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To Study the Effect Of Stiffness on the Expansion Joint of a Building Subjected to Earthquake Forces

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ABSTRACT

This paper presents effect of earthquake forces on expansion joint of a four storey building loaded as per IS 1893(part 1) and IS-456. A model of the structure is prepared in STAAD with and without expansion joint. Earthquake forces are automatically generated in the software. The stiffness of the columns of the structure is changed and its effect in the form of displacement in the structure, storey drift and change in the cost of the structure is found out.

Keywords : Multi-storey building, stiffness irregularity Earthquake forces, shape irregularity

INTRODUCTION

In this paper first of all a four storey building is modeled in STAAD. In this STAAD model earthquake parameters like importance factor, response reduction factor and soil type and zone factor are kept constant. For a particular geometry the displacement in the structure at slab levels, storey drift and cost of the structure is worked out. Now the stiffness of the columns is changed its effect on above mentioned parameters is studied. Expansion joints are now introduced in the model and its effect on the various parameters is found out.

3.0 Seismic Analysis and Design of a four Storey Building
3.1 Problem Statement:
A four storey building for a commercial complex as shown in Figure 1. The building is designed for seismic loads as per IS 1893 (Part 1): 2002.

Data of the Example
The design data is as follows:

Live load : 4.0 kN/m2 at typical floor : 1.5 kN/m2 on terrace

Floor finish : 1.0 kN/m2

Water proofing : 2.0 kN/m2

Terrace finish : 1.0 kN/m2

Earthquake load: As per IS-1893 (Part 1) - 2002

Depth of foundation below ground: 2.5 m

Type of soil : Type II, Medium soil as per IS: 1893

Storey height : Typical floor:3.65 m, GF: 3.65 m

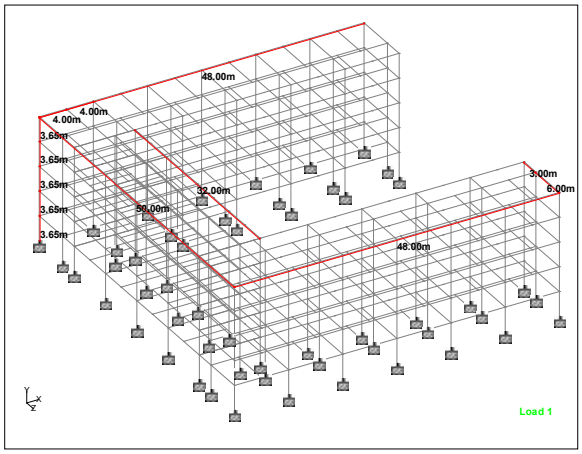
Floors : G.F. +4 upper floors.

Ground beams: to be provided at 100 mm below G.L.

Plinth level : 0.6 m

Walls : 230 mm thick brick masonry walls : Only at periphery.

Figure 1 General lay-out of the Building C-WOE



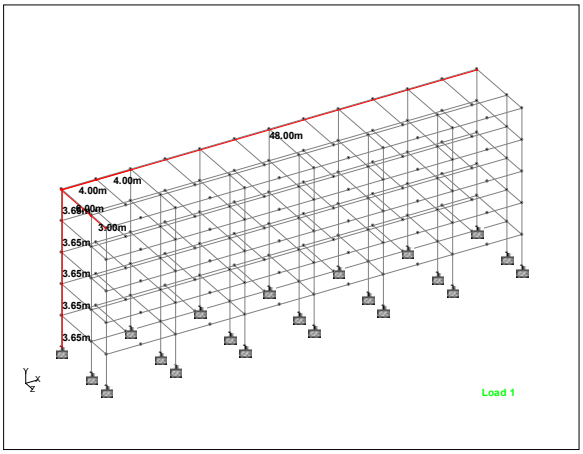


Figure 2 General lay-out of the Building with expansion joint (c-01).

