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DYNAMIC ANALYSIS AND BEHAVIOR OF INFILLED FRAMES UNDER SEISMIC LOADING

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Abstract-This paper presents a numerical method based on a straight forward linear finite element response spectrum method for the analysis of infilled R.C.C. frames subjected to earthquake excitation. The Finite element method has been used to develop stiffness matrix and consistent mass matrix of infilled frame.Finite Element Method(F.E.M.) is more correct method of analysis of infilled frame than equivalent strut method which has traditionally been used by most of the researchers for analysis of infilled frames. Consistent mass matrix is diagonalized by using Hinton E., Rock T. and Zienkiewicz O.C.(H.R.Z.)method[9] as diagonal mass matrix derived from consistent mass matrix is more sophisticated than a lumped mass matrix. This type of diagonal mass matrix gives more accurate mode shapes and the frequencies of structure. The stiffness matrix and diagonal mass matrix are put into dynamic equation of motion and this dynamic equation is solved by using a subroutine based on Jacobi's iteration method. By solving the dynamic equation, eigen values and eigen vectors are obtained. These eigenvalues and eigenvectors are used in response spectrum method of analysis to calculate seismic loads (one vertical, one horizontal and a moment) at each nodal points. These seismic loads are then applied on each node and principle stresses at gauss points and deflections at nodal points in infill panels are obtained by static analysis.

The above procedure is implemented into a computer program which is developed by the author using Fortran-77 This program has been used to solve 17 cases of bare and infilled frames ranging from three story to seven story in order to assess the effect of different factors such as the presence of infill panels, the height of structure, infill material, panel thickness, rectangularity ratio. Results show that infill panels have a great effect on the behavior of structures.

Keywords-*Consistent mass matrix; Diagonalization of matrix by H.R.Z. method; Dynamic equation*

1. Introduction

Plane frame analysis of multi story buildings does not reflect their actual behavior when openings are filled with masonry or with precast prefabricated wall panels. The tendency of designers to consider such walls as non-structural element and in turn neglect their effect in the structural response of buildings is a practice which is far from reality. Various experimental studies on R.C.C. and steel frame infilled with masonry have proved that infilled frames exhibit resistance to lateral and vertical loads more than similar frames without such infill walls.

It is a common practice to consider only the bare R.C. frame- the mass of the masonry infill is considered, but their stiffness and strength contributions are neglected. Furthermore, infill alters the behavior of buildings from one of predominantly frame action to one of predominantly shear action ,and also carry the lateral seismic force as compression axial loads along their diagonals. Structural damage reports on recent and past earthquakes have clearly stated that non-structural infill elements often have a primary effect on seismic response and should be considered in design or adequately isolated. If ignored in design, such infills can lead to unanticipated and potentially catastrophic modes of structural behavior.[1,2].

2. Objectives

Author feels that the problem of dynamic analysis and behavior of infilled frame subjected to seismic excitation still needs more consideration, even in the elastic range. Therefore, the objectives of the study may be summarized as follows :

1. To present a numerical method for the seismic elastic analysis of the infilled multistory frame problem.
2. To develop a computer program to solve this problem.
3. To study the effect of different parameters on the behavior of infilled frames.
4. From the results obtained, to draw a set of conclusions that are believed to be useful for the structural engineer.

3. Proposed Method of Analysis

Thus the proposed mathematical model for the infilled frame is composed of two types of structural elements to solve it by finite element method.

These are as follows:

1. The frame elements (beams and columns) .
2. The infill panels are considered as a plane element of thickness t. Each single infill panel is considered as a single rectangular plane element in plane stress condition, with four corner points are allowed three nodal degrees of freedom u,w and θ at each node in contact with the joint of the rigid building frame as shown in fig. 3. By introducing an in- plane rotation component θ as a degree of freedom at each of four corner nodes of plane element at junction with rigid building frame, it is possible to maintain an angle of 90^0 at the four corners which are consistent with the assumption of the rigidity of the frame. Further, when a beam element with two degrees of freedom w and θ deforms as shown in Fig. 3 (c), the resulting configuration associated with each of these generalized displacement components is described by a cubic polynomial. Similarly in columns also at its nodes, there are two degrees of freedom u and θ.

