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Feasibility of Geo-textile in Transportation Engineering- An Overview

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Abstract:- ***Nowadays various geo-synthetic materials like geo-grids, geo-textile, geocomposites, geo-nets, geomembranes, geo-synthetic clay liners, geo-foam, and geo-cells are extensively used in various civil engineering applications and projects because of their useful characteristics. Various critical situations arise due to increasing traffic day by day. Due to high traffic volume, the roads are damaging before its life. The black cotton soil posses high swelling property. Due to heavy rains, compression and contraction takes place in the form of undulations. To overcome such a problem we can use geo-textile materials. Geo-textile is one of the first textile products in human history. Geo-textile increases the bearing capacity of soil and the improvement of soil strata beneath the highway pavement so that undulations can be avoided and the life span of road increases.***
Geo-textile has been used very successfully in transportation engineering for over 30 years. Geotextiles are better materials for infrastructural works such as roads, , and many others. Geo-textiles play an important role in modern pavement design and maintenance applications. Worldwide its usage is high in general & transportation engineering in particular.
In this review, paper geo-textiles have been discussed in length with regard to its basic characteristics, function, and applications like reinforcement to improve the performance of road, in-pavement drainage system, in road construction, maintenance and erosion control, in separation and sub-grade stabilization and in support systems. The focus of this paper is on a better understanding of this relatively new tool available to the transportation engineers.

Keywords - Geo-textile, separator, drainage, filtration, reinforcement

Introduction:-

India has one of the largest networks of roads in the world. Due to rapid growth in traffic, the existing roads have become structurally inadequate. Traditionally design and construction practices do not fulfill construction standards. To overcome these constraints, researchers are forced to seek alternative using sub-standard materials and innovative design practices. To find out the alternative solution of geo-materials which have good strength parameters as well as deformation parameters is a burning task for various geo-engineering applications. Several researchers are exploring the possibility of using different by-products or waste materials like fly ash, fiber, rice husk ash, geo-synthetic material like geo-textile, geo-grid, geo-membrane, geo-mats, geo-webs, etc. and recycled tire materials as geo-materials. Figure No.1and Table No.1 shows the types of geo-synthetic material and its applications.

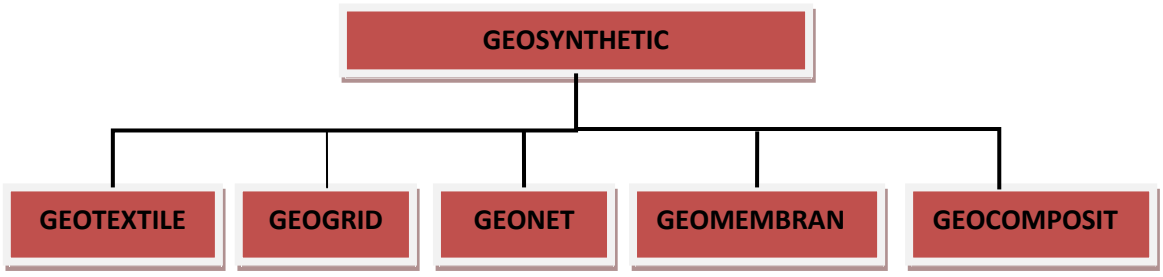

Figure No. 1 Types of Geosynthetic Material (Anitha J, 2017)

India there are so many variations in soil state to state. Some soil having very low load-bearing capacity like black cotton soil because it absorbs water, swells and lose their strength so in that areas it is essential to improve the quality of soil by mixing of geo-synthetic material in desired quantity. The use of geo-synthetic material as an engineering material has increased significantly in the last decade.
Because of increasing traffic day by day many problems related to the road are created rapidly so the adequate management of problem soil conditions and the preparation of the foundation are extremely important to make sure a long-term pavement structure that does not require excessive safeguarding. Stabilization may also be used to improve

soil workability provide a weather-resistant work stage; reduce swelling of costly materials and moderate problems associated with frost heave. Soil that is highly prone to volume and strength changes can cause severe roughness and accelerate the deterioration of to pavement structure in the form of increased cracking and decreased ride quality when combined with truck traffic. Commonly, the stiffness (in terms of resilient modulus) of some soil is highly dependent on moisture and stress state. In some cases, the sub-grade soil can be treated with various materials to improve the strength and stiffness characteristics of the soil.

