No. RW/34014/87-NH.Stds.-Part A *Dated the 11th November, 1987*

To

All Chief Engineers of States/Union Territories dealing with road.

Subject : Geotextiles and their use in road construction

Geotextiles are one of the few materials, which in the recent years have created quite a stir in the Civil Engineering community in view of the immense and diverse possibilities of their use in Civil Engineering works. Although the history of the use of modern synthetic fibres in Civil Engineering, specially in the constrcution of highways, is relatively short it has generated quite an amount of interest and enthusiasm amongst engineers and its growth in application during the last few years has been quite spectacular raising hopes for many more uses.

2. Synthetic fibres usually made from polymer materials and used as an aid for geotechnical constructions are commonly known as geotextiles.

3. A variety of geotextiles are at present being manufacuted in India. In general terms their availability is therefore not much of a problem. Ease and speed of transport and application in construction are additional points in their favour. For the actual man in the field, there are a large number of small and large problems and situations where it comes handy and convenient for use. In order to make the general highway engineer aware about the material, its functions, tests and applications a brief note has been prepared in the Ministry which is enclosed. Although the note is not comprehensive and allows only a glimpse on the subject, still it is felt that it may provide one with a basic idea about the material and its uses and may in the long run encourage the use of this material and reap the benefit from it.

4. It is requested that your considered views on the subject and the extent of its applicability in highway constructions in your State may be forwarded to the Ministry. The Ministry will be glad to consider proposals for its use in National Highway constructions where the situations specifically demand the application of such a material.

A NOTE ON GEOTEXTILES AND THEIR USES IN ROAD CONSTRUCTION

Geotextiles are the largest group of geo-synthetics. (The other members of geo-synthetic group which are geogrids, geomembranes and geocomposites are not being discussed in this note). They are textiles in traditional sense but used in geotechnical works and consist of synthetic fibres rather than natural fibres like cotton, wool, or silk. Primarily the materials are product of polymer industry. The fibres are made into a flexible and porous fabric called geotextiles by machines or they are matted together in a random non-woven-manner. Sometimes they are also knit.

1.1 Geotextiles have very large area of application in road construction because of Five discrete functions which shall be discussed subsequently in the note. The functions are separation, reinforcement, filtration, drainage and action as moisture barriers (when impregnated).

2. Manufacture

2.1 The fibres used in geotextiles are made from following materials listed in order of decreasing use.

(i) Polypropylene

(ii) Polyester

(iii) Polyamide

(iv) Polyethylene

(v) other polymers and glass

2.2 The vast majority of the fibres are hydrocarbons. Hence the petrochemicals industries are heavily involved in the geotextile market.

2.3 The basic polymers are made into fibres by melting them and forcing them through a spinneret. The resulting fibre filaments are then solidified by wet or dry or melt process. Mostly melt process is used. In this process hardening is done by cooling and stretching is done either simultaneously subsequently. The process results in monofliament yarn. The monofilament can be combined to make multifilament yarn. Sometimes from a large rope like bundle containing thousands of filaments short staples of 1 to 4 inch length are produced, which are twisted or spun into longer yarn. Another process involves cutting continuous sheets of polymer into fibres. This ribbon like fibre is referred as slit film fibre. Thus the basic fibres which make the fabric (geotextile) are as follows:

(i) Monofilament

(ii) Multifilament

(iii) Staple

(iv) Staple Yarn

(v) Slit film

2.4 The fibre mentioned are used in manufacturing fabric. The basic choices are woven, non-woven and knit fabrics. The woven fabrics are made on conventional textile weaving machinery. In the non-woven process the fibres can be bonded to make the fabric by different methods. This process can be spun bonded process here first a continuous web of filament is formed, desired orientation of fibres is achieved and then the fabric is bonded by chemical, mechanical or thermal treatment. In another process called melt bonded process the fibres are melt bonded at filament or fibre cross over points. Acrylic resin is used in resin bonding process. Needle punch process achieves mechanical bonding of individual fibres by needle punching in web trapped between plates. The knit fabrics are seldom used in geotextiles. The general choices are between

(i) woven geotextiles and

(ii) non-woven geotextiles

2.5 The basic fibre material (indicated in para 2.1) the type of fibre (para 2.3) and the process used in ferming fabric (para 2.4) control the properties of geotextiles.

