Mechanical Properties of Mechanically and Thermally Bonded Nonwoven Geotextile

[1]Suresh Maurya, [2]Manish Gupta, [3]R.Chitra
[1]Scientist C, [2]Scientist E, [3]Scientist E
[1]Central Soil and Materials Research Station,
[1]Ministry of Water Resources, RD & GR, New Delhi

Abstract: Nonwoven geotextiles are individually as well as jointly applied with other geosynthetics materials in geotechnical engineering application to perform more than one function. Combining the attributes of two different materials enhances its engineering properties and therefore it is also known as engineered fabrics. 70 % of geotextile used in construction sector are mainly produced by nonwoven technology. The major factor affecting the performance of nonwoven geotextile is manufacturing method i.e., bonding method and quality of raw materials used. Looking at the importance of bonding method, an experimental work is performed in laboratory to understand the effect of bonding method on mechanical properties. Mechanically bonded (i.e., needle punched) and thermally bonded geotextile 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 results show that increase in the mass per unit area leads to an improvement in the mechanical properties for both type of nonwoven geotextiles. However needle punched nonwoven geotextiles exhibit higher puncture and penetration resistance along with superior elongation properties than thermally bonded nonwoven geotextiles.

***Index Terms* - Geotextiles, mechanical bonding, thermal bonding, laboratory tests, mechanical properties**

1. Introduction

The knowledge of mechanical properties is very important for selection of geotextile manufactured from various bonding method. Geotextiles of all types can be damaged during installation. Reduction of mechanical strength is often connected with mechanical damage caused by direct contact between earth materials and geotextile materials under load. The placement of aggregate upon a geotextile can cause damage but this can be minimized by good installation practices and proper selection of desired geotextile.

Physical properties of needle-punched nonwoven fabric depend on the nature of component fiber, the manner in which the fibers are arranged in the structure and the degree of consolidation. The increase in needle density and penetration improves the fiber consolidation, but beyond a certain limit the fiber damage becomes greater, leading to deterioration in fabric characteristics. Higher fabric weight and introduction of scrim generally improve the functional properties of fabric. Physical properties of fabric are directly or indirectly influenced by the bulk of the materials (Midha and Mukhopadyay, 2005).

Patel and Kothari (2001) evaluated tensile properties of fibers 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.

Koerners (2010) studied the puncture resistance of PET and PP needle punched nonwoven geotextiles using three different probe shape types, according to ASTM D4833, D5495 and D6241. The result showed that, with the increase of fabric weight, the puncture resistance of all nonwoven geotextiles increased and the result values for the CBR test was higher than the Pin and Pyramid (probe shape types) test methods. The results showed that the puncture resistance of needle punched nonwoven geotextiles had measurably increased by changing the fiber's base resin from PET to PP at an equivalent mass per unit area. It was also concluded that needle punched nonwoven fabrics used for protection (or cushioning) of geomembrane was better when geotextiles were made from PP fibers than those made from PET fibers.

Dordic, et al. (2016) studied the analyzed samples of nonwoven geotextile materials made from regular polyester, recycled polyester and polypropylene fibers. Result showed that nonwoven geotextile material from regular PES fiber has better resistance to static punching than the geotextile formed from recycled PES fibers. It has also been shown that the geotextile material from polypropylene fibers has better values than the geotextile made from regular polyester fibers. This difference indicates that the quality of PP fibers largely defines the quality of the geotextile material.

1.1 Nonwoven Geotextile Manufacturing

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. The characteristics of a nonwoven geotextile can be categorized by the structure of fiber matrix, the bonding method and the raw material. Commonly prevalent raw materials for nonwoven geotextile are polypropylene (PP) and polyester (PET). Nonwoven geotextiles are obtained by process other than weaving method. Continuous monofilament are usually employed; these may, however, be cut into short staple fibers before processing. Depending upon the desired product fibers are bonded by three different methods in the initial stage of web formation i.e., mechanical bonding, thermal bonding and chemical bonding (Koerner, 2005).

