International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 7; Issue 6(H); June 2018; Page No. 13576-13581
DOI: http://dx.doi.org/10.24327/ijcar.2018.13581.2433

Research Article

REACTION OF INFILL WALLS AND ITS IMPACTS ON RCC FRAMED STRUCTURES

Thamizarasan S*

Department of Civil and Structural Engineering, Prist University Puducherry-605007

ARTICLE INFO

Article History:

Received 9th March, 2018
Received in revised form 16th April, 2018 Accepted 26th May, 2018
Published online 28th June, 2018

Key words:

Infill wall, Lateral forces, Infill failure, Failure pattern, Bare frame, Pneumatic Interface, Stiffness and Ductility factor, Cracking load, Theoretical and Experimental Investigation

ABSTRACT

In tall buildings, occurrence of vertical loads do not cause much problem in the analysis and design, but the horizontal forces due to wind, earthquake or blast loads are the matter of great concern and need very careful consideration. The reinforced concrete moment resisting frame with in-filled walls is a common structural system widely used for multi-storey building construction. Such composite structures formed through the combination of a moment resisting plane frame and infill wall is termed as 'In-filled frames'. The rationale behind neglecting infill walls in the design process is partly attributed to incomplete knowledge of the behavior of quasi-brittle materials such as unreinforced masonry (URM), of the composite behavior of the frame and the infill, as well as due to the lack of conclusive experimental and analytical results to substantiate a reliable design procedure for these type of structures, despite the extensive experimental efforts and analytical investigation over the past decades. Infill has been found to be sometimes beneficial and other times detrimental to the seismic performance of frames. This type of failure is basically due to stiffening effect of infill panels that changes the basic behavior of buildings during earthquakes and creates a new failure mechanism. To avoid this type of failure, either interaction of infill wall with frame should be considered in the design or a movable joint (Adaptive interface) between infill and frame should be provided. In this Journal, the Structural behaviour of diagonally loaded masonry in filled RC frames with different infill and interface properties under static reversed cyclic loading was investigated. Based on the test outcomes, the following conclusions can be drawn. All the specimen failed in a ductile manner due to the occurrence of plastic hinges at the ends of beams and columns. The addition of infill walls increases the stiffness of the bare frame. The initial stiffness of all in filled frame is about 10 times greater than that of the bare frame. The addition of infill walls increases the strength of the bare frame also. The initial cracking load of all in filled frames is about 5 times greater than that of bare frame. The ultimate load of all in filled frame is about 2 times greater than that of bare frame. In filled frame structures will be the better option to prefer in the seismic region, as in the case of bare frame, ultimate load is very less than the other in-filled frames, which may cause the early collapse of the frames during the strong earth quake shaking.

INTRODUCTION

In RC framed buildings, infill walls are usually provided for functional and architectural reasons. They are normally considered as non-structural components and hence the effect of infill walls on structural behavior is always ignored in seismic design of RC structures.

Behavior of in-filled frames

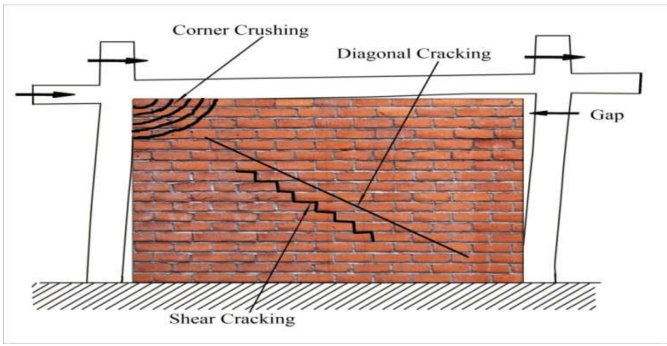
It has been observed from the past Earthquakes that the infill contribute in the enhancement of overall lateral stiffness of the structure. Frames with in-filled panels provide an efficient method for bracing the buildings.

