Technical Note

Effect of Dynamic Loading on Compressional Behaviour of Spunbonded Nonwoven Fabrics

V. K. Kothari & A. Das
Department of Textile Technology, Indian Institute of Technology, Hauz Khas, New Delhi-110 016, India

ABSTRACT

Spunbonded nonwoven fabrics are extensively used in a number of technical applications due to their physical, mechanical and hydraulic characteristics. In geotextile application, when these types of fabrics are used under the road or railway track, the fabrics are subjected to dynamic loads. The compressional behaviour of these types of fabrics changes with the dynamic loading cycles. The change in compressional behaviour with dynamic loading has been studied using laboratory equipment. After the application of a known dynamic load with a particular frequency for different durations, the needle punched spunbonded nonwoven fabrics show a very prominent change in their compressional behaviour, while the changes in the compressional behaviour in the case of the thermally bonded spunbonded nonwoven fabrics is relatively small.

1 INTRODUCTION

Spunbonded nonwoven fabrics are used extensively in many geotechnical applications. The nonwoven geotextiles when placed under the road or rail track are subjected to compressional loads. These loads are of two types, i.e. one is surcharge load of the total structure and the other is repeated dynamic load of moving vehicles. With repeated dynamic
loading over a period of time different properties of the nonwoven geotextiles change depending on their compressional behaviour. Floss et al. (1990) in their study on the behaviour of geosynthetics used in roads as separation and filter layers, have simulated dynamic loading conditions using laboratory equipment. The migration of fine particles from soft subsoil in and through geotextiles and the change of geotextile properties (tensile strength, mass per unit area, thickness) were documented under dynamic loading. McMorrow (1990) in his paper describes laboratory tests to assess the separating ability offered by a range of nonwoven geotextiles under dynamic loading conditions similar to those obtained at subgrade level in situ. In our earlier papers (Kothari & Das, 1992, 1993) we have described the compressional behaviour of different types of nonwoven fabrics before dynamic loading. A detailed study has now been carried out to see the effect of number of dynamic loading cycles on the compressional behaviour of different spunbonded structures. The compressibility of thermally bonded spunbonded fabrics has been compared with that of several types of spunbonded needle punched fabrics.

2 EXPERIMENTAL

Three different types of commercially available spunbonded nonwoven fabrics are used in the present study. The details of the samples are given in Table 1. The samples of Group A are polyester spunbonded needle punched fabrics, the samples of Group B are polypropylene spunbonded needle punched surface calendered fabrics and the samples of Group C are polypropylene thermally bonded spunbonded fabrics. The fabrics have varying mass per unit area.

Laboratory equipment as shown in Fig. 1 has been set to apply dynamic load to the fabric samples at a given frequency. Mass \( M \) moves down which results in the pressure foot \( H \) applying a dynamic compressional load on the fabric sample \( K \). The rate of change of load on the fabric depends on the compressional behaviour and the initial thickness \( T_0 \) of the fabric keeping all the machine parameters constant. The mass \( M \) and the area of the pressure foot were so selected that the maximum compressional pressure would be 200 kPa.

The fabric samples are placed on the supporting anvil \( I \) and are subjected to repeated dynamic loading. In the present work we have chosen 0, 200, 500, 1000 and 2000 cycles for studying the change in compressional behaviour with the number of dynamic loading cycles. After a certain number of loading cycles, the fabric is immediately tested
Table 1
Details of Fabric Samples