During the process of severe rut formations, non-uniformity in load spreading phenomenon results in the inadequate sub-grade reaction at one side (where thinning of the aggregate layer occurs) and more than adequate sub-grade reaction at another side (i.e. where thinning of the aggregate layer occurs). Such type of condition reduces the design life of the roads affect the riding quality and increase maintenance cost. In such a situation, one of the feasible alternatives is to reinforce the road by introducing a reinforcement layer in the form of geo-textile at the interface of a granular sub-base layer and prepared sub-grade. It is common practice to lay an unbound aggregate layer directly on the original sub-grade or in a shallow cutting. Generally, the construction of roads on a soft sub-grade can only support relatively and it is often impossible to construct a stable and durable base course without losing a large amount of base material into the sub-grade. Using fabric to enhance pavement stabilization provides such a solution.

Table No. 1 – Summary of Geo-synthetic Application

Application	Primary function	Products
Sub-grade/pavement stabilization	Separation Reinforcement Filtration	Geo-textile/geo-grid
Railroad Track bed Stabilization	Drainage Separation filtration	Geo-textile/geo-grid
Asphalt Overlay	Stress relieving layer Waterproofing	Geo-textile/geo-grid
Soil Reinforcement Embankment Steep Slopes Vertical Walls	Reinforcement Reinforcement Reinforcement	Geo-textile/geo-grid Geo-textile/geo-grid Geo-textile/geo-grid
Subsurface drainage (French drains)	Filtration	Geo-textile
Subsurface drainage	Filtration Fluid transmission	Prefabricated drainage composites
Erosion control filter (under rip-rap)	Filtration Separation	Geo-textile
Surface Erosion Control	Turf reinforcement	Erosion control mats fabric forming mats
Canal/pond lining	Moisture barrier	Geo-membrane
Land fills	Drainage Separation Filtration Barrier Reinforcement	Geo-textiles/geo-grids/ Geo-membranes Geosynthetic clay liners
Geo-membrane protection	Protection/cushion	Geo-textile

The first use of fabricated material to improve pavement performance in the US was in the 1920s. The state of southern California used a cotton textile to reinforce the underlying material in a road that had poor quality soils (Beckham et al., 1935). However, because of their susceptibility to degradation, cotton fibers have since been replaced with synthetics polymer, which can better resist harsh conditions. The application of geotextiles in road construction on soft sub-grade soil has become popular in the past thirty years, and it has successfully applied in several cases (Sprague and Cioff, 1993; Tsai et al., 1993). Currently, one of the important roles of geo-textiles is as a separator between the granular base layer and the natural sub-grade (Al-Qadi et al., 1998).

Background:-

Geo-textile is used in the pavement to either extend the service life of the roads and to minimize the thickness of the pavement system. Geotextiles are made from polypropylene, polyester, polyethylene, polyamide (nylon), polyvinylidene chloride, and fiberglass. Polypropylene and polyester are the most used. The physical properties of these materials can be varied by the use of additives in the composition.

During the last thirty years, geo-textile is known to be better for improving the performance of paved or unpaved roads. Both women, as well as non-woven geo-textiles, can be effectively used in the stabilization/separation of the primary

highway, secondary or low traffic volume roads, unpaved and paved (access roads, forest roads, haul) roads, parking lots and industrial yards. Modern geo-textile are generally made from synthetic polymers-polypropylenes (85%), polyesters (12%), polyethylenes (2%), and polyamides (1%) which do not decay under biological and chemical process (Koerner, 1999). This makes them useful in road construction and maintenance.

Generally, the process involved in the formation of geo-textile can be explained by mainly three steps. The first step is the formation of polymers from the polymeric materials. The second step is the melting of such polymers into fibers or yarn, where a yarn can consist of one or more fibers). The resulting fiber filaments are hardened or solidify by three processes: wet, dry, or melting, to form the different types of fibers of desired shape or size. Then obtained fibers is used in the construction of geo-textile are monofilament, multifilament, staple yarn, slit-film monofilament, and slit-film multifilament. In the last step, the fiber or yarns are formed into geo-textile using woven, non-woven or knit process (even though knit fabrics are seldom used as geo-textile) (Koerner, 1999). Table No. 2 shows the geo-textile interface products with their applications.

