Geosynthetic Materials in Transportation Engineering

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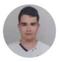

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Geosynthetic Materials in Transportation Engineering

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Abstract

As in all areas of technology, an increase is observed in the production and use of innovative materials in engineering applications. Geosynthetics are materials produced from polymeric materials and are widely used in civil engineering, and the main ones can be listed as geonet, geomembrane, geotextile, geogrid, geocomposite, geofoam, and geocell. Conservation of resources and energy in the realized applications and existing projects necessitates the preference for quality geosynthetic materials and qualified geosynthetic applications to ensure sustainability. Transportation engineering, which is a branch of civil engineering, covers roads (pavements), airports, ports, and railways. Besides, geosynthetic materials increase the performance and design life of transportation structures, especially in areas where soil strength is weak. Geosynthetics offer much higher value than traditional road construction products and greatly reduce construction with a fast, simple installation process. This study reviews the various functions and benefits of several geosynthetic material types in transportation structures.

1 INTRODUCTION

Geosynthetic materials have become widespread in recent years because they offer applicable and more economical solutions in engineering applications worldwide. These different types of materials are also used in civil engineering structures in Turkey. This review article summarizes the purpose and benefits of using geosynthetic materials on highways, railways, and airports, using previous publications.

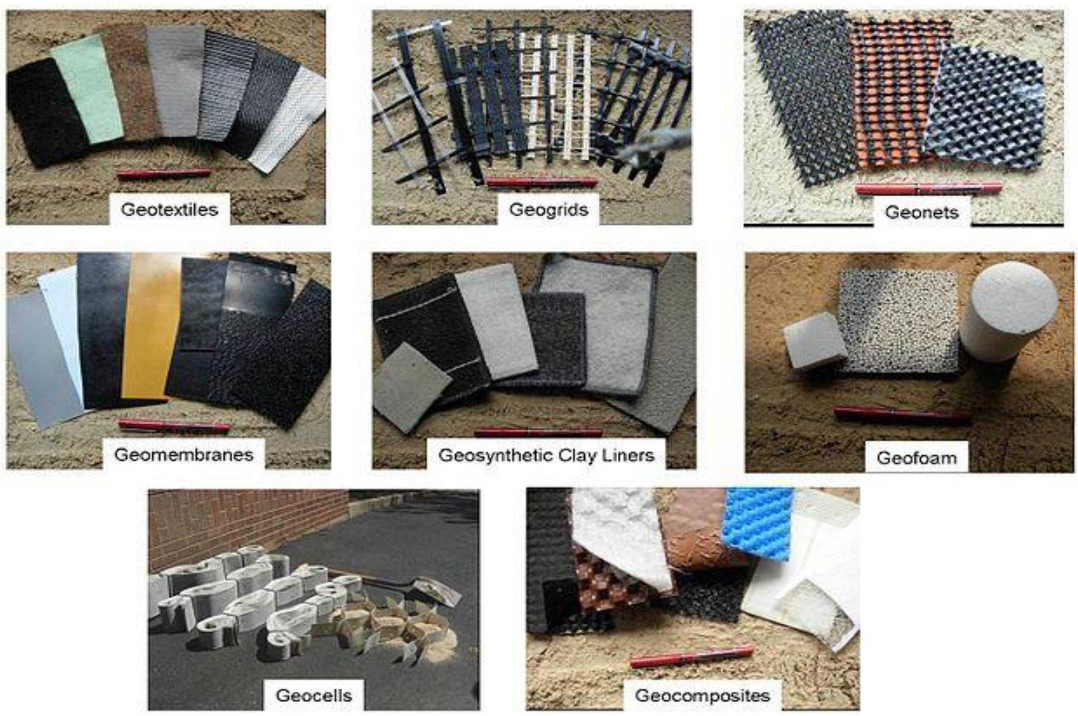

Figure 1. Types of Geosynthetic Materials [1]

