STRUCTURAL STABILITY OF FERROCEMENT GARBAGE DISPOSAL BARGE

Ronaldo Gallardo [1], Susan Gallardo [2] and Irene Olivia Ubay – Anongpouth [1]
[1] Civil Engineering Department, Gokongwei College of Engineering, De La Salle University
[2] Chemical Engineering Department, Gokongwei College of Engineering, De La Salle University

Abstract: The solid waste disposal problem of Metro Manila has attained significant attention for over the last decade and waste generation has increased by almost 50%. Dumping, land filling, recycling, and segregation are insufficient disposal methods that compromise the well being of the environment and human health, prompting the need for a more effective method of permanent garbage disposal. A proposed solution to the given dilemma is the construction of a Ferrocement barge that would incorporate non-biodegradable and non-recyclable solid wastes in the structure. The structural integrity of a Ferrocement garbage disposal barge reinforced with bamboo and plastic mesh was evaluated by fabricating and comparing ordinary Ferrocement panels and substituted reinforcement Ferrocement panels. Two strength tests that were in accordance with ASTM were conducted on the different panel types that were fabricated: Transverse and Axial Compression. The proposed bamboo-reinforced (BR) hybrid panels were at par with the typical steel-reinforced (SR) ferrocement panels in terms of compressive strength results. However, the hybrid panels behaved poorly in terms of tests in tension. From test results, it would be plausible to use hybrid panels only as walls in the proposed barge.

Key Words: ferrocement, barge, bamboo, strength tests, deformation

1. INTRODUCTION

Ferrocement is an economic and environment friendly method of reinforced-concrete construction. Marine structures crafted using this technology have lasted a considerable amount of time (Naaman, 2000). However, one of the invariable challenges in working with steel is its high cost and susceptibility to corrosion, thus the need for an alternative resource. Bamboo possesses similar mechanical properties as steel. It has proven to be an effective substitute for steel in ordinary reinforced concrete. However, its performance with the addition of plastic mesh in creating a hybrid Ferrocement panel has yet to be evaluated.

The study aims to determine whether a Ferrocement panel reinforced with bamboo and plastic mesh would be an effective replacement for a steel reinforced panel. The specific objectives would be to compare and contrast the mechanical properties of a steel reinforced Ferrocement panel and a bamboo and plastic mesh reinforced Ferrocement panel by conducting two types of strength tests.

2. METHODOLOGY

2.1. Fabrication Process

The panels were designed in accordance with a blueprint of the proposed barge model. According to ASTM E 72-05, a panel's height should conform to the height of the structure where it will be applied. In this case, the height was designated at 2.4 meters, which was also the maximum height that the apparatus could accommodate. The said width was limited to 1.2 meters and the thickness was at 0.05 meters. Figure 1 shows the skeletal reinforcements of the cross section of the panel. Table 1 gives the summary of the panel design. Refer to Figure 2 for the actual photos of the fabrication process.

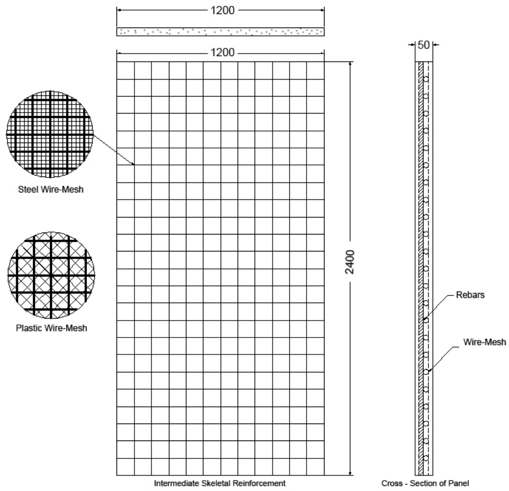

Figure 1. Skeletal Reinforcements of Panels

Table 1. Panel Design Summary

Criteria	Regular Panel	Hybrid Panel
Intermediate Skeletal Reinforcements	10mm RSB	¾" Bamboo
Spacing	100mm	100mm
Wire-Mesh Reinforcements	1"x1" Welded Wire Mesh	1"x1" Hexagonal Plastic Mesh
Cement	Type I, Portland Cement	Type I, Portland Cement
Sand	Crushed Sand	Crushed Sand
Water	Potable Water	Potable Water
Mix Design	1C: 2S: 0.5W	1C: 2S: 0.5W
Thickness	50mm	50mm

Figure 2. Layout of Steel-Reinforced (left) and Bamboo-Reinforced (right) Panels

2.2. Transverse Load Test

The two-point loading was used for this test. The panels were treated as a simple beam on a span 76 mm less than the specimen length. The remaining length of the specimen was divided into four equal parts and at a distance of one quarter from the center, two equal loads were applied on the left and right of the span. The load on the specimen included the weight of the specimen between the supports. An initial load of 0.5 kN was applied to the specimens. Increases in the loading on the panel were at increments almost equal to the initial load applied to each test. Adequate readings of the increasing load and the corresponding deformation of the panel were recorded to be able to plot the Load-Deformation Curve. The transducer, a deformation-measuring apparatus that measures with sufficient precision, was used to be able to get an accurate load-deformation relationship. Two transducers were placed on top of the specimen in each side of the hydraulic jack instead of placing them below the specimen in order to avoid unwanted damages to the apparatus in case the specimen suddenly fails during the conduct of the test.

2.3. Axial Compressive Load Test

An initial load of 5kN load was applied to the specimens of the axial compression load test. To apply the load uniformly throughout the width of the specimen, an I-Beam was placed on top of the panel.

