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Seismic analysis of infilled frames

V.K.R. Kodur*, M.A. Erki** and J.H.P. Quenneville**

A numerical example illustrates the steps associated with the seismic design of masonry infilled frames. The example accounts for the effect of the infill in all the design stages: computing seismic loading, predicting the response and assessing the strength of the infilled frame. Numerical results show that the normal design procedures can account for infills in the seismic design of frames.

A popular form of construction consists of orthogonally placed frames and infill walls or panels in the plane of the frames. Frames may be of steel, reinforced concrete, or concrete encased steel frame construction. Materials for infill panels may be solid or hollow bricks, reinforced or unreinforced concrete blocks, light-weight concrete, composite material, or reinforced concrete and the infill may be with or without openings. With the panel connected to the frame, the total system acts as a single unit. With the panel separated from the frame, the frame system can deform independent of the infill during an earthquake.

Properly designed, the infills can increase the overall strength, lateral resistance, and energy dissipation of the structure. Infills reduce lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. Hence, accounting for the infills in analysis and design leads to slender frame members, reducing the overall cost of the structural system.

Improperly designed infills can decrease the natural period of the structure and increase the effect of seismic forces leading to overloading of parts of the structure. Unsymmetrically placed infills may induce torsional effects, and partial masonry infills can redirect the formation of ductile plastic hinges away from the desirable location at the ends of the beams to the top of the columns, resulting in dramatic increase in column shears. The frame-infill interaction may also cause local damage in frame element either near beam-column joints, or at mid-height of columns. The combination of frames having low lateral stiffness with stiff but poor quality infills may lead to premature failure and subsequent collapse of infills.

TREATMENT OF INFILLS IN DESIGN

Designers often neglect the structural contribution of infills. Codes of practice, which do not recognise the effect of infill panels, recommend that the base shear be calculated based on the natural period of frame alone. Besides being unrealistic, such an approach can lead to unsafe designs because frame members receive unintended shear and axial forces. Changes in frame behaviour owing to the presence of infills contributed to structural damage in recent earthquakes[1-4].

For seismic loads, the accuracy of the predicted force on the infilled frame depends on the accuracy of the calculated dynamic characteristics of the structure, namely, natural frequencies, vibrational modes, and damping. The New Zealand masonry code[5] recognises the effect of infills by requiring that the interaction of all structural and non-structural elements affecting the response of the structure or the performance of non-structural elements be considered in the design. Seismic load considerations largely govern the design provisions in this code, ensuring satisfactory structural performance during major earthquakes. Canadian Standards Association[6], in conjunction with the National Building Code of Canada[7] (NBCC) defines specified loads, load effects and load combinations, which govern the structural design of masonry.

In almost all the Codes due to lack of reliable analytical models describing the behaviour of infilled frames[8] there is a dearth of information to guide the engineer in the analysis and design of infilled frames. Currently efforts are for developing simple guidelines for the design of reinforced masonry in all seismic zones[9].

METHODS OF ANALYSIS

The designer can use static or dynamic analysis to design infilled frames subjected to seismic loading. The static

* Institute for Research in Construction, National Research Council Canada, Montreal Road, Ottawa, K1A 0R6, Canada.
** Department of Civil Engineering, Royal Military College of Canada, Kingston, Ontario K7K 5L0, Canada.

analysis involves the analysis of the frame for the equivalent static loads arising from seismic activity, while the dynamic analysis requires analysis in the time domain. Current codes of practice accept that the equivalent static analysis will be sufficient for the seismic design of general multi-storey structures. This is because the dynamic analysis, though accurate, is quite complex.

Static or dynamic analysis can be classified into three broad categories: elastic, plastic and nonlinear analysis. For most applications, codes of practice recommend the elastic analysis. Four major methods used for elastic analysis are, the stress function method, the equivalent diagonal strut method, the equivalent frame method and the finite element method. Results from any of these four methods depend on the assumptions made and the idealization of the structure used in the analysis.