Table No. 2 Sub-grade-Granular Interface Products (Elseifi, 2003)

S. .No.	Interface Type	Application
1.	Woven Geo-textile	Separation, Filtration
2.	Non-woven Geo-textile	Separation, Filtration, Moisture Barrier

Objective:-

The objectives of this study are as follows-

1. To study about geo-textile that can be used in road construction and pavement construction materials.
2. To check the suitability of these materials.
3. Analysis and interpretation of results.

Geo-textile:-

Geo-textile is the most versatile and cost-effective ground improvement materials. Their use has expanded rapidly into nearly all areas of civil, geotechnical, environmental, coastal, and hydraulic engineering. They form the major component of the field of geo-synthetics, the others being geo-grid, geomembranes, and geocomposites. The ASTM (1994) defines geo-textiles as permeable textile materials used in contact with soil, rock, earth or any other geotechnical related materials as an integral part of the civil engineering project, structure or system. Almost all geo-textiles available in the United States are manufactured from either polyester or polypropylene. Polypropylene is lighter than water (specific gravity of 0.9), strong and very durable. Polypropylene filaments and staple fibers are used in manufacturing woven yarns and non-woven geo-textile. High tenacity polyester fibers and yarns are also used in the manufacturing of geo-textiles. Polyester is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environment. Table No. 3 shows the relevant properties and their ASTM standards.

Table 3: Geo-textile properties and associated ASTM standard test method

Property	Reporting units	Standard test designation
Grab strength	(KN)	ASTM D 4632
Sewn seam strength	(KN)	ASTM D 4632
Tear strength	(KN)	ASTM D 4533
Puncture strength	(KN)	ASTM D 6241 / ASTM D 4833
Permittivity	Sec^{-1}	ASTM D 4491
AOS	US Sieve NO. (mm)	ASTM D 4751
Ultraviolet Stability	%	ASTM D 4355

Geotextile is a permeable textile material and may be woven, non-woven or knitted. Figure No. 2 shows Scanning Electron Microscopic views of typical geo-textiles. Depending on the weaving technology and the fibers used (a polymer used, and the technology of drawing) the strength of woven fabrics can be as high as 1100 kN/m at 5% elongation. On the other hand, the non-woven geo-textiles are better known for their filtration and drainage in view of their high porosity. Even when thin and of low strength they can act as separators. The main purpose of geo-synthetic material is to have better performance and to save money. However, this review will concentrate on some function of geo-textile products.

Geo-textile Manufacture:-

(1) Woven geo-textile:- In woven construction, the warp yarns, which runs parallel with the length of the geo-textile panel (machine direction), are interlaced with yarns called fill or filling yarns, which run perpendicular to the length of the panel (cross direction) as shown in figure 2. Woven construction produces geo-textile with high strengths and module in the warp and fills directions and low elongations at rupture. The modulus varies depending upon the rate and direction

in which the geo-textile is loaded. Woven construction produces geo-textiles with a simple pore structure and narrow range of pore sizes or openings between fibers.

(2) Non-woven geo-textile:- It is formed by a process other than weaving or knitting, and they are generally thicker than woven products. This geo-textile may be made either from continuous filaments or from staple fibers. The fibers are generally oriented randomly within the plane of the geo-textile but can be given preferential orientation.

