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Design of Multi-Storied Building with and without soft stories using STAAD Pro

Diseño de edificios de varios pisos con y sin pisos blandos usando STAAD Pro.

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ABSTRACT

Soft stories are one of those structures containing structural irregularities, especially vertical irregularities. Soft stories case is generally related to sudden and abrupt change or increase in the stiffness of the storey. This soft storey is soft target for dynamic displacing forces, especially in the horizontal direction, due to its more flexibility in nature and leads to collapse of structure which it supports and, thus ultimately whole structure collapse in shear. If not designed well, soft storey causes failure not only due to external forces but also to drifting of mass by external lateral forces, from its original position. In the present study, the analysis of the ten-storey building with or without soft storey was carried out to investigate the effect of soft storey under identical loading conditions as per Indian standards. The previous studies were carried out on the structures considering ground floor as soft storey. Structure has been modeled and analyzed using well-established software STAAD-Pro V8i. Results showed that drift of M5 type structure was increased by 1.6 times approximately M0 type structure. Base shear was reduced by due to reduced stiffness by 7.5% and time period in the orthogonal direction increased by 5%.

Keywords: STAAD Pro, Soft Storey, Irregularities, Multi-Storied Building

RESUMEN

Los pisos blandos son una de esas estructuras que contienen irregularidades estructurales, especialmente irregularidades verticales. El caso de pisos blandos generalmente se relaciona con un cambio o aumento repentino y abrupto en la rigidez del piso. Este piso blando es un objetivo fácil para las fuerzas de desplazamiento dinámico, especialmente en la dirección horizontal, debido a su mayor flexibilidad en la naturaleza y conduce al colapso de la estructura que soporta y, por lo tanto, en última instancia, al colapso de toda la estructura por corte. Si no se diseña bien, el piso blando causa fallas no solo debido a fuerzas externas sino también al desplazamiento de la masa por fuerzas laterales externas, desde su posición original. En el presente estudio, se llevó a cabo el análisis del edificio de diez pisos con o sin piso blando para investigar el efecto del piso blando bajo condiciones de carga idénticas según los estándares indios. Los estudios previos se realizaron sobre las estructuras considerando la planta baja como piso blando. La estructura ha sido modelada y analizada utilizando el software bien establecido STAAD-Pro V8i. Los resultados mostraron que la deriva de la estructura tipo M5 aumentó 1,6 veces aproximadamente en la estructura tipo M0. El corte de la base se redujo debido a la reducción de la rigidez en un

7,5% y el período de tiempo en la dirección ortogonal aumentó en un 5%.

Palabras clave: STAAD Pro, Soft Floory, Irregularidades, Edificio de varios pisos

INTRODUCTION

Regular structures don't have any noticeable plan or vertical configuration discontinuities. Some physical discontinuities in irregular structures, whether in plan, elevation, or both, have an effect on how well they perform when subjected to lateral loads. Plan discontinuities can be used to describe horizontal irregularities. Vertical irregularities are defined as variations in the distribution of mass, stiffness, and geometry along a building's height. Structures with soft stories typically involve a dramatic change in the rigidity of the storey or an increase in it. A soft storey has lateral stiffness that is less than 80% of the average stiffness of the three storey above or less than 70% of the storey above. Due to its greater flexibility, this soft storey is a soft target for dynamic displacement pressures, especially in the horizontal plane, which finally causes the collapse of the entire structure in shear. It also causes the structure it supports to collapse. If not handled properly, soft storey can fail not only from external forces but also from the mass drifting from its initial location as a result of external lateral forces. The soft story is one of those constructions with irregular structural elements. It falls under the category of structural vertical irregularities, in other words. The term "floor diaphragm" refers to a floor or portion of a floor that is believed to be indefinitely inflexible and does not bend (Chopra, 2005, Rajoriya et al., 2016).

