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Seismic Analysis Of The Impact Of Infill Wall On Irregular RC Building With Varying Re-Entrant Corner

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Abstract: Masonry infill walls are usually used as partition walls and external walls to fill the space left by the RC building structure. The effect of an infilled wall is often ignored in the normal practice of designing RC building frames, which can lead to unsafe and expensive designs. Infill walls alter the behavior of RC frame structures by making them stiffer under lateral load. Therefore, the effect of infill masonry wall should be taken into account for safe design. Due to the limited availability of building space in desirable sites in metropolitan cities, architects have been forced to design structures with asymmetrical shapes in the modern age. Re-entrant building designs effectively used f irregular or limited plots to enhance space usage in densely populated locations. The redistribution of forces and displacements within the structure is caused by the considering the infill wall. Increase in the stiffness due to infill wall results in increased in base shear and story shear significantly as well as natural time period, story displacement and story drift is decreases across all the model. Hence for safe design, the effect of infill wall in must be considered in seismic analysis

Key Terms **–** Infill wall, Response Spectrum,Re-entrant corner

I INTRODUCTION

Generally in standard design practice the URM infill wall is considered as non-structural element. However a building's behaviour under lateral loads is altered when infill walls are taken into account. Which can results in unsafe and uneconomical design. Infill wall increase the stiffness of the RC frame and alter the behaviour of RC frame structure under lateral load. Therefore, the effect of infill masonry wall should be taken into account for safe design

In the modern era, the scarcity of building space in locations of prime importance in high-tier cities has led architects to plan buildings that are asymmetrical in shape. Re-entrant building design maximize space utilization in dense urban areas by efficiently using irregular or constrained plots. These irregularities bring different challenges for a structural engineer who must design the building in such a way that it can resist these lateral forces and perform appropriately in these critical situations without putting the life of the structure or its occupants in danger.

1.1 Infill wall

R.C. structures with masonry work infill walls have been widely used for commercial, industrial, and residential development. Bricks or concrete blocks are typically utilized as masonry infill boards to cover the spaces between R.C. frames. The brick work infill boards are typically viewed as non-structural elements and are not taken into account during the study and design of the structure. However, research has shown that the actual presence of infill walls has a major impact on how a reinforced concrete structure frame responds to earthquakes. Analysis shows that the weight of the R.C. building increased when the effect of infill was considered. The weight of the building influences the inertial forces produced by earthquake movement, however infill improves and stiffens the reinforced concrete structure while shortening its natural duration. Therefore, the influence of an infill masonry wall should be taken into account for safe design.

1.2 Re-entrant Corner

According to IS 1893: 2016(Part-1) a building is said to have a re-entrant corner in any plan direction when its structural configuration in plan has a projection of size greater than 15 percent of its overall plan dimension in that direction. A re-entrant building is a building with re-entrant corners, which are inside corners that form an angle of 180° or less. Re-entrant corners can occur in buildings with L-, U-, E-, H-, T-, +, or O-shapes

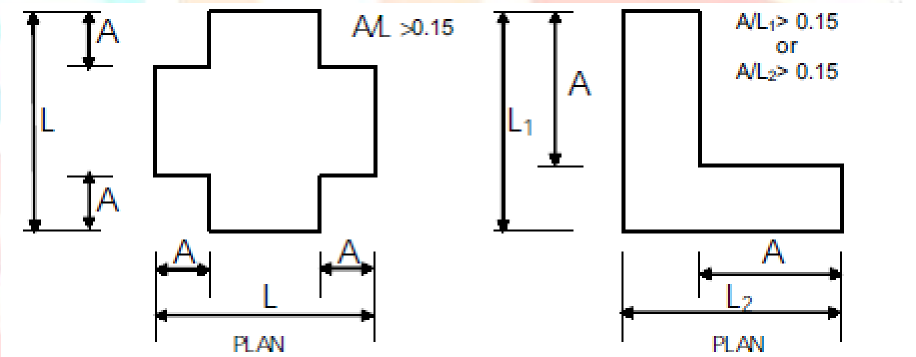

Figure 1: Re-entrant corner [Reference IS 1893 (Part 1): 2016]

Re-entrant building are designed in the urban area to maximize space utilization in dense urban areas by efficiently using irregular or constrained plots. Re-entrant corners are sometimes provided from the aesthetical point as its unique shape improves the appearance of the structure. These re-entrant corners bring different challenges for a structural engineer who must design the building in such a way that it can resist these lateral forces and perform appropriately in these critical situations without putting the life of the structure or its occupants in danger.

