Aseismic Performance of 3d RC Frame using ETABS

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Abstract

Moderate and severe earthquakes have struck different places in the world, causing severe damage to reinforced concrete structures. Earthquake often effect the bond between the structural elements and masonry in-fills of the building. Masonry in-fills are often used to fill the void between horizontal and vertical resisting elements of the building frame. An infill wall enhances considerably the strength and rigidity of the structure. It has recognized that frames with in-fills have more strength and rigidity in conditions. Comparison to the bared frames. Hence the studies about the behavior of 3D- frames with or without masonry in-fills are necessary. In this project, the performance of 3D- frames with diagonally in-filled masonry is quantified under dynamic loading conditions.

Keywords: 3D RC, Earthquake, 3D- frames

I. INTRODUCTION

A. General

The rapid industrialization and increase in population have called for optimum use of scale land due to which multi-storey building have become inevitable. Apart from dead and live loads, the structures have to withstand lateral foes. Under the action of natural wind and earthquake a tall building will be continually buffeted by gusts and other dynamic foes.

Most Reinforced Concrete frame buildings in developing countries are in-filled with masonry walls. Experience during the past earthquakes has demonstrated the beneficial effects as well as the ill-effects of the presence of infill masonry walls. In at least two moderate earthquakes (magnitude 6.0 to 6.5 and maximum intensity VIII on MM scale) in India, frame buildings with brick masonry infills have shown excellent performance even though most such buildings were not designed and detailed for seismic response.

B. Earthquake Resistant Structures

Earthquake resistant structures are structures designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake-resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts.

According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of functionality should be limited for more frequent ones.

To combat earthquake destruction, the only method available to ancient architects was to build their landmark structures to last, often by making them excessively stiff and strong.

C. Seismic Design Factors

The following factors affect and are affected by the design of the building. It is important that the design team understands these factors and deal with them prudently in the design phase.

1) Torsion:

Objects and buildings have a center of mass, a point by which the object (building) can be balanced without rotation occurring. If the mass is uniformly distributed then the geometric center of the floor and the center of mass may coincide. Uneven mass distribution will position the center of mass outside of the geometric center causing "torsion" generating stress concentrations. A certain amount of torsion is unavoidable in every building design.

2) Damping:

Buildings in general are poor resonators to dynamic shock and dissipate vibration by absorbing it. Damping is a rate at which natural vibration is absorbed.

3) Ductility:

Ductility is the characteristic of a material (such as steel) to bend, flex, or move, but fails only after considerable deformation has occurred. Non-ductile materials (such as poorly reinforced concrete) fail abruptly by crumbling. Good ductility can be achieved with carefully detailed joints.

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4) Strength and Stiffness:
Strength is a property of a material to resist and bear applied forces within a safe limit. Stiffness of a material is a degree of resistance to deflection or drift (drift being a horizontal storey-to-storey relative displacement).
5) Building Configuration:
This term defines a building's size and shape, and structural and nonstructural elements. Building configuration determines the way seismic forces are distributed within the structure, their relative magnitude, and problematic design concerns.

D. Objectives
- To study the aseismic performance of multi-storeyed frame under dynamic loads using E-TABS.
- To study the behavioral changes of frame with & without Masonry Infill.
- To compare it with the obtained experimental values.

E. Scope of The Project
- In this project the analytical work has been carried out on a two bay, three storey R.C frame subjected to lateral loading
- Load is applied in one direction (X- direction)
- Brick infill is considered in study

II. LITERATURE REVIEW

A. General
To provide a detailed review of the literature related to modeling of structures in its entirety would be difficult to address in this chapter. A brief review of previous studies on the analytical study of aseismic performance of multi storey frame using E-TABS is carried on. This literature review focuses on recent contributions related to aseismic performance of multi storey frame and past efforts most closely related to the needs of the present work.

B. Literature Review
Cinitha et al (2015) performed Nonlinear Static analysis to assess seismic performance and vulnerability of code - conforming RC buildings. Nonlinear analysis described in National Earthquake Hazards Reduction Program (NEHRP) guidelines has been used for the seismic rehabilitation of buildings. Analysis was done using SAP2000. 4 and 6 storey buildings are designed according to the code IS456:2000 and IS1893:2002. The data used for analysis were gravity load design ground acceleration - 0.36g and seismic load design ground acceleration- 0.16g with medium soil. The buildings were designed for two cases, such as ordinary moment resisting frame (OMRF) and special moment resisting frame (SMRF). A 100% dead load + 50% live load is applied to the lateral load on the structure. Inelastic beam and column members were modelled as elastic elements with plastic hinges at their ends. The analysis results observed for displacement shows that the modern codes for framed structure are within collapse prevention level.

