Multilateral Seismic and Cost Assessment Of Building with Stiffness Irregularity In Zone V

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Abstract

Parking facility in high rise buildings is essential these days because of the lack of spaces and the need of green area around the building. When such facility is provided on the stilt level; it results in a soft story. Basically because of the lack of infill walls or due to difference in the floor height the discontinuity in the rigidity of structure happens that is called the soft storey. It behaves differently from rest of the structures at the time of earthquake that results in stress concentration and ultimately damage to the structure. As per Indian codal provisions IS:1893 (2002) the columns, beams and shear walls of the soft storey are to be designed for higher storey shear forces. Higher the storey shear more will be sectional area of steel and concrete. In this paper, an attempt has been made to compare the structural cost of a basement, ground and 6 upper floors building with and without the provision of soft storey (Stilt floor) through dynamic analysis of a residential building in Zone-V comprises of entire northeastern India, parts of Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Rann of Kutch in Gujarat, parts of North Bihar and Andaman & Nicobar Islands. The results of the study would open the door for further research in the area of seismic design of structures under different seismic intensities and related cost management studies.

Keywords: **Structural Modeling, Cost Assessment, Seismic Analysis, ETABS, Building Modeling.**

1. INTRODUCTION

Post analysis on a building shows that the building always cracks from the weakest point present on it. It is also a mare truth that we can't build fully earthquake resistant structure but can consider earthquake effect at the design stages because the actual forces that appear on the structure during earthquake is much greater than the design force. The earthquake force at different level come down along the column to the ground which is called the load path. If abnormal inter-storey drifts occurs between adjacent stories, the distribution of lateral forces do not occur suitably throughout the structure and it gets concentrated on the storey having large displacement. (Vipin V. Halde, 2015) the We define a term soft storey for those buildings which has no or very few infill walls at a floor. As in a soft storey building the stress get concentrated on the ground storey as there is no or very few infill walls on that floor which leads to the damage or collapse of the building. The seismic performance of the soft storey building were very poor, when compared with the normal RC Structure (S. Arunkumar, 2015). Most of the cases in Indian scenario the open spaces in soft storey is desirable either aesthetically or commercially for the purpose of recreational use, parking or for retail or commercial site. Hence there is very less opportunity to provide walls for distribution of lateral forces and to make building to manage the swaying characteristic of an earthquake. Many buildings with an open ground storey intended for parking collapsed or were severely damaged in Gujarat during the 2001 Bhuj earthquake. As per IS:1893(2002), the soft storey is defined as one which has lateral stiffness less than 70% of the storey above or less than 80% of average lateral stiffness of the three storey above, i.e.

$k_i < 0.7\ k_{i+1}$ (1)

or $ki < 0.8(k_{i+1}+k_{i+2}+k_{i+3})/3$ (2)

Where K_i is the lateral stiffness at ith floor.

ASCE 7-05 Reference Section Table 12.6-1 defines that the lateral stiffness of soft storey is less than 70% of that in the storey immediately above, or less than 80% of average stiffness of the three stories above.

The buildings that are called as soft storey building has a discontinuity in the stiffness of the building, which have at least one of the following characteristics: (a) one storey is significantly more flexible than adjacent storeys, (b) have vertical discontinuity (e.g. possess fewer columns in one storey than that of storey above), (c) have a heavy superstructure (Ari Wibowoa, 2015).

2. Objective

The objective of this research paper is to compare the structural cost of two building in seismic zone V with and without shear storey on ground floor as per different provisions provided in the relevant Indian Standard codes. The specifications of structural members, the moment of inertia and the quantity of concrete is considered same for both the structures with and without soft storey. The comparison is done in terms of the extra reinforcement provided only. Further this paper provides scope for the correlation between the number of storey and the structural cost.

3. Description of Soft Storey And Related Codal Provisions

The earthquake causes shaking of ground and in turn generates inertia forces that are proportional to the building mass. Since most of the building mass is present at floor level, earthquake induced forces are maximum at floor levels. These forces when travels down on the load path when finds irregularity in terms of lateral stiffness a stress concentration takes place that leads to the breakdown of the structure.

Soft storey is the one of which the rigidity is lower than any other storeys due to the fact that it has not got the walls with the same properties the other ones have. If vertical load bearing structural elements and the partitioning wall continue in all the storeys, there is no soft storey in the construction. Soft storey is generally present at the entrance floors of the buildings. This situation depends on the constructional properties of the cities and countries (Dr. Mizan DOĞAN, 2002). When the stiffness irregularity is noticed in the structural analysis of the building subjected to equivalent static lateral loads, designers may choose one of following options, namely

(a) Designing all members of the frame according to the irregular forces,

(b) Strengthening the columns and beams in the vicinity of the irregularity for higher forces than those received from structural analysis, and

(c) Reducing the stiffness irregularity by adding a *new* stiff lateral load resisting system in the building, whose lateral stiffness is much larger than that of the original system of the building that has irregularity, *e.g.*, RC structural wall in a RC moment frame building with unreinforced masonry infills (C. V. R. Murty, 2013).

