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Study of Compressive and Flexural Strengths on Hollow Core Wall Panel (HCWP) in the Precast Concrete System

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Abstract: Hollow Core Wall Panel (HCWP) is one of the partition walls commonly used in the construction industries in Malaysia since the conventional method have many lacks in vary aspect such as increasing the material and labour demands, quality of construction, cost of project and time management. Hence, the objective of this study is to investigate compressive strength between HCWP and Normal Brick Wall (NBW) and to study on flexural strength between HCWP and NBW where HCWP samples collected at ACOTEC Sdn. Bhd. factory at Johor, Malaysia. By using three samples of HCWP and three samples of NBW for compressive and three-point bending test, the compressive and flexural of wall samples can be compared due to its mechanical properties. Thus, the result of this study shows the compressive test data that initiates the strength of wall samples as non-load bearing and the deformation and cracking from flexural test that justified the wall samples to resist load from the structure members. From the analysis that has been done, HCWP have higher compressive strength than NBW but in term of flexural strength, HCWP have lower strength compared to NBW. It shows that HCWP cannot support directly other structure members as it has low flexural strength.

Keywords: Mechanical Properties, HCWP, Non-Load Bearing Wall

1. Introduction

The construction process using conventional method nowadays are less effective and not environmentally for big construction industry although it is commonly use in Malaysia. The conventional method used formwork in site and gain more cost of labour, raw materials, and the period of construction process [1]. The IBS systems provided a new solution to reduce the materials used and improved the performance of construction project. According to M. Rohana [2], it recommends enhancing the economics of IBS adoption and increasing the organizer for IBS supplier. For example, Building Information Modelling (BIM) design library and overall regulatory support can be improved by establishing the IBS catalogue along with it.

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However, rapid construction of building is producing major problems in the depletion of natural aggregates in Malaysia and the creating large quantities of concrete waste. The usage of natural aggregates will increase the depletion of natural aggregate resources and if there is no effective regulation for aggregate consumption, Malaysia would suffer the reduction in aggregate supply [3]. The result of a shortage of certain construction materials is that construction costs will rise and shifting the burden to end users. One of the best suggested ways is increasing the IBS usage such as HCWP in our country to achieve sustainable concept.

The quality of construction also affecting the construction process. The cost of cement is quite higher and transporting it may delay the work process. Precast concrete is made from factory with advanced mix designs and better vibrations which require less concrete cement and steel [4]. Precast concrete requires less concrete cement and steel, and compressive strength and tensile performance may be varying. Thus, this study is to investigate the compressive strength and flexural strength of HCWP to compare with the conventional method wall samples.

2. Literature Review

Precast concrete is very reliable than conventional method to utilize in any construction project. IBS method helps increase the sustainability of the project with the implementation of prefabrication during the building process, reducing the overall construction time, including improvements in occupational safety, material conservation and reduced waste from the site [5].

2.1 Flexural Strength Properties of Partition Wall

The mechanical properties of precast concrete gives many advantages on structure strength and sustainability compared to conventional method. According to Zhu *et al.* [6], the structural system, the shear ability, deformation, and seismic resistance may be improved with the use of the enhanced precast concrete. This statement also supported by Marwan *et al.* [7], has also been shown to have a substantial impact on seismic performance and deformation of the structural work system of the precast concrete. It shows that the dimensions manufactured from the factory improves it deformation and seismic ability of concrete on building.

2.2 Compressive Strength Properties of Partition Wall

Precast concrete manufacture usually provides higher compressive strength by using additives cement than cast in-situ concrete to have low water/cement (w/c) ratio and high compressive strength. According to ASTM 129 [8], non-load bearing masonry units should achieved 3.45 MPa for individual units and 4.14 MPa for average three units' wall. Therefore, the IBS system should improve the compressive strength of wall by its interlocking systems compared to conventional wall. Refer to [9], the dead load of structural members can be reduced via using lightweight concrete, which is not significantly relevant for typical buildings and constructions but plays a significant role in high rise structures.

2. Materials and Methods

The Hollow Core Wall Panel (HCWP) samples are collected at precast concrete manufacture (ACOTEC Sdn. Bhd.) which 10 samples of HCWP provided with dimension 300 mm x 600 mm x 100 mm. The Normal Brick Wall (NBW) samples are produced by batching mortar with 1:4 ratio and plastering at the final process of brick wall samples. The following sub-section shows the raw materials and processes for produced NBW samples.

