TECHNICAL NOTE

The durability of polypropylene geotextiles

Polypropylene is a durable polymer commonly used in aggressive environments including automotive battery casings and fuel containers. Utilizing polypropylene in the production of nonwoven geotextiles for waste containment systems is advantageous due to its outstanding resistance to harmful chemical environments. This highlights the beneficial application of this versatile polyolefin. Presently, nonwoven polypropylene geotextiles are used in more than 80% of all waste containment applications.

The primary focus of this technical note is to address the suitability of nonwoven polypropylene geotextiles for waste containment applications. It is important to note that woven polypropylene geotextiles (primarily used in civil engineering applications) are becoming more common in waste containment applications. Woven polypropylene geotextiles are extremely durable (typically more than nonwoven geotextiles), because the individual yarns used to manufacture woven geotextiles (shown in Figure 1) typically have a much larger cross-sectional area than the fibers used to manufacture nonwovens (shown in Figure 2).

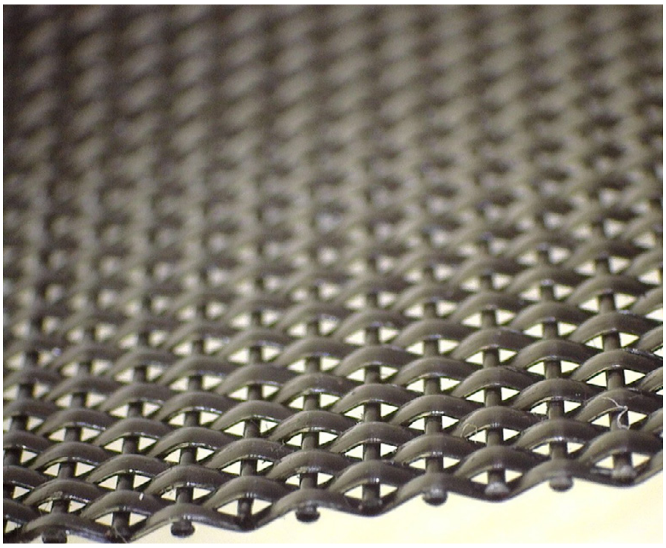

Figure 1: Woven monofilament yarns

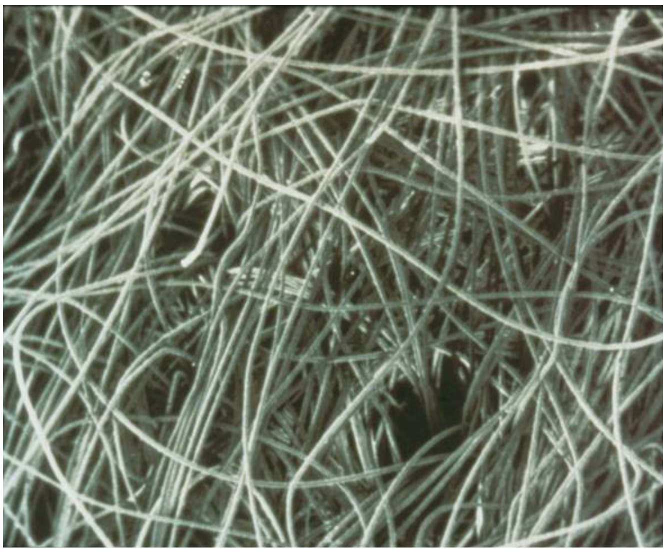

Figure 2: Nonwoven filaments

Moisture resistance

Unlike nonwoven polyester geotextiles, polypropylene does not absorb water nor does the presence of water have any effect whatsoever on tensile strength or other mechanical properties.

Chemical resistance (pH)

Extensive research has shown polypropylene is resistant to certain concentrations of aggressive chemicals such as nitric acid, hydrochloric acid, sulfuric acid, sodium hydroxide and potassium hydroxide. Therefore, polypropylene geotextiles have been found acceptable in most solid and hazardous waste landfills.

