NEEDLE-PUNCHED NON-WOVEN GEOTEXTILE PERFORMANCE FOR SEPARATION AND PROTECTION APPLICATIONS

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Abstract: Recent advances in geosynthetics applications influence many aspects of geotechnical engineering. Many of these applications include the use of non-woven geotextiles with various primary functions, and performances such as filtration, separation, protection and with secondary functions such as reinforcement. Separation and protection applications are very important in many cases and geotextile characteristics must be evaluated with attention in order to ensure a correct design approach and laying procedures. Needle-punched non-woven geotextiles are made from polypropylene or polyester fibres that are tangled together by a needle-punching process and obtain their strength from interlocking. Needle-punched non-woven geotextiles have excellent water flow rates and are used for the filtration of fine soil in drainage applications including trench drains, such as perforated pipe wrapping, erosion protection, and combined with three-dimensional structures to create prefabricated drains. The needle-punched non-woven geotextiles with protection functions are used with geomembranes with the purpose of preventing puncture. The needle-punched non-woven geotextile provides a cushion for the geomembrane and adds tensile strength that can help resist puncture during construction and in service. A correct design of the geotextile type must take into account the site conditions, the weight of water or waste placed on top of the geomembrane, and construction access stresses.

In this paper the resistance to installation damage is investigated. This resistance is to be considered the most important factor in geotextile design, especially when coarse grained, sharp edged fill material is used. A standard test method which simulates these dynamic stresses is the Cone Drop Test, in which various geotextiles test values are compared. With this test it is possible to compare the different performances of the various geotextile types clearly and related closely to practice. The test shows significant differences between the examined geotextiles.

Keywords: needle punched geotextiles, separation, puncture test, landfill, protective layer, installation damage.

INTRODUCTION

Needle-punched non-woven geotextiles can be made from polypropylene fibres that are tangled together in a needle-punching process. Needle-punched non-woven geotextiles are commonly used for the purpose of improving the physical, mechanical and hydraulic soil characteristics for the purpose of improving the global performances of the soil mass for the chosen application. For a good design and employment of needle-punched non-woven geotextiles inside civil engineering applications, it is very important to identify the requested functions taking into consideration all eventual undesirable events or limits states that are to be avoided. With this aim, the needle-punched non-woven geotextiles choice must satisfy some general rules using a synthetic design list as follows:

- The “fundamental characteristics” that the needle-punched non-woven geotextiles must guarantee the maximum performance for the required application;
- The test methodologies, according to the International Standards necessary to determine the “fundamental characteristics”;
- The minimum values of the significance of the fundamental characteristics, which are divided into three classes. In particular, these classes shows the different boundary conditions that can have an affect on the geotextile inside the specific application;
- The minimum mass per unit area of the needle-punched non-woven geotextiles should be used in each class.

The terminology, identification, use and classification criteria for needle-punched non-woven geotextiles are defined by rules that represented the minimum standard accepted level and are shown in Table 1.

Table 1. Geotextiles and geotextile-related products main EN ISO standards

Description	Standards
Identification on site	EN ISO 10320
Sampling and preparation of test specimens	EN ISO 9862
Determination of thickness at specified pressures -- Part 1: Single layers	EN ISO 9863
Test method for the determination of mass per unit area of geotextiles and geotextile-related products	EN ISO 9864
Wide-width tensile test	EN ISO 10319
Static puncture test (CBR test)	EN ISO12236
Determination of water permeability characteristics normal to the plane, without load	EN ISO11058
Determination of the characteristic opening size	EN ISO12956
Determination of water flow capacity in their plane	EN ISO12958
Terms and definitions	EN ISO10318

The above table identifies the most important standards for geotextiles and geotextile-related products but others may be taken into account for the specific application. Only with a rigorous respect of these EN ISO standards is it possible to guarantee a correct design approach and a good geotextile performance. Figure 1 shows a microscopic view of a needle-punched non-woven geotextile where it is possible to observe the PP typical fibre was reported.

