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Comparative Study on Non-Linear Analysis of Infilled Frames for Vertically Irregular Buildings

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ABSTRACT: *The performance of a structural system can be evaluated resorting to non-linear static analysis. This involves the estimation of the structural strength and deformation demands and the comparison with the available capacities at desired performance levels. This study aims at evaluating and comparing the response of thirty reinforced concrete buildings, systems with different with and without infill materials by the use of methodology namely the ones described by the FEMA-273 using nonlinear static procedures, with described acceptance criteria. The methodology is applied to a 4 and 10 storey frames system with and without vertical irregularity, both designed as per the IS 456-2000 and IS 1893-2002 (Part I) in the context of Performance Based Seismic Design procedures.*

Present study aims towards doing Nonlinear Static Pushover Analysis of G+3 medium rises and G+9 high rises RCC residential building frame which is to be designed by Conventional Design Methodology. A Non-linear Static Analysis (Pushover Analysis) had been used to obtain the inelastic deformation capability of frame. It was found that Ferro cement infilled irregular model 4 (300%) high rises building decrease in deformation or displacement of the building as it's stiffer than other buildings.

KEYWORDS - *Base shears, Displacement, Push-over curve, Static Push-Over Analysis, etc.*

I. INTRODUCTION

Over the past twenty decades and more it has been recognized that damage control must become a more explicit design consideration which can be achieved only by introducing some kind of non-linear analysis into the seismic design methodology. Following this pushover analysis has been developed during past decades and more and has become the preferred method of analysis for performance-based seismic design, PBSD and evaluation purposes. It is the method by which the ultimate strength and the limit state can be effectively investigated after yielding, which has been researched and applied in practice for earthquake engineering and seismic design. Non-linear response history analysis is a possible method to calculate structural response under a strong seismic event.

However, due to the large amount of data generated in such analysis, it is not preferred practical and PBSE usually involves non-linear static analysis, also known as push-over analysis. The simplified approaches for the seismic evaluation of structures, which account for the inelastic behaviour, generally use the results of static collapse analysis to define the inelastic performance of the structure. Currently, for this purpose, the non-linear static procedure (NSP) or push-over analysis described in FEMA-273, ATC-40 documents are used. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of push-over analysis.

II. MODELING

2.1 General

The Push-over Analysis is defined as a non-linear static approximation of the response a structure that will undergo when subjected to static earthquake loading. Because we are approximating the complex static loading characteristic of ground motion with a much simpler monotonically increasing static load, there are bound to be limitations to the procedure. The objective is to quantify these limitations. This will be accomplished by performing the Push-over analysis of reinforced concrete of four and ten stories with and without vertical irregularity with different infills like bare frame, brick infilled frame, Ferro cement infilled frame.

2.2 Assumed data of G+3 & G+9 RCC frame

This is the basic and the with & without vertically irregular structure of the building having 6 bays in both the directions and four storeys and ten storey on the ground storey, the dimension of the storey is reduced after consecutive one storey as shown in the fig.1.The typical storey height and ground storey height is same i.e., 3.0m. The bay width is 3.5 m. The detail basic specifications of the building are given in the below table:

Table 2.1 Preliminary Assumed data of G+3 & G+9 RCC frame

Sl.no	Contents	Description
1	No. of storeys	G+3,G+9
2	Height of each floor	3.0m
3	Thickness of infill wall	230 mm
4	Imposed load	3 kN/m²
5	Materials	Concrete (M25) Reinforcement (Fe415)
6	Size of G+3 columns	Storey2,3, interior columns and4allcolumns=250*250 mm
		Storey2,3 outer columns = 280*280 mm
		Storey 1 all columns = 280*250 mm
7	Size of G+9 columns	Storey 2 to 9 outer columns and storey 10 all columns = 250* 250 mm
		Storey 2to 9 inter columns = 280*280 mm
		Storey 1 all columns = 280*250 mm
8	Size of beam for G+3 and G+9	230*280 mm
9	Depth of slab	150 mm
10	Specific density	RCC= 25kN/m³
		Brick =20kN/m³
		Ferro cement=22.243kN/m³
11	Modulus of Elasticity	Concrete=25000M Pa
		Brick=2100M Pa
		Ferro cement=4011.06M Pa
12	Seismic zone	V
13	Zone Factor	0.36
14	Type of soil	Medium
15	Important Factor	1
16	Live load on roof	1.5kN/m²
17	Response reduction factor	5
18	Dead load on frames	Brick infill= 12.51kN/m
		Ferro cement infill=14.54 kN/m

With respect to the above structural & seismic data for modelling the plan of the base model as shown below. All dimensions are in mm.

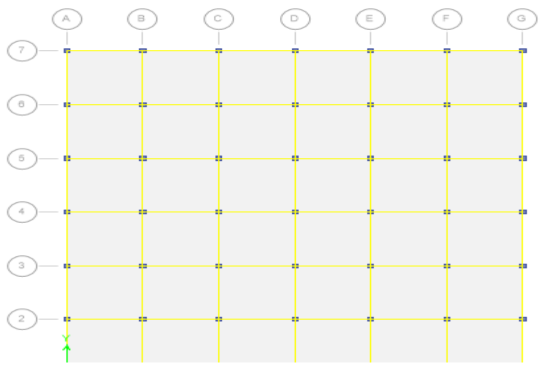


Fig.2.1 Base plan

2.3 Geometric Irregularity

To know the effect of mass irregularity on the shape (vertical geometric) irregular building the geometry is changed by reducing the no. of bays in X-direction vertically downward, as per the IS 1893:2002 (part-1). The structural data is same. Depending on this change of structural data the elevation & 3-D view of the model as shown below.

