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Axial Compression Behaviour Of Cross Laminated Wood-Wool Cement Composite Panel Wallettes Bonded With Lightweight Cement Mortar

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Abstract: As a building and housing component, wood-wool cement composite panel (WWCP) has outstanding potential due to it's highly biological degradation resistance and has excellent heat and noise insulation capabilities. In the construction industry, it is hard to find a new sustainable structural wall system that produced from renewable materials. In order to maintain a sustainable environment and to improve living conditions, it is important to find a new alternative in this sector. The main research objective is to investigate an axial compression behaviour of cross laminated wood-wool cement composite panel wallettes bonded with lightweight cement mortar. In the fabrication of wallettes, the 50 mm thickness of WWCP's was laid in two layers at different orientation of panel arrangement to form a 900 mm x 900 mm wallettes. The panels were bonded together by using lightweight cement mortar of 15 mm thickness reinforced with A6 wire mesh. Three samples of wallettes were fabricated accordingly and tested under axial compression load up to failure to determine the load carrying capacity of wallettes. The results indicated that the wallettes have an ability to sustain the maximum axial compression load of 102 kN. This show that an application of lightweight mortar used as bonding agent reinforced with A6 wire mesh has a great potential in the fabrication of wood-wool cement composite wallettes.

Keywords: WWCP, Cross Laminated, Lightweight Cement Mortar

1. Introduction

Nowadays, wood is a material that is widely used in industry because of its potential to produce a new product. There are various of construction product that has been made by using of wood as their based material. In panel industry, wood has been widely used in the manufacturing of the panel such as plywood, particle board, oriented strand board, fibre board and wood based composite material panel. The wood composite industry is one of Malaysia's fastest developed industries [1]. In the construction industry, wood-cement composite product has acted as building and construction material for more than

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60 years [2]. Special characteristics that make wood-cement composite board desirable is a high fire and decay resistance, low water absorption and strong dimensional stability [3].

As one of the main forms of wood-cement composites, the use of wood-wool cement panel (WWCP) as a building material has become increasingly popular. WWCP has different properties compared to wood cement board, which is WWCP is known as less denser with a porous surface while wood cement board high density with smooth surface. It was composed and made of wood-wool, cement and small amount of additive where, wood-wool act as the reinforcing agent, while cement as a binder and additive as the catalyst in the manufacturing process. Wood-wool is attracted to use as a noncombustible sound absorbing ceiling, wall panels and thermal insulations [2]. As a building and housing component, WWCP has outstanding potential since it is resistant to biodegradation and has outstanding insulation heat and noise capabilities [4].

There were few studies had been conducted by previous research, [4] in studying the mechanical properties of WWCP made from the least known local species known as *Kelampayan*. The mechanical properties were strongly influenced by its density where the reduction of strength was recorded as the density has decreased [4]. WWCP are identified as potential material that will be used in the construction of wall element. Studies have been made to investigate in wallettes behaviour made from WWCP under axial compression load [5]. The findings showed that, the new panel arrangement technique bonded with a normal mortar mix enhanced stability and increased wallettes load carrying capacity significantly [5]. The experimental results revealed that wallettes is controlled by the strength of the panel itself and mortar strength. The selection of an appropriate panel thickness, panel arrangement technique and bonding agent significantly improve load carrying capacity of the wall and can be considered as a load bearing wall system in building construction.

Lightweight cement mortar generally known as aerated or foamed concrete. It is a cellulose material composed by cement and sand matrices constituting a large of small pores in diameter of 0.1 to 1.0 mm [7]. Foamed concrete can be characterized as light cellular concrete that has a density range of 400 to 1850 kg/m^3 depended on a random air-free mixture of foaming agents in mortar [8]. The proper control in foam dosing will provide a wider range densities of foamed concrete and applicable in building construction such as partition, separation and filling applications [9]. By the application of this type of concrete in the construction, it eliminates the structure and foundation dead loads on it, leads to savings of energy and decreases labor costs during the construction. Furthermore, this also reduces the manufacture cost and building materials transportation relative to normal concrete.

