Review on chemical resistance of geosynthetic materials

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Abstract

Geosynthetic materials used in various applications such as retaining walls, transportation, waste landfill, roads, dam, canals, erosion control, steepened slopes, etc must maintain its inherent physical and mechanical properties when comes in contact with aggressive chemicals present in waste, soil, ores etc. In this paper, literature on chemical resistance geosynthetics have been searched and reviewed to study the effect of chemicals on different geosynthetic materials during use. Various ways adopted to enhance the chemical resistance of these materials have also been discussed in this review.

Key words:

Geosynthetics; Chemical resistance; Acid and alkali resistance

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1.0 Introduction

Geosynthetics is a growing field having worldwide application. These are polymeric products synthesized into planar materials used with geo materials like earth, soil, sand etc. for the applications such as roads, transportation, hydraulics, embankment, waste landfill, canals, erosion control, revetments, steepened slopes, etc. Based on its application, there are various key factors in selecting geosynthetic materials such as its tensile strength, water permeability, puncture resistance, slope stability, resistance to weathering etc. Besides this chemical resistance of geosynthetic materials is also important when these materials come in contact with extreme liquors of highly acidic and alkaline environment such as evaporation ponds, heap leaching, mining industry, and with cement. Different types of synthetic polymers such as polyester, polypropylene, polyethylene, nylon etc. are used in manufacturing of geosynthetics. The continuous exposure of polymeric material to non-standard solutions can cause oxidation and hydrolytic degradation of the polymers due to antioxidant depletion. During the degradation, polymer undergoes embrittlement, molecular weight reduction, free radicals generation, loss of additives and plasticizers, and transparency impairment. Some fibers are resistant to organic acids, esters, ketones, alcohol, inorganic acids and alkalis such as polypropylene, polyethylene due to its chemical inertness and stability as compared to other fibers. PET based geosynthetic materials are mostly used in construction of highway due to its high strength and low creep property compared to polyolefin's, however polyester fibers can hydrolyse in strong acids and alkali due to its weak chemical stability which cannot be neglected for the design strength of civil engineering applications.

In this review, we have searched and synthesized the current literature on chemical resistance of different geosynthetic materials when it comes in contact with solutions of different pH in various applications and different possible techniques to improve the properties of the material against it.

2. Geotextiles

Geotextiles are one of the major groups of geosynthetics. These are based on natural or synthetic fibers such as polyethylene, polypropylene, polyester and categorised as woven, non-woven or knitted textiles [1][2]. These are flexible and permeable in nature having good strength, good corrosion resistance, water permeability and better antibacterial property. Functions of geotextiles include surface erosion control, filtration, reinforcement, reverse filtration, isolation, protection, drainage, and separation.

Geotextiles are generally used to strengthen roadbed, slope protection, coast and river embankment, hazardous wastes treatment plant, railway, underground engineering, and mineral tailing pond. The characteristics of wastes in different applications are different. For example, acidic leachate solution is generated due to organic degradation of waste in landfill and broke down producing strong alkaline leachate solution changing pH value of waste leachate solution from pH 3 to pH 12 then pH 8 in 3 months [3]. Similarly in the softening process of aluminium oxide, sodium hydroxide was used as a dissolving agent from which alkaline liquid waste gets generated [4]. During the

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application, for filtration, protection, strengthening, isolation and drainage property, geotextiles came in direct contact with chemicals in soil or water solution which results in reduction of properties of geotextiles. Researchers throughout the globe have studied the effect of acid and alkaline solutions on geotextile materials.

H Y Jeon et al [3] studied the chemical resistance of eight nonwoven geotextiles based on recycled or normal polyester, polypropylene (PP) and their composites as given in table 1. Samples were immersed in different solutions such as pH 3, 8 and 12 and waste leachate solution for 180 days at temperature 25, 50, 80^{O}C respectively as per (Environmental Protection Agency) EPA 9090 Test Method for Chemical Resistance of FML (Flexible Membrane Liner). Tensile strength testing of treated samples was done with standard ASTM D4632 and average tensile strength retention was calculated to estimate chemical resistance behaviour. Figure 1 shows the average tensile properties retention of geotextiles immersed in different solutions.

Table 1 Composition of geotextile used in study [3]

Geotextile	Composition
GT-1	600 GSM needle punched with polypropylene staple fiber
GT-2	1000 GSM needle punched with polypropylene staple fiber
GT-3	600 GSM needle punched with recycle polyester staple fiber and carbon black
GT-4	1000 GSM needle punched with recycle polyester staple fiber and carbon black
GT-5	600 GSM spun bonded with polyester filament fiber,
GT-6	600 GSM polypropylene staple fiber and 400 GSM recycle polyester with carbon black
GT-7	1000 GSM sandwiching of recycle polyester fibers between two layers of polyester nonwoven geotextile

