

MECHANICAL BEHAVIOUR OF NONWOVEN GEOTEXTILES

by

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Department of Textile Technology

*Thesis submitted
in fulfilment of the requirements
for the degree of*
DOCTOR OF PHILOSOPHY



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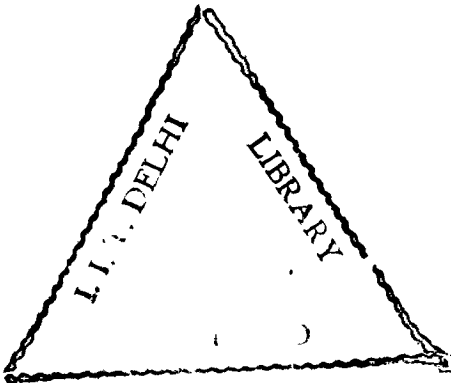
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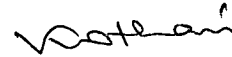


*Dedicated to
my dear wife*

CERTIFICATE

This is to certify that the thesis entitled "**MECHANICAL BEHAVIOUR OF NONWOVEN GEOTEXTILES**" being submitted by **Mr. P. C. Patel**, to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy in Textile Technology, is a record of bonafide research work carried out by him. Mr. P. C. Patel has worked under my guidance and supervision and has fulfilled the requirements for submission of this thesis, which to my knowledge has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.



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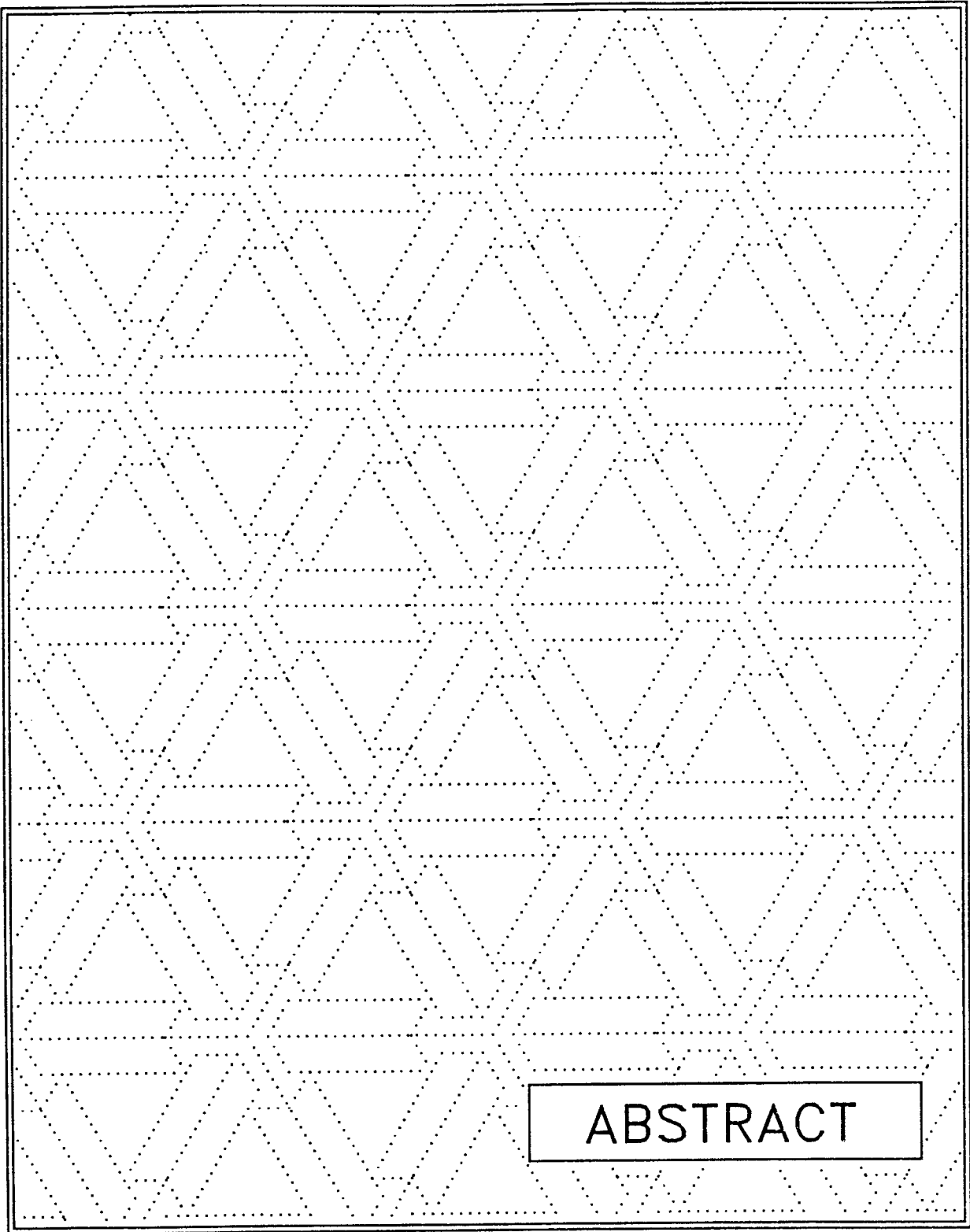
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[P.C. Patel]



