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# Experimental Study of Mortar Joint Bond Strength of Autoclaved Aerated Concrete Masonry Prism

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***Abstract***

*The quality of masonry determined through bond strength between mortar and brick masonry. Yogyakarta earthquake disaster on 2006 show that most of the damage was caused by the interface failure of mortar joint. The aim of the research was to carried out the mechanical characterization of Masonry wall due to the shear bond strength test based on Experimental test result. The type of masonry wall is Autoclaved Aerated Concrete. This research used 36 masonry prism test samples in four groups, which were STB and SSB with water cement ratio 0.15, 0.2, and 0.25 (18 specimen); STC and SSC with composition of mortar were 1PC:4PS, 1PC:5PS and 1PC:6PS (18 specimen) by volume using water cement ratio of 0,9. The type of mortar used thin bed and cement-sand mortar were 3mm and 1.5cm in thick dimension. This research dealt with four tests (tensile bond strength (tensile test), shear strength bond test, porosity, and specific gravity). The test result show that the masonry wall using thin bed mortar as mortar joint have higher strength (splitting tensile test and shear strength) compare with cement-sand mortar. This means that the autoclaved aerated concrete with thin bed mortar have good resisting performance under earthquake induced lateral loading.*

***Keyword**: autoclaved aerated concrete, bond strength, masonry*

## 1. INTRODUCTION

Yogyakarta Earthquake on May, 27th 2006 cause 5.760 people died, 102,234 people injured, more than 2 million people evacuated, and destroyed 124,348 houses (Bappenas, 2007). One of the causes of the deaths were due to underneath the walls of the building as a result that too big shear forces, so cannot be held by mortar joint. The Mortar used still belongs to the conventional, with only rely on the bond between lime, red sand and cement. Brick is a non-structural elements in building construction, because of the considerable mass of 1700kg/m$^3$ would cause the increasing lateral load on building structure.

Nowadays, One of the innovations that are developing is the use autoclaved aerated concrete which has a mass of light enough for 300 up to 1800kg/m$^3$. In cases of building, producers always "assume" that one product autoclaved aerated concrete can reduce use of cement (instant cement/ powerbond mortar), due to his considerable masonry with a thick layer of mortar 3 mm and the 600mmx200mm in dimension. The assumption is acceptable for autoclaved aerated concrete masonry prism as a partition. But when a construction work requires the wall is part of the building structure, the above assumptions are still need to be rethought its reliability.

Especially about bond strength of thin bed mortar, Modulus of Elasticity, shear strength, compressive strength, flexural strength, and so on. This research intends to test the reliability of autoclaved aerated concrete masonry prism using thin bed mortar and ordinary mortar, the scope of test conducted on shear test of the mortar joint and splitting tensile test aiutoclaved aerated concrete masonry prism. The test results are expected to be made about the reliability of evidence the performance wall aeration (AAC).

## 2. THEORY

### 2.1 Autoclaved Aerated Concrete

Aerated concrete is either a cement or lime mortar, classified as lightweight concrete, in which air-voids are entrapped in the mortar matrix by means of a suitable aerating agent. Broadly speaking aerated concrete falls into the group of cellular concrete (microporite being the other). The prominent advantage of aerated concrete is its lightweight, which economises the design of supporting structures including the foundation and walls of lower floors.

Aerated concrete is relatively homogeneous when compared to normal concrete, as it does not contain coarse aggregate phase, yet shows vast variation in its properties. The properties of aerated concrete depend on its microstructure (void paste system) and composition, which are influenced by the type of binder used, methods of pore-formation and curing (Narayanan, 2001).

### 2.2 Sustainable energy

AAC usage can conserve energy consumption on the earth, a comparison of the use of a variety of material is presented in Figure 1 and 2 below.

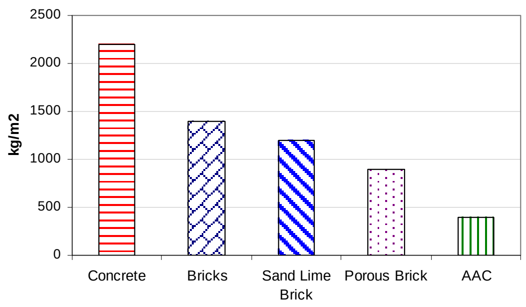


Figure 1. Raw material consumption for the production of various building materials

(Sources: Folker H. Whitman, 2011)

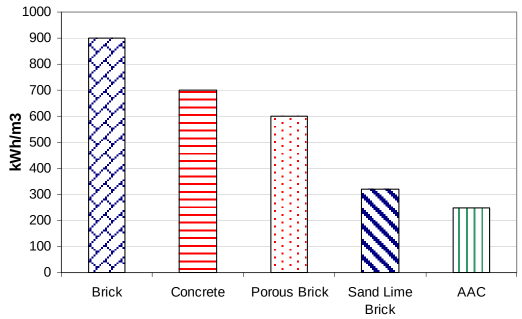


Figure 2. Energy consumption for the production of various building materials

(Sources: Folker H. Whitman,2011)

### 2.3 Masonry wall behaviour based on earthquake load

Load distribution at the time of the earthquake takes place in all directions, so at the moment through the walls, load distribution can take place at the direction of the axis of the strong walls (strong direction wall) or weak direction wall. The imposition of strong axis takes place on the wall give prisoners better than the lateral axis of the weak walls. The earthquake load that occurred on the axis of the wall can cause changed the geometry of the shape of the parallelogram. Change of geometry going on, in addition to causing damage to the other element that is in the field such as a window or a wall of glass, can also cause damage/the collapse of the wall. On the other hand on the axis of the weak walls, can cause the wall to collapse (Murty, 2006).

