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Study of Different Infill Material on the Seismic Behaviour of Multi-Storey Building With Soft Storey

Dattatraya L. Bhusnar[1], Dr. C. P. Pise[2], D. D. Mohite[3], Y. P. Pawar[3], S. S. Kadam[3], C. M. Deshmukh[3].

P.G. Student, Department of Civil Engineering, SKNSCOE, Pandharpur, Maharashtra, India[1]

Professor and HOD, Department of Civil Engineering, SKNSCOE, Pandharpur, Maharashtra, India[2]

Assistant Professor, Department of Civil Engineering, SKNSCOE, Pandharpur, Maharashtra, India[3]

ABSRTACT: Present situation growth of Multistory building is very high because of rapid urbanization all over the world. Open first storey is generally provided for parking, reception lobbies, communication halls or any purpose in multi-storey building. But in case of earthquake multi-storey building with soft storey gives poor performance. There are various factors affects on the behaviour of multi-storey building i.e. irregularity in plan and elevations, uneven distribution of mass etc. Infill wall in frame building provides stiffness and improves the behaviour of building under lateral loads. In the present work, study of different infill materials on the seismic behaviour of multi-storey building with soft stories is carried out. For that, G+12 (Reinforced cement concrete) RCC model is selected. Different infill materials like siporex and clay brick are used. Different location of soft stories are considered for the analysis. To study of different infill material on the seismic behaviour of multistory building, linear dynamic analysis (Response spectrum analysis) in ETABs software is carried out. Different seismic parameters like time period, storey shear, storey displacement and storey drift are checked out.

KEYWORDS: Multi-storey building, infill materials, Response spectrum analysis, seismic behaviour, RCC frame.

1. INTRODUCTION

Presently urbanization rising fastly in all countries and increases demand of space therefore there is need in construction of multi-storeyed building to optimize accommodation in vertical direction and for minimize the space in horizontal direction. And therefore number of multistorey buildings constructed in recent times with a special feature such as ground storey is left open for the purpose of parking , i.e columns in the ground storey do not have any partition walls of masonry or RCC. These type of buildings are often called open ground storey buildings or buildings on stilts. The relatively flexible in the ground storey or the relative horizontal displacement it undergoes in the ground storey is much larger than the above storeys, this flexible ground storey is called soft storey[1,2]. Soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above[3]. Hence in multistory building with no infill walls in the first storey or any intermediate storey is known as soft storey[4]. In soft storey building one or more floors which are "soft" due to structural design, Soft story which has a lot of open space or large retail spaces or floors with a lot of windows[5]. A soft storey also known as weak storey. Soft storey building that provides less resistance or stiffness than the stories above or below[6]. A simple understanding of soft storey is sudden change of lateral storey stiffness within the structure[7].Hence in multistory building with no infill walls for particular storey is known as soft storey[8]. The infills provided in the above storey levels may absorb the seismic forces and becomes stiffer, as the ground storey without any infill is less stiffer than the above stories[9,10]. Therefore it is important that buildings are designed to existing design codes perform well in earthquakes with respect to safety of human life, loss of economy, usage and extent of damage to structures[11]. India is divided into four seismic zones according to seismic activities. As per Seismic Zoning Map of IS code IS: 1893-2002, they are Zone II, III, IV and V[12]. Soft storey in multistoried buildings areinherently vulnerable to collapse due to earthquake load. These multistorey buildings with soft storey are collapsed due to irregularities[13]. Generally masonry walls are provided in multistorey RCC buildings for functional and architectural requirements. It has been accepted that infill materials sinificantly affects on the seismic performance of the infilled framed structures [14,15].

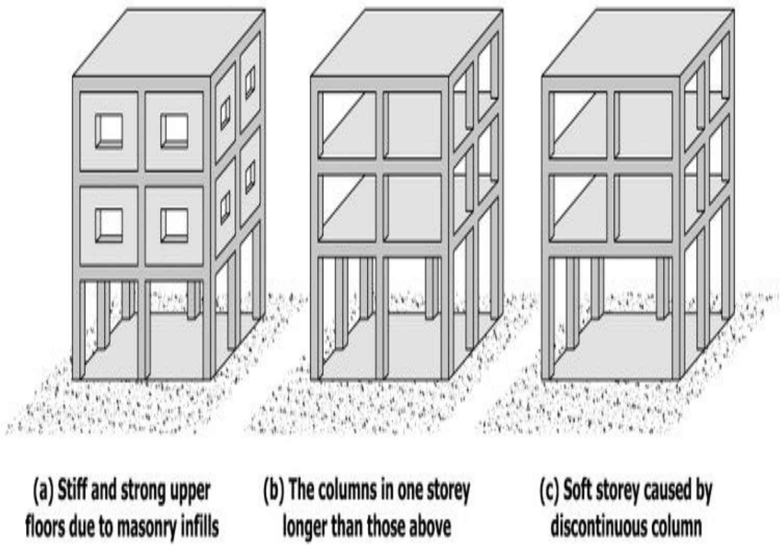


Fig.1.1 Multistory building with soft storey
[A. Charleson, Seismic Design for Architects, Architectural Press 2008, p.146, Fig. 9.3]