Leachate compatibility

Many independent landfill leachate immersion tests conducted in accordance with EPA Method 9090 have shown no significant reduction in mechanical properties of our nonwoven polypropylene geotextiles.

Biological resistance

Since polypropylene does not support, attract, or deteriorate from fungal growths, **MIRAFI®** nonwoven geotextiles are rot and mildew resistant.

Temperature stability

Polypropylene can withstand temperatures of at least 165 C (329 F) without melting.

Ultraviolet resistance

Because polypropylene degrades during extended exposure to sunlight, **MIRAFI** nonwoven polypropylene geotextiles are produced with carbon black and other UV inhibitors. These additives allow our nonwoven polypropylene geotextiles to be exposed for up to 14 days between laydown and cover.

Installation survivability

Nonwoven polypropylene geotextiles made from staple fibers in the needle punched manufacturing process have superior puncture strength, which increase their installation survivability. Staple fibers are typically 3–5 in (7.6–12.7 cm) long.

Lifetime prediction

When properly stabilized and buried, nonwoven polypropylene geotextiles are expected to last up to 200 years.

Introduction

By virtue of its chemical composition, molecular structure, and thermodynamic properties, polypropylene is one of the most resistant organic raw materials known today. This is one of the reasons that over 80% of all geosynthetics are made from polypropylene (Schneider 1989).

Methods of degradation

Chemical degradation of geotextiles is a result of environmental and polymer compositional factors. Regarding environmental factors, the greatest amount of degradation generally occurs: (1) at relatively high temperatures (i.e., > 100 C [> 212 F]), (2) in soils which are chemically active; (3) and when the geosynthetic is under stress. Key chemical degradation mechanisms that can be found in some soil and waste environments include oxidation, hydrolysis, and environmental stress cracking.

An oxidation reaction can either be initiated by ultraviolet radiation or thermal energy, but must have sufficient oxygen present. Since the geosynthetic will be buried in most applications, thermally activated oxidation is of most interest. Polypropylene oxidation is the reaction of free radicals within the polymer with oxygen, resulting in breakdown and/or degradation of the molecular chains and embrittlement of the polymer.

Antioxidants are typically added to the polymer to prevent oxidation during processing and use. Broad classes of antioxidants often used in geosynthetics include phenolic and hindered amine light stabilizers (HALS). As the antioxidants are consumed, resistance of the polymer to oxidation will decrease. The rate of polymer oxidation is dependent on the following: how much and what type of antioxidant is present initially, at what rate it is used, how well it is distributed within the polymer, and how fast it can be leached out by the flow of fluids, such as water, into and around the polymer. Environmental factors which affect the rate of oxidation include temperature and oxygen concentration.

In soil, oxygen concentrations can vary from 21% in gravels at shallow depth to 1% in fine-grained soils at deeper depths. The presence of transition metal ions, such as iron or copper may act as catalysts to accelerate the oxidation reaction. Thermal oxidation at typical in-soil temperatures appears to be quite slow (Allen and Elias, 1996). The stabilizers and potentially the resin carriers for the stabilizer additive package represent the only small fraction of the geotextile which is not 100% polypropylene.

Toxicology

Polypropylene is biologically inert and used for packaging food intended for human consumption (e.g., yogurt containers, Tupperware®, etc.). To ensure that the processing performed does not alter these characteristics, skin and mucous laboratory tests have shown that polypropylene does not cause irritating effects. An extensive series of repeat insult patch testing in humans and many years of extensive use in diverse products such as infant diapers, feminine hygiene products, and surgical fabrics have confirmed that adverse effects on the skin should not be expected. Furthermore, polypropylene is considered to be without significant oral toxicity. When tested by the Food and Drug Administration's specific methods, polypropylene is well below the specified limits of extractables. In addition, the United States Pharmacopoeia (U.S.P.) specifies oral toxicity testing on plastics intended for medical uses. Polypropylene materials have never caused toxicity when tested according to the U.S.P. method (MATAFAXX, 1992).

