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FLEXURAL CRACKS OF THE REINFORCED CONCRETE (RC) WITH THE ADDITION OF COCONUT FIBERS

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ABSTRACT
In this study, the behaviour of flexural cracking in the highly reinforced concrete of the concrete beams of was examined. Investigations were conducted on 27 reinforced concrete beams with the dimensions of 150x150x500mm. The concrete strength is 25 map, with the bar diameter 12 mm in the tension and compression zone, and 8 mm for the links stirrups were the factors examined in this work. In between each link the length is 10 mm. In this study, the coconut fibres are used to strengthen the concrete's flexural properties and to control the cracks in the reinforced concrete members from spreading. In addition to the coconut fibres, the coconut fibre-reinforced concrete also contains cement, fine, water, and coarse aggregate. In this experiment, the flexural cracking behaviour of the reinforced concrete beams with varying percentages of the coconut fibres (3 and 6%) is compared to the control sample, at 7, 14, and 28 days. The beams are tested for the third-point loads. To assess the flexural cracking behaviour of the concrete beams, factors such as the first cracking load, maximum crack width, and crack number are also examined. The outcomes demonstrate that the inclusion of the coconut fibres greatly reduces the flexural crack width. After 28 days of cure, the concrete with a 6% fibre content had 68% smaller maximum crack width than the control concrete (without fibre). The outcomes also demonstrate that the inclusion of the coconut fibres increases the initial cracking load and maximum load.

Keywords:
Coconut fibers reinforced concrete (CFRC), flexural strength, flexural cracks, crack width, first crack load

INTRODUCTION

Many nations are looking for an affordable way to cut building expenditures as the economic growth is accelerating. Concrete serves as the major building material and is crucial to the development of structures like buildings, bridges, retaining walls, etc. According to a report published in 2022, the world's expected cement production for 2020 was 4.4 billion metric tons (Lim et al., 2020). The natural fibre that can be used for the building includes fibre that goes by other names, such as Coir fibre. Depending on the use, many types of fibres can be utilized, however brown fibre from natural coconut is typically used. Fibres are used to stop and restrict shrinkage caused by the curing of concrete and plastic. The addition of fibres to concrete may enhance the material's various qualities, including flexural toughness, flexural strength, fatigue resistance, impact resistance, and post-crack strength, provided that more studies and research development to be conducted (Behbahani., 2010). Besides that, there will be a failure if the structure of the beam column is a problem. According to Norhaiza & Zulhelmi (2023), a new approach in the structural design is required to avoid structural failures from occurring at the beam-column connection.

The unreinforced concrete cracks extensively and fails unexpectedly under stress. Concrete is typically reinforced with steel rebar. In the majority of the developing nations, is the process is pricey. Natural fibres are widely available in the tropical areas and when they are used, it will lower the price of the reinforced concrete and enhance its performance (Adisa et al., 2013). For the concrete structures to be designed correctly, the research on crack development behaviour in concrete under increasing loads and control of cracking becomes important. At active loads cracks form in the reinforced concrete members, if it is caused bythe cracks, it cannot be removed. At this point, it is accepted. The concrete is weak in tension, and that is why the reinforcement is added to the flexural concrete member's tension zone to withstand the tensile force generated by the load applied (Mansor, 2014) Having that scenario, it is utilised in the construction all over the world. The concrete is a necessary the component of the buildings. The cost of the project will increase when more reinforced bars are incorporated into the design since reinforced bars are used in the majority of projects to ensure stability and safety because concrete has low flexural and stress resistance (Syed et al., 2020). Moving on to the concrete's physical performance, cracks can be seen in the concrete one day after casting. In certain circumstances, these fissures could enlarge over time. Wider cracks not only detract from the structure's aesthetics but also expose the steel reinforcement to the elements, which can lead to the corrosion.

This study is an experimental works which concentrating on the flexural behaviour of cracks in the reinforced concrete is to determine the value of the first crack load that occurs under the flexural test. Secondly, it is also to study the maximum crack width and the number of cracks in the flexural zone. Finally, it is to determine the maximum flexural strength of the reinforced concrete beam with the addition of the coconut fibre until it causes a failure. Besides that, one experiment includes coconut fibres with CFRC reinforced concrete in varying percentages to determine the flexure strength test on steel beam mold. In this study, 27 samples were created using various percentages. Three beams were used for each percentage, and the curing time are 7, 14, and 28 days. At the lab of Infrastructure University Kuala Lumpur (IUKL), all research testings are conducted. Overall, a realistic goal is to assess crack number, crack width, and the first crack that develops on the reinforced concrete beam.

