Analysis and Design of Mono-Column Building

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Abstract - *The structure supported by a single column is the structural framework of Monocolumn. Since the entire structure is supported on a single column (monocolumn), all other members serve as cantilevers and the crucial one is the mono-column structure. These are unique structures. Eccentric loading may cause twisting of the structure in either direction and may cause system failure. Design and analysis is done by using STAAD-Pro (STRAP). Various steps used in designing a Monocolumn building were geometric modelling, assigning sectional and material properties, fixing supports and boundary conditions, assigning loads and load combinations, special commands, analysis specification, design command and report. The Design process is backed up by using relevant IS codes. The results are studied for maximum stress, bending moment, node displacement, deflection and storey drift and presented in tabular and graphical form. Provision of shear walls is considered for seismic strengthening of the building. Shear wall is modelled in STAAD-Pro and provided with required material properties and thickness. Comparative study between different shear wall configurations is carried out. Results of comparison for shear wall along middle bays and corner bays are presented in graphical form.*

Key Words: **STAAD Pro, Serviceability, Node displacement, Storey drift, Shear wall**

1.INTRODUCTION

1.1 General

Urbanization and rise in population have increased the demand of high-rise structures in the cities of INDIA. Considering Mono-column structures for their better aesthetic view, uniqueness, broad operational floor space and maximum serviceability is a good option in zone III areas. Since there is only one column, less space is occupied for base, allowing more space for parking and other purposes. Eccentric loading may cause twisting of the structure in either direction and structural system might fail. Planning, analysis and design of a 5-storey Mono-column RCC framed structure have been achieved. STAAD. Pro software is used for the analysis of the structure. STAAD. Pro is a structural analysis and design software based on stiffness matrix method. The procedure followed in the software is geometric modeling, assigning supports, assigning section properties, assigning loads and then the structure was analyzed. Graphical user interface (GUI) has been followed for geometric modelling of the structure in STAAD Pro. The designed Mono-column structure in zone III area is designed to serve its purpose with all the required safety checks and requirements. Seismic load strengthening discussed and the analysis of the designed Mono-column structure with and without shear wall has been carried out and compared in the software. This was done to make the structure safe against lateral forces.

1.2 Literature review

Chintakrindi V. Kanaka Sarath et. al. [1] designed a building the entirely rests on a single column. M30 grade of concrete was used in the single column structure with high yield strength deformed bars. Analysis carried out in STAAD. Pro software and the structure were safe to serve its purpose.

EK Mohanraj et. al. [2] analyzed and designed an office building on a single column, satisfying all stability requirements. STRAP (Structural Analysis Package) was used to analyze the structure. Ring beams and inclined beams were provided to reduce the beam's cantilever span. Considering maximum space utilization provides maximum serviceability.

Ankur Pandey et. al. [3] analyzed a single-story Mono-column structure under three specifications of different types of modeling approach, which are, RCC, composite and composite with steel strut. Modeling and analysis are done in the ETABS software. IS standards specifications were followed for static loading. On comparison of the structure under static loads, it was found that the composite structure with steel structure was less deflected.

Madireddy Satyanarayana [4] analyzed a proposed G+5 residential mono-column building using STAAD Pro 2007. AutoCAD was used to layout the plan and design of footing. All code provisions have been followed. The structure was analyzed and found safe serving its purpose. Drawings of structural members are given.

T. Subramani et. al. [5] aims to design and layout a mono-column structure proposed at a site of 190m^2 in Salem. The structure was analyzed in STAAD Pro and checked with manual calculations. Lateral displacement of the structure in different zones has been studied.