In this study, two layers of 50 mm thickness of WWCP were used to fabricate small scale wall namely, as wallettes and bonded with 15 mm thickness of lightweight cement mortar reinforced with 6 mm diameter fabric wire mesh A6. The main objective of this study is to investigate an axial compression behaviour of wallettes subjected to the static axial compression load. A total of three replicates of cross laminated WWCP wallettes were prepared in the laboratory and tested until failure. The axial load carrying capacity, vertical displacement was recorded and the failure mode behaviour of each wallettes was observed along the testing period.

2. Materials and Methods

2.1 Materials

• Wood wool cement composite panel (WWCP)

WWCP is the main material used in the fabrication of wallettes that have been supplied by Duralite (M) Sdn. Bhd. in the standard panel size of 600 mm width, 2400 mm length and 50 mm thickness. The WWCP has been cut into 3 desired small panel size of 300 mm x 450 mm, 300 mm x 500 mm and 300 mm x 200 mm in width and length respectively as shown in Figure 1(a). The strength properties of WWCP were obtained by the previous study that used the same panel size and manufacture is shown in Table 1 [5].

Table 1: strength properties of wood-wool cement composite panel [5]

WWCP thickness (mm)	Density (kg/m^3)	Bending properties		Compressive strength		Tensile strength (N/mm^2)
		MOE (N/mm^2)	MOR (N/mm^2)	Perpendicular (N/mm^2)	Parallel (N/mm^2)	
50	328	444	1.15	0.84	1.00	0.060

• lightweight cement mortar

The lightweight cement mortar was used as an adhesive and bonding agent of wallettes consist the mixture of ordinary portland cement (OPC) (See Figure 1(b)), sand (Figure 1(c)) and a foaming agent. Sand used were sieved to passing 2 mm size for finer grained of aggregate. The prescribed design mixed of lightweight cement mortar comprised of cement to sand ratio of 1:2 and 0.4 of water to cement ratio and foaming agent. The target density of mortar in this study is 1700 kg/m^3. Three samples of lightweight cement mortar are a different mix process. Therefore, each mix was tested in different sample to get the accurate data. The strength properties of lightweight cement mortar in term of density, flexural and compressive strength at 28 days age were investigated in accordance to BS EN 1015-11:2019 [10].

• Fabric wire mesh A6

In order to enhance the strength properties of wallettes, the lightweight cement mortar was reinforced with A6 fabric wire mesh as shown in Figure 1(d). The wire mesh was cut in the dimension of wallettes and embedded in lightweight cement mortar.

Figure 1: (a) WWCP (b) Portland cement (c) fine sand (d) A6 wire mesh

2.2 Fabrication of wallettes

The fabrication process of wallettes in this study was similar as constructed in the previous study [6] where two layers of the WWCP panel with thickness 50 mm were laid in different panel orientation. Each layer consists of 4 pieces of 300 mm x 450 mm, 2 pieces of 300 mm x 200 mm and 1 piece of 300 mm x 500 mm and arranged at an opposite direction. The both layers of panel were bonded together using 15 mm thickness of lightweight cement mortar to form the wallettes with dimension of 900 mm x 900 mm x 115 mm. Three replicates of wallettes denoted as W1,W2 and W3 were bonded with lightweight mortar. A6 wire mesh was embedded inside the mortar core. The configuration of wallettes and the fabrication process of wallettes are shown in Figure 2 and Figure 3.

