TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

Department of Material and Environmental Technology

DURABILITY OF GEOSYNTHETICS IN ESTONIAN ROAD CONSTRUCTION

THESIS TITLE IN ESTONIAN
Eesti teedes kasutatavate geosünteetide vastupidavusuuring

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare, that I have written this thesis independently.

No academic degree has been applied for based on this material. All works, major viewpoints and data of the other authors used in this thesis have been referenced.

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THESIS TASK

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Thesis topic:

(in English) DURABILITY OF GEOSYNTHETICS IN ESTONIAN ROAD CONSTRUCTION
(in Estonian) Eesti teedes kasutatavate geosünteetide vastupidavusuuring

Thesis main objectives:

1. Data analyzation and evaluation of geosynthetics material used in Estonia.
2. Forecasting performance of environmental condition on mechanical properties.
3. Clarify main durability aspects of geosynthetics.

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Literature review of geosynthetics	01.05.2018
2.	Finalization of experimental work	14.05.2018
3.	Analysis of experimental results and compiling the report	22.05.2018

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PREFACE

This thesis topic has been purposed and suggested by the faculty of Technology of Wood, Plastic and Textiles department. The research material has been provided by ministry of road department and the experimental work has been carried out in Lab of materials and environment (Plastic and textile laboratory). The main inspiration came from the family members and friends, while the technical assistance has been provided by Prof Andres Krumme and the supervision assisted by Dr. Viktoria Vassiljeva. This thesis work has been dedicated to all supporting staff members of Laboratory of Polymers and Textile Technology of TTU which remains connected and provide guidance in order to achieving this mile stone.

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATION	SYMBOLS
GTP	Geotextile related product
MD	Machine direction
CMD	Cross machine direction
PE	Polyethylene
PP	Polypropylene
HDPE	High density polyethylene
LDPE	Linear density poly ethylene
LLDPE	Linear low-density poly ethylene
MDPE	Medium density poly ethylene
PS	Poly styrene
EPS	Expendable polystyrene
PA	Poly amide
PET	Poly ethylene terephthalate
CBR	California Bearing Ratio
BRR	Base course reduction ratio
TBR	Traffic benefit ratio
CH_3	Methyl
$TiCl_3$	Titanium chloride
$MgCl_2$	Magnesium chloride

INTRODUCTION

The purpose of the topic “DURABILITY OF GEOSYNTHETICS IN ESTONIAN ROAD CONSTRUCTION” is to organized a mechanism which can investigate the importance of the factors relevant to existing materials used in Estonian road construction.

Twenty different materials have been provided for data analyzation and evaluation for the setting up significance of standard quality control. The precautionary step has been carried out at every stage of research work in order to make sure the informative appraisal equipped with features.

The selective methods and condition has been studied vastly to understand the mechanism between the selection to end use characteristics of “GEOTEXTILE” and “geogrids” products for road construction. The European standard for “geotextile and geotextile related product- characteristics required for use in road construction of roads and other trafficked areas” were followed generally with the normative individual references. The product mostly application relevant to provide reinforcing as a primary characteristic with incorporation of road structural layers. The universal wide-width tensile test method has been chosen as it would be recommended with the reinforcement mechanism. As the environmental condition is composed of factors which can relates to durability below to ground are as follows resistance to aggressive media (Acid and alkaline solution), Thermal temperature, oxidation and hydrolysis, heat treatment, Short and prolonged exposure to temperature and elevated condition. All the necessary condition was taking into the test procedure while creating artificial aging mechanism. The samples initial and final condition is pre-accessed before and after the comparison of residue for evaluation of the results. The analysis is vital for the geosynthetics evaluation since the development history for geotextile consist of 25 years and for geogrids 16 years. The pre-assessed data will be helpful for the all relevant departments from manufacturer to end user because it will be overcasting the materials behavior in terms of service life.

1 LITERATURE OVERVIEW

1.1 GEOSYNTHETICS

In the past four decades, extended development has taken place within the space of geosynthetics and their applications. Geosynthetics are currently Associated with applied science of construction material and have distinctive characteristics like all alternative construction materials such as steel, concrete, timber, etc. This chapter provides a general description of geosynthetics including their basic characteristics and producing processes. [1].

The term 'Geosynthetics' has two sections: the prefix 'geo', alluding to an end utilize related with enhancing the execution of structural building works including earth/ground/soil and the postfix 'synthetics', alluding to the way that the materials are only from man-made items, system or structure. [1].

1.1.1 CLASSIFICATION OF GEOSYNTHETICS

The most common synthetic products categorized in the following [1]

- Geotextile
- Geogrids
- Geonets
- Geomembrane
- Geo composite.

Geotextile consist of polymeric textile product in shape of flexible sheet. According to further classification on the basis of manufacturing process are [1]

- Woven geotextile
- Nonwoven geotextile
- Knitted geotextile
- Stitched geotextile

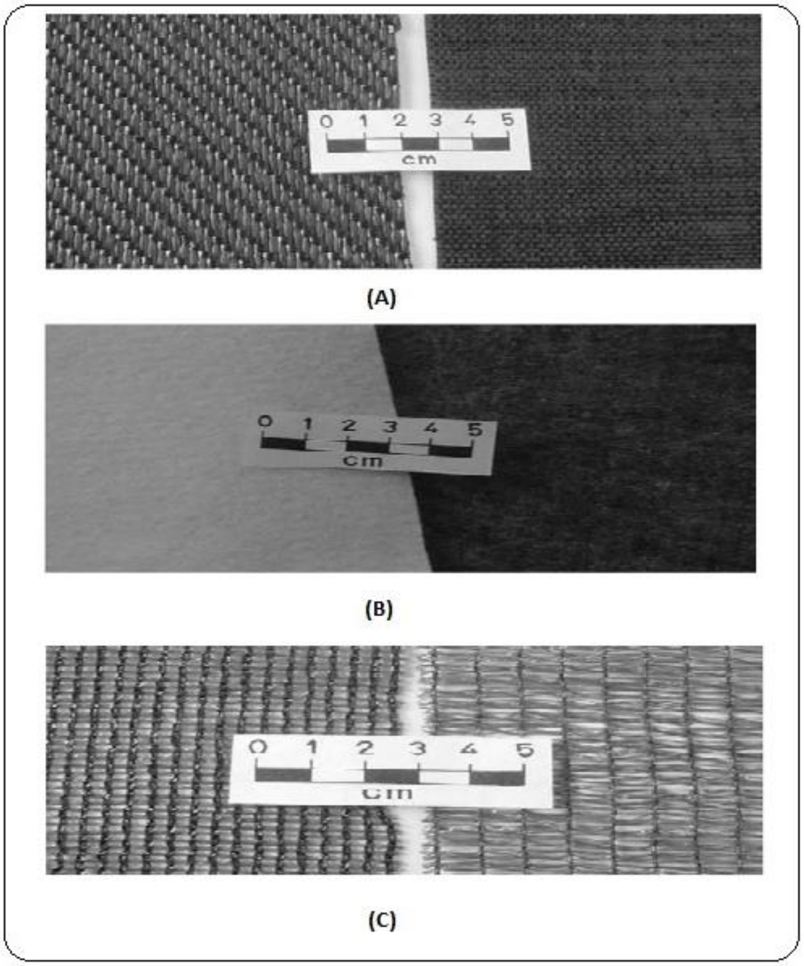

Figure 1.1 (a) woven geotextile (b)non-woven geotextile (c) knitted geotextile

Geogrids are polymeric materials and the formation consist of intersecting element(ribs) joined at the junction like mesh planner product. The further types of geogrids are as follows [2]

- Uniaxial geogrids
- Biaxial geogrids
- Bonded
- Woven

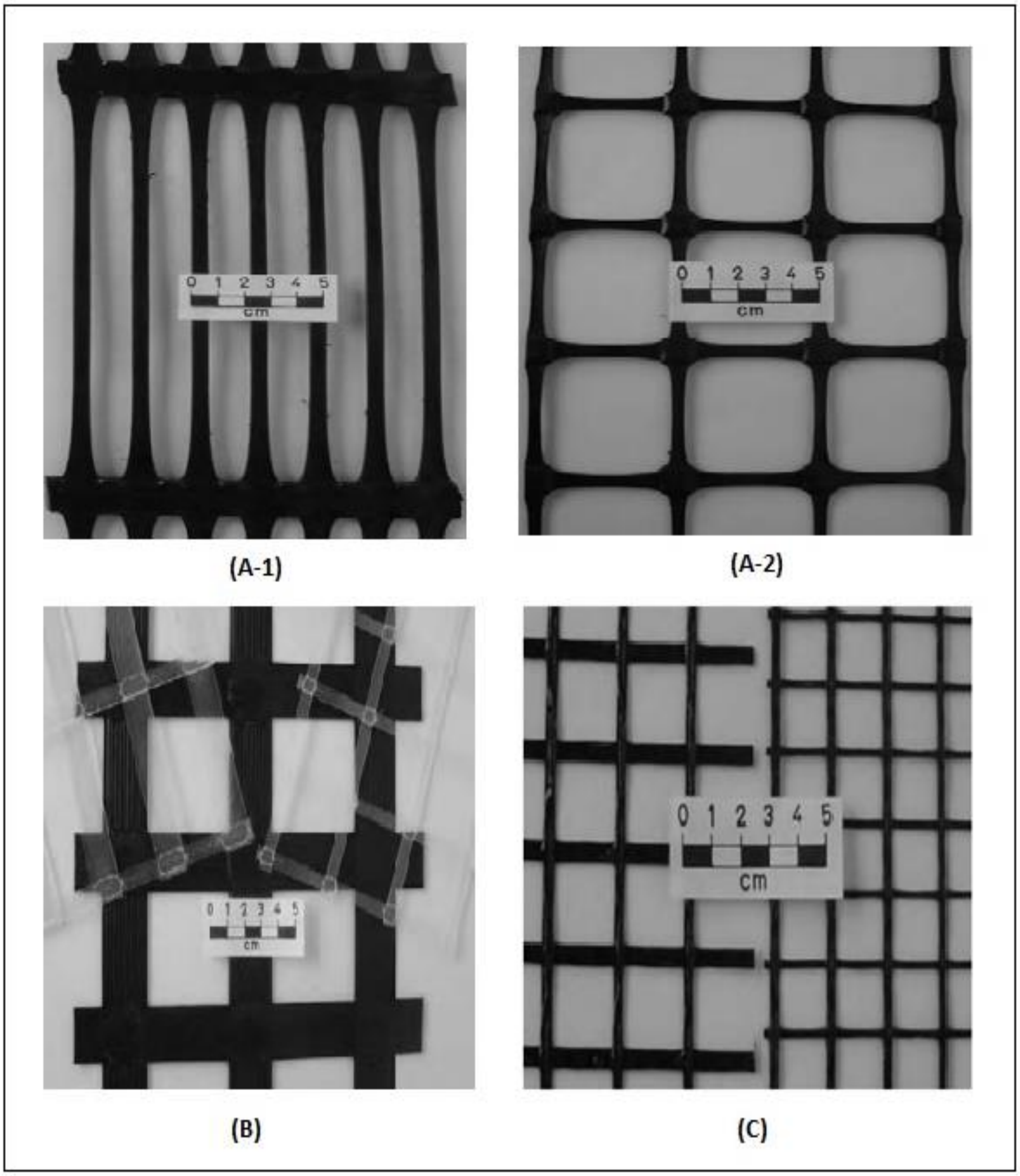

Figure 1.2GEOGRID (A-1) uniaxial (A-2) biaxial (B) bonded (C) woven [2]

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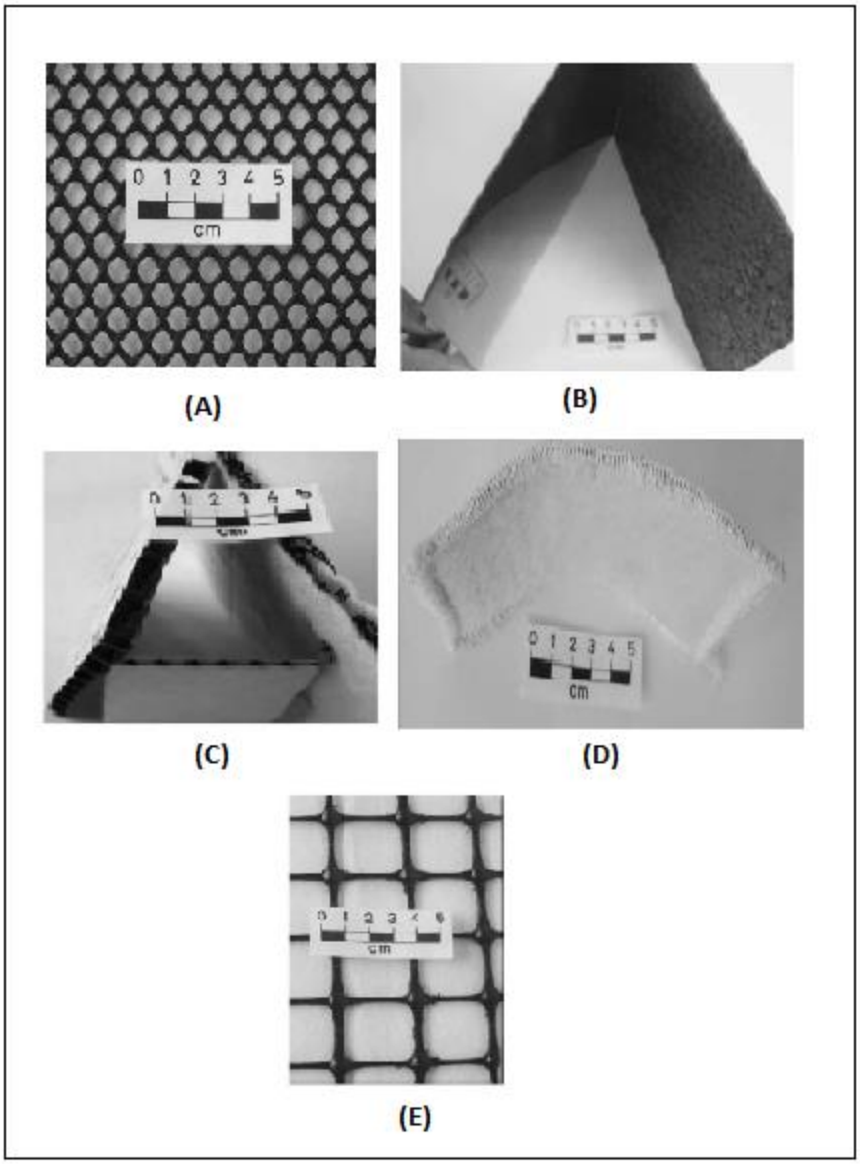


FIGURE 1.3 (A) GEONET (B) GEOMEMBRANE (C) REINFORCED DRAINAGE SEPARATOR (D) DRAINAGE COMPOSITE (E) GEOSYNTHETIC CLAY LINER [2]

Geonet is a type of planer polymeric product consisting of integrally ribs of parallel sets overlying with an angle [1] .

Geomembrane is a type of planer, moderately impermeable which consist of synthetic sheet manufactured from low permeable materials as a barrier or linear to control flow migration [1].

Geo-composite the term specifically applied to the product which has been assembled or manufactured in form of lamination or composite of two or more material in which existing one material preferably geosynthetic [1].

