Borneo Engineering & Advanced Multidisciplinary International Journal (BEAM)
Volume 3, Issue 2, November 2024, Pages 6-10

Utilised of Coconut Fibre in Green Concrete

Full Paper

Rahim Ishak[1]*, Hassan Ismail[2], Sinatu Sadiah Shapie[3]

[1]Department of Civil Engineering, Politeknik Mukah, KM 7.5 Jalan Oya, 96400 Mukah, Sarawak, Malaysia
[2]Department of Civil Engineering, Politeknik Merlimau, 77300 Merlimau, Melaka, Malaysia
[3]Department of Civil Engineering, Politeknik Port Dickson, KM 14, Jalan Pantai, Si Rusa, 71050 Port Dickson, Negeri Sembilan, Malaysia

*Corresponding author: rahim.ishak@pmu.edu.my
Please provide an **official organisation email** of the corresponding author

Article history
Received
29 March 2024
Received in revised form
2 September 2024
Accepted
6 September 2024
Published online
1 November 2024

Abstract

The agricultural industry in Malaysia is rapidly developing, particularly in the cultivation of coconut trees, which is a key contributor to the Malaysian economy. Coconuts are widely used in making cakes, drinks, etc. Disposing of coconut coir on land, considered waste, will pollute the environment. Therefore, this study was carried out to produce new sustainable concrete. The objective is to assess concrete's workability and compressive strength using coconut fibre as an additive ingredient in a new green concrete product. The mass of cement determined the proportion of coconut fibre material. The grade 40 suitable for footing and paving slabs structure for car parks was determined by applying the mix design guidelines for normal concrete proposed by the Building Research Establishment in the United Kingdom. A slump test was carried out immediately after the mixing of fresh concrete. 24 concrete specimens, each measuring 150x150x150mm, were prepared. The compressive strength of the specimens was evaluated at 7 and 28 days. The finding discloses that the workability of mixed concrete is higher when the coconut fibre is increased. The optimum compressive strength was examined with a 0.6% additive of coconut fibre in concrete. This study concluded that coconut fibre can potentially be utilized as an additive in concrete to develop environmentally green concrete.

Keywords: - Green concrete, coconut fibre, compressive strength, slump

1. Introduction

In the construction industry, concrete is an essential material that is used substantially. The main ingredients of concrete are cement, coarse aggregate, fine aggregate, and water, mixed according to the necessitated mixture ratio. The rapid advancement in the future will result in a decrease in the ingredients used in the concrete mix. Green cement and steel play a significant role in sustainable development. By choosing these materials, industries can lessen their environmental impact, foster economic growth, and promote social progress. Moreover, these materials align with the United Nations' Sustainable Development Goals (SDGs), especially those related to responsible consumption and production, climate action, and industry, innovation, and infrastructure. Therefore, it is essential to discover additive of materials that could be incorporated into concrete. Concrete might be manufactured from alternative materials, and this is feasible in practical applications (Sekar & Kandasamy, 2019).

Green concrete incorporates waste materials as at least one of its components utilizes an environmentally friendly production process, or it possesses high performance and life cycle sustainability (Obla, 2009; Suhendro, 2014). Producing green concrete is an alternative method that utilizes natural sources to substitute ingredients in concrete. Incorporating coconut fiber into concrete mix in addition to corn husk ash polymer is recommended (Appiah-Kubi et al., 2021). Additional coconut fibre will increase the compressive strength of concrete (Shreeshail et al., 2014). The usage of coconut fibers in concrete structural applications is favorable (Ahmad et al., 2020). Concrete containing coconut fiber can function as an additive or accelerator while continuing to retain compressive strengths that are equal to normal concrete (Otunyo & Nyechieo, 2017). It is strongly stated that the construction concept presented will be helpful in the production of secure and inexpensive housing when coconut fiber reinforced concrete is utilized (Ali, 2016). Coconut fibre composite concrete contributes to environmental benefits in reducing carbon dioxide (Vélez et al., 2022). Coconut fibre has been used to enhance concrete and mortar and has proven to improve the toughness of the concrete and mortar (Gram, 1983; Ramakrishna & Sundararajan, 2005). However, the problem of long-term durability has not yet been solved. It has also been noticed that the degree of enhancement of concrete by coconut fibres depended on the type of coconut species and the sub-region that the coconut plant was cultivated.

