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Parametric Study of Irregular RC Structure with Different Stiffness Parameters in Severe Seismic Zone as per is 1893:2016

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ABSTRACT—

Now a day, RC Irregular Buildings are very common type of construction in India. Irregular Structures can be those which have discontinuity in geometry, distribution of mass, stiffness etc. These buildings are highly prone to earthquake and due to that loss of life and other damages are there. In such structures, analytically while modelling the structure, we design the beams, columns & footing only which transmits the load, where the impact of walls on the lateral response of the structure is neglected. From previous studies, it is found that their impact in the global behaviour of RC frames subjected to seismic loads is very high. So it is very important to study its behaviour on such irregular structures also. The infill wall changes the stiffness of building which helps to regular the frequency of structure under seismic loading. In accumulation to that, it also decreases the storey drift ratio under the certain limit, which ultimately decreases the structural member size and makes the structure economical. So in this paper, a parametric study has been carried on an example of tall building G+10 with the effect of infill walls having varying percentage of openings and different kind of irregularities like stiffness and mass to bring out their importance and recognizing their presence in the analysis. This study presents a linear dynamic analysis using E-tabs for reinforced concrete (RC) frames. In this study, a G+10 storied reinforced frames with infill as a strut with and without openings & other vertical irregularities like mass and stiffness parameters are considered and evaluated through linear dynamic analysis. The main parameters are mainly focused in this study are time period, mass participation, storey drifts, storey displacement & base shear. Taking the above parameters into consideration, we can compare the performance and their effect in such irregular structures in seismic zone V as per IS 1893:2016.

Keywords: RC frames, Infill Walls, Time period, Stiffness, Base shear, Mass Distribution, Response Spectrum.

1.1 Introduction -

Due An Earthquake is the most natural disaster in which shaking of the earth's surface takes place. Ground rupture and ground shaking are the most vulnerable effects creates by earthquakes, resulting in less or more severe destruction to building and other rigid infrastructure. Though many studies and experiments are done about earthquake, it is difficult to avoid the structure undergoing damage or failure during this distinctive shaking. Earthquake damages is caused due to deficiency in few aspects such as, the building with irregularities, soft storey, insufficient lateral strength, structural behaviour between the building and the ground (type of foundation used).

Many building structure having parking or commercial areas in their ground stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below.

During an earthquake, if abnormal inter-story drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey (or stories) having large displacement(s).

1.2 IRREGULAR STRUCTURES -

In Modern Urban Infrastructure, irregular structure constitutes a larger portion. Also, it is the major characteristics which affect the structure during earthquake. Irregular Structures are those which have discontinuity in geometry, distribution of mass, stiffness. As per IS Code 1893 (Part 1):2016, irregularities are classified as Plan Irregularities and Vertical Irregularities.

Plan Irregularity -

The coverage area of the building is concerned with this type of irregularity. The most common irregular structures are L-shape, C Shape and other plan wise irregular building. So it can be say that, when the two adjacent sides are not orthogonal to each other, the building is said to be irregular.

1) Irregularity of Torsion

2) Re-entrant Corners

3) Discontinuity of Diaphragm

4) Out of plane offsets

5) Non-parallel the Systems

B. Vertical Irregularity

The building: irregularity of rigidity irregularity of mass, vertical geometric irregularity, etc. The vertical irregularity of the building is involved. This is more prevalent than it-plan irregularity

1) Irregularity of Stiffness

2) Irregularity of Mass

3) Irregularity of Vertical Geometric

4) Capacity Discontinuity- Weak Storey.

1.3 Objectives of the Study

This paper deals with an parametric study with different stiffness and mass irregular Tall building with the addition of infill walls with and without openings. The building will be modelled and designed using ETAB V18 software and linear dynamic analysis has been carried out. The main parameters are focused on time period, storey drifts, storey displacement, and storey stiffness.

2. METHODOLOGY

SPECIFICATIONS:

Five models for G+10 storey RC Structure of area 24 m x 24 m. have been prepared, designed and compared in zone V as per IS 1893:2016. The models with infill properties & different vertical irregularities have been prepared and compared with regular bare frame model whose performance and results were studied and compared.

