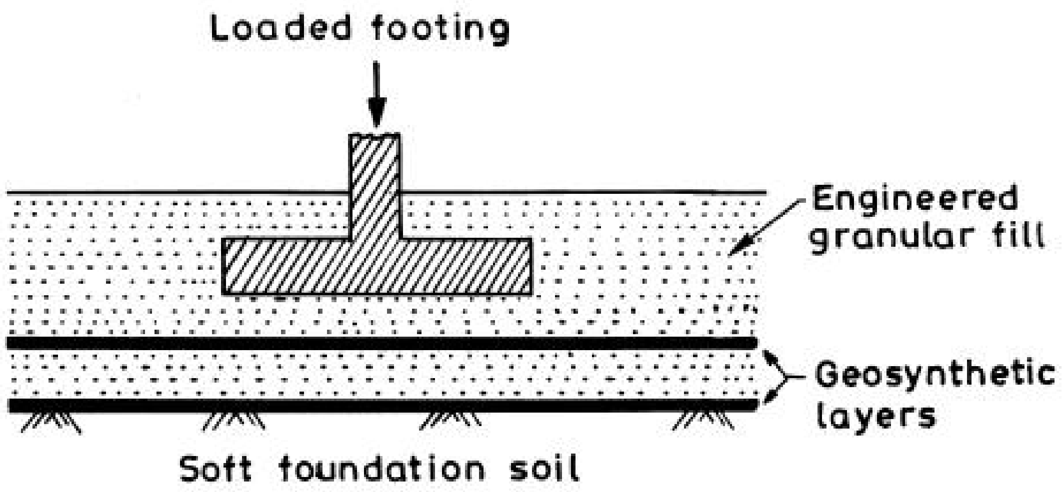
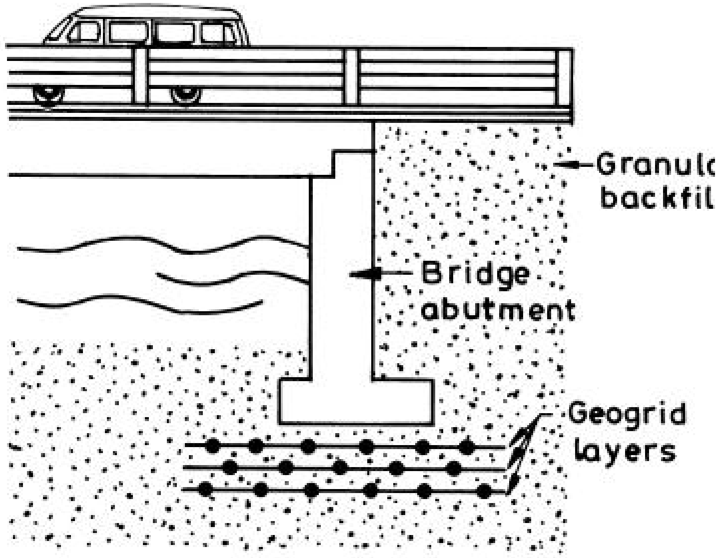
Application areas

Shallow foundations

- The geosynthetic-reinforced foundation soils are being used to support footings of many structures including warehouses, oil drilling platforms, platforms of heavy industrial equipments, parking areas, and bridge abutments.

- In usual construction practice, one or more layers of geosynthetic (**geotextile, geogrid, geocell, or geocomposite**) are placed inside a controlled granular fill beneath the footings


Loaded footing
Engineered granular fill
Geosynthetic layers
Soft foundation soil


Bridge abutment
Geogrid layers

- Such reinforced foundation soils provide improved load-bearing capacity and reduced settlements by distributing the imposed loads over a wider area of weak subsoil.

- In the conventional construction techniques without any use of the reinforcement, a thick granular layer is needed which may be costly or may not be possible, especially in the sites of limited availability of good-quality granular materials.

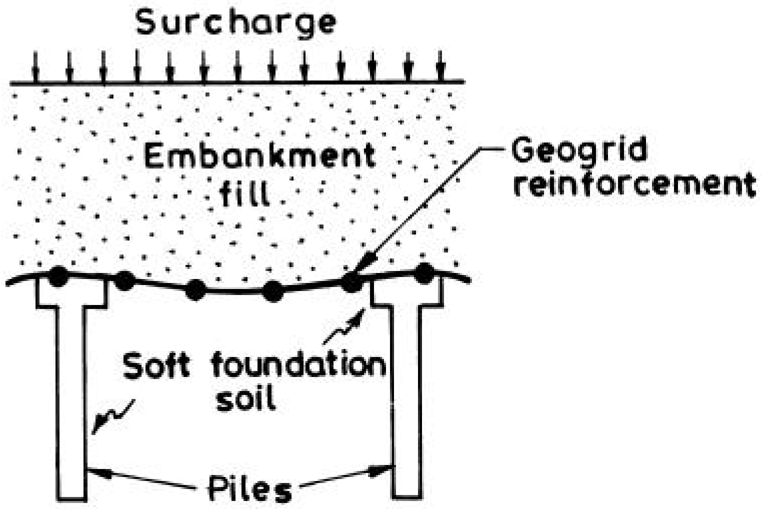
- The geosynthetics, in conjunction with foundation soils, may be considered to perform mainly **reinforcement and separation** functions.

- Geosynthetics (particularly, geotextiles, but perhaps also geogrids) also improve the performance of the reinforced soil system by acting as a separator between the soft foundation soil and the granular fill.

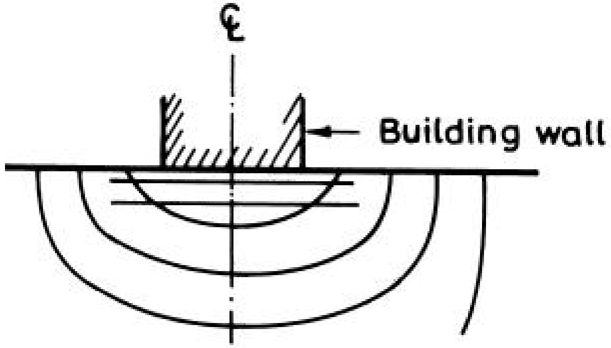
- The improved performance of a geosynthetic-reinforced foundation soil can be attributed to an increase in shear strength of the foundation soil from the inclusion of the geosynthetic layer.

- The soil–geosynthetic system forms a composite material that inhibits development of the soil-failure wedge beneath shallow spread footings.

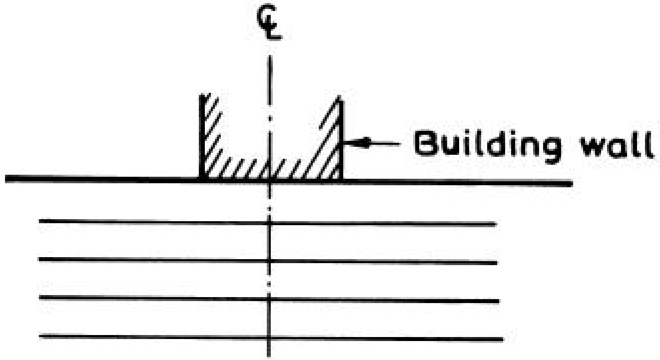
- Geosynthetic products like ‘Paralink’ can be ver effective for use over soft foundation soils as well as ove voids and piles.



- The ideal reinforcing pattern has geosynthetic layers placed horizontally below the footing, the reinforcement should be placed in the direction of the major principal strain.