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Table 1. Functions of Geosynthetics

Material	Filtering	Drainage	Separation	Strengthening	Insulation
Geotextiles	x	x	x	x	x
Geogrids				x	
Geonets		x			
Geomembranes					x
Clay Liners			x		x
Geocomposites	x	x			

ASTM (American Society for Testing and Materials) defines geosynthetics as "a planar product made of polymeric materials used in conjunction with soil, rock, soil, or other geotechnical engineering-related material as part of a construction project, structure, or system". According to the types of production, these materials include geotextiles, geogrids, geomembranes, geonets, geocomposites, geosynthetic clay liners, geofoam, and some other products, are used together with conventional materials in applications. Figure 1 demonstrates the types of geosynthetic materials. Geosynthetic materials are used in civil engineering projects for many purposes, especially for functions such as separation, drainage, reinforcement (strengthening), insulation, and filtration. Also, these materials can reduce the uneven settlement by applying PV drains. The mentioned purposes are summarized in Table 1 according to the types of geosynthetic materials.

2 APPLICATIONS

Geosynthetic materials are used for various purposes within the scope of transportation engineering. These objectives are summarized below as subsections by reviewing previously published papers.

2.1 Pavements

Pavements, one of the most studied areas of transportation engineering, consist of 5 layers in total. These layers are in order from top to bottom, asphalt overlay, original pavement, base, subbase, and subgrade. The mentioned layers and their functions are summarized in Figure 2.

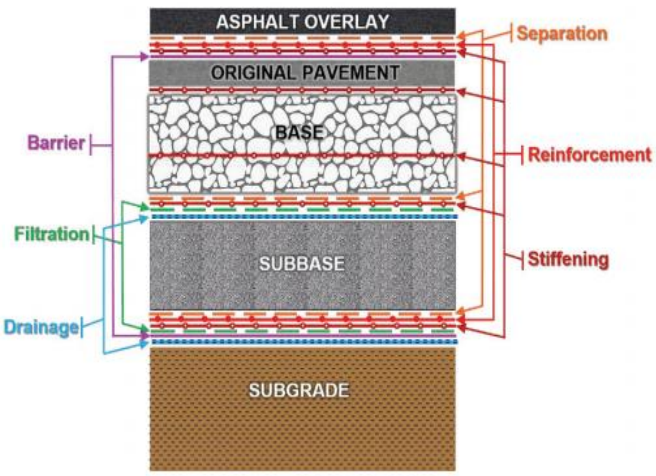

Figure 2. Functions of Geosynthetic Materials in Pavements [2]

2.1.1 Separation

Geosynthetic materials were originally used in pavement applications only to perform the separation function. In this application, a geosynthetic material is placed between two soil layers with different particle size distributions. As is known, the reason for the failure of these structures built on soft foundations is the mixing of aggregate and base material (base and subgrade). The reason for this situation may be the penetration of the aggregate into the weak subsoil due to exceeding the localized bearing capacity under the stresses caused by the

wheel load (live load) or the penetration of fine-grained soils into the aggregate due to the subsoil weakening and the pressure of excess pore water. A geosynthetic placed between the base and the subgrade can act as an effective separator role by preventing the subsoil and aggregate base layer from mixing.
This function can be used in airport pavement likewise highway pavement.

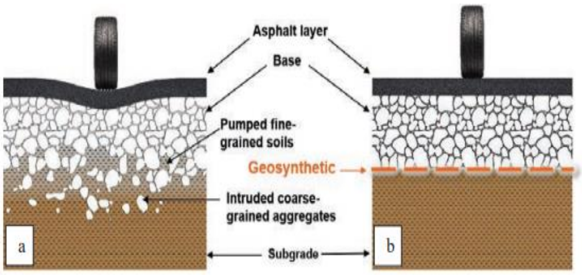

Figure 3. Separation [2]

