Dynamic Analysis of Reinforced Concrete Framed Structures with Infill Wall

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Abstract— Masonry infill (MI) panels have been used as a means to strengthening existing moment resting frames and there is evidence that they improved the performance of structures under severe earthquake loading. In this paper dynamic analysis has been performed using Equivalent lateral force, Response spectrum for different reinforced concrete (RC) frame building models that include bare frame, infilled frame and different percentages of opening in infilled frame. The results of bare frame, infilled frame and different percentages of opening in infilled frame are discussed and conclusions are made.The opening size of the infill has a significant influence on the Modal period, displacement storey drift and maximum storey acceleration, and base shear. Generally they increase as the opening size increases. The base shear decreases as the opening size increases. In modelling the masonry infill panels the Equivalent diagonal Strut method is used and the software ETABS is used for the analysis of all the frame models.

Key words: Masonry infill (MI), Mainstone R.J formulae, Equivalent Static Force Method

I. Introduction

Masonry infill (MI) panels can be frequently found as interior and exterior partition in reinforced concrete (RC) and steel frame structure. Masonry infill (MI) panels have been used as a means to strengthening existing moment resting frames and there is evidence that they improved the performance of structures under severe earthquake loading.

In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced-concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints.

II. Building Description

A Commercial building is considered. Other details are given below

Modeling details of building	
Plan dimension	24m x 16m
No of storey's	G+2,G+6,G+14
Storey height	3.3m
Zone factors	0.16(Zone III)
Importance factor	1.5
Response reduction factor	3.0
Soil condition	Medium soil
damping	5%
Type of frame	Ordinary moment resisting frame
Height of building	9.9m,23.1m,49.5m
Building type	Commercial building
Concrete grade	M25
Steel grade	Fe-415
Beam size	0.3m x 0.4m
Column size	0.6m x 0.6m
Live load on roof & floor	2kN /m^2,3kN /m^2
Floor finish	1.5kN /m^2
Thickness of slab & infill	0.15m,0.25m

Details of RC frames	
Breadth of beam (b)	0.3m
Breadth of column	0.6m(3rd,7th,15th storey building)
Depth of beam	0.4m
Depth of column	0.6m(3rd,7th,15th storey building)
Thickness of masonry infill	0.25m
Height of masonry infill(h)	3.3m
Height of column	3.3m
Moment of inertia of column	0.0108m^4(3rd,7th,15th storey building)
Moment of inertia of beam	$1.6x10^{-3}$ m^4
Modulus of elasticity of concrete	$25000x10^3$kN /m^2
Modulus of elasticity of masonry infill	$4.6x10^6$kN /m^2
Slope of the diagonal to the horizontal	0.4501 & 0.6265radians

III. Building Models

The structure is modeled and analysed using standard package ETAB. In this project different types of frames are considered for this analysis are Bare frame, complete infill without opening,10% opening infill frame,20% opening infill frame,30% opening infill frame,40%opening infill frame. Using equivalent diagonal strut method & finding the width of the strut according to Mainstone R.J formulae.static and dynamic analysis is performed for all the models. Comparision carried out between G+6 storey building & G+14 storey building.Following models are considered for the study.

G+6 storey building
M1-Bare frame
M2-complete infillwall without opening
M3-10%opening infill frame
M4-20%opening infill frame
M5-30%opening infill frame
M6-40%opening infill frame

G+14 storey building
M7-Bare frame
M8-complete infillwall without opening
M9-10%opening infill frame
M10-20%opening infill frame
M11-30%opening infill frame
M12-40%opening infill frame

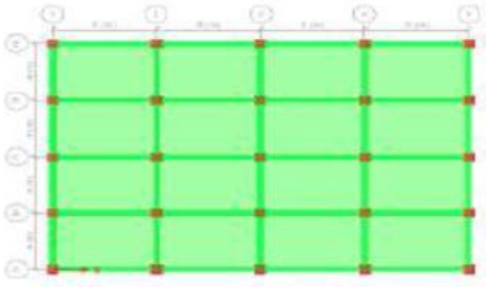

Fig. 3.1: structural model of G+6 storey building in ETAB(plan view)

