

# **LINEAR STATIC ANALYSIS OF MASONRY INFILLED R.C.FRAME WITH & WITHOUT OPENING INCLUDING OPEN GROUND STOREY**

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*Abstract:* Masonry infill walls are mainly used to increase initial stiffness and strength of reinforced concrete (RC) frame buildings. It is mainly considered as a non-structural element. In many cities of India, it is very common to leave the first storey of masonry infilled reinforced concrete (RC) frame building open preliminary to generate parking space or any other purposes (Ex-Reception lobbies) in the first storey. This Open First storey is also termed as “Soft Storey”. The upper storeys have brick infilled wall panels with various opening percentage in it. This type of buildings are highly undesirable in seismically active areas because various vertical irregularities are created in such buildings which have consistently performed very poor behavior during past earthquake. In the present study, it is attempt to access the performance of masonry infilled reinforced concrete (RC) frames with open first storey of with and without opening. In this paper, symmetrical frame of college building (G+5) located in seismic zone-III is considered by modeling of initial frame. With reference to FEMA-273, & ATC-40 which contain the provisions of calculation of stiffness of infilled frames by modeling infill as a “Equivalent diagonal strut method”. Therefore, the infill panels are modeled as a equivalent diagonal strut method. This linear static analysis is to be carried out on the models such as bare frame, strut frame, strut frame with centre & corner opening, which is performed by using computer software STAAD-PRO from which different parameters are computed. In which it shows that infill panels increase the stiffness of the structure. While the increase in the opening percentage leads to a decrease on the lateral stiffness of infilled frame.

**Keywords;** Masonry infilled frame, Stiffness, Equivalent Diagonal Strut Method, Seismic Effect .

## **I. INTRODUCTION**

Many urban multistorey buildings in India today have open first story as an unavoidable feature. This leave the open first storey of masonry infilled reinforced concrete frame building primarily to generate parking or reception lobbies in the first storeys. It has been known for long time that masonry infill walls affect the strength & stiffness of infilled frame structures. There are plenty of researches done so far for infilled frames, however partially infill frames are still the topic of interest. Though it has been understood that the infill's play significant role in enhancing the lateral stiffness of complete structures. Infills have been generally considered as non-structural elements & their influence was neglected during the modeling phase of the structure leading to substantial inaccuracy in predicting the actual seismic response of framed structures. The performance of the structure can be significantly improved by the increase of strength and dissipation capacity due to the masonry infill's even if in presence of an increasing in earthquake inertia forces. In most cases, first storey columns were either damaged severely or failed completely thereby damaging the buildings strengthening of open first storey is recommended by national codes of few countries: India-IS1893 (BIS2002), Israel-SI413 (SII 1993) & Bulgaria (Bulgarian seismic code 1987). These codes require the open storey beams & columns to be designed for higher forces obtained by multiplying the seismic forces with predetermined factors varying from 2.1 to 3.0. In addition, provisions in Eurocode-8 (CEN 2003) for reinforced concrete buildings with a soft storey required that the first storey columns be designed for 1.5-

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4.68 times the design seismic forces depending upon several parameters. However, in Eurocode-8 the natural period of building is calculated using empirical expressions that use cross sectional area of infill's in the first storey .While, In case of open first storey frames the cross sectional area of infill's in the first storey is zero because of absence of infill's in the first storey. Hence the empirical expressions for calculation of natural periods cannot be used for such buildings & it may be inferred that buildings with open first storey are not anticipated by Eurocode -8 and as per Indian standard 1893 (part -I) 2002 code (BIS-2002) some design criteria are to be adopted after carrying out the earthquake analysis ,in which the columns and beams of the soft stories are the designed for 2.5 times the store shears and moments calculated under seismic loads.

## II. ANALYTICAL METHODS

Static or dynamic analysis can be classified into three broad categories, namely elastic analysis, plastic analysis and nonlinear analysis. Elastic analysis refers to the analysis where a linear elastic behaviour is assumed for the frame and the infill, and geometric and material nonlinearities are not included. In the case of a plastic analysis, an elastic-plastic stress-strain relationship is assumed for the materials, and the failure load of the infilled frame corresponding to collapse stage is determined. In the nonlinear analysis, the different sources of nonlinearity are included, and the response of the structure is traced in the entire loading range, from pre cracking to collapse. For most applications, codes of practice recommend an elastic analysis; because of the inherent complexity of a nonlinear analysis. The different models available for the elastic analysis of infilled frames can be classified into four groups based on their complexity. They are the stress function method, the equivalent diagonal strut method, the equivalent frame method and the finite element method.

