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- (71) **Applicants:** **HOUSING AND DEVELOPMENT BOARD** [SG/SG]; 480 Lorong 6 Toa Payoh, HDB Hub, Singapore 310480 (SG). **NANYANG TECHNOLOGICAL UNIVERSITY** [SG/SG]; 50 Nanyang Avenue, Nanyang Technological University, Singapore 639798 (SG).
- (72) **Inventors:** **WONG, Liang Heng, Johnny**; 23 Jalan Raja Wang #27-10, Singapore 329216 (SG). **WANG, Chien Looi**; 146B Braddell Road The Medallion, Singapore 359950 (SG). **LIM, Han, Vincent**; Blk 440A Fernvale Link #19-183, Singapore 791440 (SG). **KEW, Huiling**; Blk 336 Jurong East Ave 1 #06-1612, Singapore 600336 (SG). **CAI, Hanwei, Leonard**; Blk 269C Punggol Field

#04-205, Singapore 823269 (SG). **RAHARDJO, Hari-anto**; 25A Nanyang Valley, Singapore 639691 (SG). **LE-ONG, Eng Choon**; 45 Minaret Walk, Singapore 467415 (SG). **NIO, Alfredo Satyanaga**; 48 Lakeside Drive, #04-24, Singapore 648305 (SG). **ZHAI, Qian**; BLK 64 JLN Ma'MOR #01-69, Singapore 320064 (SG).

(74) **Agent:** **YUSARN AUDREY**; 24 Raffles Place, #27-01 Clifford Centre, Singapore 048621 (SG).

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(54) **Title:** A BAG, SYSTEM AND METHOD FOR USING THE SAME

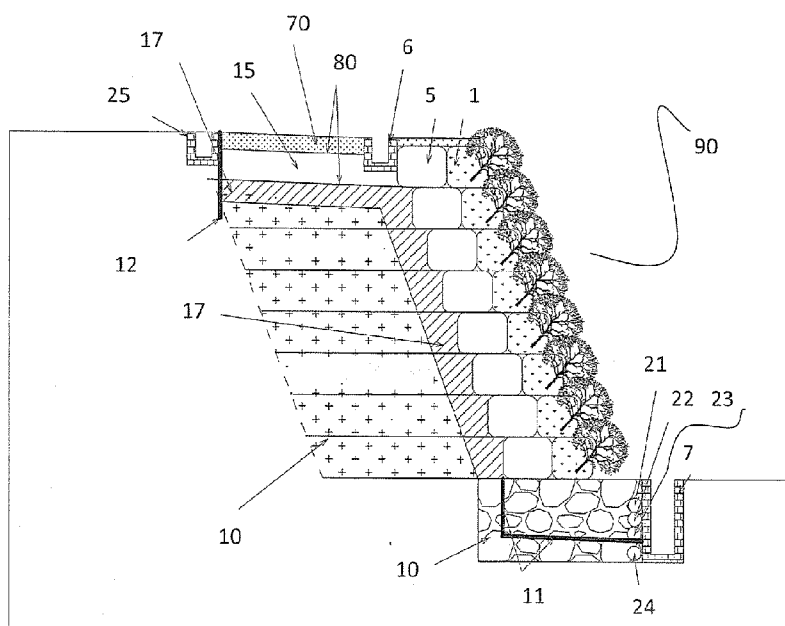


Figure 9

(57) **Abstract:** The present invention relates to a bag, associated system and method for covering, retaining and/or stabilising a slope or embankment. The said bag has an opening for accommodating a plant, securing means to seal the bag, and a cover that overlaps the opening wherein the cover is positionable to direct the direction of growth of the plant. The said bag is utilised in the construction of a geobarrier system which comprises of a plurality of units placed side by side and/or stacked on top of each other wherein each unit comprises of an anchorage mechanism attached to a base of the said bag; a first portion of the anchorage mechanism adjacent to the said bag capable of receiving a second bag containing a first material; a second portion of the anchorage mechanism capable of receiving a second material, wherein the second material comprises at least one hydraulic property contrasted with respect to at least one hydraulic property of first material to form a capillary barrier, and a third portion of the anchorage mechanism capable of receiving a third material comprising compacted soil.



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A BAG, SYSTEM AND METHOD FOR USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of and priority from Singapore Patent
5 Application No. 10201507996T, filed on 25 September 2015, entitled "a bag and
system for using the same," and from Singapore Patent Application No.
10201601395Y, filed on 24 February 2016, entitled "a bag and system for using
the same," the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a bag, associated system and method, in
particular a bag and system directed to creating a slope or embankment, and a
system and method for covering, retaining and/or stabilizing the slope or
embankment.