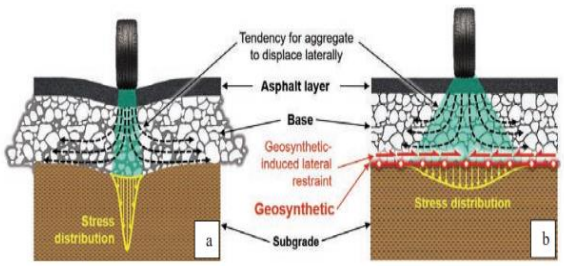

Figure 4. Stabilization of the Road bases [2]

2.1.2 Stabilization of Road Bases

Road applications where geosynthetics are utilized to preserve the stiffness of the foundation aggregate materials are known as foundation stabilization. The lateral displacements of aggregate-geosynthetic materials can only be controlled by stiffening.

The mechanical characteristics of the fundamental aggregate are deteriorated by a phenomenon called lateral displacement of aggregate particles because of repetitive vehicle loads. This type of displacement is especially crucial at the lowest portion of the base layer, just beneath the wheel track, where tensile stresses are more likely to form. The lateral displacements that can occur inside the base layer are depicted in Figure 4.a. The aggregate's lateral stresses are decreased because of the displacements, and this has a substantial impact on the base material's modulus. The limitation on lateral displacement afforded by geosynthetic inclusion is seen in Figure 4.b. Shear stresses from the base material are transferred to tensile stresses in the geosynthetic due to the interaction between the base aggregate and the latter. As a result, stabilizing the base layer requires rather strong interfacial shear transfer. To support the base, a geosynthetic with reasonably high stiffness is needed.
This function can be used in airport pavement as well as highway pavement.

2.1.3 Horizontal Drainage

Moisture at the base and base layers of pavement is a bad situation because it interferes with the mechanical capabilities of these floors. The impact of humidity on road performance in both the foundation and subsoil layers is depicted in Figure 5. The need for lateral (internal) drainage in a roadway is sometimes disregarded by designers in favor of constructing thick, high-quality layers of material. Unfortunately, moisture that is trapped beneath a pavement may increase pore pressures and degrade the subfloor, which will exacerbate pavement issues.
The application of a geosynthetic with in-plane drainage qualities is shown in Figure 5. In this illustration, a horizontal geosynthetic drain is positioned directly beneath the pavement to laterally channel any moisture that may have seeped into the base layer through possible downward leakage caused by the existence of pavement fractures.
As a result of capillary rise from a relatively higher level of the water table, the underlying subsoil may have become excessively saturated and can be reduced in moisture content with geosynthetics.

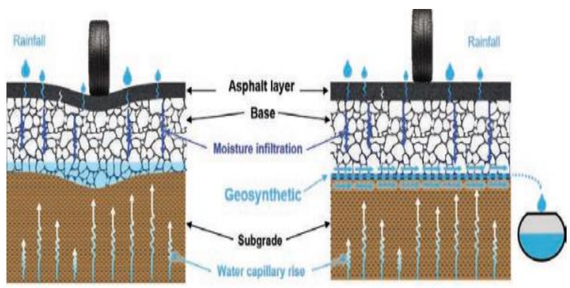

Figure 5. Horizontal Drainage [2] **Figure 6.** Stabilization of the Road Subgrades [2]

2.1.4 Stabilization of the Road Subgrades

To strengthen the carrying capacity of soft subgrade soils, subgrade stabilization is the process of applying geosynthetics to a highway. In this application, separation, filtration, stiffening, and strengthening all play a role. The stiffening function helps to reduce lateral movement inside the base, whereas the reinforcing function results in an improvement in the bearing capacity of soft foundation soils. The geosynthetic tensile strength is thus a crucial design element for the reinforcing function.

