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Optimum location of Soft Storey in Tall Buildings over the Height using Response Spectrum Method

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Abstract - *Construction of high rise or multi storey buildings is must in the developing countries like India in order to occupy space and also due to increase in population. These constructions of multi storey buildings often have soft stories due to requirement or needs of the occupants in the building. For example, open ground storey for the purpose of vehicle parking or the soft storey for the commercial use such as showrooms etc. This soft storey due to lack of stiffness fail to resist the lateral loads due to Earthquake or wind forces which may lead to the damage or collapse of the building. In this project the investigation is made to study the behavior of the single and Multi soft storey at different levels in the Multi storey building during Earthquake and to find the optimum location of the soft storey using Response Spectrum Method. This project also aims to provide strength to the columns which may help in increasing the stiffness to the soft storey and reduce the risk of damage or collapse of the building due to Earthquake.*

Key Words: Soft storey, Stiffness, Response Spectrum Method.

1. INTRODUCTION

Vast growth in the population in India is one of the main reasons for the construction of tall buildings in major cities. Soft storey is provided in the multi storey buildings depending on the needs of the occupants in the building. For Ex: providing car parking at the basement or the stories used for commercial purpose.

A soft storey is defined as "If the storey is lesser than 70% stiff than that of the storey exactly above or lesser than 80% stiff as the average three storey above it, is known as soft storey". Due to the lesser stiffness in this storey the lateral forces due to earthquake must be resisted by columns and if these columns are weak then this will lead to the severe damage or collapse of the building. To provide the resistance to the earthquake forces and to avoid this soft storey effect many of the papers involved the study by providing alternative materials such as R.C Shear wall, RCC or steel bracings etc., in the soft storey. This project involves the study of behavior of the soft stories at different locations in the building and to provide the solution to reduce the values in the analytical results.

1.1 Earthquake Response of Tall Buildings having Soft storey

Generally the tall building is considered as the one with maximum number of floors and requires a mechanical vertical transportation. This includes apartments, Hotels and Office buildings etc. Approximately about 23m to 150m high buildings are considered as the tall buildings.

The collapse or the damage of the high rise building due to soft storey is very often, the ground floor soft storey during earth quake fail to resist the lateral earthquake forces. Since the distribution of the lateral forces in the high rise buildings is purely dependent on the mass and the stiffness of the building. The soft storey which has less stiffness (no infill) depends upon the column to resist the lateral forces, and if the columns are week it fails to resist the adequate lateral forces and hence leads to the larger displacements and also larger inter-storey drift.

1.2 Response Spectrum Method

In analyzing the performance of structures in earthquakes, Response spectrum is one of the useful tools, since many systems behave as single degree of freedom systems. Thus, if you can find out the natural frequency of the structure, then the peak response of the building can be estimated by reading the value from the ground response spectrum for the appropriate frequency.

Response spectrum is a plot of maximum response of a SDF for various value of the period for a given input. The IS-1893 gives an average Response spectrum can be employed in earthquake resistant design.

1.3 Objectives

The objectives of the project are as listed below:

1) To study the optimum location of soft storey over the height of the building.
2) To increase the stiffness of soft storey by providing interconnecting columns.
3) To obtain Displacement, Storey drift, Storey shear, Time period and Frequency by Response spectrum method.

4) Comparing the analytical results of a building with and without interconnecting columns.

2. STRUCTURAL MODEL

For this study, building with G+ 11 storeys is considered. The Area of all the buildings are exactly same i.e 300 m². The structural models have the bottom storey height of 1.5m and 3m height for the remaining storey throughout the building height and have a uniform mass distribution over their height. Building 3D view is shown below in Fig-1 & Fig-2. The dimensions of the structural elements considered are as follows:

Column (mm): 200X1000, 200X1200, 200X1400, 300X1200
Beam (mm): 200X600
Slab: 175mm
Interconnecting Column sizes (mm): 900X900
Interconnecting Beam sizes (mm): 200X600

