Design of Geogrid reinforcement and Drainage composite for flexible pavement: Present challenges in practical applications.

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Engineering a Better Solution

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- Functions of Geosynthetics
- Benefits of using Geosynthetics in pavements
- Global scenario & Indian Scenario
- Practical challenges
- Geogrid mechanism and its design
- Drainage composite mechanism and its design
- Conclusion

Introduction

- ❖ Majority of roads in India are constructed as Flexible pavements.

- ❖ Two ways are available to improve the serviceability of the pavement:
  - (i) Increasing the thickness of different pavement layers
  - (ii)By inserting polymeric materials like Geosynthetics.

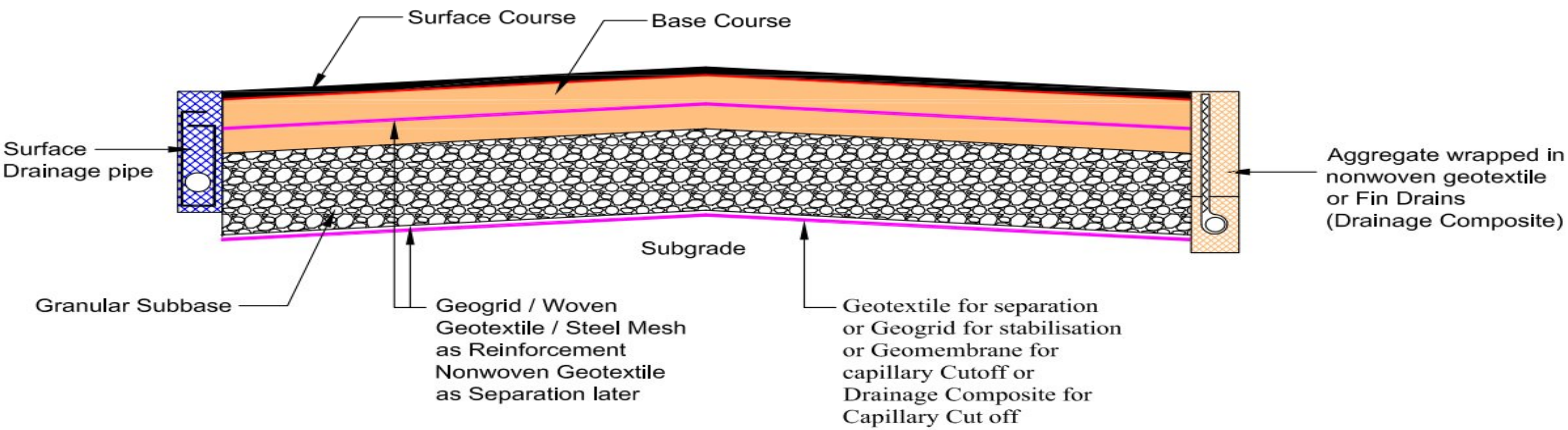
- ❖ Geosynthetics are used in modern civil engineering are used in conjunction with soil to improve the overall performance.

- ❖ In view of large potential, Geo-synthetics helps for cost savings, environmental protection, improved performance, durability in the infrastructural development.

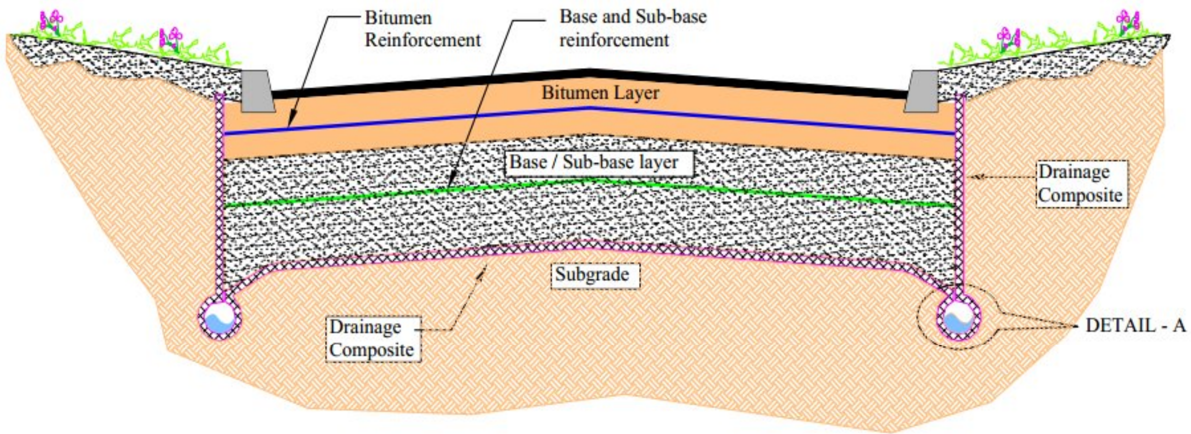
Applicability & Benefits of Geosynthetics in roads

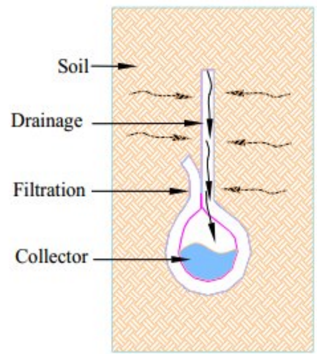
Permanent Paved and Unpaved Roads- Geosynthetic Applicability

