Erosion control methods using geosynthetics in agriculture and aquaculture

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ABSTRACT: Current erosion control techniques are both costly and can detract from the natural environment. The purpose of this paper is to describe how to use geosynthetics, how to proceed natural and innovative erosion protection project located along slope of agriculture and aquaculture area in the Republic of Korea. A number of erosion control methods were investigated and they were applied to streams, channels, embankments, and slope of rural road with using natural fiber geocomposite, geocell, geotextile bag, geotextile tube and natural geosynthetics in agriculture and acquaculture area. The use of geotextiles manufactured from natural fibers is one of the way in which renewable materials can be incorporated in geotechnical, road and hydraulic engineering. Several types of earth slope protection methods are being used in practice such as fiber reinforced sand spray, geocell, mesh type geotextile foam, and framework system. The maintenance and protection of steep slope against the erosion during the rainy season is not easy task to deal with it. The vegetation growth on the slope is very important to protect the slope from erosion.

1 INTRODUCTION

Erosion is a natural process caused by the forces of water, wind, ice, and gravity. It is influenced by a number of factors, such as soil type, vegetation and landscape, and it can be accelerated by various activities that occur on a specific field installation. Uncontrolled erosion processes can cause major damages to existing structures and to the environment. Erosion control methods have been developed by installation riprap, gabion with conventional type, however, when the thickness for protection is not enough, the soil particles become dislodged and they can be carried by surface runoff. As the speed of runoff increase, more soil particles are transported. Due to increased public environmental awareness and rising costs of repairing sites damaged by erosion, erosion and sedimentation control have become serious considerations.

Erosion control is rapidly growing as a result of more eco friendly policies in various countries. Environmental policy demands a carefully considered management of interactions with the natural environment and the economical use of raw materials. The magnitude and economic impact of soil-erosion problems has led to the development of various control measures. These include the use of natural control materials and systems like as straw, wood chips, jute cloth as well as geosynthetic systems, or a combination of both.

Geosynthetics can be used for erosion control in works such as slope protection, channels, drainage ditches, waterways, shoreline protection, reclamation, revegetation, scour protection, rockfall netting, breakwaters, weirs, and embankments. Depending on project and site characteristics, an erosion control work may involve the use of one or more geosynthetic products such as geotextiles, geomats, geonets, geocomposites, and other related material. Some erosion control mats are manufactured using biodegradable wood fibers. As new materials, geosynthetics has emerged as a major discipline for many applications in geotechnical, geoenvironmental, hydraulic and transportation engineering.

Recently, geosynthetics has been studied as a woven, porous polyethylene material used for construction site erosion control (Rickson, 2006), improving drainage and enhancing reinforcement of marginally stable slopes (Vishnudas et al., 2006), and as anaerobic lagoon odor control covers (Miner et al., 2003). Double layers of geotextile cloth fabricated into a bag design and filled with various materials have been used to reduce bridge abutment scouring (Korkut et al., 2007) and for beach erosion mitigation (Elko and Mann, 2007). Further, hydraulically loaded geotextile bags and geotextile tubes are used to dewater dredge slurry (Shin et al., 2002).

There were investigated about erosion control method which was applied to streams, channels, embankments, and slope of rural road with using natural fiber geocomposite, geocell, geotextile bag, geotextile tube and natural geosynthetics in agriculture and acquaculture area.It was also studied about environmental slope protection method applied to the rural road in Korea.

This paper briefly reports the application of agricultural and aquaculture using geosynthetics, and the main emphasis is given to recent innovative applications with natural geotextile technology, geocell technology, geotextile bag, geotextile tube technology, and slope of rural road.

2 EROSION CONTROL SYSTEM

2.1 *Mechanism of erosion*

To deal with water erosion problems, five of erosion and their characteristics must be understood so that appropriate control measures can be selected. Raindrop exposes soil by the impact of raindrop. Raindrop erosion is related to rain intensity and raindrop size. On a slope, the particles will move down the slope because of gravity. Sheet erosion occurs when the shallow water usually moves as a uniform sheet for only a few feet before concentrating in low spots and other uneven spaces. The small channels cut into the soil surface by erosion are called rills. Rill erosion begins when the shallow sheet flow begins to concentrate in the low areas of the soil surface. Gully erosion is deeper than rill erosion. In some soils, a heavy rain can change a rill into a major gully in a very short time. Channel erosion occurs when the velocity of the flow in a stream is increased or when the bank vegetation is damaged or destroyed. Figure 1 shows the mechanism of erosion by seepage.