3. **Properties and Standard Test**

3.1 **Test for Physical Properties**

3.1.1 The specific gravity of the materials from which the fibres are made are mostly as follows:

Poly propylene	0.91
Polyester	1.22 to 1.38
Nylon	1.05-1.14
Polyethylene	0.92 to 0.95
Polyvinyl alcohol	1.26 to 1.32
Glass	2.04

3.1.2 **Mass per Unit area (also referred as weight per Unit area)**

Can be determined as per ASTM Test D 1910. Generally it ranges between 135 to 680 g/m^2

3.1.3 ASTM D1777 can be referred for determining the thickness of geotextiles. The pressure 0.02 kg/cm^2 is adopted for determining the thickness. Normally the thickness ranges from 10 to 300 mils (1 mil= 0.001 inch).

3.2 **Test for Mechancial Properties**

3.2.1 Compressibility of fabric is determined from its thickness at varying applied normal pressure. The slope of initial portion of the curve is compressibility modulus. The more a fabric compresses under applied load the less amount of water will flow through it and its utility to drain out water will reduce.

3.2.2 Tensile strength is the most important geotextile property from stress (load per unit width) versus strain (deformation divided by original specimen width) curve four values are obtained.

(a) maximum tensile strength (referred to as fabric strength)

(b) strain at failure (often given as maximum elongation)

(c) Toughness (area under stress strain curve)

(d) modulus or stiffness (initial slope)

Regarding the specimen size (length, width, aspect ratio i.e length to width ratio) on which the tensile test is conducted the investigation is continuing. ASTM D 1682 and D 751 allow for a number of variations. The currently popular specimen sizes are narrow strip of 1 or 2" width (2.5 cm 5 cm), grab where the specimen is 4" (10 cm) wide and tension is applied through clamp in 1" (2.5 cm) width, wide width of about 8" (20 cm) and very wide width of 20" (50 cm).

3.2.3 Fatigue strength is defined as the ability of the fabrics to withstand repetitive loading before undergoing failure. The tensile test specimen is stressed longitudinally at a constant rate to predetermined length and then back to zero load.

3.2.4 Mullen burst test which is covered by ASTM D774 is the most common burst test. In this an inflatable rubber membrane is used to distort the fabric into the shape of a hemisphere. Bursting of the fabric occurs when no further deformation is possible.

3.2.5 During the installation often the geotextiles are subjected to tearing stresses. In the tongue tear test ASTM D751, a 3 in by 5 in (7.5×12.5 cm) fabric specimen with 3 in (7.5 cm) initiation cut is subjected to tensile forces to make the fabric tear along initiation cut. Element of tear test covered in ASTM D1424 is another tear test applicable for only woven fabric. Here the premade cut is continued by a falling pendulum apparatus and the work done in tearing the specimen is divided by twice the length of the tear.

3.2.6 To assess the impact resistance of fabric the fabric can be clamped in an empty CBR mould and the amount of cone penetration (falling freely from a standard height) can be noted. In another test the impacting cone is attached to the pendulum arm. The impact pendulum devices for other materials such as metal are covered under ASTM A370 and ASTM D256.

3.2.7 ASTM D3787 described a puncture test. The property is imporant to assess geotextile resistance to objects such as rocks, or sticks under quasi static condition.

3.2.8 In many design problems such as reinforced soil, it is necessary to know the soil to fabric friction behaviour. This can be determined by direct shear apparatus with fabric firmly placed in one half of the device and soil in the other half. Adhesion of geotextile to soil and friction angle can be determined by the devices.

3.2.9 Within the reinforced function the geotextiles are often required to provide anchorage. The pullout resistance needed for anchorage, can be measured by sandwiching the fabric between soil on each side in a shear box and pulling it under different normal loads.

3.3. Test for Hydraulic Properties

3.3.1 The following hydraulic properties are relevant

(i) Porosity 'n' $= 1 - \frac{m}{pt}$

Where m = massper unit area
p = overall fabric density
t = fabric thickness

(ii) Per cent open area

(iii) Apparent opening size AOS or equivalent opening EOS (This refers to standard sieve size which has opening equivalent in size to the opening in fabric)

(iv) Permittivity which is ratio of co-efficient of permeability normal to the fabric and its thickness.