Details of Models:

Model 1 – Regular Frame Building without infill walls with 6 m span in x & y direction respectively

Model 2 – Regular Frame Building with infill walls without opening with 6 m span in x & y direction respectively

Model 3 – Regular Frame Building with infill walls with the opening of 5% with 6 m span in x & y direction respectively

Model 4 – Regular Frame Building with infill walls with the opening of 10% with 6 m span in x & y direction respectively

Model 5 – Regular Frame Building with infill walls with the opening of 15% with 6 m span in x & y direction respectively

Model 6 – Regular Frame Building with infill walls without opening, actual stairs and central core shear with 6 m span in x & y direction respectively

Model 7 – Regular Frame Building with infill walls with the opening of 5%, actual stairs and central core shear with 6 m span in x & y direction respectively

Model 8 – Regular Frame Building with infill walls with the opening of 10%, actual stairs and central core shear with 6 m span in x & y direction respectively

Model 9 – Regular Frame Building with infill walls with the opening of 15%, actual stairs and central core shear with 6 m span in x & y direction respectively

Model 10 – Regular Frame Building with infill walls without openings & soft storey at ground floor, 4^{th} floor & 8^{th} floor with 6 m span in x & y direction respectively

Model 11 – Regular Frame Building with infill walls with the opening of 5% & soft storey at ground floor, 4^{th} floor & 8^{th} floor with 6 m span in x & y direction respectively

Model 12 – Regular Frame Building with infill walls with the opening of 10% & soft storey at ground floor, 4^{th} floor & 8^{th} floor with 6 m span in x & y direction respectively

Model 13 – Regular Frame Building with infill walls with the opening of 15% & soft storey at ground floor, 4^{th} floor & 8^{th} floor with 6 m span in x & y direction respectively

Model 14 – Regular Frame Building with infill walls without openings & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

Model 15 – Regular Frame Building with infill walls with the opening of 5% & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

Model 16 – Regular Frame Building with infill walls with the opening of 10% & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

Model 17 – Regular Frame Building with infill walls with the opening of 15% & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

Model 18 – Regular Frame Building with infill walls without openings, soft storey at ground floor, 4th floor & 8th floor & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

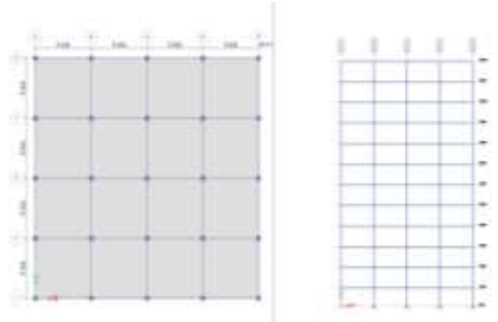
Model 19 – Regular Frame Building with infill walls with the opening of 5%, soft storey at ground floor, 4th floor & 8th floor & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

Model 20 – Regular Frame Building with infill walls with the opening of 10%, soft storey at ground floor, 4th floor & 8th floor & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

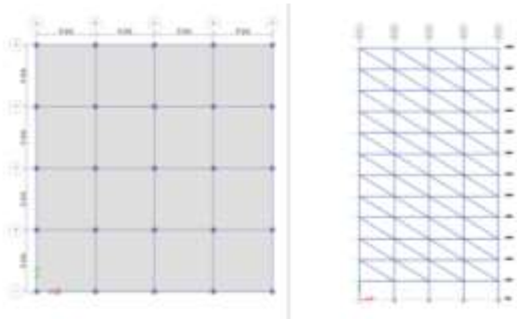
Model 21 – Regular Frame Building with infill walls with the opening of 15%, soft storey at ground floor, 4th floor & 8th floor & heavy mass at 5th floor & 9th floor with 6 m span in x & y direction respectively

The dimensions of beams and columns have been designed according to the span length. Other data used for the purpose of analysis have been taken from IS 1893:2016