There are various geosynthetics accessible today, including networks, lattices, nets, cross sections, and composites. which are in fact not materials; be that as it may, they are utilized as a part of the blend with or set up of geotextiles. Every single such item is regularly called geotextile-related product (GTP). Some basic GTP and different sorts of geosynthetics are quickly portrayed underneath [1]

Geocell is a type of geosynthetics in which the assembling formation taken place with the help of geogrids and special bodkins couplings in triangle or square shape in terms of three dimensional, permeable, polymeric honeycomb and web structure. [2]

Geofoam A polymeric material made by the use of the polymer in the semi-fluid frame using a frothing specialist to have a lightweight material in chunk or piece shape with high void substance for use as lightweight fills, warm protectors, and waste channels. [2]

Geomat A three-dimensional, porous, polymeric structure made of coarse and unbending fibers fortified at their intersections used to fortify foundations of vegetation, for example, grass and little plants and broaden the disintegration control cutoff points of vegetation for lasting establishment [2]

Geomesh A geosynthetic or geonatural for the most part with a planar woven structure having substantial pore sizes, which fluctuate from a few millimeters to a few centimeters for use in principally disintegration control works. [2]

Geopipe A plastic pipe (smooth or creased with or without apertures) set underneath the ground surface and in this manner refilled. [2]

Geospacer A three-dimensional polymeric shaped structure comprising of cuspidate or ridged plates with expansive void spaces. [2]

Geostrip A polymeric material in the form of a strip. [2]

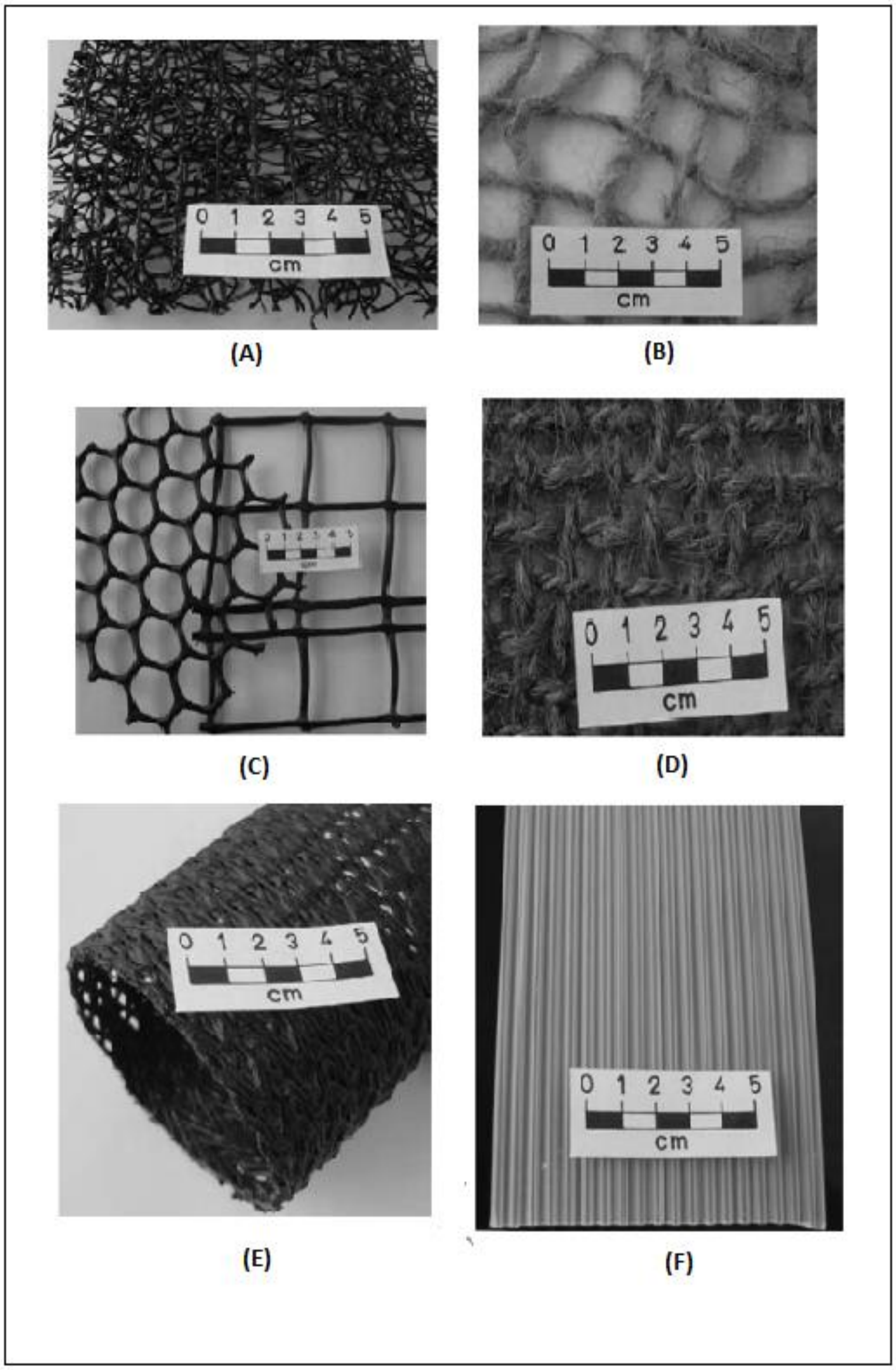


Figure 1.4 (a) GEOMAT (b) geo-mesh plastic (c) geo-mesh woven coir (d)geo-mesh jute coir (e)Geopipe (f)geospacer [1]

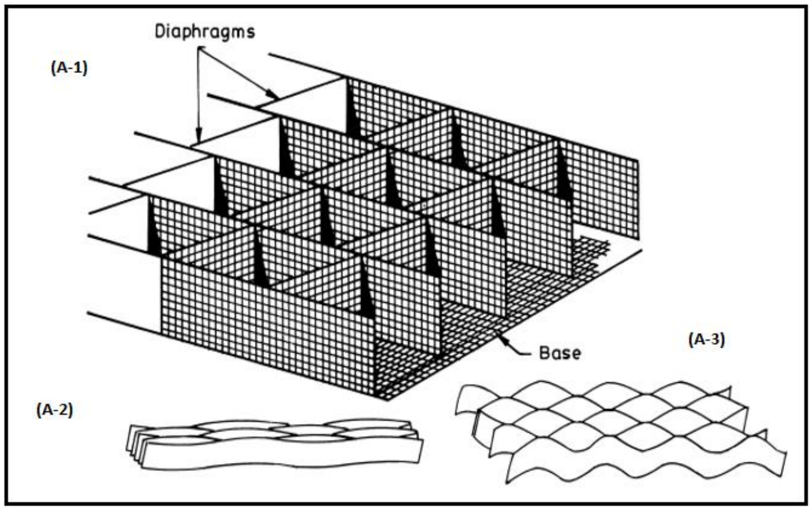


FIGURE 1.5 (A-1) GEOCELL (A-2) SITE ASSEMBLED (A-3) FACTORY PRODUCE [2]

1.1.2 HISTORICAL BACKGROUND

Early decades of 19th century the first application usage of fabrics held in 1926 by the South Carolina department of highway for reinforcing the road. The first thirty years could not be narrated to involved any polymer in the evolution of reinforcing road are as follows [1].

- 1933 Poly Vinyl Chloride (PVC) used.
- 1939 Linear low-density poly ethylene (LDPE) & Polyamide(PA) used.
- 1950 Expended polystyrene(PS) used.
- 1953 Polyester Terephthalate (PET) used.
- 1955 High density Poly ethylene (HDPE) and Poly Propylene (PP) used.

Latterly after 1950 the fabric is generally used for the separation and filter layers between weak subsoils and granular filler was manufactured. In this era the woven fabric played a major part for the filtration of costal parts of USA and Netherland [1].

In 1960 the Rhone-Poulenc Textiles in France started working with nonwoven needle-punched geotextiles for very extraordinary applications. Geotextile have been used for highway and railway track support system. The chlorosulphonated polyethylene has been developed in 1965 [1].

In 1970 the geotextile used in the dam construction while the standard formation for the process has been started as ASTM D-13-18 and the first sample of tensar grid were made in the lab of UK in 1978. The first conference of geosynthetics were held in Paris in 1978 [1].

In 1980 the geosynthetics were used in the construction for the eco-friendly to the environment. The first application known as geonet was developed in 1984, The foundation of geosynthetic international society was held in 1983 and the first collection international journal published in 1984 [1].

In 1990 there would be more publication in terms of standards (ASTM, ISO, BSI, BIS etc.) and the second journal relatively to internationally standard was first published in 1995 [1].

TABLE 1.1 PRODUCT NAME AND CLASSIFICATION [2]

Product name	**Product classification**
Tensar 160RE	Uniaxial geogrid
Tensar SS40	Biaxial geogrid
Secutex 301 GRKS	Needle-punched geotextile
Naue Fasertechnik PEHD 406	Geomembrane both sides smooth
Terram W/20-4	Woven polypropylene geotextile
Terram CE 131	Composite reinforced drainage separator
Terram paralink 600S	Geonet
Terram Grid 4/2-W	Welded Geogrid
Secumat ES 601 G4	Single layer erosion control layer with woven fabric

1.2 FUNCTION AND APPLICATION OF GEOSYNTHETICS IN ROADWAY CONSTRUCTION

The geosynthetic materials most regularly utilized as a part of roadway frameworks incorporate geotextiles (woven and non-woven) and geogrids (biaxial and multiaxial), despite the fact that disintegration control items, geocells, geonets (or geo-composite seepage items) and geomembranes have additionally been joined in various applications. These different sorts of geosynthetics can be utilized to satisfy at least one particular capacities in an assortment of roadway applications. For instance, geosynthetics have been being used since the 1970s to enhance the execution of unpaved streets on delicate subgrade soils. Starting in the 1980s, geosynthetics were used to limit intelligent splitting in black-top overlays and also to enhance the execution of base total layers. [3]

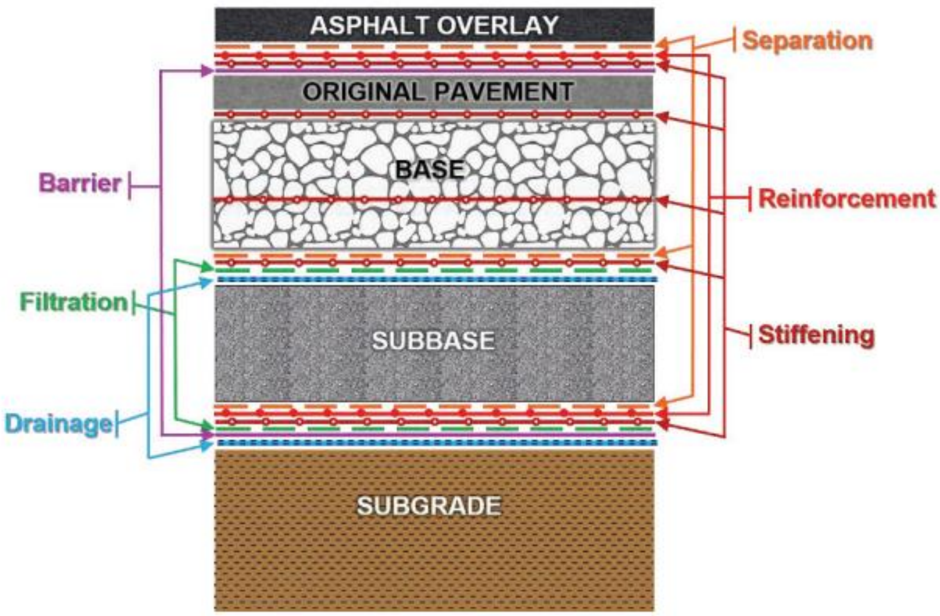


FIGURE 1.6 FUNCTION OF GEOSYNTHETICS IN ROAD CONSTRUCTION [3]

1.2.1 FUNCTION OF GEOSYNTHETICS IN ROADWAY CONSTRUCTION

The basic function of geosynthetic in roadway construction are as follows; [3]

SEPARATION

The geosynthetic, set between two divergent materials, keep up the trustworthiness and usefulness of the two materials. It might give relief against long-term stress. Key outline properties to play out this capacity incorporate those used to portray the survivability of the geosynthetic amid installation.

FILTRATION

The geosynthetic permits fluid stream over its plane while holding fine particles on its upstream side. Key outline properties to satisfy this capacity incorporate the geosynthetic permittivity (cross-plane water powered conductivity per unit thickness) and measures of the geosynthetic pore-estimate dispersion (e.g. obvious opening size).

REINFORCEMENT

The geosynthetic creates ductile powers expected to keep up or enhance the strength of the soil-geosynthetic composite. A key plan property to complete this capacity is the geosynthetic tensile strength.

STIFFENING

The geosynthetic creates ductile powers expected to control the distortions in the soil-geosynthetic composite. Key plan properties to achieve this capacity incorporate those used to evaluate the firmness of the soil-geosynthetic composite.

DRAINAGE

The geosynthetic permits fluid (or gas) stream inside the plane of its structure. A key outline property to measure this capacity is the geosynthetic transmissivity (in-plane water powered conductivity incorporated over thickness). [3]

1.2.2 APPLICATION OF GEOSYTHETIC IN ROADWAY CONSTRUCTION

The following five applications would be named as follows and described in details in table1.2. [3]

- mitigation of reflective cracking in asphalt overlays;
- separation;
- stabilization of road base;
- stabilization of road subgrade;
- lateral drainage.

TABLE 1.2 BRIEF OUTCOMES OF GEOSYNTHETICS AS APPLICATION [3]

Application	Objective	Mechanism	Geosynthetic Functions Primary	secondary	Implications in Roadway Performance
Mitigation of reflective cracking in asphalt overlays	Retard or eliminate reflective cracking in asphalt overlays	Reduction of stress concentration in asphalt overlays in the vicinity of preexisting cracks	Reinforcement	Stiffening Barrier Separation¹	Reduced impact of degradation mechanisms in asphaltic layers that are caused (or accelerated) by water intrusion
Separation	Avoid contamination of aggregate base material with fine-grained subgrade soils	Minimized loss of aggregate particles into the subgrade and migration of fine-grade particles into the base layer	Separation	Filtration	Minimized time-dependent decrease in base layer thickness and in the quality of the aggregate base material
Stabilization of road bases	Minimize a time dependent decrease in the modulus of the aggregate base material	Lateral restraint, which involves minimizing the time-dependent lateral displacements of aggregate base material	Stiffening		Minimized lateral displacements in the base aggregate material. This facilitates maintaining the original (comparatively high) aggregate confinement and, consequently, maintaining the original (comparatively high) aggregate modulus that results in a comparatively wide distribution of vertical loads and decreased base-subgrade contact stresses
Stabilization of road soft subgrades²	Increase the bearing capacity of subgrade soils	Development of membrane-induced tension under the wheel path and of soil-geosynthetic interface shear transfer beyond the wheel path	Reinforcement²	Stiffening Separation Filtration	Decreased vertical stresses in the subgrade under the wheel path, and beneficial redistribution of shear and normal stresses beyond the wheel path
Lateral drainage	Minimize the accumulation of moisture within the base and subgrade materials	Gravity-induced lateral drainage (for saturated conditions) and suction-driven lateral drainage (for unsaturated soil conditions)	Drainage (inplane)	Filtration Separation	Minimized generation of positive pore water pressures (for saturated conditions) and decreased soil moisture content (for unsaturated conditions). This in turn avoids moisture-induced reduction of shear strength and modulus, both in the aggregate base and in the subgrade materials

1.3 GEOSYNTHETICS MATERIAL USED FOR ROAD CONSTRUCTION

A variety of geotextiles are used in road reinforcement applications including woven, nonwovens, and geo-composites consisting of woven-nonwoven composites, geotextile-geogrid composites, nonwoven geotextiles with imbedded high-strength modulus inline filaments, and geotextile-geonet composites [4].

1.4 GEOSYNTHETICS IN REINFORCING PAEVAD

The utilization of geosynthetics in paved roadways presents a few plan choices to the asphalt build that considers enhanced asphalt execution in a financially productive way. Geosynthetics might be utilized as a development practical taking into account decreased development time and cost, or as an outline segment proposed to control trouble initiated by operational movement. A paved roadway configuration fusing geosynthetics might be monetarily productive from the point of view of lessening development costs as well as activity and upkeep costs. [2]

In this section, a qualification is made between geosynthetics when utilized for development purposes and when utilized as a planned segment for the control of asphalt trouble under operational movement. The four elements of reinforcement, separation, filtration, and drainage can be used for both development and task applications, be that as it may, the systems by which the geosynthetic gives these capacities, the choice of the best possible geosynthetic item and the plane strategies utilized, can be fundamentally unique. [2]

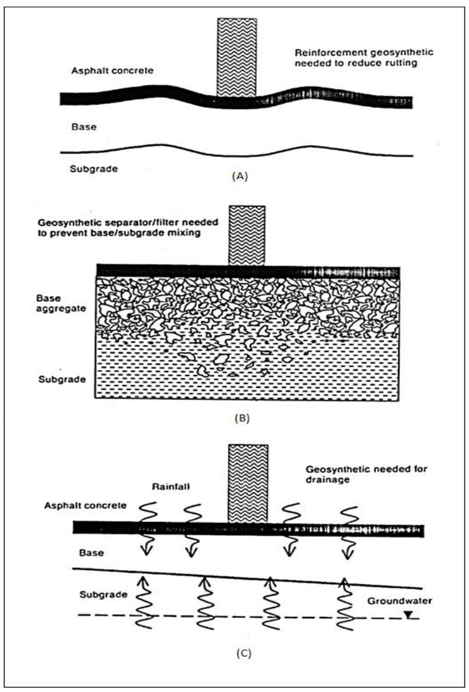


Figure 1.7 Situations where geosynthetics can be used for the prevention of roadway distress as (a) reinforcement (b) separator/filter (C) drain [2]

The capacity of reinforcement relates to the capacity of the geosynthetic to help in supporting operational vehicular activity loads. The tensioned-layer fortification system is depicted, where it is noticed that moderately expansive mis happenings of the roadway surface are important to activate this specific support component. Since a cleared roadway is, for the most part, thought to be inoperable once a groove profundity in an overabundance of roughly 25 mm is achieved, the tensioned-film support component isn't material for paved roadways. The important instrument in charge of support in paved roadways is one by and large alluded to as base course sidelong limitation. This capacity was initially portrayed by Bender and Barenberg (1978) and was later expounded on by Kinney and Barenberg (1982) for geotextile-strengthened unpaved streets. This name might be to some degree misdirecting in that the capacity, as imagined, consolidates components notwithstanding counteracting the horizontal development of the base course total. A more proper depiction may be to portray this fortification capacity, and its related components, as one of a shear-opposing interface as recommended in Perkins et al. (1998b). [2]

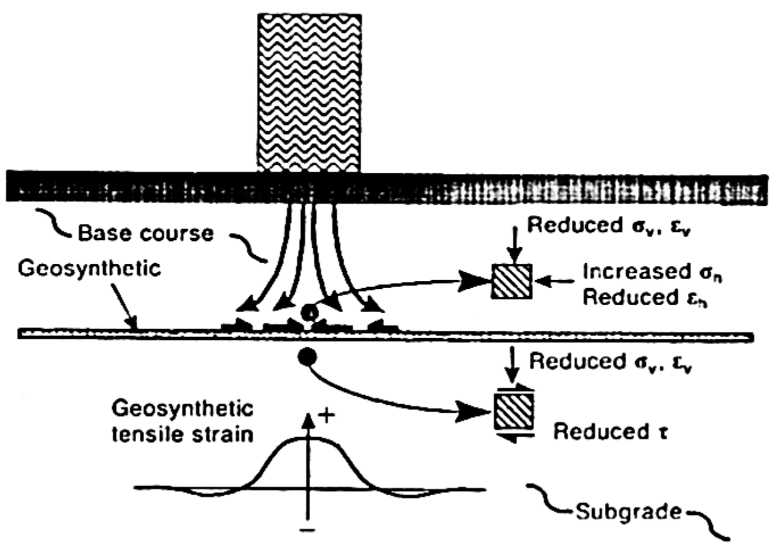


FIGURE 1.8 MECHANISM OF SHEAR RESISTANCE INTERFACE [2]

