ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EARTHQUAKE ANALYSIS OF RC BUILDING USING CEMENT INFILL WITH REGULAR AND IRREGULAR GEOMETRY

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ABSTRACT

Reinforced concrete frame buildings have become common form of construction with masonry infills in urban and semi urban areas in the world. The term infilled frame denotes a composite structure formed by the combination of a moment resisting plane frame and infill walls. The infill masonry may be of brick, concrete blocks, or stones. In the current practice of structural design in India infill walls are considered as non-structural elements and their strength and stiffness contribution are neglected. The effect of infill panels on the response of reinforced concrete frames subjected to seismic action is widely recognized and has been subject of numerous experimental and analytical investigations over last five decades. The framed building behaves differently as compared to a bare framed building (without any infill) or a fully infilled framed building under lateral load. A bare frame is much less stiffer than a fully infilled frame; it resists the applied lateral load through frame action and shows well-distributed plastic hinges at failure. In this study high rise buildings of regular and irregular geometry with 200 mm cement infill thickness under earthquake zones-V with different infill positions are considered so as to evaluate the efficient building frame. These are achieved by comparing the result with different parameter like moment, shear force, peak displacement and drift.
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KEYWORDS: Infill structure, seismic zones, framed structure, moment, forces, drift, displacements, etc.

INTRODUCTION

The most likely reason of neglecting the influence of infill walls is due to their complicated failure mode. While the infill walls show brittle failure, the reinforced concrete sustains lateral loads over large post yield deformation. Moreover past research works show that there is considerable improvement in the lateral load resisting capacity by the addition of infill walls. Inclusion of stiffness and strength of infill walls in the building frames decreases the fundamental time period compared to a bare frame and consequently increases the base shear demand and the design forces in the beams and columns. This increased design forces in the beams and columns of the buildings are not captured in the conventional bare frame analysis. An appropriate way to analyse the buildings is to model the strength and stiffness of infill walls. Unfortunately, no guidelines are given in IS 1893: 2002 (Part-1) for modelling the infill walls. As an alternative, a bare frame analysis is generally used that ignores the strength and stiffness of the infill walls. Different types of analytical models based on the physical understanding of the overall behaviour of an infill panels were developed over the years to simulate the behaviour of in filled frames. The elastic analysis based (Smith and Carter, 1969), the plastic analysis based (Liauw and Kwan, 1983), and the ultimate load based (Saneinejad and Hobbs, 1995) approaches are among them.

The presence of infill walls in buildings accounts for the following issues:

i) Increases the lateral stiffness of the building frame.
ii) Decreases the natural period of vibration.
iii) Increases the base shear.
iv) Increases the shear forces and bending moments in the columns.

It was observed by **Merabi (1994)**, the brittle shear failure of the column on the windward side while investigating the infilled frame structure which had strong infill panel and weak frame. He reported that the infill has significant improvement on the lateral strength and stiffness of a bare frame and also significantly improves the energy dissipation capability of the structure. **Fardis (1996)** investigated the seismic response of an infilled frame which had weak frames with strong infill material. It was observe that the strong infill which was considered as non structural is responsible for earthquake resistance of weak reinforced concrete frames. On the contrary, since infill is extensively used, it would be cost effective if positive effects of infill is utilised. **Al-Chaar (1998)** performed studies on the behaviour of reinforced concrete frames with masonry infill. The test was conducted on two half scale specimens in which one of the frames was stronger than the other. The stronger frame specimen showed diagonal tension cracking while the weak frame failed because of diagonal cracking as well as hinging of the column at lower end. Both the frames were reported to have shown the ductile behaviour but the extent of ductility is not specific. However, he concluded that the infill wall improves the strength, stiffness and energy absorption capacity of the plane structures which are useful for structures in seismic regions. **Dominguez (2000)** studied the effects of non-structural component on the fundamental period of buildings. The model consists of five storeys, ten storeys and fifteen storeys with diagonal struts as the infill (non-structural component). It was reported that the presence of infill decreases the fundamental period of the structure. The trend of decrease in period with increase in thickness is decreasing with the increase in height. **Doudoumis (2006)** studied the importance of contact condition between the infill and frame members on a single storey finite element model. He reported that the interface condition, friction coefficient, size of mesh, relative stiffness of beam to column, relative size of infill wall have significant influence on the response of infilled frame, while the effect of orthotropy of infill material was reported to be insignificant. That means that the infill can be treated as homogeneous material. When the mesh density was made finer the stress pattern within the infill was also improved, with the maximum values of stresses at the compressive corners. The existence of friction coefficient at the interface was reported to increase the lateral stiffness of the system. However, friction coefficient is dependent on the quality of material and workmanship, which is difficult to define accurately. The response parameters were also increased with the stiffness of frame and infill and the relative size of frame and infill plane. However, this study was conducted for a single storey model under monotonic loading, therefore it is important to conduct similar studies for more number of stories under earthquake load. **Asokan (2006)** studied how the presence of masonry infill walls in the frames of a building changes the lateral stiffness and strength of the structure. This research proposed a plastic hinge model for infill wall to be used in nonlinear performance based analysis of a building and concludes that the ultimate load (UL) approach along with the proposed hinge property provides a better estimate of the inelastic drift of the building. **J. Dorji and D.P. Thambiratnam (2009)** concluded that the strength of infill in terms of its Young's Modulus (*E)* has a significant influence on the global performance of the structure. The stresses in the infill wall decrease with increase in (*E)* values due to increase in stiffness of the model. The stresses varies with building heights for a given E and seismic hazard.

