of SP 16 are considered for the design of section. After the completion of function hall building we did many more buildings which include Residential building consists of C+G+2 floors and a Hospital building having G+3 floors[3,4].

About the Softwares

STAAD.Pro: STAAD.Pro is one of the leading analysis and design software used in the industry. It stands for Structural Analysis and Design Program.

STAAD.Pro is designed for engineers by engineers who understand the process of modeling, analysis and designing a structure. It is a general purpose program for performing the analysis and design of a wide variety of structures[5–8].

The basic three activities which are to be carried out to achieve the goals are:

- Model Generation
- Calculation to obtain the analytical results.
- Result verification (Post processing).

Salient Features:

- Following are the salient features of STAAD.Pro
- STAAD.Pro is the only structural analysis and design software which meets the rigid requirements of NUPIC/NCR (Nuclear Regulatory Commission).
- STAAD.Pro has the building codes of the countries including India, US of A, Britain, among others. More are constantly being added.
- STAAD.Pro easily generates comprehensive custom reports and it can be exported to Microsoft word or Microsoft excel.
- STAAD.Pro Structure wizard contains a library of trusses and frames using which models can be generated quickly.

Projects Undertaken

Function Hall Located at K.R. Nagar

Technical Data:

- Structure type : Framed structure
- No of storey : Cellar plus Ground plus one

- Height of cellar floor : 3m
- Height of ground floor : 3.4m
- Height of first floor : 3m
- SBC of soil : 200 KN/m^2
- Grade of concrete f_{ck} : 20 N/mm^2
- Grade of steel f_y : 415 N/mm^2

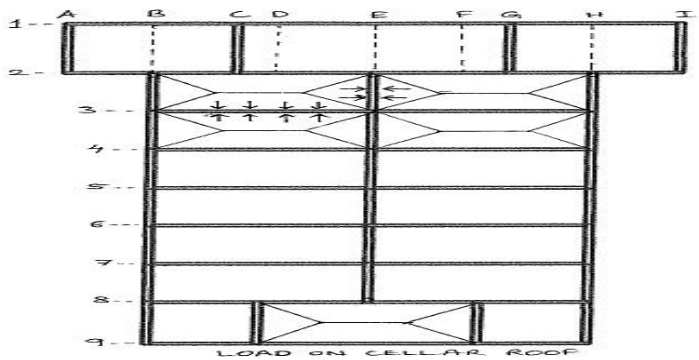

Figure 1. Cellar plan

Calculation of Loads **Load calculations for Rooms in Cellar:**
Assume 150 mm thick slab

$$\begin{aligned}\text{Dead load of slab} &= 0.15 \times 25 = 3.75 \text{ kN/m}^2\\ \text{Live load} &= 2 \text{ kN/m}^2\\ \text{Floor finish and partition} &= 2 \text{ kN/m}^2\\ \text{Total} &= 7.75 \approx 8 \text{ kN/m}^2\end{aligned}$$

Load on beam AC and GI: Assume beam size 230mm×450mm

$$\begin{aligned}\text{Self weight of beam} &= 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}\\ \text{Load from slab} &= \frac{wl_x}{6}\left[3 - \left(\frac{l_x}{l_y}\right)^2\right] = \frac{8 \times 4.80}{6}\left[3 - \left(\frac{4.8}{4.93}\right)^2\right]\\ &= 13.13 \text{ kN/m}\\ \text{Weight of wall} &= 0.225 \times 2.8 \times 20 = 12.6 \text{ kN/m}\\ \text{Total} &= 28.3 \approx 30 \text{ kN/m}\end{aligned}$$

Load on beam 1-2 along A and I: Assume beam size 230mm×380mm

$$\begin{aligned}
\text{Self weight of beam} &= 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m} \\
\text{Load from slab} &= \frac{wl_x}{3} = \frac{8 \times 4.80}{3} = 12.8 \text{ kN/m} \\
\text{weight of wall} &= 12.6 \text{ kN/m} \\
\text{Total} &= 27.58 \approx 30 \text{ kN/m}
\end{aligned}$$

Load calculation for Hall and kitchen:
Assume 150 mm thick slab

$$\begin{aligned}
\text{Dead load of slab} &= 0.15 \times 25 = 3.75 \text{ kN/m}^2 \\
\text{Live load} &= 4 \text{ kN/m}^2 \\
\text{Floor finish and partition} &= 2 \text{ kN/m}^2 \\
\text{Total} &= 9.75 \approx 10 \text{ kN/m}^2
\end{aligned}$$

Load on beam CG along 1: Assume beam size 230mm×550mm

$$\begin{aligned}
\text{Self weight of beam} &= 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m} \\
\text{Load from slab} &= \frac{10 \times 4.80}{6}\left[3 - \left(\frac{4.8}{7.24}\right)^2\right] = 20.48 \text{ kN/m} \\
\text{Weight of wall} &= 0.225 \times 2.8 \times 20 = 12.6 \text{ kN/m} \\
\text{Total} &= 36.24 \approx 37 \text{ kN/m}
\end{aligned}$$

Load on beam 1-2 along C and G:

$$\begin{aligned}
\text{Self weight of beam} &= 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m} \\
\text{Load from slab} &= \frac{8 \times 4.80}{3} + \frac{10 \times 4.80}{3} = 28.8 \text{ kN/m} \\
\text{Weight of wall} &= 0.225 \times 2.8 \times 20 = 12.6 \text{ kN/m} \\
\text{Total} &= 43.5 \approx 44 \text{ kN/m}
\end{aligned}$$

Load on beam CG along 2:

$$\begin{aligned}
\text{Self weight of beam} &= 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m} \\
\text{Load from slab} &= \frac{10 \times 4.80}{6}\left[3 - \left(\frac{4.8}{7.24}\right)^2\right] + \frac{10 \times 3.76}{6}\left[3 - \left(\frac{3.76}{6.22}\right)^2\right] \\
&= 37 \text{ kN/m} \\
\text{Total} &= 41 \text{ kN/m}
\end{aligned}$$

Load on beam AC & GI along 2:

$$\text{Self weight of beam} = 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}$$
$$\text{Load from slab} = 13.13 + 16.5 = 29.63 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 2.8 \times 20 = 12.6 \text{ kN/m}$$
$$\text{Total} = 45 \text{ kN/m}$$

Load on beam BE & EH along 3 to 7: Assume beam size 300mm×750mm

$$\text{Load from slab} = \frac{10 \times 3.66}{6}\left[3 - \left(\frac{3.66}{6.22}\right)^2\right] \times 2 = 32.37 \text{ kN/m}$$
$$\text{Self weight of beam} = 0.3 \times 0.75 \times 25 = 5.625 \text{ kN/m}$$
$$\text{Total} = 38 \text{ kN/m}$$