Amin et al (2015): In an attempt to investigate the effect of soft storey for multistoried reinforced concrete building frame, four building models (3, 6, 9 and 12 storey) with identical building plan were analyzed. Equivalent diagonal struts were provided, as suggested in FEMA-273, in place of masonry to generate infill effect. Earthquake load was provided at each diaphragm’s mass centre as a source of lateral load as set forth by the provision BNBC (1993). Soft storey level was altered from ground floor to top floor for each model and equivalent static analysis was carried away using 9.6.0 analysis package. It shows a general changing pattern in lateral drift irrespective to building height and location of soft storey. Inter-storey drift ratio was found increasing below the mid storey level and maximum ratio was obtained where the soft storey was located. The rate of increase in drift ratio at any particular floor (kept soft) for different building height increases linearly from bottom to top floor. As the building height increases, location of soft storey goes downwards from mid storey level to produce maximum lateral drift. Detailed analysis could be performed using various percentages of infill in each floor level and different orientations considering soil-foundation-structure interaction.

Md Zibran Pawaar et al (2015) studied the performance based seismic analysis of RC building considering the effect of dual systems. In this study, the buildings have been modeled as a series of load resisting elements. The lateral loads to be applied on the buildings were based on the Indian standards. The study was performed for seismic zone V as per IS 1893:2002. The frames were assumed to be firmly fixed at the bottom and the soil structure interaction is neglected. The linear-static and non-linear static analysis with different shear wall arrangements on dual systems such as flat slabs and shear walls & moment resisting frames and shear walls for different irregular plans using 9.7.4 software. The base shear for dual system model for diaphragm discontinuity was more than that of E model making E model dual system better compared to diaphragm discontinuity model.
Mohammad H. Jinya et al (2015) studied the seismic behavior of RC frame building was analysed by performing multi-model static and dynamic analysis. The results of bare frame, masonry infill panel with outer wall opening, and soft storey has been discussed. The conclusions made in this study was infill wall (diagonal strut) change the seismic performance of RC building. Storey drift and displacement were decreased. It was suggested that the soft storey should be provided with outer masonry infill panel to increase stiffness of soft storey.

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Lova Raju et al (2015) studied the effective location of shear wall on performance of building frame subjected to earthquake load. Four types of structures, with G+7 are considered in which one of the frame without shear wall and three frames with shear wall in various position. The Non Linear Static analysis is done using E-TABS v9.7.2 software. The structure was designed for Seismic zone II, III, IV and V. In pushover analysis the lateral force increase with increase in height of building. The behaviour of structure was determined including ultimate load and maximum deflection. The pushover curve was generated by plotting base shear and roof displacement. Frame with shear wall performs better and the base shear increased by 9.82% when compared to the frame without shear wall. Shear wall performs better to lateral displacement and it reduces by 26.7% when compared to the frame without shear wall.

Karwar et al (2014) conducted a performance of RC framed structure using pushover analysis. In this study, the G+8 and G+12 building as bare frame and these buildings with shear wall and infill and the building with shear wall and infill with soft storey has been considered in this study. The nonlinear analysis of a structure was an iterative procedure. The effective damping depends on the hysteretic energy loss due to inelastic deformations, which depends on the final displacement. The result shows the base shear is minimum for bare frame and maximum for frame with infill for G+8 building. For G+12 building, the base shear is minimum for bare frame and maximum for frame with shear wall. Capacity curve and plastic hinges gave an insight into the real behavior of structures.

C. Conclusions of the Literature Review

- The presence of infill wall can increase the strength and stiffness of the structure.
- Axial foe in column increased, storey displacement and storey drift are decreased and base shear is increase with higher stiffness of infill.
- Base shear increases with the increase of mass and number of storey of the building, also base shear obtained from pushover analysis is much more than the base shear obtained from the equivalent static analysis.
- Stiffness and strength of infilled frame is significantly high as compared with the bare frame.
- The finite element models presented here can accurately reproduce the load–displacement response, crack patterns, and failure mechanisms of the infilled frames.
- Infill Frame specimen while apply the loads in diagonally the cracks are formed (first crack) at the infill portion and the cracks are extended in diagonally`
- In infilled frame, failure of each of the walls is brittle in nature and is, therefore, associated with sudden drop in base shear.
- The study demonstrate that masonry infill highly increases the stiffness and strength of a structure as long as the seismic demand does not exceed the deformation capacity of the infills

D. E-Tabs Software

Early releases of E-TABS provided input, output and numerical solution techniques that look into consideration the characteristics unique to building type structures, providing a tool that offered significant savings in time and increased accuracy over general purpose programs.

As computers and computer interfaces involved, E-TABS added computationally complex analytical options such as dynamic non linear behavior, and powerful cad-like drawing tools in a graphical and object based interface. Although E-TABS version 8 looks radically different from its predecessors of 30years ago, its mission remains the same to provide the profession with the most efficient and comprehensive software for the analysis and design of the buildings.