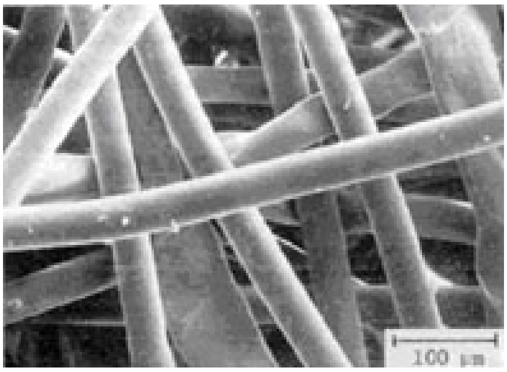

Figure 1. A needle-punched non-woven geotextile microscope view

NEEDLE-PUNCHED NON-WOVEN GEOTEXTILES SEPARATION APPLICATIONS

The separation function is one of the main applications for a non-woven geotextile, where two soils with different granulometric composition are prevented from mixing. For example, this function prevents gravel and road ballast (or sub-base) from sinking into a soft sub-soil without obstructing the water flow. The main characteristics of the needle-punched non-woven geotextiles that affect this application are tensile strength and elongation at the yield point, puncture strength and durability. High values of tensile strength together and good elongation characteristics enable the needle-punched non-woven geotextiles to provide increased resistance against the mechanical damages produced by the coarse grained material placed in the upper layers. In particular, the ability of the geotextile to deform permits a strain compatibility with the soil without a reduction in tensile strength. Therefore the previous characteristic is very important when the upper layer is made of granular material and/or when an upper layer induces the geotextile to sink into a soft sub-soil.

In design, when taking the previous aspects into account, it may be seen that the tensile strength and the elongation at yield are the main parameters to be considered; geotextiles with high tensile strength and low elongation at yield are not able to perform the design function. It may be stated that from a mechanical point of view, needle-punched non-woven geotextiles that have a good tensile strength, elongation at yield above 50% and good resistance to static puncture (CBR) are very well suited to perform a separation function. In fact a good static puncture resistance can guarantee against the inter-contamination of the soil layers, especially when the granular layer contains highly angular particles such as rail ballast. Guide lines are available to identify the requirements for a needle-punched non-woven geotextiles used for road construction and for other areas subjected to traffic loading.

The following characteristics, typically exhibited by needle-punched non-woven geotextiles, help ensure the required performance of the product throughout its service life:

- High resistance to mechanical damage;
- Ability to retain soil particles;
- High permeability perpendicular to its plain, thus enabling pore water to pass pressure between the upper and lower soil layers in the structure;
- Durability to maintain the geotextile's original performance characteristics.

Importantly, the presence of the geosynthetic can increase of the long-term bearing capacity at the surface; this is very important and many people have investigated this behaviour. The bearing capacity increases depends only in part on the mechanical characteristics of the geotextile, the main contribution results from the separation of the soil layers; the contribution by the stiffness characteristics of the geotextile are negligible. In fact, for almost any strength value of the geotextile, the increase in bearing capacity is about 60%. Analyzing the equations of the soil bearing capacity for cohesive soil without (1) and with a geotextile (2), it is possible to estimate the increase in capacity obtained when a geosynthetics is used.

$$P_c = \pi \cdot c_u \qquad (1)$$

$$P_c = \pi \cdot c_u + 2\, c_u + p_g \qquad (2)$$

Where P_c is the soil bearing capacity, c_u is the cohesion in term of total stress and p_g depends on the geotextile strength. The equation (2) clearly shows that the $2c_u$ value increment of soil bearing capacity does not depend on geotextile strength.

The mechanical, hydraulic and durability properties of needle-punched non-woven geotextiles should be evaluated with respect to the site condition, and the risk associated with the separation and filtration properties must be take into account where these could be compromised by different uses during the installation phases and service states. The typical parameters used for the evaluation of the severity of condition of usage can be summarised as follows:

- Physical characteristics of the soil (the soil placed and compacted over the geotextile will result in damage to the geotextile proportional to the size and angularity of the soil particles);
- The thickness of the compacted soil layer;
- The use of appropriate compaction plant (induced stress inside the geotextile depends on the compacted energy and the induced soil pressure);
- Traffic volume.

