Seismic Behavior of Buildings with Plan Irregularity with and Without Structural Infill Action

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Abstract— It is understood that buildings which are regular in plan (regular building) perform much better than those which have irregularity in plan (irregular building) under seismic loading. Irregularities are not avoidable in construction of buildings. However a detailed study to understand structural behaviour of the buildings with irregularities under seismic loading is essential for appropriate design and their better performance.

In the present study, a 5 bays X 5 bays, 10 storeyed structure with provision of lift core walls and each storey height 3.2 m, having no irregularity in plan and elevation, is considered as the basic 3-D structure with which the seismic behaviour of three different plan irregularity buildings are compared of the three irregular buildings which have the same area as that of the regular building, two are symmetrical about X axis ('C' shaped buildings in plan) and one has no axis of symmetry ('L' shaped building in plan). Both regular and irregular buildings are assumed to be located in zone III.

Linear dynamic analysis using Response Spectrum method of all the buildings, irregular, regular are carried out using the standard and convenient software package ETABS 2013.

For this the behaviour parameters considered are 1) Eccentricity, 2) Maximum displacement and drift, 3) Base shear, 4) Maximum storey acceleration 5) Time period and 6) Member force in a typical beam and column

It is found that plan irregularity of buildings leads to increase in displacement, drift, storey acceleration, time period and member forces, but reduces the base shear. Infilled frame action develops additional lateral stiffness so that the quantities such as displacement, drift, storey acceleration, time period and member forces are reduced, while the base shear is increases.

Index Terms— plan irregularity, lift core walls, 'C' and 'L' shape, , Linear dynamic analysis.

I. INTRODUCTION

Irregularities in building structures refer to the non-uniform response of a structure due to non-uniform distribution of structural properties. There are two types of structural irregularity; vertical (also termed in-elevation) and plan (also termed plan asymmetry). Vertical irregularity typically refers to the uneven distribution of mass along the height of a multi-storey structure or geometrical set-backs changing the floor plan between adjacent floors. During a seismic event, the result can be a soft storey mechanism. Plan irregularity typically refers to the uneven distribution of stiffness or strength in the plan of a structure resulting in a torsional response of the structure when subjected to a seismic excitation. Structures with plan irregularity quite often suffer severe damage in earthquake events because the response of the structure is not only translational, but also torsional.

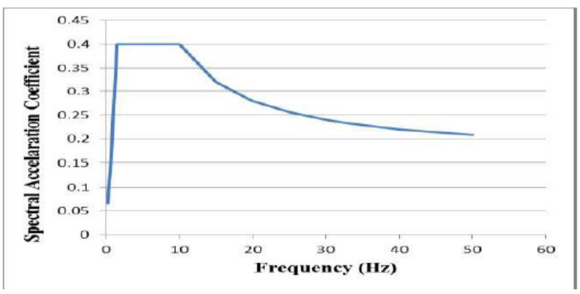
II. METHOD OF ANALYSIS

This study is conducted to understand the structural behaviour of plan irregular buildings in comparison to regular building under seismic loading. It is recommended that for analysis of plan irregular buildings dynamic analysis needs to be carried out, equivalent static method being more suitable for regular buildings. Hence response spectrum method of dynamic analysis is chosen for analysis by utilizing software ETABS 2013 (version 13.1.2).

Spectrum Acceleration Coefficient For The Response Spectrum Method

For the generation of the Design Spectra, the maximum considered earthquake (MCE), Zone factor (Z) III, Importance factor (I) 1.00, Response reduction factor (R) 5.00 and Medium soil site condition are considered.

Design horizontal seismic coefficient $A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$



Design Spectrum for Seismic Zone III

A 10 storey building of 5 X 5 bays in both X and Y direction with typical storey height of 3.2 m containing lift core walls is considered as regular building (Fig 1.1) for analysis. Three buildings (irregular in plan) are considered to study the effect of irregularity and on seismic behavior (Fig 1.1, 1.2, 1.3)

Two types of analysis are carried

- Analysis of bare frame (considering all beams carry wall load, but no infill action)

- Analysis as infilled frame (considering infill action as equivalent diagonal strut)

Cross Sectional Properties and Material Constants

Number of storeys : G+ 9 storeys (H=33.5m)