Table 1 lists the different methods available for the analysis of infilled frames, together with salient features. Among these, the stress function method is the least accurate requiring a large number of trials, while the finite element method is the most complex requiring considerable skills on the part of the designer. In the equivalent diagonal strut method, diagonal struts bracing the frame replace the action of the infills. In the case of the equivalent frame method, a frame having equivalent stiffness replaces the frame-infill composite system.

TABLE 1
ANALYTICAL METHODS FOR THE ANALYSIS OF INFILLED FRAMES

Method	Salient Features
Stress Function Method[18]	• The panel and frame elements of infill panel are assumed to resist a percentage of the total load • The load carried by infill and frame is estimated through an iterative approach • The analysis can be carried out using hand calculations; However, the method is approximate.
Equivalent Diagonal Strut method[19,20]	• The infill is idealised as diagonal struts, and the frame is modelled as beam or truss elements. • Frame analysis techniques are used for the elastic analysis • The idealization is based on the assumption that there is no bond between frame and infill.
Equivalent Frame Method[15,21]	• Frame–infill composite system is replaced by an equivalent frame, and equivalent transformed properties are established.. • Elastic analysis is carried out using beam elements. • Idealization is suitable for specifying varying properties or to account for openings
Finite Element Method[22,23]	• Infilled frame system is idealised as panel elements, beam elements, and interface elements. • Interface conditions can be properly simulated by adjusting the properties of interface elements. • The analysis requires the use of a computer and detailed results can be obtained.
Plastic Method of Analysis[24,25]	• The frame infill system is idealised as either integral, or semi–integral or non–integral frame depending on the interface conditions. • Plastic collapse load corresponding to different possible mechanisms is determined.
Nonlinear Analysis[26]	• The infilled frame is idealised for analysis by the finite element method and the response of the system is traced by incrementing the load • Effects of geometric and material nonlinearity can be accounted for in the analysis, but require considerable skill and effort.