<table>
<thead>
<tr>
<th>Groups</th>
<th>Sample No.</th>
<th>Fabric mass/area (g/m²)</th>
<th>Initial thickness (mm)</th>
<th>Bulk density (kg/m³)</th>
<th>Description of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A₁</td>
<td>120</td>
<td>1.45</td>
<td>83</td>
<td>Polyester needle punched spunbonded fabrics</td>
</tr>
<tr>
<td></td>
<td>A₂</td>
<td>167</td>
<td>1.49</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₃</td>
<td>195</td>
<td>1.72</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₄</td>
<td>355</td>
<td>3.41</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>B₁</td>
<td>102</td>
<td>1.11</td>
<td>92</td>
<td>Polypropylene needle punched surface</td>
</tr>
<tr>
<td></td>
<td>B₂</td>
<td>200</td>
<td>1.90</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B₃</td>
<td>322</td>
<td>2.72</td>
<td>118</td>
<td>Calendered spunbonded fabrics</td>
</tr>
<tr>
<td></td>
<td>B₄</td>
<td>395</td>
<td>3.24</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>C₁</td>
<td>72</td>
<td>0.34</td>
<td>212</td>
<td>Polypropylene thermally bonded spunbonded fabrics</td>
</tr>
<tr>
<td></td>
<td>C₂</td>
<td>93</td>
<td>0.34</td>
<td>274</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C₃</td>
<td>170</td>
<td>0.48</td>
<td>354</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C₄</td>
<td>290</td>
<td>0.72</td>
<td>403</td>
<td></td>
</tr>
</tbody>
</table>

for its compressional behaviour. The compressional study has been carried out in the same way which we have used earlier (Kothari & Das, 1992) using a Essdical thickness gauge.

From a least square analysis for curve fitting (Kothari & Das, 1992)

Fig. 1. Schematic diagram of the arrangement for applying dynamic load on the fabric samples (O, shaft; A, pulley; B, connecting pin; C, rocking lever; D, horizontal ram; E, loose pulley; F, connecting chain).
of the data for loading and unloading, it has been found that eqn (1) represents the compressional behaviour for all the nonwoven fabrics irrespective of their structures and the type of bonding.

\[ T/T_o = \alpha \ln(P/P_o) \]  

(1)

But during release of loads the thermally bonded spunbonded fabrics follow a different equation to that of spunbonded needle punched and needle punched surface calendered fabrics. Equation (2) represents the recovery behaviour of fabrics of Groups A and B and (3) the recovery behaviour for Group C fabrics.

\[ T/T_f = (P/P_f)^{-\beta} \]  

(2)

\[ T/T_f = 1 - \beta \ln(P/P_f) \]  

(3)

In the above equations \( T_o \) and \( T_f \) are the initial and final thicknesses at initial and final pressures \( P_o \) and \( P_f \) respectively. \( T \) is the thickness at any unknown pressure \( P \). \( \alpha \) and \( \beta \) are two dimensionless constants representing the compressional and recovery behaviour of the fabrics respectively. \( \alpha \) is a compressional parameter and \( \beta \) is a recovery curve parameter.

The resilience parameter (\( \gamma \)) is a measure of the extent of recovery from the compressed state.

For fabric of Groups A and B,

\[ \gamma = \left| \left( (P_f/P_o)^{-\beta} - 1 \right) \left( 1 - \alpha \ln(P_f/P_o) \right) \right| / \left| \alpha \ln(P_f/P_o) \right| \]

and fabrics of Group C,

\[ \gamma = \left| 1 - \alpha \ln(P_f/P_o) \right| \times \beta / \alpha \]

For total elastic recovery, the value of resilience parameter \( \gamma \) will be one and for total plastic deformation it will be zero.

The percentage reduction in thickness (\( T_r \)) after a number of loading cycles is a measure of the reduction in thickness during dynamic loading and is given by,

\[ T_r(\%) = \frac{T_o - T_{on}}{T_o} \times 100 \]

where \( T_o \) is the thickness before dynamic loading and \( T_{on} \) is the thickness after \( n \) dynamic loading cycles.

