IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X,
PP 66-72
www.iosrjournals.org

Effect of Locked Brick Infill Walls on the Seismic Performance of Multistoried Building

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Abstract *The main objective of the study was to investigate the importance of locked brick infills in multistoried buildings thereby adopting horizontal sliding joints in Reinforced concrete frames. Non linear static analysis is performed on multistoried frames with solid and locked brick infills. The effect of locked brick infill walls on the seismic performance of the multistoried buildings are studied in details as the height of the buildings are increased. From the numerical studies, equivalent diagonal strut method can be adopted for modelling the infill wall panels. When locked bricks are used as infills in buildings, the total displacement gets much reduced when compared to solid brick infills. This property can be used in case of buildings subjected to larger displacements, especially in case of soft storied building with solid brick infill walls where this effect is maximum. In the present study the material properties of locked brick units were determined by conducting standard experiments suggested by IS codes. Numerical non linear static analysis of medium to high rise 2D building with locked brick infill walls and solid brick infill walls were performed to compare the effectiveness of using locked brick infills instead of solid brick infills. The maximum deflection, storey drift etc were determined for both the cases.. From the studies, It was concluded that with the increase in number of stories, there are additional lateral loads added for increased story level. Hence, the maximum top deflection of the frame increases gradually. The maximum deflection of frames with solid brick infill wall and locked brick infill wall are compared and it was found that, the maximum deflection of each storeys reduced by about 30 - 60 % when number of stories is increased from 5 to 10.*

Keywords *- Displacement, Equivalent diagonal strut method, Locked brick infills, Storey drift*

I. Introduction

The most common structural system in our country for both residential and commercial buildings is multi-storey RC frames with masonry infills. A great deal of research work has been done on the masonry infilled reinforced concrete frames in the past several decades. Mortar bind is generally used for normal brick construction in order to create a continuous structural form and also to bind together the individual units in brickwork. In normal brick construction works, mortar and bricks provides the high strength in the brickwork system. But, conventional brickwork system with the provision of mortar requires great cost and incures large time of construction. The higher demand of construction gives reason to find ways to fulfil and to solve the various problems related to the construction. Interlocking bricks is an alternative system which uses less or minimum mortar to bind the bricks together. Most of the countries started using locked brick infills especially in seismic regions. Interlocking brick system in building works is a fast and cost effective construction system and provides good solution in construction. Hence there is a need to hasten the effort to determine the effectiveness of using interlocking brick in construction system. Locked brick unit have shear keys in perpendicular direction which increases the out of plane stability of the infill, also it does not use mortars in between the brick layers which forms horizontal sliding joints at every brick layer, thus limiting the panel action of the panel.

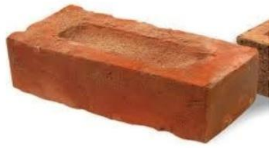

Fig 1: Locked brick

1.1 Equivalent Diagonal Strut Method

From previously conducted several studies, it showed that Equivalent diagonal strut method can be adopted for modeling the brick infill wall to easily represent the inplane action due to lateral load. Hence, the Infill wall panels can be analytically replaced by equivalent diagonal struts. The end points of the equivalent strut connected to the frame is generally pin jointed to avoid the moment from frame to infill. In this method the infill wall is idealized as diagonal strut and the frame is modelled as beam.The width of the diagonal strut is given as

$$w = 0.175\,(\lambda' h)^{-0.4} d'$$

Where, Contact length parameter $(\lambda') = \sqrt[4]{\frac{Ef\ t\sin(2\theta)}{4Ei\ Ic\ h}}$

II. Experimental Investigations

In order to understand the mechanical behaviour of a given structure, it is essential to conduct experimental tests on it. Therefore physical properties such as density, dimension etc. and mechanical property, compression of the brick units are determined. Fig.2 shows the test set-up for compression test for the brick.

Fig.2. Test set-up for compression test

2.1 Determination of the material properties of the Locked brick

The properties of bricks were obtained by experimental testing according to standard.
Dimensions of interlocking brick
Length = 270 mm
Breadth = 105.6 mm
Depth = 102.5 mm
Maximum reading in compression testing machine = 1000 kN
Maximum load taken by the brick = 250 kN

Maximum compressive strength of the interlocking brick = $\frac{250}{270\ x\ 105.6}$

Weight of the brick = 8.5 kg
Density (mass per volume), $\delta = \frac{8.5}{.27\ x\ .1056\ x\ .1025}$
= 2908.5 kg/m^3
Weight per volume, W = 29.09 kN/m^3

III. Finite Element Analysis

To study the performance of masonry infilled RC frames with Locked Brick, a study was conducted to investigate the behaviour of Locked brick infill RC frames under lateral loading by using finite element software ANSYS 14.5.

