Evaluation of mechanical properties on the degradation of fibers netting subjected to rainfall

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ABSTRACT: Malaysia is a tropical country characterize with high rates of rainfall, thus, leading to high erosion rates, with running water being the main driving agent. In view of this, the current study addresses this problem with the aim to minimize erosion by using natural and biodegradable fibers including coir, jute, and kenaf fibers in the form of nettings which aid as vegetative turfing along the eroded soil areas. These nettings are intended to protect the soil by providing a physical barrier between the soil particles and rainwater. The effects of rain-drought cycles on the structural and mechanical properties of the treated nettings were evaluated. Tensile strength tests were performed on the treated and untreated fiber nettings. Results of the tensile strength of the treated fiber nettings indicate that after 60 days of laying, the area on which the treated coir net fiber was laid showed superior strength relative to the areas on which the treated jute and kenaf net fibers were laid. Coir net fiber retained 21.1% of the strength while the jute and kenaf net fibers retained 20.1% and 14.7% respectively. The high values retained by the coir net fiber may be due to its high lignin content and its ability to absorb rainwater better than the other fibers.

Keywords: fibers netting; rainfall; mechanical and structural properties; degradation

1 INTRODUCTION

Generally, soils in Malaysia are infertile and arid due to low clay activities and lack of buffering capacity which results in soil acidity. Also, extreme temperature conditions and high-intensity rainfall contributes to drought and lack of nutrients which reduces the rate of survival and growth of potential plants. Moreover, percolating rainwater with the ability to leach basic soil elements such as calcium, magnesium, potassium, and sodium also contributes to soil acidity. As such, soil acidity has a huge negative impact on fertility, biological activities, and plant productivity which may lead to erosion problems. However, the use of flora and its relationship with bacteria have great potential to lessen soil acidity and erosion problems. Furthermore, heavy metal tolerant plants also play an important role in phytoremediation. Therefore, the proper plantation and administration of plants in polluted and acidic soils may significantly contribute to restoring the natural environment. The practice of utilizing vegetation, known as “Bioengineering” combines ecological, mechanical and hydrological concepts for soil improvement has been effectively applied to minimize soil erosion in Malaysia (Osman, N & Barakbah SS, 2011). Well-combine plant choices and planting technique help in preventing soil erosion as well as in providing other benefits including biodiversity production, low-cost maintenance, sustainable self-development, and an environmentally friendly approach (Osman, N & Barakbah SS, 2011). However, the interaction of vegetation and soil is complex due to varying soil properties, soil pollutants and different types of vegetation cover (Lekha, K.R, 2004).

Fibers produced by plants, animals, and geological processes are known as natural fibers. Natural fibers such as coconut, kenaf, among others are cheap and locally available in many countries (Anggraini, V et al 2015, 2016., Anuar H & Zuraida, A 2011, Rashdi, A.A.A et al 1970., Fidelis, M.E.A et al 2013). Therefore, their application as reinforcement materials for improving soil properties is cost effective. Furthermore, in their utilization/installation process heavy machinery are not required, finally, their application provides novel sustainable solutions to complex and challenging problems (Ramakrishna, G & Sundararajan, T, 2005., Rowel et al, 2000, Siregar J.P et al 2012). In the utilization of these fiber nets for soil improvement and prevention of soil erosion, certain principal factors are considered among them include; evaluating the structural properties of the netted fibers after periods of rainfall and also, the strength retention capacity of the treated fiber nettings.

The study had as objectives to evaluate the effectiveness of a new method of treating natural fibers in order to reduce fiber nettings degradability in acidic soils in Malaysia, thus preventing soil erosion. Also, the study aimed to identify the best chemical treatment of natural fibers, and finally, to propose the most suitable natural fiber(s) for rainfall areas prone to soil erosion.

2 MATERIALS AND METHODS

2.1 *Materials*

Three natural fibers were used in this study, among them include coir, jute, and kenaf fibers. The fibers were chemically treated by Sodium Hydroxide (NaOH) and Calcium Chloride ($CaCl_2$) solutions.

