International Journal of GEOMATE, March., 2023, Vol.24, Issue 103, pp.17-25
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2023.103.3325
Geotechnique, Construction Materials and Environment

EXPERIMENTAL STUDY OF FLEXURAL CAPACITY STRENGTH IN-PLANE LOAD ON WALL PANELS USING AUTOCLAVED AERATED CONCRETE BLOCK AND BAMBOO REINFORCEMENT

Endah Tri Puspitasari[1], Sri Murni Dewi[2] and Dan Agoes Soehardjono[3]

[1,2,3]Department of Civil Engineering, Faculty of Engineering, Brawijaya University, Indonesia

*Corresponding Author, Received: 09 April. 2022, Revised: 08 December. 2022, Accepted: 00 May. 2022

ABSTRACT: Concrete wall panels are widely used due to their faster and more efficient application, but they generally have considerable weight. This study will further discuss the flexural capacity of wall panels using autoclaved aerated concrete blocks, and bamboo reinforcement is given in-plane loads. This research was conducted at the Laboratory of Construction Materials and Structures, University of Brawijaya, Malang, Indonesia. Model-scale wall panels with dimensions of 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm, using bamboo reinforcement with dimensions of 10 mm × 10 mm, and light brick type autoclaved aerated concrete as filler to reduce the panel weight were applied. The wall panels were tested for their flexure with in-plane loads at three-point loads. Based on the research results, it can be seen that there were differences in the characteristics of the weight of the wall panels; wall panels using AAC have a lighter weight than wall panels without AAC, with reduction differences of 33.74% for size 40 cm × 80 cm × 3.5 cm and 35.54% for size 60 cm × 120 cm × 5 cm.

Keywords: Light Brick, Bamboo Reinforcement, In-plane Load, Flexural Capacity

1. INTRODUCTION

Walls are an important part of a building. Not only have they planned as space dividers, but they also function to bear building loads, whether they be gravity or earthquake load. It is undeniable that Indonesia is geographically located on the most active earthquake paths in the world. Such a geographical positioning makes Indonesia frequently experience earthquakes. In earthquake-prone areas, it is necessary to pay attention to the use of lightweight building materials so that when an earthquake occurs, the number of casualties caused by the collapse of building materials can be reduced. In a building, the component that is prone to destruction during an earthquake is the wall.

Structural and non-structural walls can be built directly or using a precast system. The advantages of precast walls are that they can be installed quickly, allowing for less execution time and that they have a typical shape and strength. Precast walls are usually lightweight panels that can be spliced. Therefore, to get around this, it is necessary to use lightweight materials such as autoclaved aerated concrete (AAC). Conventional red masonry walls have a specific gravity of 16.67 kN/m^3, which is much heavier than AAC materials, which have a density of 4.9–6.4 kN/m^3 and strength of > 3 Mpa.

The flexural strength of a composite beam with a light brick height of 6.5 cm has a greater strength of 2.4%, which is heavier than a composite beam with a light brick height of 8.5 cm [1]. Other studies have shown that bracing provides additional wall stiffness and strength. In the steel bracing model, the wall strength increased by 13.33%, and the displacement due to the bracing installation on the steel model was 93.34% smaller than in the unbraced steel model. The presence of bracing in the bamboo model increases the strength of the walls by 29.73%, and the displacement of the bamboo model using bracing is 32.23% smaller than the bamboo model without bracing [2]. In this study, the use of autoclaved aerated concrete (AAC) bricks as replacement fill-in at the free space between ribs of grid slabs simplifies the concrete formwork and reduces the overall volume weight by 15% [3].

Walls, as non-structural elements, suffer from severe damage after an earthquake. So far, designers need to pay more attention to the contribution of strength to masonry walls in buildings because the wall-forming material's brittle nature results in low strength. Some of the significant reasons to conduct this research are related to damage patterns, hook systems, and loading mechanisms on masonry walls to withstand earthquake loads in the in-plane and out-of-plane directions [4]. In this study, AAC and bamboo were used as materials for panels that can function as precast walls, doors, or shutters. The panels were tested under in-plane loads. The output to be achieved through this research is the engineering of a concrete wall panel model containing AAC.

1.1 Wall Panels

Walls are the vertical part of a building that serves to limit a space from other spaces and function as a load recipient. There are three types of walls, namely:

1. Structural walls, which serve as building structures;
2. Non-structural walls, which do not support the load and only serve as barriers; if these walls are torn down, the building will remain standing; and
3. Partition or insulation walls, which provide vertical boundaries in a room.

Wall panels are one of the non-structural components of a construction building that are made from unitary blocks of partial walls assembled into solid walls. Precast wall panels can be conventionally reinforced or prestressed for greater structural efficiency, which can reduce panel thickness and increase span length. Precast wall panels can serve as support walls with the ability to support a cast-in-place concrete or steel floor and roof system.