II OBJECTIVE OF STUDY

Generally in standard design practice the URM infill wall is considered as non-structural element. However a building's behaviour under lateral loads is altered when infill walls are taken into account. In the present work aims to parametric study of bare and infilled irregular RC building situated in soft soil with varying re-entrant corner, Re-entrant ratio and their effects on Time period, storey shear, base shear, Floor displacement and storey drift are to be studied. The primary objective of the study is to:

(1) Analyse the impact of infill walls on seismic behaviour of RC frame.
(2) Determine the effect of different re-entrant ratio in bare and infilled RC frame.
(3) Conduct a parametric study using varying re-entrant ratios to understand their influence on key seismic parameters such as time period, base shear, storey shear, floor displacement, storey drift, and vertical settlement.

III RESPONSE SPECTRUM METHOD

Response spectrum method is commonly used approach in structural dyna Spectra for Response spectra method Spectra for Response spectra method mics for calculating a structure's maximum response to dynamic loading—particularly seismic loads like earthquake. It simplifies the complex process of dynamic analysis by utilizing pre-calculated response spectra.

Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period. The response spectrum represents the point at which a single damping ratio-based SDOF system exhibits its highest response. Response spectra thus helps in determining the peak structural responses under linear range, which can be utilized to determine the lateral forces created in a structure as a result of an earthquake, thereby facilitating the design of structures that are earthquake-resistant**.**

For designing horizontal seismic forces coefficient A_h for a structure shall be determined by following equation

$$A_h = \frac{Z\ I\ S_a}{2\ R\ g}$$

Where Z = Zone factor as per table 3 of IS1893:2016(Part-1)

I = Importance factor as per table 8 of IS1893:2016(Part-1)

R = Response reduction factor as per table 9 of IS1893:2016(Part-1)

Sa/g = Average response acceleration coefficient as per IS1893:2016(Part-1) shown in figure 2

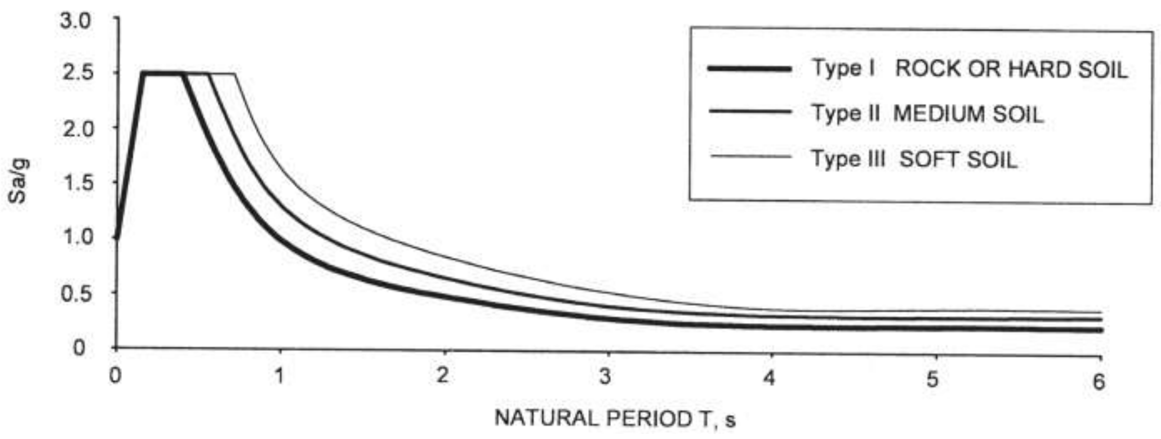

Figure 2: Spectra for Response spectra method [Reference IS 1893 (Part 1): 2016]

Design lateral Force V_b is determined by the equation

$$V_b = A_h \, X \text{ W}$$

Where A_h = Horizontal seismic coefficient

W = Seismic weight of the building

IV MODEL STRUCUTURAL CONFIGRATION

The buildings considered are Reinforced concrete frame building of G+7 storeys situated in Zone IV with Plan irregularity due to Re-entrant corner as per IS 1893:2016(part 1). Plan of four models, Regular model, L1- Model, L2- Model, L3- Model are shown in Figure 3 and elevation of all the model is same for all bare frame and infill models shown in the figure 4 and figure 5 respectively.

Table 1: The plan configuration

R Model	Regular building with 10BAY X 10 BAY
L1 Model	Re-entrant corner in L shape. Both projections provided are 20% in X-direction and Y-direction respectively
L2 Model	Re-entrant corner in L shape. Both projections provided are 40% in X-direction and Y-direction respectively
L3 Model	Re-entrant corner in L shape. Both projections provided are 60% in X-direction and Y-direction respectively