3.1 Development of Stiffness Matrix[k] and Consistent Mass Matrix[M] for Infill Panel Element

Fig.4 shows an idealized infill panel element of size LXD surrounded on all sides by beams and columns elements. The dotted line 1234 shows centre line position of beams and columns. We also call it as virtual panel as its deformation is well consistent with deformation of actual panel of size LXD.Also we assume in the derivation of stiffness matrix that there is no separation between infill and surrounded beams and columns within elastic limit. We consider degree of freedoms u,v&θ of beams and columns and panel at node points 1,2,3&4 only. Since deflected mode shapes of virtual panel are well consistent with real panel, so we shall consider virtual panel for derivation of shape functions of real panel but integrations are done within boundary LXD of real panel for derivation of stiffness matrix[k] and consistent mass matrix[M] of real panel. Value of [k] and [M] of infill panel derived in this way are given in APPENDIX-A.

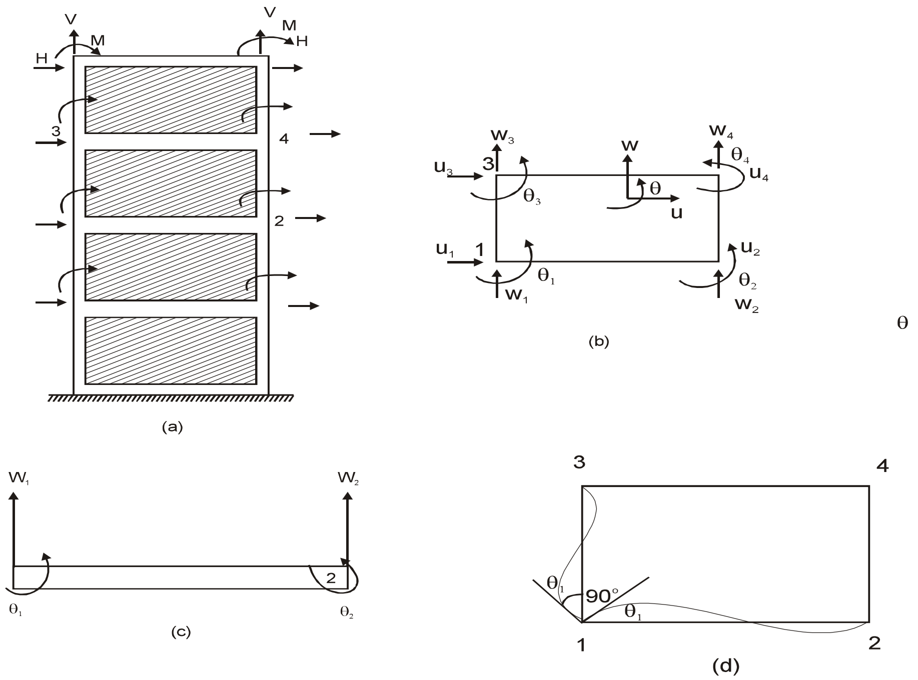

Fig.3 Mathematical Modeling of Infilled Frame

3.2 Diagonalization by Hinton E., Rock T. and Zienkiewicz O.C. method [6,9]

A diagonal mass matrix that is more sophisticated than a lumped mass matrix, can be derived from a consistent mass matrix. [6,9]. Diagonal mass matrix greatly facilitates matrix calculations.

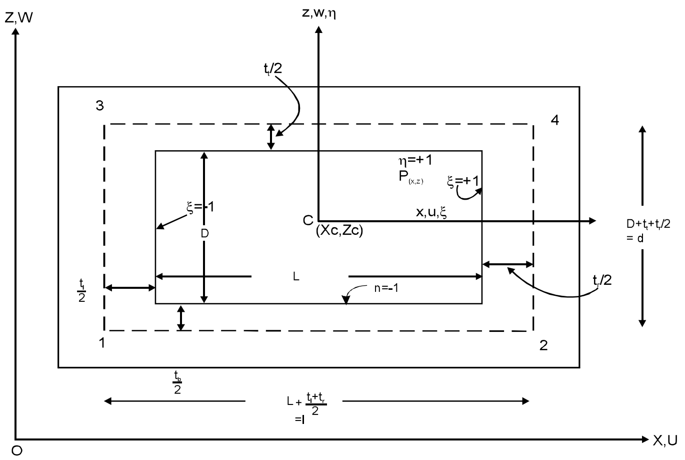

Fig. 4 Idealization of Panel Element in Natural and Global Coordinate System

Where l = $L+\frac{t_r+t_l}{2}$ & d = $D+\frac{t_b+t_t}{2}$

t_b=depth of bottom beam, t_t=depth of top beam

t_l=depth of left column, t_r=depth of right column

C=Centre of natural coordinate system,

O=origin of global coordinate system

3.3 Stiffness Matrix of Frame Elements

Members of the frame are treated as beam elements neglecting shear deformation. Therefore, the element stiffness matrix may be found to be [3], considering three degree of freedom u, w and θ at each node,

