International Journal of Business and Technology Management
e-ISSN: 2682-7646 | Vol. 5, No. S3,68-77, 2023
http://myjms.mohe.gov.my/index.php/ijbtm
SPECIAL ISSUE: International Virtual Go Green 2023 (i-VGG 2023)

Coir Fibre in Concrete: A Review

Nur Atira Abdul Razak[1], Asmat Ismail[1*], Azamuddin Husin[1], Mohammad Ezad Hafez Mohd Pahroraji[1]

[1] Postgraduate Studies, Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi MARA (UiTM), 32610, Perak Branch, Perak, Malaysia

*Corresponding Author: asmat926@uitm.edu.my

Received: 9 July 2023 | Accepted: 10 August 2023 | Published: 1 October 2023

DOI: https://doi.org/10.55057/ijbtm.2023.5.S3.8

Abstract: *Concrete in Malaysia has encountered several issues relating to low waterproofing, low tensile strength, GHG emission, and depletion of natural resources. This study was conducted to review the current issues and problems associated with the characteristic of normal concrete and previous research conducted on coir fibre-reinforced concrete in improving the properties of concrete. The study reviewed extensive research findings in numerous articles and journals. The potential of the chosen new sustainable resource method, coir fibre, in the concrete mix is determined via comprehensive reading. The study revealed that coir fibre-reinforced concrete has numerous benefits in proving the properties of concrete.*

Keywords: Concrete in construction, coir fibre, low waterproofing, low tensile strength, greenhouse gas emission

---

1. Introduction

Concrete is one of the elements that can increase carbon emissions. Concrete manufacturing generates greenhouse gases both directly and indirectly through the use of energy, primarily from the combustion of fossil fuels. Malaysia mainly uses non-renewable energy sources such as fossil fuels and coal to power its manufacturing activities. However, if the economy becomes overly reliant on these sources, greenhouse gas emissions will rise, contributing to global warming. To overcome the increasing greenhouse gas emission issue, Malaysia has formulated a goal in Rancangan Malaysia Ke 12 (RMK 12) to become carbon-neutral by as early as 2050 (Raihan & Tuspekova, 2022). In order to realize RMK 12 goals, it is necessary to research other materials that will lower cost and be environmentally friendly while boosting concrete strength (Busch et al., 2022)

The construction industry's research and development of fibres, matrix materials, and fabrication processes have grown rapidly in recent years. From the literature review, coir fibre can be used as an alternative material to enhance conventional concrete. Their advantages over other building materials are increased workability of concrete, low water absorption, increased strength of concrete, and potential resistance to environmental conditions, which will also result in potentially low maintenance costs. Using this fibre also can help reduce the use of cement in concrete and increase the strength of the concrete (Nadgouda, 2019). Therefore, this paper aims to review the use of coir fibre in concrete. Several objectives have been formulated to achieve this aim, including identifying the current issue regarding concrete in construction, describing the advantages of coir fibre in concrete, reviewing the previous study conducted on the effect of coir fibre on the properties of concrete and determining the application of coir fibre concrete in construction.

2. Materials and Methods

The information was gathered by examining previous studies on the related topic from journals and published articles on the website. The literature review is conducted to review the concrete's mechanical properties, including the strength or characteristics of normal concrete and the use of coir fibre in concrete to improve the properties of concrete. Journal articles and other published materials related to the coir fibre concrete were collected, filtered, and reviewed. The critical review aims to investigate the advantages of using coir fibre in concrete and identify the suitable application of coir fibre concrete in the construction industries.