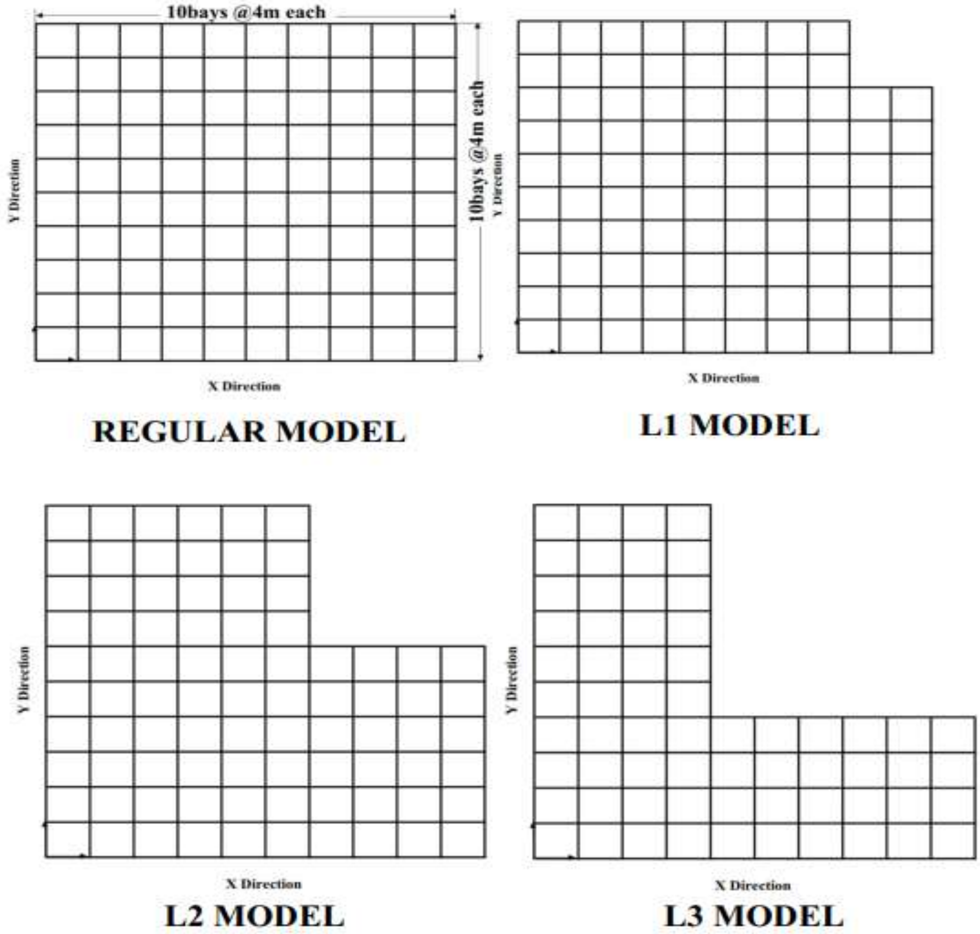

Figure 3: Plan of all models

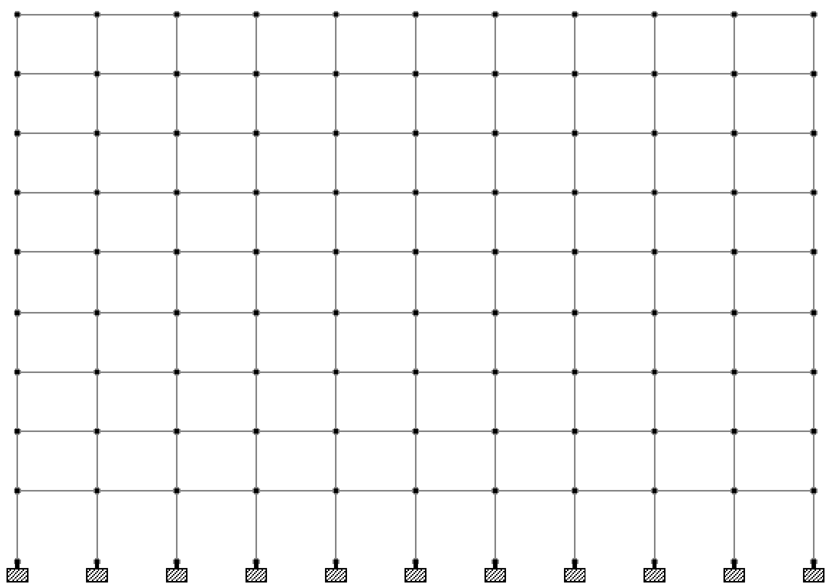

Figure 4: Elevation of bare frame

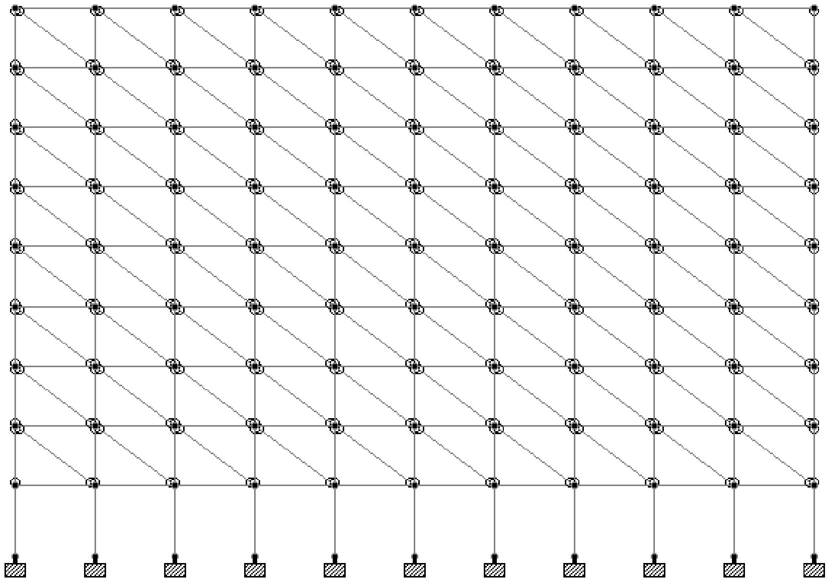

Figure 5: Elevation of infill frame

The properties consider for modelling and analysis of the building are listed in the table 2

Table 2: Information of the models

S.No.	Description	Value
1	No. of storey	G+7
2	Floor to floor height	3m
3	Thickness of slab	125mm
4	Size of column	600mmX600mm
5	Size of Beam	250mmX400mm
6	Size of foundation	3.5mX3.5m
7	Depth of foundation from plinth level	3.5m
8	Thickness of foundation	600mm
9	Thickness of wall	230mm
10	Unit weight of concrete	25KN/m3
11	Total dead load on the Floor (including floor finish load)	4 KN/m2
12	Dead load of brick wall	14KN/m
13	Live load on floor	3KN/m2
14	Live load on roof	1.5KN//m2
15	Zone , Z	IV, 0.24
16	Response reduction factor, R	5 (SMRF)
17	Importance factor, I	1.2
19	Type of structure, ST	1 (RCC frame building)
20	Type of soil	soft soil(N<10)
21	Damping ratio	0.05 for Concrete

EQ_X =Earthquake load in X direction is calculated as per IS1893:2016(Part-1)

EQ_y =Earthquake load in X direction is calculated as per IS1893:2016(Part-1)

The load combinations for analysis and design of structure {as per IS: 456-2000 and IS: 1893 (Part 1)-2016}

- 1.5(DL+LL)
- 1.2(DL+LL+EQ_X)
- 1.2(DL+LL+EQ_y)
