ICEST-2K24 [International Conference on Engineering, Science and Technology]
In Association with
International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN - 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)

Effect of Brick Bond Pattern Under Plane Loading with Various Aspect Ratio

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ABSTRACT

Several types of brick bond patterns are used to construct masonry walls. A masonry wall's reaction to shear, compression and in-plane stresses may be significantly affected by the bond pattern of its bricks. This study's objective was to examine the performance of a brick masonry wall constructed using various brick bond patterns when in-plane loads are applied to the wall also, analysed the effect of different location of opening on overall brick masonry wall. In the present research, the simplified macro-modelling method was adopted. The simplified macro-modelling process combines an
extended finite element system with constitutive models based on plasticity. The Stretcher, Header, English, Flemish are only some of the many possible configurations for the brick wall. Here in the brick bond pattern of the stretcher bond was also employed to model a masonry wall and was
analytically investigated under an in-plane load. The finite element method (FEM) was used to conduct this research.

Keywords: Brick masonry; compressive strength; variability; probability distribution function; shear bond strength; in-plane loading; Simplified macro-model approaches.

I. INTRODUCTION

1.1. General

A brick wall undergoing an earthquake global acceleration field is subjected to both in-plane and out-of-plane loads. The former results from the story shear force under horizontal loading and the latter is either due to the out-of-plane inertia force caused by the considerable mass of the brick wall or the out-of-plane action of a flexible floor on the wall. The presence of one type of loading on a structural element affects the strength of that element against another type of loading. Considerable experimental, numerical and analytical studies have been carried out on the behavior of masonry buildings, particularly under earthquake loading and mostly on the behavior of brick walls.

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Hossain et al. (1997) Investigated the in-situ deformation characteristics of bricks and mortar joints. Couplets with inclined bed joint were tested for shear bond strength by uniaxial loading. Failure for all the specimens was observed within the joint. Mean shear bond strength and nonlinear shear stress-strain behavior were evaluated. Sarangapani et al. (2005) Studied the effect of brick-mortar bond strength on the compressive strength of masonry. The compressive strength, flexural bond strength and shear bond strength of the masonry made with local bricks and mortar was determined experimentally. In order to improve the bond strength of mortar, use of some bond- enhancing techniques like cement slurry and epoxy resin coating for lean mortars was suggested. It was observed that with the increase in flexural and shear bond strength, the compressive strength of masonry increased. Poor bond strength was observed responsible for the failure of prism along the brick-mortar joint. Similarly, high bond strength resulted in diagonal failure of masonry under compression. Therefore, the study highlighted the relation between bond strength, compressive strength and mode of failure in brick masonry. Reddy and Gupta (2006) Investigated experimentally the tensile bond strength of masonry constructed using soil-cement blocks and cement-soil mortars. The studied was aimed to find the effect of different block properties (such as initial moisture content, cement content, strength and surface characteristics) and mortar properties (such as workability and composition of cement-soil mortars) on the direct tensile strength of masonry couplets. It was observed that bond strength is affected by initial moisture content of blocks as partially saturated blocks provided good strength in comparison to completely dry or fully saturated blocks. Thus, this paper provides the importance of initial moisture content for achieving bond strength. Similarly, the higher bond strength was achieved with the increase in cement content on the block. It was found that cement-soil mortar achieved 15-20% higher bond strength in comparison to conventionally used cement mortar. Reddy et al. (2007) Studied the influence of shear bond strength on compressive strength of soil-cement block masonry. The methods to improve the shear bond strength of soil-cement block masonry was also suggested. The methods developed to improve the shear bond strength included making the bed surfaces texture of blocks rough, surface coatings and altering the frog size and area. It was experimentally observed that rough textured blocks and cement slurry coated blocks obtained higher shear bond strength. Similarly, no significant changes were observed in stress-strain and compressive strength properties of masonry with the change in shear bond strength when the masonry block unit modulus is greater than that of mortar. But it was found that enhancing bond strength improves the compressive strength of soil- cement block masonry. Reddy and Vyas (2008) Presented the influence of bond strength on compressive strength and stress-strain characteristics of soil cement block masonry with cement lime mortar. It was found that the bond strength increased by three to four times with the application of surface coating and making the surface texture rough. In this study, three different cased of block masonry with different block to mortar elastic modulus ratio were considered. From the extensive experimental tests, it was found that bond strength and compressive strength of masonry depend considerably on the block to mortar elastic modulus ratio. Pavia and Hanley (2010) Investigated the bond strength of masonry with natural hydraulic lime mortar. The study aimed to correlate bond strength with mortar hydraulicity, water content, workability and water retention. The experimental programmed included the determination of flexural bond strength by bond wrench test for different hydraulic strength lime mortars. It was suggested that water retention property of natural hydraulic lime mortar enables higher bond strength. Kurdo F. Abdulla et al. (2017) Presented combination of constitutive models had employed together with the extended finite element method (XFEM) to simulate 3D masonry structures used a simplified Micro- modelling approached. In the new approached progressive cracked and non-linear post-failure behavior between the masonry joint interfaces was well-captured by used a cohesive, surface based approached with a traction separation law. In addition, cracked propagation within masonry units identified by the novel used of XFEM without the pre-definition of cracked location. The compressive failure of masonry was also included via a Drucker-Prager material constitutive model. Thus, all key local and global behavior and failure modes of masonry captured. The capability of the proposed model demonstrated by validation studied of the response of masonry structures