## 3. METHODOLOGY

### 3.1 Masonry tensile bond strength (Splitting test)

This test is intended to determine tensile bond strength of autoclaved aerated concrete. Testing method for tensile bond strength of masonry prism is presented in Figure 3 below.

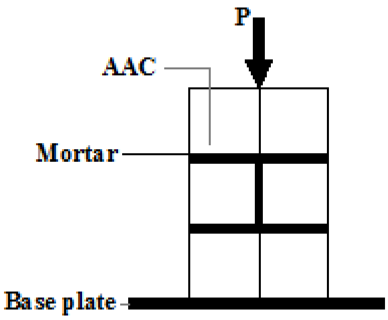


Figure 3. Tensile bond test apparatus

(Sources: Mojsilović, et.al, 2009)

The tensile bond strength of masonry prism (Mojsilović, et.al, 2009), obtained using equation 1 below:

$$\sigma_T = \frac{C.F}{D.t}; \ with \ \ D = \sqrt{\frac{h.L}{\pi/4}} \quad (1)$$

*Where: h* and *l* are the specimen height and width, respectively. In addition, *t* denotes the specimen thickness; *F* is the applied load and *C* a constant of 0.648. This constant depends on brick/joint stiffness and the chosen value was based on modulus of elasticity ratio of brick and mortar, *Eb*/*Em*, of approximately 2

### 3.2 Shear strength bond test

Testing method for shear strength bond test of masonry prism is presented in Figure 3 below (Tung, 2008).

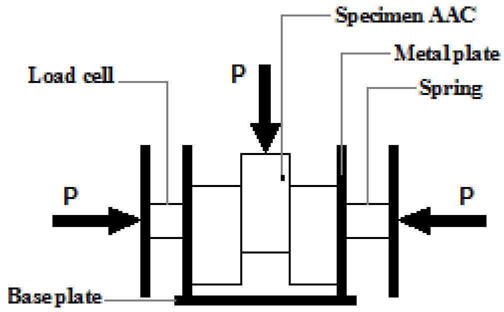


Figure 4. Shear strength apparatus (Sources: Tung, 2008)

The shear strength of masonry prism, obtained using equation 2 below:

$$F = \sigma. A \quad (2)$$

Where: F= applied load (N); σ= shear strength (MPa); A=shear plane area ($mm^2$)

### 3.3 Porosity

Porosity test is to obtain how much water is absorbed in the autoclaved aerated concrete. The porosity calculated using this equation 3 below:

$$Porosity = \frac{A - B}{B} x100\% \quad (3)$$

where: A = wet weight/saturated (gr); B = dry weight (gr)

### 3.4 Specific gravity

Testing specific gravity was carried out to determine the specific gravity per-$m^3$. it can be calculated using Equation 4 below:

$$\text{Specific gravity} = \frac{B}{V} \quad (4)$$

where: B = weight (kg); V = volume content of specimen ($m^3$)

## 3.5 Research Material

Materials used in this research were fine aggregate of Krasak, Sleman Yogyakarta; Portland pozoland cement (PPC) type I from Gresik Indonesia. AAC type Citicon, thin bed mortar max 3mm in thick. water cement ratio re 0.15; 0.20 dan 0.25. weiht of volume proportion are 1:4; 1:5 dan 1:6.

## 3.6 Research Tool

Mixer mortar, trowel, Compression Testing Machine trade mark Wfi (Wykeham Farrance International) from Blough, England, Capacity of 2000 kN; and others.

# 4. ANALYSIS RESULT AND DISCUSSION

## 4.1 Masonry tensile bond strength (Splitting test) and shear bond test of autoclaved aerated concrete.

Masonry bond strength and shear bond test of autoclaved aerated concrete is to find out the capacity of performance of masonry wall, the test results of autoclaved aerated concrete presented in Table 1 below.

Table 1. Tensile test and shear bond test autoclaved aerated concrete

| No | Specimen | water cement ratio | Weight of content | Splitting test Shear bond stress (MPa) |
|---|---|---|---|---|
| 1 | $STB_{1,2,3}$ | 0.15; 0.2; 0.25 | | 1.40 |
| 2 | $STC_{1,2,3}$ | | 1:4; 1:5; 1:6 | 0.31 |
| 3 | $SSC_{1,2,3}$ | 0.15; 0.2; 0.25 | | 0.40 |
| 4 | $SSB_{1,2,3}$ | | 1:4; 1:5; 1:6 | 0.04 |

where: STB = tensile bond strength (splitting test) thin bed mortar; STC = Splitting tensile strength ordinary mortar; SSC = Shear strength ordinary mortar; SSB = Shear strength bed mortar.