1.2 Concrete

The compressive strength of concrete is the ability of concrete to accept axial compressive forces per unit area and is expressed in MPa or N/mm^2. The test method used is to gradually apply a compressive load to a test object until the test object is crushed [5].

$$\boldsymbol{f'_c = \frac{P}{A}(\mathrm{N/mm^2})} \quad (1)$$

1.3 Light Brick of AAC

Autoclaved aerated concrete (AAC) is a novel building material, one of the most suitable and sustainable in the present building construction industry. AAC blocks have resulted from the productive use of recycled industrial waste, e.g., fly ash; hence, this material can be classified as a sustainable building material. The inherent properties of AAC blocks result in fast and efficient construction techniques. Hence, autoclaved aerated concrete (AAC) has become an efficient building construction material that is applicable to a wide range of residential, commercial, and industrial buildings, and it has been used in the Gulf countries for the last 40 years, in Europe for 70 years, and in Australia and South America for the past 20 years. Since they are readily available as raw materials or a manufacturing process, have excellent durability, are energy-efficient, are cost-effective, and are recyclable, it is fair to say that autoclaved aerated concrete (AAC) blocks are green and sustainable building materials [6].

Light bricks of AAC (Autoclaved Aerated Concrete) are aerated concrete, where air bubbles are produced by a chemical reaction. The AAC mixture generally consists of quartz sand, cement, lime, a little gypsum, water, and aluminum paste as a developer (chemical air filler). In general, the weight of a lightweight concrete brick is 5.88–15.69 kN/m^3 [7]. A perfect bond between brick units and mortar is crucial in the masonry wall. The bond strength becomes significantly important when the masonry is subjected to in-plane and out-of-plane loadings during seismic tremors [8]. The vulnerability of existing masonry buildings can be decreased considerably by employing efficient retrofitting methods. The earthquake behavior of masonry structures can be improved by simple strengthening techniques [9].

In this study, the lightweight concrete bricks used have a density of about 7.85 kN/m^3, with a strength of 4 MPa, and function as panel filler with bamboo reinforcement.

1.4 Bamboo Reinforcement

In a recent development, bamboo has been processed into some sort of reinforcement bars of various sizes, which may be used instead of conventional steel bars [10, 11]. For lightweight reinforced concrete Àexural structures, bamboo bars are suitable for reducing weight and cost. The tensile strength of bamboo is relatively high, which can reach 370 MPa. This makes bamboo a suitable alternative to steel in tensile load applications. The ratio of tensile stress to the specific weight of bamboo is six times greater than that of steel [12]. Although bamboo has a fairly large tensile strength, maintenance is a must.

Application of treatment to bamboo, such as coating with a waterproof layer, aims to prevent absorption between bamboo reinforcement and concrete. Meanwhile, the sand coating is carried out to roughen the surface of the bamboo reinforcement so as to prevent slippage between the reinforcement and the concrete.

1.5 Loading on Panels

When the structure is thin, and the external load acting in its direction is in the plane of the structure, this condition is called plane stress. In this condition, the values of the stress components σ_z, τ_{zx}, and τ_{zy} are very small compared to other components. Thus, they are considered 0 (zero). Meanwhile, the stress components that must be taken into account are σ_x, σ_y, τ_{xy} [13].

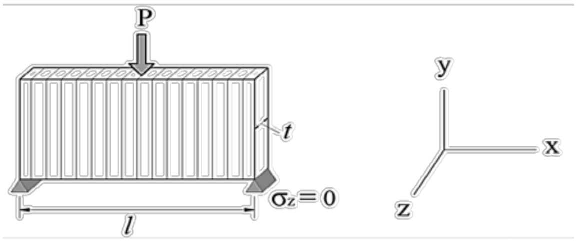

Fig.1 In-plane Loading Modeling

Figure 1 shows that the in-plane loading modeling, or what is better known as plane stress condition, is the provision of a force that works parallel to the wall against the strong axis of the wall so that this force has more strength than the out-of-plane lateral force because the out-of-plane lateral force is a force that works parallel to the wall against the axis weak wall [14].

1.6 Crack-stress of cement composites

Considering the homogeneous nature of the cement composite, the crack stress in flexure can be obtained in the elastic range as [15]

$$\boldsymbol{\sigma_{cr}} = \frac{\boldsymbol{L\,t\,P_{cr}}}{\boldsymbol{12\,I}}(\mathbf{N/mm^2}) \quad (2)$$

2. RESEARCH SIGNIFICANCE

Wall panels can be used as partition walls for houses, high-rise buildings, commercial buildings, basement wall coverings, retaining covers for underpasses and flyover buildings, guardrails on toll roads, and so forth. In this study, in addition to trying to reduce the weight of wall panels, the researchers intended to make wall panels that have more strength to withstand in-pane loads by using environmentally friendly materials. Therefore, the researchers took an interest in conducting an experimental study of the flexural strength of in-plane wall panels using autoclaved aerated concrete blocks and bamboo reinforcement.

3. METHODOLOGY

3.1 Panel Description

The design parameters used in this study are as follows:

1. Wall panels sized 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm with bamboo reinforcement with and without the addition of AAC. The details of bamboo-reinforced wall panels with AAC and without AAC can be seen in Fig. 1 and Fig. 2, and the specification of the test object can be seen in Table 1.