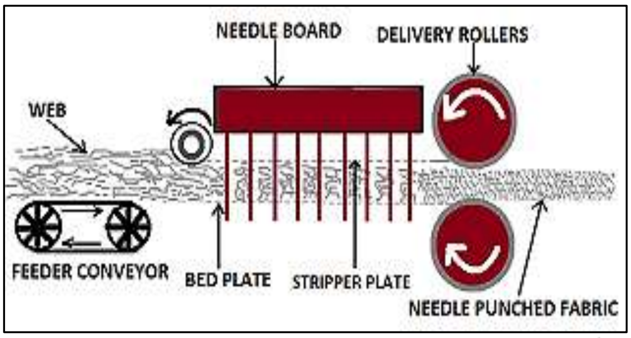

Fig.1. Needle punched nonwoven process

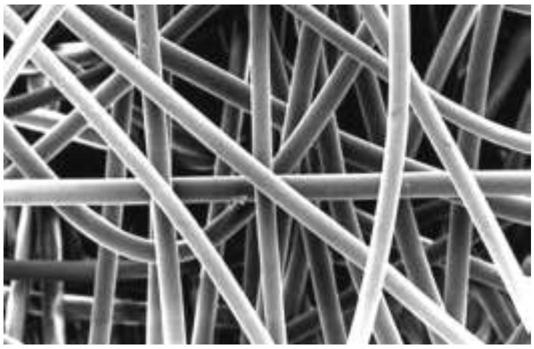

Fig.2. Magnified view of needle punched fabric

Mechanical bonding (also called needle punching method)

In this method randomly oriented fibers are bonded together through the process of needling as shown in Fig.1. Fibrous web is introduced into a machine equipped with hundreds of specially designed needles. The needles are about 75 mm long and each has three to four downward oriented barbs. While the web is trapped between the bed plate and a stripper plate, sequentially punching and pulling out the barbed needles through the moving fiber matrix, reorient the fibers in a needle loom. Mechanical bonding is achieved throughout the length and width of fabric. Nonwoven geotextiles are manufactured through the process of needle punching that involves forcibly entangling layers of loose fibers into three dimensional structures. Figure 2 shows magnified view of needle punched fabric.

Thermal bonding (also called melt bonding or heat bonding)

In thermal bonding the fibers are bonded together through heating process as shown in Fig. 3. In this process, the web which is composed of fibers, is melted together at filament or fiber crossover point or calendered when the fiber surface is compressed with heated roller drums. The thermal bonding method creates a relatively thin, less flexible nonwoven with a comparably flat, smooth surface and lower elongation characteristics than needle-punched nonwovens. The resultant fabrics are rather stiff in texture and feel. Higher fabric strength can also be achieved with this type of manufacturing at lower fabric thickness & weights than for other fabric styles, owing to the fiber bonding utilized in the process. Figure 4 shows magnified view of thermally bonded fabric.

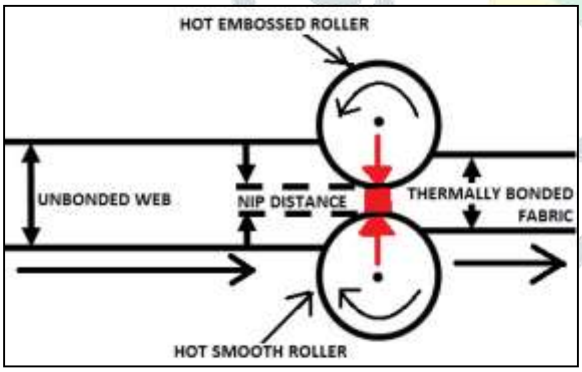

Fig.3. Thermally bonded method

Fig.4. Magnified view of thermally bonded fabric

Chemical bonding (also called resin bonding)

In chemical bonding the fibers are bonded together through chemical coating or fibrous web is either sprayed or impregnated with an acrylic resin. After curing and/or calendaring, bonds are formed between fibers. A forced air drying operation is used to re-establish the fabric's open pore structure before the resin has hardened or cured.

2. EXPERIMENTAL WORK

An experimental work is performed in laboratory to understand the direct impact of bonding method for nonwoven geotextile on mechanical properties. Needle punched and thermally bonded materials of similar mass per unit area were selected and subjected to wide width tensile test & 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.

2.1 Materials

In this work, both needle punched and thermally bonded nonwoven geotextile manufactured from 100 % polypropylene fibers were subjected to mechanical test. The physical properties of both kinds of nonwoven geotextiles having different mass per unit area used in the test are shown in Table 1.

Table 1.Physical properties of nonwoven geotextiles

Physical properties	Needle punched nonwoven geotextile			Thermally bonded nonwoven geotextile		
Mass per unit area (g/m^2)	124	211	304	122	210	300
Thickness (mm) at 2 kPa	1.2	2	2.5	0.5	0.7	0.8

2.2 Tests and Method

In order to investigate the mechanical properties of nonwoven geotextiles, wide width tensile test, static CBR puncture test and dynamic cone drop test were conducted.

