

Comparative Analysis of the Mechanical Properties of Coconut Fiber Cement Board and Concrete Hollow Blocks

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Abstract

In order to determine if the CFB panel is superior to the CHB, this study, "Comparative Study of the Mechanical Properties of Coconut Fiber Cement Board and Concrete Hollow Blocks," compared the two products' prices, dead loads, and compressive strengths. Three samples of each of the two products were used in the experiment, which the researchers conducted. The tensile strength test, parametric test, and Universal Testing Machine (UTM) were used to gather the data for this study. The compressive strength test was performed at the TERMS Concrete and Materials Testing Laboratories Inc. in Tayuman, Manila. The study assumed that: CFBs are less expensive than CHBs; carry less weight than CHBs; and have greater structural strength. Results show that CFB has an average compressive strength of 1,004.167 PSI. In comparison to a CHB, the CFB has more compressive strength. The researchers also concluded that a CFB would carry less weight than a CHB at 5.4721 lb. In both panels' cost analyses, the price of CFB is deemed to be higher than the price of CHB. Fiber Cement Board (CFB) offers a substantially more cost-effective alternative. By enhancing the walling system for residential establishment, this study will benefit the Philippine construction industry.

Keywords

CHB, CFB, Construction Industry, Compressive Strength, and UTM

1. Introduction

In the Philippines, the construction industry contributes largely to its economy. In the fourth quarter of 2020, there is a gross value added of about PhP 336 billion. This refers to the total construction expenditure by private and public firms. CHB or Concrete Hollow Blocks are commonly used construction materials when building residential due to its affordability and availability. In an article of Desai (2020), it is stated that Concrete Hollow Blocks have a relatively low compressive strength and load-bearing capacity which is not ideal in large-load bearing structures. Also, CHBs when delivered require extra workforce due to its weight which requires precaution as it could break easily when dropped. The proponents thought of a wall panel system that could further strengthen the load bearing capacity of the structure of residential housing while using its most abundant resources. The Philippines is considered as one of the top producers of coconut in the world, there are 9 billion coconut husks every year that are burned because it takes years for them to decompose (Pogosa et al. 2018). The proponents developed a cost-effective and high quality panel called Coconut Fiber Cement board made with cement and coconut husk and this panel will be used as permanent

formworks in residential construction. Furthermore, this study aims to prove that the developed product supersedes the existing construction material which is the CHB in terms of its mechanical properties, while being environmentally friendly.

1.1 Objectives

This study primarily aims to compare and analyze the mechanical properties of the coconut fiber cement board (CFB) and concrete hollow blocks (CHB). The researchers will compare the Cost, Dead Load, Compressive Strength of the CFB and CHB. By the end of this study, the researchers are to determine if the CFB panel can be a cost-effective, and sustainable material in construction and an alternative to the most commonly used construction material in the Philippines which is CHB.

2. Literature Review

2.1 Permanent Formwork Wall Panel

A study by Biruk and Jaskowski (2017) defined formwork as a structure in which concrete is poured into and molded into specific dimensions. Different formwork systems offer a variety of concrete building methods that can be customized to a particular structure's requirements. In addition, Kulshrestha et al. (2017) defined a wall panel as a rectangular-shaped piece of material that is flat and is usually used for wall coverings and is also said to provide insulation, soundproofing, and durability. Furthermore, the term permanent formwork wall panel is also termed sandwich wall panel. Al-Rubaye et al. (2019) defined a sandwich wall panel as a panel made up of an insulation layer sandwiched between two layers of concrete.

2.2. Coconut Fiber as a material

In the study of Ahmad et al. (2020), the mechanical properties of coconut fiber reinforced high strength concrete was investigated, and the result shows that coconut fibers have the greatest known toughness out of any natural fiber. According to Pagasa, the average annual temperature in the Philippines is 26.6 degrees Celsius. The Philippines is considered a tropical country wherein the temperature is usually hot and humid, which proves that insulation in every residential household is essential. As stated in the study by Iwaro J. & Mwashia A. (2019), coconut fiber is the most preferred insulator because it has the characteristics needed to improve energy efficiency and maintain thermal comfort in a residential house.

Moreover, in the study of Hadi and Sudrajat (2020), composite materials like the coconut fibers are said to be known for the convenience of its weight, which despite being light, it still has great strength and durability, which can be compared to metals, while still having its property to be resistant to corrosion. Although this is the case, there is still a method that can be done in order to optimize the quality of using coconut fibers as a material, it is accomplished by using %5 NaOH as a solution to submerge the coconut fiber for 2 hours, to gain an optimal tensile strength value of 21.075 Mpa. In addition to this, to further improve the thermal stability of the material, treatment with alkaline solution is done.

