"ANALYSIS OF INFILL WALL BUILDING BY USING RESPONSE SPECTRUM METHOD USING ETABS"

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Abstract: -

RC moment resisting frame buildings are the most preferred type of construction in developing countries like India; due to its relatively low cost, fast and rapid progressive construction. Other important factors like its aesthetic appearance and good functional behavior under earthquake loading makes it the ultimate choice. In addition to above, brick masonry has good characteristics like thermal and acoustic insulation and fire resistance. RC moment resisting frame buildings consist of moment resisting frame with masonry wall as Infills. These walls are considered as non structural elements in construction practices. In present day practice of building design, buildings are designed as framed structures while effect of infill masonry walls is ignored and considered as non structural elements. Due to the above reason, buildings behave in different manner with infill wall when compared with only moment resisting frames. In past four decades, through lots of analytical and experimental studies importance of brick infill has been recognized however its strength and stiffness contribution has been neglected by considering it as non structural elements.

Seismic analysis is a subset of structural analysis and is the calculation of the response of the building structure to earthquake and is a relevant part of structural design where earthquakes are prevalent. The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behaviour of the overall structure. The analysis may be static or dynamic in approach as per the code provisions.

Keywords-Response spectrum, Static & Dynamic analysis, strenght & Stiffness.

INTRODUCTION

RC moment resisting frame buildings are the most preferred type of construction in developing countries like India; due to its relatively low cost, fast and rapid progressive construction. Other important factors like its aesthetic appearance and good functional behavior under earthquake loading makes it the ultimate choice. In addition to above, brick masonry has good characteristics like thermal and acoustic insulation and fire resistance. RC moment resisting frame buildings consist of moment resisting frame with masonry wall as Infills. These walls are considered as non structural elements in construction practices. In present day practice of building design, buildings are designed as framed structures while effect of infill masonry walls is ignored and considered as non structural elements. Due to the above reason, buildings behave in different manner with infill wall when compared with only moment resisting frames. In past four decades, through lots of analytical and experimental studies importance of brick infill has been recognized however its strength and stiffness contribution has been neglected by considering it as non structural elements.

I.TERMINOLOGY

Earthquake resistance through brick masonry Infill wall

Under strong earthquake shaking RC framed buildings get forces through various members like columns, beams and walls. Whenever columns receive earthquake forces in horizontal direction, they try to move in the same directions but presence of infill resists this movement. Whereas while resisting earthquake forces, these walls develop cracks once their capacity to resist earthquake forces exceeds. (Figure 1.2). Performance of brick masonry infill wall depends on strength of brick. In India strength of brick may vary from north India to south India,

depending on soil available in these areas. In north, brick strength is good whereas in south; brick strength is lesser. Second important factor which contributes is mortar strength and bond between brick and mortar. Crushing of masonry due to strut action can be observed in the masonry part of the building. Shear cracks and diagonal cracks can be observed during strong earthquake. While separation
of infill frame and the masonry wall can also be seen. In case of long buildings where enough strut action cannot happen along diagonal, it into out of plane collapse.

Soft storey effect:
This type of effect occurs for the mid rise buildings where walls are not continued till ground floor for the purpose of parking. During strong earthquake shaking, ground storey experiences more horizontal displacement as it becomes weak due to absence of wall. Plastic hinges formed at column ends at soft story level with crushing of concrete core and buckling of reinforcement and yielding of stirrups (Figure 1.3).

Effect of floating Columns
A notable cause of prominent failure reinforced concrete infill building was due to floating columns (Figure 1.4). In most of the construction practices infill wall from upper floor are discontinued in the lower floors. These types of construction practices are not harmful for vertical loading but give hazardous results in case of lateral loading caused by earthquake. As the wall is discontinued from the upper floors, a clear load path is not available to transfer the lateral load to the foundation due to which overturning forces develop in the columns of the ground floor. Because of this the column begins to deform and buckle results in total collapse of the building The practice of floating columns in the upper storeys is very common in the cities in India

Bearing strength of soil:
Past earthquake shows the amplification of soil during earthquake leading to collapse of buildings; this is due to higher value considered for actual lower bearing strength of soil at the time of foundation designing. Soil amplification caused large forces in the buildings leading to collapse.