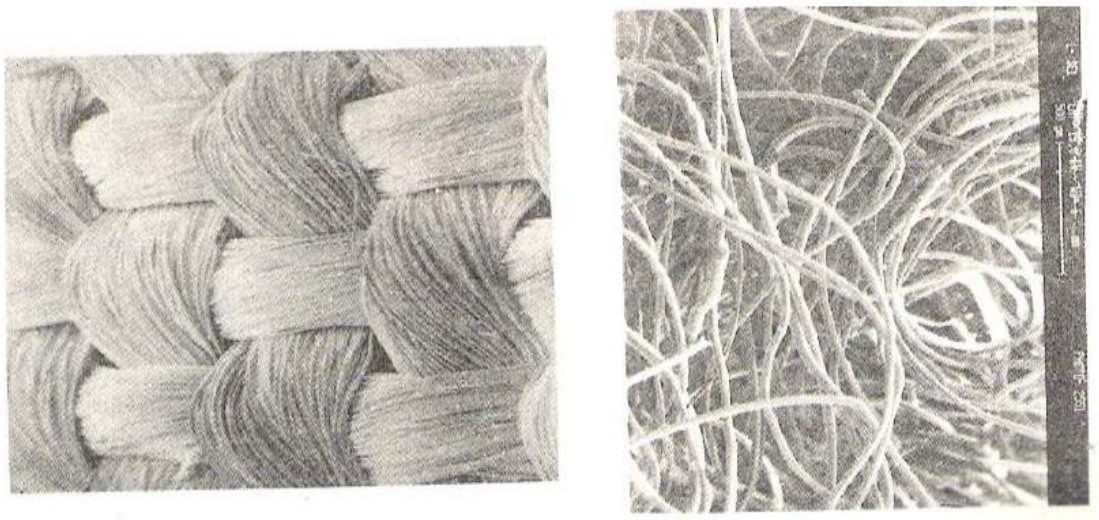

Figure No 2. SEM view of (a) Woven geo-textile (b) Non-woven geo-textile

(3) Knitted fabric is woven: - It is manufactured by another process which is obtained from the clothing textiles industry, namely that of knitting. In this process interlocking, a series of loops of yarn together is made. An example of a knitted fabric is illustrated in below figure No. 3. All of the knitted geo-synthetic is formed by using the knitted technique in conjunction with some other method of geo-synthetics manufacture such as weaving.

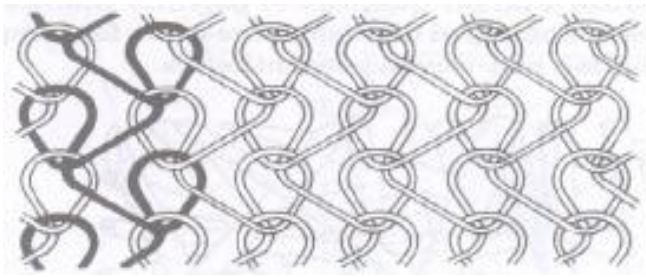

Figure No.3 SEM view of Knitted geo-textile (Bipin Agrawal, 2011)

Due to its polymeric nature, it is suitable for the places where it requires a high level of durability. However, they can be used in exposed condition because of its proper formulation. Based on function, geo-textile can be used and the functions are-

(1) Filtration
(2) Separation
(3) Durability
(4) Barrier
(5) Reinforcement
(6) Protection

Geo-textile in Pavement:-

The road constructed on weaker soil shows large deformation, causing in maintenance cost and interruption of traffic service. If the sub-grade of the pavement contains the expansive soil (black cotton soil) because of its susceptibility to moisture change which results in high shrinkage and swelling characteristics. Such soil possesses less strength and bearing capacity. So it is required to improve the quality of the soil for long term durability. Use of geo-synthetic material like geo-textile above the soft sub-grade (expansive soil) found to be one of the feasible and economic solutions to modify the road pavement and thereby increasing service life.

Many detrimental factors affect the service life of roads and pavements including environmental factors, sub-grade conditions, traffic loading, utility cuts, road widening, and aging. These factors include an equality wide variety of pavement conditions and problems which must be addressed in the maintenance or rehabilitation of the pavements, if not

deal with during initial construction. The main cause of distress in pavements is that they are quite permeable with 30 to 50% of precipitation surface water infiltrating through the pavement, softening and weakening the pavement sub-grade and base, accelerating pavement distress such as surface cracks the rapid reflection of cracking up through the maintenance treatment.

Therefore, the preferred strategy for long-term road and pavement performance is to build in safeguards during initial construction. These performance safeguards include stabilizing the sub-grade against moisture intrusion and associated weakening; strengthening road base aggregate without preventing efficient drainage of infiltrated water; and, as a last resort, enhancing the stress absorption and moisture proofing capabilities of selected maintenance treatments. Geotextiles are the most cost-effective tools for safeguarding roads and pavements in these ways. Figure No. 4 shows the pavement with or without Geo-textile.