- Most buildings are of straight forward geometry with horizontal beams and columns. Although any building configuration is possible with E-TABS, in most cases a simple grid system defined by horizontal floors and vertical column lines can establish building geometry with minimal effort.
- Many of the floors levels in the buildings are similar. This commonality can be used numerically to reduce computational effort.
- The input and output connections used correspond to common building terminology. With E-TABS, the models are defined logically floor-by-floor, column-by-column, bay-by-bay and wall-by-wall and not as a stream of non-descript nodes and elements as in general purpose programs. Thus the structural definition is simple, concise and meaningful.
- In most buildings, the dimensions of the members are large in relation to the bay width and storey heights. Those dimensions have a significant effect on the stiffness of the frames. E-TABS corrects for such effects in the formulation of the member stiffness, unlike most general-purpose programs that work on centerline-to-centerline dimensions.
- The results produced by the programs should be in a form directly usable by the engineer. General-purpose computer programs produce results in a general form that may need additional processing before they are usable in structural design.

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III. DESIGN DETAILS

A. 3d Rc Frame

Fig. 4.1: Model 3D RC frame

B. Design of Frame

The datas considered are:
Seismic zone: IV
No. of Storeys: 3
Size of column: 100mmx100mm
Size of beam: 100mmx100mm
Unit weight of RCC= 25 KN/m^3
Unit weight of infills: 20KN/m^3
Type of soil: Hard soil
Data of frame:
Earthquake load:As per IS 1893 part I 2002
Storey height : Typical floor: 0.9m, ground floor : 1.05m
Floors : GF+2 upper floors
Walls : 100 mm thick brick masonry walls
Steel :HYSD reinforcement of grade Fe 415 confirming to IS 1786 is used throughout.

C. Mix Proportions

Cement = 413 kg/m^3
Water = 186 kg/m^3
Fine aggregate = 706 kg/m^3
Coarse aggregates = 1117 kg/m^3
Water cement ratio = 0.45
Yield =2422 kg
Thus the mix ratio for M30 grade concrete is 1:1:2

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D. Design Details & Modelling