Other effects on RC frame
During earthquake failure of the beams and slabs can be observed which may be due to bending. In case of non-uniform arrangement of infill walls, structure becomes unstable during earthquake and settlements of columns have been observed.

Scope of the thesis
Past studies on RC framed brick infill buildings includes many experimental, analytical and numerical studies. Though experimental studies are more realistic, they cost too much if we go for variety of wall sizes, different material and many trials. Infill are widely used as interior partitions and external walls in buildings, but they are usually treated as non-structural elements and in a lot of cases their stiffness is not included in the reinforced concrete design. While performing the evaluation of existing reinforce concrete buildings, to know the actual behaviour of structure, effect of infill need to be incorporated in seismic evaluation. The masonry infill has been modelled as an equivalent diagonal structural element using Main-stone theory.

Results show that infill, if present in all storeys, gives a significant contribution to the energy dissipation capacity. Seismic performance assessments indicate that, the infill frame has the lowest collapse risk and the bare frame is found to be the most vulnerable to earthquake-induced collapse.

4 Modelling of Masonry Infilled Frames

Experimental tests of masonry infilled reinforced concrete (RC) frames provide a unique chance for researchers to investigate the complicated seismic behaviour of this kind of building. However, the high cost of these tests has limited the number of experiments that have been conducted. Macro models, such as strut-type models, represent the overall force-displacement relationship of these types of frames in computationally efficient models. However, the properties of such models can be difficult to validate based on experiments. This difficulty is due to different reasons, especially the uncertainties in the material properties of the different components of the infilled frame used in the experiment, which prevent a direct comparison between the experiment and macro-model in the calibration process. For instance, two prism samples made from the same brick and mortar may not give the same compressive strength of the masonry. This fact may introduce some errors in the process of the calibration of macro models to the experimental results.

These reasons motivated researchers to develop micro-models using finite-element analysis tools to represent complex aspects of masonry infilled frames, including brittle failure mechanisms in the infill at mortar joints and the infill-frame interaction. Micro-models provide a chance to simulate the response of masonry infilled frames with different configurations with a lower cost compared to the experiment with no uncertainty in the material properties in the macro-model calibration process. Moreover, micro-model can potentially represent the multiple failure modes which can occur in the infill or frame. Although micro-models has been shown to accurately simulate the response of infilled frames, the approach is computationally intensive and is not practical to be implemented in the PBEE frame work where a nonlinear model needs to be run for a suite of ground motions scaled to different levels. The computational difficulty of micro-modeling shows the need for a more simplified modeling approach, such as strut-type models, which, if appropriately developed, satisfies the both the needs of accuracy and efficiency.

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Objectives

In-filled frame structures are commonly used in buildings, even in those located in seismically active regions. Present codes unfortunately, do not have adequate guidance for treating the modelling, analysis and design of in-filled frame structures. This thesis addresses the major objectives of the research work are as follows:

- To find out the influence of masonry infill wall panel in Reinforced Concrete framed Structures in terms of deformation.
- To study the behavior of frame with brick masonry infill by modeling masonry infill as a diagonal strut. Etabs is to be used for the development of the model.
- The present study is aimed at findings out the effects of various parameters on frame structures due to horizontal loading. The various parameters are number of story , plan geometry , different types of infill material .
- The main objective of this study is to investigate the contribution of masonry infill walls to lateral strength and lateral stiffness of the buildings. A comparative study was performed on 3-D analysis model created in ETABS, a commercial computer program for the analysis of structures. Masonry infill walls were model as compression struts. Their tensile capacities, which is negligible, are disregarded..
- Results in terms of tip deflection, fundamental period, inter-storey drift ratio and stresses etc are presented and they will be useful in the seismic design of in-filled frame structures.