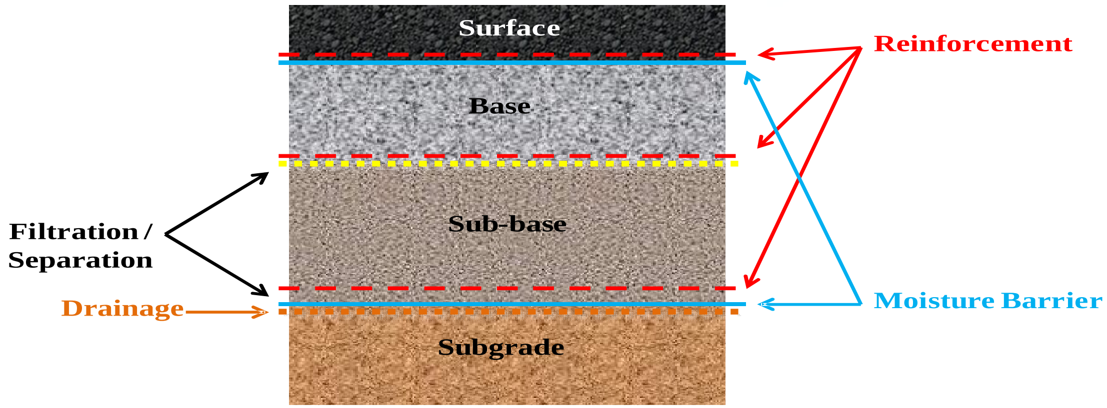
The main applicability of Geosynthetics are stabilization, separation & filtration , erosion control, drainage etc



Permanent Paved and Unpaved Roads- Geosynthetic Applicability







Functions of Geosynthetics

1.SEPARATION: to prevent the intrusion of fines from the sub-grade into the base layer due to traffic loads.

2.FILTERING: to prevent fine particles being washed from the subgrade into the base layer due to water.

3.REINFORCEMENT: to improve the tensile strength & stiffness of a pavement layer.

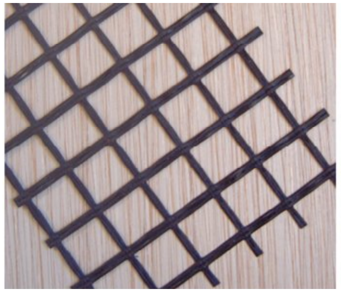
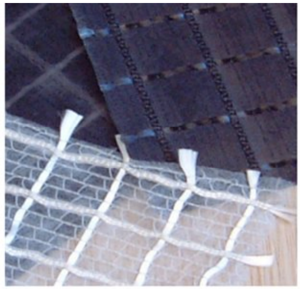
4.DRAINAGE:to collect and removal of subsurface water.

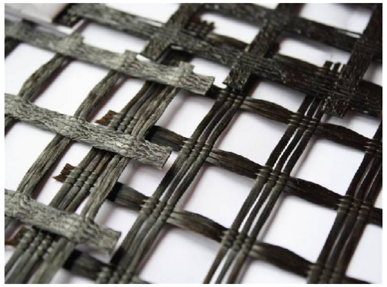
5.STRESS RELIEF: to allow for larger deformations in the interlayer by dissipating the energy

Geogrids in Roads and Pavement related works

Geogrids are increasingly thought of as pavement materials and are now widely used in pavement structures to improve performance or reduce component thicknesses.

Although the pavement material types and local conditions might be extremely variable, a geogrid can be installed and provide uniform performance anywhere within a pavement section, over the length of roadway or in any region around the world.



Geogrids in Roads and Pavement related works

ASPHALT REINFORCEMENT

When a geosynthetic is placed as a tensile element within the BOUND layer, to increase the service life of the pavement by preventing fatigue and reflective cracks

BASE AND SUBBASE STABILISATION

When a geosynthetic is placed as a tensile element at the bottom or within a flexible UNBOUND base (or sub-base) course to eventually increase the bearing capacity of the subgrade thus having:

(i) improvement of the service life;

(ii) an equivalent performance with a reduced structural section;

BASAL REINFORCEMENT

The reinforcement is used at the embankment-subgrade interface to enhance the resistance of the embankment to avoid failure through excessive deformation or shear in the foundation

Flexible Pavement failures- Bound layers

Surface cracking is the most visible sign of pavement deterioration

Once cracking occurs, surface water can penetrate to the underlying road construction. This in-turn can cause the premature failure of the entire pavement.