Table 1 Specification of the test object

Specimen	Dimension (cm)	Amount
WAAC 1 1D WAAC 2 1D WAAC 3 1D	40 × 80 × 3.5	3 units
WAAC 1 2D WAAC 2 2D WAAC 3 2D	60 × 120 × 5	3 units
NAAC 1 1D	40 × 80 × 3.5	1 unit
NAAC 1 2D	60 × 120 × 5	1 unit

2. The quality of concrete and mortar was f'c > 5 MPa.
3. The bamboo main reinforcement used was 5D10.
4. The tensile stress of the bamboo reinforcement was in accordance with the tensile test of the reinforcement, following the regulations/ standards for testing reinforcing steel.
5. The test was carried out after the age of the wall panels reached 28 days.
6. The test was carried out with simple support of roller joints and with a load of 1 point in the middle of the span to facilitate the calculation analysis.
7. Panels were labeled according to their composition. Specimens with AAC were labeled WAAC, and specimens without AAC or with no AAC were labeled NAAC.

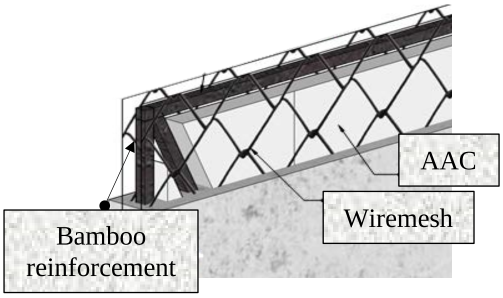

Fig.2 The details of bamboo-reinforced wall panels with AAC

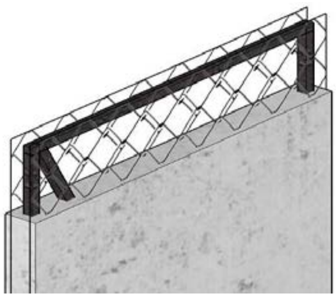

Fig.3 The details of bamboo-reinforced wall panels and without AAC

3.2 Research Program

The flexural strength test on wall panels used a loading frame and a deflection measuring instrument in the form of LVDT. Some of the research activities carried out in laboratory tests were as follows:

1. Take the test object from the treatment place after 28 days.
2. Putting the test object on a loading frame centrally.
3. Installing the LVDT at a specified location and then setting the reading.
4. The test begins with the constant application of vertical axial load on a hydraulic jack.
5. Performing the above steps according to the number of test objects to be examined.
6. Doing analysis and closing stage.

3.3 Testing Set-Up

Based on the ideas mentioned in the previous discussion section, the researchers attempted to visualize the plan for setting up the testing of the test object that was to be carried out. According to Figure 4, the test was carried out using a three-point flexural test model. Supports in the form of roll joints were installed with a distance between supports of 70 cm, leaving 5 cm to the edge of the panel sized 40 cm × 80 cm × 3.5 cm, and with a pedestal distance of 110 cm, leaving 5 cm to the edge of the panel sized 60 cm × 120 cm × 5 cm, in anticipation of expected collapse in the form of a flexural collapse in the middle of the span. The vertical LVDT mounted below the mid-span was used to read the deflection when a load was applied. Between the hydraulic jack and the load distributor, a load cell was installed as a reader of the load that was applied to the panel.

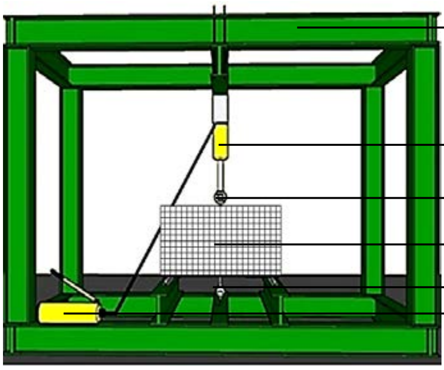

Fig.4 Plan of testing setting up

4. RESULTS AND DISCUSSION

4.1 Panel Test Object

The average weight of wall panels that are with AAC and sized 40 cm × 80 cm × 3.5 cm is 159.16 N or 81.10 N lighter than wall panels that are without AAC but with the same size, that is, 240.26 N. Meanwhile, wall panels that are with AAC and sized 60 cm × 120 cm × 5 cm is 409.92 N or 226.04 N lighter than wall panels that are without AAC but with the same size, that is, 635.96 N. This shows that the weight of the bamboo-reinforced wall panels with AAC is lighter than the normal panels with bamboo-reinforced concrete composition without AAC, with a percentage reduction of 33.74% for the size 40 cm × 80 cm × 3.5 cm and 35.54% for the size 60 cm × 120 cm × 5 cm. The results of the weight testing panels can be seen in Table 2.

4.2 Cylinder Compressive Strength

Testing of cylinder compressive strength was carried out to obtain the concrete quality value shown in Table 3. The average cylinder compressive strength for concrete is 9.74 MPa.