Fig 1.2 Actual view of multistorey building with soft story

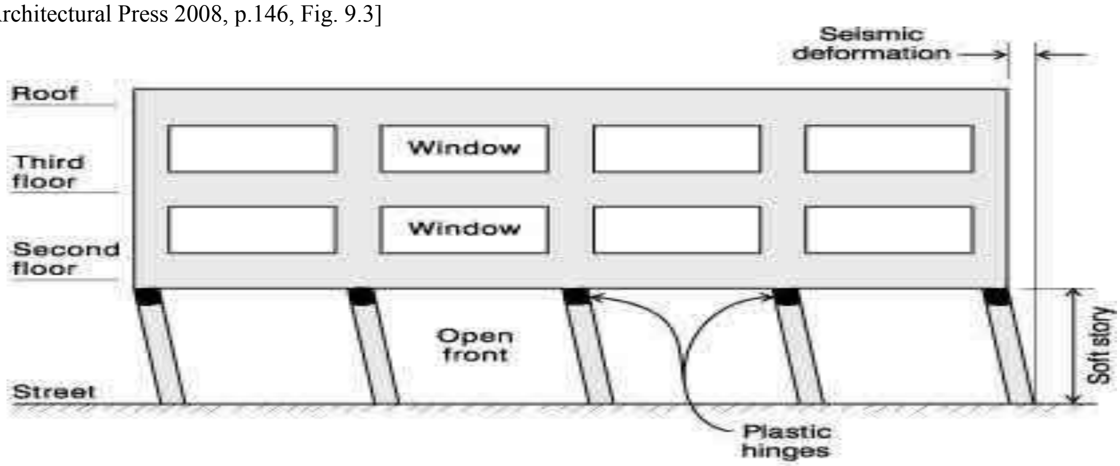


Fig 1.3 Detailing of soft story multistorey building
[A. Charleson, Seismic Design for Architects, Architectural Press 2008, p.146, Fig. 9.3]

1.1 Structural action of infill frames:

Generally infill frames consisting of RCC frame with different infill materials used. It is generally considered as non structural part. But infill walls provide stiffness to the structures. And infill wall improves the seismic behaviour of structures. The opening provided in the masonry infill wall reduces the lateral strength of the structures. Because of infill materials building improves resistance of lateral load. Therefore infill wall plays vital role in structural action.

2. ANALYTICAL WORK

Response spectrum method is used for seismic analysis of a 13 storied RCC multistory building with soft storey. The different infill materials with different locations of soft storey are used to study the effect of position of soft storey on behaviour of building. Infill wall provides stiffness and lateral strength to building. The behaviour of multistory building is studied for different parameters like time period, story shear, lateral displacement, story drift, etc[16].

2.1 Infill materials considered for seismic analysis of multistory building:

1. Clay Bricks
2. Siporex Blocks

2.2 Different Models considered for analysis:

Model No. 1: Multistory building with Soft storey at ground floor.

Model No. 2: Multistory building with Soft storey at seventh floor.

Following figures shows the Models done in ETABs software

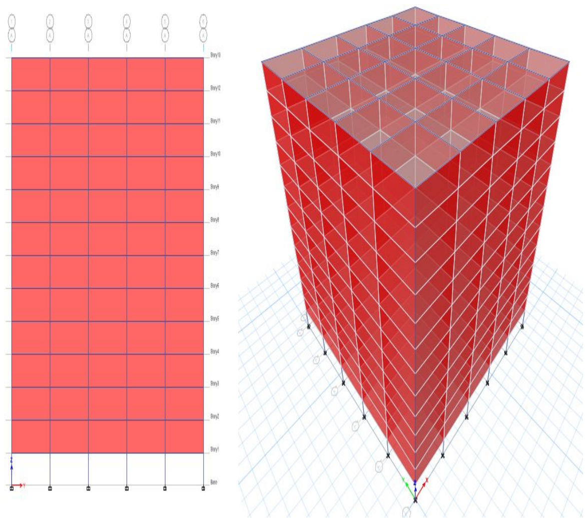


Fig. 2.1 Model No. 1: Multistorey building with Soft floor at ground floor

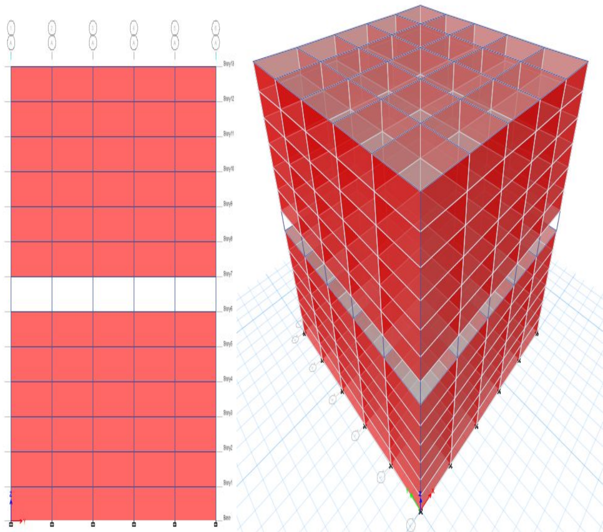


Fig. 2.2 Model No. 2: Multistorey building with Soft storey floor at seventh floor.

2.3 Structural data:

Structural data as shown in table 2.1 given below

Table 2.1 details of structural data

Sr. No.	Parameters	Description
1	Type of structure	Residential (G+12)
2	Floor to Floor to height	3 M
3	Size of Beam	300mmX500mm
4	Size of column	500mmX500mm
5	Slab thickness	130mm
6	Wall thickness	150 mm
7	Live Load	$2KN/m^2$
8	Floor Finish Load	$1KN/m^2$
9	Type of structure	RCC
10	Seismic zone	V
11	Importance factor (I)	1
12	Response reduction factor (R)	3
13	Damping of structure	5%
14	Zone factor (Z)	0.36
15	Infill materials	**1.**Clay Brick **2.** Siporex Block