The mechanisms of failure may be categorized as

- Reflective cracking
- Traffic induced
- Thermally induced
- Surface initiated

Flexible Pavement failures- Bound layers

Fatigue cracking

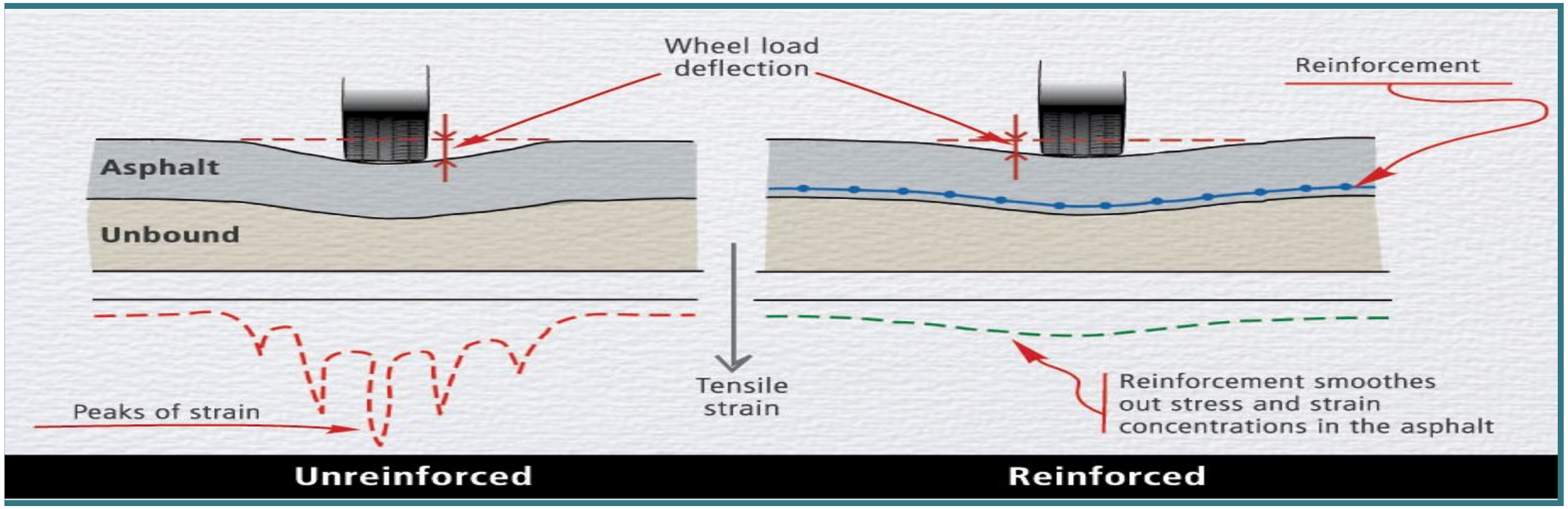
Rutting, Shoving/ structural

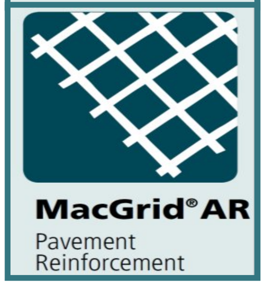
Longitudinal / settlement

Edge break/ haunching

Asphalt Reinforcement

Reinforcement provides a lateral restraint within the asphalt that produces a threefold increase in the service life of pavements by relieving and redistributing stress concentrations





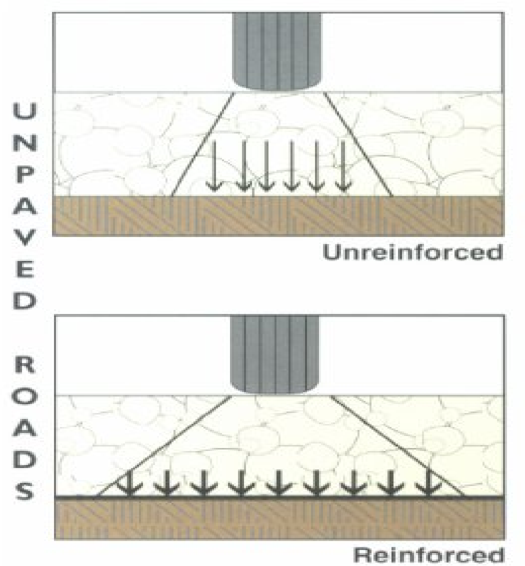
Benefits of Asphalt reinforcement

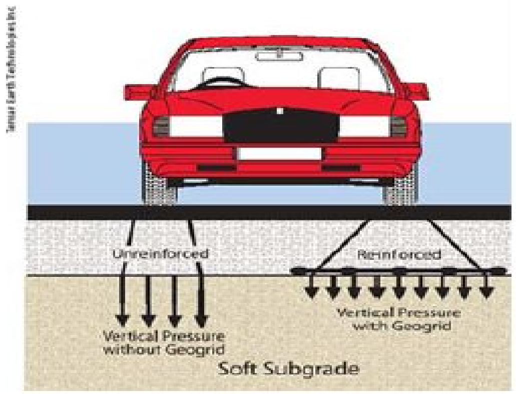
- Changes crack behaviour in asphalt
  - Delayed initiation
  - Slower growth
  - Narrower width
  - Wider spacing
  - Deviation at grid
- Lateral restraint
  - Reduces rutting and shoving
  - Little effect on modulus in the short term
- Cost benefit up to 35%
- Overlays
  - Extends life x 1.4 – 1.9
  - Most benefit for thicker overlays (> 75mm)

MECHANISM- Base & Subbase Reinforcement

Load distribution

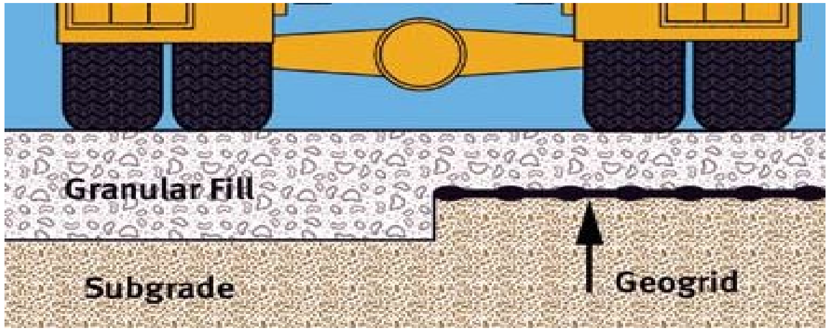
- Increased load distribution below vehicles wheels;
- Pressure applied to subgrade is decreased, hence **settlements and deformations are reduced**.





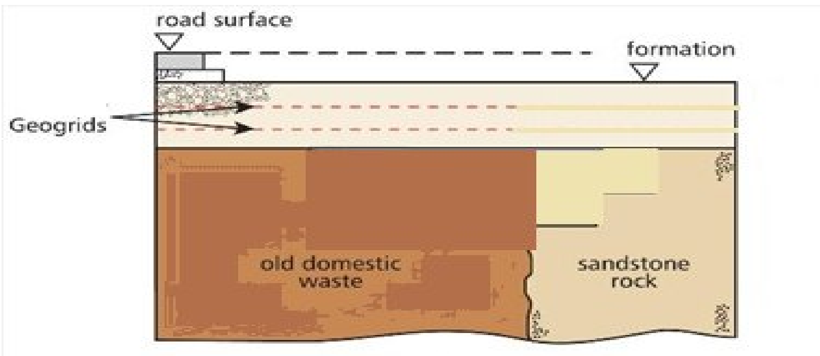
BENEFITS- Base & Subbase Reinforcement

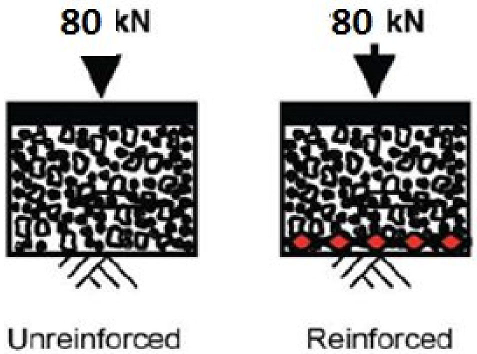
Thickness reduction at equal values of c, φ, N;

