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RESPONSE SPECTRUM ANALYSIS OF SOFT STOREY IN RC BUILDING

Mudassir.M.Inamdar *
Salman Shaikh**

Abstract- Soft storey or Open ground storey is a unavoidable feature in the multistorey building. It is open for the purpose of parking or reception lobbies. It is also called as stilts storey. A large number of buildings with soft storey have been built in India in recent year. But it gives poor performance during past earthquake. Therefore it is need to immediate measures to prevent the indiscriminate use of soft first storeys in buildings, which are designed without regard to the increased displacement and force demands in the first storey columns. So this project argue about provided strength and stiffness to the building frame by modified soft storey provision in two way, (i) By provide stiff column & (ii) By provide adjacent infill wall panel at each corner of building frame. And also studied, the comparisons of modified soft storey provisions with complete infill wall frame and bare frame models.

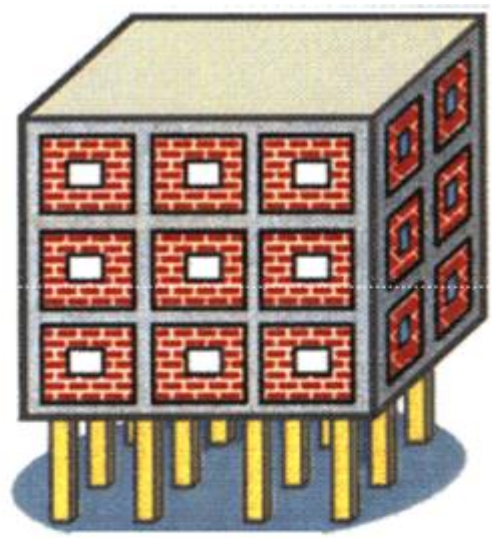
Introduction

The relatively flexible in the ground storey or the relative horizontal displacement it undergoes in the ground storey is much larger than the above storey's, this flexible ground storey is called soft storey (Fig.1). Reinforced concrete (RC) frame buildings are becoming increasingly common in urban India. Many such buildings constructed in recent times have a special feature - the ground storey is left open for the purpose of parking , i.e columns in the ground storey do not have any partition walls (of either masonry or RC) between them. Such buildings are often called open ground storey buildings or buildings on stilts.

Performance of soft storey building:

A large number of buildings with open ground storey have been built in India in recent years. Open ground storey buildings have consistently shown poor performance during past earthquakes. Huge number of similarly designed and constructed buildings exist in the various towns and cities situated in moderate to severe seismic zones of the country. The presence of walls in upper storeys makes them much stiffer than the open ground storey. Thus, the upper storeys move almost together as a single block, and most of the horizontal displacement of the building occurs in the soft ground storey itself. It gives result to collapse of the building.

* Student in ME (Structural Engg)
** Asst Prof in Civil Dept of Sanmati Engg College Washim



Methods of seismic analysis

Once the structural model is selected, it is necessary to perform analysis to determine the seismically induced forces in the structure. Lot of research is carried out in this area to propose simplified methods that will predict results with reasonable accuracy. So there are different methods of analysis are invented which provide different degrees of accuracy. The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behaviour of structure or the structural materials and the type of structural model selected.

Based on the type of external action and behaviour of structure, the analysis can be further classified as linear static analysis, linear dynamic analysis, nonlinear static analysis, or non-linear dynamic analysis as shown in following diagram. Linear static analysis or equivalent static analysis used only for regular structure with limited height. Linear dynamic analysis considers the effect of the higher mode of vibration and the actual distribution of forces in the elastic range in a better way. This analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method.

Types of cases used for analysis of structure

There are three basic cases with sub-cases considered to analyze 10-storey structure so that proper provision of soft storey can be predicted.

(I) General building models:

(**I.1**)Building model has one full infill masonry wall (230mm) (External &internal wall) in all storey included ground storey. i.e. complete infill wall frame model.
(**I.2**) Building modeled bare frame. However, masses of the walls as in model **I.1** are included in the model.

