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Macro-Finite Element Modelling of Dry-Stack Masonry

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Abstract: *The aim of this research work is to simulate the behavior of dry-masonry numerically. Different modelling strategies are available for simulation of the masonry. In this research work, macro-modeling strategy has been used, in which the masonry was treated as a homogeneous, isotropic continuum. A Dry-stack wall was modelled in ABAQUS/CAE and checked for its compressive strength by applying different stories load. The maximum stresses and displacements produced for each story and the effects compared with the single story load.*

Keywords: *Dry-Stack Masonry (DSM), ABAQUS/CAE, Macro-modelling*

I. INTRODUCTION

Conventional masonry is composed of two materials; masonry unit and mortar. Various tests have been performed by many researchers using different load conditions and orientations. Enough literature is available on masonry with different approaches, i.e., uniaxial and biaxial behavior of the masonry. Backes (1985) investigated the uniaxial performance by applying a tensile load parallel to the bed joint. According to the author, two common failure mechanisms occurred; (a) Saw-toothed pattern, (b) straight crack pattern, which purely patterns depends on the combined strength of masonry units and mortar. He concluded that if the strength of the mortar is stronger than the brick unit, then the wall could cracks along the bed joint, i.e., the shear failure and if the case is reversed, then we may have cracks propagation along with the entire panel of the wall including mortar and brick units, i.e., diagonal, corner crushing. Similar behavior of the masonry, subjected to tensile load been observed by Schubert (1988) in both directions to bed joints. While, Binda*et al.* (1988) carried out an experimental study on the wall subjected to compressive load, applied perpendicularly to the mortar joint. The authors concluded that masonry with strong mortar has high stiffness and compressive strength than weaker mortar. Ferretti et al. (2015) has performed uniaxial compressive strength of masonry with respect to the different orientation of bed joints. He concluded that the uniaxial behavior mostly depends on the load applied; therefore, the compressive strength of masonry becomes more significant when the uniaxial load is applied either perpendicular or parallel to the bed joints. This was also observed by Luca *et al.* (2017) during cyclic compressive behavior of an unreinforced masonry wall perpendicular to the bed.Many discrepancies in conventional masonry are due to insufficient properties of mortar. Nowadays, Dry-stack Masonry (DSM) is used in various constructions. DSM is a technique in which interlocking blocks are used as masonry units while no mortar used. The interlocking mechanism works as binding material.

In order to study the compressive behavior of dry-stack masonry, it is necessary to develop numerical techniques. There are two main approaches to numerically model the dry-stack masonryi-e Finite Element modelling and Discrete Element Modeling. Besides, there are three approaches to numerically model structures; Detailed micro-modelling, Simple micro-modelling and Macro-modelling (Lourenco et al. 1996).

Thanoon et al, (2008) studied the uniaxial compressive behavior of interlockingdry-stack concrete masonry prisms, in which mathematical relations were used to model the nonlinear behavior of dryjoints under compression. Mohr–Coulomb criterion was used for interface failure andthe behavior of dry-stack prisms was predicted. The numerical results were shown tocompare well with the experimental response.

This paper is aimed to study the compressive behavior of Dry-Stack Block Masonry Wall using finite element package ABAQUS. Macro-Modelling approach has been used for the analysis, wherein the wall is modelled as a homogeneous material. The subject wall has dimensions of 3 m span x 2.50 m height x 220 mm thickness.

II. FINITE ELEMENT MODELLING

A finite element model is developed in ABAQUS. Various material and geometrical properties are assigned to the model. The Hydraform blocks are available in various strengths, ranging from 5 MPa to 23 MPa (Ngowi 2005).Properties of the 23 MPa block are given in Table 1. The layout of the wall is shown in Fig. 1.