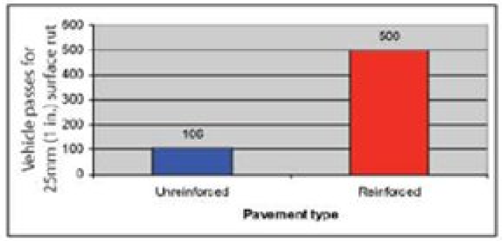


Lifetime increase at equal values of h, c, φ

Reduce the quality of fill at equal values of N, h







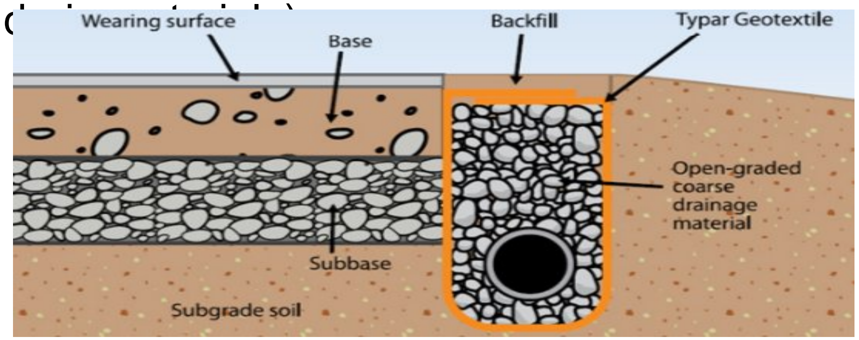
Drainage- Conventional approach

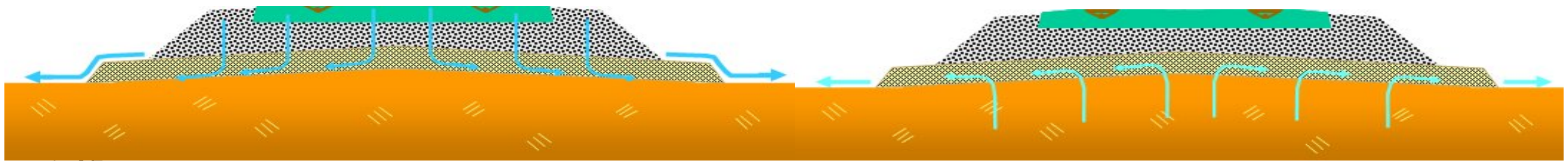
Traditionally, gravel layer is provided as the draining layer

- Provision of graded aggregates in the subbase course in order to effectively drain the water from the pavement structure
- Provision of french drains (Trench with free d
- Functions of French drains are

  Collect surface water run-off

  Control ground water flow





Problems associated with conventional approach

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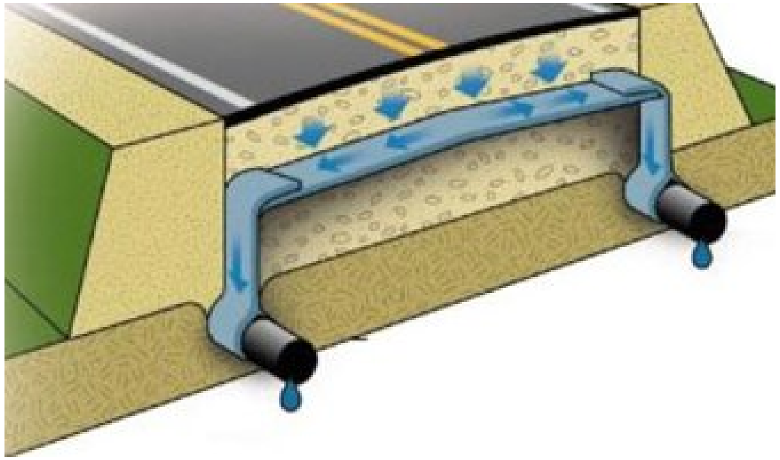
- Satisfying the drainage criterion for conventional graded filter design is extremely expensive.- Non availability of required aggregates
- Clogging: Ground water flows towards the drain carrying some fine particles from the base soil and consequently, the aggregates become blocked after some period having no adequate water removal capacity.
- Internal erosion of the base soil
- Requires considerable time for installation as it is to be installed as per gradation
- Require Skilled labor
- Material quantity and quality tend to differ along the length of the wall due to construction sourcing and human error issues.
- Increase in carbon footprints and Pressure on natural resources