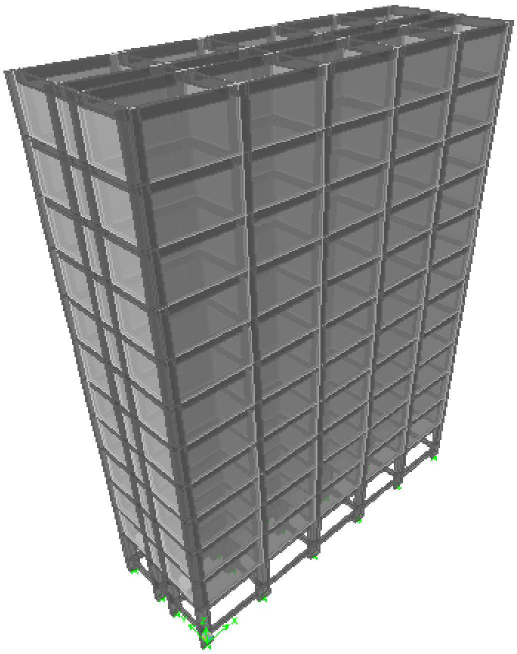

Fig -1: Building 3D view (ETABS Model)

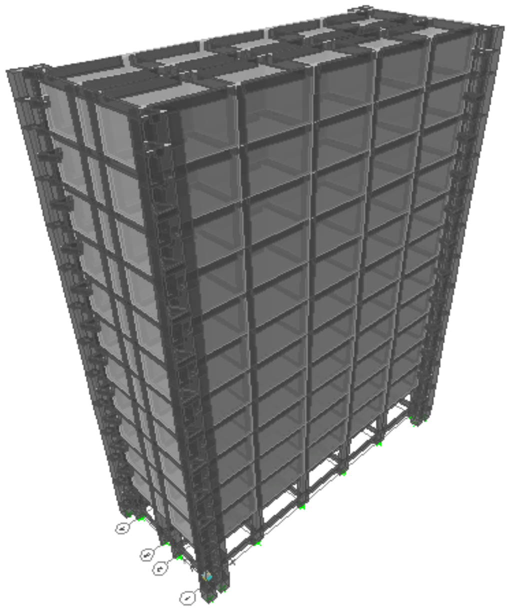

Fig -2: Building 3D view with Interconnecting Columns (ETABS Model)

2.1 Types of models

T1: Model with soft storey at Ground floor of the building.
T2: Model with soft storey at Middle floor of the building.
T3: Model with soft storey at Top floor of the building.
T4: Model with soft storey at Ground floor of the building with inter-connecting columns.
T5: Model with soft storey at Middle floor of the building with inter-connecting columns.
T6: Model with soft storey at Top floor of the building with inter-connecting columns.

2.2 Methodology

All the structural models are done using ETABS 9.7.1 software. Response Spectrum Analysis is carried out according to IS: 1893-2002 (part 1), Parameters used for the building model are mentioned in the Table1 below.

Table -1: Seismic Parameters

Parameters	All Models
Response Reduction Factor	R=5
Importance Factor	1
Zone Factor	0.16
Sa/g	Type 2
Function input	0.1
spectrum case name	specX & specY
structural and function damping	0.05
model combination	CQC

directional combination	SRSS
input response spectra	specX=1.848 specY=1.096
eccentricity ratio	0

3. RESULT AND DISCUSSION

1) Time Period (sec)

Referring to the chart-1 Time period graph (comparing T1, T2 & T3 models) this chart shows, the time period is maximum for the model T1 (soft storey at the bottom floor), whereas the time period is minimum for the model T2 & T3 (soft storey at middle and top floor). The case is similar with the models consisting of interconnected columns showing Time period in both X and Y direction.

Table -2: Time period in seconds for T1, T2 & T3 models

	SOFT STOREY WITHOUT INTERCONNECTING COLUMNS		
modes	Period T1	Period T2	Period T3
1	1.317357	1.421444	0.952316
2	0.842453	0.77053	0.513476
3	0.564657	0.512164	0.434785
4	0.424288	0.282309	0.332123
5	0.218931	0.260811	0.226954
6	0.181758	0.206257	0.217597
7	0.157496	0.143124	0.151392
8	0.109634	0.128573	0.145125
9	0.095588	0.100625	0.122305
10	0.083376	0.096207	0.095063
11	0.072407	0.082241	0.09134
12	0.069228	0.075924	0.082688