## III. EQUIVALENT DIAGONAL STRUT METHODS

The simplest equivalent strut model includes a single pin-jointed strut. Holmes who replaced the infill by an equivalent pin-jointed diagonal strut made of the same material and having the same thickness as the infill panel suggest a width defined by,

$$\frac{w}{d} = \frac{1}{3} \quad \dots\dots\dots (3.3.1)$$

Paulay and Priestley [32] suggested the width of equivalent strut as,

$$w = 0.25d \quad \dots\dots\dots (3.3.2)$$

Where,

- $d$  = Diagonal length of infill panel
- $w$  = Depth of diagonal strut

However, researchers later found that this model overestimates the actual stiffness of infilled frames and give upper bound values. Another model for masonry infill panels was proposed by Mainstone in 1971 where the cross sectional area of strut was calculated by considering the sectional properties of the adjoining columns. The details of model are as shown in Fig. 4.2. The strut area  $A_s$  was given by the following equation..

$$A_s = W t$$

$$W = 0.175 (\lambda H)^{-0.4} D$$

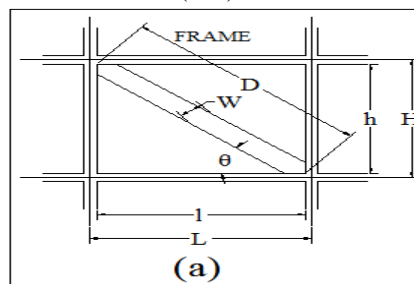


Fig.1 Brick Infill Panel As Equivalent Diagonal Strut

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$$K = \sqrt[4]{\frac{E_i t \sin(2\theta)}{4 E_f I_c h}}$$

Where,

$E_i$  = the modulus of elasticity of the infill material, N/mm<sup>2</sup>

$E_f$  = the modulus of elasticity of the frame material, N/mm<sup>2</sup>

$I_c$  = the moment of inertia of column, mm<sup>4</sup>

$t$  = the thickness of infill, mm

$H$  = the centre line height of frames

$h$  = the height of infill

$L$  = the centre line width of frames

$l$  = the width of infill

$D$  = the diagonal length of infill panel

$\theta$  = the slope of infill diagonal to the horizontal.

**Infills frame with Opening:** Area of opening,  $A_{op}$  is normalized with respect to area of infill panel,  $A_{infill}$  and the ratio is termed as opening percentage (%).

$$\text{Opening percentage (\%)} = \frac{\text{Area of opening (A}_{op}\text{)}}{\text{Area of infill(A}_{infill}\text{)}}$$

## IV. ANALYSIS EXAMPLE

Type of structure	COLLEGE BUILDING (G+5)
ZONE	III
FOUNDATION LEVEL TO GROUND LEVEL	1 M
FLOOR TO FLOOR HEIGHT	4M
EXTERNAL WALL	230 MM
INTERNAL WALL	230 MM
LIVE LOAD	5 KN/M <sup>2</sup>
MATERIAL	M20 AND Fe415
SEISMIC ANALYSIS	EQUIVALENT STATIC METHOD (IS 1893 (Part I) - 2002)
SIZE OF COLUMN	C1= 300X700 C2= 400X750
SIZE OF BEAM	B1=300X500 B2=300X400
DEPTH OF SLAB	140 MM
DESIGN PHILOSOPHY	LIMIT STATE METHOD CONFORMING (IS 456-2000)
DUCTILE DETAILING CODE	IS 13920-1993

