Effect of Infills in Influencing the Dynamic Responses of Multistoried Structures

E. Rahmathulla Noufal

Abstract—Investigating the dynamic responses of high rise structures under the effect of siesmic ground motion is extremely important for the proper analysis and design of multitoried structures. Since the presence of infilled walls strongly influences the behaviour of frame systems in multistoried buildings, there is an increased need for developing guidelines for the analysis and design of infilled frames under the effect of dynamic loads for safe and proper design of buildings. In this manuscript, we evaluate the natural frequencies and natural periods of single bay single storey frames considering the effect of infill walls by using the Eigen value analysis and validating with SAP 2000 (free vibration analysis). Various parameters obtained from the diagonal strut model followed for the free vibration analysis is then compared with the Finite Element model, where infill is modeled as shell elements (four noded). We also evaluated the effect of various parameters on the natural periods of vibration obtained by free vibration analysis in SAP 2000 comparing them with those obtained by the empirical expressions presented in I.S. 1893(Part I)-2002.

Keywords—Infilled frame, eigen value analysis, free vibration analysis, diagonal strut model, finite element model, SAP 2000, natural period.

I. INTRODUCTION

DYNAMIC loads can lead to undesirable vibrations in multistoried structures during seismic ground motion due to the generation of critical stresses [1], [2]. Designing reinforced concrete frames with masonry infills, thereby forming a composite structure through a combination of moment resisting plane frame and infill walls, can help tackling this issue [3]. Even though these infilled walls play an important role in determining the overall behaviour of a structure, especially when subjected to lateral loads, they are often neglected as structural elements of secondary importance and only the bare frames are considered. This results in a non-representation of the true behaviour of a structure, thereby leading to faulty design of buildings. Of late, the significant influence of the effect of infilled masonry on the structural responses of multistoried structures has been realized by structural engineers boosting up the research activities in this field.

In this manuscript, we perform a comparison of the natural frequency of vibration of bare frame and infill frame attained by using stiffness approach and the free vibration analysis in SAP 2000 program in a single bay single storey frame [4]. We have also performed a comparative study between infill frames modeled as diagonal struts and within the Finite

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Element model, where infill is modeled as shell elements (four noded), of the parameters like natural period, frequency, circular frequency and eigenvalues for varying modes [5]. After validating the results obtained from SAP 2000, we proceeded to investigate the variation in natural periods for multibay, multistoried frames in the case of bare frame as well as infill frames and a comparison of the periods obtained from a free vibration analysis is of both cases are then compared with the period obtained from codal equations.

II. FORMULATION

Investigation of the natural period of vibrations of Reinforced Concrete buildings under the effect of bare frame and infilled frame is performed in this work. For the evaluation of dynamic responses of structures, the basic dynamic characteristics that need to be considered are their natural period and the free vibration mode shapes. Here the evaluation of the natural frequencies and natural periods of single bay single storey frames considering the effect of infill walls by using the Eigen value analysis is first performed [6]-[8]. These results are then validated using free vibration analysis in SAP 2000. In the above free vibrational analysis, the infill wall has been modeled by using the concept of equivalent (or diagonal) strut presented by Smith (1966) and subsequent modification by Khan and Ekramul (2006) [9], [10]. A comparative study of natural period, frequency, circular frequency and eigen values for varying modes between this diagonal strut model and Finite Element model, where infill is modeled as shell element (four noded), is also performed. The natural periods of vibration obtained by free vibration analysis in SAP 2000 is then compared with those obtained by the empirical expressions presented in I.S. 1893(Part I)-2002 [11] for multi bay, multistoried structures.

III. RESULTS AND DISCUSSION

Based on the above formulation, validation of the results was performed for analysis of infilled and bare frames. The results are validated for a single bay, single storey frame as shown in Fig. 1. For analysis, first stiffness matrix and mass matrix is derived using direct stiffness approach and then the Eigen value problem is solved for the above two matrices [12]. The natural period thus obtained is compared with free vibration analysis of SAP 2000.