Figure 1: HCWP Samples with Dimension of 300 mm x 600 mm x 100 mm

2.1 Raw Materials for NBW samples

i. Clay brick

The used of brick in this study is clay brick which available in UTHM laboratory. The clay brick is more strength in term of brick performance. The clay bricks will be combine using mortar to form normal brick wall samples. The mortar ratio used in this study is 1 (cement): 4 (sand) to produce the samples.

ii. Cements

Ordinary Portland Cement (OPC) is type of cement that used often in construction. OPC was manufacturing in accordance with the quality requirements defined in the Malaysian Standard, MS 522: 1: 1989 Specifications for OPC (Malaysian Standard for OPC Manufacturing Quality). The cement was kept in faculty of Civil Engineering and Built Environment (FKAAB) laboratory for project and student learning purpose. Type of mortar use is type 0 mortar mix where it is suitable for non-load bearing wall.

iii. Sand

The sand used in mortar ratio is natural sand where it is available at the FKAAB laboratory. It is suitable for bricklaying and plastering where it has better grain form and a smooth texture and required less moisture because water has already been trapped within its particles during the manufacturing process.

iv. Water

The water-cement ratio for NBW samples is 0.4 to 0.6 according to ASTM C270 [10] for mortar performance on binding the bricks.

Figure 2: NBW samples preparation

2.2 Methods of Testing

The **table 1** shows the testing series for HCWP and NBW that conducted compressive strength test and flexural strength to analyze it.

Table 1: Testing Series for HCWP and NBW

Type of testing	Testing Designation	Wall width (mm)	Wall length (mm)	Wall height (mm)	No. of samples	The volume of wall sample (m^3)
Compression test	HCWP	100	300	300	3	0.009
	NBW	100	300	300	3	0.009
Three-Point Bending Test	HCWP	100	600	300	3	0.018
	NBW	100	600	300	3	0.018
	Total				12	0.054

The testing conducted on HCWP and NBW samples are compressive test using compressive test machine and three-point bending test using Universal Testing Machines (UTM) at Jamilus Research Centre (JRC), UTHM laboratory. The **figure 3 (ASTM C129)** and **figure 4 (ASTM C78)** shows the machine conducted to obtained data for this study. The loading rate of 0.5 kN per minute was applied to the UTM machine by referring to the ASTM C78 standard.

Figure 3: Compressive Test in Laboratory

Figure 4: Three-point bending test by UTM machine

3. Results and Discussion

The results and discussion section presents data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 Compressive Strength

Compressive strength test conducted to evaluate the compressive strength of HCWP and NBW. The results are compared toward the average of strength data for both samples. Before the test are conducted, the physical properties of HCWP and NBW need to assess to determine the difference of mechanical properties of wall samples. The **table 2** shows the difference of physical properties for both samples tested in the laboratory.

Table 2: HCWP and NBW Density Properties

Type of sample	Number of samples	Weight (kg)	Average weight (kg)	Density (kg/m^3)	Average density (kg/m^3)
HCWP	1	13.19		1477	
	2	13.36	13.29	1484	1480
	3	13.31		1479	
NBW	1	22.94		2549	
	2	21.75	22.09	2417	2455
	3	21.59		2400	