BACKGROUND TO THE INVENTION

The following discussion of the background to the invention is intended to
facilitate an understanding of the present invention. However, it should be
appreciated that the discussion is not an acknowledgment or admission that any
20 of the material referred to was published, known or part of the common general
knowledge in any jurisdiction as at the priority date of the application.

Slope stability is the potential of soil covered slopes to withstand and
undergo movement and this is typically determined by the balance of shear stress
and shear strength. Water induced failure caused by sufficient rain fall is one of
25 the climatic events that can make a slope actively unstable, leading to mass
movements like a slip or landslide.

A common method of preventing a slip or landslide would be to build a
retaining wall starting at the base of the slope. A retaining wall is a structure
designed and constructed to resist the lateral pressure of soil when there is a
30 desired change in ground elevation that exceeds the angle of repose of the soil.

This would involve building a concrete and/or steel structure of sufficient height and depth, such that it is able to hold back the soil. Steel and/or concrete retaining walls are expensive and generally unsightly. Further, such a retaining wall still requires maintenance since in time the soil being retained would shift and even
5 then should sufficient fluids be built up, the retaining wall would be overcome.

To make retaining walls that are aesthetically pleasing, some retaining walls have been made to have an outer layer of soil or plant growth medium that permit growth of a shallow vegetative ground cover such as ornamental grass.

One of the current approaches to preventing soil loss on slopes of less than
10 an certain inclined angle with respect to a horizontal surface or plane (e.g. ground) is to use a capillary barrier system (CBS) to minimise rainwater infiltration into soil slopes. The CBS is a man-made double layer cover system designed as an unsaturated system which harnesses the distinct different hydraulic properties between a fine-grained layer and a coarse-grained layer of soils, whereby a soil
15 mix can be laid on top to provide green vegetative cover. However, long term monitoring studies showed that CBS materials tend to slide down a steep slope surface if they are used solely as an added layer of preventive measure. Further CBS is unable to be deployed for slopes having angles above a certain incline, since this may lead to 'slumping' or the migration of materials down the slope. As
20 such, the CBS may not be suitable for deployment as a retaining wall for steep slopes.

There is accordingly a need to improve existing techniques, systems and equipment in preventing a slip, slump, or landslide.

25 SUMMARY OF THE INVENTION

The abovementioned need is met at least in part and an improvement in the art is made by a bag or associated system or method in accordance with this invention.

Accordingly, an aspect of the present invention relates to a container for
30 retaining a slope, comprising a bag capable of containing a plant growing medium, the bag having an opening for accommodating a plant, and the opening having

securing means to seal the bag and prevent the plant growing medium from leaking from the bag, wherein said opening further comprises a cover that overlaps said opening and the cover being positionable to direct the direction of growth of the plant.

5 Another aspect of the present invention, relates to a geobarrier system for retaining a slope, comprising a unit, the unit comprising a first bag capable of containing a plant growing medium, the first bag having an opening for accommodating a plant and said opening comprising a cover that overlaps said opening and the cover being able to direct the direction of growth of the plant, an
10 anchorage mechanism attached to a base of the first bag;

a second bag capable of containing a first material, wherein said second bag locatable on a first portion of the anchorage mechanism adjacent to the first bag; and

a second portion of the anchorage mechanism capable of receiving a
15 second material, wherein the second material comprises at least one hydraulic property contrasted with respect to at least one hydraulic property of the first material to form a capillary barrier in use.

Another aspect of the present invention, relates to a method of constructing a geobarrier for retaining a slope, comprising the steps of:

20 forming a first layer by placing an anchorage mechanism attached to a base of a first bag at the base of a slope;

filling the first bag with a plant growing medium, the first bag having an opening for accommodating the plant and said opening comprising a cover that overlaps said opening and the cover being positionable to direct the direction of
25 growth of the plant;

placing a second bag on a first portion of the anchorage mechanism adjacent to the first bag

filling the second bag with a first material;

30 placing a second material comprising a contrasting hydraulic property with respect to the first material on a second portion of the anchorage mechanism;

placing compacted soil on a third portion of the anchorage mechanism; and

forming a second or subsequent layer on top of the first or below layer wherein a first bag of the second or subsequent layer sits over a join where the first bag is adjacent to the second bag of the first or below layer.

Other aspects of the invention will become apparent to those of ordinary skill in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

10 Figures 1A and 1B illustrates an embodiment of the present invention, also referred to as a 'Geo Barrier System (GBS)'.

Figures 2A and 2B illustrates the front or side and view of the opening of a bag of the present invention.

15 Figures 3A and 3B illustrates the front or side and view of the opening of a bag of the present invention.

Figure 4 illustrates a side view of an example of the bag.

Figure 5 illustrates front and side views of examples of the bag with an anchorage tail with examples of different types of stiffeners.

