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Assessment of performance of Bare Frame and Infilled Frame Buildings under Seismic Load

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Abstract: *In some buildings of Dhaka city, the first storey of the RC frame building open to generate parking space called open ground storey also termed as Soft storey. In this study, the equivalent static force method is carried out for bare frame and masonry infill frame following Bangladesh National Building Code (BNBC) 2006. The study has been performed to investigate as well as compare the performances of bare, full in-filled and open ground story buildings subjected to seismic load. The paper mainly follows the procedures of ETABS 9.5.0 software in the seismic analysis of residential buildings in earthquake zone II of Bangladesh. Modeling of infill is considered by "Equivalent diagonal strut method". The performances of the buildings are determined in terms of displacement, drift and base shear. The analysis shows that the performance of an in-filled frame is much better than a bare frame structure. It is seen that the inclusion of in-fill leads to significant change in the performance. Buildings with a bare frame in the ground level reduces the performance of the structure significantly and makes them most vulnerable type of construction in earthquake prone areas.*

Keywords: *Base shear, Drift, Displacement, Equivalent diagonal strut method, Soft Storey.*

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I. Introduction

Earthquake engineering has come a long way since its birth, and seems to grow rapidly as we gain experience. Each time an earthquake happens, something new is available to learn and the profession grows to accommodate it. Both research and practice used to be mostly concerned with the design of structures that would be safe, in the sense of surviving a seismic event with minimum number of causalities structure designed to higher standards, chosen to meet the specific needs and able to remain functional after a small but relatively frequent event and being safe in a rare destructive earthquake costs slightly higher but still preferred now-a-days by building owners. Nonlinear analysis is the simplified elastic method to find the behavior of the structure in earthquake.

In last few years, the widespread damage to RC building during earthquake generated greater demand for seismic evaluation and retrofitting of existing buildings in Dhaka. Furthermore, most of our buildings built in past two decades are seismically deficient because of the lack of awareness regarding structural behavior during earthquake and reluctance to follow the code guidelines. The structures, whose performance were evaluated in this study, are designed with the provisions from BNBC, (2006). BNBC equivalent static force method of determining earthquake force is limited to the structures having height of less than 20 meters. Hence this study deals with medium rise buildings (six-storied).The purpose of the thesis is to summarize the basic concepts on which equivalent static force method analysis of medium height residential RC buildings as seen in Dhaka city and investigate the changes in structural behavior due to different infill configurations.

The proper evaluation of seismic performance is essential for decision making involved in managing the risk of infrastructures in seismically active areas like Bangladesh. With a view of evaluating the performance of building designed as per BNBC (2006), the objectives of the thesis are set as follows:

- To study the displacement, drift and base shear characteristics of bare frame structure due to seismic load.
- To study the displacement, drift and base shear characteristics of different in-filled conditions of frame structure (i.e. fully in-filled, particular floor empty and open ground storey) due to seismic load.
- To compare the displacement, drift and base shear characteristics between bare frame and in-filled frame structure.

To increase stiffness and strength of reinforced concrete (RC) frame buildings is used masonry infill. Masonry walls diagonally loaded in compression, the effect of the masonry panels in infilled frames subjected to lateral loads could be equivalent to a diagonal strut. Diagonal struts are used to resist lateral loads and lateral deflection hence control the damage caused by the earthquake.

II. Methodology

Introduction

This chapter presents the analytical procedures for evaluating the performance of existing buildings various analysis methods, both linear and nonlinear are available for the analysis of existing concrete buildings. Linear analysis method includes code static lateral force procedures, code dynamic lateral force procedures and elastic procedures using demand capacity ratios. Simplified nonlinear analysis includes the capacity spectrum method (CSM), the displacement coefficient method and the secant method. User should choose appropriate method to determine most probable earthquake load depending upon configuration of the structure, performance that is to be achieved.

2.1 Equivalent Static Method

Earthquake is a dynamic load. Due to earthquake load, a structures vibras in different mood shapes and the load on the structure, its intensities and direction are depend on the mode shapes for example, the Fig.2.1 shows first three fundamental modes of a shear type building. From Fig.2.1 it is seen that different mode shape of structure causes different load intensities and direction to the structure. If only first mode is considered and assumed linear mode shape then the structure experiences a triangular shaped lateral load. Equivalent static load method as adopted in building codes is simple approximation of first mode of variation with the mode shape considered as linear.

