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Optimum Performance of Nonwoven Geotextile through Combination of Bonding Methods

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Abstract

Nonwoven geotextile have proved to exhibit significant potential in several application such as road and railway construction, landfills, erosion control, flood protection work, slope stabilization etc. Such applications require geotextiles to perform more than one function. Owing to the fact that, with an increase in both necessity and demand of nonwoven geotextile products in several applications, research activities are ever increasing in geotextile field for manufacturing of new products. One of such product is nonwoven geotextile produced through combination of bonding method at manufacturing stage. Experimental work is performed in the laboratory on mechanically-thermally bonded (MTB) products and its mechanical test results are compared with mechanically bonded (MB) i.e., needle punched and thermally bonded (TB) nonwoven geotextile of similar mass per unit area. The results show that MTB product ensures optimum performance at lower weight.

Keywords: *Geotextiles, Needle punched, Manufacturing, Mass per unit area.*

1. Introduction

Nonwovens are manufactured by high speed and low cost processes. As compared to the traditional woven and knitting technology, a larger volume of materials can be produced at a lower cost by using nonwoven technology. Table 1 shows comparative production rates of geotextiles. The characteristics of a nonwoven geotextile can be categorized by the structure of fibre matrix, the bonding method and the quality of raw material.

Table 1: Comparative production rates of geotextiles (Raghvendra and Sravanthi, 2017)

Type of production	Production rate of fabrics
Nonwoven geotextile	Nearly 100 m/min
Knitted geotextile	Nearly 2 m/min
Woven geotextile	Nearly 1 m/min

Commonly prevalent raw materials for nonwoven geotextile are polypropylene (PP) and polyester (PET). Continuous monofilament are usually employed; these may, however, be cut into short staple fibres before processing. The processing involves continuous laying of the fibres or filaments on to a moving conveyor belt to form a loose web slightly wider than the finished products. When the web passes along the conveyor and bonded by punching thousands of small barbed needles through the loose web, such bonding is called mechanical bonding or needle punched nonwoven geotextile. Bonding obtained by heat or by partial melting of the fibres is called thermal bonding. Chemical bonding are obtained by fixing the fibres with a cementing medium, such as glue, latex, cellulose derivative or synthetics resin [1]. Depending upon the desired product fibres are bonded by three different methods in the initial stage of web formation i.e., mechanical bonding, thermal bonding and chemical bonding, which is in contrast to weaving process. Figure 1 shows flow chart of nonwoven geotextile manufacturing process.

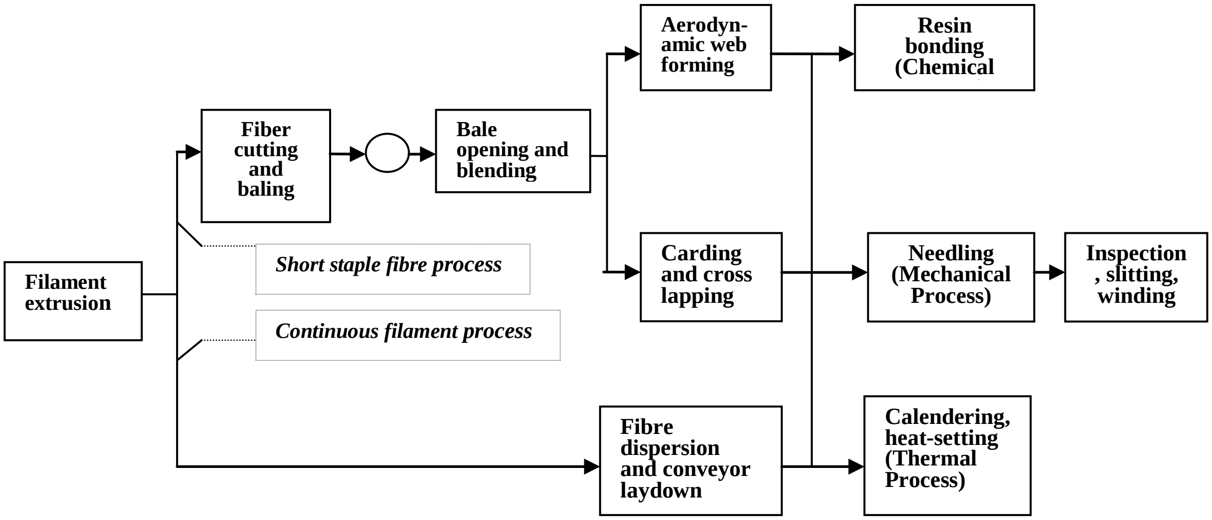

Figure 1: Flow chart of nonwoven geotextile manufacturing process (Koerner R. M., 2016)