under monotonic in-plane, out-of-plane and in- the seismic performance of the masonry room used macro modeling. Modeling techniques demonstrate high effective in representing the masonry wall in general and the nonlinear properties of materials in particular. The case studied for masonry wall analysis in two ways applied lateral loaded and applied controlled displacement. The results confirmed the reliability of the representation techniques used the ABAQUS software. Danna Darma yadi et al. (2019) Presented the three-dimensional Finite Element Model that has been constructed for Masonry Wall under lateral force by using Abaqus software. This research aimed to investigate the behavior of Masonry Walls under lateral force and developed load-displacement curve. From the result that the numerical model using the Abaqus Software can represent the load-displacement curve of Masonry Walls due to lateral forces.

1.2. Types of Bonds in Brick Masonry Wall Construction

The most commonly used types of bonds in brick masonry are:

1. Stretcher bond
2. Header bond
3. English bond and
4. Flemish bond

Other Types of bonds are:

plane cyclic loaded, which was able to reproduced experimentally observed behavior with accuracy and without numerical convergence difficulties. previously.

Ali Laftah et al. (2017) Presented numerical representation used the finite element method of the programmed based on the representation techniques (micro, Simplified, macro modeling) of the masonry wall and evaluate the seismic performance of the masonry room.

1. **Facing bond**
2. **Dutch bond**
3. **English cross bond**
4. **Brick on edge bond**
5. **Raking bond**
6. **Zigzag bond**
7. **Garden wall bond**

1. Stretcher bond

Longer narrow face of the brick is called as stretcher as shown in the elevation of (figure below 1 Stretcher bond) also called as running bond, is created when bricks are laid with only their stretchers showing, overlapping midway with the courses of bricks below and above. Stretcher bond in the brick is the simplest repeating pattern. But the limitation of stretcher bond is that it cannot make effective bonding with adjacent bricks in full width thick brick walls. They are suitably used only for one-half brick thick walls such as for the construction half brick thick partition wall. Walls constructed with stretcher bonds are not stable enough to stand alone in case of longer span and height. Thus, they Then need supporting structure such as brick masonry columns at regular intervals. Stretcher bonds are commonly used in the steel or reinforced concrete framed structures as the outer facing. These are also used as the outer facing of cavity walls. Other common applications of such walls are the boundary walls, gardens etc. (figure below 1 Stretcher bond)

