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Finite Element Modelling of Two Storeyed Frame Infilled with Laterite Interlocking Blocks

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Abstract— In framed building constructions, infill panels are used to serve the purpose of partition walls or as cladding. Generally, these infill panels are treated as nonstructural elements by the structural engineers. The contribution of infill towards resisting lateral load is neglected. Presence of infill panel increases the lateral stiffness of the structure, thus shifting the natural period of vibration during earthquake. This paper aims to find out the vibrational characteristics of a two storeyed frame infilled with laterite interlocking blocks. The finite element modelling of a two storeyed single bay bare frame and masonry infilled frame with laterite interlocking blocks were performed. The material properties required for numerical analyses was determined experimentally. Modal analysis was carried out to identify the effects of masonry infill on RC frames.

Index Terms— ANSYS, Finite Element Modelling, Infilled Frame, Laterite Interlocking Blocks, Modal Analysis, Mode shape, Natural frequency

1 Introduction

MASONRY is the oldest form of building material, being present in most of the existing built heritage. The use masonry walls offer a durable and available solution. Nowadays, the material used for masonry purpose is different in different location. This include brick, stone, concrete blocks etc. These materials have their own distinguish mechanical properties. The main advantages of masonry include sound absorption, durability, fire resistance, aesthetics and low maintenance cost. The primary function of masonry is either to protect the inside of the structure from the environment (rain, snow, wind, etc.) or to partition the space. One of the cost efficient masonry unit is the interlocking blocks, in which conventional bricks are replaced by these interlocking blocks. One major advantage of interlocking blocks is the requirement of no mortar. And so the interlocking bricks are gaining popularity and acceptancy rate is increasing. Because of its technological simplicity and local resource dependence, mortar less-brick construction is more appropriate to many local communities than conventional mortared-brick techniques.

The term *infilled frame* is used to denote a composite structure formed by the combination of moment resisting plane frames and filler walls. A typical infilled frame may be either made up of steel or Reinforce Cement Concrete (RCC) frame filled with masonry unit. The usual practice by structural engineers is that, they ignore the presence of masonry infills as just partition walls. The combined action of infill and frames are not taken into account. But the frame act more efficiently under the action of lateral loads if infill walls are provided. Separately, the wall is stiff but brittle and the frame is relatively flexible and ductile. The combination provides the infill frame to be strong and tough.

Depending up on the connection of infill panel and frame infilled frames are categorized are of two types:

1. Non-integral infilled frame: If there is no connections or bonding between infill and frames, it is classified as non-integral infilled frames.

2. Integral infilled frames: If the frame and infill are provided with shear connectors or strong bonding at different interfaces, then the infilled frame is said to be integral infilled frame.

The modelling of infill can either be done as micro or as macro model. Catherin *et al.* [7] discuss the macro modelling of infill frames in which the infill panels are modelled as equivalent pin joint diagonal strut system. It was observed that with the effect of infill the vertical load carrying capacity does not significantly increase, whereas lateral load carrying capacity is found to be increased.

The innovation in the construction arena helps in the development and use of interlocking blocks. The need for faster and less labour intensive building system has showed the platform for the development of interlocking dry stackable block masonry unit. The interlocking mechanism of the block relies on the protrusions of the block to that of next course. Most of interlocking blocks lock by either having a prostration and depression or tounges and grooves sometimes called as male and female features. Marzahn [1] investigated the shear strength of mortarless masonry. It was found that shear strength of mortarless masonry was less compared to its ordinary masonry. Adedeji and Fasakin [2] focused on the factors for the performance of interlocking masonry in house delivery in Nigeria. It was conclude that the overall cost and net output per productivity hour was more for interlocking compared to ordinary conventional bricks.

In the present study Laterite Interlocking Building

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Blocks (LIBB) are used as infill panels. Laterite being locally available cheaper and more important environmental friendly becomes ideal material choice for the construction in the present scenario. The laterite soil and Ordinary Portland Cement (OPC) are materials required to make LIBB. The objective of the present study is to prepare a Finite Element (FE) model and perform a modal analysis to find out vibrational characteristics and to check the effectiveness of the connections.

2 Experimental Study

Experiment were conducted to study the physical properties of laterite interlocking blocks. Compressive strength and water absorption were the preliminary experiment conducted on both of the interlocking block.

Five sample were tested of each type of block and the result are given below.