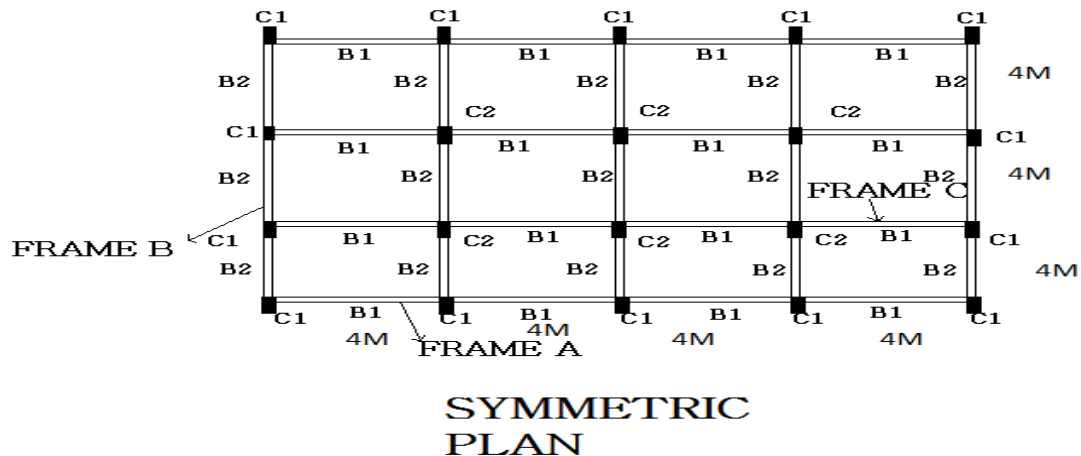
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## STRUCTURAL DETAIL

### Symmetrical View Of Building



The above mentioned frame has been designed by using STAAD-Pro software. For getting results some column has been selected for getting results and they are as column no...1, 2 the results shown in the form of

- ❖ DEFLECTION
- ❖ AXIAL FORCE
- ❖ MOMENT
- ❖ AST

## V. ANALYTICAL MODELS CONSIDERED

- 1) Model I. Bare Frame (RC frame with infill Masonry, but effect of masonry infill not considered)
- 2) Model II. Open Ground Storey of Complete Strut Frame.
- 3) Model III. Open Ground Storey of Strut Frame With 25% Centre Opening (RC Frame with Masonry Infill S.M.R.F. Frame)
- 4) Model IV. Open Ground Storey of Strut Frame With 25% Corner Opening (RC Frame with Masonry Infill S.M.R.F. Frame)

## VI. Materials:

### a) Concrete:

Concrete with following properties is considered for study.

- Characteristic compressive strength ( $f_{ck}$ ) = 20 MPa
- Poissons Ratio = 0.3
- Density = 25 kN/m<sup>3</sup>
- Modulus of Elasticity ( $E$ ) =  $5000 \times \sqrt{f_{ck}} = 22360.67$  MPa

### b) Steel :

Steel with following properties is considered for study.

- Yield Stress ( $f_y$ ) = 415 MPa

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- Modulus of Elasticity (E) =  $2 \times 10^5$  MPa

### c) Masonry infill

- Clay burnt brick, Class A, confined unreinforced masonry
- Compressive strength of Brick,  $f_m = 10$  MPa
- Modulus of Elasticity of masonry ( $E_i$ ) =  $550 \times f_m = 5500$  MPa
- Poissons Ratio = 0.15

