UNIT 1

BASIC DESCRIPTION OF GEOSYNTHETICS, RAW MATERIALS THEIR DURABILITY AND AGEING

Q.1. What are geosynthetics and how are they classified? *[K.U.K. 2013]*

Ans. Geosynthetics may be defined as a generic term which includes geotexties, geomembranes, geogrids, geonets, geocomposites and all other similar materials used by civil engineers to improve or modify soil rock behaviour.

Classification of geosynthetics : Geosynthetics are classified into following types.

1. Geotextiles
2. Geomembrane
3. Geogrid
4. Geocomposites

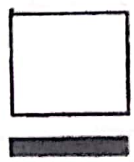
1. Geotextiles and related products are being increasingly used world over for every conceivable application in civil engineering be it in roads, foundations or earth and earth retaining structures. Their current use is estimated to be of the order of 1000 million sqm per annum. The reasons for such wide spread use, are that they are :

(*i*) Good alternatives to conventional designs

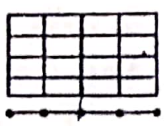
(*ii*) Sometimes the only means of construction

(*iii*) Amenable for rapid installations

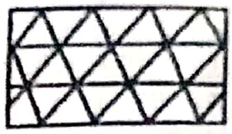
2. Geomembrane is defined as a continuous membrane type linear and barrier composed of asphaltic, polymeric of combination thereof materials with sufficiently low permeability so as to control fluid migration in a geotechnical engineering-related man-made project, structure or system.



3. Geogrid is any synthetic planer structure formed by a regular network of tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, earth or any other geotechnical material. They are also characterized by high dimensional stability and high tensile modulus at very low elongation.



4. **Gecomposites :** When georids/geotextiles /geomembranes are combined with woven or non-woven geotextiles or geogrids for specific applications like drainage, erosion control, bank protection etc, they are designated as geocomposites.



Geonets/geowebs/geomats could be coarse woven/or joints obtained by partial melting made of strips rigid filaments or extracted strands. They are generally flexible and junctions of overlapping strands not firmly connected.

Q.2. Discuss historical development and nomenclature of geosynthetics.

Ans. Historically, early civilizations have, used natural materials to improve soil behaviour e.g. ziggurautts of Babylonia where in woven mats of reeds were used, and tree branches were placed in the Great Wall of China. In India it is common to see dry branches and leaves or trees being used to reinforce soft soil in which heavy trucks get hogged down in raining season. Textile material was perhaps first used in road construction in South Carolina in the early 1930's. The first use of a woven synthetic fabric for erosion control was in 1950's in Florida. In 1960's, geotextiles were extensively used for erosion control-both in Europe as well as U.S.A. Later in 1969 nonwoven fabrics were used as a filter in the upstream face of an earthen dam. In 1971, use of woven fabrics as reinforcement for embankments constructed on very soft foundations was initiated. Today the use of such materials is more common for a wide range of civil engineering applications.

The Nomenclature : According to ASTM, a GEOTEXTILE is "any permeable textile material used with foundation, soil, earth or any other geotechnical engineering-related material, as an integral part of a man-made project structure or system".

The term which is proposed in 1983 by Professor Robert M. Koerner, Director of Geosyntheitc Research Institute and now being increasingly used is geosynthetics which encompasses :

(*i*) Geotextiles

(*ii*) Geomembranes

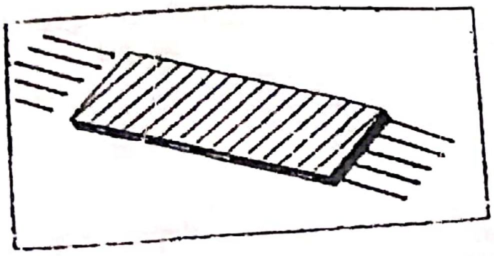
(*iii*) Geogrids

(*iv*) Geocomposites

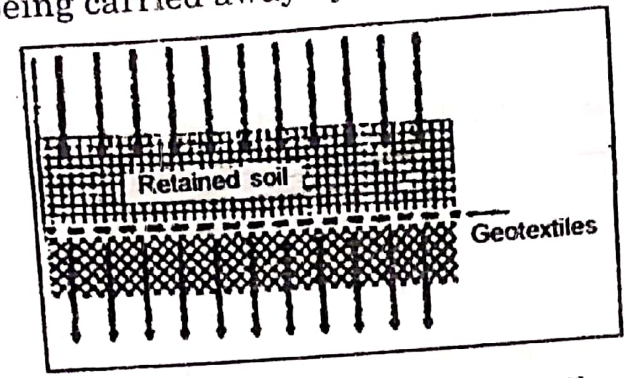
Q.3. Write down the functions of geosynthetics. ***[K.U.K. 2011/12]***

Ans. Geosynthetics serve the following basic functions.

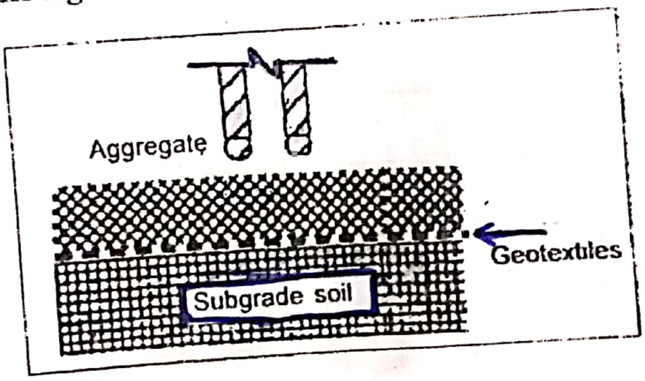
1. **Fluid transmission :** A geotextile can collect a liquid or a gas and convey it along its own plane, providing fluid transmission as shown in fig. This has been conventionally termed as drainage function.



2. **Filtration :** A geotextile acts as filter when it is normal to its own plane, while preventing from being carried away by the illustrated in fig.

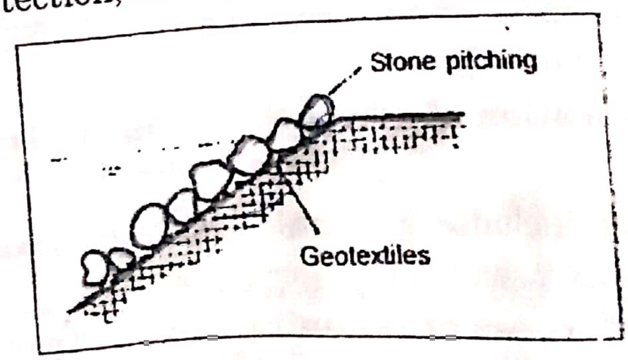


3. **Separation :** When placed between a fine soil and a coal (gravel, stones etc.), a geotextile prevents the coarse material from moving under the repeated applied loads as shown in fig.

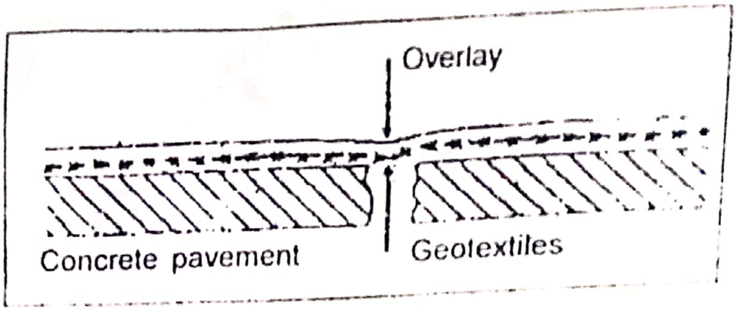


4. **Protection :** A geotextile protects a material when it alleviate/contributes stresses and strains transmitted to the pitching material. This can be

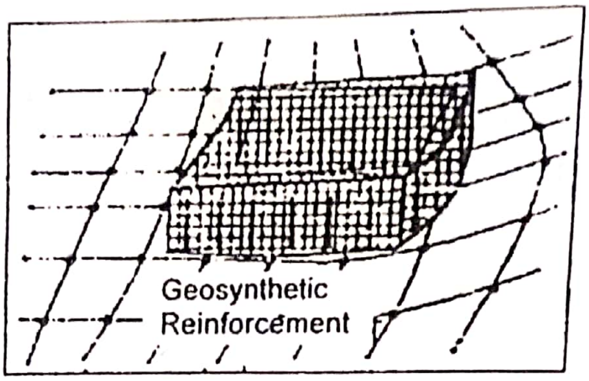
(*i*) For surface protection, as in crosion fig.

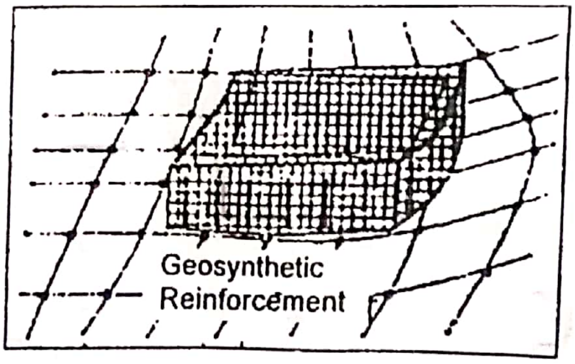


(ii) For interface protection, *i.e.*, alleviation of reflection cracking as shown fig.



(iii) Provide tensile modulus and strength through interface friction, as in fig.





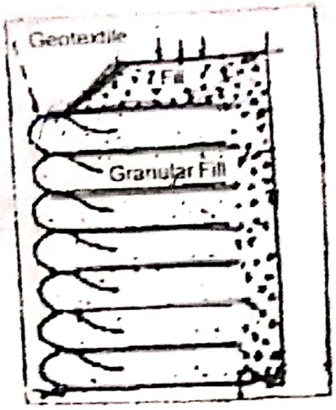
The last two functions are usually combined together and termed as reinforcement function". In many applications geosynthetics may perform more than function. This is illustrated in fig.

Q.4. Discuss application of geosynthetics in civil engg. project.

[K.U.K. 2013]

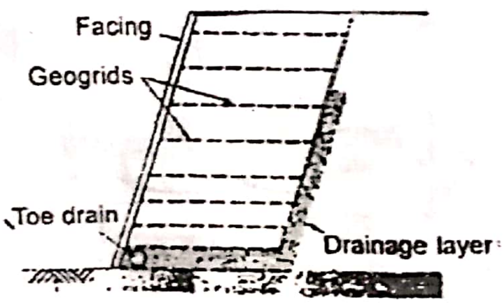
Ans. Geosynthetics includes geotextile, geogrids, geonets etc. In civil engg. projects, Geosynthetics are used in following application :

1. Internal reinforcement-retaining walls : Geotextiles and geogrids in internally reinforced soil walls (Fig.) allow reinforcement of the soil mass, creating a stable fill area behind the wall face. This application is an alternative to conventional gravity or cantilever retaining walls used in many civil engineering structures. In a retaining wall, as a result of vertical loading a horizontal pressure builds up against the back of the wall. The consequent lateral displacement of the wall is minimized by the reinforcement.

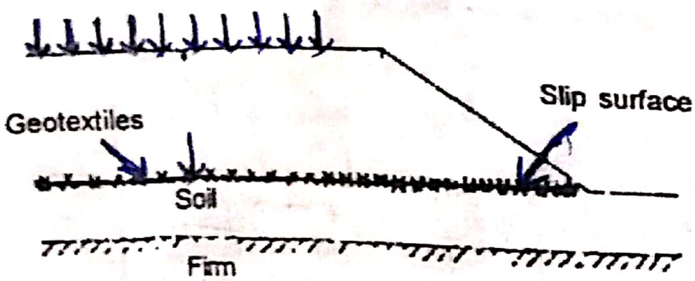


The use of geosynthetics allows a significant reduction in concrete required, decreases the cost of the wall construction, and reduces the load-carrying requirements of the wall facing element.

2. Steep slope reinforcement : Geotextiles and geogrids can allow construction of slopes with far steeper face angles as shown in fig than permitted by the soil's natural angle of repose which allows for more efficient land use.



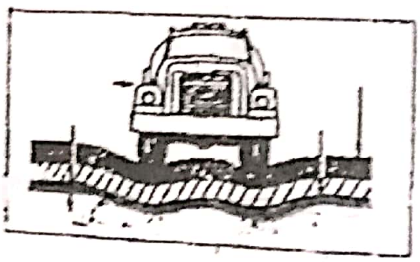
Reinforced Embankments Over soft soils : If the foundation soils underlying the embankment is too weak to permit the construction of an embankment to the required height, then geosynthetic-reinforced embankments can be provided with definite advantage.



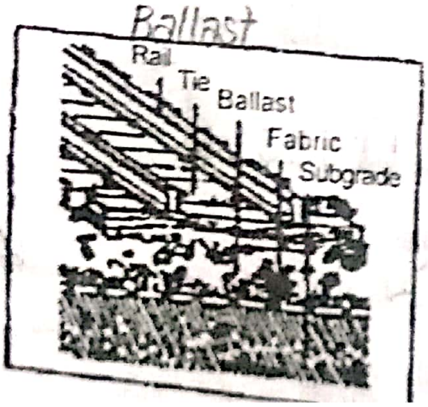
Conventional soil mechanics analysis techniques are used to evaluate the soil conditions and the embankment geometry. From this analysis, a design can be generated that provides the required reinforcement strength of geosynthetic. Both geotextiles and geogrids can serve this function.

The geosynthetic is placed over the foundation soil, generally with minimal disturbance of the existing materials. The embankment is then built using conventional construction equipment until the required embankment height is reached. One or more layers of geosynthetic may be used to provide the reinforcement necessary for embankment stability.

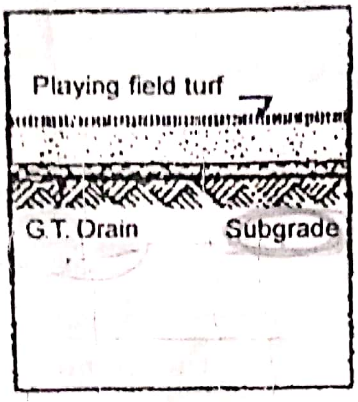
3. **Subgrade stabilization** : A geosynthetic can improve load carrying capability and reduce rutting when constructing roads over weak soils. The geosynthetic provides a separation barrier to prevent fill from punching into the subgrade under construction traffic. Typical woven and nonwoven geotextiles are used in this separation application. The desired properties of the geosynthetics are dependent upon the subgrade support strength and loads applied during construction. The geosynthetic may also provide filtration and drainage functions if required. Installation techniques vary with the application, but geosynthetics are typically placed directly on the subgrade followed by placement and compaction of adequate depth of stone.



