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Impact of Mass per Unit Area on the Mechanical Properties of Needle Punched Nonwoven Geotextile

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Abstract

The application of nonwoven geotextile is determined by its performance, which is governed by its properties. Mass per unit area is the basic physical property used for quality control to determine material conformance. It is directly proportional to fiber packing density. Higher the value tightest is the structure matrix and more is the density. Such types of structures show the highest resistance to mechanical deformation. Therefore behavior of mechanical properties with respect to its mass per unit area is important to understand geotextile resistance to tensile stresses mobilized from applied load and installation condition. In this study, experimental work is performed in the laboratory to know the impact of mass per unit area on mechanical properties of needle punched nonwoven geotextile produced from 100 % polypropylene (PP) fibers. The results show that increase in the mass per unit area leads to an improvement in the mechanical properties i.e., tensile strength, CBR puncture resistance, penetration resistance (cone drop) and trapezoidal tear strength.

Keywords: *Nonwoven Geotextiles, Needle Punched, Laboratory Tests, Tensile Strength.*

1. Introduction

The use of geotextiles in civil engineering applications has grown up substantially since their first usage in 1960 and is now widely applied in most of the civil engineering applications. Geotextile used in construction sector are mainly produced by nonwoven technology, representing approximately 70 % of the whole amount of fabric used for this purpose. The most common bonding method i.e., 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. The function of geotextile filtration is to allow passage of fluid and prevent uncontrolled passage of soil particles. The drainage function of geotextiles is to collect and transport fluids in its own plane of the fabric without the loss of soil particles. Therefore, the filtration and drainage functions differ mainly in terms of direction of liquid flow. The separation function of geotextiles involves segregation followed by retention of soil particles so that the integrity and function of both dissimilar materials can remain intact. By virtue of tensile characteristic, geotextile fabric resist stresses and reduces deformation in structure. Nonwoven geotextile also become suitable in protection of other geosynthetics products like geomembrane etc. by preventing local damages due to

concentrated mechanical stresses. Thus, the nonwoven geotextile structure should be designed to fulfill the criteria demanded by the end user applications [1].
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 [2].

Nonwoven geotextile are fibrous structures formed by random arrangement of fibers in all direction, including in third direction. The tensile behavior of material is highly dependent on the lateral pressure, as it controls the magnitude of the friction among fibers. Thus, when a nonwoven geotextile is subjected to a tensile load the fibrous network deform to align the fibers in the direction of the force applied. Hence extension of fabric take place in the direction of applied load and contraction of fabric take place in the transverse direction [3, 4].

Carvalhol et al. [3] carried out laboratory test on needle punched nonwoven geotextiles and presented results for mechanical properties. The results obtained show that there is a significant correlation between the mechanical properties of the geotextiles and the aerial mass. Moreover, the use of a woven fabric as second layer in hybrid structures presents a positive effect to decrease the initial deformation under tensile.

Naughton and Kempton [5] carried out field and laboratory simulated damage trails on various geotextile which showed that the retained strength is correlated to mass per unit area, strain energy and the deflected shape of geotextiles in situ.

Koerners [6] 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.

Adam Bolt and Angelika Duszynska [7] carried out laboratory investigation for the undisturbed geotextile before placement in embankment and recovered test samples after placement in embankment for physical and mechanical properties (Wide width tensile strength and CBR Puncture test. The aim of the study was to determine the influence of installation and the estimation of puncture resistance of geotextiles, and comparisons of tensile strength parameters of undisturbed and recovered samples of non-woven geotextiles.

Askari, et al. [8] studied the effects of speed and weight on needle punched nonwoven geotextiles subjected to CBR and Puncture tests. The results of the CBR tests indicate that the fabric weight significantly influenced the puncture resistance as well as the puncture energy and elongation while speed only affected the fabric puncture resistance and puncture resistance.

2. Experimental Work

An experimental investigation was conducted in order to know the impact of mass per unit area on various mechanical properties of needle punched nonwoven geotextiles when fiber type, quality, and manufacturing method is same. The most important property of a geotextile is its tensile strength. Invariably all geotextiles applications rely on this property either as the primary function (as in reinforcement application) or as secondary function (as in separation, filtration or drainage) [9]. The most prevalent tests of mechanical durability are static CBR puncture test, dynamic cone drop test and tear test, therefore included in experimental work. The mechanical properties discussed here indicate a geotextiles resistance to stresses mobilized from applied loads and/or installation conditions.

2.1 Materials

In this work, nonwoven geotextile fabric with varying mass per unit area manufactured from 100 % polypropylene (PP) fibers with needle bonding method are taken for the study. Six different samples were tested for mass per unit area as per ASTM D 5261 [10] and mechanical properties [11-14] to know the influence of mass per unit area on mechanical properties. Table 1 shows mass per unit area of samples taken for the study.