2.4 The plan layout of the multistory RCC frame building with G+12 Storey is shown in fig. 2.3

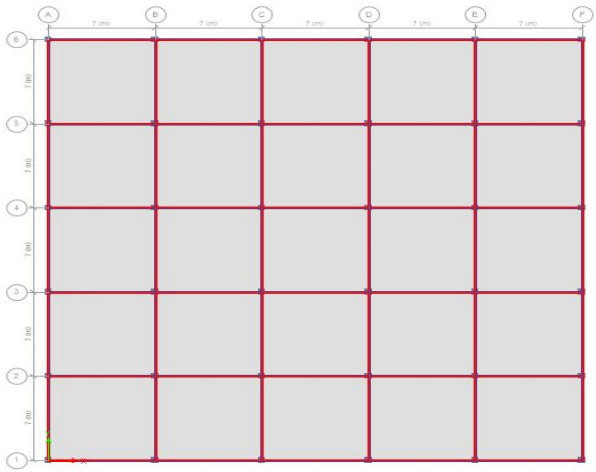


Fig. 2.3 Typical plan of considered model for study

3. RESULT ANALYSIS AND DISCUSSION

Results obtained from ETABs software for different condition given as follows:

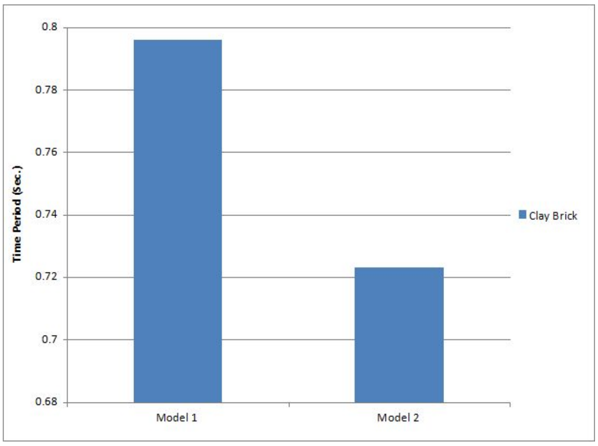
3.1 Clay Brick as an infill material

3.1.1 Time period Time

Time period in sec. is given below in table 3.1.

Table 3.1 Time period for Clay Brick (Sec.)

Infill material	Model 1	Model 2
Clay Brick	0.796	0.723



Graph 3.1 Time period

From graph 3.1 it is observed that the time period is obtained 9.171% less for Model 2 as compare to Model 1 in case of Clay Brick as an infill material in multistorey building with soft story. It indicates that soft storey at seventh floor is most suitable than soft storey at ground floor in multistorey building. Time period is depends on position of soft storey in building.

3.1.2 Storey shear:

Storey shear is the sum of design lateral forces at all levels above the storey under consideration. Base shear is an estimate of the maximum expected lateral forces that will occur due to seismic ground motion at the base of structure.
Base shear is calculated as shown in table 3.2.

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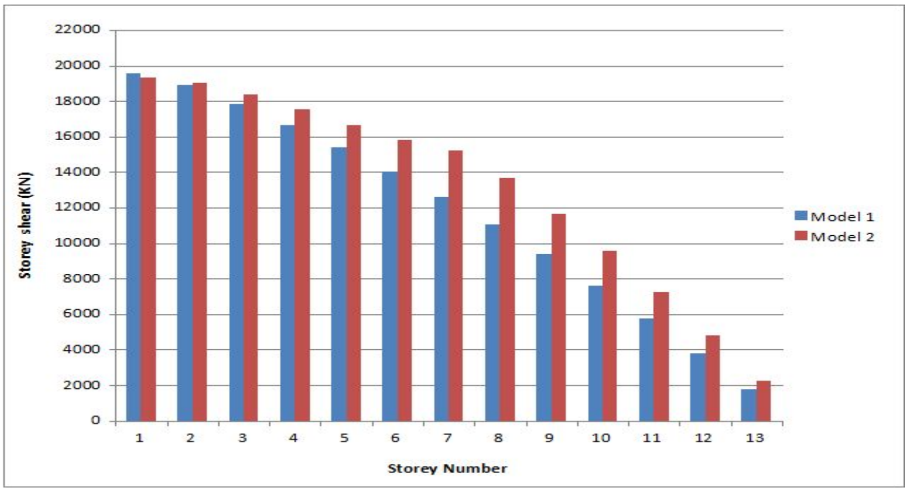
Table 3.2 Storey shear for Clay Brick (KN)

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	1744.281	2217.649
Story 12	36	3796.79	4807.99
Story 11	33	5759.214	7254.133
Story 10	30	7621.125	9540.774
Story 9	27	9378.643	11667.39
Story 8	24	11032.12	13655.32
Story 7	21	12583.79	15199.33
Story 6	18	14036.25	15816.52
Story 5	15	15391.86	16633.4
Story 4	12	16652.74	17533.18
Story 3	9	17817.92	18377.01
Story 2	6	18892.33	19024.36
Story 1	3	19537.53	19303.8



Graph 3.2 Variation of Storey shears along X & Y- Direction for Clay Brick

From graph 3.2 it is observed that for Model 1 Storey shears is found more in comparison to Model 2. And Base shear is 1.17% greater for Model 1 as compare to Model 2. As shown in results the position of soft storey not significantly effective. Base shear is also depends on position of soft storey in building. pounding and estimating maximum storey drift to avoid destruction of non-structural elements.