LITERATURE REVIEW

Concrete is made up of cement paste, a cement and water mixture that acts as the binding agent, and aggregate of various sizes that are normally divided into fine (sand) and coarse categories (typically crushed stone or gravel). The filler, which makes up a greater portion of concrete and is a bulky aggregate that is less expensive than cement, Concrete's constituent materials come from stone that has been cast, rebuilt, or replicated. Concrete must be distinguished from stone as a distinct material with very differing durability, weathering, and maintenance needs (Karasin et al., 2014).

Concrete has high compression strength but poor tension strength. To be utilised in the construction, concrete is mixed with a material that has a high tensile strength. The oldest and most popular method is using steel to combine or strengthen concrete. In the reinforced concrete constructions, steel and concrete interact to allow the former to endure the compressive pressures and the latter to withstand the tensile stresses. Concrete typically cracks due to the brittle failure, which occurs abruptly and without warning. Steel has a more ductile behaviour, and when it is combined with concrete, it creates a composite material that can withstand more deformations before breaking (White G, 2013). According to Mohamed Eliwa & Mohamad Ayob, 2020, To create a safe and suitable environment design, the construction waste materials must result positively in the future innovation. A study by Norul Wahida, et. al, 2023, mentioned that, the laterite could aggregate as a normal aggregate in replacement in concrete mix. This shows that not only waste materials is being approached but many other materials are also possible.

A coconut fibre is one of the top fifteen plants and animal fibres in the world. The coconut fibre has a long history of use. After being employed for the first time in late 19th-century inventions, the coconut fibres are currently used to make a large variety of goods. More than 25 distinct products, such as ropes, beds, toothbrushes, and seatbelts, can be made from coconut fibres (Thu & Bui., 2021). The main advantages of attempting to modify the performance of concrete by adding fibres are to improve the plastic cracking characteristic of the material in the fresh state or up to about 6 hours after casting, to improve the tensile and flexural strength, to improve the impact of strength and toughness, to control cracking and the mode of failure using post-cracking ductility, to improve durability, and to improve the impact of strength and toughness (Bertelsen et al., 2020).Figure 1 shows the image of the coconut fruit layer in general, and the image is taken from Thu & Bui, 2021

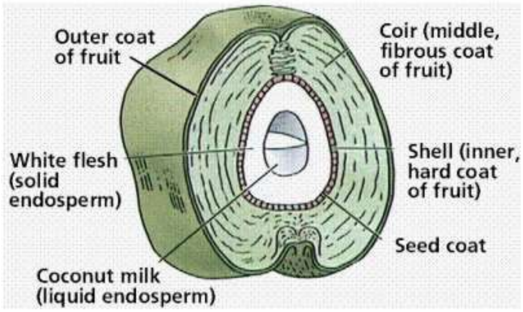

Figure 1 Coconut Fruit Layers (Thu & Bui, 2021)

Ali et al. (2012) examined the mechanical and dynamic properties of the coconut fibre in the reinforced concrete using data from earlier studies. The examination on the mixture levels of 1%, 2%, 3%, and 4% of CF by cement mass as well as fibre lengths of 2.5, 5 and 7.5 cm. According to the findings of the experiment, the features can vary and the strengths of CFRC can differ from those of conventional concrete depending on the length and composition of the fibres. The experimentation demonstrate that the concrete's flexural strength may be greatly increased by adding coconut fibres in all circumstances (Ali et al., 2012). This failure scenario occurs when the loads on the beam are larger than its bending moment. Failure mode occurs prior to flexural failure if the beam's shear strength is lower than its flexural strength (Sowik, 2019). The tructure cracks are described as the whole or partial division of a concrete structure into two or more parts as a result of cracks. Both during and after construction, cracks are indicators of structural movement (Zanke, 2020). Such movement is constant, and it frequently goes undetected because of its small size. Any type of construction with cracks loses structural integrity and safety in a specific way. The structural integrity and durability of a building are also weakened and compromised by cracks. According to S, 2018 the reasons for cracks that manifest as a result of the deterioration of concrete and corrosion reinforcement bars include unstable land selection, poor construction practices, inappropriate selection of constituent materials, shrinkage, and temperature impacts (S, 2018).

METHODOLOGY

This chapter details the experimental programmer used in this work. These details include information on the beam specimens, the materials used, and the preparation and testing procedures. The third point test was utilized to load 27 specimens of simply supported beams during the study's flexural testing. This test was used in order to determine the cracks determination. This is necessary to ensure the objectives of the study were achieved.