1) Reinforcement detail for beam

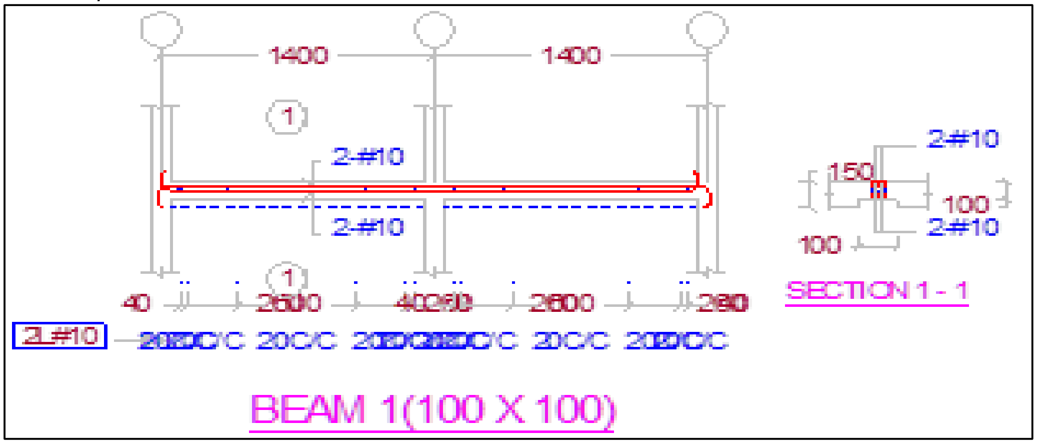

Fig. 4.2:Reinforcement detail of beam

2) Reinforcement detail for column

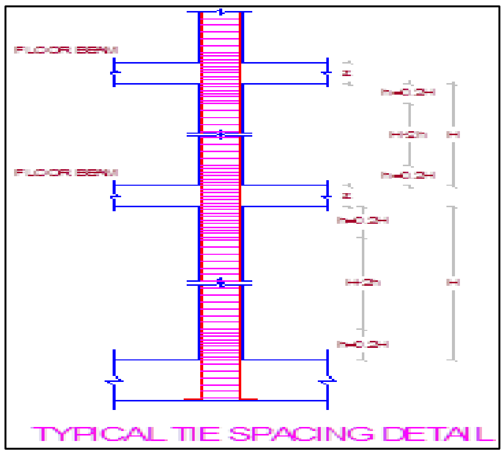

Fig. 4.3: reinforcement detail of column

3) Reinforcement detail for footing

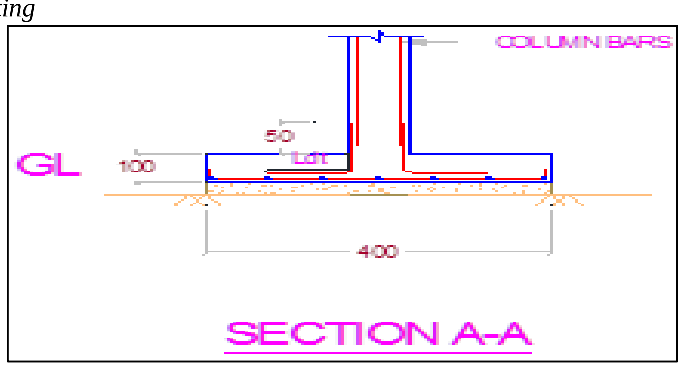

Fig. 4.4:

The design details are

4) For footings

Isolated Square Footing 400 X 400 X 100 mm
Along X Direction : 3Nos 10mm dia bars @ 300.00mm c/c.
Along Y Direction : 3Nos 10mm dia bars @ 300.00mm c/c.

5) For beams

Beams of Cross Section 100 X 100 mm
At Top : 2Nos 10mm dia bars
At Bottom : 2Nos 10mm dia bars
Shear Stirrups : 2 Legged, 10mm dia bars spacing at 250.0 mm c/c

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6) For columns

Columnss of Cross Section 100 X 100 mm
At Top : 2Nos 10mm dia bars
At Bottom : 2Nos 10mm dia bars
Shear Stirrups : 2 Legged, 10mm dia bars spacing at 250.0 mm c/c

E. Calculation of Materials

Beam =36*0.1*0.1*1.4=0.51cu-m
Column=9*0.1*0.1*2.85=0.26cu-m
Footing=9*0.1*0.1*0.4=0.15cu-m
Total volume of concrete=0.92cu-m
For 1cu-m of wet concrete=1.40cu-m of dry materials required
For M30 grade concrete (1:1:2)
0.92/1+1+2=0.23cu-m
Requirement of cement =0.23cu-m (7 bags)
Requirement of fine aggregates=0.23cu-m
Requirement of coarse aggregates=0.46cu-m

IV. EXPERIMENT PROGRAM AND RESULTS

A. Diagonal wise Infill

Fig. 5.1: Diagonally infilled experimental frame

Fig. 5.2: Fixing Of Actuators

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Fig. 5.3: Debonding effect noticed between beam-column joint and infills

Table - 5.1
Bending moment reactions at nodes

Node	*Reaction at X*	*Reaction at Y*	*Reaction at Z*	*Moment at X kN/m*	*Moment at Y kN/m*	*Moment at Z kN/m*
1	*23.93*	*11.95*	*7.02*	*40.11*	*11.71*	*12.66*
2	*26.51*	*13.88*	*9.44*	*46.60*	*12.57*	*47.86*
3	*21.53*	*11.98*	*4.27*	*40.22*	*10.90*	*12.63*

Table - 5.2
Displacement calculations

NODES	*DISP AT X*	*DISP AT Y*	*DISP AT Z*	*ROTATION AT X*	*ROTATION AT Y*	*ROTATION AT Z*
1	*10.375*	*.0055*	*0.2566*	*0.0009*	*-0.0077*	*-0.0001*
2	*0*	*25.023*	*3243*	*3026.3*	*0*	*0*
3	*70.169*	*12.653*	*1454.1*	*1589*	*-8680*	*0*
4	*49.61*	*9.325*	*2325.2*	*918.2*	*5117.3*	*0*

Shear:
Shear Force : 0.1562E+03 N
Design Shear Force with Torsion Eqv : 0.1562E+03 N
Limiting Shear Stress : 0.6188E+00 N/Sq.mm
Shear Capacity of Concrete : 0.2475E+04 N
Maximum Shear Capacity : 0.1136E+05 N
Shear to be resisted by Stirrups : 0.0000E+00 N
Maximum Shear Stress(ToucMAX)= 2.84000 N/Sq.mm
SHEAR FORCE [N] 0.217E+05 0.217E+05 0.239E+05
TouV [N/Sq.mm] 0.226768 0.226768 0.28195E+00
TouC [N/Sq.mm] 0.329636 0.329636 0.112E+01

B. Flexure design

Moment(Mu) [N-mm/mm] 0.319E+04 0.345E+04 0.345E+04.
Steel Area [Sq.mm] 0.144E+03 0.144E+03 0.124E+03
Bar Details 2-# 10 @ 100.00mm 2-# 10 @ 100.00Mm

V. BEHAVIOUR OF 3D RC FRAME WITH MASONRY INFILL USING DYNAMIC ANALYSIS

Dynamic analysis of structures covers the study of behavior of flexible structures subjected to dynamic excitation. A dynamic excitation is the one which changes with time. Dynamic loads include people, wind, waves, traffic, earthquakes and blasts. If the dynamic load changes slowly, the structure's response may be approximated by a static analysis, but if it varies quickly (relative to the structure's ability to respond), the response must be determined with a dynamic analysis. Furthermore, dynamic response (displacements, stresses) are generally much higher than the corresponding static displacements for same loading amplitudes, especially at resonant conditions.