(v) Transmissivity which is the product of permeability coefficient in the direction of the fabric and its thickness

3.3.2 The porosity is rarely measured directly. Instead the equation in para 3.3.1 (i) is used. For measuring percentage open area height can be projected through the fabric on to a large poster size card board and magnified open space measured by planimeter. AOS or EOS is determined by sieving glass beads of known size (corresponding to standard sieve size) through the fabric. The permeability test can be conducted in similar manner as for soils for determining permittivity. For determining transmissivity, a radial flow (flow through the fabric in its plane) device has been prescribed.

3.3.3 When the geotextile is used as silt curtain silt retention test involving flow of turbid water through the fabric can be conducted. When the geotextiles is impregnated with bitumen, elastomers etc. to reduce its permeability such as in case of encapsulated soil *water vapur transmission* characteristics can be determined.

3.4 Tests for Endurance Properties

3.4.1 The polymers are sometimes thought to be creep sensitive materials. *Creep tests* when fabric of wide (20 cm) variety can be stressed by means of hanging weight can be conducted at different percentage of tensile strength and rate of deformation recorded (usually deformation between 10 hours and 100 hours is taken to calculate creep rate).

3.4.2 ASTM D1175 covers several procedures for determination of abrasion resistance. results are reported in terms of per cent weight loss or strength retained under specified test and its particular condition.

3.4.3 Clogging of the geotextile can be tested by taking a specimen of geotextile, fixing it in test cyclinder, placing soil collected from site above it and allowing flow though it under constant head. At transition time of about 10 to 200 hours the soil fabric system will begin its field simulated behaviour. If the slope of response curve (flow ratio Vs time) becomes zero after transition time the fabric is compatible with soil. If slope is negative complete clogging could occur and geotextile tested is not suitable.

3.5 Environmental Properties

3.5.1 Under the environmental properties following can be studied :

(i) resistance to chemicals

(ii) resistance to temperature

(iii) resistance to light (ultraviolet) and weather

(iv) resistance to bacteria

(v) resistance to buried deterioration

3.5.2 For resistance to chemicals ASTM D543 and for resistance to temperature ASTM D793 and ASTM D746 which are related to plastics can be referred. Outdoor weathering of the plastic is covered under ASTM D1435. Generally geotextiles are susceptible to exposure of ultra violet light and such exposures cause rapid deterioration in strength. To reduce such exposure the fabric has to be treated or else it may have cover over it. Resistance to bacteria can be evaluated by keeping the fabric in a medium containing bacteria. Specific test standards for burial deterioration are not available.

4. Function

4.1 As indicatd in para 1.1 the functions of geotextiles are :

(i) separation

(ii) reinforcement

(iii) filtration

(iv) drainage

(v) moisture barrier (when impregnated)

4.2 Separation

When stone aggregates are placed on soil, the fines in the soil try to pump into stone voids or intrusion of stones into the subgrade occurs (Fig. 1a). A geotextile placd in between separates the two materials so that their performance improves (Fig. 1b). Geotextiles introduced between two dissimilar material can maintain the integrity of both the materials so that their functioning may remain intact or improve.

4.3 Reinforcement

Geotextile being a material with relatively better tensile strength properties can complement soil which is weak in tension. It can be used in reinforced soil structure to act as a vertical retaining wall or stabilise soil slopes. Membrane reinforcement occur when a vertical load is applied to a geotextile on a deformable soil.

Basically within the general function of geotextile reinforcement there are three different mechanisms (i) membranes type (ii) shear type and (iii) anchorage type.

4.4 Filtration

The function of filtration involves movement of water through the fabric but retaining the soil under or on upstream side of it. Both adequate permeability, requiring open fabric structure and soil retention, requiring tight fabric structure are needed simultaneously. The fabric should also not clog during its life time. Performance of filtration is a major function of geotextiles.

