International Geosynthetics Society
Geosynthetics in Railways: Applications & Benefits



Applications in Railways

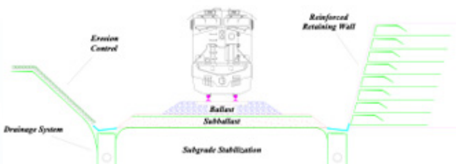
The use of geosynthetics to reduce or replace traditional layers is now an accepted part of track-bed construction and renewals around the world. When correctly specified and installed, geosynthetics are proven to:

- enhance track performance
- significantly extend design life
- reduce the time required to renew a specific length of track (or allow more to be renewed in a fixed time)
- reduce overall material costs.

Many Countries rely heavily on rail for the transportation of bulk commodities and passenger services, and has introduced faster and heavier trains in recent years due to a growing demand. Large cyclic loading from heavy haul and passenger trains often leads to progressive deterioration of the track. The excessive deformations and degradations of the ballast layer and unacceptable differential settlement or pumping of underlying soft and compressible subgrade soils necessitate frequent and costly track maintenance works. A proper understanding of load transfer mechanisms and their effects on track deformations are essential prerequisites for minimizing maintenance costs.

The rail track should be designed to withstand large cyclic train loadings to provide protection to subgrade soils against both progressive shear failure and excessive plastic deformation. The track design should also account for the deterioration of ballast due to breakage and subsequent implications on the track deformations. The potential use of geosynthetics in the improvement of track stability and reducing the maintenance cost is well established.

Geosynthetics may perform the following functions in new track construction or rehabilitation: separation of materials with different particle size distributions, filtration, drainage, basal reinforcement and soil stabilization. In railroad construction, geosynthetics may be installed within or beneath the ballast or sub-ballast layers.



Scheme of main applications of GSY in railways

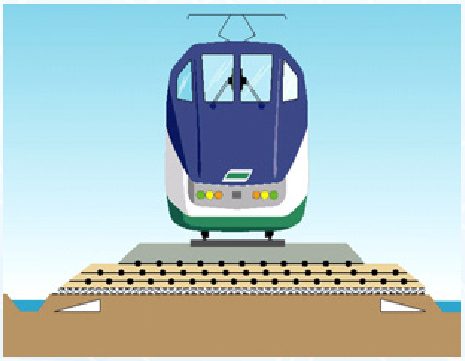
Emphasis will be given here to the use of geosynthetics within and beneath ballast and/ or sub-ballast layers. Geosynthetics that are commonly used in this application are geotextiles, geogrids, geocomposites and geocells.

The stabilization of the track by means of geotextiles, geogrids, or geocells leads to significant reduction in the downward propagation of stresses and assures more resilient long term performance. Geocomposite can provide the functions of stabilization, drainage, filtration, and separation, all in one product, thereby reducing the vertical and lateral deformations.

Applications aside the railway structure, like reinforced slopes / walls, erosion control, and basal reinforcement of railway embankments on soft soil, will not be addressed here, while reference shall be made to the specific documents.

Railways are often built on soft soils. Railways present peculiar characteristics in terms of loads applied to subgrade: a single train may produce hundreds wheels loads in few seconds, that is a train produces rapid, repeated and cyclic loads; loads are first distributed from rails to sleepers, then from sleepers to ballast, and finally from ballast to subgrade; loads are always applied to the same area. The effect of such loads on soft soils generates absolute and differential settlements, which may quickly degrade the quality of the railway segment. Geosynthetics may be used for stabilizing the railway base, in such a way as to decrease settlements and to increase the railway lifetime.

A railway line on soft soil without geosynthetics



A railway line on soft soil with geosynthetics

Separation and Filtration

The passage of trains on the rail causes movement of the track ties. As a result, fines from the subgrade may be pumped upward into the granular layers, reducing the strength and the drainage capacity of these layers

With ballast placed directly over a clay or silty subgrade there is the possibility of a slurry being formed at the ballast/subgrade interface; particularly if there are depressions or pockets at formation level. Regular traffic causes the ballast to oscillate at the interface which disturbs the clay/silt, and the presence of water in the pockets

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causes the particles to form a slurry. As the ballast dilates, the slurry moves into the void. The slurry is then pumped upwards as the ballast contracts. This rapid, cyclical effect causes the mobile clay/silt particles to be forced progressively up into the ballast.