METHODOLOGY

Significant analytical and experimental research is carried out since five decades, which attempts to understand the behaviour of reinforced concrete frames with infill walls under earthquake loading. Various types of analytical models based on the physical understanding of the overall behaviour of an infill frame were developed over the years to simulate the behaviour of infilled frames.

In this study, the effect of cement brick infill wall on a reinforced concrete moment resisting frame under earthquake loading is considered to determine the strength, stability and stiffness of building by varying infill arrangements like without, inner, outer and full infill. Comparison is done with the help of various parameter like bending moment, maximum displacement and storey displacement.

GEOMETRY

For present study 09 storey buildings are considered. The buildings are considered to have regular and irregular geometry. Storey height is taken as 3 m each in all the floors and depth of foundation as 2 m. The building is kept symmetric in both orthogonal directions in plan to avoid torsional response under lateral force. The column is kept square and size of the column is kept same throughout the height of the structure to keep the discussion focussed only on the infill and partially infill effect without getting distracted by the issues like orientation of column.

MODELLING

The building is considered to be located in seismic zone V intended for residential use. The building is observed on medium strength soil through isolated footing under the columns. Response reduction factor for the special moment resisting frame has taken as 5.0 (assuming ductile detailing). The floor finish on the floors is taken to be 1.0 kN/m^2. The live load on floor is been taken as 3.0 kN/m^2. In seismic weight calculations, 25 % of the floor live loads are considered in the analysis.

Table 1: Details of Structure

Type of structure	Residential building (G+8)
Total height of building	27 m
Height of each storey	3 m
Depth of foundation	2 m
Bay width in longitudinal direction	3 m
Bay width in transverse direction	3 m
Size of beams	230 mm X 450 mm
Size of columns	350 mm X 350 mm
Thickness of slab	150mm
Thickness of infill	200 mm
Infill material	Cement
Seismic zone	V
Soil condition	Medium
Response reduction factor	5
Importance factor	1.5
Density of cement brick masonry	18.5 kN/m^3