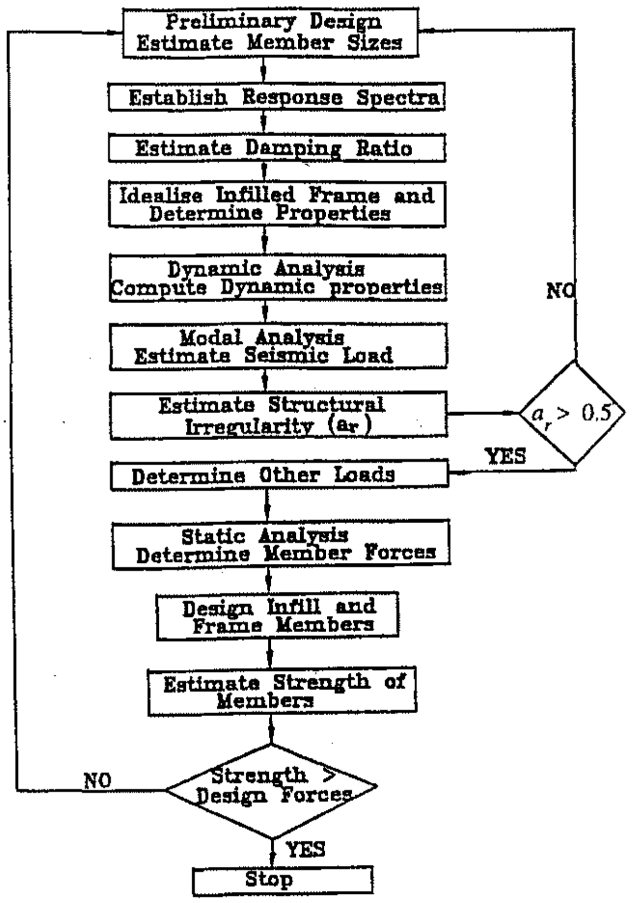


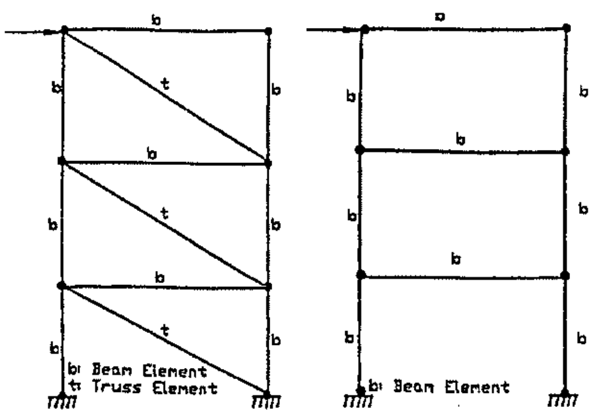
FIG.1 FLOWCHART FOR THE SEISMIC DESIGN OF AN INFILLED FRAME

Researchers have shown that the equivalent diagonal strut and equivalent frame methods give reasonable predictions. A recent study[10,11] uses these methods to propose simple guidelines for the seismic analysis and design of infilled frames. A numerical example given herein illustrates the practical application of these design guidelines.

ANALYSIS PROCEDURE

Figure 1 illustrates the steps associated with the seismic analysis and design of infilled frames[11]. A diagonal strut-frame combination (Fig.2a) or an equivalent frame system (Fig.2b) represents the infilled frame and beam and truss elements idealise the structure for the elastic analysis. The analysis accounts for the infills in computing the seismic load, in determining the forces in the members, and in determining the strength of the different components of the composite system.

Preliminary design gives an estimate of the member sizes of the composite system. Modal analysis establishes



(a) DIAGONAL STRUT (b) EQUIVALENT FRAME

FIG.2 IDEALIZATION OF AN INFILLED FRAME:

the seismic loading corresponding to an earthquake spectra, and a static analysis yields the member forces and displacements. The designer compares these forces with the strength of the infill and frame corresponding to possible modes of failure.

The designer uses dynamic analysis to predict the seismic loads and obtains the required seismic response spectra from codes. Beam and truss elements idealise the infilled frame, and a frame analysis gives the computed dynamic properties. A modal analysis procedure uses these dynamic properties to calculate the base shear[12]. The designer distributes the maximum base shear as lateral forces in the different storeys, based on the relative masses of each storey, and later distributes the corresponding lateral force to each column of the storey.

The designer establishes the total load acting on the infilled frame system, with due consideration to load factors and load combination factors given in codes of practice. Un-symmetrical distribution of the infills leads to additional loads from torsion. Using all predicted loads, a static analysis for frame can give an estimate of the member forces. These member forces are then used for the design of the columns, beams, and infills. The designer then estimates the structural irregularity parameter, a_r, for the infilled frame. If a_r is less than 0.5, the designer changes the vertical distribution of the infills, and repeats the above steps.

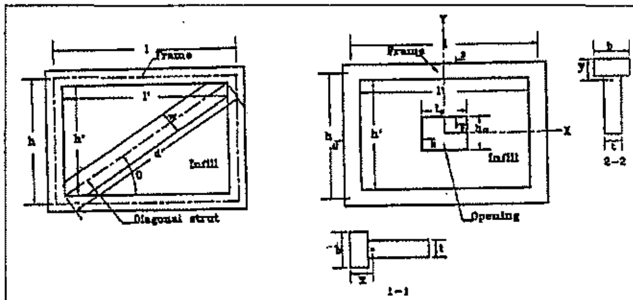
The designer checks the adequacy of the designed infilled frame system by checking the strength of the frame members against the induced force due to the loads. These checks include consideration of the cracking and failure modes for both the concrete frames and infills. The design of the frame and infill is satisfactory when the computed strength for anticipated modes of failure exceeds the design forces in these members. The possible modes of failure due to seismic loads are tension failure of the windward column, or shear failure of the columns and beams[13].