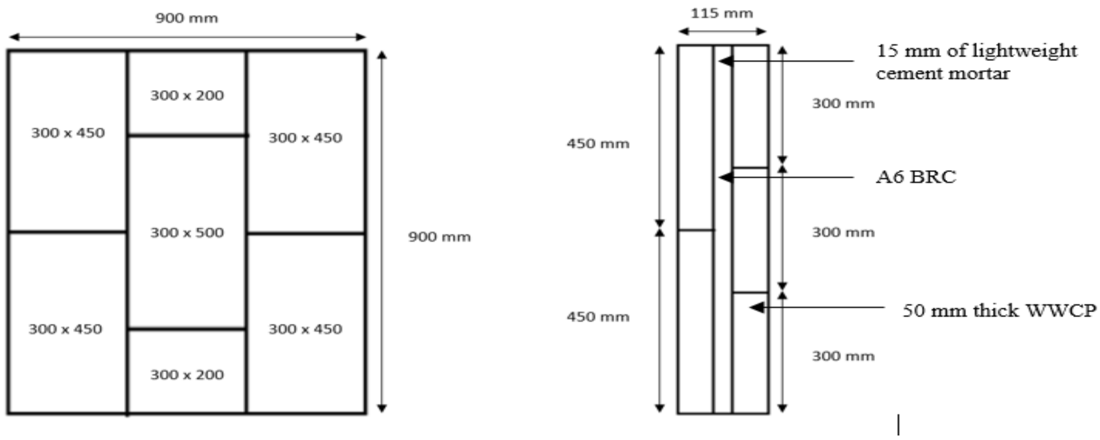

Figure 2: Configuration of fabrication wallettes using wood-wool cement composite panel

(a) Mixing the mortar

(b) Laying the rear panel strips in transverse direction

(c) Placing the steel bars and stopper on top of rear panel

(d) Rendering the 15 mm thickness mortar on top of rear panel

(e) Laying the front panel strips in longitudinal direction

Figure 3: Fabrication process of cross laminated wood-wool cement wallettes

2.4 Axial compression load testing set-up

In the axial compression load test, three replicates wallettes were tested under axial compression load after 28 days of fabrication. The wallettes was placed on top of steel beams under the steel spreader beam which directly connecting to the 1000 kN hydraulic jack. A 10 mm thickness of plywood was placed on top of specimen between the specimen and spreader beam to ensure the load will uniformly distribute to the wallettes. The testing was instrumented with three Linear Voltage Displacement Transducers (LVDT) to measure the displacement of the wall during testing. LVDT 1 was placed on the top of the wall to measure the vertical displacement and LVDT 2 and 3 were placed on each side at the middle height to monitor the horizontal displacement as well as the buckling behaviour of the wall. The maximum failure load, maximum displacement at peak and failure mode behaviour were recorded and observed along the testing conducted. The illustration and actual testing set-up of wallettes sample are shown in the Figure 4.

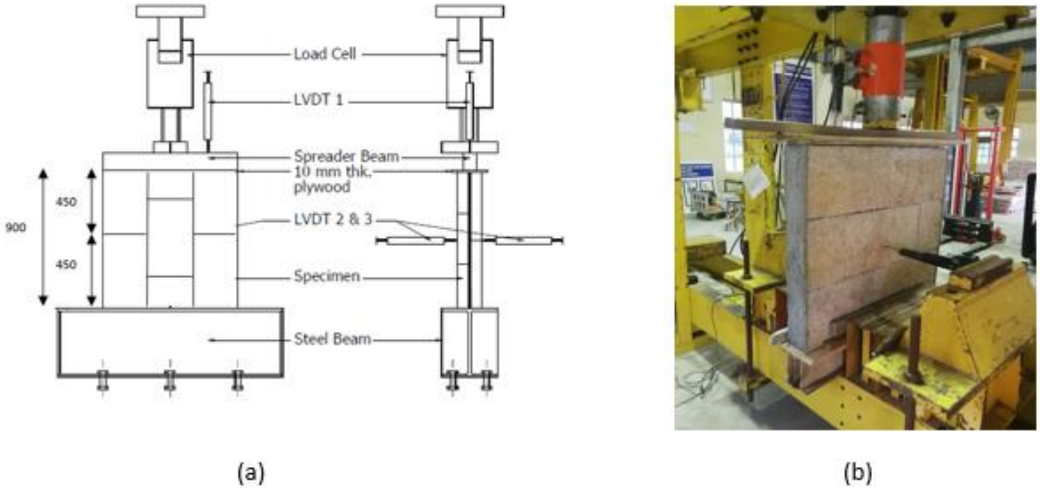

Figure 4: Axial compression load testing set-up of WWCP wallettes

3. Results and Discussion

3.1 Strength properties of lightweight cement mortar

The strength properties of lightweight cement mortar used to fabricate three replicate of wallettes are shown in Table 2.

