Study on Static Puncture Strength of Needle Punched Non-Woven Fabrics

V. ILANGO
Head of the Department, Department of Textile Technology (MMF), SSM Polytechnic College, Valayakaranoor, Komarapalayam, Erode, India.

Abstract- Geo-textile fabrics can be designed for a particular industrial application based on the static puncture test results. Different types of non-woven fabrics are available. But in particular needle punched polyester, polypropylene and its blends are very much used in industries. In this paper sisal and polypropylene fibres are used to produce different combination of blends and the static puncture analysis carried out using box-behnken experimental design.

Indexed Terms- Geo-textile, static puncture, box-behnken, sisal and polypropylene fibres.

I. INTRODUCTION

Static puncture tests that were conducted on needle punched non-woven fabrics are described in this chapter. This test is done to classify the non-woven fabrics which are intended for Geo-textiles. Geo-textiles are used in a variety of applications such as filtrations, reinforcement and embankment. Compared to tensile tests that are performed on non-woven, static puncture strength has several merits as in this test, a single value is obtained as against two values, one in machine and other in cross direction in a tensile test. The overall performance of non-woven intended for Geo- textiles is assessed by the static puncture test.

II. RESULTS AND DISCUSSION

Table 1 shows the dimensional and mechanical properties of needle punched non-woven fabrics produced, tested and analysed. It is apparent that the fabric sample containing 20%sisal and 80% polypropylene displays the highest value in comparison to 80%sisal and 20% polypropylene and 50%sisal and 50% polypropylene

Table 1: Data on static puncture test of non-woven fabric samples

Fabric code	X_1	X_2	X_3	20%sisal/80% polypropylene	80%sisal/20% polypropylene	50%sisal/50% polypropylene
				Static puncture strength (kN)	Static puncture strength (kN)	Static puncture strength (kN)
1	250	8	300	1.75	0.61	1.35
2	450	8	300	1.26	1.01	1.48
3	250	12	300	2.12	0.72	1.50
4	450	12	300	1.75	1.83	2.69
5	250	10	200	1.94	0.53	1.29
6	450	10	200	1.38	1.24	1.99
7	250	10	400	1.73	0.87	1.30
8	450	10	400	1.42	1.79	2.22
9	350	8	200	1.42	0.96	1.49
10	350	12	200	2.19	1.25	1.23
11	350	8	400	1.89	1.57	1.55
12	350	12	400	2.20	1.63	1.08

13	350	10	300	2.23	1.13	1.11
14	350	10	300	2.23	1.14	1.13
15	350	10	300	2.22	1.14	1.15

The general tendency is that the static puncture strength values increase with increase in areal density. Sample with higher areal density value has led to higher static puncture strength values. Higher areal density indicates a higher number of fibres in the cross section. The larger the number of fibres in the cross section, the greater the strength values because of the increased capacity to withstand loading.

Static puncture strength values ranging from 1.26kN to 2.23kN were observed for 20%sisal and 80% polypropylene. Values range between 0.53kN to 1.83kN for 80%sisal and 20% polypropylene while values range between 1.08kN to 2.69kN for 50%sisal and 50% polypropylene were obtained.

2.1 Effect of Strokes per minute and Needle Penetration on Static Puncture Strength of Non-woven Fabrics

The static puncture strength value increases with decrease in porosity for the sample produced with 250 and 450 areal density at 300 strokes per minute with needle penetration of 8 mm and 12 mm. This may be due to the fact that the fibres are more compact in this sample. For strokes per minute values of 200 and 400 with a needle penetration of 10 mm, the porosity remains same. For these samples, static puncture strength values decrease when the strokes per minute increase from 200 to 400. With an areal density of 250, static puncture strength values show an increase in the sample of areal density 450, because of the number of fibres in the cross section.

Decrease in porosity causes an increase in static puncture strength in case of samples produced with 200 and 400 strokes per minute with 8mm needle penetration and an areal density of 350. When the needle penetration is increased to 12mm, the static puncture strength value is slightly increased.

Static puncture strength values are higher for samples produced with 300 strokes per minute and 10 mm needle penetration compared to 8 mm and 12 mm needle penetration as the fibres are compacted due to average bulk density.

From Figures 1 to 3, it is clear that the static puncture strength value increases with increase in strokes per minute and needle penetration. It is also observed that static puncture strength values of the chosen non-woven fabrics are influenced by the fibre properties, process parameters, needle punching and calendering.