MODEL CONSIDERED FOR ANALYSIS

The following are the models used for the analysis of work

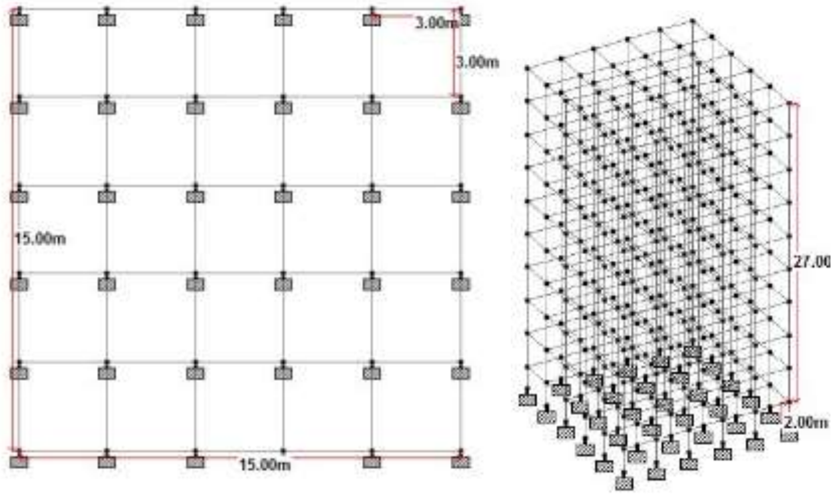

Fig. 1: Plan and elevation of the bare frame structure

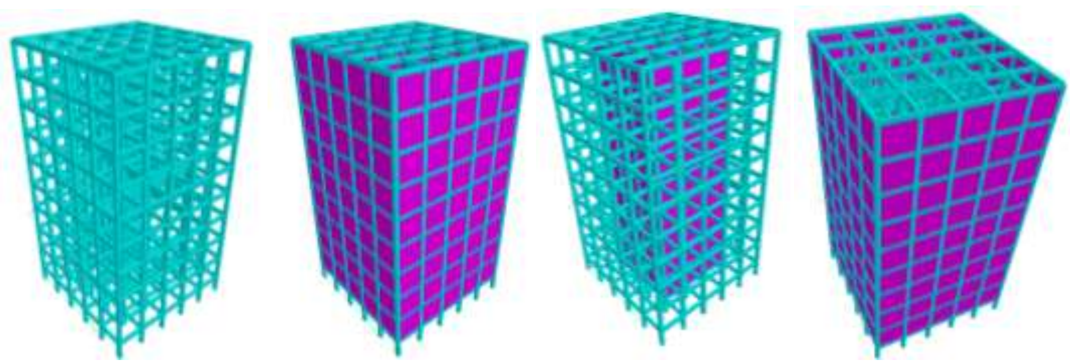

Fig. 2: 3D view of the bare infill wall frame at without, full, inner and outer respectively

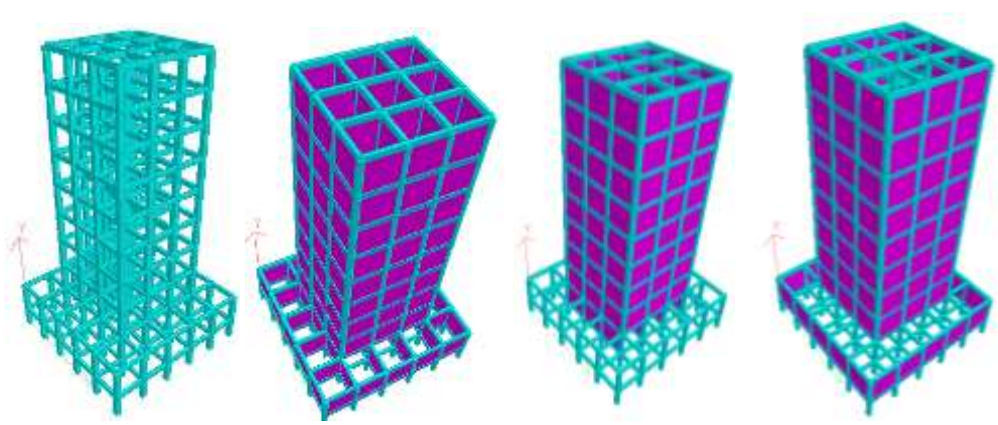

Fig.3: 3D view of the irregular plaza frame at without, full, inner and outer respectively

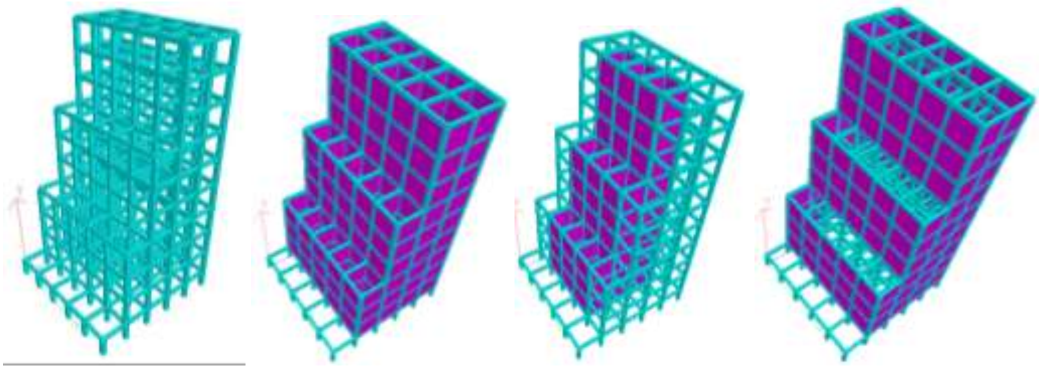

Fig. 4: 3D view of the irregular stepped frame at without, full, inner and outer respectively

RESULTS

Results for displacements, bending moment, shear force and storey displacement are given below. Results can be described under following heads.

MAXIMUM DISPLACEMENT

Maximum displacement has been found out with infill of cement brick whose details are given below

Maximum displacement in cement brick infill

Maximum displacement of cement brick infill in X and Z directions are shown below

Table 2: Maximum displacement in X and Z direction with cement brick infill

Infill	Max. displacement (mm)					
	Bare Frame		Stepped		Plaza	
	X Dir.	Z Dir.	X Dir.	Z Dir.	X Dir.	Z Dir.
Without	121.59	121.59	112.53	119.73	127.75	127.75
Outer	34.17	34.17	34.21	25.52	31.19	31.19
Inner	23.03	23.03	24.99	23.85	16.89	16.18
Full	10.60	10.60	12.27	10.01	10.42	10.68

