International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement

Miftakhul Jannah[1], Sri Murni Dewi[2], Hendro Suseno[2]
[1]Structural Engineering Student, Civil Engineering Department, Brawijaya University, Malang, Indonesia-65145
[2]Civil Engineering Department, Brawijaya University, Malang, Indonesia-65145
Email address: [1]miftakhuljannah707 @ gmail.com

Abstract**—** *This paper aims to find out how to make precast wall panel by using Autoclaved Aerated Concrete (AAC) and bamboo reinforcement so that it has a lighter weight than precast concrete wall panel without reducing structural strength. This research was conducted at the Laboratory of Structure and Construction Material of Brawijaya University, Malang, Indonesia; therefore the material parameter used is of which around the test location. There were two types of specimens made, namely precast wall panel with a size of 40 x 80 x 3.5 cm and 60 x 120 x 5 cm given the main bamboo reinforcement of 5D10. The ratio of cement, sand and coarse aggregate of 1: 2: 3 respectively aims to make concrete with fc' 5 Mpa. and 1: 2 respectively for mortar composition. Furthermore, this precast wall panel will be given flexural load based on out of plane. The results of this study will provide an efficient way of making wall panel and determine the wall panel flexural capacity (out of plane) of AAC and bamboo reinforcement.*

Keywords**—** *Precast Wall Panel, AAC, Bamboo, Flexural Strength*

I. INTRODUCTION

The geographical location of Indonesia is in the most active earthquake path in the world because it is surrounded by the Pacific Ring of Fire. Hence, the use of lightweight building materials is essential to note, so that when an earthquake occurs, the number of fatalities caused by building material falling can be reduced. To deal with this, many business people in building projects replace partitions that originally used red bricks to be replaced by lightweight bricks or Autoclaved Aerated Concrete (AAC).

Autoclaved Aerated Concrete (AAC) is an extreme lightweight concrete based material and air bubbles (SNI 03-3449-13). The Elasticity Modulus of AAC is around 2 GPa. Not only that, in addition to lightweight, AAC can reduce sound to 40 DB, reduce heat, and is suitable to use for walls. It is a cement-based construction material, so that AAC is also easily adhered to cement paste and wall paint.

In a building, a component that is prone to being destroyed during an earthquake is wall. Conventional masonry brick walls have a specific gravity of 1700 kg / m3; it is extremely heavy if compared to AAC material which has a density of 550-650 kg/m3 and strength > 3 MPa or one tenth of the strength of normal concrete.

Concrete wall panels in the market are considered quite heavy, so that to anticipate this, the wall panels are planned by using AAC as a panel filler. In this study, AAC is strengthened with structural materials, in this case, portals and bressing by using bamboo reinforcement. The use of bracing on wall structures has been proven to be able to increase strength in the function of walls, especially bracing made from bamboo reinforcement (Lilia Susanti, 2011).

Referring to the description above, it identify will arise the problems from the replacement of panel material that should have been made from pure concrete. This research is part of a grant research that examines concrete panels with AAC filler and is restrained by bamboo reinforcement. The variation given is the type of loading to the panel. Loading is done by in-plane, out of plane, and cyclic load. The arrangement of scientific paper is focused on discussing panels that are loaded based on out of plan.

The objective of this research is to obtain an SOP for the making process of AAC concrete panels with bamboo reinforcement and to conclude the different characteristics of pure concrete panel and AAC concrete panel. in addition, it will also analyzed the differences of nominal capacity of pure concrete panel and AAC concrete panel when having out of plane loads.

II. EXPERIMENTAL PROGRAM

A. *Material*

Lightweight bricks of AAC used in this study are obtained from material stores around the testing laboratory. This AAC has the same specifications as those used in development projects in the study area (Malang, Indonesia) which has an average compressive strength of 4 MPa and a weight of 9 kg with brick dimensions of 60 x 20 x 10 cm. This lightweight AAC type brick material will be cut of 2 cm thick and will be used as a filling in non-structural area on the wall panel.

