STRENGTH CHARACTERISTICS OF ALKALINE TREATED COCONUT FIBRE REINFORCED CONCRETE AT ELEVATED TEMPERATURES

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ABSTRACT

Fibre-reinforced concrete (FRC) is produced by the addition of fibrous material to concrete which improves its structural integrity. Steel and synthetic fibres are widely used for this purpose. Both steel and synthetic fibres are very expensive, having to be imported, and not being easily available in large quantities compared to natural fibres available in Sri Lanka. Relatively freely available coconut fibre is the most suitable alternative for this purpose.

This study addresses the evaluation of the tensile and compressive properties of C25 concrete at elevated temperatures with the additional use of coconut fibre as a reinforcing material. Coconut fibres were treated with 5% NaOH solution before mixing with concrete in order to improve engineering properties.

The effect of mixing 20mm, 30mm, 40mm, 50mm and 60mm long fibres was investigated with variable mix proportions of 2.0%, 2.2%, 2.4%, 2.6%, 2.85 and 3.0% by weight of cement. The overall best result was obtained with 30mm long coconut fibres with a 2.8% by weight of cement. The compressive strength, split tensile strength and flexural strength of concrete improved by 17.36, 70.73, and 50.34% of conventional concrete respectively after 28 days. Cubes, cylinders and beams with this optimum fibre content and length were exposed to elevated temperatures at different values of 100˚C, 150˚C, 200˚C and 250˚C for a period of 1 hour. The weight loss of coconut fibre concrete cube was approximately 0.7%, 1.24%, 2.04%, and 2.73% at 100°C, 150°C, 200°C and 250°C at 1hr respectively. Also, the weight loss of coconut fibre concrete cylinder is approximately 0.64%, 1.02%, 2.16%, and 2.84% at 100°C, 150°C, 200°C, and 250°C at 1 hour respectively. After that, residual compressive strength, residual split tensile strength and residual flexural strength were investigated. Results indicated that the compressive strength, split tensile strength and flexural strength decreased from 38.73 to 29.8 N/mm^2 by 23%, from 4.2 to 3.36 N/mm^2 by 20%, and from 6.54 to 5.26 N/mm^2 by 19.57% respectively with the temperature increase up to 250˚C.

Keywords: Coconut fibre, alkaline treatment, compressive strength, split tensile strength, flexural strength, residual strength, elevated temperatures

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INTRODUCTION

Concrete is relatively brittle, and its tensile strength is typically only about one-tenth of its compressive strength. Fibre-reinforced concrete (FRC) is produced by the addition of fibrous material to concrete which improves its structural integrity. Steel and synthetic fibres are widely used for this purpose. Both steel and synthetic fibres are very expensive, have to be imported and are not easily available in large quantities compared to natural fibres available in Sri Lanka. Relatively freely available coconut fibre is the most suitable alternative for this purpose.

Naturally available coconut fibre material does a major role in reducing the construction costs and weight of concrete while enhancing its strength (Chauhan, N. and Arya, N.(2018)). It has a good ability to prevent curling effects during mixing concrete compared to other types of natural fibres. Aravindh et al. (2022) concluded that alkaline treatment decreases moisture retention and increases the tensile characteristics and thermal stability of natural fibres.

Accidental fire is one of the natural hazards that attack concrete structures. Concrete, when subjected to a higher temperature, leads to severe deterioration. Sekar and Kandasamy(2019) studied the durability properties of coconut shell concrete with coconut fibre and concluded that exposure to concrete to high temperatures affects its mechanical and physical properties. Elements can become distorted and displaced due to heat-induced dimensional changes resulting in the reduction of compressive strength.

However, when focusing on the study of fire resistance, both tensile and flexural strength of concrete are very important parameters of concrete cracking and micro-crack propagation. In this study, the variation of tensile, flexural characteristics and loss of weight of coconut fibre-reinforced concrete (CFRC) is investigated against elevated temperatures after 28 days of casting. It is compared to the control condition at room temperature. The properties of concrete change with time and environment. Hence, evaluation of the effects of concrete due to elevated temperatures is important in confirming the safety evaluations.