A. Bare Frame

A single bay single storey bare frame as shown in Fig. 1 is considered first for the validation.

Properties of the materials like modulus of elasticity, Unit weight and Poisson's ratio and that of the members, like length, size, moment of inertia and mass, considered are summarized in Tables I and II, respectively.
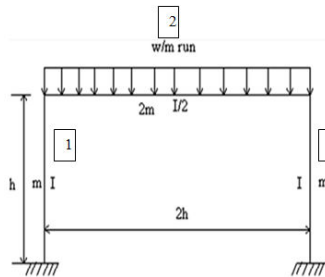

Fig. 1 Single bay single storey bare frame

TABLE I
PROPERTIES OF MATERIALS

Material	Modulus of elasticity (E)	Unit weight (W)	Poisson's ratio
Concrete	22.36068×10^6	25	0.2
Brick masonry infill	2×10^6	19.2	0.17

TABLE II
PROPERTIES OF MEMBERS

Member	Length (m)	Size (m)	Moment of inertia	Mass
Column	3	0.3×0.3	6.75×10^{-4}	229.358
Beam	6	0.15×0.3	3.375×10^{-4}	114.679

Mass of column=0.3x0.3x25x1000/9.81=229.358

Hence for 2*m* superimposed load acting over a beam

W/m = (229.358x2)-114.679=344.037 kg/m = 3.375 kN/m

Transformed stiffness matrix for column members 1 and 3 are

$$k_1 = k_2 = \begin{bmatrix} \alpha_1 & 0 & -\alpha_2 & -\alpha_1 & 0 & -\alpha_2 \\ 0 & \alpha_5 & 0 & 0 & -\alpha_5 & 0 \\ -\alpha_2 & 0 & \alpha_3 & \alpha_2 & 0 & \alpha_4 \\ -\alpha_1 & 0 & \alpha_2 & \alpha_1 & 0 & \alpha_2 \\ 0 & -\alpha_5 & 0 & 0 & \alpha_5 & 0 \\ -\alpha_2 & 0 & \alpha_4 & \alpha_2 & 0 & \alpha_3 \end{bmatrix} \tag{1}$$

$$\alpha_1 = \frac{12EI}{L^3}, \alpha_2 = \frac{6EI}{L^2}, \alpha_3 = \frac{4EI}{L}, \alpha_4 = \frac{2EI}{L}, \alpha_5 = \frac{AE}{L}$$

Transformed stiffness matrix for the beam member 2
For the beam member putting the respective values of I=I/2 and L=6m

$$K2 = \begin{Bmatrix} \beta5 & 0 & 0 & -\beta5 & 0 & 0 \\ 0 & \beta1 & -\beta2 & 0 & -\beta1 & -\beta2 \\ 0 & -\beta2 & \beta3 & 0 & \beta2 & \beta4 \\ -\beta5 & 0 & 0 & \beta5 & 0 & 0 \\ 0 & -\beta1 & \beta2 & 0 & \beta1 & \beta2 \\ 0 & -\beta2 & \beta4 & 0 & \beta2 & \beta3 \end{Bmatrix} \tag{2}$$

$$\beta_1 = \frac{12EI}{L^3}, \beta_2 = \frac{6EI}{L^2}, \beta_3 = \frac{4EI}{L}, \beta_4 = \frac{2EI}{L}, \beta_5 = \frac{AE}{L}$$

Combining the matrices using direct approach, the combined stiffness matrix becomes,

$$K = \begin{bmatrix} \alpha1+\beta5 & 0 & \alpha2 & -\beta5 & 0 & 0 \\ 0 & \alpha5+\beta1 & -\beta2 & 0 & -\beta1 & -\beta2 \\ \alpha2 & -\beta2 & \alpha3+\beta3 & 0 & \beta2 & \beta4 \\ -\beta5 & 0 & 0 & \alpha1+\beta5 & 0 & \alpha2 \\ 0 & -\beta1 & \beta2 & 0 & \alpha5+\beta1 & \beta2 \\ 0 & -\beta2 & \beta4 & \alpha2 & \beta2 & \alpha3+\beta3 \end{bmatrix} \tag{3}$$

