Finite element modeling of masonry wall with mortar 1pc : 4 lime : 10 sand under lateral force

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Abstract. This paper gives a detailed presentation of 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, Numerical Results with the Abaqus Software obtained that the magnitude of the load on condition of Plastic is 82.13 KN and experimental results obtained of 81 KN. There is a difference of 1.4%, Based on Abaqus Software with Numerical results obtained a compressive strength of masonry wall f'm = 1.8 MPa with a modulus of elasticity = 150 MPa, Calculation of the natural frequency of structures with Abaqus Software is obtained as the difference of 2.13-2.92% with the test results Hakas (2017)

1 Introduction

When structure receives earthquake, the biggest damage is non-engineering structure. Masonry Wall in their planning are often not calculated. Research on Masonry structure that receives the lateral force has been done, Boen (1994), P2KP (2006) and Siddiq (2004) examined the walls of unfettered with beam column with lateral force to find out an acceptable load by the wall. Hakas (2017) researched the prediction lateral in a plane through changes natural frequency and the damping of the structure of Masonry Wall ½ brick with mortar 1 Pc: 4 Lime: 10 Sand. Satyarno (2008) researched Masonry strength due to static and cyclic load.

The Finite Element Method has been widely used by researchers to analyse Masonry walls, the researchers using the Finite Element Method in analysing Masonry walls such as Stavridis and Shing (2010) used FE to determine the behaviour of concrete brick walls, Mohyeddin et al (2013) modelled by using the ANSYS program, Alchaar (1998) and D'ayala et al (2009) used the ALGOR program to model FE, Stavridis and Shing (2012) modelled concrete brick walls provided with seismic loads.

ABAQUS software has been widely used in the model of finite Element modeling on the Masonry wall. Chen and Zhang (2014) simulate damage to Masonry walls using the Abaqus program. Maeillyta (2012) model the Masonry walls with ABAQUS openings, Moghadam (2010) used the ABAQUS program to model the Masonry walls.

The aims of this research are to comprehensively investigate the behavior of Masonry Walls with ½ brick 1 pc: 4 Lime: 10 sand due to lateral force with (1) 3-dimensional modeling using ABAQUS Software. (2) Find the load and displacement Curve, (3) The compressive strength of masonry wall (4) Find the modulus of elasticity of walls. The results of this modeling are compared with a study conducted by Hakas (2017)

2 Experiment Model

Experiment Model Tests are 1:1 scale Masonry wall with dimensions of 3 x 3 x 0.15 m placed on reinforced concrete slabs. The masonry walls contain concrete frames with beam and column sizes of 0.15 x 0.15 m and there are plastering on both sides with a mortar of 1PC: 4 Lime: 10 sand. With 2 cm thick. The details of the reinforcement can be seen in Figure 1.

Models of Masonry was given lateral load gradually with the stages of loading which can be seen in table 1. Laboratory test was carried out on the structure of the Faculty of civil engineering of GADJAH MADA UNIVERSITY. The test settings can be seen in Figure 2.

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Table 1. Lateral Force apply in Masonry wall (Hakas, 2017)

Load	Load	
	KN	N
Load 1	60.84	60841.60
Load 2	70.25	70249.40
Load 3	90.16	90163.70

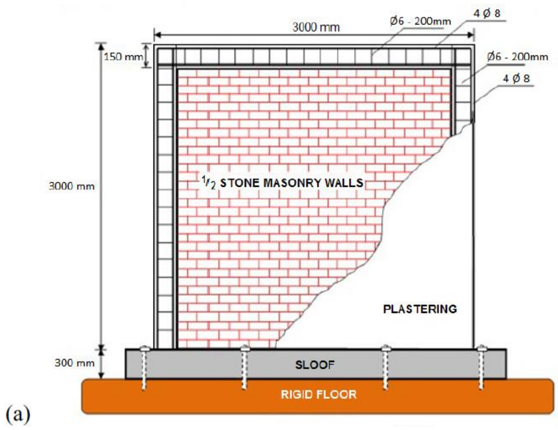

Fig. 1. specimen of the wall (Hakas 2017)