METHODOLOGY

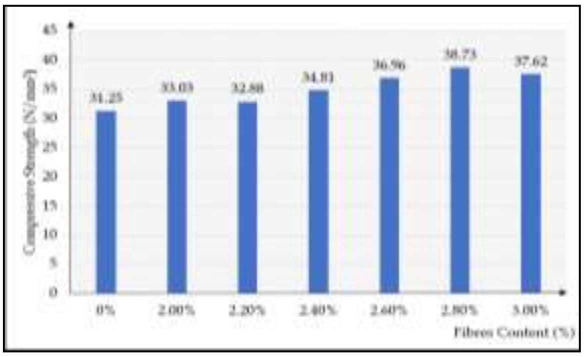
As concluded by Ng et al. (2018), coconut fibres were treated with NaOH solution that was prepared by adding 5% of NaOH into 95% of distilled water by weight and soaked at room temperature for 6 hours. The treated fibres were washed thoroughly with distilled water to neutralize NaOH and put under a sunshade until completely dried. Finally, the treated fibres were placed in the oven at 30 °C temperature for 10 to 12 minutes to remove the remaining moisture on the fibre surface. These cleaned coconut fibres were used in the concrete mixture.

Prescribed mix proportions of 1:1.5:3 by volume of cement, sand and aggregate (20mm) with a water-cement ratio of 0:55 were used to prepare Grade 25 concrete. Ahmad et al. (2022) concluded that the optimum dose of coconut fibre for FRC was in the range of 2 - 3% by volume of cement. Ramakrishna et al. (2005) and Majid Ali et al. (2012) demonstrated that the optimum length range of coconut fibre for FRC was from 20mm to 60mm. Hence, concrete mixtures were prepared varying the fibre content from 2.0%, 2.2%, 2.4%, 2.6%, 2.8% and 3.0% by volume of cement to determine the optimum percentage of fibres with a 40mm fixed length. Three test specimens were taken for each trial test. Based on the trial test results shown in Figures 1 and 2, the optimum fibre percentage was 2.8%. Thereafter, a series of tests were conducted varying the coconut fibre lengths from 20mm to 60mm in steps of 10mm with the optimum fibre percentage of 2.8%. Results indicated (Figures 3 and 4) that the optimum fibre length is 30mm. Results of compressive strength and split tensile strength tests were considered in the determination of the optimum fibre length and percentage of fibre.

A fresh set of concrete samples were cast with the determined optimum properties; i.e., 30mm long fibres and 2.8% fibre content. These samples were secured for 28 days and then kept under temperatures of 100˚C, 150˚C, 200˚C and 250˚C for a one-hour duration. Subsequent to that, compressive strength, split tensile strength, flexural strength and loss of weight of specimens were determined.

RESULTS AND DISCUSSIONS

Determination of the optimum fibre percentage



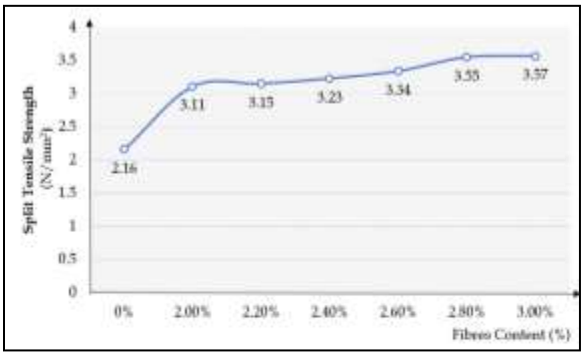


Figure 1: Compressive strength test results

Figure 2: Split tensile strength test results

Figure 1 shows an increase in the compressive strength of concrete containing coconut fibre up to 2.8%, and after that, there is a reduction in compressive strength. Figure 2 shows the splitting tensile strength of concrete increasing gradually. However, there is no considerable increment after the 2.8% fibre percentage. Previous research indicated that increasing fibre percentage beyond 3% leads to entanglement and reduces workability drastically.

Variation of workability with fibre length

Figure 3 shows the variation of the slump with fibre length. The control sample without any fibres recorded the highest slump of 92mm. It is obvious from Figure 3 that the introduction of coconut fibre has resulted in a gradual decrease in workability with increasing coconut fibre content. At the selected optimum length of 30mm, a 75mm slump was observed. During mixing, bunching of coconut fibres was visible with increasing length resulting in a gradual reduction of workability.