Once the geotextile is consolidated in the form of a fabric with its specific physical, mechanical and hydraulic qualities, it is possibly to apply finishing treatments to modify its final properties and performance. Some of the most common finishing treatments are often integrated in-line with the manufacturing process to avoid additional costs and additional arrangement in the production. Table 2 presents several common finishing processes that can be applied to geotextiles. With the advancement in machineries and fabrication techniques, innovation has expanded the production of high performance nonwoven geotextiles for various application. Hybrid forms of materials are also produced through combination of various processes in manufacturing and finishing stage. For example mechanically-thermally bonded (MTB) product will have better control in discharging the functions at installation stage. A geotextile will not perform any function if it is damaged during or immediately after installation. Critical period in the life-cycle of a geotextile is during the construction process rather than during the service life. Most of the damages to geotextile usually occur during installation stage, mainly due to impact damage during the off-loading and placement of stones etc. Usually, if the geotextile survives these installation related stresses, it will live on to perform the functions for which they have been designed.

Table 2: Common finishing processes applied to geotextiles

Process	**Description**	**Impact on product**
Thermo-fixing	Heat material to bring fibres to limit of their melting point so that fibres will bond together permanently	• Stabilization of dimensional properties of product • Increase tensile strength
Calendering	Compress geotextile under high pressure and high temperature using heated metal rollers	• Temperature stabilization of product • Calibration of hydraulic properties by adjusting density material • Reducing thickness of product
Coating and impregnation	Addition of resin or chemical composition to surface or into internal structure of material	• Modifying surface and internal properties of geotextile • Increasing the rigidity of the product • Modifying hydraulic properties of textile to render it water proof or water-resistance

Bonding	Application of adhesive, generally at a high temperature, between two layers of material and apply pressure to bond two layers together	• Associating two layers of geotextiles or geosynthetics together to obtain hybrid properties, which take advantage of specific function of both types of geosynthetics textiles
Sewing and fusion	Join two geotextile together using yarn by fusing together part of the materials	• Joining two strips of geotextiles side by side to increase total size of product • Joining two layers of geotextiles together to obtain hybrid properties and benefit from specific properties of different types of geotextiles

Patel and Kothari [2] evaluated tensile properties of fibres and nonwoven fabrics manufactured from different raw materials and bonding method. Results showed that deformation in various nonwoven fabrics depends on the type of structure formed by the bonding method. In case of heat-sealed nonwoven fabrics, initial modulus is high but it decreases gradually with the increase in stress while in case of needle punched fabrics, initial modulus is low but it increases with the further increase in load as the structure gets locked.

Raghvendra and Sravanthi [3] summarized fabrication methods used for production of novel class of micro/nano fibrillary nonwoven composites for textile applications. According to the production route different types of nonwoven web are discussed in details. Various bonding techniques used for web bonding are also covered.

2. Experimental Work

MTB, MB and TB materials of similar mass per unit area were selected and subjected to wide width tensile test and elongation, static CBR puncture test and dynamic cone drop test. The mechanical properties discussed here are very important in applications where nonwoven geotextile is required to perform a structural role, or it is required to survive installation damage and stresses mobilized from applied loads. All the types of bonded materials are also tested for water flow ($l/m^2/s$) normal to plane at 50 mm head and discussed.

2.1 Materials

In this work, MTB, MB and TB nonwoven geotextile manufactured from 100 % polypropylene fibers were subjected to mechanical [6-8] and water flow test [9]. The physical properties [4-5] of all type of bonded nonwoven geotextiles having different mass per unit area used in the test are shown in Table 3.

Table 3: Physical properties of nonwoven geotextiles

Physical properties	Mass per unit area (g/m^2)			Thickness (mm) at 2 kPa		
MTB nonwoven geotextile	120	210	300	0.85	1.3	1.60
MB nonwoven geotextile	124	211	304	1.2	2	2.5
TB nonwoven geotextile	122	210	300	0.5	0.7	0.8

2.2 Tests and Methods

Table 4 shows type of tests and their methods which has been followed for laboratory investigation

Table 4: Type of tests and methods

Sr. No	Type of tests	Method followed [4-9]
1	Mass per Unit Area	ASTM D 5261
2	Nominal Thickness	ASTM D 5199
3	Wide width tensile strength and elongation	ASTM D 4595
4	Static CBR Puncture Test	ASTM D 6241
5	Dynamic Cone Drop Test	ISO 13433
6	Water Flow	ASTM D 4491

3. Results and Discussion

3.1 Tensile strength and elongation

Figure 2 & 3 shows tensile strength and percentage elongation respectively for MTB, MB and TB nonwoven geotextiles at different mass per unit area. From the test result it is seen that no drastic change in tensile strength was observed for various bonded materials. But an elongation property shows different percentage between bonded materials for an equivalent tensile strength. MTB materials show 33.8 % more average elongation than TB materials and also provide 8 to 10 % extra tensile strength than MB materials at break. Tensile strength achieved in MTB may be due to melting of fibres which bond them together permanently.