As per Indian Standard 1893:2002 Part I, there is two more term defined apart from the soft storey which is weak storey, i.e in which the storey lateral strength is less than 80 percent of that in the storey above.

$k_i < 0.8\ k_{i+1}$ (3)

and extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffens of the three storeys above.

$K_i < 0.6\ k_{i+1}$ (4)

or $k_i < 0.7(k_{i+1}+k_{i+2}+k_{i+3})/3$ (5)

Where K_i is the lateral stiffness at i^{th} floor.

As far as the design consideration is concerned, IS 1893:2002 Part I Suggests the following:

- Dynamic analysis of building is carried out including the strength and stiffness effects of infills and inelastic deformations in the members particularly those in the soft storey.

  If we neglect the effect of infills in other storey then the following design criteria can be adopted:
- The columns and beams of the soft storey are to be designed for 2.5 times the storey shear and moments calculated under seismic load.
- Besides the columns design and detailed for the calculated storey shear and moments shear walls placed symmetrically in both the direction of the building shall be designed for 1.5 times the lateral storey shear force.

  As per IS 1893:2002, there are two kinds of building frames
- Ordinary Moment Resisting Frame (OMRF) – It is a moment resisting frame not meeting special detailing for ductile failure.
- Special Moment Resisting Frame (SMRF) – It is a moment resisting frame specially detailed to provide ductile behavior and comply with the requirements of Indian Standard.

  In this paper the analysis is done considering SMRF framed building structure.

  As per IS 1893:2002 Part I {**7.6.2** (a)}*, the time period of vibration* including moment-resisting frame buildings with masonry infill wall panels is

  $T_a = (0.09h)/\text{sqrt}(d_x)$ (6)

  Where,

  h = Height of building, in m, as defined in IS 1893:2002 Part I, **7.6.2** (a); and

  d_x = Base dimension (in m) of the building at the plinth level along the considered direction of the lateral force.

4. Methodology of Building Modeling

In this research two residential buildings of basement, ground and 6 upper floors, one with infill walls in all floors and other with infill walls in all floors except the stilt floor (Soft Storey) is taken in zone - V for analysis purpose. These two building are modeled using ETABS (9.7.4) version. The structural details of buildings are shown in Table 1.

Table 1. Description of building

Modelling details of building	
Area	10 m x 30 m
Storey details	Basement + Ground + 6 storeys
Frame type	SMRF (Special Moment Resisting Frame)
Height of basement	5 m
Height of ground storey	2.7 m
Height of typical storey	3.15 m
Purpose	Residential
Foundation support system	Fixed

Seismic Zone	Zone – V
Zone Factor (z)	0.36
Type of soil	Medium
Damping Ratio	5%
Response Reduction Factor (R)	5
Importance Factor (I)	1
Time period in X direction	0.84 sec [Clause 7.6.2, IS:1893: 2002, Part -I]
Time period in Y direction	0.50 sec [Clause 7.6.2, IS:1893: 2002, Part -I]
Material Properties	
Grade of reinforcement (longitudinal/main)	Fe-500
Grade of reinforcement (Shear/ties)	Fe-415
Concrete	
Grade of concrete	M25
Young's Modulus (E)	25 x 10^6 KN/sqm
Density	25 KN/cum
Poisson's ratio	0.20
Structural members	
Thickness of slab	130 mm
Thickness of wall	115 mm & 230 mm
Thickness of shear wall	230 mm
Dimension of beam	115 mm x 450 mm
	230 mm x 450 mm
	300 mm x 450 mm
	350 mm x 450 mm
Dimension of column	300 mm x 75 mm
	350 mm x 750 mm
Dead Load Intensities	
For 230 mm thick wall	13.5 KN/m
For 115 mm thick wall	7.5 KN/m
For parapet wall	5.61 KN/m
For railing	3.0 KN/m
For ceiling plaster and floor finish	1.45 KN/sqm
For ceiling plaster and brick coba	2.75 KN/sqm
For sunken portion (450 mm)	4.05 KN/sqm
For staircase	9.2 KN/sqm
Live Load Intensities	
For toilet, kitchen and living room	2 KN/sqm
For staircase, balcony, corridor and lobby area	3 KN/sqm
For accessible portion of terrace	1.5 KN/sqm
For non-accessible portion of terrace	0.75 KN/sqm
For parking area	5 KN/sqm

5. STRUCTURAL MODELING AND ANALYSIS

As per the model the building comprises of one basement, one stilt floor and 6 floor above it. The same is modeled in ETABS 2015 (Version 15.2.0). The structural system includes columns, beams, shear walls. The Following are the properties assigned to structural members.

Table 2. Member Properties

Sl. No.	Element	Type	Properties	Nodes
1	Beam & Columns	Line Element	Member	2
2	Slabs (Rectangular)	Area Element	Shell	4
3	Shear wall	Area Element	Member	4

Other non-structural components that don't have a significant role in analysis are not modeled. The lumping mass at different floor levels are defined as per the code. Figure 1 shows 3D view of building having basement, ground and 6 storeys along with plan of the building. Both the buildings are similar except that there is no wall load on ground storey in building with soft storey.