Corresponding author:* **Thamizarasan S
Department of Civil and Structural Engineering, Prist University Puducherry-605007

The presence of infill can also have a significant effect on the energy dissipation capacity. When an in-filled frame is subjected to lateral loading, the infill behaves effectively as a strut along its compression diagonal to brace the frame as shown in below Figure. The structural load transfer mechanism is changed from frame action to predominant truss action. The frame columns now experience increased axial forces but with reduced bending moments and shear forces.

Modes of infill failure

Three potential modes of failure of the wall arise as a result of its interaction with the frame, and these are illustrated below. The first is a shear failure stepping down through the joints of the masonry, and precipitated by the horizontal shear stresses in the bed joints. The second is a diagonal cracking of the wall through the masonry along a line, or lines, parallel to the leading diagonal, and caused by tensile stresses perpendicular to the leading diagonal. The diagonal cracking is initiated at and spreads from the middle of the infill, where the tensile stresses are maximum., tending to stop near the compression corners, where the tension is suppressed. In the third mode of failure, a corner of the infill at one of the ends of the diagonal strut may be crushed against the frame due to high compressive stress at the corner.



Modes of infill failure

In the case of frame members, the windward column is in tension and the leeward column is in compression. The frame members are also subjected to transverse shear and a small amount of bending. Consequently, the frame members or their connections are liable to fail by axial force or shear, and especially by tension at the base of the windward column.

Infilling Materials

Infill walls have traditionally been made of heavy rigid materials, such as burnt clay bricks (or) concrete blocks. However, more light weight and flexible options such as AAC blocks are now available to be used as infill material. AAC block masonry, already extensively used in building construction abroad, is likely to make very considerable headway in India too because of many advantages, such as durability, strength and structural stability, fire resistance, insulation and sound absorption it possesses.

Aim and Intention

To investigate the behavior of Autoclaved Aerated Concrete (AAC) Block In-filled RC Square frame with Pneumatic interface condition under static reversed cyclic loading, by experimental and theoretical approach**.**

The scope of this thesis includes the following:

- The study of load Vs deflection characteristics of a single bay single storey RC Square bare frame of M20 grade concrete under static reversed cyclic loading.
- The development of loading and instrumentation set up for static reversed cyclic loading of square in-filled at laboratory.
- The study of two numbers of similar RC square frames in-filled with AAC blocks under reversed cyclic loading. Out of which, one in-filled frame is provided with pneumatic interface and the other frame is provided with conventional cement mortar interface.
- The study of behavior of two numbers of similar RC square frames in-filled with clay bricks under reversed cyclic loading. Out of which, one in-filled frame is provided with pneumatic interface and the other frame is provided with conventional cement mortar interface
- Comparing the load Vs deflection behavior of above mentioned frames.

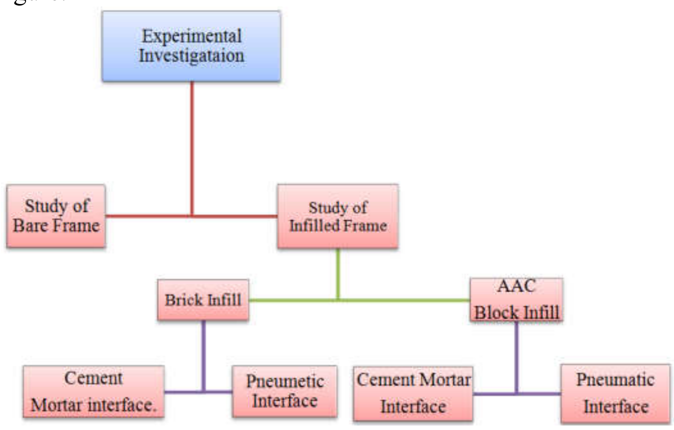
Experimental investigation:

It is planned to carry out experimental and theoretical investigations with single-bay, single-storey, quarter scale square in-filled frame models. In this chapter, the details of the investigations on square frame models are presented.

Test Program for Experimental Study

The experimental investigation consists of testing of five numbers of square frame models under reversed cyclic loading applied along the diagonal of the RC frame. For the infilling purpose brick masonry as well as AAC block masonry is used. Conventional cement mortar and pneumatic medium are used as frame-infill interface. The tests are carried out in order to get some important characteristics such as hysteretic behavior, stiffness, first cracking load and ultimate load.