STAAD is a flexible software program for structural design and analysis. It offers graphical input mode, editable files, and interactive input mode. These two modes operate simultaneously. Large corporations have adopted this programme and have used it to evaluate and build a variety of enormous constructions, including skyscrapers.

STAAD Pro was used by Rajoriye et al., 2016 to assess the soft story building (G+5) in various zones (Zones III and V) and compare the collapse scenarios. Zone V (18.67mm) had a higher maximum deflection on the soft storey than zone III, it was found (8.413mm). The seismic analysis of RC buildings with eccentric bracing at soft storey level was researched by Khana and Rawat, 2016. According to the findings, buildings with eccentric bracing had lower drift demands and collapse risks. Jain and Paliwal, 2017 used a vertical design of equivalent diagonal struts to examine the strengthening of soft storeys. Results indicated that when struts served as flooring, moment and displacement were exactly related to steel area and section size. Using STAAD Pro V8i software, Wahane et al., 2021 investigated the effect of soft storey on the multi-story building structure. One of the key factors influencing how seismically responsive a structure is in any seismic zone is the positioning of soft storey. Soft storey at the top level in all seismic zones has lower displacement values.

The major objective is to contrast the differences in the two nearly identical 10-story RCC buildings, one with a soft storey at 5^{th} floor (M5) and the other without soft storey (M0), under the same standard loading conditions used in India. STAAD-Pro V8i software was used to model and analyze the structure. According to the current study, M0 refers to a construction without any soft storey, whereas M5 has soft storey on the fifth floor.

MATERIALS AND METHODS

The structure is modeled as pin jointed space frame. Plates are used to create the model of slabs and infill walls for the structures. In contrast to horizontal members, modelled and planned as beams, vertical members are created as columns. Model was loaded with structural loadings in accordance with the IS norms after being prepared in STAAD Pro as closely as feasible to the realistic situation under consideration.

According to IS: 875-1987 (Parts 1 and 2), dead and live loads have been taken into account and earthquake loads have been taken into account as per IS 1893-2016. To compare the effect of soft storey, two almost identical models namely M0 and M5 have been prepared. In M5, soft storey is created by reducing its columns in such a way