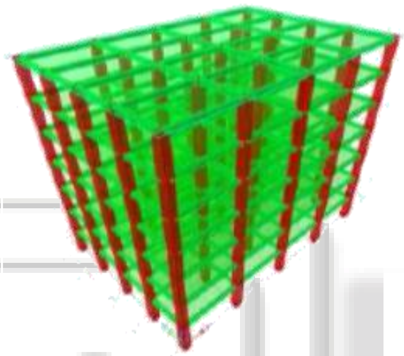

Fig. 3.2: Bare frame

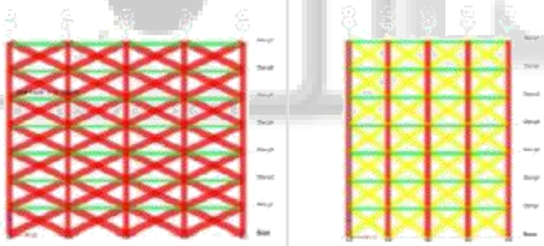

Fig. 3.3: Complete infillwall without opening

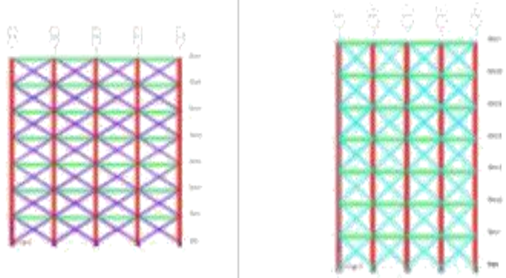

Fig. 3.4: 10%Opening infill frame

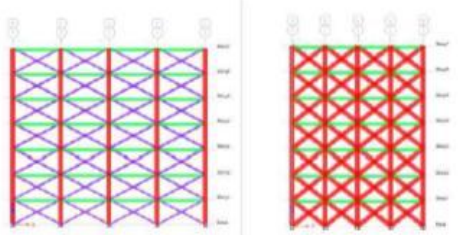

Fig. 3.5: 20%Opening infill frame

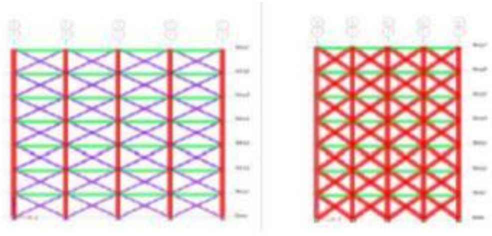

Fig. 3.6: 30%Opening infill frame

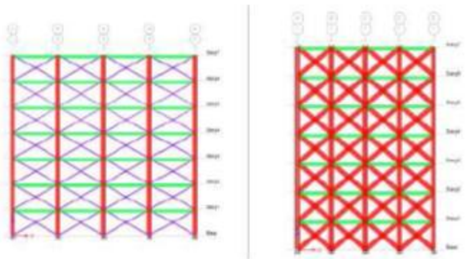

Fig. 3.7: 40%Opening infill frame

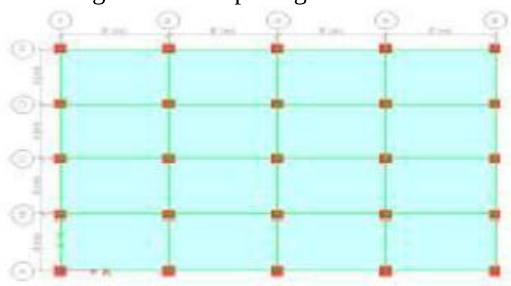

Fig. 3.8: Structural model of G+14 storey building in ETAB(plan view)