2. Methodology

STAAD. Pro software is sued for modelling and analysis of the structure. Graphical user interface (GUI) method is adapted for geometric modelling in the software. These models are subjected to equivalent lateral loading conditions. Static and dynamic analysis considering earthquake loads. The designed structure was provided shear walls in different orientation for seismic load strengthening. The obtained results from STAAD Pro with and without shear wall are studied and analysed. IS 456-2000, IS:875(Part 1)-1987, IS:875(Part 2)-1987, IS:875(Part 3)-1987, IS:875(Part 5)-1987, IS 1893 Part 1-2002 were referred and followed for all the considered loading conditions.

2.1 Structure specifications

The designed structure is an RCC framed Mono-column structure. The structure is a G+5 structure of 15mX15m dimension. The structure is designed in zone III for earthquake loading conditions. The height of the building is 19.2m. The height of each floor in the structure is 3.2m. The size of the central column is 2.8mX2.8m. M40 grade of concrete and Fe 500 grade steel are considered in the structure. The considered loads are live load, dead load, wind load and earthquake load.

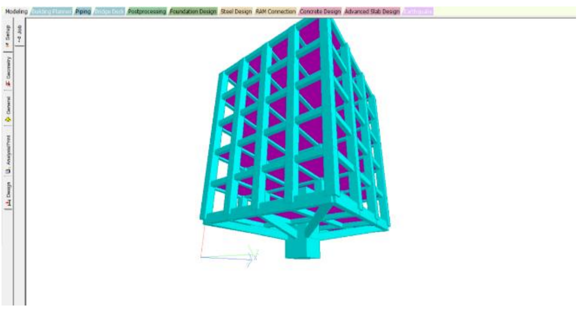

Figure 1- Rendered view of the model structure

Dead load includes self-weight: -1 kn/m^2, floor load: 4.75 kn/m^2 and roof load: 6.75 kn/m^2. Live load is considered 4 kn/m^2 at typical floor and 1.5 kn/m^2 on terrace. Since earthquake loads exceed the wind loads, only earthquake load analysis was performed. Earthquake loads were considered as per IS 1893 Part 1- 2002 in zone III.

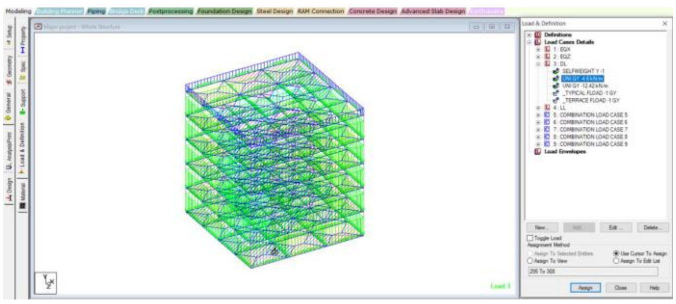

Figure 2 – Structure subjected to Dead load

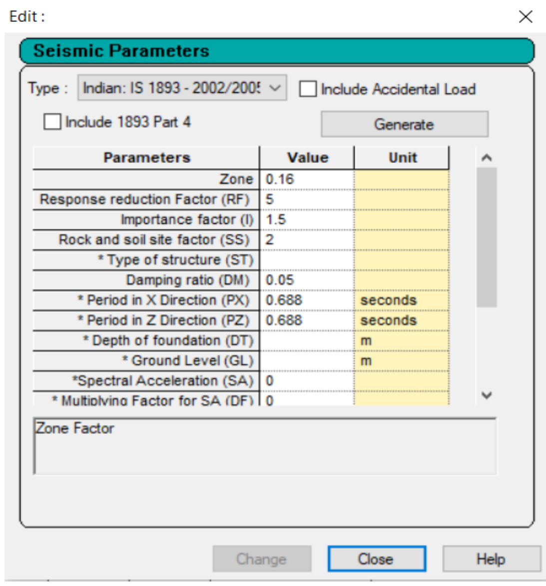

Figure 3- Seismic parameters

3. Seismic Load Strengthening

The term strengthening comprises technical interventions of the structural system of a building that improves its seismic resistance by increasing strength, stiffness and ductility. Shear walls and bracings can be used for strengthening the Mono-column structure towards lateral force.