The support capacity of a shear-opposing interface creates through the shear cooperation of the base course layer with the geosynthetic layer or layers contained in, or at the base of the base total (Fig. 1.8) and comprises of four separate fortification instruments. Vehicular burdens connected to the roadway surface make a horizontal spreading movement of the base course total. Tractable horizontal strains are made in the base underneath the connected load, as the material moves sadly far from the heap. Sidelong development of the base takes into account the vertical strain to create prompting a changeless trench in the wheel way. [2]

The reinforcement consists of four different mechanism which are described as follows the first mechanism of reinforcement corresponds to direct prevention of lateral spreading of the base aggregate. The second support system comes about because of an expansion in firmness of the base course total when sufficient communication creates between the base and the geosynthetic. The third support instrument comes about because of an enhanced vertical stress appropriation on the subgrade. The fourth support component comes about because of a decrease of shear stress in the subgrade soil. [2]

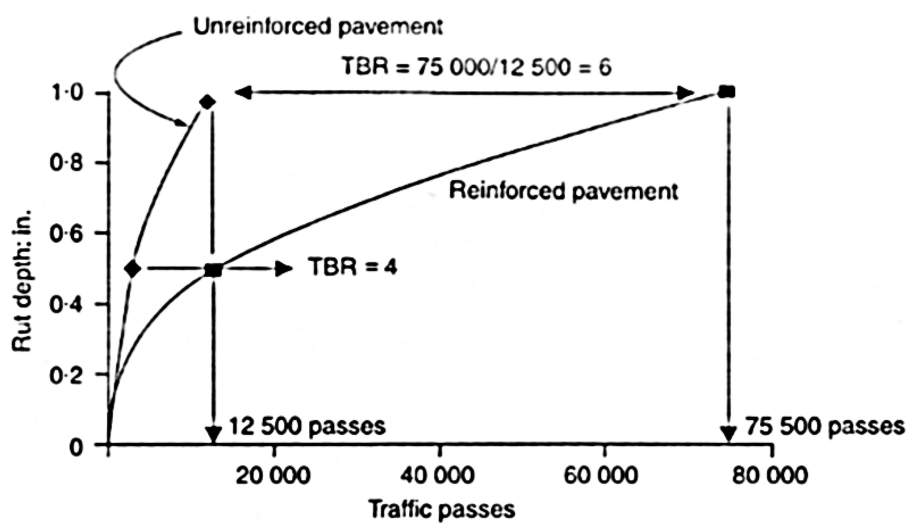


FIGURE 1.9 REINFORCEMENT BENEFIT DEFINED BY TRAFFIC BENEFIT RATIO [2]

1.5 GEOSYNTHETICS IN UNPAVED ROADS

Geosynthetics, particularly geotextiles and geogrids, have been utilized widely in unpaved roads to make their development efficient by decreasing the thickness of the granular layer and in addition to enhance their building execution and to broaden their life. A geosynthetic layer is by and large set at the interface of the granular layer and the dirt subgrade (Fig.1.6). Reinforcement and separation are two noteworthy capacities served by the geosynthetic layer (see Table 4.2). As examined in table 4.2 , if the dirt subgrade is delicate, that is, the California Bearing Ratio (CBR) of the dirt subgrade is low, say its un soaked esteem is under 3 (or splashed esteem is under 1), the support will be the essential capacity in light of sufficient elasticity assembly in the geosynthetic through extensive disfigurement, that is, profound trenches (say, more prominent than 75 mm) in the dirt subgrade. Geosynthetics, utilized with soil subgrades with an un soaked CBR higher than 8 (or splashed CBR higher than 3), will have an unimportant measure of fortification happening, and in such cases, the essential capacity will remarkably be division. For soils with halfway un soaked CBR esteems in the vicinity of 3 and 8 (or doused CBR esteems in the vicinity of 1 and 3), there will be an interrelated gathering of partition, filtration, and fortification capacities might be called adjustment capacity of the geosynthetic. Geosynthetics, particularly geotextiles and some geo composites, may likewise give execution profits by their filtration and seepage works by permitting overabundance pore water weight, caused by movement stacks in the dirt subgrade, to disseminate into the granular base course and on account of low-quality granular materials, through the geosynthetic plane itself. [1]

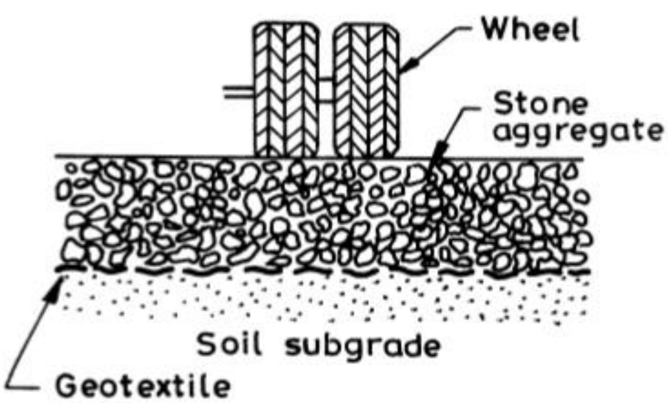


FIGURE 1.10 SUBGRADE SOIL UNDER UNPAVED SEGREGATION

TABLE 1.3 REINFORCING UNPAVED ROAD COMPARISON

SOIL SUBGRADE DESCRIPTION	CBR SOAKED	CBR UNSOAKED	Primary function	Cost comparison
Soft	Less then 3	Less then 1	Reinforcement	Less granular material utilization
Medium	3-8	1-3	Stabilization	Less granular material utilization and longer life time
Firm	Greater then 8	Greater then 3	Separation	Much longer life time

By giving a geosynthetic layer, change in the execution of unpaved roads is by and large seen in both of the accompanying two: [1]

- for a given thickness of the granular layer, the movement can be expanded
- for a similar activity, the thickness of the granular layer can be decreased, in the examination with the required thickness when no geosynthetic is utilized

1.6 ADVANTAGES OF GEOSYNTHETICS FOR ROAD CONSTRUCTION

The advantages acquired from the utilization of geosynthetics in unpaved streets can be watched not just as for basic execution and strength yet in addition as for development and economy. These advantages are condensed as takes after [2]

- On delicate subgrade soil, the establishment of a geotextile or a geogrid makes conceivable the development of the total layer without over the top loss of material. This division part is regularly the significant favorable position of geosynthetics for development on the delicate soil.
- Compaction of the total layer is made less demanding by the nearness of a geosynthetic at the interface, particularly when nearby heterogeneities (milder zones) of the subgrade are crossed. These outcomes in better homogeneity of the rock base layer and lesser spatial inconstancy of its mechanical qualities. The limit of a geosynthetic to connect heterogeneities is a result of its fortifying activity.
- A geotextile put at the interface between a fine-grained subgrade and a coarse-grained base course can limit the pollution of the base course by fine particles pumped front the subgrade under rehashed movement loads. This capacity of a geotextile to control the pumping of fines is identified with its filtration limit and opening size.

- The auxiliary limit of the unpaved street is enhanced by the strengthening activity of a geosynthetic when, under movement stack, the support set at the interface adds to a more productive exchange of worries from the base course to the subgrade. Thus, lesser rutting is experienced under rehashed stacking.
- A geotextile with high pressure driven transmissivity can guarantee that the contact zone between the subgrade and the base course will stay depleted amid times of expanded water content because of precipitation invasion. Unpaved streets don't profit by the surficial seepage that is generally given by an asphalt. In this manner, the part of underdrain, played by a geosynthetic, can be basic to the execution of the framework. [2]

1.7 GEOSYNTHETICS RAW MATERIALS AND ADDTIVES

Geotextiles are the soonest of geosynthetic items, starting around 1960. Prior to that, designing materials (additionally called building textures) were, for the most part, produced using characteristic materials, for example, grass, flax, bamboo, and jute. Albeit normal geotextiles are as yet accessible (see part: Geotextile/Geosynthetic Testing Standards Development Organizations), most by far are polymeric. An assortment of polymers can be utilized to produce manufactured fibers and fabrics. [6]

Table 1.4 Polymer usage in terms of raw materials for following products [2] [1]

Geosynthetics type	Raw material
Geotextiles	Poly propylene (PP), Poly Ethylene Terephthalate (PET), Poly amide (PA), Poly Ethylene (PE)
Geogrids	High density Poly Ethylene (HDPE), Poly Ethylene Terephthalate (PET), Poly propylene (PP)
Geonets	Medium density Poly ethylene (MDPE), High density poly ethylene (HDPE)
Geomembrane	High density poly ethylene (HDPE), linear low-density poly ethylene (LLDPE), Very low-density poly ethylene (VLDPE), poly ethylene (PE). Poly vinyl chloride (PVC), chlorinated poly ethylene (CPE), chlorosulphonated polyethylene (CSPE)
Geofoam	Expendable poly styrene (EPS)
Geopipe	High density poly ethylene (HDPE), Poly vinyl chloride (PVC), Poly propylene (PP)

1.7.1 POLYETHYLENE

"Main application usage in the production of geotextile, geogrids, and geosynthetics barriers is an alpha-olefin copolymer. Characteristic wise HDPE used for good chemical resistance, LLDPE for excellent pliability, ease of processing and good physical properties but less chemical resistant. HDPE can be susceptible to environmental stress cracking while others needed to stabilize to increase its resistant to weather and oxidation". [7]

TABLE 1.5 POLY ETHYLENE CLASSIFICATION ALONG WITH DENSITY

Category	**Abbreviation**	**Density (g/cc)**
High density poly ethylene	HDPE	>0.941
Medium density poly ethylene	MDPE	0.926-0.940
Linear low-density poly ethylene	LLDPE	0.919-0.925
Low density poly ethylene	LDPE	0.910-0.925

1.7.2 POLYPROPYLENE

PP is like PE aside from the pendant methyl (CH_3) aggregate joined to each other carbon particle along the polymer chain. The pendant group location in the long polymer chain produces three further type of polypropylene (PP) which terms as Atactic, isotactic and syndiotactic. In atactic the pendent group distributed randomly, while in isotactic the distribution remains one side of polymer chain and the alternative distribution with the regular movement of methyl group. The general structure of the isotactic compose permits the PP to take shape and be attracted to deliver fibers. Polypropylene (PP) resin with various MI ranges has been utilized for material fibers. ordered the advance of PP polymerization into three classes in view of the level of isotactic polypropylene (PP) being produced. The first and second ages depend on a Titanium chloride ($TiCl_3$) impetus yielding 90-95 to 96-97 wt% of isotactic polypropylene(PP). The third era, which has been connected to deliver business PP since 1980, utilizes magnesium chloride ($MgCl_2$) as the supporting catalyst. In spite of the fact that the percent yield of isotactic polypropylene (PP) from magnesium chloride ($MgCl_2$) is lower than the first age, going from 90 to 95 wt%, the weight level of polymer produced increments right around 1000-overlap for a unit gram of catalyst. There are three noteworthy business polymerization forms for isotactic PP generation: dissolvable slurry, mass slurry, and gas stage. [6]

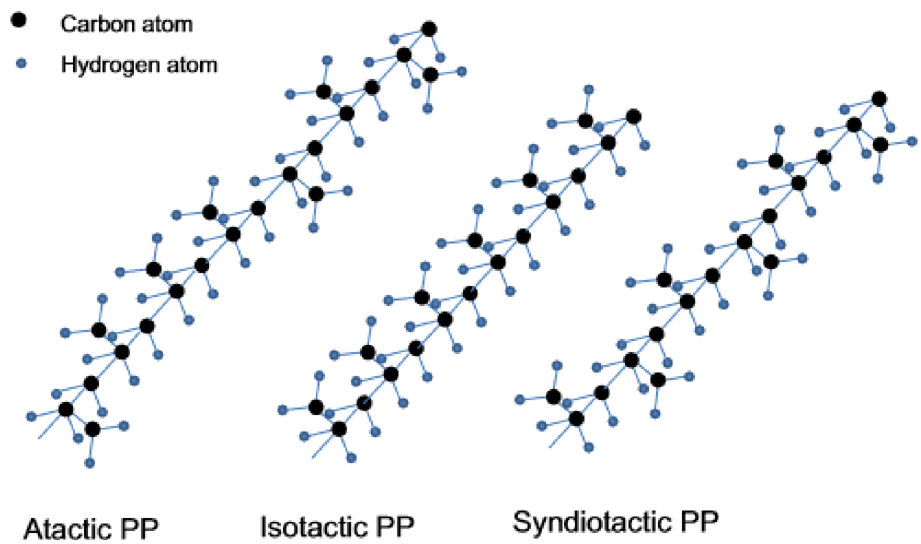


FIGURE 1.11 TYPES OF POLYPROPYLENE ALONG WITH PENDENT GROUP DISTRIBUTION [6]

1.7.3 POLYETHYLENE TERAPHTHALATE.

The most using polymer in geotextile is polyethylene terephthalate which consist of dibasic and a di-alcohol using condensation polymerization reaction. The usage below glass transition temperature and high oriented form. Good mechanical properties and chemical resistance to most acid and many solvents. Due to the presence of ester group resulting in slowing hydrolysis process and rapid reaction under high alkaline concentration. [7]

ADDITIVES

The role of additives for polymer stabilization is vital. Mostly additives participated in the production of geosynthetics are lubricants, plasticizer, UV stabilizer, antioxidants, acid scavengers, Metal ion deactivators, mineral fillers and scrims. [7]. Some general additives described in below section with example.

Antioxidants; “Antioxidants *prevent deterioration of the appearance and of physical properties of polymer caused by the oxidative degradation of polymer bonds”*. Aromatic amines, thioesters, hindered phenols and hindered amines are the main incorporated group. [7]

Acid scavengers; *“Acid scavengers provide protection of the polymer to acids resulting from catalyzer residues or oxidation/hydrolyzing process in polymer”.* Metallic stearates, lactates, hydro talcities or zinc oxides are the few example of acid scavengers. [7]

Metal ion deactivators; “*Heavy metal ions, including transition metal ions, catalyze the decomposition of peroxides, leading to the formation of reactive radicals which accelerate autoxidation”.* The stabilization may contribute by the stable inert complex with ion deactivator to such ions. [7]

Ultraviolet(UV) stabilizer; UV stabilizer provide the light stabilization to polymer during the interaction of physical and chemical processes of light induction resulting towards degradation in presence of oxygen. Carbon black, titanium oxide, nickel compounds are the application example of UV stabilizer. [7]

Polymer reaction is composed by the addition of monomer in its repeating unit. Several polymeric compounds contain different monomer structure likely describe in figure 1.8.

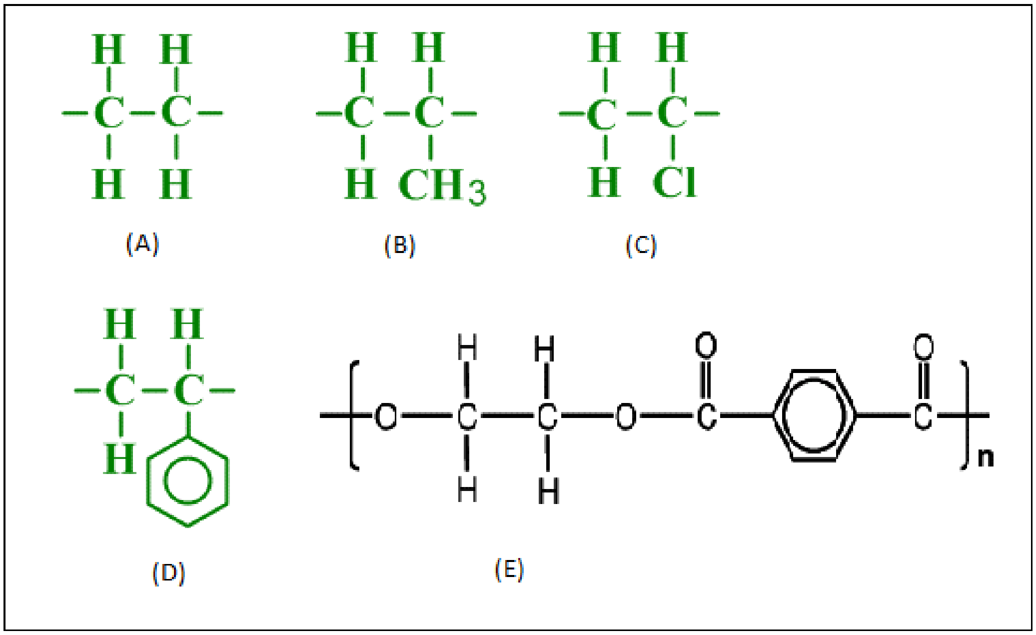


FIGURE 1.12 (A) ETHYLENE (B) POLY VINYL CHLORIDE (C) POLY PROPYLENE (D) POLY STYRENE (E) POLYETHYLENE TEREPHTHALATE [9] [10]

1.8 GEOSYNTHETICS TESTING STANDARDS

In the mid to late 1960s, the utilization of manufactured polymeric materials, at that point called structural building textures or filter textures, among a few comparative assignments, started to have a perceived use in common and geotechnical designing ventures. They were viewed as a monetary other option to what had been viewed as the standard practice for taking care of geotechnical building issues. As their utilization wound up more extensive, it was perceived that to have the capacity to determine these materials there were a need testing strategy that would give data to a designer about their material properties and execution. Simultaneously endeavors were started by three associations that had an effect around the world: [9]

- The international organization for standardization (ISO).
- The American society of testing and material (ASTM International).
- The geosynthetics Research institute (GRI).

