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# Contribution of non-structural brick walls distributions on structures seismic responses

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**Abstract.** Using of masonry infill as partitions, in flat slab frame buildings is a common practice in many parts of the world. The infill is, generally, not considered in the design and the buildings are designed as bare frames. More of fundamental information in the effect of masomary infill on the seismic performance of RC building frames is in great demand for structural engineers. Therefore the main aim of this research is to evaluate the seismic performance of such buildings without (bare frame) and with various systems of the masonary infill. For this purpose, thirteen three dimensional models are chosen and analyzed by SAP2000 program. In this study the stress strain relation model proposed by Crisafulli for the hysteric behaviour of masonary subjected to cyclic loading is used. The results show that the nonstructural masonary infill can impart significant increase global strength and stiffness of such building frames and can enhance the seismic behaviour of flat slab frame building to large extent depending on infill wall system. As a result great deal of insight has been obtained on seismic response of such flat slab buildings which enable the structural engineer to determine the optimum position of infill wall between the columns.

**Keywords:** earthquake; non-structural brick walls; bare frame; masonry infill; reinforced concrete frame; non-linear modeling; time history analysis.

## 1. Introduction

The infill masonry is seldom included in numerical analysis of structural system, because masonry panels are generally considered as structural elements of secondary importance, which introduce some unwanted analytical complexities without having pronounced effect on the structural performance. However, the significant effects of the infilld masonry on the structural responses of frames have been realized by many researchers (Harpal *et al.* 1998, Hong *et al.* 2002, Sahota and Riddington 2001, Nollet and Smith 1998)

It yields that the presence of nonstructural masonry infill can affect the seismic behavior of framed building to large extend. These effects are generally positive: masonry infill can dramatically increase global stiffness and strength of the structure. On the other hand, potentially negative effects may occur such as torsional effects induced by in plan-irregularities, soft-storey

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effects induced irregularities in elevation and short-column effects due to openings. The objective of this study is to investigate the response of reinforced concrete structure subjected to ground motion to assess structural damage by focusing on the effects of infill masonry on the structural performance. In this study, El Centro earthquake records are applied to simulate ground motion.

There is strong evidence that masonry infill enhance the lateral strength of framed building structures under severe earthquake loads and have been successfully used to strengthen the existing moment-resisting frames in some countries (Amrhein *et al.* 1985).

However, there is a common misconception that masonry infill in reinforced concrete (R/C) or structural steel frames can only enhance their lateral load performance and must therefore always be beneficial to the earthquake resistance18 of the structure. As a matter of fact, there are numerous cases of seismic damage that can be attributed to modification of the dynamic response parameters of the basic structural frame by so-called nonstructural masonry infill or even partitions.

The addition of masonry infill panels to an original bare moment resisting frame increases the lateral stiffness of the structure, thus shifting the natural time period on the earthquake response spectrum in the direction of the higher seismic base and storey shears, and attracting earthquake forces to parts of structures not designed to resist them. Furthermore, if the structure is designed to act as a moment resisting frame with a ductile response to the design level earthquakes, neglecting the contribution of infill, the stiffening effect of the infill may increase the column shears resulting in the development of plastic hinges at the top of the columns that are in contact with the infill corners (Paulay and Priestley 1992).

### 1.1 Cyclic behavior of infill panel

In this section, the model proposed by Crisafulli (1997) for the hysteric behavior of masonry subjected to cyclic loading is described. The model is capable of taking into account the non-linear response of masonry in compression. As the model allows taking into account the variation of struts cross section as a function of the axial deformation experienced by element, it is possible to consider the loss of stiffness due to shortening of the contact length between frame and panel as the lateral load increases. Stress Strain relation for the hysteric model proposed is shown Fig. 1.

A reinforced concrete structure was strengthened with solid brick infill walls. The added walls were effective in increasing base shear strength (by approximately 100%) and lateral stiffness (by approximately 500%). (Pujol and Fick 2010)

During earthquake, the infill itself is subjected to in-plane, as well as, out-of-plane forces. In in-plane action, it may fail in any of the last three modes, described above. In case of slender infill, the failure may also occur due to buckling. In out-of-plane action, the infill fails in bending tension in the case of panels with high h/t ratio, while an arching mechanism is developed, in case of panels with relatively low h/t ratio (FEMA 356 2000). Generally, the infill first crack due to in-plane action and then fail, with or without arching action, due to out-of-plane forces. The overall phenomenon is quite complex to be handled in totality. In the present study, the in-plane strength of infill and their effect on the seismic behaviour of RC frame buildings have been studied.

A bare frame (without infill) must be able to resist the earthquake effects. Infill walls must be uniformly distributed in the building. Masonry infill should not be discontinued at any intermediate story or the ground story level; this would have an undesirable effect on the load path.

When ductile RC frames are designed to withstand large displacements without collapse,

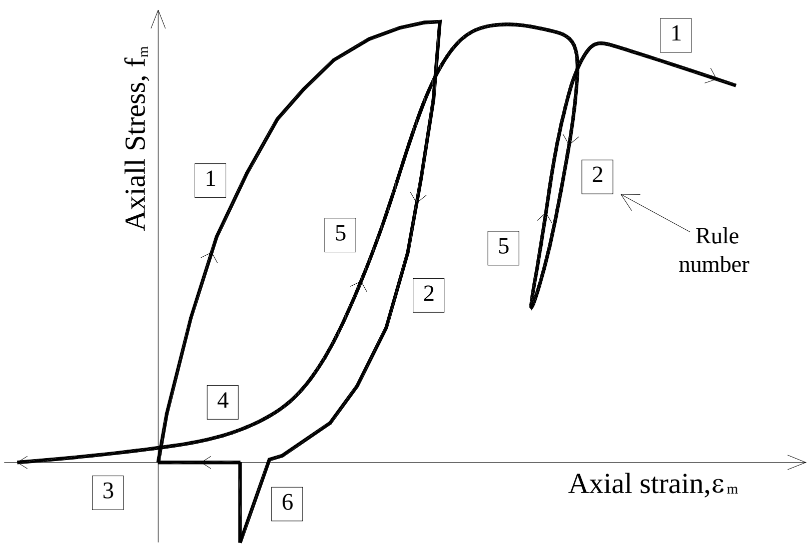



Fig. 1 Used general characteristics for cyclic axial behavior of masonry (Crisafulli 1997)

masonry infill should be isolated from the frame by a sufficient gap. In this manner, masonry infill walls do not affect the frame performance and frame displacements are not restrained. Another advantage of the isolated masonry infill is that the walls remain undamaged, thereby reducing post-earthquake repair costs. From the point of view of controlling weather conditions inside the building, the gaps need to be sealed with an elastic material; these provisions may be expensive and require good construction details to be executed with precision. Overall, based on the poor earthquake performance of non-ductile RC frame buildings and also load-bearing masonry buildings, confined masonry construction is emerging as a better alternative for low-rise buildings in developing countries (Brzev 2007). This type of construction is much easier to build than ductile frames with isolated infill.

### *1.2 In-plane behavior of infill-frames*

The masonry infill changes the mass, damping, stiffness and strength properties of the whole integrated structure. Some design codes acknowledge the difference between a bare frame and an infill-frame; however these provide recommendations mainly on the global behaviour of the structure such as the natural period or the reduction factor (Hemant *et al.* 2006).

FEMA 306 identifies the difficulty in considering the behaviour of infill-frame to the following:

a) Discontinuity of the infill resulting in a soft storey;

b) Various cracking patterns and concentration of forces in structural components;

c) Large variation in construction practice in different regions;

d)Changes in materials over time: brick, stone, concrete masonry or concrete panels, reinforced/unreinforced masonry, grouted/un-grouted masonry, steel and concrete frames.