At the point where the subgrade being stabilized meets the granular base above, a geosynthetic is installed. As was already said, in this situation a geosynthetic employed to stabilize the subgrade also stabilizes the foundation material above it. This is an example of using a single geosynthetic for two applications: base stabilization and subgrade stabilization (to enhance the subgrade bearing capacity) (to control the lateral displacement of base material and consequently maintain a comparatively high base stiffness). Although this is congruent with what is anticipated for unpaved roads, subgrade stabilization also entails the mobilization of rather significant geosynthetic stresses and the creation of relatively large rutting depths. Base stabilization, on the other hand, is activated for very modest geosynthetic stresses and the related modest rutting depths, which are consistent with those anticipated for both paved and unpaved roads. The existence of a weak subgrade may result in the formation of localized (punching) shear failure in foundation soils, which causes considerable deflections in the various overlaying layers of the road, as shown in Fig. 6.a.

A very small angle in the stress distribution inside the base layer, which leads to comparably high contact pressure on top of the subgrade layer, exacerbates this problem. The effect that adding a geosynthetic reinforcement can have on the ability of subgrade soils to support weight is seen in Fig. 6.b. The wheel loads are at least partially supported by the geosynthetic, which functions as a tensioned membrane. In other words, the geosynthetic takes on a concave form to provide a vertical component to the acting tension that directly opposes the applied wheel load. Soil-geosynthetic interface shear stresses are mobilized in the area of the road outside the wheel path as a result of the vertical deflection and membrane-induced tension under the wheel path. The subgrade heave between the wheel pathways is controlled by the tension generated by the geosynthetic beyond the wheel path.

In the end, a surcharge is imposed outside of the loaded region as a result of the vertical constraint of the subgrade. A higher bearing capacity in subgrade soils may be greatly impacted by the vertical constraint caused by such a surcharge. This function can be used in airport pavement as well as highway pavement.

2.1.5 Reduction of Reflective Cracks in Asphalt Overlays

One of the first uses of geosynthetics in paved roadways was to avoid reflective cracking in asphalt overlays. Where pre-existing fractures are situated in the oldly-constructed pavement, reflective cracks may appear in new flexible pavement overlays. Reflective cracking may be brought on by tensile strains brought on by heat changes, as well as bending and/or shear stresses brought on by repetitive traffic loads. The build-up of strains brought on by lateral motions caused by the pavement bending beneath the traffic load is seen in Fig. 7. As a result of such loads, the new pavement overlay may develop a reflective fracture that spreads throughout it, rendering it vulnerable to early failure that is aided by moisture penetration.

Geosynthetics have been utilized for one or a combination of purposes, such as reinforcement, separation (or protection), and barrier, to reduce the occurrence of reflecting fractures in their early stages. The geosynthetic can reduce the bituminous material's stresses and strains, by creating tensile pressures close to the fracture tip.

And by creating a layer that permits horizontal deformations, potentially huge movements can occur close to pre-existing fissures without failing. Also, by offering a hydraulic barrier function that serves as a waterproofing barrier for highway construction even after a surface fracture reappears.

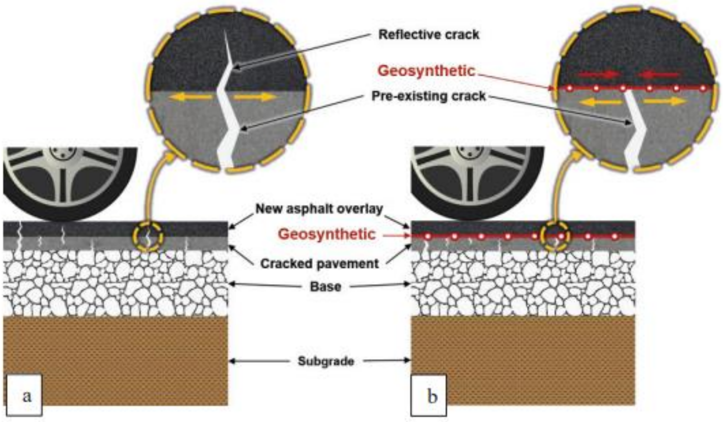

Figure 7. Reduction of Reflective Cracks in Asphalt Overlays [2]