A. Method of analysis

1) Response Spectrum Analysis

This approach permits the multiple modes of response of a building to be taken into account (in the frequency domain). This is required in in many building codes for all except for very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonics". Computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the

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structure. In this we have to calculate the magnitude of the forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following:

- Absolute – peak values are added together
- Square root of the sum of the squares (SRSS)
- Complete quadratic combination (CQC) – a method that is an improvement on SRSS for closely spaced modes

B. Analytical results for the loads of 11kN, 15kN & 17kN

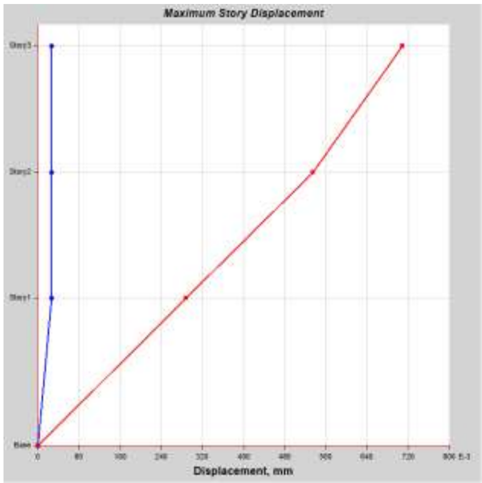

Fig. 6.1: Maximum Storey Displacement

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m		*mm*	*mm*
Story3	*2.85*	*Top*	*0.263E+02*	*0.7*
Story2	*1.95*	*Top*	*0.2634E+02*	*0.5*
Story1	*1.05*	*Top*	*0.2645E+02*	*0.3*
Base	*0*	*Top*	*0*	*0*

Table – 1:

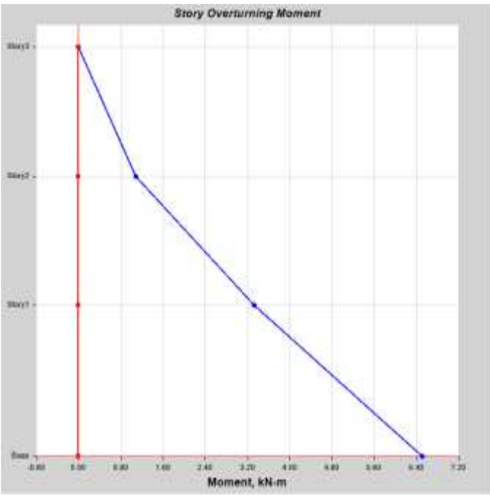

Fig. 6.2: Storey Overturning Moment

Table – 2

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m		*(E+02)xkN-m*	*kN-m*
Story3	*2.85*	*Top*	*0*	*0*
Story2	*1.95*	*Top*	*10.798*	*0*
Story1	*1.05*	*Top*	*33.326*	*0*
Base	*0*	*Top*	*65.106*	*0*

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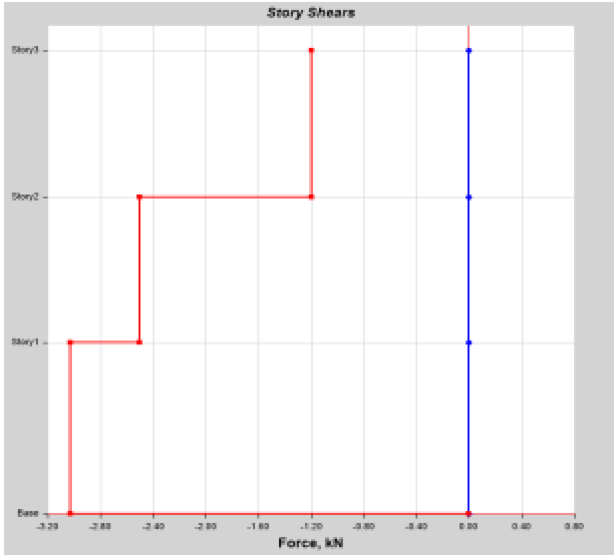

Fig. 6.3: Storey Shears

Table – 3

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story3	2.85	Top	0	1.1997
		Bottom	0	1.1997
Story2	1.95	Top	0	2.5031
		Bottom	0	2.5031
Story1	1.05	Top	0	3.0266
		Bottom	0	3.0266
Base	0	Top	0	0
		Bottom	0	0