20 Figure 6 illustrates a side view of an example of a unit of the geobarrier system.

Figure 7 illustrates a plan view of a first layer of a geobarrier with examples of a linear geobarrier (A) and a curvilinear geobarrier (B).

Figure 8 illustrates the side view of a construction of a geobarrier.

Figure 9 illustrates the cross section of the Geo Barrier system.

25 Other arrangements of the invention are possible and, consequently, the accompanying drawings are not to be understood as superseding the generality of the preceding description of the invention.

DETAILED DESCRIPTION

30 Particular embodiments of the present invention will now be described with reference to the accompany drawings. The terminology used herein is for the

purpose of describing particular embodiments only and is not intended to limit the scope of the present invention. Other definitions for selected terms used herein may be found within the detailed description of the invention and apply throughout the description. Additionally, unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one or ordinary skill in the art to which this invention belongs. Where possible, the same reference numerals are used throughout the figures for clarity and consistency.

The term "container", "bag", "geotextile bag" and "geobag" may be used interchangeably throughout the specification and will be understood to refer to a container, bag or geotextile bag for use in containing soil or a required mixture of material.

An aspect of the present invention relates to a container for retaining a slope, comprising a bag 1 capable of containing a plant growing medium, the bag having an opening 30 for accommodating a portion of the plant, and the opening having at least one securing means to seal the bag and prevent the plant growing medium from leaking from the bag, wherein said opening further comprises a cover 40 that overlaps said opening 30 and the cover 40 being positionable to direct the direction of growth of the plant. In particular, the container is suitable for retaining a steep slope.

The term "slope" or "steep slope" as used herein refers to a slope at an angle above the angle of repose affected by the material used in the slope with respect to a horizontal reference (taken as zero degree). The angle of repose, or critical angle of repose, of a granular material is the steepest angle of descent or dip relative to the horizontal plane/surface to which a material can be piled without slumping. At this angle, the material on the slope face is on the verge of sliding. The angle of repose can range from 1° to 90°. The morphology of the material affects the angle of repose; smooth, rounded sand grains cannot be piled as steeply as can rough, interlocking sands. The angle of repose can also be affected by additions of solvents; if a small amount of water is able to bridge the gaps between particles, electrostatic attraction of the water to mineral surfaces will increase the angle of repose, and related quantities such as the soil strength. At

the angle of repose the granules in the slope have attained static friction or the maximum angle before which one of the items will begin sliding. This is called the angle of friction or friction angle. It is defined as:

$$\tan \theta = \mu_s$$

- 5 where θ is the angle from horizontal and μ_s is the static coefficient of friction between the objects. Any force that is greater than the static force will cause sliding of the granules or particles.

Different materials will have a different angle of repose and the granular or particle size and moisture content of the material will also effect the angle of repose. For example sand has an angle of repose of about 15° to 34° however, crushed asphalt has an angle of repose of about 30° to 45°. Hence, in various
10 embodiments a steep slope may be between 15° and 90° and in various other embodiments a steep slope may be between 30° and 90° depending on the material of the slope. In various embodiments the steep slope may be between
15 45° and 90° or between 50° and 85° or between 60° and 85° or between 70° and 85°.

As used herein 'plant growing medium' may refer to any suitable plant growth medium. In various embodiments the plant growing medium may include a soil mix suitable for growing a plant, the plant growing medium should contain
20 enough nutrients to sustain plant growth from many months to several years. This may be achieved by artificial or natural fertilizer. Examples of natural fertilizer may include manure, compost or other similar sources of nutrients. In various embodiments the plant growing medium may have the following proportions in terms of volume: 50% top soil, 20% sand, 15% soil conditioner, 15% organic
25 compost. Additional components such as water retention gel can also be added if needed.

The bag can be stacked and has the advantage of growing larger sized plants in a geobarrier such as that depicted in Figure 1 and Figure 9. Unlike vegetative ground cover, larger plants require support of stems during the initial
30 growth stages when they are saplings' and the like. In various embodiments the cover and opening act like a pocket on the side of the bag 1 whereby the

transition between the roots and stem can be located in the opening that is sheltered by the cover and the cover extends upwards in the desired direction of the plant growth to an opening at its upper end that will permit light into the pocket. In various embodiments the cover is formed from the same textile as the bag. In various other embodiments the cover is formed from a thicker textile than the bag. The combination of the tactile and light responses of the plant to the cover extending upwards will direct the direction of any plants placed in the pocket. The cover may direct the growth of the stem in a direction towards the sky and ensure that lower stem and roots are protected from elements and sunlight without which unusual growth patterns could be triggered. The root systems of plants that can grow to a larger size would in many cases grow deep into the soil mix and provide stability to a geobarrier. Such plants will also provide shelter and shade to the inner components of a geobarrier protecting the inner components of the geobarrier from UV radiation and other damaging natural elements. Examples of various embodiments of the bag are depicted in Figures 2 to 4.