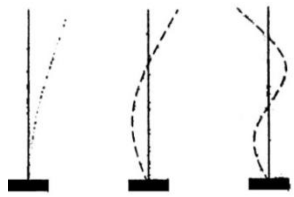


Figure 1: Fundamental mode of a shear type structure

Therefore, for a building of homogeneous mass, the lateral force is likely to be as shown in Fig. 2.2 .However for building with higher time period (flexible one), the effect of higher mood become important. This is accounted by considering an extra concentrated force Ft at the top of the building. For regular shaped and non-slender building the equivalent static load method gives an approximate estimation of seismic force demand on the structure.

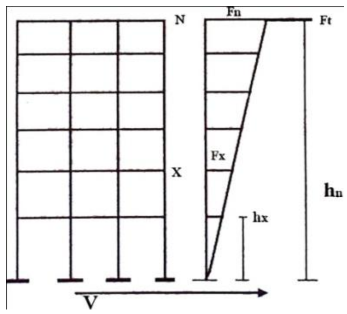


Figure 2: Distribution of lateral forces in multi-storey building

2.1 Equivalent Force Method

The total design base shear for a seismic zone is given by,

$$V = \frac{ZIC}{R} W$$

Where,

Z = seismic zone co-efficient

I = Structural importance co-efficient

C = Numerical co-efficient = 1.25S/T^(2/3)

T = Time period = Ct (hn) 3/4

Where,

Ct = 0.083 for moment resisting frame

= 0.073 for reinforced concrete frame and eccentric still frame

= 0.049 for all other structural analysis

h_n = Height in meter above base level n

S = Site co-efficient

R = Response modification co-efficient; W = Total seismic dead load

Lateral force calculated from the above equation known as base shear V, shall be distributed along the height of the structure in accordance with the following equation

$$V = F_t \sum_{i=1}^{i=n} F_i$$

Where,

Fi = Lateral force applied at storey level I and

Ft = Concentrated lateral force considered at the top of the building inadition to the force Fn

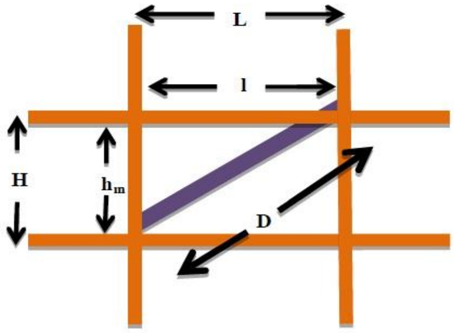
III. Method of replacement of infill

Introduction

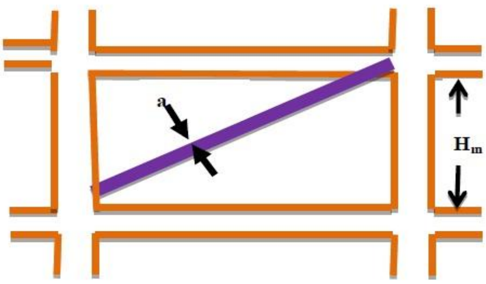
Moghaddam and Dowling (1987) [2] have reported an extensive review of research on Infilled frames through the mid 1980's. Holmes (1961) [1] proposed replacing the infill by an equilateral pin joined diagonal strut of the same material with a width one-third of the in fill's diagonal length.

3.1 Equivalent Strut Method

Saneinejad and Hobbs (1995) developed a method based on the equivalent diagonal strut approach for the analysis and design of steel and concrete frames with concrete or masonry infill walls subjected to in-plane forces. The proposed analytical development assumes that the contribution of the masonry Infilled panel in fig. to the response of the Infilled frame can be modeled by "replacing the panel" by a system of two diagonal masonry compression struts shown in fig. However, the combination of both diagonal struts provides a lateral load resisting mechanism for the opposite lateral direction of loading.



