Experimental investigation of wood fibre cement composite wall panel under axial loading

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Abstract. wood fibre cement (WFC) composite wall panels were cast and tested under axial load with 4/6 wood/cement ratio, 0.8 water/cement ratio, three chemical additives and horizontal and vertical reinforcement. Other panels with the same mix design proportion without reinforcement were also tested and compared with the commercially available WFC composite *Duralite* boards. An experimental result for the Duralite boards, the specimen showed quick failure with lower loading value and also with axial deformation. The WFC panel without reinforcement showed more brittle type of failure in that they were unable to sustain any more loading after reaching the maximum load. The failure for the WFC panel with reinforcement was gradual and this behaviour was attributed to the presence of steel as they act like bridges between cracks preventing sudden failure. The WFC panels without reinforcement results are higher than the theoretical value and also higher than the Duralite board panels.

Keywords-Wood Fibre Cement Composite; load bearing; wall panels; axial loading

1. Introduction
Wood fibre cement (WFC) composites products are lightweight (at low density of 400 kg/m^3) and can be applied for multi purposes in construction industry for both structural and non-structural element. WFC boards are suitable for non-load bearing wall structures. When it comes to economical aspects of WFC, there are two major aspects playing a role here (Frybort et al., 2008). First, the chemical additives (calcium chloride, calcium formate, soda ash and a number of organic materials) are essential in the production of WFC boards because the additives speed up the chemical reaction in the cement and water and accelerate the rate of setting and early gain in strength of cement. Thus, the type and dosage of chemical additives should be chosen carefully for compatibility with the type of wood fibre used. Secondly, the cement-wood ratio needs to be considered with the fact that wood is less expensive than cement. Wood as a naturally and almost everywhere grown material is cheaper than cement. Replacing an amount of cement (per volume) by wood or other lignocelluloses materials makes the product cheaper. Previous research with *Kelampayan* wood type had determined that the

compressive strength of WFC mixture with chemical additives is greater than the strength of WFC matrix that was made without chemicals (2). At 28 days, the average strength of mixtures with wood-cement ratio of 40:60 that were made with chemical additives is the highest (increment of 62.7% in strength) than the WFC that is made with 50:50 and 30:70. Excess amount of cement in the WFC matrix with chemicals inclusion at wood/cement ratio of 30:70 had contributed negatively to the strength and had made the matrix brittle and failed at low strength.

Duralite (M) Sdn Bhd is one of the Malaysian owned companies. Duralite (M) Sdn Bhd was formed for the purpose of manufacturing and distributing their products under the name Duralite. Duralite panel (Dura) is manufactured accordance with BS 1105 or DIN 1101 standard. These boards are made from wood fibre that are chemically impregnated and cleverly bonded under pressure with Portland cement to form light weight and homogenises panels

For load bearing wall, its strength must be sufficient to carry load from the ceiling, roof or upper floor loads placed on it down to foundations, in addition to its own weight. Load bearing wall should be braced in the form of transverse walls directly connected to the load bearing wall (3). Wall also needs to support lateral loading such as wind. WFC composites wall panel can be used as external wall of an ordinary single story house. Masonry construction using clay brick, cement and concrete block is often used in load bearing wall of building up to four stories. By increasing the bending moment and compressive strength capacity, the light weight precast wall panel can be used as load bearing structural member. With a very little addition to the standard or specifically designed parameters, the WFC composite panels can easily be used as structural components and thus taking full advantage as concrete section. Several light weight alternatives to traditional precast concrete wall panels have been used in recent years. Dissanayake (4) investigated the behaviour of the slip formed load bearing wall panels made of cement and crusher dust subjected to two different support conditions (simple and continuous). It was concluded that the slip formed load bearing wall panels can sustain higher loads with crack free state than conventional masonry. Madsen (5) studied the experimental investigation of the plant fibre composites mechanical properties as load-bearing elements. The investigations included a number of relevant parameters: testing direction, matrix type, fibre volume fraction, process temperature and conditioning humidity. Mydin (6) verified the potential of using lightweight foamed concrete (LFC) in composite load-bearing wall panels in low-rise construction. The experiment investigated the performance of LFC panels of different densities whether the composite walling system had sufficient load carrying capacity, based on compression resistance at ambient temperature.

