Effect of Antimicrobial Agents on Modification of Coir

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Abstract

Coir yarns were coated with three natural anti-microbial agents - Cashew Nut Shell Liquid (CNSL), neem oil and tulsi oil for improving its hydrophobicity, tensile strength and biological resistance. Microbial degradation study was performed with A. niger as test organism. The results indicated that coating of coir yarns was capable of increasing tensile strength by 17% and reducing moisture absorption by 34%. Microbial activity of CNSL coated coir yarns was reduced to 95%. Coating with neem oil was found to be less effective while coating with tulsi oil adversely affected the physical and engineering properties of coir.

Keywords: Coir geotextiles; CNSL; natural antimicrobial agent.

1. Introduction

The term natural fibres refers to a wide range fibres of vegetable, animal and mineral origin. They have complex three-dimensional structure composed of cellulose, hemicellulose, pectins, and lignin. Natural fibres such as jute, coir and bamboo are increasingly being used as soil reinforcement due to their tensile strength. Such reinforcements are found to reduce the development of crack during shrinkage due to improvement in the ductility behaviour of soil [1, 2]. Application of geotextiles made of natural fibres has received impetus in erosion control and as reinforcing material for short term engineering applications. Coir geotextiles have been reported to perform efficiently in areas....
of soil water interaction [3, 4, 5, 6]. Soils which exhibit low shear strength and high compressibility can be improved by the use of coir geotextiles. Jute geotextile impregnated with rot resistant bitumen is found to serve as a successful fabric form for concreting and also as a secondary liner for landfills [7]. The feasibility of using of coir geotextiles as attachment media in filters for treatment of wastewater has also been reported [8].

Natural geosynthetics can be designed based on the end use of the product. The requirements to solve an existing problem are first identified and a design is developed. A good design can result in natural fibre products which can compete with synthetic materials. In specific applications, their performance may even leave behind their synthetic counterparts [9]. For load-bearing applications, the use of reinforcements in the form of continuous aligned fibres is essential for the full utilization of fibre efficiency. Natural plant fibres possess only discrete length. For reinforcement application, the natural fibres need to be processed into yarns. These are then converted into continuous products such as mats or textiles with highly controlled fibre orientation [10].

Natural fibres are relatively inexpensive, easy to process, renewable and have less carbon footprint. However, high biodegradability of these fibres sometimes poses problems in long term engineering applications [2]. Use of natural fibres in civil engineering applications is limited mainly due to their tendency to degrade under certain environmental conditions; especially in tropical climatic conditions [11, 12]. Hence it is necessary to subject these to modification processes. Such processes are intended to clean and alter the surface properties of fibre. This ultimately reduces the moisture absorption rate and enhances mechanical properties of fibres [13].

Many attempts have been made in the past to modify natural fibres by treating them with various synthetic chemicals. Most of the conventional modification methods which are found to be efficient in altering fibre properties have proved to trigger environmental pollution [14]. In view of promoting sustainable techniques, there is a continuous pursuit for different methods of environment friendly methods for preservation of lignocellulosic materials [15]. Natural antimicrobial agents such as chitosan, neem (Azadirachta indica) oil, cashew (Anacardium occidentale) shell oil, tea tree (Melaleuca alternifolia) oil, eucalyptus (Eucalyptus radiata) oil, aloevera (Aloe barbadensis, Miller) extract and tulsi leaf (Ocimum basilicum) extract have been found to be effective in imparting antimicrobial finishing effect to textiles [16].

Neem is recognized as one of the most effective antimicrobial and insecticidal natural agents. Neem seed extract when applied on polyester/cotton blend fabric imparts antibacterial property to the fabric while maintaining its key properties [17]. CNSL is a cheap agro by-product with germicidal and fungicidal properties [18]. Coating of CNSL containing copper sulphate on coconut leaf thatch has extended its life from 1 to 4 years [19]. Copperised CNSL and copperised neem oil have proven as low cost environment friendly preservatives for wood against the attack of termites and fungi [15]. Methanolic extracts of tulsi leaf when applied on cotton fabric exhibits high bacterial reduction [20]. The application of these natural agents on lignocellulosic materials gives promising results. Studies on the effect of natural antimicrobial agents on coir have not been reported. It is expected that coir being a lignocellulosic fibre, may also respond to these natural antimicrobial agents in a similar manner. In this study, three natural antimicrobial agents, CNSL, neem oil and tulsi oil were used for modification of coir.