However it is important to realize that there can be some undesirable effects from the structural interaction between the infill and frame such as:

a) Brittle shear failure (either in the frame members or the infill);

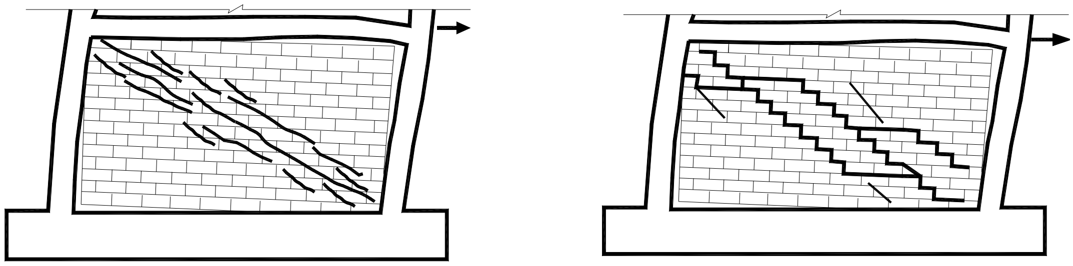
b) Altering in-plane stiffness distribution in plan and elevation due to the provision of an irregular arrangement of infill panels leading to a soft-storey and/or a magnified torsional effect;

c) Infill collapse which can cause loss of life and an increase in the number of casualties;

d) Short-column effect, especially in the case of mid-height infill or infill with an opening (partial infill) leading to unexpected ductility demand in columns. The assumption that the infill will fail under pure in-plane loads, whereas under earthquake loads they may collapse as the result of out-of-plane loads before they reach to their ultimate in-plane capacity.

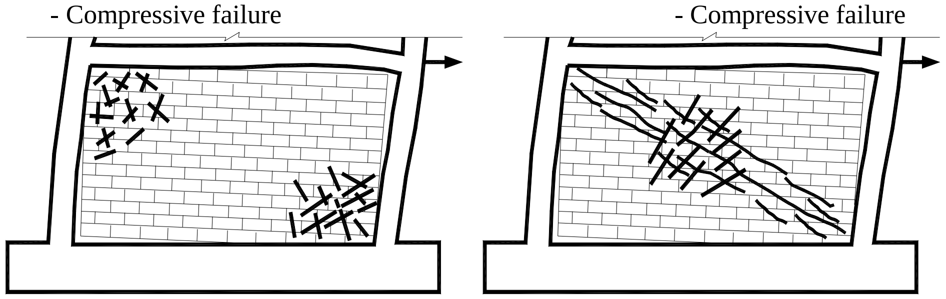
### *1.3 Out-of-plane behavior of infill-frames*

The out-of-plane behavior of infill-frames has been investigated since the 1950s. As reported by Shing and Mehrabi (2002), many studies (Angel 1994, Mander *et al.* 1993, Bashandy *et al.* 1995, and Flanagan 1999) on out-of-plane behavior of infill-frames indicate that infill panels restrained by frames can develop significant out-of-plane resistance as a result of arching effect. The out-of-plane strength of a masonry infill is mainly dependent on its slenderness. If an “x” pattern of cracks develops under both in-plane and out-of-plane loading, this implies that there may be some substantial deterioration in either in or out-of plane strength under the loading in the opposite



(a) Damage or failure of the masonry panel:
- Shear friction failure
- Diagonal tension failure
- Compressive failure

(b) Damage or failure of the masonry panel:
- Shear friction failure
- Diagonal tension failure
- Compressive failure



(c) Damage or failure of the masonry panel:
- Shear friction failure
- Diagonal tension failure
- Compressive failure:
1. Failure of the diagonal strut
2. Crushing of the corners.

Fig. 2 Types of failure modes

direction (Angel 1994). It is shown by Angel (1994) that the out-of-plane strength deterioration may reach as much as 50% for infill panels with high slenderness ratio where they have already been cracked under lateral in-plane loading. Based on the results of tests conducted by (Angel, 1994), the following behaviour can be expected due to different values of slenderness ratio:

a) Crushing along the edges for low $h_m/t$ (where $h_m$ and $t$ are the height and thickness of the infill panel, respectively);

b) Snap-through (small effect of arching) for high $h_m/t$ i.e. approximately between 20 and 30 (this limit depends on the crushing strain of the masonry which usually varies between 0.002 and 0.005).

Regarding the out-of-plane behaviour of masonry (bare) walls, it has been shown that they exhibit substantial out-of-plane displacement capacity and hence more ductile behaviour than is conventionally accepted (Griffith *et al.* 2007). A comprehensive study on the damping of masonry walls in out-of-plane (on-way) flexure can also be found in Lam *et al.* (2003).

Four types of failure modes have been identified (Pauley and Priestley 1992) in case of infill frame buildings: (1) Tension failure of the tension side column resulting from the applied overturning moments in infill frames with high aspect ratio, (2) Sliding shear failure of the masonry along horizontal mortar bed joint causing shear hinges in the columns due to short column effect, (3) Compression failure of the diagonal strut, and (4) Diagonal tensile cracking of the panel (see Fig. 2(a), 2(b) and 2(c)).

## 2. Model description

To observe the effect of infill on the global behavior of flat slab frame buildings, a 12 stories building, with identical plan, as shown in Fig. 3, have been considered. The overall plan dimensions are 10.0m x 10.0m, measured from the centre line of the columns. The height of the

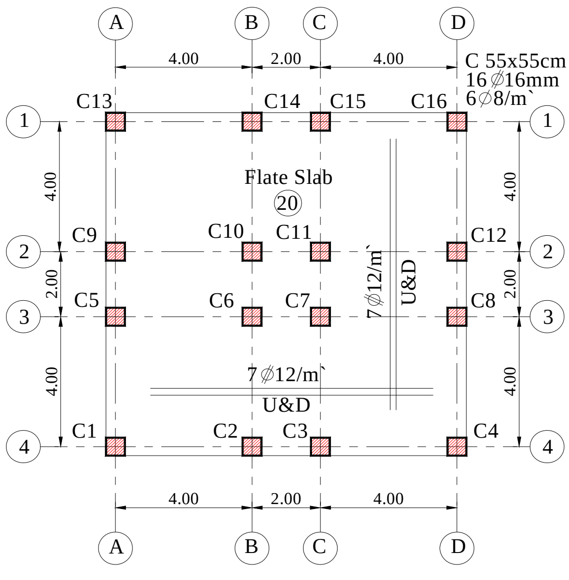



Fig. 3 Specification and plane of identical floors of the models

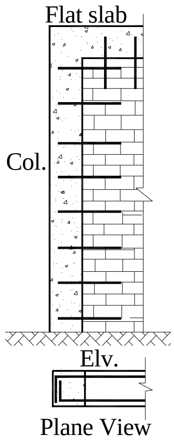



Fig. 4 Horizontal dowels at the wall-to-column interface

Table 1: Description of study cases models

| No. | Symbol | Description | No. | Symbol | Description |
|---|---|---|---|---|---|
| 1 | Bare | Flat slab frame without infill brick wall | 8 | 5th | Flat slab frame with infill brick wall except fifth floor |
| 2 | All | Flat slab frame with infill brick walls at each floor | 9 | 6th | Flat slab frame with infill brick wall except sixth floor |
| 3 | G | Flat slab frame with infill brick wall except ground floor | 10 | 7th | Flat slab frame with infill brick wall except seventh floor |
| 4 | 1st | Flat slab frame with infill brick wall except first floor | 11 | 8th | Flat slab frame with infill brick wall except eighth floor |
| 5 | 2nd | Flat slab frame with infill brick wall except second floor | 12 | 9th | Flat slab frame with infill brick wall except ninth floor |
| 6 | 3rd | Flat slab frame with infill brick wall except third floor | 13 | 10th | Flat slab frame with infill brick wall except tenth floor |
| 7 | 4th | Flat slab frame with infill brick wall except fourth floor | | | |

ground floor is 3.0 m and inters storey heights are 3 m. A flat slab of 20 cm thickness has been considered for all stories. The thickness of the exterior and interior infill has been considered as 12 cm and 25 cm. However, the effect of opening on stiffness and strength has been ignored.