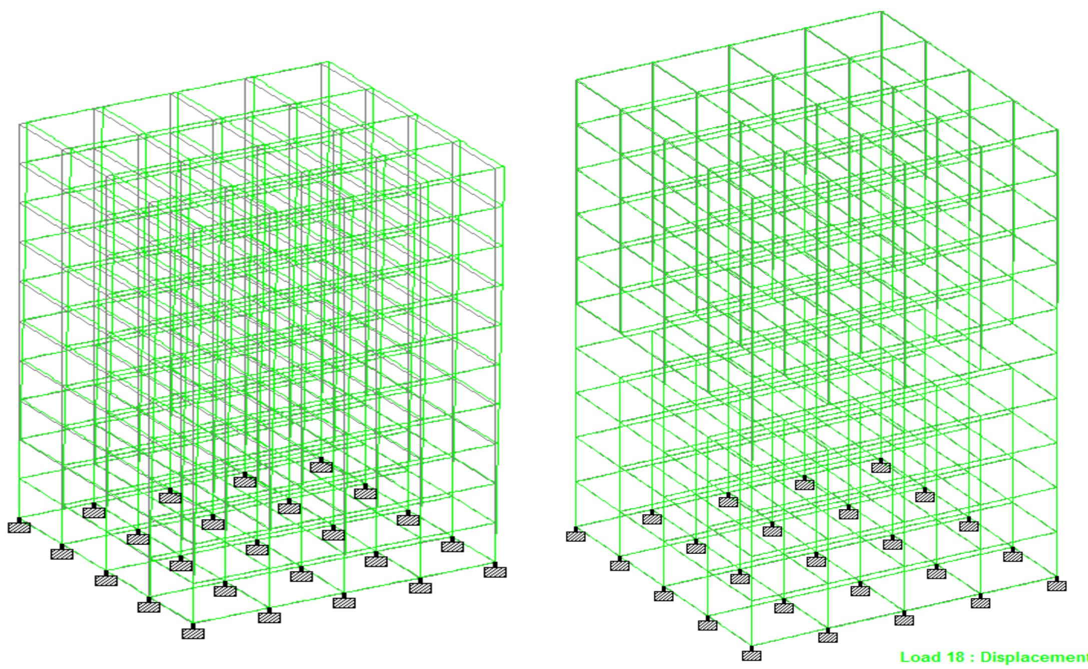

Fig. 1 a) M0 and b) M5

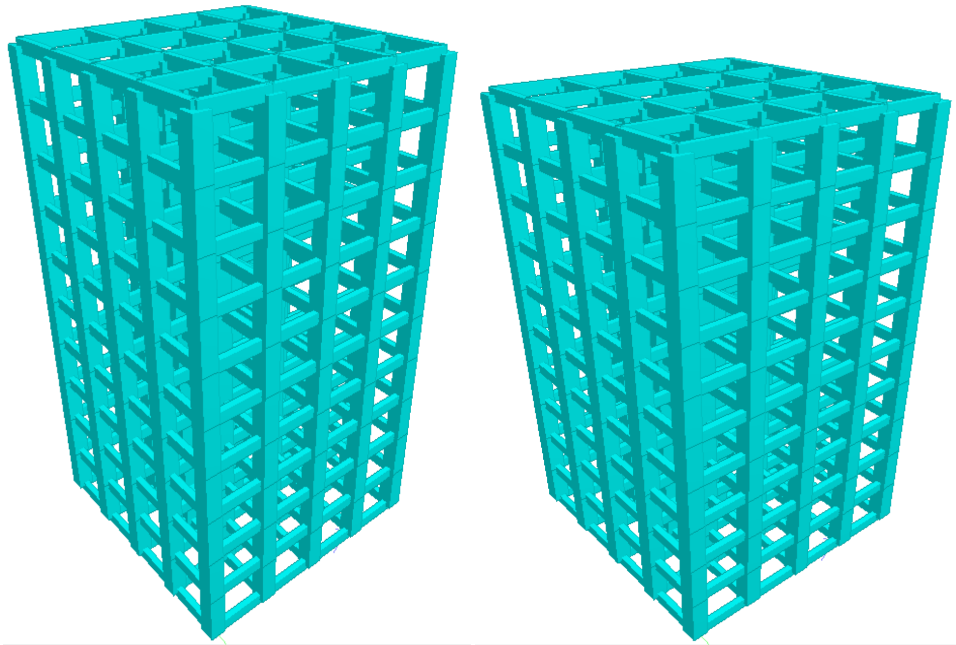

Fig. 2 a) M0 Rendered Structure and b) M5 Rendered Structure

That structural symmetry is maintained. The structure is analyzed using STAAD Pro a well-known analysis and design software from Bentley Systems. Structure is loaded with Indian Earthquake code IS 1893-2016, Part-1. Both structures M0 and M5 were analyzed using software STAAD pro based on loading combinations formulated as per IS 456-2000. Loading is considered based upon IS 1893-2016 part-1 and IS 875-1987 Part 2 &3. The general assembles drawings of both structures M0 and M5 are shown in fig. 1.

RESULTS AND DISCUSSION

Two identical 10 storied RCC buildings with and without soft storey was analyzed using the STAAD Pro software under similar conditions. The comparative results of analysis were presented in terms of base shear, drift, and support reactions.

3.1 Base shear

The base shear of both buildings M0 and M5 have been shown in table 1. Table 1 shows that the base shear reduced by 7.5% and time periods in the orthogonal direction was increased by 5%.

