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A Comparative Study on Analysis of a Conventional Multi-Storey Building & A Single Column Building

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Abstract: The comparative study on analysis of RCC Frame structure supported on a single column and multi-column is done in this project. This paper presents structural modelling, stress, bending moment, shear force and displacement, deflection design considerations for a structure and it is analysed using STAAD-Pro. Various steps involved in designing of RCC Frame structure supported on a single column and multi-column by using software are Geometric Modelling, providing material properties and sectional Properties, fixing supports and boundary Conditions, providing loads & load combinations, Special Commands, Analysis Specification, Design Command and Report. The influence of plan geometry has an important role in static analysis. Maximum values of stresses, bending moments, shear forces and displacements and deflection are presented. The acting loads considered in the present analysis were dead load, Live load, floor load, and seismic load. In these cases the floor load was applied perpendicular to the RCC structure. Comparison on the basis of analytically results occurs between RCC single column and RCC multi column is done.

In this paper, all those analysis & load calculation were executed with a Numerical Building Model by using software program, which were also compared following the analysis results. The results of the analysis on the axial forces, Base shear, Time period, Storey drift and Displacements are compared. The results are presented in tabular and graphical form.

The project is to planning & analysis by using software for a multi storied building and single column building of G+4 floors. The design is done by taking in to account the requirements and standards recommended by IS code and national building rules. Planning is done using the 3D modelling software with the help of Auto CAD 2014. STAAD-Pro uses a command language based input format, which can be created through an editor called the editor file, these powerful software graphics input generator or through Auto CAD based input generators like AutoCAD. Output generated by staad.pro consists of detailed numerical results for analysis and design.

Keywords: Multi-storeyed building, Single column building, Planning, STAAD-Pro, Modelling, Analysis...

I. INTRODUCTION

Due to increase of population into urban cities there is a need to accommodate the influx in the urban cities. However, due to rapid increase of land cost, and limited availability of land the trend is to build multi storey building. A multi storey building is a building that has multiple floors above ground in the building. Multi-storey buildings aim to increase the floor area of the building without increasing the area of the land and saving money. These multi storey building s are sky scrapers are built not just for economy of space they are considered icons of a city's economic power and the city's identity. Various types of structural system have been used to facilitate the demand of high rise structures. Thousands of multi storey building s is being built all over the world with steel as well as reinforced concrete. Many of the multi storey building s are designed with structural components consisting of various systems such as flat slab, flat plate system, including commercial and uses because the systems have various advantages.

A single column provides better architectural view compared to structure supported on many columns. They save ground space as requires less area for providing foundation and provides more space for parking. They are also unique. Single column structure can be made either by using RCC or Steel. This structure supported on a mono column provides large serviceable floor space compared to structure supported on many columns. They save ground space as requires less area for providing foundation and provides more space for parking. Maximum space utilization is considered will serve its maximum serviceability. In this research describes planning, structural analysis, design and drawings with various components and approximate cost of the whole building. This

building consists of mono column i.e. Single column structural system (each floor in whole structure is supported independently by mono column at the centre).

Earlier, modelling and structural analysis of buildings were carried out using hand calculation method based on simplified assumptions and understanding the whole behaviour of the structure. But it seems to be time consuming and complicated for high rise buildings.

At present, computer hardware's and software's for modelling and analysis of structure is widely available. We need to know how the knowledge secured in the class room is applied in these practical sides of work. When we got this project, we come into practical field to collect construction techniques and to meet the various difficulties in the construction. Also it is necessary to have sufficient knowledge regarding various software's currently used in planning analysis and design of and are not included during the design process of the primary structure. Since the 1990s specialist software has become available to aid in the design of structure with the functionality to assist the drawing, analysing and designing of structures with maximum precisions, example includes AutoCAD, STAAD-Pro, ETABS, Prokon, Revit structure, etc.

Our main aim to complete an Analysis between a conventional multi-stored building & a single column building by using STAAD-Pro against all possible loading conditions and to full fill the function for which they have built in economical expenditure. Safety requirements must be met so that the structure is able to serve its purpose with the maintain cost.

A. Objectives of The Project

Following specific objectives has been made for the present study-

- 1) To develop, planning and analysis model of the High rise structure in STAAD-Pro.
- 2) Study of seismic load applied to the structure as per IS 1893-2002.
- 3) Comparison of analytical results of seismic load applied on the structure by STAAD- Pro.
- 4) To verify deflection for a single column & multi-column structures.
- 5) To study the performance of lateral displacement at II zones.

II. METHODOLOGY

A. General

In this research describes planning, structural analysis, design and drawings with various components and approximate cost of the whole building. Structural model supported on a mono column i.e. Single column structural system (each floor in whole structure is supported independently by mono column at the centre). Design of all structural members conforms to IS: 456-2000, IS: 800-2007 & IS: 11384-1985. Primary aim of all structural design is to ensure that the structure will perform satisfactorily during its design life. Specifically, the designer must check that the structure is capable of carrying the loads safely and that it will not deform excessively due to the applied loads. This requires the designer to make realistic estimates of the strengths of the materials composing the structure and the loading to which it may be subject during its design life. In the seismic demand parameters are storey drifts, global displacement (at roof or any other reference point), storey forces, and component deformation and component forces. The analysis accounts for material inelasticity, geometrical nonlinearity and the redistribution of internal forces.