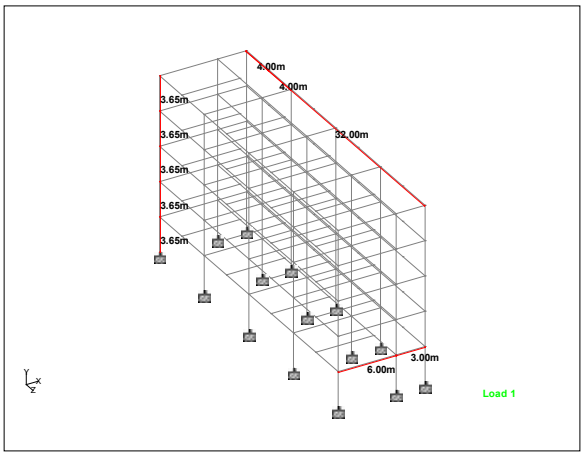


Figure 3 General lay-out of the Building with expansion joint (c-02).

3.2 Material Properties

Concrete:

All components unless specified in design: M25 grade all

Ec = 5000 fck N/mm2
= 5000 fck MN/m2
= 25000 N/mm2 = 25 000 MN/m2.

Steel:HYSD reinforcement of grade Fe 415 confirming to IS: 1786 is used throughout.

3.3Analysis by Space Frames

Table 2 Basic Load Cases Used for Analysis

.	Load case	Directions
1	DL	Downwards
2	LL(Imposed/Live load)	Downwards
3	EXTP (+Torsion)	+X; Clockwise torsion due to EQ
4	EXTN (-Torsion)	+X; Anti-Clockwise torsion due to EQ
5	EZTP (+Torsion)	+Z; Clockwise torsion due to EQ
6	EZTN (-Torsion)	+Z; Anti-Clockwise torsion due to EQ

3.4 Load Combinations

Table 3 Load Combinations Used for Design

No.	Load combination
1	1.5 (DL + IL)
2	1.2 (DL + IL + EXTP)
3	1.2 (DL + IL + EXTN)
4	1.2 (DL + IL – EXTP)
5	1.2 (DL + IL – EXTN)
6	1.2 (DL + IL + EZTP)
7	1.2 (DL + IL + EZTN)
8	1.2 (DL + IL – EZTP)
9	1.2 (DL + IL – EZTN)
10	1.5 (DL + EXTP)
11	1.5 (DL + EXTN)
12	1.5 (DL – EXTP)
13	1.5 (DL – EXTN)
14	1.5 (DL + EZTP)
15	1.5 (DL + EZTN)
16	1.5 (DL – EZTP)
17	1.5 (DL – EZTN)
18	0.9 DL + 1.5 EXTP
19	0.9 DL + 1.5 EXTN
20	0.9 DL - 1.5 EXTP
21	0.9 DL - 1.5 EXTN
22	0.9 DL + 1.5 EZTP
23	0.9 DL + 1.5 EZTN
24	0.9 DL - 1.5 EZTP
25	0.9 DL - 1.5 EZTN

EXTP: EQ load in X direction with torsion positive

EXTN: EQ load in X direction with torsion negative

EZTP: EQ load in Z direction with torsion positive

EZTN: EQ load in Z direction with torsion negative.

When the dimension of a building exceeds a certain limit, expansion joints are provided in the building. To study the effect of earthquake force on the expansion joint, a plan of a school building as shown in fig-1is taken. The building is a ground floor plus four story.

In the first case the building is modeled in STAAD without expansion joint and then analyzed and designed. now expansion joints are introduced in the building as shown in fig-2, so that the building is now split into three parts without changing the other parameters, the building is once again modeled in STAAD and analyzed in all cases earthquake load are automatically generate in STAAD and verified manually

The displacement in all the cases has been found.

In this case zone factor is taken as .16 in STAAD model. In this model size of beams 0.4 X 0.4 at plinth level and terrace level and middle floor the beam size is 0.65X0.65. Columns size is 0.45X0.45, 0.55x0.55 and 0.60x0.60 in different models.