1. Linear groove
   Compressive strength: 6.02 N/mm^2
   Water absorption: 2.456%
   Density: 1992.674 kg/m^3
2. Circular groove
   Compressive strength: 5.472 N/mm^2
   Water absorption: 3.026%
   Density: 1691.856 kg/m^3

2.1 Modulus of Elasticity (E)

Modulus of Elasticity of the block was found as ratio between the normal stress and linear strain. From the compression test on the block, linear deformation of the block was observed and linear strain was calculated. A graph was plotted between normal stress and linear strain. Modulus of Elasticity was obtained as 137.19 N/mm^2.

2.2 Poisson Ratio (μ)

Poisson Ratio was evaluated as ratio between the lateral strain and longitudinal strain. The lateral strain was calculated from lateral deformations measured along 4 different direction. Linear strain was calculated from linear deformation as mentioned earlier. A graph was plotted between lateral strain and linear strain. Poisson Ratio was obtained as 0.1563.

3 Finite Element Modelling

The basic concept of FEM modelling is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions or at a set of nodal points. The response of the mathematical model is then considered to be the discrete model obtained by connecting or assembling the collection of all elements. Within the framework of the finite element method, reinforced concrete frame can be represented either by superimposition of the material models for the constituent parts (i.e., for concrete, and reinforcing steel), or by a constitutive law for the composite concrete, embedded steel considered as a continuum.

Assumptions made in FEM modelling are:

1. The infill material, concrete and steel reinforcement are modelled as isotropic and homogenous material.
2. The maximum compressive strain in the concrete is assumed to be 0.0035 mm/mm as suggested by IS 456: 2000.
3. The frame and infill are bonded together, that is integrated infill frame are used.
4. Perfect bond exits between concrete and steel reinforcement.

In the present study, finite element modelling of individual interlocking blocks, reinforced concrete bare frame and infilled frames are modelled using ANSYS17.0.

Two type of infill frame IF-1 and IF-2 are modelled.

IF-1: Frame infilled with linear groove interlocking blocks

IF-2: Frame infilled with circular groove interlocking blocks

The different type of element adopted for modelling different material are discussed below.

3.1 Element Type

1. For three-dimensional modelling of concrete SOLID65 element was selected. The element is defined by eight nodes and has three degrees of freedom at each node.
2. LINK180 element was used to model steel reinforcement, which is a 3D spar element having two nodes and three degree of freedom at each node.
3. SOLID185 element was choose for the three-dimensional modeling of interlocking blocks. It allows for prism and tetrahedral degenerations when used in irregular regions. The element is defined by eight nodes having three degrees of freedom at each node.

3.2 Geometry

1. Laterite interlocking block with linear groove: Size of the block is 250 mm x 230 mm x 130 mm.
2. Laterite interlocking block with circular groove: Size of the block is 300 mm x 150 mm x 150 mm
3. Concrete bare frame: The outer dimension of the frame was 1300 mm x 2500 mm that is outer dimension along width was 1300 mm and overall height was 2500 mm. The frame was modelled as 2 storey having inner dimension was 1100 mm x 1100 mm in each storey level. Length of frame was taken as 230 mm. This was kept keeping the width of linear groove interlocking blocks.
4. 8 mm HYSD bars were used as longitudinal reinforcement as well as for transverse reinforcement at 20 cm c/c.

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5. Infilled frame with interlocking blocks: In order to get zig zag joints required half size of bricks were used at end position. Projecting parts of the blocks of a course to be inserted to the depressions of block placed above them. The overall width and height of frame was 1300 mm and 2500 mm respectively. Ideally the bond strength between the concrete and steel reinforcement, should be considered. Since such type of failure was not predominant in the experiment models, perfect bond between materials was considered in finite element modelling.

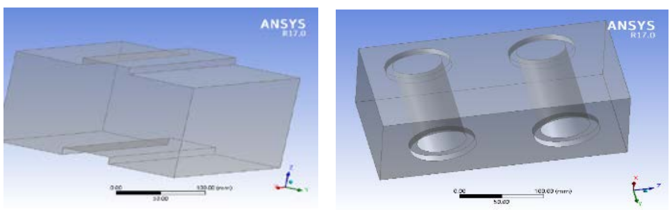

Fig.1 CAD model Laterite interlocking blocks (Linear and Circular groove)