Putting the numerical values, we get the combined stiffness matrix as,

K=1 x 10^6 x

$$\begin{bmatrix} 174.4151 & 0 & 10.06506 & -167.7051 & 0 & 0 \\ 0 & 671.2396 & -1.2578 & 0 & -41926 & -1.2578 \\ 10.06506 & -1.2578 & 25.1613 & 0 & 1.2578 & 2.5156 \\ -167.7051 & 0 & 0 & 174.4151 & 0 & 10.06506 \\ 0 & -41926 & 1.2578 & 0 & 671.2396 & 1.2578 \\ 0 & -1.2578 & 2.5156 & 10.06506 & 1.2578 & 25.1613 \end{bmatrix} \tag{4}$$

The mass matrix for column element is

$$[M_1] = \left(3 \times \frac{M}{2}\right) \times \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{5}$$

The mass matrix for the beam element is

$$[M_2] = \frac{2 \times 6 \times M}{2} \times \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{6}$$

The combined mass matrix is derived from direct approach

$$[M] = \begin{Bmatrix} 7.5m & 0 & 0 & 0 & 0 & 0 \\ 0 & 7.5m & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 7.5m & 0 & 0 \\ 0 & 0 & 0 & 0 & 7.5m & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{Bmatrix} \tag{7}$$

M=229.358kg/m

Hence the mass matrix is

$$\{M\} = \begin{bmatrix} 1720.185 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1720.185 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1720.185 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1720.185 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (8)$$

Eigen value problems are solved by using the mass matrix and stiffness matrix of the equation:

$$\left\{[K] - \omega^2 [M]\right\}\{\phi\} = 0$$

We get natural frequencies as

$$\omega_1 = 42.0971 rad/\sec, \omega_2 = 443.0407 rad/\sec$$

$$\omega_3 = 624.7601 rad/\sec, \omega_4 = 624.476 rad/\sec$$

The natural periods are T_1=0.14925 sec, T_2=0.014182 sec, T_3 = 0.010061 sec, T_4= 0.010 sec.

B. Infilled Frame

A schematic of the single bay single storey infilled frame considered for the validation is shown in Fig. 2.
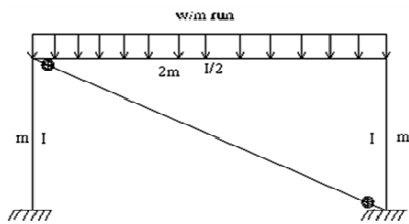
Fig. 2 Single bay single storey infilled frame

The stiffness matrix for diagonal strut element is

K = 1 x 10^6 x

$$\begin{bmatrix} 257.2031 & -41.3941 & 10.06506 & -167.7051 & 0 & 0 \\ -41.3941 & 691.9366 & -1.2578 & 0 & -0.41926 & -1.2578 \\ 10.06506 & -1.2578 & 25.1613 & 0 & 1.2578 & 2.5156 \\ -167.7051 & 0 & 0 & 174.4151 & 0 & 10.06506 \\ 0 & -0.41926 & 1.2578 & 0 & 671.2396 & 1.2578 \\ 0 & -1.2578 & 2.5156 & 10.06506 & 1.2578 & 25.1613 \end{bmatrix} \quad (9)$$

Strut width calculation:

I_c = 6.75 x 10^{-4} m^4 (moment on inertia of column)