Table 2 The results of the weight testing panels

Specimen	Dimension (cm)	Weight (N)	Remarks
WAAC 1TL	40 × 80	155.93	AAC Panel
WAAC 2TL	40 × 80	163.77	AAC Panel
WAAC 3TL	40 × 80	157.89	AAC Panel
NAAC 1TL	40 × 80	240.26	Control Panel
WAAC 1TL	60 × 120	397.17	AAC Panel
WAAC 2TL	60 × 120	403.54	AAC Panel
WAAC 3TL	60 × 120	429.04	AAC Panel
NAAC 1TL	60 × 120	635.96	Control Panel

Table 3 The results of the cylinder compressive strength test

Specimen	Weight (N)	Load (kN)	*f'c* (Mpa)
Cylinder 1	16.67	30.00	5.97
Cylinder 2	18.14	62.00	12.33
Cylinder 3	17.65	48.00	9.55
Cylinder 4	17.16	56.00	11.14
Average	17.41	49.00	9.74

4.3 Results of Panel Testing

Testing results revealed that wall panels without AAC with a size of 40 cm × 80 cm × 3.5 cm and specimen code NAAC 1TL 1D were able to accept a crack load of 19.61 kN, while wall panels with AAC and specimen codes WAAC 1TL 1D, WAAC 2TL 1D, and WAAC 3TL 1D were able to accept crack loads of 8.83 kN, 10.30 kN, and 4.90 kN, respectively, so that the average crack load capacity test result is 8.01 kN. This shows that the crack load capacity of wall panels with AAC is still lower than that of wall panels without AAC, with the latter having 144.89% of the crack load capacity of the former for the same size, namely, 40 cm × 80 cm × 3.5 cm.

The test results also revealed that wall panels without AAC with a size of 60 cm × 120 cm × 5 cm and specimen code NAAC 1 TL 2D were able to accept a crack load of 19.61 kN, while panels with AAC and specimen codes WAAC 1 TL 2D, WAAC 2 TL 2D, and WAAC 3 TL 2D were able to receive crack loads of 11.77 kN, 10.79 kN, and 10.79 kN respectively. Thus, the average result of the crack load capacity test on wall panels with AAC in size 60 cm × 120 cm × 5 cm is 11.11 kN. This shows that the crack load capacity of wall panels with AAC in size 60 cm × 120 cm × 5 cm is also still lower than that of wall panels without AAC, with the latter having 106.12% of the crack load capacity of the former.

The results of the in-plane loading testing on 40 cm × 80 cm × 3.5 cm panels can be seen in Fig. 5, and the results of the in-plane loading testing on 60 cm × 120 cm × 5 cm panels can be seen in Fig. 6

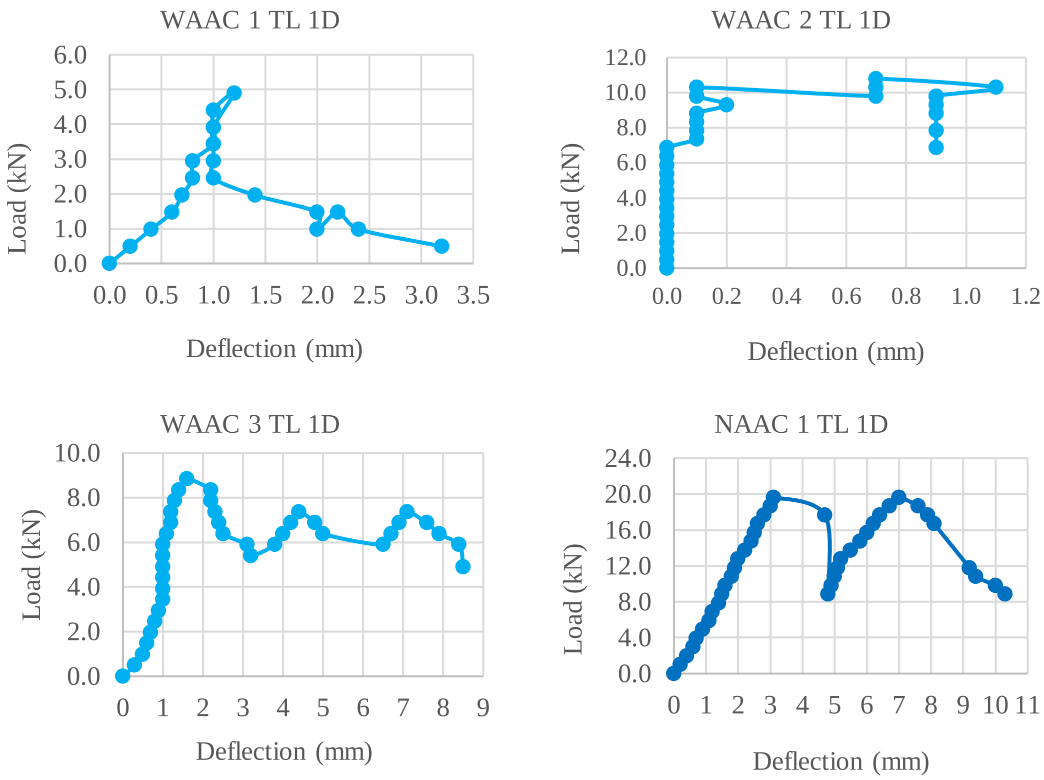

Fig.5 The results of the in-plane loading testing on a 40 cm × 80 cm × 3.5 cm panels