3.1 Material properties of the model

3.1.1Material properties of Concrete

Type of material – Isotropic
Weight per volume, Density = 25 kN/m^3
Compressive strength = 25 N/m^2
Modulus of Elasticity = 22000 N/mm^2
Poissons ratio = 0.15

3.1.2 Material properties of Solid Brick infill

Type of material – Isotropic
Weight per volume, Density = 20 kN/m^3
Compressive strength = 12 N/mm^2
Modulus of Elasticity = 8280 N/mm^2
Poissons ratio = 0.16

3.1.3 Material properties of Interlocked Brick infill
Type of material – Isotropic
Weight per volume, Density = 29.09 kN/m^3
Compressive strength = 8.76 N/mm^2
Modulus of Elasticity = 6045 N/mm^2
Poissons ratio = 0.16

3.2 Choosing Element type
In order to analyse the model, it is required to specify an adequate element type for mesh generation in ANSYS 14.5. Here the element used is BEAM 188 for modelling the beams and columns and LINK 180 for modelling the diagonal struts.

3.3 Modelling and meshing of models
The RC frames are fully modelled in software using key points at every corners. The key points are then connected together by means of straight lines. Following datas are used in the analysis of the RC framed building models.
Size of beam : 300 x 300 mm
Size of Column : 300 x 300 mm
Spacing between frames : 3500 mm
Height of the storey : 3.5 m

3.4 Applying boundary and loading conditions
The frames are fixed at the bottom. All the degrees of freedom of the displacement are restrained against movement .
Loading is done as per IS 1893 (Part I): 2002.
Z, Zone factor = 0.16
I, Importance factor = 1
Seismic zone : III
Type of frame : Ordinary RC moment resisting frame
R, Response reduction factor = 3
Design lateral force at floor i may be calculated by
(Clause 7.7.1)

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Where,
Q_i = Design lateral force at ith floor
W_i = Seismic weight of floor i
h_i = Height of floor i measured from base

3.4 Analysis of the models
For the analysis static non linear analysis is performed on the models. The effect of infills on the maximum displacement of the frames with medium to high rise buildings is considered for the analysis.Therefore deflections for Earthquake loads have been studied according to equivalent strut method for different cases and comparisons are made. The 6 cases adopted for the modelling are 3 bay 2D frames with solid and locked brick infill walls from five to ten stories.
The following parameters are discussed

3.5 Lateral displacements
It is displacement caused by the Lateral Force on the each storey level of structure. Lateral displacement will be more on top stories.

3.6 Storey drift

It is the displacement of one level relative of the other level above or below. As per IS 1893 (Part 1):2002, the storey drift in any storey shall not exceed 0.004 times storey height. The inter storey drift is defined as

$$\frac{\delta i - \alpha i}{hi}$$

Where, $(\delta i - \alpha i)$) is the relative displacement between successive storey and hi is the storey height

IV. Results And Observations

4.1 Comparison of Maximum deflection in a 3 bay 10 storied building with solid and locked brick infills

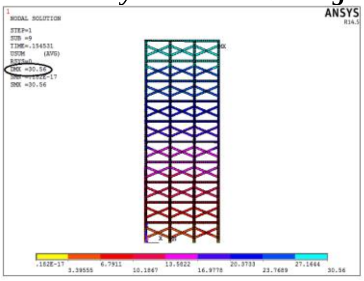

Fig.3. Ten storied building with solid brick infill walls

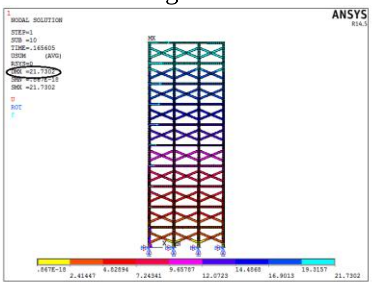

Fig.4. Ten storied building with locked brick infill walls

Table.1. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills (mm)	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
10	30.56	21.73	29
9	28.32	18.93	33.15
8	26.19	16.59	36.65
7	24.2	14.01	42.10
6	19.96	12.65	36.62
5	14.32	10.98	27.33
4	11.91	9.23	22.51
3	9.11	7.32	19.64
2	7.32	4.96	33.06
1	5.92	2.41	59.29

