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The Effect of Coconut Fiber on the Cement Mortar Properties

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Abstract: Malaysia is one of the developed countries that has successfully produced skyscrapers. Therefore, building materials are in high demand, especially sand. As a result of the high demand for sand, extensive dredging has had a major impact on the habitats and populations of fish and marine life. The main problems are the effects of pollution, sand dredging activities and dry mud problems causing many shellfish seeds to not be able to survive. This test was conducted to replace sand as the main ingredient in the mortar mix. coconut is one of the materials widely used in the food industry in Malaysia, excess coconut fiber can be used as a recycling material to replace sand. First objective is to investigate the feasibility of using coconut fibre to replace fine aggregates. The second objective is the purpose of this test is to determine the development of compressive strength of cement mortar at various percentages of coconut fibre. Third objective is to identify the mineral composition of coconut fiber mortar. In mortar mixed work, the ratio used was 1: 2.75 and the water-cement ratio was 0.6 following the standard (ASTM C 109/C 109M-02) standards. On the other hand, several tests were be conducted on coconut fiber mortar that was be compared with control samples, which is, compressive strength, scanning electron microscopy (SEM) and X-Ray Diffraction. On the other hand, several tests be conducted on coconut fiber mortar that was compared with control samples, namely, compressive strength (BS EN 196-1:2005), Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). At the end of this project, it was found that the maximum was on the control sample which was 22.0 N/mm^2 compared to the other samples. In addition, for mortar coconut fiber mixture has a mineral composition such as Quartz (Sio2), Aluminum iron (AlFe3), Cellulose Ibeta $(C6H1005)_n$, Portlandite $(Ca(OH)_2)$ and Silicon oxide (SiO2). Moreover, the addition of coconut fiber in the mortar caused a very high porosity compared to the control sample due to the occurrence of hydration in the mortar.

Keywords: Mortar Masonry, Coconut Fiber, Mechanical Properties

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1. Introduction

Agricultural waste items such as coconut fibre, rice husk, and oil palm frond fibre abound in Malaysia. These fibres have many benefits, including being renewable, nonabrasive, inexpensive, abundant, and posing less health and safety concerns during handling and processing The agricultural waste products are being identified as low-cost construction materials, especially in developing countries [1]. Mortar and concrete have become essential building materials, and they are now used in greater amounts than any other. Durability and long-term sustainability of mortar are critical construction challenges right now. Mortar is a workable paste that is used to tie building blocks like stones, bricks, and concrete masonry units together, fill and seal irregular holes between them, and apply decorative colors or patterns to masonry walls.

Therefore, in order to produce a good environment, the use of recycled materials such as coconut fiber can reduce environmental pollution and can save the use of river sand. This type of waste material utilization can alleviate aggregate shortages at various construction sites while also reducing environmental issues associated with aggregate mining and trash disposal [2]. In addition, the use of recycled materials can save construction costs and be more environmentally friendly.

2. Literature Review

Coconut fibre is a byproduct of the coconut processing industry. Coir pith is another name for coconut fibre. Coir fibre pith, coir dust, or simply coir is made from coconut husks, which are byproducts of other coconut-related industries. The coir fibre pith or coir dust obtained by processing coconut husk and removing the long fibres is the main component of coco peat. The coco peat, like a sponge, can absorb a lot of water. It is a type of material that is used for mortar, lightweight materials, sound insulation, thermal insulation, good air porosity, and cost reduction in construction. The properties of coconut fibre are shown in Table 1.

Table 1: Characteristics of coconut fiber

Item	Parameter	Value
1	Diameter (mm)	0.11 - 1.06
2	Length (mm)	37.0 - 250
3	Water Absorption (%)	150 - 190
4	Tensile Strength (N/Mm)	106

2.1 Increment Strength Of Coconut Fiber Mortar

Short coconut fibres used with regular Portland cement resulted in a significant increase in toughness, according to [3]. According to [4] investigated the use of coconut fiber-infused concrete as structural elements. The behavior of coconut fiber-concrete columns was studied, and it was discovered that non-visible degradation occurs before the column cracks. The addition of coconut fibre to cement has improved flexural strength and, as a result, crack resistance. Furthermore, the compressive strength is increased by a particular proportion. Based on study of [5] studied the mechanical characteristics of concrete having varied volume fractions of coconut fibre ranging from 0.5% to 2%. According to the findings, 1.5 percent of volume fraction of coconut fibre produces maximum strength with a 14.66% increment. Table 2 shows a summary of investigations on concrete including coconut fibre.