(a)Dislodgement (b) Flowage (c) Sliding failure

Figure 1. Mechanism of erosion by seepage

Geosynthetics as a separators help to prevent finegrained subgrade soils from being pumped into permeable granular road bases. Specialty geocomposites have been developed for the specific purpose of erosion control.

The general goal of erosion control geocomposites is to protect the soil from sheet, rill, or gully erosion either indefinitely or until vegetation can establish itself. While water is the predominant medium for erosion and the subsequent transportation of soil particles, wind is also a potential medium, as shown in Figure 2. It shows the general behavior of the soil erosion process, it does little to quantify the variety of complex processes that are involved.

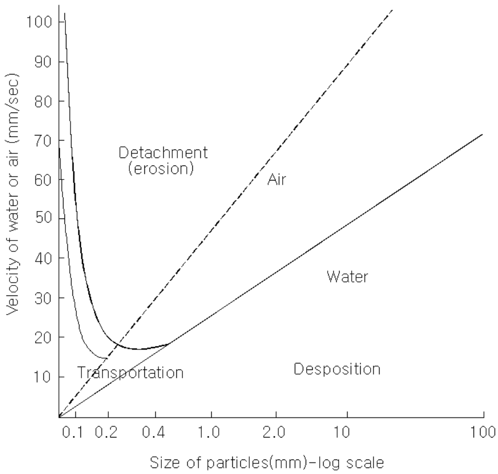


Figure 2. Erosion zone with particle due to water or air (Modified from Garrels)

2.2 *Geosynthtic materials for erosion control*

The geosynthetic material is used for temporary erosion control or permanent erosion control. Temporary erosion and revegetation materials consist of materials that are wholly or partly degradable. The natural products are completely biodegradable, while the polymer products are only partially so. Permanent erosion and revegetation materials are consisted with biotechnical related and hard armor related product. Erosion control meshes and nets are bi-axially oriented nets manufactured from polypropylene or polyethylene. Table 1 was tabulated geosynthetic materials for erosion control.

Many geotextiles between natural geotextiles, woven in mesh type structure with significant open spaces, help in the control of soil erosion. Natural geotextiles degrade to form organic mulch and helps in quick establishment of vegetation. Coir geotextiles degrade in 2 to 3 years while jute geotextile degrade in 1 to 2 years. Therefore, coir geotextiles are particularly useful in areas where vegetation takes more time to establish. Jute absorbs more moisture and is useful in areas with irregular rainfall. The natural materials are usually suitable for temporary functioning. Such systems are generally used on moderate slopes with relatively low flow velocities. The geosynthetic systems are suitable when higher hydraulic loadings are present and when long-term functioning is required composite mats, blankets, cells and preformed mats. The suitability of a particular system is needed to provide long-term or short-term protection.

Table 1 Geosynthetics for erosion control

Temporary erosion and revegetation materials	Permanent erosion and revegetation materials	
	Biotechnical-Related	Hard Armor-Related
Straw, hay, and hydraulic mulches	UV stabilized fiber roving systems	Geocellular containment systems -concrete filled
Tackifiers and soil stabilizers	Erosion-control revegetation mats	Fabric-formed revetments
Hydraulic mulch geofibers	Turf reinforcement mats	Vegetated concrete block systems
Erosion-control meshes and nets	Discrete-length geofibers	Concrete block systems
Erosion-control blankets	Geocellular containment systems-vegetated	Stone riprap
Fiber roving systems		Gabions

2.3 *Design considerations*

(a) Slope erosion
The most often-used model for soil loss by erosion is the universal soil loss equation developed by Wishmeier and Smith (1960). The equation is as follows,

$$E = RK(LS)CP \tag{1}$$

Where, E = soil loss (tons per square kilometer per year depending upon constants used)
R = rainfall factor
K = soil erodibility factor
LS = length of slope or gradient factor
C = vegetative cover factor
P = conservation practice factor

(b) Channel and ditch erosion
The velocity approach for channels and ditches calculates a design velocity and compares it with an allowable velocity for determining a factor of safety.

$$V_{reqd} = \frac{1.0}{n} R^{2/3} S_f^{1/2} \tag{2}$$

Where, V_{reqd} = flow velocity(m/sec)
n = Manning's coefficient
R = hydraulic radius=A/P
A = cross-sectional area (m^2)
P = wetted perimeter (m)
S_f = slope of channel

The shear stress approach for channels and ditches calculates a design shear stress and compares it with an allowable shear stress for determining a factor of safety

$$\tau_{reqd} = \gamma_w d S_f \tag{3}$$

Where, τ_{reqd} = required shear stress (kN/m^2)
γ_w = unit weight of water (kN/m^3)
d = depth of flow (m)
S_f = slope of channel