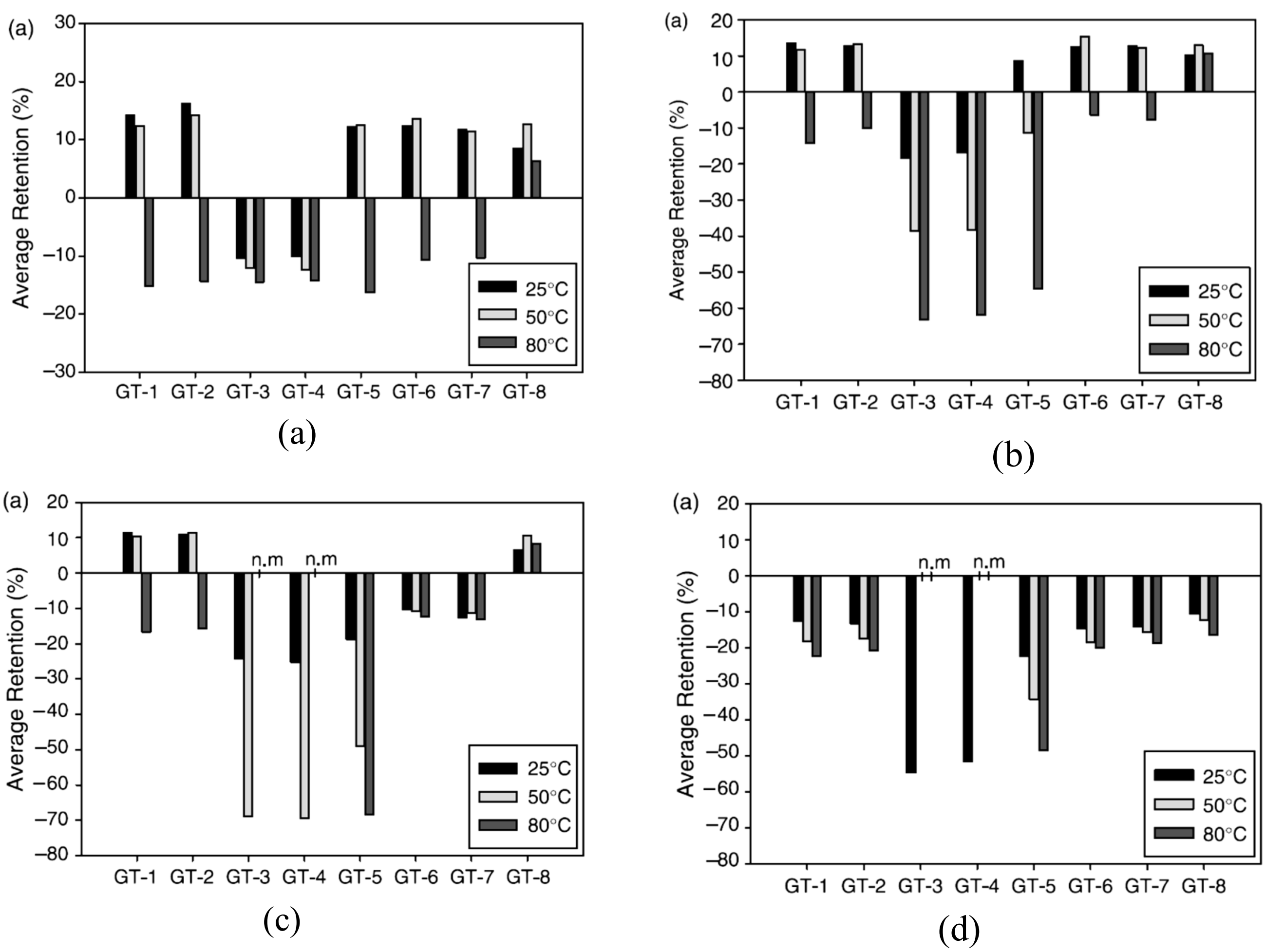
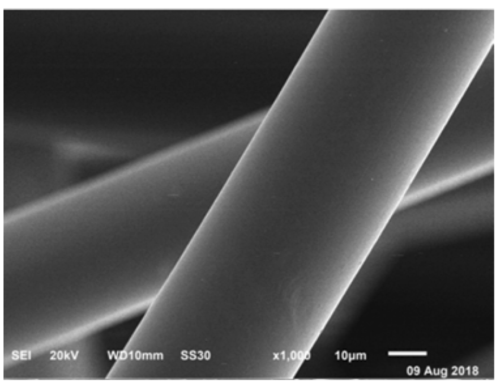


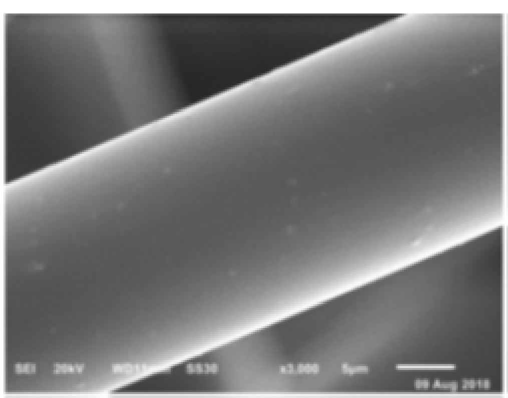
Figure 1 Average tensile strength retention of geotextiles in different solutions, (a) pH 3, (b) pH 8, (c) pH 12 and (d) waste leachate solutions [3]

In figure 1(a), GT-1–2 and GT-5–8 show increase of tensile strength at 25°C and 50°C but decrease of tensile strength at 80°C in pH 3 due to the reinforcement effect of physically absorbed water among fibers of geotextiles at low temperature. This effect reduces at high temperature due to the evaporation of water which leads to decrease in tensile strength. The samples GT-3–4 showed decrease of tensile strength at all temperatures due to thermal degradation and weak tensile properties of recycled fibers. Similar behaviour was seen with pH 8 solution except in GT-5 whose tensile strength decreased at 50°C temperature shown in figure 1(b). The strength of polyester geotextiles decreased due to hydrolysis effect in weak alkaline solution while PP geotextiles were more resistant to solution. GT-3–4 undergoes major reduction in tensile properties in pH 12 at all temperatures as shown in figure 1(c) as in presence of strong alkaline solutions, it undergoes hydrolysis. Similarly in waste leachate solution, there was reduction in tensile properties of all geotextiles, mainly GT-3–4 at 50°C and 80°C. The tensile properties of those samples were not measured because of severe damage of the specimens.

Y. Liu et al [4] in their study soaked the polypropylene and polyester geotextile with sulphuric acid and sodium hydroxide solution. SEM images of treated samples are shown in figure 2.



Polypropylene



Polyester

Figure 2 Surface structure display of geotextiles under electron microscope [4]

From the SEM image they showed that there are no corrosive characteristics on the surface of polypropylene filament while surface of polyester filament has been damaged with pit slot and corrosion.

However, all these literatures suggest that acidic and alkaline environment with extreme pH can degrade the properties of polyester geotextiles by hydrolytic degradation while PP geotextile properties are less affected. Gulec et al. in their study also showed that dipping of polypropylene geotextiles in AMD (acid mine drainage) for 22 months, did not lead to any major change in its hydraulic and strength properties [23].