In this study, bamboo reinforcement with size of 10 x 10 mm from giant bamboo type is used which is given a treatment in the form of laminate used as the main reinforcement in concrete. Bamboo is a type of plants which is commonly found in Indonesia. The ease of planting and the nature of bamboo which can grow naturally become its advantage. The test results can be seen in the following Fig. 1.

The use of bamboo as an alternative reinforcing material in concrete has been widely used by researchers. The reason for using steel as an alternative reinforcement is because the tensile strength is so good that it reaches 370 Mpa. (Sutardi, Sri Rulliaty, 2015).

Miftakhul Jannah, Sri Murni Dewi, and Hendo Suseno, "Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 2, pp. 173-177, 2020.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

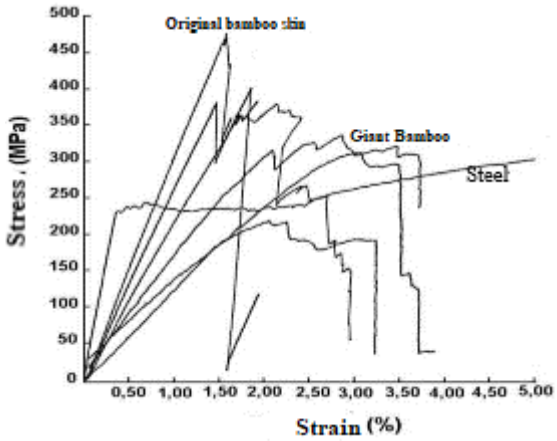


Fig. 1. Test Results of Bamboo and Steel Tensile Strength Baja (Morisco, 1999)

Fig. 2. Giant Bamboo *(Dendrocalamus Asper Backer)*

Besides, for the control wall panel, concrete was used with a ratio of cement, sand and coarse aggregate of 1: 2: 3 respectively to make concrete with fc' 5 Mpa. and mortar 1: 2 respectively; whereas, for the control wall panel, concrete was used with a ratio of cement, sand and coarse aggregate of 1: 2: 3 respectively to make concrete with fc' 5 Mpa. and mortar 1: 2 respectively. The procedure of making specimens is carried out by following Indonesian national standard (SNI 03-2847-2013).

Due to the thinness of the planned wall panel size, to anticipate flexure on the horizontal side of the panel, wiremesh is applied. In this study, the wire counter functions to provide additional strength to the wall panel when given an out of plane load. This is done so that the wall panel does not experience brittle fracture when receiving a load. Wiremesh used is a wire with woven motive in the form of a 5 x 5 mm box.

B. Specimen and Testing

This panel discusses a precast panel which is planned to be applied as a structural wall that functions as a cover or a room divider in a building.

This wall panel will receive several types of loading, including vertical loads from building components on the top of it, horizontal loads from the wind that hit the walls, and cyclic loads when an earthquake occurs. This study will focus on the horizontal loads that occur on wall panels. Perpendicular loading on the thin panel wall is usually called out of plane loading.

The application of AAC in non-structural areas can reduce the weight of the panel. Placing AAC as a substitute for concrete is put into consideration when the panel is subjected to Vertical compressive load, so that the replacement of this material may cause problems when the panel receives the load horizontally. From the results of studying the literature review, it is expected to provide an overview before the research is conducted, so that when the research is conducted, it will provide efficient and effective results.

To meet the desired plan, the test specimens prepared are the scale model with a size of 40 x 80 x 3.5 cm and 60 x 120 x 5 cm and the main bamboo reinforcement of 5D10 (Fig.3). Each wall panel has one wall panel with a composition of pure concrete as a control panel. The variables of specimens prepared are, namely, the panels are made from pure concrete with bamboo reinforcement and wall panels with AAC pairs in non-structural areas.