I_b = 3.375 x 10^{-4} m^4 (moment of inertia of beam)

$$\lambda h = 4 \times \sqrt{\frac{E_w \times t_w \times Sin 2\theta}{4 \times E_f \times I_c \times h_w}}$$

$$\lambda h = 4 \times \sqrt{\frac{2 \times 10^9 \times 0.23 \times 0.8}{4 \times 23.36 \times 10^9 \times 0.000675 \times 3}} = 1.1809 \quad (10)$$

$$s_{MS} = \frac{AE}{L} \begin{pmatrix} C^2 & CS & -C^2 & -CS \\ CS & S^2 & -CS & -S^2 \\ -C^2 & -CS & C^2 & CS \\ -CS & -S^2 & -CS & S^2 \end{pmatrix} \quad (11)$$

$$s_{MS} = \frac{AE}{L} \begin{bmatrix} \gamma_1 & -\gamma_2 & \gamma_1 & \gamma_2 \\ -\gamma_2 & \gamma_3 & \gamma_2 & -\gamma_3 \\ \gamma_1 & \gamma_2 & \gamma_1 & -\gamma_2 \\ \gamma_2 & -\gamma_3 & -\gamma_2 & \gamma_3 \end{bmatrix} \quad (12)$$

[K] =

$$\begin{bmatrix} \alpha_1 + \beta_5 + \gamma_1 & \gamma_2 & \alpha_2 & -\beta_5 & 0 & 0 \\ -\gamma_2 & \alpha_5 + \beta_1 + \gamma_3 & -\beta_2 & 0 & -\beta_1 & -\beta_2 \\ \alpha_2 & -\beta_2 & \alpha_3 + \beta_3 & 0 & \beta_2 & \beta_4 \\ -\beta_5 & 0 & 0 & \alpha_1 + \beta_5 & 0 & \alpha_2 \\ 0 & -\beta_1 & \beta_2 & 0 & \alpha_5 + \beta_1 & \beta_2 \\ 0 & -\beta_2 & \beta_4 & \alpha_2 & \beta_2 & \alpha_3 + \beta \end{bmatrix} \quad (13)$$

$$\lambda_1 = 4 \times \sqrt{\frac{E_w \times t_w \times \sin 2\theta}{4 \times E_f \times I_b \times I_w}}$$

$$\lambda_1 = 4 \times \sqrt{\frac{2 \times 10^9 \times 0.23 \times 0.8}{4 \times 23.36 \times 10^9 \times 0.0003375 \times 6}} = 1.1809$$

$$\alpha_h = \frac{\pi}{2\lambda_h} = 1.330$$

$$\alpha_1 = \frac{\pi}{\lambda_1} = 2.6630$$

$$\omega = 0.5 \times \sqrt{\alpha_h^2 + \alpha_1^2} = 1.509 \quad (14)$$

Mass of infill (m$_1$) = 19.20 x 23 x 1.509 x $\frac{1000}{9.81}$ =679.339kg/m

$$M_i = \frac{mL}{2} = \frac{m_i}{2} x6.708 = 3.354 m_i$$

This ordinate in mass matrix of bare frame is added for first two diagonals.

Similarly combined mass matrix is

$$[M] = \begin{bmatrix} 7.5m + 3.354mi & 0 & 0 & 0 & 0 & 0 \\ 0 & 7.5m + 3.354mi & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 7.5m & 0 & 0 \\ 0 & 0 & 0 & 0 & 7.5m & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (15)$$

$$[M] = \begin{bmatrix} 3998.7573 & 0 & 0 & 0 & 0 & 0 \\ 0 & 3998.7573 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1720.185 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1720.185 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (16)$$

The Eigen value problem is solved. We get the natural frequencies and natural period of vibration solving the equation:

$$\left\{[K] - \omega^2[M]\right\}\{\phi\} = 0$$

Natural frequencies

$$\omega_1 = 120.30481 rad/\sec, \omega_2 = 382.1242 rad/\sec$$

$$\omega_3 = 418.150 rad/\sec, \omega_4 = 624.6178 rad/\sec$$

The natural periods are

$T_1 = 0.052227$ sec, $T_2 = 0.01644$ sec, $T_3 = 0.015026$sec, $T_4 = 0.01006$sec

A comparison of natural period of vibration for bare and infilled frame with SAP 2000 program is presented below with the results summarized in Table III. The mode shapes followed for the analysis are plotted as shown in Figs. 3 (a) and (b) for bare frame and infilled frame.