An appropriate design method will take into account three different levels of service condition: Class 1, for low level; Class 2 for medium level; and Class 3 for high level. Tables 2 to 6 summarise a number of limit values for different commonly used service states. For each variable the limit value is associated to the level of service condition 1, 2 and 3. A general evaluation of all parameters enables the service level closest to reality to be chosen. In Table 2, which is concerned with the needle-punched non-woven geotextiles used on road construction, for each class 1, 2 and 3 the limit values suggested for each of the fundamental technical characteristics provided by the EN 13249 (Characteristics required for use in the construction of roads and other trafficked areas) are reported. The limit values chosen are reported according to the guide lines proposed and these have been applied in various countries for some years. The first step concerns definition of the foundation soil used and divides it into various categories based on the consistency value. The main parameter is the CBR* index (this value is not the same of the CBR obtained from the static puncture test for geotextiles) where 1 CBR (%) = 30 kPa (Cu). In Table 2 three different soil categories are reported. Evaluation of the service conditions can be obtained using the estimated level of traffic in each lane with the maximum amount of vehicles, taking into account the variables that determine the conditions of low, medium or high severity. In the Tables 3 and 4 the above concepts are summarized. Table 5 reports the characteristics that a needle-punched non-woven geotextiles must have in terms of strength, elongation and permeability for each severity class. Using the same approach adopted for road design, it is possible to determine approximate guide lines for the needle-punched non-woven geotextiles applied to railway design. The geotextile terminology, identification, use and classification criteria for railway applications are regulated by EN 13250 that prescribes the same fundamental characteristics of EN 13249 for use in the construction of roads and other trafficked areas. Based on these considerations, the levels of service difficulty (defined class) for railway applications were reduced to two classes. Only classes 2 and 3 were relevant at this high level of stress. Therefore, Table 5 is modified to Table 6.

Table 2. Category of foundation soil and relative consistence value

Consistence	**Soil**	**CBR*(%) – C_u(kPa)**
Soft	Soft clay	< 1 - 30
Medium	Light compacted Clay Loose Sand	1 – 30 < CBR* - C_u < 2 - 60
Dense	Compacted clay Dense Sand	> 3 - 90

Table 3. Service conditions Vs level traffic

Service condition	**Number of passages < 4.000.000***	**Number of passages > 4.000.000***
Soft	Soft clay	< 1 - 30
Medium	Light compacted Clay Loose Sand	1 – 30 < CBR* - C_u < 2 - 60
Dense	Compacted clay Dense Sand	> 3 - 90

* number of passages of commercial vehicles

Table 4. Stresses condition Vs severity parameters

Variable	**Severity category**		
	Class 1	**Class 2**	**Class 3**
Equipment	Light (55kPa)	Medium (55-280 kPa)	Heavy (>280kPa)
Foundation strength	3	1 - 2	1
Construction soil	rounded corners	sharp corners	coarse grained soil with sharp corners (>500mm)
Soil layer thickness	60 cm	40 cm	20 cm

Table 5. Geotextile characteristics Vs levels of service difficulty

Characteristics	**Standards**	**Units**	**CLASS 1**	**CLASS 2**	**CLASS 3**
Static puncture (CBR)	EN ISO 12236	kN	≥ 2	≥ 3	≥ 4
Dynamic perforation	EN 918	mm	≤ 20	≤ 15	≤ 10
Tensile strength (TD and MD))	EN ISO 10319	kN/m	≥ 13	≥ 20	≥ 25
Elongation at max load	EN ISO 10319	%	≥ 50	≥ 50	≥ 50
Characteristic open size O_{90}	EN ISO 12956	µm	≤ 120	≤ 100	≤ 80
Permeability normal to the plane (Kn)	EN ISO 11058	m/s x 10^{-3}	1	1	1

Table 6. Geotextile characteristics Vs levels of service difficulty for railway applications

Characteristics	Standards	Units	CLASS 2	CLASS 3
Static puncture (CBR)	EN ISO 12236	kN	≥ 3	≥ 4
Dynamic perforation	EN 918	mm	≤ 15	≤ 10
Tensile strength (TD and MD))	EN ISO 10319	kN/m	≥ 20	≥ 25
Elongation at max load	EN ISO 10319	%	≥ 50	≥ 50
Characteristic open size O_{90}	EN ISO 12956	μm	≤ 100	≤ 80
Permeability normal to the plane (Kn)	EN ISO 11058	m/s x 10^{-3}	1	1

Typical applications of needle-punched non-woven geotextiles in road and railway construction are presented in Figure 1.