ABSTRACT

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Mechanical behaviour of the nonwoven geotextiles is of considerable interest for the satisfactory performance of these fabrics as a constructional material. The stress-strain behaviour of the constituent fibres and the structure of the fabric are the main factors which influence the short term mechanical properties of nonwovens. The fibre creep behaviour and the structure of the fabric affect the creep behaviour of the nonwoven geotextiles. Both stress-strain and creep properties of polypropylene and polyester, two main fibres used to produce nonwoven geotextiles, are quite different. Polypropylene fibre generally has lower modulus and tends to creep more as compared to polyester fibre. Structures of the needle-punched and thermally bonded spunlaid nonwoven fabrics, widely used in different geotextile applications, are also quite different. The geometric structure developed in the needle-punched nonwovens depends on the fibre parameters, fibre orientation in the web and needling process parameters. The needle-punched fabrics generally have loose structure with flexible bonds formed due to fibre entanglement. On the other hand, thermally bonded fabrics are normally stiff and thin having rigid bonds formed due to fusion of fibres at cross over points during the fabric formation. Tensile and creep behaviours of different types of spunlaid nonwoven fabrics, and the factors affecting these behaviours has been studied.

Sample size and strain rate significantly influences the tensile test results. The effect of carrying out tensile tests with narrow width samples is to seriously underestimate the real strength of the nonwoven fabrics. The tensile testing of width specimen reduces the strain in transverse direction which is closer to the

condition of geotextiles in actual use under the ground. The influence of specimen size and strain rate on tensile behaviour of different types of spunlaid nonwoven fabrics has been studied. It has been found that these parameters influence the tensile properties of spunlaid fabrics depending on their structure. The initial modulus of wide width specimen is higher than that of narrow width specimen of needle-punched spunlaid fabrics. However, in case of thermally bonded spunlaid fabrics, because of the rigid bonds, the initial modulus is not affected significantly by the sample size. The breaking extension of narrow width specimen is found to be much lower than that of wide width specimen of the thermally bonded spunlaid samples while breaking extension of the needle-punched spunlaid fabrics is only marginally affected by the specimen width. The breaking stress of wide width specimen is found to be higher than that obtained by narrow width specimen for both thermally bonded and needle-punched spunlaid nonwoven fabrics. In case of thermally bonded spunlaid fabrics, breaking stress increases at first when the strain rate is increased from 0.5% to 10% per minute and then becomes stable as strain rate is increased further upto 100% per minute. In case of needle-punched spunlaid fabrics, the strength decreases at first when strain rate is increased from 0.5% to 10% per minute and then it remains almost unaffected with further increase in the strain rate.

Both the fibre stress-strain behaviour and the arrangement of the fibres in a nonwoven fabric influence the tensile properties of nonwoven fabrics. The fibre network theory has been used to predict the stress-strain behaviour of spunlaid fabrics using the fibre stress-strain data and structural parameters of these fabrics. A model has been developed to predict the creep behaviour of

