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"INFILL WALL STIFFNESS CONSIDERATION IN EARTHQUAKE ANALYSIS"

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Abstract:
Lots of research is held in infill wall consideration in frame structure. In this study symmetrical R/C frame structure and its lump mass model is created. Static earthquake analysis and response spectrum method is applied for to get the seismic forces in the structures. Two cases are considered for analysis such as bare frame, equivalent strut and its lump mass models. All analysis carried out by SAP 2000 software. Results on base shear, modal mass participation, first fundamental frequencies, and frame displacement are calculated and compared for all models.

Keywords: *Infill wall, high rise building, equivalent strut model, displacement, lump mass models, etc.*

I. INTRODUCTION

In metro city there is necessity to build a high rise structure due to high population and less land availability. Also the human ambition is force to create taller structure. Large numbers of high rise reinforced concrete structure are constructing to full fill the human requirement. It is seen that stiffness and strength of reinforced concrete structure is greatly increased by considering infill masonry. In conventional analysis we just consider the frame and analysis it with the help of any computer applicable software such as STADD Pro, ETAB, and SAP etc. In such analysis wall are considered just as a load on beam of frame structure and they do not carry any load. But the infill walls are providing some stiffness and strength in case when horizontal forces act on the structure. A lot of work has been carried on consideration of infill wall stiffening effect and its construction details in which most of them are based on equivalent trut method in which method, wall panels are replaced with the help of equivalent strut. In these work lump mass models of solved problem is again solved by software and compare the results of analytical and software solved problem base on above result we create lump mass model and bare frame of actual building and its base shear is compare with each other, also lump mass and frame structure of equivalent strut models are created and their base shears are compare. For manual checking base shear of both frames are found out by static method of IS 1893-2002

II. LITERATURE REVIEW

C. Donmez & M. A. Cankaya [5] "Drift Behavior of Reinforced Concrete Frames with Infill Walls at Progressing Damage Levels" in this paper they investigate the in-plane drift behavior of the RC frames With infill walls to provide hard data about the drift capacity and its distribution about the height of the frames. for that purpose they prepared Four scaled four-story reinforced concrete frames were tested with and without infill walls. Frames were subjected to pseudo-static cyclic loading with a triangular profile. Considering that natural frequencies and the modal shapes are interrelated with the stiffness and the drift behavior of the frames under dynamic loading, these parameters are also investigated. It is observed that progressing damage and infill walls caused major changes on both stiffness and drift behavior of the tested frames. Effect of changes could be either advantageous or disadvantageous depending on the failure mode. Results show that distribution of drift that is based on mode shapes indicate higher local concentrations than distribution observed under forced static conditions

A.J.Urich & J.L. Beauperthuy [6] "Protagonism of the Infill Walls on Seismic of Venezuela Buildings Performance" in this paper they used the predominant structural system used in Venezuela the reinforced concrete frames with masonry infill. It is still common that structural engineers underestimate those masonry walls' stiffness, strength and fragility, considering them only as a permanent weight and seismic mass. However, the assessments of buildings damaged by recent earthquakes have left in evidence that masonry walls, especially infill's, are the protagonists of seismic performance. Masonry walls are initially much stiffer than frames; therefore, when buildings are exposed to a seismic shake, the first pulses are resisted entirely by the infill walls, with minimal contribution from the main structure, which enter to play only after walls become broken; consequently, all the drift demand is concentrated in the building's stories or regions whose walls are the first to fail. The partially broken walls are used to cause a "soft story" and "short column" mechanisms that did not exist in the original configuration of the building.

Mr. V. P. Jamnekar & Dr. P. V. Durg [7] "SEISMIC EVALUATION OF BRICK MASONRY INFILL" The diagonal strut has been modeled by them and using SAP 2000 software and pushover analysis is performed. The example building is analysed, the effect of masonry infill in seismic evaluation of bare frame and frame with 40% infill is studied. The results obtained from the analysis are compared in terms of strength and stiffness with bare frame.