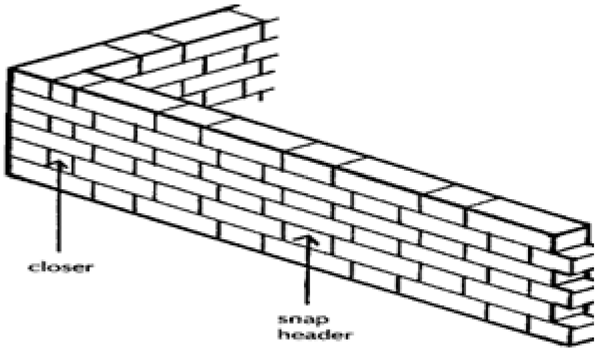

Fig.1

2. Header bond

Header is the shorter square face of the brick which measures 9cm x 9cm. Header bond is also known as heading bond. In header bonds, all bricks in each course are placed as headers on the faces of the walls. While Stretcher bond is used for the construction of walls of half brick thickness whereas header bond is used for the construction of walls with full brick thickness which measures 18cm. In header bonds, the overlap is kept equal to half width of the brick. To achieve this, three quarter brick bats are used in alternate courses as quoins. (figure below 2 Header bond)

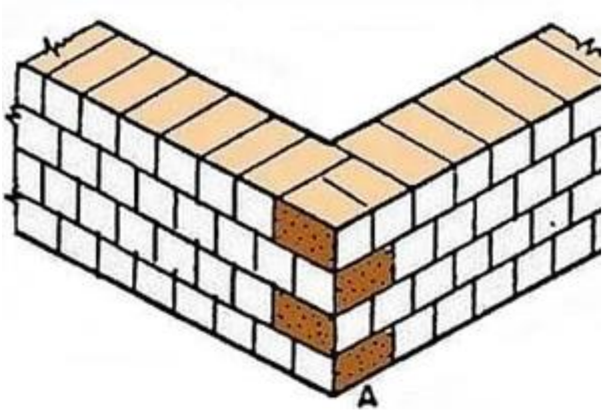

Fig .2

3. English Bond

English bond in brick masonry has one course of stretcher only and a course of header above it, i.e., it has two alternating courses of stretchers and headers. Headers are laid centered on the stretchers in course below and each alternate row is vertically aligned. To break the continuity of vertical joints, quoin closer is used in the beginning and end of a wall after first header. A quoin close is a brick cut lengthwise into two halves and used at corners in brick walls. (figure below 3 English bond)

4. Flemish Bond

For the breaking of vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header. In walls having their thickness equal to odd number of half bricks, bats are essentially used to achieve the bond. Flemish bond, also known as Dutch bond, is created by laying alternate headers and stretchers in a single course. The next course of brick is laid such that header lies in the middle of the stretcher in the course below, i.e., the alternate headers of each course are centered on the stretcher of course below. Every alternate course of Flemish bond starts with header at the corner. The thickness of Flemish bond is minimum one full brick. The disadvantage of using Flemish bond is that construction of Flemish bond is difficult requires greater skill to lay it properly as all vertical mortar joints need to be aligned vertically for best effects. Thus, if the pointing has to be done for brick masonry walls, then Flemish bond may be used for better aesthetic view. If the walls have to be plastered, then it is better to use English bond. (figure below 4 Flemish bond)

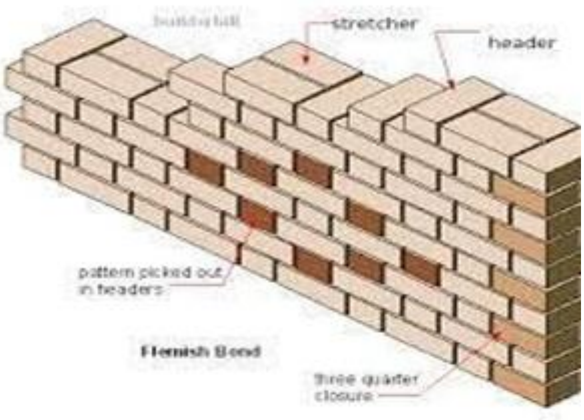

Fig.3

Masonry material

Masonry is a composite material consisting of units and mortar. These components display greatly different behavior, such as the large differences between stiffnesses and deformabilities. Hence massify is markedly non-homogeneous and anisotropic, displaying distinct directional properties due to the planes of weakness created by the mortar joints. The representation of masonry can greatly vary between the analysis methods attempting to model its behaviour. Clearly, the more realistically the behavior is treated, the more complex the analysis.