(c) Slope stability of erosion control system
Resistance force (S_N) against sliding in Figure 3 may expressed as the friction force of bottom and slope face and if friction force is neglected at the top of slope, it may expressed as follows,

$$S_N = S_3 + S_2 = N_3\mu + N_2\mu = W_3\mu + W_2\cos\theta\mu \\ = w\mu(L_3 + L_2\cos\theta) \tag{4}$$

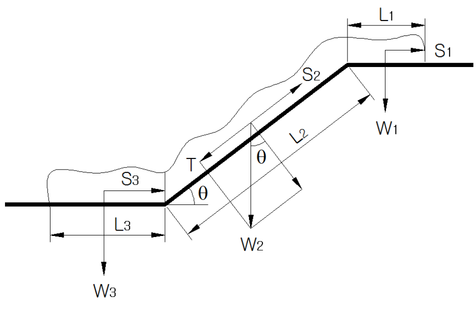


Figure 3. Sliding stability of mattress form

Sliding force (T) also may expressed the component force of slope direction for weight of fabric form mattress

$$T = W_2 \sin\theta = wL_2 \sin\theta \tag{5}$$

Thus, the safe factor (Fs) may expressed as

$$Fs = \frac{S_N}{T} = \frac{(L_3 + L_2 \cos\theta)\mu}{L_2 \sin\theta} \quad (6)$$

Where, w = average unit weight of fabric form

$L_{1,2,3}$ = length of fabric form

θ = angle of slope

μ = friction factor

$W_{2,3}$ = weight of fabric form

T = sliding force

S = resistance force

(d) Bearing capacity of erosion control system

In design, geocell systems are quite complex to assess. It could be adapted to conventional plastic limit equilibrium mechanism as used in statically loaded shallow foundation bearing capacity. Figure 4 shows the failure mechanisms with geocell confinement system. For the failure mode is interrupted by the geocell system. For such a failure to occur, the sand in particular cell must overcome the side friction, punch out of it, there by loading the sand beneath the level of the mattress. This in turn fails in bearing capacity, but now with the positive effectives of a small surcharge loading and typically higher-density conditions. The bearing capacity can be illustrated as Figure 4.

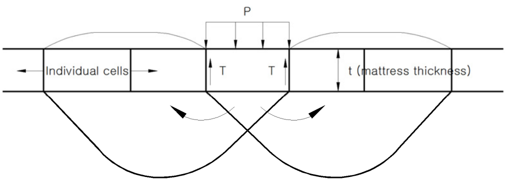


Figure 4. Bearing capacity with geocell mattress

Without mattress:

$$p = cN_c\zeta c + qN_q\zeta q + 0.5BN_r\zeta_r \quad (7)$$

With mattress:

$$p = 2\tau + cN_c\zeta_c + qN_q\zeta_q + 0.5BN_r\zeta_r \quad (8)$$

Where , p = maximum bearing capacity stress

c = cohesion (equal to zero, granular soil)

q = surcharge load ($= \gamma_q D_q$)

γ_q = unit weight of soil within geocell

D_q = depth of geocell

B = width of applied pressure system

γ = unit weight of soil in failure zone

$N_{c,q,r}$ = bearing capacity factor

$\zeta_{c,q,r}$ = shape factors used to account for differences from the plane strain assumption of the original theory

τ = shear strength between geocell wall and soil contained within it

σ_h = average horizontal force within the geocell (= pK_a)

p = applied vertical pressure

K_a = coefficient of active earth pressure

δ = angle of shearing resistance

(e) Filter calculation

The sandy subsoil is representative for the required soil tightness. From the average grain-size distribution characteristics figure are derived d_{60}, d_{10}. The internal stability of the soil structure is determined by following equation.

$$\frac{d_{60}}{d_{10}} < 10 \quad (9)$$

As the value is <10, the soil structure is stable. In connection with wind and ship waves the hydraulic loading is cyclic. Therefore, the filer function criterion is

$$\frac{O(p)}{d_{85}} < 2 \quad (10)$$

Where, O(p) is soil-tightness number in μm.