To study the effect of the infill as well as the interface materials on the frame it is necessary to carry out bare frame testing also so that the results can be compared. For that, apart from testing of four in-filled frames one bare frame is also tested. Out of the four in-filled frames two frames are in-filled with AAC block masonry infill and other two frames are in-filled with brick masonry infill. Each of the AAC in-filled and brick in-filled RC frames are provided with pneumatic interface. In order to similitude the seismic action, reversed cyclic loading is applied. The application of time varying load applied in a repetitive fashion (Alternate application of compression and tensile load in a repetitive fashion) is termed as cyclic load. The other two frames are provided with conventional cement mortar interface condition. The scheme of work for experimental study is explained in the flow chart and also in the Tabulated Column. The experimental study consists of testing of five RC frames and the details of which is shown in Tabulated column and explained in the following figure.



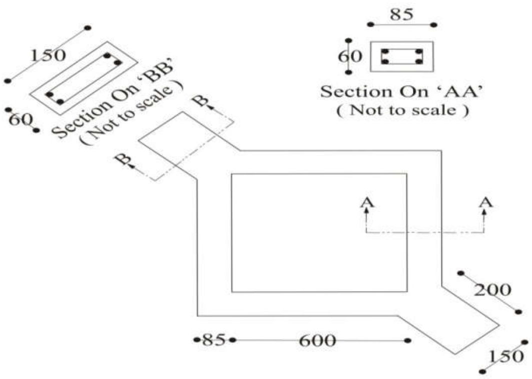
Sl. No	Frame No	Frame Designation	Definition
1	F1	BF	Bare Frame
2	F2	IFBC	In-filled Frame with Brick infill and cement mortar interface
3	F3	IFBP	In-filled frame with Brick infill and Pneumatic interface
4	F4	IFAAC	In-filled frame with AAC block infill and Cement mortar interface
5	F5	IFAAP	In-filled frame with AAC block infill and Pneumatic interface

Making of the specimen

Specimen details such as dimensions, properties of materials used, preparation and curing of frames, test set up for experimental investigation and also the theoretical investigation details are discussed here.

Dimensional details of the specimen

The frames used are square in shape and the dimensional details are shown below. The frames used are strong frames. Main reinforcement for the frame consisted of 4 nos of 6mm dia RTS bars and the shear reinforcement also consisted of 6mm RTS bars at a spacing of 40mm c/c.



Dimensional details of the square frame

Properties of materials used

The properties of materials are determined and compared with relevant IS codes. The details of the properties of materials used are assumed as per specifications.

Preparation and curing of frames

The mould is kept in a clean, flat and non-absorbent surface and the inner sides are oiled well. Suitable precautions are taken to prevent the cement slurry coming out of the mould. The reinforcement cage is placed inside the mould and cover blocks are used for the proper alignment of cage in the mould. The exact quantities of materials required for preparing the specimen are weighed and kept ready for use. Mixing of cement, sand and coarse aggregate is done in dry state and the required quantity of water is added to the dry mixture later. The mix is mixed thoroughly by hand mixing so as to get a uniform mix. Immediately after mixing the concrete is filled in three layers in the mould and compacted well manually using tamping rods. The control specimens are also casted along with the frames. The frames and the control specimens are kept in the mould for one day and after one day the moulds are removed. Wet gunny bags are used for curing the frames and the curing process is as per usual practice. After seven days of casting the frames are taken for infilling.

Process of infilling

First, the bricks and AAC blocks are cut to a size of 100mm x 75mm x 50mm. In the process of masonry infilling of frames with cement mortar interface, a layer of cement mortar of thickness 5mm is laid and the bricks are laid horizontally over the mortar layer. A cement mortar layer of about 5mm is provided in the frame infill interface. After infilling, curing is continued till the testing of frames.

Process of introducing pneumatic interface

In the case of pneumatic interface, a rubber tube of size 600mmx600mm is inserted in the frame infill interface and the nozzle of the tube is kept in such a way that it is projected outward on the top of the frame so that air pressure can applied in to the tube through this nozzle. The rubber tube is glued with the inner surface of the RC frame.