Method of connecting walls to RC flat slab frame is the interface between the masonry wall and the concrete tie-column needs to remain smooth for appearance’s sake, steel dowels should be provided in a mortar bed joints to ensure interaction between the masonry and the concrete during an earthquake (Fig. 4). It is assumed that, other than dowels, horizontal reinforcement is not provided in the walls.

Fig. 5 shows the different cases (13 cases) of study the first case bare flat slab frame building, all wall cases in the 12 stories at the centre line between columns, then a case of no walls at ground story and repeat this case in second story tell the tenth story to study the effect of absence of infill in each story on the base shear, drift of each story and base normal force in columns. Table 1 describes the 13 cases of study with its abridgment.

In bare flat slab frame building, the live load distributed on the slab equivalent to the weight of the absence brick walls which the designer does at analysing such kind of building. By using the requirements of the flat slab building no undertake into place of the brick walls, so that the full walls will be constructed between all columns in all parts.

SAP 2000 (v 8.1.2) was utilized for the heterogeneous modeling study of the masonry systems using solid and shell elements. So, SAP 2000 (v 8.1.2) will be used in this study.

### *2.1 Modeling brick in SAP2000*

Using the data of the model proposed by Crisafulli (1997) for the hysteric behavior of masonry subjected to cyclic loading as input data to the program SAP2000 and models the wall as a shell with properties of red brick wall.

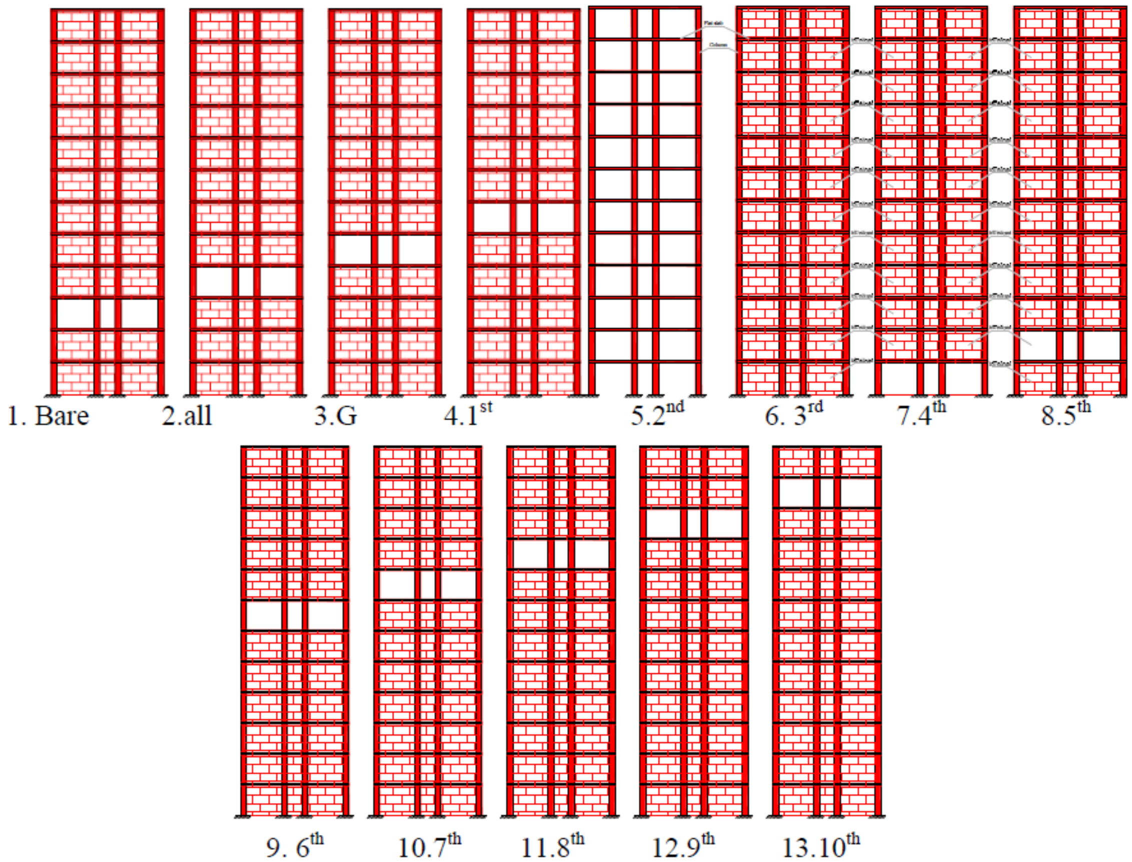



Fig. 5 Different study cases of infill arrangement in different stories

### *2.2 Input loadings*

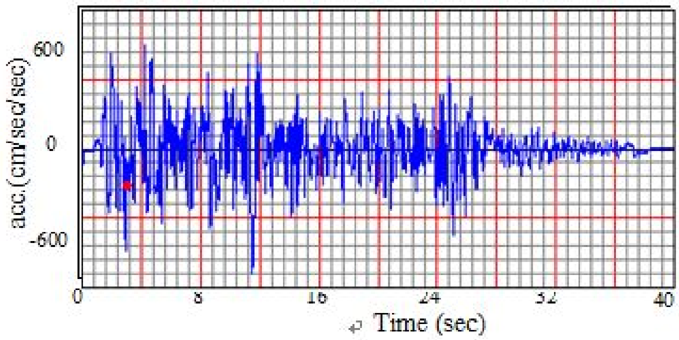



Fig. 6 El Centrio model vibration

The unit weight of walls 1.8t/m$^3$, Live load intensity on the floors and roof has been taken 1300kg/m$^2$ and 1066kg/m$^2$, for infill walls thickness 25cm and 12cm respectively (unite weight = 1.8 t/m$^3$) in the case of bare flat slab frame building, but in the all 12 other cases live lode will be 200kg/m$^2$ and cover 150kg/m$^2$ in all stories. A lightweight brick was used as alternative of red brick in the flat slab frame building of unit weight 600kg/m$^3$.

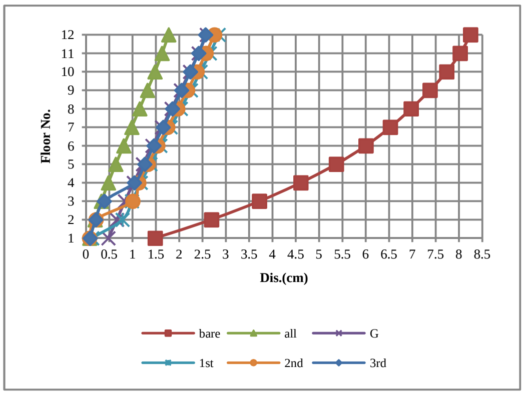
A time history analysis was carried out using El Centro earthquake and ten models are excited by three orthogonal components of seismic motion which has maximum acceleration 0.5g (Fig. 6) (the earthquake affects on two directions X, and Y of the tested model).