2.3 Traditional Formwork System

In the industry of concrete construction, one of the most commonly used systems is the Traditional Formwork System. However, with the use of sustainability performance measurement, the system was only given a score of 40.24% by the experts under three categories namely environmental, social, and economic (Al- Ashwal et al. 2017). With the help of the improvement and further incorporation of social and environmental pillars of the traditional formwork system could help in the advancement of the system to a higher level of score.

There are many factors that affect the cost effectiveness of construction of a building and other structural entity. These factors should be considered and if it becomes a problem, it should be addressed immediately without delay, because a delay can increase the cost of the process of construction. According to the study of Kurakova (2018), the factor of time and the erection of these buildings within a reasonable amount of time, while still upholding structural integrity and high quality is valuable for the competitive advantage of any construction institution. In correlation with this statement, the utilization of formwork systems and technologies can dictate the course and speed of construction of a high-quality building. In addition to this, the system used can also determine the intensity of labor required in order to finish the job. These are both important factors in cost management of a construction organization. The use of

optimized and advanced models of construction improved the efficiency of construction projects, especially to high-rise construction buildings.

With the emergence and concept of globalization, there are many studies and research that aim to improve the construction of formwork systems. This is due to the fact that in the construction of a building, the Formwork costs are at an estimate of 20%-25% of the total cost of the entire construction (Mohan Sai and Aravindan, 2020). Latest Formwork System models are said to be much more efficient and less expensive in terms of materials and labor compared to the Traditional Formwork System. This information was determined with the use of comparative studies of buildings that use the Traditional Formwork System and the newer Formwork Systems in their construction of Formwork (Mohan Sai and Aravindan 2020).

With this, a study of Hedberg, et. al (2018) asserted that the continuous development and advancement in panel and formwork systems gave rise to material innovations. In the residential construction development and increasing population people contributed to the factors to construct high-rise buildings and construction. With the development, the man made the tasks easy by inventing new machinery and new techniques as well as the materials employed in formwork systems. One such area related to high-rise construction is the type of the formwork used in the construction and the level of its compressive strength. In the early days' people used conventional type formwork where the timber planks were supported on timber columns. With the advancement of science man used plywood instead of timber planks and pipe supports with various kinds of jacks instead of timber supports.

2.4. Sustainability in Construction

Concerns about sustainability in construction projects have risen to the foreign advanced economies. Developing countries have prioritized economic development over meeting sustainability standards. Environmental concerns have been overshadowed due to the need for economic growth in developing nations, which has increased the colossal demand for construction projects (Banihashemia et al. 2017).

According to a study conducted by Abu-Jdayil et al. (2019), there is a need to develop and create insulating materials that have excellent properties while having low environmental impact and being relatively inexpensive. The article focused on studies that used renewable resources and waste in developing thermal insulations. Furthermore, in the study a light was shed on composite materials building materials, and it was found to have high thermal insulation capacity.

Zeolite is a crystalline metal mainly found in volcanic rocks and used in the study of (Samardzioska et al. 2017). In the experiment, the researchers used zeolites instead of aggregate, and using zeolite as an alternative was found to have good water absorption and high compressive strength. In addition to significantly lowering toxic waste and energy use, it contributes to a greener and safer environment. Zeolite was introduced to address some environmental concerns. The results of the parameters obtained from laboratory tests will provide opportunities for applying and using zeolite as a sustainable raw material for the construction industry.

3. Methods

3.1 Methodology

Since the focus of the study is based on the experimental analysis of CHB and CFB, the researchers will compare the two products using a criterion. This is to ensure that the researchers can accurately compare the two products' mechanical properties. The criteria are as follows

a.) Dead Load of Fiber Cement Board and Concrete Hollow Block

The dead load of the two materials can be measured by using an industrial weighing scale (given that the two products have the same surface area). This is to know which of the two materials are lighter. The lighter the material, the easier it is to be carried by a worker.

b.) Compressive Strength of Fiber Cement Board and Concrete Hollow Block

The researchers will be using a universal testing machine. The materials will undergo multiple compressions. The higher the PSI that the product can withstand, the better compressive strength.

c.) Cost of Coconut Fiber Cement Board and Concrete Hollow Block

To determine the cost of both panels, the researchers used Microsoft Excel to compute the overall cost of construction using both panels in order to determine which is more cost efficient. The lesser the cost, the more it would be beneficial to construction companies.