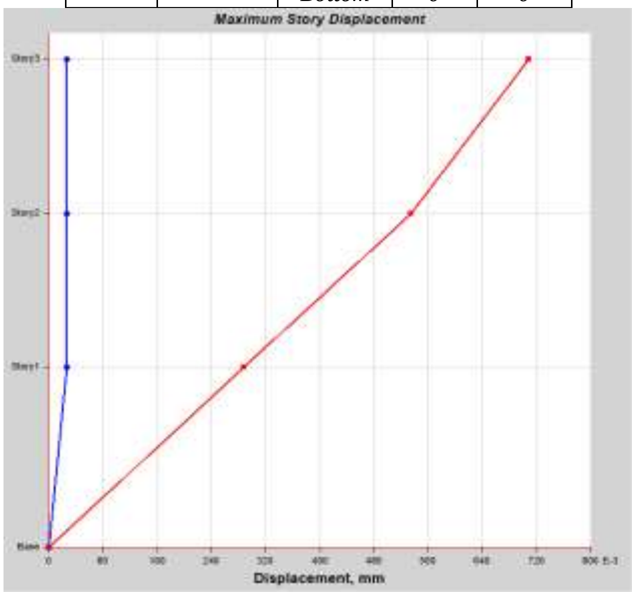

Fig. 6.4: LOADS 15kN Displacement

Table – 4

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story3	2.85	Top	0.263E+02	0.7
Story2	1.95	Top	0.2634E+02	0.5
Story1	1.05	Top	0.2645E+02	0.3
Base	0	Top	0	0

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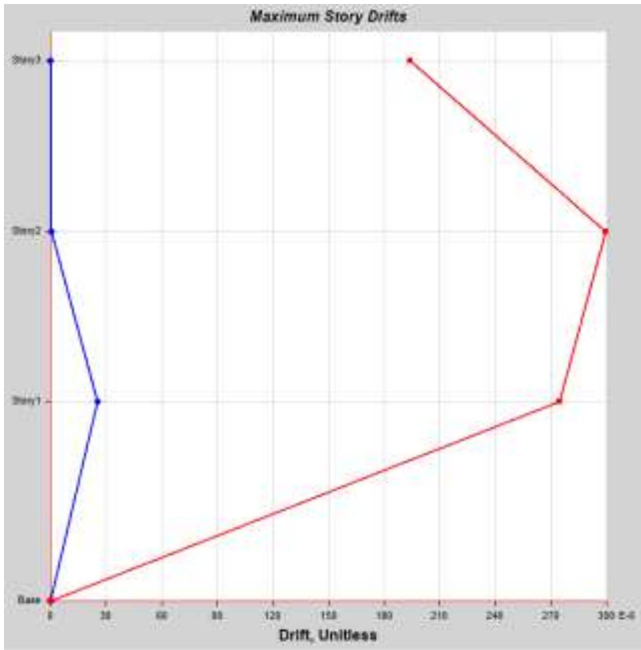

Fig. 6.5: Maximum storey drift

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m			
Story3	*2.85*	*Top*	*1.514E-07*	*0.000194*
Story2	*1.95*	*Top*	*4.327E-07*	*0.0003*
Story1	*1.05*	*Top*	*0.000025*	*0.000275*
Base	*0*	*Top*	*0*	*0*

Table – 5

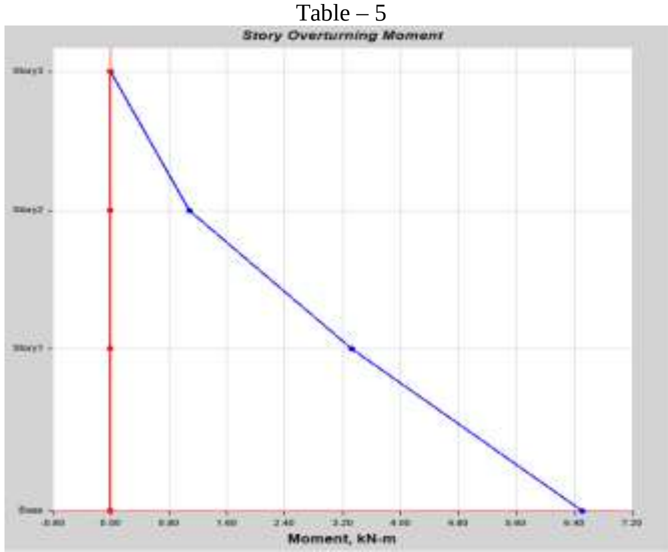

Fig. 6.6: Overturning moment

Story	Elevation	Location	X-Dir	Y-Dir
	m		(E+02xkN-m)	kN-m
Story3	2.85	Top	0	0
Story2	1.95	Top	10.798	0
Story1	1.05	Top	33.326	0
Base	0	Top	65.106	0