Figure 1. Some applications of needle-punched non-woven geotextile on road and railway construction

NEEDLE-PUNCHED NON-WOVEN GEOTEXTILES PROTECTION APPLICATIONS

A very important application for a needle-punched non-woven geotextile is their use as protection, to provide a resistance to damage from coarse fill, to a geomembrane used in landfill construction.

Moreover in the construction of waterproofing systems these geosynthetics ensure an efficacious mechanical protection of the geomembranes which come into contact with rough and irregular surfaces, such as in tunnels, dams, reservoirs, canals, and other concrete works. The PP fibres are chemically almost inert, which makes their use suitable for contact with fresh concrete or degrading agencies often present in landfill leachate.

Many case-histories have shown that the failure of the geomembrane layer is often due to localised rupture or puncture caused by the normal load transfer by the upper (waste) layer or due to the action caused by the draining gravel layer.

The geotextile cushions the geomembrane and, in addition, the tensile strength that can indirectly help support the geomembrane and thereby reduce the possibility of puncture during construction and in-service. Geotextiles are selected based on the site conditions, the anticipated vertical stress due to the waste placed on top of the geomembrane and stresses induced by construction traffic. The needle-punched process of interlocking fibres provides a protection layer with high resistance and low tendency to puncture damage with low mass per unit area, when compared with the performance of continuous filament non-woven geotextiles. This difference can be demonstrated with the Cone Drop Test according to EN 918, was used.

In Figure 2, photographs are presented of a developed modified drop test, with pyramid shaped piston. The geotextile sample is fixed in a ring clamp in the usual way, and a pyramid piston of varying weight is dropped onto the sample from a certain height. In the test, an underlying medium, plastilline was used (to simulate weak subgrade), but if necessary, the test can also be carried out with the actual on-site subgrade material. This simple practical test again proves the superior performance of geotextiles: investigated geotextiles withstand these dynamic stresses without any harm, whereas even continuous filament non-woven geotextiles are perforated easily, which makes their suitability as separation and filtration elements questionable - especially when sharp edged crushed fill material is used, or in hydraulic construction.

The current design approach to determine the ability of a geotextile to provide adequate protection against puncture damage is based on the mass value per unit area of the product. Therefore, the issue of determining the required mass per unit of the geotextile become critical.

A current method used (Koerner, 1998) to determine the factor of safety against puncture is based on equation (3) shown below. The method directly applies to 1.5mm, smooth, HDPE geomembrane protected by a virgin polymer.

Figure 2. Results of the modified drop test with pyramid piston for two different type of geotextile.

$FS = p_{allow} / p_{act}$ (3)

Where FS is the safety factor against geomembrane puncture, p_{act} is the actual pressure due to the landfill contents or surface impoundment; and, p_{allow}, is the allowable pressure using different types of geotextiles and site specific condition, which depends on the height of the protrusion above the subgrade, the modification factor for protrusion shape, packing density and arching in solids. It also depends on a reduction factor for long-term creep and long term chemical/biological degradation. Imposing a recommended safety factor (>=3) against puncture and using a tabulated values for the previous factors, is possible to calculate the required mass per unit area to provide the necessary resistance. Early work by Hullings and Koerner (1991) and field research by Richardson and Johnson (1998) indicate that the method may be conservative for geomembranes manufactured from more flexible polymers. Many other authors have investigated this problem with varying results. A typical design chart can be obtained for the most common geomembrane cushioning application based on the previous methodology (Stephen & Deron, 1999). These charts allow the user to select an appropriate virgin polymer, non-woven, needle-punched geotextile cushion. Yet, considering the Narejo & Koerner (1991) criteria for typical municipal solid waste landfills, no yield deformation should be observed on the geomembrane. Narejo et al (1996) have proposed that the mass/unit area determines the cushioning efficiency of a non-woven geotextile. The simple demonstration that follows shows that mass is relevant to geotextiles of a given type and structure, but that structural difference has a more significant effect on fundamental cushioning efficiency. In fact, lighter materials with a more rigid structure may produce more cushioning than heavier materials of a "looser" structure. Therefore, it is apparent that the structure of the geotextile is of primary consideration when considering the protection of a geomembrane from puncture. However, for any given structure, mass per unit area is a secondary determinant. Many other experimental studies use tests with truncated cones as the puncturing points, which allowed a critical cone height to be determined. The geotextile portion of the study indicates that increasing mass per unit area is the major factor for increased puncture protection. Clearly, thickness outweighs strength in preventing puncture. Other aspects of the study, such as post-treatment of the geotextile, fibre type (i.e., continuous versus staple) and polymer type reveal only nominal changes in the puncture performance of the geomembranes. In Figure 3 is shown a typical application of angular gravel particles used as a drainage layer. It is possible to observe the puncture effect produced by the grains. From this picture it is possible to understand the important role of the needle-punched non-woven geotextile when provides a cushion to the geomembrane and adds tensile strength that can help resist puncture during construction and in service. A further important characteristic that the needle-punched non-woven geotextiles must be ensured in order to guarantee the protection function is durability.