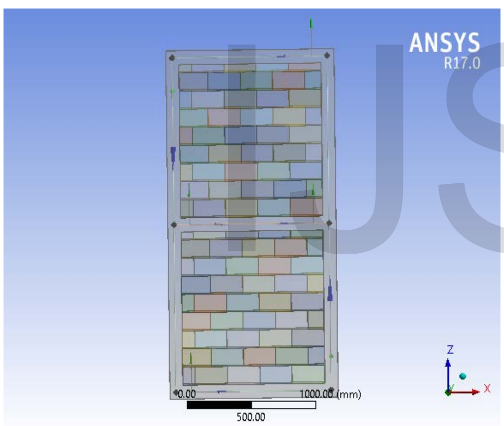

Fig. 2 CAD model of frame infilled with linear groove interlocking blocks

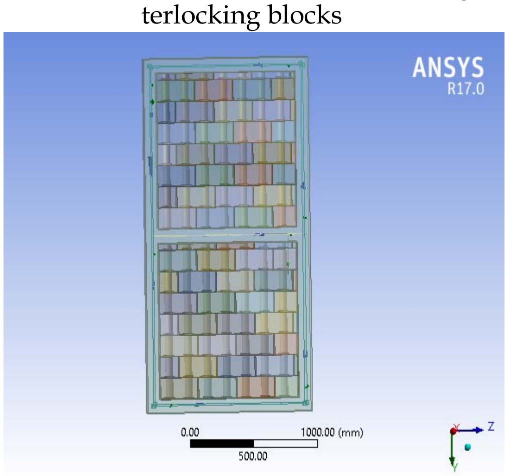

Fig. 3 CAD model of frame infilled with circular groove interlocking blocks

3.3 Material Property

1. Concrete
   Density was given as 2400 kg/m^3. Grade of concrete was adopted as M20 and modulus of elasticity was given according to the grade of concrete. Poisson ratio was assumed to be 0.18. Multilinear Isotropic Hardening (MISO) property was input for the concrete.

2. Steel reinforcement
   Density of steel was input as 7850 kg/m^3. Fe415 steel was used as steel reinforcement. The modulus of elasticity was give as 2 x 10^5 N/mm^2. Poisson ratio was taken as 0.3. Bilinear Isotropic Hardening (BISO) property was input for steel reinforcement.

3. Interlocking blocks
   The property of interlocking blocks required to be input in ANSYS17.0 was found out experimentally. This include density, compressive strength, modulus of elasticity (E) and poisson ratio (μ). These are discussed in the previous section.

3.4 Meshing

Meshing is an important criterion in Finite Element Modelling. The aspect ratio of the plane element affects the analysis of the model. The aspect ratio describes the shape of the element in the assembly.

ANSYS provide 4 types of meshing, which include: Quadrilateral, Triangular, Hexahedral and Tetrahedral. In the present study hexahedral element is opted for meshing reinforced cement concrete and interlocking blocks with linear groove. For meshing interlocking blocks with circular groove tetrahedral elements are chosen. This is due to the complex shape and irregularities of circular groove.

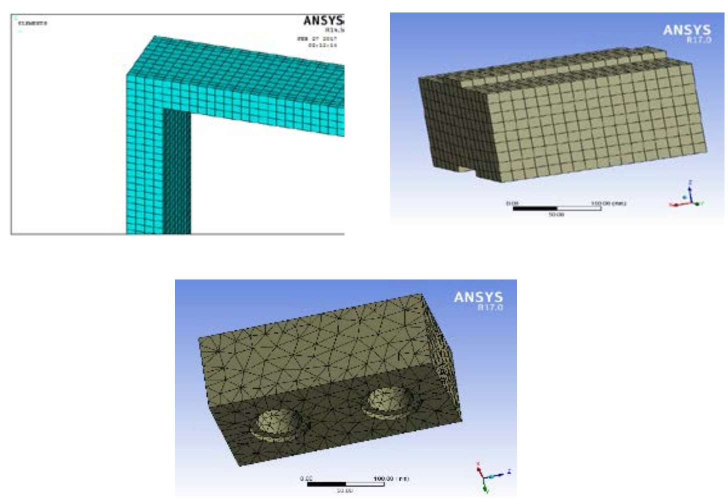

Fig. 4 Meshed view of different element

3.5 Boundary Condition

Displacement boundary conditions are needed to constrain the model to get a unique solution. To achieve this, translations and rotation of frame at the bottom were given constant value of zero, along three direction. That is fixed support condition was given at the bottom face.