$$[K]=\begin{bmatrix} \frac{EA}{l} & 0 & 0 & -\frac{EA}{l} & 0 & 0 \\ 0 & \frac{12EI}{l^3} & \frac{6EI}{l^2} & 0 & \frac{-12EI}{l} & \frac{-6EI}{l^2} \\ 0 & \frac{6EI}{l^2} & \frac{4EI}{l^2} & 0 & \frac{-6EI}{l^2} & \frac{2EI}{l} \\ \frac{-EA}{l} & 0 & 0 & \frac{EA}{l} & 0 & 0 \\ 0 & \frac{-12EI}{l^3} & \frac{-6EI}{l^2} & 0 & \frac{12EI}{l^3} & \frac{-6EI}{l^2} \\ 0 & \frac{6EI}{l^2} & \frac{2EI}{l} & 0 & \frac{-6EI}{l^2} & \frac{4EI}{l} \end{bmatrix}$$

where l = length of member
E = young's modulus
I = moment of inertia of cross section
A = area of x-section of members

Consistent mass matrix for frame elements is given by:

$$[M] = \frac{\bar{\rho}\, l}{420}\begin{bmatrix} 140 & & & & & \\ 0 & 156 & & & & \\ 0 & 22\, l & 4\, l^2 & & & \\ 70 & 0 & 0 & 140 & & \\ 0 & 54 & 13\, l & 0 & 156 & \\ 0 & -13\, l & -3\, l^2 & 0 & -22\, l & 4\, l^2 \end{bmatrix}$$

where $\bar{\rho}$ = mass per unit length of member

l = length of member

The stiffness and mass matrix with reference to the global system of axes can be found from.

$$[\bar{K}] = [T]^T [K] [T]$$
$$[\bar{M}] = [T]^T \|M\| [T]$$

where [T] = transformation matrix given by

$$[T] = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos\theta & -\sin\theta & 0 \\ 0 & 0 & 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

where θ = inclination of members with global X-axis..

3.4 To solve equation of dynamic motion by Generalized Jacobi Method

In the absence of any exiting force, the equation of motion becomes

$$K\varphi = \omega^2 M\varphi \text{ -------(1)}$$

Author has used Jacobi method for the Numerical solution of the eigen value problem given by equation

(1) to calculate N-natural frequencies ω_n and the modes of vibration ϕ_n.

3.5 Calculation of earthquake forces using Response Spectrum Analysis[4,5,7,8]

The spectrum used in the present Analysis is an idealized spectrum obtained from the

ground motion data for the EL centro earthquake of 1940.

3.6 Computer Program

The proposed method of analysis described above from art 3.1 to 3.5 is coded by FORTRAN 77 and can be run on personal computer using compiler FORTRAN 77 V 3.31. The program consists of the main segment and five subroutines. The main segment create input and output files and control all subroutines. The program can perform static as well as dynamic analysis of bare frames as well as frames with infills.

4.0 Input Data

A number of infilled framed structures with different configuration has been solved. Using the computer program mentioned in Ar3.6, following typical data have been considered unless otherwise shown on each respective case

Frame width = 5.0 m
Story height = 2.7 m
Column dimensions = 0.50 m x 0.60 m
Beam dimensions = 0.25 m x 0.60 m
Wall thickness = 0.30 m

No. of considered mode shape = 3
Damping coefficient = 10%
Applied earthquake =30% of EL – Centro
= 0.30 g
Poisson's ratio for infill material = 0.20

Modulus of elasticity of concrete = 2×10^5 N/mm^2
Modulus of elasticity of reinforced infill brick wall = 7×10^4 N/mm^2

Unit mass of concrete = 2500.00 $\frac{N-sec^2}{m^4}$

Unit mass of Reinforced brick work = 2000 $\frac{N-sec^2}{m^4}$

4.1 Parameters Studied

In order to thoroughly understand the effect of infill on structural system responses under seismic excitation the following parameters have been considered.

1. The presence and type of infill panels.
2. The height of the structure.
3. Frame support conditions.
4. Thickness of infill panel.
5. The rectangularity ratio of the frame.

4.2 Cases Considered

The above mentioned parameters have been grouped into three groups. These are as follows:

Group A: This group comprises of two cases as shown in Fig. 5. Case-1 is a bare frame, Case-2 having infill material of reinforced brick masonry. The objective of this group is to study the effect of infill on structural system response as a whole as well as on individual members under seismic excitation.

Group B: This group includes four cases of 7-storey buildings. The objective of this group is to study the effect of frame height on the response (Fig. 6).