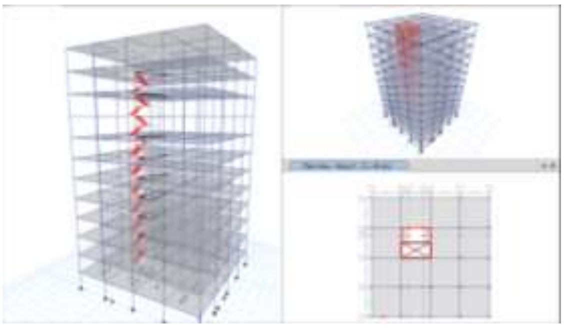
General Properties	
No. of storeys	G+10
Typical Storey Height	3.5 m.
Soft Storey Height	5.0 m.
For 4m span length:	
Size of Column	450 x 450
Size of Beam	300 x 450
Thickness of Slab	150 mm.
Thickness of Wall	230 mm.
Material Properties	
Grade of Concrete	M 30
Grade of Steel	Fe500
For Infilled wall	Unit Weight = 20 KN/m3
Type of Loading	
Wall Load	14 KN/m
Live Load	2.5 KN/m^2
HEAVY MASS	5 KN/m^2
Floor Finishing	1.5 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	V
Zone Factor	0.36
Importance Factor	1
Type of Soil	II - Medium
Building Type (R)	5 (SMRF)



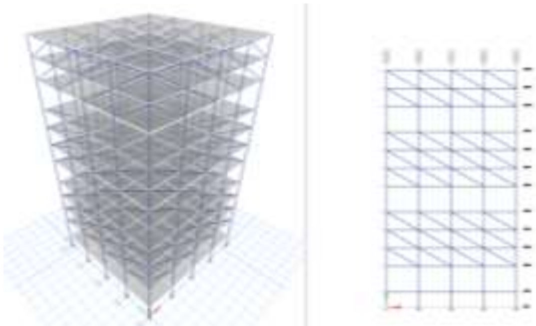
BUILDING WITHOUT INFILL WALLS



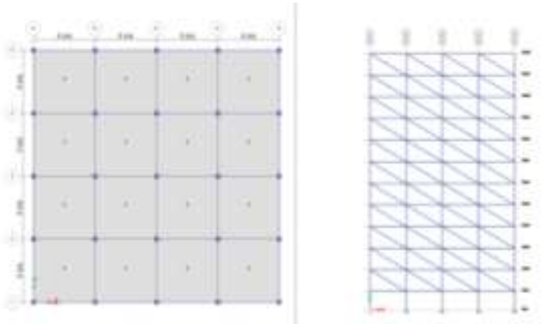
BUILDING WITH INFILL WALLS



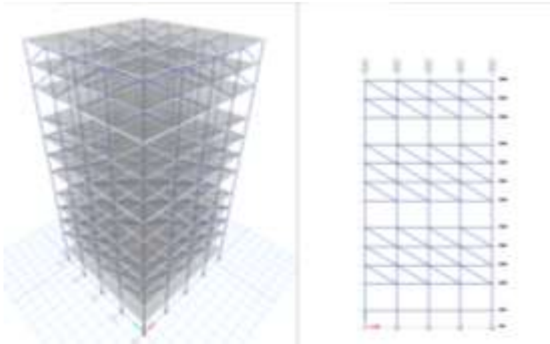
BUILDING WITH INFILL WALLS, SHEAR WALL & STAIR CASE



BUILDING WITH INFILL & SOFT STOREY



BUILDING WITH INFILL & HEAVY MASS



BUILDING WITH INFILL, SOFT STOREY & HEAVY MASS

Equivalent Strut Method

Width of Strut –

$$w = 0.175\ (\alpha)^{-0.4} L$$

Where, w = width of strut

α = Stiffness factor

L = Diagonal Length of Strut

Stiffness factor α can be given by –

$$\alpha = h\{(\frac{E_m t sin2\theta}{4E_f I_c h})^{\frac{1}{4}}\}$$

Where E_m – Modulus of Elasticity for Masonry – 550 f_m

& f_m – Compressive Strength of Masonry

t – Thickness of Infill Wall – 230 mm

θ - Angle of Inclination – (Clear Height between Beams / Clear Distance between Columns)

E_f – Modulus of Elasticity for Concrete – 5000 $\sqrt{f_{ck}}$

I_c – Moment of Inertia of Columns –

h = Clear Height between Beam of Adjacent Floors

For This Study, Percentage of Reduction in stiffness factor and is governed by percentage of opening.