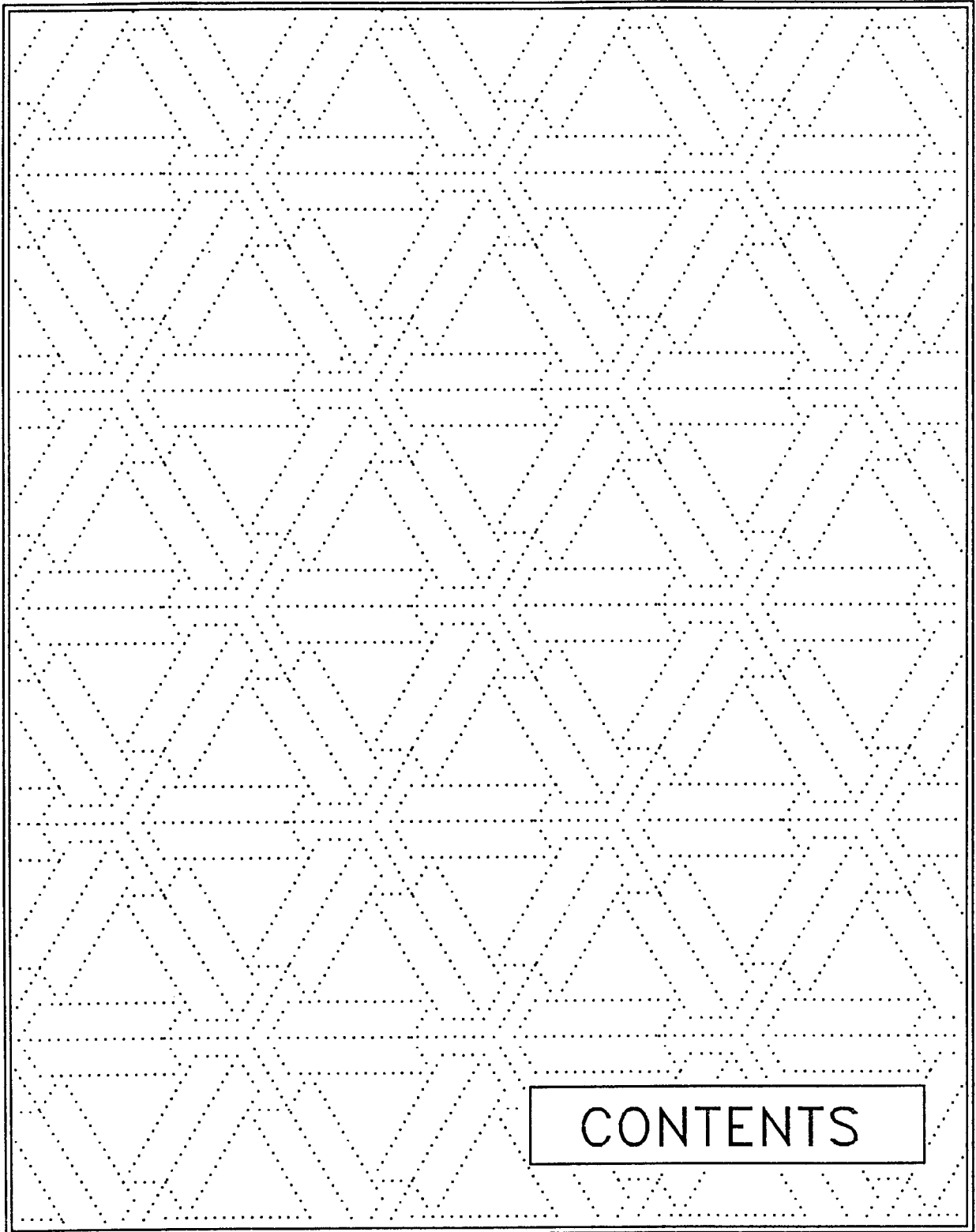
nonwovens using the fibre creep data and the structural parameters of these fabrics. The theoretical prediction of stress-strain and creep characteristics of fabrics based on experimental load-elongation and creep data of fibre and measured structural parameters of nonwoven fabrics will serve two purposes. Firstly, it will help in designing fabrics for a given application and secondly, it will eliminate the long duration fabric creep testing which is normally difficult to perform with wide width specimen, particularly at high load levels.

Special type of fabric jaws for wide width creep test have been designed and fabricated. A fibre creep apparatus and a test rig for the study of fabric creep has been designed and fabricated. Experimental set-up for studying creep behaviour of geotextiles in-soil with confining pressure has also been developed.

To understand the creep behaviour of spunlaid nonwoven geotextiles, the creep experiments on these fabrics and on the constituent fibres have been conducted for 1000 hours duration at various load levels. The creep test results of different nonwoven fabrics and the influence of the structure and polymer type on the creep behaviour of these fabrics have been presented. The creep properties have been found to be influenced by fibre creep behaviour, fibre orientation in the fabric and the bonding used to manufacture the fabric. Polyester needle-punched spunlaid nonwoven fabrics show much lower creep than the polypropylene needle-punched spunlaid nonwoven fabrics clearly indicating that the fibre creep plays an important role in the creep behaviour of nonwoven fabrics. Creep levels in case of the needle-punched spunlaid fabrics is higher due to the higher structural deformation as compared to the thermally bonded spunlaid fabrics. The results of the theoretical model developed to predict the creep behaviour of nonwoven fabrics from the fibre creep data using the

structural parameters of these fabrics and the experimental creep results on these fabrics show reasonable agreement.

Creep behaviour of four different geotextile samples has been studied, both in-air and in-soil using fine grained sand in dry condition with normal confining pressure in the range of 0 to 150 kPa to understand the actual creep behaviour of the geotextiles when they are used in the soil structure. Creep of nonwoven geotextiles has been found to be influenced by the soil-confinement and the amount of normal confining pressure. The effect of soil-confinement on needle-punched nonwoven fabrics is higher than that on thermally bonded spunlaid fabrics.



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