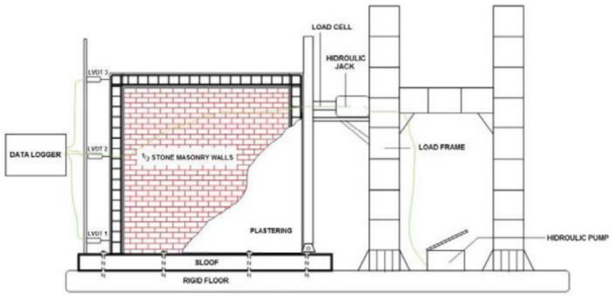

Fig. 2. Experimental set up of Wall (Hakas 2017)

3 Structural Modelling

Masonry walls are modeled using ABAQUS software, geometric details, loads and materials applied to Abaqus software described below:

3.1 Geometric and load modelling

A masonry wall with mortar was modeled with a homogeneous material. Used constrain tie to connect between the Masonry walls and concrete. Reinforcement is modeled using 2 nodes, linear truss element and embedded in concrete material performed, measure displacement is done in line with the lateral load and do unrestrain in some direction of load and restrain in another direction. Figure 3 shows the masses in modeling.

The loading of the Abaqus software is given in accordance with the experimental test results, the lateral force is given at a distance of 50 cm from the top of the masonry wall (See Figure 4).

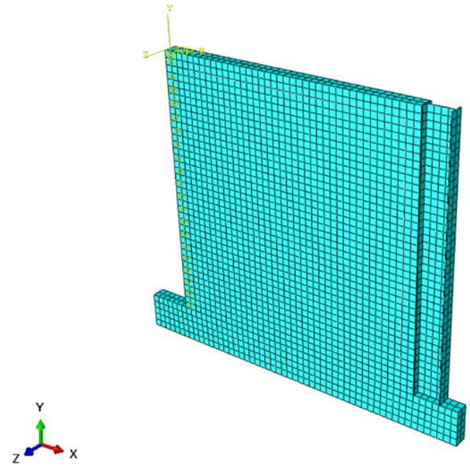

Fig. 3. Masses in modeling of Masonry wall

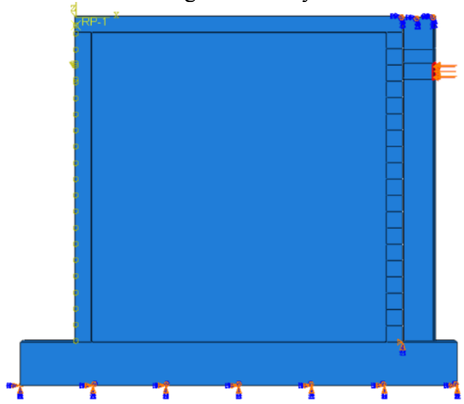

Fig. 4. Apply lateral force in a Masonry wall

3.2 Material in The Abaqus Model

Data Material of concrete and reinforcing used for the modeling in accordance with the results of material testing. Material data used can be explained as follows:

3.2.1 Steel for reinforcement.

Steel for reinforcement used grade U39 for the diameter of 8 and a diameter of 6. Figure 5 shows the results of the tensile test for the diameter of 8 and 6. Other parameters used in steel reinforcement materials are: Density = 7850 kg/m^3, Modulus of Elasticity = 197724.7 MPa, Poisson's ratio = 0.3

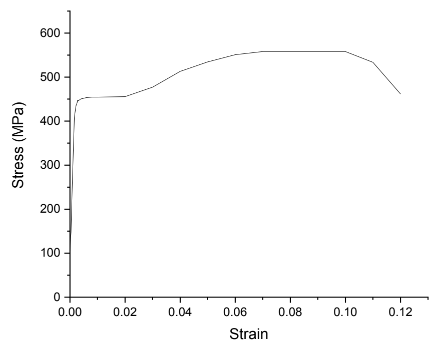

Fig. 5.a. Stress-strain curve diameter 8 mm (Hakas 2017)