Load on beam 3-4 along B & H:

$$\text{Self weight of beam} = 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m}$$
$$\text{Load from slab} = \frac{10 \times 3.66}{3} = 12.2 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 3.4 \times 20 = 15.3 \text{ kN/m}$$
$$\text{Total} = 29.6 \approx 30 \text{ kN/m}$$

Load on beam 3-4 along E:

$$\text{Self weight of beam} = 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m}$$
$$\text{Load from slab} = \frac{10 \times 3.66}{3} \times 2 = 24.4 \text{ kN/m}$$
$$\text{Total} = 26.5 \approx 27 \text{ kN/m}$$

Load on beam CG along 8:

$$\text{Self weight of beam} = 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m}$$
$$\text{Load from slab} = \frac{10 \times 3.66}{6}\left[3 - \left(\frac{3.66}{6.22}\right)^2\right] + \frac{10 \times 4.02}{6}\left[3 - \left(\frac{4.025}{6.375}\right)^2\right]$$
$$= 33.63 \text{ kN/m}$$
$$\text{Total} = 36.7 \approx 37 \text{ kN/m}$$

Load on beam 8-9 along C&G:

$$\text{Self weight of beam} = 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m}$$
$$\text{Load from slab} = \frac{10 \times 4.025}{3} = 13.416 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 3.4 \times 20 = 15.3 \text{ kN/m}$$
$$\text{Total} = 30 \text{ kN/m}$$

Load on beam 8-9 along B&H:

$$\text{Self weight of beam} = 0.23 \times 0.38 \times 25 = 2.185 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 3.4 \times 20 = 15.3 \text{ kN/m}$$
$$\text{Total} = 17.48 \approx 18 \text{ kN/m}$$

Load calculation for stair case: Assume Tread = 260mm, Rise = 150mm

$$\text{Self weight of flight slab along the slope for } 1\text{m}^2 = 0.15 \times 25 = 3.75 \text{ kN/m}^2$$
$$\text{Slab for 1m horizontal span} = 1 \times 1 \times 0.15 \times 25\sqrt{\frac{0.15^2 + 0.26^2}{0.26^2}} = 4.33 \text{ kN/m}^2$$
$$\text{Weight of one step for 1m width} = 0.5 \times 1 \times 0.26 \times 0.15 \times 25 = 0.4875$$
$$\text{No. of steps in a horizontal span} = \frac{1}{T} = \frac{1}{0.26} = 3.846$$
$$\text{Self weight of step for one horizontal span} = 0.4875 \times 3.846 = 1.875 \text{ kN/m}^2$$

Therefore total weight = weight of slab $= 4.329$ = weight of step $= 1.875$ = live load $= 5$; Floor finish and partition $= 2$ kN/m^2; Total $= 13.2 \approx 15$ kN/m^2.

$$\text{Load on beam} = 15 \times (4.125/2) = 31 \text{ kN/m}$$

Load on beam BC&GH along 8:

$$\text{Self weight of beam} = 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}$$
$$\text{Load from slab and stair case} = 16.18 + 31 = 47.18 \text{ kN/m}$$
$$\text{Total} = 50 \text{ kN/m}$$

Load on beam CG along 9:

$$\text{Self weight of beam} = 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m}$$
$$\text{Load from slab} = 17.45 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 3.4 \times 20 = 15.3 \text{ kN/m}$$
$$\text{Total} = 35.9 \approx 36 \text{ kN/m}$$

Load on beam BC & GH along 9:

$$\text{Self weight of beam} = 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}$$
$$\text{Load from stair case} = 31 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 3.4 \times 20 = 15.3 \text{ kN/m}$$
$$\text{Total} = 48.8 \approx 50 \text{ kN/m}$$

Load calculations for Rooms in ground floor:
Assume 150 mm thick slab

$$\text{Dead load of slab} = 0.15 \times 25 = 3.75\ \text{kN/m}^2; \quad \text{Live load} = 2\ \text{kN/m}^2$$
$$\text{Floor finish and partition} = 2\ \text{kN/m}^2; \quad \text{Total} = 7.75 \approx 8\ \text{kN/m}^2$$

Load on beam AC & GI along 1: Assume beam size 230×450 mm

$$\begin{aligned}\text{Self weight of beam} &= 0.23 \times 0.45 \times 25 = 2.587\ \text{kN/m}\\ \text{Load from slab} &= \frac{8 \times 4.8}{6}\left[3 - \left(\frac{4.8}{4.93}\right)^2\right] = 13.13\ \text{kN/m}\\ \text{Weight of wall} &= 0.225 \times 2.9 \times 20 = 13.05\ \text{kN/m}\\ \text{Total} &= 28.7 \approx 30\ \text{kN/m}\end{aligned}$$

Load on beam 1-2 along A & I: Assume beam size 230×380 mm

$$\begin{aligned}\text{Self weight of beam} &= 0.23 \times 0.38 \times 25 = 2.185\ \text{kN/m}\\ \text{Load from slab} &= \frac{8 \times 4.8}{3} = 12.8\ \text{kN/m}\\ \text{Weight of wall} &= 0.225 \times 2.9 \times 20 = 13.05\ \text{kN/m}\\ \text{Total} &= 28.03 \approx 30\ \text{kN/m}\end{aligned}$$

Load on beam CG along 1:

$$\begin{aligned}\text{Self weight of beam} &= 0.23 \times 0.55 \times 25 = 3.16\ \text{kN/m}\\ \text{Weight of wall} &= 0.225 \times 2.9 \times 20 = 13.05\ \text{kN/m}\\ \text{Total} &= 16.2 \approx 17\ \text{kN/m}\end{aligned}$$

Load on beam 1-2 along C and G:

$$\begin{aligned}\text{Self weight of beam} &= 0.23 \times 0.38 \times 25 = 2.185\ \text{kN/m}\\ \text{Load from slab} &= \frac{8 \times 4.8}{3} = 12.8\ \text{kN/m}\\ \text{Weight of wall} &= 0.225 \times 2.9 \times 20 = 13.05\ \text{kN/m}\\ \text{Total} &= 28.3 \approx 30\ \text{kN/m}\end{aligned}$$