The test results show that the splitting tensile test of STB and STC were the results 1.40MPa and 0.31MPa, respectively. The difference between the STB compared to STC is 78.15%. If the test results are compared with the Zurich (2009) which is equal to 0.62 MPa, then the difference of splitting tensile strength occurs is of 55.82%. This shows that the thin bed mortar has good resistance to shearing forces that occur in the structure. Shear testing on SSC, SSB with thin bed mortar and ordinary mortar, were the results 0.40 MPa and 0.04 MPa, respectively. The difference value of shear strength between SSC compared to SSB is 90.52%.

## 4.2 The porosity test of autoclaved aerated concrete

The total samples on porosity test is as much as 3 pieces with 100mmx100mmx100mm in dimension, this test is to find out how much water is absorbed in the material used, the results of the testing of porosity is presented in Table 2 below.

Table 2. porosity test of autoclaved aerated concrete

| No | specimen | Weight (gram) | Porosity (%) |
|---|---|---|---|
| 1 | $AAC_1$ | 689 | 72.53 |
| 2 | $AAC_2$ | 640 | 65.58 |
| 3 | $AAC_3$ | 612 | 71.89 |
| average | | | 69.06 |

Where: AAC = autoclaved aerated concrete specimen

Based on Table 2 above the porosity test were of 72,53%, 65,58% and 71,89%, respectively. Porosity test are at greatest $AAC_1$ and $AAC_3$. porosity Average is 69,06%. Based on the ASTM 2842-06 showed that the porosity masonry prism maximum is 90%. Based on the ASTM 2842-06, the results of testing of porosity less 22% of maximum limit specified by the ASTM 2842-06. This indicates that the results of the testing of porosity aeration concrete including into the requirements of the SNI (standard of Indonesia).

### 4.3 Crack Patern of autoclaved aerated concrete

Based on testing 9 sample test objects, damage pattern was obtained by a different test. The crack pattern of masonry is presented in the Table 3 below.

Table 3. crack pattern of AAC

| No | Specimen | Crack pattern | description |
|---|---|---|---|
| 1 | $STB_{1,2,3}$ | Interface | Water cement ratio 0.15; 0.20; 0.25 |
| 2 | $STC_{1,2,3}$ | Interface | Weight of content 1:4; 1:5; 1:6 |
| 3 | $SSC_{1,2,3}$ | AAC and mortar | Water cement ratio 0.15; 0.20; 0.25 |
| 4 | $SSB_{1,2,3}$ | Interface | Weight of content 1:4; 1:5; 1:6 |

Based on Table 3 above show that the interface failure occurs on STB, STC and SSB. On the other hand, SSC specimen occurs combination between AAC and mortar joint. This test results indicated because of thin bed mortar has better shear strength compared to ordinary mortar. So with the resources an adhesive mortar good expected lateral load earthquake could be reduced by thin bed mortar.

### 4.4 Specific gravity

Specific gravity test is to find out how much the weight unit per $m^3$ of autoclaved aerated concrete masonry is used, the test results are shown in Table 4 below.

Table 4. Spesific gravity test result

| No | Specimen | Weight (gr) | dimension (mm) | | | Specific gravity (gr/cm$^3$) | Specific gravity average (gr/cm$^3$) |
|---|---|---|---|---|---|---|---|
| | | | p | l | t | | |
| 1 | $CT_1$ | 689 | 98,2 | 98,6 | 99,9 | 0,71 | 0,68 |
| 2 | $CT_2$ | 640 | 98,4 | 95,0 | 99,4 | 0,68 | |
| 3 | $CT_3$ | 612 | 98,3 | 95,0 | 99,6 | 0,65 | |

Where: $CT_{1,2,3}$ = AAC type citicon

Based on Table 4 above indicates that the weight of Autoclaved aerated concrete masonry is 0,68 gr/cm$^3$, the result is much smaller than the 4.4% severe types of lightweight concrete type powerblock Rezha (2013).

## 5. CONCLUSION

Based on the results of testing, data analysis and discussion, can be concludes as follows:

1.1 The value of tensile bond strength autoclaved aerated concrete on the STB and STC of 1.4 MPa and 0.31 MPa, respectively.

1.2 The value of masonry shear bond strength autoclaved aerated concrete on SSC and SSB of 0.40MPa and 0.04MPa, respectively.

1.3 The crack pattern that occurs in a test object the STB, STC and the SSB is the failure of the interface, while the SSC are combination between autoclaved aerated concrete and mortar joint.

1.4 The porosity value and specific gravity of autoclaved aerated concrete of 69.06% and 0.68 gr/cm3, respectively.

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