Polypropylene has weak polarity, low surface energy and less hydrophilic property, due to which it shows excellent acid and alkali resistant property. While in case of polyester (PET), hydrolytic degradation takes place in acid and alkali solutions. Inverse reaction of the synthesis of PET is hydrolysis, in which H2O molecule split into hydrogen (H+) and hydroxide (OH-) ions of a long-chain linear molecule. Similarly there is breakage of an ester-bond in presence of acid and alkali solutions resulting in reduction of molecular weight of polymer. With hydrolytic degradation and chain length reduction, tensile properties of PET fibers reduced [5]. Hydrolytic degradation of PET geotextile can be improved by improving the chemical resistance of PET fibers.

K. Opwis et al [6] in their research modify the surface properties of PET by excimer-UV lamp irradiation to improve the alkali resistance of PET fabrics. PET fabrics were soaked in different reactive media such as diallylphthalate (DAP), cyclehexane-1,4-dimethanoldivinylether (CHMV), squalene and 1, 7 octadiene. The irradiation was done with monochromatic excimer UV light of 222 nm wavelength in an argon atmosphere avoiding a hydrophilization of the PET surface due to photooxidation with oxygen for 10 minutes per fabric per side. This causes homolytic bond breaking of polymer chains. The penetration depth of the UV light is only of a few micrometre, generating radicals only near the polyester surface due to the high absorption coefficient of PET at 222 nm. These radical species can recombine with same or neighbouring polymer chain. The radical species may react with present reactive compounds yielding products by grafting, addition or crosslinking to generate new surface properties which can protect inner polyester against hydrolysis.

Prepared samples were then treated with aqueous NaOH (25%) at 60°C for 90 min. Residual mass of irradiated sample after alkaline hydrolysis is shown in figure 3. The residual mass in an inert atmosphere without any reactive compound was about 37% compared to only 14% for the unmodified samples. This is due to photochemical decarboxylation yielding a lower content of carboxyl groups in the polymer surface, where the hydrolysis reaction starts.

In the presence of reactive media, weight loss is further improved showing improvement in alkali resistance of PET fabric.

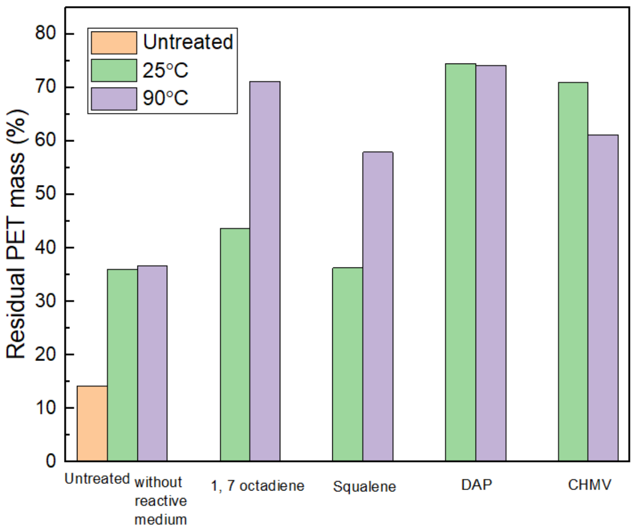


Figure 3 Residual mass of alkali treated irradiated PET fabrics [6]

C. H. Xue et al [7] in their research developed a superhydrophobic PET textile surface by chemical etching of the surface of fiber results in the self-cleaning property in the textile materials. They then coat the etched textile with polydimethylsiloxane (PDMS) and showed strong resistance of prepared samples to different pH solutions.

3. Geosynthetic Clay Liners (GCLs)

Geosynthetic clay liners are geocomposites consist of granular bentonite clay encapsulated between two geotextiles or bonded to a geomembrane. Bentonite is clay that swells by absorbing water thus having low hydraulic conductivity[1]. Different types of bentonites such as sodium bentonite and sodium activated calcium bentonite is used. Bentonites are mainly made up of smectite clay mineral montmorillonite, which is composed of thin crystal layers consisting of two silica tetrahedral sheets and one alumina octahedral sheets [31]. A trivalent Al present in the octahedral sheet is partially replaced with a divalent Mg or Fe resulting in a permanent charge deficiency [31]. These materials have high cation exchange capacity due to attraction of hydrated exchange cations such as Na+ and Ca+ by residual negative charge on clay surface results in swelling of bentonite clay [40]. The small size of montmorillonite particles leads to high specific surface area along with high swelling results in a low hydraulic conductive material that provides a tortuous path for water flow [29] and at the same time capable of adsorbing heavy metals [41]. Also, the hydraulic conductivity of GCL can be related with the swelling capacity of bentonite contained in it [31].

Geosynthetic clay liners (GCLs) are used in waste containment barrier systems such as municipal solid waste, heap leach pads, mining operations, acid mine drainage etc. due to their hydraulic performance, less cost, ease of installation, and self-healing properties to prevent contamination of groundwater and chemicals seepage and spills [29][38]. The performance of GCLs as a barrier may deteriorate due to direct exposure of leachates at waste containment facilities and mining solutions [9] because of insufficient swelling of bentonite clay in presence of chemical solutions at high temperatures. With increase in temperature, hydraulic conductivity of GCLs increases as viscosity of permeant changes with temperature and redistribution of intra and inter particle pores [13]. The effect of different types of chemicals on the swelling and hydraulic behaviour is different such as in case of Na-bentonites, higher charge cations such as Ca2+ or Mg2+ is exchanged with sodium, bentonites can become more permeable as its bulk swelling gets limited [42]. Swelling decreases with the increase in chemical solution concentration and so hydraulic conductivity increases [33]. Various studies were done to study the effect of chemicals in GCLs.

S. Ghazizadeh et al [8] in their study evaluates the internal shear behaviour of geosynthetic clay liners (GCLs) in presence of mine process solutions. Tests were conducted with three types of solutions, deionised water, copper mine process solution (Cu-PS, pH=1), bauxite mine process solution (B-PS, pH=12). GCL were treated with acidic and an alkaline solution for time duration of 1, 6, and 10 months and with deionised water for 6 months with a normal stress (σn) of 20 kPa on the treated specimens. These samples were then tested for displacement-controlled internal direct shear tests. Shearing was done with a horizontal displacement rate of 0.1 mm/min of approximately 70 mm at ambient room temperature. GCL specimens treated in B-PS and sheared under σn-s = 2000 kPa undergone a localized peak shear stress ranging between 320 kPa and 400 kPa is similar to the localized peak shear stress for samples hydrated in deionised water and sheared under σn-s = 2000 kPa. While for GCLs hydrated in Cu-PS showed a larger localized peak shear stress ranging from 600 kPa to 660 kPa when sheared under σn-s = 2000 kPa. This was due to an increase in the rigidity of the geotextiles and reinforcement fibers of the GCL along with treatment in Cu-PS.