Therefore, it is encouraged study in utilizing of coconut fibre in sustainable concrete, as it will be a valuable resource for recycling. The aim of this study is to acquire compressing strength and workability of green concrete containing coconut fibre by partially replaced cement. The study would contribute to utilize coconut fibre as considered waste to be new green concrete that could reduce cement in the concrete mix.

2. Methodology

The process of this study includes preparation of materials and laboratory experimental conducted. The sources of materials were employed in the surrounding market in Mukah. The laboratory tests were conducted in the Concrete laboratory, Politeknik Mukah.

2.1 Materials

The coconut fibre as shown in Fig. 1 was used as an additive in the concrete mix. The ordinary portland cement (OPC) used is complied with BS12:1996. Gravel size 20mm and sand were used and complied with BS 882: 1996. These aggregates were washed and dried in open air to eliminate contaminants. Tap water is considered clean water and was added to the concrete mix. A water-cement ratio of 0.47 was applied.

Fig. 1. Coconut fibre

2.2 Mix Design

Proportion materials of concrete of grade 40 were designed according to the design of normal concrete mixes by Building Research Establishment, United Kingdom. Data from aggregate test and specific gravity test is an imperative before design the proportion of normal concrete.

2.3 Curing Process

The size of cube mold used is 150x150x150mm. 24 samples of cube concrete were produced according to BS 1881-116:1983. After 24 hours hydration process, specimens were demolding and immersed in a water tank for the curing process.

2.4 Laboratory Experiment Tests

These experimental tests in the study cover the workability test. The workability test was implemented immediately after the mixing of concrete was accomplished and complied with BS 1881-102:1983 while the compressive test was conducted and complied with BS 1881-116:1983. Preparation of cube molds were made before compressing. A compressive strength test of the specimens was conducted using a 2000kN capacity compression machine. Before conducting the compressive test, the specimens were placed indoors at room temperature for approximately 2 hours. The compressive tests were done at 7 days and 28 days using a 2000kN compression machine at Concrete Laboratory, Politeknik Mukah (refer Fig. 2).

Fig. 2. Compression machine

The sieve analysis test for sand and course aggregate were done according to BS 882: 1996. The laboratory tests were conducted at Concrete Laboratory Politeknik Mukah.

Specific Gravity of the coarse aggregate is essential aspect in the design normal mix concrete (refer Fig. 3). To perform a specific gravity experiment, the aggregate is immersed in clean water for a whole day, and at the end of period, assessed the mass in water. After that, it is left in surface-dried and assessed the mass. Then, oven-dried for 24 hours, and the mass is determined and complied to BS 812-2:1995. The water Absorption of an aggregate is determined by measuring the increase of an oven dried. The water absorption of the coarse aggregate is calculated by measuring the increase of an oven-dried sample when immersed in water for 24 hours and complied to BS 812:1995. Water absorption values are obtained by assessing the mass of coarse aggregate before and after soaked in water.

Fig. 3. Specific gravity test

3. Result and Discussion

The sieve analysis test for sand and coarse aggregate was done to verify the materials are suitable for utilization. Sieve is used for the sieve analysis process of fine and coarse aggregates (Syed et al., 2020). Fig. 4 illustrates the details distribution of semi-log graph analysis of the sand. From this result, the sand size is near to the upper limit. It's showing a large percentage of smaller sand was passing finer sieve and within the specified upper and lower limit. The sand could be classified as fine and acceptable to be employed in the concrete mix and meet the standard of BS 882: 1996.