Table – 6

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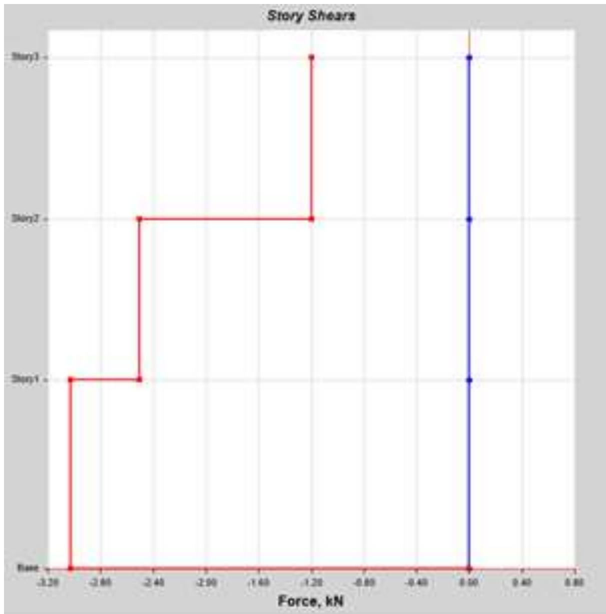

Fig. 6.7: Storey Shears

Table - 7

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m		*kN*	*kN*
Story3	*2.85*	*Top*	*0*	*1.1997*
		Bottom	*0*	*1.1997*
Story2	*1.95*	*Top*	*0*	*2.5031*
		Bottom	*0*	*2.5031*
Story1	*1.05*	*Top*	*0*	*3.0266*
		Bottom	*0*	*3.0266*
Base	*0*	*Top*	*0*	*0*
		Bottom	*0*	*0*

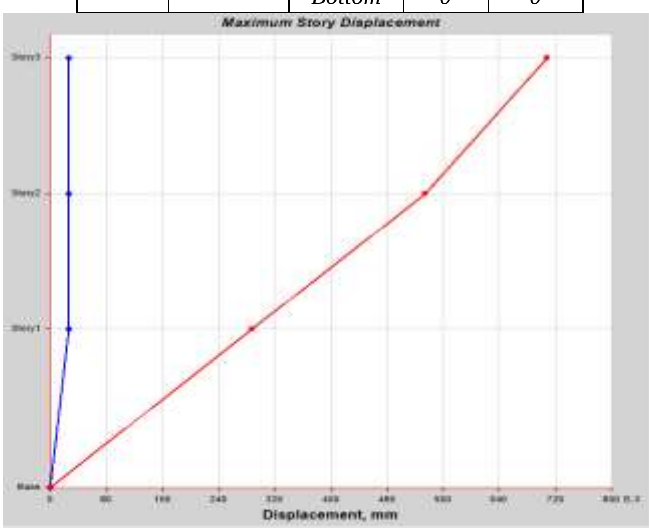

Fig. 6.8: LOADS 17kN Maximum Storey Displacement

Table - 8

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m		*mm*	*mm*
Story3	*2.85*	*Top*	*0.263E+02*	*0.7*
Story2	*1.95*	*Top*	*0.2634E+02*	*0.5*
Story1	*1.05*	*Top*	*0.2645E+02*	*0.3*
Base	*0*	*Top*	*0*	*0*

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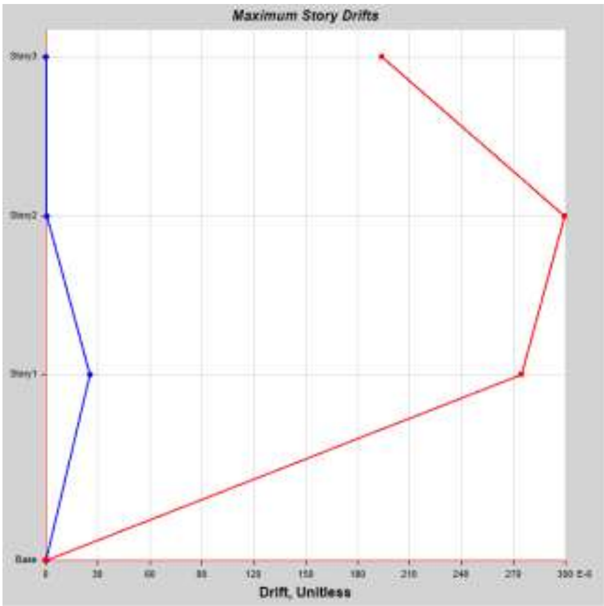