Diagonal Struts: In this idealization, an equivalent diagonal strut of length, d', and width, w_d, replaces the infills. Mainstone[14] proposes the following relationship to compute the contact length parameter (λ) and width (w)

$$\lambda = \sqrt{\frac{E_i \; t \; \sin(2\theta)}{4 \, E_f \, I_c \; h'}} \qquad (1)$$

$$w = 0.175 \; (\lambda)^{-0.4} \; d' \qquad (2)$$

where E_i is the modulus of elasticity of the infill material, E_f is the modulus of elasticity of frame material I_c is the moment of inertia of column, and t is the thickness of infill. Figure 3(a) shows the variables h, h', d' and θ and also shows the idealization of an infill panel as an equivalent strut. Knowing the values of λ and w, the designer calculates the other design parameters required for the analysis.



(a) DIAGONAL STRUT MODEL (b) EQUIVALENT PLANE FRAME MODEL

FIG.3 DIMENSIONS OF AN IDEALISED INFILLED FRAME

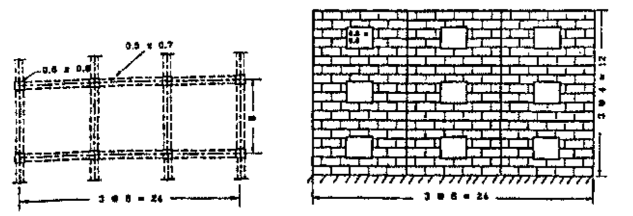
Equivalent Frame

Figure 3(b) shows an infilled frame idealised as an equivalent frame, for which the modified properties of the frame account for the effect of the infill. Liauw[15] proposes transforming the frame-infill members into equivalent sections of frame using the modular ratio of the frame and infill material. Liauw notes that the calculation uses the corner parts of the infill twice to calculate the moment of inertia of the beams and columns of the frame. As expected, this tends to increase the stiffness of the frame, because the corners of the infill stiffen both the beams and columns. Since the transformed sections of the equivalent frame normally consist of deep beams and wide columns, calculation needs to account for the shear strain energy. Using this approach the designer can account for the presence of openings in the infills while calculating the sectional properties of the equivalent frame members.

NUMERICAL EXAMPLE

Figure 4 shows the numerical example used herein to illustrate the aforementioned analytical procedure for the seismic analysis and design of an infilled frame of a three-storey, three-bay reinforced concrete building. The spacing of the frames in the X direction is 8 metres. The brick masonry walls laterally support the frames and at the centre of each wall, there is an opening, 0.8 x 0.8 m.

The numerical example[10,11] illustrates three cases for the analysis of the infilled frame. The first one, Case



All dimensions in m

FIG.4 FLOOR PLAN AND ELEVATION OF A THREE STOREY BUILDING

A, considers the contribution of the bare frame without infill. Cases B and C take into account the effect of infill throughout the frame, and the openings present in the infill respectively.

Material Properties and Loading

Table 2 summarises the material properties used in the analysis. The example uses brick masonry for the infills and reinforced concrete for the columns and beams. Figure 4 gives the beam and column cross-sectional dimensions. The thickness of the slab is 150 mm. The thickness of the masonry infill is 100mm.

TABLE 2
MATERIAL PROPERTIES OF THE FRAME AND INFILL

Property	Frame (Reinforced Concrete)	Infill (Brick Masonry)
Compressive Strength (f_c') (MPa)	20	3
Shear Strength (MPa)	–	0.5
Tensile Strength (MPa)	2.5	0.35
Elastic Modulus (MPa)	200 000	2000
Yield Strength of Reinforcement (MPa)	400	—
Unit Weight kg/m^3	2500	2500

The gravity loads on the building are:

Floors: 150-mm thick slab	3.75 kPa
Floor finish, ceiling, services	1.5 kPa
Movable partitions, carpets, etc.	0.4kPa
Total dead load on slabs	5.625 kPa
Dead load of masonry walls	1.00 kPa
Live load on all floors and the roof	2.50 kPa

The calculation for the loading from the floors and partitions on the beams uses the total dead load on slabs and the weight of walls. The total loading which is taken as the total floor weight plus that of the tributary walls, is:

W	= 412.8 kN
Total mass	= 42 080 kg
Mass density	= 15 028

The example assumes that all the load factors and material resistance factors are equal to unity.