Group- C: This group includes four cases, as shown in Fig. 7and Fig. 8 in order to study the effect of thickness of infill panel, frame support conditions, the frame rectangularity ratio (r) and strengthening technique of soft storey frame. Cases -7 and 8 are similar to case -2 except that the infill panels in case 7 have thickness varying from 0.350 m to

0.200 m while case-8 having hinged supports. Case -9 is one storey infilled frame. Case-9 has a different rectangularity ratio (r) whereas in case 10 a method has been suggested by author to strengthen soft storey building having no infill at bottom story.

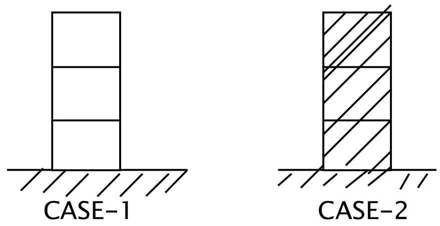

Fig-5 Cases of Group-A Infill Frames

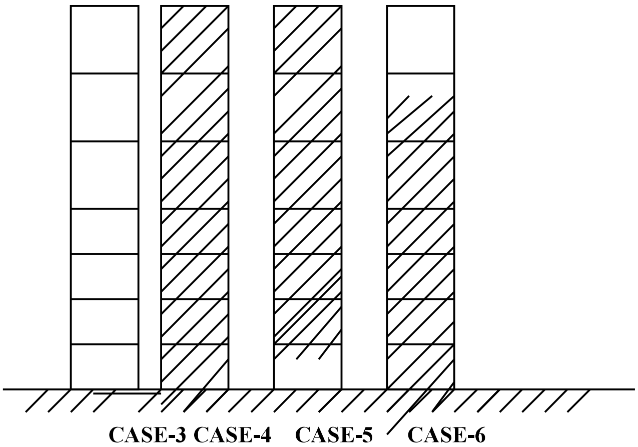

Fig-6 Cases of Group-B Infill Frames

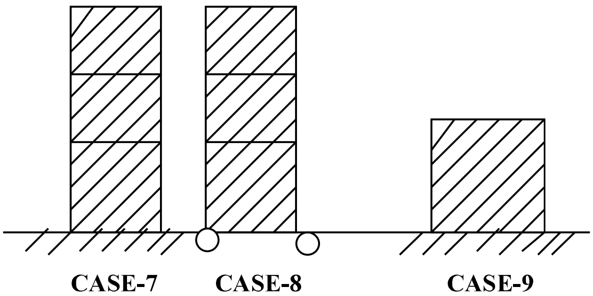

Fig-7 Cases of Group-C Infill Frames

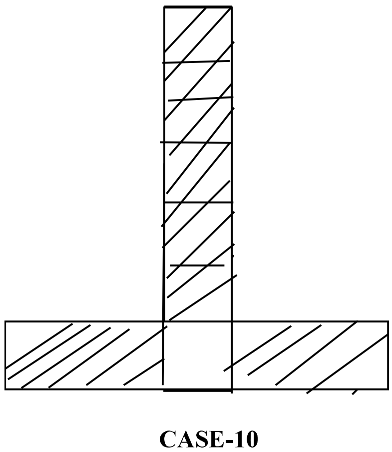

Fig-8 Strengthening of Soft Story

5. Conclusions

With numerical method based on Linear Finite Element Response Spectrum Method of Analysis of Infilled frames subjected to seismic loading, the following conclusions have been drawn by author:

1. Presence of infills increases the stiffness of the structure.

2. Presence of infills reduces shear forces and bending moments in columns and beams.

3. Presence of infills reduces joint displacements of the frame upto 90%.(Fig.9)

4. Presence of infills increases axial loads in columns and hence stresses in columns.

5. Thickness of infill greatly affects lateral loads, deflection of structure and shear forces and bending moments in columns. An optimum value of thickness may be obtained which attracts least lateral loads, deflections and straining actions in columns during earthquake excitation.(Fig.10, Fig.11)

6. Rectangularity ratio also affects system response. An optimum value of r may be obtained of panel which attracts least earthquake loads and deflection on structure.(Fig. 12, Fig. 13)

7. Period of vibration reduces as height of infilled frame increases

8. With the increase in height of infilled frames all straining actions in members of frames also increase.

9. The period of vibration of infilled frame remains unaffected by the introduction of hinges at supports.

10. Use of high performance concrete in beams and columns of frame, increases stiffness of infilled frames tremendously. It also makes structure light in weight by reduction of sizes of beams and columns which attracts less earthquake loads particularly lateral loads and lateral deflection on structure.(Table.1)