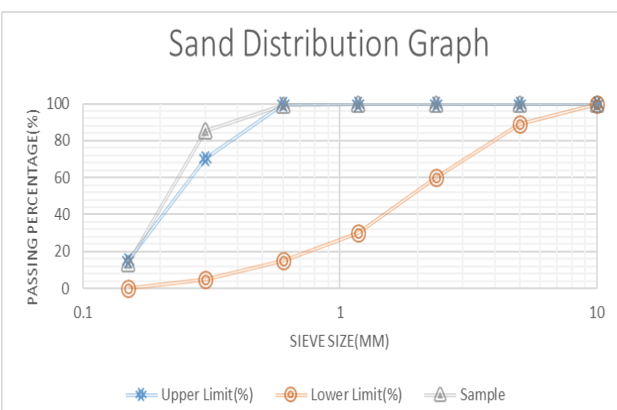

Fig. 4. Sand distribution graph

Fig. 5 shows a distribution semi-log graph analysis of local coarse aggregate. From this result, the coarse aggregate size is within upper and lower limit range and classified as sufficient and satisfactory to be employed in the concrete mix and meet the standard of BS 882: 1996. It's imperative for aggregate size within upper and lower limit to ensure the expectation results for workability and compression strength could be achieved.

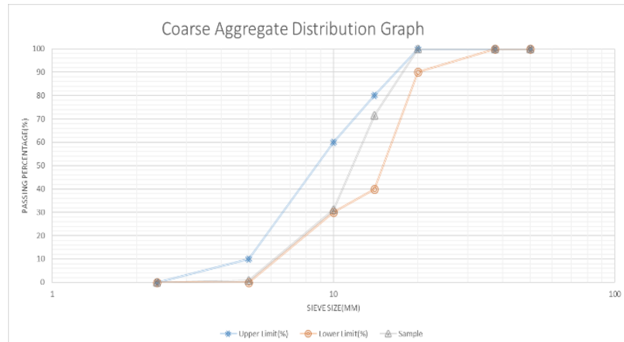

Fig. 5. Coarse aggregate distribution graph

3.1 Density, Water Absorption and Specific Gravity of Coarse Aggregates

Table 1 shows the results of density, water absorption and specific gravity of coarse aggregates following the standard formula as stated while, Table 1 shows the specific gravity test conducted. It's essential to find the value of specific gravity (SSD) before design the normal concrete. The data of this specific gravity also supported from study conducted by Ibearugbulem & Igwilo (2019). It's reported that specific gravity (SSD) is 2.55.

$$\text{Density (OD)} = 997.5\left(\frac{A}{B-C}\right) = 2514.07 kg/m^3 \quad (1)$$

$$\text{Density (SSD)} = 997.5\left(\frac{B}{B-C}\right) = 2539.46 kg/m^3 \quad (2)$$

$$\text{Water Absorption} = \left(\frac{B-A}{A}\right)\times 100 = 1.01\% \quad (3)$$

$$\text{Specific Gravity (OD)} = 997.5\left(\frac{A}{B-C}\right) = 2.52 \quad (4)$$

$$\text{Specific Gravity (SSD)} = 997.5\left(\frac{B}{B-C}\right) = 2.55 \quad (5)$$

Table 1. Density, water absorption and specific gravity of coarse aggregates

Aggregate	Coarse Aggregate Sample
Mass of OD sample in air(g)-A	1980
Mass of SSD sample in air(g)-B	2000
Apparent mass of saturated sample in water(g)-C	1214.4
Density(OD)kg/m3	2514.07
Density(SSD)kg/m3	2539.46
Water absorption(%)	1.01
Specific gravity(OD)	2.52
Specific gravity(SSD)	2.55

3.2 Design of Mix Concrete Proprtion

Table 2 shows specifications of the mixed concrete proportion of grade 40 that contains coconut fibre according to the Design of Normal Concrete Mixes by Building Research Establishment, United Kingdom. The conditions of concrete mix proportion are as follows:

Target mean strength, fck at 28 days $= 48.2 N / mm^2$

Water Cement Ratio $= 0.47$

Expected Slump $= 30 - 60 mm$

4 concrete mixtures were done, including control concrete without added coconut fibre (0%). The other three concrete mixtures were added with 0.2%, 0.4%, and 0.6% by mass of OPC as shown in Table 2. A total of 24 cube concrete were prepared for concrete mixture of 0%(6 cubes), 0.2%(6 cubes), 0.4%(6 cubes) and 0.6%(6 cubes).