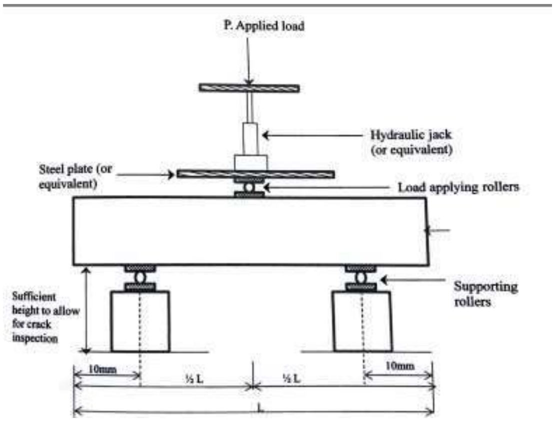

Figure 2: Third Point Loading Flexural Strength

Table 1 shows the experimental data such as test name, number of samples, percentage of fibre s and curing days.

Table 1: Mould Preparations of the study

Coconut fibre % (CF)	**Flexural test sample**			**Slump test**
	7 days	14 days	28 days	-
Control sample (0% coconut fiber)	3	3	3	1
Sample 2 (+3% coconut fiber)	3	3	3	1
Sample 3 (+6% coconut fiber)	3	3	3	1
Total samples	27			3

In this study, the BS8110 standard is used to provide the reinforced concrete design. The beam measures 150 x 150 x 500 mm, has 2T12 longitudinal bottom (tension) steel reinforcement in all beams, and top bars are still required to complete the reinforcement cage. The stirrup links are 8 mm in diameter and spaced 100 mm apart (design of Reinforced concrete beam shown in Figure 2). According to BS 8110: part 3: 1985, the nominal cover is 25 mm, and the characteristic strength of the reinforcement is fy = 460 n/mm2. The beam's dimensions and reinforcing details are shown in Figure 2.

The mixing process started with fine aggregates and cement are thoroughly combined to create a uniform mixture. The coconut fibre was added to the mixture until a certain uniform colour was achieved. The same mixture is combined with coarse aggregates, and water is added after that. To stop the bleeding care must be made to give water gradually at key points (Bui et al., 2017). Figure 3.2 shows the procedures in a specific time and material amount. All concrete ingredients are placed in a concrete mixer to get better blending if it's working, if not all mixing works will be done manually.

Figure 3: Beam mould 150 x 150 x 500m

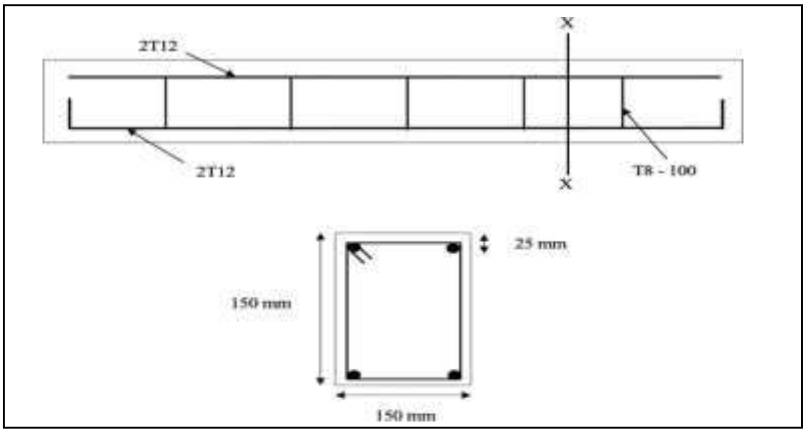

Figure 4: Reinforcement Bars Details based on Manual Calculation

This is an example concrete mix design for one beam with dimensions of 150 x 150 x 500 mm, with a volume of 0.0113 m3. 25 N/mm2 is the typical strength. The concrete mix design is shown in Appendix A of BS 5328; 1981.

Table 2 Mix Proportion of the concrete mixtures

Quantities	**Cement (Kg)**	**Fine aggregate (Kg)**	**Coarse aggregate (Kg)**
Per m^3	362	823	1005
Control Sample	4.1	9.26	11.31
3% CF	4.1	9.26	11.31
6% CF	4.1	9.26	11.31

Quantities	Water (Kg)	Fibre % by weight of cement (Kg)	Total weight (Kg)
Per m^3	210	-	-
Control Sample	2.36	-	27.03
3% CF	2.36	0.12	27.15
6% CF	2.36	0.25	27.28

According to ASTM F1575-03:2003, the three sets of flexural tests with the third point loading on 27 beams each were carried out. The third point loading flexural strength test loading configuration shown in Figure 2 was used to gauge the flexural strength of 150x150x500 mm beams. On the front, each specimen will be painted in colour. The first crack load, the largest crack width, and the total number of cracks following the failure were all measured during the experiment. The load that caused the test specimen's side to show the first indications of cracking is known as the first cracking load. All specimens from the initial cracking load that contained varying amounts of coconut fibres were examined. The load was recorded when the first crack in the reinforced concrete beam (RCB), which is when the measurement's results occurred.