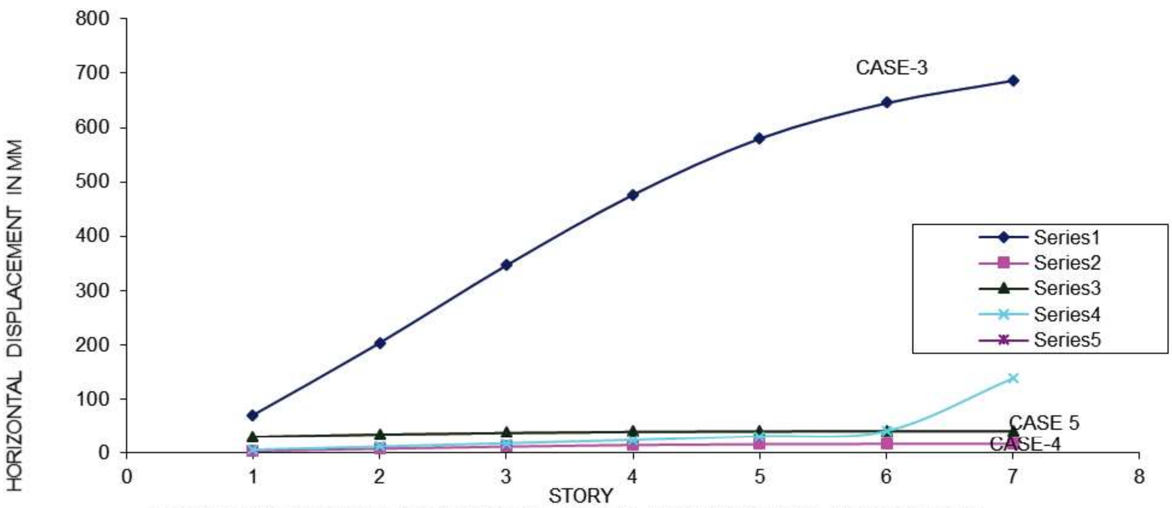

FIG.9 STORY DISPLACEMENTS OF SEVEN STORY FRAME OF GROUP-B

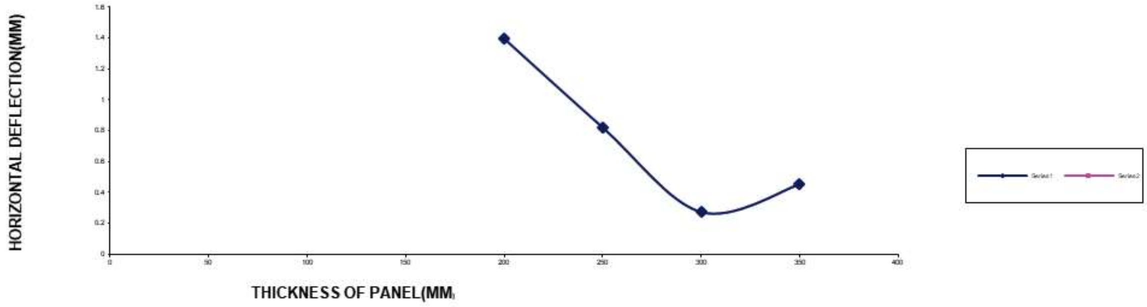

FIG.10. VARIATION OF HORIZONTAL DEFLECTION AT TOP STORY WITH THICKNESS OF PANEL

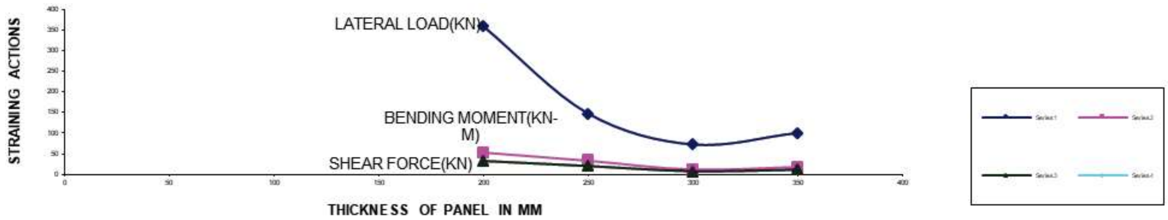

FIG.11. VARIATION OF MAXIMUM LATERAL LOAD AT TOP STORY & STRAINING ACTIONS IN BOTTOM COLUMN WITH THICKNESS OF PANEL

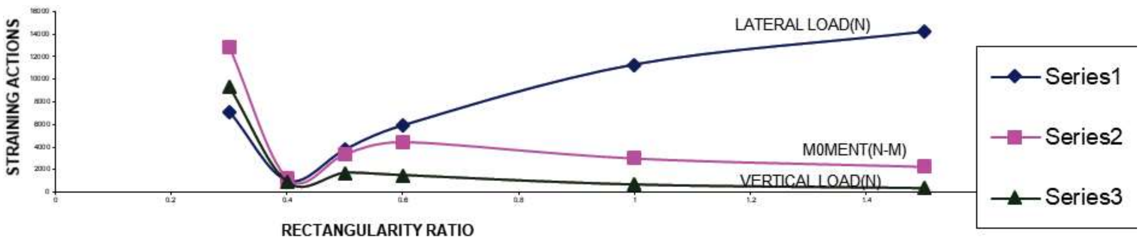

FIG. 12. EFFECT OF RECTANGULARITY RATIO ON INFILLED FRAME BY 1st MODE AT NODE1

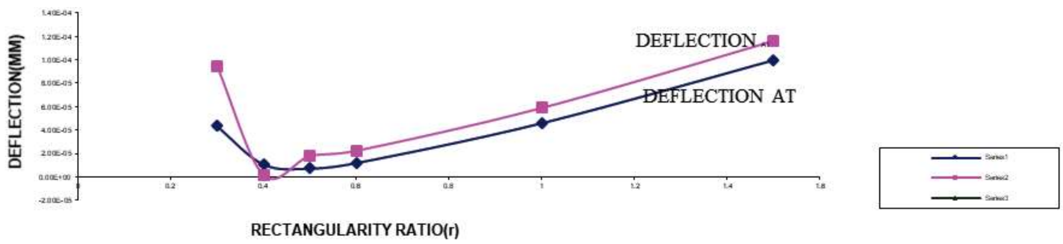

FIG 13. EFFECT OF RECTANGULARITY RATIO ON HORIZONTAL DEFLECTION OF INFILLED FRAME AT NODE 1 AND NODE 2 DUE TO COMBINED THREE MODE

RESULTS OF SOFT STORY STRENGTHENING-As value of modulus of elasticity and splitting tensile strength of concrete depends on grade of concrete, so value of modulus of elasticity of concrete E_c as per Art 6.2.3.1 of IS456-2000 is given by

$$E_c = 5000\sqrt{f_{ck}}$$

and splitting tensile strength = $\frac{2}{3} \text{x}\, 0.70 \sqrt{f_{ck}}$

For M_{80} grade of concrete

Ec = $5000\sqrt{80}$ = 4.47 x 10^4 N/mm^2

Take Ec = 4.4x10^4 N/mm^2