Geosynthetics



Drainage solutions using

Geocomposite Drainage

Drainage Geocomposite

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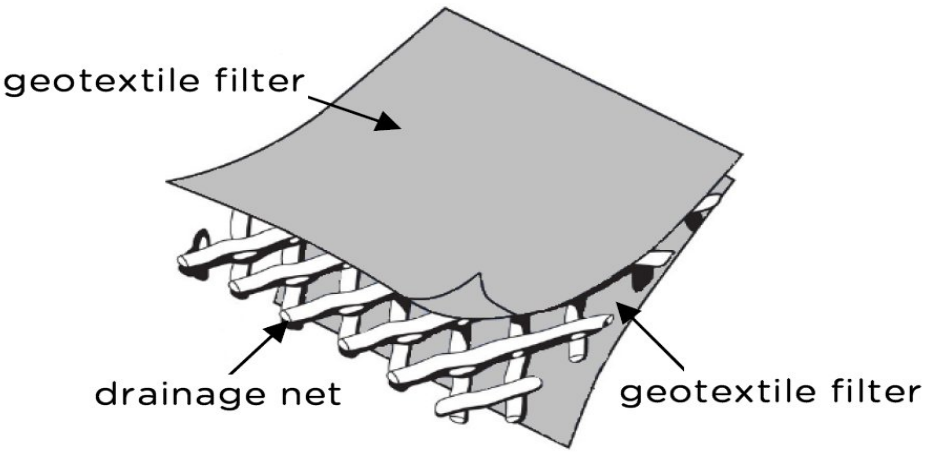
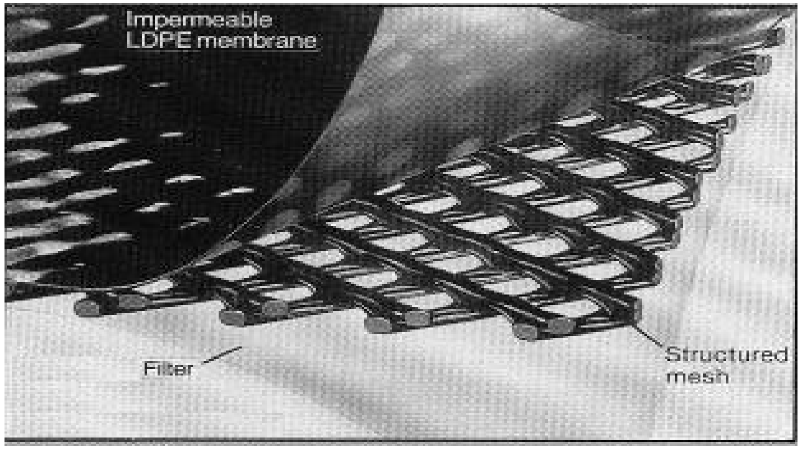
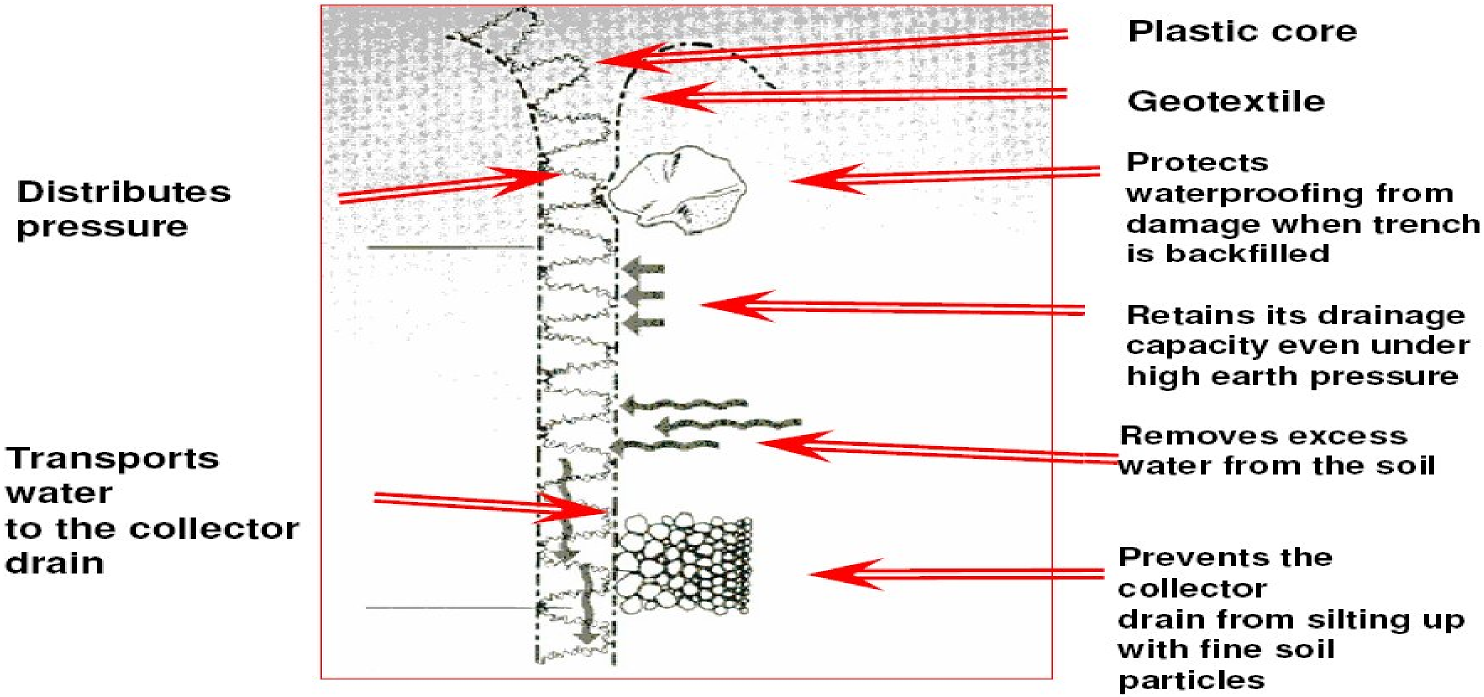
Drainage geocomposites are composed of a geotextile filter surrounding either a geonet (blanket drain), a thick preformed core (panel or edge drain), or a thin preformed core (wick drain). Some applications of drainage geocomposite are blanket drains and edge drains.