Table.2.1 Percentage of Irregularity

Sl. No	Designation	Type of Frame	Percentage irregularity
1	Model 01	Regular	0%
2	Model 02	Irregular	200%
3	Model 03	Irregular	300%
4	Model 04	Irregular	200%
5	Model 05	Irregular	300%

2.3.1 Bare frames 3D & elevation views

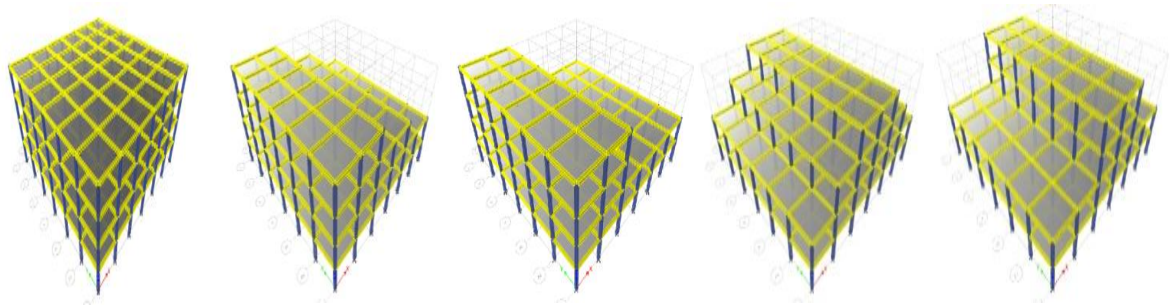


Fig 2.2G+3 Bare Frames 3D view

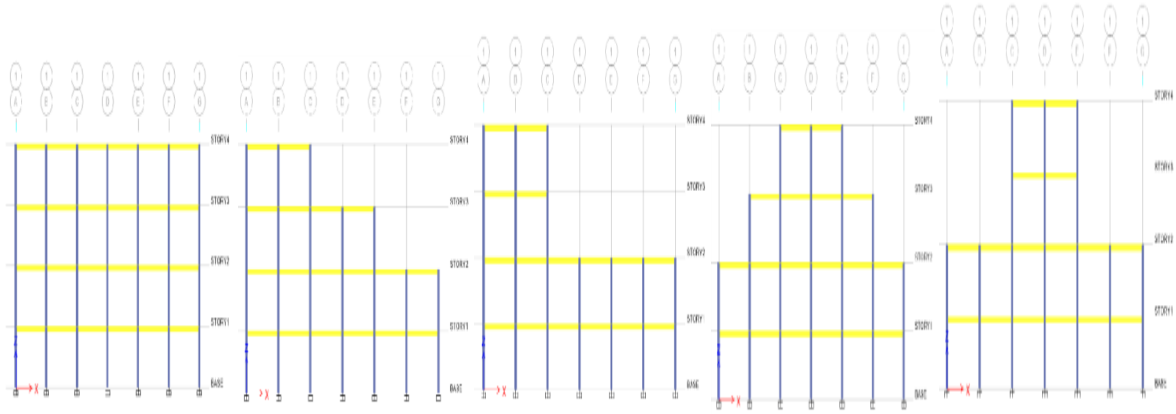


Fig 2.3 G+3 Bare Frames Elevation view

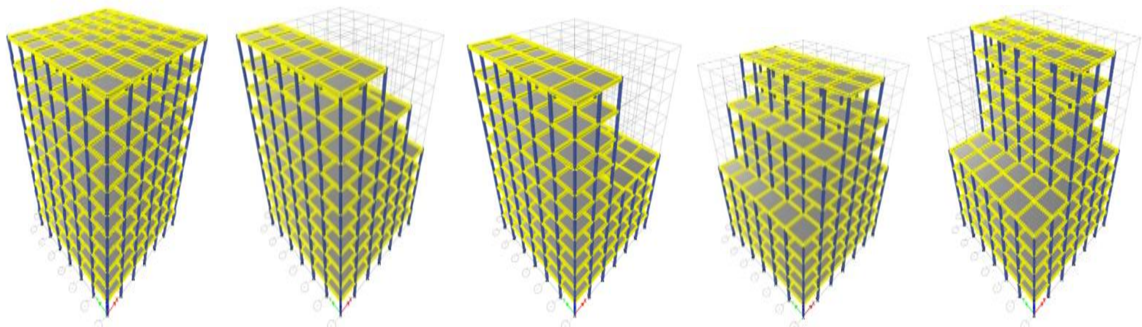


Fig 2.4 G+9 Bare Frames 3D view

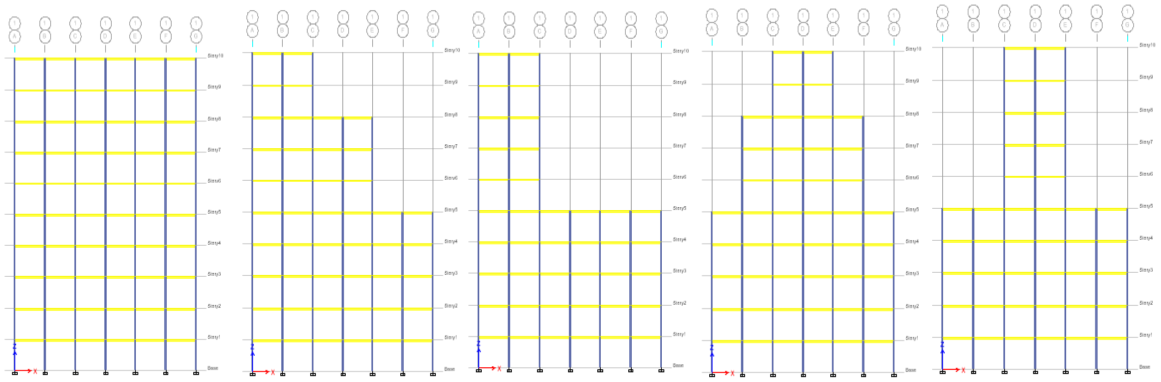


Fig 2.5 G+9 Bare frame Elevation view

2.3.2 Infilled frames 3D & elevation views

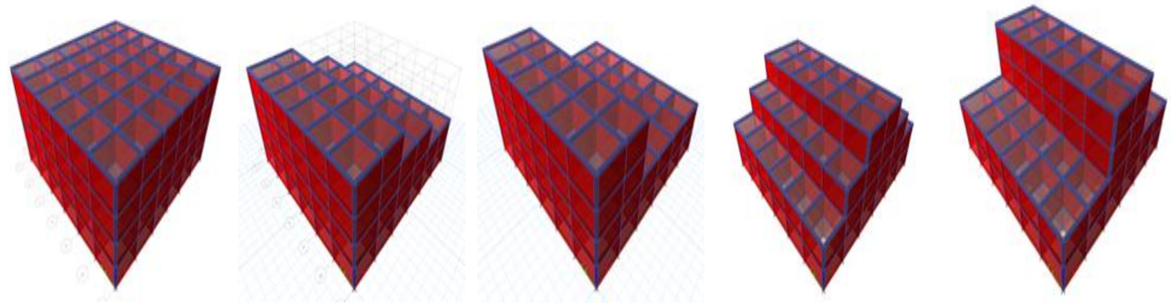


Fig 2.6G+3 Infilled Frames 3D view

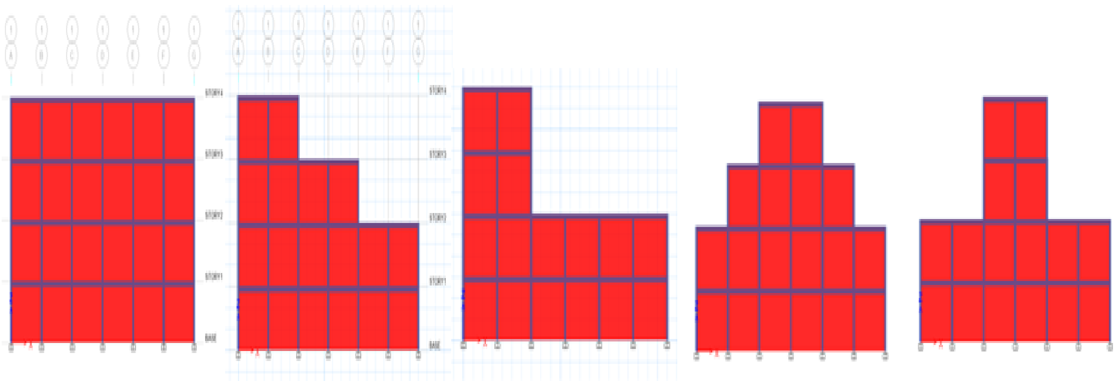


Fig 2.7 G+3Iinfilled Frames Elevation view

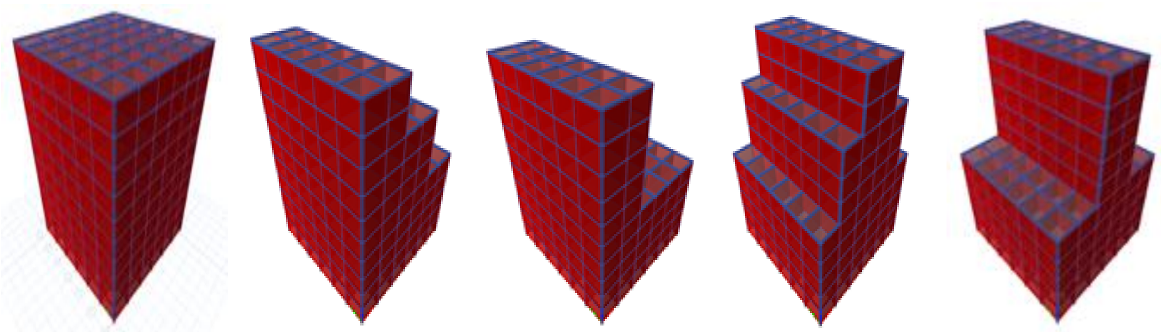


Fig 2.8 G+9 Infilled Frames 3D view

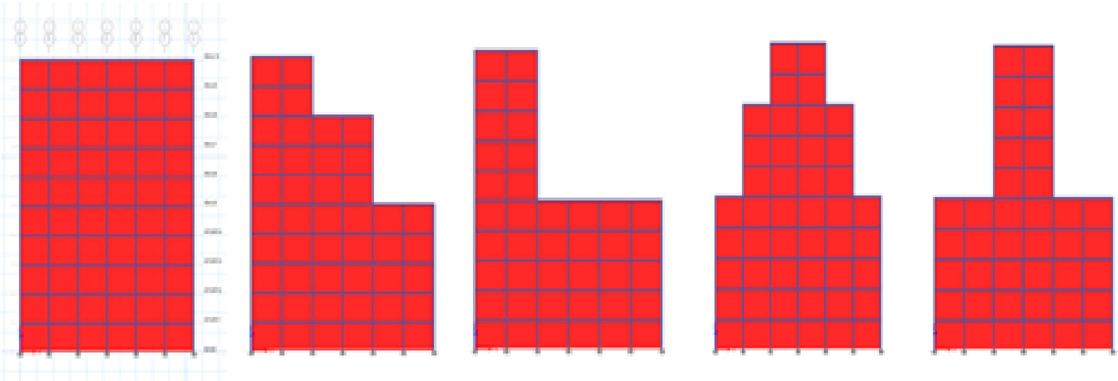


Fig 2.9 G+9 Infilled Frames Elevation view

III. RESULTS AND DISCUSSION

Analysis of G+3 and G+ 9 storied bare frame, brick infilled frame, Ferro cement infilled frame models, with and without vertical irregularity is done using ETABS-2013, from the analysis results obtained for bare frame, brick infilled frame, Ferro cement infilled frame models with and without irregularity are compared. The comparison of these results to find effect of vertical irregularity is as below.

3.1 push-Over results

Push-Over analysis is an analytical method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached, and this method predicts seismic forces and deformation demands for the purpose of performance evaluation of existing and new structures. For complex problem it is a partial and relatively simple intermediate solution to predict force and deformation demands imposed on structures and their elements by severe ground motion. Push-Over analysis is one of the analysis method recommended by Euro code and FEMA-273.