Permittivity is the volumetric flow rate of water perpendicular on the plane of the geosynthetic. The water permeability in terms of permittivity (ψ) can be defined as follows,

$$\psi = \frac{v}{\Delta h}[s^{-1}] \quad (11)$$

From this formula the following can be derived.

$$\psi = \frac{v}{\Delta h}[s^{-1}] \quad (12)$$

Where, ψ = permittivity in S^{-1}

v = Filter velocity m/s

Δh = hydraulic head difference geosynthetic

k = coefficient of permeability for laminar flow

i = hydraulic gradient

v = thickness of the geosynthetic (mm)

3 NATURAL FIBER GEOTEXTILE

3.1 *Usage of natural fiber geotexitle*

The use of geotextiles manufactured from natural fibers is one of the way in which renewable materials can be incorporated in geotechnical, road and hydraulic engineering. This involves the use of fibers such as coir sisal and jute. In addition, fiber produced in Europe, such as flax, hemp and miscanthus, are also suitable for use in geotextiles. In the past, up to 20 or 30 years age, geotextiles made of coir or jute was very often used in geotechnical, road and hydraulic engineering. Wing to the discontinuation of the use of these materials, actual and potential users now lock both knowledge and experience of their applications. This has led to the preparation of an actual updated review of the potential uses of biodegradable geotextiles.

Natural geotextiles, woven in mesh type structure with significant open spaces, help in the control of soil erosion. The system works on the principle of formation of miniature dams holding water and sediment and allowing excess water to flow over them. This layer of geotextile and water also reduces rain splash and speed of runoff and therefore reduces erosion. The geotextile helps the vegetation root density to grow to 4500 kg/hectare against normal root density of 1500 kg/hectare. When the geotextile degrades, this highly dense root structure reinforces the soil and reduces erosion losses. The canopy cover given by growing vegetation close to the ground reduces splash erosion caused by raindrops. Natural geotextiles degrade to form organic mulch and helps in quick establishment of vegetation.

3.2 *Types of natural fiber products*

(a) Jute products
This products is useful in soil erosion control in gentle slopes as in channels where the flow velocity is 2.4 m/sec ~ 4.0 m/sec. The product can absorb water to the extent of 5 times its own weight.

Jute composite geotextile like jute-jute, jute-coir, fabrics filled with nonwoven needle punched coir, to form a composite product with unique set of properties to meet specific geotechnical needs. The composite may also be pre-seeded for quick establishment of vegetation.

(b) Coir products
This product is useful in soil erosion control on gentle slope or channels where the flow velocity is 2.4 ~ 4.6m/sec. Coir geocells are 20cm wide bands of tightly woven coir geotextiles. It can be laid in a honeycomb cell like structure using bio-stakes. The structure can then be filled with soil and saplings planted in them. The product can be used for lining canals, stream banks and on embankments. It may also be used in conjunction with coir log in high flow velocity channels for quick vegetation establishment.

Sandwich composite product like coir-coir, jute-coir, filled with coir, or straw to form a composite product with unique set of properties to meet specific geo-technical needs. Geocomposite product may also be pre-seeded for quick establishment of vegetation. Non-woven needle punched coir products are available in weights of 700 g/m^2 to 1000 g/m^2 in rolls of width 2.2m and lengths of 20m for use in erosion control, filtration, drainage, mulching, weed control and other related function. The product can be pre-seeded or backed by jute cloth for additional strength.

Coir logs are constructed of coconut fibers that are bound together with biodegradable netting. Coir logs come in various lengths and diameters and need to be selected specifically for a site. Generally, they are 6 m long and 30 cm in diameter weighing around 8 to 9 kg per linear meter. Figure 5 shows various type of natural geosynthetic products.

(a) Jute product (b) Coir product

Figure 5. Natural geosynthetic products

3.3 *Application of natural geosynthetics*

Jute products are recommended for use in areas where annual rainfall exceeds 150cm. Coir products are more extensive than jute products and therefore recommended for use in areas, where annual rainfall is less than 200cm. Applications for coir logs occur in many stream bank, wetland and upland environments. The logs provide temporary physical protection to a site while vegetation becomes established. The logs can provide a substrate for plant growth, protect adjacent plants from wave erosion, serve as a transition from one revegetation technique to another, and be used to secure the toe of a slope. Figure 6 shows composites of natural geotextiles. Installation techniques of natural geotextiles on road embankments is

(1)Level the area to be treated. Regrade the slope and tamp the soil to the desired shape, remove all protruding rocks, root stumps and other obstacles.

(2)Do first seeding of grass at $10g/m^2$ or desired alternative planting, such as root slips. Tamp the surface again. Compact any loose soil.