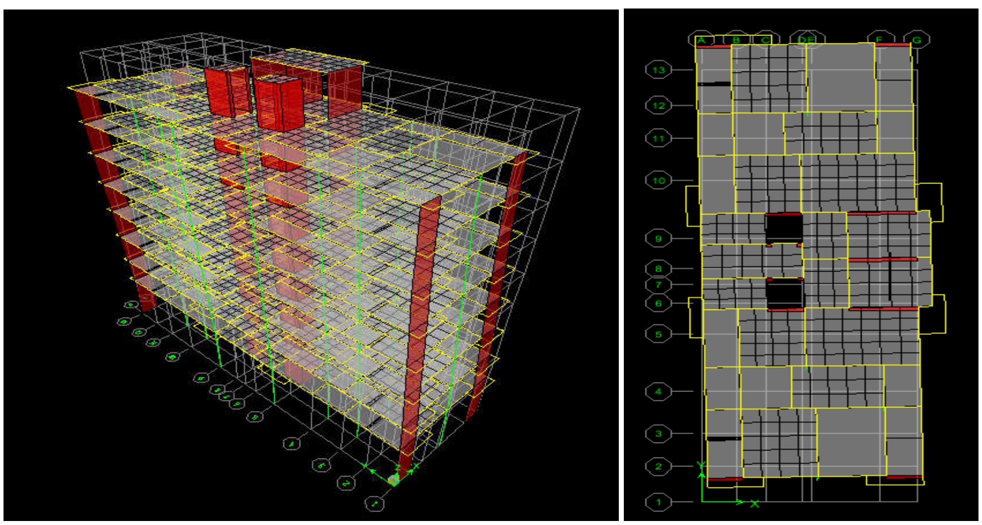

Figure 1 3D view of building modeled using ETABS 9.7.4

6. SOFT STOREY CHECK

As per IS 1893:2002 (Part1) if the stiffness is less than 70% of above storey then it will be classified as soft storey. From this it can be interpreted that if the maximum variation between two storeys is more than 30% then the storey is classified as soft storey (Aslam Faqeer Mohammad, 2012). In the below provide table 2 & 3 the % difference in K value between two adjacent floors is calculated based on the design base shear generated in ETABS 9.7.4 in X direction and Y direction respectively when there is no wall load applied on the ground floor. In table 4 & 5 the % difference in K value between two adjacent floors is calculated based on the design base shear generated in ETABS 9.7.4 in X direction and Y direction respectively when there is wall load applied on the ground floor.

Table 3. Determination of soft storey due to lateral force caused by the earthquake in X direction for building where wall load is not applied at ground level

Storey	Design Base Shear (KN)	Lateral Force (KN)	Diaphragm Displacement (mm)	Stiffness (KN/mm)	% difference in K (30 % required)	
					% difference compared to	
					Above Storey	Below Storey
MUMTY	92.66	92.66	22.70	4.08		86.27
TERRACE	690.19	597.53	20.10	29.73	628.28	7.52
SIXTH	1259.13	568.94	17.70	32.14	8.13	(13.09)
FIFTH	1685.48	426.35	15.00	28.42	(11.57)	(13.95)
FOURTH	1989.78	304.3	12.20	24.94	(12.25)	(13.16)
THIRD	2192.57	202.79	9.20	22.04	(11.63)	(14.01)
SECOND	2314.37	121.8	6.30	19.33	(12.29)	(17.91)
FIRST	2375.04	60.67	3.70	16.40	(15.19)	(65.14)
GROUND	2391.92	16.88	1.70	9.93	**(39.44)**	

Table 4. Determination of soft storey due to lateral force caused by the earthquake in Y direction for building where wall load is not applied at ground level

Storey	Design Base Shear (KN)	Lateral Force (KN)	Diaphragm Displacement (mm)	Stiffness (KN/mm)	% difference in K (30 % required)	
					% difference compared to	
					Above Storey	Below Storey
MUMTY	143.07	143.07	22.70	6.30		86.27
TERRACE	1065.73	922.66	20.10	45.90	628.32	7.51
SIXTH	1944.24	878.51	17.70	49.63	8.13	(13.09)
FIFTH	2602.58	658.34	15.00	43.89	(11.57)	(13.95)
FOURTH	3072.46	469.88	12.20	38.51	(12.25)	(13.16)
THIRD	3385.58	313.12	9.20	34.03	(11.63)	(14.01)
SECOND	3573.65	188.07	6.30	29.85	(12.29)	(17.89)
FIRST	3667.34	93.69	3.70	25.32	(15.18)	(65.18)
GROUND	3693.4	26.06	1.70	15.33	**(39.46)**	

Table 5. Determination of soft storey due to lateral force caused by the earthquake in x direction for building where wall load is applied at ground level