Table 2: The effect of coconut fibre on concrete strength [6]

No	Reference	Length Of Fibre (mm)	Optimum Contain (%)	Increment of Strength (%)
1	Baruah and Talkudar	40	1.5	14.66
2	Abdullah et al	-	9.0	26.96
3	Domke	50 - 110	3.0	16.50
4	Ruben and Baskar	30	1.0	20.59
5	Adisa et al.	82	1.0	6.70
6	Mydin et al	34	0.4	21.00

3. Materials and Methods

3.1 Mortar Preparation Process

The materials used in the preparation of the material must be in good condition and safe to use. The preparation steps are as follows. Coconut fiber is purchased and cleaned first when received from the factory. The coconut fiber will then be sieved using a sieve tray with a value of 5mm or less until it is the same size as the sand. Coconut fiber is sifted in two ways: manually and with a sieve.

3.2 Mortar Mix Design

The mortar mix design includes ordinary Portland cement (OPC), coconut fiber (CF), natural sand, and water. Ratio of mortar content, cement and sand is 1:2.75 and water per cement ratio is 0.6 to produce 5 types of mortar mix consist of control mix 100% sand (CF 0%), 97.5% sand (CF 2.5%), 95.0% sand (CF 5.0%), 92.5% sand (CF 7.5%) and 90% sand (CF 10%) were prepared. Table 3 shows the mixed proportion of mortar. The ratio and mixture of mortar has followed the procedures and standards prescribed by ASTM C109 [7].

Table 3: Mix proportion

Mix Label	Mix Ratio				Remarks
	Sand (g)	Coconut fiber (g)	Water (g)	Cement (g)	
CF 0%	2035	0	444	740	100% sand
CF 2.5%	1984	51	444	740	97.5% sand + 2.5% coconut fiber
CF 5.0%	1933	102	444	740	95% sand + 5.0% coconut fiber
CF 7.5%	1882	153	444	740	92.5% sand + 7.5% coconut fiber
CF 10.0%	1831	204	444	740	90% sand + 10% coconut fiber

3.3 Mixing Of Mortar

. The key to achieving a successful outcome while preparing specimens for mortar testing is to mix the mortar thoroughly. For various types of mortar ratios, all materials and water are weighted correctly.

Figure 1(a) shows the mortar was mixed using the manual method. mix the mortar so that all the sand, coconut fiber, water, and cement are well blended. after the mixing is done, put the mortar mixture into a cube mold 50mm x 50mm (Figure 1 (b)) with two layers

a) **b)**

Figure 1: (a) Mortar mix, (b) Cube mold 50mmx50mm

To ensure compaction, each layer is rodded 25 times. Any trapped air in the mortar will lower the cube's strength. As a result, the cubes must be completely compacted. However, it's important not to over compact the mortar, since this might lead to cement paste segregation in the mix. The final compressive strength may be lowered as a result of this. These molds were removed after 24 hours, and cube examples were exposed to water curing (Figure 2).

Figure 2: Curing of cube specimens in water

3.4 Cube Specimen

Table 4 provides the 50mm cubes specimens required for four types of mortar mix after water curing. On the 7th, 14th, and 28th days, these cubes were utilized to test compressive strength. These cubes were made in accordance with British Standard 1881-108:1983. There were thirty-six sample mortar in total; with a volume 50 x 50 x 50 mm were created from five different percentages of coconut fiber.

3.5 Coconut Fiber Mortar Laboratory Testing

To determine the properties of coconut fibre mortar, a sample test was carried out. Three property tests were performed on coconut fibre mortar: Compressive Strength (CS), Scanning Electron Microscopy (SEM), and X-Ray Diffraction (XRD). These testing were conducted according to BS EN 196-1:2005 [8], ASTM 270: 2014 [9], and ASTM C 1365 – 98 [10]respectively.

4. Results and Discussion.

4.1 Compressive Strength Test

. Figure 3 shows the development of compressive strength of different mortar mix from day 7 until day 28. The result of compressive strength on 7th days showed the control mix (CF 0%) obtained the highest strength value with 18.6 N/mm2 and followed by CF 2.5%, CF 5.0%, CF 7.5% and CF 10% with 15.6 N/mm^2, 10.7 N/mm^2, 5.7 N/mm^2 and 4.7 N/mm^2 respectively.