Table 1Base Shear and Time Periods of M0 And M5 Type Structure

Sr. No.	Parameter	M0	M5	Unit
	Base shear and time period in +Z			
1	Time period for Z 1893 loading	0.68977	0.72584	SEC
2	S_A/g per 1893	1.45	1.378	-
3	Load factor	1	1	=
4	V_b per 1893= 0.1392 X 48642.37	6769.91		KN
	V_b per 1893= 0.1323 X 47511.41		6283.89	KN
5	V_b act based on Clause 7.2.1	6769.91	6283.89	KN
6	V_b Min based on Clause 7.2.2	778.28	760.18	KN
	Base shear and time period in -Z			
1	Time period for Z 1893 loading	0.68977	0.72584	SEC
2	S_A/g per 1893	1.45	1.378	-
3	Load factor	-1	-1	-
4	V_b per 1893= 0.1392 X 48642.37	-6769.91		KN
	V_b per 1893= 0.1323 X 47511.41		-6283.89	KN
5	V_b act based on Clause 7.2.1	-6769.91	-6283.89	KN
6	V_b Min based on Clause 7.2.2	-778.28	-760.18	KN

3.2 Drift

The drift of both the structures M0 and M5 have been given in table 2. Drift of M0 type structure was observed as L/547 whereas drift of M5 type of structure was L/351. Therefore, the drift increase was 547/351=1.56 times drift of M0 type of structure which had no soft storey. Soft storey drift caused excessive eccentricity in mass and the loading column of this storey is supporting so column bracings and staircase beams also may be suitably used to brace the whole structure diagonally.

Table 2 Value of Drift Check for M0 and M5 Structure

Storey	Height	Load	Avg. displacement		M0	M5
			X	Y		
6	0.5487	0.8537	0	0.0272	L/ 547	L / 351
6	0.5487	0.8533	0	0.0276	L/ 547	L / 351
6	0	0.0276	0.5487	0.8533	L/ 547	L / 351
6	0	0.0272	0.5487	0.8537	L/ 547	L / 351
6	0.5487	0.8533	0	0.0276	L/ 547	L / 351
6	0.5487	0.8537	0	0.0272	L/ 547	L / 351
6	0	0.0272	0.5487	0.8537	L/ 547	L / 351
6	0	0.0276	0.5487	0.8533	L/ 547	L / 351

3.3 Support reaction

The forces (F_x, F_y and F_z) and moment (M_x, M_y and M_z) obtained from the analysis of structures of buildings have been shown in table 3 and 4, respectively. Structures of type M5 (Structures having soft storey) required more foundation area than structures of M0 (Structures with no soft storey) to support the whole structure. Moment M_y also observed among ruling cases in support reactions in case of M5 type of structures whereas there was no moment M_y for ruling case in M0 type of structures.

Table 3 Support Reactions of Building M0

			Force			*Moment*		
	Node	L/C	F_x, kN	F_y, kN	F_z, kN	M_x, kN-m	M_y, kN-m	M_z, kN-m
Max Fx	12	19 Ulc, 1.5 Dead + 1.5 Seismic (2)	440.457	1733.98	-2.796	10.825	0	-1462.29
Min Fx	12	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-440.46	1733.98	-2.796	10.825	0	1462.29
Max Fy	24	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-359.36	4104.12	0	0	0	1380.41
Min Fy	2	1 +X	-237.71	-1580.1	0	0	0	927.488
Max Fz	24	21 Ulc, 1.5 Dead + 1.5 Seismic (4)	-2.796	1733.98	440.457	1462.29	0	-10.825
Min Fz	24	20 Ulc, 1.5 Dead + 1.5 Seismic (3)	-2.796	1733.98	-440.46	-1462.29	0	-10.825
Max Mx	24	21 Ulc, 1.5 Dead + 1.5 Seismic (4)	-2.796	1733.98	440.457	1462.29	0	-10.825
Min Mx	24	20 Ulc, 1.5 Dead + 1.5 Seismic (3)	-2.796	1733.98	-440.46	-1462.29	0	-10.825
Max My	2	7 Ulc, 1.5 Dead + 1.5 Live	4.501	1774.66	-4.501	9.381	0	9.381
Min My	2	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-353.77	-819.756	-2.796	10.825	0	1402.06
Max Mz	12	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-440.46	1733.98	-2.796	10.825	0	1462.29
Min Mz	12	19 Ulc, 1.5 Dead + 1.5 Seismic (2)	440.457	1733.98	-2.796	10.825	0	-1462.29