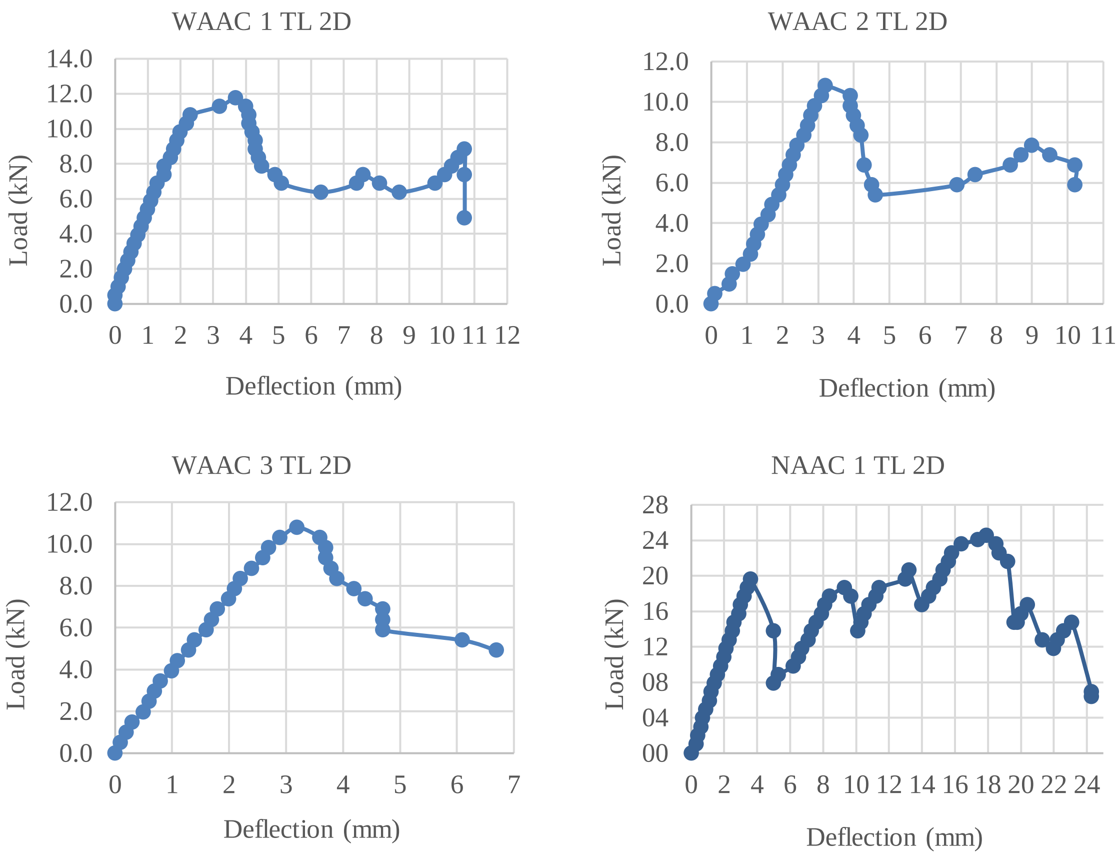

Fig.6 The results of the in-plane loading testing on a 60 cm × 120 cm × 5 cm panels

4.4 Results of Panel Analysis Calculation

The panel analysis calculation was modeled into strut (press) and tie (tensile) elements. The strut element in the strut and tie model is an idealization of the concrete compressive stress field, where the strut is in the same direction as the concrete compressive stress. The tie element may be a single or a collection of reinforcement or a group of well-anchored prestressing tendons. Furthermore, it is assumed that the reinforcement will experience yielding at the ultimate limit state.

The calculation of the crack load capacity of wall panels with AAC and wall panels without AAC in sizes 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm when modeled in the strut and tie method is depicted in Fig. 7.

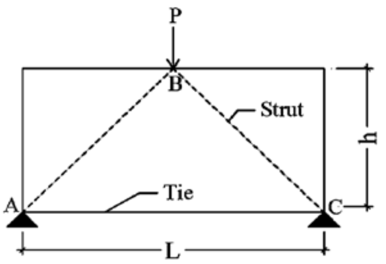

Fig.7 Strut and tie method panel analysis modeling

The analysis of crack loads that can be accepted by panels sized 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm, both with and without AAC, and applied to the middle of the span in-plane under the strut and tie method can be seen in Table 4 and Fig. 8.