Properties of an Equivalent Frame

An equivalent frame replaces the infilled frame for Cases B and C. Figure 3(b) shows the idealised rectangular infilled frame with an opening at the centre, together with its dimensions. The cross-sectional area of the beam of an equivalent frame, A_{eq}, is:

$$A_{eq} = Bh_x + rt(b - b_o) \tag{3}$$

where r is the ratio of the Young's modulus of the infill to that of frame (E_i / E_f).

The distance of the centroid, y, of the composite section from the outer fibre of the actual beam is:

$$\bar{y} = \frac{1}{2}\,\frac{Bh_x^2 + rt(b - b_o)(b - b_o + 2h_x)}{Bh_x + rt(b - b_o)} \tag{4}$$

Moment of inertia, I_b, with respect to the centroidal axis X for the beam member of the equivalent frame is:

$$I_b = \sum (I_x + Ay^2) - A_{eq}\,\bar{y}^2 \tag{5}$$

in which the quantities on the left hand side refer to the actual frame member and the infill. Hence I_b is:

$$I_b = \frac{1}{12}[Bh_x^3 + rt(b - b_o)^3] + \frac{1}{4}[Bh_x^3 + rt(b - b_o)(b - b_o + 2h_x)^2] - \frac{1}{4}\left[\frac{B\,h_x^2 + rt(b - b_o)(b - b_o + 2h_x)}{Bh_x + rt(b - b_o)}\right]^2 \tag{6}$$

Calculations for the equivalent properties of the column member proceed similarly. Table 3 summarises the equivalent properties of the column and beam, corresponding to the three cases considered in the analysis. The values from Table 3 show that the effect of the infill was to increase the moment of inertia of the column by 20 times.

TABLE 3
EQUIVALENT PROPERTIES OF THE FRAME

Property	Bare Frame (A)	Infilled Frame (B)	Infilled Frame with Opening (C)
Distance to cg (column) (m)	0.3	0.500	0.464
Distance to cg (beam) (m)	0.35	0.403	0.384
Area of Column (m^2)	0.36	0.397	0.393
Area of Beam (m^2)	0.35	0.367	0.363
Moment of Inertia (column) (m^4)	0.011	0.208	0.156
Moment of Inertia (beam) (m^4)	0.014	0.041	0.027

Dynamic Properties

Figure 5 illustrates the use of the frame analysis program with a two-dimensional idealization to calculate the dynamic properties of the building. Table 4 summarises the resulting natural frequencies, periods and corresponding modes of vibration. It is seen that the infill significantly reduces the natural period for Case B. The presence of openings, (Case C), results in a slightly higher natural period as compared to that for Case B. As expected, the

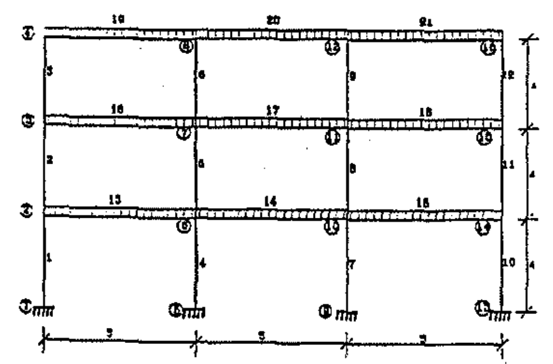


FIG.5 IDEALIZATION OF A TWO-DIMENSIONAL FRAME FOR DYNAMIC ANALYSIS

TABLE 4
DYNAMIC CHARACTERISTICS FOR THE FRAME

Property		Bare Frame (A)			Infilled Frame (B)			Infilled Frame with Opening (C)		
Mode Number		1	2	3	1	2	3	1	2	3
Natural Frequency (Hz)		1.59	5.12	8.84	3.72	14.1	14.9	3.21	12.5	14.8
Period (sec)		0.627	0.195	0.113	0.269	0.071	0.067	0.311	0.08	0.07
Mode	1	0.329	–1.127	2.446	0.234	–1.147	–0.286	0.232	–1.14	–0.27
Shape	2	0.743	–0.778	–2.365	0.636	–1.03	–0.214	0.637	–1.07	–0.27
(Col)	3	1	1	1	1	1	1	1	1	1

natural period in all three cases decreases with higher modes. The mode shapes vary widely indicating that the calculated behaviour of an infilled frame depends on the idealization used in the analysis.