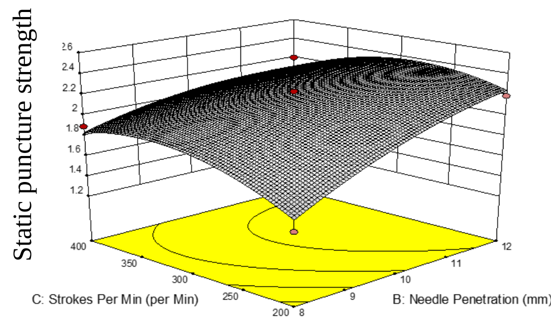

Figure 1: Effect of strokes per minute and needle penetration on static puncture strength of 20%sisal and 80%polypropylene non-woven fabric

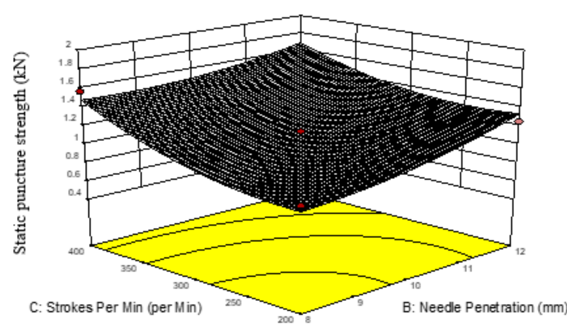

Figure 2: Effect of strokes per minute and needle penetration on static puncture strength of 80%sial and 20%polypropylene non-woven fabric

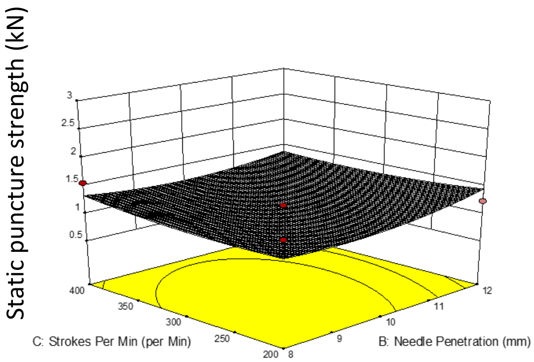

Figure 3: Effect of strokes per minute and needle penetration on static puncture strength of 50%sisal and 50%polypropylene non-woven fabric

2.2 Effect of Areal Density and Strokes per minute on Static Puncture Strength of Non-woven Fabrics

Static puncture strength and porosity show a decrease by 33.22% and 20.37% respectively for samples having 250 and 450 areal density at 300 strokes per minute with 8 mm and 12 mm needle penetration. This may be due to less compactness and the number of fibres: static puncture strength and porosity increase by 32% and 0.5% with 200 and 400 strokes per minute and 350 areal density. This means that the porosity has not changed much in 200 and 400 strokes per minute.

For the samples with areal density of 250 and 450 in 10 mm needle penetration and with 200 and 400 strokes per minute, a static puncture strength value shows a decrease by 10.86% in 250 areal density and an increase by 28.3% in 450 areal densities.

The reason is due to the fact that the sample of 450 areal density has better compactness and more fibres in the cross section. Static puncture strength values increase with sample of 350 areal density and 300 strokes per minute, which are attributed to better compactness and better fibre interlacements.

Figures 4 to 6 show the effect of areal density, strokes per minute on static puncture strength values. Static puncture strength value increases by 20%, 0.5% and 23% with an increase in areal density and strokes per minute. Porosity is proportionately increased with more fibre compactness and better interlocks between fibre from top and bottom layer fibres.

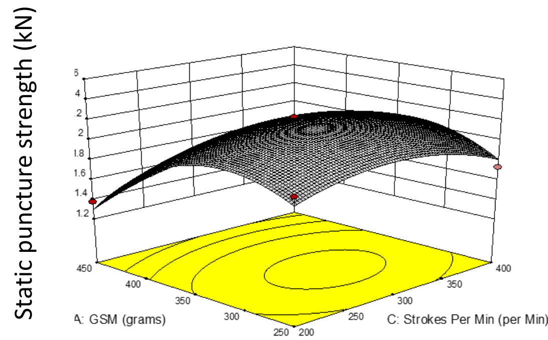

Figure 4: Effect of areal density and strokes per minute on static puncture strength 20%sisal and 80%polypropylene non-woven fabric

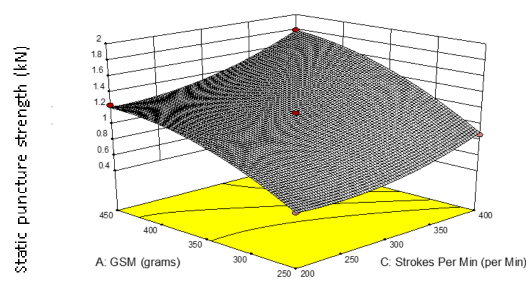

Figure 5: Effect of areal density and strokes per minute on static puncture strength of 80%sisal and 20%polypropylene non-woven fabric