Many researchers have improved the chemical resistance of GCLs by various methods. These methods include the use of chemical-resistant bentonites, hydrated bentonites before putting into chemical solutions and to limit bentonites with a higher effective stress [9]. Bentonites can be chemically modified with substituted alkyl ammonium cation, benzyloctadecyldimethyl ammonium to reduce its permeability as studied in ethanol water solutions [30]. Similarly, use of polymerized bentonite can reduce the hydraulic conductivity as intercalation of the polymer in the interlayer region of clay took place which helps in increasing its swelling properties. With the increase in polymer dosage, swell index and liquid limit increases as it can maintain the initial osmotic efficiency in the long term and can resist collapse due to double layer thickness of polymer treated bentonite [32].

N. Prongmanee et al. [11] studied the effect of geosynthetic clay liner with polymerized bentonite in presence of chemical solutions. The polymerized bentonite was synthesized by free radical polymerization of sodium acrylate. Potassium persulfate ((K2S2O8) was used as initiator. Neutral pH was maintained during the reaction. Initiator to monomer ratio was 0.2 with a monomer content of 10% of the mass of bentonite. Free swelling index (FSI) tests were performed on untreated and polymerized bentonite with different pH solutions as per standard ASTM D5890. Polymerized bentonite was then placed between non woven geotextile and woven geotextile to make GCL sample. A circular damaged hole was made to perform leakage test to calculate self-healing capacity of untreated and polymerized bentonite GCLs.

As shown in figure 4, free swelling index of polymerized bentonite is higher compared to those of untreated bentonite for all pH solutions. For acidic solution, the FSI value of untreated bentonite (UB) reduced significantly as compared with value in deionized water, while in case of polymerised bentonite (PB), reduction is mild. This is due to the carboxylate group in the Na-PAA, which can partly balance the hydrogen ion and reduce the effect of pH on the FSI. For the alkaline solutions, the FSI value of the UB continuously decreased with increasing pH is due to increase in Na+ ions in the solution. However, with increase in pH the FSI value of PB was increased. This enhanced swelling was due to the repulsive force between the anionic functional group present in the Na-PAA [12]. The estimated values of the self-healing ratio (α) after leakage rate test are shown in figure 5. There was slight lowering of α values of UB-GCL as compared to those of the PB-GCL in the pH range of 3 to 11 while it is significantly lower for pH of 1 and 13

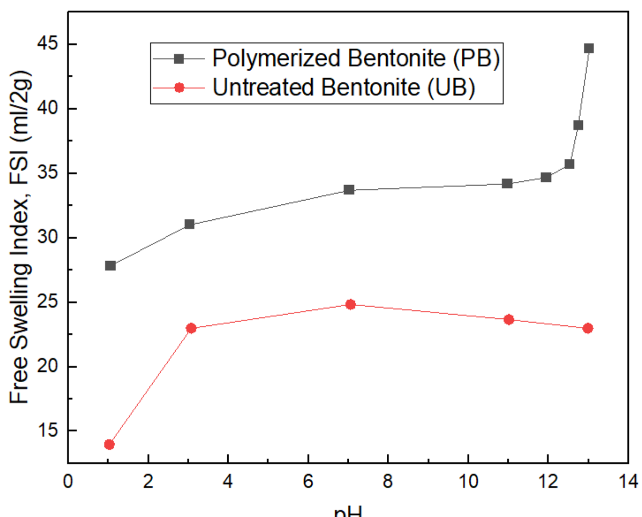


Figure 4 FSI versus pH of the untreated bentonite and the polymerized bentonite [11]

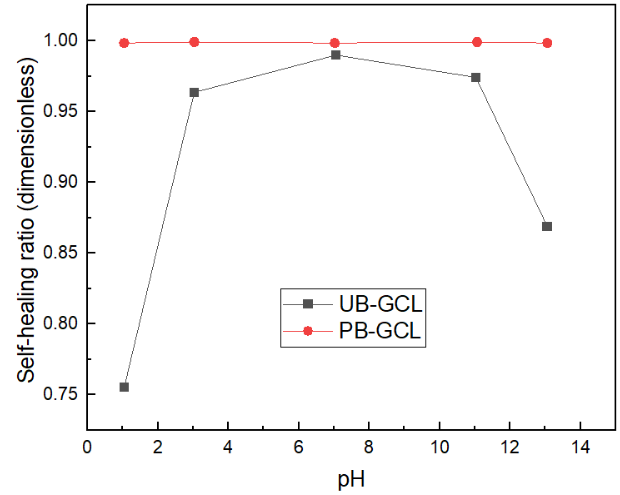


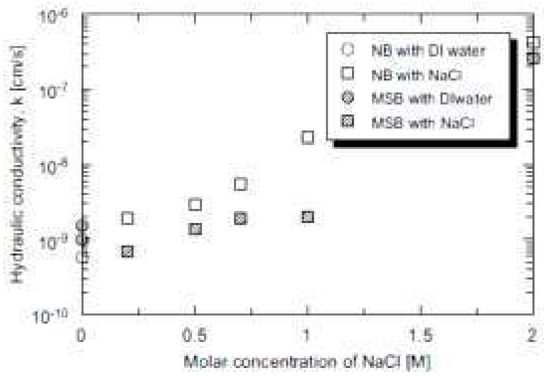
Figure 5 Results of self healing ratio at different pH [11]

T. Katsumi et al. [9][27] evaluate the barrier performance of two types of bentonites i.e., natural bentonite (NB) and (b) multiswellable bentonite (MSB) against NaCl solution, two types of GCLs i.e., geosynthetic clay liner (GCL), and (d) dense prehydrated geosynthetic clay liner (DPH-GCL) against CaCl2 solution. In multiswellable bentonite, propylene carbonate (PC) was present which activates the osmotic swelling. Granular bentonite was loosely packed in a mould for test as per the standard ASTM D5084.