Column size : 800 mm X 800 mm

Plinth beam size : 300 mm X 450 mm

Beam size : 300 mm X 800 mm

Slab thickness : 230 mm

Masonary wall thickness : 230 mm

Height of typical floor : 3.2 m

Depth of foundation : 1.5 m

Number of lift core : 4 NO

Lift core size : 2 m X 2 m

Thickness of lift core : 230 mm

Grade of Concrete : M25

Grade of Steel : Fe 415

Characteristic strength of concrete, fck : 25Mpa

Density of Concrete : 25 KN/m3

Modulus of elasticity of concrete : 25000Mpa

Poisson's ratio of concrete, μ : 0.20

Density of brick masonry, ρ : 19.2 KN/m3

Modulus of elasticity of brick masonry, E_{me} : 1.8 X10^6 KN/m^2

Poisson's ratio of brick masonry : 0.20

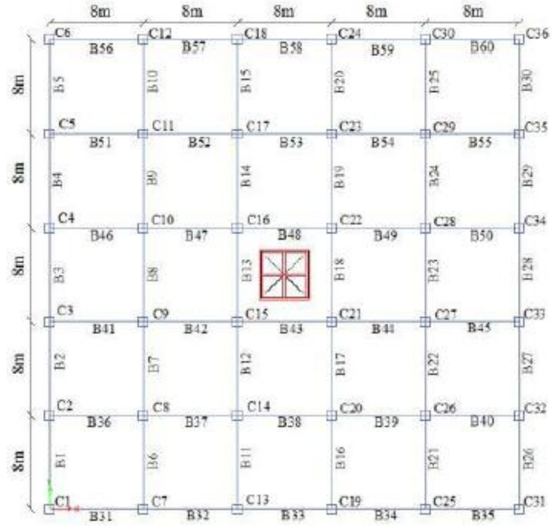


Fig 1.1 (Model 1) Plan of Regular Building

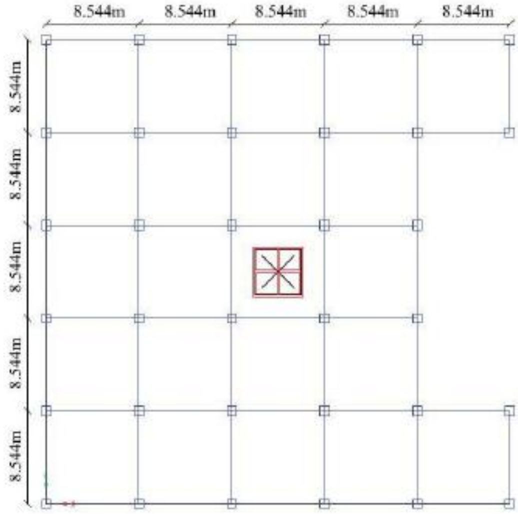


Fig 1.2 Model 2 (plan)

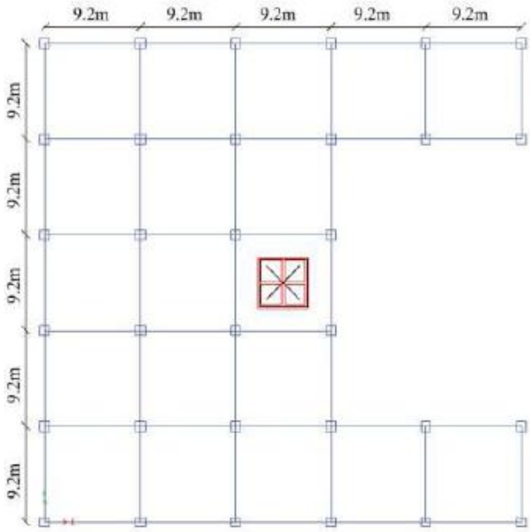


Fig 1.12 Model 3 (plan)