1.8.1 STANDARDS USED IN ROAD CONSTRUCTION

The European standard [FprEN 13249] is beneficial for the manufacturer, designer, end-users and relevant to road construction using geosynthetics materials. In the given below table the standard regarding geotextile and geotextile related product described with type of methods, properties and function is considering for the assessment and evaluation.

TABLE 1.6 STANDARD METHODS AND FUNCTIONAL CHART FOR GEOTEXTILE AND GEOTEXTILE RELATED PRODUCT FOR ROAD CONSTRUCTION [7]

Characteristic	Test method	Functions		
		Filtration	Separation	Reinforcement
(1) Tensile strength	EN ISO 10319	A	A	A
(2) Elongation at maximum load	EN ISO 10319	A	A	A
(3) Stiffness at 2 %,5 % and 10%	EN ISO 10319	-	-	S
(4) Tensile strength of seam jointsc	EN ISO 10321	S	S	S
(5) Static puncture resistance (CBR test)	EN ISO 12236	S	A	A
(6) Dynamic perforation resistance (cone drop test)	EN ISO 13433	A	A	A
(7) Friction	EN ISO 12975-1 EN ISO 12975-2	S	S	S
(8) Tensile creep	EN ISO 13431	-	-	-
(9) Resistance to damage during installation under repeating loading	EN ISO 10722	S	S	S
(10) Characteristic opening size	EN ISO 12956	A	A	-
(11) Water permeability normal to the plane (velocity index)	EN ISO 11058	A	A	S
(12) Durability	According to Annex B	A	A	A
A: relevant to all condition of use S: relevant to specific condition of use "-": indicates that the characteristic is not relevant for that function				

Standardization is an ongoing effort. Technology changes, new items go ahead the market, new applications advance, and the requirement for data identified with these requires the proceeded with an exertion of all Standards Development Organizations. [9]

1.8.2 PHYSICAL PROPERTIES

The important aspects of physical properties relative to geosynthetic are as follows, [1]

SPECIFIC GRAVITY

The specific gravity is defined as a ratio of its volume weight (without any voids) to that of water at 4°C during the manufacturing process of geosynthetics. Displacement method is frequently used for determination. The particular gravity of a base polymer is an imperative property since it can help with recognizing the base polymer of the geosynthetics. The term specific gravity widely used for the determination of geomembrane identification and quality control. [1]

MASS PER UNIT AREA

The unit mass (or weight) of a geosynthetic is estimated as far as mass (or weight) per unit area rather than mass (or weight) per unit volume because of varieties in thickness under connected compressive stresses. It is generally given in units of a gram for each square meter (g/m^2). It is calculated by measuring square or round test examples of known measurements (for the most part region at least 100 cm^2), cut from the areas conveyed over the full width and length of the lab test. Direct measurements ought to be estimated with no tension in the sample. The figured qualities are then found the middle value to acquire the mean mass per unit area of the research facility test. Mass (weight) per unit area, with information of the structure of the geosynthetic, can be a decent pointer of cost and a few different properties, for example, elasticity, tear strength, puncture strength, and so forth., It can be utilized for the quality control of conveyed geosynthetics to decide sample conformance. [1]

THICKNESS

The thickness of a geosynthetic is the separation between its upper and lower surfaces, estimated ordinary to the surfaces at a predefined typical compressive pressure (for the most part 2.0 kPa for geotextiles and 20 kPa for geogrids and geomembranes, for 5s). It ought to be estimated by utilizing a thickness-testing instrument to an exactness of no less than 1 mil (= 0.001 in. $\approx$ 0.025 mm). The thickness-testing instrument is essentially a thickness measure that comprises a base (or blacksmith's iron) and a free-moving weight foot-plate with parallel planar appearances having a territory of in excess of 2000 mm^2. [1]

THERMAL PROPERTIES

Polymers display a temperature-subordinate versatile viscoelastic conduct. Temperature impacts can influence the predictability of geosynthetics. Both tensile and extension are influenced by temperature. To guarantee that the geotextile will perform sufficiently amid its outline life, it ought to be tried to comprehend what the adjustment in quality will be because of various warm atmospheres.

Oxidation induction time

OIT estimations empower portrayal of the long-term strength of hydrocarbons, for example, fats and oils and also plastics, for example, polyolefins, particularly polyethylene and polypropylene. The oxidative strength can be controlled by utilizing Differential Scanning Calorimetry (DSC) in government-sanctioned test techniques. The OIT tests can be effectively performed and give helpful dependability information. Also, they can help anticipate the thermo-oxidative execution of materials and accomplish disappointment counteractive action [10].

1.8.3 MECHANICAL PROPERTIES

Mechanical properties are essential in those areas where a geosynthetic is required to survive unharmed during the installation process and limited anxieties or play a structural role while under stress. There are several ways to describe mechanical properties, yet only a few of among important regarding specific geosynthetics.

Tensile property:- The assurance of tensile properties, for the most tensile strength and tensile modulus, of geosynthetics, is critical when they have to oppose tensile stresses exchanged from the soil in fortification kind of applications. The tensile strength is the most extreme protection from distortion produced for a geosynthetic when it is subjected to pressure by an outer force. Because of the particular geometry and unpredictable cross-sectional region that can't be effectively characterized, the rigidity of geosynthetics can't be communicated helpfully as far as stress. It is, consequently, characterized as the peak (or greatest) stack that can be connected per unit length along the edge of the geosynthetic in its plane. Tensile properties of a geosynthetic are considered utilizing an elasticity test in which the geosynthetic example is stacked and the relating force– prolongation bend is gotten. [1]

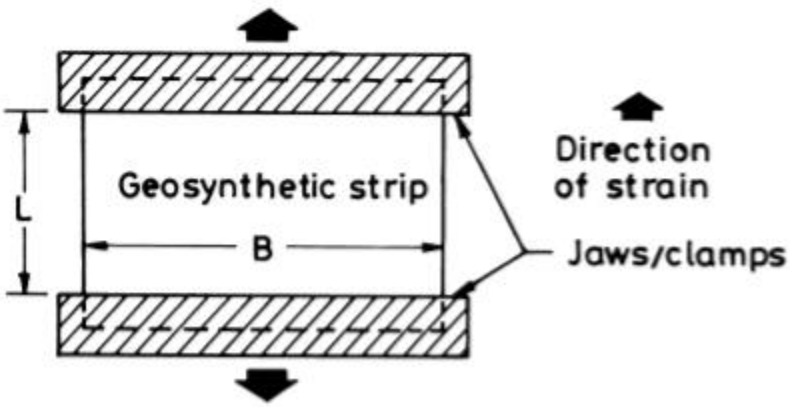


FIGURE 1.13 WIDE-WIDTH TENSILE TEST [1]

tensile strength is generally dictated by the wide-width strip pliable test on a 200-mm wide geosynthetic strip with a measured length of 100 mm (Fig. 1.13). The whole width of a 200-mm wide geosynthetic sample is held in the jaws of a rigidity testing machine and it is extended one way at an endorsed steady rate of augmentation until the point when the sample cracks (breaks). Amid the expansion procedure, both load and deformation are estimated. The width of the example is kept more noteworthy than its length, as some geosynthetics tend to contract ('neck down') under load in the gauge length zone. The more prominent width lessens the withdrawal impact of such geosynthetics, and by approximating plane strain conditions, it all the more intently mimics the deformation experienced by a geosynthetic when installing in soil under field conditions. The test gives parameters, for example, peak strength, elongation, and tensile modulus. The tensile properties rely upon the geosynthetic polymer and assembling process prompting the structure of the completed item. The deliberate quality and the crack strain are a component of numerous test factors, including test geometry, grasping strategy, strain rate, temperature, beginning preload, molding and the measure of any typical repression connected to the geosynthetic. [1]

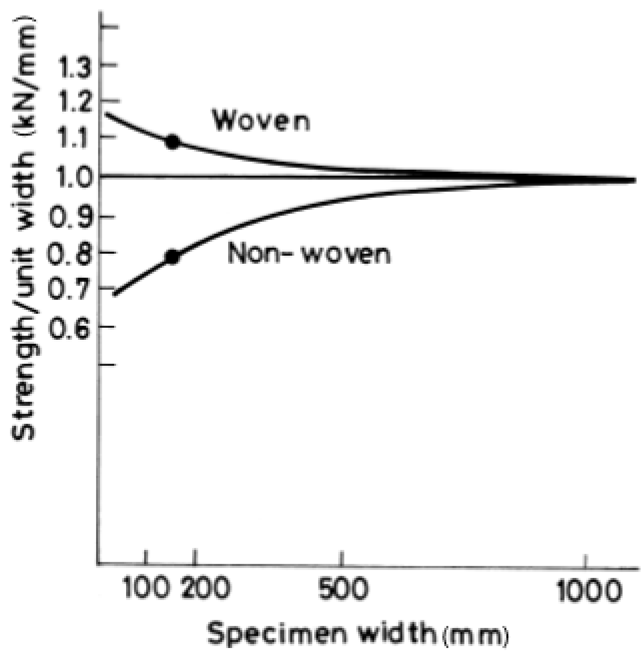


FIGURE 1.14 INFLUENCE OF GEOTEXTILE SPECIMEN WIDTH ON ITS TENSILE STRENGTH [1].

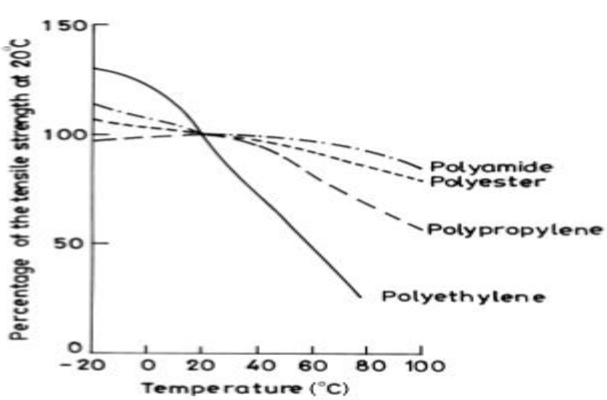


FIGURE 1.15 INFLUENCE OF TEMPERATURE ON THE TENSILE STRENGTH OF SOME POLYMERS [1]

Figure 1.14 demonstrates the impact of the geotextile example width on the tensile strength. To limit the impacts, the test example ought to have a width-to-gauge length proportion (a.k.a. viewpoint proportion) of no less than two, and the test ought to be done at a standard temperature. The real temperature affects the quality properties of numerous polymers (Fig. 1.15). The tensile strength of geosynthetics is firmly identified with a mass per unit territory (Fig. 1.16) [1].

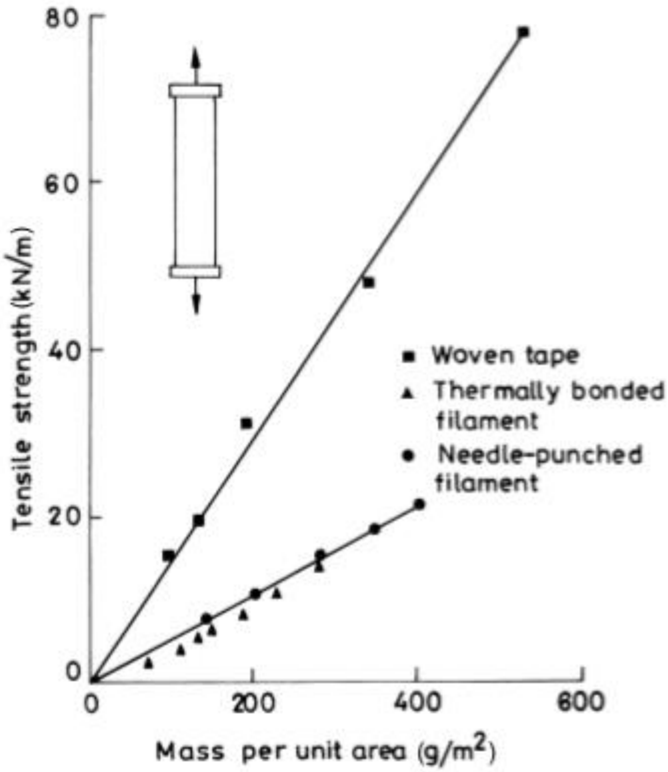
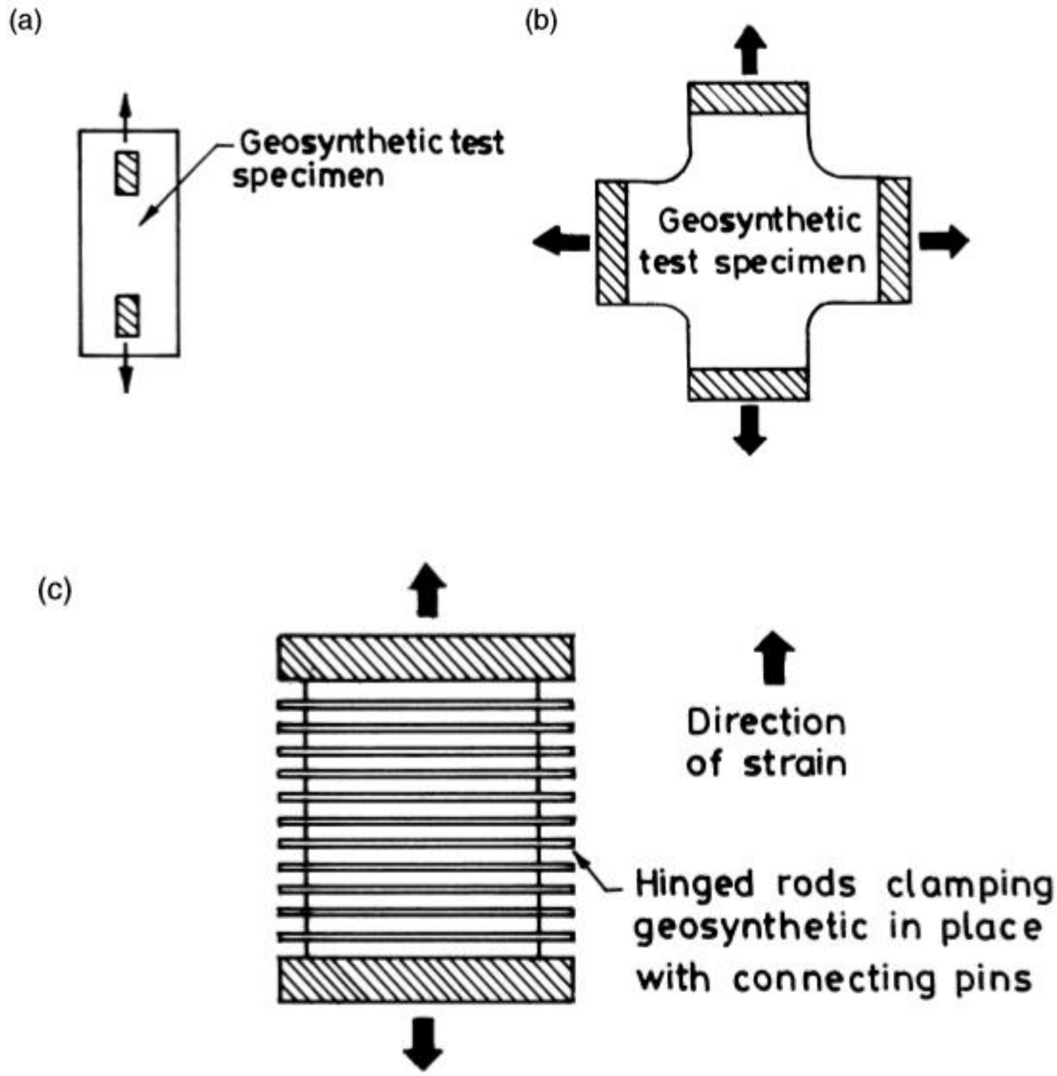


Figure 1.16 Variation of tensile strength with mass per unit area for PP geotextiles (after Ingold and Miller,1988).