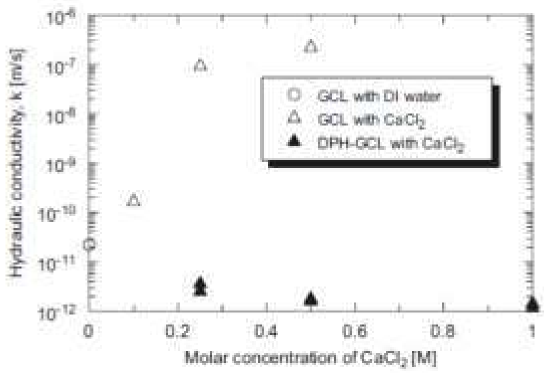
The hydraulic conductivities of both bentonites are shown in figure 6a. The hydraulic conductivity of natural bentonite increased continuously with increase in NaCl solution concentration while that of multi swellable bentonite is low up to molar concentration of 1.0 M, i.e, k < 1.0×10-9 cm/s and becomes identical to NB with 2.0 M molar concentration. This is due to the swelling of propylene carbonate (PC) present in MSB as propylene carbonate can forms hydrogen bonds with the external cations and thus the space between adjacent clay layers can be expanded. The osmotic swelling ratio of bentonite was activated by MSB in fresh water and electrolytic chemical solutions.

The nonprehydrated GCL shows increase in hydraulic conductivity value with increase in CaCl2 concentration as shown in figure 6b. While prehydrated DPH-GCL shows extremely low hydraulic conductivity values for the CaCl2 solutions at all tested concentration level. This is due to prehydration effect and the consolidation effect of bentonite, as prehydrated bentonite helps to improve the hydraulic conductivity performance of CaCl2 chemical solutions. .

Similarly GCLs with different bentonite have different hydraulic conductivity values when used to absorb bauxite liquor from aluminium refinery. Three types of bentonites were conventional granular sodium-bentonite, conventional powdered sodium bentonite and bentonite-polymer composite. Samples were first hydrated with water content of 100% with 2500 mg/L NaCl solution and then bauxite



(a)



(b)

Figure 6 Hydraulic conductivity of (a) NB and MSB, (b) GCL and DPH-GCL [9][27]

liquor was permeated. Hydraulic conductivity of granular bentonite based GCL raised immediately with a final hydraulic conductivity of 5.0x10-10 m/s due to suppression of swell of bentonite. While powdered bentonite based GCL had lower hydraulic conductivity (1.8x10-11 m/s) despite little swelling of the bentonite due to precipitation of aluminium complexes in the fine pores of the powdered bentonite. In case of GCL with sodium polymer composite, hydraulic conductivity was very low (1.0x10-12 m/s) due to polymer hydrogel clogging intergranular pores, but eventually increased to 1.3x10-10 m/s due to larger intergranular pores mainly due polymer coming out from the pore space.

C. H. Benson et al. [28] conducted tests of hydraulic conductivity on two GCLs having powdered Na-bentonite treated with a additive with different dosages to decrease the effect of chemicals alterations during tests. Permeant liquid used in the test were 1.3 mM CsCL solution, a mixture of 1 M NaOH and 1.3 mM CsCl and DI water. The hyperalkaline solution of NaOH and CsCl was prepared with pH similar to leachate from aluminium refining operations. As bentonite is highly soluble in NaOH solution, CsCl salt was added to decrease its dissolution. Treatment in CsCl solution decreased the hydraulic conductivity of both GCLs by 1.5-1.8 as low ionic strength of CsCl solution enters the pores of bentonite leading to its increased osmotic swelling. However, such decrease in hydraulic conductivity values does not have major practical impact on GCLs. While in case of treatment with NaOH–CsCl solution, hydraulic conductivity of both GCLs rise moderately which then levels off or reduces slightly. This rise in hydraulic conductivity is due to high ionic strength of permeant solution which reduces the osmotic swelling of interlayer and dissolves the minerals present in bentonite clay. However, levelling off and slight decrease is associated with packing of pore spaces that overcome the effect of mineral dissolution. In this study, additive dosage had no significant impact on hydraulic conductivity of two GCLs but it affects the reaction occurring in GCLs during permeation as higher dosage causes greater buffering of pore water.

4. Geogrid

Geogrids are planar grid structures made from polymers with cross over points called junctions. Based on load carrying capacity, geogrids are mainly classified as three types uniaxial, biaxial and triaxial. In uniaxial geogrids, there is high orientation in one direction due to its stretching in one direction during manufacturing only thus used in mechanically stabilized earth walls. Biaxial geogrids have tensile strength in both directions as it was stretched in machine as well as in cross machine direction. Triaxial geogrids have properties in multi direction due to its triangular structure. These materials have high level of in-plane stiffness making its use in base course reinforcement [1].

The aperture of geogrids can interlock with soil or other earth materials thus act as a reinforcement material. These are widely used in transportation, infrastructure, and structural applications [14]. Geogrids are made from polyester, high-density polyethylene or high-density polypropylenes. High-density polyethylene (HDPE) geogrids have been used in civil engineering in soil structures such as embankments, walls, slopes and in landfills with a long-term perspective of 120 years of design life of structures [15]. The acidic or alkaline soils or waste presents in landfills can chemically affect the geogrids. Depending on the type of chemical compound, change in the polymer structure takes place. The chemical degradation is affected by the service temperature [19], pH and mechanical stress [20].

A. Kiersnowska et al. [15] compared the mechanical properties of two HDPE geogrid samples, one is new and other is aged for 20 years in a landfill and exposed to changing weather conditions. Tensile strength of aged sample changed slightly from 60.99 kN/m to 48.92 kN/m and no difference in the FT-IR spectra of both the samples which indicates strong chemical resistance of HDPE geogrid as HDPE are non-polar in nature.