Table 1: Material Properties of the Masonry	
Density (kg/m^3)	2114.44
Compressive strength (MPa)	23
Modulus of Elasticity (N/m^2)	1.993×10^{10}
Poisson Ratio	0.2

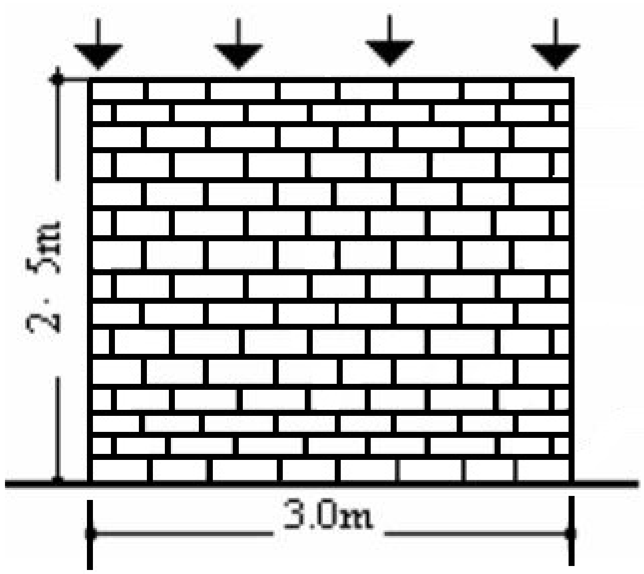

Figure 1: Geometry of the wall

A single story load is applied on the top of the wall, which produces a stress of 344.738 KN/m^2 on the top of the wall.

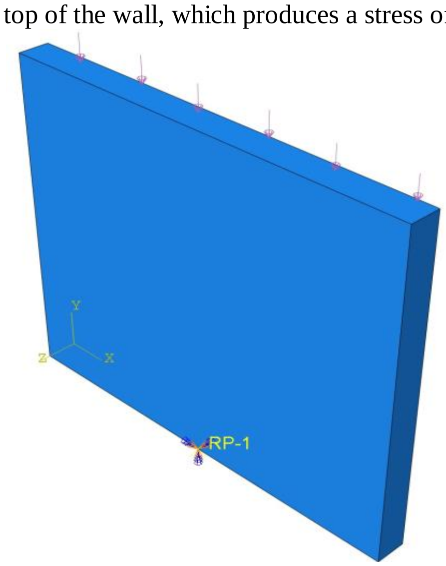

Figure 2: 3D Model with vertical compressive load and B.C

III. RESULTS AND DISCUSSIONS

For each story load, Von-Misses Stresses and Displacements were found out. The Von-Misses stress and displacement at various locations for each story load are shown in Fig. 3 to Fig. 10. The figures suggest that the displacement is zero/minimum at the bottom of the wall, while maximum at the top of the wall.

