Case Studies on the Usage of Geosynthetics in Earthen Dams and Embankments

Raju, N. Ramakrishna
Chief General Manager
e-mail: nrk.raju@nccltd.in
EDTD, Nagurjuna Construction Corporation Limited, Hyderabad, India

ABSTRACT

Geotextile is a permeable synthetic membrane designed for use with geotechnical materials as an integral part of a man made project structure or system. There are two basic categories of geotextiles – woven and non-woven. Woven geotextiles can generally categorize as slitfilm or filament. Woven geotextiles are made from either monofilaments or multifilaments of slitfilms. Non-woven geotextiles are manufactured from either staple fibers or continuous filaments. Geotextiles can serve several basic functions when used in soil (or) soil/geosynthetic systems. Geotextiles are commonly used to separate, filter, conduct planar flow and reinforce soil masses. Geotextile can prevent the downward movement of road base stone into subgrade and conversely the upward pumping of weak subgrade material into clean stone during dynamic loading. Here geotextile is serving a function of separation. Other important function of Geotextile is filtration where geotextiles permit free flow of water across the plane of it while restricting the passage of solid soil particles. Geotextiles also acts, as a tensile member, in a structural system that is weak in tensile strength and strong in compressive strength like soil. Geotextiles are also used as membrane in raw water reservoir to avoid loss of water by percolation. In this paper two case studies are discussed. In one case-study, use of geotextile for filtration and in other case-study use of geotextile as soil reinforcement. Sri Sathya Sai Trust has taken up work for rehabilitation of Telugu Ganga project, which supplies drinking water to Chennai. Polypropylene geotextiles are used as filter material below the riprap provided for protecting slope of earth dam against waves from reservoir water. Geotextiles are used as BASAL reinforcement in power project in Srilanka to improve short term shear strength of soft clay to carry grade fill and construction equipment loads.

1. INTRODUCTION

Geotextile is permeable geosynthetic comprised solely of textiles. Geotextiles are used with foundations, soil, rock, earth or any other related material as an integral part of human made project, structure or system.

The use of natural fabric in the construction industry probably occurred decades ago when some innovative individual with the idea of strengthening the material, decided to embed it within soil. The concept of embedding straw and branches in clay could be considered to fall within this category.

Geosynthetics, which comprise a variety of products, largely grouped under geotextiles, geogrids, geomembranes and geocomposites have been found to be of immense use in the many infrastructure projects (Koerner, 2004).

At present this paper will cover the two case studies for the following applications
(a) Geotextiles as a filter material for Drainage purpose – This is applied in the construction of Kandaleru earthen bund reservoir, Tamilanadu for the Rehabilitation of Telugu Ganga project.
(b) Geotextile as reinforcement to increase the short term shear strength parameters of soft clay soil to make a required platform for the Power Project in Srilanka.

2. GEOTEXTILE TYPES AND PROPERTIES

Main Types of Geotextiles
Materials
Geotextiles are made from polypropylene, polyester, polyethylene, polyamide (nylon), polyvinylidene chloride, and fiberglass (Koerner, 2004). Polypropylene and polyester are the most used material for the geotextiles.

Woven Geotextiles
In woven constructions, the warp yarns, which run parallel with the length of the geotextiles panel (machine direction), are interlaced with yarns called till or filling yarns, which run perpendicular to the length of the panel (cross direction). Woven construction produces geotextiles with high strengths and moduli in the warp and fill directions and low elongations at rupture. The modulus varies depending on the rate and direction in which the geotextile is loaded.

When woven geotextiles are pulled on a bias, the modulus decreases, although the ultimate breaking strength may increase. The construction can be varied so that the finished geotextile has equal or different strengths in the warp and fill directions. Woven construction produces geotextiles with a simple pore structure and narrow range of pore sizes or openings between fibers. Woven geotextiles are commonly plain woven. Woven geotextiles can be composed of monofilaments or multifilament yarns. Multifilament woven construction produces the highest strength and modulus of all the constructions but also highest cost. A monofilament variant is the slit-film or ribbon filament woven geotextile. The fibers are thin and flat and made by cutting sheets of plastic into narrow strips. This type of woven geotextile is relatively inexpensive and is used for separation, i.e. the prevention of intermixing of two materials such as aggregate and fine-grained soil.