S. S. Yeo et al [18] studied the tensile creep behaviour of PET and HDPE geogrid and showed that PET is better than polyethylene and polypropylene in terms of creep resistance. Polyester geogrids undergoes less creep deformation than high density polyethylene geogrids under the same tensile strength. Polyester geogrids undergoes primary as well as tertiary creep, while in case of high density polyethylene geogrids, primary, secondary, and tertiary creep were there before rupture. Furthermore, the strain rate of the primary creep does not depend on the applied loads for the polyester geogrid, while it increased exponentially for the high density polyethylene geogrid. Althrough polyester material has high mechanical strength and better creep property, its strength reduces in presence of chemicals as polyester easter group gets hydrolyzed in it. PET yarn can be coated with resin such as acrylic or polyvinyl chloride to improve its chemical resistance property.

H.Y. Jeon et al. [17] studied the effect of polymer intrinsic viscosity and coating material on the chemical resistance of geogrid. Samples were exposed to NaOH solution with pH 13 and a Ca(OH)2 solution with pH 12.6 at different pH and temperature conditions for four months. Geogrid prepared with high IV (0.91) polyester yarn was labelled as TG 2 and with low IV (0.80) polyester yarn having similar carboxyl end group was labelled as TG 5. Figure 7 shows the tensile strength retention of polyester high-performance yarn and found that chemical resistance of polyester yarn prepared with high IV is higher than that of polyester prepared from low IV chips. It was due to less polymer hydrolysis from high IV polyester chips, thus offering high chemical resistance.

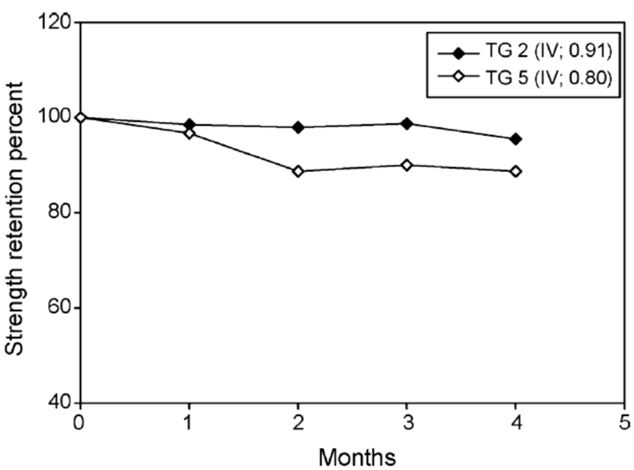


Figure 7 Strength retention percentage of polyester high-tenacity yarn [17]

To study the effect of coating material, two types of textile geogrids were taken, i.e, PVC coated geogrid labelled as TG 6 and acrylic coated geogrid labelled as TG 7. As shown in Figure 9, in presence of high alkaline solution of NaOH with pH 13, there was 40 and 100% tensile strength reduction at 23 and $50^{o}C$, respectively for acrylic coated geogrid, while for PVC coated geogrids have tensile strength reduction of 25 and 70% respectively. In presence of NaOH solution of pH 9, there was only slight change as shown in figure 8. In case of Ca(OH)2 solution, tensile strength reduction of acrylic coated geogrid was 15 and 5% at $50^{o}C$ and $23^{o}C$ irrespective of pH, while there was no change in strength observed for PVC coated geogrids. This shows that both coating are more stable in calcium hydroxide solutions than to sodium hydroxide at higher pH value. Also strength retention in case of PVC coated geogrid material is more than that of acrylic coated geogrid material.

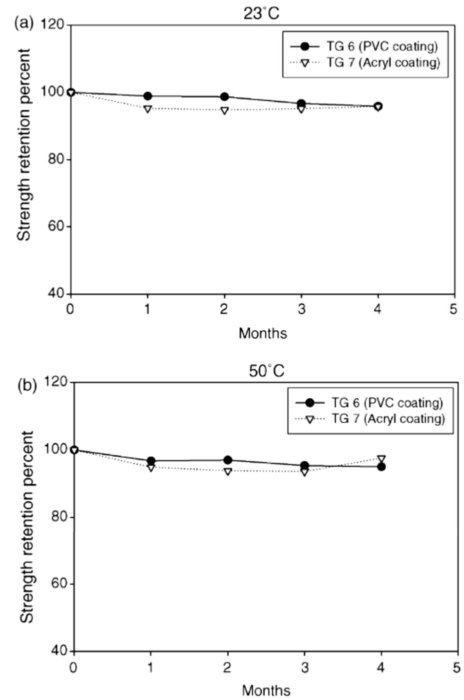


Figure 8 Strength retention percentage of geogrid with coating at pH 9, NaOH solution [17]

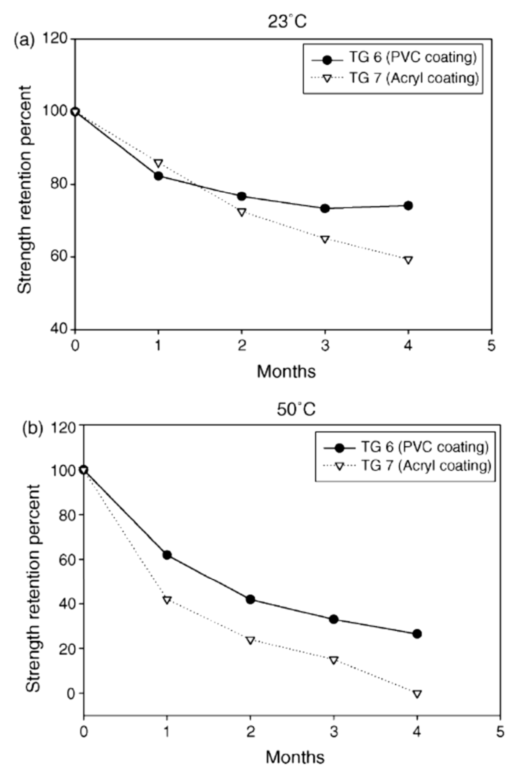


Figure 9 Strength retention percentage of geogrid with coating at pH 13, NaOH solution [17]