TABLE 1. Specimen Variable

Test Specimen Code	Dimension	Number	Remarks
DBR 1 1D **DBR 2 1D** **DBR 3 1D**	40 x 80 x 3.5 cm	3 units	AAC specimen
TBR 1 1D	40 x 80 x 3.5 cm	1 unit	Control specimen
DBR 1 2D **DBR 2 2D** **DBR 3 2D**	60 x 120 x 5 cm	3 units	AAC specimen
TBR 1 2D	60 x 120 x 5 cm	1 unit	Control specimen

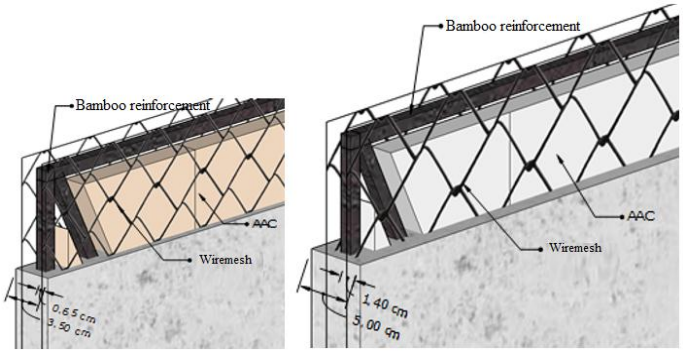


Fig. 3. AAC wall panel specimens with bamboo reinforcement

This experimental study aims to find out the flexural capacity of the panel which is weighted based on out of plane in the middle of the span. This is done as an approach to the planned application of wall panels as room coverings.

To make the flexural capacity that can be resisted by the panel, then it is simplified the evenly distributed load that occurs into a line load (Knife Edge Load). In the laboratory, the line load will be loaded by a hydraulic pump which is continued by using a long iron, along the width of the panel. While the two columns that curb the panel, it will be held by using a roller support. By applying force in the middle of span, the support of the roller or commonly referred to as the three point flexural test.

Miftakhul Jannah, Sri Murni Dewi, and Hendo Suseno, "Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 2, pp. 173-177, 2020.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

III. Result and Discussion

A. Material Testing

The tests carried out in this study include compressive strength of concrete cylinders and mortar testing, bamboo tensile strength and wire tensile (wiremesh) testing. Cylinder compressive strength testing is needed to predict the compressive strength of the concrete plan.

1. *Compressive Strength of Concrete Cylinders and Mortar Testing*

This compressive strength of concrete test is carried out by using a concrete compressive machine test method on cylindrical specimens with a diameter of 8 cm and a height of 16 cm which is carried out on concrete and mortar at 28 days. The testing and preparation procedures are carried out by following Indonesian National Standard (SNI 1974-2011).

This test is used to obtain the quality value of concrete and mortar which is shown in Table 2 and Table 3. The average results of the compressive strength of the cylinder obtained for concrete is 9.40 MPa and for mortar with a composition of 1: 2 ratio is 2.30 MPa. The quality of concrete and mortar obtained from the compressive strength of the cylinder test will be used to analyze the crack load *(Pcr)* for each panel size with AAC material and control panel without AAC (pure concrete).

TABLE 2. Test result of compressive strength of cylinder concrete

No.	Material	Weight (Kg)	Compressive Strength (kN)	Compressive Strength (MPa)
1	Specimen 1	1.75	56.00	11.15
2	Specimen 2	1.80	48.00	9.55
3	Specimen 3	1.72	43.00	8.56
4	Specimen 4	1.85	42.00	8.36
Average		1.78	47.25	9.40
Volume (m^3)		$1/4\ \pi\ d^2$		0.001
Mass (kg/m^3)		m / v		2214.37
E_c (Mpa)		$\rho^{1.5} 0.043 \sqrt{f_c'}$		13741

TABLE 3. Test result of cylinder mortar compressive

No.	Material	Weight (Kg)	Compressive Strength (kN)	Compressive Strength (MPa)
1	Specimen 1	1.70	14.00	2.79
2	Specimen 2	1.50	11.00	2.19
3	Specimen 3	1.75	11.00	2.19
4	Specimen 4	1.70	10.30	2.05
Average		1.66	11.58	2.30
Volume (m^3)		$1/4\ \pi\ d^2$		0.001
Mass (kg/m^3)		m / v		2068.20
E_c (Mpa)		$\rho^{1.5} 0.043 \sqrt{f_c'}$		6139

2. *Bamboo Tensile Strength Testing*

Bamboo tensile testing is carried out to determine the tensile capacity of bamboo by using UTM (Universal Testing Machine) tool which will later be used as reinforcement on a wall panel to substitute steel reinforcement. The type of bamboo used as reinforcement on the wall panel is the type of giant bamboo *(Dendracalamus Asper).* The average value obtained from bamboo tensile testing is 246.12 MPa.