Preparation of frames for testing

The details of preparation of frames for testing. loading arrangements and instrumentations such as fixing of linear potentiometers, making connection between the load cell and the head projection of frames, etc are discussed here. One day prior to the starting of testing process, the specimen is wiped off its surface so as to remove the surface moisture and the grit over it. Then the specimen is white washed and kept for drying. After the whitewash has dried, the surface of the frame and infill are marked with lines to study the crack patterns. All the four corners of the specimens, where the deflection measurements are to be taken by using potentiometer are cleaned well and adhesive is applied over the frame surface on to which L shaped light gauge steel plates are fixed to measure the deflection.

Loading and instrumentation

In all the frame tests, loads are applied through a 100 kN capacity hand operated hydraulic pump and a push-pull jack fixed to the vertical loading frame of 400 kN capacity. A calibrated electronic universal load cell of 100 kN capacity with digital indicator is used to record the loads through which the load is transmitted from the top head projection to bottom head projection along the diagonal of the frame. The least count of load cell is 0.01 kN. The load frame, loading jack (push-pull jack) and the load cell is arranged in such a way that the reversed cyclic loading is applied diagonally. In the instrumentation part, four potentiometers with a least count of 0.01mm are used for taking both horizontal and vertical displacements. Two along the vertical diagonal for vertical displacement measurement and the other two along the horizontal diagonal to measure the horizontal displacement. The horizontal displacement measurements are monitored to control the accidental eccentricity of loading arising due to practical factors like slight changes in the cross sectional dimensions, improper tightening of some of the bolts and nuts, etc. gauges.

The connection between the head of RC frame and the load cell was achieved through 4 nos of 16 mm dia bolts provided both at the top and bottom head projections of RC frame. In order to facilitate the bolted connection at the time of testing, 4 nos of 16 mm dia holes were provided in all the RC frames, both at the top and bottom head projection. In case of testing of pneumatic interface, Digiqual automatic pressure control system is used to maintain a constant air pressure of 4psi (0.27 BAR) inside the pneumatic interface during testing. Scooter tyre tube is used as a storage source of air, during the testing.

Testing procedure

All the frames are tested only after 28 days of infilling. The frame is erected vertical (true to plumb) on the loading frame and adjusted in such a way that the loading is through the diagonal. The potentiometers are fixed in position where the displacements need to be measured and connection between the frame and load cell. The frame is then ready for testing. For all the tests, the technique of reversed (full) cyclic loading till failure is adopted. To start with, the frame was loaded with small loads and then unloaded to check the effectiveness of the instrument setup and loading. This process was repeated till the readings were consistent. For bare RC frame, the loads are gradually increased at 1kN interval and for in-filled frames the loads are gradually increased at 2 kN interval and the deflections at various points for each increment of loading are recorded. As the load is gradually incremented careful observations are made to locate the cracks.

The behavior of the tested specimens has been verified by theoretical investigation using plastic analysis for bare frame and Stafford Smith method for in-filled frames. The details of theoretical investigation has been carried out.

Outputs and Analyses

The scheme of experimental work is objectively aimed at quantifying the difference in the behavior of square in-filled RC frames with different infill and interface materials. The influence of different infill and interface materials are evaluated by different ways of comparison. For example, by comparing the cracking load, ultimate load, the stiffness degradation and the ductility factor of all the five specimens. The summary of both experimental and theoretical test results is presented in this chapter.

Experimental Outputs

In this section, the results of the experimental investigation like the damage behavior, first cracking load, ultimate load, hysteretic behavior, stiffness and ductility factor, etc for all the five specimens are presented.

Failure pattern

All the specimens failed due to the occurrence of plastic hinge forming at the ends of the beams and columns. Severe damage also occurred in the in-filled wall at the ultimate load. Bare frame specimen exhibited fairly ductile behavior. In the case of bare frame, Cracks firstly initiated at the corner of beam-column junction. With the increasing of the loading amplitude, cracks initiated at the top and bottom corner of the frame. In the case of in-filled frames, cracks along the frame-infill interface are observed first in the early loading stage. With the increasing of loading amplitude, other modes of failure of infill walls such as corner crushing, diagonal crack development, etc are initiated.