Moisture

Polypropylene is a paraffinic hydrocarbon and does not adsorb water like the polyamides polyester (PET) or nylon. The moisture gain of polypropylene fibers is insignificant and water has no effect on tensile strength and other mechanical properties. Therefore, water alone does not cause any noticeable degradation in polypropylene fibers. Fibers subjected to boiling water or steam for long periods show no loss of strength (Cook, 1984).

Ultraviolet (UV) resistance

Like polyethylene, polypropylene is attacked by atmospheric oxygen and the reaction is stimulated by sunlight. Polypropylene fibers will deteriorate on exposure to light, but may be effectively protected by stabilizers (Cook, 1984).

Without site-specific environmental conditions, Solmax recommends a maximum exposure period of 14 days between laydown and cover of all of our nonwoven geotextiles. This is in compliance with guidelines issued by the US Environmental Protection Agency (EPA 1993). If the maximum exposure period will exceed these guidelines, we recommend that the installer either (1) utilize an economical, lightweight woven geotextile, such as **MIRAFI** 600X as a temporary cover; or (2) install a test roll on the most southward facing slope and remove samples every 30 days of actual exposure to evaluate possible strength loss. Site personnel should carefully cut a representative roll-width by 5-foot sample (1.5 m); label with contact name, address and telephone number; period of exposure; a roll number, style and project name; place in a strong black wrap and send to a laboratory. It is the responsibility of the Construction Quality Assurance (CQA) engineer to identify the index tests required to determine the actual strength retention.

Three different Solmax nonwoven geotextiles were exposed in accordance with ASTM D 5970-96, Deterioration of Geotextiles From Outdoor Exposure, starting June 15, through July 15, 1996 in Northwest Georgia, USA. Machine direction (MD) and cross-machine direction (CMD) coupons for each style were attached to a test frame oriented to 45 from horizontal and facing due south. Unexposed coupons were retained for control testing. After 30 days exposure, five specimens from each coupon were tested for tensile strength and elongation in accordance with ASTM D 4632. The exposed results were then compared to the unexposed test results and the percent strength retained was calculated. The results are shown in Table 1. Please note that Geotex 801 and 1601 are now called **MIRAFI** 180N and 1160N respectively.

Product	Percent strength retained		
Style	MD	CMD	Average
MIRAFI 180N	96	85	91
MIRAFI 1160N	90	89	90

Table 1: Results of 30-day outdoor exposure tests

Temperature stability

High temperatures

The mechanical properties of the fibers deteriorate as temperature increases, but polypropylene performs better than polyethylene in this respect. The softening point of polypropylene fibers is approximately 150 C (300 F), and the fibers "melt" at 165 C (329 F). The softening and melting points of polypropylene are determined in the way which crystallinity has been influenced during and after spinning. Shrinkage of polypropylene fibers depends greatly upon the treatment the fiber receives during processing. After 20 minutes of exposure to boiling water, monofilament yarns may shrink as much as 15%; multifilament and staple fibers only shrink between 0–10% (Cook, 1984). However, polypropylene exhibits a moisture regain of only 0.01–0.1 weight percent (Cox, 1994).

Flammability

Polypropylene is a hydrocarbon and will burn, but when exposed to open flames, the fibers melt and draw away from the flame, extinguishing itself. When tested in accordance with BS2963, polypropylene fabrics are self-extinguishing and therefore of low flammability, (as defined in BS3121). Construction, additives, finishes, and the presence of other fibers have a considerable influence on the burning characteristics of any particular fabric or structure. For the purpose of fire insurance, polypropylene fabric is included in the same class as wool (Cook, 1984).

Low temperature

The low temperature flexibility of polypropylene is excellent for most applications. Solmax polypropylene geotextiles retain normal flexibility from -40 C to 150 C (-40 F to 302 F). Below -40 F, polypropylene can become less flexible and not suitable for all applications.