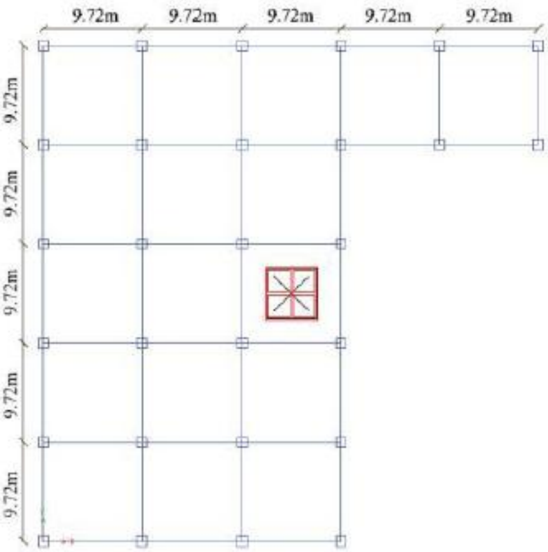
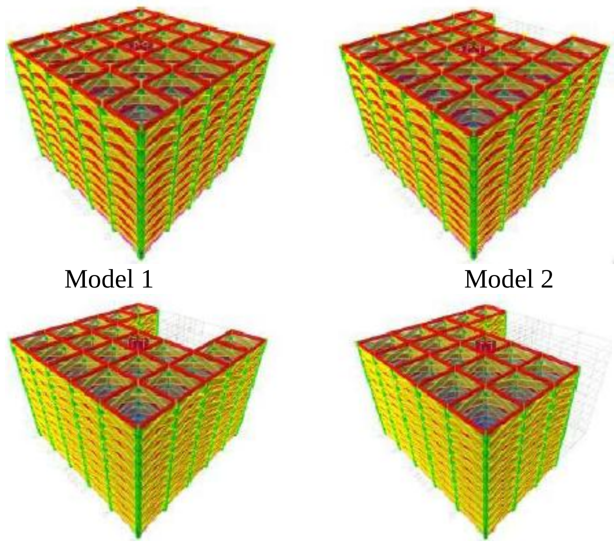


Fig 1.3 Model 4 (plan)


Model 1 Model 2

Model 3 Model 4

Fig 1.4 Typical 3D Model of Infilled Frame

III. PRIMARY LOADS

The structural systems are subjected to 4 types of Primary Load Cases as per provisions of Indian Standard Code of Practice for Structural safety of Buildings, loading standards IS 875-1987 (Part I), they are:

1. Dead Load case (Vertical or Gravity load), denoted as "DL"
2. Live Load case (Vertical or Gravity load), denoted as "LL"
3. Seismic Load in X-direction (Lateral or Earthquake load), denoted as "EQ X"
4. Seismic Load in Y-direction (Lateral or Earthquake load), denoted as "EQ Y"
5. Response spectra in X-direction, denoted as "RS X"
6. Response spectra in Y-direction, denoted as "RS Y"

IV. LOAD COMBINATIONS

The structural systems were subjected to 19 types of Load Combinations as per provisions of IS1893 (Part 1):

2002, Clause 6.3.1, that deals with "Criteria for Earthquake Resistant Design of Structures", they are:

a) Non- Seismic Load combination: 1.5(DL + LL)

b) Seismic Load combination:

1.2(DL+LL+EQ X)
1.2(DL+LL-EQ X
1.2(DL+LL+EQ Y)
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)
1.2(DL+LL+RS X)
1.2(DL+LL+RS Y)
1.5(DL + RS X)
1.5(DL + RS Y)
(0.9DL + 1.5RS X)
(0.9DL + 1.5RS Y)

V. RESULTS

In the present investigation an attempt has been made to study the effect of plan irregularity and effect of infill frame action of a ten storey building with lift core provided. The seismic analysis is carried out using the Linear Dynamic analysis (Response Spectrum Method).

The following parameters of the results obtained from analysis are considered for the study. Results are presented in Fig 1.5 to Fig 1.13.

A. Eccentricity
B. Maximum displacement and drift
C. Base shear
D. Time period
E. Member forces in typical Beam (B54) and Column (C29)