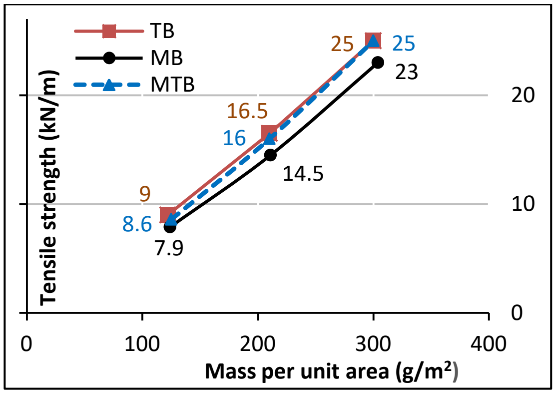

Figure 2: Tensile strength for MTB, MB and TB nonwoven geotextiles

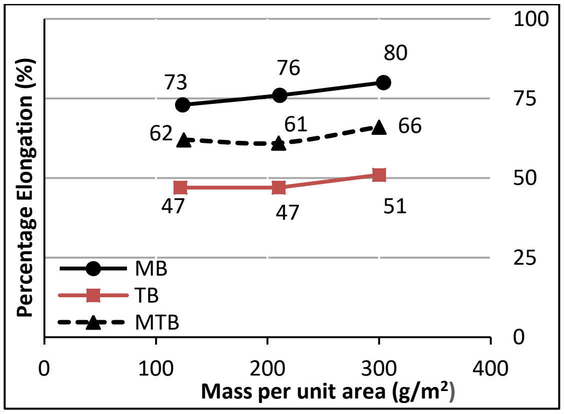

Figure 3: Percentage elongation for MTB, MB and TB nonwoven geotextiles

The initial modulus describes the behaviour of a geotextile at low deformation. Using a secant modulus at 5 % strain gives a clear indication of initial modulus. A line is drawn from the axis origin to the curve at 5% strain as shown in figure 4. The initial modulus (slope) is measured as K= T/ε. The steeper the gradient the higher the modulus. The higher the tensile strength of a geotextile at an initial deformation i.e., at 5 %, the higher the initial modulus. Figure 4 shows the stress-strain curves for different bonded nonwoven geotextiles of similar mass per unit area (i.e., 210 gm/m^2). Looking at the initial portion of the stress-strain graph MTB product shows high initial modulus than MB products and more than 60 % overall elongation at break. This gives resistance to damage during and after the installation. From the stress-strain curve, it is seen that MTB products gain strength when compared to MB products and gain elongation as compared to TB products. MTB materials provide optimal balance of properties which results from the dimensional stability of the product and give all-round performance in all function expected of nonwoven geotextile.

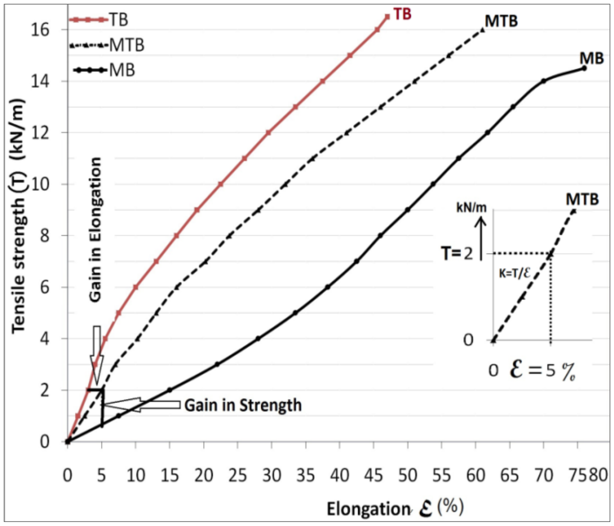

Figure 4: Stress-strain curves for different bonded nonwoven geotextile

Performance energy (PE) for MTB product is the area below the stress-strain curve in figure 4. It is the ability of the geotextile to absorb construction stress. Performance energy is described as the combination of its elongation and its applied strength (i.e., PE = ½ (tensile strength x elongation). The larger this area, the more successfully is the product in resisting damage during its performance.