Geosynthetic used under railway track (as shown in Fig.) may provide for additional roadbed filtration, planer (Lateral) permeability strength and modulus improvement, and separation of subgrade and ballast. Through use of geotextile even reinforced rail sleepers are in use in Nehterlands, instead of the conventional timber/concrete sleepers.

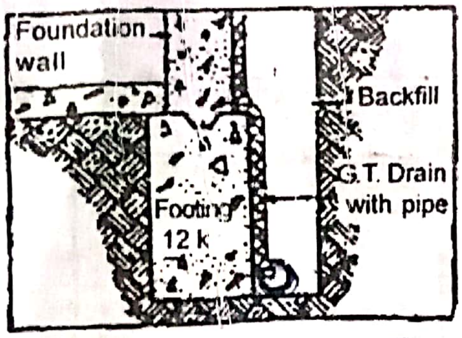


4. **Subsurface drainage** : Geotextiles are used in subsurface drainage systems as a permeable separator to keep soil out of the drainage media, but permit water to pass freely. Uncontrolled ground water can be destructive, so subsurface drainage is needed under highways, parking lots, shorelines, walls etc. Permittivity (capacity to water flow) and pore size (opening size) are critical characteristics. Nonwoven fabrics because of their high flow capacity and small pore size are typically used.



In most subsurface drainage applications strength is not a primary concern. It is only critical during installation. Care should always be taken to assure an effective installation.

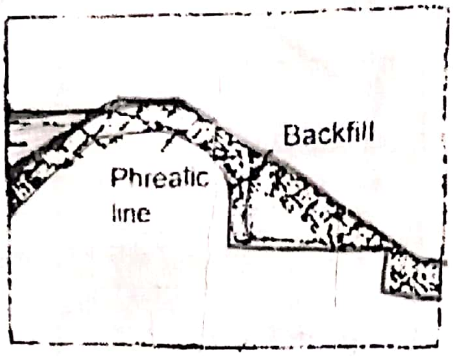
5. **Drainage-Prefabricated composites** : Prefabricated drainage composites (Fig.) are engineered to replace costly, conventional aggregate drain systems. They provide consistent in place drainage and can reduce the material cost, installation time and design complexity associated with aggregate drainage systems.



6. **Erosion control/Turf reinforcement** : Three-dimensional erosion control mats are used to establish a reinforced turf in ditches, channels and slopes. The mat entangles with the root and stem network of vegetation to greatly enhance its resistance to flow velocity.

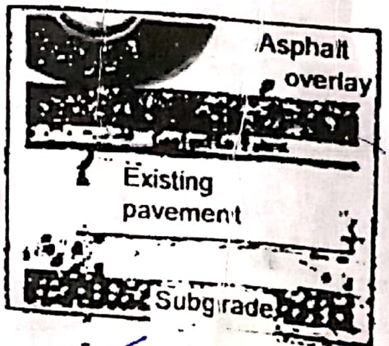
Erosion mats used for turf reinforcement have a strong, stable three-dimensional structure with adequate porosity to retain soil while allowing roots and stems to grow through. Correct installation requires pinning the mat to the ground and burying mat edges and ends. Top soil cover may be used to enhance temporary erosion protection and early vegetative growth.

7. Geomembrane protection : Geotextiles may be placed on one or both sides of the geomembrane (synthetic) to protect it from installation and design stresses. These geosynthetic lining systems are gaining popularity in hazardous and non hazardous waste landfills. They replace conventional sand/protective layers.

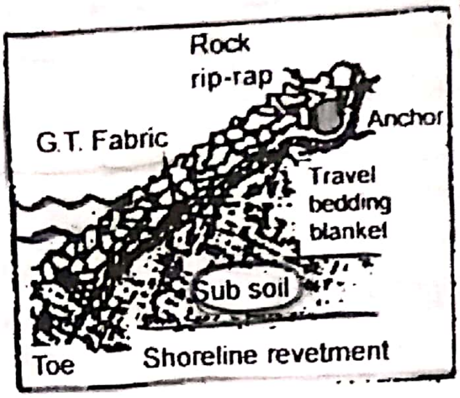


Typical geotextiles used for geomembrane protection are medium-to-heavyweight fabrics. Geotextiles protect the geomembrane by acting as a cushion. Geotextiles minimize the chance of the liner being punctured by sharp objects and damaged from construction stresses. Important geotextile properties for this application are typically weight fabric thickness and puncture, burst and tear strength.

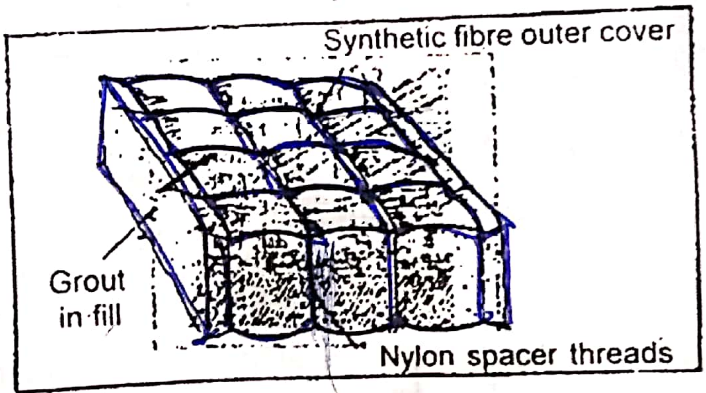
8. Asphalt overlay : Excess moisture in road bases is the primary cause of premature road failures. Ninety percent of subgrade and base moisture problems stem from rain melting snow or ice entering the road through the surface. Heavy vehicle loads can cause extensive damage to roads, especially when the base is wet and weakened.



9. Erosion control under rip-rap : To prevent the erosion of soil through the layer, geotextils are used as an interface as shown in fig. The geotextile is in lieu of a conventional grade aggregate filter. In this application, large stone or in some cases flexible concrete mattresses, are to protect the soil against erosion and wave attend use of a geotextile in such situation usually provide stantial savings over conventional aggregage filted terms with far greater control during constructed particularly in underwater applications.



10. Erosion Control-Fabric-Forming Mats : A cost effective alternative to stone rip-rap is a cone forming system. The mats as shown in fig are typically constructed of water permeable; double layer woven fabric. The fabrics are positioned on the area to be protected, where they are filled with a pumped structural grout. In many cases the mats can be installed at a lower cost than conventional methods since all construction is performed in place.

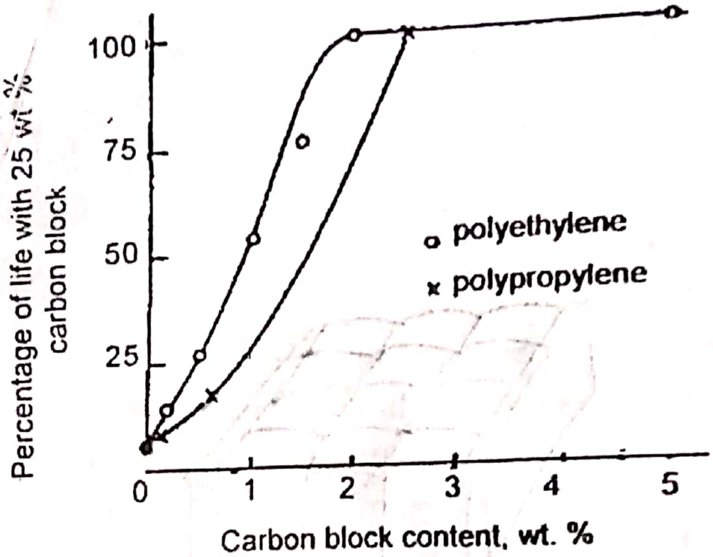


Q.5. Discuss the process of chain scission in degradation of polymeric material? ***[K.U.K. 2011,'12/13]***

Ans. Polyolefins in an unprotected state have poor resistance to sunlight with brittleness developing in this sections in less, than six months. This brittleness or loss of flexibility, resulting from oxidation energized by the ultra-violet component of ordinary sunlight is accompanied by physical changes, principally chain-linking. The net result of these changes is a brittle material having little strength.

In order to give protection against degradation initiated by UV light, the only form of degradation which is a direct result of weathering alone, all Tensar geogrids incorporate an appropriate amount of finely divided carbon black. From information provided by resin suppliers, the lives to be expected for the various grades of Tensar geogrids were estimated. These estimates are now believed to be conservative, as most research on UV degradation has been carried out on samples much thinner than even the ribs of these geogrids (Raumann, 1982). It is notable that the materials with the heaviest filaments showed the least deterioration : 20% loss in strength in 1 year, but even these fabrics had filaments of order of magnitude finer than the ribs of Tensar geogrids.

The life of product containing 0.75% carbon black can be estimated from fig. It can be seen that with 0.75% carbon block PP degrades on more than 4.5 times as fast with 2.5% carbon black and the rate of attrition is therefore 2.5 × 4.5 = 11.25m per year. At this rate the lightest Tensar geogrid containing 0.75% carbon black (SS1) which has a minimum rib thickness of 0.5mm, would retain 90% of its initial strength for 4.4 years. Thus no significant deterioration will occur even if geogrids are exposed on sire for many months before burial.



The resistance to ageing of any given polylefin-carbon black compound depends upon-three factors :

(i) Type and particle size of carbon black

(ii) Concentration of carbon black and

(iii) Dispersion of carbon black

In order to ensure extended UV protection the carbon black must be a Channel type with a particle size of less than or equal to 20 nanometers, must be concentrated at 2% minimum and must be well dispersed in the polyolefin.

Q.6. Briefly describe the raw materials used in the manufacture of geotextiles.

Ans. The synthetic materials used for manufacture of geosynthetics include amorphous thermoplastics, semicystalline thermoplastics and elastomers. Polymers are made by chemically linking very large molecules together in chains. Following is a brief description of the polymers used in geosynthetics.

1. Polyolefins : Ployolefins are made from any long chain synthetic polymer composed of at least 85% by weight of ethylene propylene etc. In general they offer a high degree chemical inertness, light weight, high strength and abrasion resistance.

Polypropylene (PP) a polyolefin made from propylene monomer obtained from naptha is widely used in - geosynthetics. Increasing the linertty of the polymer structure increases the density and strength of the polymer.

Polyethylene (PE) (a polyolefin) is made ethylene monomer obtained from naptha and depending upon the nature of polymerisation, two varieties are usually obtained Low Density Polythylene (IDPE) and High Density Polyethylene (HDPE).

By suitable modifications to ethylene monomer, other polymers such as chlortnai polythylene (CPE) and chlorosulphonated polythylene (CSPE Hypalon) are produced. These are used in the manufacture of Geomembranes.

2. Polyester (PET) : It is made of from Dimethyl Terapthalate (DMT) and ethylene Geycol (MEG) in place of DMT. Modern processes use Pure Terepthalic Acid (PTA). All these monomers are obtained from Naptba. Polyester fibres offer high strength as well as chemtcal interness to solvents water, acid and abrasion resistance. It has high resistance to creep and no variation in mechanical behaviour at temperatures upto 200°C.

Polyamides (PA) : The polyamide family is extensive. Nylon is a polyamide obtained by polymerising caprolactum monomer (which is made from Benzene Buterdine obtained from Naptha). Polyamides are high resistant to abrasion. They have certain sensitivity to aqueous solution.

Polyvinyl chloride : A polymer made from polymerisation of vinyl chloride monomer (obtained from naptha) is polyvinyl chloride.

Elstomers : Synthetic rubbers like butyl rubber, Neoprene, Ethylene propylene diene monomer (EPDM) are included in this category. For all these, the basic raw materials are fractions of Naptha cracker.

Q.7. What are the possible causes of deterioration of geosynthetics? Briefly discuss phenomenon of durability?

Ans. The possible causes of deterioration of geosynthetics are such as

(i) Ultra violet degradation

(ii) Thermal and oxidative degradation

(iii) Chemical attack

(iv) Microbial attack

(v) Environmental stress cracking

Durability : The term "durability" expresses the preservation in time of the characteristics or performance, of a material which are checked at the time delivery or before placing and service.

The whole question of durability has become of greater relevance in recent years as geosynthetics structures have found their more sophisticated application in civil engineering construction. Uutil the early 1980's most of the geosynthetics were used in passive roles. For example temporary consolidation of embankment surfaces, separation of soil aggregate layers in foundation and or drainage function etc. witnessed their major uses in early ages. In all these cases, retention of mechanical properties over specified (short) times was not of importance and hence not a performance requirement in the application. But more recently the use of geosythetics as reinforcing media in civil engineering structures with higher level of quantifiable performance required has been increased. In such more active end uses, Catastrophic loss of mechanical properties during their design lifetimes could have serious implication with regard to the stability of civil engineering structures as a whole or in part. Consequently, the question of durability of geosynthetics has become a matter of vital concern.

Q.8. What are various degrading agencies to which geosynthetics are subjected to?

Ans. No geosynthetic is ever exposed to a single degrading agency in geotechnical situation. Instead, the most easily identified factors are often acting in combination and thus attack on geosynthetic structures occur in a most complex and little understood manner. It must be recognized that prior to and during installation, exposure to the environment and human activity can have serious implications with regard to geopolymertic lifetimes both directly after actual damage or indirectly. In the latter case, such exposure may sensitise the structure to more rapid and subsequent in-situ degradation. For example UV exposure of a geosynthetic during transportation, storage or installation can sensitise component polymer to hydrolytic damage after installation. Similarly, weathering involves the critical exposure of synthetics to the physical and chemical effects of sunlight rain wind and atmospheric pollutant gases and particulates.