2.2 Railways

The use of geosynthetics in railways can be summarized as strengthening the infrastructure and superstructure of the railway by preventing irregular and high settlements, creating drainage structures, ensuring the stability of slope structures, and providing waterproofing in tunnel areas. Although it is mostly used as a protective auxiliary element for geomembrane and geogrid layers, it is also used as a strengthening function by providing equal distribution of stresses and preventing deformation. Geotextiles, which are also a good separator between ballast-sub-ballast layers, are used to prevent mixing of the mechanical structure of these layers and to help drainage with their water permeable feature. The use of geotextiles is mechanized during platform leveling operations and is therefore much more economical as it can reduce maintenance and replacement costs and there is no freeze damage.

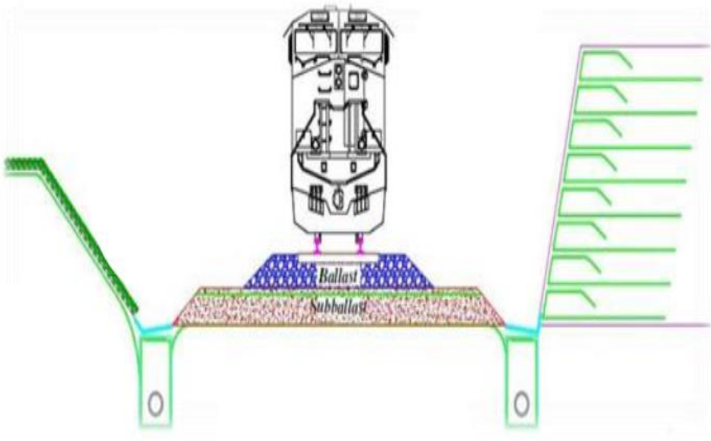

Figure 8. Geosynthetics in Railway [3]

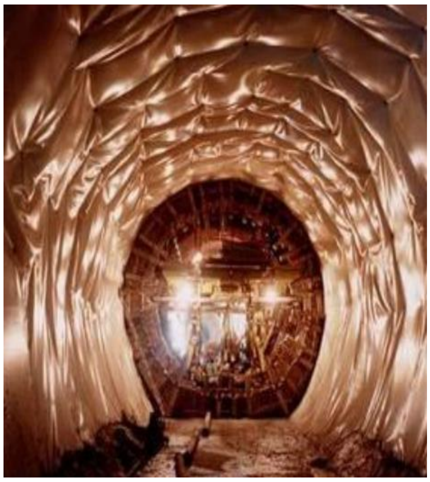

Figure 9. Geomembranes in Tunnel [3]

The use of geotextiles in railway engineering is as shown in Figure 8;

- Providing insulation in tunnel areas with geomembranes (Figure 9).
- Geotextiles prevent fine-grained materials from entering the gravel ballast layer (Fig.8) and provide a suitable lateral slope in the infrastructure. (Some institutions have encountered problems such as ballast perforation of geotextile and deterioration of lateral slope when geotextiles are used alone without placing an auxiliary geosynthetic material, without using a subballast layer, and by reducing the ballast thickness.)
- Geotextile prevents the thickness of the ballast and lower ballast layer from decreasing in the distribution of vertical loads, so its mechanical strength increases in transport systems under periodic loading.
- The geomembrane placed for waterproofing protects the layer and prevents the layer from being damaged by sharp and hard objects and soil particles.

- Geotextiles, with their hollow structures, provide drainage in the railway structure, while preventing the physical disturbances that may be encountered due to the mixing of the infrastructure and superstructure layers due to the limited size of the voids.
- A new type of geofoam is also used as embankment at the edges of railways and highways (Fig.10).