Wide width tensile tests were conducted according to ASTM D 4595. In this test method tensile strength and elongation of geotextiles is assessed using a wide strip specimen of 200 mm (length) x 200 mm (width) with gauge length of 100 mm between jaw faces. The jaw faces must be sufficiently wide to grip the entire width of the samples. Upper and lower jaws are assembled in FIE Universal Testing Machine (UTM) of accuracy ± 1% which is of constant rate of extension type (CRE). Upper jaw is supported by a free swivel which allows the clamp to rotate in the plane of fabric. A test specimen is held in the jaws and longitudinal force is applied at a strain rate of 10 ± 3 % per minute until the specimen ruptures. UTM has a facility of recording data in panel. The maximum force per unit width to cause a specimen to rupture is recorded and designated as the tensile strength. Figure 5 shows wide width jaws assembled in UTM and recording panel.

Fig. 5. Wide width jaws assembled in UTM and recording panel

Static CBR puncture tests were conducted according to ASTM D 6241. It uses a conventional soil testing CBR plunger and mould. The penetrating steel rod is 50 mm in diameter and the geotextile is firmly clamped in an empty mould of 150 mm inside diameter with the help of circular plates. The clamp and plunger were installed on FIE UTM. Machine is operated at a speed of 50 mm/min until the plunger completely ruptures the test specimen. Maximum force recorded is designated as puncture strength. Figure 6 shows CBR plunger, empty mold and circular plate.

Fig. 6.CBR plunger, empty mold and circular plate

Dynamic cone drop tests were conducted according to ISO 13433. It is used to measure the resistance of geotextile to the penetration by a steel cone of 1000 g when dropped from a fixed height of 500 mm onto the center of specimen. Geotextile specimen is secured between clamping rings of internal diameter of 150 mm. The degree of damage is measured by insertion of a narrow angle graduated cone into the hole. The penetration value is indicative of the damage likely to be caused by dropping sharp stones on to the geotextile. The smaller the hole, the greater is the penetration resistance of geotextile to damage. Figure 7 shows dynamic cone drop test apparatus with damaged specimen.

Fig. 7. Dynamic cone drop test apparatus with damaged specimen

3. TEST RESULTS AND DISCUSSION

Figure 8 shows the comparison of tensile strength and elongation results value for mechanically and thermally bonded nonwoven geotextiles. From the comparison it is seen no drastic change in strength was observed but elongation properties of mechanically bonded materials was much higher than thermally bonded materials in all cases.

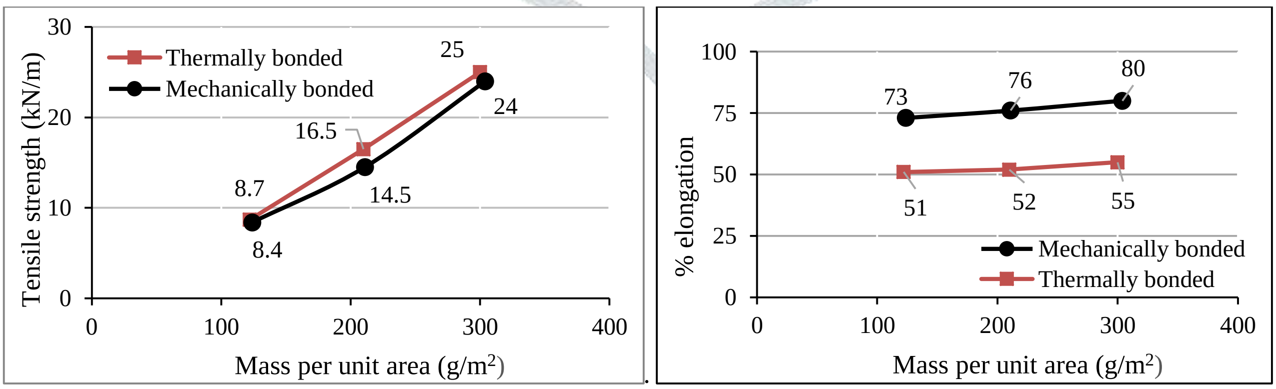

Fig. 8. Tensile strength and elongation results for mechanically and thermally bonded nonwoven geotextiles

Figure 9 shows comparisons of static CBR puncture strength results for mechanical and thermally bonded nonwoven geotextiles. From the comparison it is seen that mechanically bonded materials were more resistant to static CBR puncture and can absorb more impact energy than thermal bonded nonwoven geotextiles.