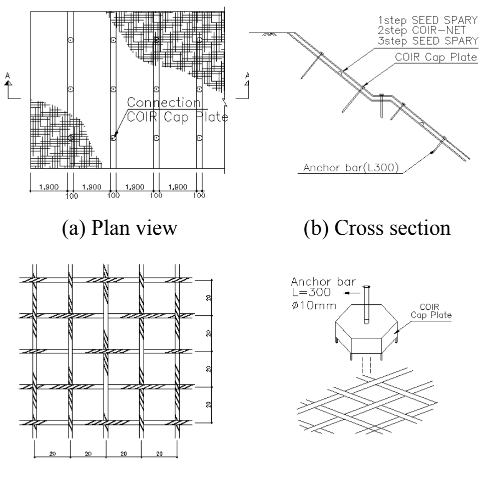
(3)Lay the geotextile in rolls or grids in the direction of water flow. Adjoining netting should overlap by 15 cm or be stitched.

(4)Secure top and bottom ends of the netting into slots about 30 cm deep, dug into the slope for the purpose. Fill in the slots with soil and tamp it flush with the soil surface.

(5)Peg down the netting using staples of 3 mm steel or wire or similar. Staples should be driven down at intervals of 60 cm along the sides.

(6)Do second seeding of grass at $10g/m^2$ after the geotextile is in place. Finally, tamp the netting flush with the soil surface.

(7)Irrigate the slope as required to promote the growth of vegetation.



(a) Plan view (b) Cross section

(c) Section A-A of (a) (d) Coir protection

Figure 6. Schematic of protection by natural geosynthetics

In case of slope, it grades slope and remove large rocks, wood, and other obstacles and then apply fertilizer and then seed prior to installing blankets. After anchoring blankets at top of slope, walks backward down the slope to allow the blanket to unroll slowly. Place blankets loosely and in full contact with the soil and overlap edges of the blankets approximately 15 cm and staple, install blankets so edge overlaps are shingled away from prevailing winds. Overlap blanket ends 15 cm, with upper blanket over lower blanket, and staple using five staples. After cutting excess blanket with scissors, anchor at end of slope. In case top soil is absent, 50 mm of top soil should be laid before laying down the blanket. Figure 7 shows the construction steps of slope protection by jute product.

(a) Grade slope (b) Staple blanket

(c) Spray seed (d) Completion

Figure 7. Application of jute product for slope protection

In case of channels, it grades and contour channel and then apply fertilizer and seed prior to installing blankets. After anchoring blankets at top of channel, back fill with check slot material. For culvert out falls, place blanket under pipe at least 30cm upstream from pipe opening. It installs a blanket in the center of the channel, in the direction of water flow. Additional blankets are installed at the edges of this centered blanket. Construct check slots with soil, gravel, or stone in the middle and at the end of each blanket. It is overlapped side channel blanket edges 15 cm over the center channel blanket and staple. After anchoring the top edge of side channel blankets, anchor the terminal ends of blankets in a check slot. Figure 8 shows the installation procedure of coir role in slope.

Figure 8. Application to streamline with coir role

In case of shorelines, it grades and contours shoreline. After applying fertilizer and seed prior to installing erosion control blankets, install blankets during lowest possible water level. Install blankets horizontally and parallel to the water's edge if the anticipated water level fluctuation will not exceed the upper level of the blanket. It secures the upper edge of the blanket, and use 5 staples every 2.5 m. After anchoring the bottom edge of the blanket, it uses 5 staples every 2.5 m. and then it overlaps blanket ends a minimum of 15 cm, and staple. For shorelines steeper than 2:1 slopes, or if the water level fluctuates more than 1.75 m, it installs blankets vertically using geotextile slope instructions. Figure 9 is an example of coir log application in pond.

Figure 9. Application to shoreline using coir log

4 AGRICULTURAL STREAM PROTECTION USING GEOCELL

4.1 *Structure of geocell*

Steep slopes, river banks, ditches, and other exposed areas are often prone to damage caused by erosion due to wind or water. Geocell can help to prevent erosion by confining soils and aggregates to within the cell structure. Geocells are three dimensional honeycomb structures that feature a unique cellular confinement system formed by a series of self containing cells. They have the ability to physically confine the soil placed inside the cells. This avoids a mass sliding off the surface layer while vegetation is being established. Geocells are also used where heavy runoff, or channel scouring is anticipated. The cell walls confine the soil and decrease the velocity of water passing across the surface. In these instances, geocells often replace the expensive riprap or concrete slope protection.