Figure 5 16- Blade Feeler Gauge 0.05 to 1.00 mm

The first cracking load is the load where the first signs of cracking occured on the side of the test specimen. The first cracking load was checked for all specimens with different percentages of coconut fibres. The results of this measurement occured when the Reinforced Concrete Beam (RCB) was exposed to the first crack, the load was recorded. The crack width was measured by using a 16-blades feeler gauge, size 0.05 – 1.00 mm, with blade dimensions (L*W*H) 100*30*15 mm as shown in Figure 3.6. The number of cracks comes in the last stage after the concrete beam collapses.

ANALYSIS AND DISCUSSION

This study examined the flexural behaviour of the rectangular concrete beams reinforced with the coconut fibre using 27 beams (CF). The percentages of CF are 0, 3, and 6% by the weight of cement, respectively. Flexural fissures in the concrete beam are being looked into. Additionally, the total weight of the beams, the initial force that generated the crack, and the quantity of cracks that appeared in the bottom zone of the reinforced concrete beam. The curing and testing of the reinforced concrete beam occurred after 7, 14, and 28 days.

Slump Test

A slump cone is used to evaluate the consistency or workability of a concrete mix created in a lab. The results for the specific characteristics are shown in Table 3. The table shows that the slump decreased and workability decreased as the additional coconut fibre was introduced. This is because the amount of fibre in the mixture was increased in the compaction resistance. Figure 6 showcases the slump test being conducted in the laboratory.

Figure 6: Slump test results

Table 3: Slump Test Results

Mix	Slump (mm)
0% (control sample)	110
3% (CF)	100
6% (CF)	80

Load-Carrying Capacity

The load carrying capacity is a parameter in which the sample were tested in order to obtained the maximum capacity. The specimens were tested in 3-point load test. The replacement with the concrete fibre definitely affected the end results of the study.

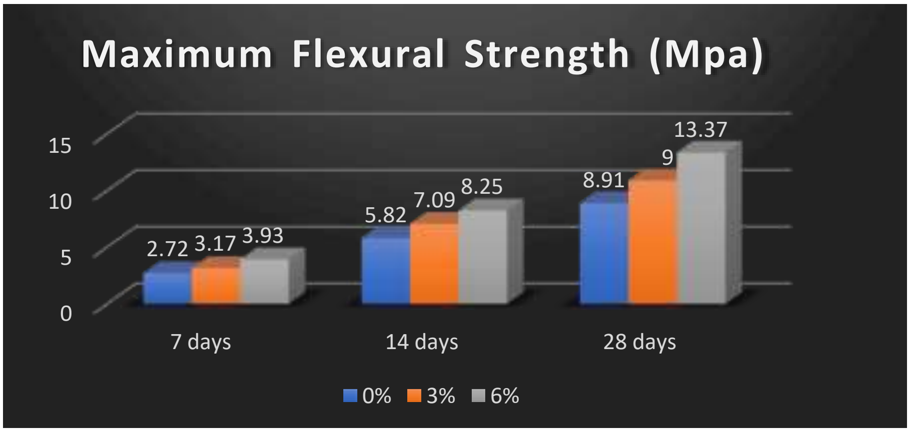

Figure 7 Maximum Flexural strength of CFRC Beams

Figure 7 shows that adding process of the coconut fiber to a reinforced concrete beam increased the flexural strength in all ages. When 6% of coconut fiber was added its gave the results of the height in all different ages compared to 3% and 0% of coconut fiber. It shows that the increment has resulted in the reflects on the maturity of the concrete. This increment has a promising results in which leads to a conclusion of the replacement of the concrete fibre is possible.

Crack Formation and Propagation: First Crack Load

The load that caused the test specimen's side to show the first indications of the cracking was the first cracking load. Figure 8 shows the loads at first cracking based on the experimental findings. The reinforced concrete beam containing 3% coconut fiber showed an increase of 19% compared to the control sample, RC beam containing 6% coconut fiber showed an increase by 33% compared to the control sample at 28 days of curing. This might be connected to the coconut fibre's enhancement of the link between concrete components and the resulting arresting of crack formation. The first crack load is very important in determining the capability of the concrete. This indicate that the addition of the coconut fibre has indeed increase the strength of the concrete.