3. *Wiremesh Testing*

Tensile testing is carried out by using UTM (Universal Testing Machine) machine. The method used to carry out the wiremesh testing is by cutting 3 rows of woven wiremesh with a length of 14 cm and 2 rows of webbing in the middle. Then, the woven wiremesh at its center is removed. This is done so that when wiremesh is conducted, the connection point of the webbing is not broken off.

TABLE 4. Test Result of Bamboo Tensile Strength

No.	Material	Strain	Tensile Strength (N)	Tensile Strength (Mpa)
1	Specimen 1	0.0754	3756.30	187.82
2	Specimen 2	0.0690	5398.10	269.91
3	Specimen 3	0.0722	5612.70	280.64
	Average	0.0722	4922.37	246.12
	E_c (Mpa)	stress/strain		3410

TABLE 5. Test Result of Wiremesh Tensile

No.	Material	Strain	Tensile Strength (N)	Tensile Strength (Mpa)
1	Specimen 1	0.0274	193.30	492.48
2	Specimen 2	0.0124	203.10	517.45
3	Specimen 3	0.0171	204.20	520.25
4	Specimen 4	0.0152	220.70	562.29
	Average	0.0180	205.33	523.12
	Ec (Mpa)	stress/strain		28990

From the test results of the wiremesh by using UTM, the average value of the wiremesh capacity is 523.12 MPa.

B. Panel Making

The ways of making AAC wall panels with bamboo reinforcement are as follows:

1. Prepare the formwork with the size according to the wall panel that will be made.
2. Brush the formwork with used oil so that it is easy to remove
3. Pour mortar with a thickness of 1.40 cm for panels measuring 120 x 60 x 5 cm, and 0.65 cm for panels measuring 80 x 40 x 3.5 cm
4. Place wiremesh with a width size according to the panel size.
5. Place the bamboo reinforcement and AAC on the wiremesh that has been placed on the mortar

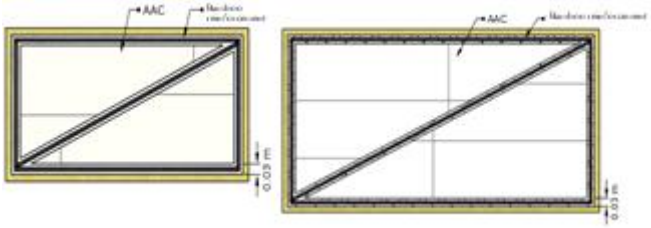


Fig. 4. AAC wall panel specimens with bamboo reinforcement

6. Pour the concrete in the bamboo reinforcement area until it has a level height with AAC.
7. After smoothing, replace the wiremesh to cover AAC and concrete pairs in the reinforcement area for the upper side.
8. Pour the mortar back until smooth with formwork.

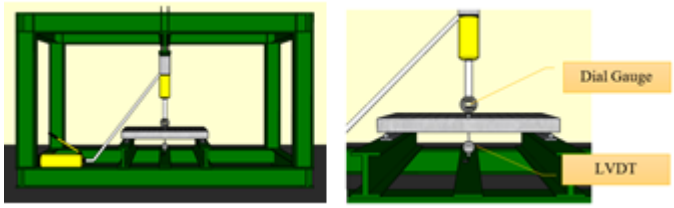
C. Panel Testing

The testing and preparation procedures are carried out by following Indonesian National Standard (SNI 4154-2014).