2.2 *Chemical treatment on the fiber nets*

The chemical treatment method used for loading of $Ca(OH)_2$ solutions on the surface of the fiber and fiber pores is extensively outlined in a previous publication (Anggraini, V et al 2016). The treatment was carried out at ambient conditions of temperature and pressure. 50g of coir fibers were soaked in 500 mL $CaCl_2$ aqueous solution of 0.5M concentration for 24 hours in order to uniformly fill the pores and surfaces of the fibers by the $CaCl_2$ solution. The soaked coir fibers were then separated from the $CaCl_2$ aqueous solution and incubated in a beaker. 500 mL aqueous sodium hydroxide solution of 0.5M concentration was later added to the fibers and kept for 24 hours. During the above treatment, $CaCl_2$ quickly precipitated as nanoparticles on the fiber surfaces and their pores. Finally, the coir fibers were separated from the sodium hydroxide solution and were washed with distilled water in order to remove the undesired residues from the reaction such as NaCl and NaOH. The fibers were then dried at ambient room temperature.

2.3 *Fabrication of fibers nets*

Six nets of natural handmade fibers were laid out. Each net composed of different types of untreated and treated natural fibers. The size of each net was 1000mm x 1000mm (100cm x 100cm) and the spacing between the lines of the net was 17.5mm (1.75cm).

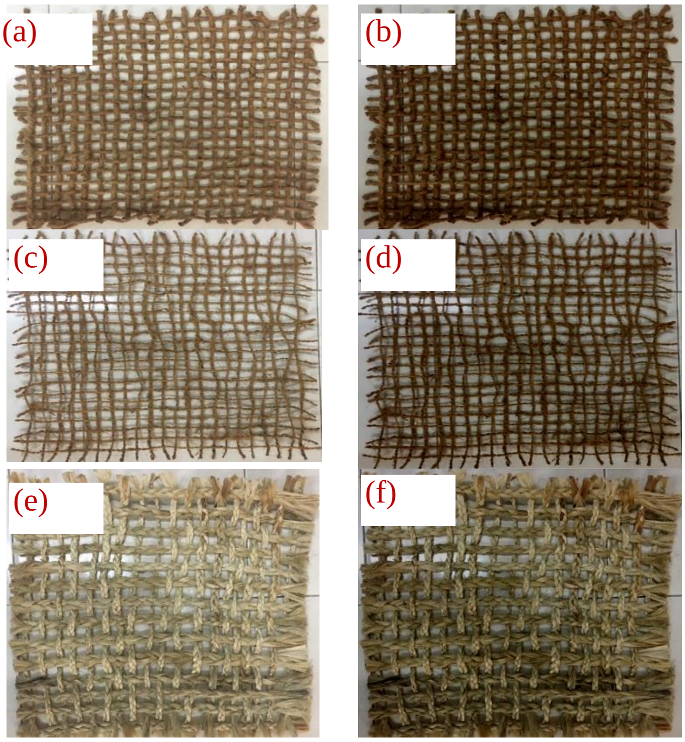

Figure 1. Fiber netting: (a) untreated coir (b) treated coir (c) untreated jute (d) treated jute (e) untreated kenaf (f) treated kenaf

2.4 *Field layout and installation procedure*

After the fabrication of the fiber nets, the nets were laid on slopes to cover the soil. Figure 2 shows a field layout at Serdang slope, Selangor Malaysia. Before installation, the slope was clean from grasses and trees. The cleaning was done using a steel hoe. After cleaning, the nets were laid to cover the soil. Steel catchers and soils were used to install the nets. Soils were also used to cover the nets ensuring that the nets stick to the soil and do not move from their original place as a result of rainfall or strong winds. Steel nets were also used in covering and protecting the area from animals or humans which may damage or alter the experiment. Samples of the 1st, 30th and 60th days after laying of the netted fibers were periodically collected from the site and their mechanical properties tested in the laboratory.

Figure 2. Field layout netted fiber

2.5 *Tensile strength test*

Fiber tensile test was conducted based on ASTM standard (ASTM D3379). The tensile strength was evaluated in order to investigate the effect of chemical treatment on the tensile strength of the netted fibers due to continue rain-sun periods.
Tensile strength tests were performed on 18 samples of natural fibers. 9 samples were the treated fibers consisting of the three different fiber types (coir, kenaf, and jute) and the remaining 9 samples also included the three different untreated fiber types. The tests were performed with a curing duration of the 1st day, 30 days and 60 days.