Response characteristics that can be obtained from the both structural analysis (single column & multi-column structure) are summarized as follows:

- 1) Estimates of force and displacement capacities of the structure.
- 2) Estimates of force (axial, shear and moment) demands on potentially brittle elements and deformation demands on ductile elements.
- 3) Estimates of global displacement demand, corresponding inter-storey drifts and damages on structural and non-structural elements expected under the 20 earthquake ground motion considered.
- 4) Sequences of the failure of elements and the consequent effect on the overall structural stability.
- 5) Identification of the critical regions, when the inelastic deformations are expected to be high and identification of strength irregularities (in plan or in elevation) of the building. Structural analysis delivers all these benefits for an additional computational effort (modelling nonlinearity and change in analysis algorithm) over the linear static analysis. Step by step procedure of structural analysis is discussed next.

B. Problem Definition

For analysis work, models of building (G+4) 5 storey's floors are made to know behavior of building during earthquake. Typical bay width is taken 4m in both X and Z direction. Number of bays in both directions are 4. Storey height (Floor to Floor) 3.0m were considered. All the joints of beam, column and inclined beams are rigid. The models were analyzed by STAAD-Pro software. All the columns are fixed from base for foundation.

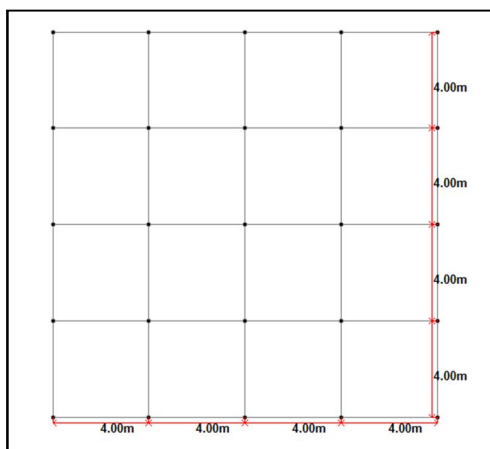


Fig. 2.1 Common Plan for All Building Model

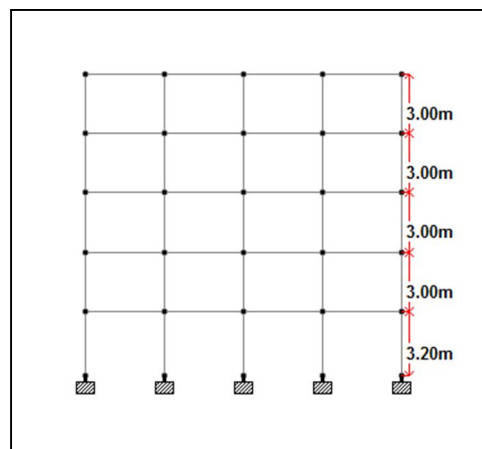


Fig. 2.2 Elevation of plan

Building parameters considered for the study is given below

Sr. No.	Particular	Details of Multi-column building structure	Details of Single column building structure
1	Type of construction	R.C.C framed structure	R.C.C framed structure
2	Dead Load	Self weight : -1 Member load:-11.96KN/m Floor load :-1.8KN/mm ²	Self weight : -1 Member load:-11.96KN/m Floor load :-1.8KN/mm ²
3	Live Load	3 KN/m ² at typical floor, 1.5KN/m ² on terrace	3 KN/m ² at typical floor, 1.5KN/m ² on terrace
4	Wind Load	As per IS 875 – Not designed for wind load, since earthquake loads exceed the wind loads	As per IS 875 – Not designed for wind load, since earthquake loads exceed the wind loads
5	Earthquake Load	Select Zone II (as per IS-1893 (Part 1) – 2002)	Select Zone II (as per IS-1893 (Part 1) – 2002)
6	Number of stories	G+4 (5 storey's)	G+4 (5 storey's)
7	Depth of foundation below ground	2.8m	1.2m
8	Slab Thickness	150 mm	150 mm
9	Type of soil	Type II, Medium as per IS:1893	Type II, Medium as per IS:1893
10	Storey height	Floor to Floor – 3m Floor to Ground Floor – 3.2m	Floor to Floor – 3m Floor to Ground Floor – 6.2m

11	Plan size	16 m X 16 m	16 m X 16 m
12	No. of bays in X direction	4	4
13	No. of bays in Y direction	4	4
14	Grade of concrete	M-20	M-20
15	Grade of steel	Fe 415 Structural Steel	Fe 415 Structural Steel
16	Central Column size	-	1.8m X 1.8m
17	Column size	0.40m X 0.50m	0.40m X 0.50m
18	Inclined Beam size	-	0.50m X 0.60m
19	Beam size	0.40m X 0.40m	0.40m X 0.40m
20	Building importance factor	1	1
21	Response reduction factor for concentric and eccentric respectively	3	3
22	Height of building	15.2m	18.2m

C. Equivalent Static Analysis Method

Static analysis defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to “yielding” of structure, many codes apply modification factors that reduce the design forces. Inherently, equivalent static lateral force analysis is based on the following:-

1) Assumptions

- Assume that structure is rigid.
- Assume perfect fixity between structure and foundation.
- During ground motions every point on the structure experience same accelerations Dominant effect of earthquake is equivalent to horizontal force of varying magnitude over the height.
- Approximately determines the total horizontal force (Base shear) on the structure. However, during an earthquake structure does not remain rigid, it deflects, and thus base shear is disturbed along the height.