2. Materials and Methods

2.1. Materials

Coir geotextiles for the experimental work (Vycome coir, simple weave panama) were collected from Charangattu Coir Manufacturing Co. (P) Ltd., India. Properties of coir geotextiles are listed in Table 1. Processed CNSL was supplied by Vijayalaxmi Cashew Company, India. Neem oil manufactured by HIMEDIA and tulsi oil manufactured by Greenleaf Extraction Pvt. Ltd. were used for coating applications. Kerosene was procured from a local supplier. Copper sulphate and sodium hydroxide pellets (bacteriological grade), potato dextrose powder and potato dextrose agar (bacteriological grade) were used for experiments.

2.2. Coating application

Experiments were conducted on coir yarns pulled out in warp direction from coir geotextiles. Coir yarns were cleaned and washed in slightly alkaline solution containing sodium hydroxide and oven-dried until constant weight was attained. Yarns were pre-treated by dipping in 1% copper sulphate solution for 24 hours and were then dried at
Table 1. Properties of coir geotextiles.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of mesh</td>
<td>Simple weave panama</td>
<td>Visual observation</td>
</tr>
<tr>
<td>Yarn</td>
<td>Vycome</td>
<td>Visual observation</td>
</tr>
<tr>
<td>Mass/Unit area</td>
<td>1390 g/sq.m</td>
<td>IS 15868(Part 1) [21]</td>
</tr>
<tr>
<td>Mesh size</td>
<td>3mm x 5mm</td>
<td>IS 15868(Part 6) [21]</td>
</tr>
<tr>
<td>Thickness at 2KPa</td>
<td>8.42mm</td>
<td>IS 15868(Part 2) [21]</td>
</tr>
<tr>
<td>% Swell</td>
<td>14.33</td>
<td>IS 15868(Part 3) [21]</td>
</tr>
<tr>
<td>% Water absorption</td>
<td>60</td>
<td>IS 15868(Part 4) [21]</td>
</tr>
<tr>
<td>Breaking Load</td>
<td>22.76 kN/m</td>
<td>IS 13162(Part 5) [22]</td>
</tr>
</tbody>
</table>

70°C. Pre-treated yarns were coated using 10-30% CNSL, neem oil and tulsi oil solutions for 1 hour and dried under sun. Kerosene was used as solvent and nitric acid (1%) was used as precursor. Higher concentrations of neem oil and tulsi oil exhibited drying problems. Hence, experiments were limited to a concentration of 30%.

2.3. Weight gain and water absorption

Total weight of coated yarns were evaluated before and after coating in order to determine the extent of coating attached to the yarn [17]. Increase in weight of yarns is directly linked to moisture absorption of yarn. Water absorption of coated and uncoated yarns was estimated by immersing 25 cm long samples in distilled water for 24 h. The weight of absorbed water was expressed as a percentage in terms of initial sample dry weight.

2.4. Tensile strength and elongation

Tension test was conducted on coir yarns as per ASTM D 2256-02 [23] in Universal Testing machine for coir geotextiles and yarn. Sample size was fixed as 30. Gauge length was maintained as 250±3mm and rate of loading was fixed as 150±mm/min so as to ensure a break time of 20±3s from the start of the test. All tests were conducted on yarns of uniform thickness of 5.3mm. Breaking load and maximum elongation were recorded. Failure strain was expressed as a percentage in terms of elongation and initial gauge length.

2.5. Morphology

Scanning electron microscopy (SEM) was carried out to examine the surface properties of coir. Uncoated and coated yarns were examined using JOEL JSM-5600. Samples 2-3mm long were sputter coated with a thin layer of gold before test. The observations were carried out at accelerating voltage of 15 kV.

2.6. Microbial resistance

Microbial resistance of coated yarns was tested under dynamic contact conditions following ASTM E2149-13a [24]. This test method is adopted to evaluate antimicrobial agents that are not removed from the surface due to aqueous conditions. A. niger was used as test organism due to its efficiency in attacking lignocellulosic fibres [25, 26]. Coir yarns weighing 1±0.1g were added to fungal inoculum introduced into potato dextrose broth with absorbance of 0.28±0.2 at 475mm, measured spectrophotometrically. This was shaken for 5 hours at 30°C and plated out in triplicate in potato dextrose agar after serial dilution. Colony forming units (CFU) were counted after an incubation period of 48h at 30°C.

Anti microbial activity was determined as [(A-B) / A] x 100 where A is the CFU/ ml for treated sample after specific contact time and B is the CFU/ml for untreated sample after a contact time of 48h.