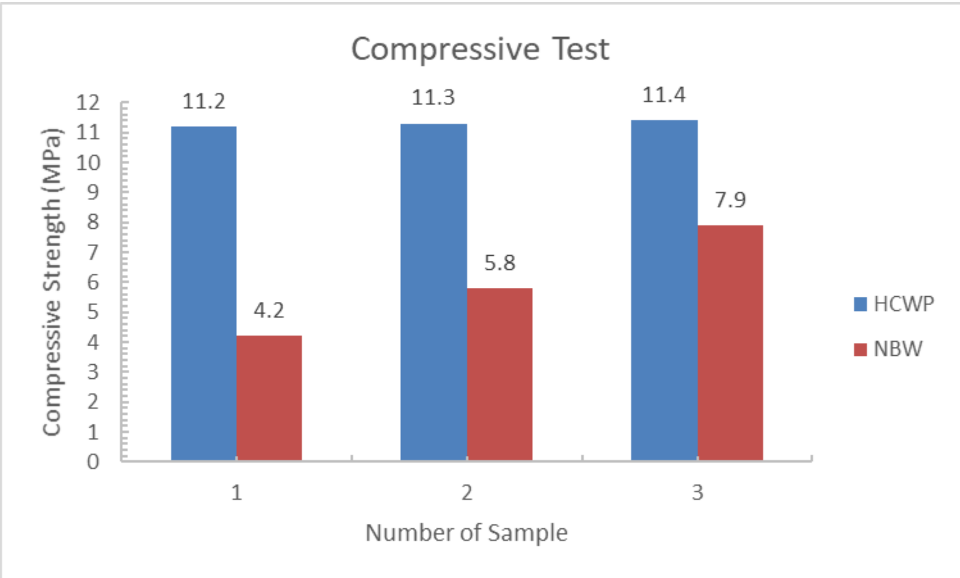

Figure 5: HCWP and NBW Compressive Strength Test Data Obtained

Based on the **figure 5**, the compressive strength test act shows that HCWP have higher compressive strength than normal brick wall samples. The highest strength achieved by sample HCWP is 11.4 MPa by HCWP 3. The normal brick wall samples achieved the highest strength on NBW 3 sample where it produced 7.9 MPa. As state before, the strength of each wall sample is considered acceptable for in this study, and it is not lower than the minimum strength of non-load bearing wall which is 4.14 MPa wall strength according to [8]. The strength of partition walls should higher as it should resist the load from the structure members. Moreover, the HCWP are lighter in term of wall weight where it is easy to install in site compared to conventional method. As partition wall, it is suitable for non-load bearing wall as it can resist higher compressive loading while it was lightweight based on its density. Thus, it also reduced the wastage construction that commonly produced in conventional method in terms of constructing partition wall and construction wastage.

3.3 Flexural Strength Test

The flexural strength is determined by using the three-point bending testing which is UTM machine is used in JRC laboratory refer to ASTM C78 [11] guideline. The table 3 shows the average maximum load applied and deflection of wall samples can resist towards the load act at the middle of sample span.

Table 3: Average Maximum Load and Deflection of HCWP and NBW

Wall Sample	No. of Sample	Maximum Load (KN)	Deflection of Wall (mm)
HCWP	1	34.83	0.898
	2	29.40	0.734
	3	36.05	1.058
	Average	33.43	0.896
NBW	1	62.78	4.238
	2	62.48	3.610
	3	63.74	5.419
	Average	63.74	4.423

From **figure 6**, the HCWP samples shows consistency in the term of graph slope where it can resist the stress act at the middle span. The highest maximum load can be resisted by HCWP sample is 36.05 KN with 1.058 mm deflection obtained. However, all the HCWP samples appeared to have less flexural strength compared to NBW. One of the obvious things that related toward HCWP is the hollow section. The ultimate failure occurred throughout the hollow section at the HCWP middle span. It shows that structural member such as roof beam where it cannot directly transfer the force towards the HCWP. It cannot support higher loading due to the hollow section where it intends cracking failure at the area. Nevertheless, the HCWP still provide less deformation where it is suitable for non-load bearing wall in term of the usage of HCWP in high rise building will help to resist load in the structure. In addition, standard deviation has been analysed for all samples to indicate the accuracy of failure load occurred as shown in **table 4**. The HCWP shows it have better accuracy of failure load compared to normal brick wall.