Table.2 Storey drift in a 10 storied frame

Storey No.	Solid brick infill walls	Locked brick infill walls
10	6.4×10^{-4}	8×10^{-4}
9	6.08×10^{-4}	6.68×10^{-4}
8	5.68×10^{-4}	7.37×10^{-4}
7	1.21×10^{-3}	3.88×10^{-4}
6	1.61×10^{-3}	4.77×10^{-4}
5	6.88×10^{-4}	5×10^{-4}
4	8×10^{-4}	5.45×10^{-4}
3	5.11×10^{-4}	6.74×10^{-4}
2	4×10^{-4}	7.28×10^{-4}
1	1.69×10^{-3}	6.88×10^{-4}

4.2 Comparison of Maximum deflection in a 3 bay 9 storied building with solid and locked brick infills

Table.3. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills (mm)	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
9	27.96	19.05	31.86
8	24.23	17.11	33.15
7	21.11	15.19	28.04
6	19.61	13.20	26.21
5	15.23	11.41	25.08
4	13.63	9.23	32.28
3	11.32	7.19	36.48
2	8.49	5.23	38.39
1	6.2	2.41	61.19

4.3 Comparison of Maximum deflection in a 3 bay 8 storied building with solid and locked brick infills

Table.4. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills (mm)	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
8	23.48	15.21	35.22
7	20.11	13.73	31.72
6	17.32	11.98	35.56
5	14.91	10.1	32.26
4	11.43	8.91	22.04
3	9.19	6.92	24.7
2	7.63	4.01	47.44
1	5.32	2.13	59.96

4.4 Comparison of Maximum deflection in a 3 bay 7 storied building with solid and locked brick infills

Table.5. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills (mm)	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
7	21.27	14.24	33.05
6	18.11	11.81	34.78
5	15	9.53	36.46
4	11.32	7.83	27.38
3	8.01	4.91	38.7
2	5.91	2.46	58.37
1	2.3	1.43	37.82

4.5. Comparison of Maximum deflection in a 3 bay 6 storied building with solid and locked brick infills

Table.6. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
6	17.27	9.76	43.48
5	13.14	7.32	44.29
4	10.32	5.61	45.63
3	7.34	4.92	32.97
2	5.91	3.14	46.86
1	3.1	1.08	65.16

4.6 Comparison of Maximum deflection in a 3 bay 5 storied building with solid and locked brick infills

Table.7. Comparison of maximum deflection in each storey

Storey No.	Maximum deflection in building with solid brick infills (mm)	Maximum deflection in building with locked brick infills (mm)	% decrease in deflection of LBIW with reference to SBIW
5	13.6	4.79	64.77
4	10.01	3.13	68.73
3	8.44	2.65	75.11
2	6.46	1.41	78.17
1	3.04	0.32	89.47

Table.8. Storey drift in 5 storied frame

Storey No.	Solid brick infill walls	Locked brick infill walls
5	1.02×10^{-3}	4.74×10^{-4}
4	4.48×10^{-4}	1.37×10^{-4}
3	5.65×10^{-4}	3.5×10^{-4}
2	9.77×10^{-4}	3.11×10^{-4}
1	8.68×10^{-4}	$9.14 \quad 10^{-5}$

V. Conclusion

The seismic analysis of multi-storeyed building frames with infill walls (solid and locked brick infills) is conducted. 3D analysis will give more realistic values of deflection and stresses. Since this type of study is not feasible in terms of analysis time taken, we have adopted 2D model for the present study. A three bay two dimensional building frame is considered with the number of stories varying from 5 storied to 10 storied. The loading applied is as per IS 1893 (Part I): 2002. Equivalent diagonal strut method is adopted for modelling Locked Brick infill walls. The following conclusions are made based on the analysis done in ANSYS 14.5

- The presence of locked brick infill walls reduces deflection to a large extend compared to solid brick infill walls due to its shear sliding mechanism

Table.9. Percentage decrease in deflection

No. of Stories	% decrease in deflection of top stories in LBIW with reference to SBIW
10	29
9	31.86
8	35.22
7	39.05
6	43.48
5	64.77

- Effect of number of Storey

1. As the Storey number increases, there are additional lateral loads added up for increased story level. Hence, the maximum top deflection of the frame increases gradually.
2. The maximum deflection of frames with solid brick infill wall and locked brick infill wall are compared and it was found that, the maximum deflection of each storeys reduced by about 30 - 60 % when number of stories is increased from 5 to 10.
3. The storey drift is found to be within permissible limit .

VI. Scope Of Future Works

The present study may be regarded as a preliminary work for an extensive research work on the effect of various parameters on infilled frames due to lateral loading.

The analysis may be performed by considering

1. Effect of number of bays
2. Effect of various spans of bay
3. Effect of various geometrical properties of beams, columns and infills etc.

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