Seismic Loading

The design earthquake response spectrum used for this example is normalised to a peak ground acceleration[7] of 1g. The infilled frame is in the seismic zone with a peak ground acceleration of 0.4 g. The damping ratio[16] of the infilled reinforced concrete frame system is 3% for all three Cases. The ordinates S_d', S_v' and S_a' from first three mode shapes, multiplied by 0.4 give the design values of spectral displacements (S_d), velocities (S_v), and accelerations (S_a) corresponding to the first three natural periods. Table 5 lists the values corresponding to three natural modes.

TABLE 5
DESIGN SEISMIC SEPCTRUM VALUES FOR THE FRAME

Property	Bare Frame (A)			Infilled Frame (B)			Infilled Frame with Opening (C)		
Mode Number	1	2	3	1	2	3	1	2	3
Period (sec)	0.63	0.195	0.113	0.269	0.071	0.067	0.311	0.08	0.07
S_d (m)	0.1	0.016	0.008	0.032	0.0019	0.0018	0.036	0.002	0.002
S_v (m/sec)	0.9	0.56	0.38	0.7	0.156	0.152	0.72	0.16	0.152
S_a (m/sec^2)	0.9	1.6	1.6	1.6	1.44	1.44	1.6	1.44	1.44

Use of a spreadsheet and the modal analysis procedure gives the seismic loading on the building[12]. Kodur et al.[10,11] illustrate the calculations of the modal participation factors, horizontal deflections, equivalent lateral forces and base shear. Table 6 compares the resulting base shears.

The National Building Code[7] gives the provisions for the base shear due to seismic loading, using a static approach to estimate the base shear. The minimum design base shear is:

$$V = v\,S\,I_i\,F_f\,W \tag{7}$$

where v is the zonal velocity ratio, S is seismic response factor, I_i is the seismic importance factor, F_f is the foundation factor, and W is the weight of the structure. The seismic response factor is a function of time period (T) and the velocity.

Table 6 presents the maximum probable base shear and the base shears for the three modes for Cases A, B, and C, together with the base shear as per the NBCC[7]. The second and third modes have little influence on the maximum probable base shear values. The maximum probable base shear is significantly higher in Cases B and C, indicating that the presence of infills attracts higher seismic loads. The increased seismic acceleration from the reduced natural period results in higher shear. The base shear from the code is higher than that obtained from modal analysis for all three cases. The Code formula does not recognise the effect of infill panels and is very conservative when compared with the base shear of the bare frame.

TABLE 6
EQUIVALENT LATERAL FORCES AND BASE SHEARS FOR THE FRAME

Property	Bare Frame (A)			Infilled Frame (B)			Infilled Frame with Opening (C)		
Mode Number	1	2	3	1	2	3	1	2	3
Max. Probable Base shear	99 772			163 507			163 206		
Base shear	97718	19145	6245	161058	24800	13410	160784	25818	10878
NBC Base shear	186 000			186 000			186 000		

Note: All units in Newtons

The different storeys receive proportional amounts of the maximum probable base shear, with respect to their masses, except for the top floor, which receives 10% of the base shear to account for the influence of higher modes in increasing moments and shear at higher levels.