Table 2. Mix Concrete Proportion of Grade 40

Percentage of Coconut Fibre (%)	Mass					
	Cement (kg/m³)	*Coconut Fibre (kg/m³)*	*Sand (kg/m³)*	*Coarse Aggregate (kg/m³)*	*Water (L)*	Target Mean Strength (N/mm^2)
0	446	0	490	1260	205	48.2
0.2	401.4	0.89	490	1260	205	48.2
0.4	356.8	1.78	490	1260	205	48.2
0.6	312.2	2.68	490	1260	205	48.2

3.3 Workability Test

Fig. 6 displays a slump test graph of concrete with coconut fibre substitution to assess workability, while Fig. 7 exhibits a successful slump test result. From the observation, the workability test value increased as the amount of coconut fiber in concrete increased when added 0.4% and 0.5% coconut fibre in concrete. The slump value of concrete with 2% coconut fiber addition is highest for a water-cement ratio of 0.44 (Riza et al., 2020).

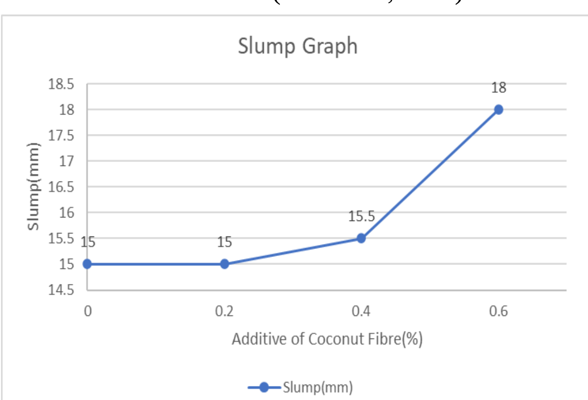

Fig. 6. Slump graph

Fig. 7. Slump test

3.4 Compressive Test

Concrete reinforced with waste coconut fiber has higher strength in concrete (Naamandadin et al., 2020). In this study, Fig. 8 shows the compressive strength versus the percentage of coconut fibre as additive in concrete. It has been reported that an increase in coconut fibre percentage in concrete at 7 days will increase the value of the compression strength of concrete, while compressive strength at 28 days displayed decrease when added 0.2% coconut fiber. However, the compressive strength increased at 0.4% and 0.6%. The value of this graph strongly reported that the addition of coconut fibre of 0.6% is the highest and more significant than the control sample at 7 days and 28 days.