(a) Strut Geometry



(b) Placement of Strut

3.2 Calculation of Equivalent Strut Width

L = 16 feet

H = 10 feet

Length of Strut = $\sqrt{(16)^2 + (10)^2}$=18.86 feet

Width of Strut = $\frac{1}{3}$x Length of Strut

= 6.28 feet

Area = 75*5 inch2 = 375 inch2

IV. Building studied

4.1 Material Properties

- Default concrete materials was used in the design of RC beam and column having the following property,
- Cylindrical strength of concrete f'c = 4 ksi
- Yield strength of concrete, fy = 60 ksi
- Modulus of concrete, Ec = 3605 ksi
- Standard steel bar is used as reinforced material.

4.2 Geometry
- 3-D models of buildings are used for analysis
- Partition wall is not modeled, applied as dead load on slab
- Structure is assumed to have strong column weak beam
- All supports are fixed support

4.3 Loading Condition
4.3.1 Gravity load
- Self-weight is calculated automatically by the programme
- Total dead load of 40 psf for floor is applied
- All partition wall were assumed to be located directly on beams and load of 25plf is applied
- Live load of 40 psf is considered

4.3.2 Earthquake load
- Calculated by UBC 94
- Seismic zone coefficient, Z = 0.15
- Seismic modification factor, R = 8
- Site coefficient, S = 1.5
- Structure importance coefficient, I = 1

4.4 Design Details

Table 1: Properties of slab, beam & column

Member	Size (inch)	Load	
Slab	5	Live load	40 psf
Beam	12x15	Partition wall	25 psf
Grade Beam	12x18	Floor finish	25 psf
Column	20x20	f'c = 4 ksi	fy = 60 ksi

Table 2: Properties of equivalent brace

Width (inch)	Thickness (inch)	Cross-sectional area ($inch^2$)
75	5	375

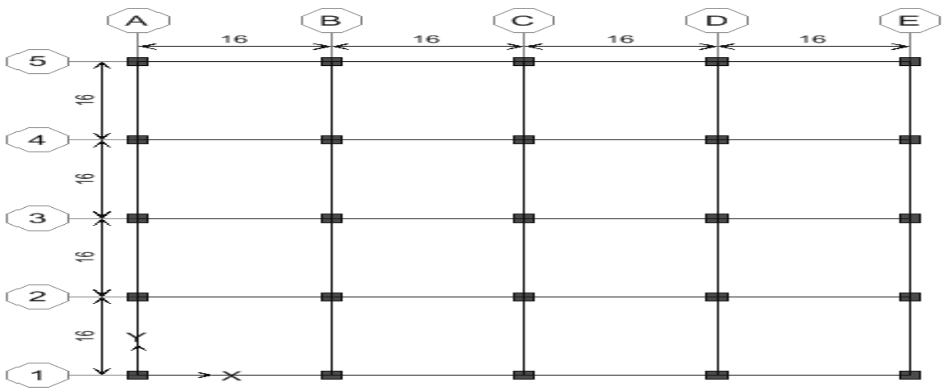
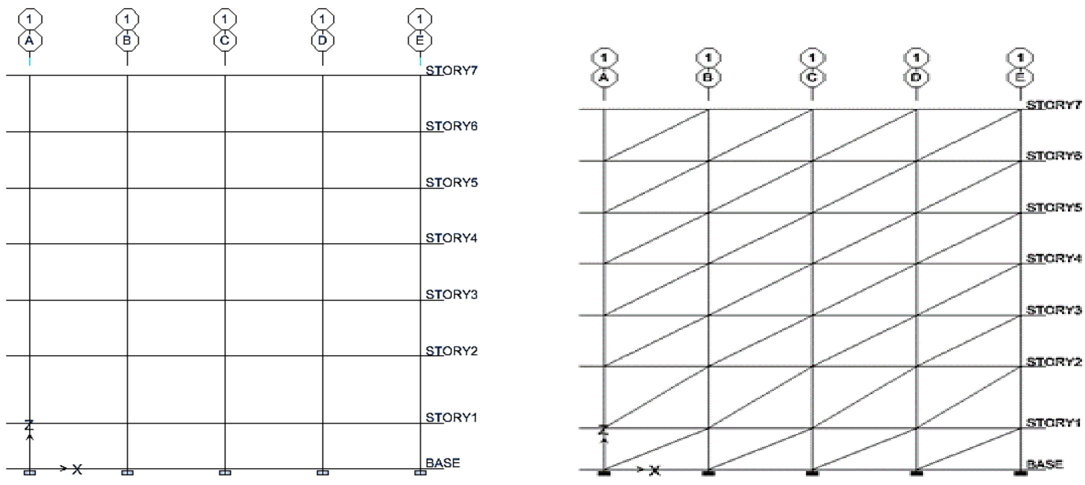
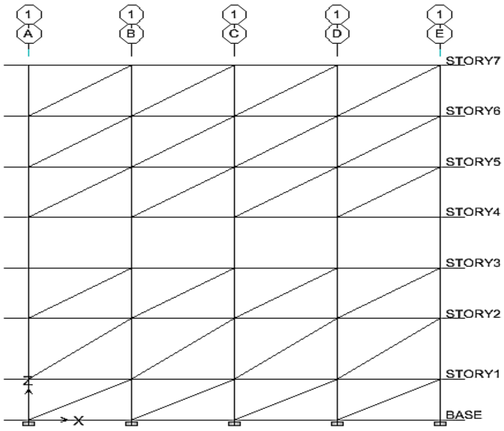