Storey	Design Base Shear (KN)	Lateral Force (KN)	Diaphragm Displacement (mm)	Stiffness (KN/mm)	% difference in K (30 % required) % difference compared to	
					Above Storey	Below Storey
MUMTY	96.93	96.93	22.70	4.27		86.27
TERRACE	722.05	625.12	20.10	31.10	628.34	7.51
SIXTH	1317.24	595.19	17.70	33.63	8.12	(13.08)
FIFTH	1763.28	446.04	15.00	29.74	(11.57)	(13.96)
FOURTH	2081.63	318.35	12.20	26.09	(12.25)	(13.16)
THIRD	2293.77	212.14	9.20	23.06	(11.63)	(14.01)
SECOND	2421.19	127.42	6.30	20.23	(12.29)	(17.90)
FIRST	2484.66	63.47	3.70	17.15	(15.19)	(4.22)
GROUND	2512.64	27.98	1.70	16.46	**(4.05)**	

Table 6. Determination of soft storey due to lateral force caused by the earthquake in y direction for building where wall load is applied at ground level

Storey	Design Base Shear (KN)	Lateral Force (KN)	Diaphragm Displacement (mm)	Stiffness (KN/mm)	% difference in K (30 % required) % difference compared to	
					Above Storey	Below Storey
MUMTY	149.67	149.67	22.70	6.59		86.27
TERRACE	1114.93	965.26	20.10	48.02	628.35	7.51
SIXTH	2033.98	919.05	17.70	51.92	8.12	(13.09)
FIFTH	2722.71	688.73	15.00	45.92	(11.57)	(13.95)
FOURTH	3214.28	491.57	12.20	40.29	(12.25)	(13.16)
THIRD	3541.85	327.57	9.20	35.61	(11.63)	(14.01)
SECOND	3738.6	196.75	6.30	31.23	(12.29)	(17.90)
FIRST	3836.61	98.01	3.70	26.49	(15.18)	(4.22)
GROUND	3879.82	43.21	1.70	25.42	**(4.05)**	

As from Table 2 & 3 it can be interpreted that the % difference in *k* Value is 39.44 and 39.46 for X and Y directions at ground floor level which is more than 30%, hence soft storey formation is taking place in first case. And in Table 4 & 5 the % difference in *k* Value is 4.05 for both the directions hence soft storey formation is not taking place in second case.

The design base shear due to lateral force caused by the earthquake in X and Y direction for building where wall load is not applied at ground level is 2391.92 KN and 3693.4 KN respectively, whereas it is 2512.64 KN and 3879.82 KN in case of building where wall load is applied at ground level respectively. It is seen that the design base shear for building where wall load is not applied at ground level is approximately 4.80% less than for building where wall load is applied at ground level in both X and Y direction.

7. LOAD COMBINATIONS

The load combinations are defined as per the IS 1893:2002 and modified for beams and columns as 1.5 times storey shear and for shear wall as 1.5 times the storey shear. So 1.2(DL+LL+EQ) becomes 1.2(DL+LL+2.5EQ) for columns and beams and 1.2(DL+LL+1.5EQ) for shear wall respectively. This modified load combination is only applied for the soft storey where there is no wall load present and rest all floors are analyzed for standard load combinations in ETABS 9.7.4. The list of all load combinations is given in the table 6 below.

Table 7. Load combinations used for analysis in ETABS for building with and without soft storey

LOAD COMBINATIONS		
For building without soft storey and for storey except soft storey	**For beams and columns in soft storey**	**For shear walls in soft storey**
1.5(DL + LL)	1.5(DL + LL)	1.5(DL + LL)
1.2(DL + LL + EQX)	1.2(DL + LL) + 3 EQX	1.2(DL + LL) + 1.8EQX
1.2(DL + LL + EQX)	1.2(DL + LL) + 3 EQY	1.2(DL + LL) + 1.8EQY
1.5(DL + EQX)	1.5 DL + 3.75 EQX	1.5 DL + 2.25 EQX
1.5(DL + EQY)	1.5 DL + 3.75 EQY	1.5 DL + 2.25 EQY
0.9 DL + 1.5 EQX	0.9 DL + 3.75 EQX	0.9 DL + 2.25 EQX
0.9 DL + 1.5 SPECY	0.9 DL + 3.75 EQY	0.9 DL + 2.25 EQY
1.2(DL + LL + SPECX)	1.2(DL + LL) + 3 SPECX	1.2(DL + LL) + 1.8SPECX
1.5(DL + SPECY)	1.5 DL + 3.75 SPECX	1.5 DL + 2.25 SPECX
1.2(DL + LL + SPECY)	0.9 DL + 3.75 SPECX	0.9 DL + 2.25 SPECX
1.5(DL + SPECX)	1.2(DL + LL) + 3 SPECY	1.2(DL + LL) + 1.8SPECY
0.9 DL + 1.5 SPECX	1.5 DL + 3.75 SPECY	1.5 DL + 2.25 SPECY
0.9 DL + 1.5 EQY	0.9 DL + 3.75 SPECY	0.9 DL + 2.25 SPECY
1.2(DL + LL - EQX)	1.5 DL - 3.75 EQX	1.2(DL + LL) - 1.8EQX
1.2(DL + LL - EQY)	1.5 DL - 3.75 EQY	1.2(DL + LL) - 1.8EQY
1.5(DL - EQX)	0.9 DL – 3.75 EQX	1.5 DL - 2.25 EQX
1.5(DL - EQY)	0.9 DL – 3.75 EQY	0.9 DL – 2.25 EQX
0.9 DL – 1.5 EQX	1.2(DL + LL) - 3 EQX	0.9 DL – 2.25 EQY
0.9 DL – 1.5 EQY	1.2(DL + LL) - 3 EQY	1.5 DL - 2.25 EQY