Table 4 The results of panel analysis using the strut and tie method

Specimen	Pcr (kN)	
	Analysis Result	Test Result
NAAC 1D	18.36	18.63
WAAC 1D	18.36	4.25
NAAC 2D	18.69	18.63
WAAC 2D	18.69	10.46

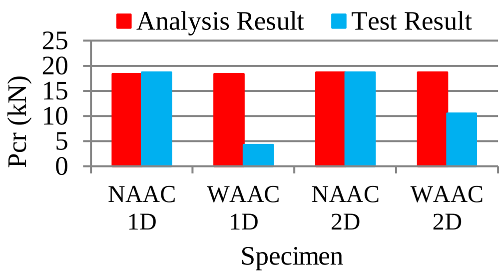

Fig.8 Graph of comparison on the value of crack load between the analysis result and testing

4.5 Panel Flexural Strength Analysis

The calculation of flexural strength from the panel test results in panels without AAC in size 40 cm × 80 cm × 3.5 cm resulted in an increase of 1.49% from the analysis with the strut and tie method. It is in contrast to the calculation of flexural strength of the panel test results in panels with AAC in size 40 cm × 80 cm × 3.5 cm that resulted in a decrease of 76.85% from the analysis with the strut and tie method. Meanwhile, the calculation of flexural strength of the panel test results in panels without AAC in size 60 cm × 120 cm × 5 cm resulted in a decrease of 0.26% from the analysis with the strut and tie method, and the calculation of flexural strength of the panel test results in panels with AAC in size 60 cm × 120 cm × 5 cm resulted in a decrease of 44.01% from the analysis with the strut and tie method, as shown in Table 5 and Fig. 9.

Table 5 The results calculation of panel flexural strength

Specimen	Flexural Strength (MPa)	
	Analysis Result	Test Result
NAAC 1D	40.12	40.714
WAAC 1D	40.12	9.299
NAAC 2D	19.05	40.714
WAAC 2D	19.05	10.667

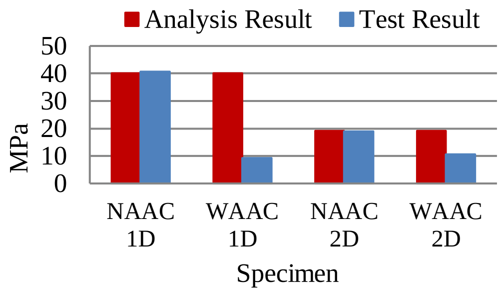

Fig.9 Graph of comparison on calculation results of panel flexural strength

4.6 Panel Crack-Stress Of Cement Composites

The crack stress in bending can be obtained in the elastic range of the panel. The calculation of the crack stress on panels without AAC in sizes 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm resulted in decreases of 21.05% and 20.67%, respectively, from the analysis with the strut and tie method. In the same vein, the calculation of the bending stress on panels with AAC in sizes 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm also resulted in decreases of 7.12% and 17.21%, respectively, from the analysis with the strut and tie method, as shown in Tables 6 and Fig. 10.

Table 6 The results calculation of panel crack-stress in flexure

Specimen	Crack stress (MPa)	
	Analysis Result	Test Result
NAAC 1D	0.000230	0.000048
WAAC 1D	0.000082	0.000006
NAAC 2D	0.000501	0.000104
WAAC 2D	0.000180	0.000031

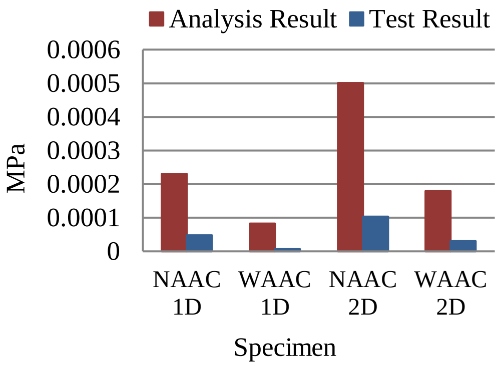

Fig.10 Graph of comparison on calculation results of panel crack-stress in flexure

4.7 Ductility

Panels with AAC that measured 40 cm × 80 cm × 3.5 cm obtained an average crack load (Pcr) when they were loaded at 1.96–5.88 kN and experienced an average deflection of 0.00–1.00 m. Meanwhile, panels measuring 60 cm × 120 cm × 5 cm were found to experience cracks when receiving a load of 9.81–10.79 kN, with a deflection of 2.30–2.90 mm. Thus, it can be concluded that panels can receive a greater load to reach a crack in a larger plane. The amount of deflection that occurred in the wall panel when it was given a constant in-plane load can be seen in Table 7. The ductility of wall panels with AAC and without AAC that was given initial loading until the peak load was achieved is summarized in Table 7. Panels with a size of 60 cm × 120 cm × 5 cm have better ductility than that panels with a size of 40 cm × 80 cm × 3.5 cm, with a difference in ductility of 0.139 or 10.70% between both. Wall panels with AAC have a higher amount of ductility increase than that panels with AAC. It was found that 40 cm × 80 cm × 3.5 cm panels and 60 cm × 120 cm × 5 cm had increases of 39.17% and 22.69% in ductility, respectively.

Wall panels with AAC and without AAC in sizes 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm had different forms of crack shapes when given loads, which can be seen in Fig. 11 and Fig.