- However, for practical simplicity, geosynthetic sheets are often laid horizontally.



Roads

- Roads often have to be constructed across weak and compressible soil subgrades. It is therefore common practice to distribute the traffic loads in order to decrease the stresses on the soil subgrade.
- This is generally done by placing a granular layer over the soil subgrade.
- The granular layer should present good mechanical properties and enough thickness.
- The long-term interaction between a fine soil subgrade and the granular layer, under dynamic loads, is likely to cause pumping erosion of the soil subgrade and penetration of the granular particles into the soil subgrade, giving rise to permanent deflections and eventually to failure.

- Based on the type of pavement surfacing provided, roads can be classified as (i) unpaved roads and (ii) paved roads.

- If roads are not provided with permanent hard surfacing (i.e. asphaltic/bituminous or cement concrete pavement), they are called unpaved roads.

- Such roads have stone aggregate layers, placed directly above soil subgrades, and they are at most surfaced with sandy gravels for reasonable ridability; thus the granular layer serves as a base course and a wearing course at the same time.

- If permanent hard pavement layers are made available to unpaved roads, to be called paved roads.

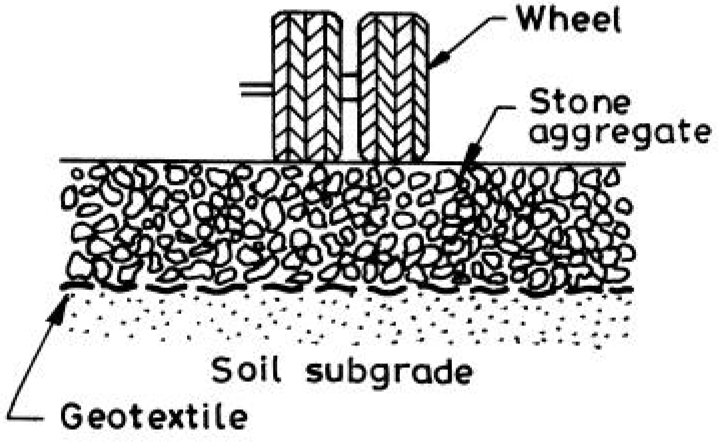
- It can be noted that unpaved roads can be utilized as temporary roads or permanent roads.

- whereas paved roads are, in most cases, utilized as permanent roads which usually remain in use for 10 years or more.

Unpaved roads

- Geosynthetics, especially **geotexiles and geogrids**, have been used extensively in unpaved roads to make their construction economical by reducing the thickness of the granular layer as well as to improve their engineering performance and to extend their life.

- A geosynthetic layer is generally placed at the interface of the granular layer and the soil subgrade



- **Reinforcement and separation** are two major functions served by the geosynthetic layer.

Soil subgrade description	CBR		Primary function of the geosynthetic	Cost justification for use of the geosynthetic
	Unsoaked	Soaked		
Soft	Less than 3	Less than 1	Reinforcement	Significantly less granular material utilization
Medium	3–8	1–3	Stabilization (an interrelated group of separation, filtration, and reinforcement functions)	Less granular material utilization and longer lifetime
Firm	Greater than 8	Greater than 3	Separation	Much longer lifetime

- By providing a geosynthetic layer, improvement in the performance of an unpaved road is generally observed in either of the following two:

1. for a given thickness of granular layer, the traffic can be increased;

2. for the same traffic, the thickness of the granular layer can be reduced, in comparison with the required thickness when no geosynthetic is used.

- The introduction of a geotextile layer can typically save one-third of the granular layer thickness of the roadway over moderate to weak soils.

- Giroud *et al*. (1984) reported reduction of about 30–50% of thickness of the aggregate layer with the inclusion of geogrids.

- Improvement in the performance of unpaved roads can also be observed in the form of reduction in permanent (i.e. non-elastic) deformations to the order of 25–50% with the use of geosynthetics, as reported by several workers in the past

Paved roads

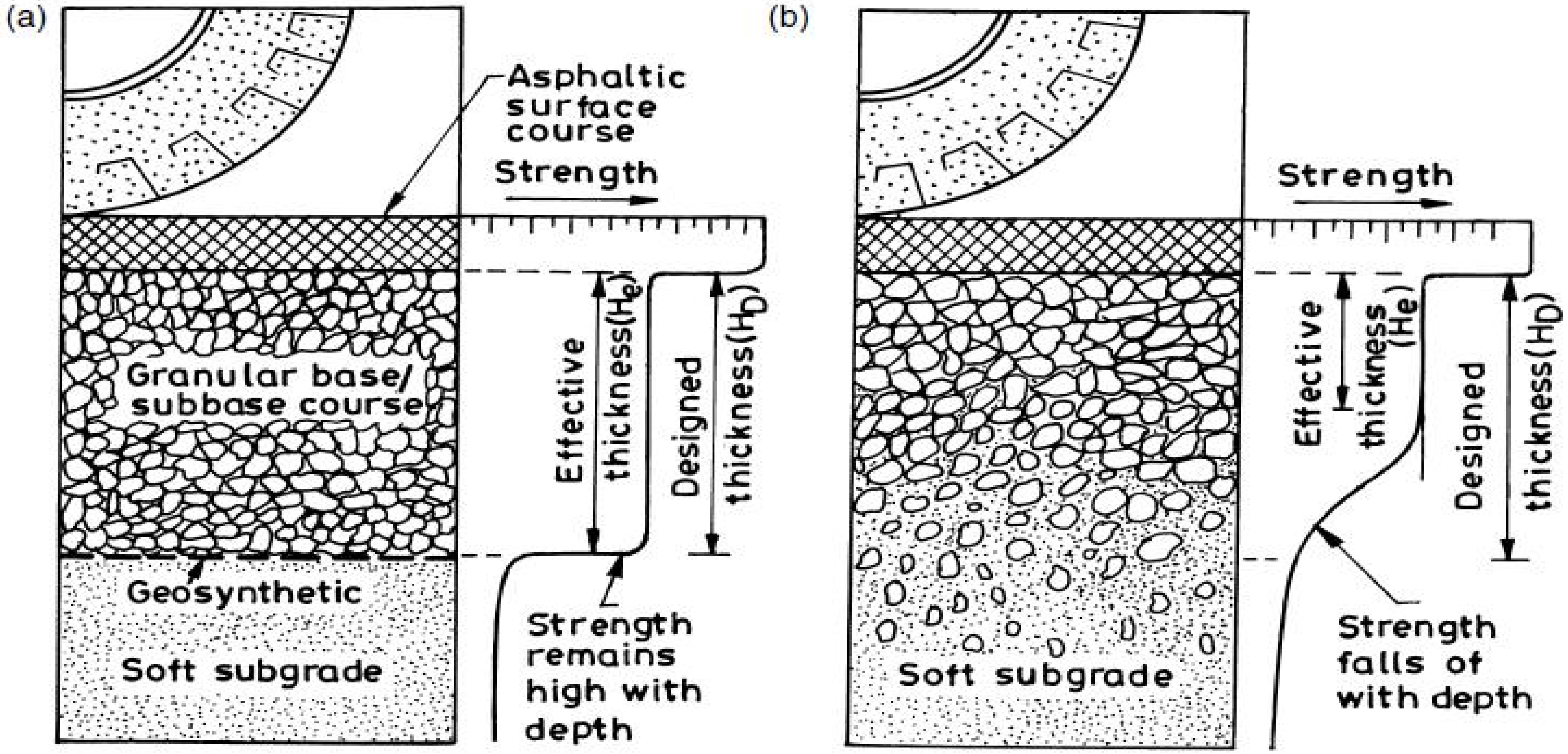
Geosynthetic layer at the soil subgrade level

Geosynthetic layers are used in paved roads usually at the interface of the granular base course and the soft soil subgrade during the initial stage of their construction and may be called *unpaved age*, as a stabilizer lift, to allow construction equipment access to weak soil subgrade sites, and to make possible proper compaction of the first few granular soil lifts.