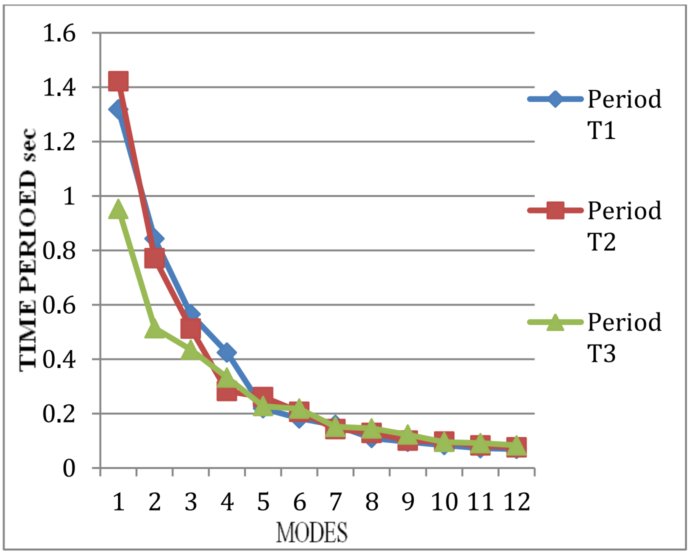

Chart -1: Time period graph (comparing T1, T2 & T3 models)

From chart-2 Time period graph (comparing T1 & T4 models) it can be seen that the Time period for the model T4 (Soft storey at bottom floor with interconnecting column) is much lower than the Time period for the model T1 (Soft storey at bottom floor without interconnecting column), the reduction percentage of Time period at mode1 was found out to be 30%. This shows the provision of interconnecting columns helps in reducing the time period. The case is similar to the models with the soft storey at middle and top floors showing Time period in both X and Y direction.

Table -3: Time period in seconds for T1 and T4 models

modes	Period T1	Period T4
1	1.317357	0.922165
2	0.842453	0.624928
3	0.564657	0.527989
4	0.424288	0.298069
5	0.218931	0.198339
6	0.181758	0.16767
7	0.157496	0.140481
8	0.109634	0.111891
9	0.095588	0.111891
10	0.083376	0.110814
11	0.072407	0.108111
12	0.069228	0.107137

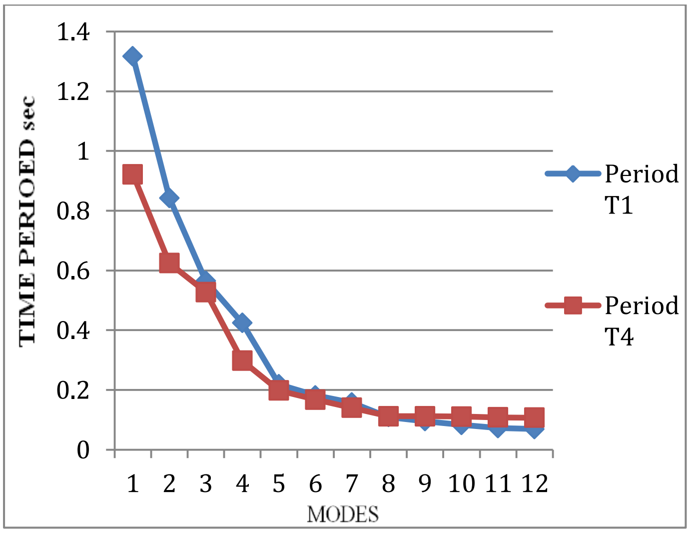

Chart -2: Time period graph (comparing T1 and T4 models)

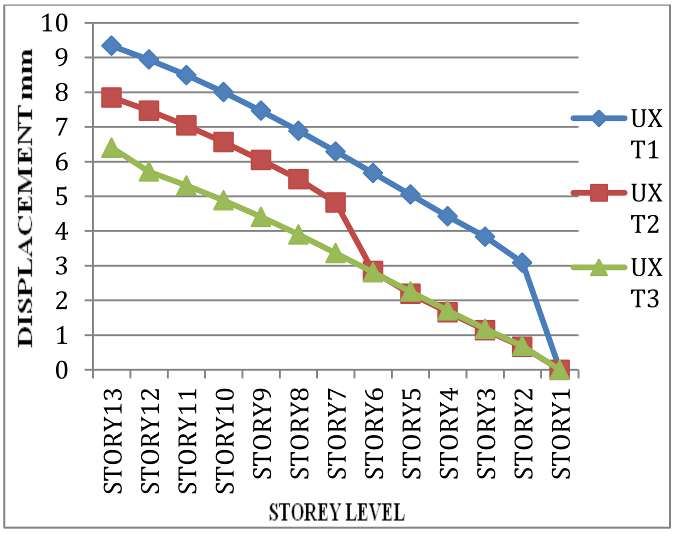

Chart -3: Displacement graph (comparing T1, T2 & T3 models)

2) Displacement (mm)

This figure shows that the displacement at storey12 is maximum for the model T1, quite lesser displacement in model T2 than T1, whereas the displacement is minimum for the model T3. This clearly indicates that the displacement of a building is lesser if the soft storey is provided at the top floors of the building. The case is similar with the models consisting of interconnected columns showing the displacement graph in both X and Y direction.