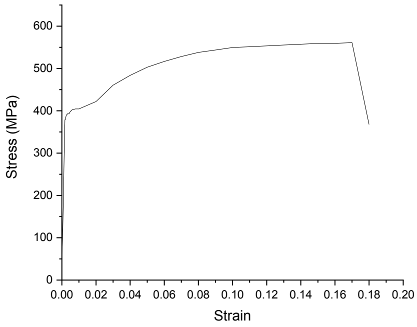

Fig. 5.b. Stress-strain curve diameter 6 mm (Hakas 2017)

3.2.1. Concrete

Concrete used for beams and columns have compressive strength 15.6142 MPa. Stress-strain curve for concrete compressive strength calculated based on BS EN 1992-1-1 and for tensile strength based on Wang and Hsu. (See Figure 6). Other parameters used in concrete are Density = 2400 kg/m^3, modulus of Elasticity = 18569, 46 MPa, Poison Ratio 0.2, Dilation Angle = 30^0, Flow potential eccentricity = 0.1, Ratio of initial equi-biaxial compressive yield stress to initial uni-axial compressive yield stress = 1.16, Ratio of second stress invariant = 0.667, Viscosity parameter = 0.005.

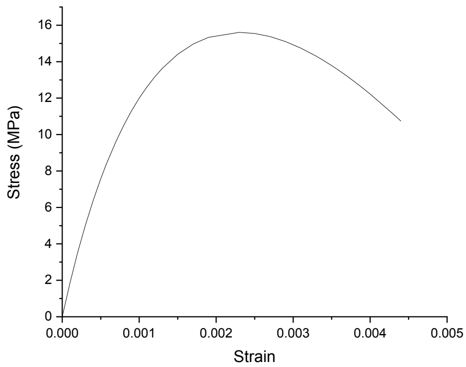

Fig. 6.a. Constitutive model in Abaqus for Compressive strength of Concrete

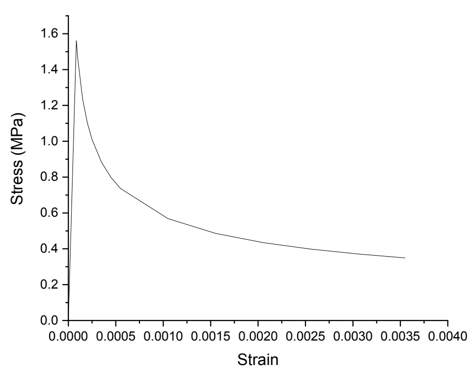

Fig. 6.b. Constitutive model in Abaqus for tensile strength of concrete

3.2.2. Masonry

For the calculation of compressive strength masonry walls using T. Paulay et al (1991). where parameters used are the size of a brick, the distance between the thicknesses of the mortar, compressive strength of brick, compressive strength of mortar. Equations used for calculation are:

$$f'_m = \emptyset\lfloor xf'_p + (1-x)f'_g \rfloor \qquad (1)$$

Where:

$$f'_p = f_y = \frac{f'_{cb}(f'_{tb}+\alpha f'_j)}{U_u\ (f'_{tb}+\alpha f'_{cb})} \qquad (2)$$

Where:
f'm = compressive strength of Masonry Wall (MPa)

For Calculated Modulus of Elasticity masonry wall used Code as shown in table 2

Table 2. Modulus of Elasticity

No	Code	Modulus of Elasticity
1	Euro code 6	Em = 1000 x f'm
2	BS 5328	Em = 900 x f'm
3	Canadian masonry code S304.1	Em = 850 x f'm
4	Paulay and Priestley (1992)	Em = 750 x f'm
5	IBC / MSJC	Em = 700 x f'm
6	FEMA 356	Em = 550 x f'm
7	Drysdale et al. (1994)	Em = 210 x f'm
8	Ni Nyoman Rita R et al (2016)	Em = 153 x f'm
9	Wisnumurti et al (2013)	Em = 144 x f'm