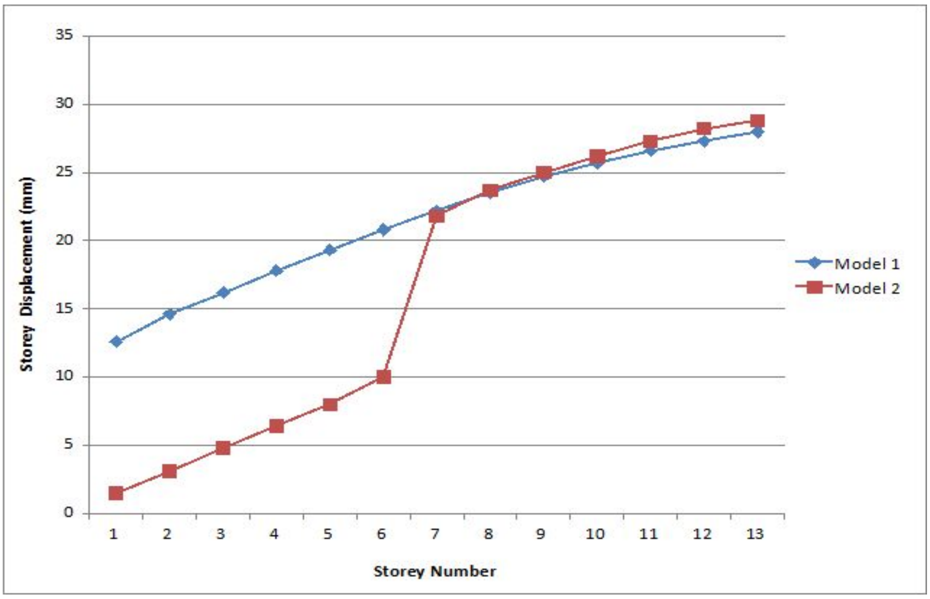
3.1.3 Storey displacement:

For seismic design it is important to estimate, maximum lateral displacement of the structures due to sever earthquake for several reasons. Such as estimating minimum separation joint width to avoid

Story displacement is calculated as shown in table 3.3 for multistorey building.

Table 3.3 Storey displacement for Clay Brick (mm)

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	28	28.8
Story 12	36	27.3	28.2
Story 11	33	26.6	27.3
Story 10	30	25.7	26.2
Story 9	27	24.7	25
Story 8	24	23.5	23.7
Story 7	21	22.2	21.8
Story 6	18	20.8	10
Story 5	15	19.3	8
Story 4	12	17.8	6.4
Story 3	9	16.2	4.8
Story 2	6	14.6	3.1
Story 1	3	12.6	1.5



Graph 3.3 Variation of Storey displacements along X & Y- Direction for Clay Brick

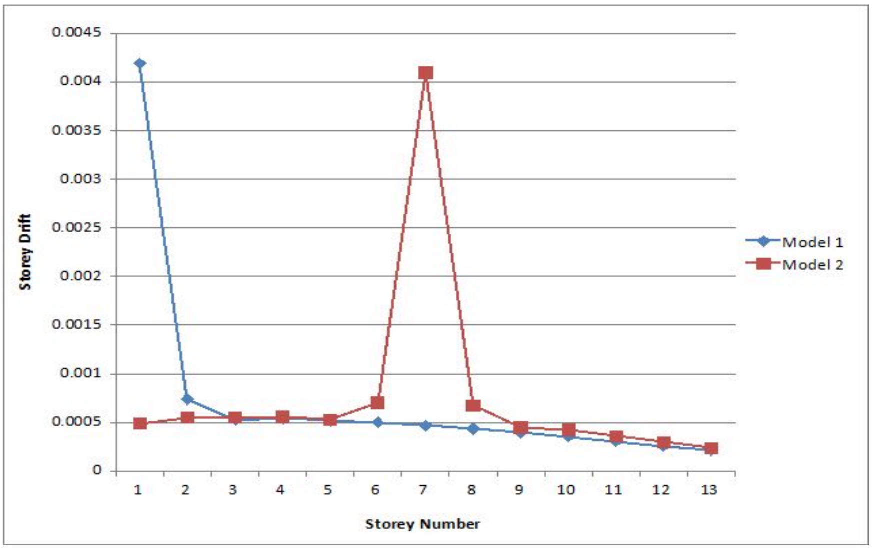
From above graph 3.3 it is observed that the storey displacement at initial stage i.e. First storey is less for Model 2 as compare to Model 1. As shown in graph in Model 2 displacement is suddenly increases because of soft story is provided at middle of multistory building. From reference of above graph more displacement obtains at rising level of soft storey. Therefore it is observed that soft storey provides at perticular floor the story displacement raises suddenly for that particular floor where soft story is provided. Storey displacement is obtained 2.857% less for Model 1 as compare to Model 2.

3.1.4 Storey drift:

It is the displacement of one level relative to the other level above or below. Drift is the maximum lateral displacements of the structure with respect to total height or relative inter storey displacement. Drift have three primary effects on a structure; the movement can affect the structural elements, non- structural elements and adjacent structures, without proper consideration large deflection and drifts have adverse effects on structural elements, non-structural elements and adjacent structures. Story drift is calculated as shown in table 3.4.

Table 3.4 Storey drift for Clay Brick

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	0.000211	0.000238
Story 12	36	0.000257	0.000296
Story 11	33	0.000307	0.000359
Story 10	30	0.000354	0.000423
Story 9	27	0.000397	0.000449
Story 8	24	0.000436	0.000674
Story 7	21	0.000469	0.004096
Story 6	18	0.000498	0.000704
Story 5	15	0.000519	0.000529
Story 4	12	0.000545	0.000558
Story 3	9	0.000523	0.000549
Story 2	6	0.00074	0.00055
Story 1	3	0.004192	0.000489



Graph 3.4 Variation of Storey drift along X & Y- Direction for Clay Brick

As per IS 1893:2002 maximum storey drift should not be more than 0.004 times to storey height of the structure. Here value of limiting storey drift is 0.012 where height of storey is 3m. From the graph 3.4 it is observed that the values of the storey drift for all the stories are found to be within the limits.

3.2 Siporex Block as an infill material:

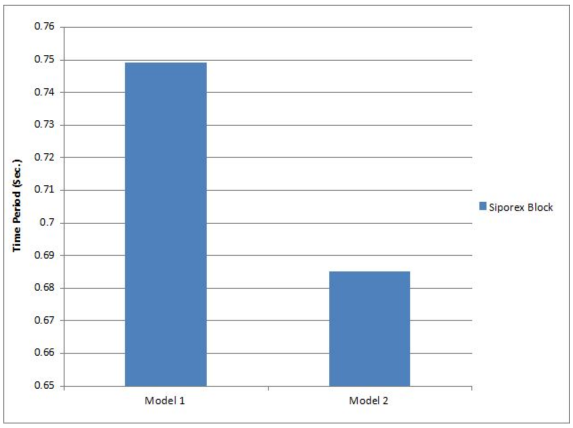
3.2.1 Time period

Time period in sec. is given below in table 3.5.