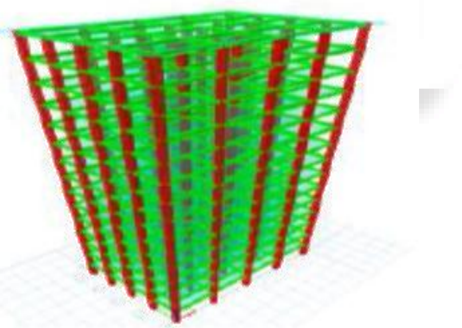

Fig. 3.9: Bare frame

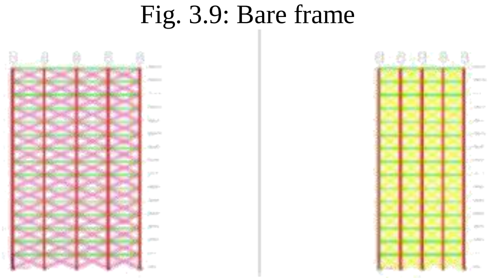

Fig. 3.10: Complete in fill wall without opening

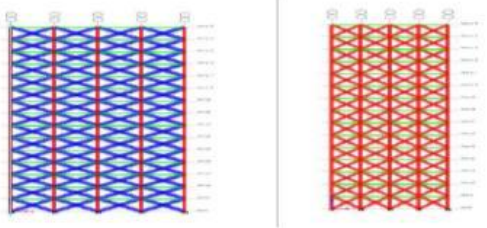

Fig. 3.11: Complete in fill wall without opening

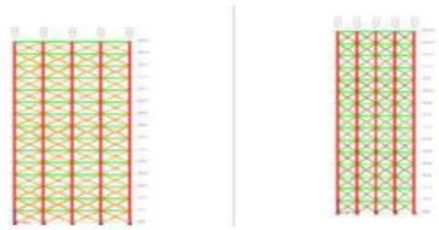

Fig. 3.12: 20%Opening infill frame

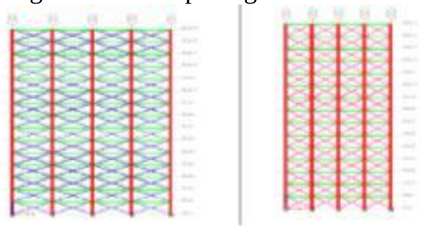

Fig. 3.13: 30%Opening infill frame

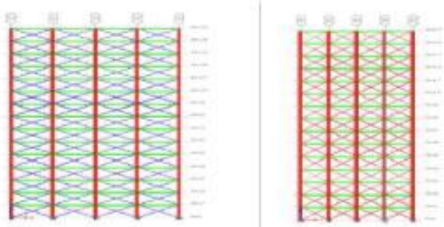

Fig. 3.14: 40%Opening infill frame

IV. RESULTS AND DISCUSSIONS

A. Calculation of Displacement By Equivalent Static Force Method

Displacement for G+6 building in x direction .

The Resultant Displacement In Y Direction At Various Storey Levels For Considered Models Is As Indicated In The table and the graph is as shown in fig .the maximum displacement for the building is obtained in the top storey

No of storey	Displacement in X X direction					
	M1	M2	M3	M4	M5	M6
7	61.3	3.6	5.0	6.9	9.0	11.9
6	55.2	3.4	4.6	6.4	8.3	11
5	47	2.9	4.0	5.9	7.3	9.6
4	36.9	2.4	3.3	4.5	6.0	7.8
3	25.6	1.8	2.5	3.4	4.4	5.8
2	14.3	1.4	1.6	2.2	2.8	3.6
1	4.6	0.5	0.7	0.9	1.1	1.4

Table 4.1: Comparision of Displacement In X Direction For G+6 Building

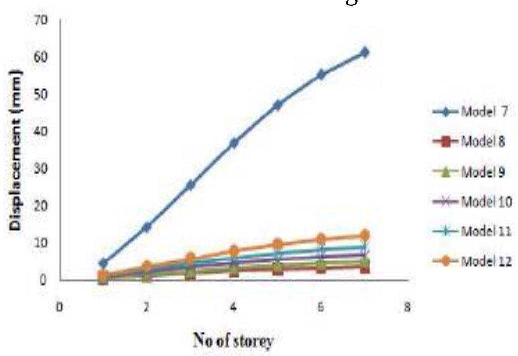

Fig. 4.1: Displacement for with and without in fill wall in Uxdirection

From the study it was observed that the decrease in the top Displacement in model 6 compared to bare frame(M1)was nearly 89% and nearly 84%,80%,76% and 69% in M3 ,M4 & M5 at different levels in x direction compared to bare frame models.

No of storey	Displacement in YY direction					
	M1	M2	M3	M4	M5	M6
7	45.6	5.1	10.8	8.8	11.5	14
6	41.4	4.6	9.8	8.1	10.4	13
5	35.5	4.0	8.5	7.0	9.1	11
4	28.1	3.2	6.9	5.7	7.4	9.3
3	19.8	2.4	5.1	4.2	5.5	6.8
2	11.3	1.5	3.2	2.7	3.4	4.2
1	3.8	0.4	1.3	1.4	1.5	1.6