4 Result

4.1 The compressive strength of Masonry Wall

For the calculation of compressive strength masonry walls using T. Paulay et al (1991) with Equation 1 and 2. And the result of compressive strength wall can see at Table 3

Table 3. Compressive strength of masonry walls

Dimension of Brick			Gap of 2 BrickS	Mortar thickness	strength of Brick	strength of Mortar	Stress Non uniformity	Net area Ratio	Height factor			Compression of Masonry Wall
mm	mm	mm	mm	mm	Mpa	Mpa						
L	B	H	a	j	fcb	fg	Uu	x	α	f'p	φ	f'm
202	103.4	43.2	23	23	2.63	1.6	1.5	0.674	0.130	1.365	1.000	1.8

4.1. Modulus of Elasticity Of Masonry

Based on the compressive strength of the Masonry wall then determined the modulus of elasticity masonry wall based on Table 2 and the following results are obtained:

Table 4. Modulus of elasticity masonry wall

No	Code	Modulus elasticity	Fm MPa	Em MPa
1	Euro code 6	1000 x f'm	1.8	1800
2	BS 5328	900 x f'm	1.8	1620
3	Canadian masonry code S304.1	850 x f'm	1.8	1530
4	Paulay and Priestley (1992)	750 x f'm	1.8	1350
5	IBC / MSJC	700 x f'm	1.8	1260
6	FEMA 356	550 x f'm	1.8	990
7	Drysdale et al. (1994)	210 x f'm	1.8	378
8	Ni Nyoman Rita R et al (2016)	153 x f'm	1.8	275.4
9	Wisnumurti et al (2013)	144 x f'm	1.8	259.2

Based on the Compressive strength and elastic modulus of masonry wall then compared with experimental results in the laboratory, Figure 7 shows the comparison of Load-displacement curve with a various modulus of elasticity variance with laboratory test result 90 KN lateral load

Based on Figure 7 it can be seen that the elastic modulus of the experimental results has a lower value compared to the rules contained in Table 4. The difference in the modulus of elasticity is due to the mixture of mortars in experimental specimens having a mixture of low strength. In the study Wisnumurti et al (2013) had mortar with a mixture of 1 PC: 5 Sand, while Ni Nyoman Rita et al (2016) used mortar with a mixture of 1 PC: 5 Sand to 1 PC: 8 Sand. While the mortar used on experimental specimens using mortar with a mixture of 1 PC: 4 Lime: 10 Sand.

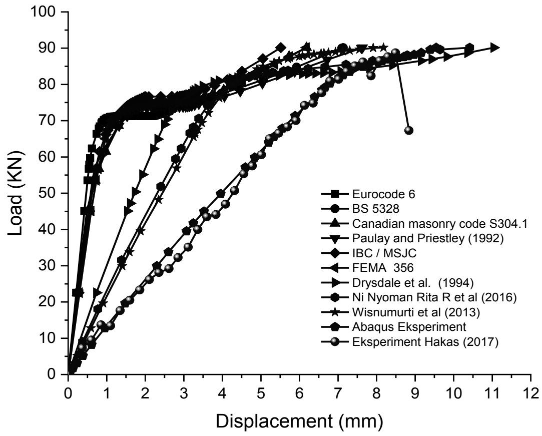

Fig. 7. Load-Displacement with a various modulus of elasticity and experimental with lateral load 90 KN

4.2 Comparison between Finite Element and experimental result

Figure 8 shows the load-displacement ratio between the Abaqus results and the Hakas experiment on the lateral force of 90 KN. From the Figure 9 can be seen that the experimental results of the test object experienced plastic condition at 81 KN load and Abaqus results obtained began to experience plastic conditions at the load 82.13 KN there is a difference of 1.4% between the experimental results and the Abaqus results.