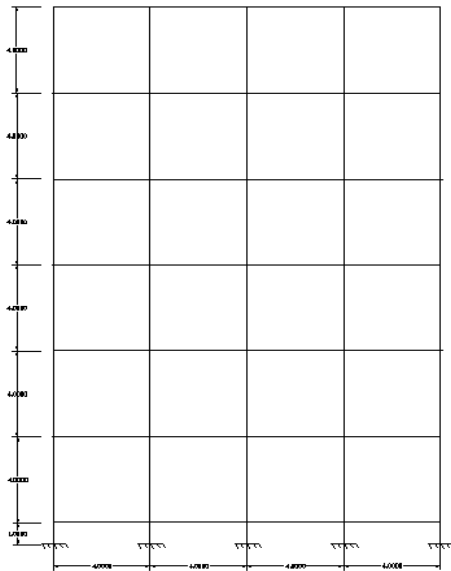


Fig6.1; MODEL I: BARE FRAME

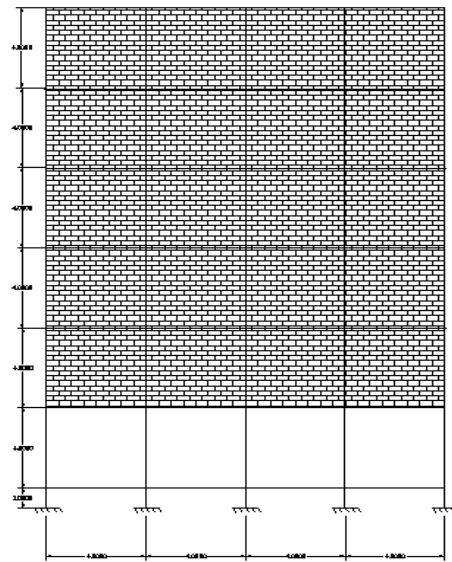


Fig6.2; MODEL II: WITH FULLY INFILLED FRAME

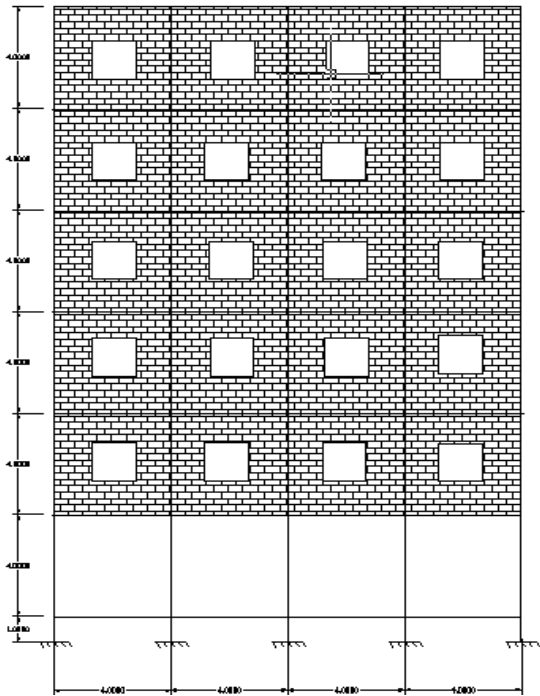


Fig6.3; MODEL III: INFILLED FRAME WITH CENTRE OPENING

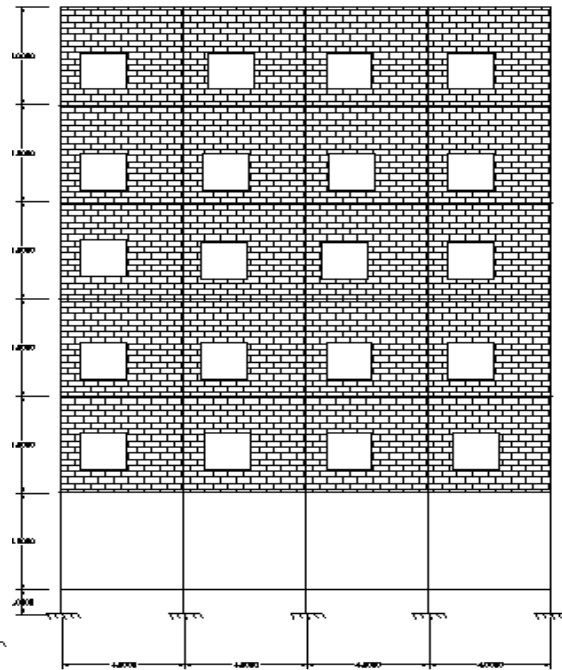


Fig6.4; MODEL IV : INFILLED FRAME WITH CORNER OPENING

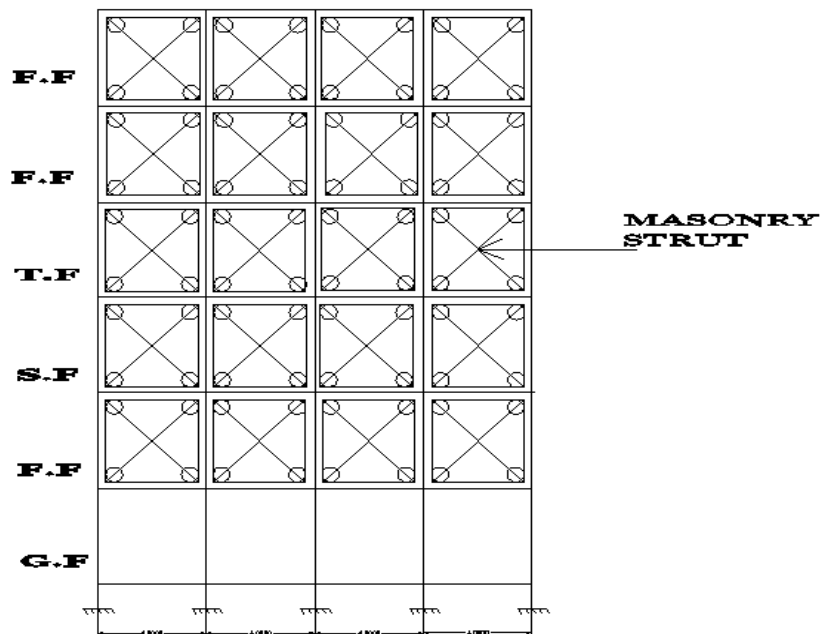


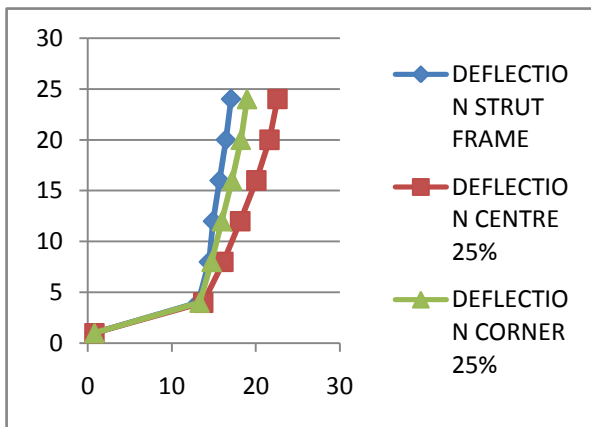
Fig6.5; EXAMPLE OF STRUT FRAME MODEL