Figure 3. Gravel layer for base drainage with sharp corners

In some applications, such as landfill construction, the geotextile is often un-protected from ultra violet (UV) light for a long period of time; exposure to atmospheric agents could be keep for many weeks. The exposure to UV light is the most important factor of geotextile degradation and can result in a significant reduction of the geotextile's functionality. The durability is very important because it determines the geotextile's capacity to maintain its design performance during its working life. The main factor influencing the durability is the chemical composition fibre used to make the geotextile. The current experience together with the experimental studies enable us to affirm that a virgin fibre, such as high tenacity polypropylene, will provide a greater durability compared to that offered by a recycled or low-cost fibre. In Table 7 are listed the European Standards for geotextile durability. In Table 8 the mass per unit area for each of the service difficulty (defined class) were reported.

Table 7. European test standards for geotextile durability

Description	Standards
Determination of resistance due to weathering (UV)	EN 12224
Determination of the resistance to acid and alkali liquids	EN12960
Determination of the resistance to oxidation	EN 13438
Resistance to micro-biological attack by soil burial test	EN 12225
Procedure for simulating damage during installation	EN 10722
Evaluation following durability testing	EN 12226
Determination of resistance due to weathering (UV)	EN 12224
Determination of the resistance to acid and alkali liquids	EN12960)
Determination of the resistance to oxidation	EN 13438
Resistance to micro-biological attack by soil burial test	EN 12225

Table 8. Synthetic table for geotextile determination on landfill construction

Characteristics	Standards	Units	CLASS 1	CLASS 2	CLASS 3
Static puncture (CBR)	EN ISO 12236	kN	≥ 5	≥ 7	≥ 10
Tensile strength (TD and MD))	EN ISO 10319	kN/m	≥ 20	≥ 30	≥ 40
Elongation at max load	EN ISO 10319	%	≥ 50	≥ 50	≥ 50
Mass per unit area	EN ISO 9864	g/m^2	≥ 600	≥ 800	≥ 1200

EUROPEAN HARMONIZED STANDARDS

In 2002 a wide range of geotextile products each differing characteristics were available for Civil and Environmental Engineering construction applications. The European directive 89/106/CEE sought to assist the designer in selecting an appropriate geotextile for construction. The directive defines ten major applications for geosynthetics; for each application was defined the specific function required to the products. In the Figure 4 are listed the applications abbreviated to a single letter:

- R: Reinforcement;
- S: Separation;
- F: Filtration;
- D: Drainage;
- P: Protection

The three letters are used to signify the level of obligation to meet the required characteristics:

- H: obligatory, that is the values that must be declared and maintained inside a specific tolerance;
- A: obligatory only if required by specifics of the project;
- S: obligatory only if required by special and particular service conditions.

CONCLUSIONS

In this paper the experience obtained in the use of needle-punched non-woven geotextiles inside civil engineering applications of separation and protection are reported. The following conclusions can be made:

- For the investigated applications three levels of service difficulty are defined and, for each, minimum values of the fundamental characteristics of the geotextile are obtained.
- From field experience the needle-punched non-woven geotextiles show a higher resistance to mechanical damage with a considerably inferior unit weight to some other geosynthetic products, as a result of a high tolerance to localised deformation.
- The protection efficiency is due to the use of high tenacity polypropylene fibres, mechanically bonded in order to obtain a high thickness product with excellent puncture resistance.
- The even distribution of fibres within the geotextile, and the carding process before the needle-punching of the fibres, ensure good results in uniformity of mechanical and hydraulic characteristics without "weak points" within the fabric.