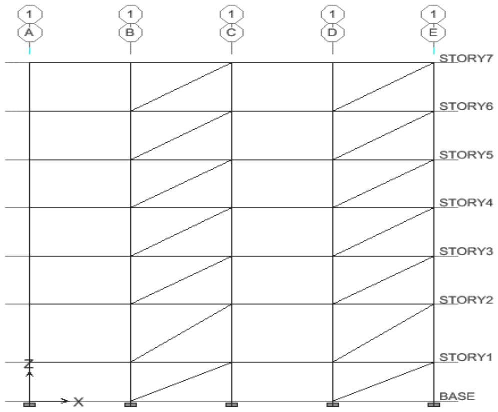
Figure 3: Plan of the building



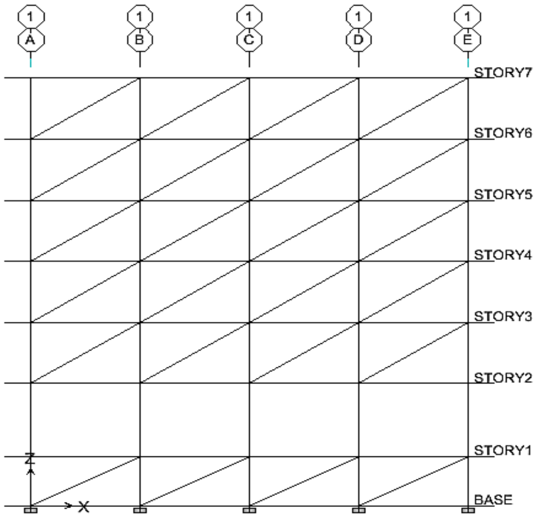
(a) In-filled Frame Structure (b) Bare Frame Structure