**VII.COMPARISON OF RESULTS**

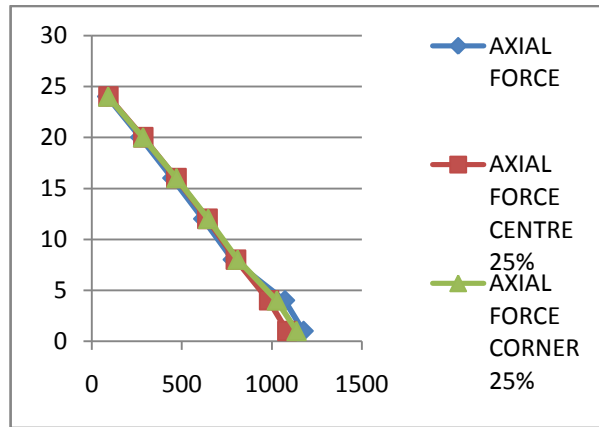
Here, Comparison is done in between bare frame and centre and corner opening only. And it is shown with the help of graph.

**GRAPH FOR STRUT FRAME WITH 25% CENTRE AND CORNER OPENING COLUMNS**

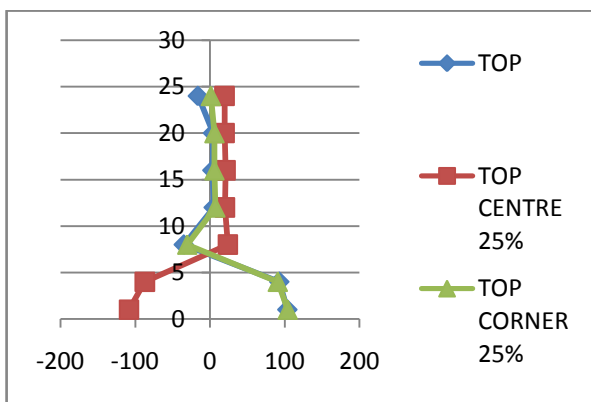
On X-Axis there is a different parameter of Deflection, Moment, Axial Force; Area of steel and on Y-Axis Height of building is fixed in all cases.