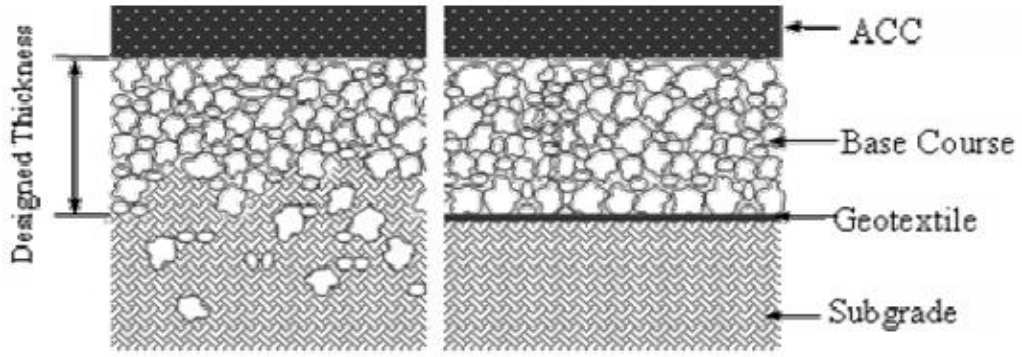

Figure No. 4 Pavement with and without geo-textile (Bipin Agrawal, 2011)

Christopher and Holtz 91985) propose the function of geo-textile for the corresponding sub-grade strength is shown in Table No. 4.

Table No.4 Function of geo-textile (after Christopher and Holtz, 1985)

Un-drain Shear Strength (KPa)	Sub-grade CBR (%)	Functions
60-90	2-3	Filtration and possible separation
30-60	1-2	Filtration, separation and possible reinforcement
<30	<1	All function

The four main applications for geo-textile in roads are sub-grade separation and stabilization, base reinforcement, overlay stress absorption, base reinforcement, overlay stress absorption, and overlay reinforcement. Sub-grade stabilization and base reinforcement involve improving the road structure as it is constructed by inserting an appropriate geo-textile layer. Sub-grade separation and stabilization apply geo-textile to both unpaved and paved roads. Geo-textile can be used as interlayer by placing them below or within the overlay. Some geo-textile relieves stress and others are able to reinforce the overlay. The products may also provide a moisture barrier.

Why Geo-textile:-

(a) An innovative solution to solve difficult problems economically and expediently.
(b) Enables the use of local materials sustainable solution.
(c) Use of unskilled labors
(d) Easy installation
(e) Does not requires heavy equipment
(f) It reduces maintenance cost and increases life
(g) Quality can be controlled since it's factory-made

Important Characteristics of Geo-textile:-

The characteristics of geo-textiles are broadly classified as:-

(a) Physical Properties:-

(1) Specific Gravity
(2) Weight
(3) Thickness
(4) Stiffness
(5) Density

(b) Mechanical Properties:-
(1) Tenacity
(2) Tensile strength
(3) Bursting Strength
(4) Tearing strength
(5) Frictional resistance

(c) Hydraulic Properties:-
(1) Porosity
(2) Permeability
(3) Permittivity
(4) Transitivity
(5) Turbidity/soil retention

(d) Degradation Properties:-
(1) Biodegradation
(2) Hydraulic degradation
(3) Photo degradation
(4) Chemical degradation
(5) Mechanical degradation

(e) Endurance properties:-
(1) Elongation
(2) Abrasion resistance
(3) Clogging length and flow

The function of Geo-textile:-
The mode of operation of a geo-textile in any application is defined by six discrete functions: separation, filtration, drainage, reinforcement, sealing, and protection. Depending on the application the geo-textile performs one or more of these functions simultaneously. On the basis of experience, people investigate that when the sub-grade condition possess poor soil, low un-drained shear strength, a high water table, and high sensitivity, the primary function of geo-textiles in stabilizing the sub-grade is separation. The protection function is not discussed here as it is not related to transportation applications. The basic introduction of each function of geo-textile material is as follows (Koerner, 1994):

(1) Separation: - The separation is the main function of geo-textile in highway pavement, generally when it is used to increases the bearing capacity of highway sub-grade (Al-Qadi, 2002 and Al-Qadi et al., 1994). The main purpose is to place a thin layer between two dissimilar materials to avoid the intermixing of the two materials. Basically, two mechanisms are happening with the geo-textile as a separator in the wet, soft and weak soft sub-grade road. One is to prevent the migration of sub-grade soil into the base course aggregate and the second thing is to prevent the penetration action of base course aggregate into the sub-grade soil, which also affects the strength of base course layer (Al-Qadi et al., 1994; Austin and Coleman, 1993; Barksdale et al., 1989; Bell et al., 1982; Christopher and Holtz, 1991; Van Santvoort, 1994). Figure No. 5 shows the pavement with or without Geo-textile.