In case of thicker granular bases, the geosynthetic layer may be placed within the granular layer, preferably near midlevel, to achieve optimum effect.

- The presence of a geosynthetic layer at the interface of the granular base course and the soft soil subgrade improves the overall performance of paved roads, with their long operating life, because of its ***separation, filtration, drainage*****, and** ***reinforcement*** functions.
- During construction as well as during the operating life of paved roads, contamination of the granular base course by fines from the underlying soft soil subgrade leads to promoting pavement distress in the form of structural deficiencies (loss of vehicular load-carrying capacity) or functional deficiencies (development of conditions such as rough riding surface, cracked riding surface, excessive rutting, potholes, etc. causing discomfort) that result in early failure of the roadway.
- This is mainly because of the reduction of the effective granular base thickness, by contamination, to a value less than the design value already adopted in practice.

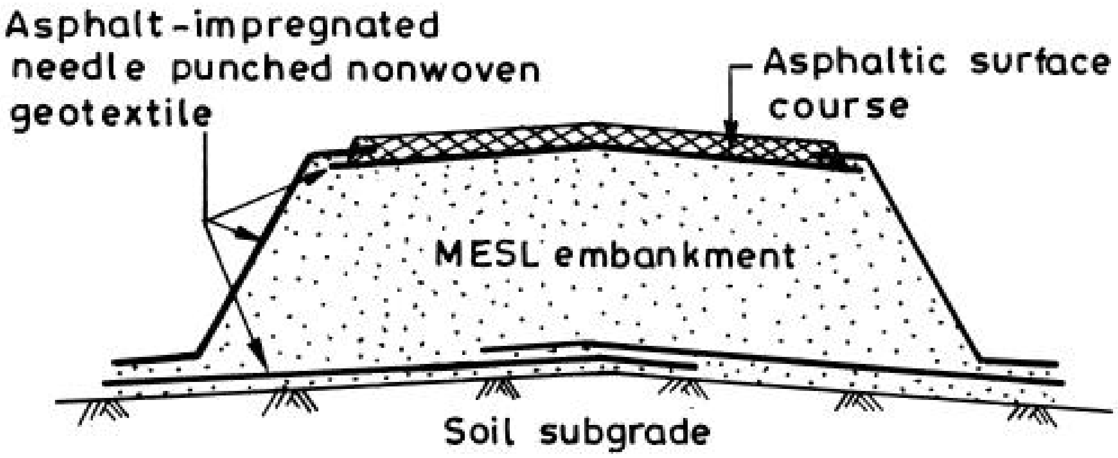
- This problem may cease to exist in the presence of a geosynthetic layer at the interface of granular base course and the soft soil subgrade because of its role as a separator and/or a filter.



- Geosynthetics, especially **bitumen-impregnated geotextiles**, are used to improve the paved roads, as a separator and/or a fluid barrier, by providing capillary breaks to reduce frost action in frost-susceptible soils (fine-grained soils – silts, clays, and related mixed soils).

- The paved roads can also be improved by providing the **membrane-encapsulated soil layers (MESL)** as a moisture-tight barrier beneath the wearing course with an aim to reduce the effects of seasonal water content changes in soils.

- If good-quality granular materials are not available for base/subbase courses, then the concept of MESL can be used to construct base/subbase courses of paved roadways even using locally available poor-quality soils.



- Commercially available **thin-film geotextile composites** are also used as moisture barriers in roadway construction to prevent or minimize moisture changes in pavement subgrades.

- Pavement distress can also be caused by inadequate lateral drainage through granular base course.

- It has been observed that adequate drainage of a pavement extends its life by up to 2–3 times that of a similar pavement having inadequate drainage (Cedergren, 1987).

- A geosynthetic layer, especially **a thick geotextile or a drainage geocomposite,** can act as a drainage medium to intercept and carry water in its plane to side drains on either side of the pavement.

- The use of a geosynthetic layer also helps in enhancing the **structural characteristics and in controlling the rutting** of the paved roadway through its reinforcement function.

- It is to be noted that the principal reinforcing mechanism of the geosynthetic in paved roads is its *confinement effect.*

- The lateral confinement provided by the geosynthetic layer resists the tendency of the granular base courses to move out under the traffic loads imposed on the asphaltic or cement concrete wearing surface.

- In the case of paved roads on firm subgrade soils, prestressing the geosynthetic by external means can significantly increase lateral confinement to granular base course.

- It also significantly reduces the total and differential settlements of the reinforced soil system under applied loads

- It is to be noted that prestressing the geosynthetic can be an effective technique to adequately improve the behaviour of geosynthetic-reinforced paved roads in general situations, if it is made possible to adopt the prestressing process in field in an economical manner.

Geosynthetic layer at the overlay base level

- Commonly a paved road becomes a candidate for maintenance when its surface shows significant cracks and potholes. Cracks in the pavement surface cause numerous problems, including

- riding discomfort for the users;
- reduction of safety;
- infiltration of water and subsequent reduction of the load-bearing capacity of the subgrade;
- pumping of soil particles through the crack;
- progressive degradation of the road structure in the vicinity of the cracks due to stress
- concentrations.

- The construction of bituminous/asphalt overlays is the most common way to renovate both flexible and rigid pavements.

- Most overlays are done predominantly to provide a waterproofing and pavement crack retarding treatment.

- A minimum thickness of the asphalt concrete overlay may be required to provide an additional support to a structurally deficient pavement.

- The cracks under the overlay rapidly propagate through to the new surface. This phenomenon is called ***reflective cracking***, which is a major drawback of asphalt overlays.

- Reflective cracks in an asphalt overlay are basically a continuation of the discontinuities in the underlying damaged pavement. When an overlay is placed over a crack, the crack grows up to the new surface.

- Methods for controlling reflective cracking and extending the life of overlays consider the importance and effectiveness of overlay thickness and proper asphalt mixture specification.

- Asphalt mixes have been improved and even modified by adding a variety of materials.
- In the past a number of potential solutions have also been evaluated including unbound **granular base ‘cushion courses’ and wire mesh reinforcement.**
- All have been found either marginally effective or extremely costly.

- The most basic way to slow down the reflective cracking is to increase the overlay thickness.

- In general, as the overlay thickness increases, its resistance to reflective cracks increases.