8. MODEL ANALYSIS

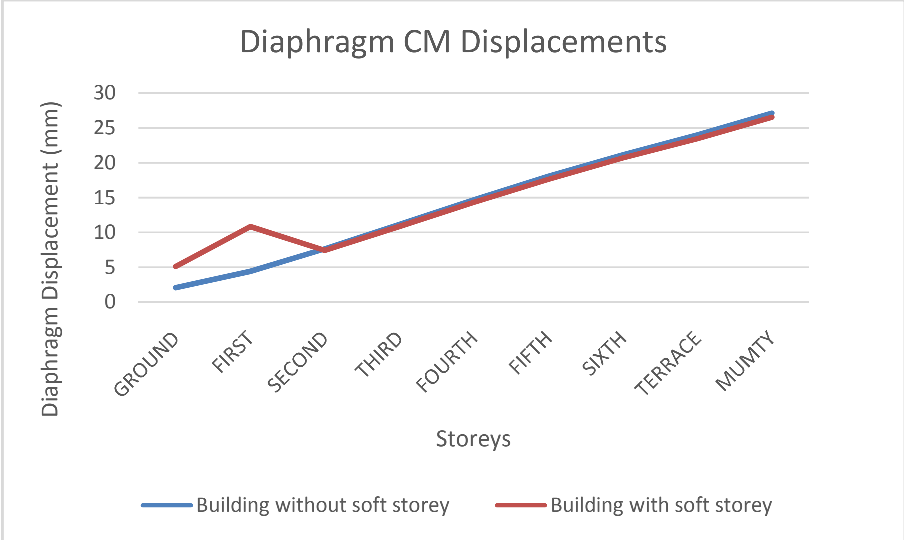

Figure 2 Diaphragm displacement at Stilt and first storey for building with and without soft storey

Diaphragm displacement is higher for building with soft storey at ground and first storey when compared to building without soft storey which can be seen from graph 1. The magnification factor 2.5 applied in building with soft storey is partially the reason behind this.

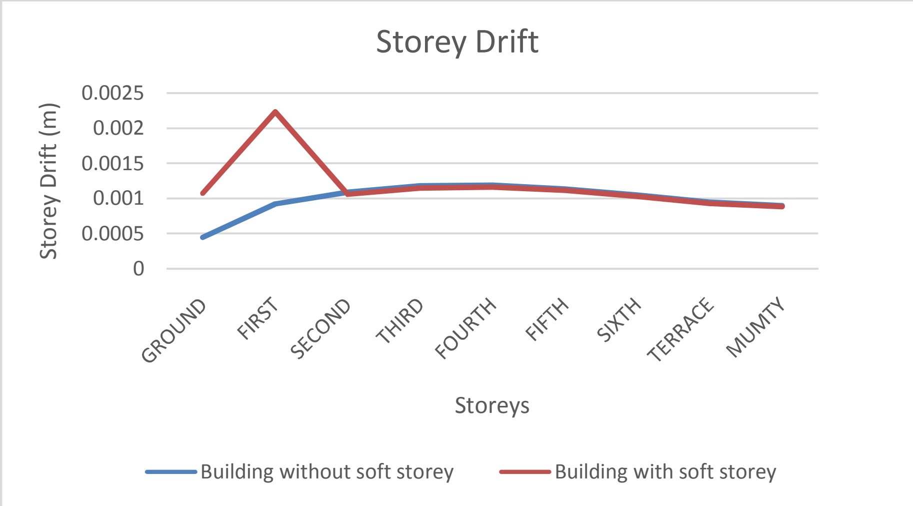

Figure 3 Storey Drift at different floors for building with and without soft storey

It is observed from Graph 2 that storey drift for building with soft storey is more than building without soft storey at both ground and first storey level. The magnification factor 2.5 applied in building with soft storey is partially the reason behind this.

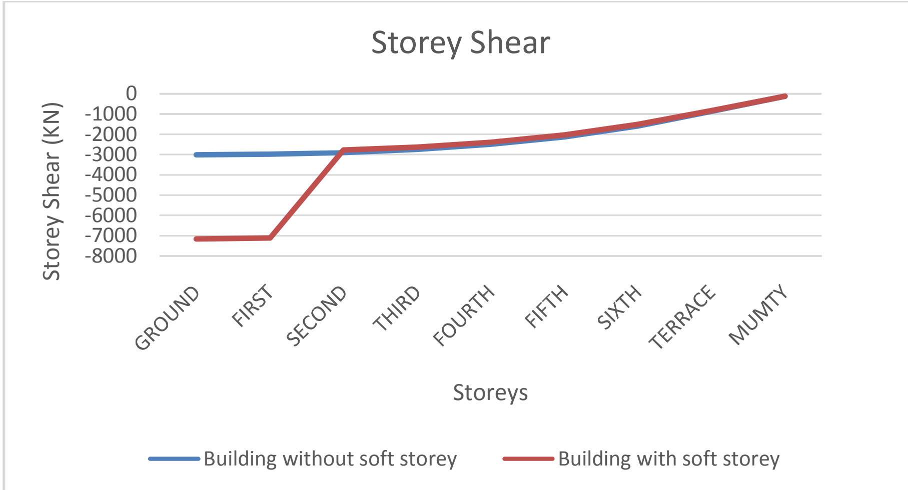

Figure 4 Storey Shear at different floors for building with and without soft storey