3. Previous and Current Issues Regarding Concrete in Construction

Concrete still needs development after being used for years because of its numerous drawbacks.

a) Low Waterproofing

Since Malaysia has an annual average rainfall of 3300 mm to 4600 mm and humidity levels of 80 to 90%, which are abnormally high, the concrete structure will be severely damaged. Concrete is not impermeable due to its porous nature, which allows water to pass through. Therefore, this issue will lead to several adverse effects on the properties of precast concrete, which are: -

i. Steel Corrosion

Concrete water absorption causes corrosion in the reinforcing steel. Corrosion of the reinforcing steel and other embedded metals is the most frequent reason for concrete degradation. Steel corrodes because it is a synthetic substance. Rust develops when steel corrodes, taking up more room than steel. This expansion causes tensile tensions to build in the concrete. It might be challenging to carry out long-lasting repairs on corrosion-damaged reinforced concrete after it has occurred. On the other hand, corrosion may cause a severe decrease in the cross-sectional area of the reinforcing bar before any other type of degradation is noticed (Chernin, 2018). Figure 1 shows that the expansion of corroding steel creates tensile stresses in the concrete.

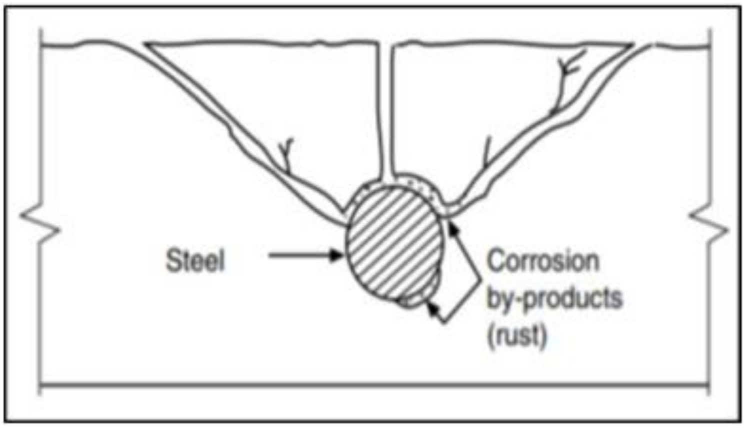

Figure 1: The expansion of corroding steel creates tensile stresses in the concrete.
Source: Topçu & Uzunömeroğlu, (2020).

ii. Crack

Concrete absorbs water because it is porous, like a sponge. As a result, this circumstance will cause a crack to occur. Concrete cracks impair a structure's strength and durability, resulting in unanticipated maintenance expenses. Cracks have implications beyond the realm of mechanics. In actuality, fissures allow for the penetration of hostile compounds and foreign materials into the concrete. These might weaken and harm the reinforcements and concrete. In this situation, urgent action is required to prevent the structure's service life from being shortened and potential structural problems. Concrete is not impervious to water. Concrete becomes substantially more humid when fractures are present, which also causes steel to corrode at a faster pace. The water will enlarge and deepen the fracture with mechanical processes like runoff. Water in a fissure caused by frost may swiftly lead to much more severe damage (Topcu et al., 2020).

iii. High Maintenance Cost

Corrosion and crack will lead to high maintenance costs for concrete. The concrete market has grown greatly as more areas become industrialised, and there is a stronger need for long-lasting building materials that can resist harsh weather and long-term wear. It has influenced the price of concrete over time. Steel prices increased due to the Russia-Ukraine conflict from 19 May 2022 until now, as these two countries are among the world's largest steel producers. It has disrupted the global supply chain. The Building Materials Cost Index (BCI) increased for all building categories in Peninsular Malaysia by 0.1 to 1.6 per cent, Sabah by 0.1 to 0.9 per cent, and Sarawak by 0.1 to 2.6 per cent. To overcome this disadvantage, which is a reduction in building strength, the study of other materials that will lower the cost while enhancing the strength of concrete is required (Busch et al., 2022).

b) Low Tensile Strength

Because of its low strength, concrete in IBS has experienced significant workability and tensile strength issues. Concrete makes up the bulk of the building's structure. Strength is a good sign of a concrete product's quality because it directly relates to the long-term performance of the concrete structure. The interfacial transition zone of concrete is directly correlated with the low tensile strength found between rock aggregates and cement paste (Adeyemi et al., 2019). Figure 2 shows the crack in concrete due to the low tensile strength.

Figure 2: ***The crack on concrete due to the low tensile strength***
Source: Raza et al., (2020).