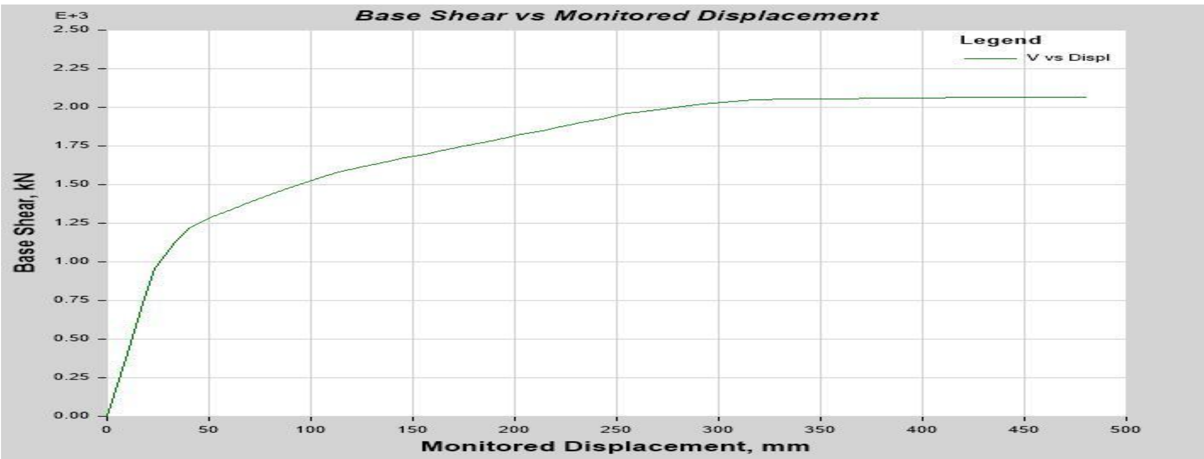


Fig 3.1 Push-Over curve of the model 3 bare frame G+3 building

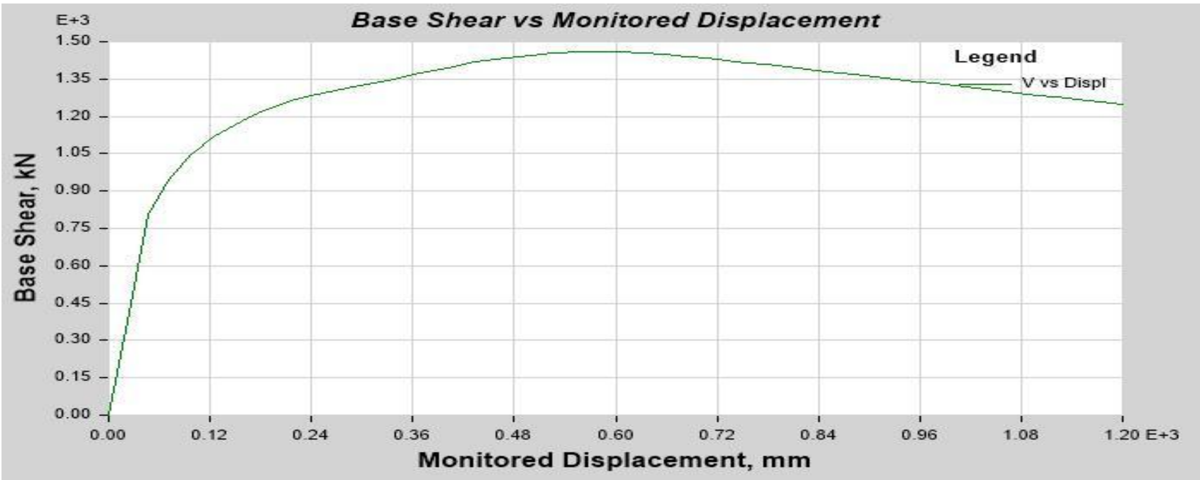


Fig 3.2 Push-Over curve of the model 3 bare frame G+9 building

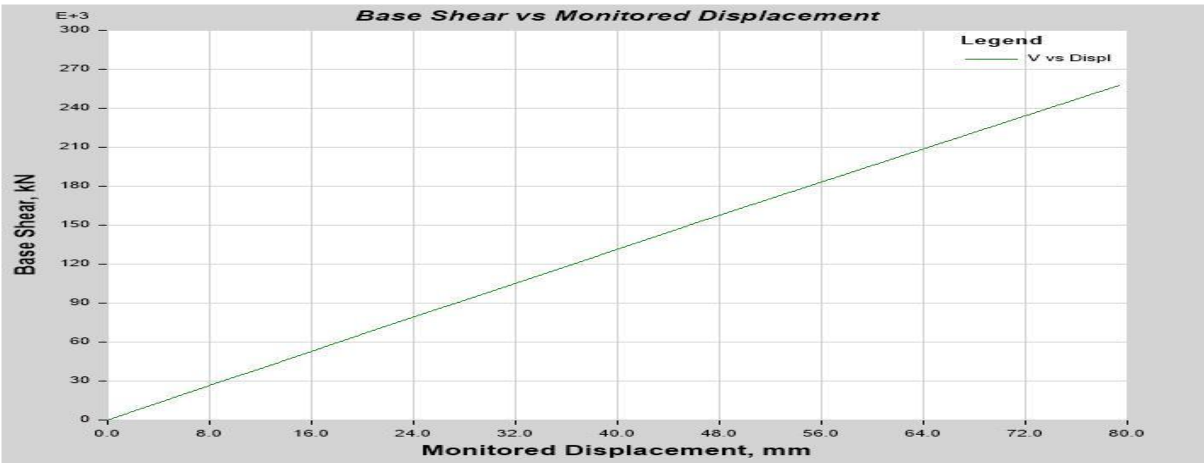


Fig 3.3 Push-Over curve of the brick infilled frame G+3 building model 3