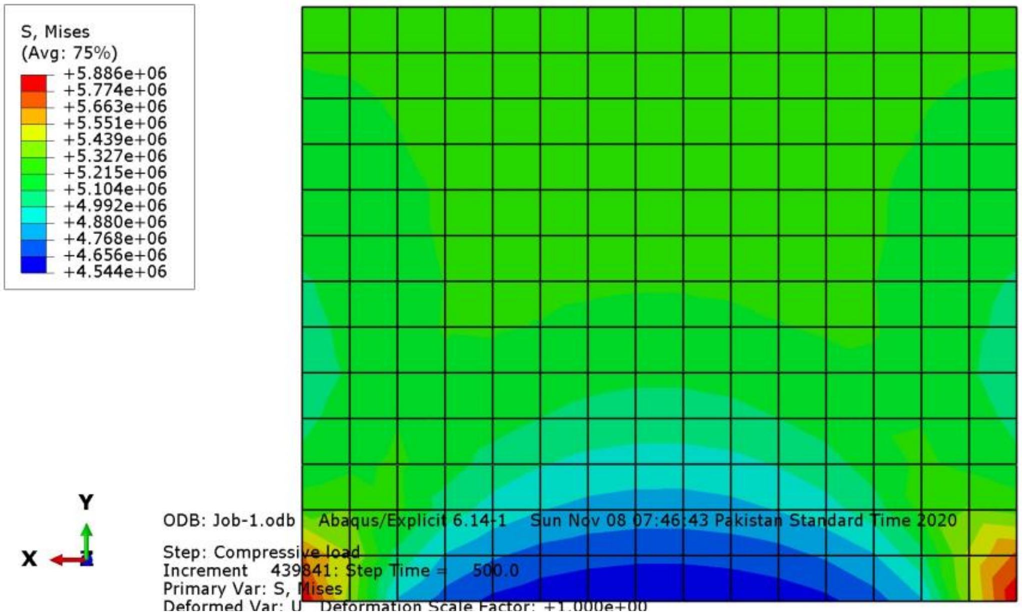

Figure 3: Von Misses Stresses for single story load

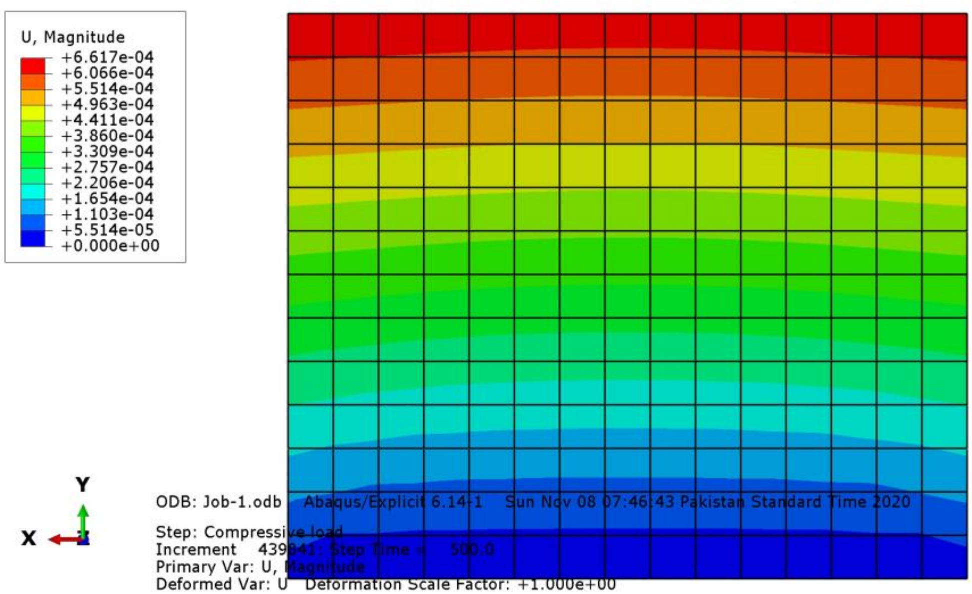

Figure 4: Displacement distribution for single story load

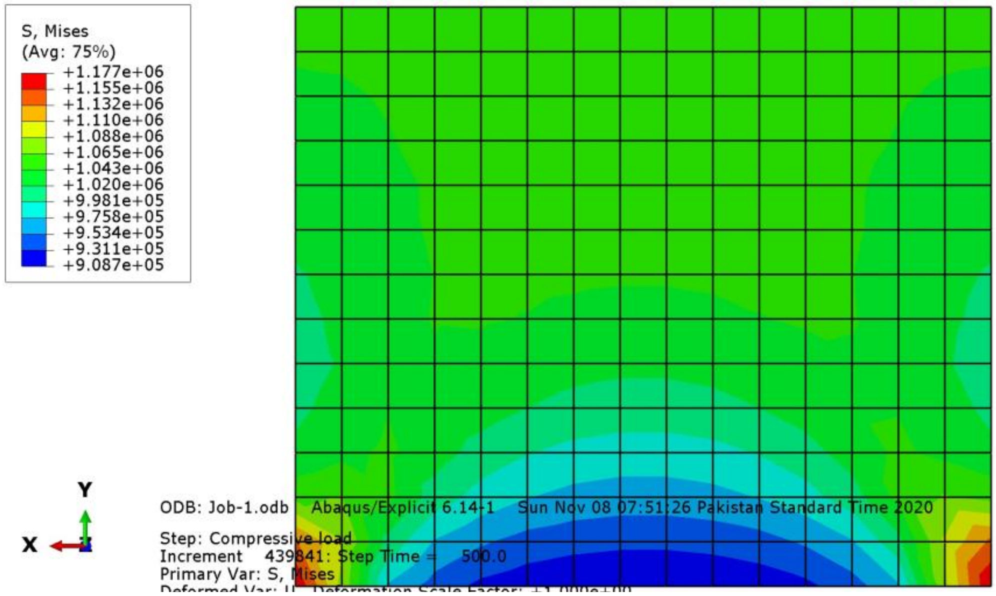

Figure 5: Von-Misses stresses for two-story load

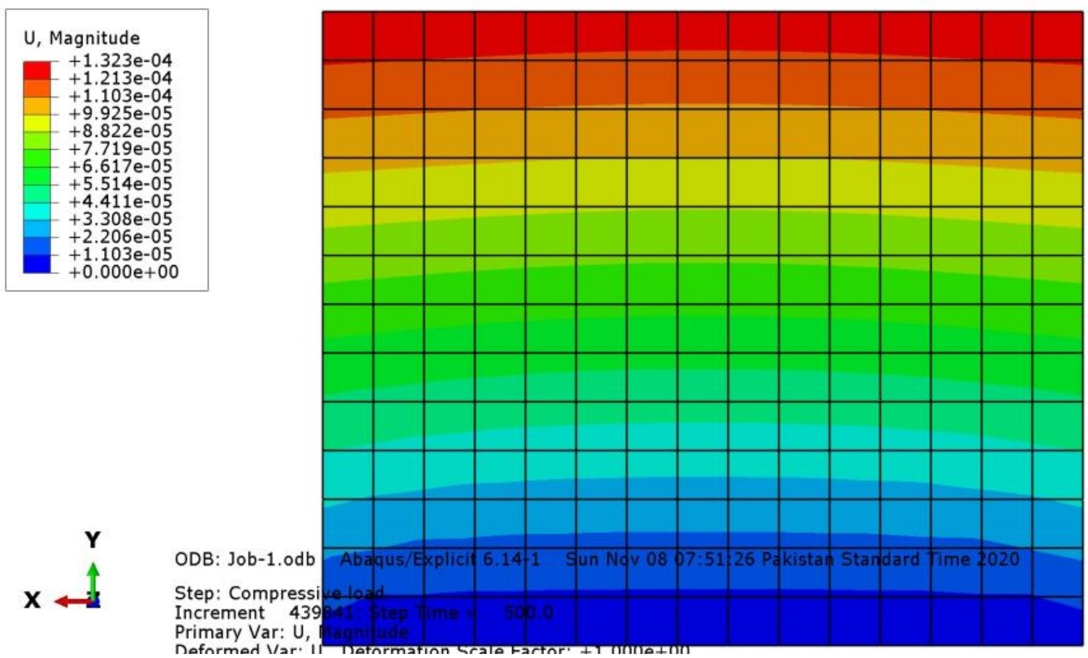