Percentage of Opening – (Area of Opening / Area of Infill Walls)

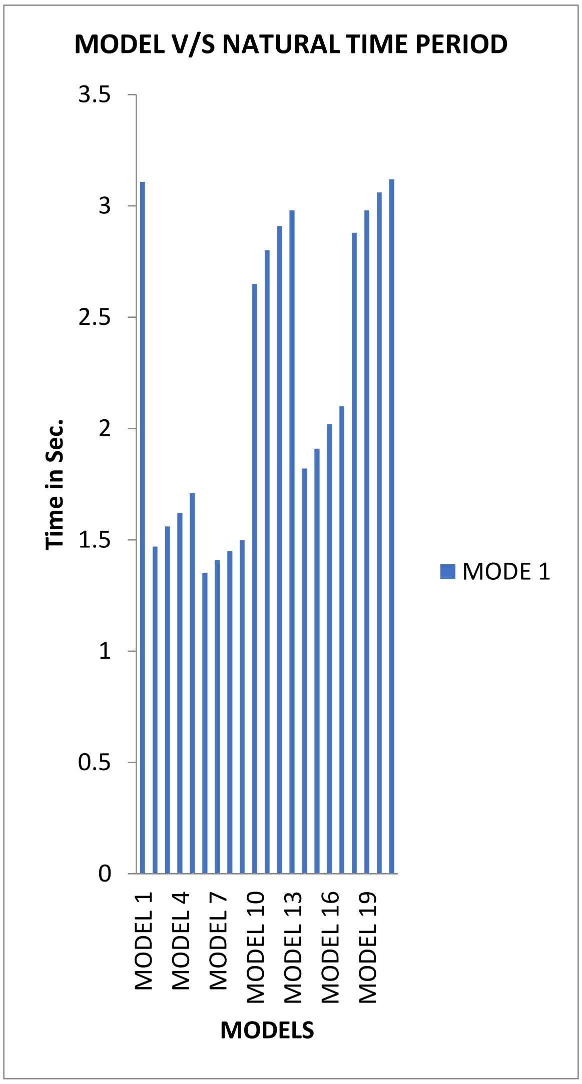
Percentage Considered –

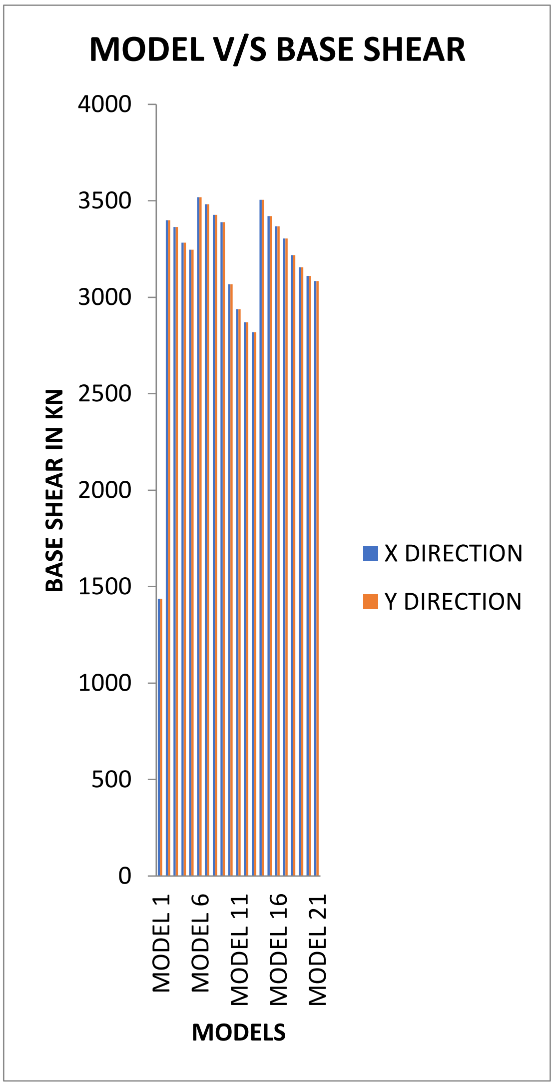
1. 5%
2. 10%
3. 15%

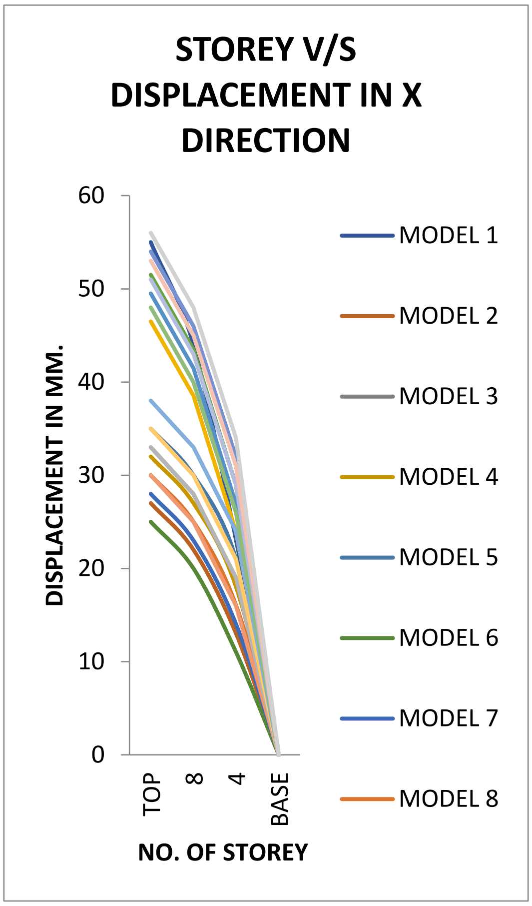
3. RESULTS -

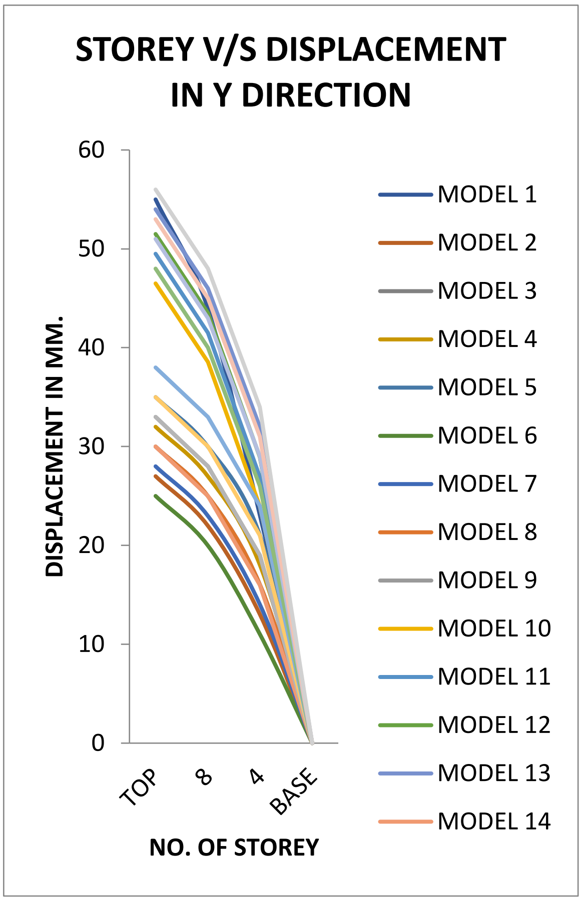
The scope of the study gives an idea about the seismic performance of regular