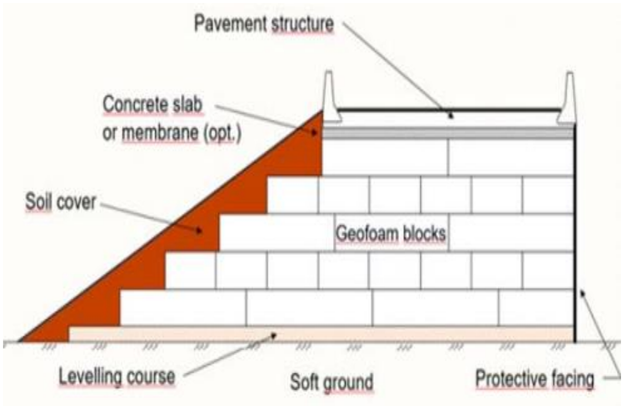

Fig 10. Embankment with geofoam [4]

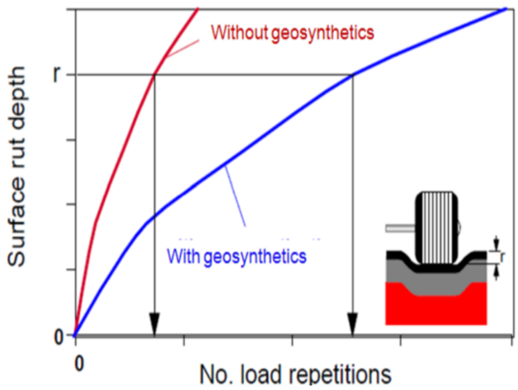

Fig 11. Rut depth with geosynthetics [5]

3 FURTHER DISCUSSIONS

Chapter 2 focuses on the ease and advantages of geosynthetic materials in application. In addition, these materials are in an economically advantageous position. Srapriya et. al. (2019) has done a study on this subject. At study, in order to understand how the subgrade improved for single, two, and three geosynthetic layers in the CBR mould, several geosynthetic materials, such as geo-grid, geo-textile, and geo-membrane, were utilized as subgrade reinforcement members. The findings demonstrate that the bearing improved consistently as the number of layers increased, and that this improvement varied depending on the type of geosynthetic materials used. The CBR properties of geogrid are the best of the three geosynthetic materials. For the ideal number of layers for geogrids, a cost analysis and flexible pavement design were conducted. Using geogrid as a subgrade reinforcement element resulted in a decrease of construction costs of approximately 6.38 percent.

In addition, 'rut depth' lengths are also very important in terms of increasing the economic life of pavements. Mounes et. al. (2011) tested for two pavements with and without geosynthetics, and the number of loads required to reach a certain rut depth is higher for pavement with geosynthetic reinforcement (Fig.11). In other words, it has been concluded that it is more economical because it has a longer economic life.
Apart from these, efficiency studies can be done for different types of various geosynthetic materials. For example, Brusa et. al. (2016) applied shear box test for different geosynthetic reinforcements and compared their bonding properties.
It is also possible to increase such studies. For example, the interlocking property of soil can be examined for various types of geogrids (with triangular, square holes).

4 CONCLUSION

With the development of geotextile materials in the 1960s, the application of geosynthetic materials in the field of geotechnical engineering began. Today, many areas of civil engineering, including the construction of roads, make extensive use of these materials. Geosynthetic materials are used in transportation engineering to create drainage structures, separate various layers, stop uneven settlements, provide waterproofing, protect items that provide waterproofing, and strengthen the superstructure and infrastructure layers. These applications are both more economical as they extend the life of the structures and are more ergonomic because they are easy in terms of applicability.
In Turkey, as in other countries, the usage of geotextile and geomembrane materials in road engineering is widespread, and various applications are commonly observed in accordance with the functions of these materials. However, as is obvious from the research, despite the fact that geogrid material has been used in several applications to improve pavement stability and lower the thickness of the ballast and sub-ballast layers throughout the world, one has yet to be developed in Turkey.

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