Scope of the thesis

Past studies on RC framed brick infill buildings includes many experimental, analytical and numerical studies. Though experimental studies are more realistic, they cost too much if we go for variety of wall sizes, different material and many trials. Infill are widely used as interior partitions and external walls in buildings, but they are usually treated as non-structural elements and in a lot of cases their stiffness is not included in the reinforced concrete design. While performing the evaluation of existing reinforce concrete buildings, to know the actual behavior of structure, effect of infill need to be incorporated in seismic evaluation. The masonry infill has been modeled as an equivalent diagonal structural element using Main-stone theory.

Results show that infill, if present in all storeys, gives a significant contribution to the energy dissipation capacity.Seismic performance assessments indicate that, the infill frame has the lowest collapse risk and the bare frame is found to be the most vulnerable to earthquake-induced collapse.

V.LITERATURE REVIEW

Masonry infill MI walls confined by reinforced concrete RC frames on all four sides play a vital role in resisting the lateral seismic loads on buildings. It has been shown experimentally that Masonry infill walls have a very high initial lateral stiffness and low deformability . Thus introduction of Masonry infillI in RC frames changes the lateral-load transfer mechanism of the structure from predominant frame action to predominant truss action Murty and Jain 2000, as shown in Figure below

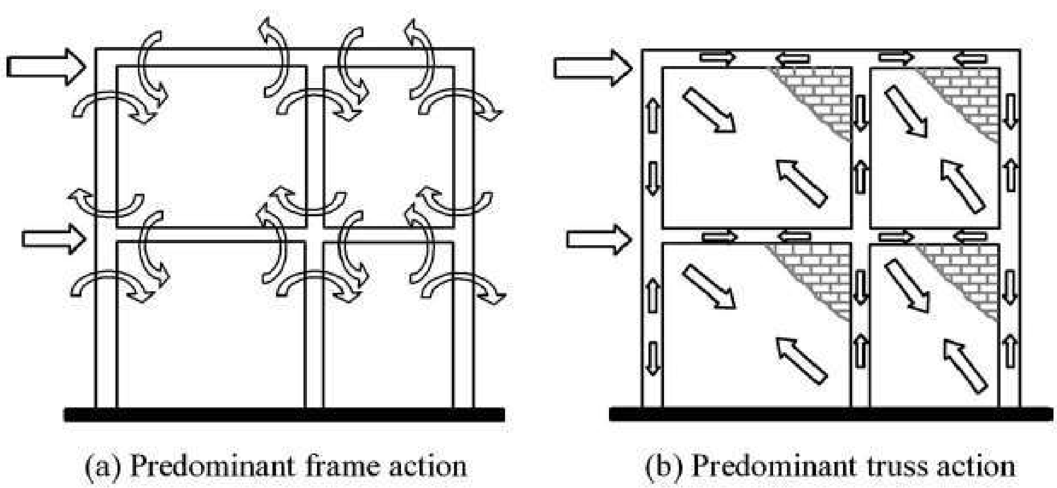


Fig 2.1 Predominant frame action to predominant truss action

responsible for reduction in bending moments and increase in axial forces in the frame members. In addition, construction of MI is cheaper because it uses locally available material and labor skills. Moreover, it has good sound and heat insulation and waterproofing properties, resulting in greater occupant comforts and economy.

T. Mahdi and V. Bahreini,evaluated that the nonlinear seismic behavior of intermediate moment-resisting reinforced concrete (RC) space frames with unsymmetrical plan in three, four and five stories . The plan

configurations of these space frames contain reentrant corners. Analyses of these buildings are made with and without considering the masonry infill (MI).
For infills, author made three types of arrangements and two material types (strong and weak). For lateral seismic loads, two types of lateral loads distributions have been assumed. The results revealed that the existence of infill increases the stiffness and decreases the drifts. However, by omitting infills from the ground floor (the soft story arrangement), the beams and the columns of the ground floor show inferior performance