By the age of 14 days, compressive strength has plateaued, similar to strength on the 7th day, which follows the same pattern from highest to lowest by CF 0 %, CF 2.5 %, CF 5.0 %, CF 7.5 %, and CF 10% with 19.5 N/mm^2, 16.7 N/mm^2, 11.3 N/mm^2, 6.5 N/mm^2, and 4.4 N/mm^2 correspondingly. The control mix has attained its minimum strength of 17.2 N/mm^2 based on the test findings (ASTM 270:2014) [9]. Meanwhile, CF 2.5%, CF 5.0 %, CF 7.5 %, and CF 10% have lower strength in early age than the control mix due the water absorption on mortar. Coco-peat has the property of being a water absorbent material [11] .

Followed by the age of 28 days, for control mix and CF 2.5% showed compressive strength that is almost the same with 22 N/mm^2 and 21.6 N/mm^2 respectively. compared to CF 5%, 7.5% and 10% with 14.1 N/mm^2 7.1 N/mm^2 5.2 N/mm^2 which experienced a sharp decrease in strength as a result of the increased rate of coconut fiber replaced with sand.

Overall, the results show that the performance of mortar using coconut fiber shows a decrease in strength with the percentage rate of coconut fiber, as the percentage of coconut fibres in the concrete mix increased, the compressive strength of the concrete decreased [12] The mortar curing period of 28 days showed the optimal period for the determination of compressive strength to replace 2.5% of coconut fiber compared to the period of 7 days and 14 days. Finally, it is believed that the compressive strength for CF 5.0%, CF 7.5% and CF 10% does not exceed the masonry mortar cement standard of 17.2 N/mm^2 (ASTM 270: 2014) [9] due to more amount water absorption capacity of coir pith [13]

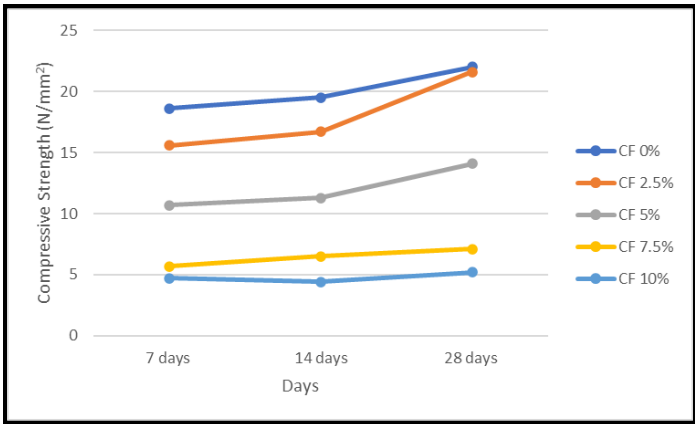


Figure 3: Compressive strength of mortar development until the 28th day

4.2 X-Ray Diffraction Test

A total of six samples were taken to perform this test. The samples taken were CF 0%, CF 2.5% and CF 5% for a period of 7 and 28 days of curing. This test is done to identify the chemical elements in the mortar that has been mixed with coconut fiber to replace the sand. This procedure has followed ASTM C 1365 – 98 [10]. Standardization curves connecting the measured intensity of each peak, relative to the intensity of the internal standard peak, to the known proportion of the phase must be generated once the standardization mixtures have been evaluated. Each sample was evaluated at a particle size of 63 m to allow the x-ray beam to be deflected in the best possible direction for reliable readings. The X-ray intensity is typically measured in "counts" or "counts" that represent Y-axis of the XRD graph while 2θ is the angle formed by the transmitted and reflected beams that represent X-axis.