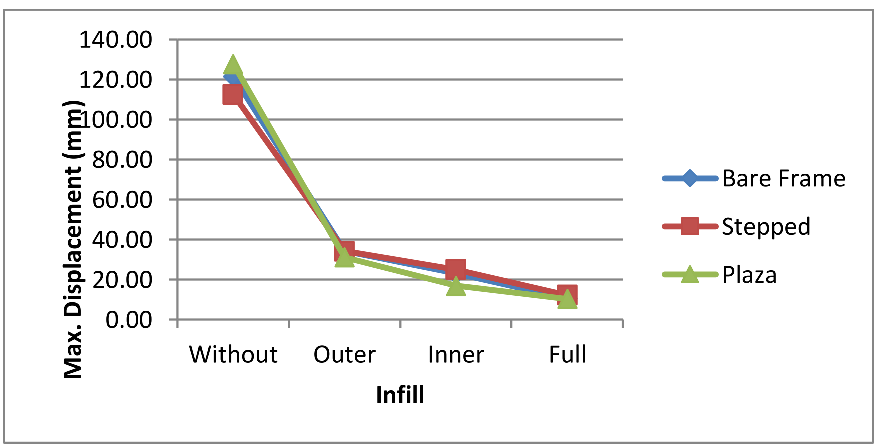

Fig. 5: Maximum displacement in X direction with cement brick infill

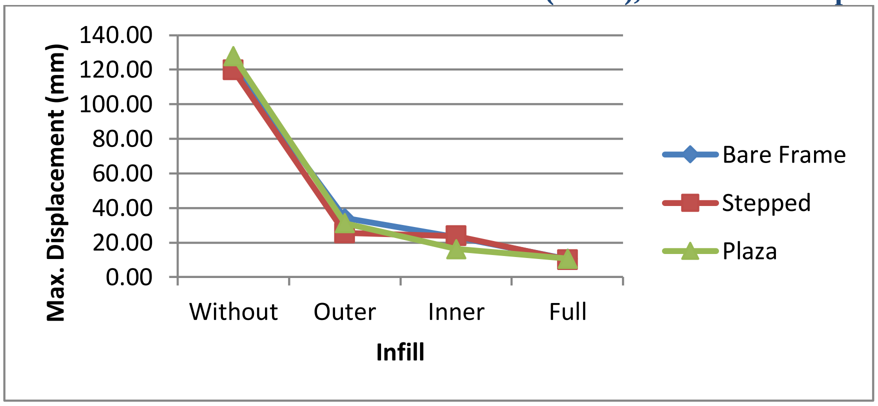

Fig. 6: Maximum displacement in Z direction with cement brick infill

Maximum displacement is observed in without infill plaza structure and minimum in full infill stepped structure in Z direction

STOREY DISPLACEMENT

Storey displacement has been found out with infill of cement brick whose details are given below

Storey displacement in cement brick infill

Storey displacement of cement brick infill X and Z direction are shown below

Table 3: Storey displacement in X and Z direction without infill

Storey	Storey disp. (mm)					
	Bare Frame		Stepped		Plaza	
	X Dir.	Z Dir.	X Dir.	Z Dir.	X Dir.	Z Dir.
Base	0.00	0.00	0.00	0.00	0.00	0.00
GF	2.93	2.93	1.55	1.55	1.85	2.32
1st floor	12.75	12.75	6.89	6.89	9.14	10.13
2nd floor	23.26	23.26	17.67	17.67	17.19	18.64
3rd floor	33.73	33.73	29.84	29.84	25.10	27.37
4th floor	43.89	43.89	41.74	41.74	34.31	36.05
5th floor	53.45	53.45	53.05	53.05	43.42	44.43
6th floor	62.08	62.08	63.36	63.36	51.41	52.46
7th floor	69.40	69.40	72.24	72.24	59.79	60.61
8th floor	74.97	74.97	79.19	79.19	66.84	66.86
9th floor	78.45	78.45	83.78	83.78	71.41	70.65