2) The Limitations Of Equivalent Static Analysis

- In the equivalent static force procedure, empirical relationships are used to specify Dynamic inertial forces as static forces.
- These empirical formulas do not explicitly account for the dynamic characteristics of the Particular structure being designed or analyzed.
- These formulas were developed to approximately represent the dynamic behavior of what are called *regular* structures (Structures which have a reasonably uniform distribution of mass and stiffness). For such structures, the equivalent static force procedure is most often adequate.

Structures that are classified as *irregular* violate the assumptions on which the empirical formulas, used in the equivalent static force procedure, are developed. Common types of irregularities in a structure include large floor-to-floor variation in mass or centre of mass and soft stories etc. Therefore in such cases, use of equivalent static force procedure may lead to erroneous results. In these cases, a dynamic analysis should be used to specify and distribute the seismic design forces.

D. Step by Step procedure of Static Equivalent Analysis in STAAD-Pro
For Multi-Column Structure

1) Step 1: Modelling of structure as per geometry.

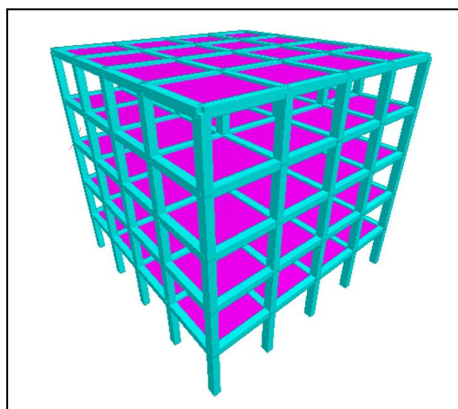


Fig. 2.3 3D model of Structure

2) Step 2: Assigning supports and member properties to beams and columns.

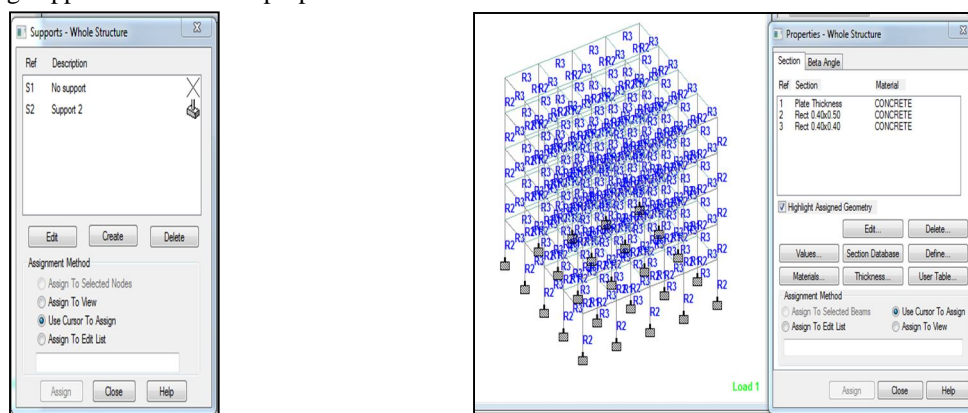


Fig.2.4 Structure with fixed support and assigned member property

3) Step 3: Assigning loads

Structure is analysed for following loadings:

- Dead Load
- Live Load
- Seismic Load

Dead load consists of self weight of structural member plus weight of walls.

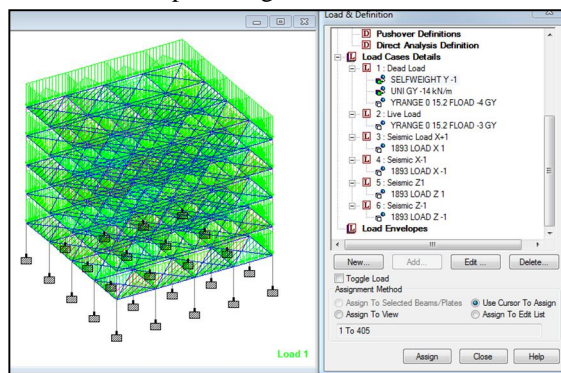


Fig. 2.5 Structure subjected to dead load

Residential building live load for analysis was taken as 3 KN/m^2 as per IS 875 Part II

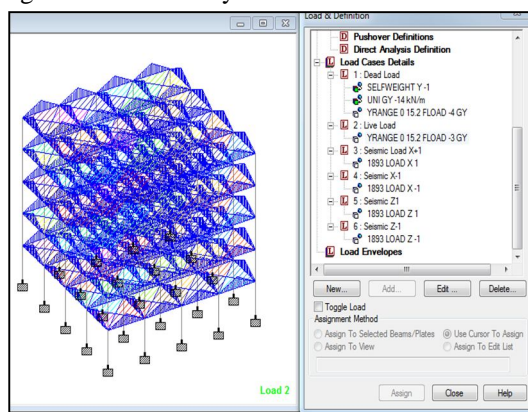


Fig. 2.6 Structure subjected to live load

Static seismic load is calculated as per the guidelines of IS 1893:2002 by specifying parameters shown in fig.