(c) Structure with no Partition Walls



(d) Structure with alternative Partition Walls



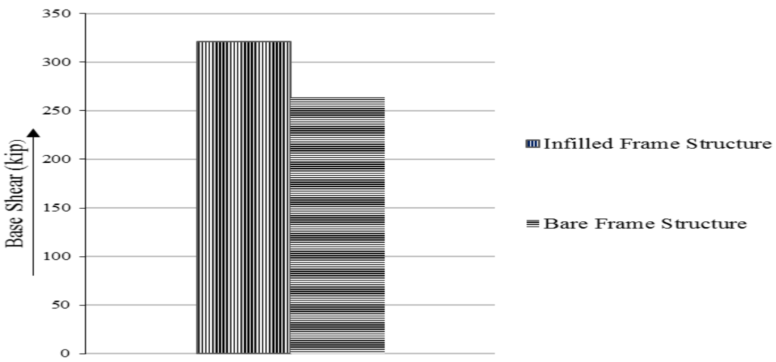
(e) Open Ground Story Structure

Figure 4: Elevation of the building

V. Results and discussions

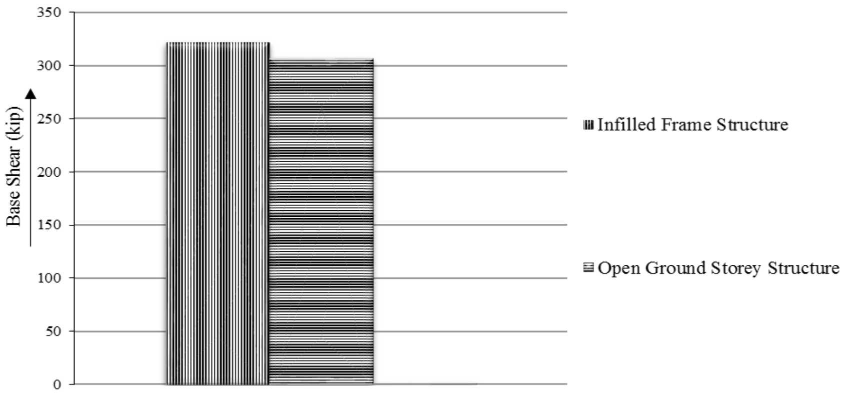
5.1 Base Shear

(a) The base shear of in-filled frame structure and bare frame structure is 321 kip and 264 kip respectively. It is observed that base shear of in-filled frame structure 17.75% higher than that of bare frame structure.



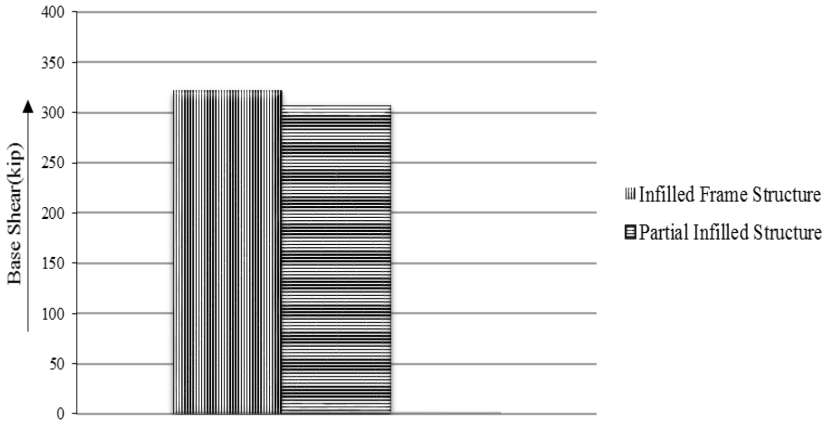
(a) For Infilled frame & Bare frame

(b)The base shear of open ground storey structure is 306 kip. It is also observed that base shear of in-filled frame structure 4.67% higher than that of open ground storey structure.



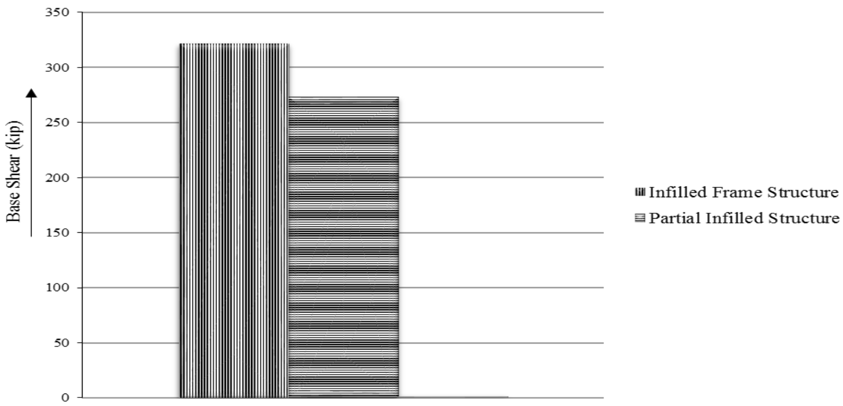
(b) For Infilled frame vs Open Ground Storey

(c) The base shear of structure with no partition walls on a particular floor (partial infilled) is 307 kip. It is also observed that base shear of in-filled frame structure 4.36% higher than that of structure with no partition walls on a particular floor (partial infilled).



(c) For Infilled frame vs Partial Infilled

(d)The base shear of structure with alternative partition walls (partial infilled) is 273 kip. It is also observed that base shear of in-filled frame structure 14.95% higher than that of structure with alternative partition walls (partial infilled).