According to Gereziher & Zhutovsky (2022), concrete must be cured appropriately to achieve the desired mechanical and durability properties. However, improper curing can result in losing 50% of the concrete's strength, whereas proper curing guarantees 90% of the strength. On the other hand, proper curing maintains the relative humidity of the concrete's capillary pores at or above 80%. Curing also guards against early strength and durability losses, shrinkage, and permeability loss. If the concrete is not fully cured and is left out in the dry for three days, it can achieve nearly half of the strength of fully cured concrete; however, if it is fully cured for seven days, it can achieve up to 80% of the strength. The development of drying shrinkage in concrete results from insufficient curing, which is still a common cause of structural defects.

c) Greenhouse Gas (GHG) Emission

According to estimates, Malaysian cement production is predicted to reach 1500,00 tonnes by the end of this quarter. According to our econometric models, Malaysia's Cement Production will trend around 1500,00 tonnes in 2023 and 1900,00 tonnes in 2024 in the long term (Ramesh et al., 2021). Around 0.9 pounds of carbon dioxide are discharged into the atmosphere for every pound of cement produced. Cement manufacture generates greenhouse gases both directly and indirectly through the use of energy, primarily from the combustion of fossil fuels. Malaysia mainly uses non-renewable energy sources such as fossil fuels and coal to power its manufacturing activities. However, if the economy becomes overly reliant on these sources, greenhouse gas emissions will rise, contributing to global warming (Busch et al., 2022). Figure 3 shows Malaysia's bar chart of greenhouse gas emissions from 2012 to 2020.

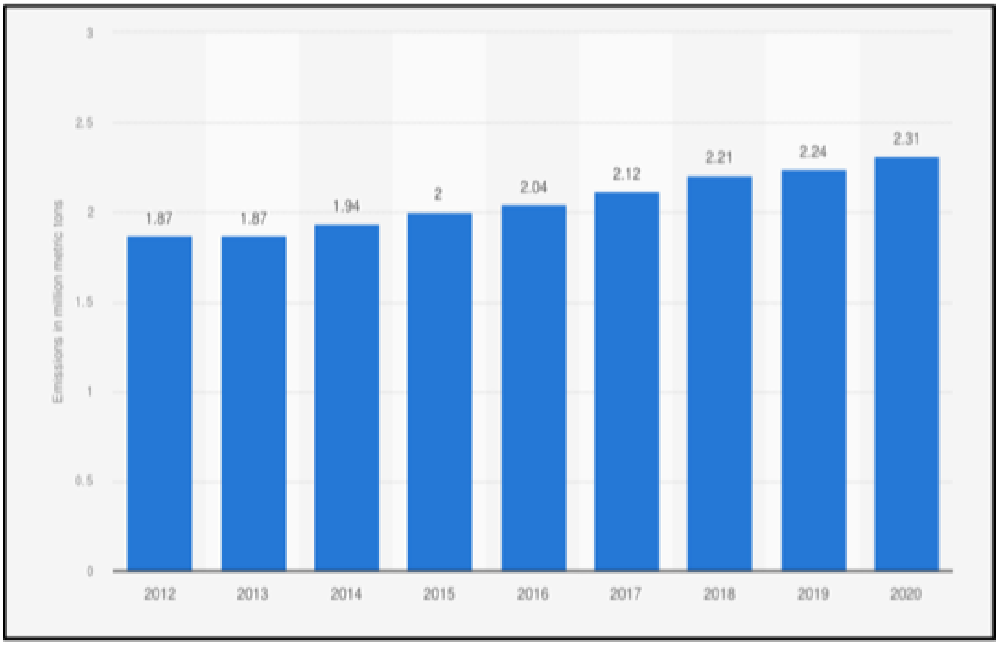

Figure 3: ***The bar chart of greenhouse gas emission in Malaysia from 2012 to 2020*.**
Source: Moore & Miller (2020)