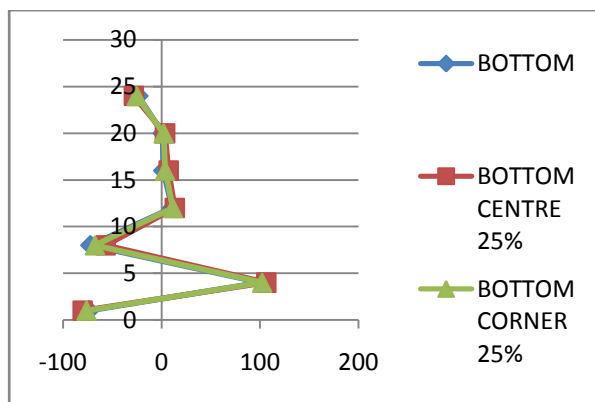
**Fig 7.1:Deflection In (mm) for column no 1**



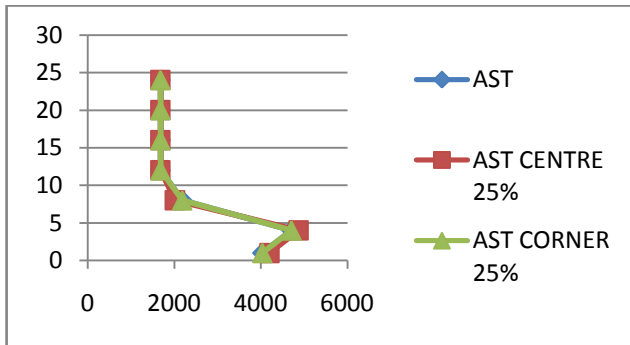
**Fig 7.2;Axial Force In (KN) for column no 1**



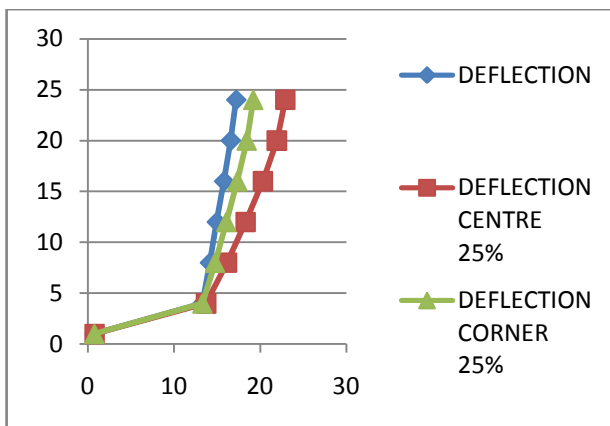
**Fig 7.3; B.M (Top) In (KN-M) for column no1.**



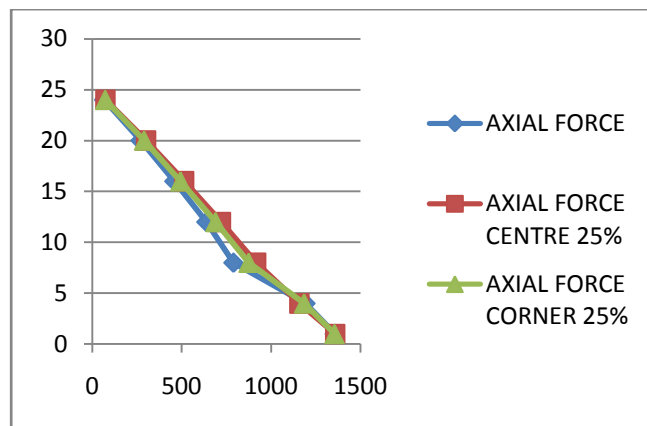
**Fig 7.4; B.M (Bottom) In (KN-M) for column no 1**