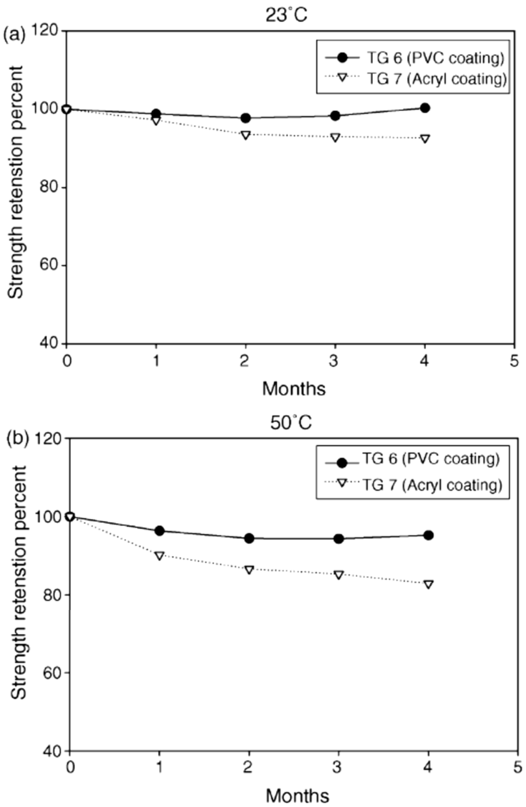


Figure 10 Strength retention percentage of geogrid with coating at pH 9, Ca(OH)2 solution [17]

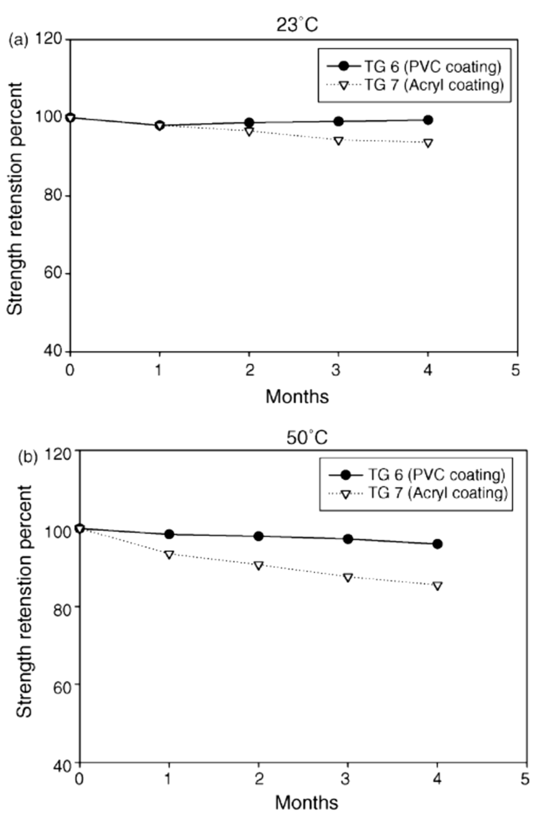


Figure 11 Percent strength retention of geogrid with coating at pH 12.6, Ca (OH)2 solution [17]

Similar study was done by V Elias et al. [5] in which there is no significant change observed in geogrid specimen coated with PVC when treated in severe conditions, i.e. in distilled water at T = $80^{O}C$ for 145 days and in an aqueous NaOH solution with a pH = 12 at T = $50^{O}C$ for 134 days. This shows that weight loss and surface erosion rate due to alkali hydrolysis can be reduced by PVC coating.

5. Geomembrane

Geomembranes are polymeric sheet which are impervious largely used as fluid barriers. These are mainly prepared with polyvinyl chloride and high density polyethylene polymer extruded either as flat sheet or as a tube which then split in the machine direction. These sheets are then prepared by calendaring or spread coating. It can also be prepared by treating a geotextile with asphalt, or as multi-layer bitumen composites. The raw material used in its preparation can be a plastic, a rubber or both [1][37].

Geomembranes are used as main components in mining facilities include base liners for heap leaching pads, tank liners, control and mitigation of acid mine drainage (AMD) from tailings or waste rock dumps. The dual action of acids and temperatures upto $70^{O}C$ on an exposed geomembrane surface can soften, swells or wrinkles the materials which can create problems in high density polyethylene liners in concrete basins. This softening of HDPE and other polyolefin liners occurs due to organic component absorption from solvent extraction process solutions that used in uranium and copper ore extraction. Cracks may also generate along heat affected areas which is difficult to repair [22]. Geomembranes when used in waste leachate can also be degraded by oxidation of polymeric material by free radical polymerization. The oxidative degradation took place in three steps, a) Reduction in antioxidants present in geomembrane formulation, b) Onset of degradation, c) Degradation to failure [43]. Depletion of antioxidants took place by its chemical reaction with oxygen, alkyl peroxides, free radicals, and physical loss by diffusion. H. P. Sangam et al conducted tests to observe the reduction of antioxidants from high density polyethylene geomembranes by exposing the samples to water, air and municipal solid waste leachate. They found that antioxidant depletion is faster in waste leachate, then in water and least in air. They estimated the life of geomembrane of atleast 40 years when used as a solid waste landfill primary liner at temperature $33^{O}C$ and over 150 years at a temperature of $13^{O}C$ [36].

Groundwater or surface water quality around the mine sites was determined by pH and metal concentration from acid leachate or AMD from waste rock dumps. Gulec et al. [23] compared the antioxidant recuction rates of high density polyethylene geomembranes after immersion, in synthetic AMD and municipal solid waste MSW leachate. Their work revealed that the antioxidant reduction rate for AMD exposure was two to four time lower than that of MSW leachate. Thus, geomembranes were found to be short term degradation resistant when comes in contact with AMD liquids. Similar study was done by S. B. Gulec et al. in which high density polyethylene geomembrane was dipped for 22 months in synthetic AMD, acidic water, or deionised water at 20, 40, and 60°C and indicated resistant to acidic mine waste liquids for short term [21]. Geomembranes present in different environment behaves differently as shown in a study by G.R. Koerner et al. [34] in which they have measured temperature of geomembrane in dry and wet landfills for a longer duration of 10.5 years. In dry landfills, liquid flow was minimized while wet landfill was filled with waste at high moisture content. They found that in case of dry landfill temperature of geomembrane covers maintains at constant temperature of 20^{O}C for a long period of 5.5 years and then increases to 30^{O}C after 6 years with slightly increase afterwards. While in case of wet landfill, initial temperature of geomembrane covers is slightly higher, i.e, 25^{O}C to 28^{O}C than that of geomembrane cover in dry landfill and then increases gradually with the final temperature of 41^{O}C to 46^{O}C. However, temperature of liner in geomembrane remains intact. Such data helps in prediction of life time of geomembrane when present with different chemical conditions [34].