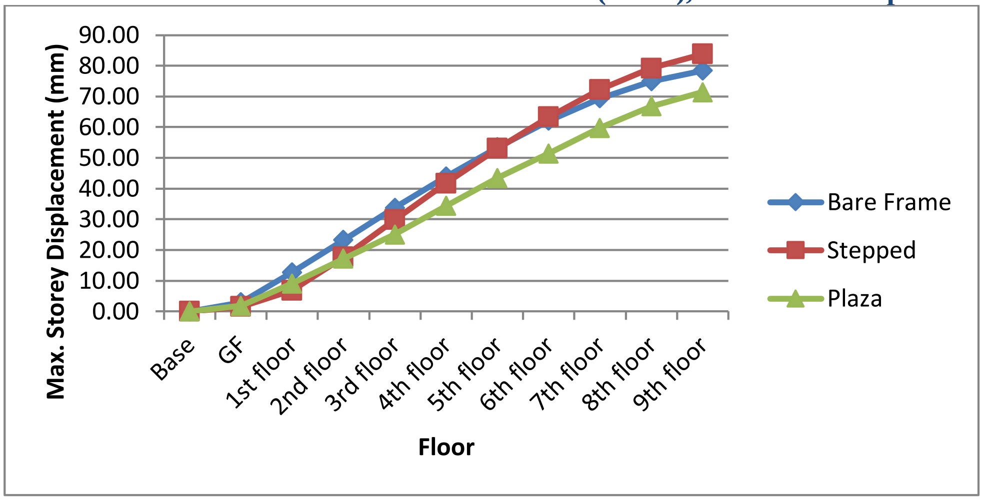

Fig. 7: Storey displacement without infill in X direction

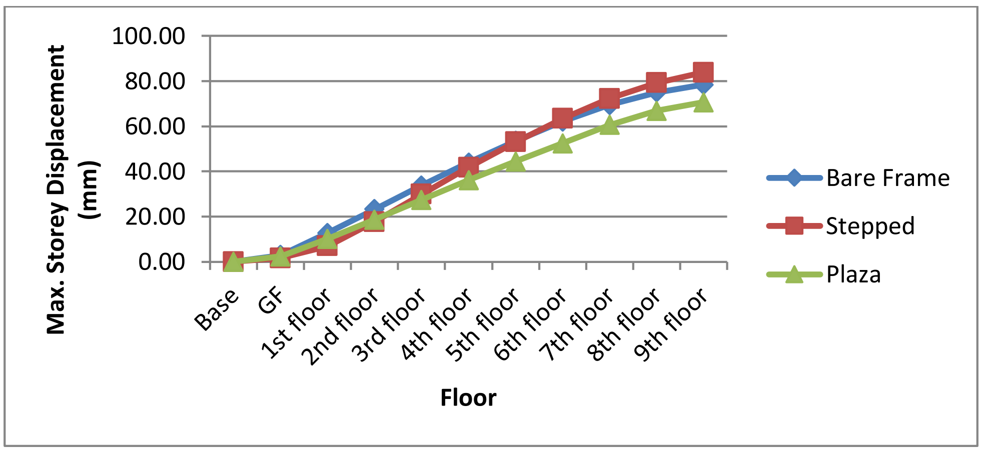

Fig. 8: Storey displacement without infill in Z direction

Maximum storey displacement without infill is in stepped structure and minimum in plaza structure

Table 4: Storey displacement in X and Z direction with outer infill

Storey	Storey disp. (mm)					
	Bare Frame		Stepped		Plaza	
	X Dir.	Z Dir.	X Dir.	Z Dir.	X Dir.	Z Dir.
Base	0.00	0.00	0.00	0.00	0.00	0.00
GF	5.42	5.42	3.81	0.99	2.09	2.09
1st floor	5.83	5.83	4.14	3.89	8.22	8.22
2nd floor	6.24	6.24	4.53	7.04	9.19	9.19
3rd floor	6.68	6.68	4.99	9.56	10.21	10.21
4th floor	7.13	7.13	5.58	11.20	11.31	11.31
5th floor	7.59	7.59	6.23	13.12	12.44	12.44
6th floor	8.05	8.05	6.86	16.07	13.58	13.58

7th floor	8.49	8.49	7.66	16.39	14.73	14.73
8th floor	8.91	8.91	8.42	16.64	15.86	15.86
9th floor	9.31	9.31	9.14	16.88	16.96	16.96