The various degrading agencies are

(*i*) UV

(*ii*) Sunlight

(*iii*) Air

(*iv*) Rain

(*v*) Wind

(*vi*) Pollutant gases

(*vii*) Stress

(*viii*) Micro-organisms

Q.9. Write short note on the following :

(*i*) Polyester

(*ii*) Polyethylene & polypropylene

(*iii*) Polyamide & polyaramide paraproducts

Ans. (*i*) Polyester : This polymer is the prime candidate for their use in geosynthetic structure, because of its high strength, modulus and creep resistance coupled with general chemical inertness. However it may be physically attacked by polar aromatic species such as benzyl alcohol and phenols. It is resistant to diesel and other fuel oils. Its principal chemical weakness lies in its sensitivity to hydrolysis in acidic and especially basic media. This, therefore, poses the question of long term durability of polyester in aqueous environments over the pH range 3-10 typical of values in natural and pollutant soils. However, calculation based on laboratory ageing tests suggest that in spite of some hydrolysis occurring in PET exposed to ambient alkaline condition of pH 7-10 lifetime in excess of 50 years may be expected. Moreover, its resistance to UV' radiation is not exceptional and thus, its storage "and installation should be undertaken with care to avoid" unnecessary exposure.

(*ii*) Polyethylene & polypropylene : Both these conventionally melt spun polymers are creep prone because of their low Glass Transition (T_g)values. Whenever, the purely hydrocarbon structures create a significant degree of inertness, although they are vulnerable to permeation and swelling aromatic solvents like toluene and Xylene. Resistance to aliphatic solvents are as diesel and lubricating oils acceptable.

Resistance to chemical ageing is poor if oxidising species are present and this is especially true for polypropylene which is vulnerable to with thermal-oxidation and photo-oxidation. However, mechanisms of these agencies are well understood, and effective antioxidants and UV radiation stabilizer systems are available for both polymers. One of the simplest and at most effective light stabilizer is finely dispersed carbon black, hence its absence is found in many geosynthetics. Polyethylene or polypropylene are not attacked by micro-organisms. Polypropylene tapes subjected to aerated water can have life times of 30-50 years, and in the general construction yields of application 100 years are expected.

(*iii*) Polyamide & polyaramide paraproducts : The use of polyamide and polyaramide in geopolymeric structures. This is a consequence of several factors, apart from the cost considerations, these high strength tough polymers have lower modality as compared to polyester and polypropylene and are most vulnerable to UV degradation. Like polyester, they are also prone to hydrolysis. They are quite resistant to neutral and weakly alkaline condition but on acidic attack. Soil burial tests have resulted in strength posses. So the use of polyamide fibres in geotechnical application may be questioned if long lifetimes are expected. On the contrary, of course, the extreme creep resistance over polyester paraproducts, coupled with their very high strength and modulii-and superior solvent and hydrolysis resistance of poly-paraaramid fibres "has attracted" interest for their use in high performance geotextiles and geogrids. A prime weakness of all aramide materials, however, lies in their vulnerability to UV attack.

Q.10. Discuss the effect of microbial attack on durability of polymers.

Ans. In an extensive research by Albertsson, HDPE samples were incubated at 250°C for 800 days in aerated cultures of various organisms. The HDPE was in the form of 0.02mm thick unoriented film or fine milled powder and in most experiments was used free of antioxidant in order to accelerate testing. Two effects were identified: biotic auto-oxidation, and a biological defect. No possible biological of degradation could be found. The only effect found was that the micro-organisms consumed the very low molecular weight 'extractable' fraction of polymer This consumption was proportional to surface/volume ratio and after two year was less than 0.1% per year for a powder with a surface/volume ratio of $10.5m^2/g$. As Tenser and Melton geogrids have a maximum surface/volume ratio = $5 \times 10m^2/g$ this effect would be barely measurable even over 100 years. In addition the rate of consumption was reduced by a factor of 3 by the inclusion of an antioxidant in the polymer. It is expected that PP will behave similarly.

Further work by Albertson states that average chain length strength of HDPE molecules above weight average 1000 Mw (Molecular weight) are inert to microbial attack because of the lack of suitable enzymes that split the C-C bond. Tensar HDPE Geogrids are produced from resins with molecular weight averages between 150,000 – 200,000.

Griffin summarized that the biological resistance of polyolefins has in fact led to serious concern about the effect on the environment of the longevity of the vast quantity of these materials used in the modern packing industry. Research has been carried out to try and increase their biodegradability. The only method found to encourage the biological breakdown of such products was the incorporation (upto 40%) of a nutrient filer such as starch.

The resistance of HDPE to attack by large organisms was confirmed by the results of 15 year marine exposure tests carried out from 1956 to 1970. No significant attack occurred on 'HDPE, even from marine borers, the most aggressive organisms encountered.

Finally, the biological resistance of the particular polymer systems, including stabilizers and carbon black, used in Tensar Geogrids is confirmed by the approval given for similar compounds to be used portable, water conveyance.

Q.11. What is effect of chemical attack on durability of geosynthetics?

Ans. It is defined as the resistance of manufacturing material to the chemical action. Both HDPE and PP have good chemical resistance. Soaking in water for 6 months has no effect on the stress-strain behaviour of Tensar SR2.

In buried applications HDPE has been for even longer period, in particular in the critical applications of distributing gas and drinking water. For some pipe diameters it has been the main material for upto 30 year. For gas distribution, HDPE pipe supplied must have a minimum life of 50 years. The chemical resistance of HDPE increases with density and thus the performance of the grades used for Tensar SR geogrids at SG 0.941 will exceed that of the pipe grades at SG 0.935 – 0.945.

There is no known solvent which will dissolve either PP or HDPE at ambient temperatures.

Q.12. Discuss various modes of failure of reinforced soil beneath a foundation? *[K.U.K. 2012]*

Ans. HDPE is highly resistant to most aggressive chemicals which make it at first an attractive material for in-soil applications. But HDPE continuously deforms under a given load, until it fails. This phenomenon is also termed as creep. Failure comes rapidly when the load is heavy. Under small loads. Failure comes more slow-but may be very sudden. when it does occur with no significant indication. This is brittle failure which is very difficult to predict.

The process of brittle failure to which polyethylene is intrinsically prone may be greatly accelerated in certain environments which favour the development of cracks and existing defects, even if microscopic, especially in the zone subjected to stresses.

In the present state of knowledge and not to mention the various aggravating factors encountered in soil reinforcement applications (installation, temperature etc.) it would seem prudent to refer to some specifications such as those laid down by ASTM and the Plastic Pipe industries:

(*i*) Service life must never exceed 50 years:

(*ii*) Tensile stress must not in practice, exceed 10% of short term breaking stress (and possibly less depending on a maximum deformation criterion);

(*iii*) Each product must have come through a series of qualifying tests carried out at different temperatures relying itself on certain correlations. This approach aims at ensuring that, in the conditions of use. There is risk of the brittle failure zone being reached before the end of the service life.

UNIT 2

MANUFACTURING METHODS, TESTING AND EVALUATION

Q.1. What are the basic steps involved in the manufacturing of geotextile? What are the characteristics of fibres used?

Ans. Starting from the Polymer Chips, the manufacture of geotextile accomplished in two basic steps.

(*i*) Making linear elements as fibres and yarns

(*ii*) Combining these to make a planer structure designed as a fabric/geofabric/geotextile.

This involves various stages of production and is rather complex. The technology of producing a fabric from a polymer chip is highly advance in some cases.

Fibres : Fibres are characterised by the following :

1. High ratio of length to thickness (1000 : 1)
2. Very fine diameter (10 to 30μ)
3. Flexible in nature
4. Having high strength and low elongation
5. Having good stability at sufficiently high temperature.

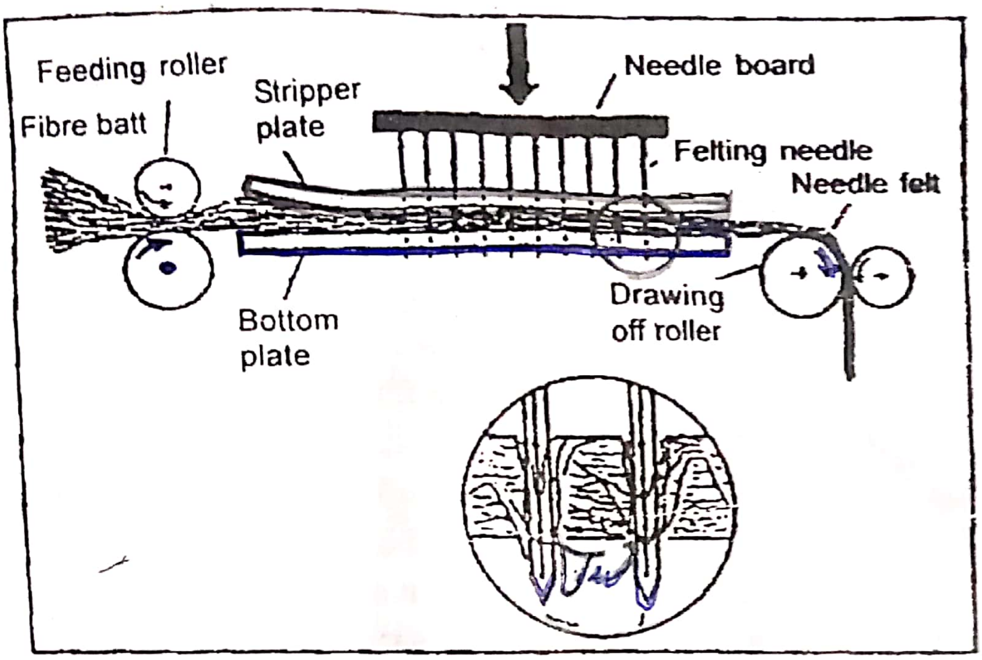
Generally they are available in three different forms. viz.

1. Filaments (continuous filaments)
2. Stable fibres
3. Slit films

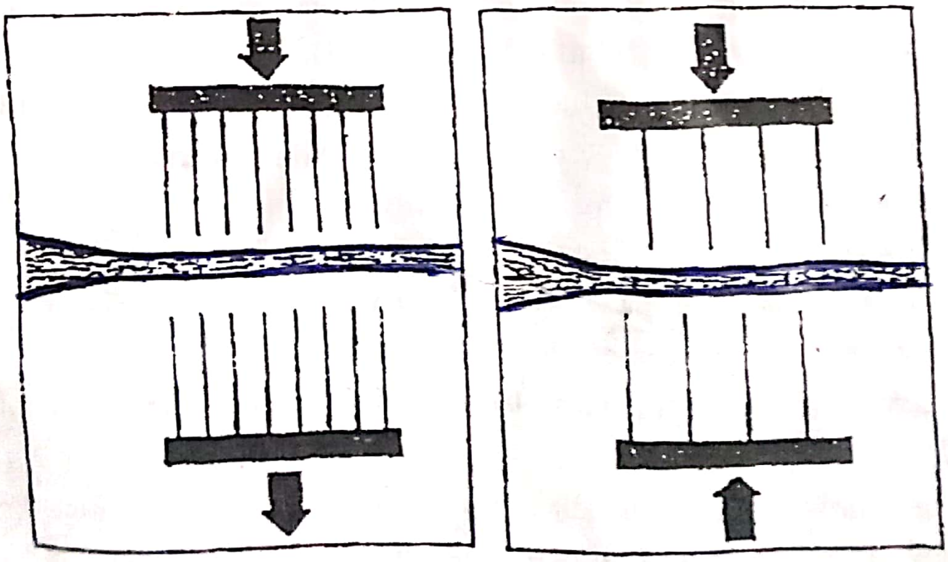
Q.2. Explain the process of needle punching or Mechanical Bonding.

Ans. The loose web passes through a system whereby one or more board comprising of several specially designed barbed needles are punched through the web either from one side or from both sides as shown in Fig. This way the loose fibres/filaments get entangled as the web moves forward slowly. By this process one can obtain rather thick fabrics upto even 5mm or more. Several variations in the type of fabric can be achieved' by varying' the type of needles, depth of needle penetration, punch density (punches per unit area), angle of needle penetration etc. There are several manufacturing units in India which make this kind of fabric.

typically. Bombay Dyeing, Sri Dinesh Mills, Hitkari, Porrits and Spencer, Supreme, Nonwoven, Uniproducts, United Felts and Carpets.



Immediately after the web formation and needle punching, a synthetic resin may be sprayed on the fabric or it may be immersed in the resin and later squeezed. This way one obtains a nonwoven fabric bonded both mechanically and chemically. Figure shows the Scanned electron micrograph (SEM) view of such a fabric, made by Tata Mills under NTC. It appears similar to a needle punched fabric, as no change in fabric structure occurs during resin impregnation except chemical bonding.



Q.3. Discuss the processes used for bonding.

Ans. The loose web formed is compressed and bonded by using one or combination of the following processes.

(*i*) Mechanical bonding (needle punching)

(*ii*) Thermal bonding (under heat and pressure)

(*iii*) Chemical bonding (using bonding agents)

(*i*) Mechanical bonding : *Refer to Q.2.*

(*ii*) Thermal bonding : By partial melting, the filaments of staple fibres get fused and bonded to one another. This can be achieved by mixing with a finer/filaments of low melting temperature, which helps in bonding at lower temperature thus not effecting the majority fibres. This process usually results in thin fabrics which are stiff and rigid.

When the needle punched fabric is passed through calenders (or rollers) under pressure, some of them get heated. It is possible that a smoother finish is obtained by surface heat effects. Such a process is known as calendering.

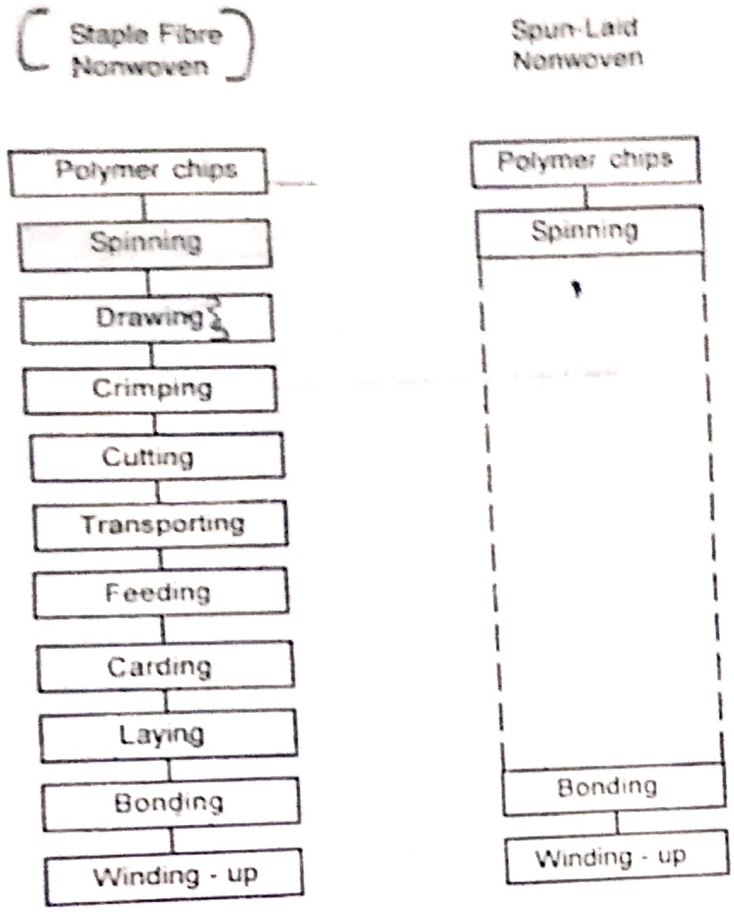
If the entire process as described above viz., filament extrusion, drawing web formation and bonding is done in a single continuous process the fabric obtained is of better quality and is called spun bonded regardless of the process of bonding.