3.2 Conceptual Framework

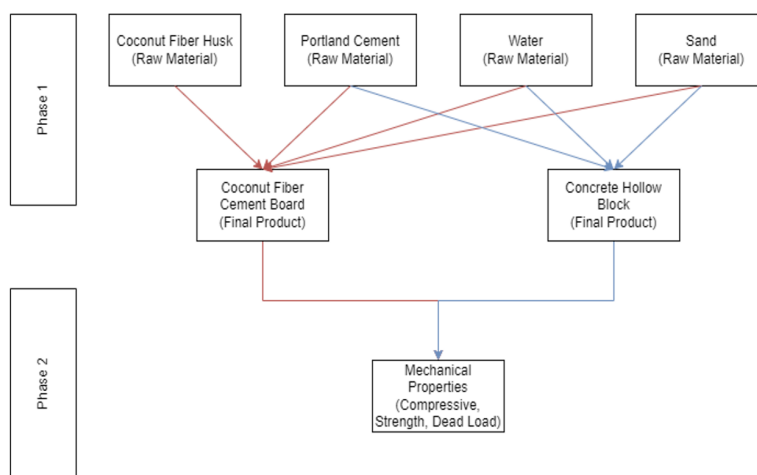


Figure 1. Conceptual framework for producing and testing coconut fiber cement board.

It is found that the factors or criteria: Dead Load, Structural Capacity, and Cost will be made possible in comparing CHB to CFB. Weighing both materials in an industrial weighing scale, measuring the compressive strength (PSI) with the universal testing machine, and computing the overall cost of both materials when used in construction. The conceptual framework shows the different phases in testing both CHB and CFB. In phase 1, the proponents consider the raw materials, coconut fiber husk, portland cement, water, and sand as independent variables that will be used as materials when making and testing CHB and CFB. The mix is determined by the colored arrows (red for CFB, and blue for CHB). Phase 1 Also shows the Final Product based on the mix of CHB and CFB. Phase 2 shows that when both of the CHB and CFB have been made, it will be compared with each other based on their mechanical properties.

4. Data Collection

The researchers did not have a survey questionnaire since the study is purely experimental. The subjects in this study were coconut fiber, cement, and aggregate. In accordance with ASTM C140/C140M, which is the Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units, if there is no specified specimen to be tested, three full-sized units shall be tested. With this, the researcher created 3 samples and after creating the samples needed, the researcher tested the compressive strength of the samples using the Universal Testing Machine (UTM). Furthermore, the samples will be created at Laguna with the help of one mason and the samples will be tested for compressive strength and dead load at the Terms Concrete and Material Testing Laboratory.

4.1 Testing of Compressive Strength

To test our product, the researchers measured the compressive strength of CHB and CFB in PSI. Both products were tested on a Universal Testing Machine (UTM), and the data (in PSI) are recorded to determine which of the two products will break first. The Universal testing machine used was the controls digital semi-automatic compression machine with wizard basic. The universal testing machine has a power of 750 W and a capacity of 1500 kN. It could also carry a maximum weight of 550 kg, and the overall dimension of the machine is 770 mm x 1000 mm x 430 mm.

4.2 Testing of Dead Load

The researchers also weigh the two materials given that the two products will have the same area on a digital weighing scale to see which of the two is lighter. This is to ensure the 1:1 comparison of the weight from both materials. In measuring the samples, the Asuki digital weighing scale was used. It is a weighing scale that is battery-

operated and has high mobility. Moreover, it has a dimension of 230 mm x 24 mm x 300 mm, with a power supply of 220V and an internal resolution of 1/600,000.

4.3 Mixture in preparing CFB

Coconut Fiber Cement Board (CFB) is a panel made from coconut coir or shredded porting of the coconut tree and portland cement with a ratio of 60-70% Cement and 30-40% coconut fiber by weight. CFB is made by forming the cement-fiber mixture ratio into mats and pressing them to desired thickness

4.4 Production of Coconut Fiber Cement Board

In order to produce the prototype for Coconut Fiber Cement (CFB), the following equipment and materials will be used: Fiber Cement Board, coconut fiber (30%) and cement mixture(70%), and shredder. The process in the production of CFB is as follows:

- (1) The Fiber Cement Board will be cut into two (2) 4” by 8” (inches) rectangular boards.
- (2) In between the two Fiber Cement Boards, a 2” by 3” by 1” wood was drilled to act as a support between the two boards
- (3) Lastly, with the previous assembly, the cement mixture was poured inside. This will be identical in form with the Concrete Hollow Blocks (CHB) and is now ready for the strength testing.