d) Depletion on Natural Resources

In tandem with economic growth, the rapidly expanding construction sector necessitates a significant increase in the production and consumption of construction minerals such as rock materials (aggregate) and sand (Al-Hamrani et al., 2021). Concrete is the most valuable material in the construction sector. Rock and sand are used as critical raw construction materials. As a result, to support the country's economic development, the mining and quarry industry, as a producer of construction minerals, should ensure an adequate and ongoing supply of raw materials to the construction sector. A lack of certain building materials will result in higher construction costs, which will then be passed on to end users, harming national development. Although natural aggregate supply is expected to be adequate for development in the coming years, aggressive consumption will deplete non-renewable aggregate resources if no control measures are implemented (Devi et al., 2021). Proper planning and prevention are required to avoid the effects of a shortage and address issues that may affect supply in the future (Medineckiene et al., 2018). Figure 4 shows the percentage of aggregate production around the world.

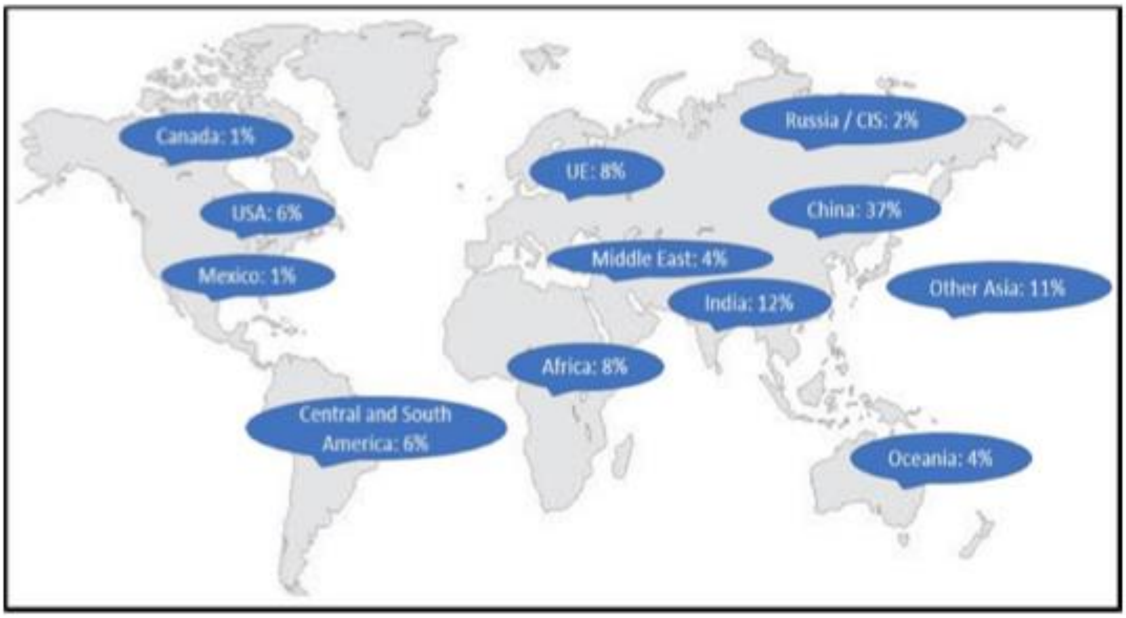

Figure 4: The percentage of aggregate production around the world.
Source: Medineckiene et al., (2018).

e) Fibre Reinforced Concrete (FRC)

Ragavendra et al. (2018) stated that concrete is substantially more brittle and has lower tensile strength than other construction materials like metals and polymers. Based on fracture toughness ratings, steel is at least 100 times more resistant to crack formation than concrete. As a result, concrete in service fractures rapidly, providing easy access to harmful chemicals, resulting in early saturation, freeze-thaw damage, scaling, discolouration, and steel corrosion. In addition, concrete that has been reinforced with fibres made of various materials greatly reduces the issues associated with the material's poor fracture toughness. Fibre-reinforced concrete (FRC), a product with a randomly distributed pattern of short, discontinuous fibres, is gradually gaining acceptance as a standard building material. In the past thirty years, there has been a significant advancement in understanding fibre-reinforced cementitious materials' short- and long-term performances, leading to various unique and creative applications.