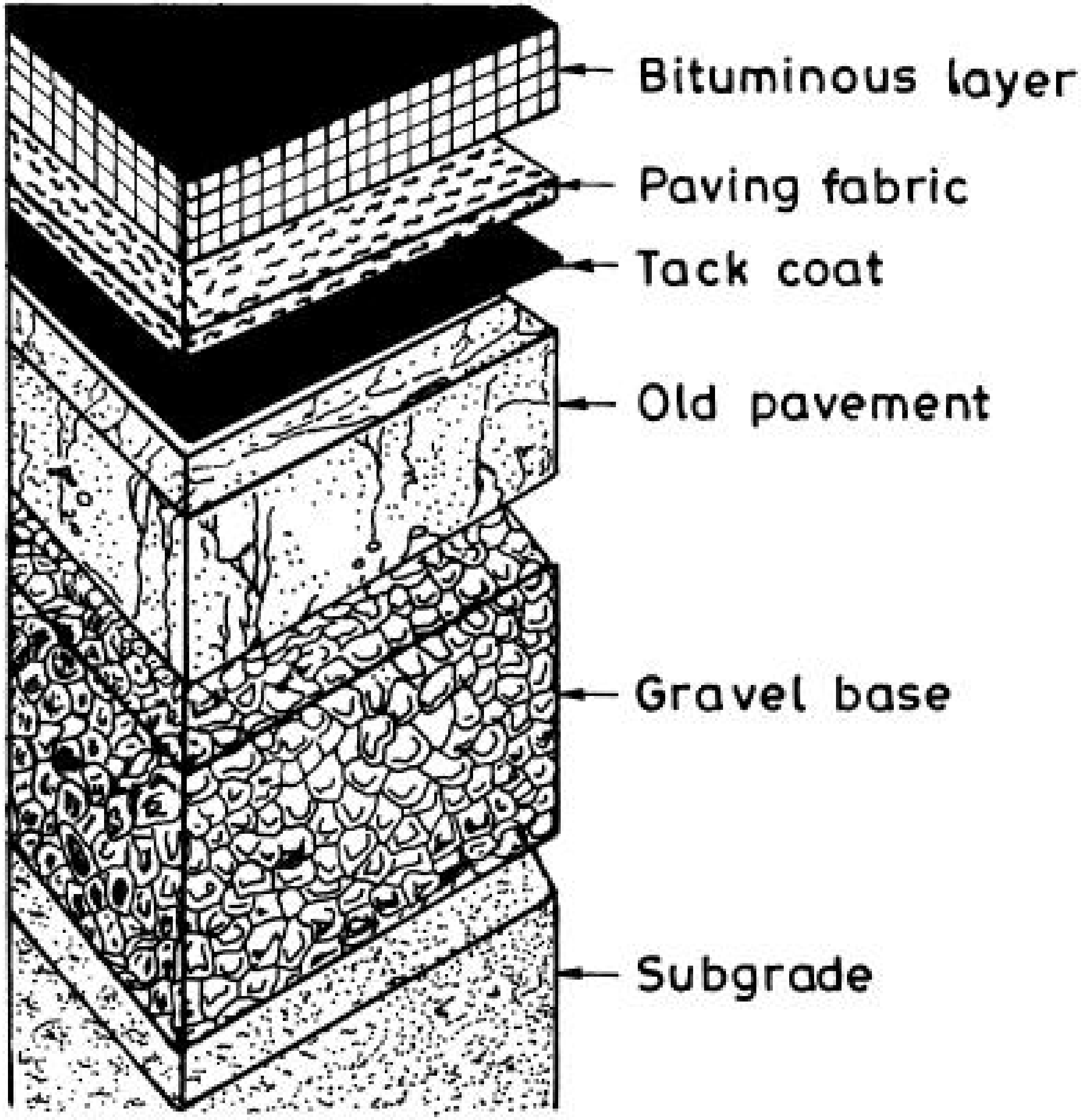
- However, the upper limit of overlay thickness is highly governed by the expense of the asphalt and the increase in height of the road structure.

- Asphalt additives do not stop reflective cracking, but do tend to slow down the development of cracks.

- The crack resistance of the overlay can also be enhanced via interlayer systems.
- An interlayer is a layer between the old pavement and new overlay, or within the overlay, to create an overlay system. The benefits of a geosynthetic interlayer include

- waterproofing the pavement;
- delaying the appearance of reflective cracks;
- lengthening the useful life of the overlay;
- added resistance to cracking;
- saving up to 50 mm of overlay thickness.

A geosynthetic layer, especially a **geotextile layer**, is used beneath asphalt overlays, ranging in thickness from 25 to 100 mm.

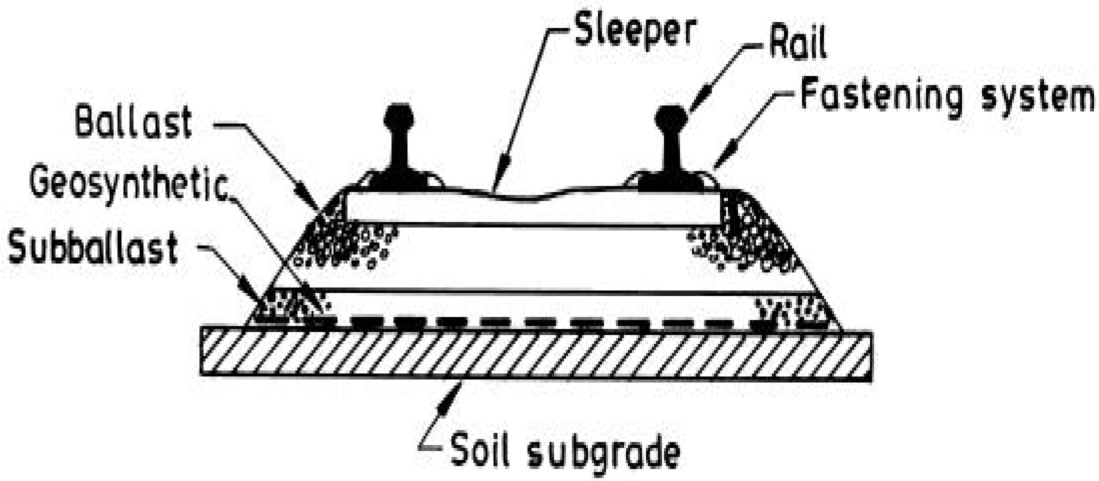


When properly installed, a geotextile layer beneath the asphalt overlay mainly functions as the following:

- fluid barrier
- cushion, that is, stress-relieving layer for the overlays, retarding and controlling some common types of cracking, including reflective cracking.

Railway tracks

- Railway tracks serve as a stable guide way to trains with appropriate vertical and horizontal alignment.
- To achieve this role each component of the track system must perform its specific functions satisfactorily in response to the traffic loads and environmental factors imposed on the system.



- Geosynthetics play an important role in achieving higher efficiency and better performance of modern-day railway track structures.

- They are nowadays used to correct some track support problems. Acceptance and use of geotextiles for track stabilization is now common practice in the USA, Canada and Europe.

- Geotextiles are also being used in high maintenance locations such as turnouts, rail crossings, switches and highway crossings.

- One of the most important areas served by geotextiles is beneath the mainline track for stabilization of marginal or poor subgrade, which can suffer from severe mud-pumping and subsidence.