Biological resistance

Insects

Polypropylene cannot be digested by insect and related pests, such as termites, dermestid beetles, silverfish, and moth larvae. Polypropylene fiber is not liable to attack unless it becomes a barrier beyond which the insect much pass to reach an objective. In this case, the insect may cut through the fiber without ingesting it. Furthermore, polypropylene does not attract nor is it a food source for insects or rodents. As stated earlier, much like humans, it is believed that rodents would not be adversely affected by ingesting small quantities of polypropylene.

Micro-organisms

Polypropylene fibers will not support the growth of mildew or fungi. Some micro-organisms, however, may even grow on the very small amount of contaminants which may develop on the surface of fibers or yarns in use. Such growth has no effect on the strength of any materials made from polypropylene fiber. Similarly, polypropylene is an inert resin which does not support or attract fungal growths and does not deteriorate due to fungal presence (Cox, 1994).

Chemical resistance

Polypropylene is inert to a wide range of chemicals. Its resistance and susceptibilities are similar to those of polyethylene, but its higher crystallinity tends to make it more resistant than polyethylene to those chemicals which degrade polyolefin fibers. There is no known solvent for polypropylene at room temperature (Cook, 1994). Extensive information on the chemical resistance of polypropylene shows that it is very resistant to acids and alkalis at room temperatures (Ahmed, 1994). For example, polypropylene is acceptable at room temperature for use with the following chemical concentrations (Table 2) which covers the entire measurable pH range (Cox, 1994).

Chemical (concentration)	pH level
Nitric aid (up to 39%)	1
Hyrdochloric acid (up to 37%)	1
Sulfuric acid (up to 96%)	1
Sodium Hydroxide (up to 70%)	14
Potassium Hydroxide (10%, 25%)	14

Table 2: Chemical resistance of polypropylene at various pH levels

However, polypropylene is vulnerable to the following substances: highly oxidizing substances (peroxide), concentrated nitric acid (> 40%), concentrated sulfuric acid, chlorosulphonate acid, pure halogen, certain chlorinated hydrocarbons (halogenated hydrocarbons), and certain aromatic hydrocarbons (Schneider, 1989).

Polypropylene does not show any tendency to develop surface cracks when subjected to stresses in the presence of detergents or other substances (Cook, 1994). Polypropylene is extremely stable chemically due to its structural properties from hydrocarbon construction. Extensive studies testing the chemical stability of polypropylene when exposed to hundreds of organic and inorganic chemicals have shown it to be highly stable against: acids; alkalis; aqueous solutions of inorganic salts; detergents; oils and greases; and gasoline and lubricants.

Actual test results are shown in Table 3, below.

Chemical	% change in mass per unit area*	
	23 C (73 F)	60 C (140 F)
Sulfuric acid (98%)	-0.2	-0.2
Nitric acid, fuming	-0.1	-
Sodium Hypochlorite (20%)	0.1	-2.1
Gasoline	4.8	6.6
Benzene	3.4	0.6
Xylene	7.0	0.3
Menthylene Chloride	5.5	1.6
Carbon Tetrachloride	13.5	0.9
Turpentine	9.5	10.5
Transformer oil	0.4	14.9

* The weight change as listed is due to the sum of the effects of swelling and dissolution.

Table 3: Physical effects of chemicals on polypropylene (Schneider)

In accordance with ASTM D543, Solmax has evaluated the chemical compatibility of our nonwoven geotextiles with JP4 jet fuel. A sample of Solmax **MIRAFI** 140NC (4.5 oz/yd^2 or 150 g/m^2) nonwoven geotextile was exposed to the fuel for 7 days at room temperature. It was then evaluated for retention of grab tensile properties in accordance with ASTM D4632. The results are as follows:

Product	Percent strength retained		
Style	MD	CMD	Average
MIRAFI 140NC	91.5	87%	89