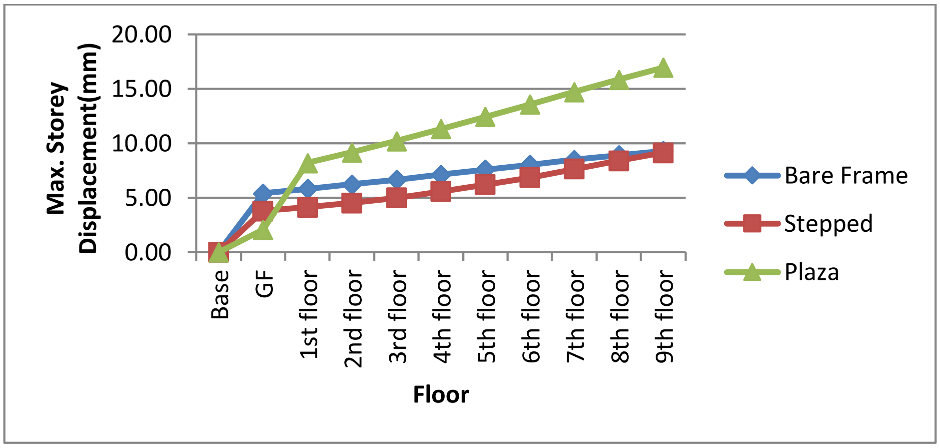

Fig. 9: Storey displacement with outer infill in X direction

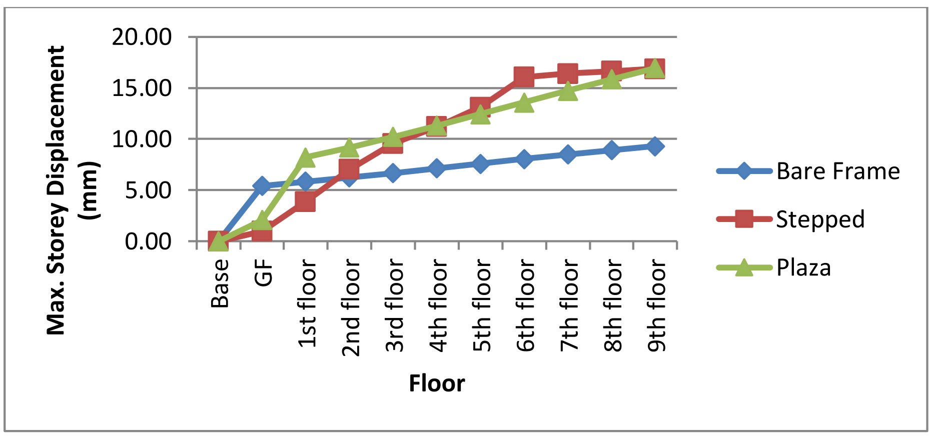

Fig. 10: Storey displacement with outer infill in Z direction

Maximum storey displacement with outer infill is in plaza structure and minimum in stepped structure

Table 5: Storey displacement in X and Z direction with inner infill

Storey	Storey disp. (mm)					
	Bare Frame		Stepped		Plaza	
	X Dir.	Z Dir.	X Dir.	Z Dir.	X Dir.	Z Dir.
Base	0.00	0.00	0.00	0.00	0.00	0.00
GF	0.98	0.98	0.61	2.87	1.56	2.25
1st floor	3.30	3.30	2.21	3.62	4.55	2.85
2nd floor	5.17	5.17	3.58	4.26	5.22	3.66
3rd floor	6.81	6.81	4.79	5.00	5.98	4.56
4th floor	8.39	8.39	6.21	5.79	6.80	5.52

5th floor	9.97	9.97	7.71	6.63	7.66	6.51
6th floor	11.55	11.55	9.19	7.50	8.56	7.53
7th floor	13.07	13.07	10.94	8.40	9.46	8.56
8th floor	14.41	14.41	12.57	9.31	10.36	9.57
9th floor	15.34	15.34	13.72	10.17	11.26	10.58

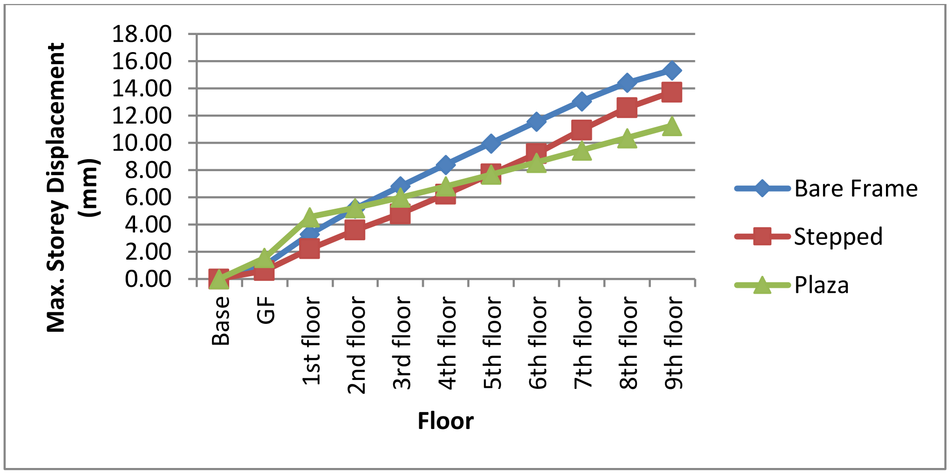

Fig. 11: Storey displacement with inner infill in X direction

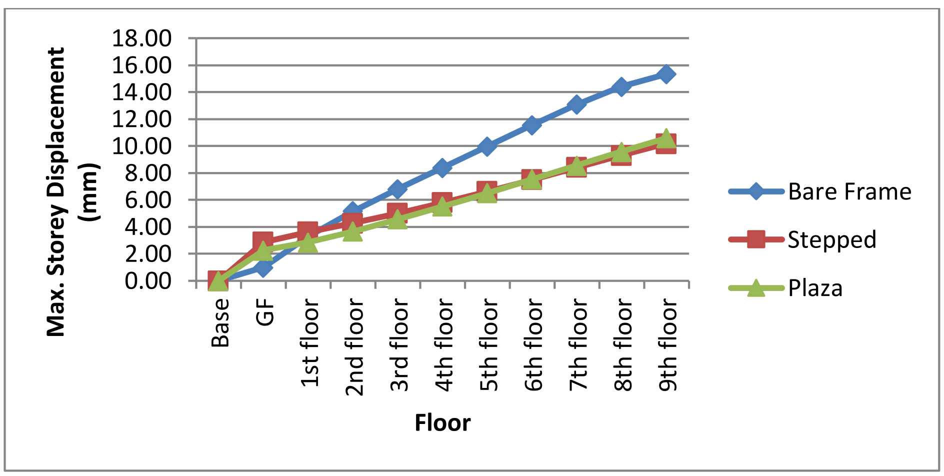

Fig. 12: Storey displacement with inner infill in Z direction

Maximum storey displacement with inner infill is in bare frame and minimum in stepped structure