- 1.2(DL+LL-EQ_X)
- 1.2(DL+LL-EQ_y)
- 1.5(DL+EQ_X)
- 1.5(DL-EQ_X)
- 1.5(DL+EQ_y)
- 1.5(DL-EQ_y)
- 0.9DL+1.5EQ_X
- 0.9DL-1.5EQ_X
- 0.9DL+1.5EQ_y
- 0.9DL-1.5EQ_y

Where x and y are the two orthogonal horizontal plan direction

V MODELLING OF URM INFILL WALL

In the present work, for modelling the Un-Reinforced Masonry (URM) infill walls, the procedure proposed in Clause 7.9 of IS 1893 (Part 1): 2016 is followed. The brick masonry infill wall is modelled as an equivalent diagonal compression strut element. Both ends of the equivalent diagonal strut connect beam-to-column junctions with pin joint connection. Rigid joints connect the beams and columns. The effective width, strength and elastic modulus of the infill wall are calculated using the expression in Clause 7.9 of IS 1893 (Part 1): 2016. The length of the strut is given by the diagonal distance of the infill panel. The thickness of the equivalent diagonal strut is taken as same as the thickness of the infill wall. The mass of an infill wall should be incorporated separately as a uniform mass on the supporting beam. Modulus of the strut is taken as masonry Young's modulus, which is equivalent to $550f_m$, Where f_m is the compressive strength of masonry prism in MPa.

$$f_m = .433 {f_b}^{.64} {f_{mo}}^{.36}$$

Where f_b= Compressive strength of brick (in MPa)

f_{mo}= Compressive strength of mortar (in MPa).