## 3. Results and discusion

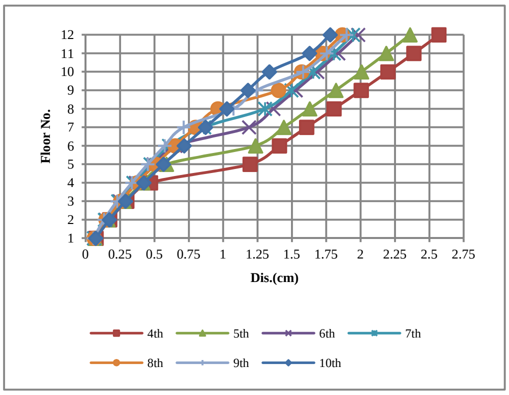
To study the performance of brick walls in flat slab frame building subjected to earthquake, 13 models were studied and the bare flat slab frame (without any infil brick walls) chose as a reference case, which will compare the other cases.

Fig.7 displays the displacement values for each storey in the various study cases. Fig. 7(a) shows the displacement of each storey in the cases bare (as reference case), all, G ,1$^{st}$ ,2$^{nd}$, 3$^{rd}$ 4$^{th}$,5$^{th}$,6$^{th}$,7$^{th}$,8$^{th}$,9$^{th}$,10$^{th}$ with 12 cm wall brick thickness. Fig. 7(b) shows the displacement of each storey in the cases bare (as reference case), all, G, 1$^{st}$ ,2$^{nd}$, 3$^{rd}$ 4$^{th}$,5$^{th}$,6$^{th}$,7$^{th}$,8$^{th}$,9$^{th}$,10$^{th}$ with 25 cm wall brick thickness. The displacement of each floor in bare case is greater than the displacement of each floor in case of all by nearly 6 times for each case of study from 1$^{st}$ to 10$^{th}$. The ratio between displacement of bare case and the other cases equal to nearly 20 in first floor of the model in each case study from 1$^{st}$ to 10$^{th}$. The displacement as shown in figures increase by nearly 2 times after the floor which is absence of brick in every case studied from 1$^{st}$ to 10$^{th}$ cases, but in case all displacements equals 0.2 times displacement of bare case, and displacement in G case equals to 0.33 times of displacement in the bare case for each floor (from first to twelve floors). Displacement in case of 12cm brick wall thickness is less than 25cm brick wall thickness by nearly 1.2 times in all cases.

Fig. 8 shows the base shear in all columns for various cases of brick wall arrangements, brick wall thickness 12cm and 25cm, and lightweight brick wall.