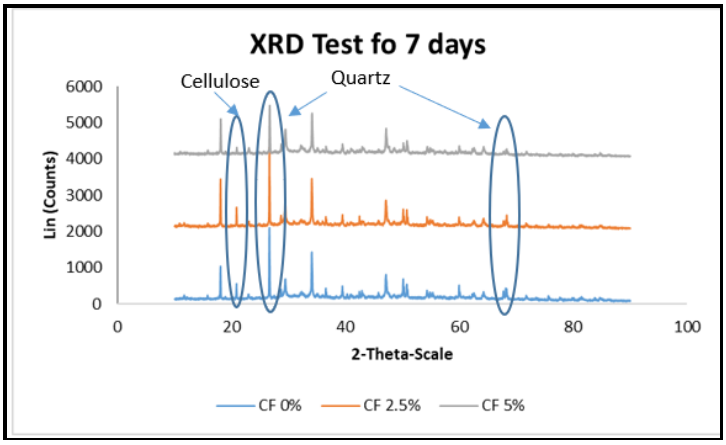


Figure 4: X-ray diffraction of coconut fiber particles for 28 days

Table 5: Extract value from the XRD graph at peak value on Quartz and Cellulose for 7 days

Description	Control (CF 0%)		CF 2.5%		CF 5%	
Quartz	2θ	27°	2θ	27°	2θ	27°
	Lin (counts)	2399	Lin (counts)	2316	Lin (counts)	1472
Cellulose	2θ	-	2θ	23°	2θ	23°
	Lin (counts)	-	Lin (counts)	480	Lin (counts)	500

Based on the Table 4.5, Quartz value for CF 2.5% is higher compare to CF 5% at angle 27°, which is 2316 and 1472 respectively. This is because the present of sand slightly more in sample CF 2.5% that effect increasing of Quartz in the sample. Due to the exposed surface of the sand particle, deformation in the SCM (sand, cement, mortar) occurred in the sand-matrix interface or transition zone, which is typically more porous and less densified [14]. However, Quartz CF 2.5% slightly less than control sample (CF 0%) because no additives of coconut fiber.

Besides that, for cellulose mineral show the highest value 500 in sample CF 5% compare to CF 2.5% 480 at the angle 23°. This is because the presence of coconut fiber at the sample CF 5% is higher than sample CF 2.5%. The unrutted coir fibre has low crystallinity based on the comparatively low peak intensities, which is due to the crystalline cellulose micro-fibrils being embedded in huge quantities of lignin, hemicellulose, and pectin materials [15].

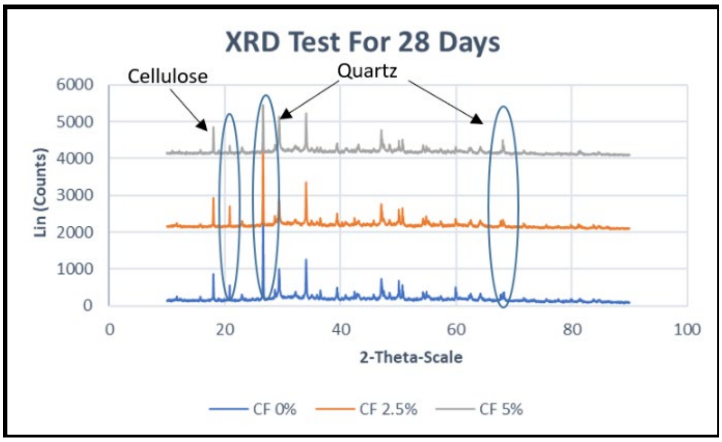


Figure 5: X-ray diffraction of coconut fiber particles for 28 days

Table 6: Extract value from the XRD graph at peak value on Quartz and Cellulose for 28 days

Description	Control (CF 0%)		CF 2.5%		CF 5%	
Quartz	2θ	27°	2θ	27°	2θ	27°
	Lin (counts)	2697	Lin (counts)	2430	Lin (counts)	1457
Cellulose	2θ	-	2θ	23°	2θ	23°
	Lin (counts)	-	Lin (counts)	430	Lin (counts)	550

On the hand, the result for 28 days shows that the Quartz for control dominant the highest peak compares to others two sample which is CF 2.5% and CF 5%. The highest peak value from control sample is 2697. The increase of Quartz due the presence of sand that was explain in the previous statement above. Moreover, the cellulose is higher in sample CF 5% 550 compare to CF 2.5% 430. The is because the presence of the coconut fiber more in sample CF 5% compared to CF 2.5% that also explain detail in previous statement above.