(a)

(b)
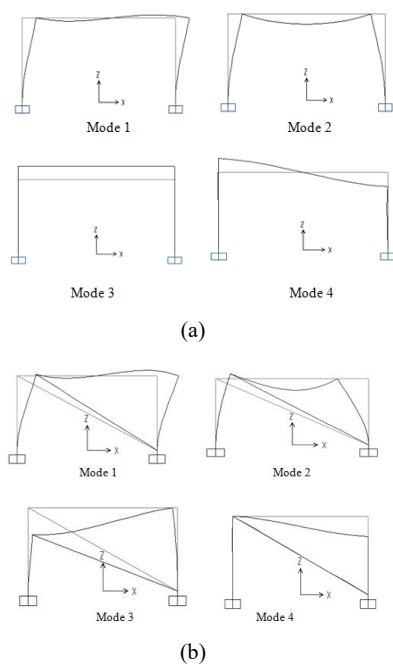
Fig. 3 (a) Mode shapes for single bay single storey bare frame, (b) Mode shapes for single bay single storey infilled frame

The results obtained by numerical analysis using stiffness approach and the SAP 2000 are exactly matched thereby validating the results.

TABLE III
COMPARISON OF THE NATURAL FREQUENCY OF VIBRATION OF BARE FRAME AND INFILLED FRAME ATTAINED BY USING STIFFNESS APPROACH AND THE SAP 2000 PROGRAM

Mode no.	Bare frame		Infilled frame	
	Analytial	SAP2000	Analytical	SAP2000
1	0.149254	0.149293	0.052227	0.052238
2	0.0141819	0.014184	0.01644	0.016445
3	0.010061	0.010063	0.15026	0.015028
4	0.010057	0.010059	0.01006	0.010061

C. Comparison of the Model Analysis of Infill Wall Modeled as Diagonal Strut as Well as Finite Elements

Here we have performed a comparative study between this diagonal strut model and Finite Element model (FEM), where infill is modeled as shell elements (four noded), as shown in Figs. 4 and 5, respectively. For the above free vibrational analysis, the infill is modeled as diagonal struts.

The results clearly suggest that the values obtained by modeling infill as diagonal struts are close to that of the Finite Element Analysis. The bending moment diagram and the displacement contour obtained while modeling the infill under FEM are shown in Figs. 6 and 7, respectively. The parameters considered for the comparison are natural period, frequency, circular frequency and eigenvalues for varying modes. The results are summarized in Table IV.

Load calculation is performed as follows.

Weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey

i) Slab load = 0.12 x 1 x 25 = 3 kN/m^2 assuming one-way load distribution.

Slab load /m run = 3 x 3/2 = 4.5 kN/m for inner frame it is 9 kN/m

ii) Floor finish load = 1 x 3/2 = 1.5 kN/m for inner frame it is 3 kN/m

iii) Wall load = 19.2 x 0.23 x (3-0.53) x 1 = 12.09312 kN/m

iv) Live load = 2 x 3/2 = 3 kN/m), for inner frame it is 6 kN/m

Hence total floor load acting in the form of uniformly distributed load = 30.09312 kN/m for inner frames.

Deducting live load for terrace = 16.896 kN/m.

