A preliminary study on puncture resistances of top and bottom layers of multi-layered needlepunched nonwoven geotextiles

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Abstract. Needlepunched nonwoven textiles are commonly used as geotextiles for various applications. Considering both environmental and economical benefits, utilization of recycled fibres in nonwoven geotextiles has become an attractive issue. Within this scope, the aim of this study is to evaluate the puncture resistance performances of top and bottom layers of multi-layered needle punched nonwovens made of recycled fibres to be used as membrane protective geotextiles by comparing them with those of made from polypropylene and polyester fibres. Puncture resistance results indicated that nonwovens made of recycled fibres demonstrated good performances at this preliminary stage.

1. Introduction
Geotextiles are defined as permeable fabrics generally obtained through nonwoven technology to be used in association with soil considering their ability to separate, filter, reinforce, drain, or protect. In recent years recycled fibres are commonly used in nonwoven geotextiles for their cost effectiveness and their replaceable strength performances with that of the originals. The assessment of mechanical strength and durability performances of nonwoven geotextiles consisting of original and recycled fibres have attracted great attention from researchers for several applications [1-6]. From this standpoint the aim of this study is to evaluate the convenience of needle punched nonwovens made of recycled fibres to be used as membrane protective geotextiles by comparing their puncture resistance performances with those of made from polypropylene and polyester fibres. The puncture resistance test of the fabrics were carried out according to the test standard TS EN ISO 12236.

2. Materials
Fibre fineness and staple length values of the standard polypropylene fibre and polyester fibre were 6 dtex and 64 mm respectively. Recycled fibres were gained by mechanical recycling of any type of textiles consisting of various fibres with length values in rank of 20 mm-80 mm and fineness values changing between 6-12 dtex.

3. Production Step

3.1 Preparation for needlepunching
Fibres opened up from the bales were applied an antistatic agent to prevent static electric charging and were laid out for 24 hours. Thereafter they were fed into a fan for twice and blown up to the fiber storage area. By this way the fibres were opened and dispersed for the preparation for carding process. In the carding zone fibers passed over 3 pairs of opener and cleaner drums and licked-in to the main carding zone in which they were aligned in an essential parallel direction and carded by 6 pairs of...
band type wired carding drums. The web formed by this way on the card was removed from the card by doffer to the cross lapper. Folding of the layers were adjusted to meet the mass per unit area values for each type of fabric and layered form of the webs were delivered to preneedle punching passing through the web feeder.

3.2 Needlepunching Process
Preneedle punching loom used for this research was 12 cm x 240 cm in size and contained approximately 3600 needles vertically arranged. Needle type was 5 x 18 x 32 x 3 ½ R333 G 1002. Production speed was adjusted to 3.67 meters/minute. Considering these production parameters punch densities of the fabrics were calculated through the formula given below where;

\[ \varepsilon = \frac{n}{P/m} \]

- \( \varepsilon \) is punch density \((m^2)\),
- \( n \) is number of needles in the unit width of needling loom \((m^{-1})\),
- \( P \) is production speed \((m.min^{-1})\)
- \( m \) is number of punches in unit time \((min^{-1})\).

Needlepunch densities of the nonwoven fabrics were calculated through this formulation as indicated below and found to be 10.218 punches/m\(^2\) for each type of nonwoven fabric which can be considered as a soft preneedle punching process.

\[ \varepsilon = \frac{1}{3.6/3} = 10218 \text{ punches/m}^2 \]

In the end, 12 types of preneedle punched nonwoven fabrics consisting of three types of raw materials and 4 equivalent masses were produced through a conventional needle punching system. Properties of fabrics which will be used as top and bottom layers of muti-layered end-products are given in Table 1.
Table 1. Nonwoven fabric properties.

| Raw material    | Mass per unit area (g/m²) | Fabric Thickness (mm) | Needlepunch density (punches/m²) |
|-----------------|----------------------------|-----------------------|----------------------------------|
| Polypropylene   | 100                        | 2.592                 | 10218                            |
| Polypropylene   | 150                        | 3.876                 | 10218                            |
| Polypropylene   | 200                        | 4.743                 | 10218                            |
| Polypropylene   | 250                        | 5.337                 | 10218                            |
| Polyester       | 100                        | 2.482                 | 10218                            |
| Polyester       | 150                        | 4.260                 | 10218                            |
| Polyester       | 200                        | 4.456                 | 10218                            |
| Polyester       | 250                        | 4.750                 | 10218                            |
| Recycled fibre  | 100                        | 2.128                 | 10218                            |
| Recycled fibre  | 150                        | 2.927                 | 10218                            |
| Recycled fibre  | 200                        | 3.580                 | 10218                            |
| Recycled fibre  | 250                        | 4.170                 | 10218                            |

4. Test Procedure

The determination of puncture resistance performances on nonwoven geotextiles has a great importance to evaluate required features for durability of the products [7]. Test procedure was carried out according to “Geotextiles and geotextile-Related products-Static puncture test” TS EN ISO 12236. Test specimens were prepared through the instructions and conditioned for 24 hours. Five samples were duplicated for determining puncture resistance.