Table -4: Displacement in mm for T1, T2 & T3 models

	SOFT STOREY WITHOUT INTERCONNECTING COLUMNS		
	UX T1	UX T2	UX T3
STOREY13	9.3336	7.8447	6.3979
STOREY12	8.9383	7.4674	5.7108
STOREY11	8.4929	7.0393	5.3107
STOREY10	7.9988	6.5623	4.8824
STOREY9	7.462	6.0419	4.4083
STOREY8	6.8896	5.4976	3.899
STOREY7	6.29	4.8192	3.3637
STOREY6	5.6724	2.844	2.8128
STOREY5	5.0472	2.1895	2.2575
STOREY4	4.4236	1.6589	1.7098
STOREY3	3.834	1.1431	1.1828
STOREY2	3.0918	0.6654	0.6902
STOREY1	0	0	0

From Chart-4 Displacement graph (comparing T1 & T4 models) it can be seen that the displacement for the model T4 is much lower than the displacement for the model T1 (Soft storey at bottom floor without interconnecting column), the reduction percentage of displacement at storey12 was found out to be 14.5%. This shows the provision of interconnecting columns helps in reducing the Displacement. The case is similar to the models with the soft storey at middle and top floors showing displacement in both X and Y direction.

Table -5: Displacement in mm for T1 and T4 models

	UX T1	UX T4
STOREY13	9.3336	7.9797
STOREY12	8.9383	7.7545
STOREY11	8.4929	7.4731
STOREY10	7.9988	7.1344
STOREY9	7.462	6.7418
STOREY8	6.8896	6.3
STOREY7	6.29	5.8146
STOREY6	5.6724	5.2923
STOREY5	5.0472	4.7404
STOREY4	4.4236	4.1658
STOREY3	3.834	3.5972
STOREY2	3.0918	2.869
STOREY1	0	0

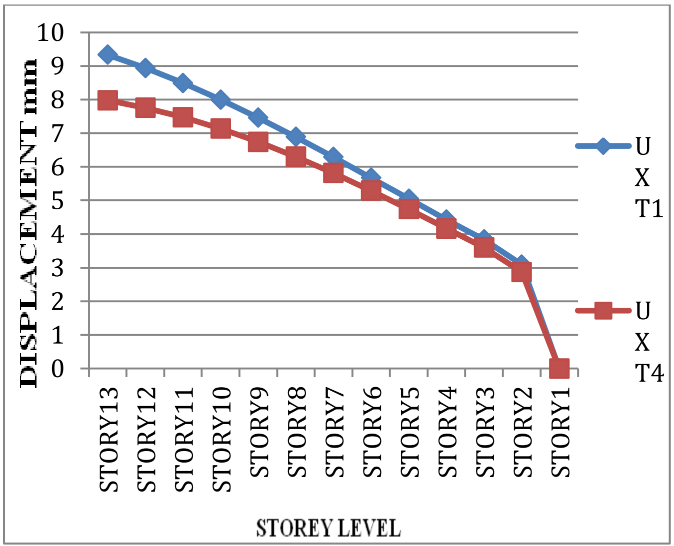

Chart -4: Displacement graph (comparing T1 and T4 models)

3) Storey Drift

In the below results it is seen that by providing the soft storey at top floors (Chart-5) or by providing the interconnecting columns (Chart-6) the storey drift in the structure is reduced.