(d) For Infilled frame vs Partial Infilled

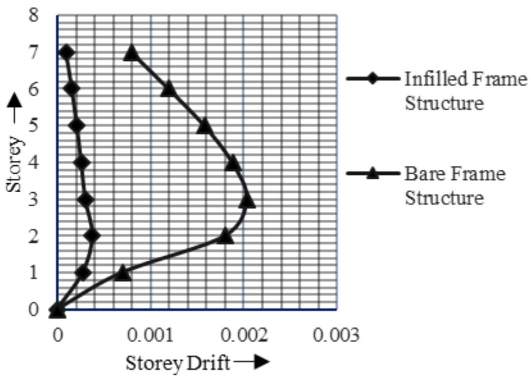
Fig. 5: Comparison of Base Shear

Table-3: Comparison of Base Shear

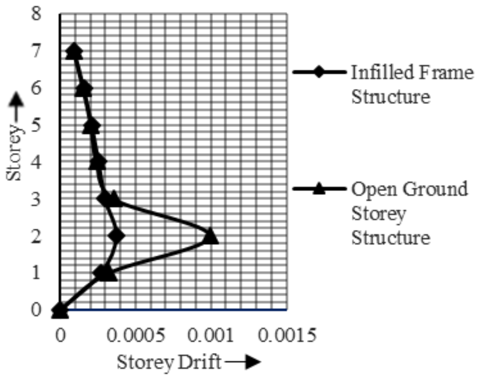
Type	Base Shear (kip)	% Variation (Comparison with In-filled Frame Structure)
In-filled Frame Structure	321	17.75
Bare Frame Structure	264	17.75
Open Ground Storey Structure	306	4.67
Structure with no partition walls on a particular floor	307	4.36
Structure with alternative partition walls	273	14.95

5.2 Lateral Drift

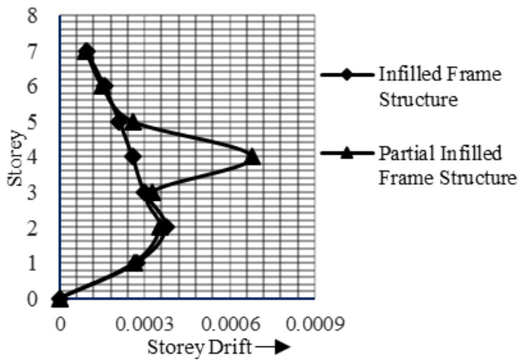
(a)The storey drift of in-filled frame structure and bare frame structure is 0.000374 inch and 0.0002036 respectively. It is observed that storey drift of in-filled frame structure 81.63% smaller than that of bare frame structure. (b)The storey drift of open ground storey structure is 0.000993 inch. It is also observed that storey drift of in-filled frame structure 62.33% smaller than that of open ground storey structure. (c) The storey drift of structure with no partition walls on a particular floor (partial infilled) is 0.000678 inch. It is also observed that storey drift of in-filled frame structure 44.83% smaller than that of structure with no partition walls on a particular floor (partial infilled). (d) The storey drift of structure with alternative partition walls (partial infilled) is 0.000475 inch. It is also observed that storey drift of in-filled frame structure 21.26% smaller than that of structure with alternative partition walls (partial infilled).



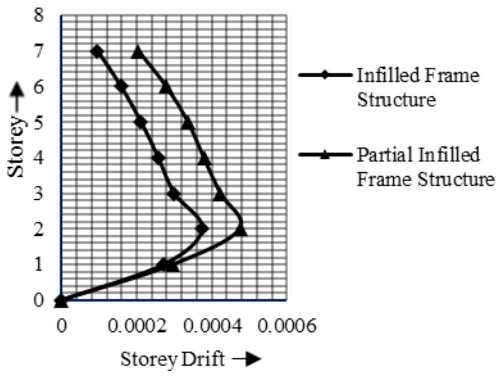
(a) For Infilled frame & Bare frame



(b) For Infilled frame & Open Ground Storey



(c)For Infilled frame & Partial Infilled



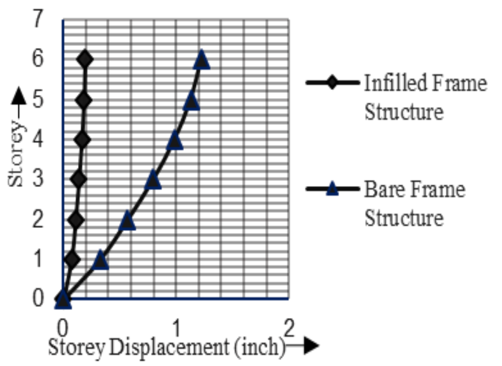
(d) For Infilled frame & Partial Infilled