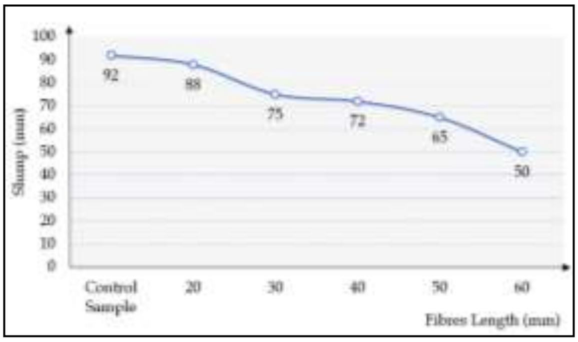


Figure 3: Slump cone test results

Determination of the optimum fibre length with the optimum fibre percentage (2.8%)

Figure 4 shows that the compressive strength of concrete recorded the peak values (38.59 and 38.73 N/mm^2 respectively) for 30 and 40mm fibres. Figure 5 shows the split tensile strength of concrete increasing gradually up to 4.2N/mm^2 when the fibres are 30mm long. Thereafter, when the fibre length is increasing beyond 30mm, split tensile strength gradually reduces resulting in the optimum length of 30mm for fibres.

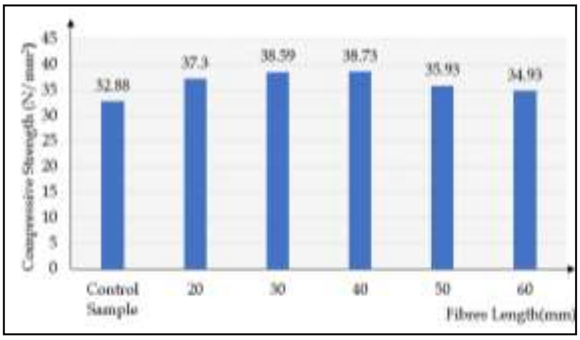


Figure 4: Compressive strength test results

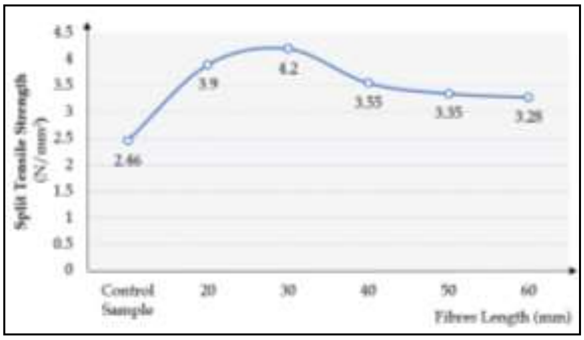


Figure 5: Split tensile strength test results

Percentage weight loss of concrete on elevated temperatures

Figure 6 shows the weight loss of coconut fibre concrete. The percentage weight loss of cubes is approximately 0.7%, 1.24%, 2.04% and 2.73% at 100°C, 150°C, 200°C and 250°C respectively. Concrete cylinders also show a similar trend. The loss of weight is probably due to the dehydration of the hydration products and the loss of water from the fine pores in the coconut fibre cement paste and aggregate particles.