(*iii*) Chemical bonding : In chemical bonding process an adhesive in suitable form is used to bond the fibres in the web at cross-over points. They can be applied in various ways and forms viz. by spraying immersing foaming part, dissolving etc. either during web forming or after web forming process. According to the end use requirement the bonding agent may be applied homogeneously throughout the fabric or partially on the surface. In all cases warmth and sometimes pressure too is required after the bonding agent has been applied before bonding can take place.

With present day technology only chemical bonding does not seem the logical way of binding the fibre web for geotechnical purpose because the fibre to fibre adhesion is far from good. Although the fibres that go to make the product are in themselves strong, the composite strength is very low. Many bonding agents loose their effect with ageing or if exposed to moisture.

Q.4. Draw the flow diagram of manufacturing process of non woven geotextile?

Ans. Fig. shows the block diagram depicting the manufacturing process of staple nonwoven and spun laid nonwoven fibers.



Q.5. Give comparison of properties of staple fibre and spun-laid nonwoven fibers?

Ans. A comparison of Staple Fibre and Spun-laid Nonwovens is given in the following table.

S. No.	Stable Fibre Nonwoven	Spun-laid Nonwoven
1.	Lower Modulus	Higher Modulus
2.	Lower Strength	Higher Strength
3.	Higher Ext. at Break	Lower Ext. at Break
4.	Lower Isotropy	Higher Isotropy
5.	Lower Uniformity	Higher Uniformity
6.	Lower Production Speed	Higher Speed of production
7.	Lower plant capacity	Higher plant capacity
8.	Lower Investment	Higher investment
9.	Greater product flexibility	Lower product flexibility

Q.6. Distinguish between woven and non-woven geotextiles?

[K.U.K. 2011/12/13]

Ans. Comparison of properties of Woven and Non-woven Fabrics of similar area and density is given in the following table:–

S. No.	Property	Woven	Non woven
1.	Fibre Arrangement	Orthogonal	Random
2.	Properties	Directional	Nondirectional
3.	Breaking strength	Higher	Lower
4.	Breaking Elongation	Lower	Higher
5.	Initial Modulus	Higher	Lower
6.	Tear resistance	Lower high	Higher
7.	Openings	Can be Regular	Irregular
8.	Filtration	Single Layer	Often Multi-layer
9.	Porosity	35-45%	55-93%
10.	Inplane Flow	Low	Can be High
11.	Edge	May Ravel	Does not Ravel

Q.7. Write a note on development of directionally structured filament fabric (DSF).

Ans. The first generation geotextiles were those textiles which were already available for industrial applications but used in civil engineering applications. Their initial success encouraged the manufacturers to develop stronger fabrics or more permeable fabrics by making the earlier ones thicker stronger more ultra violet resistant etc. for either general or particular applications.

These were the second generation geotextiles made in the same looms (woven/nonwoven) as for other industrial fabrics.

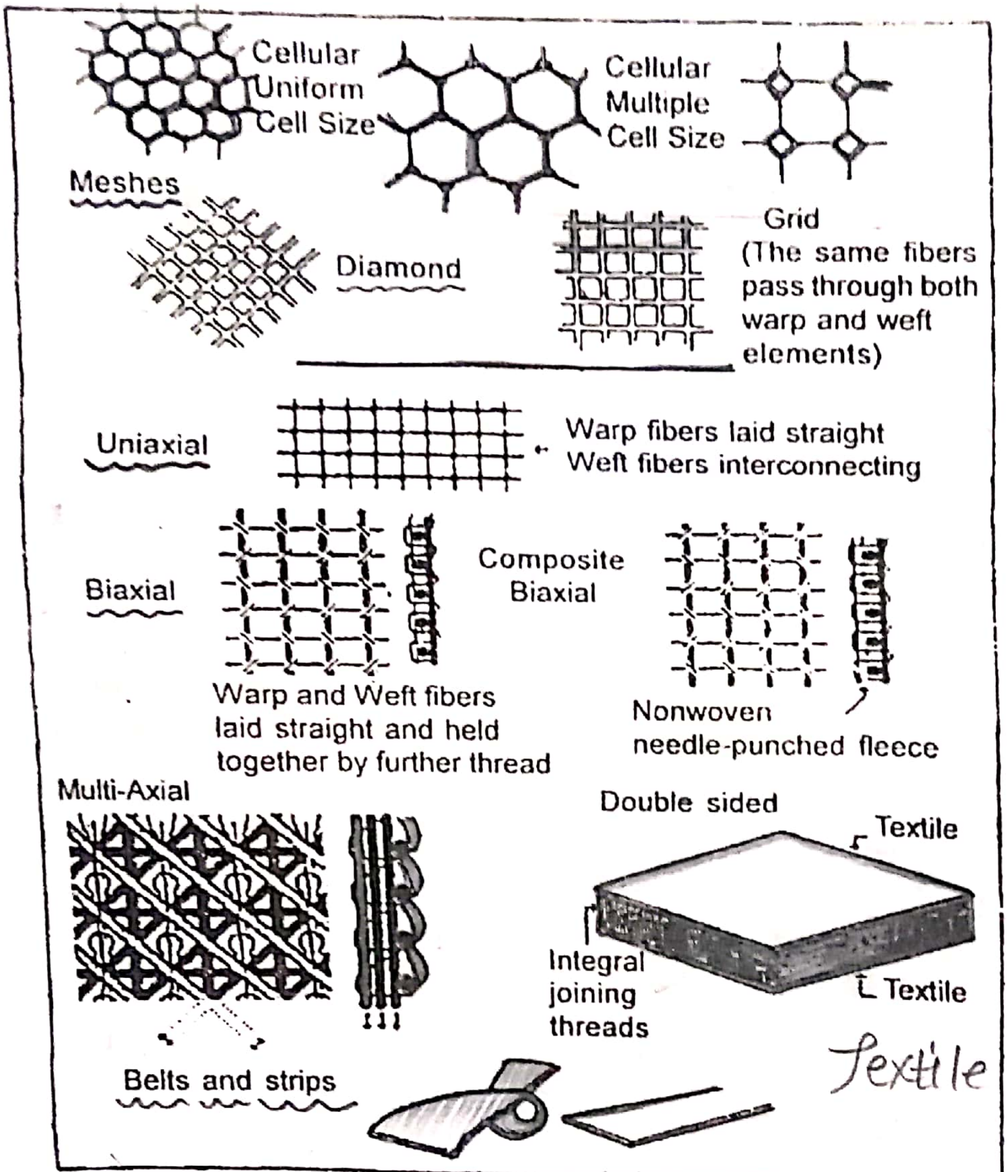
The advent of Directionally Structured Filament (DSF) fabrics pioneered in the UK and France since 1986 achieved in Raschel Machines has opened up new vistas in development of geotextiles.

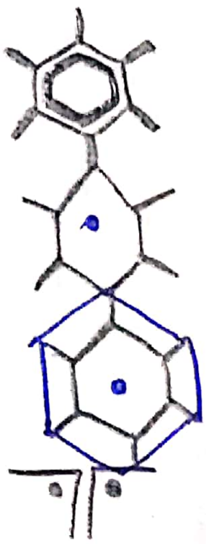
In this technique filaments/yarn can be placed connected predetermined configurations appropriate to the end function requirement.

Because the filaments can be mechanically connected at more points geotextiles permeability can be varied without any change in structural stability. They can be custom designed from any material. They can be laid.

In any direction so that strength and extensibility can be designed as per requirement and node spacing varied to fit specified filtration and permeability properties.

Fig shows the fundamental cell structures of DSF geotextiles.





Primarily, responsible for the development of advanced DSF geotextile configurations has been the West Germany firm of Karl Mayer Textile maschimenfarlite GmbH Pushing forward this technology they have created a new range of DSF fabrics called DOS (Directionally Oriented Structures).

Q.8. What are geogrids? Discuss the factors influencing their testing.

Ans. The material made from punched sheets that are drawn to align the polymer molecules is known as geogrids. They are characterised by large opening size.

With the increasingly wide-spread use of polymer grids in long-life civil engineering structures it is appropriate that the manner of their testing be understood properly. Compared to metals polymeric materials have large ranges of deformation, modulus and tensile strength. All the polymeric materials and hence geosynthetics behave linearly at low levels of strain but become non-linear at high strain levels.

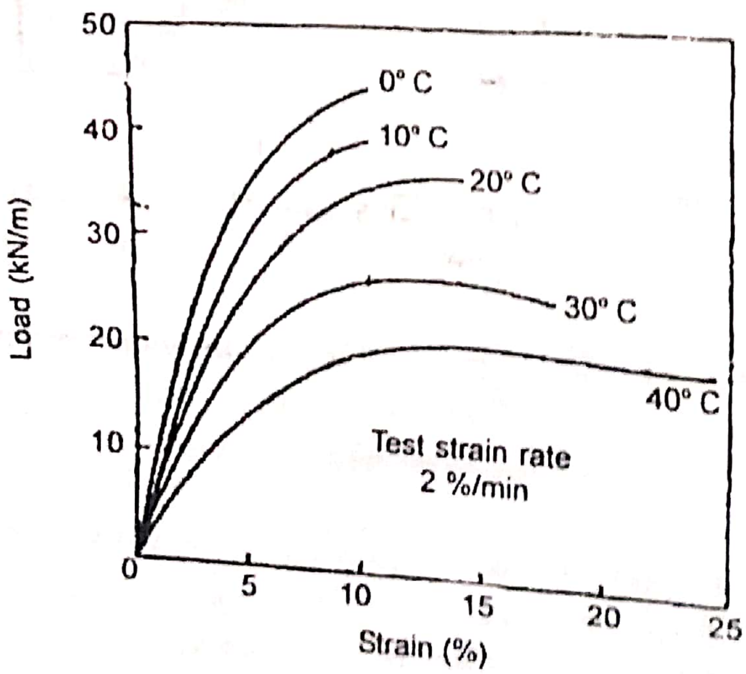
To understand their behaviour rationally studies have to be conducted on their mechanical properties as well as durability. Studies are also required to be conducted "insoile" condition to obtain the interaction parameters.

Factors influencing testing of geogrids : All polymeric and hence also geosynthetic products are known to be visco-elastic and their properties are directly related to the environmental factors. This means that their strain performance is dependent on the ambient temperature, humidity, the level of load, the rate at which the load is applied and the duration of application of load. It is, therefore, important that common test conditions be used while comparing different products.

Humidity and Temperature are two factors which shall be fixed for all tests and shall be mentioned with each test result.

Humidity : Both BS 1051 : 1972 (3) and ASTM : D 1776 specify the relative humidity of atmosphere of testing to be standard to 65 ± 5% for almost all the tests.

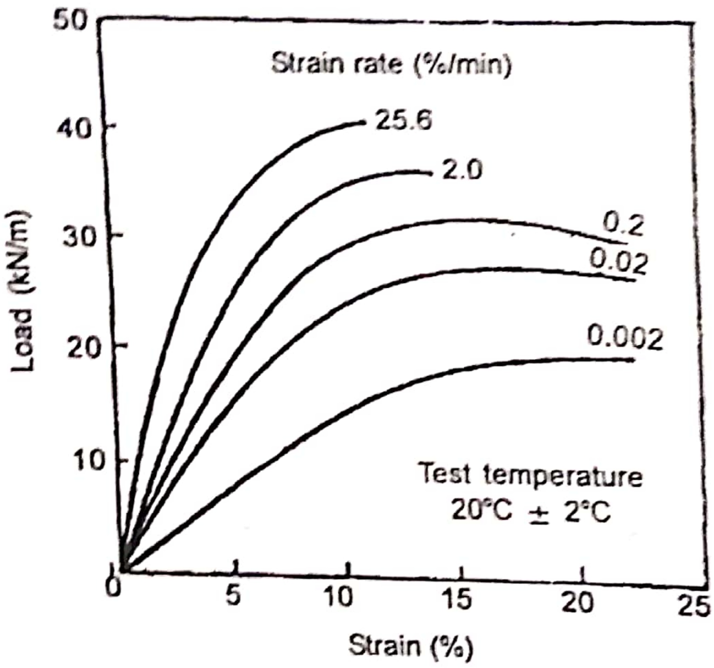
Temperature : Fig shows the influence of temperature on polymeric based product.



It may be seen that as the ambient temperature decreases the stiffness (i.e., modulus) and the peak load of polymer based product increases. Thus it is imperative that a standard test temperature need to be adopted for conducting all the tests.

BS 1051 : 1972 (3) specifies the standard temperature of the testing as 20 ± 2°C while ASTM : D 1776 specifies it as 21 ± 2°C. As there is not much variation, any specification can be chosen and mentioned with test results.

Strain Rate : In all the polymeric products the stiffness and peak load increases with rate of loading. Fig shows the influence of strain on polymeric based products. It can be observed that in all the cases an increase in load causes an increase in strain. Under a constant load the strain rate gradually increases with time.



Due to this, BS 6909 Part I. specifies that the strain rate adopted should lie between 7% and 13% per minute depending upon the initial gauge length of the specimen.

Q.9. Explain the process of sampling for measurement of properties of geotextiles.

Ans. Sampling : It is an method used for callecting sample to measure the properties.