Figure6: Displacement distribution for two-story load

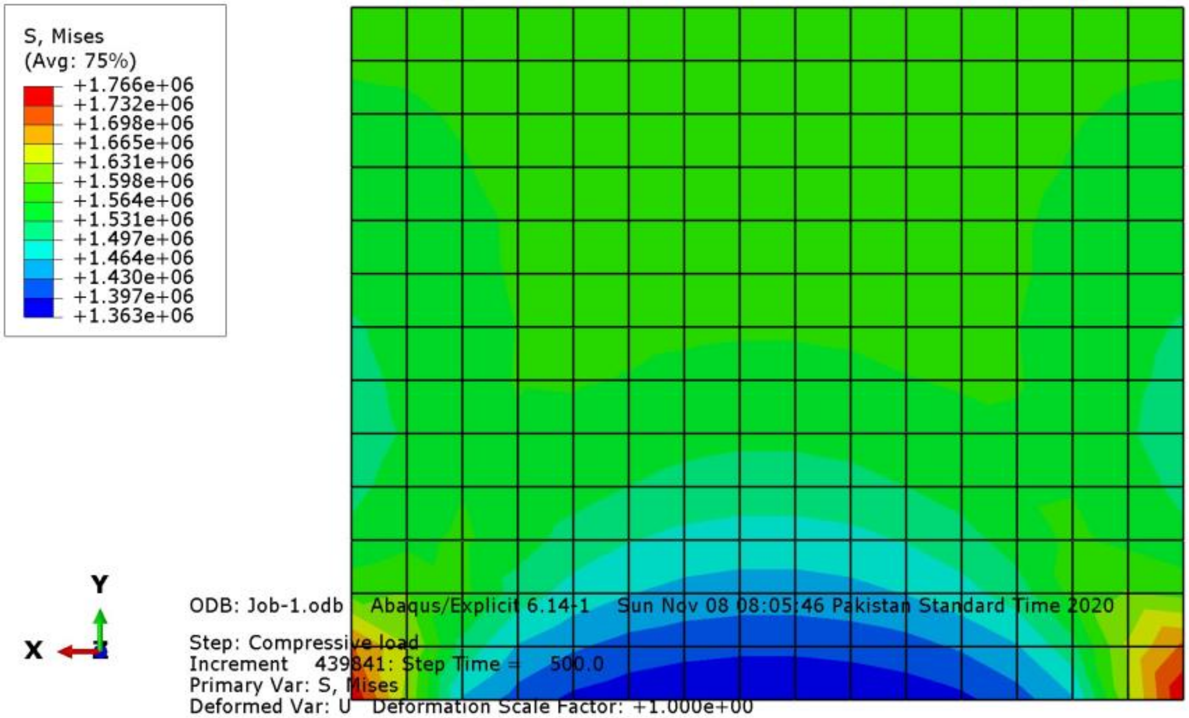

Figure 7: Von-Misses stresses for three-story load

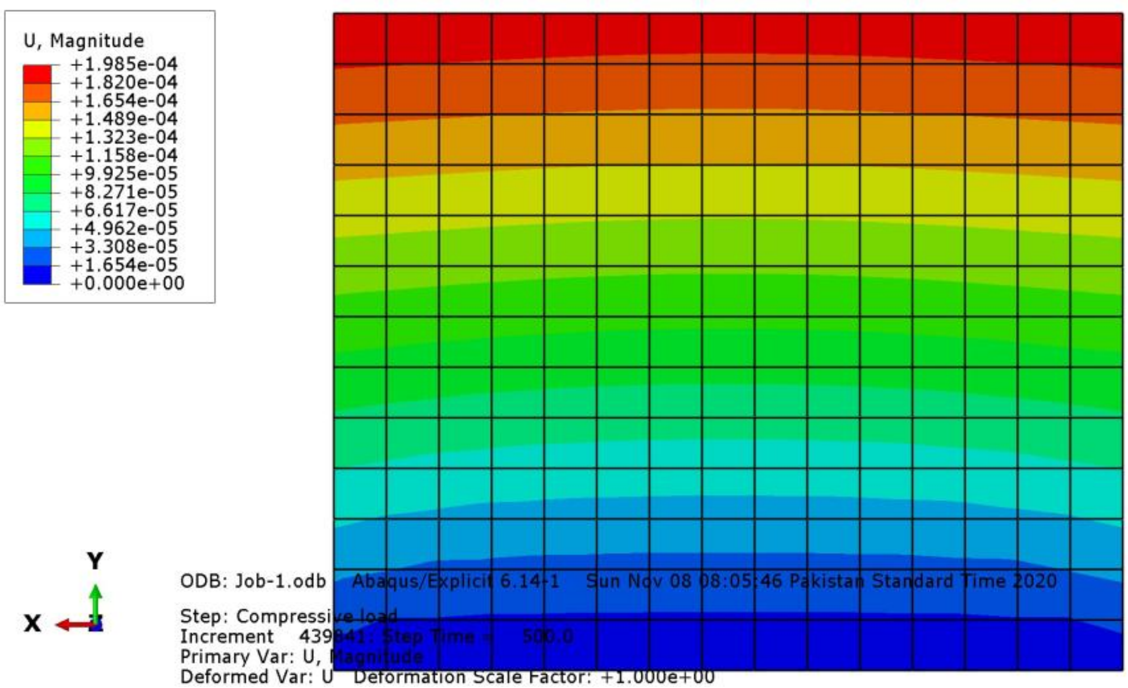

Figure 8: Displacement distribution for three-story load

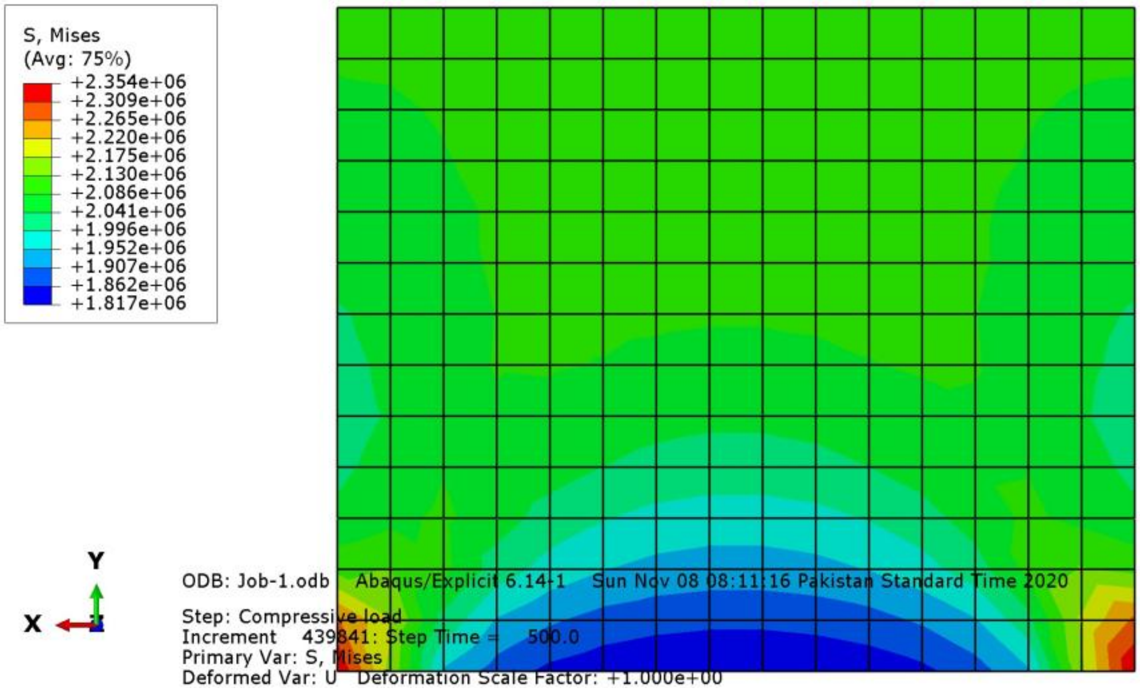

Figure 9: Von-Misses stresses for four-story load