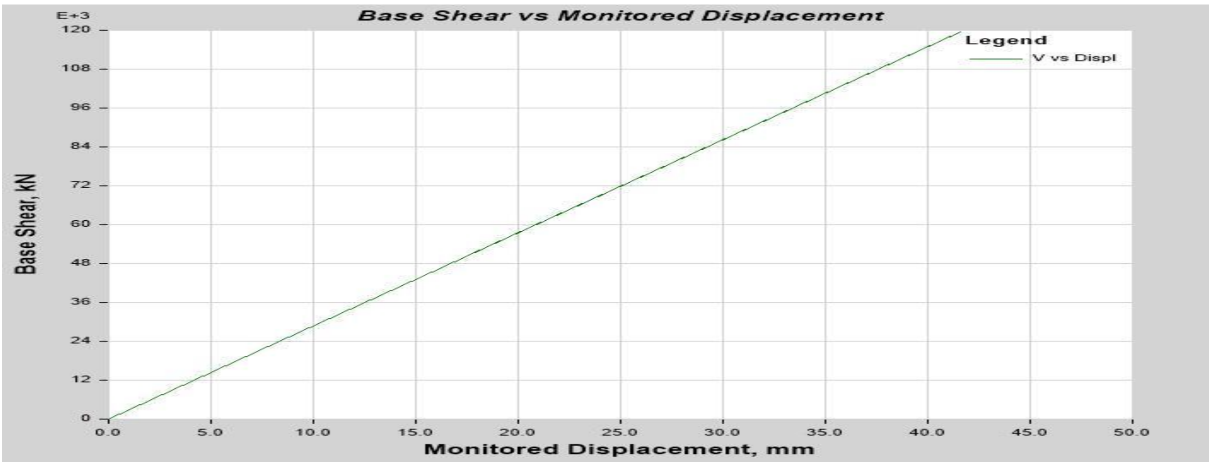


Fig 3.4 Push-Over curve of the brick infilled frame G+9 building model 3

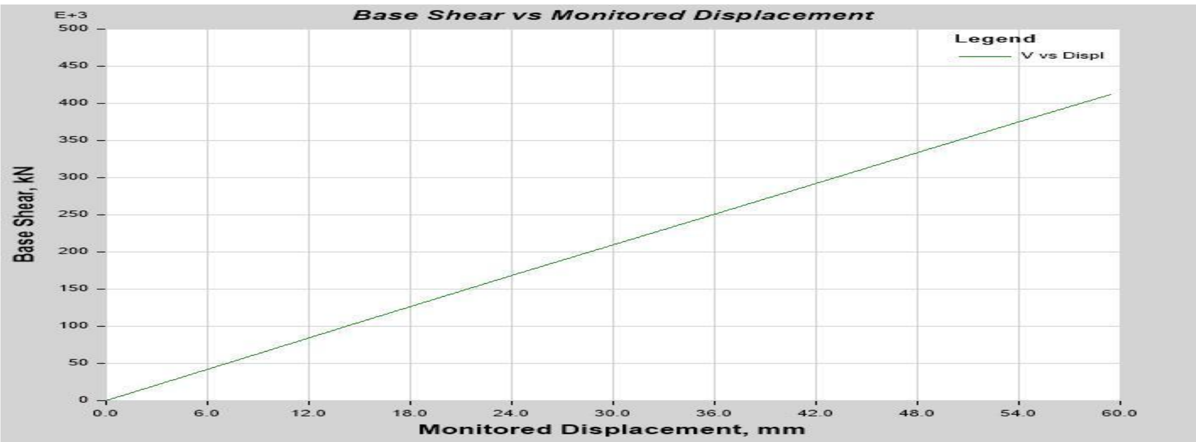


Fig 3.5 Push-Over curve of the Ferro cement infilled frame G+3 building model 3

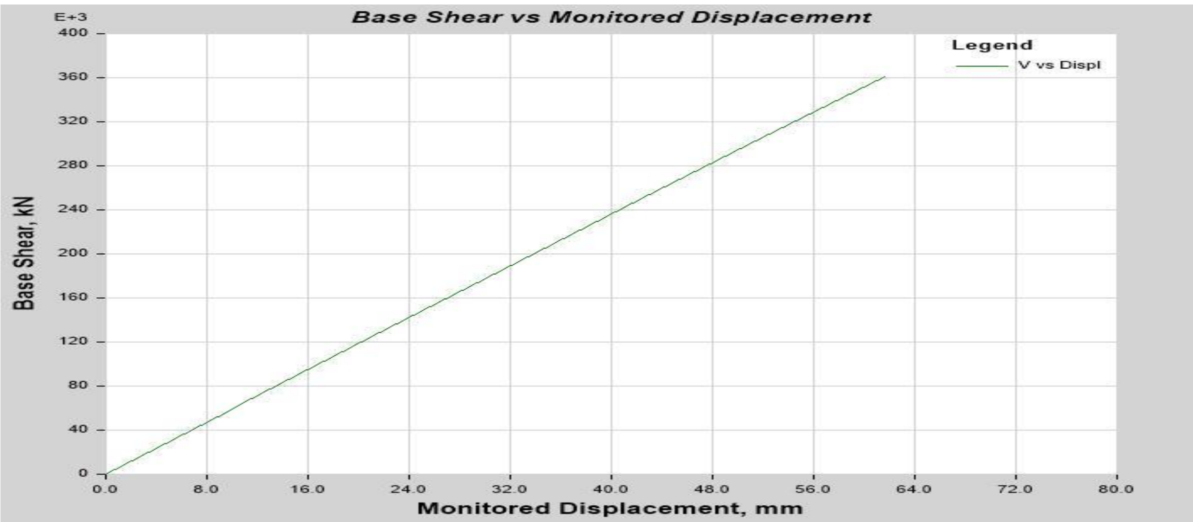


Fig 3.6 Push-Over curve of the Ferro cement infilled frame G+3 building model 5