Figure 3. Tensile strength of netting fiber

3 RESULTS

3.1 *Biodegradation of fiber netting*

Being a natural fibrous material, fibers are susceptible to degradation due to microbial action in the soil and also as a result of the continuous alternating rain-sun periods. Susceptibility to biodegradation of natural fibers fabric was studied based on tensile strength on the fiber samples which were periodically collected from the site.

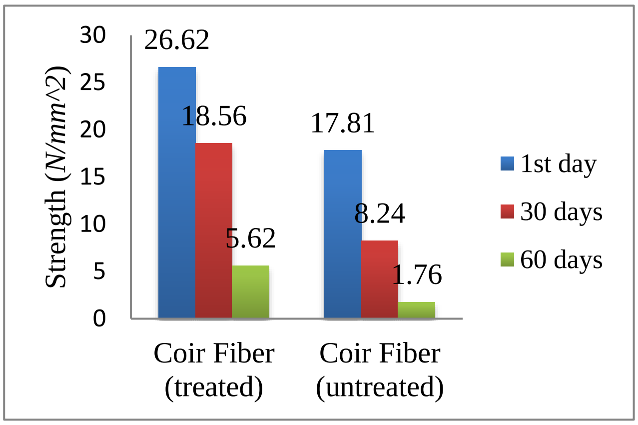

Figure 4. Comparison between treated vs untreat-ed coir fiber

Figure 4 shows that the treated coir fiber has better performance than untreated coir fiber in regards to fiber degradation. The figure indicates that the treated coir fiber control sample (1st day) had a strength of 26.62 N/mm^2 and the untreated sample had a lower strength of 17.81 N/mm^2, with a difference in strength percentage by 33.1 %. The sample of 30 days curing also indicated that the treated sample is stronger by 56 % with a value of 18.56 N/mm^2 relative to the untreated sample with a value of 8.24 N/mm^2. The last sample of coir fiber, after 60 days, shows that the treated sample is stronger with a value of 5.62 N/mm^2 and the untreated sample had a value of 1.76 N/mm^2 with better performance for the treated sample by 69 %.

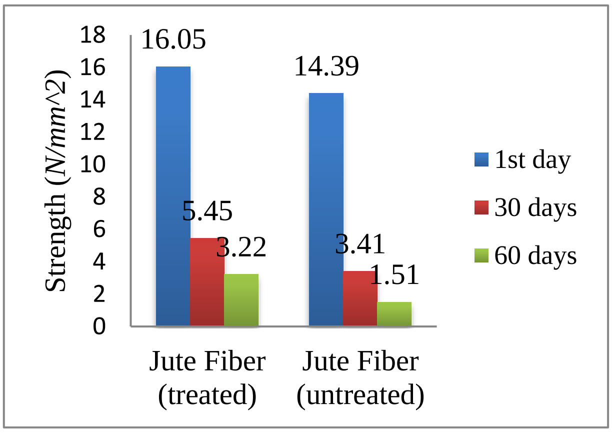

Figure 5. Comparison between treated vs untreated jute fiber

Figure 5 illustrates that treated jute fiber has better performance than untreated jute fiber. From the figure, it can be seen that the strength value of the control sample (1st day) of the treated jute fiber is 16.05 N/mm^2 and that of the untreated sample is 14.39 N/mm^2, with the treated sample stronger by 10.34 %. The 30 days sample also showed a better strength for the treated sample by 37.43 % increase relative to the untreated sample with a value of 5.45 N/mm^2 and the untreated sample had a value of 3.41 N/mm^2. For the last sample of the jute fiber after 60 days, the treated sample had a strength value of 3.22 N/mm^2 and the untreated sample showed a value of 1.51 N/mm^2 with better performance for the treated sample by 53.11 %.