Y. Sanada, D. Konishi, Maidiawati, Swezinwi[l], described the effects of nonstructural brick infills on the seismic performance of reinforced concrete (R/C) buildings. Experimental and analytical studies were conducted focusing on an Indonesian earthquake-damaged building due to the 2007 Sumatra earthquakes. Structural details of the building are summarized . A brick wall was extracted from the earthquake-damaged building and transported to Japan from Indonesia to experimentally evaluate its seismic performance. Two R/C single-bay frame specimens were constructed, and the imported wall was installed in one of the specimens. Comparing the seismic performance of specimens with and without the brick infill through quasi-static cyclic loading tests, the effects of infill on the overall frame performance were quantitatively evaluated. Moreover, the seismic performance of the earthquake-damaged building was evaluated numerically considering the findings of the tests. In particular, the contributions of nonstructural brick infills to the seismic performance were discussed through the probabilities of collapse computed under several artificial earthquake ground motions.
Lila M. Abdel-Hafez, A.E.Y. Abouelezz , Faseal F. Elzefeary, Experimental tests was carried out to study the behavior of different single story frames infilled with brick masonry under the in-plane lateral load influence. Three phases of frames were tested. The first phase was conducted on individual reinforced concrete bare frame used as control frame. The second phase was conducted on two model frames representing individual reinforced frame infilled with masonry panels constructed between two columns, then constructed the top beam, and the other one constructed as bare frame and then infilled with masonry. The third phase was strengthened with different methods to improve its behavior. Glass fiber reinforced polymer (GFRP) sheets, steel rebar impeded in frame, plastering and ferrocement meshes were used. The drift, toughness, ductility and failure load were improved by using such masonry wall due to like-shear wall effect which also increased frame capacity to resist lateral load. The ferrocement strengthening method was recommended to improve the ductility and ultimate failure loads of the existed frames. Also casting concrete of frame over the masonry ''Balady'' method; increases the ultimate load capacity of frame by 145% of bare frame ultimate failure load. Also it increases its ductility and toughness by 33% and 195%, respectively. The ductility of infilled frame strengthened with ferrocement was the best of all strengthened frames, while strengthening with GFRP increases its ultimate load carrying capacity but reduces its ductility

Mr. V. P. Jamnekar, Dr. P. V. Durge observed that masonry infill have significant effect on dynamic characteristics, stiffness, strength and seismic performance of buildings. IS: 1893-2002 gives highly conservative time period formula for infilled frame buildings. It had observed from the study that the without infill structure showed early formation of plastic hinges and structures failed at an early load stage itself. Whereas the partial infill 3D structure with brick infill showed a delayed formation of plastic hinge and improving the lateral capacity of the structure. The locations of plastic hinges are changed and generally the damage contributions in different storey are also changed, thus the infill walls prevents the damages concentrated in top storey and had a positive effect on damage contributions in all directions. As expected, the presence of infill can guarantee higher overall stiffness and strength, reducing the inter-storey drift demand of the structure

C V R Murty and Sudhir K Jain conclude that buildings Masonry infill wall panels increase strength, stiffness, overall ductility and energy dissipation of the building. More importantly, they help in drastically reducing the deformation and ductility demand on RC frame members explains the excellent performance of many such buildings in moderate earthquakes even when the buildings had not been designed or detailed for earthquake forces. Most multistorey building constructions in the developing countries consist of RC frames with URM infills. Often the RC frame had not even formally designed for seismic loading even in severe seismic zones. This situation not likely to change significantly in the near future. Such buildings are commonly used as residential or office buildings which typically have a fairly large number of infills placed more or less uniformly and have small to moderate panel size. It should be possible to develop suitable detailing schemes for anchoring masonry reinforcement into the frames and thereby improve the out-of-plane behaviour of the infills. In such situations, the infills could be relied upon to ensure good seismic performance.

J. Dorji and D.P. Thambiratnam conclude that opening size of the infill has a significant influence on the fundamental period, inter-storey drift ratios, infill stresses and the structural member forces. Generally they increase as the opening size increases, indicating that the decrease in stiffness had more significant than the decrease in mass.

