Needle-Punched Non-Woven Jute Floor Coverings: Part I—Influence of Fibre and Process Variables on Tensile Properties of Fabrics

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The structure and properties of non-woven jute fabrics were studied with reference to the characteristics of fibre, web, reinforcing material and needle-loom variables. The needle-punched jute web had very poor strength and dimensional stability but incorporation of a suitable reinforcing material improved the strength and dimensional stability of the non-woven remarkably. The tensile properties of non-wovens were strongly dependent on those of the reinforcing materials. Non-wovens made from woollenized jute fibre showed superior tensile properties in comparison with those of non-wovens made from untreated fibres.

Keywords: Jute floor coverings, Needle penetration, Needling density, Non-wovens, Random-laid web, Reinforcing material, Tensile properties

The load-extension curve of a needle-punched non-woven fabric is characterized by two deformation regions. The initial region shows negligible resistance to deformation, and this is followed by a jammed, stiff region. In the initial stage of extension, fibres are pulled straight, helped by slippage at crossover points, with only a nominal development of tension. This is followed by the building up of transverse forces from the fibres under tension passing round and into fibre pegs, resulting in a steep rise in load with a small increase in extension.

In this study, non-woven fabrics from jute (untreated as well as treated with a batching oil emulsion) and woollenized jute fibres of varying ranges in structure and properties were prepared by needle-punching random-laid webs. The effects of fibre, process, and machine variables on the tensile properties of these fabrics are reported.

Experimental Procedure

Woollenization of jute fibres—Jute W2-grade (IS: 271-1975) was used for woollenization. The root-end of the jute reed (244-305 cm) was cut, and the reeds in small bundles were immersed in 18% (w/v) sodium hydroxide solution at 30°C. The liquor-to-material ratio was 20:1 and the immersion period, 45 min. Following the alkali treatment, the fibres were thoroughly washed in running water. The washed fibres were soured with 1% acetic acid for 10 min, washed again till neutral, and finally dried in air.

Opening of fibres—Jute (W2-grade) in reed form was fed into a Midhurst opener, which gave a mesh-free, stapled fibre-mass. The fibre length distribution pattern of opened jute reed is shown in Fig. 1. Both the mean and model lengths of the opened fibres were found to be about 2.5 cm with a fineness of 2.3 tex. The woollenized jute fibres (2.1 tex) were also similarly opened.

Treatment with batching oil emulsion—Raw jute fibres are difficult to process as a large amount of droppings and fly are generated during web formation as well as during needle-punching. Moreover, the web obtained is uneven. These difficulties were overcome by treating the jute with a batching oil emulsion (batching oil 20%, soap 0.5%, water 79.5%) of 30% by weight of raw jute. The treated jute was conditioned for 72 h before further processing.

Preparation of web—Random-laid web was obtained by feeding the opened fibres in a Callaghan...
rando webber, comprising a hopper feeder, pre-opener, and a randomizer unit.

Preparation of needle-punched non-woven fabrics—Needle-punched fabrics were prepared by needle-punching the random-laid web with and without reinforcing material. The reinforcing materials used were: Jute hessian (54 ends x 48 picks/dm - 300 g/m²); cotton bandage cloth (120 ends x 88 picks/dm - 40 g/m²); cotton gauge cloth (60 ends x 50 picks/dm - 30 g/m²); and polyethylene film (0.045 mm thickness, 47 g/m²). Where jute hessian was used at the centre of web, two passes were given in the needling zone, the sample being reversed after the first pass. Needle-punching of all the fabrics was carried out in a James Hunter laboratory fibre locker, Model 26. Needle penetration was kept at 14.3 mm for all the samples except the ones where needle penetration was the variable.

Woollenization in the fabric form—Woollenization of needle-punched non-woven jute fabric was carried out in a manner similar to that used for the jute fibre described earlier. Area shrinkage and weight loss due to woollenization were found to be 24.9 and 9.4%, respectively.

Tensile testing—From each sample of needle-punched non-woven fabrics and reinforcing materials, ten specimens were used for the tensile test. The tensile tests of the samples were carried out on an Instron tester. The test conditions of the samples were: test specimen size, 10 x 2.5 cm; cross-head speed, 5 cm/min; and chart speed, 20 cm/min.

The stress of the samples was computed as:

\[
\text{Fabric stress (g/tex)} = \frac{\text{Load (g)}}{\left(\frac{\text{Area density of fabric} \times \text{Specimen width}}{(g/m^2) \times (mm)}\right)}
\]

Results and Discussion

Treatment of jute with batching oil emulsion—Needle-punched non-woven fabric prepared from emulsion-treated fibres shows a higher stress than the fabric prepared from raw jute (Fig. 2). This is, presumably, due to the greater pliability of treated jute fibres, which leads to better consolidation and lesser fibre breakage during the needling operation. The higher consolidation of the emulsion-treated fibre is reflected in the higher fabric densities (Table 1). The rupture of fibres during needling is also higher for the untreated jute. The initial modulus of fabric made from emulsion-treated jute is lower than that of the fabric made from untreated jute fibres (Table 1). Thus, while the emulsion treatment has reduced the inter-fibre frictional coefficient, which is reflected in the initial modulus values, a higher consolidation accompanied by less fibre breakage has resulted in a more uniform distribution of stresses during tensile deformation, which, in turn, has led to a higher specific stress.