Varying degrees of protection can be afforded by selecting alternative in-fill materials. Seeded topsoil provides protection for less exposed areas. Protection may be increased by introducing vegetation such as small shrubs

4.2 *Types and materials*

Geocell is a lightweight and flexible cellular structure made of polyethylene strips which are ultrasonically bonded together to form an extremely strong configuration. Geocell system can be filled with a wide range of material like as aggregate, concrete, sand, soil, and other materials. Most slope protection applications utilize 10cm depth, standard cell sections. Cell size is governed by slope geometry and design cover thickness. Steep slopes must have global stability or be internally reinforced before application of the geocell system. The single layer geocell system has been used on slopes as steep as 75 degrees. Anchor methods used to secure the geocell system to a slope include wood stakes, metal J-pins, and other earth tension anchors. Generally sections are connected to prevent relative movement of sections during the infilling operation using rivets or heavy-duty metal staples applied with a pneumatic stapler. A variety of rivets or staples are available to meet site environmental conditions.

High strength polyester tendons through the geocell system was provided continuous reinforcement over the entire length of the slope to be covered and provided a solution to connecting the concrete filled geocell to an anchor located at the crest of the slope. Since geocell material is portable and placed manually before infilling with ready-mixed concrete, the system could also be constructed without risk of damage to the geomembrane. Figure 10 shows geocell with honeycomb and membrane type for reinforcement of slope.

Figure 10. Geocell of honeycomb and membrane type.

4.3 Application with geocell

(a) Slopes with arid and rocky area

The soil making up a slope often has a predominantly arid area due to the lack of organic material. Under these conditions, it's necessary to ensure that an adequate thickness of topsoil is provided to allow for the growth of vegetation. Since topsoil has poor mechanical properties it can easily slide down the slope, it could also get washed away by heavy rainfall prior to the onset of vegetative growth. When eroded slopes are made from soft rocks and exhibit an unstable combination of loose rocks mixed with finer material, it's necessary to build a secure system capable of preventing the detachment of the heavier and larger sized material and simultaneously retaining any growing medium.

Geocells are particularly useful in this situation due to their high tensile strength and their dense mesh structure that is capable of molding itself to the foundation profile. This provides an effective containment system for the grassed areas, protecting the latter from erosive phenomena associated with precipitation or with non-channelled flowing waters.

(b) Impermeable banks for canals and ponds
Impermeable membranes like as polymeric or mineral clay used to seal canals, ponds, and artificial basins in general, must be protected from both mechanical puncturing and from attack by UV rays, and if possible, the part above water needs to be covered by vegetation. Both these needs can be satisfied by using the honeycomb shaped geocell. The cellular structure can be filled above the water line with topsoil and, in the submerged section, with dredged gravel or concrete, and can be successively covered.

On the construction, the geocells is filled from the top of the slope down, allowing easy raking of the concrete into the lower cells. Top-down filling also helps reduce the forces that attempt to drive the entire system down lope. A coarse broom gave the concrete its final surface texture so that the rough surface finish would provide good traction for maintenance workers on the slope. Slope maintenance, specially, vegetation control, has been greatly reduced. Because this system is inherently flexible, cracking of the infill concrete has not occurred. The geocell protection system was judged to offer a technically superior system at a cost that was within the project budget constraints. The view of geocell installation for streamline and bank protections are shown in Figures 11 and 12, respectively.


(a) Preparing stream


(b) Installing geocell


(c) Filling mortar


(d) Completion of stream

Figure 11. Installing geocell in streamline


(a) Grade slope


(b) Installing geomattress


(c) Filling granular soil


(d) Afforestation

Figure 12. Installing geocell for bank protection

5 EMBANKMENT PROTECTION USING MINI-GEOTEXTILE TUBE

5.1 *Review of geotextile tube for erosion control*

The geotextile tube had been used in 1960 as a coastal structure for the first time, which had been performed to construct as a structure for testing within a condition of oval shape geotextile tube that is smaller than 2.0m diameter. After 1982 in Brazil, geotextile tubes were developed with using strong woven geotextile which was constructed in a coastal area as 2.0m as a diameter of tube. Non-woven geotextile tube with heavy material, which is smaller than 1.5m diameter, was used in coastal area of Brazil at the same time. In 1990, geotextile tube was used in order to get a float soil stoke down to the ground. The geotextile tube of 2.8m width and 1.5m height was applied to construct in southern Florida, USA. Up to now, the geotextile tubes with 1.5m diameter has been constructed in order to preserve shoreline in coastal area and also has been used as a temporary embankment in order to protect a dike with reclamation in coastal area. Recently, the geotextile tube has been increased in use at marine area as a temporary structure like dike for constructing bridge, for protecting the beach line from the erosion by the sea wave.

For the first time in Korea, the geotextile tube was constructed as a 1.8m height tube for protection of coastal line from erosion. It was installed in Youngjin bay, Korea in 2003. After that time, it was installed in Ilsan Bridge construction site and Incheon Bridge construction site as a temporary construction platform which is constructed by stacked geotextile tube. It does not have much information available about a stacked geotextile tube.