Table -6: Storey Drift for T1, T2 and T3 models

	SINGLE SOFT STOREY WITHOUT INTERCONNECTING COLUMNS		
	DriftX T1	DriftX T2	DriftX T3
STOREY 13	0.000114	0.000109	0.000209
STOREY 12	0.000128	0.000124	0.000116
STOREY 11	0.000143	0.000138	0.000124
STOREY 10	0.000155	0.000151	0.000137
STOREY 9	0.000165	0.000157	0.000147
STOREY 8	0.000173	0.000195	0.000155
STOREY 7	0.000178	0.00057	0.000159
STOREY 6	0.00018	0.000189	0.00016
STOREY 5	0.000179	0.000153	0.000157
STOREY 4	0.000169	0.000148	0.000151
STOREY 3	0.000212	0.000137	0.000141
STOREY 2	0.000728	0.000145	0.00015
STOREY 1	0	0	0

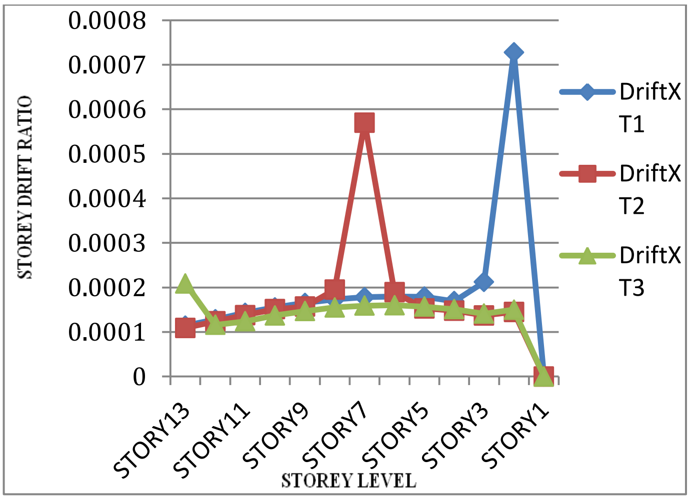

Chart -5: Storey Drift graph (comparing T1, T2 and T3 models)

Table -7: Storey Drift for T1 and T4 models

	DriftX T1	DriftX T4
STOREY 13	0.000114	0.000065
STOREY 12	0.000128	0.000081
STOREY 11	0.000143	0.000098
STOREY 10	0.000155	0.000113
STOREY 9	0.000165	0.000128
STOREY 8	0.000173	0.00014
STOREY 7	0.000178	0.00015
STOREY 6	0.00018	0.000158
STOREY 5	0.000179	0.000165
STOREY 4	0.000169	0.000163
STOREY 3	0.000212	0.000208
STOREY 2	0.000728	0.000684
STOREY 1	0	0

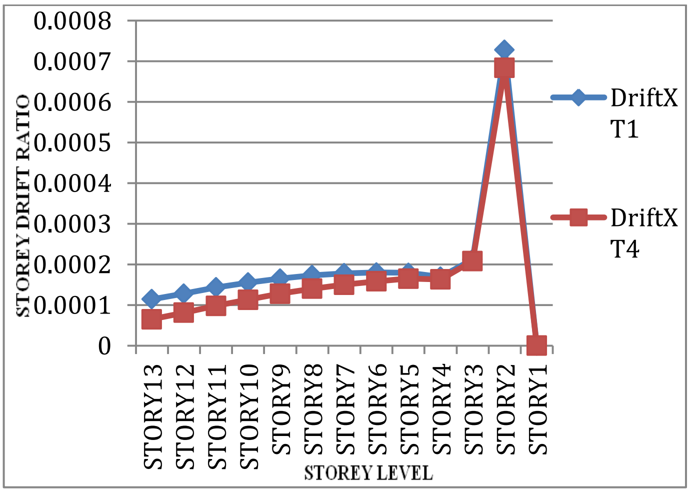

Chart -6: Storey Drift graph (comparing T1 and T4 models)

4) Storey Shear

Table -8: Storey Shear for T1, T2 and T3 models

	SINGLE SOFT STOREY WITHOUT INTERCONNECTING COLUMNS		
	VX T1	VX T2	VX T3
STOREY 13	521.78	551.67	500.97
STOREY 12	1142.29	1193.37	996.42
STOREY 11	1722.01	1775.83	1590.15
STOREY 10	2258.65	2299.32	2130.02
STOREY 9	2751.98	2769.86	2610.61
STOREY 8	3203	3196.63	3032.66
STOREY 7	3613.31	3489.12	3399.22
STOREY6	3984.67	3660.7	3713.69
STOREY 5	4318.93	3856.12	3977.72
STOREY 4	4617.62	4032.5	4190
STOREY 3	4883.18	4175.14	4346.66
STOREY 2	5057.65	4271.18	4445.58
STOREY 1	5064.67	4284.42	4458.79
Base	0	0	0