Table 1: Mass per unit area of samples taken for the study

Sample no.	Mass per unit area (g/m^2)
1	148
2	211
3	252
4	285
5	356
6	404

2.2 Testing Machine

Universal electronic tensile testing machine of constant rate of extension (CRE) type and having accuracy ± 1% was used. The machine is equipped with display panel and printer. The machine is capable of providing constant test speed, recording force and displacement reading. It has facility of cross head which can move in upward and downward direction as per the requirement of test. This machine can be equipped with various jaws and fixtures to perform test like wide width tensile strength, trapezoidal tear, static CBR Puncture test etc. at a specified rate of extension. Figure 1 shows tensile testing machine with jaws and fixtures.

Figure 1: Tensile testing machine with jaws and fixtures

3. Procedure of Tests

3.1 Wide Width Tensile Test

Wide width tensile tests were conducted according to ASTM D 4595 [11]. In this test method tensile strength and elongation of most variety 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 the tensile machine as shown in fig.1. 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 of a tensile machine and longitudinal force is applied at a strain rate of 10 ± 3 % per minute until the specimen ruptures. The maximum force per unit width to cause a specimen to rupture is designated as the tensile strength. The clamp with the specimen during the test is shown in Fig. 2.

Figure 2: Wide width jaws and specimen during testing

3.2 Static CBR Puncture Test

The Static CBR puncture tests were conducted according to ASTM D 6241 [12]. The static CBR puncture test gives an indication of the ability of the geotextile to withstand slow puncture initiation. It enables the selection of a geotextile with sufficient robustness to minimize installation damage and ensure the required properties are maintained for the service life of the product.

The test simulates big stones pressed into geotextiles laid on soft sub base. The plunger and the ring clamp are installed in tensile machine and operated at a constant rate of elongation. The cylindrical flat plunger has a radial edge of 2.5 ± 0.5 mm. The specimen is secured between the two circular clamping rings with inner dia. of 150 mm with the help of screws. The machine measures the force required to puncture a geotextile by pushing a 50 mm diameter plunger at an extension rate of 50 mm/min through the centre of 150 mm diameter specimen. The relatively large size of the plunger provides a multidirectional force on the geotextile. The test result is the mean of the push through force until the plunger completely ruptures the test specimen and designated as the puncture strength. Figure 3 shows CBR test clamp setup and plunger.

Figure 3: CBR test clamp setup and plunger

3.3 Dynamic Cone Drop Test

This test indicates the likely performance of geotextile submitted to installation stresses. It provides evidence of the suitability of the geotextiles to withstand possible damage in separation and filtration function, especially when the aggregate placed onto geotextile is sharp or angular in shape.

The test carried out as per ISO 13433 [13] simulates damage likely to be caused by dropping sharp stones onto the geotextile surface. It measure the resistance of geotextile to the penetration by a steel cone of 1000 g and 45° tip angle, dropped from a fixed height (500 mm) onto the center of 150 mm diameter specimen. The specimen is secured between the clamping rings. The degree of damage is measured by insertion of a narrow angle graduated cone into the hole. The test result is the mean hole diameter in mm. The smaller the hole, the greater is the penetration resistance of geotextile to damage. Figure 4 shows dynamic cone drop test apparatus.

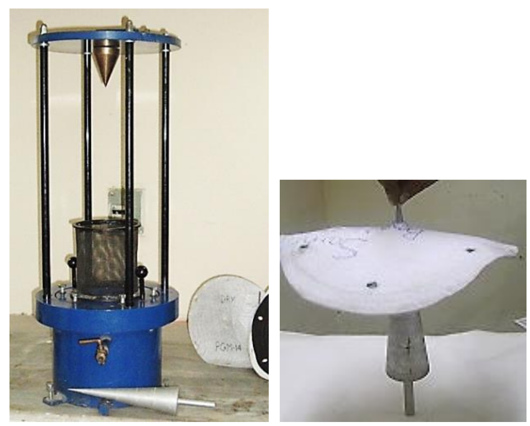

Figure 4: Dynamic cone drop test apparatus

3.4 Trapezoidal Tear Test

The tests were conducted according to ASTM D 4533 [14]. This test method is used to measure the force required to continue or propagate a tear in a geotextile by the trapezoid method. On a rectangular specimen (200 mm long and 76 mm wide) an outline of an isosceles trapezoid is marked. An initial 15 mm cut is made to start the process. The non-parallel sides of the trapezoid marked on the specimen are clamped in parallel jaws which are assembled in tensile machine. Machine is operated at a rate of 300 ±10 mm/min and the tearing force is obtained. The maximum force obtained is designated as the tear strength. Figure 5 shows the trapezoidal tear jaws.

Figure 5: Trapezoidal tear jaws

4. Test Results and Discussion

4.1 Wide Width Tensile Test

The tensile tests were carried out for nonwoven geotextile of different mass per unit area ranging from 148 to 404 g/m^2. The results of the wide width tensile test are presented in Fig. 6.