Drainage Geocomposite

Principles of the functions afforded by Drainage Geocomposite



Drainage Geocomposite

Road Side Drain Edge Drain: using Drainage Composite

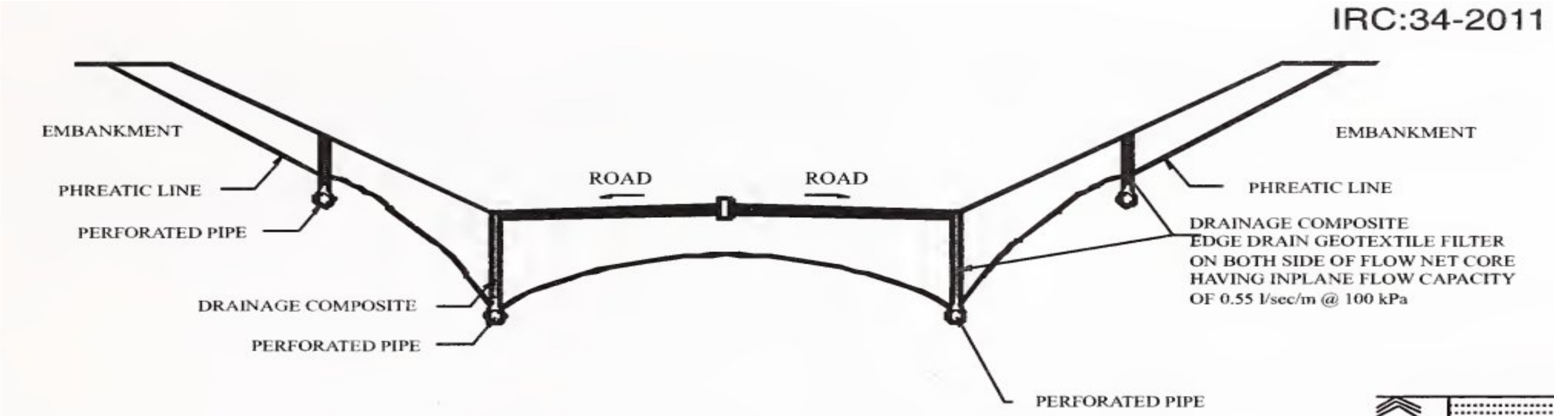


Fig. 4.6 Typical Cross Section of Road in Cutting with Drainage Composite

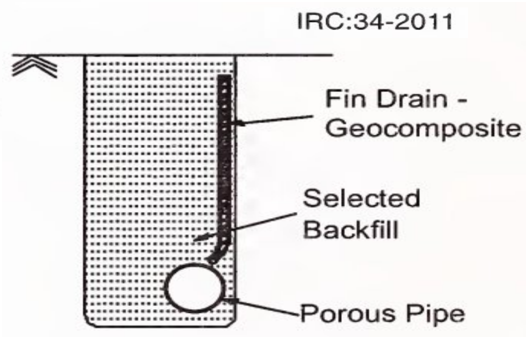
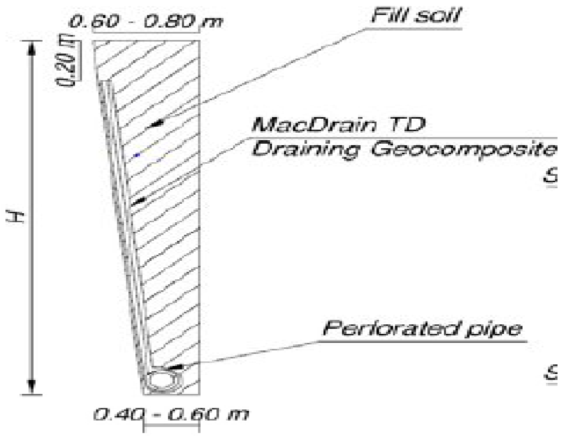