Non-Woven Geotextiles
Non-woven geotextiles are formed by a process other than weaving or knitting, and they are generally thicker than woven products. These geotextiles may be made either from continuous filaments or from staple fibers. The fibers are generally oriented randomly within the plane of the geotextile but can be given preferential orientation. In the spun bonding process, filaments are extruded, and laid directly on moving belt to process described below.

(a) Needle punching: Bonding: Bonding by needle punching involves pushing many barbed needles through one or several layers of a fiber mat normal to the plane of the geotextile. The process causes the fibers to be mechanically entangled. The resulting geotextile has the appearance of a felt mat.

(b) Heat bonding: This is done by incorporating fibers of the same polymer type but having different melting points in the mat, or by using hetero-filaments, that is, fiber composed of one type of polymer on the inside and covered or sheathed with a polymer having a low melting point.

Applications
Considering constructional point of view application of these fabrics are using mostly for the following areas.
- Separation
- Reinforcement
- Drainage
- Erosion Control
- Forms
- Impermeable Fabrics.

Separation
Fabrics are used in the context of separation by keeping two dissimilar materials apart. There are many construction applications where this is important. The role for fabrics, of course, is to do this task more economically and/or better than other current methods. Typical application areas are as follows:
- Separation of zoned sections of dissimilar materials within an embankment, earth dam, or rock-fill dam.
- Separation of stone base from subgrade beneath airfield and high-way pavements, parking lots, secondary roads, sidewalks, and so on, that is, prevention of intrusion.
- Separation of rail road ballast from soil subgrade or of railroad ties from ballast, that is, prevention of intrusion.
- Separation of stone or other material that is placed on a temporary basis to be subsequently removed, for example, surcharge loads for soft soils or down stream berms for unstable slopes.
- Separation of frost-susceptible soils into two distinct layers, thereby breaking continuity of the capillary flow zone.

Reinforcement
Problems involving subgrade reinforcement appear to be particularly well suited for fabric utilization. Currently, most fabrics appear to be used in this type of application. The concept is theoretically sound since the fabric decreases the levels of stress in the foundation soil due to horizontal shear stresses mobilized by the vertical loads. This in turn places the fabric in tension (similar in action to a prestressing tendon in reinforced concrete), which spreads the load over a large area and thereby decreases its intensity. That is, the unit vertical stress is decreased. A decrease in stress means less likelihood of failure and/or less settlement. Typical examples are as follows:
- Building of temporary roads over marshes, swamps, peat soils, or compressible fine-grained soils.
- Building of parking lots or storage handling sites over similar poor soil conditions.
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- Building of facilities of almost any nature over permafrost, muskeg, and other soils in cold weather regions.
- All of the separation problem areas listed as above where the in-situ soil needs reinforcement. In these cases the fabric is acting both as a separator and reinforcement materials.
- Construction of fabric walls and reinforcement material.
- Construction of fabric walls and reinforcing selected zones.
- Reduction of the need for removing existing soil (of relatively poor characteristics) in marginal situations.
- Increase in the stability of embankments and dams.
- Containment of soils that would spread laterally if left un-reinforced.
- Reduction of crack reflection when using a new bituminous concrete overlay over a cracked, broken, or otherwise non-suitable existing pavement.

Drainage

This is perhaps the second largest area of current fabric utilization because the controlled permeability of the fabric can be put to good and economical use in many drainage situations. Major areas of application for fabrics in drainage situations are as follows:

- Prevention of migration of soil fines in a crushed stone or pipe under-drain system. This has the major effect of eliminating the need for an inverted filter consisting of various sized gravel and sand layers.
- Prevention of penetration and loss of coarse material of high permeability into the adjacent soil. When combined with the previous comment it is seen that the fabric is acting in two ways.
- Elimination of the need for all or some of the sand blanket layer used in surcharging soils with sand drains by providing an exit for the water. This might even have a siphoning effect on the system.
- Elimination of the need for all or some of a graded filter in earth dam construction in chimney drain and drainage gallery areas.
- Providing an interceptor system to block the flow path of water and guide it in another direction, for example, from horizontal flow into an under-drain system.
- Providing drainage behind temporary and permanent retaining walls.