According to IS 1893 (Part 1): 2016. For unreinforced masonry infill walls without any opening, width (w_{ds}) of equivalent diagonal strut shall be taken

$$w_{ds} = .175 {\alpha_h}^{-0.4} L_{ds}$$

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4E_f I_c h}}\right)$$

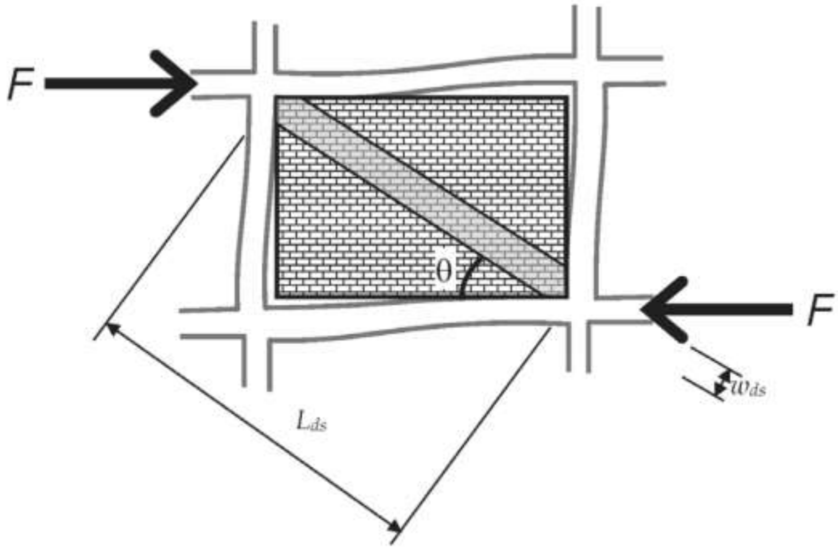

Figure 6: Equivalent diagonal strut of URM infill wall [Reference IS 1893 (Part 1): 2016]

where E_f and $E_m$are the moduli of elasticity of the materials of the RC frame and URM infill wall, respectively; Ic is the moment of inertia of the adjoining column; t is the thickness of the infill wall; h is the clear height of URM infill wall between the top beam and bottom floor slab; h is the angle of the diagonal strut with the horizontal and L_{ds} is the diagonal length of the strut. 3D frame element in STAAD Pro Connect Edition is used for the diagonal strut, but the density is not assigned. The mass of an infill wall should be incorporated separately as a member load/mass on the supporting beam. The end moments are released so that they will act like a pin-jointed diagonal strut and will not offer any moment resistance.

VI RESULT AND DISCUSSION

6.1 Time period

Time period of different modes for Regular model and L1, L2, L3 with bare frame and infilled frame situated in soft soil is shown in the table3

Table 3: Time period of different modes for Regular model and L1, L2, L3 with bare frame and infilled frame

Mode	Time Period(sec)							
	Regular model		L1 model		L2 model		L3 model	
	bare	infill	bare	infill	bare	infill	bare	infill
1	1.73682	0.80009	1.73593	0.80055	1.75176	0.80055	2.44539	0.80393
2	1.73682	0.79506	1.73536	0.79401	1.75164	0.79401	2.43826	0.79841
3	1.63427	0.75204	1.63299	0.75163	1.65317	0.75163	2.29339	0.75644
4	0.53165	0.25541	0.53124	0.25572	0.53669	0.25572	0.69944	0.25801
5	0.53165	0.25358	0.53111	0.25321	0.53667	0.25321	0.6985	0.25603
6	0.50134	0.23935	0.50076	0.23926	0.50733	0.23926	0.66057	0.24171

Time period is increased from regular model to L1, L2, and L3 model for both bare frame and infill frame. The introduction of infill significantly reduces the time period across all models and modes as the re-entrant percentage increased from L1 to L3 model the time period is increased significantly and L3 model is having highest time period in all the modes.

6.2 Base shear

Base shear for Regular model and L1, L2, L3 with bare frame and infilled frame situated in soft is shown in the figure 7