In various embodiments the opening 30 comprises a slit on top of the bag 1 that will allow for cultivating of the plants (similar in function to the pocket which acts as opening 30 at the side of the bag for the plants). This can be done when there are sufficient space on top of the bag 1 for the opening 30 in such a way that it will not interfere with stacking the bags when in use in an offset manner to form a slope of the geobarrier. The slit opening 30 is customized by providing the cover 40 in the form of a flap over the opening 30 or extended sleeves with drawstrings, to reduce possible soil loss.

In various embodiments the bag has a volume of at least 0.2 cubic metres (m^3) or 200 litres. This ensures that the bag when filled is large enough and heavy enough to be anchored on the slope but also to ensure that there is enough plant growing medium to sustain plant growth for a period, for example many months to several years. In various embodiments the bag may have a volume of at least 0.2 m^3 or 200 litres to 0.5 m^3 or 500 litres, or at least 0.22 m^3 or 220 litres to 0.45 m^3 or 450 litres. The size of the bag may be varied to suit the type or types of plants to be grown in the bag.

In various embodiments the bag further comprises an anchor mechanism. The anchor mechanism may be in the form of an anchorage tail 60 attached to a base of the bag, wherein said anchorage tail 60 is capable of further anchoring the bag within a slope.

5 The term “anchorage tail”, “tendon” and “geogrid” are used interchangeably throughout the specification. In various embodiments the anchorage tail 60 or geogrid includes a grid or markings that divide the anchorage tail into portions. The grid or markings are depicted in Figures 5 and 6. This will demarcate to a user where different materials and portions are to be placed or located when
10 forming a geobarrier. In such embodiments not only does the anchorage tail 60 help to stabilise a geobarrier by anchoring the bag on the slope but the calculation of the amount of each material used, depending on the type of material, can be marked on the anchorage tail and effectively used to control the irrigation or water movement on the slope further stabilising the materials of the slope. This is
15 particularly useful during times of excessive rainfall such as in the tropics. In various embodiments the anchorage tail 60 may be at least 1.8 times longer than the length of the bag. In various embodiments the anchorage tail 60 may be at least 1.8 times longer to 4 times longer than the length of the bag. In various
20 embodiments the anchorage tail 60 may be at least 2 times longer to 3.75 times longer than the length of the bag. In various embodiments the bags are 0.6m wide x 0.5m high x 1.5m long with a 2.8m anchorage tail. In various embodiments the anchorage tail 60 is divided into a first portion 61, a second portion 65 and a third portion 68. In various embodiments the third portion 68 is about half the length of the anchorage tail 60. In various embodiments the first portion 61 of the
25 anchorage tail 60 comprises a larger surface area than the second portion 65 of the anchorage tail 60. In various embodiments the bags are 0.6m wide x 0.5m high x 0.75m long with a 2.8m anchorage tail. In various embodiments the anchorage tail 60 comprises a tensile strength of at least 10kN/m at a 2% strain. The strength of tail depends on the height of the slope and surcharge at the crest
30 of the slope.

In various embodiments the anchorage tail is detachably attached to the base of the bag. It may sometimes be necessary to replace a bag in an erected geobarrier for example in cases where the plants in that bag contract a disease or where the bag has been damaged. In such circumstances it would be preferable to replace that affected bag only without disrupting the entire geobarrier. The base of the bags may comprise a detachable attachment device for ease of detachment of an affected bag and attachment of a new bag to the anchorage tail. When removing the affected bag, a scaffold (not shown) may be pushed and inserted around an affected bag in an erected geobarrier so as to form a temporary support to prevent other bags from collapsing when the affected bag is removed. The base of the affected bag is then detached from the anchorage tail and the entire bag (including plant growing medium and plants) is removed out of the geobarrier via a pulling action for example. The base of the new bag may then be attached to the anchorage tail and filled with plant growing medium before removing the scaffold. One example of how this is achieved is depicted in Figure 4 where the detachable attachment device is in the form of a zip 45 arranged or affixed around the base of the bag in such a way that the base can be completely removed. In this example the base is permanently sewn to the anchorage tail with one half of the zip 45 on the base and the other half of the zip 45 around a lower rim of the bag such that when the two halves are zipped together the bag is attached to the anchorage tail and when the two halves of the zip are separated the bag is detached from the anchorage tail. Other attachment means such as press studs, clips or similar attachment means can be used provided the bag is able to be attached to the anchorage tail, then detached when needed while still permitting a new bag to be attached. A similar zip 45 may be included along the entire upper rim or part of the upper rim of the bag to permit the bag to be temporarily opened to place or replace a plant growing medium inside the bag. Alternative temporary opening could include a slit on the top of the bag. In some embodiments, a portion of the detachable attachment device may be disposed on the anchorage tail 60.