Load calculations for Balcony:
Assume 150 mm thick slab; Dead load of slab $= 0.15 \times 25 = 3.75$ kN/m^2; Live load $= 3$ kN/m^2; Floor finish and partition $= 2$ kN/m^2; Total $= 8.75 \approx 9$ kN/m^2.
Load on beam BC & GH along 3 to 7:

$$\text{Self weight of beam} = 0.23 \times 0.45 \times 25 = 2.587\ \text{kN/m}$$
$$\text{Load from slab} = 9 \times 3.6 = 32.4\ \text{kN/m}; \quad \text{Total} = 34.9 \approx 35\ \text{kN/m}$$

Load on beam AC & GI along 2:

$$\text{Self weight of beam} = 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}$$
$$\text{Load from slab} = 13.13 + (9 \times 1.8) = 29.33 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 2.9 \times 20 = 13.05 \text{ kN/m}; \quad \text{Total} = 45 \text{ kN/m}$$

Load on beam 3-4 along B & H: Self weight of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Weight of wall $= 0.225 \times 2.9 \times 20 = 13.05$ kN/m; Total $= 15.24 \approx 16$ kN/m.
Load on beam BC & GH along 8: Self weight of beam $= 0.23 \times 0.45 \times 25 = 2.587$ kN/m; Load from slab $= 9 \times 1.8 = 16.2$ kN/m; Load from stair case $= 31$ kN/m; $= 49.7 \approx 50$ kN/m.
Load on beam CG along 8: Self weight of beam $= 0.23 \times 0.55 \times 25 = 3.16$ kN/m; Load from slab $= 9 \times 1.5 + 9 \times 0.9 = 21.6$ kN/m; Total $= 24.7 \approx 25$ kN/m.
Load on beam 8-9 along B & H: Self weight of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Weight of wall $= 0.225 \times 2.9 \times 20 = 13.05$ kN/m; Total $= 15.24 \approx 16$ kN/m.
Load on beam 8-9 along C & G: Self weight of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Weight of slab $= 9 \times 0.9 \times 1 = 8.1$ kN/m; Weight of wall $= 0.225 \times 2.9 \times 20 = 13.05$ kN/m; Total $= 23.3 \approx 25$ kN/m.
Load on beam BC & GH along 9: Self weight of beam $= 0.23 \times 0.45 \times 25 = 2.587$ kN/m; Load from stair case $= 31$ kN/m; Weight of wall $= 0.225 \times 2.9 \times 20 = 13.05$ kN/m; Total $= 46.6 \approx 47$ kN/m.
Load calculation for porch:
Assume 150 mm thick slab; Dead load of slab $= 0.15 \times 25 = 3.75$ kN/m^2; Live load $= 2$ kN/m^2; Floor finish and partition $= 2$ kN/m^2; Total $= 7.75 \approx 8$ kN/m^2.
Load on beam CG along 9:

$$\text{Self weight of beam} = 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m}$$
$$\text{Load from slab} = (9 \times 0.9 \times 1) + \left\{\frac{8 \times 4.5}{6}\left[3 - \left(\frac{4.5}{6.15}\right)^2\right]\right\} = 22.88 \text{ kN/m}$$
$$\text{Weight of wall} = 0.225 \times 2.9 \times 20 = 13.05 \text{ kN/m}; \quad \text{Total} = 39 \approx 40 \text{ kN/m}$$

Load on beam 9-10 along C & G: Self weight of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Load from slab $= \frac{8 \times 4.5}{3} = 12$ kN/m; Total $= 14.18 \approx 15$ kN/m.
Load on beam CG along 10:

$$\text{Self weight of beam} = 0.23 \times 0.55 \times 25 = 3.16 \text{ kN/m}$$
$$\text{Load from slab} = \frac{8 \times 4.5}{6}\left[3 - \left(\frac{4.5}{6.15}\right)^2\right] = 14.78 \text{ kN/m}; \quad \text{Total} = 17.9 \approx 18 \text{ kN/m}$$

Load calculation for top roof:
Assume 140 mm thick slab; Dead load of slab $= 0.14 \times 25 \times 1 \times 1 = 3.5$ kN/m^2; Live load $= 2$ kN/m^2; Floor finish and partition $= 2$ kN/m^2; Total $= 7.5 \approx 8$ kN/m^2.

Load on beam AC & GI Along 1: Assume beam size 230×450 mm

$$\text{Self weight of beam} = 1 \times 0.23 \times 0.45 \times 25 = 2.587 \text{ kN/m}$$
$$\text{Load from slab} = \frac{8 \times 4.80}{6}\left[3 - \left(\frac{4.8}{4.93}\right)^2\right] = 13.13 \text{ kN/m}$$
$$\text{wt of parapet wall} = 8 \text{ kN/m}; \quad \text{Total} = 23.7 \approx 25 \text{ kN/m}$$

Load on beam 1-2 along A&I: Assume beam size 230×380 mm; Self wt of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Load from slab $= \frac{8 \times 4.80}{3} = 12.8$ kN/m; wt of parapet wall $= 8$ kN/m; Total $= 22.9 \approx 25$ kN/m.

Load on beam CG along 1:

$$\text{Self wt of beam} = 0.23 \times 0.55 \times 25 = 3.1625 \text{ kN/m}$$
$$\text{Load from slab} = \frac{8 \times 4.80}{6}\left[3 - \left(\frac{4.8}{7.24}\right)^2\right] = 16.38 \text{ kN/m}$$
$$\text{wt of parapet wall} = 8 \text{ kN/m}; \quad \text{Total} = 27.54 \approx 30 \text{ kN/m}$$

Load on beam 1-2 along C & G: Self wt of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Load from slab $= 2[(8 \times 4.8)/3] = 25.6$ kN/m; Total $= 27.78 \approx 30$ kN/m.

Load on beam CG Along 2:

$$\text{Self wt of beam} = 0.23 \times 0.55 \times 25 = 3.1625 \text{ kN/m}$$
$$\text{Load from slab} = \frac{8 \times 4.80}{6}\left[3 - \left(\frac{4.8}{7.24}\right)^2\right] + (8 \times 1.8 \times 1) = 30.78 \text{ kN/m}$$
$$\text{Total} = 33.9 \approx 34 \text{ kN/m}$$

Load on beam AC & GI Along 2: Self wt of beam $= 0.23 \times 0.45 \times 25 = 2.587$ kN/m; Load from slab $= (13.13 + 14.4) = 27.53$ kN/m; Total $= 30$ kN/m.

Load on beam BH Along 3 to 7: Self wt of beam $= 0.3 \times 0.75 \times 25 = 5.625$ kN/m; Load from slab $= 1 \times 1.8 = 14.4$ kN/m; Total $= 20$ kN/m.