III. CONCEPT OF EQUIVALENT STRUT

Many investigators have proposed various approximations for the width of equivalent diagonal strut. Originally proposed by polyakov [1] (1956)and subsequently developed by many investigators, the width of strut depends on the length of contact between wall and column $\boldsymbol{\alpha_h}$ and between the wall and beam $\boldsymbol{\alpha_L}$ shown in fig 1. Stafford smith [2] (1966) developed the formulation for α_h and α_L on the basis of beam on an elastic foundation**.** the following equations are proposed

$$\alpha h = \frac{\pi}{2} \sqrt[4]{\frac{4E_F h I_c}{t \sin 2\theta E_m}}$$

$$\alpha L = \pi \sqrt[4]{\frac{4E_F L I_b}{t \sin 2\theta E_m}}$$

Where

E_F and E_m= elastic modulus of the masonry wall and frame material respectively

t, h, L thickness, height and length of infill wall respectively

I_c and I_b= moment of inertia of column and beam frame respectively.

$$\theta = \tan^{-1}(h/L)$$

Hendry [3] (1998) has proposed following equation to determine equivalent strut or equivalent or effective width of strut.

$$w_{ef} = \frac{1}{2}\sqrt{\alpha h^2 + \alpha L^2}$$

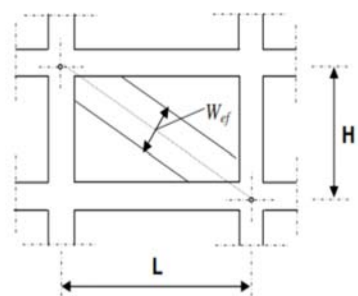

Fig1. Equivalent strut

IV. OBJECTIVE OF THE STUDY

The main objective of study is found out response of high story building with infill and without infill and compare the result of both to check the importance of infill wall on structural behavior in form of base shear, nodal displacement, etc. and make Comparative study of stiffness effect and Time period, Base, Shear etc.

V. VALIDATION OF SOFTWARE

Problem solved in Earthquake resistant Design of structure [4] page no 296-311 are again solved with the software and the result of both analytical solution and software are as follows

- **Natural time period**

i. Lump mass model without infill model

Table.1.

Mode no.	**Natural Time Period by analytical solution (sec)**	**Natural Time Period by software (sec)**
1	0.6977	0.69786
2	0.2450	0.245026
3	0.1636	0.163643
4	0.1383	0.138302

ii. Lump mass model with infill model (Equivalent strut model)

Table 2.

Mode no.	**Natural Time Period by analytical solution**	**Natural Time Period by software**
1	0.1655	0.165503
2	0.0581	0.05811
3	0.0388	0.038809
4	0.0328	0.032799

- **Mode shapes**

i. Mode shape of Lump mass model without infill as per analytical solution shown in Fig.2

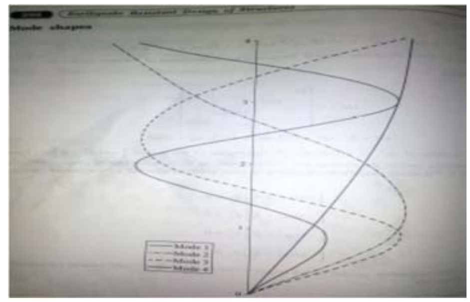

Fig.2

ii. Mode shape of Lump mass model without infill model as per software shown in fig 3.

Table3.

STOREY HEIGHT(mtr)	**MODE1**	**MODE 2**	**MODE 3**	**MODE 4**
14	0.087167	-0.08649	0.083884	-0.06956
10.5	0.079813	-0.02729	-0.04484	0.079882
7	0.060751	0.064378	-0.05396	-0.06899
3.5	0.03278	0.079456	0.080849	0.039775
0	0	0	0	0

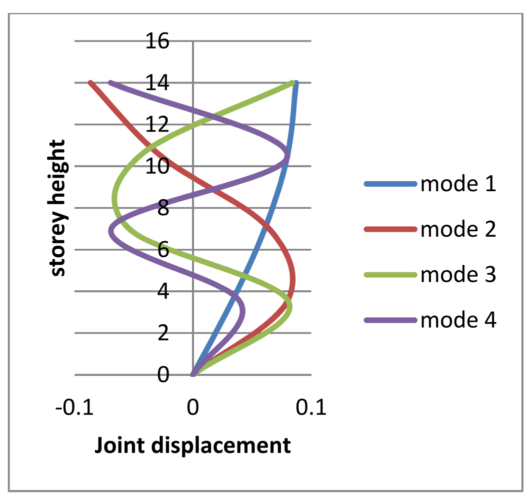

Fig.3

(Graphical representation of table 3)

iii. Mode shape Lump mass model with infill model (Equivalent strut model) as per software shown in fig 4.

Table 4.