Table 3.5 Time period for Siporex Block (Sec.)

Infill material	Model 1	Model 2
Siporex blocks	0.749	0.685

From graph 3.5 it is observed that the time period is obtained 5.1314% less for Model 2 as compare to Model 1 in case of Siporex Block as an infill material in multistorey building with soft story. It indicates that soft storey at seventh floor is most suitable than soft storey at ground floor in multistorey building. Time period is depends on position of soft storey in building.



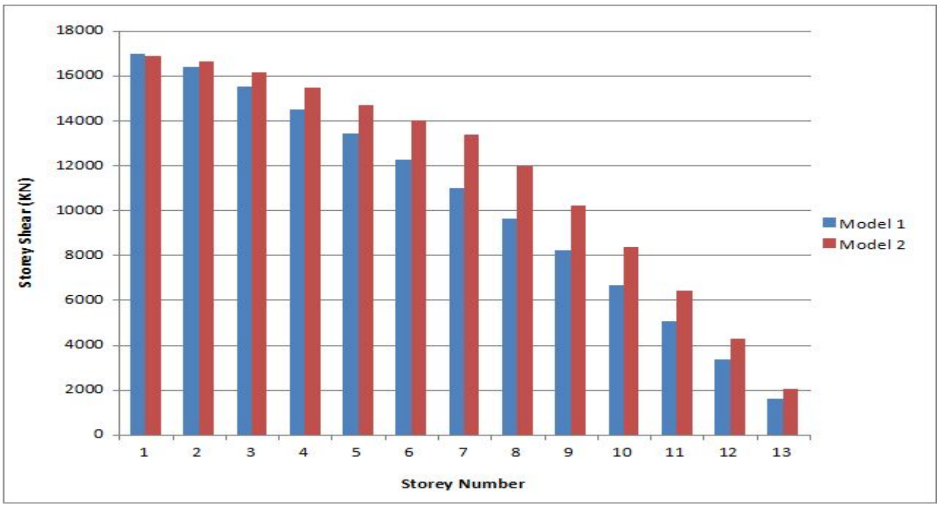
Graph 3.5 Time period for Siporex Block

3.2.2 Storey shear:

Storey shear is calculated as shown in table 3.6.

Table 3.6 Storey shear for Siporex Block (KN)

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	1595.481	2033.018
Story 12	36	3366.177	4273.093
Story 11	33	5061.898	6393.157
Story 10	30	6673.493	8379.841
Story 9	27	8196.903	10231.32
Story 8	24	9631.334	11963.38
Story 7	21	10977.45	13396.22
Story 6	18	12236.28	13994.86
Story 5	15	13408.75	14701.18
Story 4	12	14495.77	15445.92
Story 3	9	15495.92	16127.25
Story 2	6	16413.12	16642.77
Story 1	3	16983.36	16856.46



Graph 3.6 Variation of Storey shears along X & Y- Direction for Siporex Block

As shown in graph 3.6 Model 1 Storey shears is found more comparison to Model 2. Base shear is 0.747%

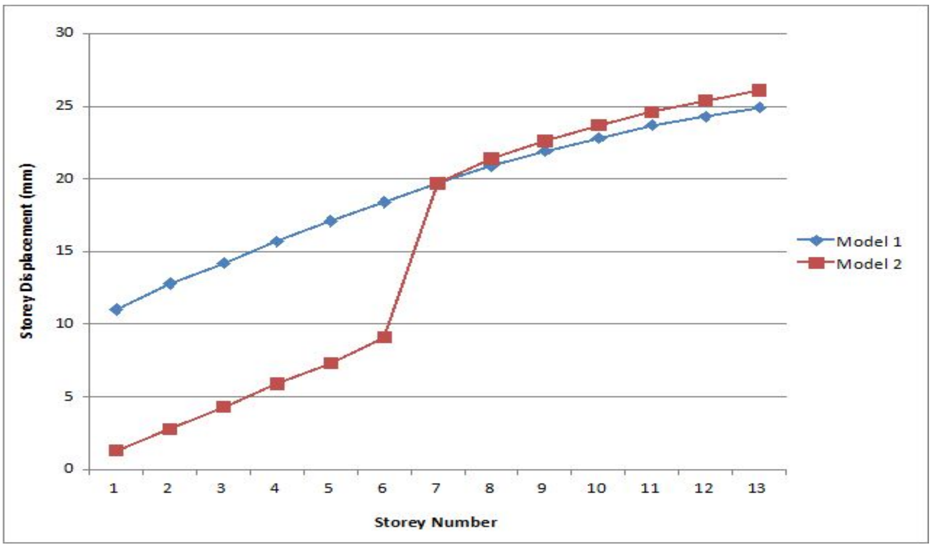
greater for Model 2 as compare to Model 1. As shown in results the position of soft storey not significantly effective. Base shear is also depends on direction and position of soft storey in building.

3.2.3 Storey displacement:

Story displacement is calculated as shown in table 3.7.