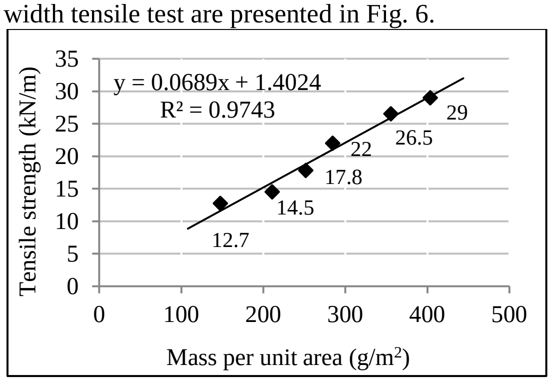

Figure 6: Wide width tensile strength of samples with different mass per unit area

Result obtained from the test shows that with higher mass per unit area there is an increase in wide width tensile strength. Increase in tensile strength may be due to higher amount of fibers placed in random direction. Increasing the number of layers and fibers in each layer forming the web, increases the bulk of the assembled mass. This means that the increase in mass per unit area is directly proportional to the increase in tensile strength.

4.2 Static CBR Puncture Test

The static CBR puncture tests were carried out for nonwoven geotextile of different mass per unit area ranging from 148 to 404 g/m^2. The results of the test are presented in Fig. 7.

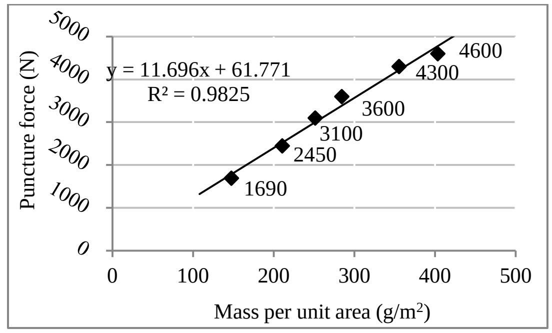

Figure 7: Static CBR puncture result of samples with different mass per unit area

Result shows that with an increase in mass per unit area there is an increase in puncture strength. A good linear correlation is observed which shows that due to increase in mass per unit area, the entwine fibers has higher surface frictional forces and therefore more force is required to puncture the fabric.

4.3 Dynamic Cone Drop Test

The dynamic cone drop tests were carried out for nonwoven geotextile of different mass per unit area ranging from 148 to 404 g/m^2. The results of the test are presented in Fig. 8.

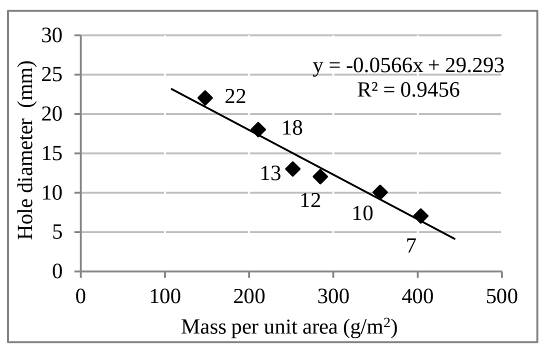

Figure 8: Dynamic cone drop test result of samples with different mass per unit area

Result obtained from the test shows that when there is an increase in mass per unit area of nonwoven geotextile, the hole diameter formed from cone drop test decreases. Higher mass per unit area samples shows good resistance to penetration.

4.4 Trapezoidal Tear Test

The tear tests were carried out for nonwoven geotextile of different mass per unit area ranging from 148 to 404 g/m^2. The results of the test are presented in Fig. 9.

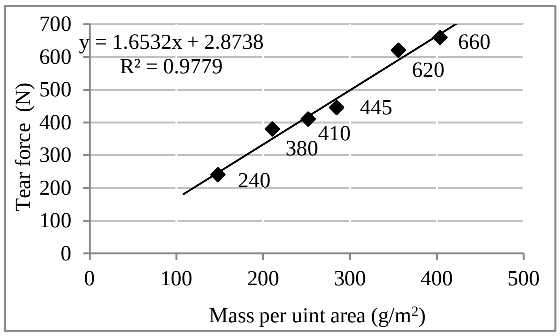

Figure 9: Trapezoidal tear test result of samples with different mass per unit area

Result obtained from the test shows that with the increase in mass per unit area there is an increase in tear strength. Once the tension is applied the load actually stresses the fibers gripped in the clamps rather than stressing the fabric structure. So with the increase in the number of fibers in the cross section more fibers are gripped in the clamps which works together to resist tear propagation and therefore more force is required to tear the geotextiles.

5. Conclusions

In this study, effect of increase in mass per unit area on the mechanical properties, namely tensile strength, static CBR puncture strength, tear strength and dynamic cone drop have been studied for needle punched nonwoven geotextile. Significant linear correlations between mass per unit area and mechanical properties have been found. Tensile strength, static CBR puncture strength and tear strength increase with the increase in mass per unit area of the materials, while the cone drop value (hole diameter) decrease with the increase in mass per unit area. The results obtained demonstrate improvement in the mechanical properties with increase in mass per unit area. The presented results can be helpful when it comes to choosing a good quality of material i.e., higher the mass per unit area tightest is the structure matrix and more is the amount of fibers in the section of the materials.

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