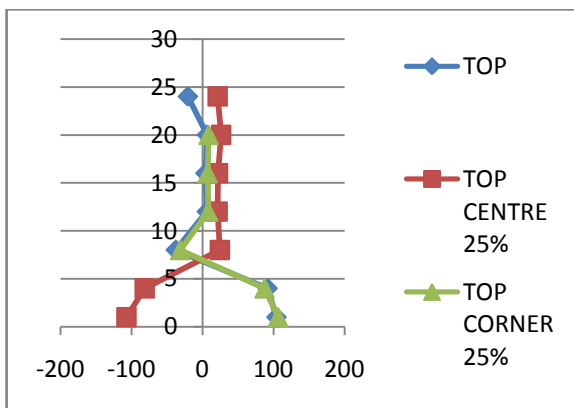
**Fig 7.5: Area of steel In (mm<sup>2</sup>) for column no 1**



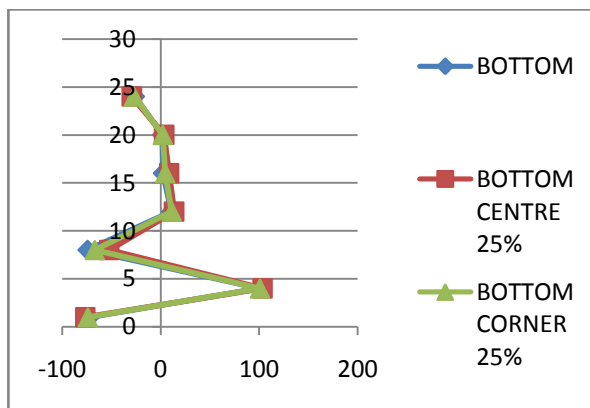
**Fig 7.6: Deflection In (mm) for column no 2**



**Fig 7.7: Axial Force in (KN) for column no 2**

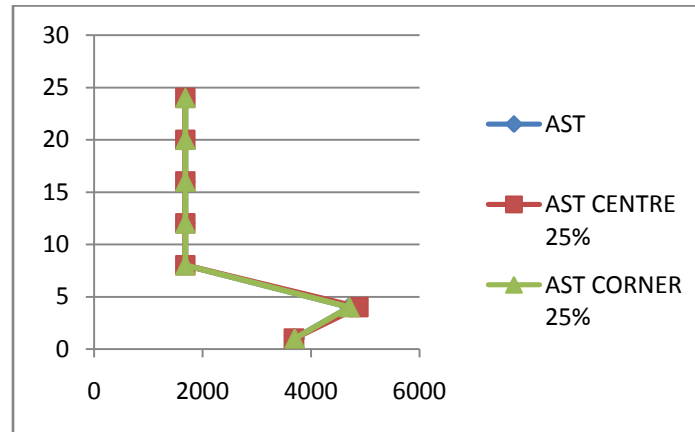


**Fig 7.8: B.M (Top) In (KN-M) for column no 2**  
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**Fig 7.9: B.M (Bottom) In (KN-M) for column no 2**  
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**Fig 7.10: Area of steel In (mm<sup>2</sup>) for column no 2**

**BARE FRAME DEFLECTION RESULT DISCUSSION (SHOWN IN GRAPH)**

According to IS1893(Part-1)-2002 Clause No.7.11.1 “Storey Drift Limitation”,the storey drift in any storey due to the minimum specified design lateral force with partial load factor of 1 shall not exceed 0.004 times the storey height.

Here, in the result of bare frame the value of deflection of all COLUMNS IS exceeding just by 4-6 mm, which is not satisfying the codal provision given above.

This variation of result is consider because of just taking bare frame in which infill wall are not provided.Due to which its stiffness is very less and deflection is more as per actual value.

By changing column orientation or variation in column size we can get the value within permissible limit given by code.

**VIII. CONCLUSION**

1. Infill panels increase stiffness of the structure.
2. The increase in the opening percentage leads to a decrease on the lateral stiffness of infilled frame.
3. From this present result it shows that, deflection is very large in case of bare frame as compare to that of Infill frame with opening. If the effect of infill wall is considered then the deflection has reduced drastically. And also deflection is more at last storey because earthquake force acting on it more effectively.
4. Maximum Axial Force at the foundation level.
5. In columns, without considering infill wall effects the value of, B.M and Ast are maximum above 1m height because of soft storey present.
6. Deflection in case of centre opening is large compare to corner opening.

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