Load on beam 3-4 Along B and H: Self wt of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Load from parapet wall $= 8$ kN/m; Total $= 15$ kN/m.

Load on beam BC & GH Along 8: Self wt of beam $= 0.23 \times 0.45 \times 25 = 2.587$ kN/m; Load from slab $= 14.4$ kN/m; Stair case $= 31$ kN/m; Total $= 47.9 \approx 50$ kN/m.

Load on beam CG along 8:

$$\text{Self wt of beam} = 0.23 \times 0.55 \times 25 = 3.1625 \text{ kN/m}$$
$$\text{Load from slab} = 14.4 + \frac{8 \times 4.025}{6}\left[3 - \left(\frac{4.025}{6.15}\right)^2\right] = 28.20 \text{ kN/m}$$
$$\text{Total} = 31.36 \approx 32 \text{ kN/m}$$

Load on beam 8-9 Along C and G: Self weight of beam $= 0.23 \times 0.38 \times 25 = 2.185$ kN/m; Load from slab $= \frac{8\times 4.025}{3} = 10.73$ kN/m; Total $= 12.9 \approx 15$ kN/m.
Load on beam BC & GH Along 9: Self wt of beam $= 0.23 \times 0.45 \times 25 = 2.587$ kN/m; Load from stair case $= 31$ kN/m; Load from parapet wall $= 8$ kN/m; Total $= 41.5 \approx 42$ kN/m.
Load on beam CG along 9: Self wt of beam $= 0.23 \times 0.55 \times 25 = 3.1625$ kN/m; Load from slab $= 13.8$ kN/m; Load from parapet wall $= 8$ kN/m; Total $= 24.9 \approx 30$ kN/m.

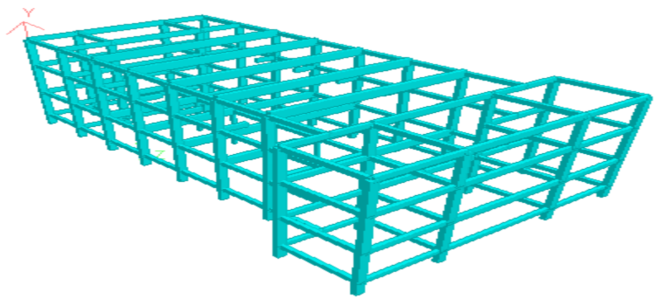

Figure 2. 3-D modelling

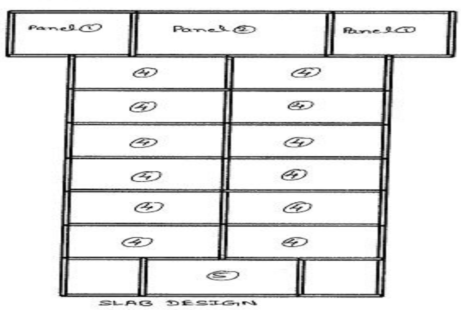

Figure 3. Slab design

Design of Slab **Design of corner slab (panel number 1&3):**

$$L_x = 4.725 \text{ m}; \quad L_y = 4.825 \text{ m}; \quad L_y/L_x = 1.02 < 2$$

Therefore Design as Two way slab. Design ultimate load $w_u = 12$ kN/m^2. Ultimate design moments: From Table 26 of IS456 2000 case-8, $L_y/L_x = 1.02$.

Long Direction:

$$\text{Negative moment on continuous edge} = 0.057 \times 12 \times 4.725^2 = 15.27 \text{ KN-m}$$

$$\text{Positive moment on mid span} = 0.043 \times 12 \times 4.725^2 = 11.52 \text{ KN-m}$$

$$\text{Negative moment on discontinuous edge} = 11.52/2 = 5.76 \text{ KN-m}$$

Short Direction: Positive moment on mid span $= 0.046 \times 12 \times 4.725^2 = 12.32$ KN-m; Negative moment on discontinuous edge $= 6.16$ KN-m.
Check for depth:

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}} = \sqrt{\frac{15.27 \times 10^6}{0.138 \times 20 \times 1000}} = 75 \text{ mm} < 150 \text{ mm Hence OK}$$

Reinforcement:
For short span:
a) Positive moment on mid span $= 12.32$ KN-m

$$\frac{M_u}{bd^2} = \frac{12.32 \times 10^6}{1000 \times 120^2} = 0.86$$

From SP 16, page number 48, $p_t = 0.249$;

$$A_{st} = \frac{0.249 \times 1000 \times 120}{100} = 299 \text{ mm}^2$$

Provide 8mm dia at 170mm c/c.
b) Negative moment on discontinuous edge $= 6.16$ KN-m

$$\frac{M_u}{bd^2} = \frac{6.16 \times 10^6}{1000 \times 120^2} = 0.43$$

From SP 16, page number 48, $P_t = 0.120$;

$$A_{st} = \frac{0.120 \times 1000 \times 120}{100} = 153 \text{ mm}^2$$

Provide 8mm dia at 300mm c/c.
For long span:
a) Negative moment on discontinuous edge $= 15.27$ KN-m

$$\frac{M_u}{bd^2} = \frac{15.27 \times 10^6}{1000 \times 120^2} = 1.06$$

From SP 16, page number 48, $P_t = 0.314$;

$$A_{st} = \frac{0.314 \times 1000 \times 120}{100} = 376 \text{ mm}^2$$

Provide 8mm dia at 130mm c/c.
b) Positive moment on mid span $= 11.52$ KN-m

$$\frac{M_u}{bd^2} = \frac{11.52 \times 10^6}{1000 \times 120^2} = 0.8$$

From SP 16, page number 48, $p_t = 0.233$;

$$A_{st} = \frac{0.233 \times 1000 \times 120}{100} = 261 \text{ mm}^2$$

Provide 8mm dia at 190mm c/c.
c) Negative moment on discontinuous edge $= 5.76$ KN-m

$$\frac{M_u}{bd^2} = \frac{5.76 \times 10^6}{1000 \times 120^2} = 0.4$$

From SP 16, page number 48, $P_t = 0.114$;

$$A_{st} = \frac{0.114 \times 1000 \times 120}{100} = 137 \text{ mm}^2$$

Provide 8mm dia at 300mm c/c.
Design of Intermediate panel (panel number 2): $L_x = 4.725$ m; $L_y = 7.175$ m; $L_y/L_x = 1.52 < 2$. Therefore Design as Two way slab. Design ultimate load $w_u = 15$ kN/m^2. Ultimate design moments: From Table 26 of IS456 2000 case 3, $L_y/L_x = 1.02$.
Short Direction:

$$\text{Negative moment on continuous edge} = 0.069 \times 15 \times 4.725^2 = 23.11 \text{ KN-m}$$
$$\text{Positive moment on mid span} = 0.053 \times 15 \times 4.725^2 = 17.72 \text{ KN-m}$$
$$\text{Negative moment on discontinuous edge} = 17.72/2 = 8.87 \text{ KN-m}$$