A post test (Solution Test) was conducted as per ASTM E2149-13a [24] for analysis of supernatant in order to check the presence of leaching antimicrobial. The samples which indicated the presence of antimicrobial agent in solution were identified.
3. Results and discussion

3.1. Weight gain and water absorption

Weight gain of coir yarns after coating with various concentrations of CNSL, neem oil and tulsi oil is illustrated in Fig. 1(a). Higher coating concentrations of CNSL and neem oil resulted in gradual weight gain up to 24% but tulsi oil coating resulted in marginal weight loss (2.36%). The results indicate that CNSL and neem oil has not adversely affected fibre properties, while tulsi oil coating has detrimental effect on fibre. Fig. 1(b) shows the relation between percentage reductions in moisture absorption with concentration of coating. Maximum moisture reduction (34%) was obtained for CNSL coated yarns. Neem oil coating did not impart significant moisture reduction even though weight gain results followed a similar pattern as that of CNSL coating. This may be due to leaching of coating in aqueous media as proved in microbiological studies. Weight loss of tulsi oil coated yarns might have exposed cell structure of fibres to surrounding environment, resulting in swelling of fibres in presence of moisture. This might have lead to higher moisture absorption (16.6%). Among the three coatings, CNSL is found to have better performance in terms of adherence with coir and hydrophobicity.

3.2. Tensile strength and elongation

Most of the modification techniques alter engineering properties of lignocellulosic fibres. Tensile strength and elongation of coated yarns were determined to evaluate this aspect. Relationship between increase in tensile strength and coating concentration is shown in Fig. 2(a). Maximum increase in tensile strength was 17% at 20% concentration of CNSL. Coatings with neem oil and tulsi oil exhibited only marginal increase in tensile strength. Elongation of CNSL coated yarns were found to decrease significantly with concentration of coating. Failure strain decreased to 9.3% at 30% CNSL coated yarns against a failure strain of 16.67% for uncoated yarn. There was only marginal change in elongation for neem oil and tulsi oil coated yarns. The results illustrated in Fig. 2(b) show that CNSL coating has reduced flexibility of coir yarns while increasing tensile strength.

3.3. Morphology

The SEM images of coir, both uncoated and coated (20%) are shown in Fig. 3. Uncoated fibre surface is uneven and contains micro pores. Surface of CNSL coated coir is relatively even and uniform. Surface of coir samples coated with neem oil and tulsi oil are uneven and detachment of coating can be observed. Evenness of coating accounts for higher hydrophobicity and microbial resistance of CNSL coated coir.

Fig. 1. (a) Percentage weight gain and (b) Percentage reduction in moisture absorption with coating concentration.
3.4. Microbial resistance

As per the post test (solution test), leaching of coatings were observed for coatings with neem oil and tulsi oil while CNSL coated on coir yarns did not diffuse into surrounding environment under dynamic contact. Colony forming units/ml for the flask containing CNSL coated yarns is tabulated in Table 2. CNSL coating of 20% was found to impart surface anti-microbial activity of 95.45%. The observations show that CNSL coating has strongly bonded on the surface of coir yarns and has exhibited efficient anti-fungal activity.
<table>
<thead>
<tr>
<th>CNSL concentration (%)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>*CFU/ml (Surviving fungal colonies)</td>
<td>220</td>
<td>30</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>% reduction in CFU/ml</td>
<td>--</td>
<td>86.36</td>
<td>95.45</td>
<td>95.45</td>
</tr>
</tbody>
</table>

*CFU/ml – Colony forming units/ml

4. Conclusions

The effect of natural coatings on various physical and engineering properties of coir yarns has been studied. Treatments with three natural agents, CNSL, neem oil and tulsi oil were carried out for enhancement of hydrophobicity, tensile strength and biological resistance of coir. Coating of coir with CNSL was found to increase short term tensile strength by 17% and reduce moisture absorption by 34%. Coating with neem oil was found to be less effective while coating with tulsi oil adversely affected coir properties. The results were complimented by microbial degradation studies and morphological observations. Microbial degradation against A. niger was reduced to 95% for 20% CNSL coated coir. Coatings of neem oil and tulsi oil applied on yarns were observed to leach in aqueous media. The present study shows that coating of coir yarns with CNSL is an economic method to increase tensile strength and hydrophobicity of coir. The efficiency of CNSL as a natural coating agent for coir can be further investigated on long term duration in association with soil.

Acknowledgements

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