First cracking load

During the experimental investigation, cracks at different loads and crack patterns are carefully tracked. The first cracking load for all the five specimens are observed and tabulated hereunder:

First cracking load of frame specimens

Sl.No	Frame No	Frame Designation	First Cracking load (kN)	Nature of load (Compression / Tension)
1	F1	BF	2.98	Tension
2	F2	IFAAC	15.79	Tension
3	F3	IFBC	20.69	Tension
4	F4	IFBP	20.00	Tension
5	F5	IFAAP	22.00	Tension

Ultimate load: The ultimate load of frame specimens are observed during the experimental investigation and are presented here:

Ultimate load of frame specimens

Sl.No	Frame No	Frame Designation	Ultimate load (kN)	Nature of load (Compression / Tension)
1	F1	BF	12.50	Tension
2	F2	IFAAC	30.24	Tension
3	F3	IFBC	30.00	Tension
4	F4	IFBP	28.00	Tension
5	F5	IFAAP	28.00	Tension

Modes of failure of infill frame

According to Stafford Smith, there are three potential modes of failure of the infill wall arise as a result of its interaction with the frame. The first is the shear failure of masonry due to shear stresses in the bed joint. The second is a diagonal cracking of the wall parallel to the leading diagonal caused by tensile stresses perpendicular to the leading diagonal. The third mode of failure is the corner crushing of infill wall due to high compressive stresses in the corner. In case of frames, the windward column is in tension and leeward column is in compression. The frame members or their connections are liable to fail by axial force or shear, and especially by tension at the base of the windward column. The modes of failure of all frame specimens are tracked during experimental investigation and are presented below.

Modes of failure of infill frames

Sl.No	Frame No	Frame Designation	Modes of failure
1	F1	BF	Occurrence of plastic hinges at Beam-column joints. Spalling of concrete at beam-column joints.
2	F2	IFAAC	Occurrence of plastic hinges at Beam-column joints. Corner crushing of masonry at joints.
3	F3	IFBC	Occurrence of plastic hinges at Beam-column joints. Diagonal cracking of masonry perpendicular to the loading diagonal.
4	F4	IFBP	Occurrence of plastic hinges at Beam-column joints. Corner crushing of masonry at joints.
5	F5	IFAAP	Occurrence of plastic hinges at Beam-column joints. Corner crushing of masonry at joints.

Results from Theoretical Investigation

Theoretical investigation was done using plastic analysis for bare frames and using Stafford Smith's method for analysis of in-filled frame with cement mortar interface and the results summarized below:

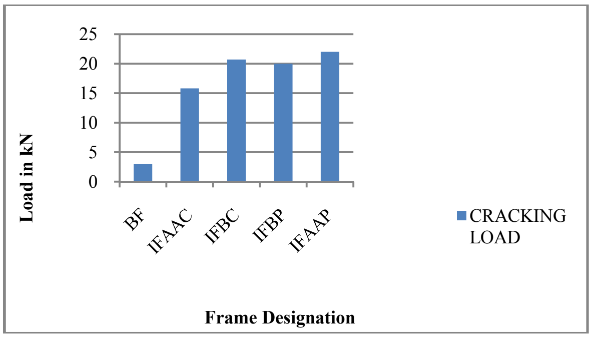
Results of theoretical investigation

Frame No	Frame Designation	Diagonal cracking Load (kN)	Shear cracking Load (kN)	Ultimate Load (kN)
F1	BF	---	---	14.85
F2	IFAAC	15.71	20.74	38.47
F3	IFBC	13.44	30.12	38.47

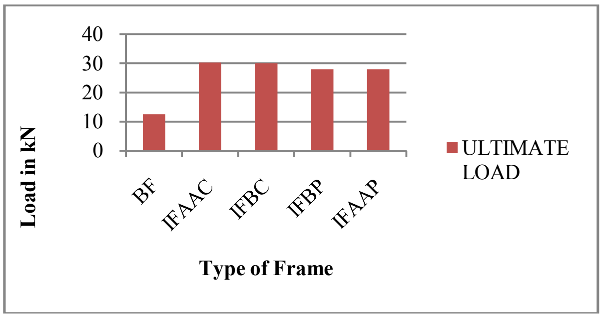
RESULTS COMPARISONS

In this section, comparison of experimental results such as first cracking load, ultimate load and initial stiffness among the five specimens are made by using bar charts, so as to make the comparison process easier. The comparison of first cracking load, comparison of ultimate load, and the comparison of initial stiffness are shown below:

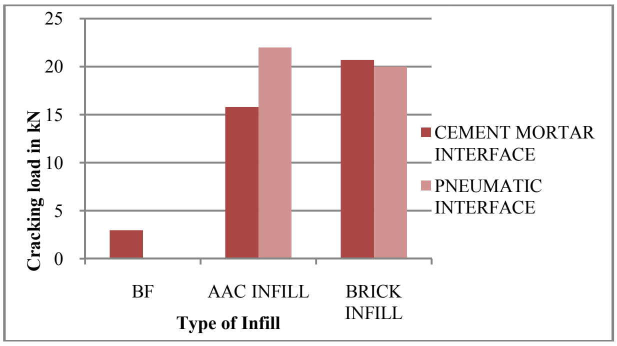
Comparison of cracking load



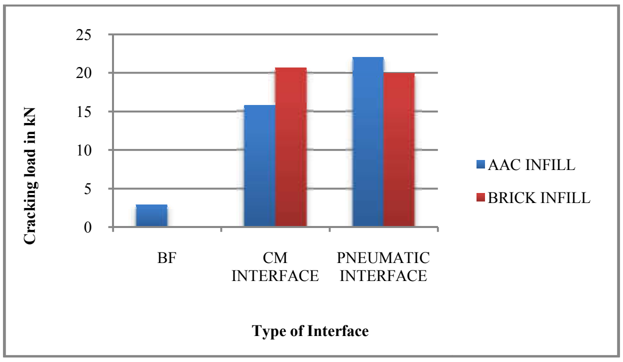
Comparison of ultimate load



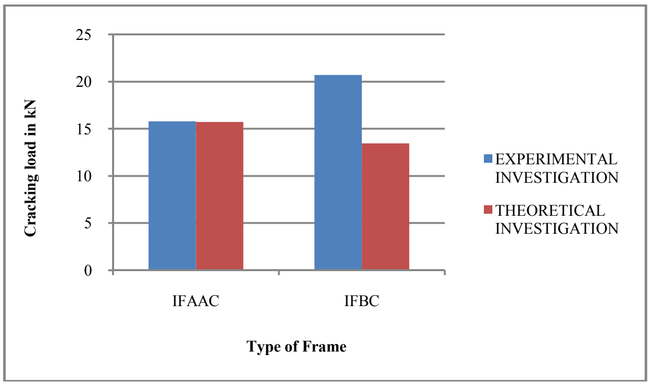
Comparison of cracking load based on type of infill



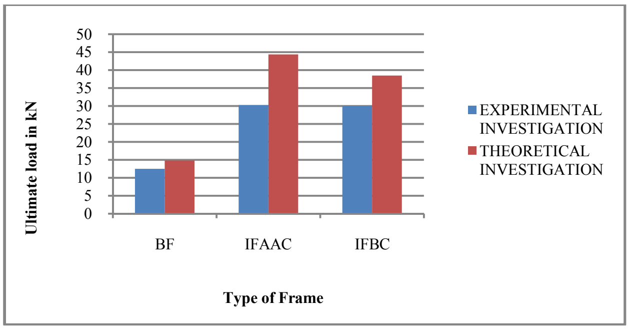
Comparison of cracking load based on type of interface



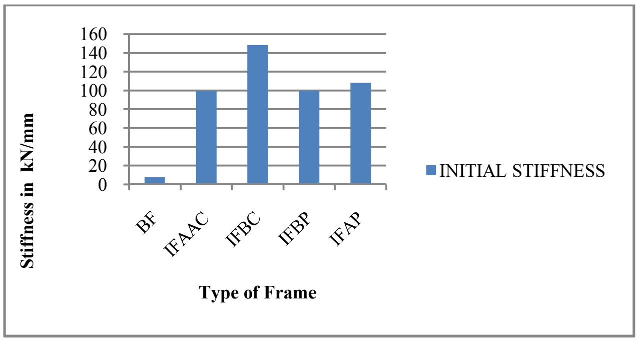
Comparison of cracking load based on type of investigation