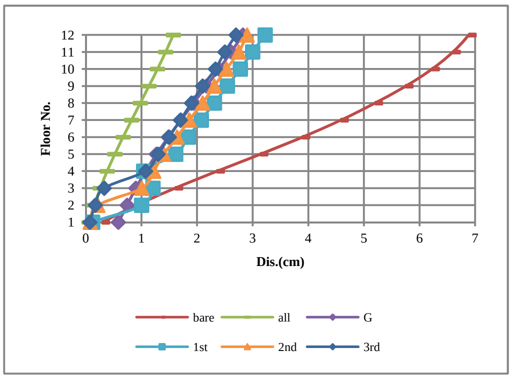



(i)Displacement of storeys in cases bare,all G,1st,2nd,3rd

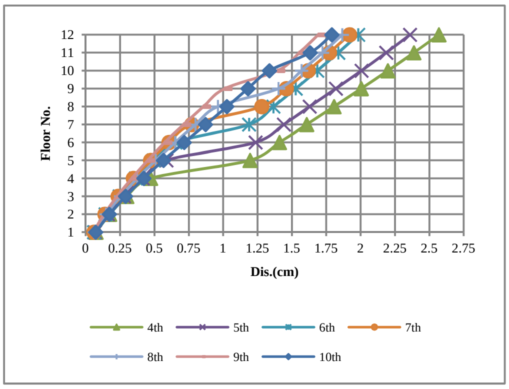



(ii) Displacement of storeys in cases 4th,5th,6th,7th,8th,9th,10th

(a) 12cm brick thickness

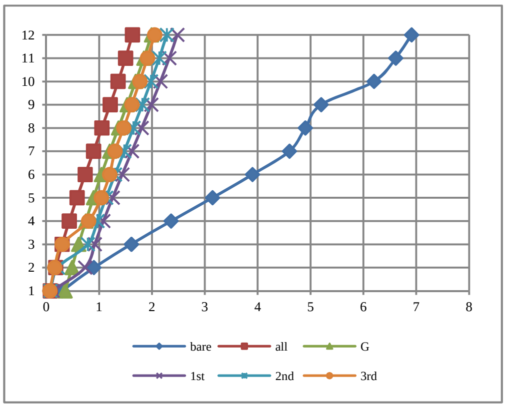



(i)Displacement of storeys in cases bare,all G,1st,2nd,3rd

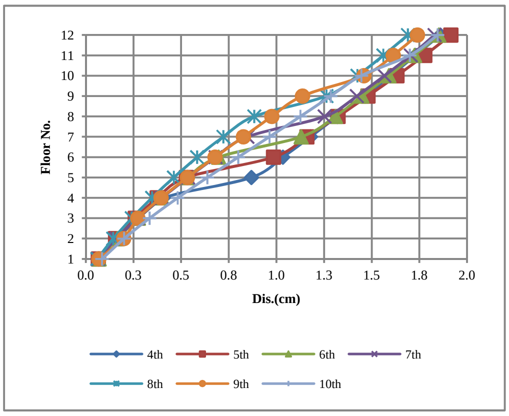



(ii)displacement of storeys in cases 4th,5th,6th,7th,8th,9th,10th

(b) 25cm brick thickness



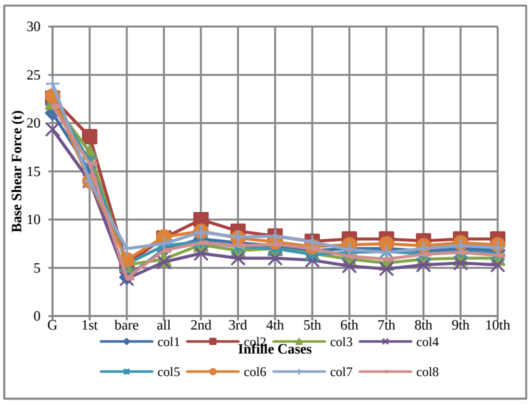

(i)Displacement of storeys in cases bare,all G,1st,2nd,3rd



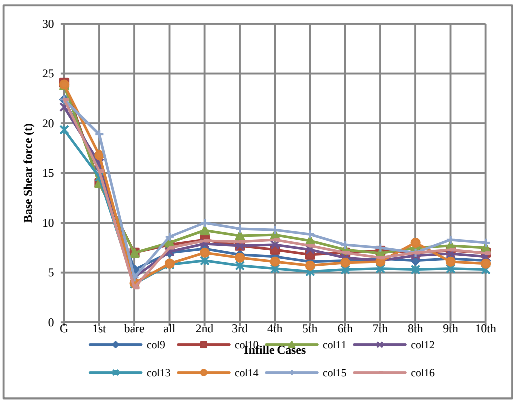

(ii) Displacement of storeys in cases 4th,5th,6th,7th,8th,9th,10th

(c) 20cm light brick thickness

Fig. 7 Displacements of storey with respect to height in each study case

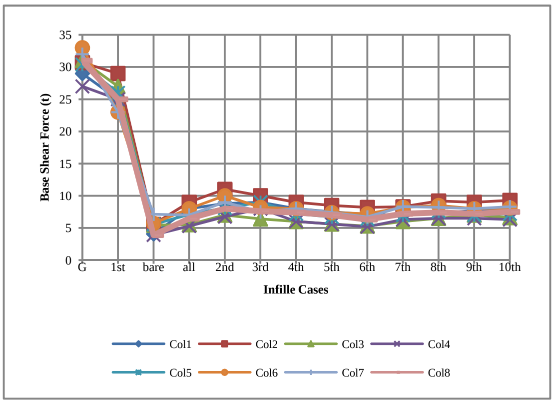



i) Base shear for columns No.1to 8

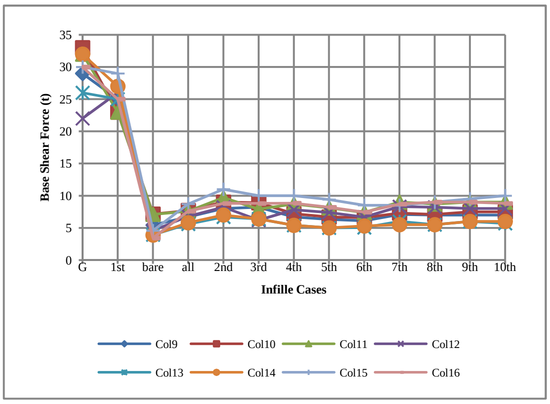



ii) Base shear for columns No. 9 to 16

(a) 12cm thickness brick walls

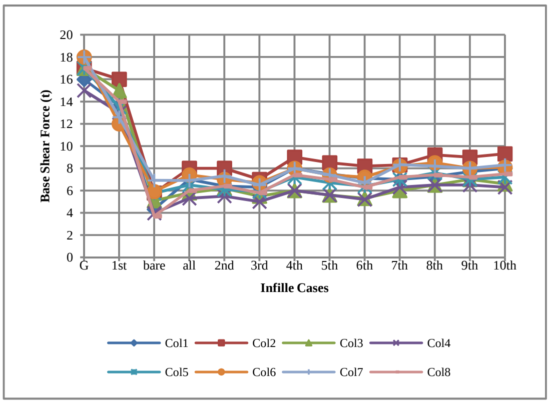



i) Base shear for columns No. 1 to 8

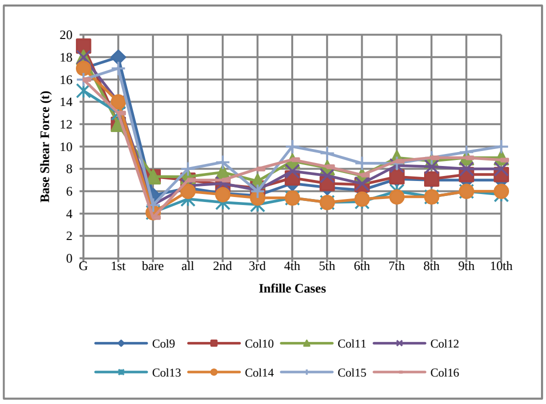



ii) Base shear for columns No. 9 to 16

(b) 25cm thickness brick walls




i) Base shear for columns No. 1 to 8




ii) Base shear for columns No. 9 to 16

(c) 20cm thickness lightweight brick walls

Fig. 8 Base shear in each study case

Fig. 8(a) illustrates the base shear of ground floor columns of 12 cm brick wall thickness. In all ground columns in all study cases the ratio between base shear G and 1st cases are equal to nearly 0.33 and 0.25 respectively.

Fig. 8(b) illustrates the base shear of ground floor columns of 25 cm brick wall thickness. In all ground columns in cases bare, all, 2nd 3rd, 4th, 5th, 6th, 7th, 8th, 9th, and 10th base shear are nearly equal in each case. The ratio of base shear for columns 1to 4, 6,8,13,14,15, and 16 in bare case equal to nearly 0.20 the base shear in cases G and 1st. The ratio of base shear in all ground columns in G and 1st cases and all other cases equals to nearly 0.25 and 0.2 respectively.

Fig. 8(c) illustrates the base shear of ground floor columns of 20 cm lightweight brick wall thickness. In all ground columns in all study cases the ratio of base shear G and 1st cases equals to nearly 0.33 and 0.25 respectively.

For 25 cm brick wall thickness shear force increase in columns than 12 cm brick wall thickness by nearly 1.5 times in G case (absence of brick walls in ground floor).

Normal forces on the ground floor columns in various cases of brick wall arrangements and different brick wall thickness. For columns 10,11,13,7,6 and 4 are the least affected columns in values of normal force between different case of brick wall arrangements and all other columns in the ratio between the normal force in all study cases and bare case equals to nearly 2.5 and equals to nearly 5 in columns 1, and 16 these analyses for brick wall thickness 12 cm and 25 cm. In case of uniformly infill buildings, the contribution of higher modes is increased. Axial force in columns increases due to the inclusion of infill in the frames. This alters the yield pattern considerably and building with a smaller aspect ratio may develop a column sway mechanism in ground storey. In case of uniformly infill frame buildings, strength capacity increases than that of bare frame buildings but ductility capacity is reduced. This effect reduces with the increase of the height of the building. In 25 cm brick wall thickness the normal force on ground columns exceed the normal force in 12cn brick thickness and lightweight brick walls because of the difference in weight of each case.

Fig. 9 shows base moment in ground columns in various cases of brick wall arrangements and thickness.

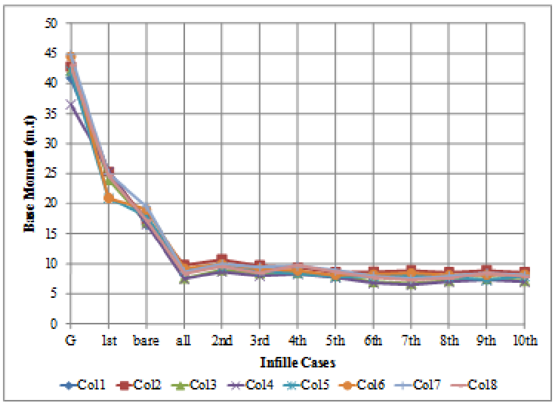
Fig. 9(a) illustrates the base moment of ground floor columns of 12 cm brick wall thickness. In all ground columns in all study cases the ratio of base moment in G case equal to nearly 2 and the ratio between G and 1st cases equal to nearly 1.65. The ratio between base moment in all ground columns in all and G cases equal to nearly 5 in all study cases.

Fig. 9(b) illustrates the base moment of ground floor columns of 25 cm brick wall thickness. In all ground columns in all study cases the ratio of base moment in G case equal to nearly 3 and the ratio between G and 1st cases equal to nearly 1.5. The ratio between base moment in all ground columns in all and G cases equal to nearly 7 in all study cases.

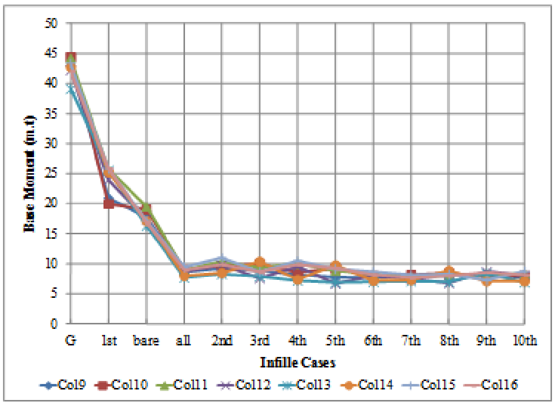
Fig. 9(c) illustrates the base moment of ground floor columns of 20 cm lightweight brick wall thickness. In all ground columns in all study cases the ratio of base moment in G case equal to nearly 2 and the ratio between G and 1st cases equal to nearly 1.3. The ratio between base moment in all ground columns in all and G cases equal to nearly 4 in all study cases.

Fig. 10 illustrates a comparison of shear force and bending moment in columns 5, and 6 (as a larger value in shear between columns) in a different cases of study for each floor with brick wall thickness 12 and 25 cm.