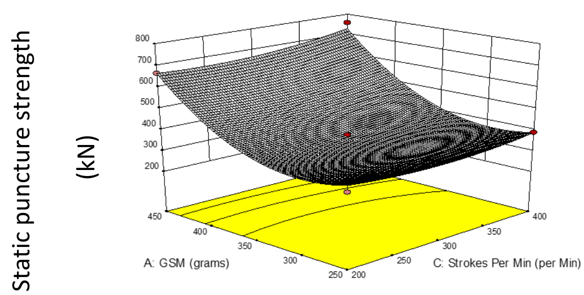

Figure 6: Effect of areal density and strokes per minute on static puncture strength of 50%sisal and 50%polypropylene non-woven fabric

2.3 Effect of Areal Density and Needle Penetration on Static Puncture Strength of Non-woven Fabrics

Static puncture strength values show a decrease by 37% and 35% for samples produced with 10 mm needle penetration, 250 and 450 areal density and 200 and 400 strokes per minute. The reason may be due to weaker fibres present. At the same time, for the samples of 350 areal density with 8- and 12-mm needle penetration, the static puncture strength value shows an increase by 53.79% and 16% due to better compactness.

With regard to samples of 250 and 450 areal density produced with 300 strokes per minute with 8mm and 12 mm needle penetration, the static puncture strength value increase by 21.18% and 38.44% respectively, which may be due to more compactness. The overall static puncture strength value increases by 4.89% at 350 areal density. Better fibre interlacement has resulted in better porosity in this case.

Static puncture strength values of 50%sisal/50%polypropylene increase with areal density and needle penetration. Needle penetration helps to bond the fibres together, increasing the fabric density. The effect of areal density and needle penetration on static puncture strength is shown in Figures 7 to 9.

The regression coefficients of the quadratic polynomial models describing the relationship between the three process parameters viz. areal density, needle penetration and strokes per minute, and responses of static puncture strength properties of needle punched non-woven fabrics was obtained from the regression equations.

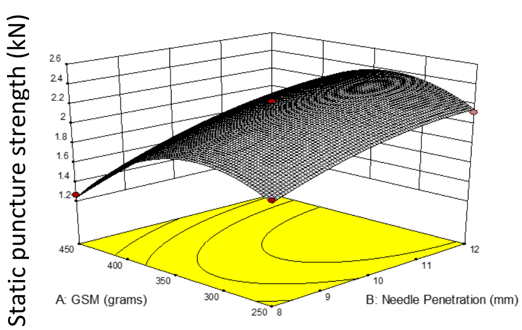

Figure 7: Effect of areal density and needle penetration on static puncture strength of 20%sisal/80%polypropylene non-woven fabric

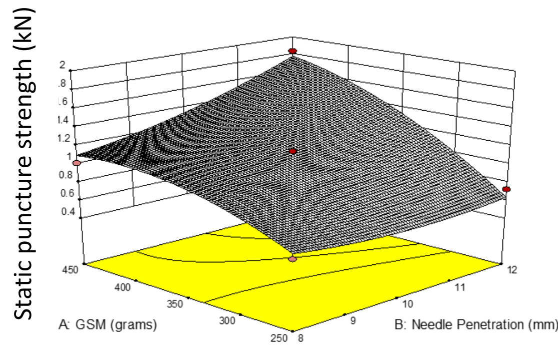

Figure 8: Effect of areal density and needle penetration on static puncture strength of 80%sisal/20% polypropylene of non-woven fabric

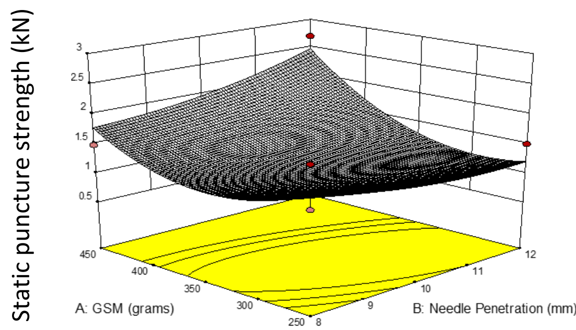

Figure 9: Effect of areal density and needle penetration on static puncture strength of 50%sisal/50%polypropylene non-woven fabric

The Box-Behnken experimental design is used for this analysis of all three blend proportions such as 20%sisal/ 80% polypropylene, 80%sisal /20% polypropylene and 50% sisal/50%polypropylene.