TABLE 1: COMPARISON OF PERFORMANCE BETWEEN ORDINARY SOFT STORY INFILLED FRAME AND STRENGTHENED SOFT STORY INFILLED FRAME

PERFORMANCE	ORDINARY SOFT STORY INFILLED FRAME IN M_{20} GRADE CONCRETE	STRENGTHENED SOFT STORY INFILLED FRAME IN M_{80} GRADE CONCRETE.
1) Beam size	0.25x0.60m	0.25x0.50m
2) Column size	0.50 x 0.60m	0.50 x 0.50 m
3) Infill thickness	0.300 m	0.300 m
4) Values of E & v	Ec=2.00x10^4 N/mm^2 v = 0.20	Ec = 4.4x10^4 N/mm^2 v = 0.17
5) Period of vibration	0.112 sec	0.0489 sec, reduction = 56%
6) Net reduction in concrete per frame	NIL	0.93 Cu-m, reduction = 9.40%
7) Net reduction in weight	NIL	23.250KN
8) Horizontal deflection at top story	42.47 mm	6.76 mm, reduction 84%
9) Maximum B.M. in column	3689.9 KN-m	506.82 KN-M, reduction 86%
10) Maximum S.F. in columns	2419.3 KN	296.80 KN, reduction 88%
11) Maximum axial load in columns	3114.9 KN (Comp.)	7467.50 KN (Comp), Increases to 139%
12) Principal stresses in bottom panel	$(\sigma_1)_{max}$ = 7.77 N/mm2 (tensile)	$(\sigma_1)_{max}$ = 1.77 N/mm2 (tensile)
	$(\sigma_2)_{max}$ = 7.62 N/mm2 (Comp.)	$(\sigma_2)_{max}$ = 1.78 N/mm2 (Comp.), reduction = 76%