In fact, it has been tried seldom by now to carry out an analysis about stability or behavior of geotextile tube injected by sand or dredged soil. It is also rarely existed of the seepage analysis against ground water level after geotextile tube had been completely installed as a temporary large scale structure in coastal area. Geotube project list was tabulated in Table 2.

Table 2. Geotube projects in the Republic of Korea

Year	Project	Quantities
1998	Erosion control for submerged dyke, Youngjin beach	4.0km geotextile tube of 3.0m diameter.
2001	Offshore breakwater, Uljin	2.0km geotextile tube of 3.5m diameter.
2004 ~ 2005	Containment dykes, Ilsan bridge	8.5km geotextile tubes of 5.0m diameter. 4.0km geotextile tubes of 4.0m diameter.
2004 ~ 2006	Containment dykes, Incheon bridge	7.6km geotextile tubes of 3.5m diameter.
2004	Emergency dykes, Gwangyang Soo-ur dam	1.8km geotextile tube of 3.5m diameter.
2006 ~ 2007	Seamangum tide embankment	2.7km geotextile tube of 1.2m diameter.
2007	Containment dikes, newport Busan	3.11km geotextile tube of 4.25m diameter.

5.2 *Construction with geotextile tube mattress*

Korea Rural Community Corporation constructed 2.7km-long Semangum tide embankment along the west coast of the Korean Penisula for the land reclamation from the sea to create the farm land. The major construction equipments used for installation of geotextile tube mattress are hydraulic pumping, excavator, bargeship, and towboat. The construction sequences of geotextile tube mattress are shown in Figures 13~17.

Figure 13. Saemangum tide embankment view

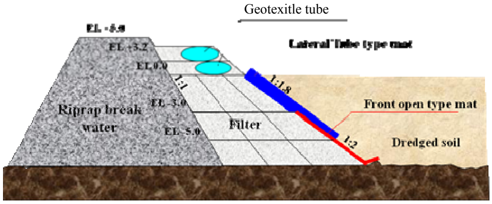


Figure 14. Cross-section of sea dyke filter using geotextile tube mattress

Figure 15. Tube mattress installation

Figure 16. Tube mattress injection

Figure 17. Filter section shape after injection

5.3 *Field monitoring of tube mattress in pond*

It is performed to analysis the weight possibility of tube mattress against seepage flow. The internal friction angle is 40 degree between tube mattress and rubble. When the velocity of seepage flow is 0.75 m/sec, the safety factor of uplift indicates 1.0 at 0.5m tube mattress. According to the height of tube mattress increases, the safety factors intend to increase rapidly. Also the safety factor of sliding increases gradually as to the height of mattress increases. The safety factor of sliding satisfies minimum 1.5, when the velocity is up to 0.85 m/sec of seepage flow. The result of tube mattress uplift safety factor for seepage flow is plotted in Figure 18. Also, it is also preformed to analyze the sliding safety factor by using the sliding force for tube mattress self-weight and ratio of sliding to seepage force and sliding resistance force. The sliding safety factor of tube mattress is plotted in Figure 19.

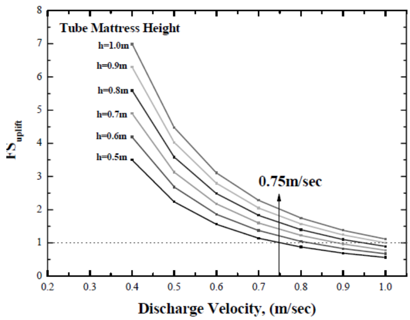


Figure 18. Uplift safety factor for seepage flow

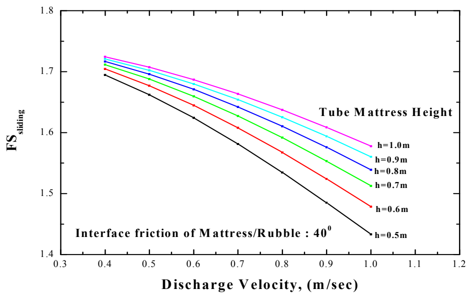


Figure 19. Factor of safety by sliding in geotube

6 EROSION PROTECTION OF REINFORCE SLOPE IN RURAL ROAD

Several types of earth slope protection methods were introduced in practice such as fiber reinforced sand spray method, straw mat seed spray method, geobag system, geotextile bag system, and fabric form. The fiber reinforced sand spray method requires a special designed equipment to spray the sand and long polyester fiber on the earth slope, simultaneously. The amount of multifiber used in this method is about 0.15～0.25% by weight of sand to obtain the required cohesive strength through the interfacial friction between sand particles and fibers. The example of construction work with this method is illustrated in Figure 20. In similar methods, straw mat seed spray method which has a resistance about 20~ 30% higher than that of seed spray method, core net seed spray method which is about 50% higher than that of seed spray method, core carpet seed spray method which is about 90% ~ 95% higher than that of seed spray method against rainfall.