STOREY HEIGHT (mtr)	MODE1	MODE 2	MODE 3	MODE 4
14	0.087167	-0.08649	-0.08388	0.069563
10.5	0.079813	-0.02729	0.044835	-0.07988
7	0.060751	0.064378	0.05396	0.068988
3.5	0.03278	0.079456	-0.08085	-0.03978
0	0	0	0	0

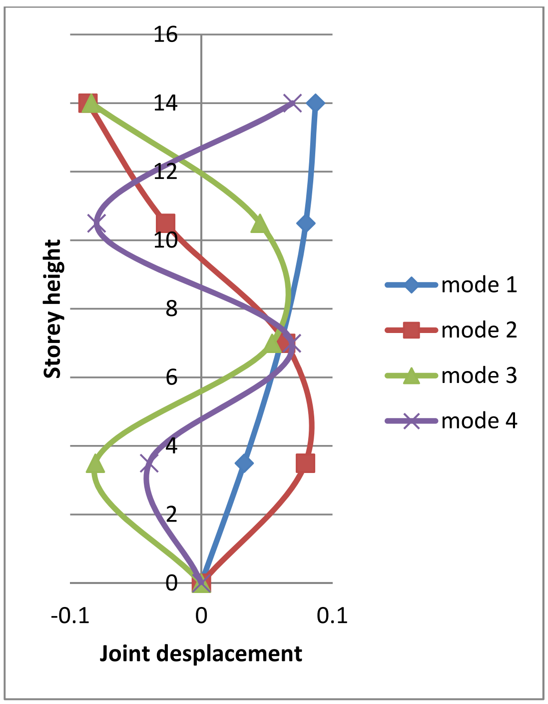

Fig.4

(Graphical representation of table 4)

- **Eigen values**

i. Lump mass model without infill model

Table5.

FROM ANALYTICAL SOLUTION	FROM SOFTWARE
81	81.063
657	657.56
1475	1474.2
2065	2064

ii. Lump mass model with infill model (Equivalent strut model)

Table6.

FROM ANALYTICAL SOLUTION	FROM SOFTWARE
1442	1441.3
11698	11691
26227	26211
36719	36697

- **Base shear**

i. Ratio of base shear as per analytical solution With and without infill wall

$= \frac{125.699}{80.930} = 1.5$

ii. Ratio of base shear as per software With and without infill wall

$= \frac{122.62}{99.856} = 1.3$

All the above results are satisfactory

VI. METHODOLOGY

The mathematical modeling of building structure is as per IS 1893-2002. In order to compare the bare frame, equivalent strut model we create their lump mass models and results are

compare with them. Methods adopted for these Analyses are Response Spectrum analysis and static earthquake analysis.
The given structure will be analyses for the cases mentioned bellow

1. Bare frame and its lump mass models.
2. Equivalent strut model and its lump mass model.

The structure will be analyses by response spectrum analysis as per IS-1893 for zone III, typical framing pan of 6 storey building shown in fig.2 building symmetrical in plan having each story height 3 m.

Parameters consider for analysis

- Floor to floor height= 3 m
- Slab thickness= 0.15 m
- External and internal wall thickness
- = 0.23m
- Beam size= 0.23 X 0.5 m
- Column size =0.70x0.70 m
- Live load =3 kn/m^2
- Floor finish= 1 kn/m^2
- Seismic zone=III
- Density wall = 20 kn/m
- Density concrete= 25 kn/m
- Grade of concrete= M20/M25
- Modulus of elasticity of frame
- $=5000\sqrt{fck}$= 22360.00N/mm^2
- Modulus of elasticity wall =13800N/mm^2

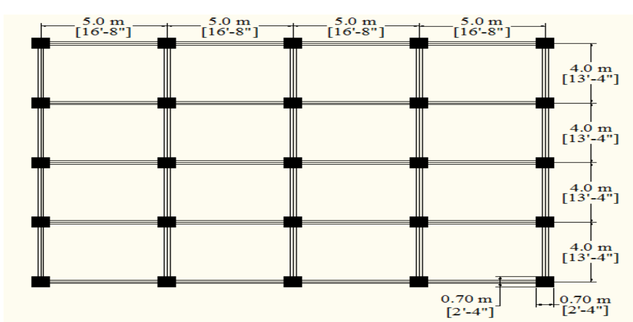

Fig.5 building plan

VII. RESULT AND DISCUSSION

To solve the above problem the lump mass model of frame structure and bare frame structure is created without considering the infill wall effect and base shear is checked for both structures.