Fig. (10(a-i,ii)) shows the shear force in columns 5 and 6 (brick wall thickness 12 cm), it is clear the effect of absence infill in storey on the impact increase of shear force in columns 5 and 6. Two

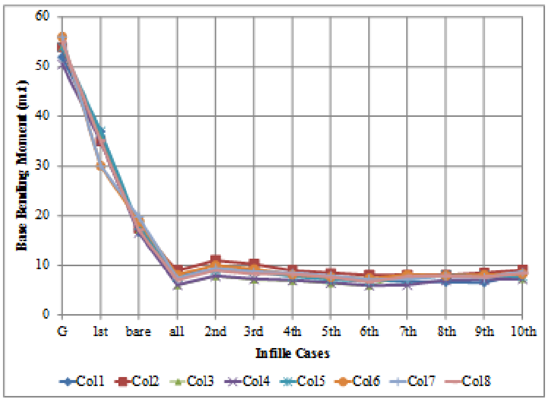



i) Moment in col. No. 1 to

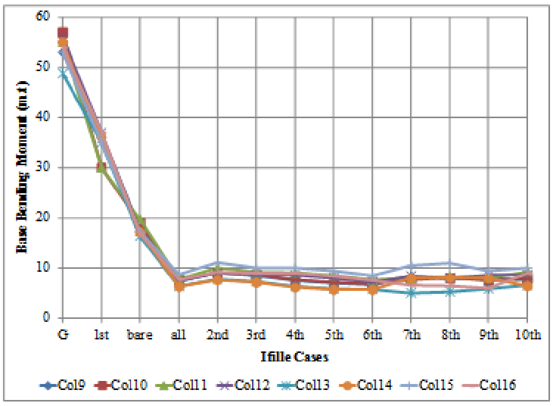



ii) Moment in col. No. 9 to 16

(a) 12cm thickness brick walls

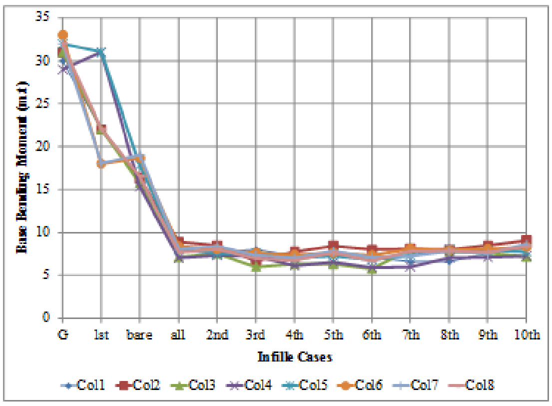



i) Moment on col.No. 1 to 8

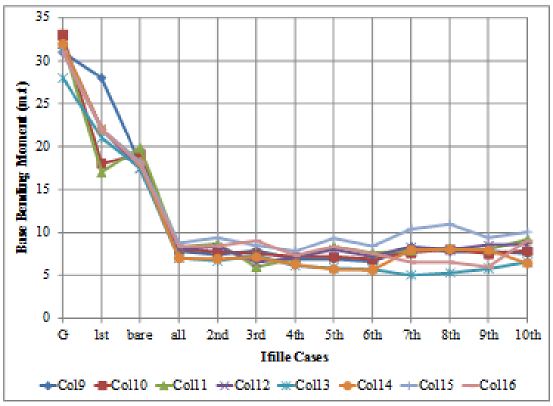



ii) Moment on col. No. 9 to 16

(b) 25cm thickness brick walls



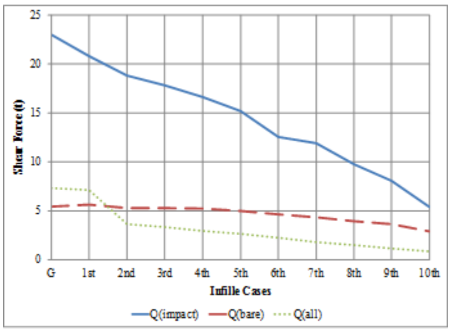

i) Moment on col.No. 1 to 8



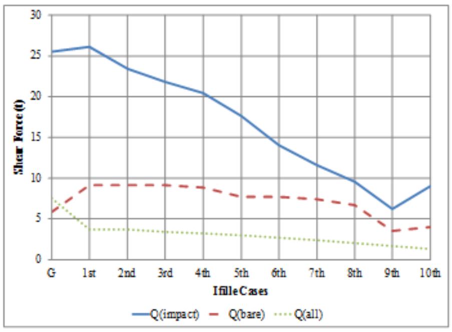

ii) Moment on col. No. 9 to 16

(c) 20cm thickness lightweight brick walls

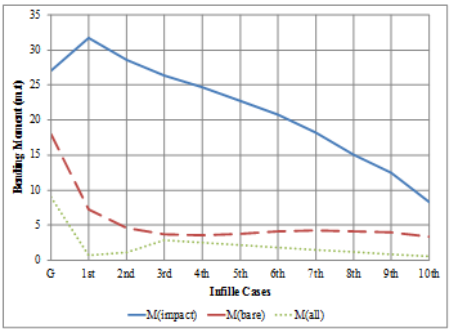
Fig. 9 Bending moment for base columns



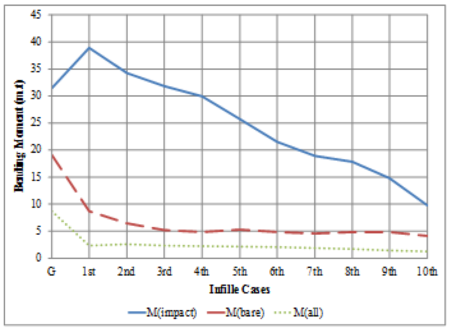

i) Shear force col. 5




ii) Shear force col. 6

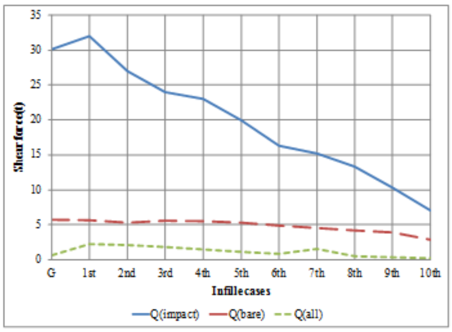



iii) Bending moment col. 5

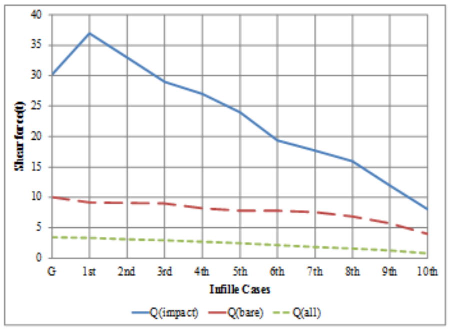



iv) Bending moment col. 6

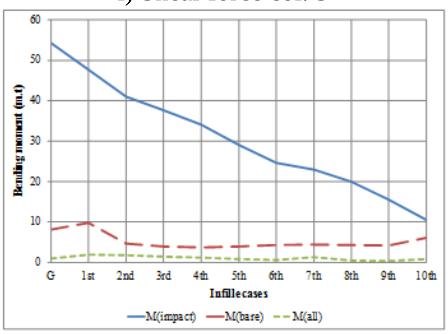
(a) 12 cm thickness brick walls



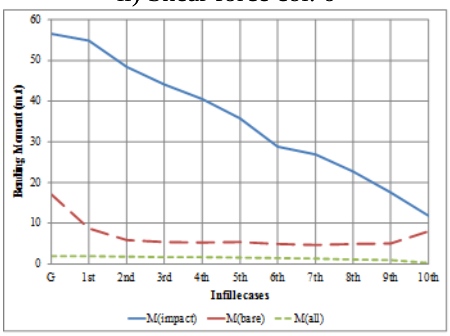

i) Shear force col. 5




ii) Shear force col. 6



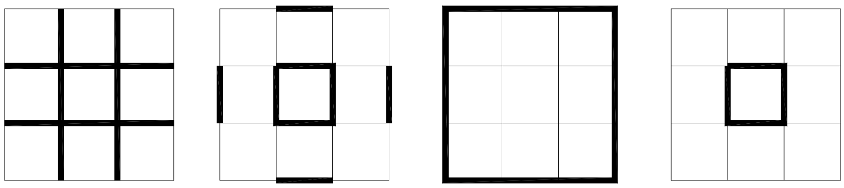

iii) Bending moment col 5




iv) Bending moment col 6

(b) 25cm thickness brick walls

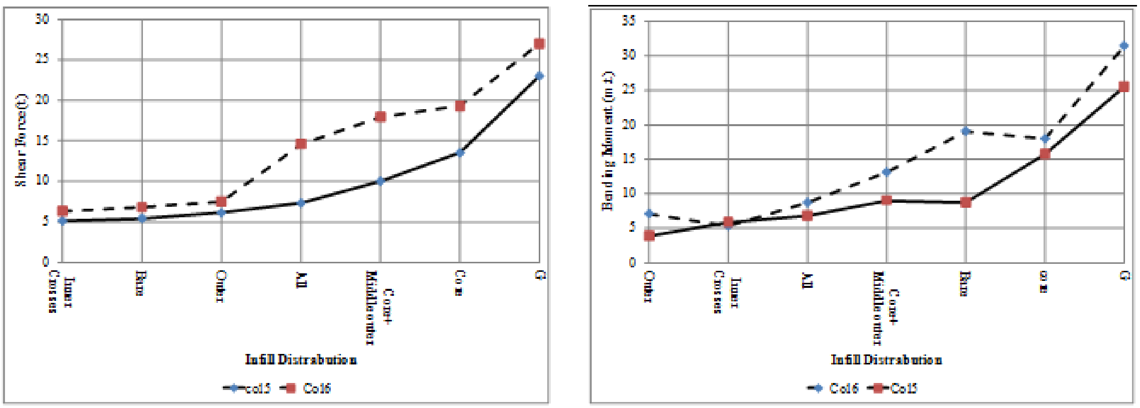
Fig. 10 Impact shear force and bending moment for columns 5, 6



i) Inner Crosses ii) Core + Middle iii) Outer iv) Core

Brick Wall

Fig. 11 New distributions of brick walls in ground floor




i) Base shear force in columns 5, 6 ii) Base moment in columns 5, 6

Fig. 12 Effect of distribution of walls in ground floor on shear force and bending moment for columns 5, 6 at 12 cm brick walls thickness