3.2 CBR Puncture and Cone drop test

From the figure 5 MTB products shows 16-32 % more puncture resistance than TB products and 2-7 % less puncture resistance than MB products. From the comparison it is seen that MTB and MB products are more resistant to static CBR puncture and can absorb more impact energy than thermal bonded nonwoven geotextiles. Figure 6 shows comparisons of dynamic cone drop test results for MTB, MB and TB nonwoven geotextiles. It is seen that cone drop value (hole diameter) in MTB and MB products were lower than TB products which show that MTB and MB products have greater penetration resistance than TB materials.

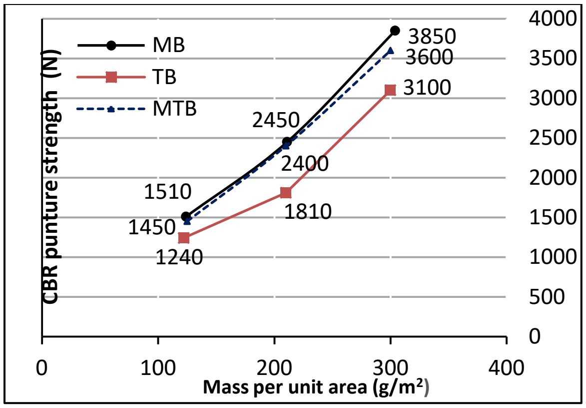

Figure 5: Static CBR puncture strength for MTB, MB and TB nonwoven geotextiles

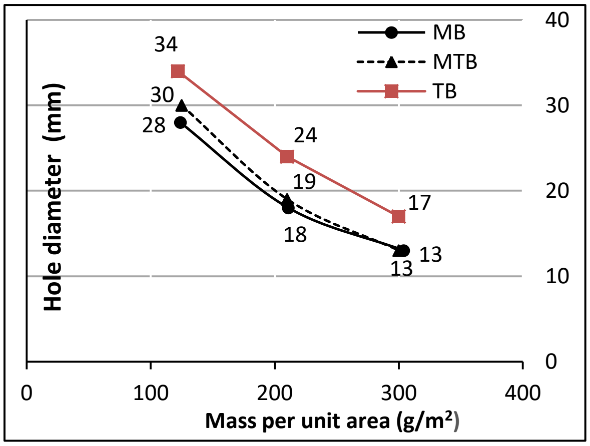

Figure 6: Dynamic cone drop results for MTB, MB and TB nonwoven geotextiles

3.3 Water flow

Figure 7 shows water flow normal to plane at 50 mm head for MTB, MB and TB nonwoven geotextiles. The water flow of the MB and the MTB product is higher than that of the TB product. As a result water flow performance permits the use of MB and MTB product for a much larger range of soils than with the TB product. MTB product i.e., TB after needle punching brings dimensional stability and its pore structure is also stable for optimum filtration. MTB materials are produced under high pressure and temperature using heated metal rollers in the finishing stage, therefore geotextile materials gets compressed and chances of retaining soil fines and particles within its thin structure also gets reduced.

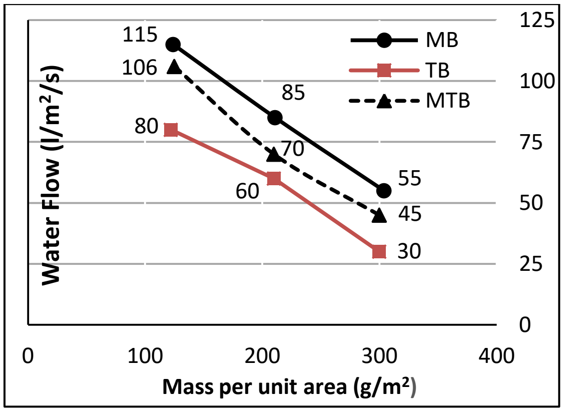

Figure 7: Water flow normal to plane for MTB, MB and TB nonwoven geotextiles

4. Conclusion

The primary challenge facing any geotextile is to survive the harsh installation conditions, and to remain undamaged. Most of the damages to a geotextile take place during installation. Only those that survive the severe initial installation stresses will live on to perform the functions for which they have been designed. So to perform during installation stage it is important that the material has required tensile strength and optimum elongation. MTB materials shows good tensile strength and elongation more than 60 % at break which makes them flexible and capable enough of accommodating soil irregularities. High initial modulus helps MTB product to survive severe installation stresses. MTB materials provide optimal balance of properties which results from the dimensional stability of the product and give all-round performance in all function expected of nonwoven geotextile. The bonding process changes the structure of nonwoven geotextile and therefore has a direct impact on the capacity of the geotextile to perform its function in the soil. Thus, the selection of proper bonding method is important in defining final properties of the nonwoven based products. Based on the end use application, appropriate processing as well as bonding techniques should also be given importance in selecting nonwoven geotextile.

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