Table 6: Storey displacement in X and Z direction with full infill

Storey	Storey disp. (mm)					
	Bare Frame		Stepped		Plaza	
	X Dir.	Z Dir.	X Dir.	Z Dir.	X Dir.	Z Dir.
Base	0.00	0.00	0.00	0.00	0.00	0.00
GF	3.33	3.33	2.19	2.88	1.93	1.90

1st floor	3.65	3.65	2.48	3.16	1.99	2.01
2nd floor	4.00	4.00	2.82	3.44	2.46	2.50
3rd floor	4.37	4.37	3.20	3.75	2.97	3.03
4th floor	4.76	4.76	3.64	4.07	3.55	3.62
5th floor	5.17	5.17	4.13	4.41	4.16	4.26
6th floor	5.58	5.58	4.62	4.76	4.79	4.91
7th floor	5.98	5.98	5.19	5.11	5.43	5.57
8th floor	6.37	6.37	5.75	5.44	6.07	6.23
9th floor	6.76	6.76	6.30	5.76	6.68	6.87

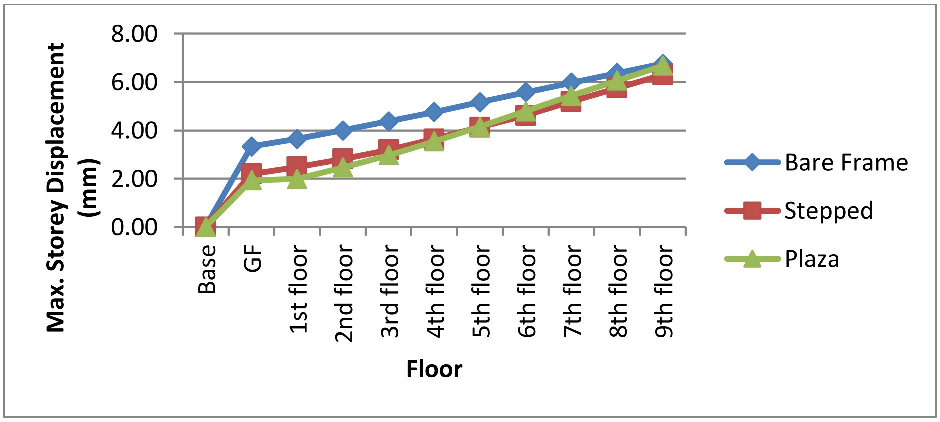

Fig. 13: Storey displacement with full infill in X direction

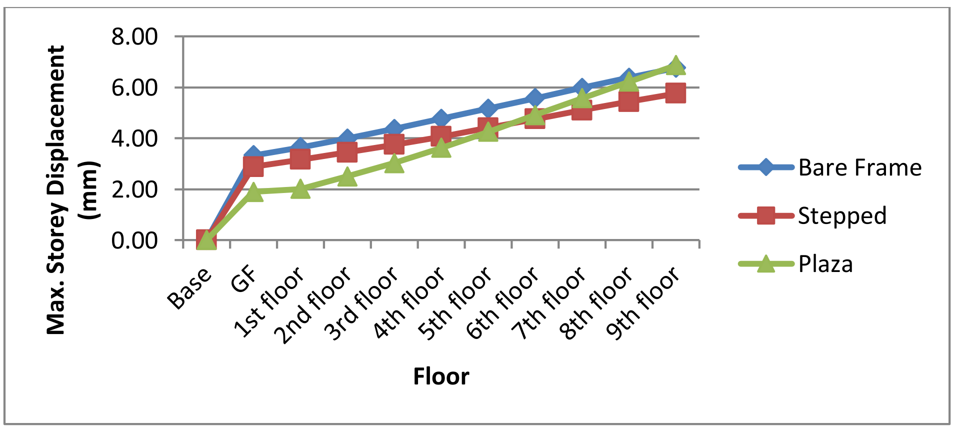

Fig. 14: Storey displacement with full infill in Z direction

Maximum storey displacement with full infill is in bare frame and minimum in stepped structure