Vikas P. Jadhao, Prakash S. Pajgade ,found that the Indian standard codal provisions do not provide any guidelines for the analysis and design of RC frames with infill panels. It had been also found that the presence of infill reduces the displacement capacity of structure and modifies the structural force distribution significantly. The base shear experienced by models with AAC blocks had significantly smaller than with conventional clay bricks which results in reduction in member forces which leading to reduction in required amount of Ast to resist member forces. So economy in construction can be achieved by using AAC blocks instead of conventional clay bricks. The performance of AAC block infill was superior to that of Conventional brick infill in RC frame. Therefore, the AAC block material can basically be used to replace conventional bricks as infill material for RC frames built in the earthquake prone region.compared the performance of frame with full infill as conventional clay bricks and AAC blocks was significantly superior to that of bare frame.

Alurwad Rajeshwarreddy R., Dr. Arshad Hashmi , Prof. Kulkarn V, suggest Completely filled frame gives least displacement at top and bottom, Soft Story give largest displacement. The setback frame improves the earthquake resistance of soft storey structure. The Additional setback for frame, without making the structure irregular improve the earthquake resistance of soft storey structure.

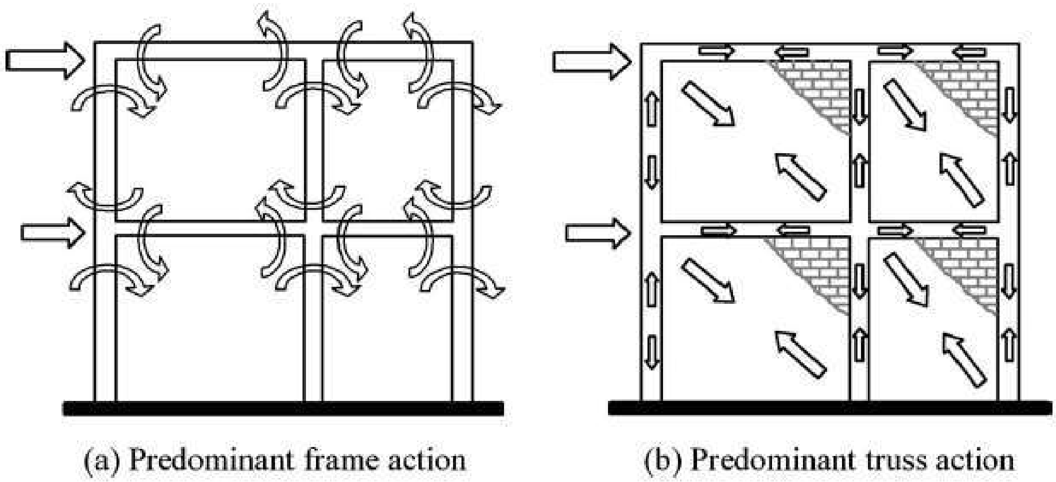
Matjaz DOLSEK And Peter FAJFAR worked on the seismic response of infilled RC frames and its mathematical modelling. Several variants of a four-story and a three-story reinforced concrete (RC) building, tested pseudodynamically at the European Laboratory for Structural Assessment (ELSA) in Ispra, had been

analysed. In addition, a shaking table test performed at ISMES on an asymmetric two-story RC building was simulated numerically. The results proved that the influence of infills is important and that they should be included in mathematical models. It had been shown that the nonlinear seismic response of RC frames with masonry infill can be adequately simulated by a combination of conventional nonlinear elements, i.e. beam elements with concentrated plasticity for beams and columns, and equivalent strut elements for infill panels.
G. Amato, L. Cavaleri, M. Fossetti, M. Papi[l], discussed mechanical behaviour of single store – single bay infilled meshes has been and an analytical procedure available in the literature for the identification of a pin-jointed strut equivalent to the infill had been generalized to take the influence of vertical loads into account. A numerical experimentation based on a FEM discretization of the frame-infill system, the lateral stiffness of some infilled frames is evaluated; then the ideal cross-section of the strut equivalent to the infill is obtained for different levels of vertical loads by imposing the equivalence between the frame containing the infill and the frame containing the diagonal strut. Many models use equivalent strut elements in order to represent the infill but among the several parameters influencing the interaction between frame and infill the level of vertical loads is hardly considered. Nevertheless, neglecting this effect may produce inaccuracy because the axial deformations of the loaded columns can produce non-negligible variation in the contact region between infill and surrounding frame, influencing the seismic response of the infilled frame.