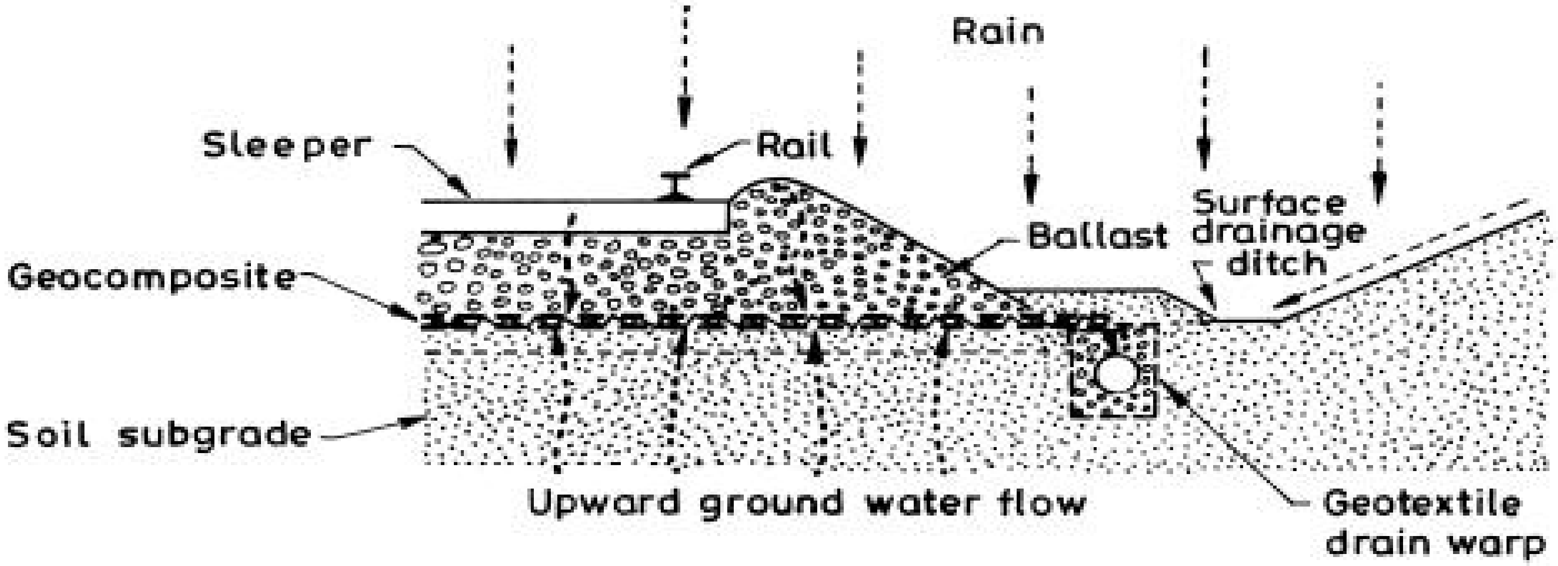
- The subgrade mud-pumping and the load-bearing capacity failure beneath railway tracks are problems that can be handled by the use of geotextiles, geogrids, and/or geomembranes at the ballast–subgrade interface.

- The design difficulty lies in the choice of the most suitable geosynthetic.

- It is important to underline that not all fines originate from the ground below. As ballast ages, the stone deteriorates through abrasive movement and weathering, producing silty fines which reduce the performance of ballast until it needs cleaning or replacing.

Four principal functions are provided when a properly designed geosynthetic is installed within the track structure:

- **separation**, in new railway tracks, between soil subgrade and new ballast;
- separation, in rehabilitated railway tracks, between old contaminated ballast and new clean ballast;
- **filtration** of soil pore water rising from the soil subgrade beneath the geosynthetic, due to rising water conditions or the dynamic pumping action of the wheel loadings, across the plane of the geosynthetic;
- lateral confinement-type **reinforcement** in order to contain the overlying ballast stone;
- **lateral drainage** of water entering from above or below the geosynthetic within its plane leading to side drainage ditches.



Rain
Sleeper
Rail
Ballast
Surface drainage ditch
Geocomposite
Soil subgrade
Upward ground water flow
Geotextile drain warp

- The separation function of the geotextile in railway tracks is to prevent the ballast, which is both expensive and difficult to replace, from being pushed down into the soil subgrade and effectively lost.

- Similarly, the geotextile needs to prevent the soil subgrade working its way up into the ballast, contaminating it, and causing loss of ballast effectiveness.

- The drainage has been found to be the most critical aspect for achieving long-term stability in the railway track structure. Excess moisture in the track is found to reduce the subgrade strength and provide easy access for soil fines to foul the open ballast.

- The drainage function of the geotextile is to allow any ground water within the subgrade to escape upwards and through the geotextile towards the side drains.

- If water is trapped beneath a geotextile, it may weaken the soil foundation to a very significant extent – which is why a geotextile is made permeable.

- A well-engineered geotextile allows groundwater to escape upwards easily, involving the reduction in excess pore water pressures generated from repeated applied axle loads of a passing train.

- At the same time, during rainfall, the downward flow of water is encouraged by the geotextile to be shed into trackside drains.

- Instead, an impermeable membrane can be used, because it keeps the rain water from reaching the soil subgrade, as well as separating the soil.

- Railway track specifications seem to favour relatively **heavy nonwoven needle-punched geotextiles** because of **their high flexibility and in-plane permeability (transmissivity)** characteristics.

- The logic behind high flexibility is apparent, since geotextiles must deform around relatively large ballast stone and not fail or form a potential slip plane.

- In-plane drainage itself is not a dominant function, because any geotextile that acts as an effective separator and filter would preserve the integrity of the drainage of the ballast.

- The extension of existing railway routes or construction of new rail routes, to take higher axle loads as well as higher volume and speed of traffic, requires that the load-carrying system should be strengthened.

- In particular, the load-carrying capacity of the railway subballast must be increased.

- A subgrade protective layer between the subgrade and the subballast can bring about an increase in load-carrying capacity and reduce settlement.

- A high-strength **Geogrid** works effectively as a subgrade protective layer, even at small deformations, because they can absorb high tensile forces at low strain.

- The geogrid layer has a stiffening effect on the track structure, reducing the rate of track settlement to that approaching a firm foundation.

- The elastic deflections are also reduced, smoothing out variable track quality.

- If the construction of railway track project has to be completed in a very limited time-span, then in the present-day track construction technology, use of geogrid layers is the best option

- Excess water may create a saturated state in ballast and subballast and cause significant increases in track maintenance costs.

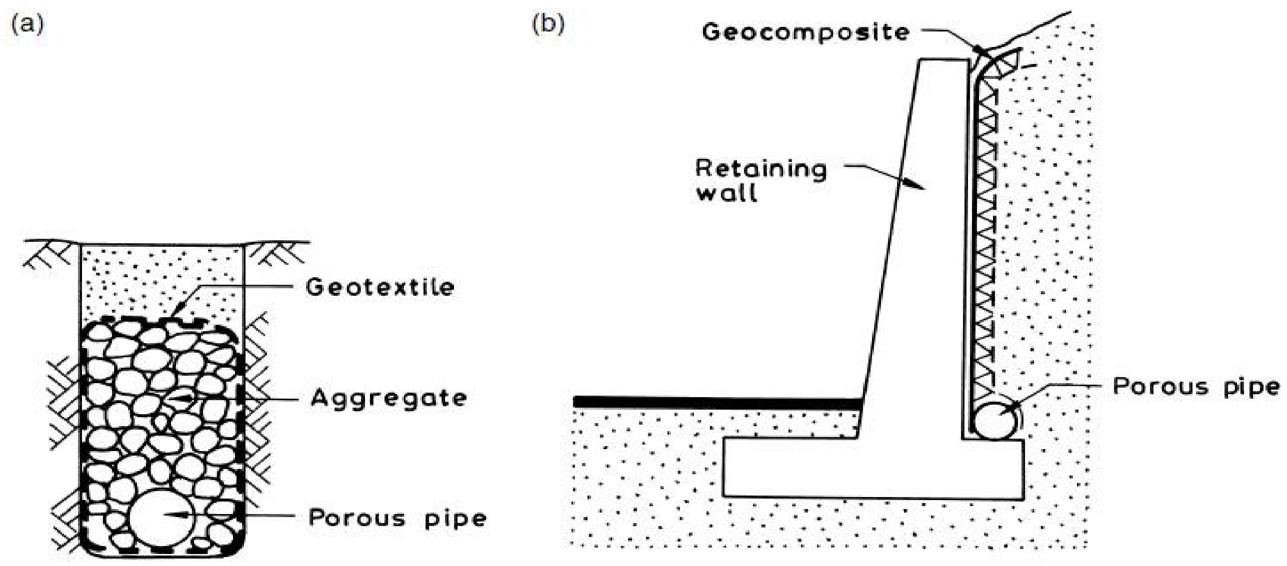
- Because each source of water requires different drainage methods, the sources must be identified in order to determine effective drainage solutions.