Long Direction:

$$\text{Positive moment on mid span} = 0.028 \times 15 \times 4.725^2 = 9.372 \text{ KN-m}$$
$$\text{Negative moment on continuous edge} = 0.037 \times 15 \times 4.725^2 = 12.39 \text{ KN-m}$$
$$\text{Negative moment on discontinuous edge} = 4.76 \text{ KN-m}$$

Reinforcement:
For short span:
a) Positive moment on mid span $= 17.72$ KN-m: $\frac{M_u}{bd^2} = \frac{17.72 \times 10^6}{1000 \times 120^2} = 1.23$; $p_t = 0.34$; $A_{st} = \frac{0.34 \times 1000 \times 120}{100} = 408$ mm^2; Provide 8mm dia at 120mm c/c.
b) Negative moment on discontinuous edge $= 8.87$ KN-m: $\frac{M_u}{bd^2} = \frac{6.16 \times 10^6}{1000 \times 120^2} = 0.395$; $P_t = 0.115$; $A_{st} = \frac{0.120 \times 1000 \times 120}{100} = 212$ mm^2; Provide 8mm dia at 240mm c/c.
c) Negative moment on continuous edge $= 23.11$ KN-m: $\frac{M_u}{bd^2} = \frac{23.11 \times 10^6}{1000 \times 120^2} = 1.6$; $p_t = 0.4$; $A_{st} = \frac{0.4 \times 1000 \times 120}{100} = 480$ mm^2; Provide 8mm dia at 100mm c/c.

For long span:
a) Negative moment on continuous edge $= 12.39$ KN-m: $\frac{M_u}{bd^2} = \frac{12.39\times10^6}{1000\times120^2} = 0.86$; $P_t = 0.249$; $A_{st} = \frac{0.249\times1000\times120}{100} = 285$ mm^2; Provide 8mm dia at 170mm c/c.
b) Positive moment on mid span $= 9.372$ KN-m: $\frac{M_u}{bd^2} = \frac{9.372\times10^6}{1000\times120^2} = 0.65$; $p_t = 0.187$; $A_{st} = \frac{0.233\times1000\times120}{100} = 218$ mm^2; Provide 8mm dia at 220mm c/c.
c) Negative moment on discontinuous edge $= 4.7$ KN-m: $\frac{M_u}{bd^2} = \frac{4.7\times10^6}{1000\times120^2} = 0.21$; $P_t = 0.085$; $A_{st} = \frac{0.085\times1000\times120}{100} = 153$ mm^2; Provide 8mm dia at 300mm c/c.
Design of panel number 4: $L_x = 3.6$ m; $L_y = 6$ m; $L_y/L_x = 1.67 < 2$. Therefore Design as Two way slab. Design ultimate load $w_u = 15$ kN/m^2. Ultimate design moments: From Table 26 of IS456 2000 case 3, $L_y/L_x = 1.02$.
Short Direction: Negative moment on continuous edge $= 0.061 \times 15 \times 3.6^2 = 11.86$ KN-m; Positive moment on mid span $= 0.047 \times 15 \times 3.6^2 = 9.142$ KN-m; Negative moment on discontinuous edge $= 9.142/2 = 4.57$ KN-m.
Long Direction: Positive moment on mid span $= 0.028 \times 15 \times 3.6^2 = 5.52$ KN-m; Negative moment on continuous edge $= 0.037 \times 15 \times 3.6^2 = 7.19$ KN-m; Negative moment on discontinuous edge $=$ 2.73 KN-m.
Reinforcement:
For short span:
a) Positive moment on mid span $= 9.142$ KN-m: $\frac{M_u}{bd^2} = 0.41$; $p_t = 0.116$; $A_{st} = 209$ mm^2; Provide 8mm dia at 230mm c/c.
b) Negative moment on discontinuous edge $= 4.57$ KN-m: $\frac{M_u}{bd^2} = 0.203$; $P_t = 0.085$; $A_{st} = 153$ mm^2; Provide 8mm dia at 300mm c/c.
c) Negative moment on continuous edge $= 11.86$ KN-m: $\frac{M_u}{bd^2} = 0.53$; $p_t = 0.147$; $A_{st} = 265$ mm^2; Provide 8mm dia at 180mm c/c.
For long span:
a) Negative moment on continuous edge $= 7.19$ KN-m: $\frac{M_u}{bd^2} = 0.139$; $P_t = 0.090$; $A_{st} = 162$ mm^2; Provide 8mm dia at 300mm c/c.
b) Positive moment on mid span $= 5.5$ KN-m: $\frac{M_u}{bd^2} = 0.24$; $p_t = 0.085$; $A_{st} = 153$ mm^2; Provide 8mm dia at 300mm c/c.
c) Negative moment on discontinuous edge $= 2.73$ KN-m: $\frac{M_u}{bd^2} = 0.121$; $P_t = 0.085$; $A_{st} = 153$ mm^2; Provide 8mm dia at 300mm c/c.
Design of panel number 5: $L_x = 3.9$ m; $L_y = 6.478$ m; $L_y/L_x = 1.66 < 2$. Therefore Design as Two way slab. Design ultimate load $w_u = 15$ kN/m^2. Ultimate design moments: From Table 26 of IS456 2000 case 7, $L_y/L_x = 1.02$.
Short Direction: Negative moment on continuous edge $= 0.090 \times 15 \times 3.9^2 = 20.54$ KN-m; Positive moment on mid span $= 0.069 \times 15 \times 3.9^2 = 15.74$ KN-m; Negative moment on discontinuous edge $= 15.74/2 = 7.87$ KN-m.
Long Direction: Positive moment on mid span $= 0.043 \times 15 \times 3.6^2 = 9.81$ KN-m; Negative moment on discontinuous edge $= 4.91$ KN-m.
Reinforcement:
For short span:
a) Positive moment on mid span $= 15.74$ KN-m: $\frac{M_u}{bd^2} = 1.093$; $p_t = 0.327$; $A_{st} = 393$ mm^2; Provide

8mm dia at 120mm c/c.
b) Negative moment on discontinuous edge $= 7.9$ KN-m: $\frac{M_u}{bd^2} = 0.5465$; $P_t = 0.163$; $A_{st} = 240$ mm^2; Provide 8mm dia at 200mm c/c.
c) Negative moment on continuous edge $= 20.54$ KN-m: $\frac{M_u}{bd^2} = 1.46$; $p_t = 0.448$; $A_{st} = 538$ mm^2; Provide 8mm dia at 100mm c/c.
For long span:
a) Positive moment on mid span $= 9.81$ KN-m: $\frac{M_u}{bd^2} = 0.68$; $p_t = 0.2$; $A_{st} = 240$ mm^2; Provide 8mm dia at 200mm c/c.
b) Negative moment on discontinuous edge $= 4.91$ KN-m: $\frac{M_u}{bd^2} = 0.34$; $P_t = 0.2$; $A_{st} = 240$ mm^2; Provide 8mm dia at 200mm c/c.