(II)Building models present with soft storey:

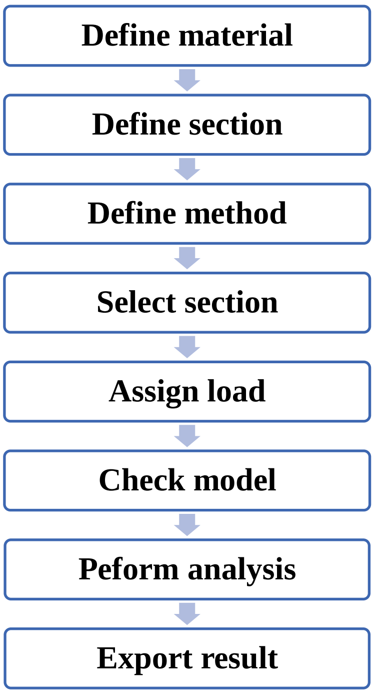
(**II.1**)Building model has no masonry wall in first ground storey and one full infill masonry wall (230mm) (External &internal wall) in upper storey
(**II.2**)Building model has no masonry wall in first three storey (G+2) and one full infill masonry wall (230mm) (External &internal wall) in upper storey
(**II.3**)Building model has no masonry wall in first six storey (G+5) and one full infill masonry wall (230mm) (External &internal wall) in upper storey

(III) Building models present with modified soft storey provision:

(**III.1**)Building model has one full infill masonry wall at the adjacent side of each corner in first ground storey and one full infill masonry wall (230mm) (External &internal wall) in upper storey,
(**III.2**)Building model has no masonry wall in first ground storey and one full infill masonry wall (230mm) (External &internal wall) in upper storey, and provided first ground storey columns are much stiffer as compared to upper storey columns.

Analytical work

Flow of total analytical work by ETAB2016 has many steps which are indicated in detail as follows



Flow diagram for ETABS2016 step

Structural Data

Building consists of 10 m in short direction and 16.8 m in long direction, so from preliminary design the sizes of various structural members were estimated as follows
Brick masonry wall Thickness:
Brick masonry wall (modulus of elasticity E as per IS code& poissons ratio of masonry μ= 0.15) is provided with 230 mm thickness for all storey of different cases. And 1.5m height parapet wall is also considered.
Storey height is kept as 3m for soft storey or open ground floor and 3m for all upper floors. Grade Fe-500 hot rolled deformed steel is used. Concrete having M-25 ($E=5000\sqrt{f_{ck}}$ as per IS456) strength for columns, beams and slabs is to be employed.
Column Size:
Columns were kept of 9”x24” (230x600mm) size for overall structure and 14”x24” (350x600mm) size only for stiff column provision to avoid the local eccentricity.
Beam Size:
All beams are of uniform size of 9″ × 24″ (230 × 600mm) having 5″ (125 mm) thick slab for all the spans.

Gravity loading

Gravity loading consists of dead and live loading. Dead loading can be predicted reasonably accurately from the designed member sizes and material densities. Dead load due to structural self weights and superimposed dead loads are as follows:

Dead Load (DL):

Intensity of wall (External & Internal wall) =12.34 KN /m (for 3m height)

Intensity of parapet wall =7.71 KN /m (for 1.5m height)

Intensity of floor finish load =1 KN /m

Intensity of roof treatment load =1.5 KN /m

Live load (LL):

Intensity of live load =2 KN /m

Lateral loading

Lateral loading consists of earthquake loading. Earthquake loading has been calculated by the program and it has been applied to the mass center of the building.

Since the building under consideration was in Zone - V with standard occupancy so the total base shear was computed as follows: (All the calculation made for Column No **C8**)

Case: SPECX and SPECY

Period Calculation: Program Calculated

Top Storey: Storey- 10

Bottom Storey: Soft storey or Open ground storey or Base

Response reduction factor, R = 5

Importance factor, I = 1

Building Height H = 30 m

Soil Type = II (Medium Soil)

Seismic zone factor, Z = 0.36

BM &SF for Load combination of 1.2(DL+LL+SPECX/SPECY)