4.5 Drainage

Drainage in the geotextile can be defined as the equilibrium of fabric to soil system which allows for free water flow (but not soil loss) in the plane of fabric over an indefinitely long period of time. The characteristics to be looked for are transmissivity, soil retention and long term capability. Thick needled non-woven fabrics have considerable space to allow for water transmission.

4.6 Moisture Barrier

Moisture barrier function can be achieved by rendering the fabric relatively impermeable to both cross plane and in-plane flows. The permeability can be reduced by spraying bituminous, rubber bitumen or polymeric mixes. Quite possibly the permeability can be reduced to the permeability of soils in clay family.

4.7 Combined Function

Geotextiles often serve multiple or a combination of functions listed in para 4.1. For example geotextile at subgrade level can serve the function of separation, reinforcement and filtration at the same time.

5. Application

Geotextiles can be used.

(i) on subgrade below subbase or base of the road (Fig. 1)
(ii) between soft subsoil and road embankment (Fig. 6)
(iii) between foundation soil and retaining wall
(iv) behind the retaining wall or gabion (Fig. 5)
(v) below sand blanket at the base of embankment
(vi) under the pitching
(vii) between old and new asphaltic layers
(viii) to wrap the soil in encapsulated fabric system
(ix) to construct geotextile reinforced wall (Fig. 2)
(x) to stabilise slopes temporarily
(xi) to bridge over cracked or jointed rock
(xii) to hold graded filter mattresses
(xiii) to anchor facing panel in reinforced earth wall
(xiv) to prevent puncture of geomemrabes
(xv) inplace of granular soil filter
(xvi) around crushed stone surrounding underdrains (Fig. 7c)
(xvii) around perforated under-drain pipe (Fig. 7b)
(xviii) between backfill soil and gabion or retaining wall (Fig. 4)
(xix) around sand columns in sand drains
(xx) as a drainage blanket beneath a surcharge fill
(xxi) as an alternative to sand drain
(xxii) as a capillary break

The above list of uses is not an all-inclusive one and there can be many more areas of use of geotextiles. A few typical uses of geotextile are illustrated in Fig. 1 to 7.

6. Design Consideration

6.1 In designing the geotextile for separation of two dissimilar materials, it has to be ensured that the geotextile has necessary burst resistance, tensile strength, puncture (tear) resistance and impact resistance necessary for the function.

6.2 A geotextile placed on soft subgrade has some reinforcing effect which can reduce pavement thickness. Generally reinforcing effect is significant if CBR of subgrade is less than 3. Manufacturers have developed set of curves to arrive at pavement thickness when geotextile is used. Other design method can be based on theoretical analysis. Design can also be based on CBR obtained by laboratory testing, modelling the field situation with geotextile in the mould.

6.3 In geotextile-reinforced walls the external stability is checked by conventional methods just like a retaining wall. For checking internal stability allowable stress in the fabric (sometimes taken as one third of grab strength), geotextile to soil adhesion and friction angle are primarily needed. Required embedment length of fabric, overlap, vertical spacing are calculated.

6.4 One or more layers of geotextile can be placed in the embankment to improve its stability or reduce side slopes. Conventional limit equilibrium analysis can be carried out in such a case taking into account forces in the direction of fabric which may be taken as equivalent allowable geotextile tensile strength.

6.5 When geotextile is used behind retaining wall flow net can be drawn to claculate discharge and obtain required permitivity of fabric. Geotextile should have desirable AOS.

6.6 Similarly in underdrains once the discharge is known required permitivity can be obtained. AOS can be calculated from soil retention criteria, the idea being that geotextile shoulders allow desired discharge through but prevent movement of soil.

6.7 When flow occurs along the plane of the fabric required transmittivity can be calculated from required discharge.

6.8 In a geotextile placed under fill on soft saturated and compressible subsoil flow through the fabric occurs under pressure. Required transmittivity can be calculatd using the co-efficient of consolidation and co-efficient of permeability.

6.9 Geotextile can be used to prevent reflection crack in bituminous pavement overlap. If fabric effectiveness factor (ratio of design traffic number in reinforced case and unreinforced case) is known the modified design traffic number with fabric reinforcement can be calculated and Asphalt Institute curve applied to calculate overlay thickness.

Main reference used in preparation of the note

"Designing with geosynthetics"
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