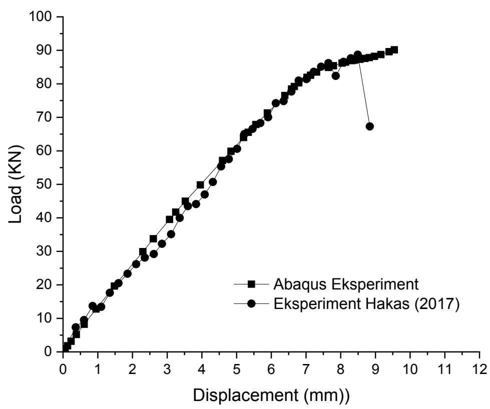

Fig. 8. Load-displacement curve between the Abaqus results and the Hakas experiment on the lateral force of 90 KN

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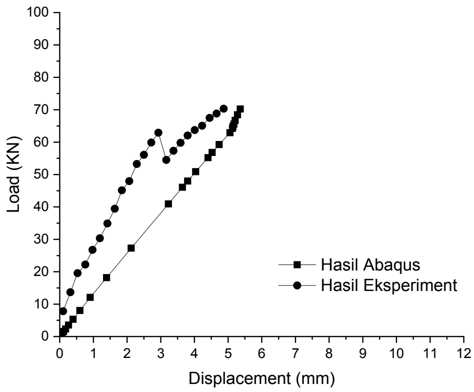

Fig. 9. Load-displacement Curve between the Abaqus results and the Hakas experiment on the lateral force of 70 KN

From Figure 9 we can see that there is a difference between the experimental results and the Abaqus results in the lateral load of 70 KN in this condition because they have slipped at LVDT reading at load 60 KN in this experiment.

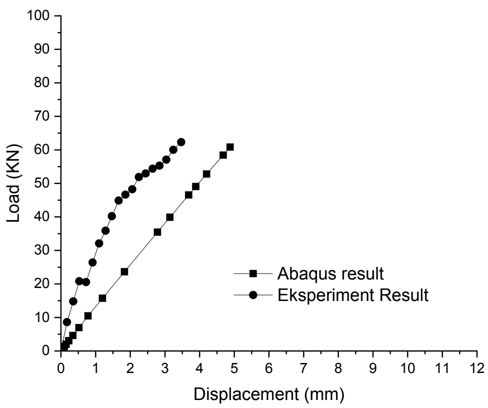

Fig. 10 load-displacement Curve between the Abaqus results and the Hakas experiment on the lateral force of 60 KN

4.2. Natural Frequency

Based on an analysis using Abaqus obtained results defined for some conditions, Figure 11 shows the natural frequency is defined on the structure of a brick wall without Load condition, it can be seen that the greatest frequency is 39, 6255 Hz.

Figure 12 shows a graph of the frequency due to the imposition of 90 KN, of graphs can be seen that the frequency of 33.12 Hz. And Figure 13 shows a graph of the frequency due to the imposition of 70 KN, it can be seen that the natural frequencies of structures are 37.72 Hz, and in Figure 14 are obtained by the natural frequency of 38 Hz with the Load of 60 KN.