and irregular buildings. Various seismic response parameters which include top storey displacement, base shear, inter-storey drift, etc. are taken into consideration to justify thE conclusion.

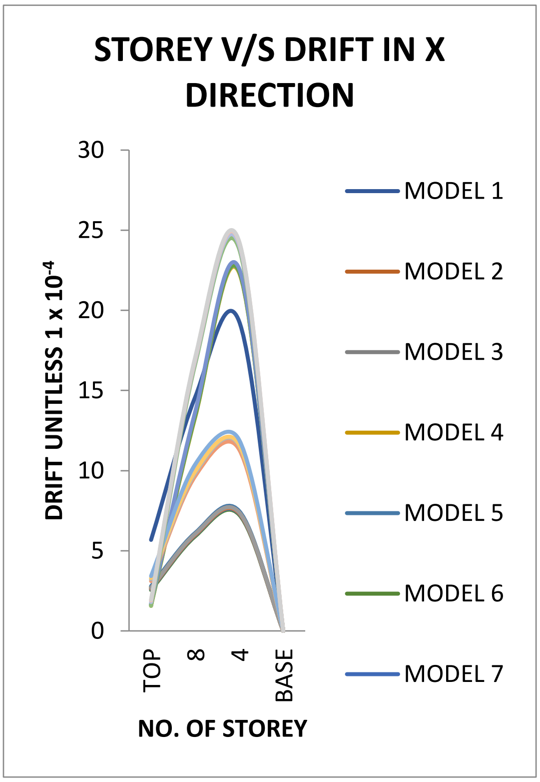
TIME PERIOD – This graph shows tabular values for natural time period corresponding to the first mode of the modal analysis.