Erosion Control

The use of fabrics in erosion control has seen numerous applications. In many cases the fabric acts both as a separator and a drainage layer, but when its primary function is to aid in erosion control it is placed in this separate category. Typical situations are the following:

- As shore and coastal beach protection, where the fabric acts as a mechanism to hold the soil in place while allowing for germination of vegetation and weed growth.
- As a boundary material beneath a stone layer, rip-rap or gabions in protecting slopes adjacent to flowing water or in tidal areas.
- As protection against erosion at water and sewer outfalls.
- As erosion control mattresses to protect slopes adjacent to flowing water or in tidal areas.
- As an artificial seaweed to allow for buildup of natural sediments and plant growth.
- As silt fencing to block migration of soil from fines being carried by water or by winds.

3. CASE STUDY – 1

Construction of Kandaleru Earthen Bund Reservoir, Chennai

![Fig. 1: A view of the Existing Kandaleru Dam](image)

Problem & Cause
Kandaleru reservoir earthen dam was eroded at chainage 7.50KM to 8.12KM due to high current forces from the reservoir. Slope stabilisation of existing Kandaleru Dam for a length of 500m Long. The Height of Earthen Dam is 45m.

Methodology Adopted
Laying the drainage layer – Using Polypropylene instead of conventional filter materials.

- Filling with Riprap of 450mm thick
- Tie the Riprap with gabions

Rectification Works
Removed all loose materials, boulders, vegetation etc., from the eroded surface and compacted with light compaction techniques and also made the vertical cut to 1:1 slope to join the actual profile at some locations.

Provided at trench of 1.0m wide and 0.5m deep (minimum) at 1.0 to 1.5m on upper side of the eroded portion to hold / anchoring the filter material. Also made similar trench at toe level of eroded portion for anchorage purpose.
Provided a thin sand bed of 100mm thick over the cleaned surface and laid the Polypropylene filter membrane on top of sand cushion. This filter membrane is anchored at trenches on both upper and toe level of the eroded portion with folding of filter membrane and by using crushed stones / riverian material.

Fig. 2: Laying of Geotextile Layer

Provided 150mm thick broken stone material with size varies from 20 to 80mm over filter membrane. Gabion is placed at toe level. Dumped riprap is provided over this crushed stone layer to match the slope of the regular reservoir with intermediate gabion walls as shown in below Fig 3. Figure 4 shows the application of geotextile as a filtration along with placement of gabions during construction.

Fig. 3: Rip Rap Tied with Gabions

Application: Geotextile as a Filtration

The required properties for Filtration area as follows:

1. Permanent Filter Function.
   - **Mechanical**: Apparent Opening size; Thickness.
   - **Hydraulic**: Geotextile Permeability; Long-term Performance: Chemical protection of water and soil; Chemical stability; Decay resistance.

2. Temporary Filter Function.
   - **Mechanical**: Apparent Opening Size (AOS); Thickness.
   - **Hydraulic**: Geotextile Permeability; Long-term Performance: -

The following are properties of geotextile used at the site.

- Apparent Opening size (AOS) = <0.7mm
- Permeability
  - For Soil = 0.000055 cm/Sec.
  - For Geotextile = 0.00055 cm/Sec.
- Permittivity
  - = <0.2 / Sec & > 0.55 /Sec.
- Flow condition
  - = Mild current.
- Maximum spacing of securing pins = 0.6m.
- Minimum overlap
  - = 0.3 to 0.45m.
- Grab strength
  - = 578.47 N
- Puncturing strength
  - = 177.99 N
- Trap tear
  - = 177.99 N
- Burst strength
  - = 1,446.9 kN/m²

4. CASE STUDY – 2

**BASAL Reinforcement in AES Kelantissa Project in Sri Lanka**

It is required to reclaim the site proposed power plant by earth filling, as it is situated in a low-lying area. The area is to be raised up to +2.25m above the existing ground level. Raising the land by earth filling may give rise to instability as the surficial layer consists of soft peat deposit (Fig. 5). Therefore, in order to improve short-term margin of safety, it is proposed to use a basal reinforcement in the form of geotextile. Status of site before filling is showing in Fig. 6.

Fig. 5: Top – Very Soft Clayey Soil
Basal reinforcement is used to provide the additional stability only; its role is to maintain equilibrium until consolidation can occur in the soft foundation soil. The foundation soil strengthens with time during consolidation and finally supports the grade filling loading without need for the reinforcement.

Reinforcement of embankment / filling on soft soil reduces construction material quantities, reduces land acquisition and reduces construction time. Where the basal reinforcement is used to provide stability and prevent differential settlements and localized moments, its role is to intercept and interrupt the localized shear deformations which can occur in the embankment / grade filling due to presence of void in the foundation soil.