		Road UNI EN ISO 13249			Railway UNI EN ISO 13250			Foundation UNI EN ISO 13251			Drainage system UNI EN ISO 13252			Erosion control UNI EN ISO 13253			Field and Dam UNI EN ISO 13254				Canals UNI EN ISO 13255				Tunnels UNI EN ISO 13256	Solid Waste UNI EN ISO 13257				Liquid Waste UNI EN ISO 13265		
		R	S	F	R	S	F	R	S	F	S	D	F	R	S	F	R	P	S	F	R	P	S	F	P	R	P	S	F	R	P	F
MECHANICAL CHARACTERISTICS																																
Tensile strength (TD and MD)	EN ISO 10319	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Elongation at max load	EN ISO 10319	H	A	A	H	A	A	H	A	A	A	A	A	H	A	A	H	H	A	A	H	H	A	A	H	H	H	A	A	H	H	A
Tensile test for joints/seams by wide-width method	EN ISO 10321				S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Static puncture test (CBR test)	EN ISO 12236	H	H	S	H	H	S	H	H	S	H	-	S	H	H	S	H	-	H	S	H	-	H	S	-	H	-	H	S	H	-	S
Dynamic perforation	EN 918	H	A	H	H	A	H	H	A	H	A	-	H	H	A	H	H	H	H	H	H	H	A	H	H	H	H	A	H	H	H	H
Procedure for simulating damage during installation Part 1: granular materials	EN ISO 10722-1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Determination of friction characteristics -- Part 1: Direct shear test - Part 2: Inclined plane test	prEN ISO 12957-1 prEN ISO 12957-2	A	S	S	A	S	S	A	S	S	S	S	S	A	S	S	A	S	S	S	A	S	S	S	S	A	S	S	S	A	-	-
Determination of tensile creep and creep rupture behaviour	EN ISO 13431	A	-	-	A	-	-	A	-	-	-	A	-	A	-	-	A	-	-	-	A	-	-	-	S	A	-	-	-	A	A	A
Long term protection efficiency of geotextiles in Contact with geosynthetic barriers	prEN 13719	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H	-	-	-	H	-	-	H	-	H	-	-	-	H	-
HYDRAULIC CHARACTERISTICS																																
Characteristic open size O90	EN ISO 12956	-	A	H	-	A	H	-	A	H	A	-	H	-	A	H	-	-	A	H	-	-	A	H	-	-	-	A	H	-	-	H
Permeability normal to the plane (Kn)	EN ISO 11058	A	A	H	A	A	H	A	A	H	A	-	H	A	A	H	A	-	A	H	A	-	A	H	-	A	-	A	H	A	-	H
Determination of water flow capacity in their plane	EN ISO 12958										-	H	-								-	-	-	-	-	-	-	-	-	-	-	-
DURABILITY CHARACTERISTICS																																
Determination of the resistance to weathering	EN 12224	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Method for determining the microbiological resistance by a soil burial test	EN 12225																															
Screening test method for determining the resistance to liquids - for determining the resistance to oxidation - for determining the resistance to hydrolysis	ENV ISO 12960 ENV ISO 13438 ENV 12447	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

Figure 4. Engineering application Vs geotextile characteristics in according to the European harmonized standards

- Especially in protection applications, the durability properties are very important. The UV radiation resistance, when fibres were used that are UV stabilised, is guaranteed with the advantage of not needing to cover the geotextile immediately after installation. This avoids fragmentation of work processes. Therefore, high chemical and biological resistance and high durability, which are a result of the high quality virgin polypropylene fibres, mean that initial product characteristics are conserved at over time even in aggressive environments.
- Tests were conducted on a developed modified drop test with pyramid piston to evaluate the capacity of geotextile resistance to puncture. The tests demonstrated the superior performance of geotextiles as the investigated geotextiles withstood all these dynamic stresses without any harm, whereas even continuous filament non-woven geotextiles are perforated easily, which makes their suitability as separation and filtration elements questionable - especially when sharp edged crushed fill material is used (e.g. such as in landfill construction or in hydraulic applications).
- The technical tables reported, are divided into three levels of service difficulty that offer a good approach to assist the selection of an appropriate needle-punched non-woven geotextile for the required application.

Finally, for each engineering application in which a needle-punched non-woven geotextile may be used, its characteristics are regulated by the European harmonized standards. The standard defines ten main geosynthetic application fields. For each of these applications the specific function required to the products are defined.

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