(a) Spray sand (b) Long polyester fiber

Figure 20. Fiber reinforced slope with sand spray.

Geocell system is also applied in the slope protection and basal reinforcement in soft ground for road and railway track. The gravel or sand or any types of natural soils can be used as a filling material. This cellular confinement system consists of HDPE cell with perforated holes. The thickness of cell ranges from 75mm to 200mm. It can be constructed either by covering the earth slope with using the J-pin or staged construction in horizontal layers. The great advantages of this system are inducing the lateral confinement and facilitate the drainage capacity. The vegetation can be easily grown from the filling soil in the cell which is placed on the slope or staged system. The performance of geocell system on the slope is shown in Figure 21.

Figure 21. Slope reinforcement by geocell.

Geotextile bag system for slope protection has applied and has tested in reinforced wall in Korea. It has studied on the geotextile bag system for urgent restoration of a collapsed roadbed. In the study, the suitable geobag size was proposed as 44cm wide and 66 cm long with basis on the under static and dynamic loading tests. Static behavior of reinforced railway roadbed by geotextile bag also has studied in Korea. Static loading which simulated train load applied on the geotextile bag reinforced railway roadbed and unreinforced railway roadbed. The performance of the geotextile bag wall was performed to investigate, and was performed uniaxial compression tests for a recycled waste concrete geotextile bag was executed in the laboratory. Figure 22 shows reinforced wall with geotextile bag.

(a)Installation geobag (b)Reinforced wall

Figure 22. Reinforced wall by geotextile bag

Fabric forms which are connected to each other at filer point by twin spacer tapes, made of high strength polyamide, in square grid pattern of minimum 10 x 10cm. The spacer tapes are perpendicularly crossing the mattress at the binder points and are continuously interwoven between the filter points in each opposite fabric parallel to the warp direction. Mattresses are designed to be laid flat on prepared slope, joined together, and then filled with mortar. Figure 23 shows the sequence of fabric form method.

(a) Before construction (b) Grade slope

(c) Installing fabric form (d) Injection &anchoring

(e) After completing (f) After vegetation

Figure 23. Reinforced slope by fabric form method

7 CONCLUSION

In this paper, a number of products and design methodologies are presented in which the geotextile serves an erosion control function. They are applied to streams, channels, embankments, and slope of rural road with using natural fiber geocomposite, geocell, geotextile bag, geotextile tube and other eco-friendly materials in agriculture area.

- Natural geotextiles degrades, this highly dense root structure reinforces the soil and reduces erosion losses. Jute products are recommended for use in areas where annual rainfall exceeds 150cm. Coir products are more extensive than jute products and therefore recommended for use in areas, where annual rainfall is less than 200cm. Applications for coir logs occur in many stream bank, wetland and upland environments.

- Geocells have the ability to physically confine the soil placed inside the cells, and they can be used to prevent a mass sliding on the surface layer when vegetation is being established in the topsoil. Geocells are also used where heavy runoff, or channel scouring is anticipated and the system offer a technically superior system at a cost that was within the project budget constraints

- Mini-geotextile tubes constructed at Semangum along the west coast of the Korean Penisula for the land reclamation from the sea to create the farm land. In the result of monitoring for seepage flow, just 0.5m mattress tube filled with granular sand shows to be stable against seepage flow in acquaculture area.

- More than 70% of the Korean Peninsula is covered with the mountaineous area. Therefore, various slope reinforcement techniques are being used to cope with the slope stability problem along the rural road. The maintenance and protection of steep slope against the erosion during the monsoon season is not easy task to deal with it. The vegetation growth on the slope is very important to protect the slope from erosion. Combined techniques which can provide the services with soil reinforcement and slope protection are necessary.

From the above mentioned method it that besides the main functional requirements of as an erosion control method, soil tightness, filter function, and the requirements for strength of geosynthetics have to determine the kind of method to be applied. In some cases it is also advisable to make demands on the durability of the geosynthetic to be prepared for UV-radiation and thermic oxidation. Geosynthetics have proved to be a good and reliable material in erosion control applications, when designed and applied in a reasonable way. The role of the geosynthetics in the total design concept of the whole structure must be fully understood and the proper design criteria must be available or developed.

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