Random variability of masonry

Masonry properties such as flexural tensile strength exhibit a high degree of random variability. The main factors affecting variability include inherent variation in materials, variation in manufacturing processes, unit and mortar properties (surface conditions, porosity, moisture content and suction rate), shrinkage and workmanship Masonry quality is especially susceptible to variations due to workmanship because of the labor-intensive nature of its construction and as a result, experimental results generally display a relatively large amount of scatter. While every care was taken to minimize the variability in the experimental study, it was not possible to eliminate it. Hence sufficient number of replicates was required to quantify the variability that existed between test specimens.

Causes of in-plane loading

The foundation of an URM structure transmits seismic motion from the ground to the stiffest elements, the in-plane structural walls. The structural walls excite the floor diaphragms that in turn excite the in-plane walls for in-plane action of URM buildings, the walls constitute the majority of the total mass. Hence for seismic loading, out-of-plane bending arises as a result of the inertia forces caused by the transverse horizontal component of the ground motion (Farris, 1995). The magnitude of these forces is affected by the mass, stiffness, fundamental period and damping of the structure, as well as the magnitude of the earthquake (Potter, 1994). For multi-storey buildings, the inertial forces are higher for upper storey, therefore the in plane loading experienced for these storeys is also greater than for lower storeys. Consistent with this is the identification of one of the groveling weak links in the seismic load path of URM being the inadequate out-of-plane bending strength of walls near the tops of buildings (Klopp, 1996). This is due to a combination of higher out-of- plane loading and a lower level of axial loading, which produces stabilizing moments and acts to strengthen the walls.

Problem Description

The effect of brick bond patterns under plane loading with various aspect ratios is a critical aspect of structural engineering and construction. Understanding how different bricklaying techniques and the shape of the structure can impact its stability and load- bearing capacity is essential in designing resilient and efficient buildings. In this discussion, we will delve into the significance of brick bond patterns and aspect ratios in structural design and explore their implications on the structural integrity and performance of masonry constructions. The numerical simulation of a reinforced concrete structure requires an accurate model of the structural elements and its constituent members acting as a composite made up of concrete and steel. A sketch of each section is created separately with ABAQUS, which can then be extruded in any direction; this is why a 3D solid element in “modeling space” using deformable type for beam was created. In order to develop concrete beam, 8- node continuum solid element was utilized. The solid element has eight nodes with three degrees of freedom at each node – translations in the nodal x, y, and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing.

Modelling approach

Introduction to Abaqus 2017 ABAQUS is a finite element analysis (FEA) software developed by Dassault Systems' SIMULIA brand. While my knowledge is based on information up to 2022, I can provide a general introduction to ABAQUS 2017. ABAQUS 2017 is a specific version of the ABAQUS software suite, and it was released in 2017. ABAQUS is widely used for simulating and analyzing mechanical, structural, and Multiphysics engineering problems. It's particularly popular in industries like aerospace, automotive, civil engineering, and biomechanics. Key features of ABAQUS include its ability to perform complex finite element analysis, simulate various materials and behaviors, model nonlinearities, and study dynamic or static behavior of structures. ABAQUS uses a scripting language for customization and automation, making it a powerful tool for researchers and engineers to solve a wide range of simulation challenges.