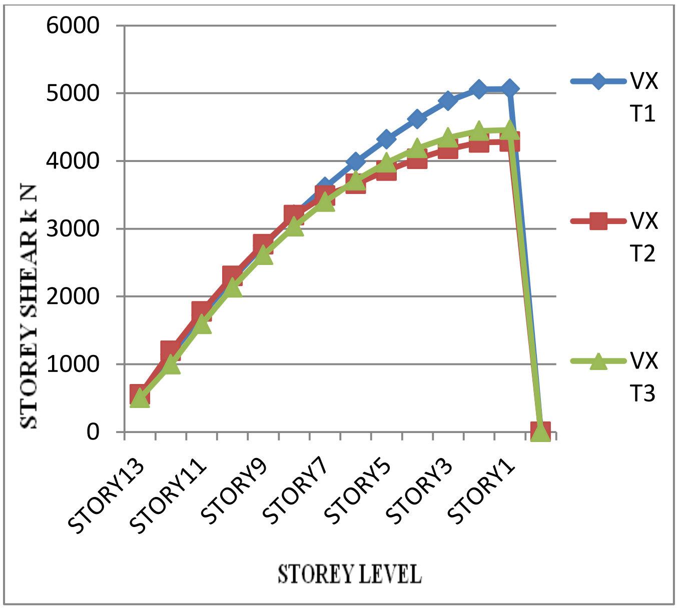

Chart -7: Storey Shear graph (comparing T1, T2 and T3 models)

Table -9: Storey Shear for T1 and T4 models

	VX T1	VX T4
STOREY 13	521.78	541.53
STOREY 12	1142.29	1222.99
STOREY 11	1722.01	1872.72
STOREY 10	2258.65	2484.43
STOREY 9	2751.98	3054.89
STOREY 8	3203	3582.67
STOREY 7	3613.31	4067.6
STOREY 6	3984.67	4510
STOREY 5	4318.93	4909.89
STOREY 4	4617.62	5266.02
STOREY 3	4883.18	5576.71
STOREY 2	5057.65	5776.19
STOREY 1	5064.67	5785.35
BASE	0	0

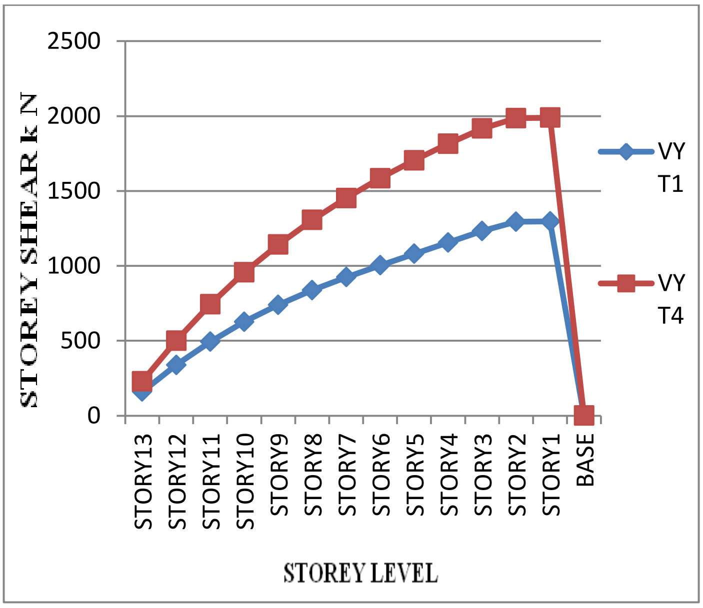

Chart -8: Storey Shear graph (comparing T1 and T4 models)

3. CONCLUSIONS

[1] Comparison of single soft storey at different locations in the building is developed and we found the earthquake response is maximum in the model with soft storey at ground floor (T1) and minimum in the model with soft storey at the top floor (T3). From this one can say that the top soft storey will absorb more energy which results in the reduction of Earthquake response of the building.

[2] This study has tried to reduce the Earthquake Response of the building which has soft storey at different location over the height. So by introducing Interconnected Columns at the corners of the building, the Earthquake Response of the building can be reduced even in ground floor Soft storey.

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