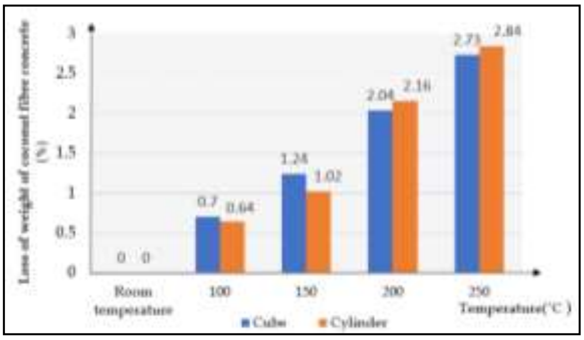


Figure 6: Percentage loss of weight of CFRC

Compressive strength and Split tensile strength Test at Elevated Temperatures

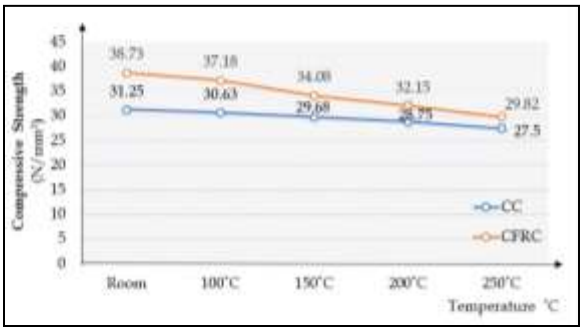


Figure 7: Compressive test results

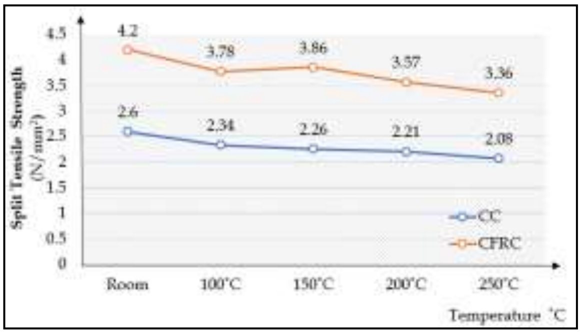


Figure 8: Split tensile test results

The compressive strength of coconut fibre reinforced concrete (CFRC) and conventional concrete (CC) decreased from 38.73 to 29.82 N/mm2 and from 31.25 to 27.50 N/mm^2 respectively with increasing temperatures as shown in Figure 7. Similarly, according to Figure 8, the split tensile strength of CFRC and CC decreased from 4.20 to 3.36 N/mm^2 and from 2.60 to 2.08 N/mm^2 respectively. In both cases, the addition of coconut fibre has resulted in a considerable increase in strength values.

Flexural strength test at elevated temperatures

Flexural strength was measured according to BS EN 12390-5 (2000). Figure 9 shows that variation of flexural strength with increasing temperature takes a trend similar to compressive strength and split tensile strength.

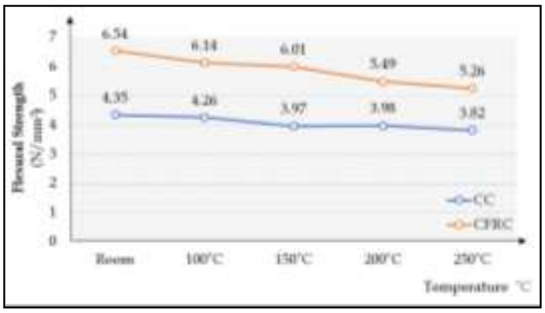


Figure 9: Flexural strength test results

CONCLUSIONS/RECOMMENDATIONS

According to the results, it can be concluded that the optimum length and mix proportions of coconut fibre required to produce coconut fibre-reinforced concrete are 30mm and 2.8% by volume of cement. The addition of coconut fibre reinforcements to conventional concrete has resulted in the enhancement of compressive, split tensile and flexural strength values within the tested temperature range. However, the magnitudes of all the above strength parameters keep decreasing as the temperature range increased from 100°C to 250°C for both coconut fibre reinforced concrete and conventional concrete.

The compressive strength of coconut fibre concrete and conventional concrete decreased by 23% and by 12% respectively when the temperature increased upto 250˚C. Both split tensile strength of coconut fibre concrete and conventional concrete decreased by 20% when the temperature increased upto 250˚C. The flexural strength of coconut fibre concrete and conventional concrete decreased by 19.6% and 12.2% respectively when the temperature increased upto 250˚C. The suspected reason is that thermal stresses create many microcracks in the dense microstructure of the concrete.

- It can be concluded that coconut fibres enhanced tensile and flexure capacity more efficiently than compressive capacity. Therefore, further research is recommended with additional pozzolanic materials such as fly ash and silica fume to improve the compressive strength capacity of CFRC.
- The workability of the concrete with fibres was found to be very low. Hence, workability needs to be improved. Thus, certain admixtures such as air-entraining agents and superplasticizers can be used to improve the flow characteristics of concrete.
- Hand mixing becomes very tedious when coconut fibres are added and lead to the formation of a non-homogeneous mix.

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