APPENDIX-A

STRAIN DISPLACEMENT MATRIX OF INFILL PANEL IS

$$[B]=\begin{bmatrix} B_{1,1} & B_{1,2} & B_{1,3} & B_{1,4} & B_{1,5} & B_{1,6} & B_{1,7} & B_{1,8} & B_{1,9} & B_{1,10} & B_{1,11} & B_{1,12} \\ B_{2,1} & B_{2,2} & B_{2,3} & B_{2,4} & B_{2,5} & B_{2,6} & B_{2,7} & B_{2,8} & B_{2,9} & B_{2,10} & B_{2,11} & B_{2,12} \\ B_{3,1} & B_{3,2} & B_{3,3} & B_{3,4} & B_{3,5} & B_{3,6} & B_{3,7} & B_{3,8} & B_{3,9} & B_{3,10} & B_{3,11} & B_{3,12} \end{bmatrix}$$

Where $B_{1,2}=B_{1,5}=B_{1,8}=B_{1,11}=0$	, and $\frac{1}{2}-\frac{3z}{2d}+\frac{2z^3}{d^3}=\overline{\overline{N}}_1(z)$	$N_2(z)=\left(\frac{1}{8}\right)\left(-d+\eta\cdot D+\frac{D^2}{d^2}\cdot\eta^2-\frac{D^3}{d^2}\cdot\eta^3\right)$
$B_{2,1}=B_{2,4}=B_{2,7}=B_{2,10}=0$	$\frac{1}{2}+\frac{3z}{2d}-\frac{2z^3}{d^3}=\overline{\overline{N}}_2(z)$	$N_{2,z}=\frac{1}{4}\left(1+\frac{2D}{d}\cdot\eta-3\frac{D^2}{d^2}\cdot\eta^2\right)$
$B_{1,1}=\overline{\overline{N}}_{1,x}\cdot N_1(z), B_{1,3}=\overline{\overline{N}}_{1,x}\cdot N_2(z)$	$N_1(x)=\left(\frac{1}{2}-\frac{3}{2l}x+\frac{2}{l^3}x^3\right)$	$N_3(z)=\frac{1}{4}\left(2+\frac{3D}{d}\cdot\eta-\frac{D^3}{d^3}\cdot\eta^3\right)$
$B_{1,4}=\overline{\overline{N}}_{2,x}\cdot N_1(z), B_{1,6}=\overline{\overline{N}}_{2,x}\cdot N_2(z)$	and derivative w.r.t. x $N_{1,x}=\left(-\frac{3}{2l}+\frac{6}{l^3}x^2\right)$ Similarly	$N_{3,z}=\left(\frac{3}{2d}\right)\left(1-\frac{D^2}{d^2}\cdot\eta^2\right)$
$B_{1,7}=\overline{\overline{N}}_{1,x}\cdot N_3(z), B_{1,9}=\overline{\overline{N}}_{1,x}\cdot N_4(z)$	$N_2(x)=\left(\frac{1}{8}-\frac{x}{4}-\frac{x^2}{2l}+\frac{x^3}{l^2}\right)$	$N_4(z)=\frac{1}{8}\left(d+D\cdot\eta-\frac{D^2}{d}\cdot\eta^2-\frac{D^3}{d^2}\cdot\eta^3\right)$
$B_{1,10}=\overline{\overline{N}}_{2,x}\cdot N_3(z), B_{1,12}=\overline{\overline{N}}_{2,x}\cdot N_4(z)$	$N_{2,x}=\left(-\frac{1}{4}-\frac{x}{l}+\frac{3x^2}{l^2}\right)$	$N_{4,z}=\frac{1}{4}\left(1-\frac{2D}{d}\cdot\eta-\frac{3D^2}{d^2}\cdot\eta^2\right)$
$B_{2,2}=\overline{\overline{N}}_{1,z}\cdot N_1(z), B_{2,3}=\overline{\overline{N}}_{1,z}\cdot N_2(x)$	$N_3(x)=\left(\frac{1}{2}+\frac{3}{2l}x-\frac{2x^3}{l^3}\right)$	Where $\eta=\frac{2z}{D}$ or $\frac{z}{D}=\frac{\eta}{2}$
$B_{2,5}=\overline{\overline{N}}_{1,z}\cdot N_3(x), B_{2,6}=\overline{\overline{N}}_{1,z}\cdot N_4(x)$	$N_{3,x}=\left(\frac{3}{2l}-\frac{6x^2}{l^3}\right)$	l=L+depth of column, d=D+depth of beam Element stiffness matrix is derived from following expression
$B_{2,8}=\overline{\overline{N}}_{2,z}\cdot N_1(x), B_{2,9}=\overline{\overline{N}}_{2,z}\cdot N_2(x)$	$N_4(x)=\left(-\frac{1}{8}-\frac{x}{4}+\frac{x^2}{2l}+\frac{x^3}{l^2}\right)$	$[K]=\int_v [B]^T\left[E^1\right]\cdot[B]dv$
$B_{2,11}=\overline{\overline{N}}_{2,z}\cdot N_3(x), B_{2,12}=\overline{\overline{N}}_{2,z}\cdot N_4(x)$	and $N_{4,x}=\left(-\frac{1}{4}+\frac{x}{l}+\frac{3x^2}{l^2}\right)$	Where $\left[E^1\right]=\frac{E}{1-v^2}\begin{bmatrix}1 & v & 0\\ v & 1 & 0\\ 0 & 0 & \frac{1-v}{2}\end{bmatrix}$
$B_{3,1}=\overline{\overline{N}}_1(x)\cdot N_{1,z}, B_{3,2}=\overline{\overline{N}}_1(z)\cdot N_{1,x}$, $B_{3,3}=\overline{\overline{N}}_1(x)\cdot N_{2,z}+\overline{\overline{N}}_1(z)\cdot N_{2,x}$	$N_1(z)=\frac{1}{4}\left(2-3\frac{D}{d}\cdot\eta+\frac{D^3}{d^3}\cdot\eta^3\right)$	E = modulus of elasticity of material v = poisson ratio