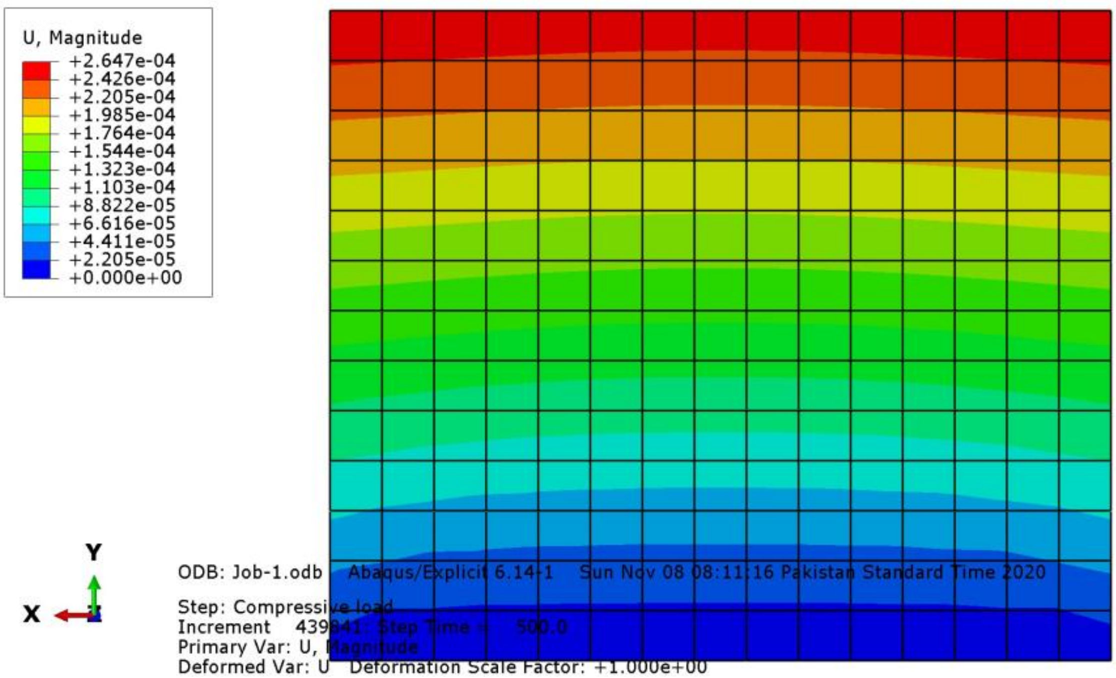

Figure 10: Displacement distribution for four-story load

For each incremental compressive load, the vertical displacement proportionally increases, which is a proof of the statement of Vasconcelos (2005) that the dry masonry behaves elastically under increased vertical compressive loading.