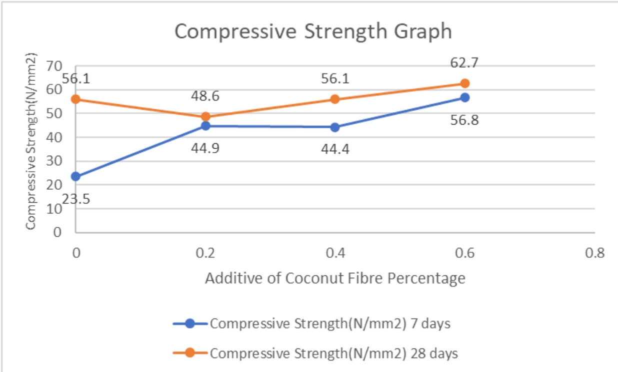

Fig. 8. Compressive strength of concrete vs additive of coconut fibre percentage

4. Conclusion

The experiment on green concrete using coconut fibre as an additive included five laboratory tests. The study concluded that locally sourced materials for sand and gravel are well-graded and suitable for use in concrete. Additionally, the workability of the concrete mix is improved with a higher percentage of coconut fibre. Workability of concrete slightly improve when additive coconut fibre of 0.4% and 0.6% in concrete. It was also observed that the compressive strength of concrete increases with the addition of coconut fibre, with 0.6% being the optimal proportion. This study suggests that the use of coconut fibre as an additive in concrete has the potential to contribute to the building industry by reducing environmental pollution. However, further research is needed to investigate the microstructure of the concrete. Though natural fibres have clear environmental benefits and are cost-saving in production, the thermal degradation or decomposition of plant-based fibres should be considered when using them. The chemical treatment or coating methods of plant-based fibres could be a good solution, but the evaluation of the resulting cost and environmental effects cannot be ignored.

Acknowledgement

The authors would like to thank Politeknik Mukah for permitted to utilize equipment and machines at Concrete Laboratory which makes this important research viable and effective.

References

Ahmad, W., Farooq, S. H., Usman, M., Khan, M., Ahmad, A., Aslam, F., ... & Sufian, M. (2020). Effect of coconut fiber length and content on properties of high strength concrete. *Materials*, *13*(5), 1075.

Ali, M. (2016). Use of coconut fibre reinforced concrete and coconut-fibre ropes for seismic-resistant construction. *Materiales de construccion*, *66*(321), e073-e073.

Appiah-Kubi, E., Yalley, P. P. K., & Sam, A. (2021). Strength behaviour of Corn Husk Ash polymer concrete reinforced with coconut fibre. *Cogent Engineering*, *8*(1), 1993511.

Gram, H. E. (1983). Durability of natural fibres in concrete. Swedish Cement and Concrete Research Institute. *CBI Research fo*, *1*(83), 255.

Ibearugbulem, O. M., & Igwilo, K. C. (2019). Physical and mechanical properties of river stone as coarse aggregate for concrete production. *Nigerian Journal of Technology*, *38*(4), 856-862.

Sekar, A., & Kandasamy, G. (2019). Study on durability properties of coconut shell concrete with coconut fiber. *Buildings*, *9*(5), 107.

Naamandadin, N. A., Rosdi, M. S., Mustafa, W. A., Aman, M. N. S. S., & Saidi, S. A. (2020, September). Mechanical behaviour on concrete of coconut coir fiber as additive. In *IOP Conference Series: Materials Science and Engineering* (Vol. 932, No. 1, p. 012098). IOP Publishing.

Obla, K. H. (2009). What is green concrete. *The Indian Concrete Journal*, *24*, 26-28.

Otunyo, A. W., & Nyechieo, N. D. (2017). Mechanical properties and fracture behaviour of coconut fibre reinforced concrete (CFRC). *American Journal of Civil Engineering and Architecture*, *5*(5), 208-216.

Ramakrishna, G., & Sundararajan, T. (2005). Studies on the durability of natural fibres and the effect of corroded fibres on the strength of mortar. *Cement and Concrete Composites*, *27*(5), 575-582.

Riza, F. V., Karnelia, D., & Hadipramana, J. (2020, April). Workability of coconut fiber concrete with rice husk ash as a sand replacement. In *IOP Conference Series: Materials Science and Engineering* (Vol. 821, No. 1, p. 012051). IOP Publishing.

Shreeshail, B. H., Chougale, J., Pimple, D., & Kulkarni, A. (2014). Effects of coconut fibers on the properties of concrete. *International Journal of Research in Engineering and Technology*, *3*(12), 5-11.

Suhendro, B. (2014). Toward green concrete for better sustainable environment. *Procedia Engineering*, *95*, 305-320.

Syed, H., Nerella, R., & Madduru, S. R. C. (2020). Role of coconut coir fiber in concrete. *Materials Today: Proceedings*, *27*, 1104-1110.

Vélez, E., Rodríguez, R., Yanchapanta Gómez, N. B., Mora, E. D., Hernández, L., Albuja-Sánchez, J., & Calvo, M. I. (2022). Coconut-fiber composite concrete: assessment of mechanical performance and environmental benefits. *Fibers*, *10*(11), 96.