Selection of test Specimens : From the laboratory sample, specimens are taken at random, for the measurement of tensile properties from different portion across the width, and those from different portions along the length of the sample for testing in machine and cross-machine direction respectively. Unless otherwise agreed, specimens are not taken nearer than 100mm from the selvedge or edge of the sample.

Number of Specimens : At least five test specimens in both the machine direction and the cross-machine direction are required to be tested.

Where it is necessary to determine the results within a given confidence interval of mean the number of test specimens may be determined from BS 2846: Part 2. ASTM D 4595 specifies that, when there is a reliable estimate of υ, the required number of specimens may be calculated using

$$n = (t.\ \upsilon/A)^2$$

Where,

n = Number of specimens (rounded upward to a whole number).

υ = Reliable estimate of the coefficient of variation of individual observations on similar materials in the user's laboratory under conditions of single-operator precision %

t = The value of Student's 't' for one-sides limits a 95% probability level. and the degrees of freedom associated with the estimate of υ, and

A = 5.0% of the average, the value of the allowable variation.

Twenty single ribbed specimens are selected at random ten for testing in the longitudinal direction, ten for testing in the transverse direction 50mm wide and 100mm long samples are taken in case of Netlon CE 121.

BS6906 : Part 1 describes the method for the determination of tensile properties geogrids using a wide strap but the test specimen dimensions may need to be altered to ensure that there are "not less than five complete tensile elements within the specimen width and at least one row of nodes or cross members. The specimens should be at least 200 mm wide and sufficiently long to ensure a gauge length of least 100 mm measured to within ± 3 mm

Q.10. Discuss physical and mechanical properties of geogrids?

[K.U.K. 2013]

Ans. Physical properties :

1. Mass Per Unit Area : As per ASTM : D 1010-64 a specimen measuring 1 ± 0.005 m should be weighed on a calibrated balance to the nearest 0.1% of its weight in grams. It is usually reported, in gm/m^2 to three significant figures.

To test these materials a full width sample 1.5m long is selected at random from batch and trimmed to a whole sample number of ribs. The average length of the sample is determined from measurements taken along the edges and the center of the sample. The sample is then weighed and the mass per square metre is estimated. Some typical values for Netlon and Tensar geogrids are presented in *Table below* :

Types of Geogrid	CE 131	CE 121	SS1	SS2	SR2	AR1	GS1	GM1
Mass per Unit Area (kg/m²)	0.66	0.73	0.2	0.345	0.93	0.24	0.18	0.32

Mechanical properties Important mechanical properties of geogrids are

1. Tensile strength
2. Creep
3. Characteristics strength

Q.11. Describe tensile strength characteristics of geotextiles.

Ans. These tests are conducted to obtain stress-strain characteristics and failure load of a geogrid. Two types of tests are generally conducted, viz., 'Quality control' tests and 'Index' tests.

The Quality control tests are used to monitor the variability in strength of the product. They are rapid tests that are specifically used by the Company's Quality Control Department to enable a high frequency of sampling during manufacture. The strength tests are carried out on a tensile testing machine to BS 1610 under controlled conditions and at a fixed strain rate.

The Index test conditions are selected to provide a means by which the properties of all soil reinforcing materials could be compared under standard rate of strain test condition. These tests are more relevant for the field applications because these tests are carried out on specimens whose widths are greater than their lengths and also they are carried out at much smaller strain rates compatible with the soil tests.

For conducting the Index tensile strength test it is required to hold the geogrids between the clamps. For this it is necessary to cement the geogrid specimen between metal strips with the help of a binder before their placement in the clamps. In order to ensure that the metal strips are perfectly parallel to one another special jig plates have been designed and fabricated.

In this the geogrids are placed between the metal strips coated with Araldite and cured for 24 hours under a dead load of 20 kg. This has been found to provide proper bond between the strip and the geogrids.

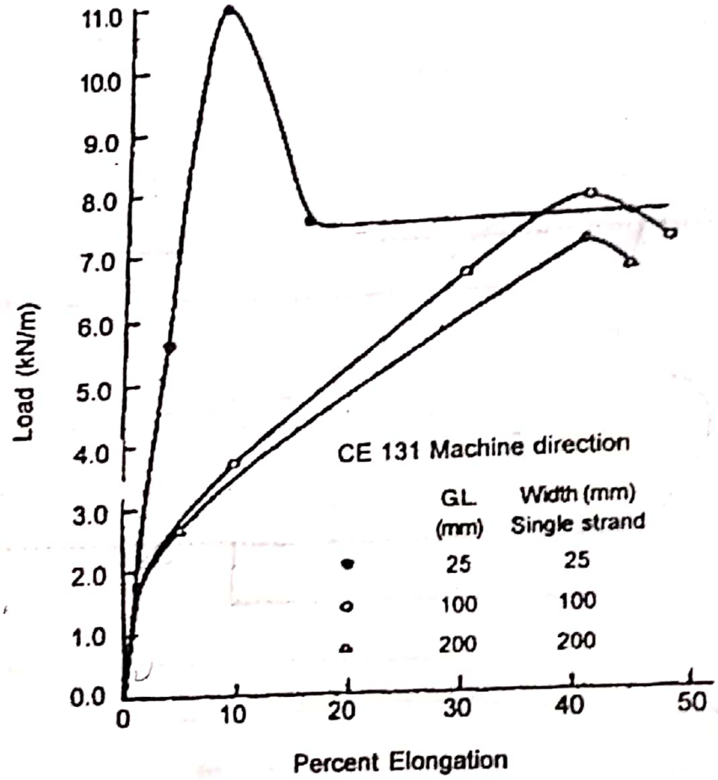
Special end clamps have been designed to hold the specimens prepared as described above. In fig these are shown in position in INSTRON 1195, at IIT Delhi.

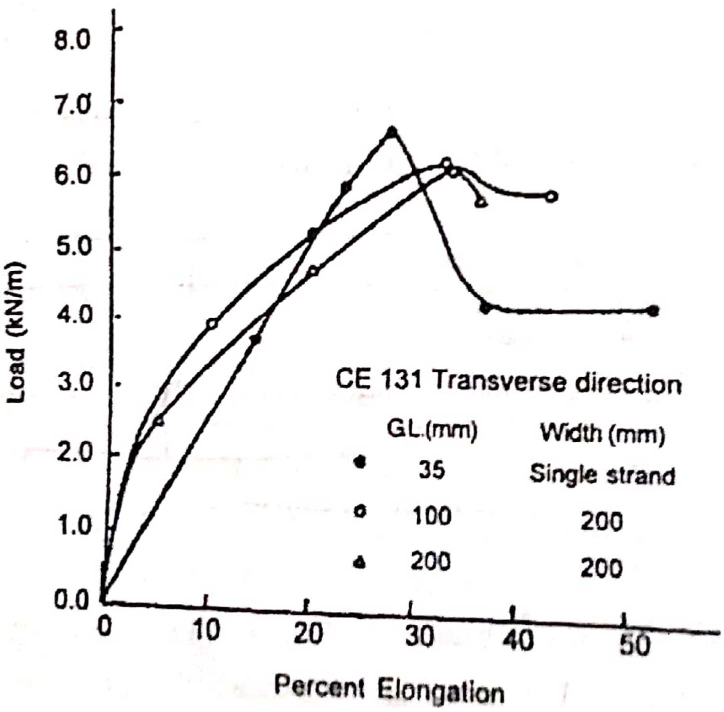
Tensar has specified special kind of clamps for carrying out tests on uniaxial samples as shown in Figure. For biaxial grids clamping is achieved by initially casting anchors around the upper and lower ribs using a low melting point alloy, and placing the specimen into the clamps prior to testing.

The geogrids tested were.

Netlon CE 121, having normal mesh aperture size 8 × 8 mm and a thickness of 3.3*mm* (Venkatappa RAO, et.al., 1989).

Netlong CE 131. having normal mesh aperture size 27 × 27 mm and a thickness of 5.8mm.





Figures illustrate typical load elongation curves for the machine and cross-machine direction for Netlon CE 131 geogrid.

Q.12. Describe creep characteristics of geotextiles.

Ans. All polymer products exhibit time dependent load-extension behavior, *i.e.*, they creep under the application of a constant load. In some Soil reinforcement applications, creep problems may need special consideration. In the soil reinforcement has to sustain the design loads for a very long periods (some times even upto 120 years) then creep may become limiting design factor.

The loads the soil reinforcement carries can be classified as

Case (*i*) Temporary

Case (*ii*) Slow, decreasing with time

Case (*iii*) Steady and permanent and

Case (*iv*) A steady permanent component together with a potential cyclic component at an unknown future date.

Some examples of applications corresponding to the above categories are

(*i*) Steep access embankment forming part of the temporary works forming.

(*ii*) Foundation support for a permanent embankment over soft deposits.

(*iii*) A permanent retaining wall or steep embankments.

(*iv*) A permanent retaining structure in an area of seismic activity.

- In case (*i*) creep is very unlikely to be problem
- In case (*ii*) the need for soil reinforcement decreases with time as the underlying soil deposits consolidate and increases in strength. Creep therefore needs to be kept within acceptable units only during this period.
- In case (*iii*) and (*iv*) the soil reinforcement must sustain the static design load through out the life of the structure.
- For case (*iv*) in addition to the above, the problem of the reinforcement ability to sustain cyclic loading after a period of ageing, possibly upto 120 years, needs to be assessed.

Creep behaviour is a function of several product factors including polymer composition, orientation, geometry and load conditions. Creep behaviour should be quantified by sustained load tests on the specific product durations of ten thousand hours (1.14 years) or longer.

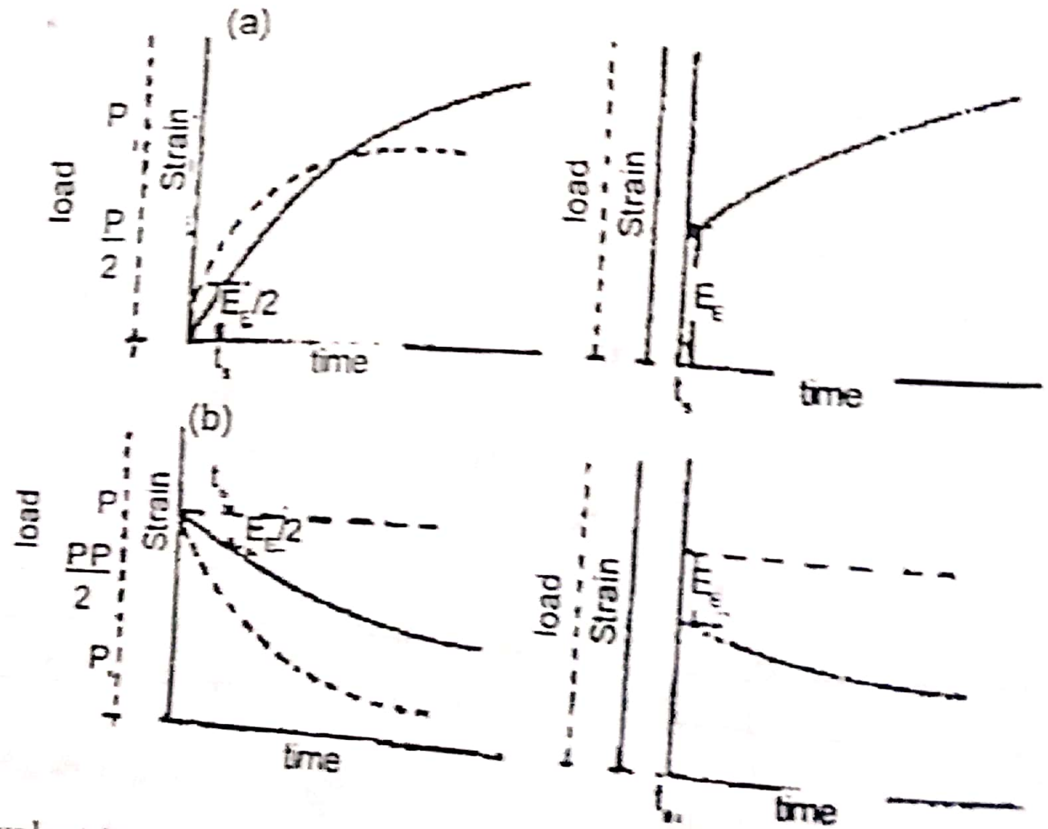
With adequate knowledge of polymers resistance to ageing, these creep results can be extrapolated for design life of 100 (+) years.

The creep test for long term design strength must incorporate a specimen clamping rig that includes 'through the junction' load transfer in order to characterize creep for the total grid structure as opposed to creep for the strands or rib alone.

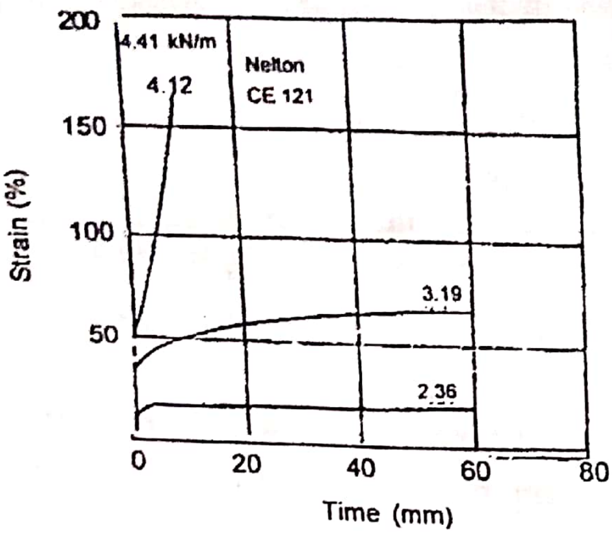
To determine the load-time, load-strain properties of Tensar geogrids, rapid loading creep tests are performed. In each test the load is applied smoothly in less than 5 second, either by direct dead load or through an adjustable 5 to 1 lever arm system.

The loads are maintained for the duration of the test at +1% of full load. The deformation of the test specimen is measured electronically over the initial rapidly varying part of the test using two LCDTs (with a data logger) but thereafter measurements are made by mechanical dial gauges.

The load-strain-time behaviour of geogrids at any temperature (T°C) comprises both elastic and plastic instantaneous strains and linear and non-linear time-dependent creep strains. In order to assess these various components of the total strain it is, however, necessary to perform a correction to the initial part of the rapid loading creep test data to establish an equivalent instantaneous loading strain-time curve. Fig shows instantaneous creep data correction for loading and unloading.