Design of Beams

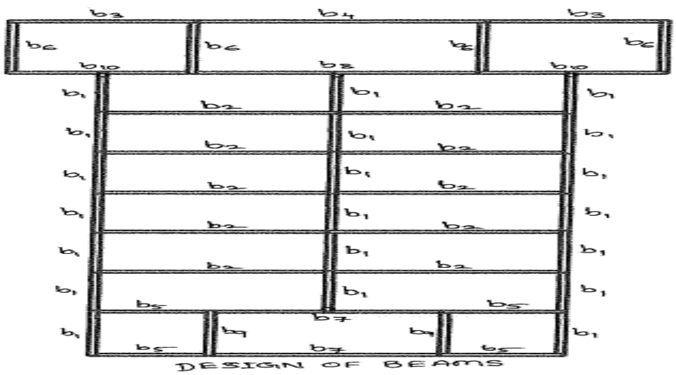

Figure 4. Design of beams

Design of beam b1: a) Maximum positive B.M $= 1.5 \times 25 = 38$ kN-m; b) Maximum negative B.M $= 1.5 \times 57 = 86$ kN-m; c) Maximum S.F $= 70 \times 1.5 = 105$ kN.

$$\text{a)}\quad \frac{M_u}{bd^2} = \frac{38 \times 10^6}{230 \times 330^2} = 1.52 \text{ (From SP 16)}, \quad P_t = 0.475$$

$$A_{st} = \frac{0.475 \times 230 \times 330}{100} = 360 \text{ mm}^2;\ \text{Provide } \phi 12\text{mm 4 no.s } (452 \text{ mm}^2)$$

$$\text{b)}\quad \frac{M_u}{bd^2} = \frac{86 \times 10^6}{230 \times 330^2} = 3.43 \text{ (From SP 16)}, \quad P_t = 1.175,\ P_c = 0.24$$

$$A_{st} = \frac{1.175 \times 230 \times 330}{100} = 892 \text{ mm}^2;\ \text{Provide } \phi 16\text{mm of 5 no.s}$$

$$A_{sc} = \frac{0.24 \times 230 \times 330}{100} = 183 \text{ mm}^2;\ \text{Provide } \phi 12\text{mm of 2 no.s}$$

$$\text{c) Max S.F}\quad \tau_V = \frac{V_u}{bd} = \frac{105 \times 10^3}{230 \times 330} = 1.38; \quad \tau_c = 0.65 \text{ (IS 456 Table 19)}$$

$$\frac{V_{us}}{d} = \frac{(1.38 - 0.65) \times 230 \times 330}{33 \times 10^3} = 1.68;\ \text{Provide } \phi 8\text{mm 2 legged stirrups @ 200mm c/c}$$

Design of beam b2: a) Maximum positive B.M $= 1.5 \times 84 = 126$ kN-m; b) Maximum negative B.M $= 1.5 \times 138 = 207$ kN-m; c) Maximum S.F $= 130 \times 1.5 = 195$ kN.

a) $$\frac{M_u}{bd^2} = \frac{126 \times 10^6}{300 \times 720^2} = 0.81, \quad P_t = 0.235;\ A_{st} = \frac{0.235 \times 300 \times 720}{100} = 508 \text{ mm}^2$$

Provide ϕ16mm 3 no.s (603 mm^2)

b) $$\frac{M_u}{bd^2} = \frac{207 \times 10^6}{300 \times 720^2} = 1.33, \quad P_t = 0.405;\ A_{st} = \frac{0.405 \times 300 \times 720}{100} = 875 \text{ mm}^2$$

Provide ϕ20mm of 3 no.s (942 mm^2)

c) $$\tau_V = \frac{195 \times 10^3}{300 \times 720} = 0.902; \quad \tau_c = 0.45;\ \frac{V_{us}}{d} = \frac{(0.902 - 0.45) \times 300 \times 720}{72 \times 10^3} = 1.36$$

Provide ϕ8mm 2 legged stirrups @ 200mm c/c

Design of beam b3: a) Maximum positive B.M $= 1.5 \times 27 = 40.5$ kN-m; b) Maximum negative B.M $= 1.5 \times 86 = 129$ kN-m; c) Maximum S.F $= 82 \times 1.5 = 123$ kN.

a) $$\frac{M_u}{bd^2} = \frac{40.5 \times 10^6}{230 \times 420^2} = 0.998, \quad P_t = 0.295;\ A_{st} = \frac{0.295 \times 230 \times 420}{100} = 285 \text{ mm}^2$$

Provide ϕ12mm 3 no.s

b) $$\frac{M_u}{bd^2} = \frac{129 \times 10^6}{230 \times 420^2} = 3.18, \quad P_t = 1.091,\ P_c = 0.141$$

$$A_{st} = \frac{1.091 \times 230 \times 420}{100} = 1054 \text{ mm}^2;\ \text{Provide } \phi\text{12mm of 2 no.s}$$

$$A_{sc} = \frac{0.2 \times 230 \times 420}{100} = 194 \text{ mm}^2;\ \text{Provide } \phi\text{20mm of 3 no.s (942 mm}^2)$$

c) $$\tau_V = \frac{123 \times 10^3}{230 \times 420} = 1.27; \quad \tau_c = 0.63;\ \frac{V_{us}}{d} = \frac{(1.27 - 0.63) \times 230 \times 420}{42 \times 10^3} = 1.48$$

Provide ϕ8mm 2 legged stirrups @ 230mm c/c

Design of beam b4: a) Maximum positive B.M $= 1.5 \times 106 = 159$ kN-m; b) Maximum negative B.M $= 1.5 \times 175 = 263$ kN-m; c) Maximum S.F $= 146 \times 1.5 = 219$ kN.