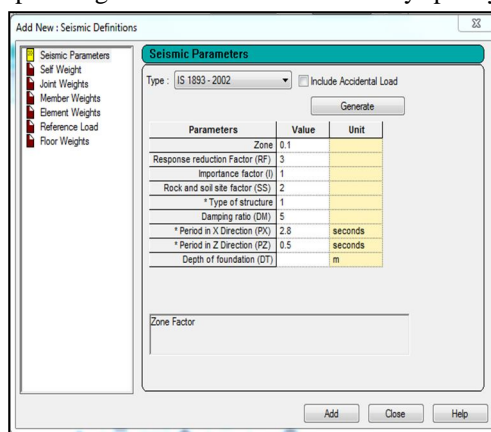


Fig. 2.7 Parameters for seismic analysis

Seismic Loading Calculations (Lump weight calculations):-

i) *Dead Load Calculations*

Density of materials used: - I. Reinforced: 25 KN/m^3

II. Flooring material (cm): 20 KN/m^3

$$\begin{aligned} \text{Total Weight of Slab} &= 0.15 \times 16 \times 16 \times 25 \\ &= 960 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Total Weight of Column} &= 0.4 \times 0.5 \times 25 \times 25 \\ &= 125.00 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Total weight of Wall} &= (\text{weight of longitudinal walls} + \text{weight of traverse walls}) \times \text{Height} \\ &= (3.5 \times 4.6 \times 4 \times 4 + 3.6 \times 4.6 \times 4 \times 4) \times 3 = 1564.68 \text{ KN} \end{aligned}$$

$$\text{Total Dead Load on Intermediate Floor} = 960 + (16 \times 16 \times 0.8) = 1164.80 \text{ KN}$$

$$\begin{aligned} \text{Total Dead Load per m}^2 \text{ on Intermediate Floor} &= 2649.68 / (16 \times 16) \\ &= 10.35 \text{ KN/m}^2 \end{aligned}$$

$$\begin{aligned} \text{Total Dead Load on Top Floor} &= 960 + (0.5 \times 125) + (0.5 \times 1564.68) \\ &= 1804.84 \text{ KN} \end{aligned}$$

$$\text{Total Dead Load per m}^2 \text{ on Top Floor} = 1804.84 / (16 \times 16) = 7.05 \text{ KN/m}^2$$

ii) *Live Load Calculations*

$$\text{Total Live Load per m}^2 \text{ on Intermediate Floor} = 3 \text{ KN/m}^2$$

$$\text{Lump Weight on Intermediate Floor} = \text{D.L.} + 0.5 \text{ L.L.}$$

$$= 10.35 + 0.5 \times 3$$

$$= 11.85 \text{ KN/m}^2$$

Lump Weight on Top Floor

$$= 7.05 + 1.5$$

$$= 10.575 \text{ KN/m}^2$$

Loading Combinations are taken as per IS 1983:2002 clause No. 6.3.1.2

6.3.1.2 Partial safety factors for limit state design of reinforced concrete and prestressed concrete structures

In the limit state design of reinforced and prestressed concrete structures, the following load combinations shall be accounted for:

- 1) $1.5 (DL + IL)$
- 2) $1.2 (DL + IL \pm EL)$
- 3) $1.5 (DL \pm EL)$
- 4) $0.9 DL \pm 1.5 EL$

In the plastic design of steel structures, the following load combinations shall be accounted for:

- 1) $1.7 (DL + IL)$
- 2) $1.7 (DL \pm EL)$
- 3) $1.3 (DL + IL \pm EL)$

4) *Step 4: Analysis of Building model*

Procedure of Analysis of Building model

In STAAD-Pro, building model were analyse for seismic loading by following way.

- a) Modeling of Building
- b) Member sizes
- c) Support Specification
- d) Application of loading
- e) Analyses
- f) Result report

E. Step by Step procedure of Static Equivalent Analysis in STAAD-Pro

For A Single-Column Structure

- 1) *Step 1: Modelling of structure as per geometry.*

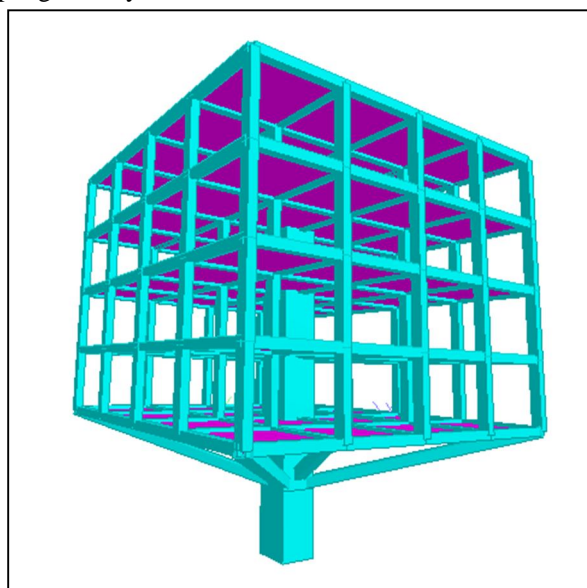


Fig. 2.8 3D model of Single column Structure

2) Step 2: Assigning supports and member properties to beams and columns.