From the analysis, it was observed that compression was increased and weight was reduced at 5th floor in case of M5 type structure. It may be due to the concentration of horizontal forces at roof diaphragm of fifth storey. As this diaphragm was solid hence column of this storey suffers more bending moment. Also due to reduction of number of columns at fifth floor and presence of columns of above storey starting from roof beam of 5th storey caused increase in shear force and bending moment in roof beams of 5th floor and that also turned out to be approximately 1.5 times that of M0 structure.

Table 4 Support Reactions and Moment for M5 Structure

		Force			*Moment*		
Node	L/C	F_y, kN	F_x, kN	F_y, kN	M_x, kN-m	M_y, kN-m	M_z, kN-m
18	28 Ulc, 0.9 Dead + 1.5 Seismic (2)	425.144	1895.05	-1.563	-14.774	-3.911	-1408.13
18	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-425.15	3176.32	-1.977	-11.378	3.933	1408.15
24	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-316.28	6288.4	-0.99	-5.487	-0.193	1248.83
24	2 -X	212.329	-2079.2	0.662	3.664	0.12	-843.447
24	21 Ulc, 1.5 Dead + 1.5 Seismic (4)	1.977	3176.32	425.149	1408.15	-3.933	-11.378
24	29 Ulc, 0.9 Dead + 1.5 Seismic (3)	1.563	1895.05	-425.14	-1408.13	3.911	-14.774
24	21 Ulc, 1.5 Dead + 1.5 Seismic (4)	1.977	3176.32	425.149	1408.15	-3.933	-11.378
24	29 Ulc, 0.9 Dead + 1.5 Seismic (3)	1.563	1895.05	-425.14	-1408.13	3.911	-14.774
26	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-320.08	2237.58	-0.779	-7.336	13.456	1246.1
20	21 Ulc, 1.5 Dead + 1.5 Seismic (4)	0.779	2237.58	320.081	1246.1	-13.456	-7.336
18	18 Ulc, 1.5 Dead + 1.5 Seismic (1)	-425.15	3176.32	-1.977	-11.378	3.933	1408.15
18	28 Ulc, 0.9 Dead + 1.5 Seismic (2)	425.144	1895.05	-1.563	-14.774	-3.911	-1408.13

CONCLUSIONS

The analysis of two almost identical structures, namely M0 (structure with no soft storey) and M5 (structure with soft storey at fifth floor) using STAAD pro software was carried out in the present work. Loading was considered as per Indian Standard Codes. The soft stories, such as public places, hospitals, community halls etc., are the structures which require more accessible space for movement, thereby reducing the effectiveness of lateral supports such as shear walls etc. On comparing both cases, the following conclusions were found as:

Soft storey leads to more severe damages in M5 type structure in comparison with M0 structure, during high intensity loads. Sudden increase in moment at storey immediately above soft storey that was in 6th storey in M5 structure. In this case, M5 structure has 1.55 times more storey drift than Mo structure at soft storey level. Maximum support reaction from STAAD pro analysis of M5 structure was found to be 1.5 times the support reaction from M0 structure approximately. Structures of type M5 (Structures having soft storey) required more foundation area than structures of M0 (Structures with no soft storey) to support the whole structure. Maximum horizontal displacement along any orthogonal axis was also increased in M5 type cases. In our particular case, it was increased by 7.5% approximately. Cost of structure increased about 1.5 times for M5 structure in comparison with M0 type structure in our model.

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