Table 2: strength properties of lightweight cement mortar

Sample	Mix ratio Cement:sand:water	Density (kg/m^3)	Flexural strength (N/mm^2)		Compressive strength (N/mm^2)	
				mean		mean
1		1718.8	3.84		13.2	
2	1:2:0.4	1484.4	2.16	4.13	6.6	14.3
3		1796.9	6.38		23.0	

From the table, the density of each sample mixture 1,2 and 3 are recorded as 1718.8, 1484.4 and 1796.9 kg/m^3 respectively. There were several factors that influenced the differences in the densities of lightweight cement mortar which is the stability and consistency. The consistency of sample 1,2 and 3 were 1.01, 0.87 and 1.05 respectively. The consistency depended on the amount of foam added to the mortar. For sample 1 and 3, the consistency were tends to unity as shown that the density of mortar were nearest to the target density. For sample 2, results show that the density of lightweight cement mortar was dropped from the target density by 12.7% and this is due to the excessive amount of foam that were added to the mortar mix.

For flexural strength, sample 3 recorded a highest strength which achieved 6.38 N/mm^2, sample 1 was 3.84 N/mm^2 and sample 2 recorded the lowest strength of 2.16 N/mm^2. From the observation, it can be seen that all recorded flexural strength is above the minimum value as recommended by ASTM C869-91 which is 0.17 MPa for lightweight concrete. The result proves that the density of lightweight cement mortar significantly influenced to the flexural strength of the mortar. In terms of compressive strength of lightweight mortar, again the sample 3 recorded a highest strength at 23.0 N/mm^2 compared to sample 1 and sample 2 which are 13.2 N/mm^2 and 6.6 N/mm^2 respectively. From the observation, the results indicated that the compression strength of lightweight cement mortar was increased as the density increase. It is an essential to have uniform compressive strength of lightweight mortar in this study since the main function of the mortar is to bond the wall panel that subjected to the compression load. Therefore, it is suggested that, to ensure the uniformity of density as well as strength properties of mortar, the mixing process of lightweight mortar should be conducted in a single batching process for all three replicates of wallettes.

3.2 Axial compression load capacity of WWCP wallettes

The maximum axial compression load capacity and vertical displacement of the three replicated of WWCP wallettes is shown in Table 3.

Table 3 : Maximum load and vertical displacement under axial compression load

Wall reference	Maximum load(kN)	Vertical displacement(mm)	Maximum load(mean)(kN)	Vertical displacement(mm)
W1	105	7.42		
W2	90	6.91	102	6.90
W3	112	6.38		

From the testing result of wallettes, The maximum axial compression load of Wallette W3 is the highest compared to Wallette W1 and W2. It shows that the W3 has the capability to resist the load up to 112 kN at a vertical displacement of 6.38 mm. Wallette W1 was recorded 105 kN of maximum load at 7.42 mm vertical displacements. It was observed as the second highest of axial compression load capacity. Meanwhile, the wallette W2 was recorded as the lowest which can only stand 90 kN axial load capacity at a vertical displacement of 6.91 mm. From the testing experiment, it can be calculated that the average maximum of load can withstand by wood-wool composite panel wallettes bonded with lightweight cement mortar was at 102 kN at an average vertical displacement of 6.90 mm. It can be seen that the axial compression load capacity of Wallette W3 was higher than W2 about 24% and higher than W1 about 7%. It was noticed that the density of mortar as the bonding component were also affecting the strength of this type of wallettes. Wallette W3 with the higher density of mortar give the highest strength of wallette under axial compression load and wallette W2 with the low density of mortar give the lower strength.