- The use of geotextile-wrapped trench drains and fin drains can provide rapid and cost-effective solutions for the requirements of subsurface and side drainage in railway tracks.

Filters and drains

- The role of groundwater flow and good drainage in the stability of pavements, foundations, retaining walls, slopes, and waste-containment systems is gaining attention from engineers, practitioners, and researchers alike.

- That is why geosynthetics are being increasingly employed either as filters, in the form of **geotextiles (nonwovens and lightweight wovens),** in conjunction with granular materials and/or pipes (Fig. 4.24(a)), or as both filters and drains in the form of geocomposites (Fig. 4.24(b)). Filters



There are several application areas for filters and drains including buried drains as pavement edge drains/underdrains, seepage water transmission systems in pavement base course layers and railway tracks, abutments and retaining wall drainage systems, slope drainage, erosion control systems, landfill leachate collection systems, drains to accelerate consolidation of soft foundation soils, drainage blanket to dissipate the excess pore pressure beneath embankments and within the dams and silt fences/barriers.

- When a geosynthetic is used as a filter in drainage applications, it prevents upstream soils from entering adjacent granular layers or subsurface drains.

- When properly designed, the geosynthetic filter promotes the unimpeded flow of water by preventing the unacceptable movement of fines into the drain, which can reduce the performance of the drain.

- Geosynthetic filters are being used successfully to replace conventional graded granular filters in several drainage applications.

- In fact, filter structures can be realized by using granular materials (i.e. crushed stone) or geotextiles or a combination of these materials (Fig. 4.25).

When using riprap–geotextile filter, it is recommended that a layer of aggregate be placed between the geotextile and the riprap, for the following reasons:

- to prevent damage of the geotextile by the large rocks;
- to prevent geotextile degradation by light passing between large rocks;
- to apply a uniform pressure on the geotextile, thereby ensuring close contact between the
- geotextile filter and the sloping ground, which is necessary to ensure proper filtration;
- to prevent geotextile movement between the rocks because of wave action, thereby ensuring permanent contact between the geotextile filter and the sloping ground, which is also necessary to ensure proper filtration.

Comparison of granular and geotextile filters

Objective	*Granular filter*	*Geotextile filter*
Similarities		
Complex structure and distribution of open area		
Sensitive in respect to changing of permeability		
Differences		
Determination of characteristic opening size	By particle size analysis	By pore size analysis
Thickness (filtration length)	Long	Very short
Porosity	25–40%	75–95%
Compactibility	Low	High for needle-punched nonwoven geotextiles
Uniformity	Natural variation in grading and density	Greater uniformity due to industrial processing and control
Transmissivity	Independent of stresses	Often dependent on exerted stresses
Internal stability	Can be unstable	Stable
Durability	High	High but not yet properly defined
Placement and execution	Proper quality control necessary, more excavation required	Quick and relatively easy placement, less excavation required

- Geotextiles with high in-plane drainage ability and several geocomposites are nowadays commercially available for use as a drain itself, thus replacing the traditional granular drains.

- The drainage geocomposites consist of drainage cores of extruded and fluted sheets, three-dimensional meshes and mats, random fibres and geonets, which are covered by a geotextile on one or both sides to act as a filter.

- The cores are usually produced using polyethylene, polypropylene, or polyamide (nylon). Geocomposite drains may be prefabricated or fabricated on site.

- Vertical strip drains (also called prefabricated vertical band drains (PVD) or wick drains) are geocomposites used for land reclamation or for stabilization of soft ground.

- They accelerate the consolidation process by reducing the time required for the dissipation of excess pore water pressure.

- The efficiency of the drains is partly controlled by the transmissivity, that is discharge capacity that can be measured, using the drain tester, to check their short-term and long-term performance.

- The discharge capacity of drains is affected by several factors such as confining pressure, hydraulic gradient, length of specimen, stiffness of filter and the duration of loading.

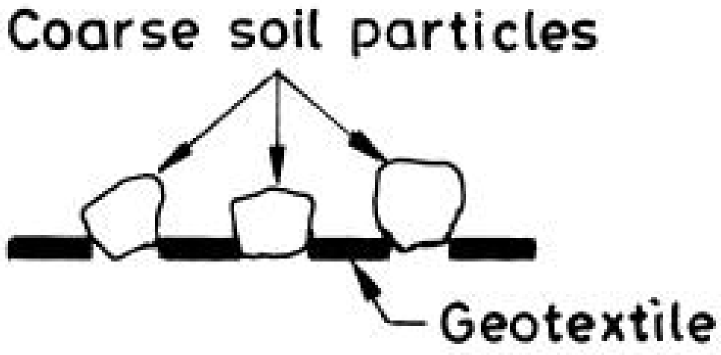
- The primary function of the geosynthetic in subsurface drainage applications is filtration.
- The successful use of a geotextile in a filtration application is dependent on a thorough knowledge of the soil to be retained.
- The essential properties to be determined are particle size distribution, permeability, plasticity index and dispersiveness. It is crucial to adequately characterize the soil to be retained in order to ensure its compatibility with the chosen geotextile.
- In certain applications, such as the use of geotextile filters below waste deposits, the nature of the leachate is of crucial importance, because the bacterial growth process may render the geotextile impermeable.
- Therefore, leachate parameters such as total suspended solids, chemical oxygen demand and biological oxygen demand may be required to be determined

- In filter applications, the design must be prepared so as to avoid, throughout the design life, the following three phenomena causing decrease of the permeability of the geotextile filter in course of time:

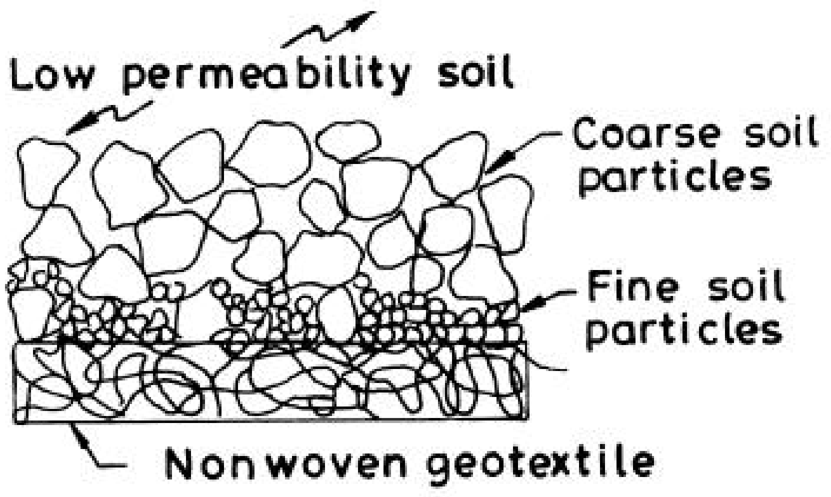
1. Blocking
2. Blinding
3. clogging.