4.5 Testing of coconut fiber cement board and concrete Hollow Blocks

For the experimental procedure in this study, the group tested the prepared samples for compressive strength. This is to check if the prototype meets the minimum standard strength of CFBs as a component of a panel system. The test was composed of a compressive Strength Test in order to determine the effectiveness of using the material as a component of the proposed panel system. The equipment to be used to test the bundled fiber and concrete hollow blocks was the Universal Testing Machine, which crushes the material depending on the applied strength on it. The test determines the ultimate compressive strength or the point before the material fractures. This is computed by dividing the maximum applied load before breaking divided by the cross-sectional area that the material to be tested possesses. This will determine the maximum load that the material can withstand, which is very vital for the proposed panel system. The proponents also purchased CHBs and performed the same procedure when testing the compressive strength of CHBs. This will serve as a comparison if CFB has better compressive strength compared to CHB.

4.6 Coconut Fiber Cement Board Design

The design will be based on Permanent framework panels (PFP) which are already existing in the construction industry. But instead of plywoods or hardiplex, the material of our outer panels is Coconut Fiber Cement Board (CFB). Once the panels are in place, the bracket that supports the two panels will be locked and the brackets on the panel will have a slot for vertical and horizontal steel bars. Once the vertical bars are in place, it is ready to be filled with cement. This will ensure that the walling system is sturdy, while maintaining good insulation.

5. Results and Discussion

5.1 Numerical Results

Table 1. Concrete hollow blocks results using the universal testing machine.

Sample Identification	Dimension		Weight	Gross Area	Machine Reading	Compressive Strength	
	Width	Length	lb	mm ²	kN	PSI	MPA
CHB	96	400	18.2	38400	205.9	777	5
	96	401	18.2	38496	206.2	777	5

	94	400	18.3	37600	220.1	849	6
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Above is the table of measured values of concrete hollow blocks using the universal testing machine and the digital weighing scale. The values in the table above include the length and width of CHB measured in mm, while the weight is in kg measured using the digital weighing scale. The gross area of the sample is measured in mm², while the machine reading is the compressive strength results using the UTM and then converted to PSI and MPA. Furthermore, all samples are tested at Terms Concrete and Materials Laboratory and the testing and measuring procedure of the samples are based on ASTM C-140.

Table 2. Coconut fiber cement board as permanent formwork panel results using the universal testing machine.

Sample Identification	Dimension		Weight	Gross Area	Machine Reading	Compressive Strength	
	Width	Length	lb	mm ²	kN	PSI	MPA
CFB	110	420	3.3	46200	372.2	1168	8
	107	421	3.1	45047	357.6	1151	8
	109	420	3.3	45780	411.3	1303	9

The table above is the measured values of Coconut Fiber Cement Board using the universal testing machine and the digital weighing scale. The values in the table above include the length and width of CFB measured in mm, while the weight is in kg measured using the digital weighing scale. The gross area of the sample is measured in mm², while the machine reading is the compressive strength results using the UTM and then converted to PSI and MPA. Furthermore, all samples are tested at Terms Concrete and Materials Laboratory and the testing and measuring procedure of the samples are based on ASTM C-140.

5.2 Graphical Results

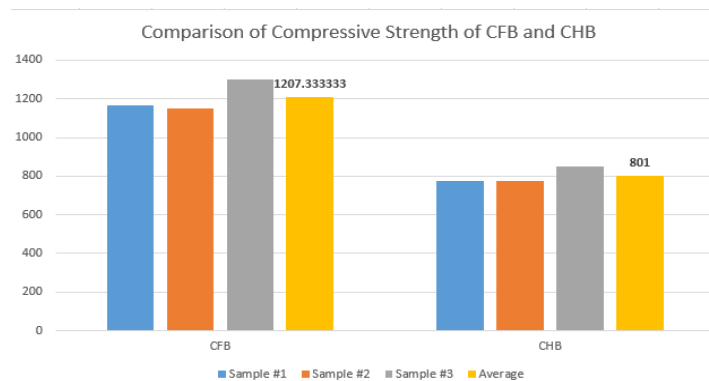


Figure 2. Comparison of compressive strength of CFB and CHB.