Influence of reinforcing material (scrim)—The reinforcing material plays an important role in the stress-strain characteristics of needle-punched jute non-wovens. Fig. 3 shows that the dimensional stability of needled, woollenized jute web (without reinforcement) is very poor. This is evident from the load-elongation curve, which shows a high non-recoverable extension before rupture.

The stress-strain curves of jute hessian-reinforced composite structure is significantly different from that of non-reinforced non-wovens. The extensibility of the reinforced non-woven is largely dependent on the
extensibility of the reinforcing material. Initially, the large extension of the reinforced non-woven is due to the removal of crimp of the reinforcing material (jute hessian cloth). Fig. 3 also shows that the needled, woollenized jute (without scrim) has a significantly lower stress value than the reinforcing material (jute hessian cloth, 300 g/m²), whereas the stress value of the reinforced non-woven occupies an intermediate position.

Influence of reinforcing material weight/web weight ratio—The effect of reinforcing material weight/web weight ratio on tenacity is shown in Fig. 4. The same reinforcing jute hessian cloth (300 g/m²) was used in all the webs of varied weights. The tenacity increases with increase in the reinforcing material weight/web weight ratio for both jute and woollenized jute non-wovens up to a certain level following which the tenacity curve gradually tends to flatten. Increase in tenacity with increase in ratio (reinforcing material weight/web weight) is due to the higher contribution of reinforcing material towards the strength of non-wovens.

The strengths of bare reinforcing material prepared with two extreme reinforcing material weight/web weight ratios are given in Table 2.

The reinforcing material suffers a greater degree of mechanical damage because of needling at a higher reinforcing material weight/web weight ratio. Hence, the tenacity curve at higher reinforcing material weight/web weight ratio tends to flatten after reaching a maximum level.

Influence of the type of reinforcing material—Fig. 5 shows the stress-strain characteristics of needle-punched non-wovens prepared using various types of reinforcing material, while Fig. 6 shows the stress-strain behaviour of the reinforcing materials only. The results of initial moduli of non-woven fabrics and reinforcing materials are given in Table 3. These results also show that the type of reinforcing material has a predominant effect on the tensile properties of the reinforced non-wovens. The shape of the stress-strain curves of reinforced non-wovens is greatly similar to that of their respective reinforcing materials (Figs 5 and 6). The curves indicate the influence of the reinforcing material towards the tensile properties of the non-

![Fig. 3—Stress-strain characteristics of (A) reinforcing material (B) needled web without reinforcing material: and (C) web with reinforcing material at base [Woollenized jute web wt. 288 g/m²; reinforcing jute hessian wt. 300 g/m²; 36 needles/cm²; needle penetration 14.3 mm].](image)

![Fig. 4—Effect of reinforcing material wt/web wt ratio on tenacity of non-wovens: (A) jute, and (B) woollenized jute [Reinforcing jute hessian wt. 300 g/m²; 36 needles/cm²; needle penetration 14.3 mm].](image)

![Fig. 5—Effect of various reinforcing materials used at the base of web on stress-strain characteristics of non-woven [(A) jute hessian, 300 g/m²; (B) cotton bandage cloth, 40 g/m²; (C) cotton gauge cloth, 30 g/m²; and (D) polyethylene film, 47 g/m²].](image)
Fig. 6—a Stress-strain characteristics of reinforcing materials: (A) jute hessian, 300 g/m²; (B) cotton bandage cloth, 40 g/m²; (C) cotton gauge cloth, 30 g/m²; and (D) polyethylene film, 47 g/m²

Table 3—Effect of Different Reinforcing Materials Used at the Base of Jute Web on Initial Modulus of Fabric

<table>
<thead>
<tr>
<th>Reinforcing material</th>
<th>Initial modulus of reinforcing material</th>
<th>Initial modulus of non-woven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute hessian (54 ends x 48 picks/dm - 300 g/m²)</td>
<td>30.0</td>
<td>4.17</td>
</tr>
<tr>
<td>Cotton bandage cloth (120 ends x 88 picks/dm - 40 g/m²)</td>
<td>11.1</td>
<td>2.38</td>
</tr>
<tr>
<td>Polyethylene film (47 g/m²)</td>
<td>5.0</td>
<td>0.54</td>
</tr>
<tr>
<td>Cotton gauge cloth (60 ends x 50 picks/dm - 30 g/m²)</td>
<td>3.1</td>
<td>0.67</td>
</tr>
</tbody>
</table>

wovens. Hence, the strength and elongation characteristics of the non-wovens closely follow those of the reinforcing materials.

Influence of the location of reinforcing material—The stress-strain behaviours of non-wovens using reinforcing material (jute hessian cloth, 300 g/m²) at the base and at the centre of web are shown in Fig. 7. The non-wovens in which the reinforcing material is used at the centre of web show an initial higher resistance to slippage but a lower value of ultimate stress compared to that for the non-wovens in which reinforcing material is used at the base of web. This reduction in stress might be due to the extent of damage to the reinforcing material, which is higher when it is at the centre of web since the number of barbs acting through the reinforcing material while at the centre of web is expected to be more than when it is used at the base of web for the same needle penetration.