M. Mohammadi Ghazimahalleh Effects of in-plane damages on the panels' out of plane strengths are studied by authors. For the purpose, some infill panels with different numbers of cracks are modeled by finite elements.It had been shown that FEMA formula can accurately predict the out of plane strength of an infill panels, having good connectivity to the surrounding frames. Nevertheless, for infills with a gap between frame and infill, which are practically created in normal earthquakes, infill out of plane strength will be ignorable. In this condition, required strength should be supplied by other elements or devices, such as reinforcements. Based on experimental results of study, during in plane loading, interface cracking will be observed in low drifts. For bigger ones, the corners of compression diagonal remain only in contact with the frame; however when the frame returns back to the normal position (zero drift), the gap can be seen all around the infill adjacent to the frame. In this case, infill has minimum out-of-plane strength, which has not been considered yet. Therefore, the out of plane strength of infill panels should be practically less than that proposed by FEMA. Tests on concrete specimens showed that infill may lean outward just for in-plane loading, even in the absence of out of plane acceleration.

VII. METHODOLOGY

Masonry infill MI walls confined by reinforced concrete RC frames on all four sides play a vital role in resisting the lateral seismic loads on buildings. It has been shown experimentally that Masonry infill walls have a very high initial lateral stiffness and low deformability . Thus introduction of Masonry infillI in RC frames changes the lateral-load transfer mechanism of the structure from predominant frame action to predominant truss action Murty and Jain 2000, as shown in Figure below



Predominant frame action to predominant truss action

responsible for reduction in bending moments and increase in axial forces in the frame members. In addition, construction of MI is cheaper because it uses locally available material and labor skills. Moreover, it has good sound and heat insulation and waterproofing properties, resulting in greater occupant comforts and economy.

T. Mahdi and V. Bahreini,[1] evaluated that the nonlinear seismic behavior of intermediate moment-resisting reinforced concrete (RC) space frames with unsymmetrical plan in three, four and five stories . The plan configurations of these space frames contain reentrant corners. Analyses of these buildings are made with and without considering the masonry infill (MI).

For infills, author made three types of arrangements and two material types (strong and weak). For lateral seismic loads, two types of lateral loads distributions have been assumed. The results revealed that the existence of infill increases the stiffness and decreases the drifts. However, by omitting infills from the ground floor (the soft story arrangement), the beams and the columns of the ground floor show inferior performance

Different Modeling Schemes for the Masonry Wall/Infill

Masonry is a highly orthotropic material due to the existence of the mortar joint. In addition, the masonry or infill wall can experience different failure mechanisms, such as cracking, sliding, and compression failure. To simulate the behavior of the masonry wall, different types of models can be developed, depending on the level of accuracy needed, as follows:

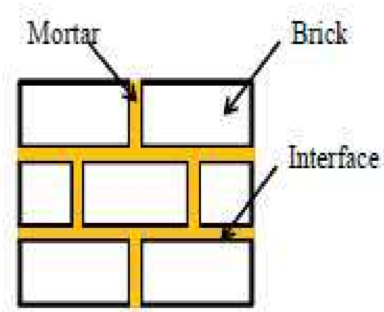
Micro-modeling:

This study uses micro-models of masonry infilled RC frames to calibrate the seismic behavior of macro-models. Finite-element analysis of "micro-models" requires modeling of the frame elements (either steel or reinforced concrete), the masonry bricks, as well as interface between the bricks and at the joint between the wall and the frame. The highly nonlinear behavior of the masonry or infill wall due to the existence of very brittle material, including the bricks and mortar, makes the modeling of this part of the structure very challenging. The micro-modeling approach is validated through comparison with results from experimental tests.