Figure 3. Actual Set-up of Test for Transverse Load Test (left) and Axial Compressive Load Test (right)

3. RESULTS AND DISCUSSION

3.1. Transverse Load Test

Based on Table 2, the data obtained for steel-reinforced (SR) specimens are closer to each other with respect to both their maximum load and deflection. Conversely, bamboo-reinforced (BR) specimens demonstrated inconsistent and erratic behaviors: the lowest maximum load carried is just 28.57% of the highest load reached; the highest maximum deflection attained is 821% that of the lowest deflection carried. Figure 5 shows the Load vs. Deflection graph of the test. The average values for the maximum load and maximum deflection of SR specimens are 21.0 kN and 43.555 mm, respectively. On the other hand, BR specimens reached an average maximum load of 1.4 kN at an average deflection of 1.939 mm. The percent difference of the load carried by the steel and bamboo panels was extremely high at 175%.

Table 2. Summary of Transverse Load Test Results

Test Specimen	Maximum Load (kN)	Maximum Deflection (mm)
SR1	21.6	42.610
SR2	20.9	47.568
SR3	20.4	40.488
BR1	1.6	0.563
BR2	0.6	0.630
BR3	2.1	4.623

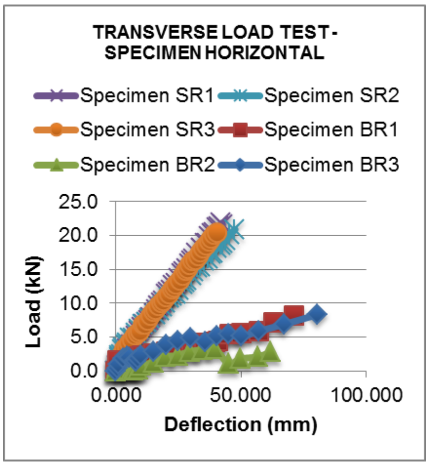

Figure 5. Load vs. Deflection Graph

3.2. Bending Modulus of Elasticity

Panels reinforced with bamboo and plastic mesh failed during the first few increments in loading, but the load was still increased to determine the maximum deflection the panels could reach using the equipment or the maximum deflection before the panel completely collapsed due to the induced load. Because of this, the elastic region considered is from zero loading and zero deflection to the loading and deflection before the panels failed.

Results of individual specimens deviate a lot from each other. No two specimens produced similar results, which show that the specimens are very inconsistent. The percent difference between specimens possessing the highest and lowest modulus of elasticity was calculated, and an extremely high percent difference of 120.41% was obtained. Again, this result shows the inconsistency of the bamboo specimens.

3.2. Axial Compression Load Test

In this experiment, loadings were increased at increments of approximately 5kN until 110.0 kN and 100.3 kN were reached for the regular panel and hybrid panel, respectively. The loadings was stopped not because the panel failed but due to the limitations set by the apparatus. The integrity of the equipment was risked during the testing of the regular panel that led to an additional 10 kN loading compared to the hybrid panel. Both panels reached a compressive strength of 1.67 N/mm^2 if 100 kN is to be used as the benchmark. Table 3 summarizes the results of the axial compression load test.

The results of the compression test show that both panels exhibited strong resistance to the load applied. The behavior of the bamboo-reinforced panel when subject to compression was more at par with the steel-reinforced panel compared to the transverse load test. This is because the resistance of bamboo when load is applied parallel to its grain is much stronger than when it is applied in the perpendicular direction (Alito, 2005).

Table 3. Summary of Axial Compression Load Test Results

Regular Panel	**Hybrid Panel**
Maximum Load (kN)	**Maximum Load (kN)**
0.0	0.0
6.3	5.9
9.8	11.4
15.9	15.4
20.9	20.4
26.6	25.4
32.3	30.4
37.7	35.2
40.1	40.4
45.9	46.1
51.2	50.7
56.1	55.9
60.7	60.9
66.2	66.4
71.9	70.9
75.9	75.2
80.2	80.7
85.4	85.5
90.4	90.4
94.7	95.7
99.7	100.3
105.5	-
110.0	-

4. CONCLUSIONS

Given that the problem on solid waste disposal is aggravating, the conditions of the existing garbage disposal procedures were examined. It was found that open and controlled dumping are both the primary means of permanent waste elimination. The analysis of the deficiencies of the current disposal procedures stimulated the conception of the Ferrocement garbage disposal barge.

In terms of tensile strength, a 175% difference was obtained in the strength of the two panel types. The load that bamboo was able to withstand was 1/10th of the load applied and endured by steel at the end of the test. The unexpected failure of the hybrid panels might have been due to the inconsistency of the mechanical properties of the chosen reinforcement. For bamboo, the expected value at failure is at 44 mm but as seen in the graphs, the average failure that occurred in the bamboo-reinforced specimen was only at 1.4 mm. In similar tension tests for bamboo, the same behavior prevailed. Another reason for the poor performance of the hybrid panel might have been the faulty bonding of the mortar and the bamboo. Steel bars have rougher surfaces compared to bamboo, which makes the adhesion between steel and the mortar a lot easier. Aside from being a rougher material, the reinforcing steel bars have embedded surfaces along their lengths, which further enhance the bonding of the two materials.

The compressive strength of bamboo on the other hand, was at par with the steel-reinforced panel up to 100kN. Bamboo is an anisotropic material and exhibits greater resistance to load applied parallel to the grain better than when load is applied perpendicular to the grain.

If the bamboo-reinforced panels are to be used in constructing the Ferrocement barge, it can be suggested as vertical walls only. The BR panels cannot sustain very heavy loads in tension and would just threaten the integrity of the barge if it were used to sustain tensile load. On the other hand, the steel-reinforced panels perform well in both tension and compression and can be applied on any part of the barge.

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