Table 3.7 Storey displacement for Siporex Block (mm)

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	24.9	26.1
Story 12	36	24.3	25.4
Story 11	33	23.7	24.6
Story 10	30	22.8	23.7
Story 9	27	21.9	22.6
Story 8	24	20.9	21.4
Story 7	21	19.7	19.7
Story 6	18	18.4	9.1
Story 5	15	17.1	7.3
Story 4	12	15.7	5.9
Story 3	9	14.2	4.3
Story 2	6	12.8	2.8
Story 1	3	11	1.3



Graph 3.7 Variation of Storey displacements along X & Y- Direction for Siporex Block

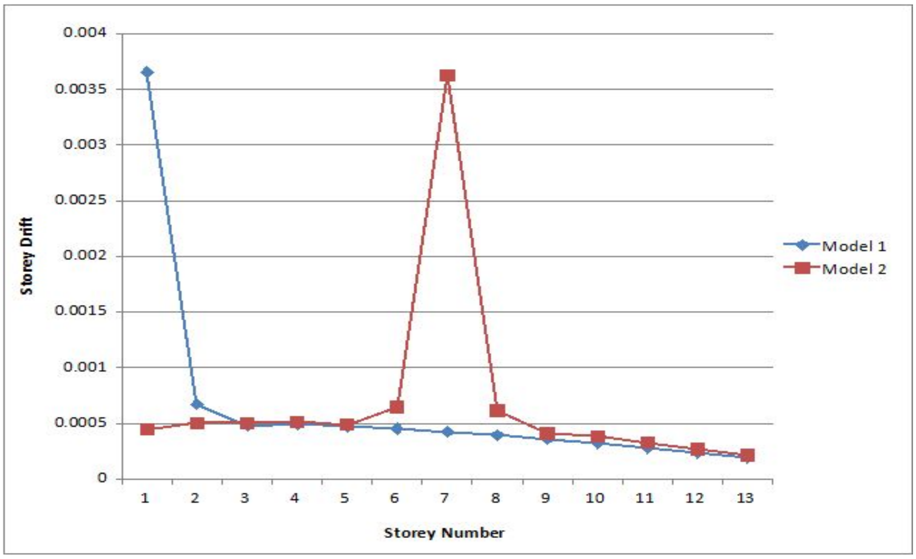
From above graph 3.7 it is observed that the storey displacement at initial stage i.e. First storey is less for Model 2 as compare to Model 1. As shown in graph in Model 2 displacement is suddenly increases because of soft story is provided at middle of multistory building. From reference of above graph more displacement obtains at rising level of soft storey. Therefore it is observed that soft storey provides at particular floor the story displacement raises suddenly for that particular floor where soft story is provided. Storey displacement is obtained 4.597% less for Model 1 as compare to Model 2.

3.2.4 Storey drift:

Story drift is calculated as shown in table 3.8.

Table 3.8 Storey drift for Siporex Block

Storey	Elevation	Model 1	Model 2
		X and Y- Dir.	X and Y- Dir.
Story 13	39	0.000188	0.000215
Story 12	36	0.00023	0.000268
Story 11	33	0.000276	0.000325
Story 10	30	0.000319	0.000383
Story 9	27	0.000358	0.000407
Story 8	24	0.000393	0.000613
Story 7	21	0.000423	0.003628
Story 6	18	0.00045	0.000645
Story 5	15	0.00047	0.000486
Story 4	12	0.000493	0.000512
Story 3	9	0.000475	0.000503
Story 2	6	0.000671	0.000503
Story 1	3	0.003654	0.000445



Graph 3.8 Variation of Storey drift along X & Y- Direction for Siporex Block

As per IS 1893:2002 maximum storey drift should not be more than 0.004 times to storey height of the structure. Here value of limiting storey drift is 0.012 where height of storey is 3m. From the graph 3.8 it is observed that the values of the storey drift for all the stories are found to be within the limits.

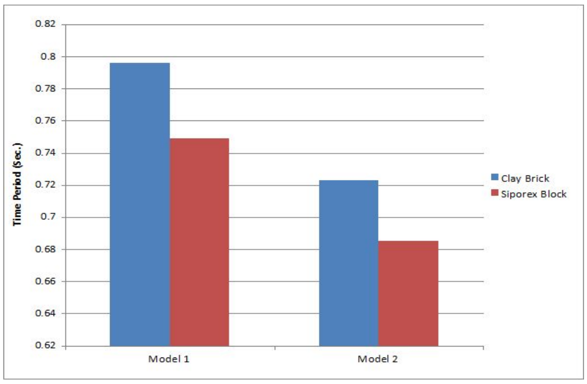
3.3 Comparison of Clay Brick and Siporex Block as an infill material:

3.3.1 Time period:

Time period in sec. is given in table 3.9.

Table 3.9 Time period for comparison of Clay Brick and Siporex Block for comparison of Clay Brick and Siporex Block (Sec.)

Infill material	Model 1	Model 2
Clay Bricks	0.796	0.723
Siporex Blocks	0.749	0.685



Graph 3.9 Time period for comparision of different infill materials

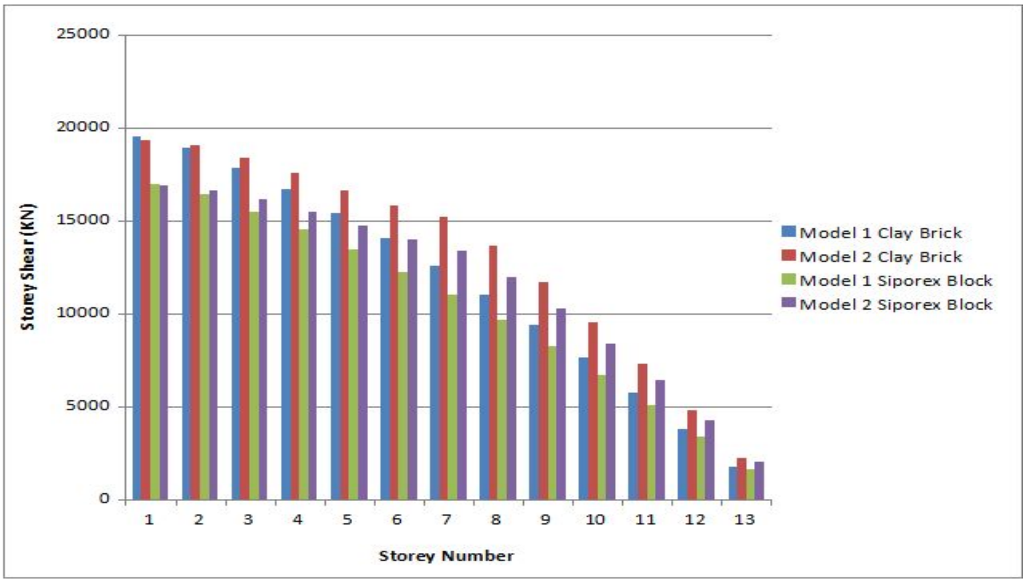
From graph 3.9 it is observed that Model 2 Siporex Block obtains minimum time period. For different infill materials i.e. Clay Brick and Siporex Block, Time Period is minimum when Siporex Block is used as infill material. It is 5.90% and 5.25% minimum than Clay Brick for Model 1 i.e. soft storey at ground floor and Model 2 i.e. soft storey at seventh floor respectively. As per reference of above graph with comparison other models, Model 2 give less time period.