An equivalent instantaneous strain time curve is obtained as shown in fig.



Q.13. What are the major functions that geotextile serve? Discuss. *[K.U.K. 2011]*

Ans. Major applications of geotextiles are

(*i*) Bearing capacity improvement

(*ii*) Temporary roads and yards

(*iii*) Permanent roads repair of permanent roads

(*iv*) Railway tracks

(*v*) Embankments in soft ground

(*vi*) Drainage applications

(*vii*) Retaining walls, and

(*viii*) Erosion control

Most of these applications are particularly suitable to the geological feature prevailing in many parts of India, Bangladesh, South-East Asia, China and Japan. Vast areas of alluvial and marine deposits in these regions contain soft clay of high compressibility and low shear strength. They give rise to problems of bearing capacity and settlement even under small superimposed loads.

Geosynthetics have been used extensively in recent years in various construction works all over the world. These materials are highly resistant to biological and chemical degradation and have sufficient tensile strength and permeability for direct ground treatment applications. Geotextiles made out of natural fibres, *e.g.* jute geotextiles, have got high permeability but they are bio-degradable and possess less tensile strength in yet to be promoted as widely as geosynthetics.

Q.14. What are principal degrading agencies, their sources and effects process?

Ans. Various degrading agencies,, their sources and effects are tabulated as below :

	Agency	Source	Effect	Accelerated-ageing Procedure/Variables
1.	Stress Pressure	Installation/in use	Rupture, creep	Tensile, grab, penetration, and creep tests/temperature, relative humidity
2.	Wind	Installation	Removal of	
3.	Water	Installation/in use	Volatiles Removal of additives and plasticisers	Leading tests/temperature
4.	Solvents/Hydrocarbons	Installation: Diesel Mineral oils Hot bitumen In use : Bitumen	Removal of additives, awelling and embrittlement	Solvent-exposure tests/ temperature
5.	Biological	Installationlin use : Birds, animals, in seets	Localised damage	
6.	Chemical :			
(*i*)	Heat	Installation :	Chain scission	Hot-air/nitrogen oven
		Hot bitumen		exposure
	(+ oxygen)	In use : ambient environment temperature	and oxidation; loss in tensile properties	typically 90 – 150°C; oxygen absorption; thermal analysis (DTA, DSC; TGA)
(*ii*)	Light (+ oxygen)	Installation : UV exposure	Chain scission and oxidation : loss in tensile properties	Xenon-are exposure/temperature, relative humidity
(*iii*)	Weather	Storagel/(installation)	Combined effects of heat, light, wind, and water	Programmed exposure to Xenon arc in light and dark water-spray cycles
(*iv*)	Water (pH)	In use hydrolyais in acid, netural soils and alkaline soils.	Chain scission; loss in tensile properties	Hot-water and steam exposures; Acid and alkali exposures/

	Agency	Source	Effect	Accelerated-ageing Procedure/Variables
				temperature concentrations
(*v*)	General chemicals	In use : exposure to natural soils and waste deposits	General degradation of polymer structure	Exposure to identified salts, waste chemicals and pollutants/ Temperature, concentration
(*vi*)	Micro-organisms	In use : bacterial and fungal attack in soils	Hydrolytic and oxidative polymer-chain degradation; loss in tensile properties	Incubated soil tests/temperature, pH
(*vii*)	Radiation	In use : Containment of low-level radioactive waste	Chain scission and cross-linking; loss in tensile properties	Exposure to defined doses of *a, b, y* and ex-radiation/chemical environment

UNIT 3 : EROSION CONTROL AND BEARING CAPACITY IMPROVEMENT WITH GEOGRIDS

Q.1. Define wind erosion. What are the factors influencing transporation of soil?

Ans. Wind erosion : The movement of soil particles caused by wind, disturbs the soil surface and leads to erosion resulting from depletion of the particles, that cement the large particles and hold the soil surface together, and is known as-wind erosion.

Erodible lands lacks the following three properties :

(i) Cohesiveness (loose and dry soil).

(ii) Protective cover (Smooth and bare ground) and

(iii) Shelter from wind (large wind exposed areas).

The traffic, improper land use, faulty cultivation desertification, and absence of vegetation cover etc. speed up the process of soil movements creating erosion to soil surface.

Factors Influencing wind erosion : Transportation of soil by wind takes place by three processes namely:–

(i) Saltation,

(ii) Surface Creep

(iii) Suspension

Which always occur simultaneously and appear more like the motion of elastic balls on impact. Saltation, which involves bouncing and Jumping motion of soil grains, takes place within few inches of ground. Saltation grains, which are largely in the range of 0.05 to 0.5 mm, by force of Impact can move individual grains, upto 200 times of their own weight. Saltation is largely responsible for Surface Creeps involving slow movement of soil surface particles, having 0.5 to 1 mm diameters under impact of grains and also leads to suspension which is wind transportation of very small particles of size 0.1mm dislodged from surface by saltation grains. Dust is considered to be the largest contaminant in arid areas. Occasionally more than 25,000 tons of dust may be suspended per cubic km of air.

Wind causing erosion has direct relevance to speed, direction, turbulence and distance from ground level because of frictional drag. When wind velocity at ground level and turbulence exceeds threshold velocity based on particle size it affects the soil movement. Above 3 to 4 kmph, all the winds are turbulent. Velocities over 12 to 15 kmph at 150 mm above ground level are the threshold velocities for grain size of 0.1 to 0.15mm.

Q.2. Define rain water erosion. Discuss various factors influencing rain water erosion.

Ans. Water erosion : Soil erosion is a phenomenon of transportation of particles by exogenous wind or water action. The erosion phenomenon starts as soon as the first particle detached from the rest of the soil gets carried away due to impact of splash and velocity of water. From this moment on, the flow is concentrated and its volume and rate facilitating carriage of subsequent particles. This results in disorders which develops from small rivulet of rill to the 'gully' and ultimately to 'erosion ditches widening and deepening in the process. All of these are chain disorders which would impair a slope stability very dangerously, If not arrested at the beginning.

Factors influencing rain water erosion : Erosiveness of rainwater describe the potential of the water flow for detaching the initial particle and initiating the phenomenon. It depends on the energy dissipation of splash and can be assessed as duration/intensity of rainfall.

Erodability of soil is described as the susceptibility of a given soil to erosion under given erosive action. This is guided by the nature of soil (clay content), particle size distribution and soil condition like saturation, density, permeability, plasticity etc.

Exogenous factors modulating erosive action encompass factors like physical features e.g. top graph and gradient of slope, presence of catch berms and vegetation growth potential etc.

Q.3.Explain various erosion control measures.

Ans. For construction engineers, occasionally shallow slopes like road/railway embankments, slopes of reservoirs, dam etc., pose the serious problems of slip owing to use of locally available material, provision of erosion control measure and/or often inadequate workmanship accelerates the problem.

Special construction measures other than vegetation growth on slope, most conventionally applied include compaction of slope and provision of revetment, protection such as using stone or bricks; impervious drainage ditches, relief wells and drains or by placement of fascines, mulch, nibbles, catch berms etc. These are designed to breakup energy in the flowing of water and prevent migration of particles by reducing the threshold velocity of erosion. Various erosion control measures are

1. Vegetation growth for erosion control
2. Reinforced vegetation
3. Geogrids.

1. Vegetation growth for erosion control : The joint action of trees grass and other plant species for protection of soil from water/wind erosion have been recognised from times immemorial. The above ground-biomass of the grass provides adequate canopy interception to the falling rain drops and save the soil from splash erosion while the mass of litter and stolons, act as speed breaker for the running water on the slope and collect soil particles to percolate more water and slope for recharging the soil profile for better vegetation yield.

2. Reinforced vegetation : Forced vegetation regeneration and a forestation programme for enhancement of slope stability is a proven method that is practised very widely. Normally the vegetation growth on a slope depends upon several factors like retention of soil moisture, slope angle, constituent soil particle size, velocity of surface runoff, type of soil cover etc. For various shallow slopes like those of a cliff face, vegetation growth may not always be sufficient due to inadequate or washed out soil cover and absence of root reinforcing system. In all such slopes, non biodegradable geogrids or geomeshes provide an unique root reinforcement to induce vegetation, by holding and conserving soil cover reducing velocity of flow and conserving soil particles.

3. Geogrids of geomeshes : Geogrids or geomeshes are flexible extruded polymer meshes of high tensile strength made by special process. In its open mesh formation it has integrally formed joints or fused joints giving it dimensional stability and stiffness. Its secant modulus is very high compared to other geosynthetics.

In India geogrids are made of high density polyethylene or polypropyene and are nonbiodegradable and antitoxic. They are also ultra voilet ray protected. These are used for earth reinforcement applications. In case of reinforced vegetation growth, it is laid in vegetation root matrix.

Q.4. What are advantage and disadvantage of using geogrid for soil reinforcement with respect to strength, elongation etc.? ***[K.U.K. 2011/12]***

Ans. Shallow eroding slopes can be caused by excessive surface run off, washing soil particles out and depositing them at the base of the slope. Geogrids with aperture 15mm to 55 mm are used extensively to prevent the mass migration of soil particles. Initially the grid breaks down the flow of water with its profile by providing numerous small check dams and hold the structure of soil in place by reducing the velocity of flow. When sowed with vegetative plants like grass or shrubs, the three-dimensional profile of the net reinforced soil cake provides erosion protection to these young plants. Once vegetation is established, the grid acts as a structural matrix for the rootmat with interwined roots in net and creates an extremely strong flexible skin to the slope. The retardation of surface water flow by using polymer reinforcement like Geogrids and its effect is reported to have a 33% increase of factor of safety for a 10m high cut slope in clay laid in 1:1 when covered with vegetation having root density of 5000 kg/ha. The effect of reinforcement provided by plastic fibre in compacted samples by direct shear testing vary directly with root density. By providing fibrous reinforcement, 2.5 fold increase in shear strength may be achieved for most soils with root area ratios less than 2%.

Geogrids contribution to related velocity of flow can be understood from the following plane slipping stability analysis where the value of Factor of Safety 'F' is expressed by equation

$$F = F_i + \frac{R_t}{L.e.\gamma \sin\beta}$$

where β is the angle of slope with horizontal

F_i is the factor of safety for soil element of thickness

R_t is the force of retention measured for geogrid strength in kN/m.

Y is the unit Wt. of soil

$$F_i = \frac{\tan\phi.\cos\beta(e.\gamma - e_w.\gamma_w) + C'}{e.\gamma \sin\beta}$$

where,

e_w is height of water perpendicular to the slope and

ϕ C' are strength parameters of soil

When $C' = 0$, $e_w = 0$ (on initiation)

$$F_i = \frac{\tan\phi}{\tan.\beta}$$

This shows that for a soil of weak binding nature, F = 27, C = O Without geogrid as retention, equilibrium is not reached for a slope in excess of 50% gradient For a slope length of 12m and fill soil of $1.8t/m^3$ the general stability, can be enhanced for a steeper slope upto 67% gradient, with $R_t < 4$ kN/m strength. In other words for the same slope with geogrids, a 33% enhancement of F.O.S., against erosion can be achieved straight away without any vegetation growth as additional support.

Q.5. Explain the process of erosion control with geogrids? *[K.U.K. 2011]*

Ans. With provision of polymer geogrid for root reinforcement, extremely high density of grass growth (4500 – 5500 kg/na) can be achieved. Geogrid reinforced slop protection has been sown the world over as providing erosion protection equivalent to 250 mm thick revetment and is treated as an attractive cost effective solution.

Geogrid root reinforcement on slope compares foavourably cost wise with conventional 'pitching'. Because of extreme high density grass growth with geogrid (4000-5000 kg/ha) there cannot be any comparison with normal turning (1500 kg/ha)ordinary turfing thus to provide erosion control on repetitive change in Climates prolonged drought in particular. Use of polymer geogird provides a permanent protection as it is not biodegradable and noncorrosive, inert product when compared with such similar root reinforcing concept using natural fibres/coir etc. It compares extremely fabourably, because of its long life and almost unfailing success rate for reinforced vegetation growth year after year. Normally, fibres sometimes used for such application invariably biodegrade within one or two seasons. With increasingly erratic weather conditions successful vegetation and its maintenance depends on Chance rain fall etc and hence longer life of 'reinforcing material is definitely essential for permanent vegetation protection apart from using the mesh as reducer of threshold velocity of erosion. Even, after degradation of grass due to chance drought the root requires reinforcing material in loose silty or sandy soils and only a polymer geogrid can provide such solutions.

Q.6. Describe pull out test to find internal friction between soil and reinforcement. *[K.U.K. 2012]*

Ans. The pull-out test models the friction developed when geogrid embedded in soil is pulled out. For this a geogrid is placed in the horizontal plane between the two halves of shear box filled with soil the force required to pull out the geogrid can be obtained which will give the pull out stress. By determining the pull out stresses one can obtain the angle of interface friction for pull out.

The pull-out resistance is only used to establish required embedment length. It does not provide an indication of allowable design loads. The rate of pull-out testing ((1 mm/min) is slow relative to most tensile strength test for quality control, but very rapid with respect to creep testing for long term design strength. So pull-out test results do not account for creep behaviour which is critical to establishing limit on design strength.

The majority of grid pull-out resistance comes from a passive resistance or soil bearing against the grids. Transverse members and skin friction perhaps accounts for only 10 to 40% depending upon the percentage opening area. The bearing members of the grid develop passive resistance within the soil and transfers the stress to the tensile member through the junction between the two.

A large number of factors that affect the interface shear resistance raise major difficulties in interpreting and comparing the results of pull observed that although, the results show some similarities for the same reinforcement embedded in similar soils there is a wide scatter in the experimental results. These differences in the pull-out test results can be partially caused by variation in sample compaction testing procedure pullout devices and associated boundary effects.

Q.7. How geogrids are placed along an earthen slopes to protect them from erosion?

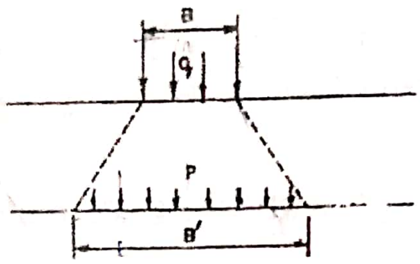
Ans. The installation of extruded polymer geogrid mesh, is simple and is done with steel or wooden pins/pegs to hold the light weight net in position for a period of 2/3 months prior to laying, the site should be dressed and all pre-existing gullies and concavities are to be filled up. Net should be laid with surface contact at all points to enable the fullest protection.