3.5 Effect of the stiffness on displacement in the building

Effect of the stiffness on displacement in the building C-WOE

level m	0.45	0.55	% Change	0.6	% Change	0.45	0.55	% Change	0.6	% Change
	x-direction displacement in cm					z-direction displacement in cm				
14.60	3.75	2.64	-29.39	2.35	-37.25	4.31	3.36	-21.91	3.05	-29.08
10.95	3.34	2.35	-29.62	2.07	-38.05	3.80	2.95	-22.39	2.65	-30.21
7.30	2.66	1.91	-28.33	1.66	-37.55	2.93	2.29	-21.87	2.04	-30.47
3.65	1.76	1.31	-25.44	1.12	-36.24	1.83	1.46	-20.32	1.28	-30.35
0.00	0.66	0.54	-18.71	0.44	-32.61	0.65	0.55	-14.68	0.47	-27.80
Effect of the stiffness on displacement in the building C-01										
level m	0.45	0.55	% Change	0.6	% Change	0.45	0.55	% Change	0.6	% Change
	x-direction displacement in cm					z-direction displacement in cm				
14.60	4.28	3.48	-18.62	3.18	-25.58	3.60	2.69	-25.12	2.42	-32.82
10.95	3.79	3.05	-19.62	2.75	-27.43	3.21	2.39	-25.42	2.13	-33.74
7.30	3.03	2.43	-19.80	2.16	-28.62	2.57	1.93	-24.84	1.70	-33.90
3.65	2.03	1.62	-19.85	1.41	-30.38	1.72	1.32	-23.60	1.14	-34.05
0.00	0.77	0.64	-16.38	0.54	-29.94	0.66	0.54	-18.47	0.45	-31.87
Effect of the stiffness on displacement in the building C-02										
level m	0.45		% Change	0.6	% Change	0.45	0.55	% Change	0.6	% Change

	x-direction displacement in cm				
14.60	4.49	3.64	-18.93	3.36	-24.98
10.95	3.94	3.19	-19.01	2.92	-25.96
7.30	3.01	2.46	-18.35	2.22	-26.25
3.65	1.81	1.52	-16.22	1.34	-25.68
0.00	0.68	0.55	-18.61	0.47	-30.14

z-direction displacement in cm				
4.42	2.69	-39.03	3.43	-22.29
3.89	2.39	-38.50	2.95	-24.14
3.05	1.93	-36.72	2.30	-24.78
1.95	1.32	-32.43	1.46	-24.89
0.77	0.54	-30.54	0.54	-30.43

3.6 Effect of the stiffness on forces in the building Torsional effect in X direction

Torsional effect in X direction in building -C-WOE

Effect on Fx in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	844.70	878.04	3.95	894.23	5.86
10.95	878.49	921.78	4.93	941.73	7.20
7.30	495.16	519.39	4.89	530.62	7.16
3.65	220.07	230.84	4.89	235.83	7.16
0.00	35.19	36.60	4.02	37.77	7.34

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
2111.75	2195.10	3.95	2235.57	5.86
2196.22	2304.44	4.93	2354.32	7.20
1237.88	1298.48	4.90	1326.54	7.16
550.17	577.10	4.89	589.58	7.16
88.97	91.51	2.86	94.42	6.13

Torsional effect in X direction in building -C-01

Effect on Fx in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	355.23	366.58	3.19	373.83	5.24
10.95	376.21	390.44	3.78	399.41	6.17
7.30	211.62	219.63	3.78	224.67	6.17
3.65	94.05	97.61	3.78	99.85	6.17
0.00	14.91	15.58	4.47	16.10	8.00

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
159.85	164.96	3.19	168.22	5.24
169.29	175.70	3.78	179.74	6.17
95.23	98.83	3.78	101.10	6.17
42.32	43.93	3.79	44.93	6.17
6.71	7.01	4.47	7.25	8.00

Torsional effect in X direction in building -C-02

Effect on Fx in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	243.12	250.07	2.86	255.27	5.00
10.95	252.09	261.42	3.70	267.82	6.24
7.30	141.46	147.05	3.95	150.65	6.50
3.65	63.20	65.23	3.21	66.83	5.74
0.00	10.34	10.71	3.63	11.09	7.27

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
389.99	400.12	2.60	408.43	4.73
403.34	418.28	3.70	428.52	6.24
226.33	235.28	3.95	241.04	6.50
101.12	104.37	3.21	106.93	5.74
16.54	17.14	3.63	17.74	7.27

Torsional effect in Z direction

Torsional effect in Z direction in building -C-WOE

Effect on Fz in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	844.70	878.04	3.95	894.23	5.86
10.95	878.49	921.78	4.93	941.73	7.20
7.30	495.16	519.39	4.89	530.62	7.16
3.65	220.07	230.84	4.89	235.83	7.16
0.00	35.19	36.60	4.02	37.77	7.34