Figure showing considered building models

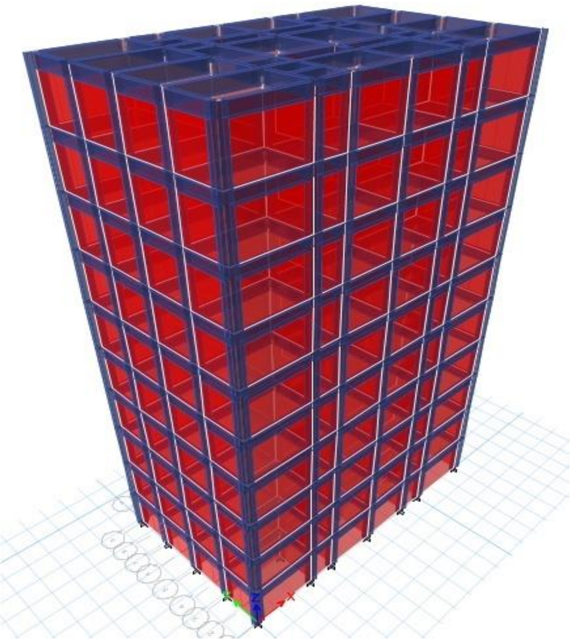


Fig.1 Complete infill masonry

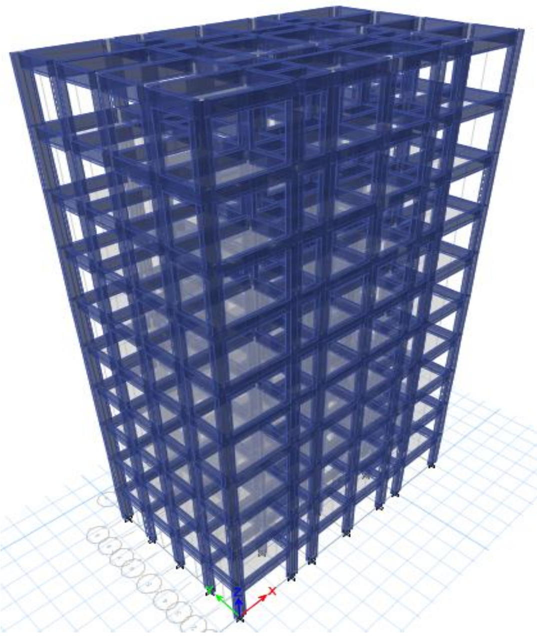


Fig 2.Bare frame

Figure showing Building models present with soft storey

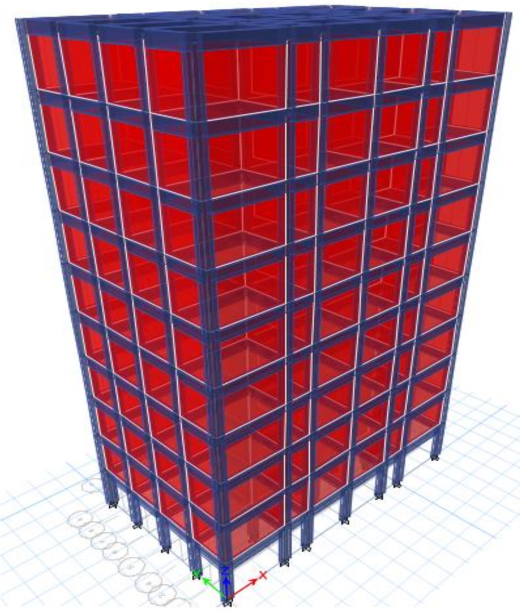


Fig .3 First ground storey as a Soft storey

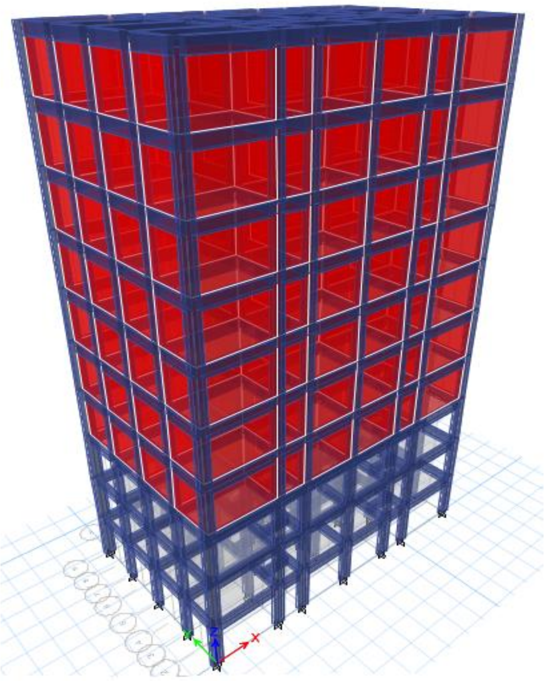


Fig .4 First three storey

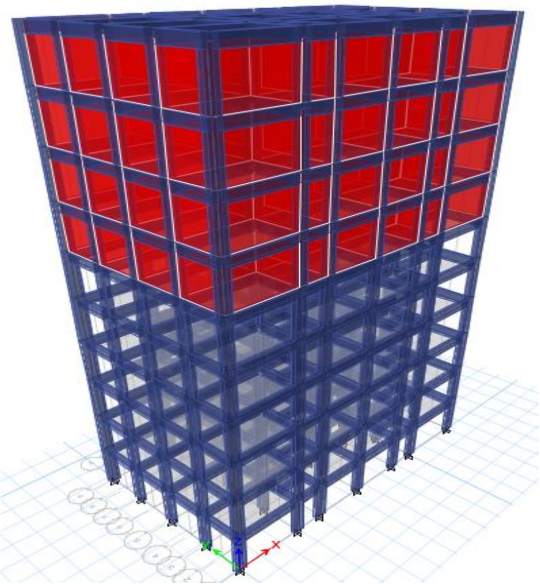


Fig.5 First six storey as a Soft storey.

Results

1. Maximum Lateral Displacement:

Table2: (I) General building models			
Maximum displacement of MODEL (2)			
Storey No.	**Storey Height (m)**	**SPECX Max (mm)**	**SPECY Max (mm)**
10	30	35.417	33.076
9	27	34.314	31.751
8	24	32.456	29.766
7	21	29.866	27.176
6	18	26.632	24.075
5	15	22.837	20.544
4	12	18.558	16.649
3	9	13.873	12.451
2	6	8.885	8.025
1	3	3.807	3.524
Base	0	0	0

Table1: (I) General building models			
Maximum displacement of MODEL (1)			
Storey No.	**Storey Height (m)**	**SPECX Max (mm)**	**SPECY Max (mm)**
10	30	2.614	4.798
9	27	2.377	4.279
8	24	2.114	3.732
7	21	1.832	3.165
6	18	1.536	2.593
5	15	1.235	2.03
4	12	0.938	1.493
3	9	0.654	1.002