A shear wall is a vertical component of seismic force resisting system designed to resist in-plane lateral forces such as wind and seismic loads. Shear walls were provided in two ways in the structure, i.e., along the corner bays and along the middle bays. Shear walls behave like vertical slender cantilever beam. Shear walls in high seismic region require high detailing.

The modeling of shear walls is done in STAAD. Pro and the properties assigned. The effectiveness of the two different positions, i.e., along corner bays and middle bays are compared.

On comparison of the results with shear wall at corner and middle bays, it was found that beam forces were less in structure with corner shear wall.

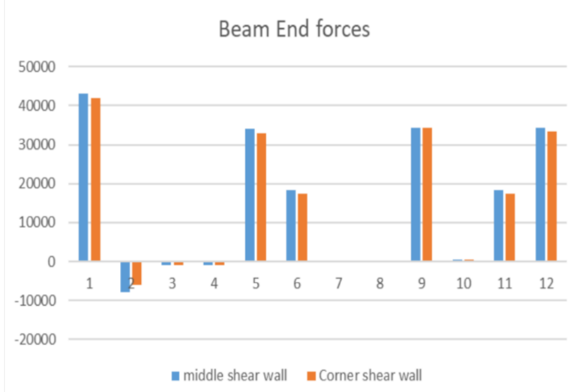

Figure 4- Comparison of Beam end forces

The nodal displacement is less in structure with corner shear wall and represented in figure 4.

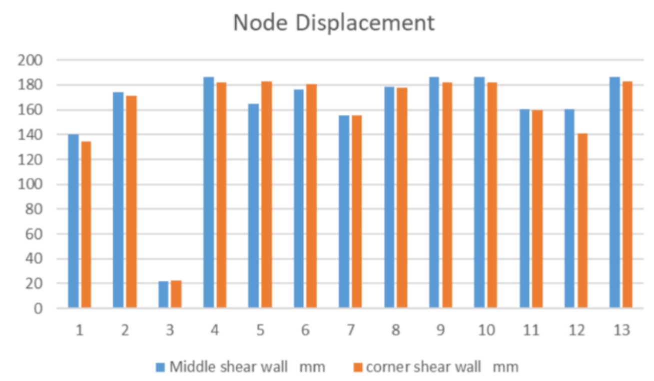

Figure 5- Comparison of Nodal displacement

The support reactions are same in both the cases but load is more equally distributed in structure with corner shear walls.

4. Results and discussion

After assigning all the loads and properties to the Mono-column structural frame, the structure is analyzed and checked for zero errors. Loads are calculated manually and compared with the loads in STAAD output file.

Nodal displacement is the relative displacement of a node before and after application of loads.

Node Displacement									
			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	Mm	rX rad	rY rad	rZ rad
Max X	140	6 COMBINATION L/C 6	32.479	-139.838	0	143.561	0	0	-0.011
Min X	31	5 COMBINATION L/C 5	-5.93	-177.564	0	177.663	0	0	0.002
Max Y	22	2 EQZ	-0.031	16.623	3.996	17.097	0.002	0	0
Min Y	106	5 COMBINATION L/C 5	-0.011	-197.353	-0.013	197.353	0	0	0
Max Z	135	7 COMBINATION L/C 7	0.053	-159.934	47.196	166.753	0.003	0	0
Min Z	22	5 COMBINATION L/C 5	-2.743	-187.892	-2.945	187.935	0	0	0
Max rX	38	7 COMBINATION L/C 7	-0.742	-161.185	4.611	161.253	0.004	0	0
Min rX	36	5 COMBINATION L/C 5	-0.934	-189.074	0.261	189.077	-0.002	0	0
Max rY	29	5 COMBINATION L/C 5	0.691	-197.243	-0.354	197.244	0.001	0	0.001
Min rY	27	5 COMBINATION L/C 5	0.691	-197.243	0.354	197.244	-0.001	0	0.001
Max rZ	137	5 COMBINATION L/C 5	-0.495	-169.019	0	169.019	0	0	0.011
Min rZ	140	5 COMBINATION L/C 5	0.495	-169.019	0	169.019	0	0	-0.011
Max Rst	106	5 COMBINATION L/C 5	-0.011	-197.353	-0.013	197.353	0	0	0

Figure 6- Nodal displacement

The forces that are generated in the beam as reaction to applied forces are called beam end forces.