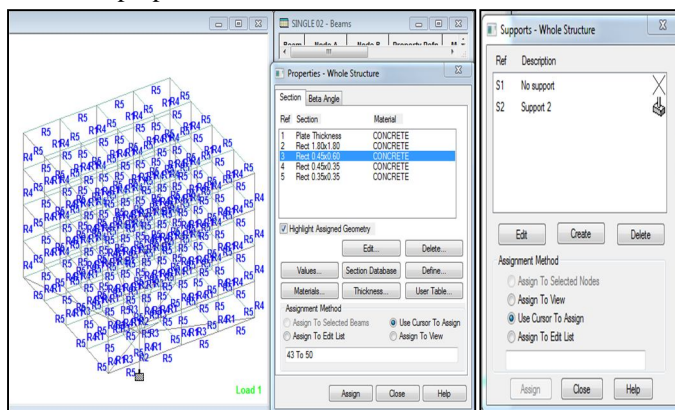


Fig. 2.9 Structure with fixed support and assigned member properties

3) Step 3: Assigning loads

Structure is analysed for following loadings:

- Dead Load
- Live Load
- Seismic Load

Dead load consists of self weight of structural member plus weight of walls.

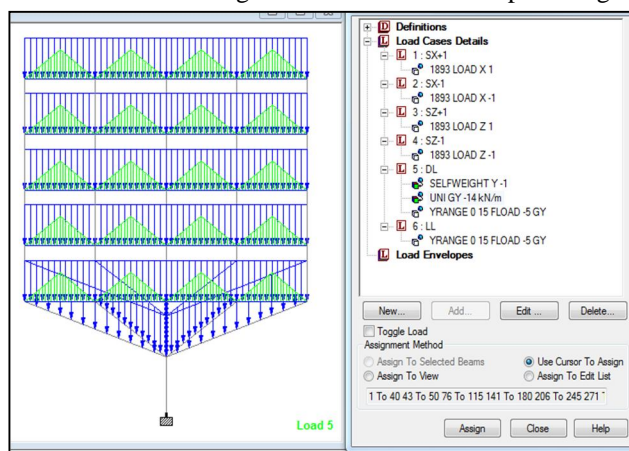


Fig. 2.10 Structure subjected to dead load

Residential building live load for analysis was taken as 3 KN/m^2 as per IS 875 Part II

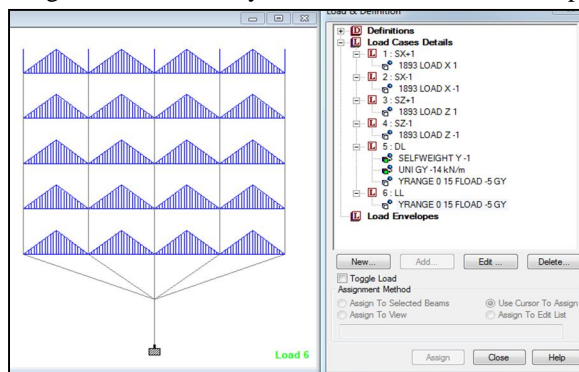
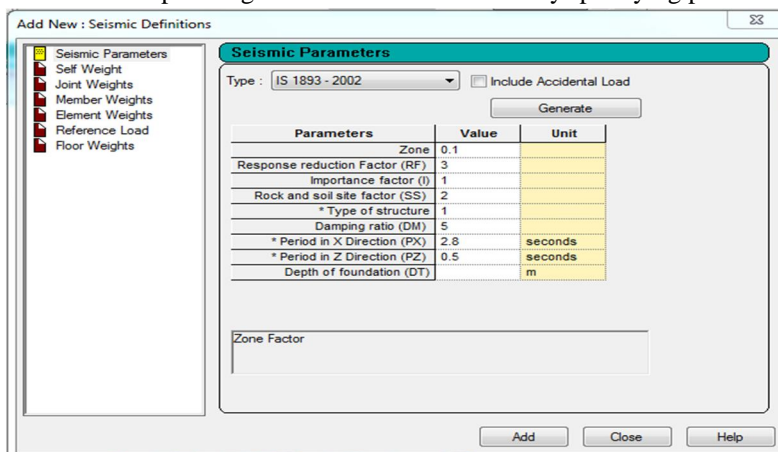


Fig. 2.11 Structure subjected to live load

Static seismic load is calculated as per the guidelines of IS 1893:2002 by specifying parameters shown in fig.