Table 4: Results of JP4 fuel tests

Landfill leachate

Solmax has performed several studies on the compatibility of our polypropylene nonwoven geotextiles with leachates at various pH solutions commonly encountered in soil or solid waste applications. Since the evaluation of long-term chemical aging of nonwoven geotextiles is nearly impossible due to the inherent stability of the polymer, laboratory immersion tests were conducted at elevated temperatures (50 C [140 F]) to accelerate behavior. Variables such as temperature, moisture, and oxygen content were controlled in the lab and samples were removed at 30-, 60-, 90-, and 120-day intervals. The results of these tests are shown in Table 5 (Boschuk, 1993 and Narejo, 1995).

Property	Test method	% change after 120 days at 50 C (122 C)	
		MIRAFI 140NC	MIRAFI 1160NC
Grab tensile	ASTM D 4632	-0.88	-1.14
Trapezodial tear MD	ASTM D 4533	-23.79	54.82
Trapezodial tear CMD	ASTM D 4533	-16.28	-7.48
Puncture	ASTM D 3786	-8.42	-6.6
Permittivity	ASTM D 4491	-15.61	-7.46

Table 5: Results of chemical compatibility testing

Lifetime prediction

Using the assumption that kinetics double with every 10 C (50 F) rise in temperature, polypropylene embrittlement would not take place for 45 years in a 30 C (86 F) landfill under anaerobic conditions (Wheat, 1992). Since the first geotextile installation occurred in North America in 1958, it is not possible to demonstrate 100-year durability with ‘real-time’ success stories.

As a result, the Geosynthetic Research Institute (GRI) designed a series of four accelerated laboratory incubation protocols to demonstrate aging progression in polyethylene geomembranes. The 'durability' (i.e., the prevention of aging) of polyethylene and polypropylene is typically extended by manufactures by adding antioxidants to the resin during processing. This prevents oxygen from attacking the polymer itself. Since it is well established that the engineering properties are not reduced until the antioxidants are completely depleted, tests were conducted at GRI to measure the amount of time to initiate polymer degradation. Series III samples were exposed to water on top and air below with a compressive stress of 260 kPa (37.7 psi). This test series is intended to model leachate or surface water collection systems in a waste containment facility. Since polyethylene and polypropylene geotextiles behave similarly to the materials in this study, the predicted antioxidant lifetime at 25 C (77 F) for the specimens evaluated is approximately 120 years (Hsuan and Koerner, 1985).

In a separate study, properly stabilized polypropylene geotextiles have been estimated to have a functional longevity of nearly 200 years in an oceanic or marine application (Wisse & Birkenfeld, 1982).

Installation survivability

Nonwoven polypropylene geotextiles have higher puncture strength than polyester nonwoven geotextiles which make them very resistant to installation stresses and enhance their construction/installation survivability success.

Properties	Test method	MARV	
		MIRAFI PET	MIRAFI PP
Mass/unit area	ASTM D 5261	8.0	8.0
Puncture strength	ASTM D 4833	100 lbs	140 lbs
Mullen burst	ASTM D 3786	380 psi	440 psi

Table 6: Selected strengths of typical needle-punched nonwoven geotextile

The structure of the needle-punched, staple fiber nonwoven has also proven to be more resistant to installation damage testing, such as puncture than continuous filament spunbond nonwoven geotextiles. This is especially true for heat-bonded spunbond geotextiles which are rarely used in waste containment applications due to their thin structure, limited permittivity, and limited resistance to damage.

Conclusion

As previously stated, polypropylene is a very durable polymer commonly used in aggressive environments. Because of its excellent resistance to harmful chemical environments, the use of polypropylene to manufacture nonwoven geotextiles for waste containment systems is a beneficial use of this versatile polyolefin. Presently, needle-punched nonwoven polypropylene geotextiles are used in more than 80% of all waste containment applications. Current knowledge on available polymers points to polypropylene being the geotextile polymer of choice for the longevity of waste containment systems.

References

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