Storey shear in building with soft storey is higher than building without soft storey as soft storey is designed for 2.5 times magnification factor.

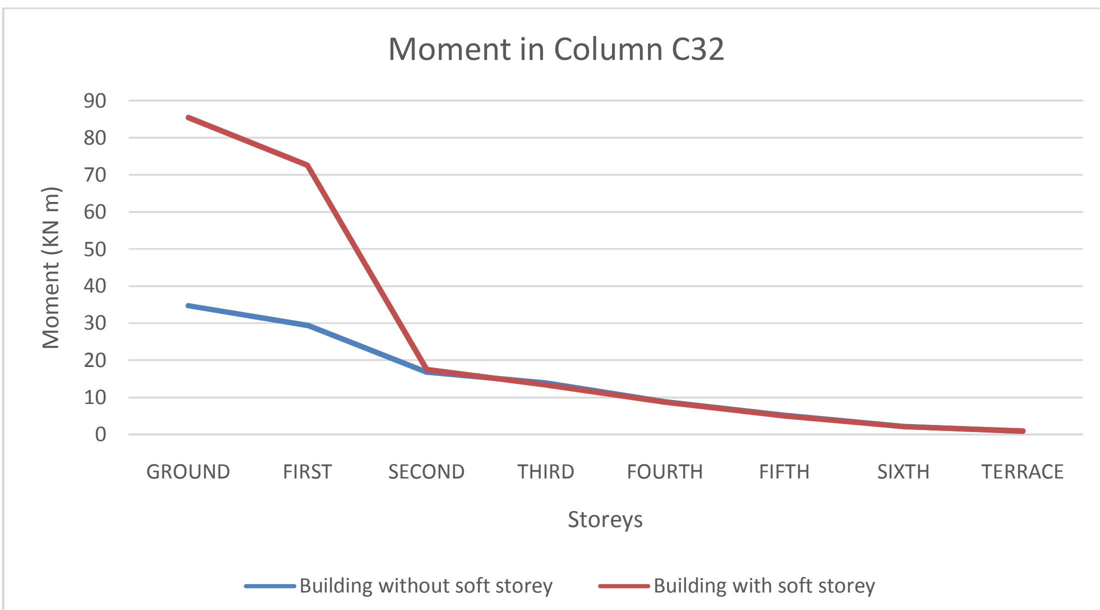

Figure 5 Comparison of moments in a column for building with and without soft storey

Bending moments and axial force for the column C32 in building with soft storey is higher than building without soft storey as soft storey is designed for 2.5 times magnification factor. Modification of load combinations caused by this factor induces more forces and moments in beams, columns and shear walls.