This research is to determine the capability of *Kelampayan* WFC composite by producing WFC composite wall with the optimized mix properties in previous research as described by Mahzabin et al. (2) with and without reinforcement to be used as load bearing wall. A laboratory test under concentric axial compression was conducted to investigate the axial behaviour of WFC load bearing wall panel. The tests were performed for all specimens to determine the ultimate load, load-deflection relationship and load-axial deformation relationship. A total of four wall panels were cast and tested, two WFC panel with reinforcement and another two WFC composite panel without reinforcement. The panels have been designated as similar to light weight concrete and were tested in one way action.

2. Experimental program

2.1. Sample preparation

The thickness of the WFC wall panels was chosen to be 100 mm to satisfy the fire resistance requirements for exterior bearing wall. It was the minimum code thickness for two hour fire resistive exterior bearing wall according to the international building code for the minimum thickness of cast in place or precast walls for various fire resistance ratings (7). The dimension of WFC composite for the application as load bearing wall panel were 600 mm for the width, 2000 mm for the height and 100 mm for the thickness (8). Two types of WFC wall panels (with two specimens for each type) were cast. The first was with 4:6 wood/cement ratio, 0.8 water/cement ratio, three chemical additives and horizontal and vertical reinforcement. The second panel was with same mixture except reinforcement.

The plane WFC wall panels without reinforcement were compared with the commercially available Duralite.

Two wall panels were reinforced with a single mesh consisting of 8 mm diameter bar with spacing of 94 mm for vertical reinforcement and 215 mm for horizontal reinforcement, placed in the centrally panel cross section. The vertical and horizontal reinforcements of panel were satisfying the minimum requirements of the British Standard BS 8110. The reinforcement layout is shown in Figure 1. This reinforcement was taken to keep the reinforcement to approximately the minimum level required by the code of practices.

2.2. Test Setup

The test frame was used to support the load testing mechanism and this frame consisted of two main steel columns each 4000 mm long. These columns were connected by complete fillet weld, to base plates. A series of channel members were used as cross beam were connected to the columns by bolts on each side. The test frame was used to support the independent hydraulic loading jack, of 500 KN capacities. The hydraulic loading jacks was attached to a strong mounted plate under the cross beam. The jack was required to transmit a uniform distributed load across the top through a loading beam. The bottom beam was identical to the upper beam and had small guide plate to prevent lateral movement. A schematic diagram of test setup is shown in Figure 2.

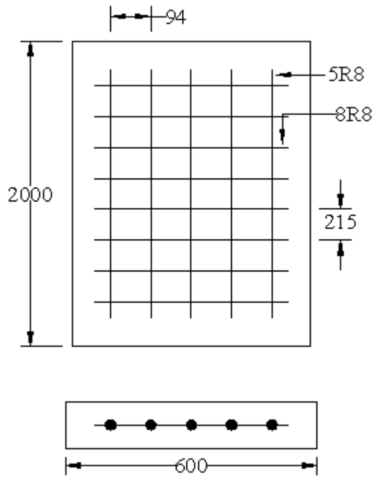

Figure 1. Arrangement of reinforcement in WFC wall panel (unit: mm).

2.3. Test Procedure

The walls were loaded with the crosshead of the machine was set to 0.5 kN/sec. With the load increments the deflection and the shortening of the panel were recorded. The linear vertical differential transducers (LVDT) were used to measure the deflection and axial deformation of the wall panel. They were placed at the centre of the panel (LVDT 2) and another one was placed on the top surface of the panels (LVDT 1).

The loading in the test program was a uniformly distributed nature along the length of the panel at the top and this distribution was achieved experimentally by transmitting the load from the fixed head of the testing device to the top through distributing with bearing plates. The detail of the test panel is shown in Figure 3.