Miftakhul Jannah, Sri Murni Dewi, and Hendo Suseno, "Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 2, pp. 173-177, 2020.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Panel testing is carried out by giving an even load that occurs into a Knife Edge Load. In the laboratory, the Knife Edge Load will be loaded by a hydraulic pump which is continued by using a long iron, along the width of the panel. While the two columns that curb the panel, it will be held by using a roller support. By applying force in the middle of span, the support of the roller or commonly referred to as the three point flexural test.



(a) (b)

Fig. 5. (a) Tool setting and testing specimen (b) the close detail

The average weight of AAC wall panels measuring 40 x 80 x 3.5 cm is 18.23 kg or 4.42 kg lighter than normal concrete panels of the same size that weighs 22.65 kg. Meanwhile, for AAC walls, the size of 60 x 120 x 5 cm is 46.45 kg or 14.55 kg lighter than normal concrete panels of the same size that weighs 61 kg. The detail of the weight properties panel test results can be seen in Table 5.5.

Below is the result of weight measurement on the wall panel with details as follows:

TABLE 6. The results of the panel properties weight test

No	Code	Size (cm)	Cast Date	Weight (Kg)	Remarks
1	TBR 1 TL	40 x 80	01 July 2019	22.65	Control Panel
2	DBR 1 TL	40 x 80	09 July 2019	19.20	AAC Panel
3	DBR 2 TL	40 x 80	08 July 2019	17.95	AAC Panel
4	DBR 3 TL	40 x 80	02 July 2019	17.55	AAC Panel
5	TBR 1 TL	60 x 120	07 July 2019	61.00	Control Panel
6	DBR 1 TL	60 x 120	06 July 2019	45.15	AAC Panel
7	DBR 2 TL	60 x 120	08 July 2019	46.60	AAC Panel
8	DBR 3 TL	60 x 120	04 July 2019	47.60	AAC Panel

Panel testing was conducted at the Laboratory of Structure and Materials of Brawijaya University from July 1 to 9 July 2019. The testing was carried out on 28-day concrete panels. The methods and tools used in the test were carried out as discussed in Chapter 3. There were 1 specimen of "Panel without AAC dimensions 40 x 80 cm", 3 specimens of "Panel with AAC dimensions 40 x 80 cm", 1 specimen of "Panel without AAC dimensions of 60 x 120 cm ", and 3 specimens of "Panel with AAC dimensions of 60 x 120 cm". The results of tests that have been carried out can be seen in the following table:

TABLE 7. Result of wall panel testing

No	Specimen	Size (cm)	*Pcr* (Kg)	Δ (mm)	Remarks
1	TBR 1 TL 2B	40 x 80	50.00	0.39	Control Panel
2	DBR 1 TL 2B	40 x 80	100.00	0.74	AAC Panel
3	DBR 2 TL 2B	40 x 80	75.00	0.61	AAC Panel
4	DBR 3 TL 2B	40 x 80	75.00	0.74	AAC Panel
5	TBR 1 TL 1B	60 x 120	100.00	1.08	Control Panel
6	DBR 1 TL 1B	60 x 120	125.00	0.93	AAC Panel
7	DBR 2 TL 1B	60 x 120	100.00	0.95	AAC Panel
8	DBR 3 TL 1B	60 x 120	100.00	0.80	AAC Panel

From the above table, it can be seen that the results of observations in the laboratory on a wall panel measuring 40 x 80 cm, on panels with AAC composition obtained an average crack load *(Pcr)* occurs when the panel is loaded of 75-100 kg, and has an average deflection of 0, 60 - 0.74 mm. Whereas, for pure concrete wall panels with the same size, the crack load is obtained when the panel is loaded with 50 kg and deflates of 0.39 mm. Likewise, on AAC panels measuring 60 x 120 cm, it is found that the average panel has cracked when receiving a load of 100 - 125 kg with a deflection of 0.80 - 0.95 mm. Besides, for pure concrete wall panels with the same size, the crack load is obtained when the panel is loaded with 100 kg and has a deflection of 1.08 mm. Hence, from the observations shown above, it can be concluded that the wall panels with AAC composition are more ductile than wall panels with pure concrete composition.