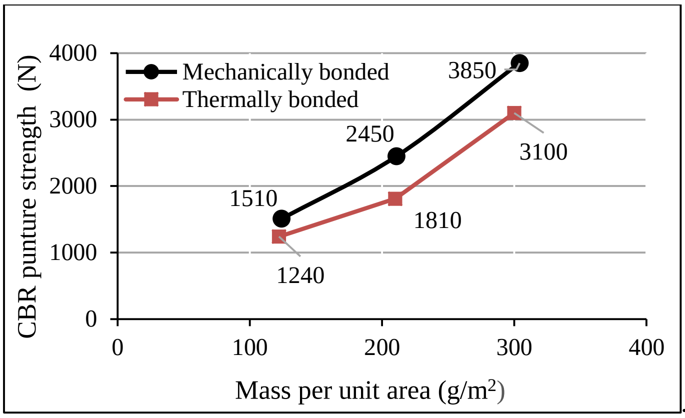

Fig. 9. Static CBR puncture strength results for mechanically and thermally bonded nonwoven geotextiles

Figure 10 shows comparisons of dynamic cone drop test results for mechanical and thermally bonded nonwoven geotextiles. It is seen that cone drop value (hole diameter) in mechanically bonded materials were lower than thermally bonded materials which shows that mechanically bonded materials have greater penetration resistance.

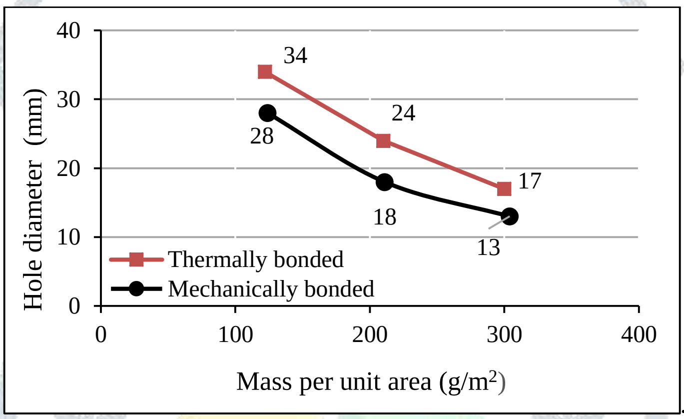

Fig. 10. Dynamic cone drop test results for mechanically and thermally bonded nonwoven geotextiles

4. CONCLUSION

Results show that bonding method in the manufacturing process plays an important role in controlling the mechanical behavior of nonwoven geotextiles. Marginally higher tensile strength and lower elongation percentage obtained for thermally bonded geotextile may be due to rigid bonds formed as a result of fusion of fibers and quality of fiber utilized in the manufacturing process. Needle punched nonwoven geotextiles shows relatively higher elongation; this may be due to the high degree of reorientation and slippage of individual fibers during the tensile load applied on these fabrics.

Mechanically bonded materials show greater static CBR Puncture resistance which represents the closest indication of protection performance of the materials. Static CBR puncture resistance gives a better indication of protection performance and is therefore useful parameter in application where it is required to protect other geosynthetics materials from concentrated mechanical stresses. Results show that mechanically bonded materials have greater penetration resistance which indicates its robustness to harsh installation, where the material is first subjected to puncture and then the material gets torn.

Due to their superior elongation behavior mechanically bonded materials can accommodate soil irregularities in a better way and are more resistant to puncture and can absorb more impact energy than thermal bonded nonwoven geotextiles. The randomly oriented fiber matrix in the needle punched nonwoven geotextile also provides excellent hydraulic properties.

From the comparison of the results presented in this paper, it is clear that mechanically bonded i.e., needle punched nonwoven geotextile can perform multiple functions. Needle punched nonwoven geotextiles are extensively used in various applications including road and railway construction, landfills, erosion control, flood protection work, slope stabilization etc. Such applications require geotextiles to perform more than one function including filtration, drainage, separation, protection and reinforcement.

REFERENCES

[1] ASTM D 4595, Standard Test Method for Tensile Properties of Geotextiles by the wide-width strip method. American Society for Testing and Materials, Pennsylvania, USA.

[2] ASTM D 6241, Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products using a 50-mm Probe. American Society for Testing and Materials, Pennsylvania, USA.

[3] Dordic, Dragan, Stepanovic, Jovan & Trajkovic, Dusan. 2016 .The analysis of the puncture strength of nonwoven geotextile materials made from polyester and polypropylene fibres. Advanced technologies, 5 (1): 87-91.

[4] ISO 13433. Geosynthetics -Dynamic perforation test (cone drop test).

[5] Koerner, R. G. and Koerner, R. M. 2010. Puncture resistance of polyester (PET) and polypropylene (PP) needle-punched nonwoven geotextiles. Geotextiles and Geomembrane, Vol. 29: 360-362.

[6] Koerner, R. M. 2005. Designing with Geosynthetics, Fifth Edition: 106-125.

[7] Patel, P. C. and Kothari, V. K. 2001. Relation between tensile properties of fibres and nonwoven fabrics. Indian Journal of Fibre & Textile Research, Volume 26: 398-402.

[8] Midha, V. K. and Mukhopadyay, A. 2005. Bulk and physical properties of needle punched nonwoven fabrics. Indian Journal of Fibre & Textile Research, Volume 30: 218-229.