TABLE IV
COMPARISON OF THE RESULT BY DIAGONAL STRUT METHOD AND FINITE ELEMENT MODE

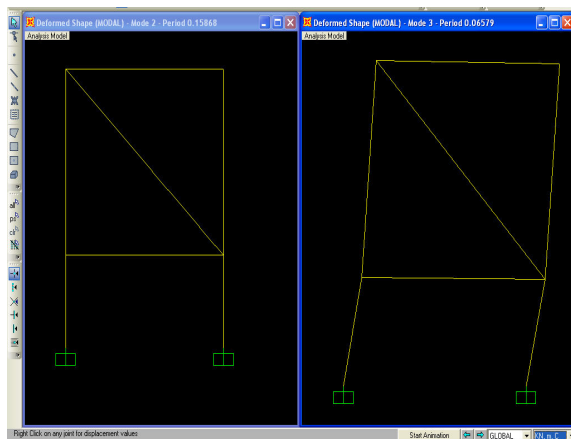| Modes	Diagonal Strut Model				Finite Element Model			
	Period	Frequency	Circular Frequency	Eigen Value	Period	Frequency	Circular Frequency	Eigen Value
UNITS	sec	cyc/sec	rad/sec	rad^2/sec^2	sec	cyc/sec	rad/sec	rad^2/sec^2
1	0.4466	2.239	14.068	197.9	0.422347	2.367	14.877	221.32
2	0.15868	6.3018	39.595	1567.8	0.1201	8.325	52.313	2736.7
3	0.0657	15.2	95.502	9120.6	0.0646	15.474	97.226	9452.8
4	0.0619	16.15	101.48	10297	0.0637	15.697	98.627	9727.4
5	0.038	26.279	165.12	27264	0.0347	28.755	180.68	32644
6	0.0237	42.14	264.8	70121	0.03088	32.379	203.44	41389
7	0.0126	79.18	497.54	247550	0.0245	40.777	256.21	65645
8	0.00948	105.43	662.41	438790	0.0171	58.282	366.2	134100

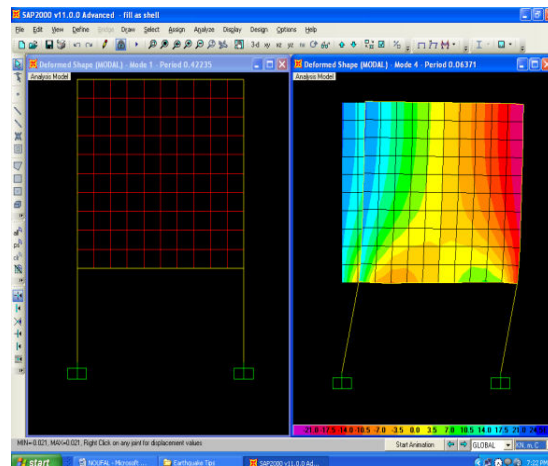Fig. 4 Infill modeled as Diagonal Strut model

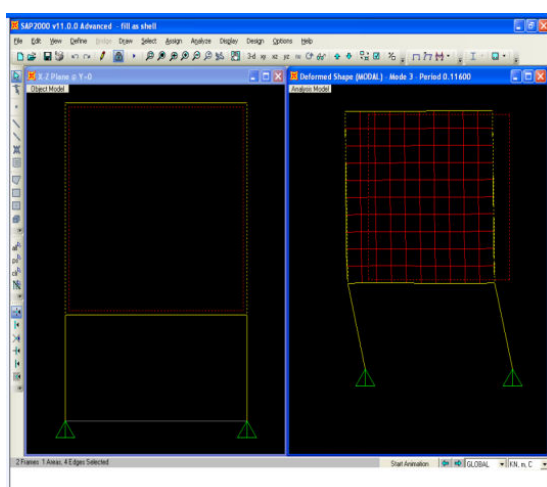Fig. 6 Bending moment diagram of Finite Element Model

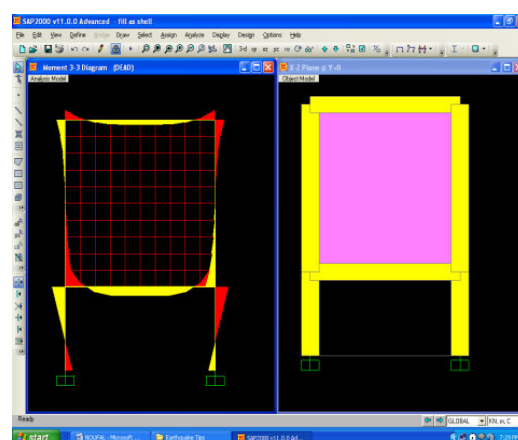Fig. 5 Infill modeled as Finite Element model