2	6	0.395	0.575
1	3	0.17	0.233
Base	0	0	0

Table 2.1: (I) General building models			
Comparison of maximum displacement of Models 1 & 2 in X-direction			
Storey No.	**Storey Height (m)**	**Disp. For Model (I.1) (mm)**	**Disp. For Model (I.2) (mm)**
10	30	2.614	35.417
9	27	2.377	34.314
8	24	2.114	32.456
7	21	1.832	29.866
6	18	1.536	26.632
5	15	1.235	22.837
4	12	0.938	18.558
3	9	0.654	13.873
2	6	0.395	8.885
1	3	0.17	3.807
Base	0	0	0

Table 2.2: (I) General building models			
Comparison of maximum displacement of Models 1 & 2 in Y-direction			
Storey No.	**Storey Height (m)**	**Disp. For Model (I.1) (mm)**	**Disp. For Model (I.2) (mm)**
10	30	4.798	33.076
9	27	4.279	31.751
8	24	3.732	29.766
7	21	3.165	27.176
6	18	2.593	24.075
5	15	2.03	20.544
4	12	1.493	16.649
3	9	1.002	12.451
2	6	0.575	8.025
1	3	0.233	3.524
Base	0	0	0

Table 4: (II)Building models present with soft storey			
Maximum displacement of MODEL (II.1)			
Storey No	Storey Height (m)	SPECX Max (mm)	SPECY Max (mm)
10	30	6.956	10.406
9	27	6.639	9.735
8	24	6.3	9.037
7	21	5.94	8.321
6	18	5.564	7.596
5	15	5.178	6.875
4	12	4.791	6.172
3	9	4.409	5.506
2	6	4.044	4.895
1	3	3.691	4.337
Base	0	0	0