a) $\dfrac{M_u}{bd^2} = \dfrac{159 \times 10^6}{230 \times 500^2} = 2.76, \quad P_t = 0.958;\ A_{st} = \dfrac{0.958 \times 230 \times 500}{100} = 1101 \text{ mm}^2$

Provide ϕ20mm 4 no.s

b) $\dfrac{M_u}{bd^2} = \dfrac{263 \times 10^6}{230 \times 500^2} = 4.57, \quad P_t = 1.512,\ P_c = 0.585$

$A_{st} = \dfrac{1.512 \times 230 \times 500}{100} = 1738.8 \text{ mm}^2;$ Provide ϕ25mm of 4 no.s

$A_{sc} = \dfrac{0.585 \times 230 \times 500}{100} = 673 \text{ mm}^2;$ Provide ϕ16mm of 4 no.s

c) $\tau_V = \dfrac{219 \times 10^3}{230 \times 500} = 1.9; \quad \tau_c = 0.78;\ \dfrac{V_{us}}{d} = \dfrac{(1.9 - 0.78) \times 230 \times 500}{50 \times 10^3} = 2.58$

Provide ϕ8mm 2 legged stirrups @ 140mm c/c

Design of beam b5: a) Maximum positive B.M $= 1.5 \times 19 = 29$ kN-m; b) Maximum negative B.M $= 1.5 \times 64 = 96$ kN-m; c) Maximum S.F $= 90 \times 1.5 = 135$ kN.

a) $\dfrac{M_u}{bd^2} = \dfrac{29 \times 10^6}{230 \times 420^2} = 0.71, \quad P_t = 0.205;\ A_{st} = \dfrac{0.205 \times 230 \times 420}{100} = 200 \text{ mm}^2$

Provide ϕ12mm 2 no.s

b) $\dfrac{M_u}{bd^2} = \dfrac{96 \times 10^6}{230 \times 420^2} = 2.37, \quad P_t = 0.786;\ A_{st} = \dfrac{0.786 \times 230 \times 420}{100} = 760 \text{ mm}^2$

Provide ϕ16mm of 4 no.s

c) $\tau_V = \dfrac{135 \times 10^3}{230 \times 420} = 1.40; \quad \tau_c = 0.59;\ \dfrac{V_{us}}{d} = \dfrac{(1.4 - 0.59) \times 230 \times 420}{42 \times 10^3} = 1.88$

Provide ϕ8mm 2 legged stirrups @ 190mm c/c

Design of beam b6: a) Maximum positive B.M $= 1.5 \times 66 = 99$ kN-m; b) Maximum negative B.M $= 1.5 \times 66 = 99$ kN-m; c) Maximum S.F $= 107 \times 1.5 = 161$ kN.

a) $\dfrac{M_u}{bd^2} = \dfrac{99 \times 10^6}{230 \times 350^2} = 3.51, \quad P_t = 1.185,\ P_c = 0.239$

$A_{st} = \dfrac{1.85 \times 230 \times 350}{100} = 953 \text{ mm}^2;$ Provide ϕ16mm of 5 no.s

$A_{sc} = \dfrac{0.239 \times 230 \times 350}{100} = 193 \text{ mm}^2;$ Provide ϕ12mm of 2 no.s

b) $\tau_V = \dfrac{161 \times 10^3}{230 \times 350} = 2; \quad \tau_c = 0.66;\ \dfrac{V_{us}}{d} = \dfrac{(2 - 0.66) \times 230 \times 350}{35 \times 10^3} = 3.1$

Provide ϕ8mm 2 legged stirrups @ 110mm c/c

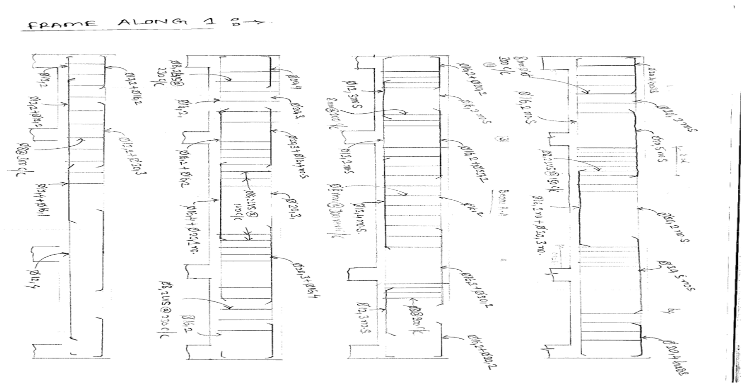

Figure 5. Detailing of frame along 1

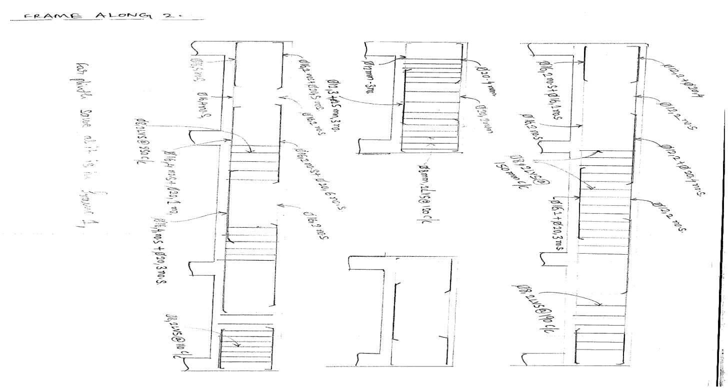

Figure 6. Detailing of frame along 2

Detailing

Design of Columns

Design of Rectangular Column with Biaxial Bending (as per SP 16):