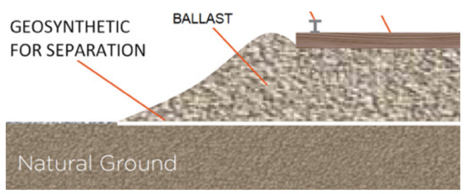
Geosynthetics provide a sound alternative to the traditional solution of using a graded sub-ballast or a sand blanket laid on the subgrade to act as a filter/separator to prevent pumping.

Unlike sand, geosynthetics are compact to transport and are rapidly laid ready for placement of the ballast. Geosynthetics afford factory controlled properties which do not rely on the need, unlike sand, for the correct thickness to be laid consistently across and along the track. In addition, excavation and disposal of fill are reduced when a geosynthetic is used to replace the sand blanket.

Geosynthetics (usually geotextiles or geocomposites) can be positively used to separate layers of the track support structure with different particle sizes and properties.

Furthermore, geosynthetics can reduce the penetration of granular particles into a soft subgrade, thereby maintaining the thickness and integrity of the granular layers and increasing track life time. To provide this function, the geosynthetic must be resistant to concentrated stresses (tear, puncture and burst) and have aperture sizes compatible with the particle sizes of the material to be retained.

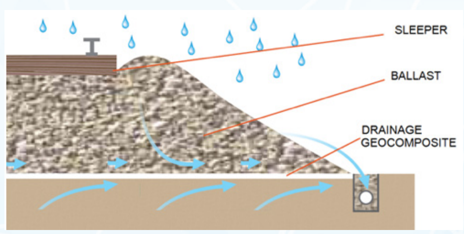
The flow of water from the subgrade into the overlying granular layers may carry fines from the subgrade. This can occur because of the increase in stress levels in the subgrade due to the passage of trains and pumping. In this case, a geotextile can act as a filter, allowing the water to pass freely while the subgrade solid particles are retained. To fulfill the filtration function, the geotextile must have adequate permeability and retention properties, and be resistant to clogging.



Example of high strength grid

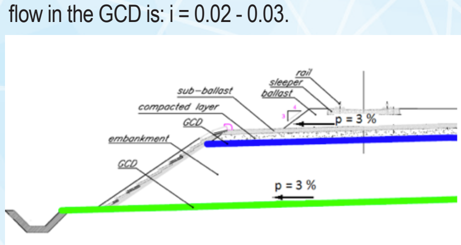
Drainage

Good drainage is critically important to avoid track deterioration due to the action of the water originating from precipitation onto the track or flowing from the subgrade into the ballast layers. A drainage geocomposite (GCD) installed at relevant points in the track structure can provide cross-track drainage, preventing the accumulation of water. In this application the geocomposite must have adequate large discharge capacity and be resistant to mechanical damage.



Example of high strength grid

The GCD can be either placed at the top of the railway embankment (usually below the sub-ballast or the compacted layer) or at the bottom of the embankment. In both cases a 2.00 – 3.0 % lateral slope is usually provided. Hence the hydraulic gradient of the water flow in the GCD is: i = 0.02 - 0.03.



Typical railway cross section with the drainage geocomposites (GCD) possibly placed at the bottom and/or at the top of the embankment

When the GCD is placed at the top of the railway embankment, the GCD is subject to few cycles of very high pressure, of the order of 500 kPa, just during the passage of the compaction roller; while during the service life the GCD is subject to millions of cycles at low pressure. Hence the flow rate of GCDs in railway applications should be measured under dynamic conditions at low hydraulic gradient, since the flow rate provided by the standard static tests may result in higher flow rates than actually available.

When the GCD is placed at the bottom of the embankment, the static load produced by the soil self weight is predominant with respect to the train wheels load, which produce negligible pressures on the GCD. Hence, when the GCD is placed at the bottom of the railway embankment, the load to be considered is a long term static load, with negligible contribution from the dynamic load produced by train wheels passages.

Installation of a draining geocomposite at the base of the railway embankment. In this case the GCD is installed across the embankment

It has to be noted that GCDs provide not only the drainage function but the filtration and separation functions as well. Moreover the drainage core makes a thick enough void space that constitutes an impassable barrier for the surface tension of the water, thus fully preventing capillary raise and fine pumping into the granular layers.