Furthermore, FRC makes up most of the composite concrete material, strengthening its structural stability. FRC is divided into two categories which are synthetic fibre and natural fibre. It comprises blends of appropriate fibres that are discrete, evenly scattered, and discontinuous in cement, mortar, or concrete. Fibres are typically utilised in concrete to prevent cracks caused by drying shrinkage and plastic shrinkage. Additionally, they lessen the permeability of concrete, lessening water leakage. Since builders and homeowners began to realise its numerous advantages, fibre-reinforced concrete has expanded quickly throughout the construction sector. Due to its faster construction and lower labour expenses, fibre-reinforced concrete is gaining popularity among concrete professionals. In addition to economic considerations, fibre-reinforced concrete also satisfies the standards for quality in construction. To sum up, FRC is one of the innovations utilised to solve the issues and problems with conventional precast concrete (Rai & Joshi, 2020).

i. Synthetic Fibres vs. Natural Fibres

Fibre-reinforced concrete is divided into two categories: synthetic and natural. Table 1 shows the comparison between synthetic fibres and natural fibres.

Table 1: The comparison between synthetic fibres and natural fibres. Types of Fibre Reinforced Concrete

Characteristics	Types of Fibre Reinforced Concrete	
	Synthetic Fibre	Natural Fibre
Fire resistance	x	✓
Strength	✓	✓
Elastic/Stretch	✓	x
Waterproofing	x	✓
Heavy load	✓	x
Biodegradability	x	✓

Source: Ruben & Baskar (2020).

Table 1 demonstrates that natural fibres have more advantages than synthetic fibres. Fibres are materials that resemble string and can be utilised for various tasks. Plants, vegetables, leaves, wood, animals, and geological processes produce natural fibres. Due to the rise in the price of high-energy materials and the availability of solutions to increase the toughness of natural strands in concrete, the trend of research on naturally reinforced solid composites is now developing. Besides that, due to environmental and ecological concerns, plant fibres are used as reinforcement in compositions instead of conventional fibres. It adopted eco-friendliness because of its benefits, easiness, and outstanding traits. However, experts and researchers 20 have discovered other types of materials in concrete, such as jute, sisal, coir, rice husk, flax, bamboo, banana, oil palm, sugarcane bagasse, and so on.

In addition, it has been noticed that sisal, coconut, and bamboo have produced much more promising results given the test conditions and their low thickness, simplicity, and biodegradability. Given their accessibility and abundance in the region, natural fibres should be employed in manufacturing concrete. Even though this concept has been around for a while, it is still somewhat new. In poor nations, a wide range of natural fibres is easily accessible for use as reinforcement (Ahamed et al., 2021).

f) Coir Fibre

Researchers now embrace natural fibres like coconut fibres to increase the characteristics of concrete due to the rising expense of building and its progressive impact on the environment. In recent years, the construction industry's research and development of fibres and matrix materials and fabrication processes has grown rapidly. The coconut's outer shell is where coconut fibre is found. Coir is the term given to coconut fibre by its common, scientific, and botanical families. Coir is everything between a coconut seed's shell and outer layer. Coir is made up of two types of fibres which are brown and white. Brown coir is made from mature, ripe coconuts and is significantly stronger but less flexible. White fibres are derived from unripe coconuts and are considerably more flexible but far less strong (Nadgouda, 2014). Figure 5 shows the interior structure of the coconut.