Fig. 7 Displacement contour by Finite Element model

TABLE V
COLUMN SIZES AND EQUIVALENT STRUT WIDTH FOR TEN STOREY FRAME

Storey No	Column Size (mm)	Strut width (cm)	Storey No	Column size (mm)	Strut width (cm)
1,2	380 x 760	2.6452	7,8	300 x 530	2.4595
3,4	380 x 685	2.5911	9	300 x 450	2.4142
5,6	300 x 600	2.5015	10	300 x 380	2.3770

D. Evaluation of Natural Periods for Multistorey Frames

For a ten-storey frame of 6m span length and 3 m storey height, column sizes and equivalent strut width is calculated as shown in Table V. To study the behaviour of multistorey frames the parameters considered are summarized in Table VI.

Here the equivalent strut width is calculated using Smith and Carter's approach. Above values are used to evaluate natural period of vibration by using SAP 2000 which is then compared with the empirical relations obtained from I.S. 1893(Part I)-2002. The results so obtained are summarized in Figs. 8-11 showing the variation of natural period for multistoried frames having number of bays starting from single bay to four bays for 3m floor height and 6m span length.

TABLE VI
PARAMETERS CONSIDERED FOR MULTISTOREY FRAMES

| Parameters	studied values
Modulus of elasticity of concrete	22.36068×10^6 kN/m²
density of concrete	25 kN/m³
modulus of elasticity of infill	2×10^6 kn/m²
density of infill	19.2 kN/m³
size of column	As in Table IV
size of beam	230 x300, 230 x380, 230 x 450, 230 x530, 230 x610 mm
number of storey	varies from 1 to 10
height of each storey	3 m, 4 m, 5 m, 6 m, 7.5 m
number of spans	1 to 4
size of each span	3 m, 4 m, 6 m, 7.5 m
thickness of infill	230 mm
Slab load	3.0 kN/m²
Floor finish load	1 kN/m²
Live load	4kN/m²
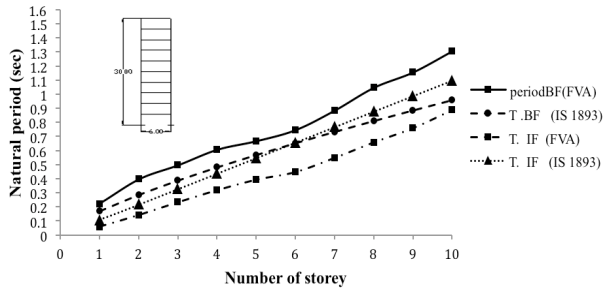
Fig. 8 Variation of natural period with change in number of figure storeys for single bay
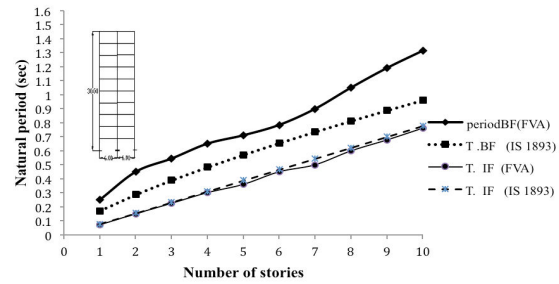

Fig. 9 Variation of natural period with change in number of storeys for two bays

TABLE VII
PERCENTAGE INCREASE IN NATURAL PERIOD BY FREE VIBRATION ANALYSIS AS COMPARED TO I.S. CODAL EXPRESSIONS

Sr. no	Frame	Single bay	Two bays	Three bays	Four bays
1	Bare frame	12-28 %	16-38%	17-32%	19-45%
2	Infilled frame	-(19 to44 %)	-(1 to 9%)	10 to 16%	22-32%