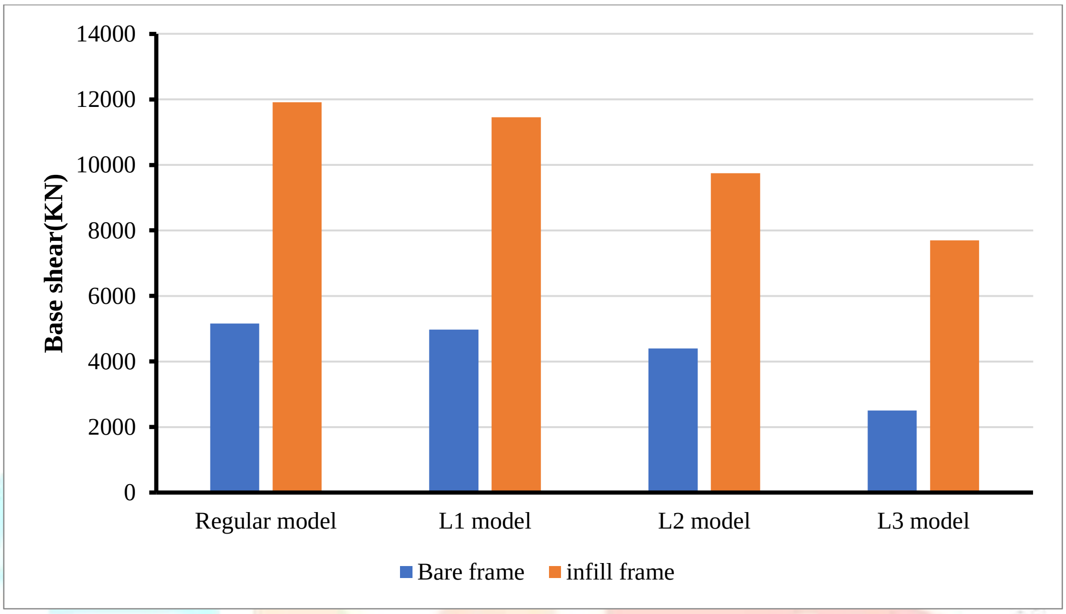

Figure 7: Base shear for Regular model and L1, L2, L3 with bare frame and infilled frame situated in soft soil.

The base shear values are significantly higher for infill frames compared to bare frames across all model for both bare frame and infilled frame. Base shear is decreasing from regular model to different re-entrant model L1, L2, L3 across model. Regular model with infilled frame is having highest base shear.

6.3 Storey shear

Storey shear for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft is shown in the figure 8

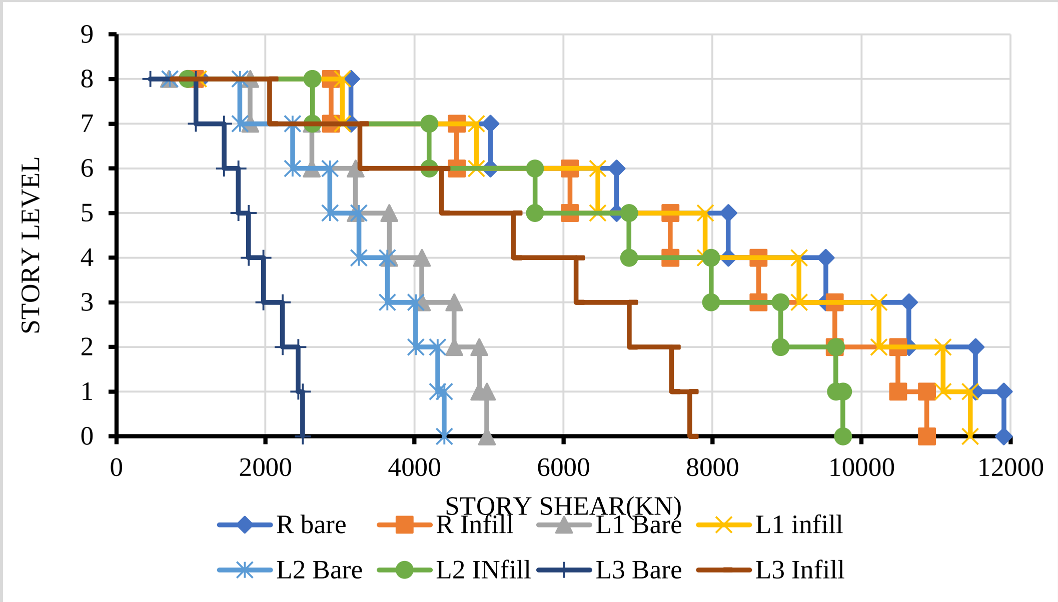

Figure 8: Storey shear for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft soil

The storey shear values are significantly higher for infill frames compared to bare frames in all story across all model for both bare frame and infilled frame. Base shear is decreasing from regular model to different re-entrant model L1, L2, L3 across model. Regular model with infilled frame is having highest storey shear in all story.

6.4 Storey displacement

Storey displacement in X direction And Y direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft is shown in the figure 9 and figure 10