Table 7 lists the resulting lateral forces, F, at each storey for columns 1, 2 and 3, owing to a seismic peak ground acceleration of 0.4g, for the three cases. Each storey receives a portion of the base shear calculated in accordance with the Code provisions. Table 7 also gives the resulting lateral forces. Figure 6 shows the variation of lateral forces over the height of the frame for three cases of analysis

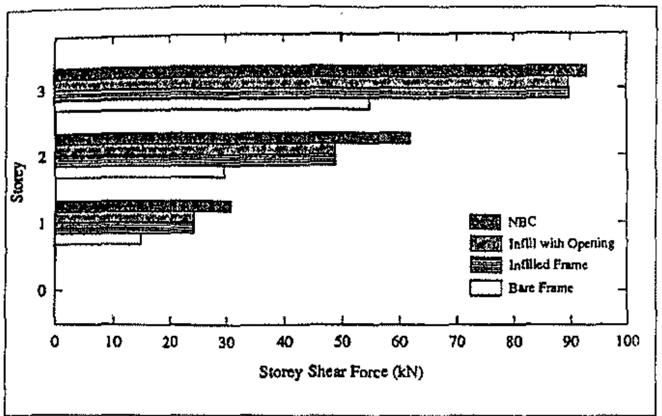


FIG.6 VARIATION OF BASE SHEAR FOR THREE CASES OF FRAME IDEALIZATION

compared to the code values. Table 7 and Fig. 6 show that compared to Case A, the lateral forces at each floor level are higher in Cases B and C, because these cases account for the infill. The lateral forces obtained through the Code are higher than those got from the other three cases.

TABLE 7 LATERALS FORCE DUE TO SEISMIC ACCELERATION				
Storey	Bare Frame (A)	Infilled Frame (B)	Infilled Frame with Opening (C)	NBC
1	14 966	24 526	24 481	31 000
2	29 932	49 052	48 962	62 000
3	54 875	89 930	89 763	93 000

Note: All units in Newtons

Structural Irregularities and Torsional Effects

The structural irregularities, both horizontal and vertical, in this example problem are almost negligible because of the symmetry of the frame. The torsional effects in the present example are not considerable because the calculation uses the actual stiffness of the infilled frame. However, Kodur et al.[10] show how to account for the structural irregularities and torsional effects in the analysis.

Static Analysis

To determine the response of the structure for seismic peak acceleration using an elastic analysis, the input values are the static equivalent loads (both lateral and gravity loads). The elastic analysis consists of a frame analysis, with the infilled frame idealised as in Fig.2. Table 8 shows the force and horizontal displacement Δ, in columns 4,5 and 6. Fig.7 shows the variation of storey deflections for three cases of frame idealization. As expected, the first storey columns receive the maximum moments, shears, and axial forces. The forces in the two intermediate columns are higher than those in the two end columns. The top storey deflection in the bare frame is nearly three times higher than that of the infilled frame. This increase in deflection occurs despite the smaller magnitude of applied lateral force at the different storey heights. The deflections increase for Case C, because of the reduction in stiffness from the presence of the openings. The resulting column shears in Cases B and C are higher than that in Case A, because of the higher applied lateral forces.

TABLE 8 MEMBER FORCES FROM STATIC ANALYSIS									
	Bare Frame (A)			Infilled Frame (B)			Infilled Frame with Opening (C)		
Column	A (kN)	V (kN)	Δ_x (m)	A (kN)	V (kN)	Δ_x (m)	A (kN)	V (kN)	Δ_x (m)
4	1326	85.5	0.004	1388	139.3	0.0008	1382	137.2	0.001
5	879	81.7	0.008	916.7	131.7	0.0021	913.4	128.7	0.003
6	432	57.1	0.011	448.1	104.3	0.0034	446.6	101.5	0.0046