Parameters	Value	Unit
Zone	0.1	
Response reduction Factor (RF)	3	
Importance factor (I)	1	
Rock and soil site factor (SS)	2	
* Type of structure	1	
Damping ratio (DM)	5	
* Period in X Direction (PX)	2.8	seconds
* Period in Z Direction (PZ)	0.5	seconds
Depth of foundation (DT)		m

Fig. 2.12 Parameters for seismic analysis

Seismic Loading Calculations (Lump weight calculations)

i) *Dead Load Calculations*

$$\begin{aligned}\text{Total Weight of Slab} &= 0.15 \times 16 \times 16 \times 25 \\ &= 960 \text{ KN}\end{aligned}$$

$$\begin{aligned}\text{Total Weight of Column} &= 0.4 \times 0.5 \times 25 \times 25 \\ &= 125.00 \text{ KN}\end{aligned}$$

$$\begin{aligned}\text{Total weight of Wall} &= (\text{weight of longitudinal walls} + \text{weight of traverse walls}) \times \text{Height} \\ &= (3.5 \times 4.6 \times 4 \times 4 + 3.6 \times 4.6 \times 4 \times 4) \times 3 = 1564.68 \text{ KN}\end{aligned}$$

$$\text{Total Dead Load on Intermediate Floor} = 960 + (16 \times 16 \times 0.8) = 1164.80 \text{ KN}$$

$$\begin{aligned}\text{Total Dead Load per m}^2 \text{ on Intermediate Floor} &= 2649.68 / (16 \times 16) \\ &= 10.35 \text{ KN /m}^2\end{aligned}$$

$$\begin{aligned}\text{Total Dead Load on Top Floor} &= 960 + (0.5 \times 125) + (0.5 \times 1564.68) \\ &= 1804.84 \text{ KN}\end{aligned}$$

$$\text{Total Dead Load per m}^2 \text{ on Top Floor} = 1804.84 / (16 \times 16) = 7.05 \text{ KN /m}^2$$

ii) *Live Load Calculations*

$$\text{Total Live Load per m}^2 \text{ on Intermediate Floor} = 3 \text{ KN /m}^2$$

$$\begin{aligned}\text{Lump Weight on Intermediate Floor} &= \text{D.L.} + 0.5 \text{ L.L} \\ &= 10.35 + 0.5 \times 3 \\ &= 11.85 \text{ KN /m}^2\end{aligned}$$

$$\begin{aligned}\text{Lump Weight on Top Floor} &= 7.05 + 1.5 \\ &= 10.575 \text{ KN /m}^2\end{aligned}$$

4) *Step 4: Analysis of Building model*

a) *Procedure Of Analysis Of Building Model:* In STAAD-Pro, building model were analyse for seismic loading by following way.

- i) Modeling of Building
- ii) Member sizes
- iii) Support Specification
- iv) Application of loading
- v) Analyses
- vi) Result report
- vii) *Cost Estimation*

Both single column and multi column structure are designed in the same way; they only differ in column orientation and their sizes.

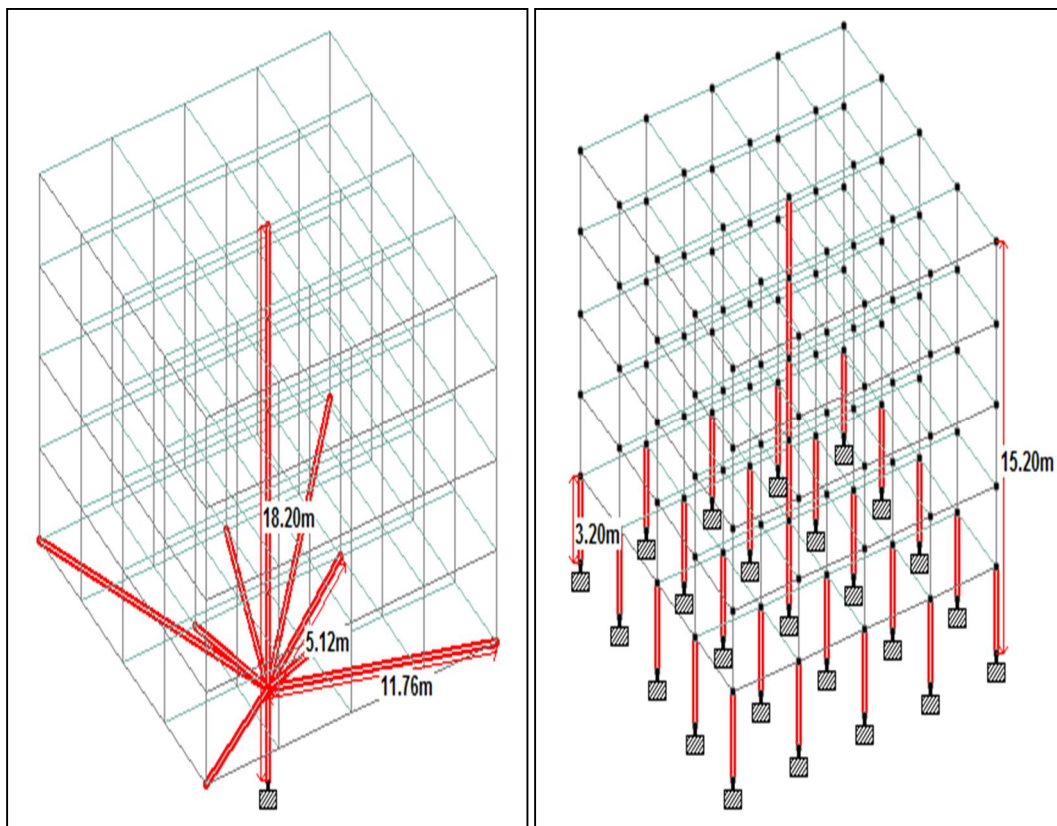


Fig 2.13: Single column and Multi column structure.