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
-2027.28	-2107.30	3.95	-2146.15	5.86
-2108.37	-2212.26	4.93	-2260.15	7.20
-1188.37	-1246.54	4.89	-1273.48	7.16
-528.17	-554.02	4.89	-565.99	7.16
-84.45	-87.85	4.03	-90.65	7.34

Torsional effect in Z direction in building -C-WOE

Effect on Fz in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	355.23	366.58	3.19	373.83	5.24
10.95	376.21	390.44	3.78	399.41	6.17
7.30	211.62	219.63	3.78	224.67	6.17
3.65	94.05	97.61	3.78	99.85	6.17
0.00	14.91	15.58	4.47	16.10	8.00

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
-852.55	-879.79	3.19	-897.19	5.24
-902.90	-937.07	3.78	-958.59	6.17
-507.88	-527.10	3.78	-539.21	6.17
-225.73	-234.27	3.78	-239.65	6.17
-35.78	-37.38	4.47	-38.64	8.00

Torsional effect in Z direction in building -C-WOE

Effect on Fz in kN/m in different direction

level m	col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
14.60	243.12	250.07	2.86	255.27	5.00
10.95	252.09	261.42	3.70	267.82	6.24
7.30	141.46	147.05	3.95	150.65	6.50
3.65	63.20	65.23	3.21	66.83	5.74
0.00	10.34	10.00	-3.26	11.09	7.27

Effect on My in kN/m in different direction

col. Size 0.45m	col. Size 0.55m	% Change	col. Size 0.60m	% Change
-109.40	-112.53	2.86	-114.87	5.00
-113.44	-117.64	3.70	-120.52	6.24
-63.66	-66.17	3.95	-67.79	6.50
-28.44	-29.35	3.21	-30.07	5.74
-4.65	-4.81	3.44	-4.99	7.27

3.7 Effect of the stiffness on cost of the building

Building C-WOE						
soil type	column size	concrete (m3)	steel kg	rate of concrete per m3	rate of steel per kg	totel cost
medium soil	0.45x0.45	727.17	96246.12	3500.00	36.36	6044603.80
medium soil	0.55X0.55	844.92	89426.39	3500.00	36.36	6208763.69
medium soil	0.60X0.60	900.67	86639.17	3500.00	36.36	6302545.34
Building C-01						

soil type	column size	concrete (m3)	steel kg	rate of concrete per m3	rate of steel per kg	total cost
medium soil	0.45x0.45	278.08	29045.00	3500.00	36.36	2029356.20
medium soil	0.55X0.55	310.96	30229.93	3500.00	36.36	2187520.25
medium soil	0.60X0.60	334.80	31804.99	3500.00	36.36	2328229.44

Building C-02

soil type	column size	concrete (m3)	steel kg	rate of concrete per m3	rate of steel per kg	total cost
medium soil	0.45x0.45	137.36	18181.68	3500.00	36.36	1141845.76
medium soil	0.55X0.55	159.63	16899.81	3500.00	36.36	1173182.17
medium soil	0.60X0.60	175.37	16263.15	3500.00	36.36	1205123.00

Overall cost of building with expansion joint (c-01x2+c-02)

soil type	column size	concrete (m3)	steel kg	rate of concrete per m3	rate of steel per kg	total cost
medium soil	0.45x0.45	693.52	76271.68	3500.00	36.36	5200558.16
medium soil	0.55X0.55	781.55	77359.67	3500.00	36.36	5548222.68
medium soil	0.60X0.60	844.97	79873.13	3500.00	36.36	5861581.88

Cost of building

Building with column size	without expansion joint	with expansion joint	% Change
0.45x0.45	6044603.80	5200558.16	-13.96
0.55X0.55	6208763.69	5548222.68	-10.64

- When the provide expansion joint the cost of developing the expansion joint is to be included.

3. conclusion

- When the stiffness increases displacement decreases
- When the stiffness increases force value increases
- When the stiffness is increase the cost of building is increase but the finally when the comparisonof with and without expansion joint the percentage change is decreases

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