Modelling Steps in Abaqus Software

1) **Created the parts of the masonry wall:**
   a) Full Brick: the full brick part of Masonry wall 1m x1m Brick is used. The
   b) Half Brick: that the 1 m x1 m Half Brick and Depth about 10m is taken.
   c) RC Beam: the RC Beam of lentgh 12mx 12m is taken.The depth of the RC Beam is 1000m
2) **Assigned the material properties to the parts of the masonry wall:**
   A) For the Brick of the Masonry wall:
      a) Mass Density: the Mass density is put in the General option in the property.i.e.,2400 Kg/m.

b) Drucker Prager: In the Mechanical option, under the Elasticity properties the Drucker Prager properties are of Brick are assigned. i.e., Angle of friction 360, Flow stress ratio1 and dilation angle 11.30 .

c) Drucker Prager Hardening the Drucker Prager Hardening property is used for the definition of the Yield stress and the Plastic Strain of the Brick material of the masonry wall.

d) Elastic property of the Brick: the material step, under the mechanical option the elastic properties of the Brick i.e., Youngs modulus 2888 MPa and Poisson’s ratio 0.15 is used.

B) For the concrete of the masonry wall:

a) Mass Density of the RC Beam of the masonry wall: Fig. h) shows that the Mass Density of the RC Beam of the masonry wall is 2400kg/m is used. The value of the density is put in General option in the property.

b) Elastic property of the RC Beam of the masonry wall the Elastic properties the Youngs modulus and the Poisson’s ratio are used.

3) **Definition of the Assembly for the masonry wall:** the Assembly step, the masonry wall is created from Full Brick, Half Brick and RC Beam using stretcher Brick bond

4) **Step of the masonry wall:** the Step, pressure loading-gravity load and cyclic loading is applied.

5) **Interaction of the masonry wall:** the Surface-to-surface contact interactions described a contact between the RC Beam and Bricks of the masonry wall.

6) **Applied load on the masonry wall:** the Load step, load and pressure is applied on masonry wall at top and the amount of load is 700KN. Boundary conditions are also created.

7) **Mesh part of the masonry wall:** the process of generating a two dimensional and three-dimensional, Mesh is created.

8) **Visualization of the Masonry wall:** the Finite Display of the models and results is obtained in the visualization step.

II. RESULTS AND DISCUSSION

Results

Fig. 4) and Fig. 5) shows that the vertical compressive stresses cause the stretcher bond to slide, crush the toe, and crack in a diagonal pattern.

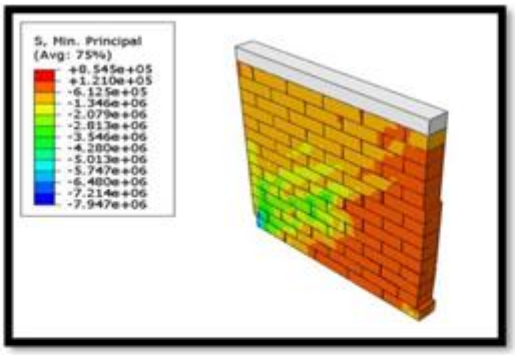

Fig. 4) Failure modes of masonry walls for stretcher bond

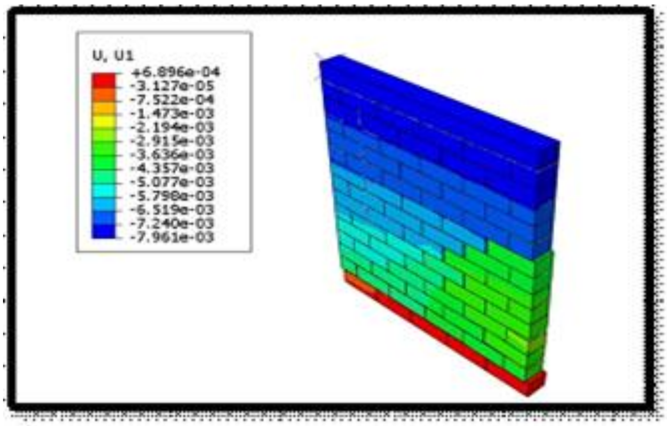

Fig. 5) Minimum principal stresses on masonry walls for stretcher bond.