The figure above compares the compressive strength of the three samples of CHB and CFB based on its average. According to ASTM C90, the minimum average required compressive strength of concrete hollow block is 600 psi. Moreover, as seen in the graph above, the average compressive strength of the tested concrete hollow block is 801 psi and the average compressive strength of the Coconut Fiber Cement Board is 1207 psi. Which means that it is clear from the findings that the Coconut Fiber Cement Board has better compressive strength than the purchased concrete

hollow blocks. This just means that higher compressive strength translates into better structural capacity and a higher PSI resistance for the panel.

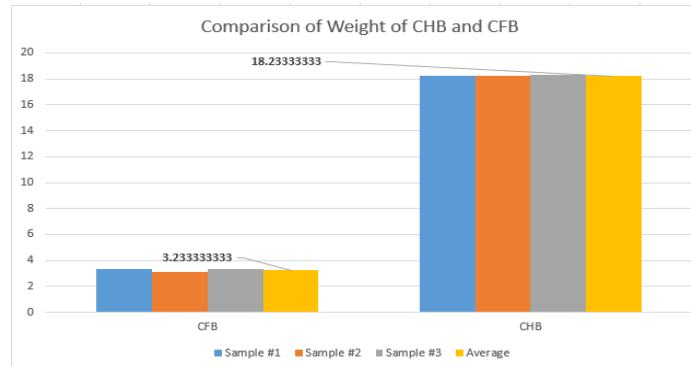


Figure 3. Comparison of weight of CFB and CHB.

The figure above compares the weight of the three samples of CHB and CFB based on its average. According to the chart above, the average dead load of the coconut fiber cement board is 9.13 lb, indicating that it has a lighter carrying weight based on the dead load. Which means that the lighter the product, the easier it is for a construction worker to carry it, especially in uphill construction sites.

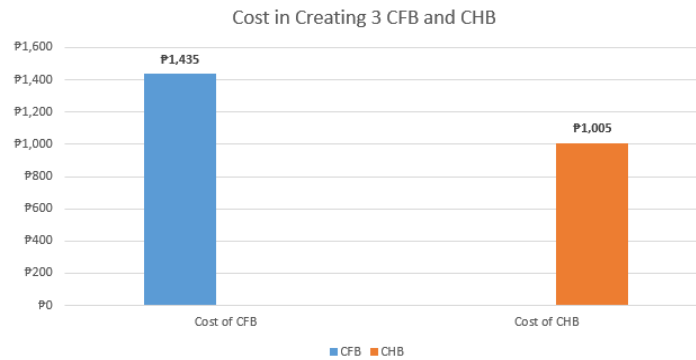


Figure 4. Cost in creating CFB and CHB.

The concluded cost in creating 3 pcs of concrete hollow blocks would be P1005.00. In addition, the cost of producing 3 coconut fiber cement boards would be P1,435.00. However, despite its slightly higher cost, the Permanent Formwork Panel which is the same concept as our CFB provides additional stability and protects concrete from deterioration, according to a Solutions Built article. Permanent formwork also allows for a faster turnaround, lower costs, and a reduction in the time and procedures required for building commercial or residential structures.

5.3 Proposed Improvements

Future studies may think about evaluating the samples using additional criteria, including as R-value, tensile strength, absorption, density, and more, to gain a deeper understanding of the mechanical characteristics of CHB and CFB. Future studies may take into account using machines and equipment to increase productivity and efficiency when performing the samples, particularly when creating the coconut fiber cement board. Different concrete mix percentages are available. With this information, future researchers may think about producing a fresh batch of samples with various concrete mix ratios to see if the new concrete mix ratio can enhance the other criteria. Finally, extended curing intervals should be taken into account by future researchers to determine whether compressive strength differs significantly between short and long curing periods.

5.4 Validation

For the validity of the study, the researchers made sure that they base on the ATSM standards for the compressive strength. The test done on CFB is also done by the expert in the field in a legitimate testing site. Also, the proper equipment for testing the compressive strength was used in order to make sure that the results that will be obtained have no bias. The results for the test are also signed by an expert mason to make sure that all of the data are validated and confirmed. For the costing of the study, the researchers made sure to keep the receipt as the basis of our costing. This is also to make sure that all of the cost that was listed in the study is not altered or manipulated. Lastly, in order to make sure that the data for comparison is accurate, the researchers used excel in order to have a better visualization of the comparison between the CFB and CHB.