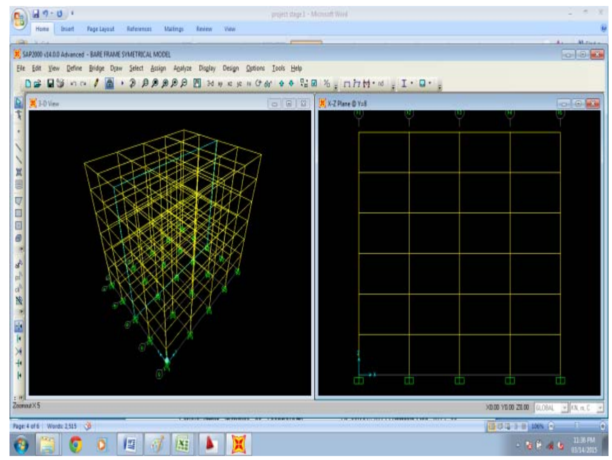

Fig 6 bare frame model

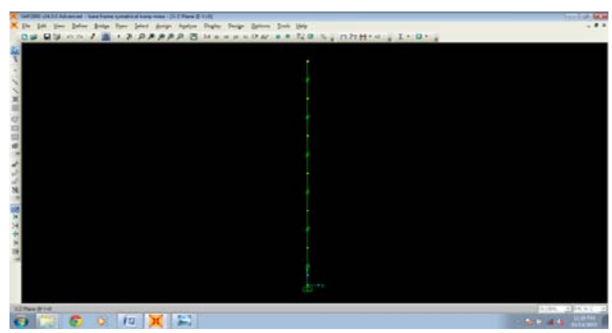

Fig 7 bare frame lump mass model

- base shear calculations bare frame model

Table7.

Base shear (kn)	Lump mass model	Bare frame model	Manually calculated
ESA	1684.959	1684.959	1652.23
RSA	1684.821	1678.5	-

- base shear calculations equivalent strut frame model

Table8.

Base shear (kn)	Lump mass model	Bare frame model	Manually calculated
ESA	1818.156	1818.157	1782.84
RSA	2072.448	2722.4	-

i. Ratio of base shear With and without infill wall for lump mass of actual structure $=\frac{2072.448}{1684.821} = 1.3$

ii. Ratio of base shear With and without infill wall for bare frame models of actual structure $=\frac{2722.469}{1678.539} = 1.6$

- Mode shapes of lump mass

i. Without strut

Table9.

STOREY HT(mtr)	MODE 1	MODE 2	MODE 3	MODE 4	MODE 5	MODE 6
18	0.011973	0.024497	0.013892	-0.00926	0.023234	-0.01732
15	0.016988	0.018473	-0.01503	-0.02012	-0.01087	0.02199
12	0.020909	0.00221	-0.02285	0.017114	-0.00953	-0.02268
9	0.023482	-0.01528	0.001411	0.013439	0.022885	0.019263
6	0.024541	-0.0243	0.02369	-0.02236	-0.01933	-0.01236
3	0.006186	0.016944	0.023309	0.023733	-0.01843	0.009524
0	0	0	0	0	0	[illegible]

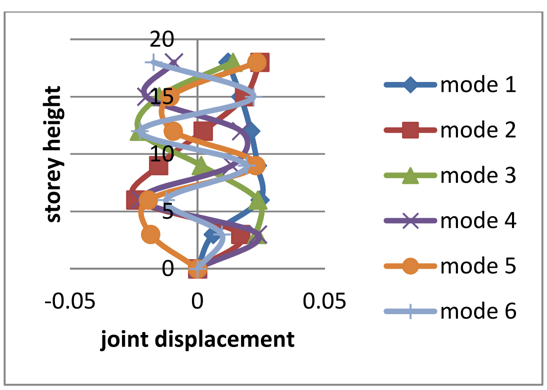

Fig 8

(Graphical representation of table 9)

ii. With strut

Table10.

STOREY HT(mtr)	MODE 1	MODE 2	MODE 3	MODE 4	MODE 5	MODE 6
18	0.01744	-0.01649	-0.00254	0.019589	0.023589	-0.01365
15	0.017447	-0.00425	-0.02309	0.012572	-0.01726	0.019942
12	0.017452	0.009283	-0.01771	-0.02204	-0.00308	-0.02256
9	0.017455	0.019986	0.007542	-0.00827	0.020914	0.02103
6	0.017456	0.024596	0.024332	0.023658	-0.02178	-0.01563
3	0.017432	-0.0237	0.020855	-0.0164	-0.01078	0.004849
0	0	0	0	0	0	0