Table 4.2: Comparison Of Displacement In Y- Direction For G+6 Building

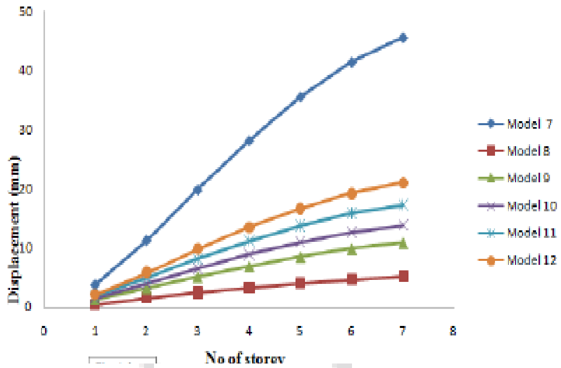

Fig. 4.2: Displacement for with and without infillwall in UY direction

From the study it was observed that the decrease in the top Displacement in model 6 compared to bare frame(M1)was nearly 89% and nearly 65%,63%,59% and 55% in M3 ,M4 & M5 at different levels in Y-direction compared to bare frame models

No of storey	Displacement in X X direction					
	M7	M8	M9	M10	M11	M12
15	182.2	20.4	21.4	25.7	27	34
14	177.6	19.5	20.7	24.5	26	33
13	171.1	18.4	19.8	23.0	25	32
12	162.7	17.2	26.1	21.4	23	30
11	152.5	15.8	17.4	19.7	22	28
10	140.0	14.4	16.0	17.8	20	26
9	127.4	12.9	14.4	15.9	18	24
8	113	11.3	12.8	13.9	16	21
7	97.7	9.7	11.1	11.9	14	18
6	81.9	8.1	9.4	10.1	12	15
5	65.6	6.6	7.7	9.9	10	10
4	49.2	5.1	6.0	8.0	7.8	7.3
3	33	3.6	4.4	6.1	5.3	4.8
2	18	2.3	2.7	4.3	3.5	3.0
1	5.7	1.0	0.9	1.4	1.6	1.8

Table 4.3: Comparison Of Displacement In X Direction For G+14 Building

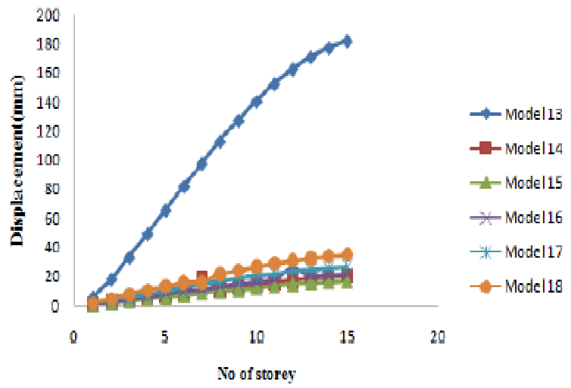

Fig. 4.3: Displacement for with and without infillwall in Ux direction

From the study it was observed that the decrease in the top Displacement in model 8 compared to bare frame(M7)was nearly 82% & nearly was 84%,82% 75%,65% in M9 ,M10 & M11 at different levels in X-direction compared to bare frame models in equivalent static analysis

No of storey	Displacement in X X direction					
	M7	M8	M9	M10	M11	M12
15	137.1	33.7	25	30	37	45
14	133.4	31.8	24	29	36	43
13	128.3	29.8	23	27	34	41
12	121.8	27.5	21	18	32	39
11	113.9	25.1	19	24	29	36
10	105	22.5	17	22	27	33
9	95	19.9	15	19	24	30
8	84.3	17.3	13	17	22	26
7	73	14.7	11	15	18	23
6	61.3	12.1	9.9	10	15	19
5	49.4	9.6	8.0	12	10	16
4	37.3	7.3	6.1	10.1	12	12
3	25.4	5.1	4.3	7.8	9.9	8.8
2	14.2	3.1	2.6	5.6	7.1	5.3
1	4.7	1.3	1.1	3.4	4.3	2.0

Table 4.4: Comparision Of Displacement In Y- Direction For G+14 Building

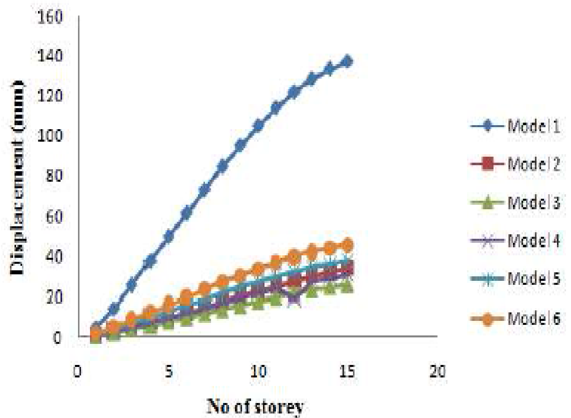

Fig. 4.4: Displacement For With And Without Infillwall In Uy Direction.