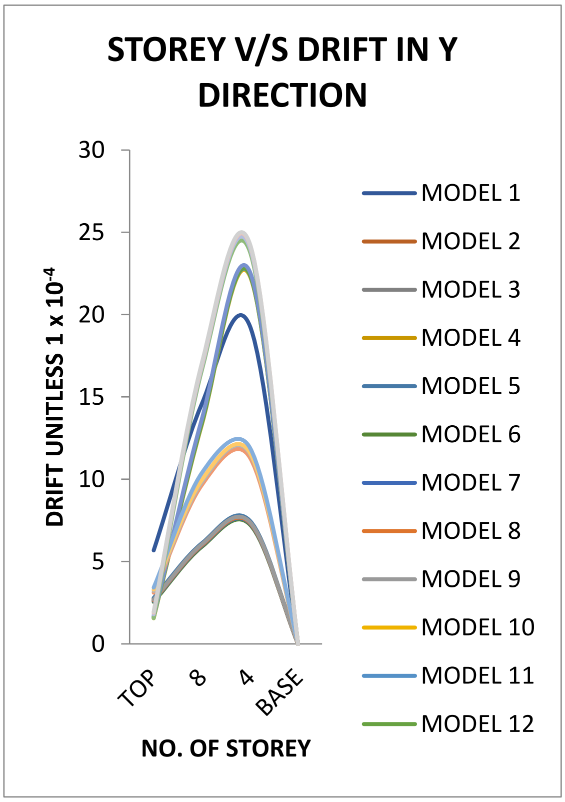





STOREY V/S DISPLACEMENT IN X DIRECTION
DISPLACEMENT IN MM.
60
50
40
30
20
10
0
TOP
8
4
BASE
NO. OF STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8


STOREY V/S DISPLACEMENT IN Y DIRECTION
DISPLACEMENT IN MM.
60
50
40
30
20
10
0
TOP
8
4
BASE
NO. OF STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9
MODEL 10
MODEL 11
MODEL 12
MODEL 13
MODEL 14


STOREY V/S DRIFT IN X DIRECTION
DRIFT UNITLESS 1 x 10⁻⁴
30
25
20
15
10
5
0
TOP
8
4
BASE
NO. OF STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7


STOREY V/S DRIFT IN Y DIRECTION
DRIFT UNITLESS 1 x 10⁻⁴
30
25
20
15
10
5
0
TOP
8
4
BASE
NO. OF STOREY
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9
MODEL 10
MODEL 11
MODEL 12

4. CONCLUSION

Following conclusion have been made from this study -

- The bare frame model possesses 24% high displacement than the models with infill wall which increases the risk of deflection during earthquake high.
- The Time period of the RC structure with Infill and stair case model is less than the RC structure without infill. The Natural Time Period also increases up to 3 % for when compared to models having openings while it increases up to 10% for the models having irregularities.
- Structure having ground floor with no walls i.e. soft storey is having 10% higher displacement value as compared to other buildings.
- Due to soft storey in any structure at any other level rather than ground floor, an increase of 14% in the drift value can be seen at that level. It occurs due to stiffness reduction at that level.
- When mass irregularity occurs in a building, there will be a abrupt change in storey displacement and drift at that level due to which drift ratio passes the permissible limit for a certain section at that level.
- Infill walls with openings have feeble performance when compared to the walls without openings. The values for displacement and drift are 5% higher as we increase the effect of openings in the wall. Anyhow, some portion of openings can be considered i.e. up to 10% which will be less effective to earthquake forces.

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