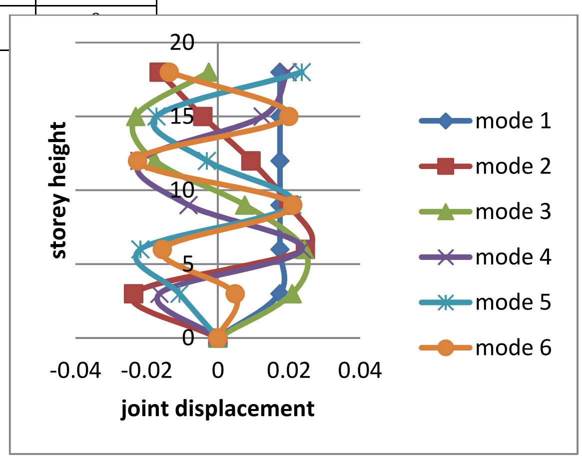

Fig 9

(Graphical representation of table 10)

- Frequencies Eigen values of lump mass modes

i. Without strut

Table11.

Mode	**Period**	**Frequency**	**CircFreq**	**Eigenvalue**
	Sec	**Cyc/sec**	**rad/sec**	**rad2/sec2**
Mode 1	0.257291	3.8867	24.421	596.36
Mode 2	0.087739	11.397	71.612	5128.3
Mode 3	0.055126	18.14	113.98	12991
Mode 4	0.042249	23.669	148.72	22117
Mode 5	0.036172	27.646	173.7	30173
Mode 6	0.033424	29.918	187.98	35338

ii. With strut

Table12.

Mode	**Period**	**Frequency**	**CircFreq**	**Eigenvalue**
	Sec	**Cyc/sec**	**rad/sec**	**rad2/sec2**
Mode 1	0.161632	6.1869	38.873	1511.1
Mode 2	0.003006	332.66	2090.2	4368800
Mode 3	0.001567	638.32	4010.7	16086000
Mode 4	0.00112	892.65	5608.7	31458000
Mode 5	0.00093	1075.8	6759.6	45692000
Mode 6	0.00085	1176.9	7394.7	54682000

- Displacement of frame

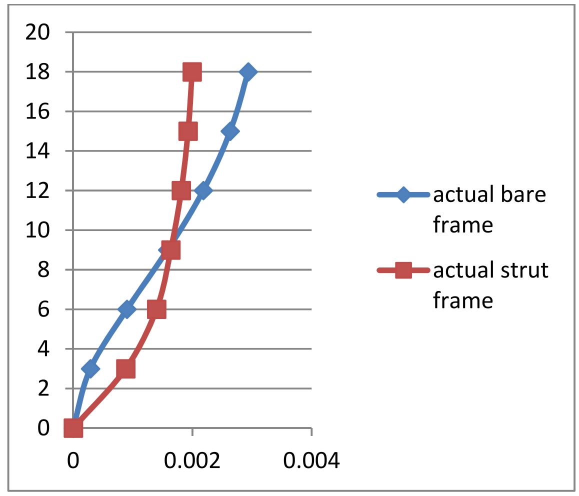

Fig 10

(Displacement of frame)

STOREY HEIGHT (mtr)	**DISPLACEMENT OF WITHOUT INFILL MODEL(MM)**	**DISPLACEMENT OF WITH INFILL MODEL(MM)**
18	0.002936	0.001995
15	0.002634	0.001927
12	0.002183	0.001813
9	0.001581	0.001638
6	0.000901	0.001397
3	0.000288	0.00088
0	0	0

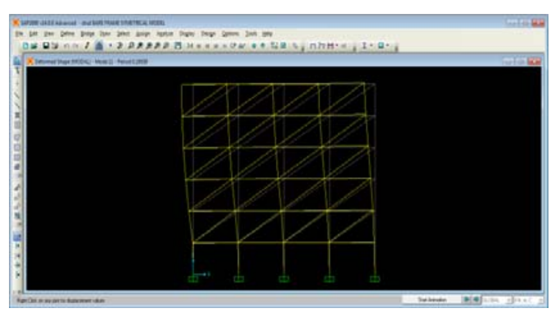

Fig 11

(Displacement of nodes in strut frame at 0.19 sec period)

VIII. CONCLUSION

Deflection of frame structure without infill is more in upper floor than with infill considered frame. The reduced deflection state that there is stiffness of infill plays some role in frame analysis.

In the case of base shear of the Response spectrum analysis of with infill i.e. equivalent strut model is increased 1.6 times of the frame structure without infill.

The first fundamental frequencies of the structure is 0.25 sec for bare frame and 0.16 sec for strut model

Maximum displacement of bare frame is 0.002936 mm

Maximum displacement of bare frame is 0.001995mm

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