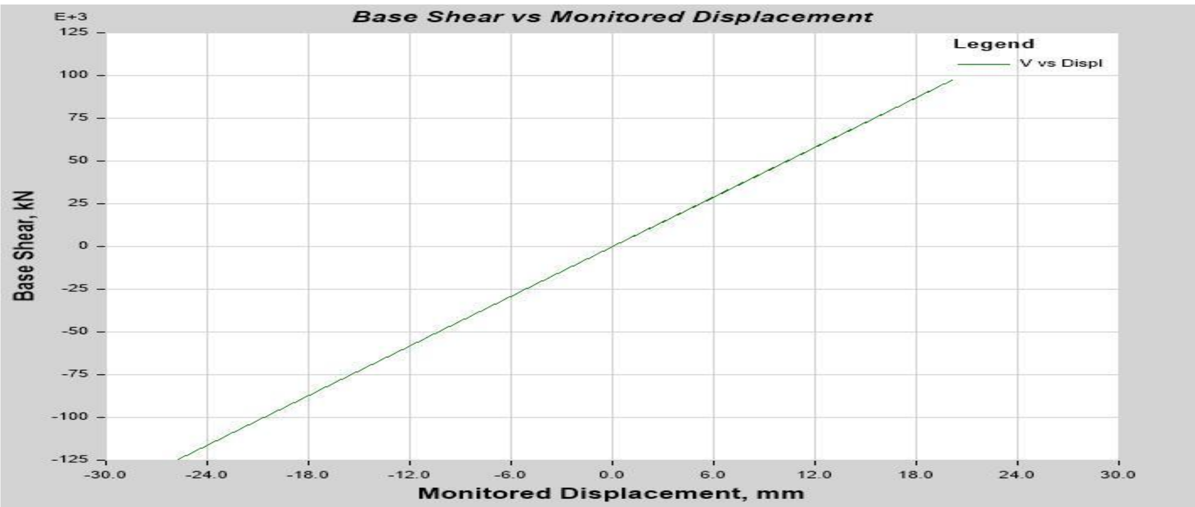


Fig 3.7 Push-Over curve of the vertical Ferro cement frame G+9 building model 3

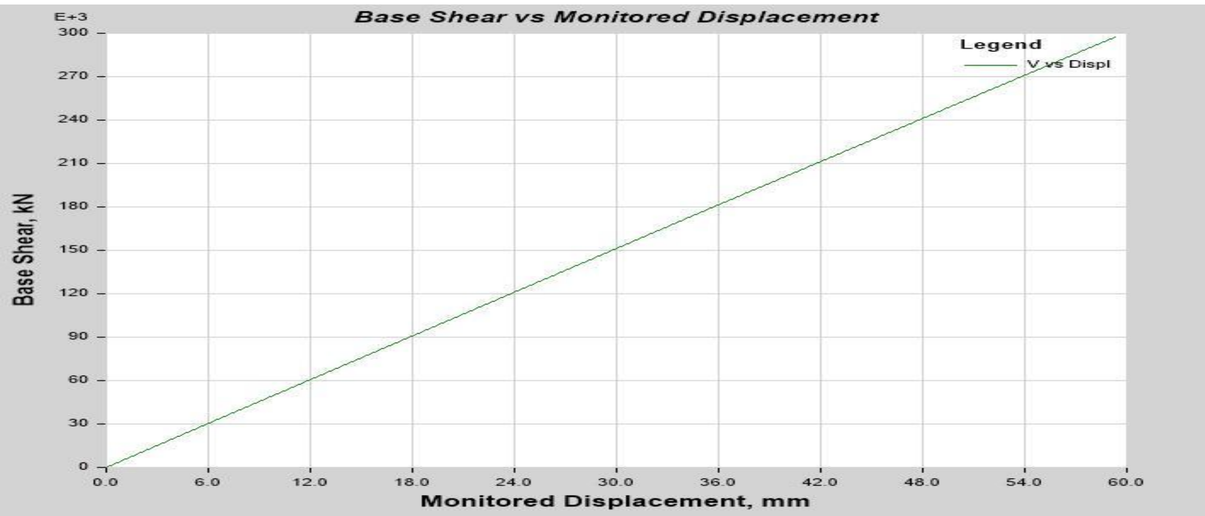


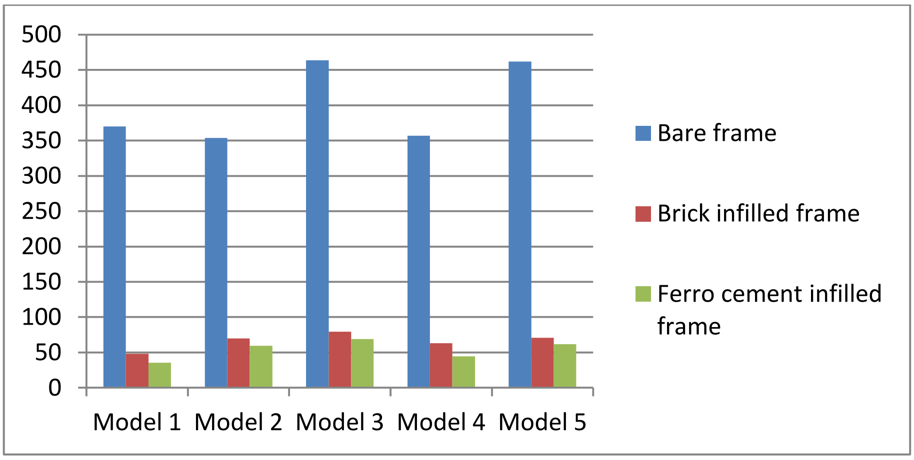
Fig 3.8 push-Over curve of the Ferro cement infilled frame G+9 building model 5

Table 3.1 Max Displacements of the models in mm