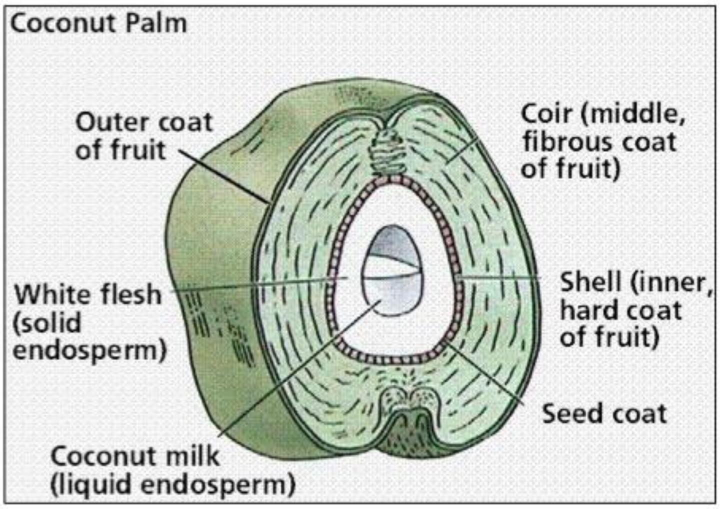

Figure 5: The interior structure of the coconut.
Source: Nduka et al., (2012)

i. Statistic of Coconut Waste in Malaysia

Coir fibre can be used as an alternative material to enhance conventional concrete because many people are unaware that the production of coconut generates a significant amount of waste in the form of coconut coir. Malaysian coconut production is approximately 5,105 tonnes per year, averaging 5.97 tonnes per hectare (Hoe, 2018).

Due to the obvious high durability of coconut coir, it will add to Malaysia's landfill capacity problem. A large amount of coconut waste will remain in landfill for a long time due to the high durability of coconut fibre. It will cause an increasing number of landfills in Malaysia. In Malaysia, there are 261 units of the landfill, only 150 of which are operational, and 111 of which are fully loaded with solid waste; the number of landfills is increasing year by year, and the land is causing a lot of problems for the earth as well as a human living. Due to its detrimental environmental impact, coir fibre has been transformed into a new material that can be utilised in the building industry (Hoe, 2018).

ii. Advantages of Coir Fibre

Their advantages over other building materials include low water absorption, soundproofing, and potential resistance to environmental conditions, which can result in potentially low maintenance costs. Coir fibre is a suitable choice as a chemical-free fibre material that is also safe for consumers due to its flexibility, durability, odorlessness, and environmental friendliness. The coconut coir fibre has the most outstanding tenacity of any natural fibre. Coir fibres can be used as reinforcement in inexpensive concrete structures due to their durability and hardness. Coir fibre makes it simple to produce since coconut coir can be found all year round and is affordable and ecologically reasonable. Additionally, natural resources may be exploited efficiently to reduce resource waste (Ranjitham et al., 2019).

iii. Previous Studies on Coir Fibre Concrete

Coconut fibre has the potential to be employed as reinforcement in low-cost constructions. The effect of 1%, 2%, 3%, and 5% fibre contents by cement mass and fibre lengths of 2.5, 5, and 7.5 cm was investigated. The result showed that 5% fibre content could improve the characteristics of concrete (Ali et al. (2012) as cited in Achudhan et al. (2018). Coconut coir is lightweight and has low thermal conductivity. Buildings could employ coconut-coir-based lightweight cement boards as insulation to conserve energy.

A comparative study on the dynamic behaviour and weight-carrying capacity of Coconut Fibre Reinforced Concrete (CFRC) beams with and without coconut rope by Ali et al. (2011) discovered that CFRC with coir rope rebars has the potential to be used as the main structural components due to its improved damping and ductility. The natural coir fibre used in the experiment was a coir fibre with a length of 7.5 cm and a fibre composition of 3% by weight of cement. Coconut rope, which has a diameter of 1 cm and a tensile strength of 7.8 MPa, is used to add the primary reinforcement.

Babafemi et al. (2019) investigated the effect of including 3%, 4%, and 5% coir fibre content on the workability, density, compressive strength, splitting tensile strength, and durability of concrete. The compressive strength was determined up to 56 days, and the splitting tensile strength was evaluated at 7, 14, and 28 days following the proper code procedures. Concrete reinforced with coir fibres was tested for durability using hardened cube examples. Coir fibre decreased the workability of concrete but had no impact on density. Concrete's compressive and tensile strengths were somewhat enhanced by coir fibre, notably at 3%. However, its sulphate attack resistance improved at only 4% and 5% of coir fibre content.