Beam End Forces									
	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	410	5 COMBINATION L/C 5	21	44703.92	0	0	0	-0.001	-0.002
Min Fx	290	5 COMBINATION L/C 5	137	-8453.876	3911.947	0	0	0	-10217.5
Max Fy	420	5 COMBINATION L/C 5	144	-860.194	9543.03	0	0	0	12328.96
Min Fy	419	5 COMBINATION L/C 5	144	-860.194	-9543.03	0	0	0	12328.96
Max Fz	410	7 COMBINATION L/C 7	143	35386.31	0	1879.946	0	26230.75	-0.001
Min Fz	421	7 COMBINATION L/C 7	143	19148.03	0	-1470.364	0	25732.47	0.001
Max Mx	315	5 COMBINATION L/C 5	137	-77.076	392.307	6.22	150.505	-11.648	716.8
Min Mx	313	5 COMBINATION L/C 5	140	-77.076	392.307	-6.22	-150.505	11.648	716.8
Max My	410	7 COMBINATION L/C 7	21	35763.14	0	1879.946	0	29426.66	-0.001
Min My	95	5 COMBINATION L/C 5	38	412.096	19.876	947.803	-3.138	-2163.46	-15.482
Max Mz	421	6 COMBINATION L/C 6	143	19148.03	1470.507	0	0	-0.001	25612.8
Min Mz	410	6 COMBINATION L/C 6	21	35763.14	1879.946	0	0	-0.001	-29426.7

Figure 7- Beam end forces

Support reactions can be used to design the foundation of the structure.

Support Reactions									
			Horizontal	Vertical	Horizontal	Moment			
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	21	5 COMBINATION L/C 5	0	44703.92	0	0.001	0	0.002
Min Fx	21	6 COMBINATION L/C 6	-1879.946	35763.14	0	0.001	0	29426.66
Max Fy	21	5 COMBINATION L/C 5	0	44703.92	0	0.001	0	0.002
Min Fy	21	1 EQX	-1566.621	0	0	0	0	24522.21
Max Fz	21	4 LL	0	4837.5	0	-0.001	0	0.001
Min Fz	21	7 COMBINATION L/C 7	0	35763.14	-1879.946	-29426.66	0	0.001
Max Mx	21	3 DL	0	24965.11	0	0.001	0	0
Min Mx	21	7 COMBINATION L/C 7	0	35763.14	-1879.946	-29426.66	0	0.001
Max My	21	7 COMBINATION L/C 7	0	35763.14	-1879.946	-29426.66	0	0.001
Min My	21	6 COMBINATION L/C 6	-1879.946	35763.14	0	0.001	0	29426.66
Max Mz	21	6 COMBINATION L/C 6	-1879.946	35763.14	0	0.001	0	29426.66
Min Mz	21	2 EQZ	0	0	-1566.621	-24522.21	0	0

Figure 8- Support reactions

5. CONCLUSION

Mono-column structure with 5-storeys was planned, analyzed and designed to resist earthquake in zone III areas. The design is based entirely on the relevant Indian Standard Codes. STAAD Pro is used for analysis of the structure and manually checked by calculations. Storey drift is within the limits specified in IS codes. More parking area and floor area are available. Mono-column structures with shear wall provide more safety against seismic and lateral forces. It is noted that reinforcement percentage in sections is more in case of software design when compared to manual calculations.

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