From the study it was observed that the decrease in the top Displacement in model 8 compared to bare frame(M7)was nearly 72% & nearly was 70%,63% 57% in M9,M10 & M11 at different levels in Y-direction compared to bare frame models in equivalent static analysis.

B. Calculation of Acceleration by Using Response Spectrum Method

ACCELARATION for G+6 building in x direction

No of storey	Acceleration In X X Direction					
	M1	M2	M3	M4	M5	M6
7	1.155	2.79	3.0	2.9	2.9	2.5
6	1.126	2.5	2.7	2.6	2.6	2.4
5	1.126	2.2	2.4	2.4	2.3	2.1
4	1.140	1.9	2.1	2.1	2.1	1.9
3	1.142	1.6	1.8	1.8	1.8	1.6
2	1.080	1.3	1.4	1.4	1.4	1.3
1	0.625	0.7	0.8	0.8	0.8	0.7

Table 4.5: Comparision Of Acceleration In X Direction For G+6 Building

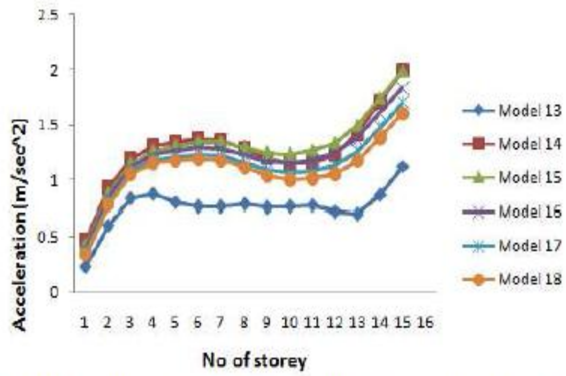

Fig. 4.5: Acceleration for with and without infillwall in Ux direction

From the study it was observed that the increase in the top Acceleration in model (M2)compared to bare frame(M1)was nearly 58% & nearly was 61%,61% 60% in M3,M4 & M5 at different levels in x-direction compared to bare frame models in response spectrum analysis.

No of storey	Acceleration In YY Direction					
	M1	M2	M3	M4	M5	M6
7	1.4	2.5	0.8	3.0	2.7	2.4
6	1.1	2.2	1.5	2.6	2.4	2.1
5	1.0	1.9	1.9	2.4	2.1	1.9
4	1.0	1.7	2.3	2.1	1.9	1.7
3	0.9	1.4	2.9	1.8	1.7	1.5
2	0.9	1.1	1.8	1.9	1.3	1.3
1	0.5	0.6	1.5	0.7	0.7	0.7

Table 4.6: Comparison Of Acceleration In Y-Direction For G+6 Building

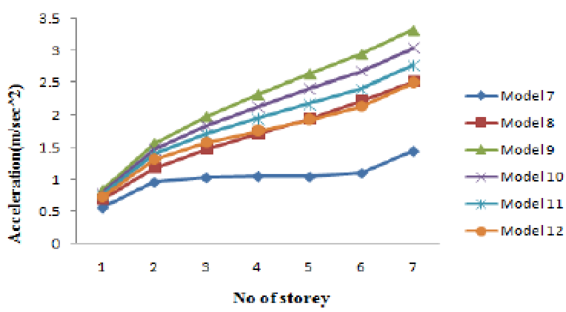

Fig. 4.6: Acceleration For With and Without Infillwall In UY Direction

From the study it was observed that the increase in the top Acceleration in model (M2)compared to bare frame(M1)was nearly 42% & nearly was 42%,47% 42% in

M 3,M 4 & M 5 at different levels in Y-direction compared to bare frame models in response spectrum analysis

No of storey	Displacement in X X direction					
	M7	M8	M9	M10	M11	M12
15	1.12	1.9	1.99	1.83	1.69	1.60
14	0.86	1.70	1.49	1.60	1.47	1.38
13	0.69	1.41	1.34	1.37	1.22	1.17
12	0.72	1.22	1.37	1.23	1.13	1.05
11	0.77	1.15	1.25	1.17	1.08	1.07
10	0.77	1.15	1.17	1.15	1.06	1.00
9	0.76	1.19	1.23	1.16	1.09	1.07
8	0.76	1.27	1.13	2.22	1.16	1.00
7	0.78	1.35	1.05	2.28	1.22	1.03
6	0.79	1.37	1.27	2.25	1.22	1.11
5	0.76	1.34	1.17	2.22	1.21	1.77
4	0.80	1.30	1.08	1.11	1.11	1.15
3	0.87	1.19	1.07	1.11	1.08	1.05
2	0.600	0.925	0.88	0.82	0.809	0.78
1	0.232	0.925	0.42	0.34	0.364	0.34