Stabilization

The train wheel load is always in the same position and the passage of each train produce fast cycles of loading – unloading (pressure and depressure), which cause fast degradation of the railway

structure due to deformations of the soft soil; the loading – unloading cycles produce pump-up of the fines from the subgrade into the ballast, which quickly loses its frictional properties; lateral and longitudinal deformations of the tracks then occur and average speed of all the railway line get reduced.

With base stabilization all deformations are minimized and the railway structure can withstand a much higher number of passages without speed reduction; a draining geocomposite placed at subgrade interface can eliminate totally the pump-up effect.

It is generally accepted that geosynthetics (particularly geogrids and geocells) can provide stabilization and lateral confinement to ballast and sub-ballast.

The confining effect of a stabilizing geosynthetic is especially important in a railway application, as lateral movement of granular particles is a major cause of sub-ballast and ballast settlement. However, the stiffening effect is also important, particularly when construction takes place on a soft subgrade: the stiffer aggregate distributes load more efficiently onto the underlying soil, thereby reducing both the dynamic movement (vertical track deflection during a single load cycle) and the longer term settlement of the roadbed due to subgrade consolidation.

Depending on the required benefit, the stabilizing geosynthetic can be placed within the ballast layer, at the interface of the ballast and sub-ballast layer, and/or directly on the subgrade; when included at the bottom or within a ballast layer, the primary benefit is an extension of the maintenance cycle, i.e., the period between ballast cleaning and replacement operations; when geogrids or geocells are used beneath to stabilize the sub-ballast the primary purpose is to increase the effective bearing capacity of the soft subgrade – stabilized sub-ballast system.

Clay particles can be pumped up even 1 m over the subgrade surface. When the railway structure is directly placed on soft subgrade, pumping up of fine soil particles can easily occur. In these cases separation and filtration are usually required together with stabilization; for this purpose specific geocomposites (geotextile – geogrid) can be laid directly on the soft subgrade for providing the three required functions.

The combined use of geocells and geogrids for lateral confinement and stabilization, and nonwoven geotextiles for separation and filtration, is a solution which has proven to afford high performances.

Based on laboratory testing and extensive experience in the use of stabilizing geosynthetics in projects throughout the world, the following benefits of stabilizing geosynthetics can be afforded:

Geotextile – geogrid geocomposite laid directly on the soft subgrade for providing separation, filtration, and stabilization

Combined use of geocells, geogrids, and nonwoven geotextiles for stabilizing railway tracks

a. Stabilization can reduce the rate of permanent settlement of tracks, particularly on soft subgrades
b. The elastic deformation of the track for an individual load cycle can be reduced due to the stiffening effect of the stabilizing geosynthetics.
c. Stabilization can extend the interval between maintenance operations by a factor of three to five
d. The use of stabilizing geosynthetics can provide important initial and long term cost savings

Dielectric Geomembranes

In some situations, particularly when the electric power is supplied from the tracks, there may be the requirement to ensure that no stray current from the tracks finds its way to the platform surface and affect passengers waiting on the platform. In these case a minimum dielectric value of 1000 Ω/m² at 10,000 V is often specified. Dielectric geomembranes, produced with specific polymers, afford high dielectric properties and are able to provide the high degree of electrical protection required for this application.

Geotextile for protection may be required to avoid compromising the integrity of the membrane during installation and in service.

The electrical properties of dielectric geomembranes include: dielectric strength, dielectric constant, dissipation factors and volume resistivity.

If properly specified and installed, geosynthetics can improve the performance of railroads, increasing their life time and the time between maintenance cycles.

About the IGS

The International Geosynthetics Society (IGS) is a non-profit organization dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies. The IGS promotes the dissemination of technical information on geosynthetics and their appropriate uses through a newsletter (IGS News), two official journals (Geosynthetics International and Geotextiles and Geomembranes), conferences and technical seminars, dedicated task forces, over 40 National Chapters, special publications, and multiple other communications and outreach methods.

Contact Us

IGSsec@GeosyntheticsSociety.org
www.GeosyntheticsSociety.org