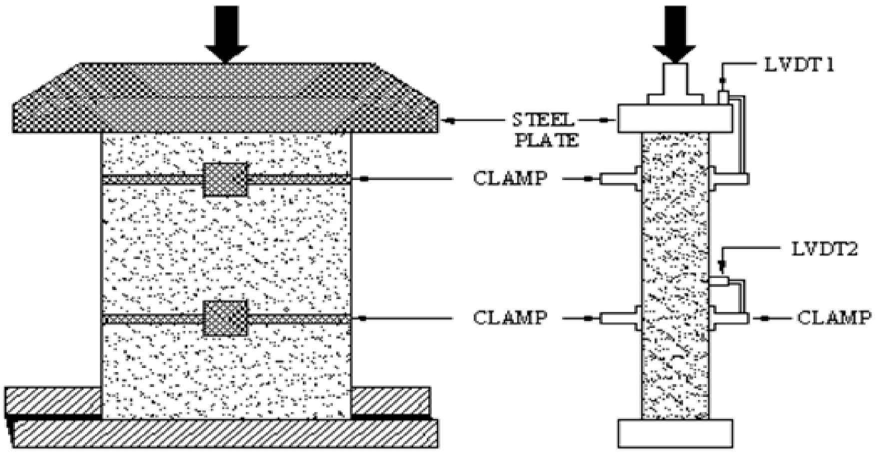

Figure 2. Schematic diagram of wall panel test setup

Figure 3. Testing setup of WFC composite wall panel

3. Results and Discussion

The wall panels were tested under concentric axial compression to determine the axial behaviour of the WFC panels as load bearing wall. All samples were tested in long direction in order to apply the WFC composite panel as load bearing slender wall. The ultimate axial load, mid span deflection and the axial deformations of the panels were determined.

The failure load for all panels tested are recorded and expressed in Table 1. The WFC panels without reinforcement results are higher than the theoretical value and also higher than the Duralite board panels. The overall test results were rather satisfactory except for the WFC panels with reinforcement results do not meet the theoretical value.

Table 1. Summary of Data of all WFC wall Panels

Panels	Experimental Ultimate load (kN)	Theoretical Ultimate Load (kN)
WFC Panel With Reinforcement	441 466.2	471.12
WFC Panel Without Reinforcement	345.2 357.8	275.17
Duralite Boards	98.2 110.9	-

The percent increase for the ultimate load of WFC panel with reinforcement is about 38.4 % and the percent decrease for the ultimate load of WFC boards without reinforcement is 27 % compared with Control panels (Duralite board). On the same time the mid span deflection of WFC panel without reinforcement is increased about 34.5 % and with reinforcement is decreased 2.11 % compared with control panels. The details of mid span deflection of all wall panels are mentioned in Table 2.

Table 2. Details of mid span deflection of all panels

Samples	Ultimate Deflection (mm)	Average Ultimate Deflection (mm)	Percent different (%)
Dura1 Dura2	15.6 12.44	14.02	Control
WP1 WP2	54.47 16.56	35.51	34.52
RWP1 RWP2	15.38 10.04	12.71	-2.11

For the Duralite boards the specimen showed failure with lower loading value at average 104.55 kN and also with small axial deformation 4.1 mm. For the WFC panel without reinforcement showed brittle type of failure in that they were unable to sustain any more loading after reaching the maximum load at 351.5 kN. The failure for the WFC panel with reinforcement was gradual and this behaviour was attributed to the presence of steel as they act like bridges between cracks preventing sudden failure. The percent increase for the ultimate load and deformation WFC panel without reinforcement is about 27 % and 48 % compared with control. However, the ultimate load of WFC panel with reinforcement is increased about 38.4 % and the deformation about 6.5 % compared with control panel. The details of axial deformation for all panels are mentioned in the Table 3.

Table 3. Details of axial deformation of all panels

Sam.	Ult. Load (kN)	Ave. ult. Load (kN)	Percent diff. (%)	Ult. Deform. (mm)	Ave. Ult. Deform. (mm)	Percent diff. (%)
Dura1 Dura2	98.2 110.9	104.55	Control	3.79 4.41	4.1	Control
WP1 WP2	345.2 357.8	351.5	27	22.85 11.37	17.11	48
RWP1 RWP2	441 466.2	453.6	38.4	6.29 5.44	5.86	6.5

For the Duralite boards, the specimen showed quick failure with lower loading value and also with axial deformation. The WFC panel without reinforcement showed more brittle type of failure in that they were unable to sustain any more loading after reaching the maximum load. The failure for the WFC panel with reinforcement was gradual and this behaviour was attributed to the presence of steel as they act like bridges between cracks preventing sudden failure.

4. Conclusion

For the Duralite boards, the specimen showed quick failure with lower loading value and also with axial deformation. The WFC panel without reinforcement showed more brittle type of failure in that they were unable to sustain any more loading after reaching the maximum load. The failure for the WFC panel with reinforcement was gradual and this behaviour was attributed to the presence of steel as they act like bridges between cracks preventing sudden failure. The WFC panels without reinforcement results are higher than the theoretical value and also higher than the Duralite board panels. The WFC panels with reinforcement results do not meet the theoretical value.

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