The precision ratio of greater than 4 in measuring R^2 and predicted R^2 values are considered to be adequate. In this work, the precision value of 11.425 has been obtained. For 20%sisal/80%polypropylene non-woven fabric, R^2 and predicted R^2 ranges closer to 1. The parameters associated with static puncture strength properties viz., areal density (X_1), needle penetration (X_2) and strokes per minute (X_3) and their effects, and the quadratic effects of static puncture strength properties of areal density (X_1^2), needle penetration (X_2^2) and strokes per minute (X_3^2) were analyzed. Based on coding factors, a mathematical equation determined by the design expert software, is given below:

Static puncture strength

$$= 2.23-0.22\times X_1+0.24\times X_2+0.038\times X_3+0.029\times X_1X_2+0.063\times X_1X_3-0.12\times X_2X_3-0.41\times X_1^2-0.097\times X_2^2-0.20\times X_3^2 \quad (1)$$

The precision ratio of greater than 4 in measuring R^2 and predicted R^2 values are considered to be adequate. In this work, the precision value of 16.190 has been obtained. For 80%sisal/20%polypropylene non-woven fabric, R^2 and predicted R^2 ranges closer to 1. The parameters associated with static puncture strength properties viz., areal density (X_1), needle penetration (X_2) and strokes per minute(X_3) and their effects, and the quadratic effects of static puncture strength properties of areal density (X_1^2), needle penetration (X_2^2) and strokes per minute (X_3^2) were analyzed. Based on coding factors, a mathematical equation determined by the design expert software, is given below:

Static puncture strength

$$=1.14+0.39\times X_1+0.16\times X_2+0.23\times X_3+0.18\times X_1X_2+0.053\times X_1X_3-0.057\times X_2X_3-0.17\times X_1^2+0.076\times X_2^2+0.14\times X_3^2 \quad (2)$$

The precision ratio of greater than 4 in measuring R^2 and predicted R^2 values are considered to be adequate. In this work, the precision value of 4.838 has been obtained. For 50%sisal/50%polypropylene non-woven fabric, R^2 and predicted R^2 ranges closer to 1. The parameters associated with static puncture strength properties viz. areal density (X_1), needle penetration (X_2) and strokes per minute(X_3) and their effects, and the quadratic effects of static puncture strength properties of areal density (X_1^2), needle penetration (X_2^2) and strokes per minute (X_3^2) were analyzed. Based on coding factors, a mathematical equation determined by the design expert software, is given below:

Static puncture strength

$$=1.13+0.37\times X_1+0.079\times X_2+0.019\times X_3+0.26\times X_1X_2+0.055\times X_1X_3-0.55\times X_2X_3+0.49\times X_1^2+0.13\times X_2^2+0.076\times X_3^2 \quad (3)$$

CONCLUSION

The results show that static puncture strength is affected by areal density, needle penetration and strokes per minute. Geo-textiles can be designed for a specific industrial application based on the static puncture test. The non-woven fabric sample containing 20%sisal and 80%polypropylene consistently shows a higher value, while 80%sisal/20%polypropylene sample displays a lower value. Areal density and strokes per minute influence static puncture strength significantly.

REFERENCES

[1] Oloo, SY, Fredlund, DG &Gan JK 1997, 'Bearing capacity of unpaved roads', Canadian Geotechnical Journal, vol. 34, no. 3, pp. 398-407.

[2] Narejo, D, Koerner, RM & Wilson-Fahmy, RF 1996, 'Puncture protection of geomembranes Part II: Experimental', Geosynthetics International, vol. 3, no. 5, pp. 629-653.

[3] Sarma, B, Kaushik, K, Bharali, R &Sharma B 2013, 'A study of CBR properties of soil reinforced with jute geotextile with reference to the road construction in Assam', In Indian Geotechnical Conference, pp. 22-26.

[4] SenthilKumar, P &Pandiammal Devi, S 2011, 'Effect of needle punched nonwoven coir and jute geotextiles on CBR strength of soft subgrade', ARPN Journal of Engineering and Applied Sciences, vol. 6, no. 11, pp. 114-116.

[5] Senthilkumar, P &Rajkumar, R 2012, 'Effect of geotextile on CBR strength of unpaved road with soft subgrade', Electronic Journal of Geotechnical Engineering, vol. 17, pp. 1355-1363.

[6] Som, N &Sahu, RB 1999, 'Bearing capacity of a geotextile-reinforced unpaved road as a function of deformation: a model study', Geosynthetics International, vol. 6, no. 1, pp. 1-7.

[7] Van Dyke, S 2014, 'Comparison of CBR and pin puncture strength testing used in the evaluation of geotextiles', PhD dissertation, The University of Wisconsin-Milwaukee.

[8] Hsieh, CW & Wang, JB 2008, 'Clamping mechanism effects on the puncture resistance tests of high strength geotextiles', Journal of Geo Engineering, vol. 3, no. 2, pp. 47-53.

[9] Anjali Karolia&Bhoj, RN 2016, 'A Comparative study on the effect of chemical and enzyme treatment on the softening of sisal fibre', International Journal of Scientific Research, vol. 5, no. 2, pp. 18-22.

[10] Askari, AS, Najar, SS &Vaghasloo, YA 2012, 'Study the effect of test speed and fabric weight on puncture behavior of polyester needle punched nonwoven geo-textiles', Journal of Engineered Fibers and Fabrics, vol. 7, no. 3, pp. 1-5.