In various embodiments said securing means comprises a drawstring 50, wherein the drawstring 50 operates to restrict the opening 30 around the plant. Such a partial closure will ensure that the plant growing medium does not escape during rainfall. Referring to Figure 2, in various embodiments the drawstring 50 is included around the cover 40 to provide further closure to the opening 30 further reducing the space from which that the plant growing medium may escape during rainfall. The drawstring 50 with cover 40 arrangement may also provide support for young plants and further direct the direction of growth of the plant by limiting the amount of light that can enter the cover when the drawstring 50 is included around the cover 40.

In various embodiments the bag 1 comprises a plurality of openings 30 each comprising a cover 40 that overlaps or overlay on said plurality of openings 30. This embodiment allows many plants to be grown within the same bag. In various embodiments the plurality of openings 30 includes two or more openings 30 this may include two to six openings 30 in each bag or six to fourteen openings 30 in each bag 1. In various embodiments the openings 30 are arranged in an alternating array in two or three rows 41. An example is depicted in figure 4 where the covered openings 40 along the top row 41a are offset and not directly above the covered openings 40 along the bottom row 41b. This has the advantage of maximising the growing space on the surface of the bag 1 but also limiting any overshadowing of a plant in the lower row 41b by a plant growing directly above.

In various embodiments the bag further comprises a stiffener 48. This provides stability of the bag on the slope when used in a geobarrier system. When in use the plant growing medium should not be too compacted so as to allow the roots to grow through the plant growing medium. As the bags are placed on top of one another when a geobarrier is formed the weight of the upper bags may press on the bags below and compress them slightly causing a remoulded shape. In various embodiments a stiffener 48 may be added to the bag as a shape retainer to help retain the shape of the bag 1 in use. Anything that structurally retains the shape of the bag 1 would be suitable to use as a stiffener. An example of a thick cloth is used as a stiffener in Figure 5A in two straps 48a over the top of the bag,

a stiff plastic strip 48b is used in Figure 5B forming a circumference around the width of the bag and a wire mesh or texturmor system 48c is used in 5C. Other formations of stiffener 48 may be used such as compartments within the bag or any other stiffeners that is able to maintain the stability of a geobarrier when in use and sufficiently constrict the compaction or reshaping a bag when filled with the plant growing medium and in use in a geobarrier.

In various embodiments the geobag comprises a bag containing a soil mix suitable for growing a plant, the bag and having an opening for accommodating the plant, and the opening having securing means to seal the bag and prevent the soil mix from leaking from the bag, where the opening further comprises a cover that overlaps the opening and the cover being able to direct the direction of growth of the plant. Further, the geobag has a tendon attached to the base of the bag, where the tendon is capable of anchoring the bag on a slope. Alternatively, the securing means comprises a drawstring, where the drawstring would restrict the opening around the plant.

Another aspect of the present invention, relates to a geobarrier system for retaining a slope, comprising a unit 3, the unit comprising a first bag 1 capable of containing a plant growing medium, the first bag 1 having an opening 30 for accommodating a plant and said opening 30 comprising a cover 40 that overlaps said opening 30 and the cover 40 being able to direct the direction of growth of the plant, an anchorage mechanism 60 attached to a base of the first bag 1;

a second bag 5 capable of containing a first material, wherein said second bag 5 locatable on a first portion of the anchorage mechanism 601 adjacent to the first bag 1; and

a second portion 65 of the anchorage mechanism 60 capable of receiving a second material, wherein hydraulic property or the first material varies from hydraulic property of the second material such that the first and second materials in use are capable of forming a capillary barrier.

As used herein a 'capillary barrier' refers to a system that utilizes the contrast in hydraulic properties of materials in unsaturated conditions to limit water percolation. In an unsaturated condition, the second material becomes the barrier

layer that restricts water infiltration. The relationship between the water content and suction of a soil is known as the soil-water characteristic curve (MWCC). The air-entry value of the soil is the matric suction value that must be exceeded before air recedes into the pores. Water-entry value, ψ_w , is the matric suction value at which water first moves into the smallest pores that form a continuous network through the initially dry of the second layer. It is also called the breakthrough head since the value corresponds to the pore-water pressure head at which water first breaks through the interface of the first material 15 and the second material 17 of the layers formed in a geobarrier system.

The barrier effect of a capillary barrier, limits the downward movement of water from the fine-grained first material 15 into the coarse-grained second material 17 can be explained using soil-water characteristic curves (SWCC) and permeability functions of fine- and coarse-grained soils. An SWCC is a relationship between water content and matric suction of a material, while permeability function is a relationship between unsaturated coefficient of permeability and matric suction of a material.