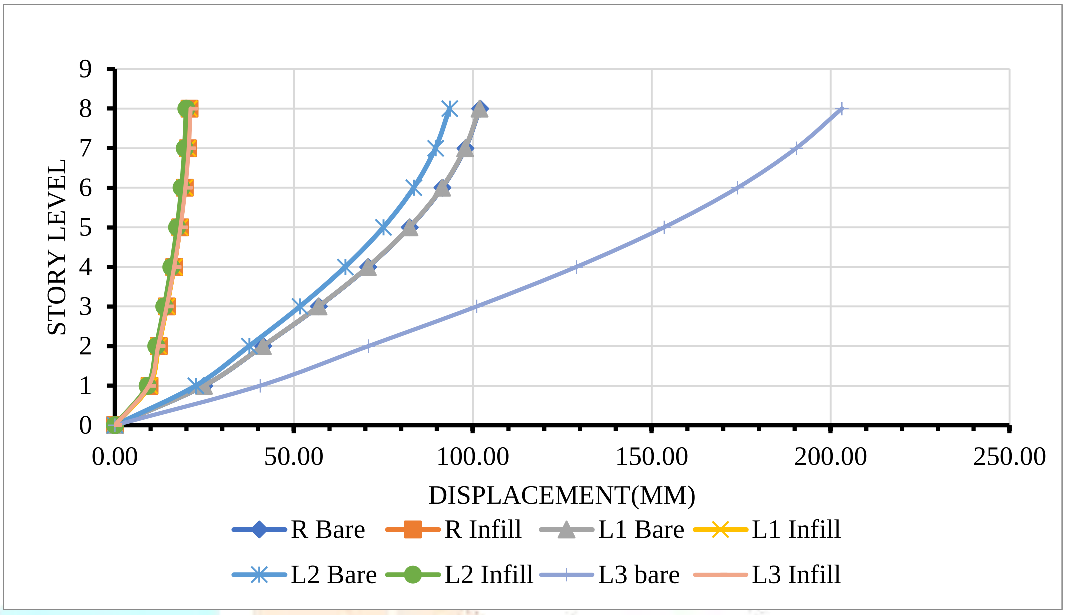

Figure 9: Storey displacement in X direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft soil

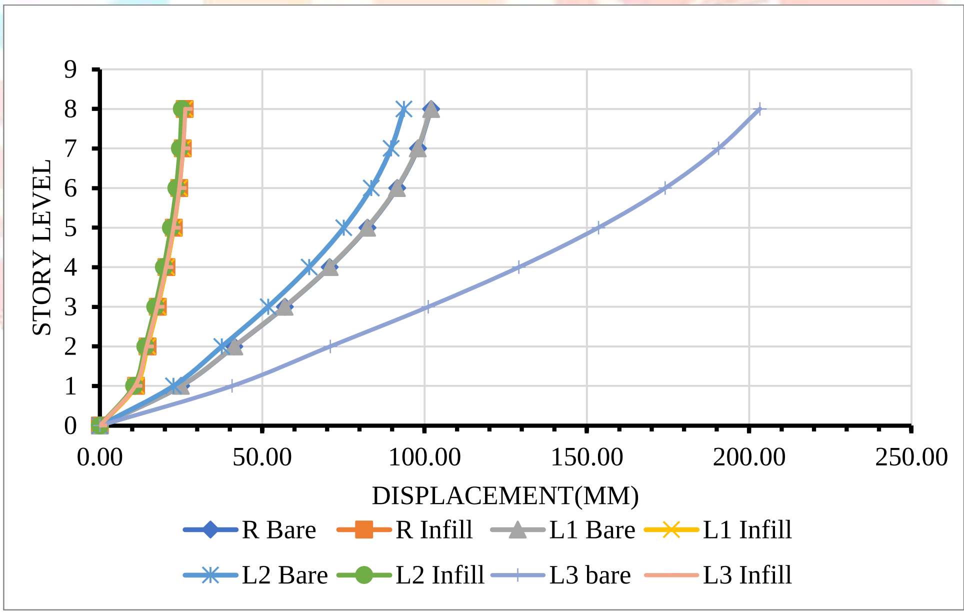

Figure 10: Storey displacement in Y direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft soil

Infill frame have significant reduction of the displacement in both x and y directions across all models and stories.L3 model have the highest displacement values in both bare frame and infill frame conditions compared to the other models, which is consistent across both x and y directions. Bare frame have similar magnitude of storey displacement in both the direction while Infill frame is having slightly higher displacement in Y direction as compare to X direction.

6.5 Storey drift

Storey drift in X direction And Y direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft is shown in the figure 11 and figure 12