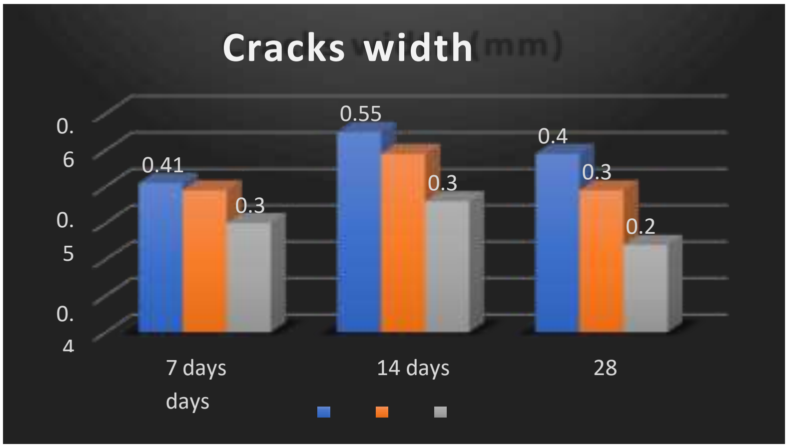

Figure 9 Maximum Crack Width of CFRC Beam

Crack Formation and Propagation: Cracks Number

The construction cracks can be considered as a part of the downfall of the failure. This test is to ensure the capabilities of adding the coconut fibre as a bonding material that can increase the strength of the reinforced concrete. The number of cracks decreased when 3% and 6% of the coconut fibre were added in the first 7 days. This can be seen in Figure 10 when after 14 days the number of cracks slightly increased when 6% was added compared to the control sample (0% CF). In 28 days the figure shows a significant increased in the number of cracks between 6% and the control sample. As shown in the figure indicated that by adding the coconut fibre does not increase the strength that much, but its near to the one with controlled mix. This is actually a promising results whereas in term of cost can be control as the coconut fibre are much cheaper than other concrete ingredients.

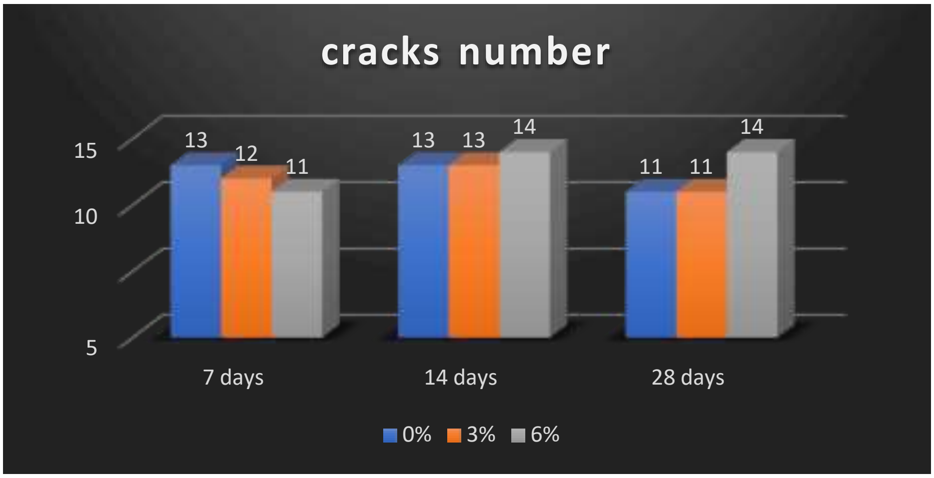

Figure 10: Cracks Number in CFRC Beam

CONCLUSION

According to the experimental findings, the additional of the coconut fibres improved the flexural strength and the ultimate load for the CFRC beams. The flexural strength of the reinforced concrete beams was 61 enhanced when the coconut fibre was added, regardless of age. When 6% of the coconut fibre was added, it produced outcomes for heights in all age groups that were superior to those of 3% and 0% of the coconut fibre. In conclusion, the addition of the coconut fibres to the concrete will increase the ultimate load, decrease the crack breadth, and improve the flexural strength. All of these will increase the first crack load. The coconut fibre ultimately produced great results at the lowest cost, thus the concrete manufacturers must begin using this type of concrete in the actual projects after confirming its effectiveness from all angles; including compressive strength, chemical reactions on concrete, etc

AUTHOR BIOGRAPHY

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