Note: The displacement is at the top end of the column

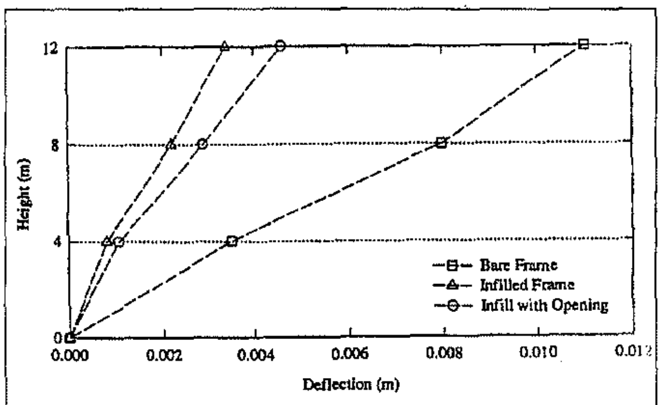


FIG.7 VARIATION OF STOREY DEFLECTIONS FOR THREE CASES OF FRAME IDEALIZATION

Strength of Frame and Infill

The strength requirements of the structure are satisfied by checking the strength of the columns and the infills under different cracking and failure modes. In concrete infills, the usual failure modes are tension cracking along the compressive diagonal, followed by crushing near one of the loaded corners. In the case of a relatively stiff frame, crushing might occur in the interior region of the infill. For infills constructed with brick masonry, shear failure can occur along the mortar joint to masonry panel. Kodur et al.[10] describe the checks for the strength of the columns and infills under different cracking and failure modes, using empirical relationships developed by previous researchers[13,17].

Strength of Column: The cracking of the concrete column occurs when the stress in the concrete reaches its tensile strength, f_t'. The cracking strength of the column, F_{wccr}, is:

$$F_{wccr} = b_c d_c f_t' + (r_s - 1)\, A_{sc}\, f_t' = 1073 \text{ kN} \qquad (8)$$

Using the tensile load required to cause yielding of the reinforcement, the ultimate collapse load of the column, F_{wcco}, is:

$$F_{wcco} = A_{sc}\, f_y = 3080 \text{ kN} \qquad (9)$$

The crushing strength of the column, F_{lccs}, which occurs when the stress in the concrete reaches its ultimate capacity, is:

$$F_{lccs} = b_c\, d_c f_c' + (r_s - 1)\, A_{sc} f_c' = 8586 \text{ kN} \qquad (10)$$

Strength of Infill: The panel ratio ($l' : h'$) of the infill is 2.03, and the value of λh is equal to 1.895. This section explains how to compute the strength of the infill under different modes of failure, knowing the values of λh and w.

Smith and Carter[13] define the crushing strength of brickwork, R_c, by:

$$R_c = \frac{(f_m'\, ht)\, \pi\, \sec(\theta)}{2\lambda h} = 1109 \text{ kN} \qquad (11)$$

and give design curves based on the following empirical relationship[17] to calculate the shear strength of brick work, R_s,

$$R_s = (f_s'\, ht)\, 1.85 \left[\frac{l'}{h'}\right]^{0.6} [\lambda h]^{-0.05} \sqrt{\frac{l'}{h'}} = 777 \text{ kN} \qquad (12)$$

The predicted tensile strengthof brickwork, corresponding to diagonal cracking is:

$$R_t = (f_t'\, ht)\ 3.1 \left[\frac{l'}{h'}\right]^{0.98} [\lambda h]^{-0.1} \left[\frac{l'}{h'}\right]^{0.47} = 794 \text{ kN} \qquad (13)$$

From the above analysis, the ultimate strength of a column and the infill are 3080 kN and 777 kN, respectively. Cracking in the column occurs at a load of 1073 kN. The maximum force in the column at the bottom storey is 1326 kN. The results of a static analysis using compatible deformations give the force in the diagonal truss member of the infilled frame induced by seismic loading. The force in the truss member is 42.8 kN at the first storey and 178.2 kN at the third storey. Since the strength of the column and the infill exceeds the total load due to seismic and gravity loading, the infilled frame satisfies the safety condition. The above procedure can check the adequacy of the design for Case C, while the check for Case A is only the strength of columns against the actual loads.

SUMMARY

This paper describes an analytical procedure for the seismic design of masonry infilled frames using a numerical example for three cases of frame idealization: bare frame, infilled frame, and infilled frame with openings. There are three stages of the analysis; computing the seismic loading, determining the forces and evaluating the strengths of infill and frame. The seismic load computed from the proposed procedure is smaller than that obtained from the National Building Code[7] reflecting the conservative nature of the Code. The normal course of design can account for infills using a frame analysis computer program and spreadsheet software, both of which are generally available in design offices.

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