Here period BF (FVA) and T. IF (FVA) stands for the natural periods for bare frame and infilled frames obtained from free vibrational analysis and T. BF (IS 1893) and T. IF (IS 1893) stands for the natural periods obtained from the Codal expressions for bare frame and infilled frames, respectively. It can be observed from graphs that as the number of storeys increases the natural period of vibration goes on increasing more or less linearly. The results obtained from bare frame analysis indicate that the codal expression underestimates the natural period of multistorey frames largely. On the other hand, for infilled frames the period obtained by codal equations is close to those obtained by the free vibration analysis, particularly, when number of bays is greater than one, supporting the acceptability of the codal equation. The percentage difference in natural period obtained by analysis and by codal expressions is in the range of 12 to 45 percent for bare frame as given in Table VII. It is also observed from the observed from graphs that in case of infilled frames, the natural period obtained by free vibration analysis is less than that by the codal provisions for single and two bays frames. However, it is more for three and four bays frames due to substantial increase in mass of the structure, which is not incorporated in codal equation. It is also observed that the span length and number of bays of multistoried frames do not have much contribution to the natural period for bare frames whereas these factors are important for infilled frames.

The percentage change in natural period as compared to I.S. code provisions for different bays is summarized in Table VII. Negative sign indicates decrease in natural period.
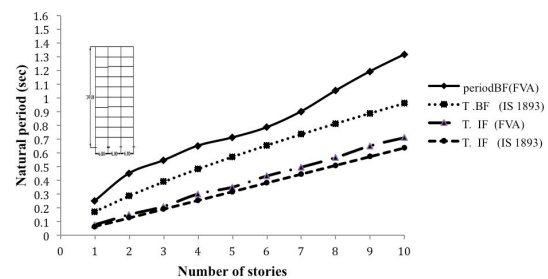

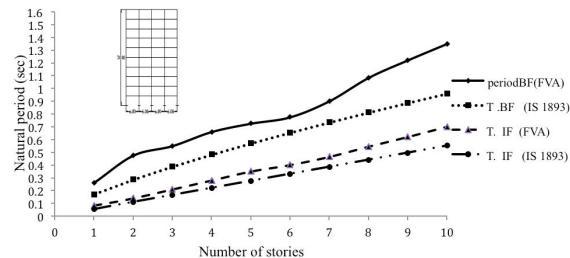Fig. 10 Variation of natural period with change number of storeys for three bays

Fig. 11 Variation of natural period with change in number of storey for four bays

IV. CONCLUSIONS

Keep in line with the increased need for understanding the influence of infilled frames in the designing of multistoried buildings under the effect of dynamic loads. In this manuscript, we evaluate the natural frequencies and natural periods of single bay single storey frames considering the effect of infill walls by using the Eigen value analysis and validating with SAP 2000 (free vibration analysis) where the infill wall has been modeled as diagonal struts. The results obtained by numerical analysis using stiffness approach and the SAP 2000 are exactly matched. A comparative study of natural period, frequency, circular frequency and eigen values for varying modes between this diagonal strut model and

Finite Element Model. Where infill is modeled as shell element (four noded) clearly suggest that the values obtained by modeling infill as multistoried frames obtained by free vibration analysis in SAP 2000 comparing them with those obtained by the empirical expressions presented in I.S. 1893(Part I)-2002. The results suggest that as the number of storeys increases the natural period of vibrations also increases almost linearly for both bare frames as well as infilled frames in both the cases. Span length and number of bays of multistoried frames do not have much contribution to the natural period for bare frames whereas these factors are important for infilled frames. In addition, it is observed that there is no significant variation in natural period when the numbers of bays are varied in case of bare frames, but there is considerable change in natural period when infilled frame effect is taken into account. These results provide important insights for understanding the influence of infilled frames in the designing of multistoried buildings under the effect of dynamic loads.

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