5) Calculation

a) For Multi-column Structure

Where, total nos. of column- 25

Size of column – 0.4m x 0.5m

Height of Column- 3.2m (Floor to Ground level)

$$\text{Quantity of Concrete} = 25 \times 0.4 \times 0.5 \times 3.2 + 1 \times 0.4 \times 0.5 \times 12$$

$$= 18.4 \text{ m}^3(\text{Y})$$

b) For Single Column Structure

Where,

Size of central column-1.8m x 1.8m - Height-18.2 - No. of column-01

Size of long inclined column-0.50 x 0.60m - Length-11.76m - No. of column-04

Size of short inclined column-0.50 x 0.60m - Length-5.12m - No. of column-04

$$\text{Quantity of Concrete} = (1 \times 1.8 \times 1.8 \times 18.2) + (4 \times 0.5 \times 0.6 \times 11.76) + (4 \times 0.5 \times 0.6 \times 5.12)$$

$$= 77.88 \text{ m}^3(\text{Y})$$

Cost comparison of RCC single column and RCC multi column can be done by just comparing the cost of columns which are highlighted in above figure. Volume of highlighted columns in single column structure is 5 times the volume of highlighted columns in multi column structure. If cost of multicolumn structure is X + Y then Cost of single column structure is X + 5Y. Where X = Cost of non highlighted part in structure which is same for both structures and Y = Cost of highlighted part in multi column structure.

In general Construction cost of columns in a building is 10% of the total cost of building. But in Fig. 5 (multi column structure) as we are considering columns only up to first floor (excluding centre column), Construction cost of highlighted columns would be 5% of the total cost of building. If total cost of multi column structure is 100 i.e. X+Y = 100, Where X = 95 and Y = 5.

Then Cost of single column structure is X+5Y = 95+5(5) = 120

Therefore, Cost of single column structure is 20 % more than multi column structure.

III.RESULT

A conventional multi-storey building & a single column building structure were analysing in STAAD-Pro and graphs were plotted for extreme corner column of building against the deflection and behaviour of columns studied. Result of deflection obtained from the software (Statics analysis method) was presented in table given below:-

A. Result Of Static Analysis For A Conventional Multi-Storey Building

1) Column Deflection for multi-storey building

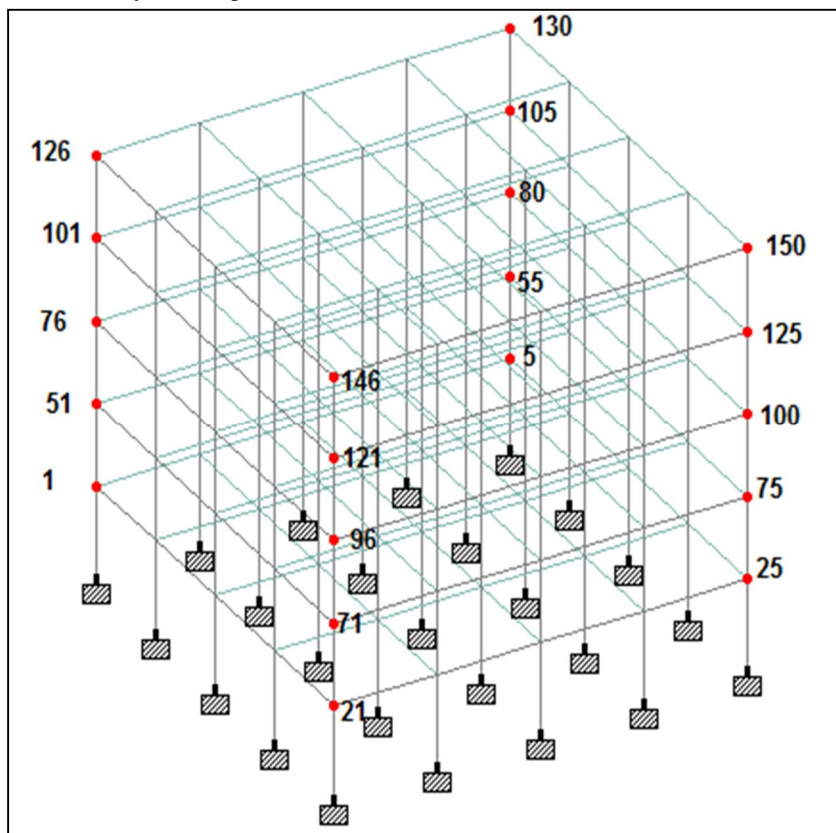


Table 4.3 Deflection of corner column node for multi-column building (C)