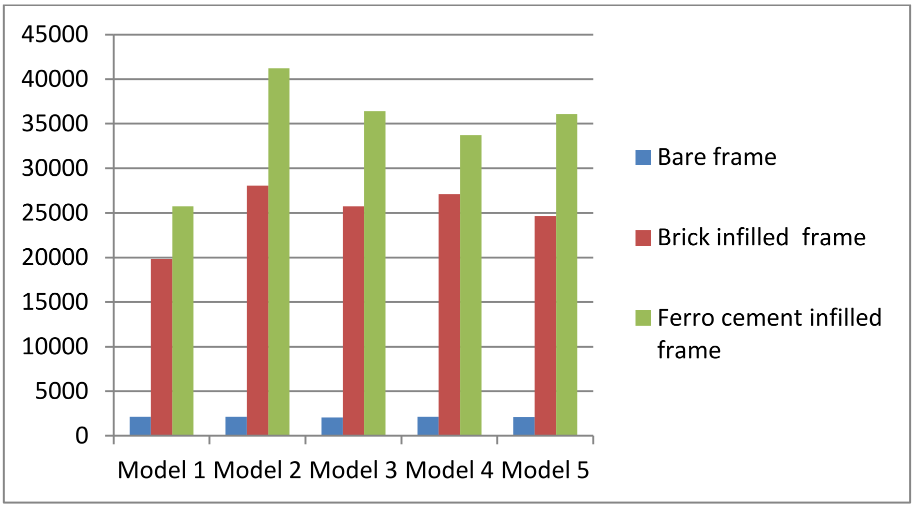
Frame type	**Bare frame**		**Brick infilled frame**		**Ferro cement infilled frame**	
	G+3	G+9	G+3	G+9	G+3	G+9
Model 1	370	594	48	45.2	35	33.7
Model 2	354	588	70	68.5	59	57.8
Model 3	464	607	79.3	41.6	69	20.1
Model 4	357	590	63.2	47.2	44	46.6
Model 5	462	612	70.8	60.2	62	59.4