5. Results and Discussion

In the case of soil-geotextile interaction the geotextile is subjected to perpendicular forces to it’s plane due to the subgrade surface irregularities [9]. Therefore researchers have studied puncture resistance performances of needlepunched nonwoven geotextiles by means of differences in testing procedures [9,10]. Puncture resistance values of the fabrics are presented in Table 2. These values are obtained for preneedled top and bottom layers of the multi-layered end-products.

Table 2. Puncture resistance results of fabrics (N).

| Raw material | 100 g/m² | 150 g/m² | 200 g/m² | 250 g/m² |
|--------------|----------|----------|----------|----------|
| Polypropylene | 1.1076   | 7.2160   | 10.0100  | 17.7375  |
| Polyester    | 1.3800   | 8.0000   | 12.0800  | 10.9200  |
| Recycled     | 13.630   | 16.2475  | 9.2700   | 21.8120  |

In this study in the case of comparing puncture resistance values from the viewpoint of mass per unit area datum between each raw material group, it is obviously seen that for both PP fabrics and PET fabrics puncture resistances increased with increasing mass per unit area values as presumed excluding the puncture resistance of the PET fabric of 250g/m². Hereby, when needling density is too high for the punched web, the bonding structure of the nonwoven is damaged and the puncture resistance of nonwoven decreases accordingly [11]. Although the thickness values of the PET fabric of 200 and 250
g/m² were very close to each other the aforementioned reason might have caused the puncture resistance result. Considering recycled fabrics it can be observed that except the puncture resistance value of the fabric of 200 g/m² rising values take place for rising mass per unit area values respectively.

In the case of statistically analyzing puncture resistances of the fabrics through SPSS13.0-One way ANOVA, the effect of mass per unit area on puncture resistance values was found to be statistically significant for each type of fabrics as seen in Table 3.

**Table 3.** The analysis of variance table for mass per unit area values of the fabrics

| Factor                  | F    | Significance |
|-------------------------|------|--------------|
| Mass per unit area      | 7.772| 0.000        |

Considering the effect of raw material type on puncture resistance performances of fabrics, it can be stated that the puncture resistance values obtained for PP fabrics were found to be the lowest values for each group of mass per unit area excepting the group of fabrics of 200 and 250g/m². The puncture resistance values of PET fabrics except the fabrics of 200 and 250g/m² can be ranked as the second for each group of mass per unit areas. The puncture resistance values belonging to recycled fabrics were found to be the highest excluding the fabric group of mass per unit area of 200 g/m². Besides, recycled fabrics performed dramatically good puncture resistance values that can be related with the entanglement of longer fibers they involve.

In the case of statistically analyzing puncture resistances of the fabrics through SPSS13.0-One way ANOVA, the effect of raw material type on puncture resistance values was found to be statistically significant for each type of fabrics as seen in Table 4.

**Table 4.** The analysis of variance table for raw material types of the fabrics

| Factor     | F    | Significance |
|------------|------|--------------|
| Raw material | 5.248| 0.008        |
Figure 1. Thickness and puncture resistance values of nonwoven fabrics

In the figure above puncture resistances of each type of fabrics were demonstrated in relation with thickness values. As it can clearly be seen from the table, puncture resistances of fabrics except that of PET 250 g/m² and recycled 200g/m²² increased in relation with the increasing thickness values. Besides, thickness values of the fabrics for each mass per unit area group were in close relationship with each other. Puncture resistance values of recycled nonwoven fabrics outperformed results of the others which might be contributed to the longer fibres they involve concluding in higher entanglement.

6. Conclusion
In this study puncture resistance performances of 12 types of preneedle punched nonwovens in 3 different raw materials and 4 equivalent mass groups were compared considering mass per unit area values and raw material types. When mass per unit area values were taken into account; between each raw material group, it was obviously seen that for both PP fabrics and PET fabrics puncture resistances increased with increasing mass per unit area values as expected excluding the puncture resistance of the PET fabric of 250g/m². Considering recycled fabrics it can be observed that except the puncture resistance value of the fabric of 200 g/m² rising values took place for rising mass per unit area values respectively.

In different raw materials groups, puncture resistance values obtained for PP fabrics were found to be the lowest values for each group of mass per unit area excepting the group of fabrics of 200 and 250g/m². The puncture resistance values of PET fabrics except the fabrics of 200 and 250g/m² came after for each group of mass per unit areas. The puncture resistance of recycled fabrics were the highest excluding the fabric group of mass per unit area of 200 g/m². Besides, recycled fabrics performed dramatically good puncture resistance values that can be related with the entanglement of longer fibers they involve.

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