Influence of woollenization in fibre and in fabric forms—Fig. 8 shows the stress-strain characteristics of needle-punched jute fabric, needle-punched woollenized jute fabric, and needle-punched jute fabric woollenized in fabric form.

Fig. 7—Stress-strain characteristics of non-wovens having jute hessian (300 g/m²) at the centre of web (x—x—x—x) and at the base of web (——) [Needle-punched fabric wt, 505 g/m²; 2 x 23 needles/cm² (two passage); and needle penetration, 14.3 mm]

With woollenization in the fabric form, a much lower modulus (Table 4) and a considerably higher elongation at break are observed, although tenacity remains largely unaffected. The lowering of modulus and the increase in extensibility are associated with the development of crimp in the reinforcing material as well as in the fibres due to woollenization. Thus, the initial high yield region in the stress-strain curve of the specimen woollenized in the fabric form is essentially due to the straightening of crimp during tensile deformation.

Influence of needling density—Figs 9a and 9b show that both the tenacity and extension of reinforced non-
Table 4 - Effect of Type of Fibre and Woollenization of Jute Fabric after Needling on Density and Initial Modulus of Fabrics

<table>
<thead>
<tr>
<th>Type of fabric and process</th>
<th>Fabric weight g/m²</th>
<th>Fabric density g/cm²</th>
<th>Initial modulus g/tex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute non-woven, needle-punched</td>
<td>909</td>
<td>0.18</td>
<td>7.7</td>
</tr>
<tr>
<td>Woollenized jute non-woven, needle-punched</td>
<td>908</td>
<td>0.21</td>
<td>10.0</td>
</tr>
<tr>
<td>Needle-punched jute fabric</td>
<td>880</td>
<td>0.22</td>
<td>3.3</td>
</tr>
<tr>
<td>Woollenized in fabric from jute non-woven, needle-punched</td>
<td>391</td>
<td>0.15</td>
<td>26.7</td>
</tr>
<tr>
<td>Woollenized jute without reinforcing jute scrim, needle-punched</td>
<td>288</td>
<td>0.09</td>
<td>0.02</td>
</tr>
<tr>
<td>Jute scrim</td>
<td>300</td>
<td></td>
<td>13.4</td>
</tr>
</tbody>
</table>

wovens decrease with increase in needling density. The tensile properties of the webs are likely to improve with a greater degree of entanglement of fibres, but successive needling action damages the structures of both web and reinforcing material, as is evident from Fig. 10, where individual contributions of web and reinforcing material towards strength vis-a-vis needling density are shown. Since reinforcing material is the main contributor to the stress-strain characteristics of needle-punched non-wovens, the progressive damage to the reinforcing material begins at the very start of the needling operation, whereas in the web it starts after reaching a certain level of needling density. Figs 9a and 9b show that the damage in jute non-wovens is higher than in woollenized jute. Since raw jute fibre is stiffer than woollenized jute, fibre breakage during needling with raw jute is higher and the exposure of the reinforcing material to the barbs is also, thus, higher.

The densities of non-wovens (Fig. 11) show that while the fabric density increases with needling density, the consolidation achieved with woollenized jute is much higher at comparable needling densities in the medium to high ranges. At low needling densities, however, the non-wovens prepared from raw jute have a higher density. This is because the woollenized jute batt has a higher loft and needs more intense needling for consolidation.

*Influence of needle penetration* - The effects of needle penetration on stress-strain properties of jute and woollenized jute reinforced non-wovens are shown in Fig. 12. The stress decreases with increase in needle penetration for both jute and woollenized jute non-wovens. The fall of stress for jute non-wovens is greater at the highest penetration than for woollenized jute non-wovens, since the breakage of jute fibres at a higher needle penetration is expected to be higher. Thus, bare barbs disengaged from the fibres due to the breakage of fibres might have resulted in greater damage to the reinforcing material also. The individual contribution of web as well as of reinforcing material towards the strength properties of non-wovens due to varied needle penetrations can be better understood from Fig. 13. The figure shows clearly that increase in the needle penetration decreases the strength of the reinforcing material considerably, whereas web strength increases initially, reaches a peak, and then falls. Hearle and Sultan observed
similar effects with needle-punched webs. Hence the combined effect of web and reinforcing material is responsible for the decrease in the strength of composite non-wovens with increase in needle penetration.

Conclusions

1. Batching oil emulsion treatment of jute fibres improves the processibility as well as properties of jute non-wovens. A higher consolidation in terms of density and a lower modulus of the non-wovens without impairing tenacity were observed.

2. Woolenized jute gives superior tensile properties to non-wovens owing to its inherent difference in fibre characteristics.

3. Needle-punched jute web has poor strength and stability but inclusion of a suitable reinforcing material improves the strength and dimensional stability of the non-wovens remarkably.

4. Tensile properties of non-wovens studied are largely dependent on the tensile properties of the reinforcing material.

References