Table 7 The ductility of wall panels on deflections of P Crack and P Ultimate

Specimen	Deflection (cm)		Ductility	Average Ductility	Percentage on control panel ductility
	Crack	Ultimate			
NAAC 1 TL 1D	3.00	3.10	1.033	1.033	
WAAC 1 TL 1D	0.70	1.20	1.714		
WAAC 2 TL 1D	0.10	0.10	1.000	1.438	139.17%
WAAC 3 TL 1D	1.00	1.60	1.600		
NAAC 1 TL 2D	3.40	3.60	1.059	1.059	
WAAC 1 TL 2D	2.30	3.70	1.609		
WAAC 2 TL 2D	2.90	3.20	1.103	1.299	122.69%
WAAC 3 TL 2D	2.70	3.20	1.185		

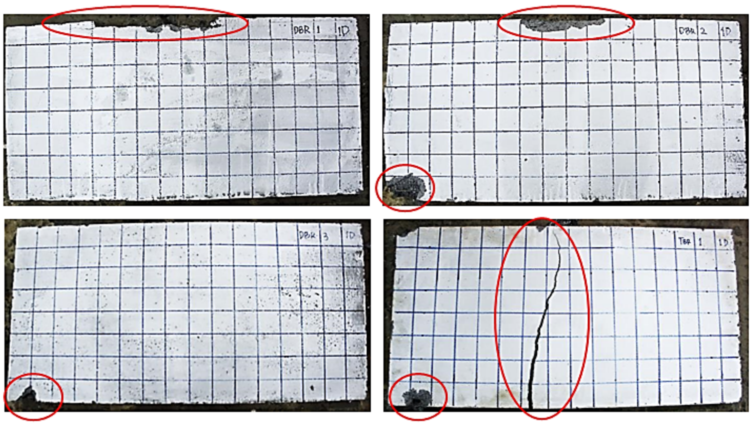

Fig.11 The different forms of crack shapes when given loads on wall panels with AAC and without AAC in size 40 cm × 80 cm × 3.5 cm

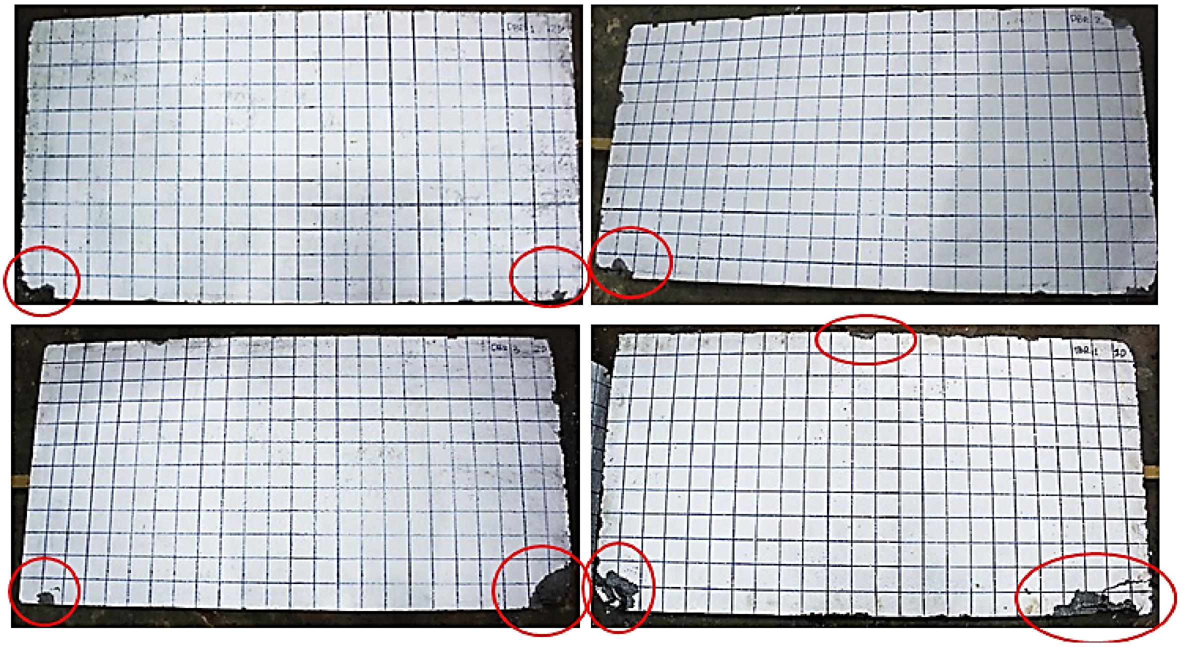

Fig.12 The different forms of crack shapes when given loads on wall panels with AAC and without AAC in size 60 cm × 120 cm × 5 cm

5. CONCLUSIONS

Based on the research results, the conclusions drawn are provided below:

1. The weight of bamboo-reinforced wall panels with AAC is lighter than wall panels without AAC, with the percentage reduction reaching 33.74% for the size 40 cm × 80 cm × 3.5 cm and 35.54% for the size 60 cm × 120 cm × 5 cm.
2. Test results for the wall panel size 40 cm × 80 cm × 3.5 cm showed that wall panels without AAC have 144.89% the crack load capacity of wall panels with AAC. Meanwhile, test results for the wall panel size 60 cm × 120 cm × 5 cm showed that wall panels without AAC have 106.13% of the crack load capacity of wall panels with AAC.
3. The calculation of flexural strength of panels without AAC in size 40 cm × 80 cm × 3.5 cm resulted in an increase of 1.49% from the analysis with the strut and tie method, while that of panels without AAC in size 60 cm × 120 cm × 5 cm resulted in a decrease of 0.26% from the analysis with the strut and tie method. In contrast, the calculation of flexural strength of panels with AAC in sizes 40 cm × 80 cm × 3.5 cm and 60 cm × 120 cm × 5 cm both resulted in decreases of 76.85% and 44.01%, respectively, from the analysis with the strut and tie method.
4. The ductility of 40 cm × 80 cm × 3.5 cm panels increased by 39.17%, and that of 60 cm × 120 cm × 5 cm panels did by 22.69%; it can be concluded that the panel with AAC is more ductile than the panel without AAC.

6. ACKNOWLEDGMENT

The authors would like to thank Brawijaya University Through the Ministry of Research Technology and Higher Education Grant for its financial support and the staff of the Civil Engineering Construction Materials and Structures Laboratory, Faculty of Engineering, Brawijaya University, Malang, East Java – Indonesia for their supports.

7. REFERENCES

[1] Prasetyo, F. S., Dewi, S. M., Simatupang, R. M. The Bending Strength of Composite Beams Of Concrete and Light Brick Bamboo Reinforcement with Variations in Height Lightweight Brick, 2016, Malang : Universitas Brawijaya. Jurnal Rekayasa Sipil / Volume 1, No. 2 – 2016 ISSN pp.466-474

[2] Susanti, L., Dewi, S. M., Nurlina, S. The Effect of Bracing on Walls of Masonry Bricks on Earthquake Response, 2011, Malang : Universitas Brawijaya. Jurnal Rekayasa Sipil / Volume 5, No.1 – 2011 ISSN 1978 – 5658 pp.19-28

[3] Dewi, S. M., Hasyim, H., Susanti, L., et al. Precast Concrete Flat Slab with Autoclaved Aerated Concrete, 2022. AIP Conference Proceedings 2489, 020005 pp.1-6

[4] Teguh, M., and Rahmayanti, N., Flexural Behavior of Confined Masonry Walls using Interlocking Concrete Blocks Subjected to Out-

Of-Plane Loads, 2021. International Journal of GEOMATE, May., 2021, Vol.20, Issue 81, pp.179-184

[5] National Standard of Indonesia. Method of Testing the Compressive Strength of Concrete with Cylindrical Test Objects, 2011. Jakarta: National Standardization. SNI 1974-2011 pp.1-15

[6] Kamal, M. A., Analysis of Autoclaved Aerated Concrete (AAC) Blocks with Reference to its Potential and Sustainability, 2020. Research Gate Publication. ISSN 2353-0057, EISSN : 2600-6936 pp.76-86

[7] National Standard of Indonesia. Procedure for the Plan of Making Lightweight Concrete Mixtures with Light Aggregates, 2002. Jakarta: National Standardization SNI 03-3449-2002 pp.1-32

[8] Raj, A., Borsaikia, A. Ch., Dixit, U. S., Bond Strength of Autoclaved Aerated Concrete (AAC) Masonry using Various Joint Materials, 2020. ScienceDirect: Journal of Building Engineering 28, 101039 pp.1-10

[9] Arslan, M. E., Celebi, E., An Experimental Study on Cyclic Behavior of Aerated Concrete Block Masonry Walls Retrofitted with Different Methods, 2019. ScienceDirect: Construction and Building Materials 200 pp. 226–239

[10] Dewi, S. M., Hasyim, H., Susanti, L., et al., The Experimental Study Of Lightweight Precast Concrete Slab with Bamboo Reinforcement, 2022. AIP Conference Proceedings 2440, 020006 pp.1-7

[11] Dewi, S. M., Simatupang, R. M., Waluyohadi, I. The Use of Bamboo and Autoclaved Concrete Block to Reduce the Weight of Precast Concrete Beam, 2017. AIP Conference Proceedings 1887, 020012 pp.1-8

[12] Ghavami, K. Bamboo as Reinforcement in Structural Concrete Elements, 2005. Journal Cement & Concrete Composite 27, pp.637-649

[13] Suhendro, B. Finite Element Method. 2000. Yogyakarta : Universitas Gajah Mada. pp.50-62

[14] Prayuda, H. In-Plane Lateral Force ½ Stone Brick Masonry Wall Portal Structure using Numerical Analysis, 2015. Jurnal Ilmiah Semesta Teknika : Vol. 18, No. 2, pp.130-139

[15] Hossain, M.Z., Awal, A.S.M.A., Flexural response of hybrid carbon fiber thin cement composites, 2011. ScienceDirect : Construction and Building Materials 25 pp. 670-677