The barrier effect that limits downward water movement is caused by the contrast in the unsaturated coefficient of permeability between fine- and coarse-grained soils. Beyond certain suction values, the coefficient of permeability of coarse-grained soil is much lower than the coefficient of permeability of fine-grained soil. Therefore, infiltrating water will be stored or diverted laterally through fine-grained soil (the first material of geobarrier system) instead of flowing into coarse-grained material (the second material of geobarrier system). As water continues to infiltrate, both the volumetric water content and the coefficient of permeability of fine-grained material will increase. When the infiltrating water reaches the interface of fine- and coarse-grained materials, matric suction of coarse-grained material at the interface will decrease. When the matric suction of coarse-grained material at the interface reaches its water-entry value, ψ_w , the coefficient of permeability of coarse-grained material will increase. Water will then start to flow into coarse-grained material. As the matric suction decreases further, the coefficient of permeability of coarse-grained material will increase rapidly and

finally exceeds that of fine-grained material. At this condition, there will be no barrier effect and water will flow easily into coarse-grained soil and the geobarrier system acts as a surface drainage that drains water in a direction parallel to the slope surface.

5 Material selection is very important in the design of geobarrier system. The four parameters that need to be considered in the selection of the fine- and coarse-grained materials, which are: ratio of the water-entry value of fine- and coarse grained materials (ψ_w -ratio); the saturated coefficient of permeability (k_s) of fine-grained material; the water-entry value (ψ_w) of coarse-grained material; and
10 the shrinkage properties of the materials. These four parameters affect the hydraulic properties of the first and/or second material either individually or in combination with one, two or all of the other parameters.

 The water-entry value of coarse-grained material (the second material) needs to be very low (preferably less than 1 kPa) (i.e., gravel, coarse recycled
15 concrete aggregate and coarse recycled asphalt with particle size larger than 10mm). It is observed that the coarser and the more uniform a material is, the lower the water-entry value is. The ψ_w -ratio of the first material to the second material needs to be large, say, at least 10 (i.e., fine sand-gravel with the ψ_w -ratio of 11.5). The saturated coefficient of permeability of the fine-grained material (first
20 material) should not be too low, say, more than 10^{-5} m/s (i.e., fine sand, fine recycled concrete aggregate and fine recycled asphalt). The reasons for this requirement is for obtaining a good drainage type of fine-grained material, hence water can easily flow into and out from the geobarrier system. The first and second materials should not exhibit shrinkage cracks on drying (shrinkage
25 potential less than 4% is preferred). In various embodiments the second material has a saturated coefficient of permeability at least 10 times less than the saturated coefficient of permeability of the first material. As a rough guide when the particle size of the second material is at least 5 times larger than the particle size of the first material then the saturated coefficient of permeability of the second material
30 is potentially at least 10 times less than the saturated coefficient of permeability of the first material.

In various embodiments the first portion 61 of the anchorage mechanism or anchorage tail 60 comprises a larger surface area than the second portion 65 of the anchorage mechanism or anchorage tail 60. The difference in surface area allows the volume of the first material to be greater than the volume of the second material that may take a large amount of time under heavy rainfall for the first material to become saturated and minimizing the infiltration of rainwater into the slope.

An example of various embodiments of the unit 3 of the geobarrier system is depicted in Figure 6. Whereby the base of the first bag 1 is attached to an anchorage mechanism or anchorage tail 60. The anchorage mechanism or anchorage tail 60 is marked to demarcate a first portion 61 where the second bag 5 may be placed; a second portion 65 where a second material may be placed and a third portion 68.

By having a unit 3 with compartments of bags 1 and 5 and the structure of an anchorage tail 60 it is possible to facilitate or form a capillary barrier structure at the interface of the first material and the second material on a steep slope without the slope collapsing. A person skilled in the art would be aware of how to determine a materials hydraulic properties such as the volumetric water content, the water entry value ψ_w the matric suction, shrinkage properties and the saturated coefficient of permeability and hence could choose the correct type, volume and ratio of the first material and second material to be used to ensure that a capillary barrier forms between the first material and the second material to minimize the infiltration of rainwater into the slope. As a rough guide when the particle size of the second material is at least 5 times larger than the particle size of the first material then a capillary barrier forms between the first material and the second material to minimize the infiltration of rainwater into the slope..

In various embodiments the anchorage tail is detachably attached to the base of the first bag. The bag described above is used as a component of the unit 3 of the geobarrier system.

In various embodiments the opening of the first bag 1 comprises a securing means to close the bag and prevent the plant growing medium from leaking from

the bag, wherein said securing means comprises a drawstring 50 to restrict the opening around the plant in a closed position.

In various embodiments the first bag 1 comprises a plurality of openings 30 each comprising a cover 40 that overlaps said opening 30. The bag described
5 above is used as a component of the unit 3 of the geobarrier system.