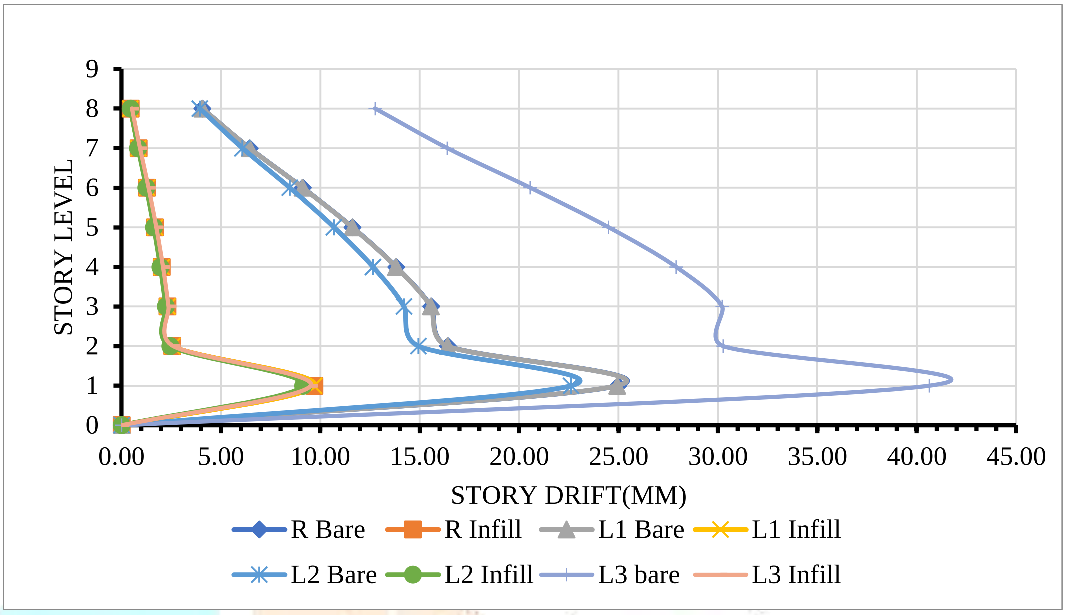

Figure 11: Storey drift in X direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft soil

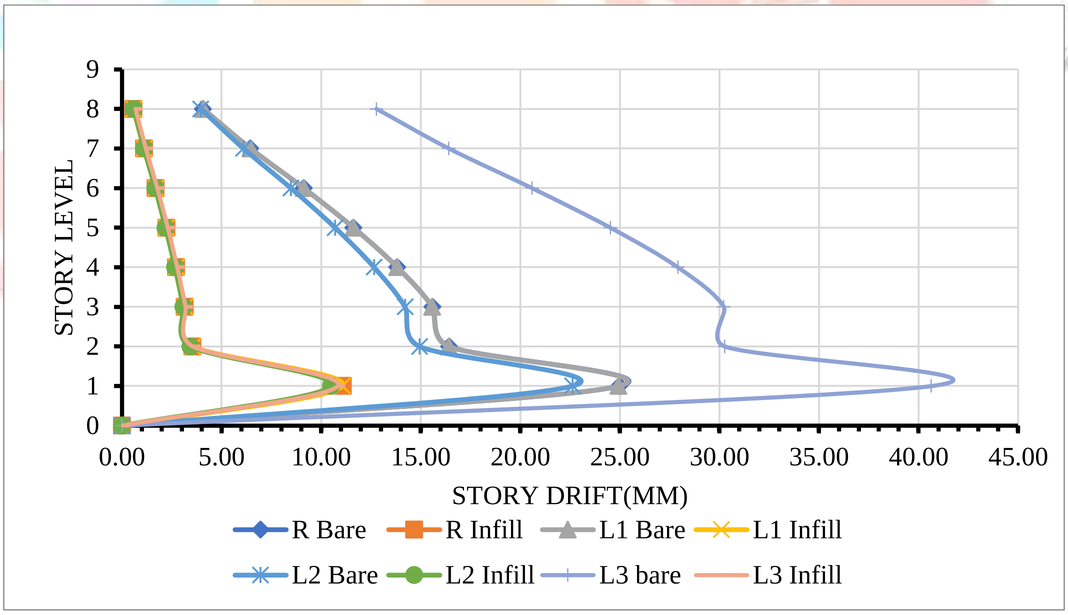

Figure 12: Storey drift in X direction for Regular model and L1, L2, L3 model with bare frame and infilled frame situated in soft soil

Infill frame structures have significantly less storey drift as compared to bare frame across all models and stories. Regular model and L1 model have same trend of storey drift variation.L2 model is having lowest story drift in all model.L3 model with bare frame is having highest drift among all the model.

VII CONCLUSION

The study's findings lead to the following conclusion:

(1) Time period is increased from regular model to L1, L2, and L3 model for both bare frame and infill frame. Infill model have significantly less time period as compare to bare model as the stiffness of the structure increases. Infill L3 Model situated in soft soil have 63% less time period as compare to bare model for mode1

(2) Base shear is significantly increased in the infilled frame indication larges lateral forces due to increase stiffness. Base shear is decreasing from regular model to re-entrant model L1, L2, L3, with regular infill model have highest base shear.

(3) Infilled regular model is having 130% more base shear as compare to bare regular model.

(4) Storey shear is significantly increased in the infilled frame indication larges lateral forces due to increase stiffness in all storey level. Storey shear is decreasing from regular model to re-entrant model L1, L2, L3, with regular infill model have highest base shear with regular infill model have highest storey shear in all level.

(5) .Infilled frame is having significant lower storey displacement in both direction due to increased stiffness.

(6) L3 model is having highest storey displacement in X direction and Y direction for both infilled and bare frame. Bare L3 frame situated in soft soil is having 6 times more roof displacement as compare to infill L3 frame

(7) L3 model is highest storey drift for both bare frame and infilled frame. Infilled frame is having significant lower storey drift in both direction due to increased stiffness in all model.

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