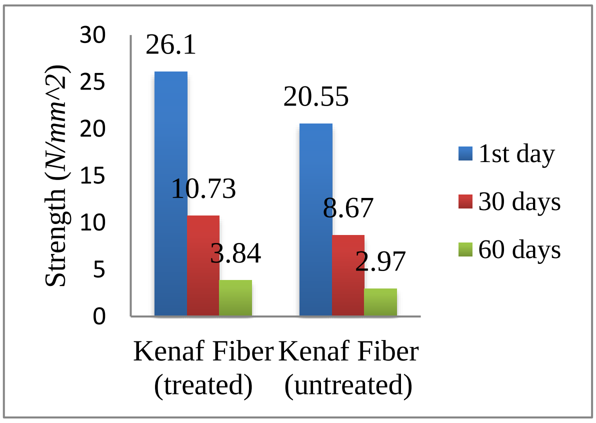

Figure 6. Comparison between treated vs untreated kenaf fiber

Figure 6 indicates that treated kenaf fiber has a better performance than untreated kenaf fiber. From the figure, it can be seen that the strength value of the control sample (1st day) for the treated kenaf fiber is 26.1 N/mm^2 and the untreated sample has a value of 20.55 N/mm^2, with an increased percentage of by 21.3 % for the treated sample. The 30 days treated sample also showed a better strength with a value of 10.73 N/mm^2 and a percentage strength increase by 19.2% relative to the untreated sample with a value of 8.67 N/mm^2. The last sample of kenaf fiber after 60 days shows the treated sample has a strength value of 3.84 N/mm^2 and the untreated sample has a value of 2.97 N/mm^2 with a percentage performance for the treated sample by 23 %.

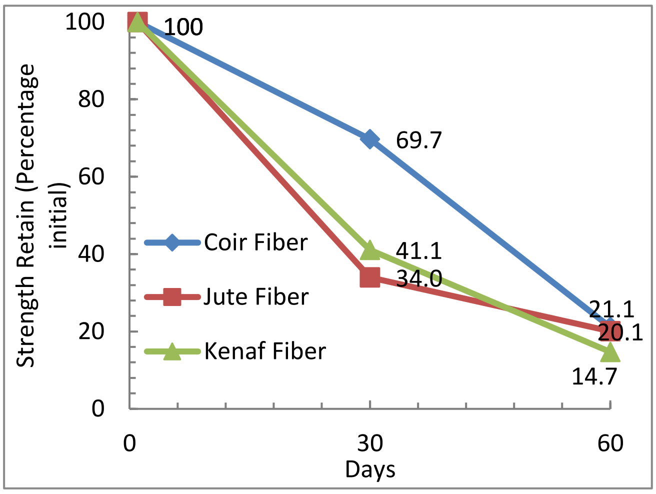

Figure 7. Strength retained of netted fibers

The stress-strain observations were obtained and the curve of ultimate strength vs age of the fiber samples was plotted as shown in Figure 7. Analysis of the ultimate tensile strength of natural fibers netting showed that after 60 days of laying, the area laid by treated coir net fiber has retained 21.1% and the jute and kenaf net fibers retained 20.1% and 14.7% respectively. The high values retained by the coir net fiber may be due to its high lignin content and its ability to absorb rainwater better than other fibers.

4 CONCLUSION

The tensile strength values of natural fibers were different for each sample. The tensile strength values for the control samples, which represent 1st day for each fiber, gave the highest strength, compared to the samples of 30 days and 60 days respectively. In increase in laying days lead to a decrease in the tensile strength of the natural fiber.

The treated natural fibers were stronger and showed better performance than the untreated natural fibers. Analysis of the ultimate tensile strength of natural fibers netting showed that after 60 days of laying, the area laid by the treated coir net fiber retained greater strength relative to the other fibers. Coir net retained 21.1% of the strength, followed by jute net 20.1% and kenaf net 14.7% respectively. The high strength retained by coir net fiber may be due to its high lignin content and its ability to absorb rainwater better than the other fibers.

5 RECOMMENDATION

Some recommendations for future work in the light of the conclusions derived from this study are:

- Additional natural fibers are required to study their strength and how it is affected by climate change.
- Use of more varieties of chemical treatments to justify which treatments can give the best applicability.
- Microstructural analyses are required to understand the main mechanisms of the treated fibers.
- Natural fibers strength testing for a longer time period greater than 60 days is required to monitor its performance.

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