In various embodiments the first bag 1 further comprises a stiffener 48. The bag described above is used as a component of the unit 3 of the geobarrier system.

In various embodiments the second material comprises a coarse grain
10 material. Material with a particle size of about 1 mm to about 80 mm may be considered a coarse grain material. In various embodiments the second material comprises a particle size of about 5 mm to about 80 mm, about 10 mm to about 70 mm, or about 20 mm to about 60 mm.

In various embodiments the first material comprises a fine grain material.
15 Material with a particle size of about 5 mm or less may be considered a fine grain material. In various embodiments the first material comprises a particle size of about 4 mm or less, about 2 mm or less or about 1 mm or less. In various embodiments the ratio of the particle size of the first material to the particle size of the second material may be 1:5, or 1:6, or 1:7, or, 1:8, or 1:9, or 1:10, or 1:11, or
20 1:12, or 1:13, or 1:14, or 1:15, 1:16 provided a capillary barrier forms between the first material and the second material to minimize infiltration of rainwater into the slope.

In various embodiments the first and second material are formed of the same or similar chemical components and differ from one another in structural
25 granular size. For example the material may be recycled concrete aggregates (RCA) whereby the RCA are ground to different granular sizes whereby the first material comprises a particle size of about 5 mm or less and the second material comprises a particle size of about 1 mm to about 80 mm. Another example is the use of reclaimed asphalt whereby the reclaimed asphalt are ground to different
30 granular sizes whereby the first material comprises a particle size of about 5 mm or less and the second material comprises a particle size of about 1 mm to about

80 mm. Using recycled material such as concrete or reclaimed asphalt is environmentally advantageous as it does not use limited resources and reuses already existing waste products.

In various other embodiments the first and second material may comprise different chemical components provided the coefficient of permeability of the second material is at least 10 times less than the coefficient of permeability of the first material. In various embodiments the first material comprises sand and second material comprises gravel with a particle size of at least 5 times larger than the sand particles of the first material.

In various embodiments the unit further comprises a third portion of the anchorage tail 60 of the first bag 1 wherein the third portion 68 is about half the length of the anchorage tail 60 for placing a third material comprising compacted soil.

In various embodiments the geobarrier system further comprises a perforated pipe 20 for the collection and diversion of rainwater away from the system. In various embodiments the perforated pipe is located at the base of the slope under the different components of each unit 3 when a geobarrier is erected or installed. Examples of such an embodiment is depicted in Figure 1B and Figure 9. In various other embodiments the pipe may be corrugated to minimise any large particles blocking the perforations.

In various embodiments the geobarrier system further comprises a plurality of units 3 that may be placed side by side and/or stacked on top of each other when containing plant growing medium, first material, second material and compacted soil in use, whereby a unit 3 stacked on top of another unit 3 is offset wherein a first bag 1 of the unit on top 3a sits over a join where the first bag 1 is adjacent to the second bag 5 of the other unit 3 below 3b.

Based on the modular structure of the units 3 it is possible to form a geobarrier of any shape to fit a wide variety of situational needs. For example where the units are arranged adjacent to one another in a straight line as depicted in Figure 7A the resulting geobarrier will be substantially straight. Similarly where

the units are arranged adjacent to one another at a slightly offset angle as depicted in Figure 7B then the resulting geobarrier will be substantially curvilinear.

Referring to Figure 8 it can be seen that when the units are stacked on top of each other containing plant growing medium 13, first material 15, second material 17 and compacted soil 10 or gravel and a next unit 3 stacked on top of the unit is offset like bricks as depicted in Figure 1A wherein a first bag of the unit on top sits over a join where the first bag is adjacent to the second bag of the other unit below and/or the unit on top sits over a join where the first bag is adjacent to a first bag of the adjacent unit this provides an increased structural integrity.

The described arrangement provides for a geobarrier system that is especially suited, but not limited to retain a slope having any incline up to almost vertical (i.e. 90 degrees) with respect to a horizontal surface. It is to be appreciated that the combination of the anchorage mechanism, arrangement of the first and second bags filled with different materials of differing permeability provides for a stable slope retaining structure or system that may be maintained in heavy rainfall.

In various embodiments the geo barrier system comprises a plurality of layers, each layer comprising a first geobag containing a soil mix suitable for growing a plant, the bag having an opening for accommodating the plant and the opening comprising a cover that overlaps the opening and the cover being able to direct the direction of growth of the plant, and a second geobag containing a concrete aggregate placed adjacent to the first geobag, and the second geobag is sited on a tendon of the first geobag.