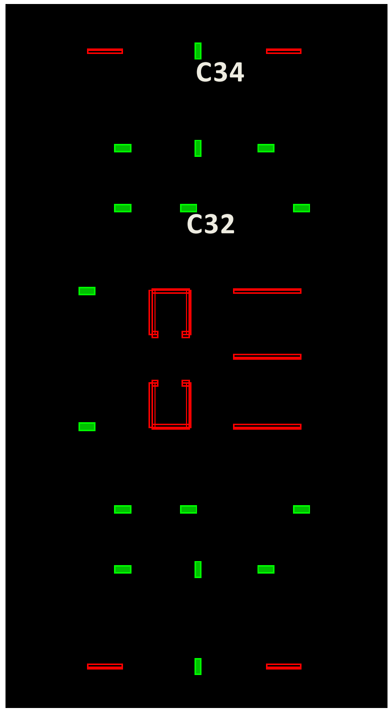

Figure 6 Column Layout showing Exterior(C34) and interior (C32) of building

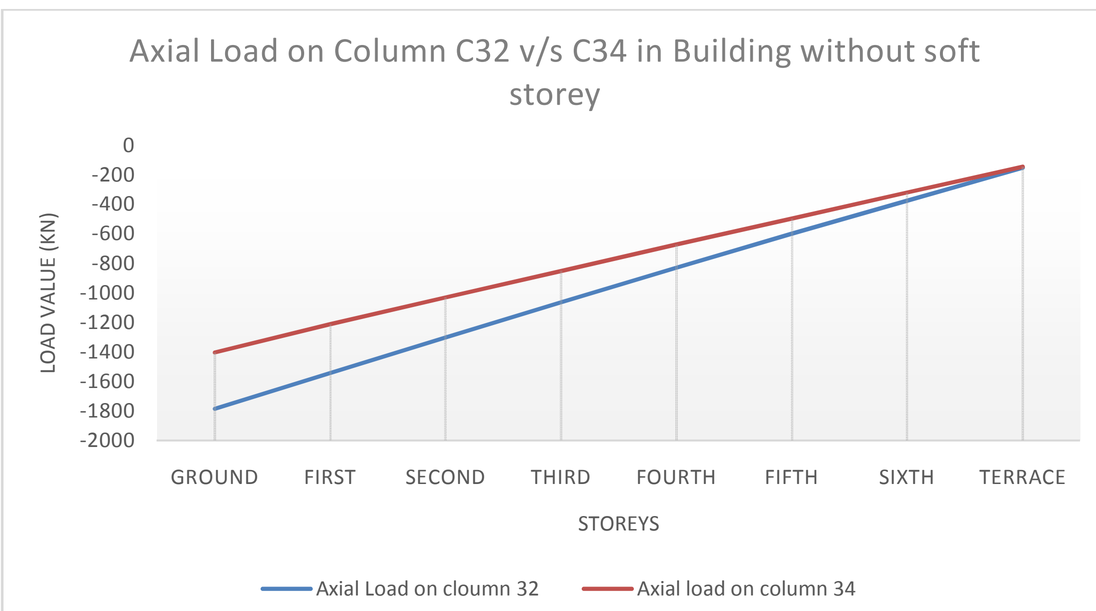

Figure 7 Comparison of Axial Load in column C32 and C34 for building without soft storey

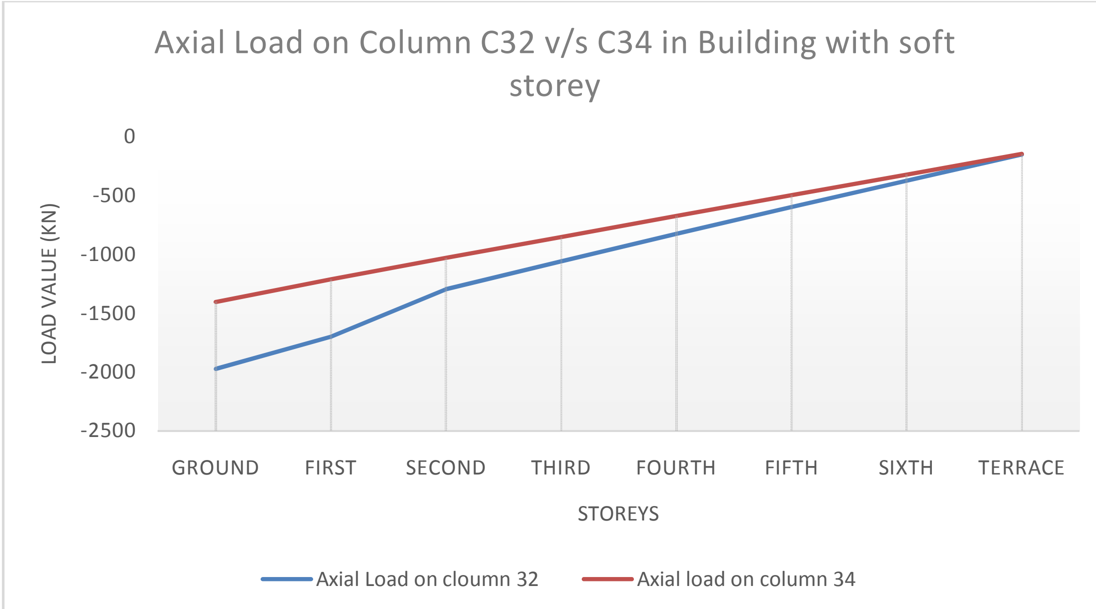

Figure 8 Comparison of Axial Load in column C32 and C34 for building with soft storey

The two columns are selected in both building without soft storey and building with soft stoorey and the axial force in both the columns are calculated and it is seen that the interior column is having more axial force as compared to the exterior column in both the cases. But the nature of curve is slightly different in both the cases.

9. ESTIMATED QUANTITY OF CONCRETE

The total quantity of concrete is estimated for a single building considering all beams, columns and the shear wall and tabulated below.

Table 8. Estimated quantity of concrete in both the buildings

Element	**Size (m)**	**Volume (cum)**
Beams	115 mm x 450 mm	7.2
	230 mm x 450 mm	135.68
	300 mm x 450 mm	55.2
	350 mm x 450 mm	13.12
Sub Total		211.2
Columns		
	300 mm x 750 mm	83.775
	350 mm x 750 mm	13.225
Sub Total		97
Shear Walls		
	230 mm (thick)	201.84
Sub Total		201.84
Total estimated quantity per building		**510.04**

The quantity of concrete estimated is 510.04 m^3 for both the cases i.e building with soft storey and building without soft storey.