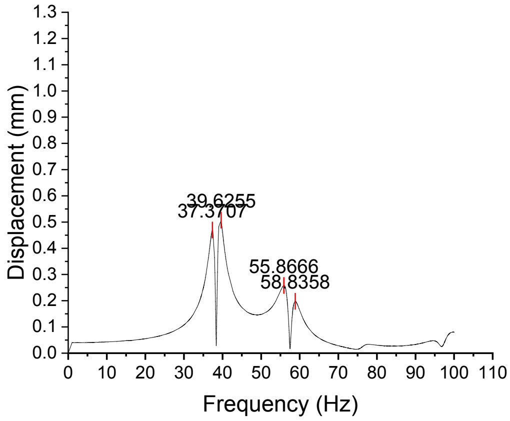

Fig. 11. Frequency-displacement Curve from Abaqus result without load condition

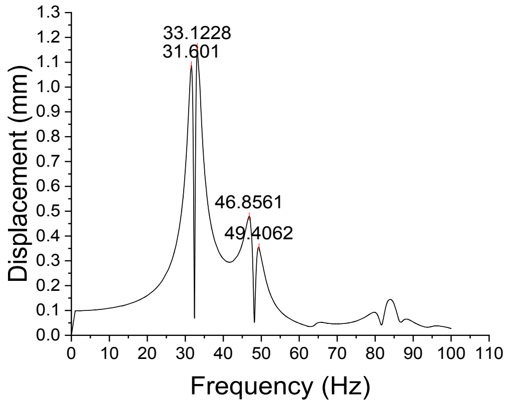

Fig. 12. Frequency-displacement Curve from Abaqus result with load condition 90 KN

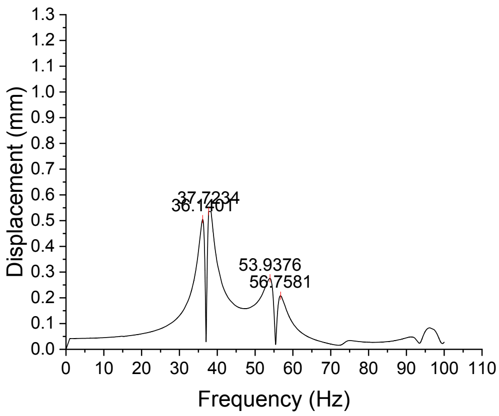

Fig. 13. Frequency-displacement Curve from Abaqus result with load condition 70 KN

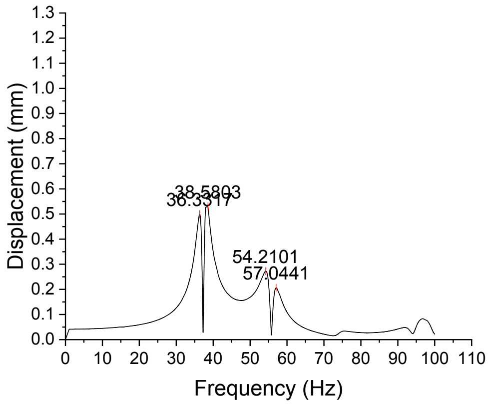

Fig. 14. Frequency-displacement Curve from Abaqus result with load condition 60 KN

If the results are compared with the results of the Abaqus and experiment by Hakas (2017) then the results obtained in Table 5:

Table 5. Natural Frequency of masonry wall

No	Condition	Result		Difference
		Abaqus Software	Eksperiment Hakas (2017)	
		Hz	Hz	%
1	Without Load	39.62	40.58	2.37
2	Load 60,84 KN	38.58	39.74	2.92
3	Load 70.25 KN	37.72	38.68	2.48
4	Load 90.16 KN	33.12	32.43	2.13

Based on Table 5 it can be seen that there is a difference of average 2.47% from Abaqus program results and experimental results Hakas (2017).

5 Conclusions

Based on the results of this research, using integrated modeling Finite Element Models of a masonry wall with the Abaqus software. The obtained results are discussed:

1. The Compressive strength of masonry wall calculations by T.Paulay and Priestley M.J.N and the result is f'm = 1.8 MPa.
2. Based on the results obtained by Numerical Abaqus Software, The elastic modulus of the masonry wall is E = 150 MPa.
3. Results Modulus of elasticity is smaller than the existing code.
4. The numerical model using the Abaqus Software can represent the load-displacement curve of Masonry walls due to lateral forces.
5. Numerical Results with the Abaqus Software obtained that the magnitude of the load on condition of plastics is 82.13 KN and experimental results obtained of 81 KN. There is a difference of 1.4%.
6. Calculation of the natural frequency of structures with Abaqus Software is obtained as the difference of 2.13-2.92% with test results Hakas (2017).

6 References

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