For the improvement of the study, it is suggested that SPSS is used for the normality test in order to make sure if the data gathered is normally distributed. Also, use t-test in order to find out and prove the significance difference or relationship between CFB and CHB.

6. Conclusion

A material or structural element's capacity to withstand loads that, when applied, cause them to reduce in size is referred to as their compressive strength. The researchers have determined that the average compressive strength of the Coconut Fiber Cement Board is 1207 PSI with 28 days curing period. The Coconut Fiber Cement Board has satisfied the average necessary compressive strength in accordance with ASTM C90 with 28 days of curing period. The findings clearly showed that the Coconut Fiber Cement Board has a higher compressive strength than a Concrete Hollow Block. In the average Dead Load of both CHB and CFB, the proponents of the study concluded that the weight of CFB would be 3.2 lb, which means that it is lighter than the concrete hollow block. This means that the carrying weight of CFB is lower than the concrete hollow blocks without the poured mixture inside. In the cost-analysis of both panels, the price of CFB is evaluated to be higher than the cost of CHB. One of the main reasons for this is the addition of the Fiber Cement Board as the base of the CFB and the additional aggregate of Coconut Fiber Husk.

Economically speaking, with regard to the price, the CHB is definitely better than the CFB but according to a Solutions Built article, Permanent Formwork Panel offers additional stability and shields concrete from deterioration despite the CFB's somewhat higher cost. It is also claimed that using permanent formworks allows for quick turnaround, lower prices, and a reduction in time and procedure needed for building commercial or residential structures. Based on the data results, CHB has a compressive strength of 801 PSI while CFB has 1207 PSI. As of the dead load, CHB has a dead load of 18.2 lb while CFB has 3.2 lb. Furthermore, the cost in creating 3 pcs of concrete hollow blocks would be ₱1005.00. In addition, the cost of producing 3 coconut fiber cement boards would be ₱1,435.00. However, despite its slightly higher cost, the Permanent Formwork Panel which is the same concept as our CFB provides additional stability and protects concrete from deterioration, according to a Solutions Built article. Permanent formwork also allows for a faster turnaround, lower costs, and a reduction in the time and procedures required for building commercial or residential structures.

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Biographies

Dyanne Trixel V. Suacoco was born in Bataan, Philippines in 2001. She is a fourth-year industrial engineering student at the University of Santo Tomas. She started her interest in engineering when she took the Science, Technology, Engineering, and Mathematics strand during her senior high school at Colegio de San Juan de Letran- Bataan. With her growing interest in business and engineering, she also took a short course, Technology Entrepreneurship: Lab to Market, at Harvard University to expand her knowledge in the field. Furthermore, to apply and improve all her learnings as an industrial engineering student, she had her internship as an industrial engineer at Melham Construction Corporation.

Mark Levinson M. Go was born in Quezon City, Philippines in 2000. He took his high school at Quezon City Science High school with a STEM (Science, Technology, Engineering and Mathematics) strand. With his interest growing towards the engineering field, he took BS in Industrial Engineering at the University of Santo Tomas, Faculty of Engineering. He is currently the CEO of KeyGenics that started in 2019, which is a small business catering niche hobbies and services that involves electronics in computer peripherals (Keyboard and Mouse). He also became a Marketing and Technical Corporate Associate at ORSP (Operations Research Society of the Philippines) in 2021-2022 and now a member of ORSP, and also became a member of the University's mother organization Industrial Engineering Circle from 2019 to 2022.

Marc Neilsen T. Elamparo was born in Manila, Philippines in 2000. He is currently a student of BS Industrial Engineering in the University of Santo Tomas. He is now the Executive Associate for Sponsorships in the UST Industrial Mother Organization, the UST Industrial Engineering Circle. He had his internship as an Analyst at Toplis Solutions Inc., under the Makati Development Corporation. He also worked as an Assistant Manager at Pet Starz Wellness Clinic during Years 2021 - 2022.

Kyle Matthew B. Espiritu was born in Manila, Philippines in year 2000. He is currently a student of BS Industrial Engineering in the University of Santo Tomas. He is the past Executive Associate for Sponsorships in the UST Industrial Engineering Circle from 2021-2022. He is now currently the Executive Coordinator for Sponsorships in the UST Industrial Mother Organization, the UST Industrial Engineering Circle. He also became a Packaging Development Intern for Monde Nissin, and helped on how to optimize systems for the for the company.