Table 4.7: Comparision Of Acceleration In X-Direction For G+14 Building

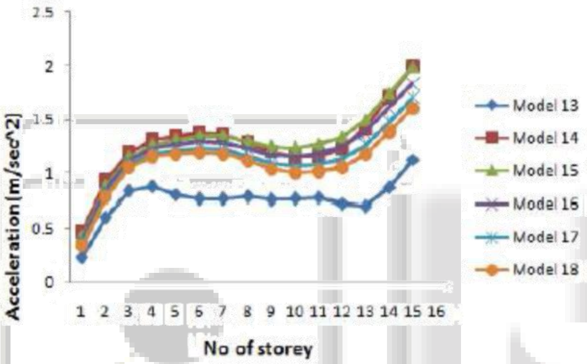

Fig. 4.7: Acceleration for with and without infillwall in UX direction

From the study it was observed that the increase in the top Acceleration in model (M8)compared to bare frame(M7)was nearly 50% & nearly was 50%,44% 39% in M 9,M 10 & M 11 at different levels in X-direction compared to bare frame models in response spectrum analysis.

No of storey	Displacement in YY direction					
	M7	M8	M9	M10	M11	M12
15	1.21	2.43	2.24	2.20	2.02	1.87
14	0.88	2.18	2.22	1.99	1.81	1.66
13	0.70	1.90	2.00	1.77	1.60	1.44
12	0.77	1.71	1.83	1.63	1.46	1.32
11	0.86	1.60	1.73	1.66	1.40	1.27
10	0.88	1.50	1.66	1.49	1.36	1.24
9	0.82	1.52	1.61	1.43	1.35	1.24
8	0.83	1.55	1.61	1.49	1.39	1.30
7	0.82	1.58	1.61	1.51	1.42	1.30
6	0.79	1.57	1.57	1.48	1.41	1.35
5	0.85	1.52	1.51	1.43	1.38	1.33
4	0.96	1.46	1.44	1.38	1.34	1.31
3	0.92	1.33	1.31	1.26	1.23	1.20
2	0.65	1.04	1.01	0.96	0.93	0.89
1	0.24	0.55	0.55	0.44	0.42	0.39

Table 4.8: Comparision Of Acceleration In Y-Direction For G+14 Building

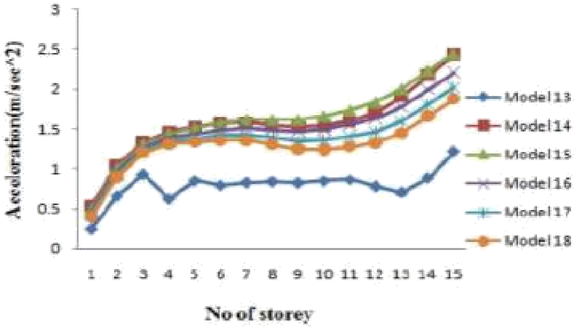

Fig. 4.8: Acceleration For With And Without Infillwall In UY Direction

From the study it was observed that the increase in the top Acceleration in model (M8)compared to bare frame(M7)was nearly 50% & nearly was 50%,44% 30% in M 9,M 10 & M 11 at different levels in X-direction compared to bare frame models in response spectrum analysis

V. CONCLUSION

- Introduction to infill panels in the RC frame reduces the time period and under estimation of lateral forces.
- The increase in the opening percentage leads to a decrease on the lateral stiffness and increase in the time period of infill frame .
- Masonry infill having small opening with have higher stiffness compare to large opening.
- The bare frame structure exibites the maximum displacements with complete infill exibites minimum displacements compared to all other in equivalent static forced method for seven and fifteen storey building.
- The opening size of the infill has a significant influence on the displacement and maximum storey acceleration ,generally they increase as the opening size increase ,indicating that the decrease in stiffness is more significant than the decrease in mass.
- Acceleration increase with increase in stiffness of the structure .RC frame with masonry infill is having highest acceleration in response spectrum analysis for seven and fifteen storey building.
- Modeling of masonry infill as equivalent diagonal strut adds stiffness and strength to the structures.Due to change in stiffness and mass dynamic characteristics of also changes.

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