While dressing and preparing side slopes, a hand held vibro-compactor should be used for ensuring compaction of loose fill. Alternatively a typical mechanical rammer compactor should be used if the vibro-type is not available. Alongwith watering and implantation of grass seed/turf the roots establish quickly if sowed just prior to rainy season. It takes about 4/6 weak to establish root and it interwines with the net aperture. For induced vegetation programmes to avoid exposure on surface from possible damage due to local reasons. It is always advisable to lay about 5 to 7.5 cm. of top soil to cover the net wherever possible in which the grass may be sown. However, sowing of seed may be done without top soil also equally effectively. At the top of net position and at top of the slope, the grid is anchored in trenches to provide additional protection against incidental damage-slip or slide.

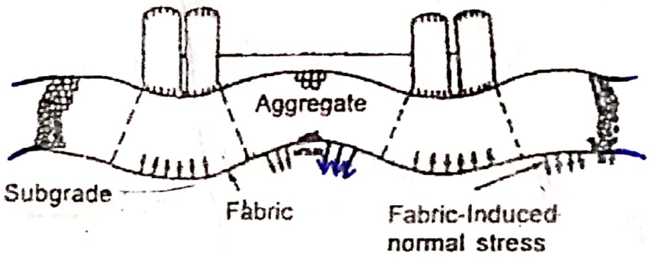
The vegetation grows automatically with or without sowing. However, to facilitate immediate grass growth, sowing is recommended. Horizontal creeping variety of grass is much advocated in Indian condition (local varities are known as "Doob", "Bhabar", "Napier" etc.) which have proved effective. Availability of root moisture is important for initial grass growth and hence sprinkling of water or use of natural rain fall is highly recommended. In case of sandy soil, it has been shown by researches conducted abroad that 12% to 18% air filled voids within sand is required for optimum root growth. A mixture of various turf seeds are often recommended for optimum yield and conservation.

Q.8. Discuss the use of geotextiles to improve bearing capacity of soil.

Ans. Geotextiles may be used for bearing capacity improvement in foundations and temporary and permanent roads and yards in soft soil. It is to be realised that introducing geotextiles in the virgin soil is not a practical proposition although such intrusion may theoretically improve the strength of the soil over all and thus effect a bearing capacity improvement. We have, therefore, to restrict our consideration to load bearing fills which are placed on the soft virgin soil to disperse the load on a soft subgrade, as shown in fig.

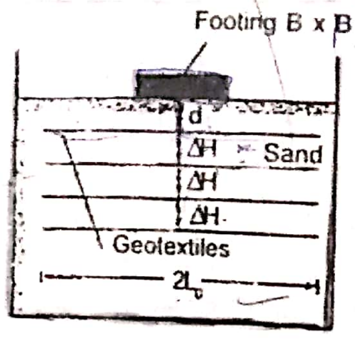


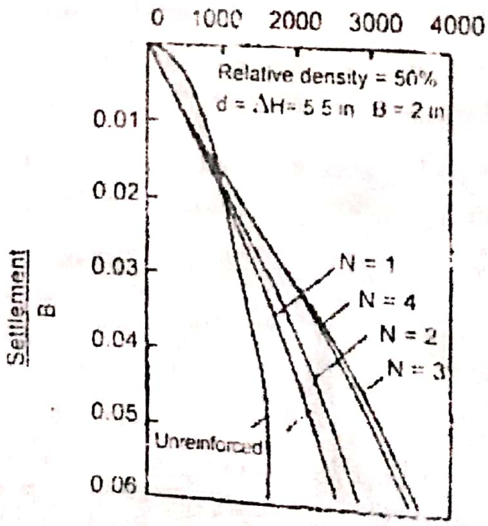
Introducing fabrics in the fill would, obviously improve the rigidity of the fill and allow a more effective load dispersion as shown in fig.



The tensile strength of the geotextile plays a dominant role in restraining the lateral movement of the fill and allows an improved load distribution on the subgrade.

The problem is best understood by considering a footing on lose sand reinforced by single or multiple layers of geotextile reinforcement, as shown in fig.





Several parameters that become important here are

d = Depth of fabric below the footing

ΔH = Vertical spacing between fabrics.

L_0 = Lateral extent of the fabric on either side footing

N = Number of fabrics

As the footing is loaded there is a settlement of the soil with an associated material flow on either side. Relative movement between the soil and the reinforcement induces interface shear stress and tension develops in the fabric. The mobilized tension depends on both vertical normal stiffness and the coefficient of friction at the soil-reinforcement interface. There are three possible modes of failure.

1. **Shear failure** in the soil below the footing and above the first layer of reinforcement. This kind of failure is possible when the top most layer of reinforcement is sufficiently below the footing (d > B). Here the fabrics do not provide any effective reinforcement with regard to shear failure in the soil above.
2. **Reinforcement pullout occurs,** if the fabrics are placed at relatively shallow depth below the footing with inadequate anchorage.
3. **Reinforcement tension failure** occurs when reinforcements are long and functional pull-out is more than the tensile strength of the fabric.

Q.9. Explain box shear test for friction coefficient determination.

Ans. Friction Coefficient : In spite of the wide usage reinforced soil technique there are number of aspects which require detailed investigation such that this technique becomes more rational. The most fundamentally important the most critical and the least understood aspect of reinforced soil in any form is the mechanisms of sliding shear resistance between soil backfill and the tensile reinforcing element and the factors affecting the same.

Box shear test is used to determine coefficient of friction between the soil backfill and reinforcing element. Initially the box tests were conducted to find out the skin friction between soil and construction materials to be used in conventional structures like piles. With the invention of reinforced soil technique the method attracted many research workers to conduct the tests to be used in the design of reinforced soil structure.

In the fast version of the tests the upper half portion of the box can be filled with the soil, lower half with some other material wrapped with the reinforcement material such that the reinforcement shall form the shear surface. In the second version of tests both the upper and lower halves of the box can be filled with the soil placing the reinforcement in between. The tests can be conducted by placing the reinforcement at different angles from the horizontal. It is possible to study the effect of various parameters viz. reinforcement material, types of soils at different densities and moisture content and deformation rates. It could be a strain or stress controlled tests.

The basic principle of the tests in all the cases of box shear test is same *i.e.* the soil is sheared over the reinforcement at different normal loads and the interfacial friction angle ϕu is evaluated.

The box shear apparatus could be modified to conduct the slide and pull-out tests. In slide tests, the reinforcement is placed between two halves filled with the soil and compacted at the required density. The friction coefficient from pull-out tests is shown to have decreased with both increase in normal stress and reinforcement widths.

Q.10. Discuss various factors influencing erosion.

Ans. Soil erosion is a phenomenon of transporting the soil particles due to exogenous wind or water action, Although glacial, marine water, river water, wind and surface runoff (rain water) are different soil erosion catalyst but of these wind and rain water pose severe soil erosion problems leading to environmental hazard.

Soil erosion, due to surface run off, is influenced by the following factors :

1. **Rain water :** Energy dissipation on splash and duration/intensity of rain water.
2. **Soil properties :** Nature of soil (clay content), particle size distribution and soil condition like saturation, compactness, permeability, cohesion etc.
3. **Exogenous factors :** Topography and gradient of slope, presence of catch berms, vegetation growth potential etc.

Unlike wind, water, because of its relatively higher viscosity and density, has ability to carry soil particles at a much lower velocity than it requires to pick them up. Therefore, once lifted into suspension, soil particle will travel considerable distance before being deposited. In addition water has inherent ability to move semi round soil aggregates by rolling them. This rolling velocity is considerable lower velocity than lifting or carrying velocity.

Q.11. Discuss materials for temporary protection of soil.

Ans. Following are the materials used for temporary protection of soil.

1. Natural Fiber Netting
2. Extruded Polymer Geonets

1. **Natural Fiber Netting :** Wherever practicable and where vegetation need elementary support for growth, nets made of woven jute or coir fibers may be used for erosion protection of slopes not steeper than 1:2 gradient. The slope more than

7m at a stretch should not be treated with biodegradable fibers. These nets biodegrade in a period of 1 or 2 seasons at the most and upon degradation provide nutrient to the root mat. However, presence of available root moisture adequately always, shall find used of such netting for erosion control. These nets are used only initially to hold rootmat in soil during germination. Due to degradation with time the reduction of erodability of soil as a check barrier is not feasible with natural erosion nets. Therefore it is not suitable for occasional drought prone slopes or the same with occasional flooding with water current up to 3 m/sec.

2. Extruded Polymer Geonets : These nets are manufactured using special continuous extrusion to allow uniform quality control and should conform to ISI mark or ISO 9002 requirements of certification. They shall be adequate for atleast 5 years of life (defined as retaining 75% of its original strength after 5 years) by providing 2.5% finely divided carbon black to prevent degradation against continuous exposure to UV radiation. Since the Geonets have much lower secant modulus and high elongation in comparison to Geogrids and high creep characteristics they shall only be used in long slopes up to 10 m length or slope usually not steeper than 1:2 gradent.

Q.12. What are the materials used for permanent protection from soil erosion.

Ans. Following are the materials used for permanent protection of soil.

1. Geogrids
2. 3-Dimensional Geomats
3. Preformed Polymer Geowebs

1. Geogrids : The Geogrids for erosion control are high tensile symmertical geomertic square or rectangular 2-dimensional form of synthetic polymer mesh made from high density Polythylene or Polypropylene by a single continuous process of extrusion and bi-directional orientation of polymer in the ratio not less than 1:6, to form a grid like mesh formation with integral joints to provide high secant modulus, dimension stability and interlocking properties.

The grid should be always placed in the direction of its component stand, therefore shall be either rectangular, square or elliptical in shape, which are dimensionally stable. They shall have integral joints and shall not be of woven, tied or knotted variety. They shall also exhibit high secant modulus of minimum 150 KN/m at 5% strain, which shall be the basis of design of plane slipping stability in the slope protection.

2. 3-Dimensional Geomats : Polypropylene Geomats are combination net formed matting used to stabilize highly erodible or steep slopes, Made in 3-dimentional thick-mesh like matting fabric. They are made from orientated Geogrid and Geonets composites and are pinned or pegged on to the slope. Geomats are usually filled with seed sustaining topsoil and hydroseeded. In case hydroseeding is not feasible manual seeding of horizontal creeping variety grass is to be sown with at least 7 days of periodic watering on to the matting for vegetation to take root. Top soil of double the thickness of matting at least shall be provided to allow soil cake formation.

3. Preformed Polymer Geowebs or Cellular Webform cells : These webform containment cells come in jointed lay flat condition and opens in to a honeycomb like container cellular structure with web height of 75mm to 150mm. The pitch of the cell diaphragm shall be between 100mm to 500mm depending on the design as shown in drawing. In very steep slope exceeding 1:1 gradient, particularly in watefront, placement of top-soil in these cells shall enable retention of the soil veneer. The diaphragm shall enable the soil from slipage.

The water fronts should be designed with Geocell webs for revetment protection and selection of suitable infill stones shall be done as per special provision mentioned in the drawing. Multiple layers of Geocells placed to increase the thickness of revetment shall be anchored using holding pins to the subgrade slope. The Geocells do not require any framed bracing for protection against plane slipping stability like conventional stone pitching of long slopes.

Q.13. Write a note on construction of geotextile reinforced unpaved roads.

Ans. Geotextile reinforced unpaved roads : Most construction sites require access to the site through weak surface deposits. Temporary roads are built by spreading a carpet of coarse granular material (stone metal) over the soft subgrade to act as a load dispersing medium which keeps (stone metal) over the soft subgrade to act as a load dispersing medium which keeps the stresses on subgrade low. However extensive rutting occurs on the surface due to the granular fill getting lost into the soft subgrade under continuous pressure from the moving vehicles. This gives rise to perennial maintenance problem. The problem can be minimised, if not overcome, by providing a suitable layer of geotextile at the interface of the granular fill and the subgrade. This not only keeps the thickness of the granular fill getting lost into the soft subgrade under continuous pressure from the moving vehicles. This gives rise to perennial maintenance problem.

The problem can be minimised, if not overcome, by providing a suitable layer of geotextile at the interface of the granular fill and the subgrade. This not only keeps the thickness of the granular fill intact but the tensile strength of geotextile allows reduction in thickness of the stone filling as well.

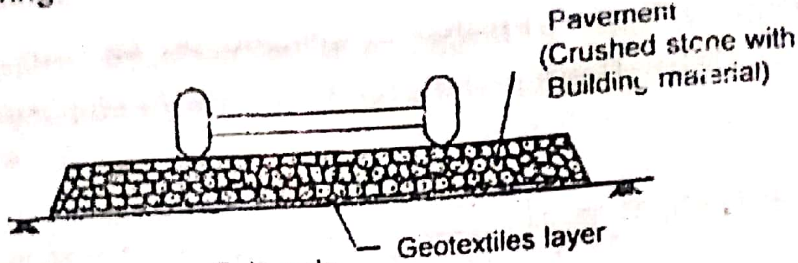


Fig. Geotextile in temporary road

Giraud and Noiray were the first to propose a design procedure for reinforced unpaved road. Use of geotextile at fill - subgrade interface was shown to reduce the thickness of fill over soft subgrade. It was assumed that the road would be rutted to a certain depth and accordingly, the geotexile at the fill-subgrade interface would be distorted. As the geotextile would be curved concave upwards below the loaded area there would be the difference between the applied pressure above and below the geotextile resulting in enhanced bearing capacity of the unpaved road. The method provided the practicing engineer with a method of determing the estimation thickness of aggregate with geotextile at the subgrade-aggregate interface.