Li et al. (2020) discovered that utilizing low-cost roofing materials made of coir fibre-reinforced cement composites with random Coir fibre distribution was significantly less expensive than the readily available roofing mat.

iv. The Application of Coir Fibre

- **Slab**

Paramasivam et al. as cited in Vijaya & Athiva (2017) stated that corrugated slabs reinforced with coir fibre used in low-cost housing have low thermal conductivity. Its sound absorption coefficients were also comparable to those of asbestos boards readily available nearby. Slabs with a flexural strength of 22 MPa, a volume fraction of 3%, a fibre length of 2.5 cm, and a casting pressure of 0.15 MPa (1.5 atmospheres) were suggested for producing the necessary slabs.

- **Roofing Material**

Coir fibre-reinforced concrete also can be used as a roofing material. A study conducted by Cook et al. 1978, as cited in Sankar (2018) discovered that a composite with a fibre length of 3.75 cm, a fibre volume fraction of 7.5%, and a pressure of 1.67 MPa was the best. Comparing prices showed that this composite was significantly less expensive than the roofing materials readily available.

- **Boards**

A study conducted to analyse the lightweight cement board made from coconut coir after 28 days revealed that better results were obtained using 6 cm long fibres that were boiled and washed. On the other hand, the ideal weight ratio for cement, fibre, and water in a mixture was 2:1:2. Additionally, compared to commercial flake board composite, the tested board had lower thermal conductivity (Asasutjarit et al. (2007), as cited in Davies and Davies (2017).

4. Conclusion and Recommendations

After reviewing the previous literature, it can be concluded that normal concrete has experienced several issues, such as low waterproofing, steel corrosion, crack, high maintenance cost, low tensile strength, increased greenhouse gas emissions and depletion of natural resources. Using coir fibre in concrete can be a promising technique to address those issues. The coir fibre can be used in concrete to enhance its properties, such as improving workability, tensile strength and eco-friendly concrete. It also has low water absorption, good soundproofing, and potential resistance to environmental conditions, which can result in potentially low maintenance costs and reduce greenhouse gas emissions. In addition, using coir fibre in concrete can reduce the fibrous waste in the environment.

Further research related to coir fibre in concrete should be conducted to improve the quality of concrete. A study on using treated coir fibre with different fibre lengths should be investigated to examine its mechanical properties since most previous researchers had used untreated coir fibre in their studies. Coir and synthetic fibre integration should also be analysed to assess its performance.

Acknowledgement
The authors would like to thank the Universiti Teknologi MARA Perak Branch for providing the supports for this study.

References

Achudhan, Hasan Ali M.J.I., Sankar, S.S & Saikumar, K. (2018). Experimental Study On Coir Fibre Mixed Concrete. International Journal of Pure and Applied Mathematics, 118 (20), 2913-2929.

Adeyemi, A. O., Anifowose, M. A., Amototo, I. O., Adebara, S. A., & Olawuyi, M. Y. (2019). Effect of Water Cement Ratios on Compressive Strength of Palm Kernel Shell Concrete. LAUTECH Journal of Civil and Environmental Studies, 2(Issue 1).

Ahamed, M. S., Ravichandran, P., & Krishnaraja, A. R. (2021, February). Natural fibers in concrete–A review. In IOP Conference Series: Materials Science and Engineering (Vol. 1055, No. 1, p. 012038).

Al-Hamrani, A., Kucukvar, M., Alnahhal, W., Mahdi, E., & Onat, N. C. (2021). Green concrete for a circular economy: A review on sustainability, durability, and structural properties. Materials, 14(2), 351.

Ali, M., Liu, A. & Sou, H. (2011). Mechanical and dynamic properties of coconut fibre reinforced concrete. Construction and Building Materials. 30. 10.1016/j.conbuildmat.2011.12.068.

Babafemi, A. J., Kolawole, J. T., & Olalusi, O. B. (2019). Mechanical and durability properties of coir fibre reinforced concrete. Journal of Engineering Science and Technology, 14(3), 1482-1496.