A heavyweight geotextile, with a higher mass for each unit zone, will generally be stronger than a lightweight geotextile. For a given geosynthetic, the tensile strength is likewise an element of the rate of strain which the sample is analyzed. At a low strain rate, the deliberate strength has a tendency to be lower and happens at a higher failure strain. Alternately, at a high strain rate, the deliberate strength has a tendency to be higher and happens at a lower failure strain. [1]


(a)
Geosynthetic test specimen
(b)
Geosynthetic test specimen
(c)
Direction of strain
Hinged rods clamping geosynthetic in place with connecting pins

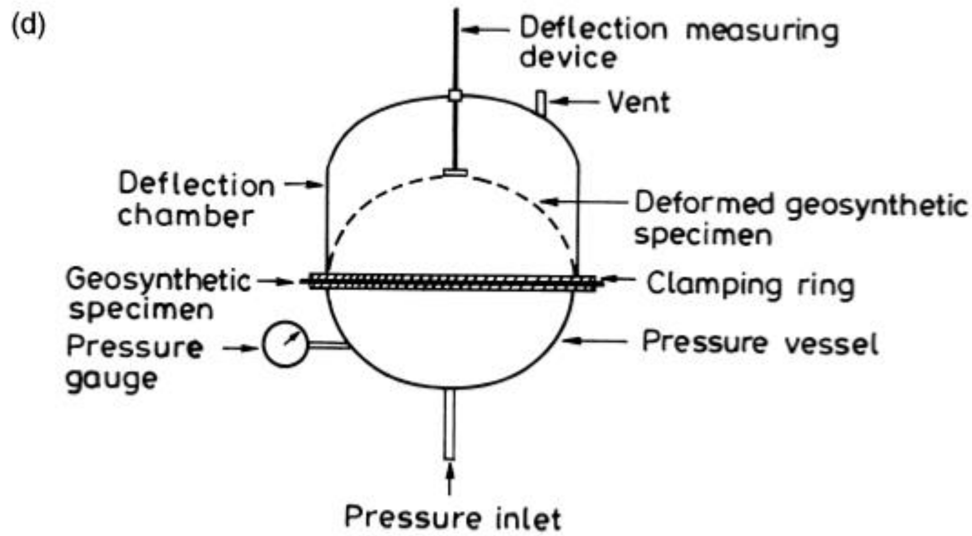


Figure 1.17 Typical arrangements of tensile strength tests:(a) grab tensile strength test;(b) biaxial tensile strength test;(c) plain strain tensile strength test;(d) multi-axial tensile strength test. [1]

Different types of tensile tests, for example, grab test, biaxial test, plain strain test, and multi-hub test are indicated schematically in Figure 1.17. The get malleable test is utilized to decide the quality of the geosynthetic in a particular width, together with the extra quality contributed by contiguous geosynthetic or other material. [1]

Compressibility: - The compressibility of a geosynthetic is estimated by the reduction in its thickness at expanding connected typical weights. This mechanical property is essential for nonwoven geotextiles on the grounds that they are regularly used to pass on the fluid inside the plane of their structure. according to the condition of applying loads at a constant rate of deformation to specimens placed between parallel plates in a loading frame can be studied under compression behavior of geosynthetics. The disfigurements are recorded as an element of load and plotted as appeared in Figure 3.2(a). Being an artificial caused by the arrangement or seating of the example, the toe locale OA may not speak to a compressive property of the material. The yield point and strain ought to be computed considering the zero-distortion point has appeared in Figure 1.18 (a). Numerous geosynthetics show compressive twisting, yet all may not display an all-around characterized compressive yield point; be that as it may, the huge change in the slope of the stress-strain curve can be utilized to decide yield point for similar purposes (Fig. 3.2(b)). According to the standard ASTM D 6364-99 variable inclined plates or set angle blocks may be used to access deformation at a various angle during loading of geosynthetics. The compressive stacking test is for the most part utilized for quality control to assess consistency and consistency inside a great deal (a unit of creation) or between samples where test geometry factors, for example, thickness or materials may change. [1]

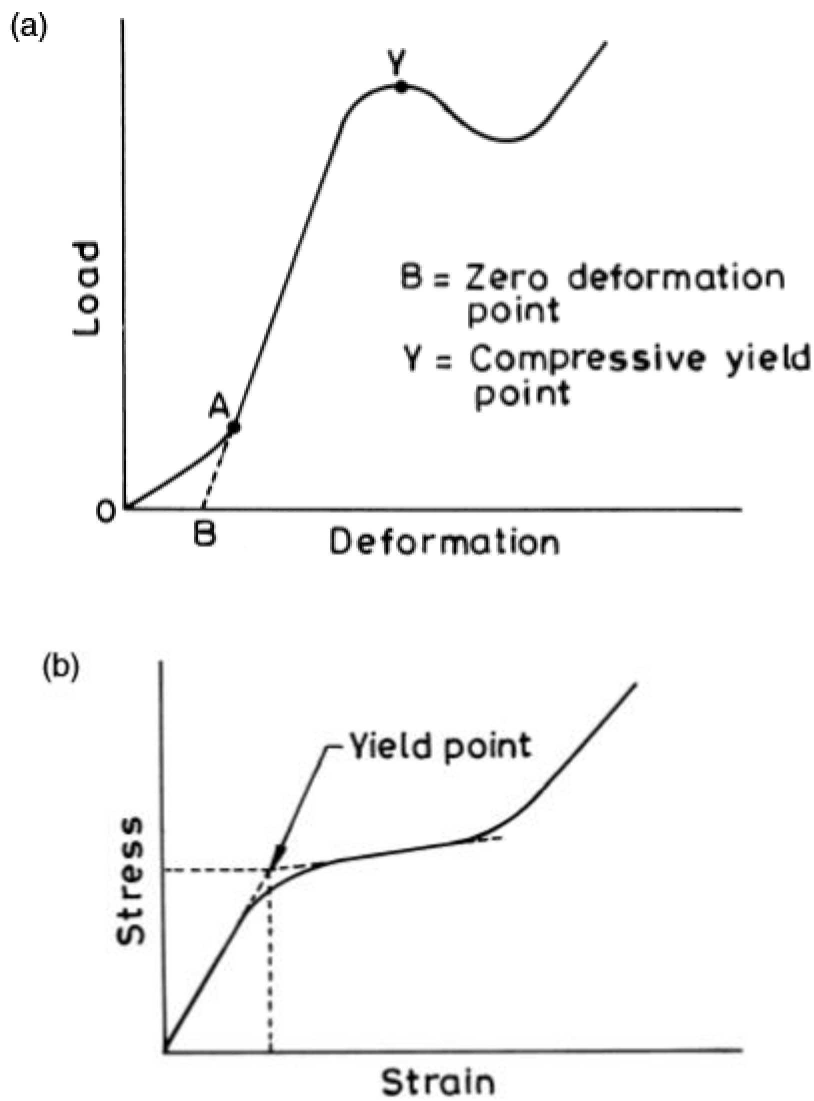


Figure 1.18 Compression behaviour of geosynthetics: (a) typical load–deformation curve; (b) typical stress–strain curve. [1]

1.9 DURABILITY

Geosynthetics can be utilized as a part of various ecological conditions: [11]

- In the land.
- Above the land.
- Under the water.
- Above the water.
- At the level of the water table.

1.9.1 DURABILITY ASSESSMENT

Geosynthetics are defined, produced, obtained, and connected with a forecast and desire of conveyed benefit life or plan life. For motivations behind this discourse, the outline life of a geosynthetics is the required time amid which the geotextile must have every single required property under the specified states of utilization, for example, the load, temperature, and presentation to natural stresses (chemicals and UV vitality). Frequently the expression "benefit life" is utilized for the plan prerequisite of the geosynthetics. For this situation, the outline life requires the geosynthetics to have properties under the specified states of utilization to guarantee the required execution. While the sort of polymer and structure of a geotextile add to its determination for a given application, the long haul usefulness of the item isn't promptly clear to the client and must be evaluated by testing the finished item and strict quality control amid generation and ensuing establishment. A significant evaluation of durability includes a hearty comprehension of the geotextile's required administration life and in addition the earth in which the geotextile will be utilized. Additionally helpful is a comprehension of the sorts of debasement that can happen. For instance, protection from degradation of geosynthetics introduced in the ground and secured may include: [12]

- The time-subordinate chemical assault that may debilitate a geosynthetics inferable from exposure to oxygen, water, or chemicals in soil.
- Vitality stacking coming about because of introduction to UV radiation or hoisted temperatures causing quickened aging.
- Mechanical burdens from additional charges, quakes, or dynamic anxieties that can cause time-subordinate distortion, weariness, and mechanical harm to a geosynthetics.

- Geosynthetic mud liners that may debilitate because of shear powers and substantial changes in the dirt and segment geotextile.
- Geosynthetic channels that may pack under load and lose auxiliary structural integrity and related practical flow limit. [12]

Also, numerous highlights of the material and its utilization have a part in a geosynthetic's protection from degradation: [12]

- Polymer type (high-density polyethylene [HDPE], polyvinyl chloride [PVC], chloro-sulfonated, polyethylene, polyvinyl acetate, etc.).
- Sample thickness and surface region to mass proportion.
- Formulation of Polymer resin along with additives.
- Remaining or produced stresses innate in the material.
- Immaculateness of crude materials and nearness of contaminations.
- Capacity or crude materials previously created and delivered material after generation. [12]

The plan life of a task including the geotextile completely or halfway relies upon the toughness of the geotextile. It is essential to recognize that whether a geotextile's intended to benefit life prerequisites couple of months or more than100 years, it is conceivable to plan, fabricate, and effectively introduce geosynthetic items that will address this issue. The accompanying areas give insights with respect to toughness difficulties and degradation instruments, sturdiness estimations, and the increasing speed of solidness evaluations. [12]

1.9.1.1 DEGRADATION MODES

The first mode is the most difficult to consider in light of the fact that it is regularly difficult to foresee the planning of significant misfortune in geotextile quality. For instance, in spite of the fact that the antioxidant prevention agent is available in a settled polyolefin geotextile, its quality is expected to remain moderately unaltered identified with oxidation. Be that as it may, once the antioxidant prevention agent has been utilized and is exhausted, the quality may fall rapidly. This is mode 1. Hydrolysis of a polyester item is generally steady since water enters the polymer structure gradually and brings about lost strength. This is mode 2. The damage caused initially during the installation acting like fast and irreversible lost to strength. Be that as it may, no further addition degradation to loss of strength relevant to fixation. This is mode 3 as described in 1.16 picture. [12]

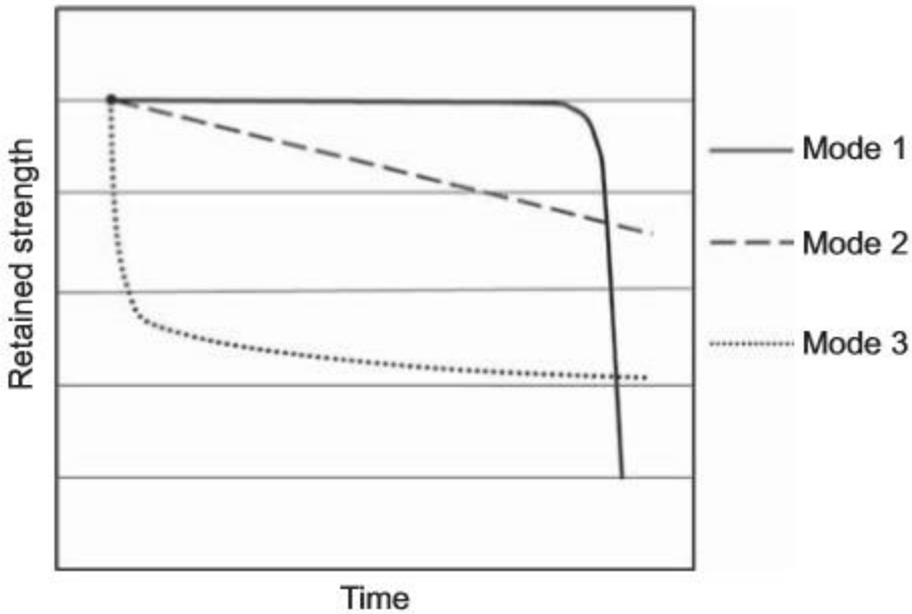


FIGURE 1.16 DEGRADATION MODES [12]

All methods of geotextile debasement are essential to comprehend and measure for benefit life expectations. Though the measure of geotextile solidness utilizes these quickening strategies to accomplish down to earth testing administrations, their specific procedural methodologies are imperative for the respectability and unwavering quality of created comes about. The following areas will survey debasement instruments, their application to geotextile materials, and how they are reported through testing. [12]

1.9.2 LONG TERM DEGRADATION MECHANISM AND LIFE TIME PREDICTION

All of the long-haul debasement systems to be portrayed outcome in some type of polymer atomic chain scission, bond breaking, or cross-connecting, or the extraction of recipe parts. [13]

Mechanism	Polyethylene (PE)	Polypropylene (PP)	Polyester (PET)	Polyamide (PA)
UV radiation	← major to all resins but only when exposed →			
Oxidation	← concern to all resins but to varying degrees →			
Hydrolysis	← water is of no real concern to resins except for PET →			
Chemical	← concern over hydrocarbons for all resins →			
Radioactive	← only a concern with respect to high level radioactive waste →			
Biological	← no concern over bacteria or fungi →			
Temperature	← heat accelerates all of above mechanisms →			

FIGURE 1.17 VARIOUS DEGRADATION MECHANISM [13]

The important degradation which tends to road construction are as follows: [13]

- Oxidation degradation.
- Hydrolytic degradation.
- Chemical degradation.
- Temperature effects on degradation.
- Exposed lifetime prediction.

In all these mechanisms the particular standard has been developed according to the type and application usage of geosynthetics. The output of these test would appropriate the final selection of geosynthetics and predicted life cycle analysis during and after the service life. It is imagined that this kind of lifetime forecast for uncovered geotextiles (and different geosynthetics) is sensibly reproduced in lab weathering gadgets. Albeit such lab lifetimes are profitable for looking at changed items or distinctive details of a similar item, the procedure can likewise be utilized for examination with a given specification. [13]

2 EXPERIMENTAL PART

2.1 MATERIALS

In this research work Twenty different geosynthetics samples were provided by road ministry and these specific materials typically used in Estonian road construction. The investigations included analyzation of standards and methods for the assurance of oxidative resistance, hydrolytic resistance, Thermal analysis at temperature and pressure which would be the most important factors during the service life of application. The material categorized in the given below table according to the type and composition where S represent sample.

TABLE 2.1 GEOSYNTHETICS BRIEF OUTLINE INFORMATION.

Type of geosynthetics	Sample Identification Number	Polymer composition
Geotextile(non-woven)	S5,S6,S7,S8,S9,S10,S11,S12,S13,S15,S16,S17,S18,S19 and S20	Polypropylene (PP)
Geogrids	S1,S2,S3,S4 and S14	Polypropylene (PP) and Polyethylene Terephthalate(PET)

Note: S- represent sample

S14 – made up of polyethylene terephthalate(PET)

Others- made up of polypropylene(PP)

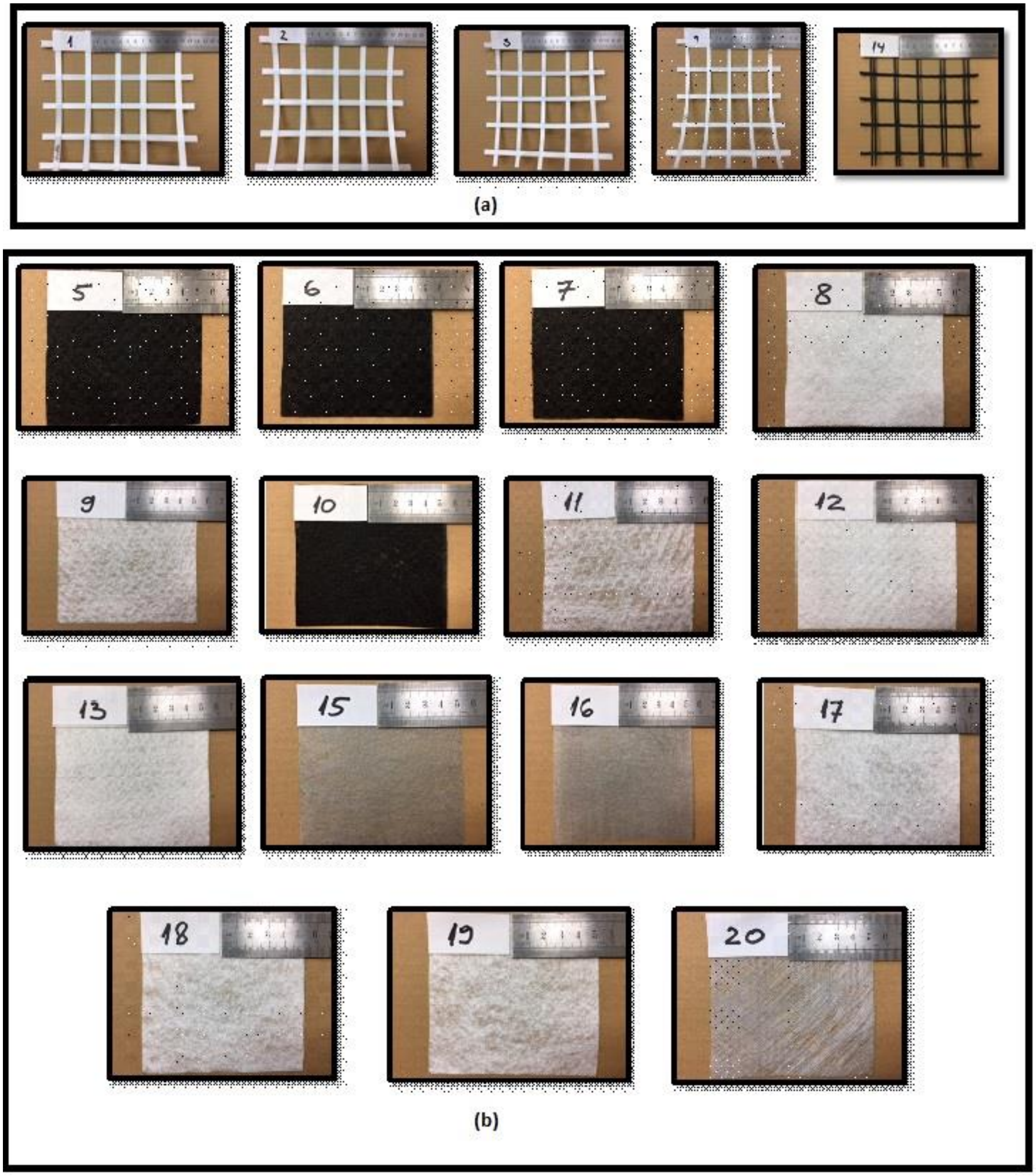


Figure 2.1 (a) Geogrid Samples (b) Geotextile Samples

2.2 INSTRUMENTS AND METHODS

2.2.1 INSTRUMENTS

The following given below tool has been used to prepare the specimen and performed test according to the standard.