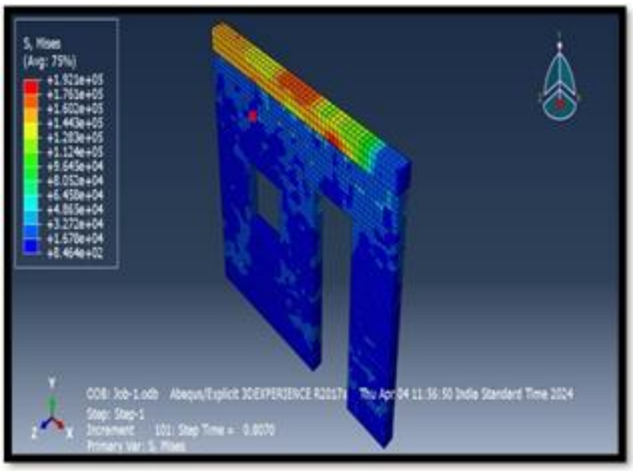

Fig. 6) Shows the load distribution of masonry wall.

Fig 6) shows the openings are provided for window and door with stretcher bond in masonry wall. After submission of job, get following results. This result for load of magnitude 10000N.

the lintel helps distribute the load across a wider area. This prevents stress concentrations directly above the opening, reducing the risk of cracks or structural failure.

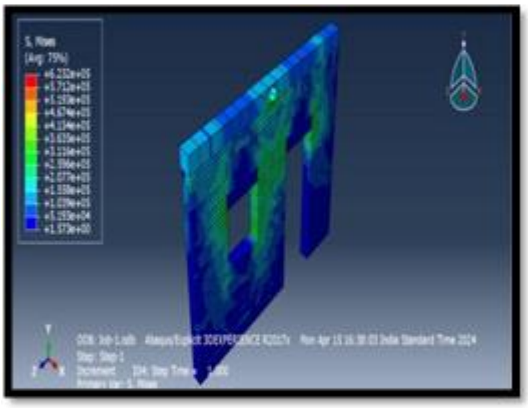

Fig. 7) opening in beam with varying load

Above fig the openings are provided for window and door with stretcher bond in masonry wall also opening is provided in beam. After submission of job, get following results. This result for load of magnitude 10000N.

the beam can safely transfer loads around the opening without excessive deflection or failure

Graph shows representation of varying displacement with increasing magnitude of force. Force applied on beam above masonry wall without lintel and contains opening. Application of force starts with force of 50000N and further continue up to 400000N. Displacement is taken in millimeters.

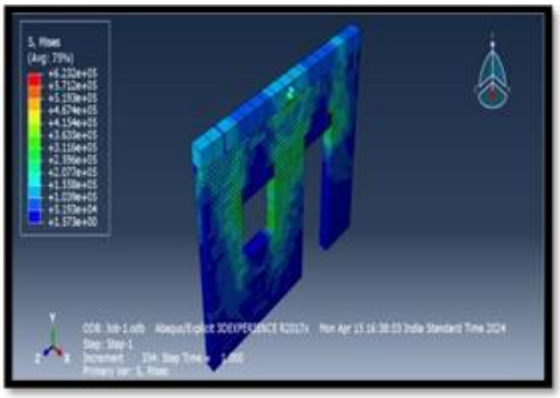

Fig. 8) opening in beam with varying load

Above fig the openings are provided for window and door with stretcher bond in masonry wall also opening is provided in beam. After submission of job, get following results. This result for load of magnitude 20000N

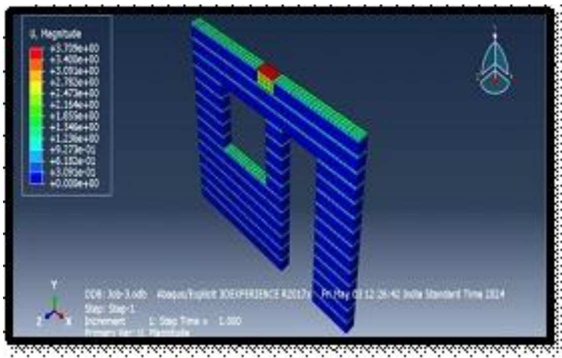

Fig. 9) Shows wall without opening and lintel

A masonry wall without openings and lintels is typically stronger and more stable than one with openings, as it provides uninterrupted structural integrity. This solid construction efficiently distributes loads throughout the wall, reducing stress concentrations and enhancing the overall durability of the structure.