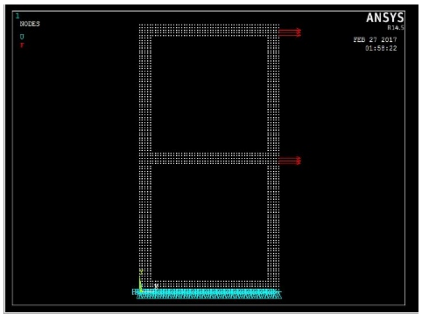

Fig. 5 Frame fixed at bottom

4 Modal Analysis

Modal analysis is used to find out the vibrational characteristics (natural frequencies and mode shapes) of a structure. ANSYS prefer to do a modal analysis prior to a transient dynamic analysis, harmonic response analysis or spectrum analysis. That is modal analysis serve as a starting point before a more detailed dynamic analysis.

The finite element model of a single bay two storey frame and infilled frame was generated and boundary condition was applied. As the analysis being modal, no dynamic excitation was applied. In the study, Block Lanczos excitation method was adopted for the modal analysis of frames. This method is recommended when the modal consists of poorly shaped solid or shell elements.

A total of eight mode shapes were expanded and eight natural frequencies were extracted. This is given in the result and discussion section.

5 Result and Discussion

From modal analysis it was observed that interlocking block infilled frame gave a lower frequency compared to bare frame. The percentage of decrease in natural frequency of interlocking blocks infilled frames was about an average of 32% for both shape of interlocking blocks.

The range of change of natural frequency was from 17.76% to 45.03% for IF-1 with respect to bare frame. In case of IF-2 the range of change of natural frequency with respect to bare frame was from 16.66% to 46.86%. The time period of bare frame was 0.0726 sec, 0.1241 sec for infilled frame with linear groove interlocking blocks and 0.1061 sec for infilled frame with circular groove interlocking blocks corresponding to the first mode.

TABLE 1
Comparison of Natural Frequencies

Sl. No.	Bare Frame (Hz)	IF-1 (Hz)	IF-2 (Hz)
1	13.772	8.056	9.425
2	15.651	19.616	18.903
3	29.795	22.595	24.716
4	51.373	42.249	42.811
5	79.936	60.338	50.556
6	106.17	61.002	58.635
7	117.51	74.809	62.449
8	146.84	80.71	78.812

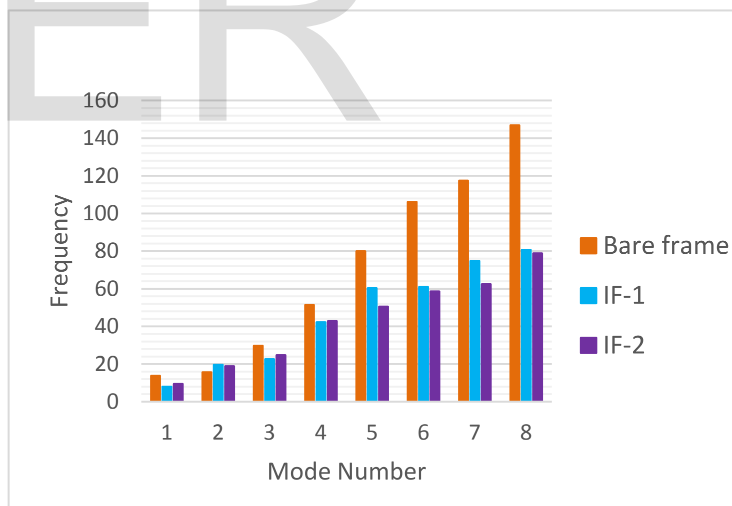

Fig. 6. Comparison of natural frequencies for Frame [Bare frame (BF), IF-1 and IF-2]

Moreover, for the present two storey frame the value of time period lies in first region where spectral acceleration coefficient (S_a/g) is directly proportional to time period for bare frame, and for infilled frame the spectral acceleration coefficient falls in constant region. The response spectra used in this study was taken from IS 1893:2002. Thus, the