$B_{3,4}=\overline{\overline{N}}_2(x)\cdot N_{1,z},\ B_{3,5}=\overline{\overline{N}}_1(z)\cdot N_{3,x},$ $B_{3,6}=\overline{\overline{N}}_2(x)\cdot N_{2,z}+\overline{\overline{N}}_1(z)\cdot N_{4,x}$	$N_{1,z}=\left(\frac{3}{2d}\right)\left(-1+\frac{D^2}{d^2}\cdot\eta^2\right)$	1 WHERE $\overline{\overline{N}}_1(x)=\left(\frac{1}{2}-\frac{3}{21}\cdot x+\frac{2x^3}{1^3}\right)$
$B_{3,7}=\overline{\overline{N}}_1(x)\cdot N_{3,z},\ B_{3,8}=\overline{\overline{N}}_2(z)\cdot N_{1,x},$ $B_{3,9}=\overline{\overline{N}}_1(x)\cdot N_{4,z}+\overline{\overline{N}}_2(z)\cdot N_{2,x}$	$B_{3,10}=\overline{\overline{N}}_2(x)\cdot N_{3,z},\ B_{3,11}=\overline{\overline{N}}_2(z)\cdot N_{3,x},$ $B_{3,12}=\overline{\overline{N}}_2(x)\cdot N_{4,z}+\overline{\overline{N}}_2(z)\cdot N_{4,x}$	$\overline{\overline{N}}_2(x)=\left(\frac{1}{2}+\frac{3}{21}\cdot x-\frac{2x^3}{1^3}\right)$

The consistent mass matrix is derived from following equation:

$$[M]=\int_v \rho[N]^T[N]dv$$

where ρ=mass density.

The [M] is known as the consistent mass matrix because it is formulated from the same shape function [N] that are used to formulate the stiffness matrix [K].

6.ACKNOWLEDGEMENTS

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7.REFERENCES

1. Goyal Alok, Sinha R. *et al.*, "Learning from Earthquake", EERI Preliminary Report on Damage to R/c Structures in Urban Areas of Ahmedabad & Bhuj".
2. Bertero V.V., Mahin S.A. and Axley J.A., "Lessons from Structural damages observed in Recent Earthquakes". Preceding of the seventh world conference on Earthquake Engineering, Sept. 8-13, 1980, Istambul, Turkey.
3. Polyakov S.V., "On the interaction between masonry filler walls and enclosing frame when loaded in the plane of the wall". Earthquake Engineering 1960, Earthquake Engineering Research Institute, San Francisco.
4. Chopra A.K., "Dynamics of Structures: Theory and Applications to Earthquake Engineering", Prentice Hall of India Pvt. Ltd., New Delhi, 2001.
5. Smith B.S. and Coull A., "Tall Building Structures: Analysis and Design", John Wiley & Sons, Inc., 1991.
6. Cook R.D., "Concepts and Applications of Finite Element Analysis", John Wiley & Sons Inc, 2e.
7. Gupta A.K., "Response Spectrum Method", Blackwell Scientific Publications, Boston Oxford.
8. Mario Paz, "International Handbook of Earthquake Engineering", Champman & Hall, 1994.
9. Hinton E., Rock T. and Zienkiewicz O.C., "A note on mass lumping and related processes in the finite element method". Earthquake Engineering and Structural Dynamics, 1976, Vol.4, 245-249.
10. Liauw, T.C. and Lee S.W., "On the behavior and the analysis of multi-story infilled frames subject to lateral loading". Proc. Instn. Civil Engrs, Part 2, 1977, 63, Sept., 641-656.