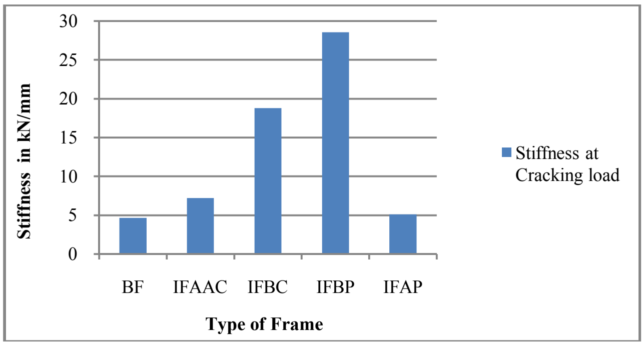
Comparison of ultimate load based on type of investigation



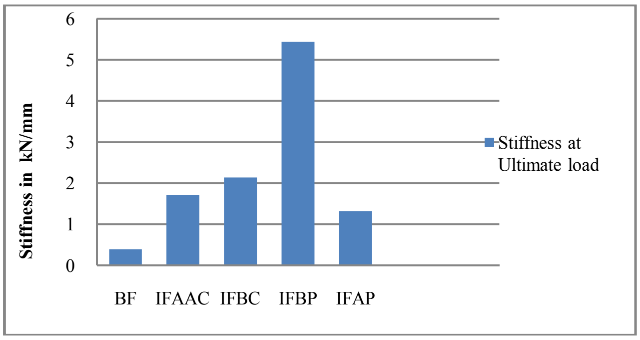
Comparison of initial stiffness



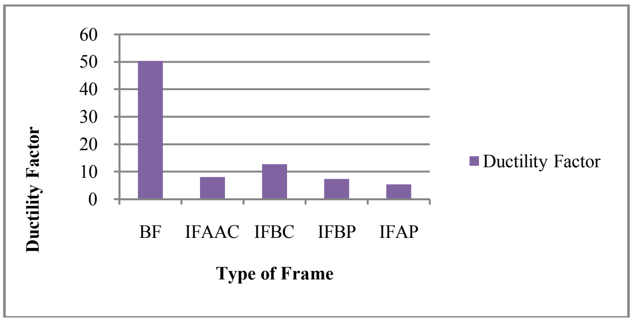
Comparison of stiffness at cracking load



Comparison of stiffness at ultimate load



Comparison of ductility factor



Outcome

In this scope of journal, the structural behaviour of diagonally loaded masonry in-filled RC frames with different infill and interface properties under static reversed cyclic loading were investigated. Based on the test outputs, the following conclusions can be drawn.

- All the specimen failed in a ductile manner due to the occurrence of plastic hinges at the ends of beams and columns.
- The addition of infill walls increases the stiffness of the bare frame. The initial stiffness of all in-filled frame is about 10 times greater than that of the bare frame.
- The addition of infill walls increases the strength of the bare frame also. The initial cracking load of all in-filled frames is about 5 times greater than that of bare frame. The ultimate load of all in-filled frame is about 2 times greater than that of bare frame. The initial cracking load of IFAAP (22 kN) is slightly higher than that of IFBP (20 kN). The ultimate load of IFAAC (30.24 kN) is slightly higher than that of IFBP (30 kN).
- The ductility factor of bare RC frame (50) is higher than that of the in-filled frames (<10).
- In-filled frame structures will be the better option to prefer in the seismic region, as in the case of bare frame, ultimate load is very less than the other in-filled frames, which may cause the early collapse of the frames during the strong earth quake shaking and to determine the Effect of AAC block masonry with cement mortar interface and AAC block masonry with pneumatic interface

Range for the Future work

Study can be extended to multi bay multi storey frame.
The entire testing can be made as pseudo-dynamic testing.