- When a geotextile is selected to retain particles of low concentrated suspensions or whenever there is a lack of direct contact between the soil and the geotextile, coarse particles of a size equal to or larger than the pore sizes of the geotextile may migrate and locate themselves permanently at the entrance of the pores of the geotextile.

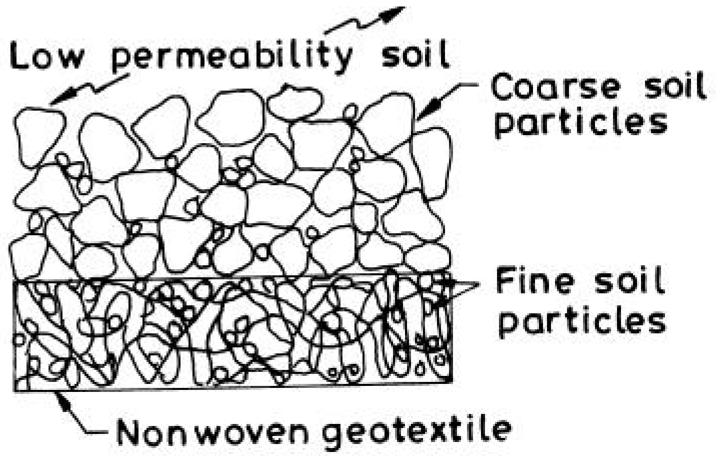
- This phenomenon that develops at the soil–geotextile interface resulting in the decrease of geotextile permeability is called *blocking*.



- *Blinding* is a phenomenon similar to blocking and is used to describe the mechanism occurring when coarse particles retained by the geotextile, or geotextile fibres, intercept fine particles migrating from the soil in such a way that a low-permeable layer (often called *soil cake*) is formed very quickly at the interface with the geotextile, thereby reducing the hydraulic conductivity of the system.



- The phenomenon of accumulation of soil particles within the openings (voids) of a geotextile, thereby reducing its hydraulic conductivity, is called *clogging*. This phenomenon may result in a complete shut off of water flow through the geotextile filter.



- It should be noted that clogging, in general, takes place very slowly. It should also be noted that blinding of the filter is far more detrimental than clogging.

- Geotextiles with a tortuous surface in contact with the soil, such as needle-punched nonwoven geotextiles, do not favour the development of a continuous cake of the fine soil particles, whereas geotextile filters with a smooth surface may favour the development of such a cake.

- geotextiles with a tortuous surface do not favour the mechanism of blocking, because they do not have individual openings.

LANDFILLS

- Our activities create several types of waste such as municipal solid waste (MSW), industrial waste, and hazardous waste.

- We should always attempt to minimize the amount of waste by designing and implementing programmes focussed on waste *reuse, recycling* and *reduction*, and may be called *RRR-concept*.

- The remaining waste has to be disposed off by suitable disposal methods such as incineration, deep well injection, surface impoundments, composting, and shallow/deep burial in soil and rock. Incineration is not a viable method of disposal for a wide variety of wastes, and furthermore, it may lead to air pollution.

- An engineered landfill is a controlled method of waste disposal. It is not an open dump. It has a carefully designed and constructed envelope that encapsulates the waste and that prevents the escape of *leachate* into the environment.

- Leachate is generated from liquid squeezed out of the waste itself (*primary leachate*) and by water that infiltrates into the landfill and percolates through the waste (*secondary leachate*).

- There are basically two major types of landfill: the *MSW landfill* (also called *sanitary landfill*) to keep the commercial and household solid wastes and the *hazardous waste landfill* for the deposition of the hazardous waste materials.

- MSW landfill is the most common type of landfill.

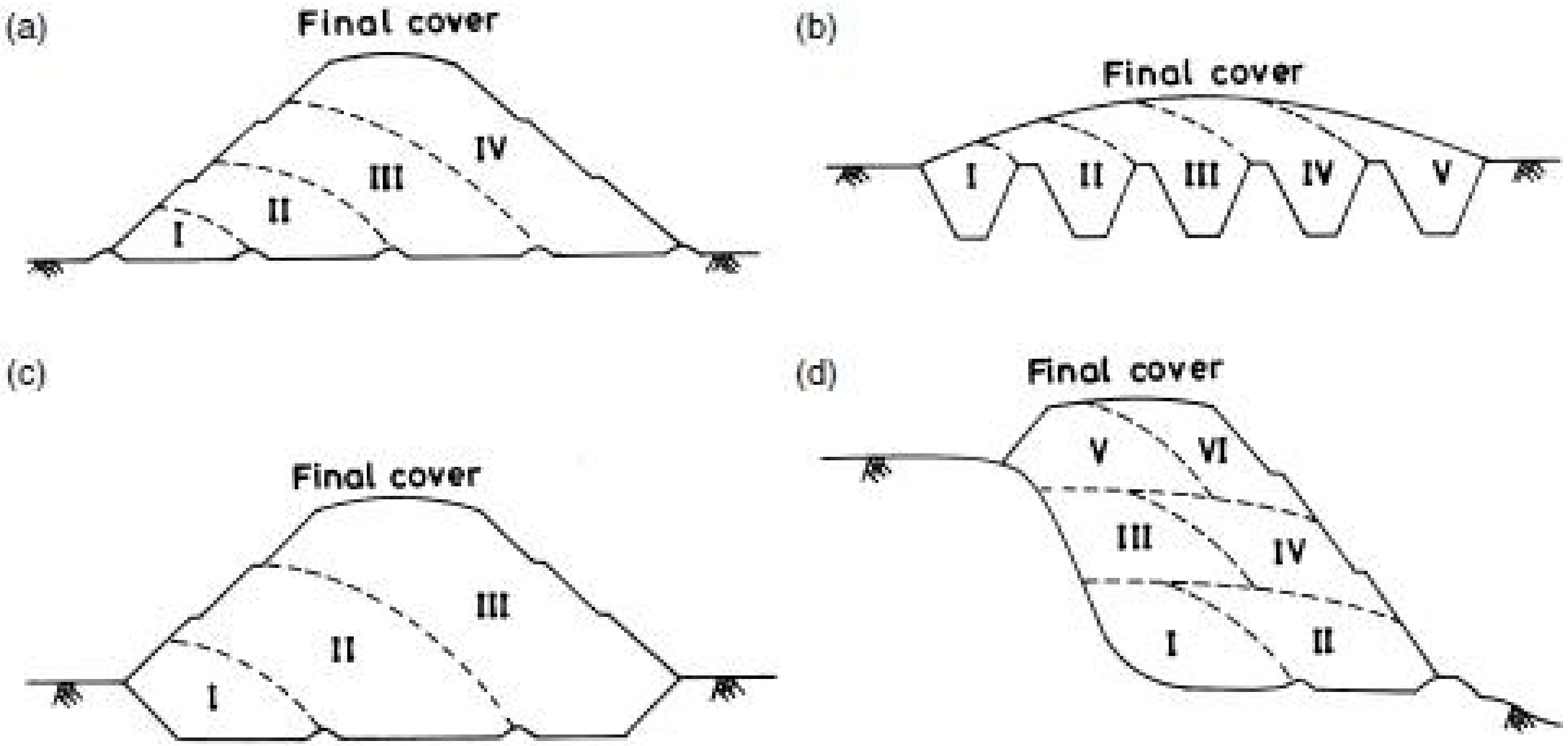
- The geometrical configurations of this landfill commonly include *area fill, trench fill, above and below ground fill*, and *valley fill.*

- The area fill type of landfill is used in areas with high groundwater table or where the ground is unsuitable for excavation.