**Design Methodology**

Design of basal reinforcement is carried out in limit state format as per BS: 8006 (1995). The following modes of failures are considered:

(a) Local stability of embankment / fill
(b) Rotational stability of embankment / fill
(c) Lateral sliding stability of embankment / fill.
(d) Foundation extrusion stability.
(e) Overall stability.

**Soil Data**

Bore log data furnished by the client suggest a general subsoil profile consisting of soft surficial deposit of peat overlying laterite in some areas and clayey sand in other areas. SPT N-values and laboratory test results show very lower shear strength for peat deposit, where as laterite and clayey sand exists in medium to stiff consistency.

**Fill Height**

Placement of earth fill over soft peat deposit, which exists at shallow depth, will cause consolidation. This consolidation, being dependent on soil parameter, will be different at different locations. As per soil report furnished by the client, the total settlements due to 1m fill at different locations are varying from 55mm to 160mm. The present level of ground +0.50m and considering extra fill height of 250mm and to archive final FGL as +2.25m the required fill height is 2.0m. Assuming linear variation of settlement of fill with load, the estimated settlements for 2.0m fill are varying from 240 to 320mm. Details are shown in Fig. 7.

![Typical fill section](image)

**Typical Earth Fill Section**

Earth fill on the soft peat deposit may give rise to problem of short-term stability. Therefore in order to improve short-term stability, 2 layers of geotextile of “PROPEX 6086” with drainage layer sandwiched in between were provided. A slope of 2H: 1V is considered at the edge of fill.

![Laying of Geotextile](image)

**Construction Procedure**

Removed all vegetation and uncontrolled fill to the required boundary lines and levels. A bed of 50mm thick sand placed over the prepared ground surface. Geotextile of “PROPEX 6086” with the following specifications was laid over sand bed.

**Specifications**

Product : PRPEX 6086
Thickness : 1.4mm

Tensile strength : 80 kN /m (warp and weft directions)

50 mm thick sand layer was laid over the geotextile and followed by drainage layer of 300mm thick with crushed stone / dust material size varying from 1mm to 28mm and compacted to 65% relative density. A layer of 50mm thick sand bed placed over the drainage layer and followed by the second layer of geotextile. Again placed a 50mm thick sand layer over the second geotextile layer (Fig. 9. The
actual laterite fill material was placed over the sand bed in layers of maximum 300mm thick and compacted to achieve 95% of Proctor density.

Fig. 9: Filling in Progress

Calculation of Tension in Geotextile
The stabilizing force provided by basal reinforcement by placing the geotextiles in tension. The maximum tensile force is calculated as greater of the below:

(a) The maximum tensile force needed to resist the rotational limit state.
(b) The sum of maximum tensile force needed to resist lateral sliding.
(c) Maximum tensile force needed to resist foundation extrusion.

The following analysis checks have been carried out for the embankment fill:
(a) Rotational Failure
(b) Lateral Sliding.

Rotational Failure
Slip circle analysis is carried out to locate the critical slip circle which gives maximum tension in the basal reinforcement. Basic equations are used as per BS: 8006-1995 clause 8.3.2.5.1. The purpose of basal reinforcement was provided only for short term stability, the total stress analysis is performed as it simplifies the analysis and generally provides a more accurate solution to short term stability (BS: 8006-1995, Clause 8.3.2.5.1).

In order to calculate maximum tension in the reinforcement, due to rotational failure, a slip circle analysis search is carried out along the reinforcement using a computer program. This analysis shows no tension in the reinforcement except at two locations, where negligible tension is estimated.

Lateral Sliding
Embankment / fill placed over basal reinforcement will have a tendency to slide horizontally along the top surface of basal reinforcement. This tendency of embankment / fill by placing the geotextile in tension. This tension will be maximum at the edge of the crest of the embankment.

5. CONCLUSIONS
Polypropylene is one of the excellent filter materials for drainage. It has been observed physically last 2 years and we have not faced any problem for Kandaleru reservoir dam. We are proposing the use of Polypropylene as a filter material for present similar kind of projects in our country.

The basal reinforcement technique for short-term shear parameter improvement is the best and economical method. We have also noticed that the basal reinforcement technique presented here have been used in most of the countries like UK, Germany, USA and in India. It is recognized as a best method of construction and also significant savings in the material cost. Construction time also can be saved by adopting this Basal reinforcement technique.

REFERENCES