- Specimen roll sheet.
- Cutting scissors, ruler and fabric marking tool.
- Sulphuric acid 95 - 97%, EMSURE® ISO analytical reagent (Merck producer), Ferric Sulphate hydrate (РЕАХИМ producer), Ferrous sulfate heptahydrate (РЕАХИМ producer) and Calcium hydroxide.
- Hot air oven.
- Two Plastic buckets of 7L each and 14 glass jars of 2L each with lid.
- Electrical weighing balance.
- Pipette rod with rubber stopper for acid and base preparation solution.
- Refrigerator for efficient cooling (-10°C to -30°C).
- Heat sensitive sensors for monitoring the temperature (-30°C to +160°C).
- Tensile testing machine with wide width jaws.
- Customized bending wooden tool.

FIGURE 2.2 (A) INSTRON-5686, (B) HOTAIR OVEN, (C) CUSTOMIZED BENDING WOODEN TOOL, (D) GEOSYNTHETIC RAWMATERIAL ROLL

2.2.2 METHODS

The samples of different materials initially prepared and treated according to the specific requirement of road construction which would be describe below in the table. Initially the samples required different preassessment conditions during the final test evaluation. The given below terminologies would describe the processes according to the appropriate standard along with the quantity in table 3.

TABLE 2.2 DESCRIPTION OF SELECTIVE METHODS AND STANDARDS

Methods	STANDARD	NAME OF THE STANDARD	MACHINE DIRECTION (MD) QTY	CROSS MACHINE DIRECTION (CMD) QTY
Sample preparation	ISO 9862	Geosynthetics – Sampling and preparation of specimens	460	460
Resistance to aggressive media	EN 14030	Determination of resistance to acid and base liquids.	100	100
Thermal cycling	ГОСТ Р 55032	Determination of resistance at below and upper 0°C.	40	40
Exposure at below freezing temperature	ГОСТ Р 55033	Determination of flexibility at different temperature at below 0°C.	40	40
Short term heating	ГОСТ Р 55034	Determination of thermal stability.	40	40
Short term exposure of hot air and liquid	EN 12447	Screening test method for determining the resistance to hydrolysis in water.	50	50
Prolonged exposure of hot air and liquid	EN 13249	Characteristics required for use in the construction of roads and other trafficked areas (Excluding railways and asphalt inclusion)	50	50
Effect of elevated temperature and pressure	Recommended by supplier	Determination the durability at modified condition.	40	40
Wide-Width tensile test	ISO 10319	Geosynthetics – Wide-width tensile test.	460	460

2.2.2.1 SAMPLE PREPARATION

This method has been adopted for the analyzation of mechanical properties according to the geosynthetics wide width test specification. The sample dimension according to finished specimen to a nominal width 200 mm ±1 mm width and the 100 mm between the jaws, among the applied tensile forced is parallel and designated to the length of dimension. This dimension would remain appropriate for all the methods constantly as described in table 3.

2.2.2.2 RESISTANCE TO AGGRESSIVE MEDIA

This method used for determining the resistance to acid and alkaline liquids. First, the solutions of acid and base were prepared by simple mechanical mixing at next concentrations:

- For an organic acid: 0.025 M Sulfuric acid [H_2SO_4] with 1 mMol Ferric Sulphate hydrate [$Fe_2(SO_4)_3.9H_2O$] and 1 mMol Ferrous sulfate heptahydrate [$FeSO_4.7H_2O$] added to the deionized water.
- For an organic base: Calcium hydroxide [$Ca(OH)_2$, used as a saturated suspension, i.e. Approximately 2.5 grams per litre.

The specimen would insert into the acid and base solution under the controlled condition where temperature remains constant (60±1) °C. Maximum five specimens would be placed in 2L bottle for controlled condition(1h) and treated condition (72h). The specimen after the specified time were tested according to the standard ISO 10319.

2.2.2.3 THERMAL CYCLING

This method used for determining the resistance of temperature at below and upper 0°C.The specimen could undergo the condition in such way that for 8h placed at (-18°C) and 16h at (23°C). This exercise would continue till 28 days. Finally, the prepared sample ready for the investigation of mechanical properties using ISO-10319.

2.2.2.4 EXPOSURE AT BELOW FREEZING TEMPERTURE

This method used for determination of flexibility of geogrids at below freezing point. According to the standard the specimen and bending equipment would remain under the refrigerator at specific temperature [-10°C, -20°C and -30°C] for minimum 20 minutes at tolerance factor ±2°C. Each bending experiment should not take longer than 15 sec, including 5 secs for the bending time. The bending equipment should not stay at room temperature longer than 20 min, after that needed to restored in refrigerator for 20 minutes. After the bending the specimen will be inspected physically with the naked eye for any visible defects.

2.2.2.5 SHORT TERM HEATING

This method is used for determining the thermal stability of geosynthetics materials used for road construction. The specimen must undergo for hot air in oven at (160±2) °C for 2h. After the time period the specimen would be cooled down to room temperature and stored at testing conditions for 24 h. Finally, the specimens were tested according to ISO 10319.

2.2.2.6 SHORT TERM EXPOSURE TO AIR AND LIQUID

The essential purpose for utilization of this method to establish a minimum level of geosynthetics to soil moisture. In this methodology the test specimen expose to the glass container at temperature (80 ± 1)°C for 6h without any kind of applied load.

2.2.2.7 PROLONGED EXPOSURE TO AIR AND LIQUID

This method is used for the determination of resistance to substances for prolonged exposure to liquid and air. The specimen must undergo for 28 days for exposure to hot water (80± 1) °C and hot air (100 ± 1) °C. Finally, the specimen was tested according to ISO 10319.

2.2.2.8 ELAVATION OF PRESSURE ON EXPOSURE TO AIR AND LIQUID

This method has been modified with recommendation of supplier. The specimen would first undergo for pressing at (temperature 160°C, Pressure 6 bar) and secondly for the exposure of hot liquid and hot air analysis as it would describe in 2.2.2.7 prolonged exposure to air and liquid. Finally, the specimen would be tested according to ISO 10319.

2.2.3 WIDE-WIDTH TENSILE TEST

This International Standard depicts a file test technique for the assurance of the tensile properties of geosynthetics (polymeric, glass, and metallic), utilizing a wide-width strip. This International Standard is pertinent to most geosynthetics, including woven geotextiles, nonwoven geotextiles, geocomposites, weaved geotextiles, geonets, geomats, and metallic items. The machine as been setting up and performed according to the conditioned described in table 2.3 .

TABLE 2.3 TESTING MACHINE BASIC SPECIFICATION

	ISO 10319
Specimen size	200 mm ±1 mm width
Strain rate	(20 ±5) % per min
Atmosphere conditioned	(20 ± 2) °C at (65 ± 5) % RH
Distance between clamps	100 mm
Number of test specimen	Machine direction=5, Cross machine direction=5
Test duration for non-woven geotextile	Max 4 min
Test duration for nets	30 secs

2.2.3.1 CALCULATIONS.

The calculation of tensile strength $\mathrm{T_{max}}$ expressed in kilonewtons per meter (KN/m), Determined directly by the tensile testing machine using the equation 1 below

$$\mathrm{T_{max}} = F_{max}\mathrm{C} \;\; \text{(kN/m)} \qquad (1)$$

Where

F_{max} is the recorded maximum tensile force, in kilonewtons (kN)

C is obtained from the formula

C=1/B

Where B is the nominal width of the specimen in meter, B=0.2

$C = \frac{1}{0.2} = 5$,

Since The mean and standard deviation values of samples properties tensile strength and strain described in graphs analysis. In the given below section of results and discussion the associated factors long with the samples behavior would compared and described according to the evaluation methods.

3 RESULT AND DISCUSSION

The purpose of selecting standards, conditions and methods to highlight the forecast of selective geosynthetics in terms of resistance against the soil reinforcement during road construction. The research work continues to evaluate the performance of geosynthetics using tensile test method. The result would be described below according to the basic comparison between the reference and conditioned samples. The direction, dimension, stabilization against the acetic, alkaline liquids, hot water, hot air, freezing temperature, Pressure would describe in details with evaluation data and recorded values.

3.1 INFLUENCE OF ACETIC AGREESIVE MEDIA ON MECHANICAL PROPERTIES OF THE MATERIALS

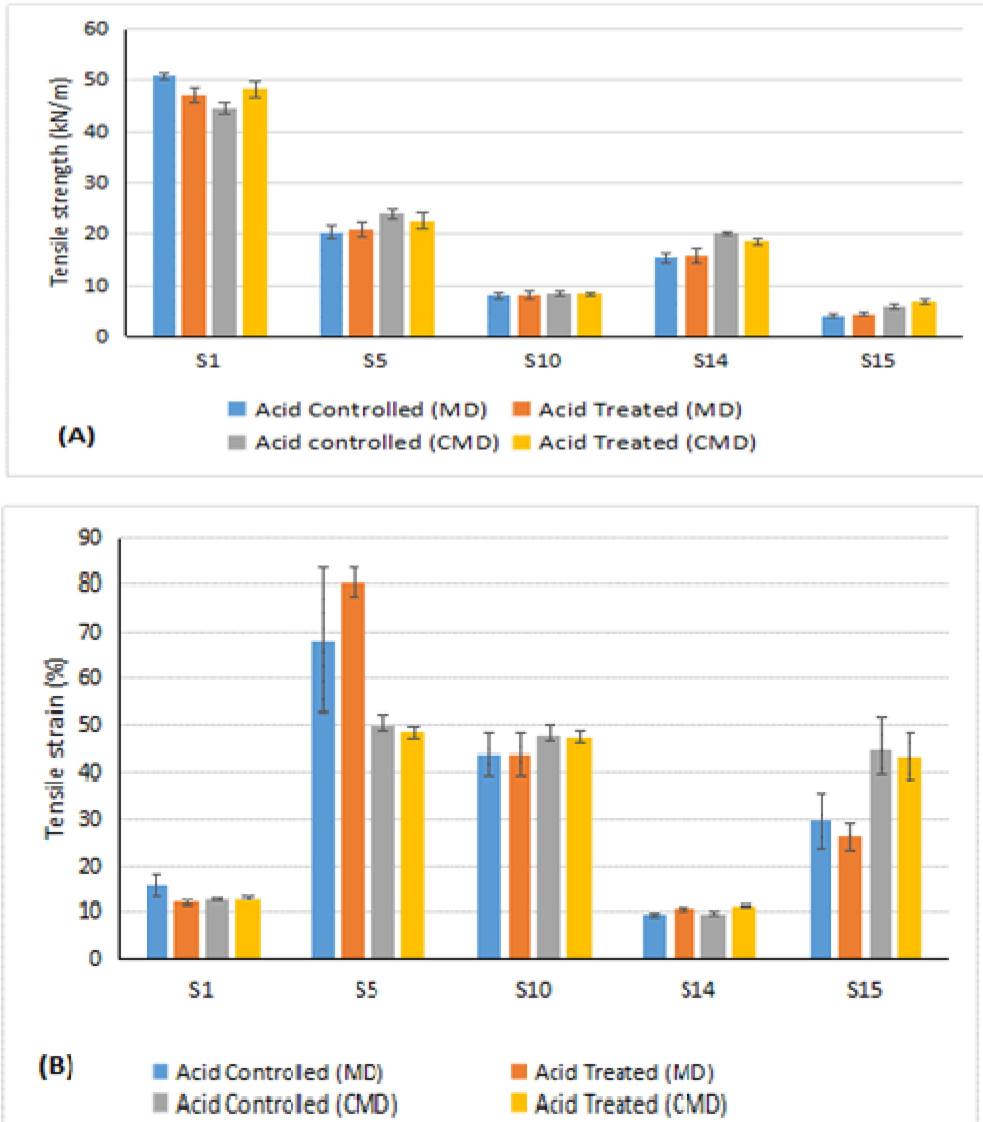
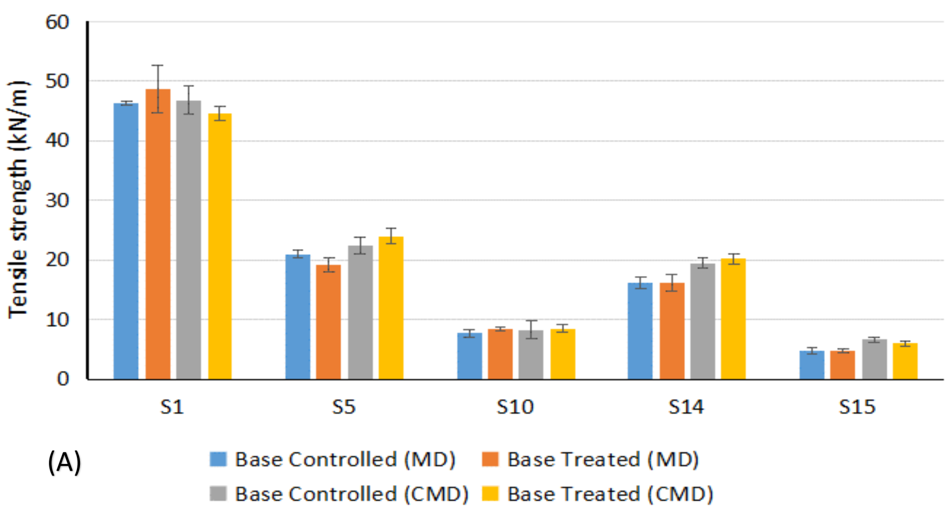


FIGURE 3.1 (A) TENSILE STRENGTH (B) TENSILE STRAIN COMPARISON WITH ACETIC AGGRESSIVE MEDIA

Five samples were chosen and tested according to the standard (EN-14030) to evaluate the resistance of the materials to aggressive media. Three belongs to non-woven geotextile (S5, S10, and S15) and two belongs to geogrids (S1, S14). It was found, that the tensile strength of S1 is slightly decreasing while other increasing in MD. The tensile strength of S1 and S15 is increasing while S5, S10 and S14 is slightly decreasing in CMD. All the changes of tensile strength in acetic aggressive media, except S1, do not exceed the standard deviation of the values and therefore are considered as negligible. According to the standard EN-13249 the minimum retained strength shall be 50%. It can be concluded, that all tested materials resist to aggressive acetic media.

The tensile strain of tested materials was calculated and analyzed. It was found, that the biggest change was registered for S5 material. The tensile strain of S5 acetic treatment increased 12,5% compared to control sample. The reason of so large change may be in thickness of the material. The thickness of S1 was four times more compared to S10.

3.2 INFLUENCE OF ALKALINE AGGRESSIVE MEDIA ON MECHANICAL PROPERTIES OF MATERIALS



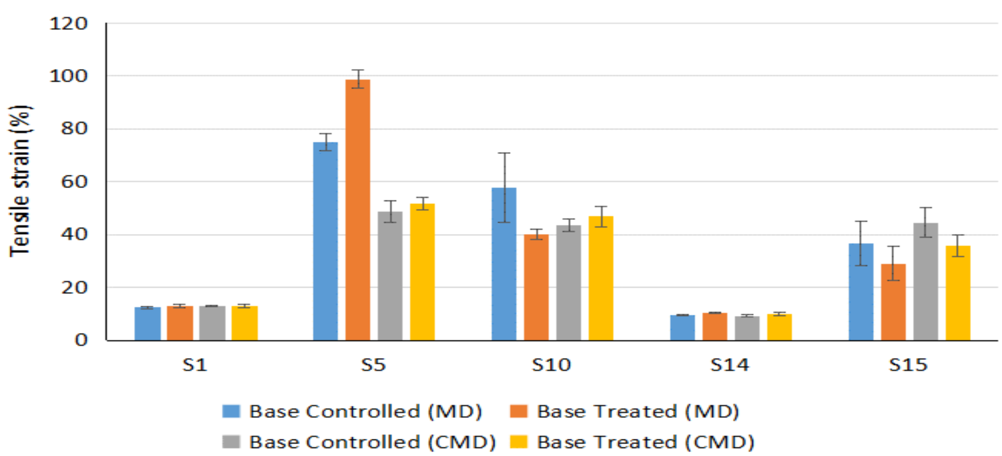


FIGURE 3.2 COMPARISON OF TENSILE STRENGTH (A) AND STRAIN (B) ON ALKALINE AGGRESSIVE MEDIA

Five samples were chosen and tested according to the standard (EN-14030) to evaluate the resistance of the materials to aggressive media. Three belongs to non-woven geotextile (S5, S10, and S15) and two belongs to geogrids (S1, S14). It was found, that the tensile strength is slightly increasing in samples (S1, S10 and S14) while constant in (S14) and decreasing in (S5) on machine direction. The tensile strength of S1 and S15 is slightly decreasing while increasing in others samples in CMD. According to the standard EN-13249 the minimum retained strength shall be 50%. All the samples sustainable against alkaline solution according to the values shown by results. Tensile strain of geogrid is remaining minimum as compared to geotextile.