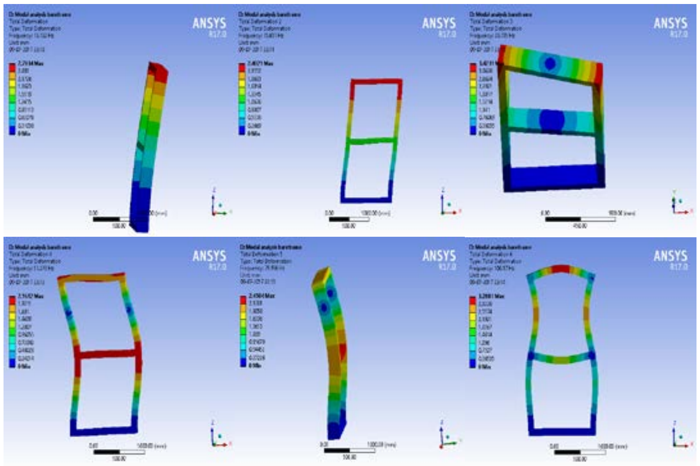

Fig. 7 First 6 mode shapes of bare frame

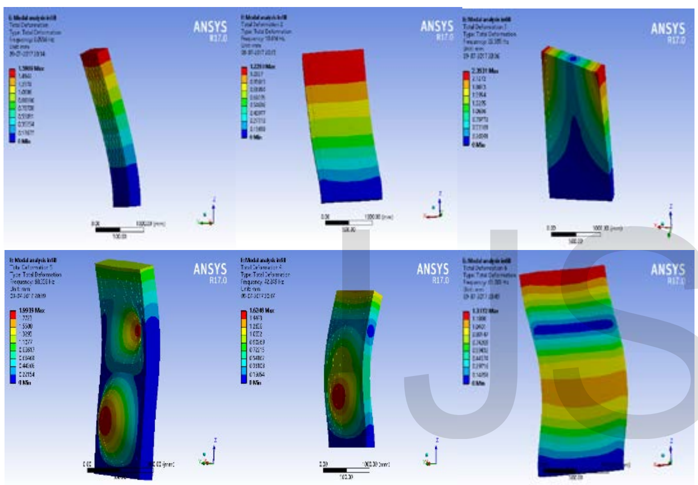

Fig. 8 First 6 mode shapes of infilled frame with linear groove

It can be seen that the mode shapes are different for bare frame and infilled frame. Thus, it can be said that the dynamic behaviour plane bare frame is different from the interlocking block infilled frame. This result shows that it is essential to consider the effect of infill panels in structural analysis. Otherwise, structures may be affected adversely by earthquakes. Ignoring the effects of infill panels does not necessarily mean staying on the safe side every time (Arslan and Durmus [4]).

6 Conclusion

Finite Element Modelling of bare frame and infill frames was done using the software ANSYS17.0. Modelling of each material was done using suitable element type present in ANSYS library. Material properties required to input in FE modelling was determined experimentally.

Modal analysis was performed and vibrational characteristics including mode shapes and natural frequencies were obtained. It was observed that, for the modelled two storeyed frame the average percentage decrease in natural frequency of infilled frame with interlocking blocks was about 32% compared with bare frame. From the mode shapes and natural frequency it can be conclude that, dynamic behaviour of bare frame is different from infill frames. Also the stiffness is also get increased by addition of infill. The modal analysis showed that the connection between different elements of model are working well.

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References

[1] G. Marzahn, "The strength of dry- stacked masonry walls," *Lacer 3*, pp. 247-262, 1998.

[2] Y.M.D. Adedeji and J.O. Fasakin, "Acceptability indices of interlocking masonry in housing construction in Nigeria," *Pakistan Journal of Social Science*, vol. 5, no. 7, pp. 696-700, 2008.

[3] S. Razaque, "Strength and behaviour of laterite interlocking building block masonry," *M. Texh. Thesis, University of Kerala, Kerala, 2004.*

[4] M.E. Arslan and A. Durmus, "Modal testing and finite element model calibration of in-filled reinforce concrete," *Journal of Vibration and Control*, vol. 0, no. 0, pp-1-14, June, 2013.

[5] G. Manju "Dynamic Analysis of Infills on R.C Framed Structures," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 3, no.9, pp. 16150 - 16158, IJIRSET, September, 2014.

[6] A.K. Ghosh and A.M. Made, "Finite element analysis of infilled frames," *Journal of Structural Engineering*, vol. 128, no. 07, pp. 881-889, ASCE, 2002.

[7] J. M. Catherin, B. R. Jayalekshmi and K. Venkataramana, "Modelling of masonry infill – A review," *American Journal of Engineering Research,* vol. 2320, no. 2, pp. 59-63, 2013.

[8] *Criteria for Earthquake Resistant Design of Structure - Code of Practice*, IS 1893 (Part 1), Bureau of Indian Standards, 2002.

[9] Y.M.D. Adedeji, "Factors for the performance for the use of interlocking masonry in housing delivery in Nigeria," *Environmental Research Journal*, pp. 284-289, 2008.

[10] *ANSYS Release 12.0 User's Manual,* PA USA 2012.