Node	COMBINATION L/C	Horizontal	
		X mm	Z mm
5	L/C 6	0.407	-
	L/C 7	-	2.302
55	L/C 6	0.471	-
	L/C 7	-	2.423
80	L/C 6	0.532	-
	L/C 7	-	2.538
105	L/C 6	0.586	-
	L/C 7	-	2.646
130	L/C 6	0.633	-
	L/C 7	-	2.747

Table 4.4 Deflection of corner column node for multi-column building (D)

Node	COMBINATION L/C	Horizontal	
		X mm	Z mm
21	L/C 6	0.322	-
	L/C 7	-	7.551
71	L/C 6	0.445	-
	L/C 7	-	7.698
96	L/C 6	0.742	-
	L/C 7	-	8.155
121	L/C 6	1.065	-
	L/C 7	-	8.623
146	L/C 6	1.378	-
	L/C 7	-	9.098

B. Result Of Static Analysis For A Single Column Building

1) Column Deflection for single column building

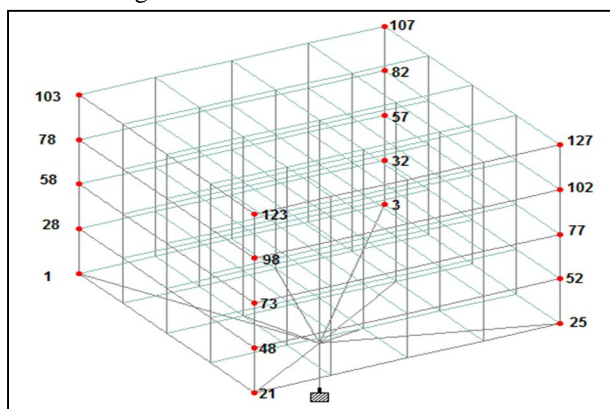


Fig.3.2 to show the all column node for single column building

Table 4.5 Deflection of corner column node for single column building (A)

Node	COMBINATION L/C	Horizontal	
		X mm	Z mm
21	L/C 6	0.308	-
	L/C 7	-	6.007
48	L/C 6	0.591	-
	L/C 7	-	6.124
73	L/C 6	0.746	-
	L/C 7	-	6.488
98	L/C 6	0.072	-
	L/C 7	-	-0.058
123	L/C 6	1.107	-
	L/C 7	-	7.238

Table 4.6 Deflection of corner column node for single column building (B)

Node	COMBINATION L/C	Horizontal	
		X mm	Z mm
3	L/C 6	0.305	-
	L/C 7	-	6.389
32	L/C 6	0.484	-
	L/C 7	-	6.5
57	L/C 6	0.674	-
	L/C 7	-	6.945
82	L/C 6	0.879	-
	L/C 7	-	7.39
107	L/C 6	1.092	-
	L/C 7	-	7.836

Table 4.7 Deflection of corner column node for single column building (C)

Node	COMBINATION L/C	Horizontal	Horizontal
		X mm	Z mm
25	L/C 6	1.275	-
	L/C 7	-	7.616
52	L/C 6	1.498	-
	L/C 7	-	7.987
77	L/C 6	1.707	-
	L/C 7	-	8.344
102	L/C 6	1.903	-
	L/C 7	-	8.683
127	L/C 6	2.135	-
	L/C 7	-	9.007

Table 4.8 Deflection of corner column node for single column building (D)

Node	COMBINATION L/C	Horizontal	Horizontal
		X mm	Z mm
1	L/C 6	0.244	-
	L/C 7	-	6.007
28	L/C 6	0.337	-
	L/C 7	-	6.124
53	L/C 6	0.562	-
	L/C 7	-	6.488
78	L/C 6	0.806	-
	L/C 7	-	6.86
103	L/C 6	1.043	-
	L/C 7	-	7.238

IV.CONCLUSION

Following conclusions can be drawn on the basis of analysis on a conventional multi-storey building & a Single column structural system:-

- A. A conventional multi-storey building & a Single column structure has been designed successfully to withstand all loads including earthquake load.
- B. Single column structure is 20 % more costly when compared with multi- column structure.
- C. We may also check the deflection of various members under the given loading combinations.
- D. The Result of deflection obtained from the software for a conventional multi-storey building & a single column building structure.
- E. RCC column give satisfactory result under static loading condition.
- F. Study the performance of lateral displacement at II zones when seismic load applied to the structure.
- G. Storey drift in high rise structures are subjected to excessive deflection. Deflection obtained by STAAD-Pro is checked by IS Codal limitation for serviceability. Base shear gives the base shears for entire structures.
- H. STAAD-Pro advanced software which provides us a fast, efficient, easy to use and accurate platform for analyzing and designing structures.

This project has been selected with utmost enthusiasm and keen interest by me and has been successfully completed with our knowledge to our satisfaction. We have applied our gained knowledge during this project. A comparative study on analysis of a conventional multi-storey building & a single column building is analyzed with special attention and it is completed. Maximum space utilization is considered while planning and designing and we assure it will serve its maximum serviceability.

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