3.3 INFLUENCE OF THERMAL CYCLING ON MECHANICAL PROPERTIES OF MATERIALS

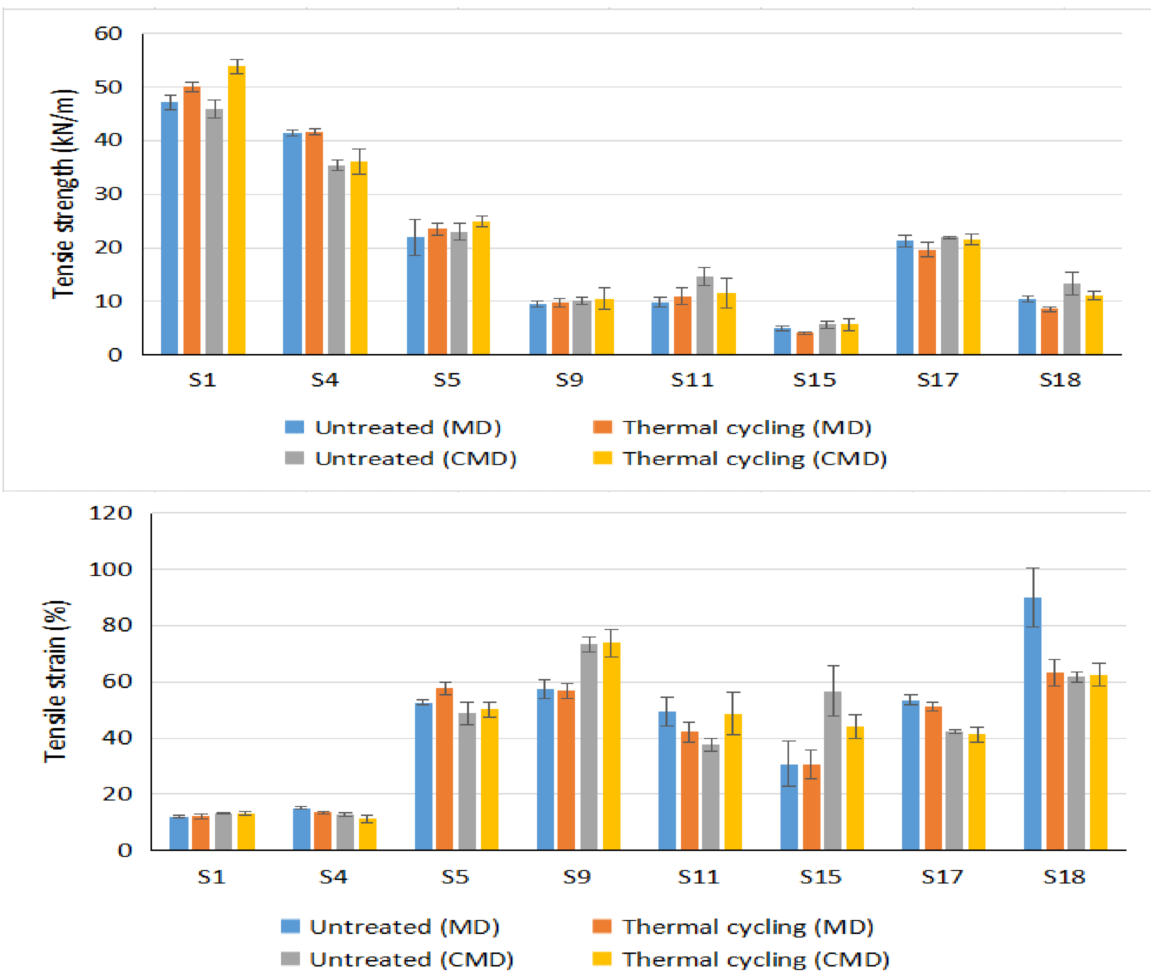


FIGURE 3.3 COMPARISON OF TENSILE STRENGTH (A) AND STRAIN (B) DUE TO THERMAL CYCLING.

Eight samples were chosen and tested according to the standard (ГОСТ Р 55032) to evaluate the resistance of the materials under the temperature below and upper 0°C.The figure 3.3 shows that the tensile strength of sample S1, S4, S5, S9 and S11 is in slightly increasing compared to untreated samples in Machine direction while the S15, S17 and S18 decreasing. The tensile strength of samples S1, S4, S5 and S9 is increasing while decreasing in samples S11, S17 and S18 on comparison with untreated in Cross machine direction. According to the standard the minimum retained tensile strength not less then 92% on comparative analysis with untreated the minimum retained strength observed in samples number S15 and S18 in Machine direction while the S11, S18 in cross machine direction. This could be because of difference of medium temperature on samples. The samples S1 and S4 are geogrid while rest of others sample were geotextile. The strain analysis show that the geogrid contains less deformation then geotextile.

3.4 INFLUENCE OF EXPOSURE AT BELOW FREEZING TEMPERTURE ON PHYSICAL PROPERTIES

This method is conductive to observed any deformation during the exposure to below freezing temperature. The geogrids sample S1 and S14 were inspected. The overall there is no changes have been observed on physical basis. The following materials have no adverse effect during the exposure as described in below table

TABLE 3.1 PHYSICAL INSPECTION AT BELOW FREEZING TEMPERATURE OF MATERIALS.

Sample number	TEMP -10		TEMP -20°C		TEMP -30°C	
	MD	CMD	MD	CMD	MD	CMD
S#1	OK	OK	OK	OK	OK	OK
S#14	OK	OK	OK	OK	OK	OK

3.5 INFLUENCE OF HEAT STABILITY ON MECHANICAL PROPERTIES OF MATERIALS

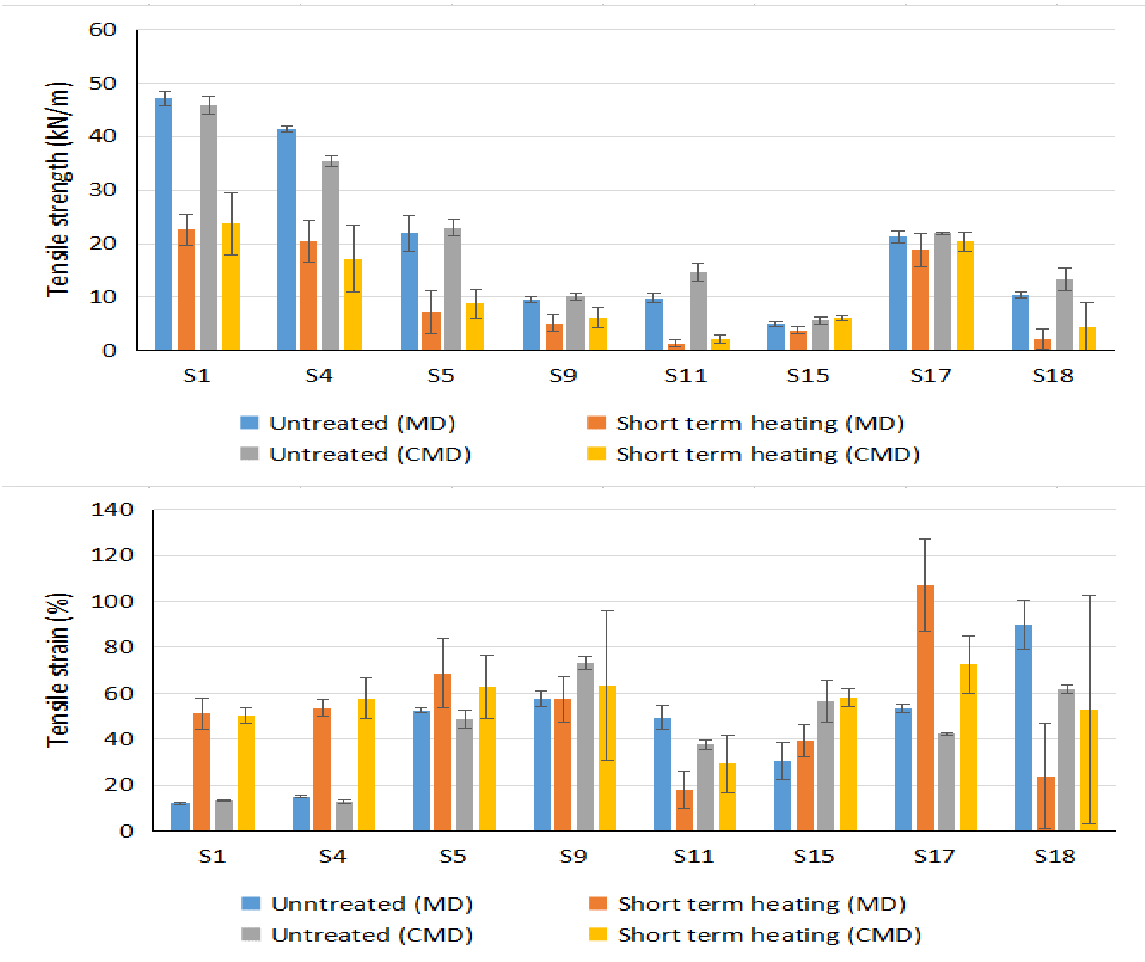
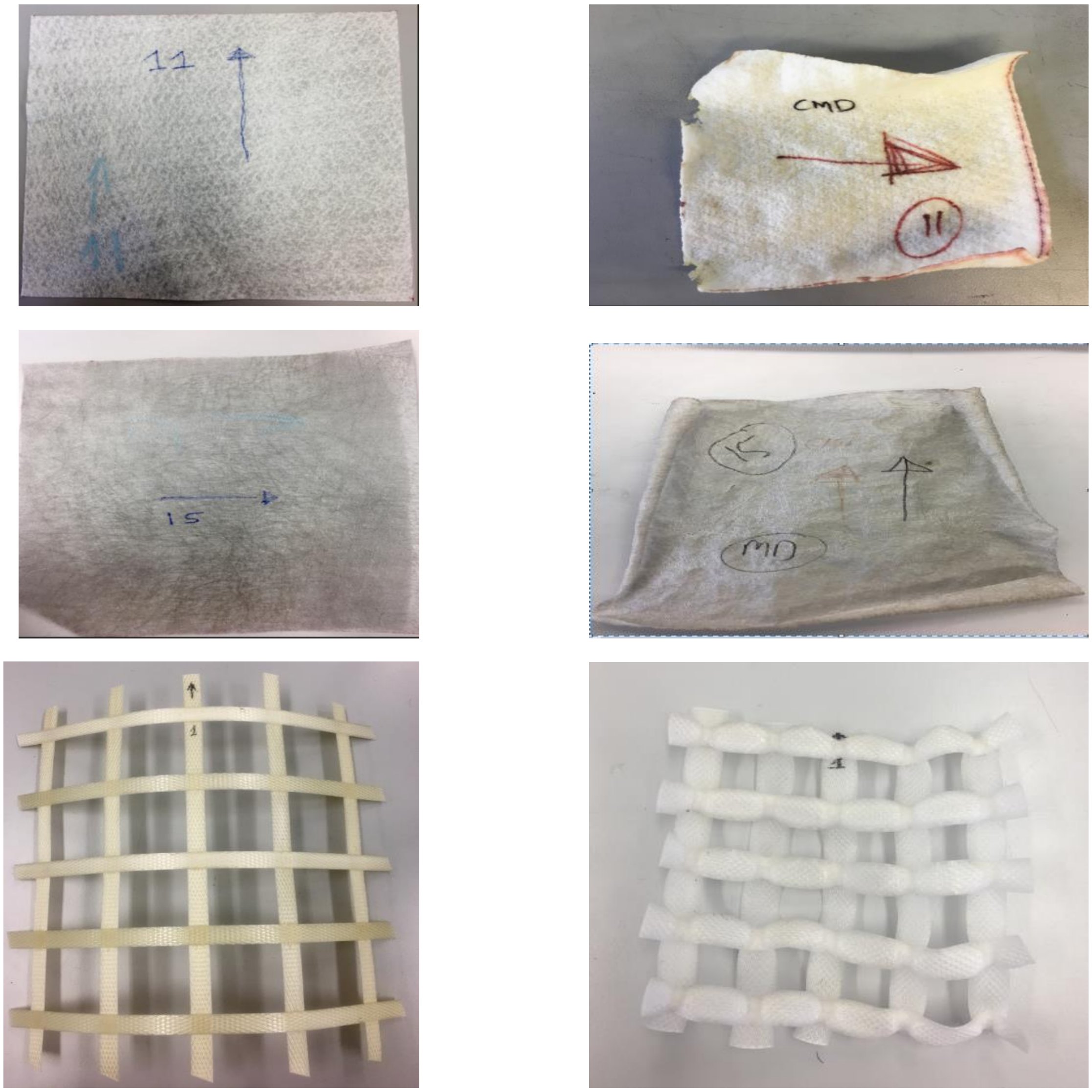


FIGURE 3.4 COMPARISON OF TENSILE STRENGTH (A) AND TENSILE STRAIN (B) ON SHORT TERM HEATING.

Eight sample had been chosen for the analysis between the Untreated and Short-term heating to evaluate the resistance on mechanical properties using the standard [ГОСТ Р 55034]. Samples S1 and S4 exhibit geogrid structure while others samples belong to geotextile products. The tensile strength is relatively decreasing as compared to untreated samples in machine direction while only two samples (S15, S17) were exhibit retrained strength (93%,107%) in Cross machine direction. The minimum retrained tensile strength is minimum up to 92% hence the only S15 and S17 achieved in cross machine direction.

The elongation values increasing trend observed in samples S1, S4, S5 and S17 on both machine and cross machine direction. The changes in structure is observed during the process of heating from 100 mm to 60 mm this is because of possible shrinkage in material structure while undergo heating process in oven.



Samples before the heating

Samples after the heating

FIGURE 3.5 PHYSICAL CONDITION OF SAMPLES EXHIBIT SHRINKAGE DURING THE PROCESS.

3.6 INFLUENCE OF SHORT AND PROLONGED EXPOSURE ON MECHANICAL PROPERTIES OF MATERIALS

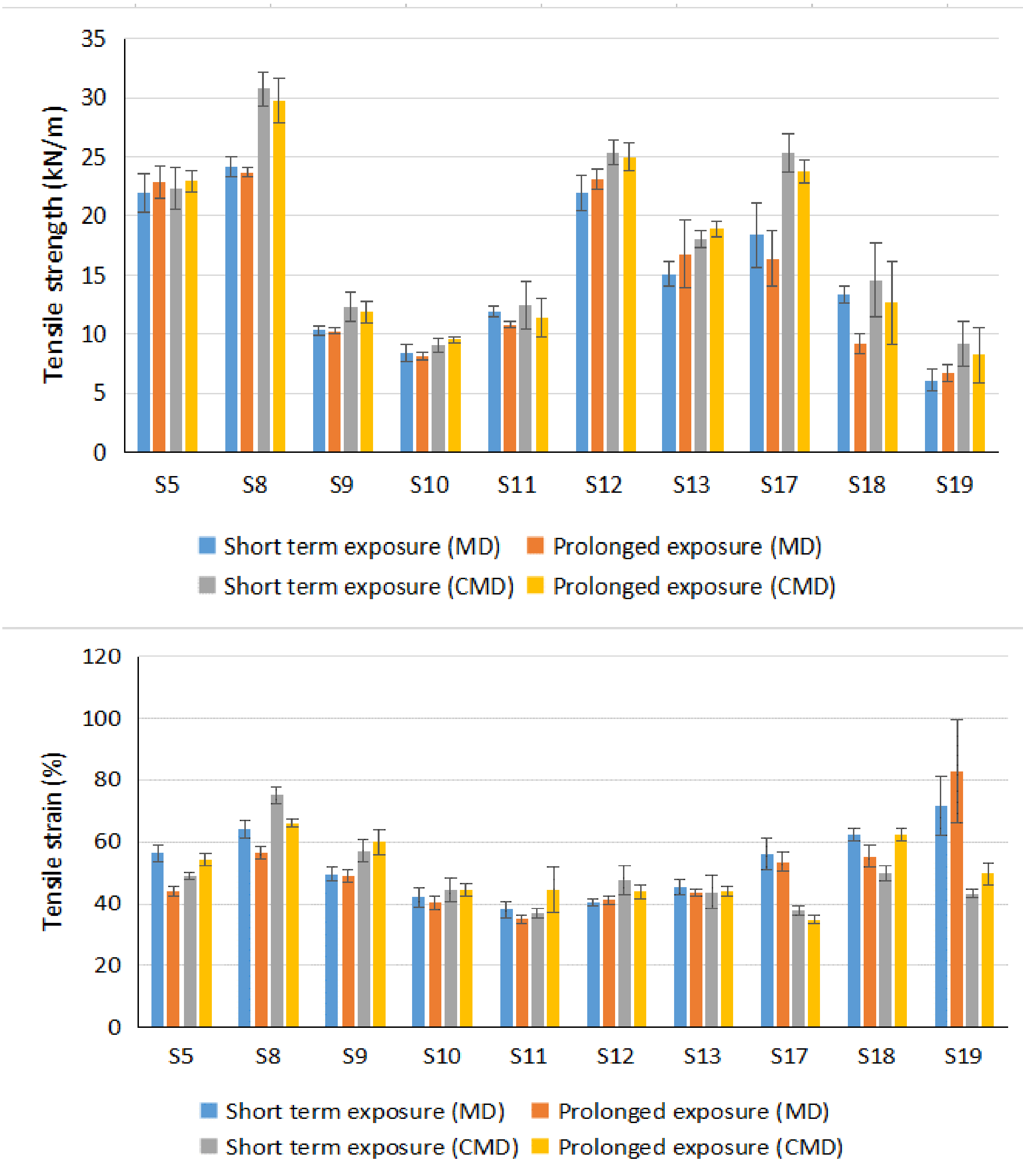
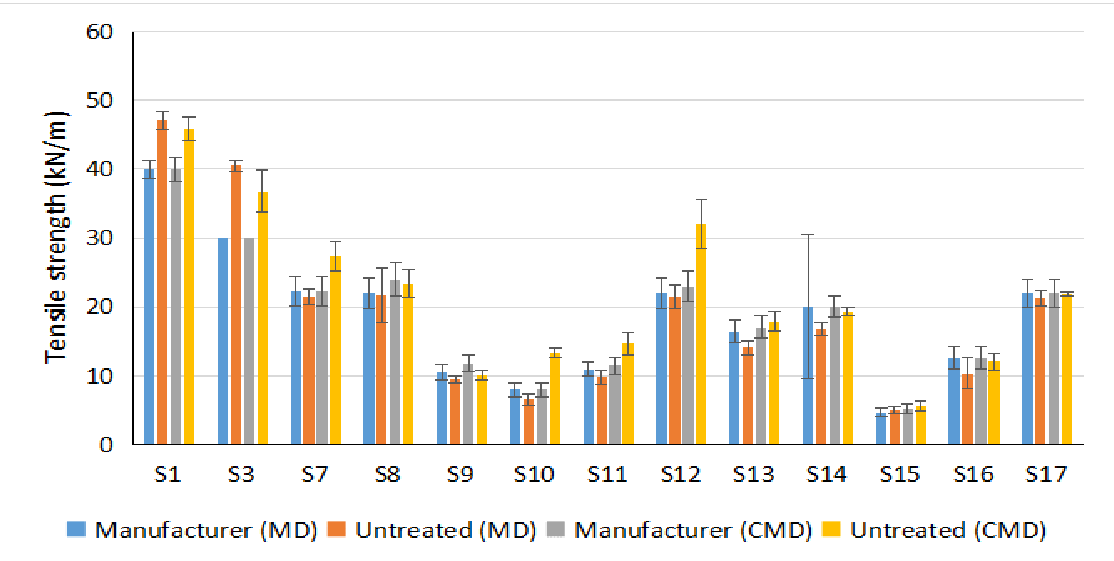


FIGURE 3.6 COMPARISON OF TENSILE STRENGTH (A) AND TENSILE STRAIN (B) DURING THE SHORT AND PROLONGED EXPOSURE

Ten different samples of geosynthetics were selected for the analyzation and undergo the influence of short and prolonged exposure to hot air and liquid. The resulted tensile strength and strain in figure ----- would be resultant outcomes during the wide width tensile test. According to the standard EN-13249 the minimum retrained in tensile strength should not be less then 50%. The available data shows that all the samples would have smaller affects which is acceptable and considered as positive. All the samples composed of geotextile materials. The minimum strain value increasing in sample S19 in machine direction while others have relatively decreasing trend. Tensile strain in cross machine direction was increased on samples S5,S9, S11,S18 and S19 while decreasing in S8,S10,S12,S13 and S17.