Fig. 6.9: Maximum Storey Drifts

Table - 9

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m			
Story3	*2.85*	*Top*	*1.514E+07*	*0.000194*
Story2	*1.95*	*Top*	*4.327E+07*	*0.0003*
Story1	*1.05*	*Top*	*25E+2*	*0.000275*
Base	*0*	*Top*	*0*	*0*

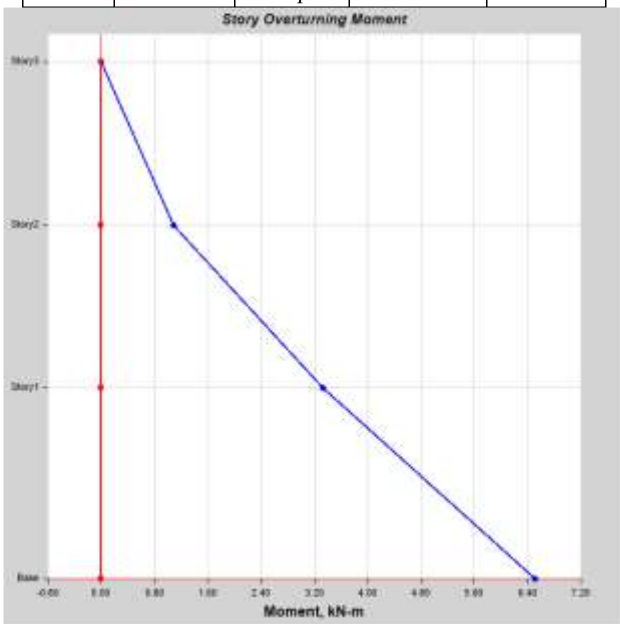

Fig. 6.10: Storey Overturning Moment

Table – 10

Story	*Elevation*	*Location*	*X-Dir*	*Y-Dir*
	m		*kN-m*	*kN-m*
Story3	*2.85*	*Top*	*0*	*0*
Story2	*1.95*	*Top*	*10.798*	*0*
Story1	*1.05*	*Top*	*33.326*	*0*
Base	*0*	*Top*	*65.106*	*0*

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VI. RESULTS AND DISCUSSIONS

A. *Analytical results*

Table – 11
Modal Periods and Frequencies :11kn

Case	*Mode*	*Period sec*	*Frequency cyc/sec*	*Circular Frequency rad/sec*	*Eigenvalue rad²/sec²*
Modal	*1*	*0.171*	*3.864*	*36.8449*	*1357.5447*
Modal	*2*	*0.145*	*4.911*	*43.4217*	*1885.4483*
Modal	*3*	*0.14*	*5163*	*45.0055*	*2025.492*

Table – 12
Modal Periods and Frequencies:15kN

Case	*Mode*	*Period sec*	*Frequency cyc/sec*	*Circular Frequency rad/sec*	*Eigenvalue rad²/sec²*
Modal	*1*	*0.171*	*3.864*	*36.8449*	*1357.5447*
Modal	*2*	*0.145*	*4.911*	*43.4217*	*1885.4484*
Modal	*3*	*0.14*	*5.163*	*45.0055*	*2025.492*

Table – 13
Modal Periods and Frequencies:17kN

Case	*Mode*	*Period sec*	*Frequency cyc/sec*	*Circular Frequency rad/sec*	*Eigenvalue rad²/sec²*
Modal	*1*	*0.172*	*3.825*	*36.5995*	*1339.5267*
Modal	*2*	*0.144*	*4.965*	*43.76*	*1914.9417*
Modal	*3*	*0.139*	*5.202*	*45.2495*	*2047.5182*

Table – 14
Comparative results

Comparison	*Experimental values*	*Analytical values*
Base Shear(kN)	*2.175*	*2.5031*
Displacement (mm)	*23.83*	*26.39*
Frequency	*3Hz*	*3.86 HZ*
Storey drift	*1.423E+06*	*1.514E+07*
Overturning moment (kN/m)	*11.71*	*10.798*
Response spectrum values (mm)	*1.5*	*1.45*

VII. CONCLUSION

- The stiffness increases when the displacement of the structure decreases
- The extent of sway at initial loads is appreciably significant and sway decay is predominant at higher intensity of loading and this sway absorption is due to masonry infills.
- The displacement is found to be more in the structure where the in-fills are not present.
- The masonry infill wall is more significant in small structures but, when the height of the structure increases, the effect of masonry infill wall reduces.
- The decay potential in absolute acceleration recedes by 12.3% for the frames with slabs, highlighting the addition of weight component effects.
- The shear and stiffness values are found to be increases with the increase in the loads
- The infill wall enhances the lateral stiffness of the structures, however the presence of openings within the infill wall would reduce the lateral stiffness.

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