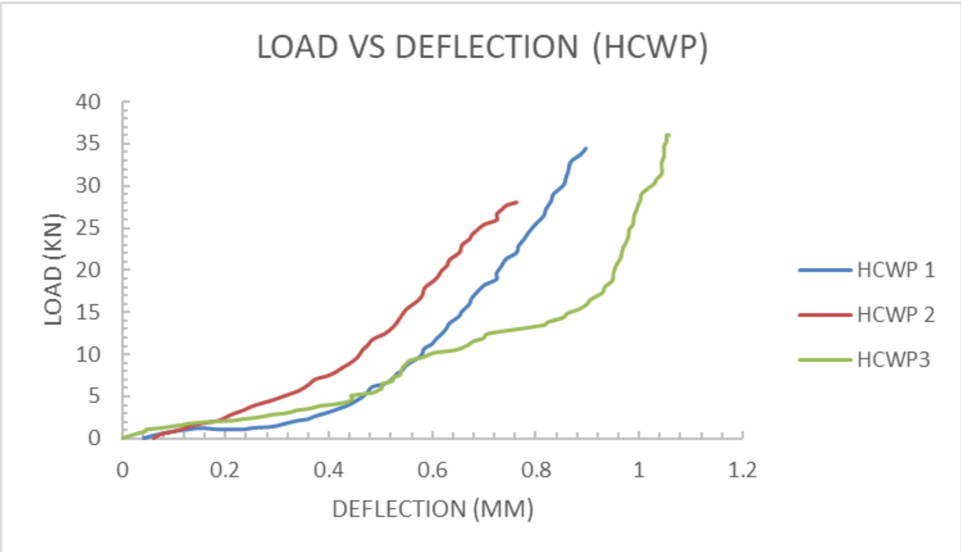

Figure 6: Load vs Deflection Graph for HCWP samples

Table 4: Average Maximum Load and Deflection of HCWP and NBW

Wall Sample	No. of Sample	Failure Load (KN)	Average Failure Load (KN)	Std Derivation	Stress (MPa)
HCWP	1	34.83			2.09
	2	29.40	33.43	1.94	2.08
	3	36.05			2.20
NBW	1	62.78			1.16
	2	62.48	63.74	3.54	0.98
	3	63.74			1.20

For three NBW samples tested, the results show from **Figure 4.7** that NBW 3 have the highest maximum loading with 65.97 MPa while the NBW have the lowest maximum loading with 60.48. The factors that effected the NBW flexural strength is it produced solid area at the middle span where loading act on the samples. NBW samples took a longer time to achieve ultimate load failure due to it can resists more loading from the test. From the graph, the slope of the three samples is vary due to some error occurred during testing. These were produced by human error during the initial point load attachment prior to testing. Another aspect was the middle span of a wall covered with a wooden plate during testing, which caused the deflection length of the wall sample to be disrupted. However, NBW samples have less average standard deviation value compared to HCWP that can be seen in **Table 4**. The accuracy of failure load of this sample testing is lower than HCWP where the testing handling may be the factors that affected the samples failure loading value. It shows that NBW are more suitable in resisting the stress from the loading given where it can support the structural member better than HCWP. It can conclude that conventional method is higher in resisting tensile stress but still lack in its physical properties compared to HCWP.

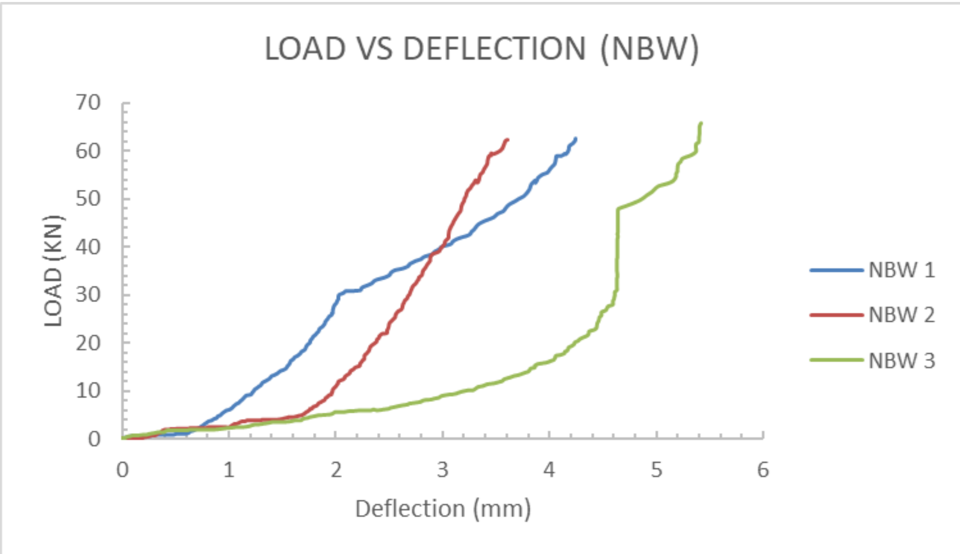

Figure 7: Load vs Deflection Graph for NBW Samples

4. Conclusion

From the observation made, it shows that HCWP have higher compressive strength compared to NBW where it is suitable for construction purposes as partition walls due to it has higher compressive strength, lightweight and reduce the cost and time of construction process. This shows that HCWP are capable to replace the conventional method in order to achieve the sustainability of construction. In term of flexural strength, HCWP has less flexural strength where it should have another support to resist load from the structure members. The other factor is the HCWP sample have hollow section at the middle span where it is easy to crack occurred then lead to the ultimate failure. For future studies, it is recommended that the HCWP should been add with reinforcement to obtained it is suitable to be load bearing wall. This will contribute to IBS innovation and awareness on construction industries in Malaysia.

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