In terms of load and vertical displacement relationship, the load-displacement behaviour of three replicates of wallettes under axial compression load test is presented in Figure 5.

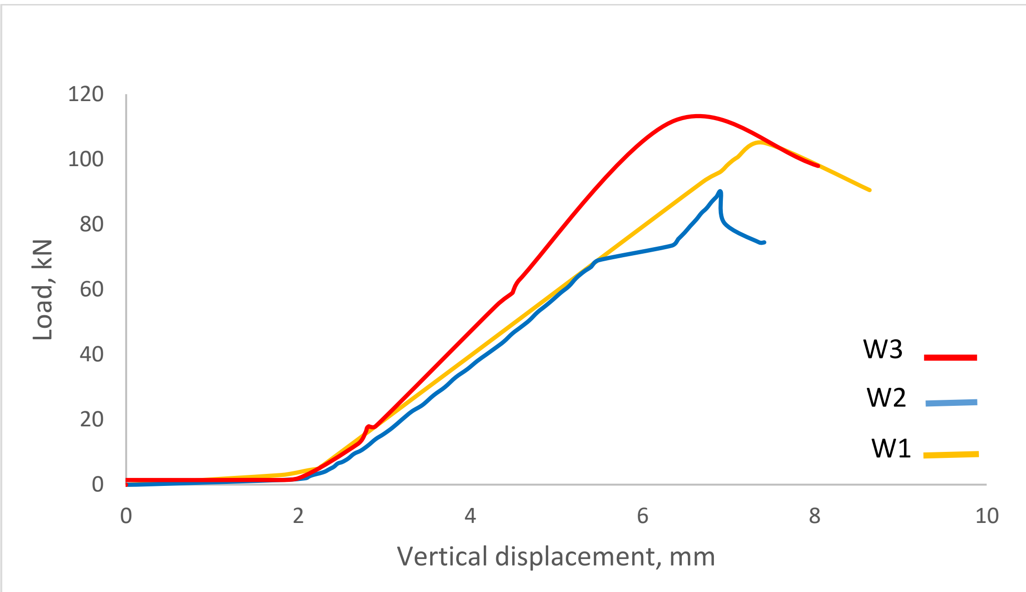

Figure 5: Load-vertical displacement curve

The experimental results of load-vertical displacement for W1 show the applied load increase linearly to the maximum load of 105 kN at a vertical displacement of 7.42 mm. After its reaching the maximum load, the curves show the load were slowly dropping until its final failure. Wallettes W2 shows that the applied load flat increase up to very low compression at first and increase linearly to the maximum load of 90 kN and vertical displacement of 6.91 mm. After the load is reaching to the maximum, a drastically drop in applied load was observed and could not withstand further load beyond this point indicating that the wallettes were cannot resist load after this point. For wallettes W3, the applied load were flat linearly increase up to very low compression at first until 2 kN and it slightly increase to the maximum load of 112 kN at vertical displacement of 6.38 mm. After reaching the maximum load, it shows as similar trend with the W1, the curves show the load were slowly drop until its final failure indicating that before its final failure, the wallets were still resisting load.

4. Conclusion

Based on experimental testing of axial compression load of cross laminated wood-wool cement panel wallettes bonded with lightweight cement mortar, the several conclusions can be drawn as follows;

- The density were affected the strength of lightweight cement mortar. The higher density of lightweight cement mortar gives the higher flexural and compressive strength.
- The new cross laminated technique gives a significant enhanced the stability of wallettes as well as increased the load carrying capacity of wallettes.
- The average value of the axial compression load capacity of wallettes bonded with lightweight mortar was 102 kN.
- The axial compressive strength of wallettes was governed by the strength of lightweight mortar act as WWCP bonding agent.
- The compressive strength of wallettes can be calculated as high as 113 kN/m and can be considered as a load bearing wall system for single storey buildings.

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