10.ESTIMATED QUANTITY OF STEEL

The model is analyzed in ETABS and then for various sections the area of steel is obtained. The dimensions of the section are then multiplied by the corresponding area to get the quantity of steel in cum. Using standard weight of reinforcement as 7850 kg/cum the weight of reinforcement in kg is obtained. For Shear wall, two values of the percentage of steel for each cross-section is obtained when analyzed using the assigned load combination and the maximum value is taken for the reinforcement calculations. By multiplying with the length and the density of reinforcement the weight of reinforcement is obtained. For the shear reinforcement 8 mm dia bar is considered and the average spacing is considered as 200 mm in case of columns throughout and 150 mm near the supports. For beams the spacing is reduced near the support till two times the effective depth of beam and taken as 125 mm and for rest of the beams it is taken as 175 mm Taking various cross-sections, the per unit length weight of shear reinforcement is obtained.

Table 9. Weight of steel used in building with soft storey

Members	**Weight (kg)**
Beam (Longitudinal reinforcement)	
Ground & First Storey	9494.302
Second to Terrace stirey (6 levels)	23351.56
	32845.86
Beam (shear reinforcement)	
	2.94 kg/m
Subtotal (Shear reinforcement)	5629.51
Total reinforcement in beam	38475.37
Column (Longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	14140.40
Column (Shear reinforcement)	
Average weight of shear reinforcement per meter length of column	13.5 kg/m
Subtotal (Shear reinforcement)	5745.6
Total reinforcement in column	19886.00
Shear Wall (Longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	18190.61
Shear Wall (Shear reinforcement)	
Average weight of shear reinforcement per meter length of shear wall	
Shear reinforcement per meter length for Shear wall 1	18.90 kg/m
Shear reinforcement per meter length for Shear wall 2	33.64 kg/m
Shear reinforcement per meter length for Shear wall 3	55.2 kg/m

Subtotal (Shear reinforcement)	8371.8
Total reinforcement in shear walls	26562.41
Total weight of reinforcement used in building with soft storey	**84923.78**

Table 10. Weight of steel used in building without soft storey

Members	**Weight (kg)**
Beam (Longitudinal reinforcement)	
Ground & First Storey	7430.83
Second to Terrace stirey (6 levels)	19270.19
	26701.02
Beam (shear reinforcement)	
	2.94 kg/m
Subtotal (Shear reinforcement)	5629.51
Total reinforcement in beam	32330.53
Column (Longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	10064.84
Column (Shear reinforcement)	
Average weight of shear reinforcement per meter length of column	13.5 kg/m
Subtotal (Shear reinforcement)	5745.6
Total reinforcement in column	15810.44
Shear Wall (Longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	13221.68
Shear Wall (Shear reinforcement)	
Average weight of shear reinforcement per meter length of shear wall	
Shear reinforcement per meter length for Shear wall 1	18.90 kg/m
Shear reinforcement per meter length for Shear wall 2	33.64 kg/m
Shear reinforcement per meter length for Shear wall 3	55.2 kg/m
Subtotal (Shear reinforcement)	8371.8
Total reinforcement in shear walls	21593.48
Total weight of reinforcement used in building without soft storey	**69734.45**

Total built up area = 2920.92 m^2

Total requirement of reinforcement for structural frame (beams & Columns) in building with soft storey = 84923.78/2920.92 = 29.07 kg/m^2

Total requirement of reinforcement for structural frame (beams & Columns) in building without soft storey = 69734.45/2920.92 = 23.87 kg/m^2

11.COSTING

The cost of reinforcement (Fe-500D) (code No 1005) taken from Delhi schedule of Rates is INR 3730/Quintal i.e INR 37.30/kg (Analysis Of Rates for Delhi, Part – I, Volume – 1, 2016). For the building without soft storey the total cost of reinforcement consumed (Fe-500D) = 69734.45 x 37.30/kg = INR 2601094.99 and for the building with soft storey the cost of reinforcement consumed (Fe-500D) = 84923.78 x 37.30/kg = INR 3167656.99. The cost difference is 21.78 %.

12. RESULT

The quantity of steel per sqm of built-up area is increased from 23.87 kg/sqm to 29.07 kg/sqm. Likewise, the total steel in case of building without soft storey was 69734.45 kg and in case of building with soft storey it was 84923.78 kg. and the per sqm of built-up area cost in case of building without soft storey is 23.87 INR/sqm while the per sqm of built-up area cost in case of building with soft storey is 29.07 INR/sqm.

13.CONCLUSION

The soft storey configuration is almost unavoidable as it gives vast functional and aesthetic opportunity to a designer. But when designed with taking suitable parameters for both the buildings the comparison shows that the structural cost difference as well as difference in the quantity of steel for building with soft storey and building without soft storey is 21.78%. This approximate increase of 21.78% is significant in this case and may be a deciding factor for large scale projects. In the performance analysis it is seen that when different geometrical as well as seismic parameters are considered the Diaphragm displacement, storey drift, storey shear, bending moment & shear force are always greater when the storey is soft storey in the building. To avoid the structural damage of the building during earthquake because if the sift storey there should not be communication gap between various consultants e.g architectural, structural as well as between various government authorities including local bodies those are associated with the final approval of a building.

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