cases were taken to compare the shear force with an impact case (absence of walls in the floor level) the first is bare and the second is all cases. In absence of infill in ground floor bending moment in columns 5 and 6 increase by 1.5 times than bare case and increase by nearly 4.5 times than the bare case in 1st , 2nd, 3rd, 4th,5th,6th, and 7th cases, but in the rest cases increase by nearly 3 tines than bare case. Bending moment in bare case in G case less than the individual cases in impact case by 50%, but in 1st case less than bare case by nearly 10times and in cases 5th to 8th equal to nearly 2 times, but in cases 2nd ,9th and 10th equal to 4 times.

Fig. 10(b-i,ii) show shear force in columns 5 and 6 (brick wall thickness 25 cm), it is clear the effect of absence infile in storey on the impact increase shear force in columns 5, and 6. Two case were taken to compare shear force with an impact case (absence of walls in the floor level) bare and all cases. In Fig. 10(b-i) the ratio between the shear force of impact and bare cases for column 5 in cases G, 1st,2nd,3rd,4th,5th is equal to 4, and in cases 6th,7th,8th,9th,10th is equal to 3. The ratio between the shear force of impact and bare cases for column 5 in cases G is equal to 50, and in cases 1st,2nd,3rd,and 4th is equal to 13, and in cases5th,and 6th is equal to 20, and in case 7th is equal to 10,and in cases 8th,9th,10th is equal to 30. In Fig. 10(b-ii) the ratio between the shear force of impact and bare cases for column 6 in cases G, 1t,2nd,3rd,4th,5th is equal to 3, and in cases 6th,7th,8th,9th,10th is equal to 2. The ratio between the shear force of impact and bare cases for column 6 in cases G,1st,2nd,3rd, 4th,5th , 6th,7th,8th,9th,10th is equal to 10.

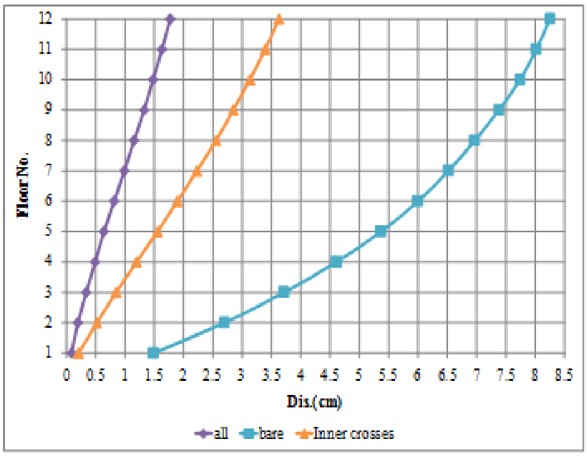
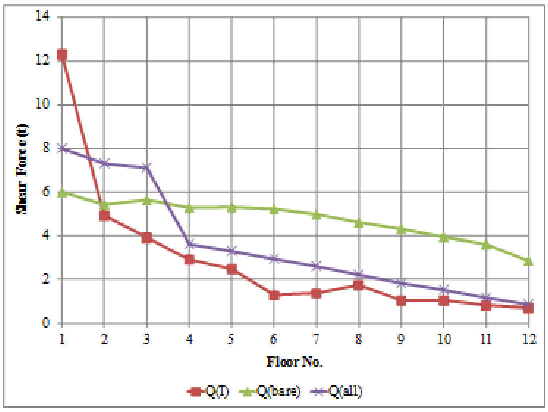
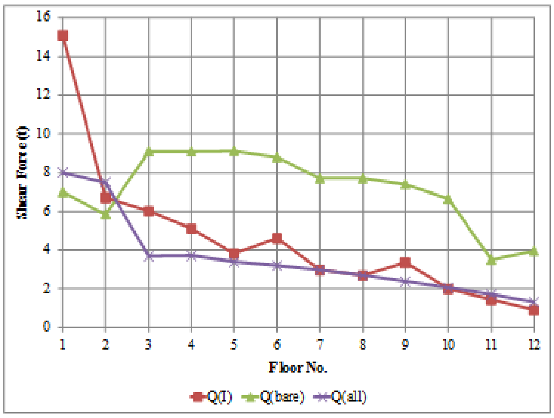


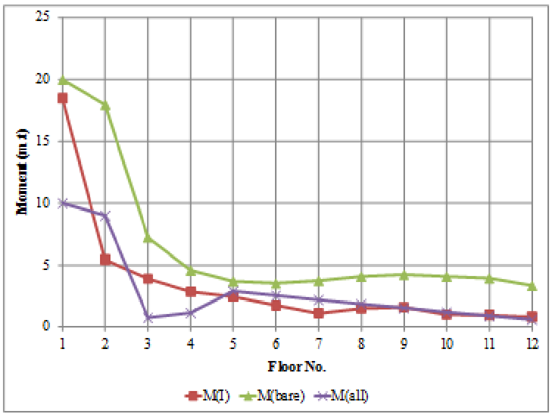

Fig. 13 Displacement of model use inner crosses distribution in each floor with respect to all and bare cases