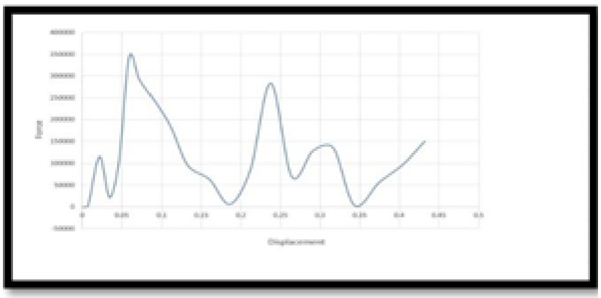

Fig. 10) Beam opening without lintel

Graph shows representation of varying displacement with increasing magnitude of force. Force applied on beam above masonry wall with lintel and contains opening. Application of force starts with force of 5000N and further continue up to 45000N. Displacement is taken in millimeters.

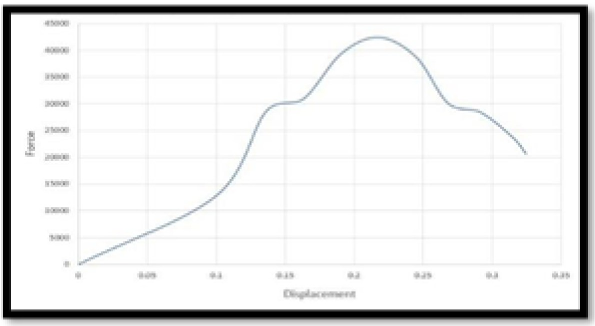

Fig. 11) Beam opening with lintel

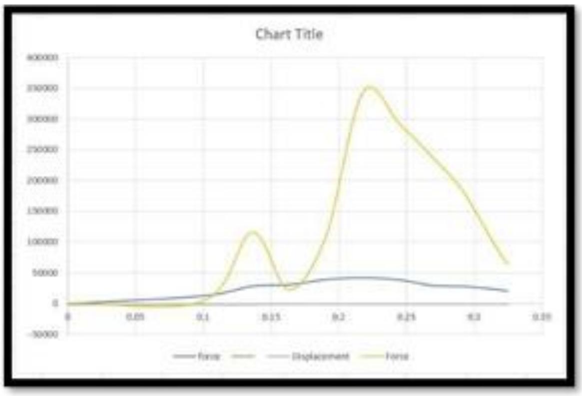

Fig. 12) Graphical representation of comparison between beam opening with and without lintel

Blue line represents graphical representation of beam opening without lintel and yellow line represents graph of beam opening with lintel. Values of displacements are constants for graph of beam opening with lintel. Graphical representation of beam opening without lintel is nearly parallel to X-Axis. Above figure shows the comparison between beam opening without lintel and with lintel simultaneously.

Discussion

In this micro modeling analysis, following outcomes and behavior of masonary wall are obtained. The red color in masonry wall shows that earlier failure in masonry wall and blue color shows that slow failure in masonry wall.

III.CONCLUSION

In the project stage-I, effect of stretcher brick bond is studied.

The analysis of masonry wall for the stretcher brick bond is obtained with the help of ABAQUS software.

- In this micro modeling analysis, following outcomes and behavior of masonary wall are obtained. From Fig.4.1. a) The red color in masonry wall shows that earlier failure in masonry wall and blue color shows that slow failure in masonry wall.
- Macro-model analysis of stretcher brick bond pattern is done by using finite element modelling. For the comparison of results other types of brick bonds are required. Other types of brick bond models will be prepared in further progress.
- From above analysis, we conclude that when load is applied of 10000N then maximum stress is at middle of the beam and minimum stress on total surface of masonry wall.

- By varying load about 20000N, one corner of beam shows maximum stress and one shows minimum. Amount of stress about some extent is transferred to the masonry wall.
- By varying load about 30000N, As compared to above result beam shows less stress and wall shows more stress.

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