Table 3: (II)Building models present with soft storey			
Maximum displacement of MODEL (II.2)			
Storey No	Storey Height (m)	SPECX Max (mm)	SPECY Max (mm)
10	30	14.15	14.948
9	27	13.834	14.386
8	24	13.501	13.809
7	21	13.153	13.221
6	18	12.794	12.625
5	15	12.426	12.031
4	12	12.055	11.445
3	9	11.673	10.864
2	6	8.039	7.362
1	3	3.458	3.217
Base	0	0	0

Table 5: (II)Building models present with soft storey			
Maximum displacement of MODEL (II.3)			
Storey No	Storey Height (m)	SPECX Max (mm)	SPECY Max (mm)
10	30	21.177	20.796
9	27	20.819	20.172
8	24	20.445	19.532
7	21	20.056	18.88
6	18	19.643	18.211
5	15	17.065	15.599
4	12	13.663	12.408
3	9	10.056	9.106
2	6	6.354	5.771
1	3	2.697	2.502
Base	0	0	0

Table5.1: (II)Building models present with soft storey				
Comparison of maximum displacement of Models 3, 4 & 5 in X-direction				
Storey No	Storey Height (m)	Disp. For Model (II.1) (mm)	Disp. For Model (II.2) (mm)	Disp. For Model (II.3) (mm)
10	30	6.956	14.15	21.177
9	27	6.639	13.834	20.819
8	24	6.3	13.501	20.445
7	21	5.94	13.153	20.056
6	18	5.564	12.794	19.643
5	15	5.178	12.426	17.065
4	12	4.791	12.055	13.663
3	9	4.409	11.673	10.056
2	6	4.044	8.039	6.354
1	3	3.691	3.458	2.697
Base	0	0	0	0

Table 5.2: (II)Building models present with soft storey				
Comparison of maximum displacement of Models 3, 4 & 5 in Y-direction				
Storey No	**Storey Height (m)**	**Disp. For Model (II.1) (mm)**	**Disp. For Model (II.2) (mm)**	**Disp. For Model (II.3) (mm)**
10	30	10.406	14.948	20.796
9	27	9.735	14.386	20.172
8	24	9.037	13.809	19.532
7	21	8.321	13.221	18.88
6	18	7.596	12.625	18.211
5	15	6.875	12.031	15.599
4	12	6.172	11.445	12.408
3	9	5.506	10.864	9.106
2	6	4.895	7.362	5.771
1	3	4.337	3.217	2.502
Base	0	0	0	0

Maximum Bending Moment (BM) and Shear Force (SF):

Table6.1: Maximum BM and SF in X-direction.

	Max Moment(KNm)		**Max Shear(KN)**	
Models	First Column	Second Column	First Column	Second Column
1	0.627	0.6175	0.7759	0.3378
2	24.8366	31.4189	22.0322	23.7509
3	24.9076	0.6449	28.24	0.1782
4	5.6358	0.3485	6.9499	0.2545
5	46.909	0.6059	54.2046	0.1137

Table6.2: Maximum BM and SF in Y-direction.

	Max Moment(KNm)		**Max Shear(KN)**	
Models	First Column	Second Column	First Column	Second Column
1	4.3442	4.7071	7.3224	6.5479
2	81.1853	101.6525	122.3793	115.1795
3	164.5855	3.7614	194.8538	1.5039
4	47.0129	3.8658	58.6718	3.2323
5	131.986	4.2587	161.12	0.3911

Conclusion

In this study, the seismic vulnerability of building with soft first storey is shown through an example building. The main object of this investigation is to study the effect of horizontal loading on reinforced concrete frame with brick masonry infill wall (panel) for different conditions including soft storey models. In this section only the conclusion obtain from the analysis result and their discussions are presented. In performed analysis the frame is assumed to be restrained at ground floor level. Deflections are one of the most important parameter to be considered in the design and analysis of tall building. Therefore deflection and other important parameters for lateral loads have been studied. Three different cases (I) General building models, (II) Building models present with soft storey & (III) Building models present with modified soft storey provision have been analyzed as a space frame system using a standard package ETABS subjected to lateral and gravity loading. This study leads to following conclusion.

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