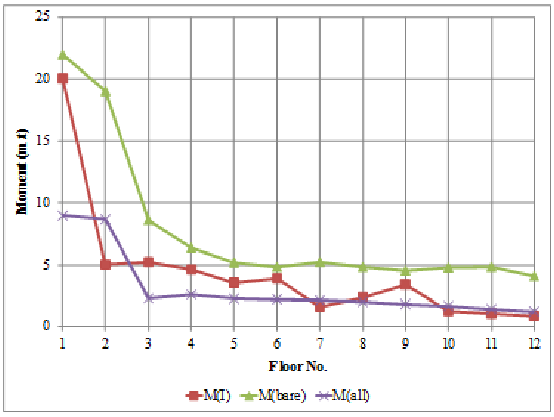

i) Shear force in col (5)




ii) Shear force in col (6)




iii) Moment in col (5)




iv) Moment in col (6)

Fig. 14 Effect of inner crosses distribution of brick walls in each floor on shear force and bending moment in columns 5, 6 comparisons with bar and all cases

Fig. 10(b-iii,iv) show bending moment in columns 5 and 6 (brick wall thickness 25 cm), it is clear the effect of absence infile in storey on the impact increase bending moment in columns 5, and 6. Two cases were taken to compare bending moment with a impact case (absence of walls in the floor level) bare and all cases. In Fig. 10(b-iii) the ratio between the bending moment of impact and bare cases for column 5 in cases G, and $6^{th}$ is equal to 6, and in cases $1^{st}$,$6^{th}$,$7^{th}$, $8^{th}$, and $9^{th}$ is equal to 5, and case $10^{th}$ is equal to 2. The ratio between the bending moment of impact and bare cases for column 5 in cases G,$6^{th}$,$8^{th}$, and $9^{th}$ is equal to 60, and in cases $1^{st}$,$2^{nd}$,$3^{rd}$,$4^{th}$ ,$5^{th}$, $7^{th}$ ,$10^{th}$ is equal to 20. In Fig. 10(b-iv) the ratio between the bending moment of impact and bare cases for column 5 in cases $1^{st}$,$2^{nd}$,$3^{rd}$,$4^{th}$,$5^{th}$, $6^{th}$,$7^{th}$ is equal to 7, and $8^{th}$,$9^{th}$ cases is equal to 6, in $10^{th}$ case is equal to 1and in G case is equal to 3. The ratio between the bending moment of impact and bare cases for column 6 in cases G, $1^{st}$,$2^{nd}$ is equal to 30, in cases$3^{rd}$,$4^{th}$,$5^{th}$, $6^{th}$,$7^{th}$,$8^{th}$,and $9^{th}$is equal to 25, and $10^{th}$ case is equal to 50.

To reduce the impact of the sudden absence of infill some distribution of infill walls will be checked to find the most affected distributed walls with the most effect ratio on the floor to reduce the impact effect and to reduce this effect to arrive to the values of shear force and bending as the bare frame flat slab values. Fig. 11 illustrates the suggested arrangements of infill walls in frame flat slab, Fig. 11(i) illustrates an arrangement (inner crosses) with 50% of all floor walls, Fig. 11(ii) core + middle is a 33%, Fig. 11(iii) outer walls is a 50% , and Fig. 11(iv) core is a 16.7% of total infill walls of the floor.

Fig. 12 shows the effect of rearrange of infill with specified ratios on columns 5 and 6 on the ground floor. Fig. (12-i) illustrates the base shear of column 5 and 6 in different cases of infill wall arrangements. The shear force in columns 5 and 6 in cases inner crosses (50% infill walls) and outer (50% infill walls) is nearly equal to bare case shear force. Fig. 12(ii) shows bending moments of column 5 and 6 in different cases of infill wall arrangements. Bending moment in column 5 in cases inner crosses (50% infill walls), outer (50% infill walls) and all are less than bare case bending moment by nearly 15%, and in column 6 in cases inner crosses (50% infill walls), outer (50% infill walls) all, and core + middle outer are less than bare case bending moment by nearly 20% . So, the percentage of brick wall infill cannot be less than 33% of the total infill brick walls in the whole floor plane.

Fig. 13 displays displacements of each floor with inner crosses brick walls distribution comparison with bare and all cases. The new distribution of walls in each floor gives a flexibility in reduce walls in each floor as architectures demands. The new distribution displacements in each floor are smaller than displacements in bare frame by nearly 0.5 and bigger than all case by nearly 1.75.

Fig. 14(i,ii) display shear force in columns 5, and 6 in each floor with inner crosses brick walls distribution with respect to bare and all cases. The new distribution of brick walls on each floor seems to be smaller than all case except in the first floor in both columns.

Fig. 14(iii,iv) display bending moment in columns 5, and 6 in each floor with inner crosses brick walls distribution with respect to bare and all cases. The new distribution of brick walls on each floor seems to be smaller than all and bare cases for column 5 but, for column 6 bending moment for inner crosses distribution seems to be nearly equal with all case, and also, smaller than bare case.

## 4. Conclusions

Nonlinear time history analysis is carried out 13 models to study the effects of nonstructural infill walls on the seismic response of flat slab frame buildings, which are realized with or without infill walls for shopping use or architectures demands, is presented. The stability and integrity of reinforced concrete frames are enhanced with masonary infill walls. The following conclusions can be drawn as follows:

- Presence of infill brick walls in the structural analysis of flat slab building frames can modify the global seismic behaviour of frame buildings and alters considerably the top displacement to reach 17% of the bare frame which may be unacceptable displacement in soft story frame.
- Irregular distributions of masonary infill wall in elevation (absence infill wall in one floor) result in an increase in the displacement of that floor which reaches to 100% to 150% in upper and lower floors respectively. The stability and integrity of these building frames (bare frames) are enhanced with higher thickness of infill walls which create a diaphragm action. The results showed relatively lower values of top displacements by 20% as the wall thickness varies from 12 cm to 25 cm.
- In case of absence of infill brick wall which is widespread for shop use as architectural demands, it is adequate to build 33% to 50% of all wall floor plane lengths where the external faces are tied to the inner core. This regular distribution in building elevation in all stories causes top displacements amounts 40% of that bare frame.
- The contribution of infill brick walls demonstrates capability and effectiveness in reducing the shearing forces of columns about 50% to 60% of that induced in the bare frames. Moreover absence of infill walls from one floor has pronounced effects on columns shear forces especially in lower stories (ground and first floor). The shearing force extreme values could reach from 3 to 4 times that induced in the bare frame without infill wall in the ground floor (thickness 12 cm). While it reaches 4 to 5 times that of bare frames without infill wall thickness 25cm in the ground floor.
- The use of infill walls as diaphragms has been proven to lead to appreciable reduction in the column base bending moments. Using uniform distribution of infill walls complete in plane and elevation (all model) decreases the base moment by 25% to 50% in external and internal columns respectively compared to the bare frames. The base bending moments in columns are sensitive to absence of infill wall especially the ground and first floor. The absence infill wall in the ground and first floors will increase the base moment about 1.5 to 3 times corresponding values in bare frame in external and internal columns respectively. The absence of infill wall action in the first floor is more severe where the base moments are about 1.5 to 4.5 times the corresponding values in the internal and external bare columns.
- Finally in the light of the above conclusions, it is appropriate to consider the contribution of the infill brick walls in the seismic response of the flat slab building.

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