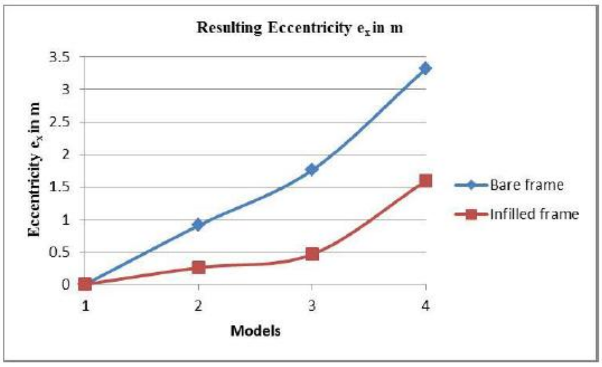


Fig 1.5 Resulting Eccentricity e_x in m

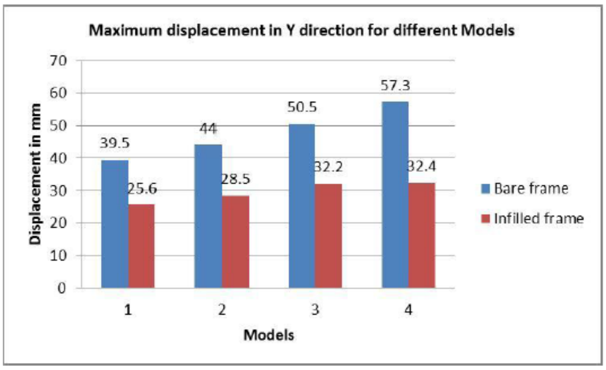


Fig 1.6 Maximum displacement in Y direction for different Models

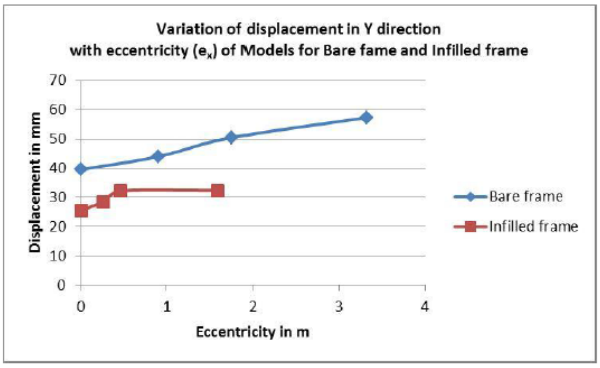


Fig 1.7 Variation of displacement in Y direction with eccentricity (e_x) of Models for Bare fame and Infilled frame

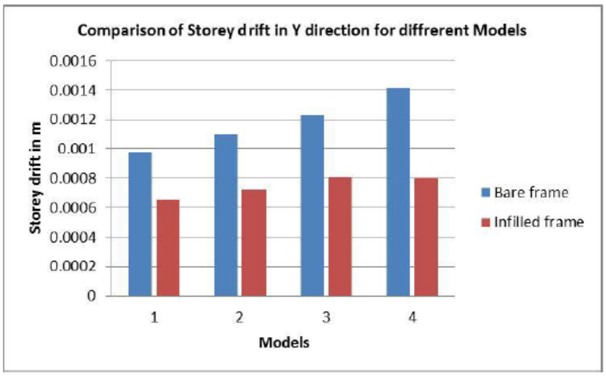


Fig 1.8 Comparison of Storey drift in Y direction for different Models

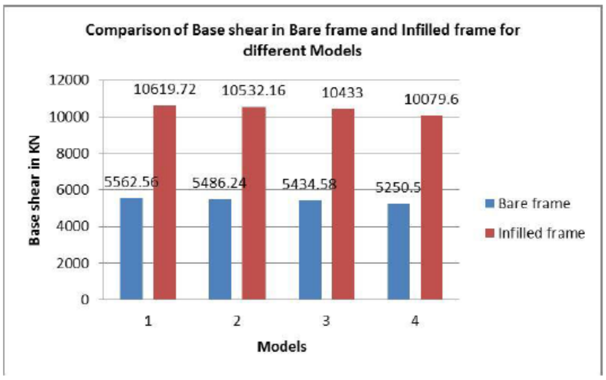


Fig 1.9 Comparison of Base shear in Bare frame and Infilled frame for different Models

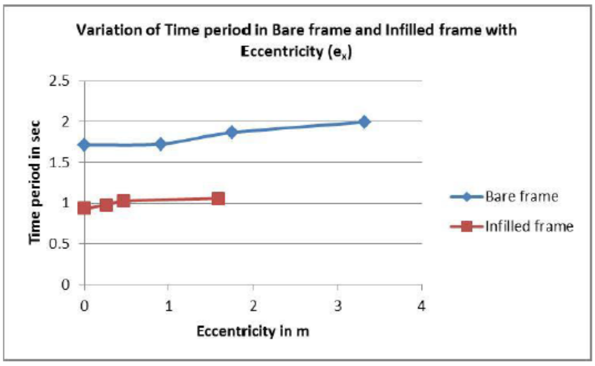


Fig 1.10 Variation of Time period in Bare frame and Infilled frame with Eccentricity (e_x)