- The trench fill is generally used only for small waste quantities. The depth of trench excavation normally depends on the depth of the natural clay layer and the groundwater table.

- Above and below type of landfill is like a combination of the area fill and the trench fill.

- If the solid waste is kept between hills, that is in the valley, it is called a valley fill type of landfill.



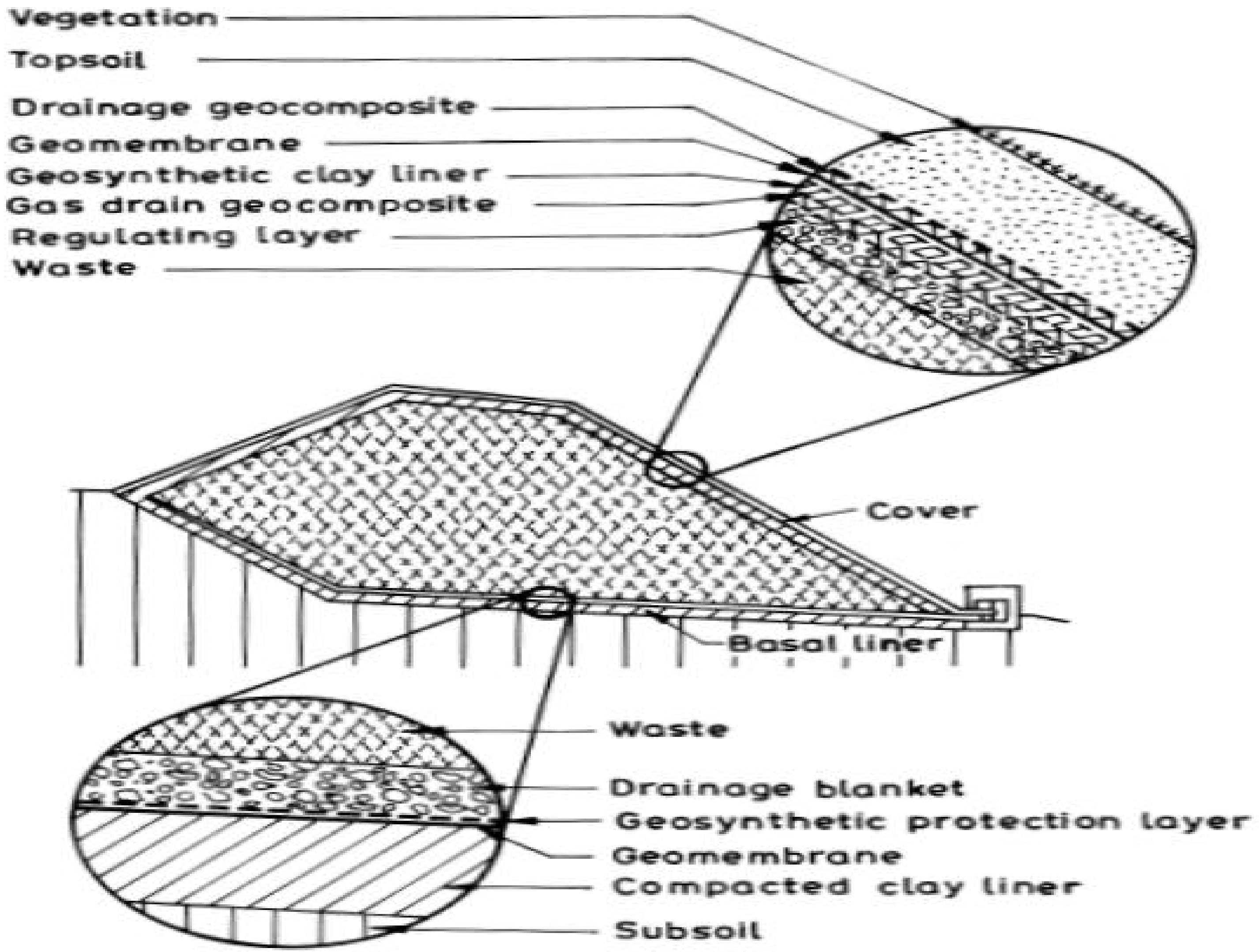
(a)
Final cover
I
II
III
IV
(b)
Final cover
I
II
III
IV
V
(c)
Final cover
I
II
III
(d)
Final cover
V
VI
III
IV
I
II

- The process of selecting a landfill site is complex and sometimes costly; however, a proper siting can be economical to the extent it contributes to the reduction in design and/or construction costs, as well as in long-term expenses with operation and maintenance.

- Factors that must be considered in evaluating potential sites for the long-term disposal of solid waste include haul distance, location restrictions, available land area, site access, soil conditions, topography, climatological conditions, surface water hydrology, geologic conditions, local environmental conditions and potential end uses of the completed site.

- The geology of the site is an important barrier to the migration of harmful substances. The ground should have a low hydraulic conductivity and a high capacity for the adsorption of toxic material; it must be sufficiently stable and should not undergo excessive settlements under the load of the landfill body.

The engineered landfills, particularly the MSW landfills, consist primarily of the following elemen



- *Liner system:* This system consists of multiple barrier and drainage layers and is placed on the bottom and lateral slopes of a landfill to act as a barrier system against the leachate transport, thus preventing contamination of the surrounding soil and groundwater.

- *Leachate collection and removal system*: This is used to collect the leachate produced in a landfill and to drain it to a wastewater treatment plant for treatment and disposal.

The materials used to construct this system are high-permeability materials including the following:

soils such as sands and gravels, often combined with pipes;

geosynthetic drainage materials such as thick needle-punched nonwoven geotextiles,

geonets, geomats and geocomposites.

- *Gas collection and control system*: This is used to collect the gases (generally methane and carbon dioxide) that are generated during decomposition of the organic components of the solid waste. One can use the landfill gases to produce a useful form of energy.

- *Final cover (top cap) system*: This system consists of barrier and drainage layers to minimize water infiltration into the landfill so that the amount of leachate generated after closure can be reduced.

- most of the major types of geosynthetics, namely geomembranes, geotextiles, geonets, geosynthetic clay liners, and geogrids, are used in landfill engineering to perform various functions: drainage, filtration, protection and reinforcement.
- In landfills, the geotextiles replace conventional granular soil layers resulting in decreased weight and reduction in landfill settlement. They also prevent puncture damage to the geomembrane liner by acting as a cushion in addition to functioning as a filter in leachate collection systems.
- Thus, geotextiles can be replace conventional protective soil layers for geomembrane liners.
- Even with a geotextile, the minimum protective soil layer should be 300 mm thick. The geotextile will have better puncture protection, if it has a higher mass per unit area.