Micro-modeling is a modeling technique which considers the effect of mortar joints as a discrete element in the model. Considering the fact that mortar joint is the weakest plane in a masonry wall, micro-modeling can be considered to be the most exact modeling approach for the masonry wall.

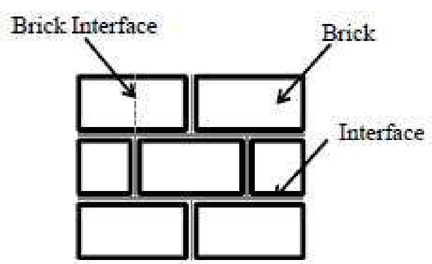
Micro-modeling can be conducted in two levels.

Detailed micro-modeling: In this approach, the brick and mortar joints are modeled as continuum elements and interface between the brick and mortar is modeled by an interface element, as shown in Figure.



Both the continuum elements and interface elements may be defined by nonlinear stress-strain relations. Separate constitutive models are used to define 1) the bricks, 2) the mortar joint and 3) the interface between the mortar and bricks.

Simplified micro-modeling or meso-modeling: In this approach, bricks are modeled by continuum elements, but the mortar joint and its interface with bricks is modeled together in an interface element, as shown in Figure



There is another improvement possible for modeling the brick in either the micro-modeling or simplified micro-modeling approaches. Experimental results showed that the diagonal cracking of the infill panel usually goes through the bed joints and head joints. However, cracking sometimes occurs vertically through the middle of the bricks. This could be due to the dilatation effect of the mortar joints. To capture this mechanism, a vertical interface can be added at the middle of each brick.

Macro-modeling

Macro-modeling can be considered in two levels, as following:

Homogenized model: In this approach, the effect of the brick, mortar, and brick-mortar interface is modeled as one continuum element.

Strut model: In this approach the infill is modeled by one or more struts in each direction. Strut models have been discussed previously

Reinforced concrete (RC) framed buildings with infill walls are usually analysed and designed as bare frames, without considering the strength and stiffness contributions of the infills. However, during earthquakes, these infill walls contribute to the response of the structure and the behaviour of infilled framed buildings is different from that predicted for bare frame structures. Therefore, based on the understanding of the actual response, design provisions need to be developed. Fortunately, a few countries already have codal provisions

for seismic design of RC framed buildings with brick masonry infills. The present study evaluates these available provisions with a view to identify design methodologies that exploit the benefits of infills in a rational manner, for improving the contribution of these infills and for reducing the detrimental effects.

In the equations given in table below,

H = height of the frame,

θ = angle made by the strut with the horizontal,

Ec = Young's modulus of column

Ic = Moment of inertia of column

Em, t and hm are the Young's modulus, thickness and height of masonry infill respectively.

In Hendry's equation, αh and αL are the contact length between wall and column and beam respectively at the time of initial failure of wall.

Equations for strut width value for full infill by various researchers.

Researchers	Strut width (w)	Remark
Holmes	$0.333d_m$	d_m is the length of diagonal
Mainstone	$0.175D(\lambda_1 H)^{-0.4}$	$\lambda_1 H = H[E_m t \sin 2\theta / 4E_c I_c h_m]^{0.25}$
Liauw and Kwan	$0.95h_m \cos\theta/\sqrt{(\lambda h_m)}$	$\lambda = [E_m t \sin 2\theta / 4E_c I_c h_m]^{0.25}$
Paulay and Priestely	$0.25d_m$	d_m is the length of diagonal
Hendry	$0.5[\alpha_h + \alpha_L]^{0.5}$	$\alpha_h = \pi/2[E_c I_c h_m / 2 E_m t \sin 2\theta]^{0.25}$ and $\alpha_L = \pi[E_c I_b L / 2 E_m t \sin 2\theta]^{0.25}$

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