Sources

1. Chiou Y.J., Tzeng J.C., and Liou Y.W. (1999), ‘Experimental and analytical study of masonry infilled frames’, *Journal of Structural Engineering*, Vol.125, No.10, pp. 1109-1117.
2. Murty C.V.R. and Jain S.K. (2000), ‘Beneficial influence of masonry infill walls on seismic performance of RC frame buildings’, Proceedings of the 12th World Conference on Earthquake Engineering, Auckland, Newzealand, Paper No.1790, pp.1-6.
3. Palanisamy M. and Premalatha J. (2013), ‘Experimental study on diagonally loaded Rcc frames with masonry infilled wall’, *Australian Journal of Basic and Applied Sciences,* Vol.7(11), pp.148-152.
4. Umarani C. and Basil Gnanappa S.(2010), ‘Structural behavior of reinforced concrete frames with confined infill under cyclic loading’, *International Journal of Earth Sciences and Engineering*, Vol.03, No.06,pp.904-911.
5. Suyamburaja A., Subramanian K., Perumal Pillai E.B. and Santhakumar A.R. (2007), ‘RC infilled frame-RC plane frame interactions for seismic resistance’*, Journal of Applied Science*, Vol.7, Issue 7, pp.942-950.
6. Mehrabi A.B., Shing P.B., Schuller M.P. and Noland J.L.(1996), ‘Experimental evaluation of masonry infilled RC frames’, *Journal of Structural Engineering*, ASCE, Vol.122, No.3, pp.228-237.
7. Pires F. and Carvalho E.C. (1992), ‘The behavior of infilled reinforced concrete frames under horizontal cyclic loading’, Proceedings of the Tenth World Conference on Earthquake Engineering, Balkema, Rotterdam, pp.3419-3422.
8. Marjani F. and Ersoy U. (2002), ‘Behaviour of brick infilled reinforced concrete frames under revesed cyclic loading’, Proceedings of the International Symposium on Structural and Earthquake Engineering, Middle East Technical University, Ankara, Turkey, pp.142-150.
9. Zovkic J., Sigmund V. and Guljas I. (2012), ‘Testing of R/C frames with masonry infill of various strength’, Proceedings of 15th World Conference on Earthquake Engineering, Lisbon, Portugal.
10. Jiang H. J., Mao J.J. and Liu X.J.(2013), ‘Experimental study on Reinforced concrete Moment-resisting frames with infilled masonry walls subjected to cyclic loads’, Proceedings of the 5th International Conference on Advances in Experimental Structural Engineering, November, Taipei, Taiwan.
11. Stylianidis K.C. (2012), ‘Experimental investigation of masonry infilled R/C frames’, The Open Construction and Building Technology Journal, Vol.6, pp.194-212.
12. Siddiqui U.A., Sucuoglu H. and Yakut A. (2013), ‘Seismic performance evaluation of reinforced concrete frames infilled with autoclaved aerated concrete masonry’, Proceedings of the 2nd Turkish Conference on Earthquake Engineering and seismology, Antakya, Turkey, pp.1-15.
13. Nauman M. and Islam N.(2014), ‘ Behaviour of RCC multistory structure with and without infill walls’, *International Journal of Innovative Research in Science, Engineering and Technology*, Vol.3, Issue 1, pp.8455-8465.
14. Asteris P.G., Kakaletis D.J., Chrysostomu C.Z. and Smyrou E.E. (2011), ‘Failure modes of in-filled frames’, *Electronic journal of structural Engineering*, Vol.11(1), pp.11-20.
15. Ganesan T.P (2000), ‘Model analysis of structures’, Universities press, (India) Ltd.
16. Stafford Smith B.(1962), ‘Lateral stiffness of infilled frames’, *Journal of Structural Engineering Division, ASCE,* Vol.88, No.6, pp.183-199.
17. Stafford Smith B. and Carter C.(1969), ‘A method of analysis for infilled frames’, Proceedings of the Institution of civil Engineers, Vol.44, September, pp.31-48.
18. Liauw T.C. and Kwan K.H. (1985), ‘Static and cyclic behaviours of multistory infilled frames with different interface conditions’, *Journal of Sound and Vibration*, Vol.99, No.2, pp275-283.

****