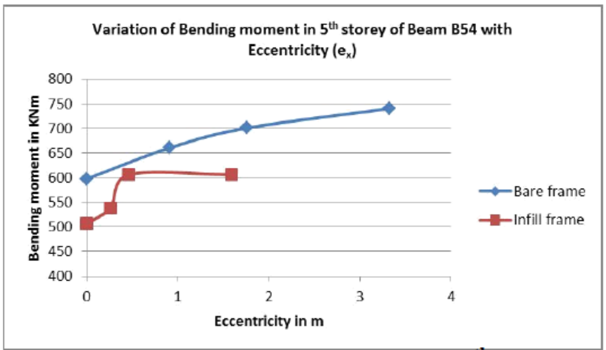


Fig 1.11 Variation of Bending moment in 5th storey of Beam B54 with Eccentricity (e_x)

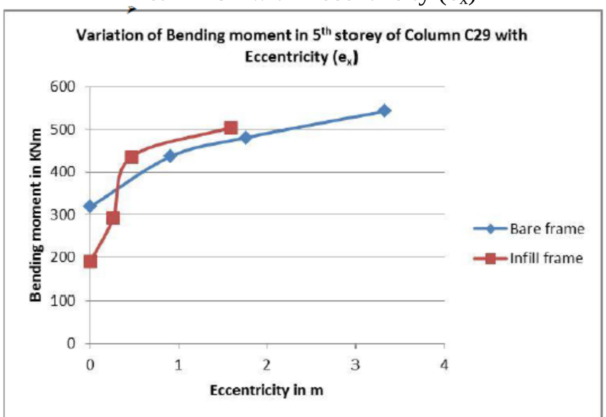


Fig 1.12 Variation of Bending moment in 5th storey of Column C29 with Eccentricity (e_x)

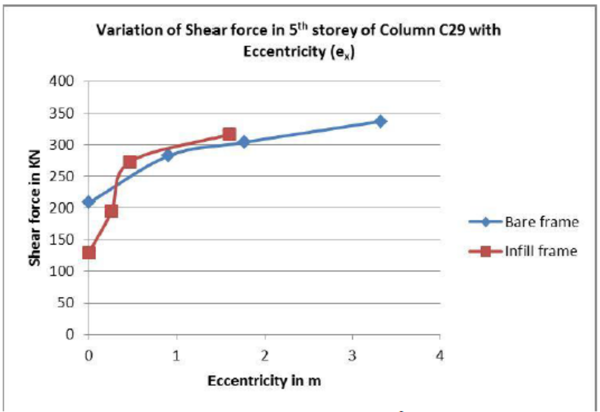


Fig 1.13 Variation of Shear force in 5th storey of Column C29 with Eccentricity (e_x)

Displacement at any storey level and maximum displacement reduce due to infill action because of the increase in lateral stiffness of frame. The percentage reduction in displacement due to infill action slightly increases with increase in eccentricity.

With increase in the eccentricity of building in both X and Y directions, the base shear in Bare frame and Infilled frame slightly decrease with increase in plan irregularity.

Due to infill action percentage increase in base shear increases as the irregularity increases showing that the irregular building needs to be designed for higher base shear than a regular building.

In case of both bare frame and infilled frame the Time period gradually increases with increase in plan irregularity.

Due to infill action the time period in infilled frame substantially reduces in comparison to bare frame because of high stiffness of infilled frame.

With increase in eccentricity from Model 1 to Model 4, the maximum bending moment, shear force in Beam B54 and beding moment, shear force, axial force in Column C29 increases in bare frame, as well as, in infilled frame.

The effect of infill frame action reduces the bending moment, shear force in Beam as well as in column.

VI. CONCLUSIONS

As the plan irregularity of a building increases, eccentricities e_x and e_y which are zero for regular building, increase gradually in case of building modeled as both Bare frame and Infilled frame

The Maximum displacements in both bare frame and infilled frame in X and Y direction increase as the eccentricity or plan irregularity of the building increase along X and Y direction.

With increase in plan irregularity, the maximum storey drifts in X and Y direction increase in both bare frame as well as infilled frame.

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