The aggregate layer was assumed to provide pyramidal distribution of pressure over an area of L × B. Thus for a vertical load *i.e.*, P_o the pressure at the base of the aggregate, would be

$$P_o = \frac{P}{2(B+2h_o \tan\alpha_o)(L+2h\tan\alpha)} + \gamma h_o \text{ ——— without geotexile}$$

$$P = \frac{P}{2(B+2h\tan\alpha)(L+2h\tan\alpha)} + \gamma h \text{ ——— with geotextile}$$

where γ = Unit weight of aggregate

P_o, P = pressure at the base of aggregate layer

h_o, h = Thickness of aggregate layer

α_o, α = Load distribution angle

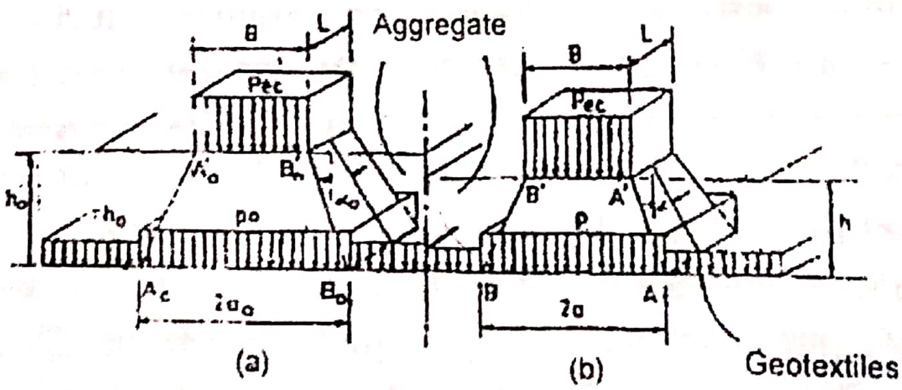


Fig : Load dispersion through aggregate layer :
(*a*) Without geotextile (*b*) With Geotextile

Classical two-dimensional approach was considered estimation of limiting pressure. Giroud and Noiray suggested elastic bearing capacity for unpaved roads without geotextile, *i.e.*,

$$(\pi + 2)\, Cu = \frac{P}{2(B + 2h\tan\alpha)(L + 2h\tan\alpha)} \quad \frac{K_\varepsilon}{a\sqrt{1 + \left(\frac{a}{2s}\right)^2}}$$

Where K = modulus of geotextile fabric

e = strain in the geotextile fabric

a = half dispersed width below fill

s = settlement under wheel (rut depth)

The difference in aggregate thickness fabric $h_0 - h = \Delta h$ gives the savings in aggregate thickness due to the presence of fabric.

Q.14. What do you understand by the following

1. Thermomechanical analysis (TMA)

2. Dynamic mechanical analysis (DMA)

Ans. 1. Thermomechanical Analysis : TMA measures a linear dimension as a function of temperature. Basically a low friction quartz probe rests on the sample and its displacement is measured by a LVDT. The uses of TMA include measuring the linear coefficient of thermal expansion (LCTE) glass transitions and softening points. Three modes of operations are commonly used : *i.e.* expansion, penetration and shear flow with the use of parallel polished plates.

An expansion experiment uses a 2.5 or 6.0 mm diameter robe loaded with small weights (<10 g).

Penetration experiments involve a 1.0mm diameter probe and weights upto 50g. The polished plates used in a shear flow experiments are 9.5mm in diameter and the sample is placed between them and loaded with 20-50 g weights. The selection of probe type and load is a way to vary the force on the sample during an experiment.

2. Dynamic Mechanical Analysis : DMA is the most complex thermal technique but also the most sensitive. By measuring the mechanical response of a material as it is deformed under a periodic stress, the viscoelastic properties of the material can be obtained. Viscoelasticity refers to the property found in polymers which allows them to behave both like an elastic spring and a viscous fluid.

The DMA measures both the dynamic storage modulus (E') and the dynamic loss modulus (E"). These properties give information about the amount of energy stored and the amount lost as heat. In practical terms, the storage modulus is a measure of stiffness and the loss modulus is used to see how materials can dissipate energy and to measure glass transitions and softening points.

Although DMA is not as yet widely used for applications such as the characterization of geosynthetics its outstanding sensitivity and precision of measurements makes it an ideal technique for this use.

UNIT 4. CASE STUDIES-MEDACREEK IRRIGATION SCHEME, KAPARPER CANAL LINING, DHAROIDAM, HIRAN-II DAM

Q.1. Write short note on Meda creek Irrigation scheme? ***[K.U.K. 2011/13]***

Ans. Meda creek is located on western Saurashtra coast between Porbandar and Dawarka. It remains as a sea inlet creek during winter when fresh water does not come from the inland areas and turns into lagoon during summer when the spit extends northwards and closes the mouth. Only during monsoon it turns into an estuary having interplay of saline and fresh water. Five reasonal rivers-Varta, Sorti, Sindhi, Falku and Kanan meet the Arabian sea through this creek. Except three months of monsoon, all of these rivers remain dry.

In 1973 AD, as a part of mission against salinity ingress, a barrage was constructed at about 3 km from the shore to stop the ingress of sea water further inside. The barrage also helps the storage of fresh water runoff during the monsoon period which is later on used for the irrigation purpose.

This has resulted into large scale changes in the land forms of the area.

Medha creek irrigation scheme is a part of project to prevent salinity ingress in the coastal area of Saurashtra near Porbandar. The dam is situated across a tidal creek very near to the Arabian Sea. Downside slope is subjected to tidal currents and waves. It was therefore, necessary to protect fine-grained soil of downstream slope with thick pitching. Application of Geotextile was therefore made to protect the base soil by providing a layer of Geotextile between embankment soil and filter below pitching.

The total coastal length of Gujarat is 1600 km out of which 300 km length is covered by Valsad, Navsari, Surat and Bharuch districts of South Gujarat having its western boundary as Arabian Sea. (From Unargam of Valsad District to Gulf of Khambhat in Bharuch District). These four districts are experiencing coastal erosion. For coastal Erosion Protection, Danti-Moti Danti C.W.P.R.S., Pune have studied the problem on wave flume study and furnished the design section of anti sea erosion rubble mound wall with armor layer of polypropylene rope gabions. Round head protection wall will have to be constructed at the ends of the sea wall. It will protect the ends of constructed sea wall from the wave action erosion, tide currents etc. during the high tide and ebb.

The Gujrat coastline is marked by several small and large estuaries and creeks. In most of the estuaries tidal flow has stopped because of construction of barrage. Meda creek is one such estuary where a barrage has been constructed.

The study has shown as increase in marine influence over the fresh water as indicated by water quality, sediment texture and foraminferal species of composition in the Meda creek area. There is dilution of salinity and enrichment of nutrients as observed in monsoon samples which may not be directly related to inflow from the catchments. Although the Meda creek has large catchment, factors like low rainfall, several dam schemes and the barrage constructed immediate upstream of the creek hinders entrance of freshwater into the downstream. However, no study is available for the similar parameters before the construction of barrage and so, direct comparison is not possible. The recovery of charophytes and brackish water from the subsurface samples and presence of mangrove swamps much beyond the place of barrage indicate a relatively less saline condition and regular freshwater discharge through the Meda creek during pre-barrage period.

Domination of clay, except near the creek mouth, indicates sheltered nature of the basin. Mouth bar formed due to long shore currents forms a barrier, and absorbs and stops the wave energy from entering into the creek. Presence of montmorillonite clay is obvious as it is a weathering product of the basalts which are commonly found in the catchment area and being dominant rock types of the Saurashtra plateau. Kaolinite and illite and the weathered products of acidic igneous rock. However, there is no major acidic igneous rock or mica rich rock in the catchment of the creek. Although a part of the Barda Hills consists of granophyres but it, remains out of Meda catchment Illite and kaolinite is dominantly present as suspension load in the coastal waters and continental shelf region of the Arabian Sea. Therefore, it can be inferred that these clay minerals are contributed by the sea. On comparing the Meda creek bottom sediments with those of the upstream of barrage, it is found that the sediments of this part are coarser and its clay mineralogy is also indicative of fluvial dominance.

Profoundness of saline waters and low energy conditions in the Meda creek is reflected in the foraminferal species composition. However, changes in microenvironments within the creek, indicated by water quality and distribution. Ammonia sp. is the dominant species throughout the creek. This must be due to adaptation of the genus to the large variation of salintity. It also prefers fine sediments and a shallow depth and so, finds this creek as a favourable habitat.

The significance of the variation in the foraminiferal morphogroups has been identified by various workers. The sediment turbulence caused by factors like currents, depths, morphology of shares and monsoon controls the distribution of morphogroups of foraminifera. The angular asymmetrical forms indicate less energy whereas, rounded symmetrical forms indicate turbulent environment. Rounded symmetrical forms are most abundant at Station 5 which is right on the mouth of the creek, indicating higher energy conditions and influence of the sea waves.

The same forms show five times higher occurrence at Station 1 close to the fishermen jetty of Miyani which is frequently traversed by boats. This stations lies on the lagoon terrace where breaking of waves might be leading to an increase in turbulence. These facts further substantiate the relationship between rounded symmetrical forms and the higher energy conditions. There is also a positive correlation between clay content and angular asymmetrical forms. The stations marked by higher percentage of angular asymmetrical forms also have a ,lower abundance of reworked foraminifera.

Species diversity indicates overall impact of the creek environment on the foraminifera. Species diversity is lowest at Station 1 and 2 and maximum at Station 3 followed by the Station 4. There could be several reasons for this but, the most prominent are lower salinity due to fresh water discharge. Sensitive species were either absent or in fewer numbers at Station 1. In contrast, study Ammonia beccarii is dominant contributing 60% of the total population. From the above discussion it can be concluded that the geo-environment of the Meda creek is influenced by upstream barrage reducing fresh water income that has resulted in to an increased influence of the sea in terms of water quality, clay mineralogy and presence of foraminifera and mouth bar which absorbs all the wave energy, making it as sheltered lagoon.

As far as foraminiferal diversity and morphogroups are concerned, none of the parameters singularly control the distribution of foraminifers, and so the foraminifera as a proxy of environment point towards more than one geo-ecological variable.

Q.2. Describe Kaparper canal lining with geosyntehtics.

[K.U.K. 2011/13]

Ans. Kaparper a water resource project is located at village kakarper, subdivision mandvi in distt Surat of Gujrat. Dam has been built in the year 1954 with Basalt masonary with maximum height of 15.48 m above the lowest point of foundation and 7315 on length at the top on Tapi river with catchment area of 59904 km^2. Total area at full reservoir level is 442 km^2. Two canals with length 64km *(Right)* and 64 km left have been laid with discharge capacity of 72.23 m^3 (right) and

85.63m³/sec left. The gross commanded area is 100220 (right) and 247000 hectare (left) culturable commanded area is 58745 hectare (right) and 145335 hectare (left).

To avoid soil boiling and slurry flow phenomenal action on the toe side of earth dam, as an initial measure a loading berm over the affected strip and a series of relief wells planned to control seepage. Indigenous nonwoven needle punched fabric was laid between ground and loading berms. Its was extended to relif wells replacing thick annular filter. Canals are lined with IPCL-LDPE agro film.

Geotextile reinforced road on Expansive clay in Gujarat at command area of Ukai-Kakrapar in south Gujarat has been built. Imported woven, non-woven and needle fleeced geotextiles are used. Formation width of road 10m and width of Geotextile roll was 4.5m, and therefore, it was laid in three passes with an overlap of 25cm-10 cm layer of sand over. Geotextile was laid to act as cushion while compacting the sub-base before laying hand broken metal of 63mm-40mm size and compacted by 4 ton roller. Compaction was possible after sand below aggregate is made wet. After 2nd layer of aggregate 8 ton roller was used and finally finished surface of 20mm semi dense carpet of WBM. As far as distress is concerned the performance of non-woven was better. Lining of Bardoli and Surat Branch Canal for seepage control under flowing water condition was essential to prevent excessive seepage. Due to lining of canal under full water condition, the other methods of canal lining are prudent and therefore concept of ULOMAT technique was conceived by UK cementation and that made indigenous by MSU and implemented at site by GERI and Cemindia. Double layered fabric separated by spacer yarns in filled with sand cement grout is employed for the purpose. Stitched fabric is placed across the canal & spread out evenly with aid of pontoon infilling of Grout was carried from both upstream & downstream side of anchor portion of fabric at edges of banks of canal. Performance studies carried out in the subsequent year have revealed that it is satisfactory from the point of view of seepage loss. Rugosity coefficient study was carried out after and before the lining that was almost same as in other methods of lining.

Q.3. Write a note on Dharoidam.

Ans. Dharoidam is located on River Sabamati vill. Dharoi dist Mehsana in Gujrat. Maximum height above lowest point of foundation is 45.87 m and length at the top of dam is 1207m. Area of catchment is 5475 km². Construction work was started in 1971 which got completed in 1978. Length of canal at left bank is 29.52 km and on left bank is 44km with discharge capacity of 5m³/sec and 20m³/sec respectively. Gross commanded area is 81754 hectare (Left) and 15670 hectare (Right). Culturable commanded area is 70454 ha. (Right) and 12145 ha. (left). No of village covered is 236, Spillway length is 219 m which employs roller bucket energy dissipater with maximum discharge of 21652 m^3/sec.

Subsequent to reservoir filling soil boiling and slurry flow phenomenal act were observed on the down stream side beyond the toe of the earth dam. As initial measure, a loading berm over the affected strip and a series of relief w were planned to control seepage. Indigenous non-woven needle punched fabric laid between ground and loading berm. Its use was extended to relief well replac thick annular filter. Canals are lined with IPCL-LDPE agro films to avoid seepage

Q.4. Write short on Hiran-II Dam.

Ans. Hiran-II Dam is situated in district Junagarh (Gujrat) on river Hi near veravals. It is an earthen dam built for the purpose of irrigation. Importa data regarding the dam is given below :

Location : Vill Umrethi, Distt, Junagarh

Purpose : Irrigation

River : Hiran

Area of catchment : 349km^2

Maximum height above the lowest point of foundation : 15.70m

Length at the top of dam : 3050m

Area of full reservoir : 8km^2

Length of canal : 16.50 km

Capacity : 3.5 m^3/sec

Gross Cammanded area : 1583.6ha.

Cultruable commanded area : 9552.8ha.

Spillway length : 189m

Energy dissipator : Roller bucket

Maximum discharge : 3559 m^3/sec

Number of villages under commanded : 21

Ground level near toe of envelope and in river channel near left end of spillwa had difference of 9m. Washing away of the envelope material as well as soil fro sleep slope has aggravated the problem of upstream slope erosion. The dam seat resting on millionite limestone. Remedial measures were planned to seal the caviti of limestone by grouting to stabilize steep slope.

The protection of slope against washing is achieved by free draini Polypropylene nonwoven geotextile overlain by gabon 2m × 1me × 0.5m size create slope of 2:1.