IV. Conclusion and Recommendation

The difference in characteristics of pure concrete panel and AAC concrete panel is in the weight of the wall panels with a size of 40 x 80 x 3.5 cm with an average weight of AAC wall panels is 18.23 kg or 4.42 kg lighter than concrete panels normal with the same size ie weighing of 22.65 kg. Meanwhile, for AAC walls, the size of 60 x 120 x 5 cm is 46.45 kg or 14.55 kg lighter than normal concrete panels of the same size that weighs 61 kg. In other words, each has a weight reduction of 19.5% and 23.85%.

There are differences in flexural capacity caused by out of plane loads on pure concrete wall panels and AAC wall panels. From the results of testing in the laboratory, for wall panels with a size of 40 x 80 x 3.5 cm on a panel with a pure concrete composition, it is found that the value of the flexural capacity can withstand a crack load (Pcr) of 50 kg, while for panel specimens using AAC, it is found that an average value average crack load (PCR) of 83.33 kg or an increase in flexural capacity of 66.67% of wall panels occurs by using AAC compared to wall panels composed of pure concrete.

Besides, for wall panels with a size of 60 x 120 x 5 cm on panels with pure concrete composition, the value of flexural capacity can withstand a crack load (Pcr) of 100 kg, and for panel specimens using AAC, the average value of crack load (Pcr)) is 108.33 kg or an increase in the flexural capacity of 8.33% of the wall panels occurs by using AAC compared to wall panels composed of pure concrete. Therefore, it can be concluded that the wall panels with AAC composition are more ductile than wall panels with pure concrete composition.

References

[1] Morisco. (1999). Rekayasa Bambu. - Yogyakarta : Nafiri Offset.
[2] Ghavami Khosrow. (2005). Bamboo as reinforcement in structural concrete elements Journal Cement & Concrete Composite. p. 13-2005.
[3] Park, R., & Paulay, T. (1975). Reinforced Concrete Structures. John Wiley & Sons, New York. 769 pp.
[4] SNI 03-2847-2013. (2013). Persyaratan Beton Struktural Untuk Bangunan Gedung. Jakarta: Badan Standarisasi Nasional.
[5] Badan Standardisasi Nasional. (2011). Cara Uji Kuat Tekan Beton dengan Benda Uji Silinder (SNI 1974:2011). Jakarta: Badan Standardisasi Nasional.
[6] Badan Standardisasi Nasional. (2014). Metode Uji Kekuatan Lentur Beton (Menggunakan Balok Sederhana dengan Beban Terpusat di

Miftakhul Jannah, Sri Murni Dewi, and Hendo Suseno, "Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 2, pp. 173-177, 2020.

Tengah Bentang) (SNI 4154:2014). Jakarta: Badan Standardisasi Nasional.
[7] Sutardi S. Rulliaty., Nadjib, N., Muslich, M., sulastiningsih, I.M., & Komaryati, S. (2015). Sari Paket Iptek Informasi Sifat Dasar dan Kemungkinan Penggunaan 10 Jenis Bambu. Pusat Penelitian dan Pengembangan Hasil Hutan Badan Penelitian, Pengembangan dan Inovasi Kementerian Lingkungan Hidup dan Kehutanan. Bogor.
[8] Susanti, Lilya., Dewi, Sri Murni., Nurlina, Siti. (2011). Pengaruh Penggunaan Pengekang (Bracing) Pada Dinding Pasangan Batu Bata Terhadap Respon Gempa.
[9] Grosser, D. & W. Liese. (1971). On the Anatomy of Asian Bamboos, with Special Reference to their Vascular Bundles. Wood Sci.Technol. 5: 290-312.
[10] Xiaobo Li. (2004). Physical, Chemical, And Mechanical Properties of Bamboo and Its Utilization Potential For Fiberboard Manufacturing. Unpublished Doctoral Thesis, Faulty of the Louisiana State University.

Miftakhul Jannah, Sri Murni Dewi, and Hendo Suseno, “Experimental Study of Flexural Strength (Out of Plane) on Wall Panel by Using Autoclaved Aerated Concrete and Bamboo Reinforcement,” *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 2, pp. 173-177, 2020.