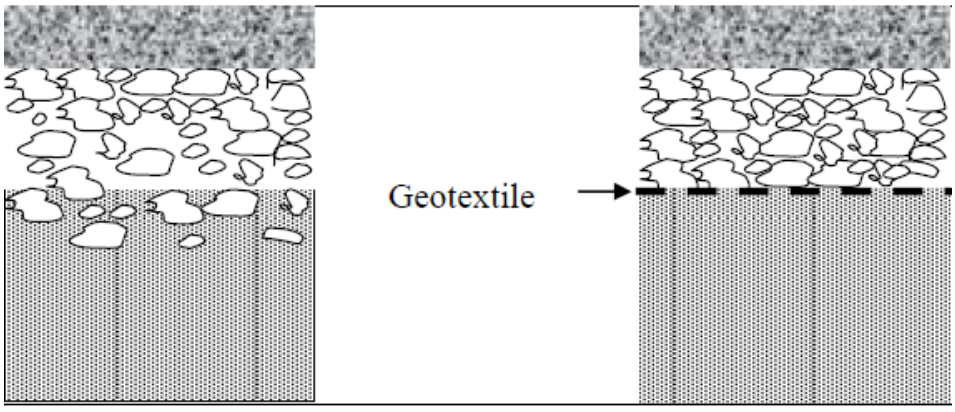

Figure No. 5 Stone base mixing and prevention in Highway (Rankilor, 1981)

(2) Drainage: - A geo-textile can collect a liquid or a gas and convey it along its own plane, as in Figure No. 6. thus providing fluid transmission. This refers to the ability of thick non-woven geo-textile whose three-dimensional structure provides a possibility for the flow of water through the plane of the geo-textile. This is normally termed as drainage

function and is valuable in strip drains and chimney drains. Here the geo-textile promotes a lateral flow thereby dissipating the kinetic energy of the capillary rise of groundwater.

The geo-textiles generally quantified by its transmissivity, which is defined as-

$$\Theta = k_p * t$$

Where Θ is the transmissivity, k_p is the in-plane hydraulic conductivity, and t is the geo-textile thickness at a specified normal pressure.

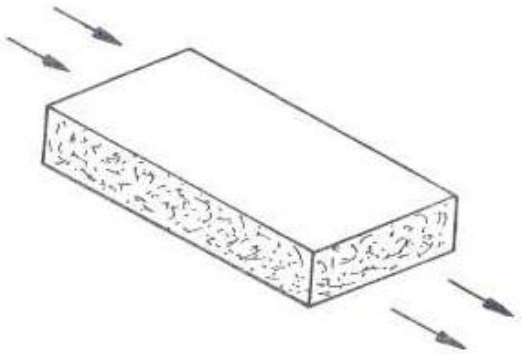

Figure No. 6 Drainage Function of Geo-textile

(3) Filtration: - It is defined as the equilibrium of a geo-textile soil system that permits for sufficient liquid flow with limited soil loss across the plane of the geo-textile over a service lifetime well-suited with the application under consideration (Koerner, 2005). Geo-textile acts as a filter when it allows liquid to pass normally to its own plane while preventing most soil particles from being carried away by the liquid current.

The geo-textile soil system should gain an equilibrium that permits for enough liquid flow under conditions of consideration. As the flow of liquid is perpendicular to the plane of the geotextile, filtration refers to the cross-plane hydraulic conductivity or permittivity, which is defined as –

$$¥ = k_n / t$$

Where ¥ is the permittivity, k_n is the cross-plane hydraulic conductivity, and t is the geo-textile thickness at a specified normal pressure. A common application of geo-textile as filtration function in a pavement edge drain is shown in figure No. 7.