BENDING MOMENT

Maximum bending moment of cement brick infill are shown below

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

Table 7: Maximum bending moment with cement and clay brick infill

Maximum bending moment (kNm)			
Infill	Bare Frame	Stepped	Plaza
Without	204.249	211.988	223.859
Outer	97.057	113.628	189.076
Inner	118.235	105.163	116.92
Full	31.132	78.78	45.754

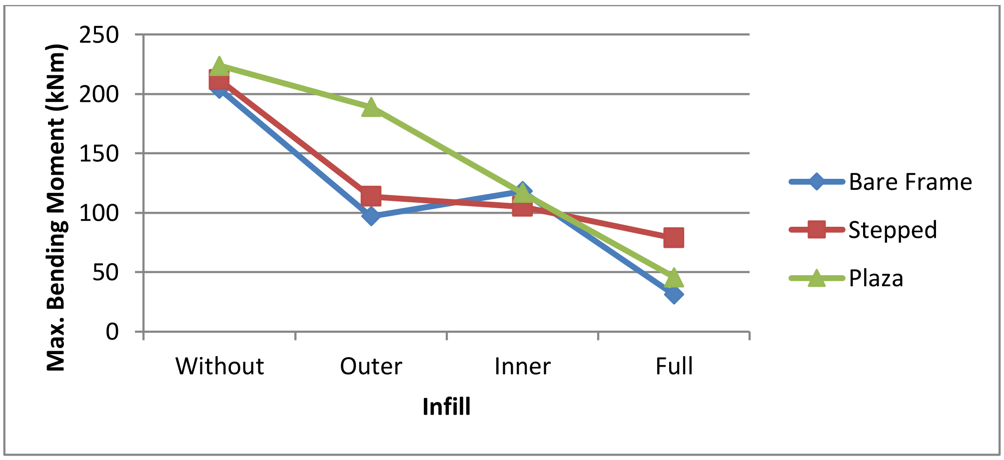

Fig. 15: Maximum bending moment with cement brick infill

Maximum bending moment is in without infill plaza structure and minimum is in full infill bare frame

SHEAR FORCE

Maximum shear force of cement and clay brick infill are below

Table 8: Maximum shear force with cement brick infill

Maximum shear force (kN)			
Infill	Bare Frame	Stepped	Plaza
Without	139.738	145.379	149.561
Outer	75.459	76.219	123.891
Inner	72.802	61.757	73.15
Full	33.085	48.194	43.826

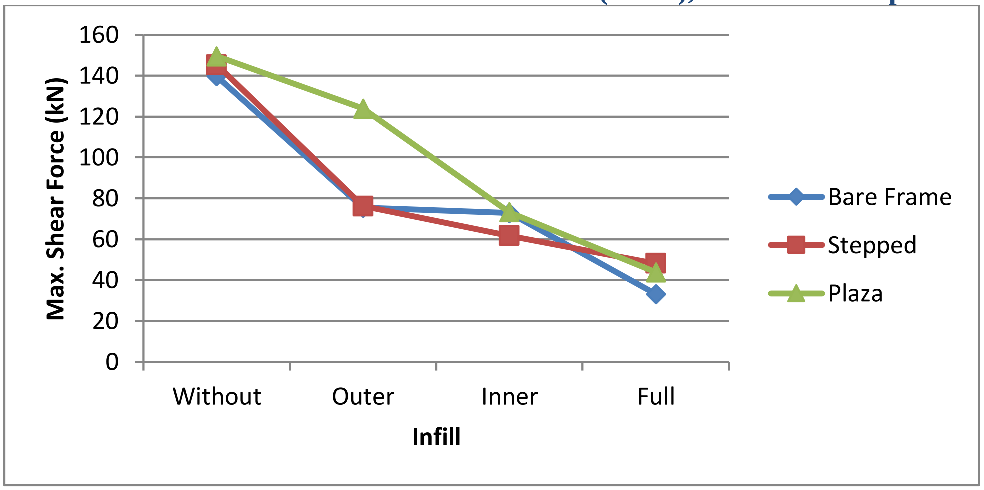

Fig. 16: Maximum shear force with cement brick infill

Maximum shear force is in without infill plaza and minimum is in full bare frame

CONCLUSION

- The value of maximum displacement, storey displacement, maximum bending moment and maximum shear force is observed highest in without infill structure and it is comparatively less in case of inner infill structure, still less in outer infill structure and lowest in full infill structure.
- It can be concluded from the study that the value of various distractive parameter namely maximum displacement, storey displacement, maximum bending moment and maximum shear force Full infill is best and efficient pattern because these parameter are lowest in this case further based on same line we can conclude that inner infill and outer infill is second best and third best respectively whereas without infill structure can be termed as critical structure.
- If we consider irregular structure than plaza structure is more effective compared to other structure because plaza structure shows lower parameters
- Although the dead weight of the structure increases with infill but it increases the stiffness of the structure which is an important factor in seismic design of structures

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