Busch, P., Kendall, A., Murphy, C. W., & Miller, S. A. (2022). Literature review on policies to mitigate GHG emissions for cement and concrete. Resources, Conservation and Recycling, 182, 106278.

Chernin, L. (2018). Effect of Corrosion on the Concrete-reinforcement Interaction in Reinforced Concrete Beams. Technion-Israel Institute of Technology, Faculty of Civil and Environmental Engineering.

Devi, S. V., Gausikan, R., Chithambaranathan, S., & Jeffrey, J. W. (2021). Utilization of recycled aggregate of construction and demolition waste as a sustainable material. Materials Today: Proceedings, 45, 6649-6654.

Davies, E.E. & Davies, O. (2017). Agro-waste-cement particleboards: A review. Journal of Environmental Science. 2. 10-26.

Gereziher Atsbha, T., & Zhutovsky, S. (2022). The effect of external curing methods on the development of mechanical and durability-related properties of normalstrength concrete. Construction and Building Materials, 324.

Hoe, T. K. (2018). The current scenario and development of the coconut industry. The Planter, Kuala Lumpur: 94 (1108): 413-426 (2018)

Medineckiene, M., Turskis, Z., & Zavadskas, E. K. (2018). Sustainable construction taking into account the building impact on the environment. Journal of environmental engineering and landscape management, 18(2), 118-127.

Moore, F.C., & Miller, S. A. (2020). Climate and health damages from global concrete production. Nature Climate Change, 10(5), 439-443.

More, F. M. D. S., & Subramanian, S. S. (2022). Impact of fibres on the mechanical and durable behaviour of fibre-reinforced concrete. Buildings, 12(9), 1436.

Nduka, N. & Onuba, O. & Ogbonna, U. (2012). Development of a Coconut Dehusking Machine for Rural Small Scale Farm Holders. 2. 1-7.

Nadgouda, K. (2014) Coconut Fibre Reinforced Concrete. Proceedings of Thirteenth IRF International Conference, 14th September 2014, Chennai, India, ISBN: 978-93-84209-51-3

Ragavendra, S., Reddy, I. P., & Dongre, A. R. C. H. A. N. A. A. (2018). Fibre reinforced concrete-A case study. Proceedings of the Architectural Engineering Aspect for Sustainable Building Envelopes, Khairatabad, Hyderabad, India, 10-11.

Rai, A., & Joshi, Y. P. (2020). Applications and properties of fibre reinforced concrete. Journal of Engineering Research and Applications, 4(5), 123-131.

Raihan, A., & Tuspekova, A. (2022). Toward a sustainable environment: Nexus between economic growth, renewable energy use, forested area, and carbon emissions in Malaysia. Resources, Conservation & Recycling Advances, 15, 200096.

Ramesh, G. (2021). Green Concrete: Environment Friendly Solution. Ind. J. Des. Eng, 1, 13-20.

Ranjitham, M., Mohanraj, S., Ajithpandi, K., Akileswaran, S., & Sree, S. D. (2019, July). Strength properties of coconut fibre reinforced concrete. In AIP Conference Proceedings (Vol. 2128, No. 1, p. 020005). AIP Publishing LLC.

Raza, M. S., Kumar, H., Kumar, D., & Bheel, N. (2020). Effect of Various Curing Methods and Curing Days on Compressive Strength of Plain Cement Concrete. Quaid-e-Awam University Research Journal of Engineering, Science & Technology, 18(02), 29–32.

Sankar, S. S. (2018). Experimental Study On Coir Fibre Mixed Concrete. International Journal of Pure and Applied Mathematics. 118. 2913-2929.

Topçu, İ. B., & Uzunömeroğlu, A. (2020). Properties of corrosion inhibitors on reinforced concrete. Journal of Structural Engineering, 3(2), 93-109.

Vijaya, T. B. & , Ajitha. B (2017). Flexural Behavior of High Strength Coir Fiber Reinforced Concrete Blended with Silica Fume. International Journal of Engineering Science and Computing, 10594 – 10599.