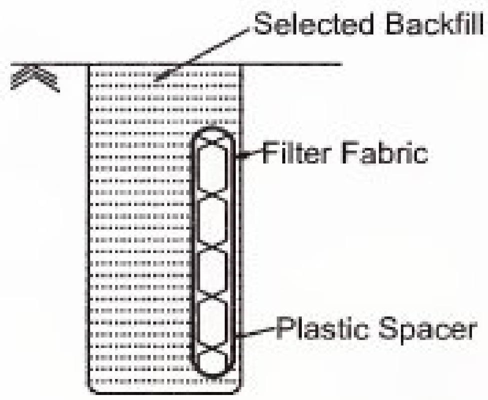
Fig. 4.5.2.7 Fin Drains

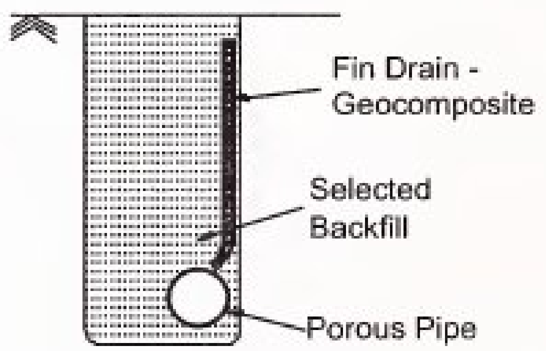
Drainage of Structures

Drainage Geocomposite

TRENCH AND EDGE DRAINS

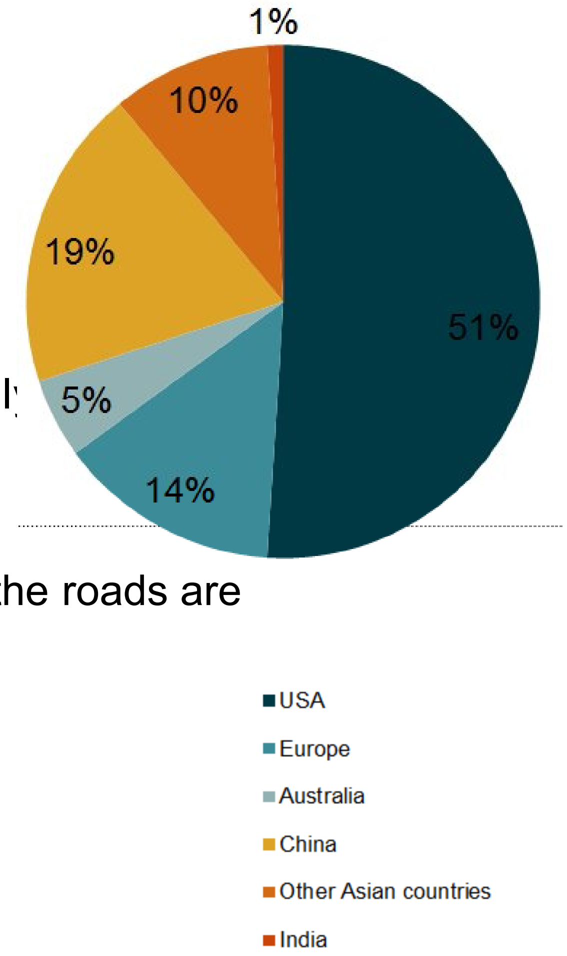






Global Scenario of Geosynthetics

- USA dominates the consumption of Geosynthetics.
- China Fast Catching up.
- India consumes less than 1.5% Geosynthetics, produced globall
- Tremendous Potential Exists in India-
- India has the world's second largest road network, and 95% of the roads are flexible pavement.
- Increased focus on infrastructure development



Practical challenges for Geosynthetic applications.

Despite many successful projects and research it is recognized that the use of geosynthetics in roadways is relatively limited compared to other applications.

Major reasons for limited use in pavement applications

- Geosynthetics are perceived as special materials that are considered only if problem areas need to be fixed
- lack of awareness of benefits of associated with use of geosynthetics.
- Existing numerical models for pavement design without Geosynthetics.
- Lack of required standards on Geosynthetic products as well as on

design, construction and installation guidelines

Ref. Berg et al. (2000), Perkins et al. (2005c), and Gabr et al. (2006)

Practical challenges for Geosynthetic applications.

➢Deficient of policy / regulatory initiatives by the central and state governments.

➢Lack of awareness of standards and guidelines by the site engineers / field staff.

➢Incompleteness of existing standards and guidelines.

➢They say, it [geosynthetics] was never used before, so they [will] wait for its first use," "They don't look at international experience or practice and want everything to be Indian-made.

➢*Lack of an accepted design method:* Currently the use of base reinforcement applications is based on prior experience and empirically based design approaches which are limited to the conditions of the related experiments.

Geogrid Reinforced Pavement

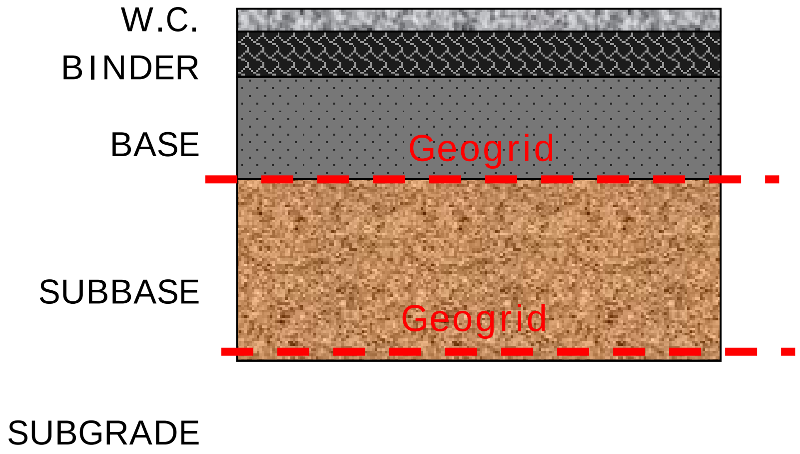
How to incorporate Geogrid properties in Pavement

•Complexity of layered pavement system and loading conditions- simple design method for incorporating Geogrid reinforcement

•Series of performance tests to evaluate contribution of geogrid to derive design parameters & incorporating into a design methodology.

•Early design approaches to be modified to reflect the benefit achieved by the addition of geogrid by a pavement reinforcement design term Viz., **LCR**.

•**LCR** — Layer Coefficient Ratio: A modifier applied to the layer coefficient of the aggregate.



Base & Subbase design using Geogrid

The process of design is as follows:

- Determine the sub grade CBR and design traffic load for which the flexible pavement is to be designed.
- Unreinforced section thickness shall be determined according to the IRC: 37-2012 for specified sub grade CBR and Design Traffic.
- Resilient moduli MR_{GB} and MR_{GSB} are evaluated for the base and sub-base.
- The tensile horizontal and vertical strains are evaluated for the conventional section for the subgrade.

Base & Subbase design using Geogrid

- Structural layer coefficients a_2, a_3 for granular base and sub-base layer of unreinforced section shall be determined from its resilient modulus (in psi) using following equations from AASHTO 1993.

$$a_2 = 0.249(log_{10}E_{GB}) - 0.977$$

$$a_3 = 0.227(log_{10}E_{GSB}) - 0.839$$

Where E_{GB} and E_{GSB} are resilient modulus of base and sub-base layers in psi.

Base & Subbase design using Geogrid

➢Benefit of inclusion of geogrid reinforcement in the pavement layers will be represented in improvement of resilient modulus of respective layer. Accordingly the corresponding structural layer coefficient(s) is / are modified by multiplying the corresponding layer coefficient ratios.

$$LCR_2 a_2 = 0.249(log_{10} E_{GB}) - 0.977$$

$$E_{GB.GS} = 10^{\frac{(LCR_2 a_2)+0.977}{0.249}}$$

$$LCR_3 a_3 = 0.227(log_{10} E_{GSB}) - 0.839$$

$$E_{GSB.GS} = 10^{\frac{(LCR_3 a_3)+0.839}{0.227}}$$

Where $E_{GB.GS}$ and $E_{GSB.GS}$ are modified resilient modulus of base and sub-base layers in psi

Base & Subbase design using Geogrid

- $E_{GB.GS}$ and $E_{GSB.GS}$ are converted from Psi to kPa to arrive $M_{R.GB.GS}$ and $M_{RGSB.GS}$.