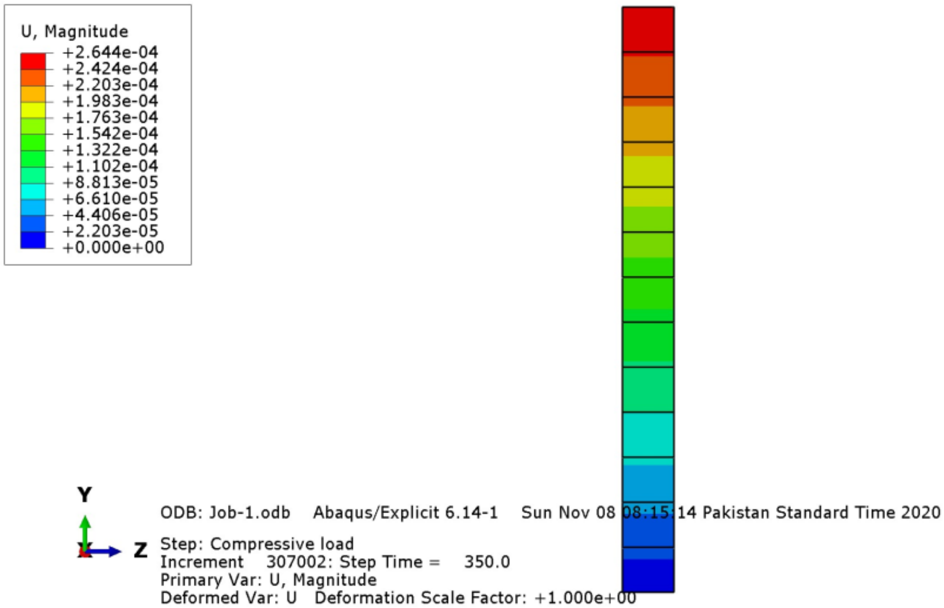

Figure 11: Side View of the wall (no lateral displacement)

IV. CONCLUSIONS

- The model accurately predicted the Stress distribution and displacement contours.
- The stresses are maximum at bottom corners of the wall.
- There is only vertical displacement and no lateral displacement in the model for all loads.
- The Von-Misses stresses distribution is according to the experimental test results.
- Increasing the vertical load causes equal increment in the vertical displacement but lateral displacement is not predicted.

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