Length of the column $(d) = 450$ mm; Breadth $(b) = 230$ mm

$f_{ck} = 20$ N/mm^2; $f_y = 415$ N/mm^2; Factored Load $(P_u) = 1050$ kN

$M_{ux} = 9$ kN-m; $M_{uy} = 32$ kN-m; Trial steel percent $p\% = 1.8$

$p/f_{ck} = 0.09$; $d' = 40$; $d'/D = 0.0889$; $P_u/(f_{ck}bd) = 0.5072$

$M_{ux1}/(f_{ck}bd^2) = 0.09$; $M_{ux1} = 83.835$ kN-m

$d'/b = 0.1739$; $M_{uy1}/(f_{ck}db^2) = 0.08$; $M_{uy1} = 38.088$ kN-m

$P_{uz}/A_g = 19$; $P_{uz} = 1966.5$ kN; $P_u/P_{uz} = 0.5339$

$M_{ux}/M_{ux1} = 0.1074$; $M_{uy}/M_{uy1} = 0.8402$

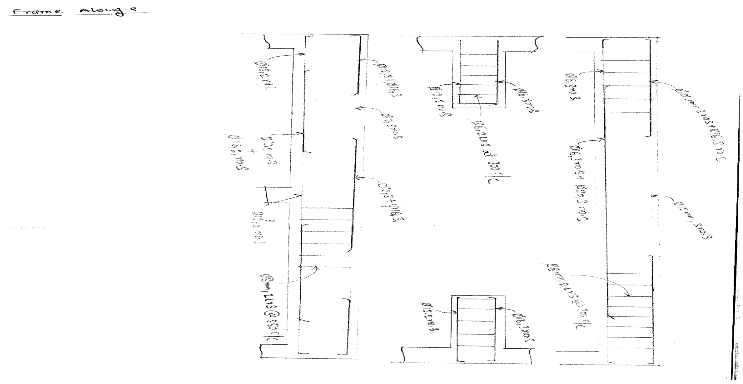

Figure 7. Detailing of frame along 3

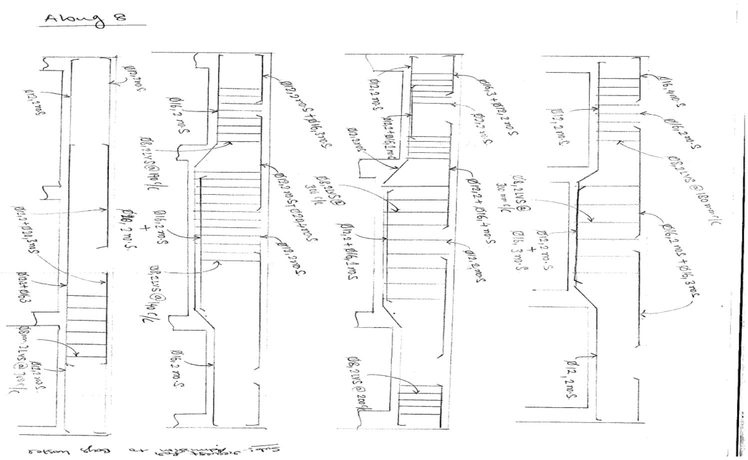

Figure 8. Detailing of frame along 8

Referring to chart, permissible value of M_{ux}/M_{ux1} corresponding to P_u/P_{uz} and M_{uy}/M_{uy1} is 0.6. Increase in steel percentage; Revised % of steel = 3.

$$p/f_{ck} = 0.15; \quad P_u/(f_{ck}bd) = 0.5072; \quad M_{ux1}/(f_{ck}bd^2) = 0.05; \quad M_{ux1} = 46.575 \text{ kN-m}$$
$$M_{uy1}/(f_{ck}db^2) = 0.04; \quad M_{uy1} = 19.044 \text{ kN-m}; \quad P_{uz}/A_g = 13; \quad P_{uz} = 1345.5 \text{ kN}$$
$$P_u/P_{uz} = 0.7804; \quad M_{ux}/M_{ux1} = 0.1932; \quad M_{uy}/M_{uy1} = 1.6803$$

Referring to chart, permissible value of $M_{ux}/M_{ux1} = 0.6$.

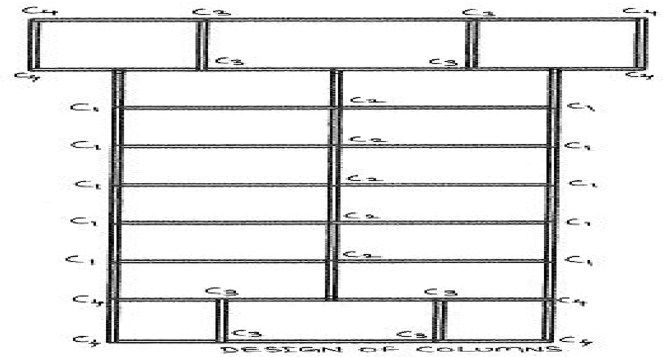

Figure 9. Design of columns

Table 1. Column details for function hall

Grid	b	D	$P_{u,cr}$	$M_{u,cr}$	$\frac{P_u}{f_{ck}bd}$	$\frac{M_u}{f_{ck}bd^2}$	$P_t\%$	A_{st}	Main / Ties
C1	300	450	1050	188	0.39	0.18	2.8	3780	8-#25 / #8@300
C2 (circ.)	300	570		15		0.8		565	6-#16 / #8@200
C3	300	450	1782	82.5	0.64	0.12	3.2	4320	6-#25,6-#20 / #8@300
C4	300	450	891	84	0.33	0.15	2.4	3573	6-#25,2-#20 / #8@300

Table 2. Details for foundation

Footing	$P_{u,cr}$ (kN)	$M_{u,cr}$ (kN-m)	SBC (kN/m^2)	L (m)	B (m)	D (mm)	Reinf. length	Reinf. breadth
F1	1053	15	200	2.5	2.5	500	#12@130	#12@130
F2	697	0	200	1.5	1.5	400	#10@120	#10@120
F3	1782	55	200	3.25	3.25	600	#12@100	#12@100

Design of Foundation

Conclusions

- Knowledge about visualization of structure is obtained.
- Design of slabs, beams, columns, footing is done manually.
- All the design requirements were checked for codal provisions.
- An exposure to Staad Pro software are been obtained.
- Knowledge about preparation of structural design report is obtained.
- Practical knowledge regarding execution of various construction stages in the site.

References

[1] IS 456: 2000, "Indian Standard Code for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi.

[2] IS 1893 (Part1): (2002), "Indian Standard Criteria for Earthquake Resistant Design of Structures", General provision and buildings, Bureau of Indian Standards, New Delhi.

[3] SP 16: 1980, "Design Aids for Reinforced Concrete to IS: 456-1978", Bureau of Indian Standards, New Delhi.

[4] SP 34: 1987, "Handbook on Concrete Reinforcement and Detailing", Bureau of Indian Standards, New Delhi.

[5] IS 875: 1987, "Indian Standard Code of practice for" – IS: 875 – PART 1: Dead Loads, Bureau of Indian Standards, New Delhi.

[6] IS: 875 – PART 2: Imposed Loads, Bureau of Indian Standards, New Delhi.

[7] S. Ramamrutam and R. Narayan, (1999), "Design of Reinforced Concrete Structures", Dhanpat Rai Publishing Company, New Delhi.

[8] N. Krishna Raju, "Advanced Reinforced concrete design", CBS publishers and distributors, New Delhi.