Table-4: Comparison of Storey Drift

Type	Maximum Storey Drift (inch)	% Variation (Comparison with In-filled Frame Structure)
In-filled Frame Structure	0.000374	81.63
Bare Frame Structure	0.002036	81.63
Open Ground Storey Structure	0.000993	62.33
Structure with no Partition Walls on a Particular Floor	0.000678	44.83
Structure with alternative Partition Walls	0.000475	21.26

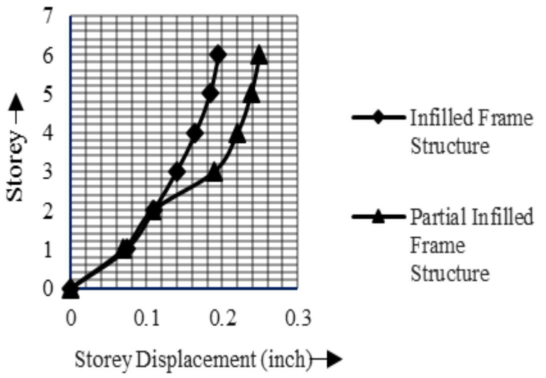
5.2 Lateral Displacement

(a) The maximum displacement of in-filled frame structure and bare frame structure is 0.1948 inch and 1.2239 inch. It is observed that displacement of infilled frame structure 84.08% smaller than that of bare frame structure. (b) The displacement of open ground storey structure is 0.2935 inch. It is also observed that displacement of in-filled frame structure 33.63% smaller than that of open ground storey structure. (c) The displacement of structure with no partition walls on a particular floor (partial infilled) is 0.2494 inch. It is also observed that displacement of in-filled frame structure 21.89% smaller than that of structure with no partition walls on a particular floor (partial infilled). (d) The displacement of structure with alternative partition walls (partial infilled) is 0.276 inch. It is also observed that displacement of in-filled frame structure 29.42% smaller than that of structure with alternative partition walls (partial infilled).

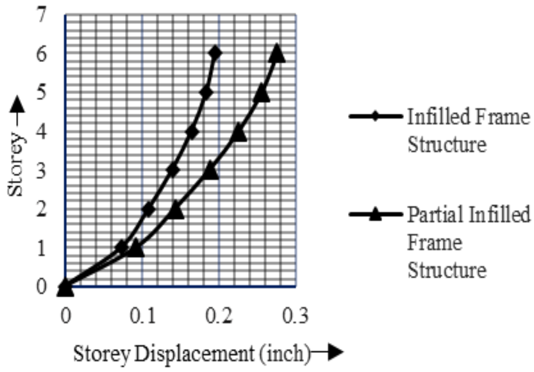


(a) For Infilled frame & Bare frame

(b) For Infilled frame & Open Ground Storey



(c) For Infilled frame & Partial Infilled



(d) For Infilled frame & Partial Infilled

Table-5: Comparison of Storey Displacement

Type	Maximum Storey Drift (inch)	% Variation (Comparison with In-filled Frame Structure)
In-filled Frame Structure	0.1948	84.08
Bare Frame Structure	1.2239	84.08
Open Ground Storey Structure	0.2935	33.63
Structure with no Partition Walls on a Particular Floor	0.2494	21.89
Structure with alternative Partition Walls	0.2760	29.42

VI. Conclusion

Based on the study the main conclusions can be summarized as follows:

- The seismic performance of full in-filled frame has been observed to be better than that of bare frame. Deformation pattern of fully in-filled frame is uniform and total deformation is the smallest among the type of structures analyzed.
- The addition of infill in the upper stories leaving the ground floor open causes significant reduction in the capacity of the structure.
- For the three types of structure considered (bare, full in-filled, open ground storey), roof displacement is the highest for bare frame and ground floor displacement is the highest for open ground storey.

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