On this finding, it can be concluded that Quartz at control sample CF 0% get the highest result follow with the result Quartz of CF 2.5% and lastly Quartz of CF 5%. This is because the composition of Quartz decreases as coconut fiber increase [16]. Cellulose mineral shown CF 5% get highest result at the 7 days and 28 days of curing compare to CF 2.5%. The higher coconut fiber added, the higher increment of cellulose [14]

4.3 Scanning Electron Microscopy Test

The microstructural image of those mortar mineral's reaction products was revealed by the SEM analysis results. This analysis can also reveal visual changes in void, particle size, and shape for control mortar and coconut fibre mortar. Each sample was magnified at various magnifications ranging from 1000x to 10000x or more in order to clearly see the changes that occurred.

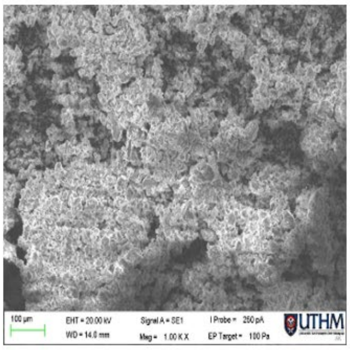
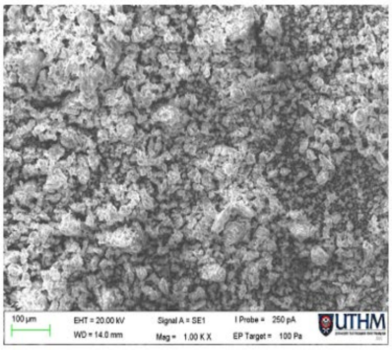
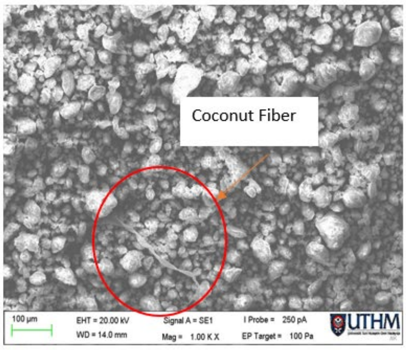
CF 0% (Control)	CF 2.5%	CF 5%
		

Table 7: SEM result for three difference coconut fiber percentage

The micrograph image for the control mortar sample (CF 0%) as can be seen in Table 7 shows uneven shapes such as angular surface texture, elongated surface texture and epict sharp. There is no coconut fiber appearance due to no additives of coconut fiber in control sample. Meanwhile, for sample CF 2.5% show there is no appearance of coconut fiber but a few shapes of admixtures particles (cement and sand) can only be seen even though 2.5% of coconut fiber is added to the sample. However, when 5% coconut fiber are added, it can be seen the appearance of coconut fiber in sample CF 5%. It can be said that, the more coconut fiber is added, the clearer the appearance of coconut fiber due to fewer sand in the mortar. This also support by [14], because of the exposed surface of the sand particle, it was discovered that the deformation in the SCM (sand, cement, mortar) occurred in the sand-matrix interface or transition zone, which is typically more porous and less densified.

5. Conclusion

At the end of this project, it was found that the maximum was on the control sample which was 22.0 N/mm2 compared to the other samples. In addition, for mortar coconut fiber mixture has a mineral composition such as Quartz (SiO_2), Aluminum iron ($AlFe_3$), Cellulose Ibeta $(C6H1005)_n$, Portlandite ($Ca(OH)_2$) and Silicon oxide (SiO_2). Moreover, the addition of coconut fiber in the mortar caused a very high porosity compared to the control sample due to the occurrence of hydration in the mortar. therefore, to increase the strength of the mortar, the use of chemicals as additives to prevent porosity due to water absorption by coconut fiber is strongly encouraged to curb the occurrence of porosity and cause the mortar to decrease in strength. A few recommendations for future research are during the mortar mixing process, make sure the entire mortar is compressed more carefully when inserted into the mold to avoid honeycomb, because honeycomb will cause the mortar to lose strength. Next, when performing a compression test, make sure the condition of the mortar surface is placed in a flat position so that the reading can be taken more accurately. Furthermore, for Scanning Electron Microscopy (SEM) test it is recommended to use an SEM machine that has readings for EDS so that the mineral readings found in the mortar can be identified before performing X-Ray Diffraction (XRD) test. Moreover, add additives such as chemicals to the mortar so that the chemicals can perform treatment to remove compounds that inhibit the action of re-hydration, thereby improving the mechanical properties of compost

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