Table 3.2 Max Base shears of the models in kN

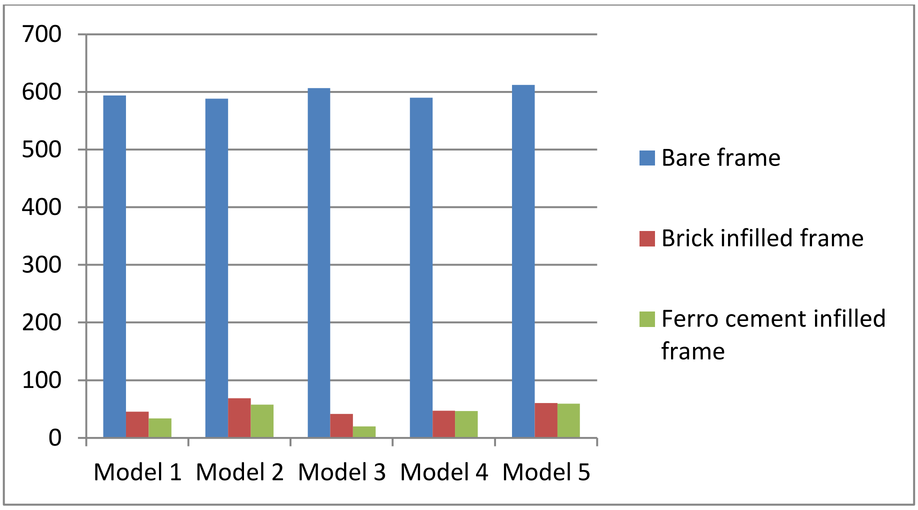
Frame type	**Bare frame**		**Brick infilled frame**		**Ferro cement infilled frame**	
	G+3	G+9	G+3	G+9	G+3	G+9
Model 1	2117	1337	19808	11638	25727	14343
Model 2	2125.6	1441	28069	19140	41214	26995
Model 3	2066.8	1458	25729	11953	36413	9731.7
Mode 4	2129.7	1445	27103	13388	33735	21997
Model 5	2080.9	1461	24662	17946	36075	29766



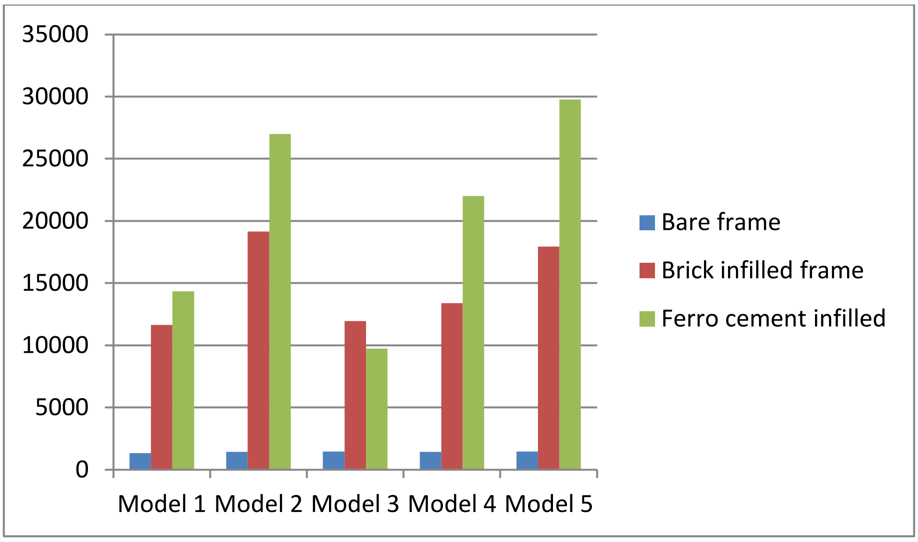
DISPLACEMENT GRAPH OF G+3 IN mm



BASE SHEAR GRAPH OF G+3 IN kN



DISPLACEMENT GRAPH OF G+9 IN mm



BASE SHEAR GRAPH OF G+9 IN kN

From the results it is clear that as the bare frames displacement increases the base shear decreases. The values of the displacement and the base shear are vice versa. And as the height of the building increases the displacement increases and the base shear decreases.

But in the infilled frames it is like as the displacement of the building increases the base shear of the building also increases. And as the height of the building increases the displacement and the base shear decreases. The behaviour of the bare frames is opposite to the infilled frames.

IV. CONCLUSIONS

G+3, G+9 with & without vertical irregularity Models are analysed using Standard Software ETABS-2013,with different infill's like bare frame, brick infilled frame, Ferro cement infilled frame and the following conclusions are drawn based on the present study.

1. Bare frame produces more displacement in comparison with brick infill and Ferro cement infill frames.
2. Ferro cement produces least displacement than brick infill and brick infill produces least displacement than bare frame.
3. Bare frames produces less Base shear than brick infilled and Ferro cement infilled frames.
4. Model 3 (300% irregularity)for the Ferro cement infilled frames produces least displacement compared to the model 1 (0% irregularity i.e., regular building)
5. Model 2 (200% irregularity) produces max displacement for brick infilled and Ferro cement infilled when compared to regular building i.e., model 1.
6. Ferro cement infilled frame is highly recommended for model 3 that is vertically irregular to 300% as it produces least displacement.

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