6. Geopack

Geosynthetics packs are high strength geotextile bag like structures used for weak ground reinforcement for shore protection. H.Y Jeon et al. [26] prepared two geosynthetic pack by using PET and basalt woven mat. Samples were tested for chemical resistance in solution with pH 4 and 10 at temperature 25 and 50°C for 180 days by EPA 9090 Test Method. Basalt mat showed excellent chemical resistance as its tensile strength did not changed. However, strength of polyester mat lowered significantly at high pH and high temperature, while did not change with acidic pH.

7. Geocomposites

The combination of geogrids, geonets, geotextiles or geomembranes forms geocomposite structures. These structures are prepared by adhesive bonding, heat lamination, stitching and welding [1]. These materials can be effectively used as water and soil conservation, waste landfill applications, barriers [35] etc.

T.T. Li et al. [24] designed woven/nonwoven hybrid geotextiles for improving performance. Nylon fabric with different areal density was used as layers on both sides. In between two nylon fabric layer, three types of interlayer are enclosed, i.e., glass fiber plain weave fabric, a glass fiber grid, or 3D mesh fabric. This three layers composite was prepared with needle punch processing technology. When composed of a 3D mesh fabric as the interlayer, the proposed woven/nonwoven hybrid geotextiles had better chemical resistance. The use of a 3D mesh fabric as the interlayer with the needle punched composite geotextiles provides the highest tensile resistance, puncture resistance. This allows the hybrid geotextiles to stabilize water and conserve soil in adverse conditions.

H.Y. Jeon et al. [25] developed PVA geotextile/HDPE geomembrane composites for waste landfill application with improved frictional property, chemical and ultraviolet stability etc. The developed composite was compared with polypropylene and polyester geotextile based geocomposites. Polyester is better to polypropylene in terms of mechanical performance but may cause degradation when exposed to acid or alkali in higher temperature due to hydrolysis while polypropylene based geotextiles are more efficient in long term performance but when exposed to alkali and ultraviolet in high temperature, they also decompose. Prepared samples were immersed in different solutions of pH 3, 12 and 8.4 (leachate) at different temperature and found that strength retention of PVA geotextile based geocomposite is better that polypropylene and polyester based geocomposites. In this study the tensile strength of polyester geotextile based geocomposite was less than polypropylene geotextile based geocomposite.

8. Conclusion

Polyester is superior to polypropylene and high density polyethylene (HDPE) in terms of mechanical performance as it has high-tensile strength and excellent creep properties but due to its weak chemical stability and the breaking of the ester group, its mechanical properties easily detoriates. All these literatures conclude that acidic and alkaline environment with extreme pH can degrade the properties of polyester based geosynthetic materials by hydrolytic degradation while polypropylene and high density polyethylene (HDPE) based geosynthetic materials are less affected and show more resistant to chemical solutions due to its weak polarity, low surface energy and less hydrophilic property. The effect of chemicals on degradation of geosynthetic materials is increased with the increase in temperature, chemical concentration, time, stress and presence of ultraviolet light in the environment. Various methods have been proposed by different researchers to improve the chemical resistance of polyester based geosynthetic materials significantly such as surface modification of polyester by excimer-UV lamp irradiation, chemical etching of fiber surface and then coating with polydimethylsiloxane (PDMS) for preparation of superhydrophobic polyester textile surface with self-cleaning property, polyvinyl chloride or acrylic coating, use of high IV polyester chips for preparation of polyester based geosynthetic materials. With respect to geosynthetic clay liners, hydraulic conductivity increases in presence of chemicals due to the increased swelling of bentonites. Use of chemical-resistant bentonites, hydration of bentonites prior to chemical solutions and confinement of bentonites with a higher stress in GCL are some of the ways to enhance the chemical resistance of GCLs. Hybrid geotextile with 3D mesh interlayer and PVA geotextile/HDPE geomembrane composite are some of the new designs proposed by researchers to enhance the chemical resistance of geosynthetic materials.

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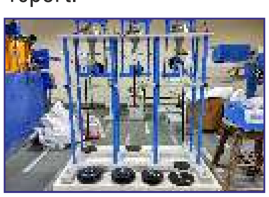
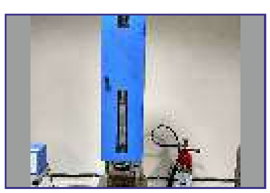
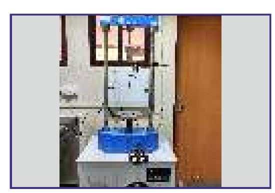
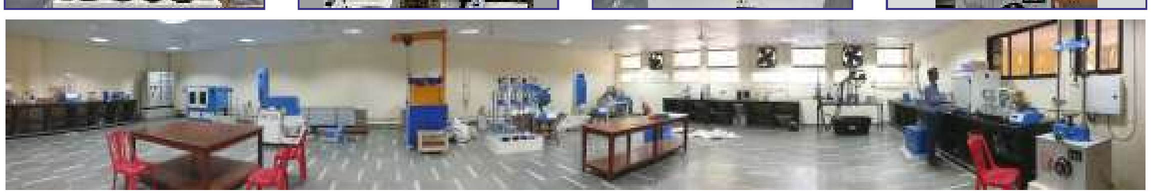
Installation Damage of Geosynthetics

The geosynthetics are prone to some amount of damage during their installation. To assess the quantity of the installation damage, a standard method was initially developed by Watts and Brady of the Transport Research Laboratory in the United Kingdom. The procedure has also discussed in the ASTM D 5818 with similar requirements. We are at BTRA doing the test following same ASTM D 5818 method followed by respective tensile strength. For the time being we are using the construction site for the sample preparation. If customer will agree, BTRA will collect the sample from site after standard procedure and provide the report.









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