- $M_{R.GB.GS}$ and $M_{RGSB.GS}$ are then used to determine the reduced thicknesses of the pavement components by mechanistic empirical.

- Further, these values are imposed in the IRC recommended IITPAVE software.

- By using critical tensile strain and compressive strain induced at the bottom of the bituminous course and top of the sub grade respectively, the allowable traffic should be determined for fatigue and rutting failures using equations from IRC: 37-2012.

- Obtained traffic value from critical strains should be more than the design traffic value.

Drainage design using geocomposite drain

1. Input flow rate/ flow capacity of core net calculation

$$\boxed{QD = FSQ \cdot (Q_R + Q_S)}$$

Where, FSQ = Factor of Safety on input flow rate

Q_R = Input flow rate due to rainfall (m^3/s/m or l/s/m)

Q_S = Input flow rate due to additional surficial flow (m^3/s/m or l/s/m)

Drainage design using geocomposite drain

2. Available flow rate calculation

The discharge capacity of Geocomposite can be given in terms of Transmissivity and specific flow rate.

$$\boxed{\text{Transmissivity } \theta = (q / B) / i}$$

$$\boxed{\text{Specific flow rate } Q = q / B}$$

Where, θ = Transmissivity of the Geocomposite (l/s/m or m3/s/m)

B = Width of Geocomposite specimen in the flow rate test (m)

q = Measured flow rate for a Geocomposite specimen of width B (l/s or m3/s)

Q = Specific flow rate per unit width of the Geocomposite (l/s/m or m3/s/m)

Drainage design using geocomposite drain

3. Allowable flow rate of drainage composite

$$\boxed{Q_a = Q_L/(RF_{in} .\ RF_{cr} .RF_{cc} .RF_{bc})}$$

Where, Q_a = available long term flow rate for the Geocomposite

Q_L = short term flow rate obtained from laboratory tests

RF_{in} = Reduction Factor for the intrusion of filter geotextiles into the drain core

RF_{cr} = Reduction Factor for the compressive creep of the Geocomposite

RF_{cc} = Reduction Factor for chemical clogging of the draining core

RF_{bc} = Reduction Factor for biological clogging of the draining core

Creek kalatalav sanesh road, Bhavnagar, Gujarat

Previous Site Conditions

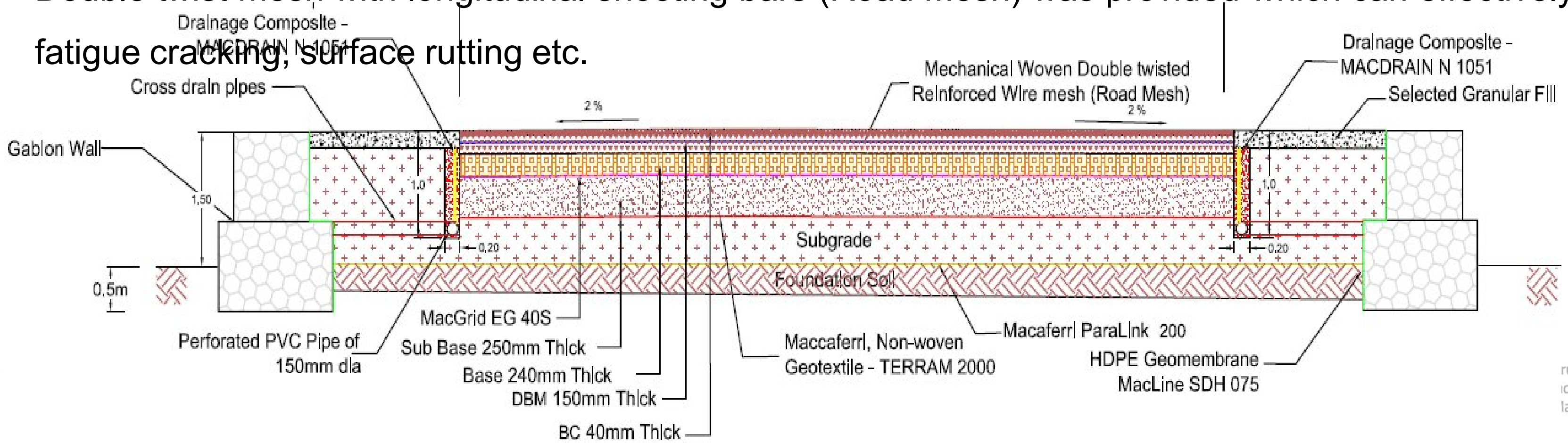
- Poor Soil properties
- Low CBR value, soft soil
- Critical site conditions i.e possibilities of the Water on both sides of the road
- Heavy loading (Salt Industries and Sheep breaking industries nearby)

Creek kalatalav sanesh road, Bhavnagar, Gujarat,,

Creek kalatalav sanesh road, Bhavnagar, Gujarat

Solution:

- High Strength Unidirectional Geogrid (ParaLink) having tensile strength **200 kN/m** as basal reinforcement to improve the subgrade properties
- Geotextile (MacTex) was used as separator
- **Extruded polypropylene biaxial geogrid (MacGrid EG) of strength 40 kN/m** as reinforcing material
- Drainage composite (MacDrain) was used in edge drains to drain out the surface runoff
- Double twist mesh with longitudinal shooting bars (Road Mesh) was provided which can effectively prevent fatigue cracking, surface rutting etc.



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CONCLUSION

- Outlook for geosynthetics is positive, as these materials score high both on sustainability and environment front.

- However to realise full potential, issues need to be addresses effectively by formulation of standards for design, product specifications, installation guidelines, quality control tests, increasing awareness etc.

- Geogrid and geocomposite when used properly in flexible pavements shall yield a significant reduction in thickness of aggregate layers, enhance the serviceability of the and thus can reduce the overall cost of pavements.

- However a proper design and well established methodology is essential to utilize this technology in a proper way.


Thank You
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