3.3.2 Storey shear:

Storey shear is calculated as shown in table 3.10.

Table 3.10 Storey shear for for comparison of Clay Brick and Siporex Block (KN)

Storey	Elevation	Model 1 Clay Brick	Model 2 Clay Brick	Model 1 Siporex Block	Model 2 Siporex Block
		X and Y- Dir.	X and Y- Dir.	X and Y- Dir.	X and Y- Dir.
Story 13	39	1744.282	4807.99	1595.481	2033.018
Story 12	36	3796.791	7254.133	3366.177	4273.093
Story 11	33	5759.214	9540.774	5061.898	6393.157
Story 10	30	7621.126	11667.39	6673.493	8379.841
Story 9	27	9378.643	13655.32	8196.903	10231.32
Story 8	24	11032.12	15199.33	9631.334	11963.38
Story 7	21	12583.79	15816.52	10977.45	13396.22
Story 6	18	14036.25	16633.4	12236.28	13994.86
Story 5	15	15391.86	17533.18	13408.75	14701.18
Story 4	12	16652.74	18377.01	14495.77	15445.92
Story 3	9	17817.92	19024.36	15495.92	16127.25
Story 2	6	18892.33	19303.8	16413.12	16642.77
Story 1	3	19537.53	19303.8	16983.36	16856.46



Graph 3.10 Variation of Storey shears along X & Y- Direction for comparision of different infill materials

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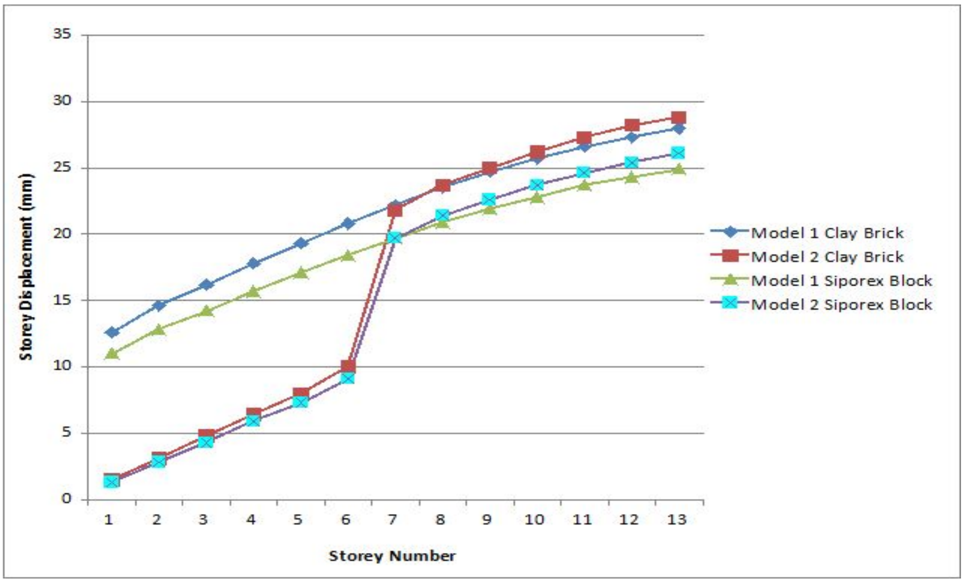
As shown in graph 3.10 it is observed that Base shear is greater for Model 1 i.e. soft storey at ground floor for both infill materials. Base shear is 13.07% and 12.678% maximum for Clay Brick as compare to Siporex Block for Model 1 i.e. soft storey at ground floor and Model 2 i.e. soft storey at seventh floor respectively. It shows that the Base shear is depends on weight of structures. It represents that position of soft storey is not significantly affect on the value of Base Shear.

3.3.3 Storey displacement:

Story displacement is calculated as shown in table 3.11.

Table 3.11 Storey displacement for comparison of Clay Brick and Siporex Block (mm)

Storey	Elevation	Model 1 Clay Brick	Model 2 Clay Brick	Model 1 Siporex Block	Model 2 Siporex Block
		X and Y- Dir.	X and Y- Dir.	X and Y- Dir.	X and Y- Dir.
Story 13	39	28	28.8	24.9	26.1
Story 12	36	27.3	28.2	24.3	25.4
Story 11	33	26.6	27.3	23.7	24.6
Story 10	30	25.7	26.2	22.8	23.7
Story 9	27	24.7	25	21.9	22.6
Story 8	24	23.5	23.7	20.9	21.4
Story 7	21	22.2	21.8	19.7	19.7
Story 6	18	20.8	10	18.4	9.1
Story 5	15	19.3	8	17.1	7.3
Story 4	12	17.8	6.4	15.7	5.9
Story 3	9	16.2	4.8	14.2	4.3
Story 2	6	14.6	3.1	12.8	2.8
Story 1	3	12.6	1.5	11	1.3