3.7 INFLUENCE OF MATERIALS CONDITION ON MECHANICAL PROPERTIES



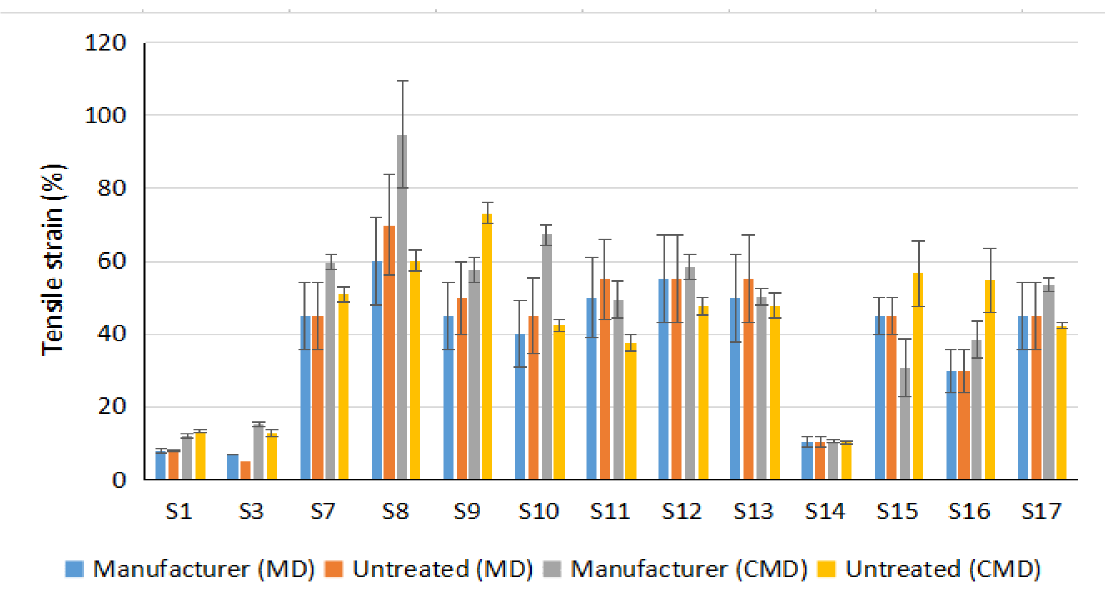


FIGURE 3.7 COMPARISON OF TENSILE STRENGTH (A) AND TENSILE STRAIN (B) WITH REFERENCE TO MANUFACTURING AND UNTREATED SAMPLES

Thirteen samples were selective for the comparison between the manufacturing data and lab reference data without prior to any further treatment termed as (untreated). The figure 3.11 shows that the tensile strength values difference in the range of (0-20%) for the samples S7, S8, S9, S10, S11, S12, S13, S14, S16 and S17 while the S1, S3 and S15 have improved values in Machine direction. The tensile strength in terms of percentages in cross machine direction shown that the relatively lesser observed in the samples S8, S9, S14 and S16 in range (0-14%) and for others samples is much more than the reference. Generally, the overall tensile strength comparison relates that the geogrid S1, S3 have more strength then S14. The geotextile related samples S7, S8, S12 and S17 have comparatively same characteristic in terms of tensile strength. S15 exhibit low strength values of overall comparison between the samples.

Tensile strength comparative analysis revealed that the geogrid (S1, S3 and S14) exhibit lower elongation comparatively with the others samples of geotextile products. The strain value remains unchanged in machine direction of specimen S1, S7, S12, S14, S15, S16 and S17 while others exhibit much more improved results. The strain in cross machine direction is positive for samples S1, S9, S15 and S16 while others exhibit decreasing trends between the range (0 to 37%).

3.8 INFLUENCE OF PRESSSURE AND EXPOSURE ON MECHANICAL PROPERTIES OF MATERIALS

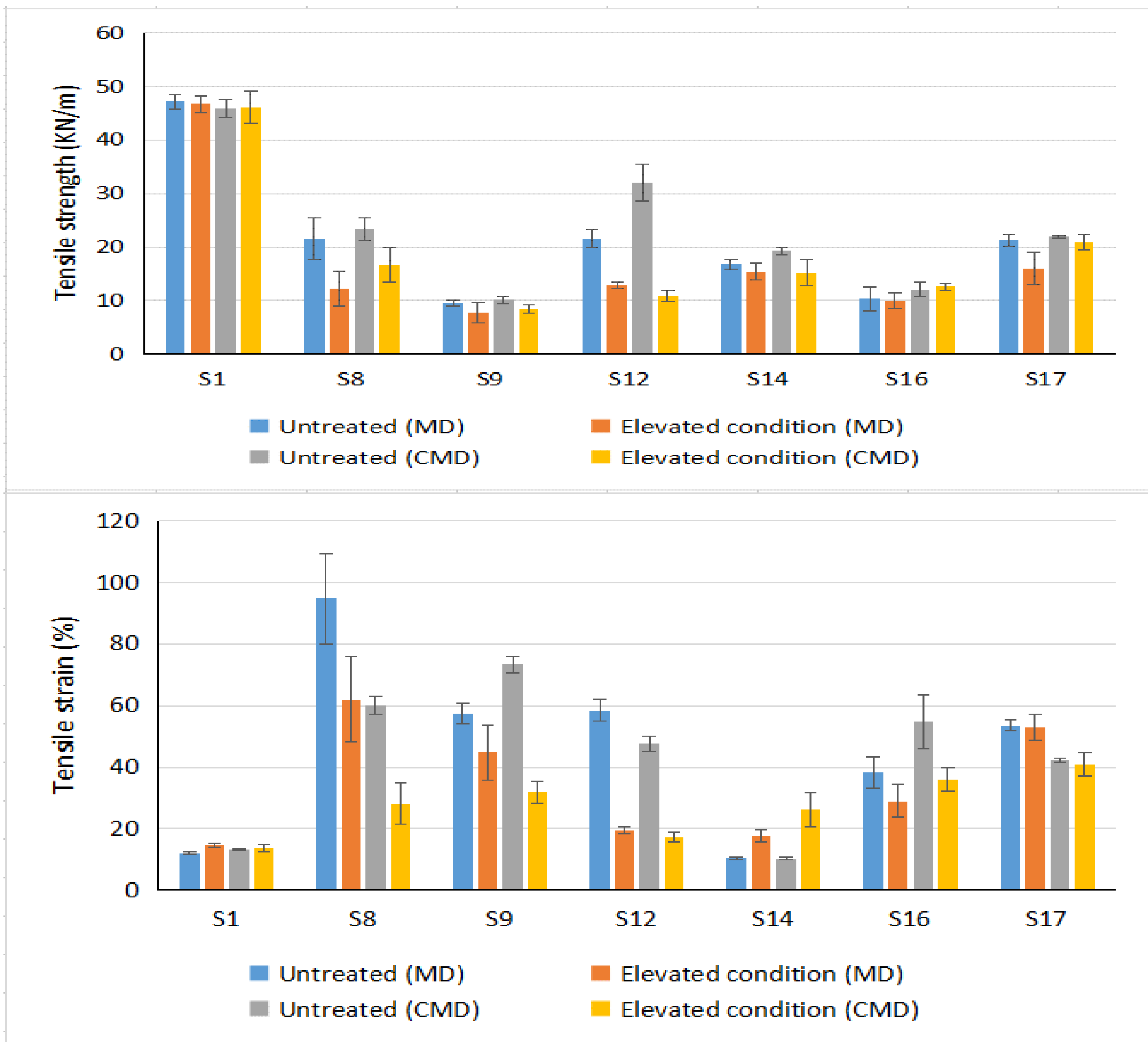


FIGURE 3.8 COMPARISON OF TENSILE STRENGTH (A) AND TENSILE STRAIN (B) IN BOTH DIRECTION AT ELEVATION EXPOSURE.

Eight different samples were tested to observed the influence of elevated temperature and pressure. The sample S5 have no results because of degradation taken place while others samples have normally tested. This process is additionally modified by the addition of hot pressing. The tensile strength in machine direction exhibit reduction values in sample S8(57%), S12(60%) while other samples ranges (75-99 %). In cross machine direction the retained strength is 34% while others samples exhibit values between (71-100%).

The strain values reveals that the samples S8,S9,S12 and S16 exhibit decreasing trends in both direction while the samples S1 and S17 comparatively unchanged. The reduction ratio is much more wider in sample S8,S12 compared to S9 and S16. The increasing trend is observed only in sample S14 in both direction.

FIGURE 3.9 SAMPLE **S5** DEGRADATION RECORDED DURING THE TEST ANALYZATION

4 CONCLUSION

The experimental study shows that the evaluation of geosynthetics performance under the influence of certain artificial medium have certain characteristic behavior. The major contact during the selection of geosynthetics with soil and other base layer materials which intended to show interaction must retained strength. The samples which contains geogrid structure were shown good tensile strength and less elongation in the medium against climate condition (rains, alkaline, temperature below the ground). The geotextile has more elongation comparatively to geogrid. The variation in the properties would be acceptable because different grades of geosynthetics having their own characteristic behavior against the same artificial condition. These geosynthetics were shows adverse effects when they exposed to high temperature for shorter period. The weathering condition during assembling, transportation, storage would be the key factors for starting degradation. The shrinkage has been observed while different ambient condition during drying of samples which could relate the significance wetting and dryness of materials during the service life.

Generally, the provided geosynthetics have different mechanism of manufacturing process and materials formulation so their major properties which can relates the durability is tensile strength. This property is calculated on the basis of retained tensile strength. According to standard ISO/TS 13434:2008 the minimum bearable retained strength should be 50 % which can evaluate a service life (25 years). The available geosynthetics which can be suitable for the road construction have been evaluated by the laboratory process. Since the market of geosynthetics is steady at the time but it would be expected to grown widely according to the market survey **"Global Geosynthetics Market"** [14]**.**

The significance of geosynthetics have been expected near future in the transportation and civil work. The above factors would relate the difference of materials while selection and during service life. The evaluation of the data is much more important for the inspection of materials at different stages.

5 ABSTRACT

This experimental study evaluates performance of geosynthetics under influence of certain environmental conditions and artificial medium. The geosynthetics must retain their strength in contact with soil and other base layer materials during their useful life period during tens of years. The geosynthetics have different mechanism of manufacturing process and materials formulation so their major common property, which can be evaluated regarding durability, is tensile strength.

Twenty different geosynthetics (geogrids and geotextiles) were selected for testing. The following characteristics of the geosynthetics were evaluated in this work:

- The effect of climate conditions and chemical factors on mechanical properties of geosynthetics.
- Durability of geosynthetics for Estonian road construction. The geosynthetics is composed of different polymers, which may have certain limitations in application and should be therefore evaluated according to the standards under certain condition during application of road structure.
- The effect of temperature and pressure in terms of installation and service life below and above freezing temperature of geosynthetics.
- Resistance of hydrolysis and oxidation according to the standards.

All the samples tested in this work according to standard ISO/TS 13434:2008 retained strength above 50 % and can therefore have service life up to 25 years. The same was also valid for acid and alkali environment. Mechanical properties reduced more significantly, if pressure and elevated temperature was applied before the durability test.

6 KOKKUVÕTE

Käesolev eksperimentaalne uuring hindas geosünteetide vastupidavust erinevates keskkonnatingimustes ja tehiskeskkondades. Geosünteedid peavad säilitama oma tugevuse kontaktis pinnase ja muude aluskihtidega mitukümmend aastat kestva kasutusea jooksul. Peamine ühine parameeter, mille abil käeolevas töös geosünteetide vastupidavust hinnati oli tõmbetugevus, kuna geosünteedid olid erineva keemilise koostisega ja valmistatud erinevate meetoditega.

Katseteks valiti 20 erinevat geosünteeti (geotekstiilid ja geovõrgustikud). Hinnati järgnevaid geosünteetide omadusi:

- Kliimatingimuste ja keemiliste faktorite mõju mehaanilistele omadustele;
- Geosünteetide vastupidavus Eesti teekonstruktsioonides. Kuna geosünteedid olid valmistatud erinevastest polümeeridest, mis võivad omada erinevaid piiranguid, tuli läbi viia standardikohane uuring jäljendamaks paigaldustingimusi ja keskkonda teekonstruktsioonides;
- Geosünteedi paigalduses ja kasutuses rakenduva temperatuuri (all ja ülevalpool külmumispunkti) ja rõhu mõju;
- Standardikohane vastupidavus hüdrolüüsile ja oksüdatsioonile.

Kõik katsekehad, mida antud töös vastavalt standardile ISO/TS 13434:2008 katsetati omasid jääktugevust üle 50 % ja nende kasutusiga on seega kuni 25 aastat. Sama kehtis ka standardikohase aluselise või happelise keskkonna kohta. Mehaanilised omadused vähenesid siiski märgatavalt, kui enne vastupidavuskatsetusi rakendati kõrgendatud temperatuuri ja survet.

7 BIBLIOGRAPHY

[1] J.-H. Y. Sanjay Kumar Shukla, Fundamentals of Geosynthetic, Netherland: Taylor & Francis/Balkema, 2006.

[2] Sanjey kumar shukla, Geosynthetics and Their Applications, London: Thomas Telford Ltd, 2002.

[3] *. Jorge G. Zornberg a, "Functions and applications of geosynthetics in roadways," *Procedia Engineering 189 (2017),* no. Saint Petersburg,, pp. 298-306, 2017.

[4] B. Christopher, "Geotextiles used in reinforcing paved and unpaved roads and railroads," 2016.

[5] Y.G.Hsuan, Geotextiles from design to application, R.M.Koerner, Ed., USA,UK: Woodhead Publishing, 2016.

[6] I. 13434:2008(E), "Geosynthetics-guidelines for the accessment of durability," 2008.

[7] "Substech," [Online]. Available: http://www.substech.com/dokuwiki/doku.php?id=polymer_structure. [Accessed 6 june 2018].

[8] "research gate," [Online]. Available: https://www.researchgate.net/figure/Molecular-structure-of-PET-plastic-in-this-article_fig2_324497945. [Accessed 6 june 2018].

[9] L. D. Suits, "geosynthetic testing standards development organizations," in *Geotextile: from design to application*, NY,USA, woodhead publishing, 2016, pp. 89-104.

[10] "Oxidative-Induction-Time-(OIT)-Measurements-of-Polyolefins-and-Thermoplastic-Elastomers-by-using-DSC.pdf," 23 JUNE 2013. [Online]. Available: https://www.azom.com/suppliers.aspx?SupplierID=8400.

[11] "Durability of geosynthteics," [Online]. Available: https://www.geosynthetica.net/wp-content/uploads/Publication243_Durability_C187.pdf.

[12] S.R.ALLEN, "Geotextile durability," in *Geotextile from design to application*, Austin,USA., Woodhead publishing, 2016.

[13] R.M.KOERNER, "Lon term geotextile degradation mechanism and exposed liftime prediction," in *Geotextile design to application*, Philadelphia, PA, United States, wood head publisher, 2016, pp. 217-233.

[14] "prnewswire," [Online]. Available: https://www.prnewswire.com/news-releases/geosynthetics-market-to-be-driven-by-increase-in-demand-from-transportation-and-civil-engineering-sector-till-2022--million. [Accessed 5 6 2018].

[15] Robert.M.Koerner, Designing with geosynthetics(fifth edition), New jersey: Pearson Education, Inc. , 2005.

[16] P. A. M. M. G.T. Torosian, "properties, behavior, and testing of geotextiles," in *Geotextiles: From Design to Applications*, Wood head publishing series 175, 2016, pp. 110-111.

[17] J. G. Zornberg, "Functions and applications of geosynthetics in roadways," *Transportation Geotechnics and Geoecology, TGG 2017, 17-19 May 2017, Saint Petersburg, Russia,* vol. Procedia Engineering 189 (2017) 298 – 306, no. science direct, 2017.