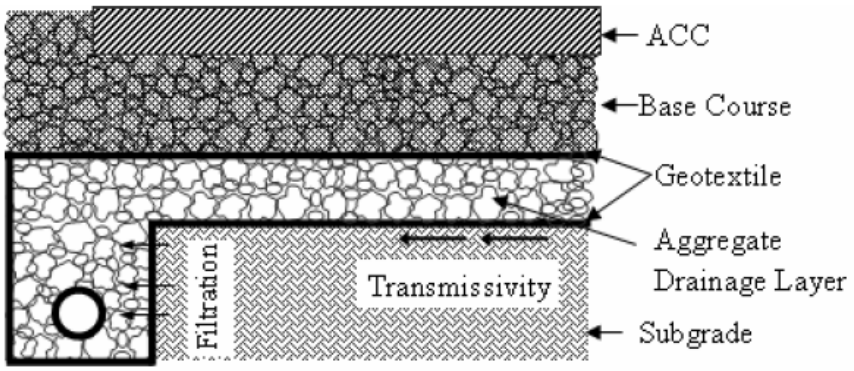

Figure No. 7 Filtration and transmissivity function (Khalid Meccai, 2004)

Advantages of using Geo-textile in Drainage and Filtration:-

(1) Eliminates the filter sand with dual media backfill.
(2) Replaces well-graded lab analysis sand gravel with the less expansive non-graded mix.
(3) Eliminates the need for perforated pipe in some cases.
(4) Cases where only sand backfill is available, Geo-textile can be used to wrap the drainage pipe to act as a screening agent. Geo-textile results in preventing sand from entering the perforation in the pipe.
(5) Trench excavation depth can be reduced using Geo-textile.

(4) Reinforcement: - To improve the strength and stiffness of the highway pavement for long term durability, the geo-textile material it provides into the pavement layers. The reinforcement function of geo-textile in the U.S. has been fulfilled by geo-grids; geo-textiles have been used at a large scale as reinforcement inclusions, in transportation areas

(Bueno et al. 2005, Benjamin et al., 2007). The reinforcement function can be developed primarily through the following three mechanisms (Holtz et al., 1998):

(a) Lateral restraint: - When any pavement is subjected to traffic loading then aggregate tend to move laterally unless it is restrained by the sub-grade or geo-textile reinforcement. Soft, weak sub-grade soils offer very little restraint, so rutting develops when the aggregate moves laterally. A geo-textile with good frictional capabilities can afford good tensile resistance to lateral aggregate movement.

(b) Increased bearing capacity: - Inclusion of geo-textile in the pavement layer improves the shear strength as well as bearing capacity of the soil sub-grade.

(c) Membrane support: - It provides support for the wheel roads.

(d) Protection: - It refers to the placement of a geo-textile to act as a stress relief layer.

Geo-textile Advantages:-

Geo-synthetic, including geo-textiles, geo-membranes geo-nets, geogrids, geocomposites, and geosynthetic clay liners, often used in combination with conventional materials, offers the following advantages over traditional materials-

Space-saving- sheet-like, geo-textile take up much less space in a landfill than do comparable soil and aggregate layers.

Material quality control- Soil and aggregate are generally heterogeneous materials that may vary significantly across the site or borrow area. Geo-textile on the other land is relatively homogeneous because they are manufactured material variation.

Construction quality control- Geo-textile is manufactured and often factory "prefabricated" into large sheets. This minimizes the required number of field connections or seams. Both factory and field seams are made and tested by trained caused by weather, handling, and placement.

Cost saving- Geo-textile materials are generally less costly to purchase, transport and install than soil and aggregates.

Technical Superiority- Geo-textile has been engineered for optimal performance in the desired application.

Construction timing- Geo-textile can be installed quickly, providing the flexibility to construct during short construction seasons, break in inclement weather, or without the need to demobilize and remobilize the earthwork contractor.

Material deployment- layers of geo-textile are deployed sequentially, but with a minimum of stagger between layers allowing a single crew to efficiently deploy multiple geo-synthetic layers.

Material availability- Numerous suppliers of most geo-textile and ease of shipping ensure competitive pricing and ready availability of materials.

Environment sensitivity- geo-textile systems reduce the use of natural resources and the environmental damage associated quarrying, trucking, and material handling activities.

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