Graph 3.11 Variation of Storey displacements along X & Y- Direction for comparision of different infill materials

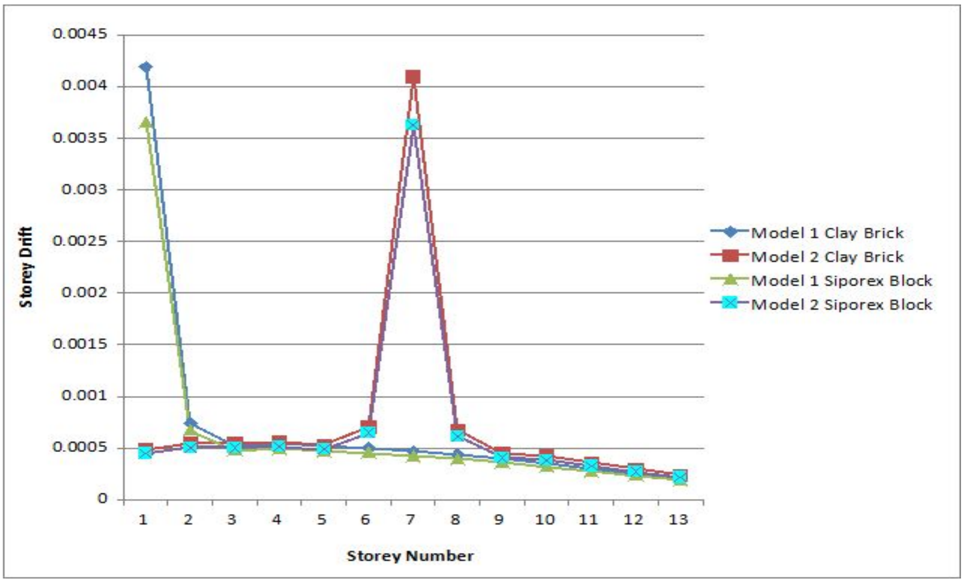
From above graph 3.11 it is observed that at initial level Model 2 Clay Brick i.e. soft storey at seventh floor gives least storey displacement but later it achieves great at top floor. For different infill material storey displacement suddenly rises where soft storey is provided and it goes on increasing uniformly along height of structure. Storey displacement is maximum for Clay Brick as an infill material in multistorey building. And it is 11.071% and 9.37% maximum than Siporex Block for Model 1 i.e. soft storey at ground floor and Model 2 i.e. soft storey at seventh floor respectively.

3.3.4 Storey drift:

Story drift is calculated as shown in table 3.12.

Table 3.12 Storey drift for comparison of Clay Brick and Siporex Block

Storey	Elevation	Model 1 Clay Brick	Model 2 Clay Brick	Model 1 Siporex Block	Model 2 Siporex Block
		X and Y- Dir.	X and Y- Dir.	X and Y- Dir.	X and Y- Dir.
Story 13	39	0.000211	0.000238	0.000188	0.000215
Story 12	36	0.000257	0.000296	0.00023	0.000268
Story 11	33	0.000307	0.000359	0.000276	0.000325
Story 10	30	0.000354	0.000423	0.000319	0.000383
Story 9	27	0.000397	0.000449	0.000358	0.000407
Story 8	24	0.000436	0.000674	0.000393	0.000613
Story 7	21	0.000469	0.004096	0.000423	0.003628
Story 6	18	0.000498	0.000704	0.00045	0.000645
Story 5	15	0.000519	0.000529	0.00047	0.000486
Story 4	12	0.000545	0.000558	0.000493	0.000512
Story 3	9	0.000523	0.000549	0.000475	0.000503
Story 2	6	0.00074	0.00055	0.000671	0.000503
Story 1	3	0.004192	0.000489	0.003654	0.000445



Graph 3.12 Variation of Storey drift along X & Y- Direction for comparision of different infill materials

As per IS 1893:2002 maximum storey drift should not be more than 0.004 times to storey height of the structure. Here value of limiting storey drift is 0.012 where height of storey is 3m. From the graph 3.12 it is observed that the values of the storey drift for all the stories are found to be within the limits. Storey drift values are obtained greater where soft storey is provided for Model 1 i.e. soft storey at ground floor and Model 2 i.e. soft storey at seventh floor. In which Siporex Block provide minimum Storey Drift comparison of Clay Brick.

4. CONCLUSIONS

By analyzing seismic behavior of G+12 multistory building for Clay Brick and Siporex Block as an infill material using ETABS following conclusion can be drawn:

For different infill materials i.e. Clay Brick and Siporex Block Time Period is minimum when Siporex Block is used as infill material. It is 5.90% and 5.25% minimum than Clay Brick for Model 1 and Model 2 respectively. Base shear is greater for Model 1 and it is 13.07% and 12.678% maximum for Clay Brick as compare to Siporex Block for Model 1 and Model 2 respectively. It represents that position of soft storey is not significantly affect on the value of Base Shear. Storey displacement is maximum for Clay Brick as an infill material in multistory building. It is 11.071% and 9.37% maximum than Siporex Block for Model 1 i.e. soft storey at ground floor and Model 2 i.e. soft storey at seventh floor respectively.

The value of storey drift for all stories for all cases are found to be within permissible limit i.e. As per IS 1893:2002 they should not be more than 0.004 times to storey height of the structure. Storey drift found minimum where Siporex Block used as an infill material. From above it shows that the light weight infill material i.e. Siporex Block provides less Time Period, Base Shear, Storey Displacement And Storey Drift etc.

Considering all cases i.e. seismic behavior, weight, time of building construction etc. Siporex Block is more efficient material as an infill material for multistory building soft storey.

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