### 3 RESULTS AND DISCUSSION

Figure 2(a), (b) and (c) show the percentage reduction in thickness during dynamic loading cycles for fabrics of Groups A, B and C res-
Fig. 2. Effect of number of dynamic loading cycles on the thickness reduction ($T_r$) (%): (a) needle punched fabrics; (b) needle punched surface calendered fabrics; (c) thermally bonded fabrics.

respectively. With the increase in the number of dynamic loading cycles, the percentage reduction in thickness increases due to frictional locking among the fibres and the reduction is faster in the initial stage and gradually becomes very small with the increase in number of cycles. The thickness reduction in the case of needle punched spunbonded nonwovens is much higher than for the thermally bonded spunbonded structures due to more fibre to fibre slippage in case of needle punched spunbonded nonwoven fabrics in the initial stages of compression. In
Fig. 3. Effect of number of dynamic loading cycles on the compressional parameter (a): (a) needle punched fabrics; (b) needle punched surface calendered fabrics; (c) thermally bonded fabrics.

In the case of needle punched spunbonded fabrics, the fibres within the structure are held together merely by frictional force, whereas there is positive bonding between fibres in the thermally bonded spunbonded nonwovens due to fibre fusion. The fabrics of lower bulk density show comparatively higher percentage reduction in thickness particularly in
the case of needle punched fabrics, because fibre to fibre slippage in the case of low bulk density needle punched fabrics is easier. This is due to comparatively low inter-fibre frictional resistance for loose fabric structures.

Figure 3(a), (b) and (c) show that the needle punched spunbonded fabrics have highest compressibility followed by needle punched surface calendered spunbonded fabrics and the thermally bonded spunbonded fabrics have lowest compressibility. With the increase in the number of dynamic loading cycles, the needle punched fabrics show an initial quick reduction in the compressional parameter which gradually becomes stable as the number of cycles increases. On the other hand, the thermally bonded fabrics show almost no change in compressibility due to loading. This is due to lower free volume, fibre arrangement in the fabric and the nature of the bonding in the thermally bonded spunbonded fabrics. Figure 4(a), (b) and (c) show similar trends for the recovery curve parameter. Even after the maximum number of cycles, the needle punched fabrics show higher compression and recovery curve parameters.

Figure 5(a), (b) and (c) show the change in resilience parameter with the number of dynamic loading cycles. Needle punched fabrics show an initial increase in resilience and after a certain number of cycles of dynamic loading it becomes stabilized (Fig. 5(a) and 5(b). The thermally bonded fabrics show no or very little change in resilience with the increase in the number of loading cycles (Fig. 5(c)). Lower resilience in the case of needle punched fabrics may be due to more chances of fibre to fibre slippage as there is no positive bonding between the neighbouring fibres because the fibres are held together by frictional contact only. On the other hand, in the case of thermally bonded spunbonded structures due to positive bonding between the fibres there is no or very little fibre to fibre slippage and thus very small changes in resilience of the fabric with an increase in the number of loading cycles.

4 CONCLUSIONS

The compressional behaviour of spunbonded nonwoven fabrics changes with the number of dynamic loading cycles. Fabric compressibility gradually decreases as the number of dynamic loading cycles increases. The percentage reduction in thickness initially increases rapidly and then very gradually as the number of dynamic loading cycles increases. The needle punched spunbonded nonwoven fabrics show the
Fig. 4. Effect of number of dynamic loading cycles on the recovery curve parameter ($\beta$): (a) needle punched fabrics; (b) needle punched surface calendered fabrics; (c) thermally bonded fabrics.

The compressional and recovery curve parameters decrease initially
Fig. 5. Effect of number of dynamic loading cycles on the resiliency parameter ($\gamma$): (a) needle punched fabrics; (b) needle punched surface calendered fabrics; (c) thermally bonded fabrics.
to some extent but after a certain number of cycles of dynamic loading the change becomes very slow. Fabric bulk density has a prominent effect on the compressional behaviour of spunbonded nonwoven fabrics. The changes in compressional behaviour with dynamic loading cycles in the case of thermally bonded spunbonded nonwoven fabrics is extremely small.

REFERENCES