Another aspect of the present invention, relates to a method of constructing a geobarrier for retaining a slope, comprising the steps of:

forming a first layer by placing an anchorage mechanism attached to a base of a first bag 1 at the base of a slope;

filling the first bag 1 with a plant growing medium, the first bag having an opening 30 for accommodating a plant and said opening comprising a cover 40 that overlaps said opening 30 and the cover being positionable to direct the direction of growth of the plant;

placing a second bag 5 on a first portion 61 of the anchorage mechanism adjacent to the first bag 1;

filling the second bag 5 with first material 15;

placing a second material 17 comprising a contrasting hydraulic property to the first material on a second portion 65 of the anchorage mechanism;

placing compacted soil on a third portion 68 of the anchorage mechanism; and

forming a second or subsequent layer on top of the first or below layer wherein a first bag of the second or subsequent layer sits over a join where the first bag is adjacent to the second bag of the first or below layer.

In various embodiments the first layer is formed by placing a plurality of units 3 side by side wherein each unit 3 is adjacent to each next unit 3 and each unit 3 comprises a first bag 1 attached to an anchorage mechanism or anchorage tail 60 at a base of the first bag 1 and a second bag 5 placed on a first portion 61 of the anchorage mechanism or anchorage tail 60; filling each of the first bags 1 with the plant growing medium 13, filling each of the second bags 5 with the first material 15, placing the second material 17 on each of the second portions 65, placing compacted soil 10 on each of the third portions 68; placing a second layer on top of the first layer wherein the second layer comprises a plurality of units side by side on top and inset to the first layer such that each first bag of the second layer sits over a join where the first bag is adjacent to the second bag of the first layer and/or the unit on top sits over a join where the first bag is adjacent to a first bag of the adjacent unit.

Referring to Figures 7 and 8 it can be seen that when the units 3b are laid out at the base of the slope with the first bag 1 facing away from the base and the anchorage tail 60 being stretched out along the base into the slope. Each of the first bags are filled with the plant growing medium 13, then each of the second bags are filled with the first material 15, the second material 17 is placed on each of the second portion 65 of the anchorage tail 60 and compacted soil is placed on each of the third portion 68 of the anchorage tail 60. This results in a first layer at the base of the slope with defined compartments of plant growing medium 13 at

the front of the slope, first material 15 behind the plant growing medium in the slope, second material 17 behind the first material further into the slope and compacted soil 10 or gravel at the back of the base of the slope. Referring to Figure 8 a second layer is formed on the first layer by stacked units 3a on top and inset to the first layer. The second layer formed in the same way as the first layer with each compartment of each unit containing plant growing medium 13, first material 15, second material 17 and compacted soil 10. A third, fourth, fifth, sixth, seventh, eighth, or subsequent layer can be formed in the same way with a next unit stacked on top of the unit is offset like bricks as depicted in Figure 1A wherein a first bag of the unit on top sits over a join where the first bag is adjacent to the second bag of the other unit below and/or the unit on top sits over a join where the first bag is adjacent to a first bag of the adjacent unit this provides an increased structural integrity.

In various embodiments a plant is secured in the opening. This may be achieved by the shape of the cover and/or by a drawstring or other means of tethering the plant to the cover. Any plants may be suitable that are known to grow root systems of a slightly smaller volume than the volume capacity of the bag. Examples of plants used in an experimental trial geobarrier include *Russelia equisetiformis*, *Xiphidium caeruleum*, *Epipremnum aureum*, *Calathea loeseneri*, *Phyllanthus cochinchinensis*, *Wedelia trilobata*, *Philodendron erubescens*, *Piper sarmentosum*, *Hymenocallis speciose*, *Ophiopogon jaburan Vittatus*, *Nephrolepis exaltata*, *Davallia denticulate*, *Pandanus pygmaeus*, *Asplenium nidus*, *Philodendron Xanadu* and *Monstera deliciosa*, however, any plants that are known to grow in the region and light conditions of the location where the geobarrier is erected would be suitable provided the root systems of the plants can grow to a slightly smaller volume than the volume capacity of the bag.

In various embodiments each anchorage tail 60 is detachably attached to the base of each first bag 1. In various embodiments the method further comprises replacing a first bag 1 with another first bag as described above. Filing the replaced first bag 1 with a plant growing medium removing the scaffold and securing a plant in an opening 30 of the replaced first bag 1.

In various embodiments the opening 30 of the first bag 1 comprises a securing means 50 to close the bag and prevent the plant growing medium from leaking from the bag, wherein said securing means comprises a drawstring to restrict the opening around the plant in a closed position.

5 In various embodiments the first bag 1 comprises a plurality of openings 30 each comprising a cover 40 that overlaps said opening 30 wherein a plant is secured in each opening as described above.

In various embodiments each first bag further comprises a stiffener 48 as described above.

10 In various embodiments the second material 17 comprises a coarse grain material as described above.

In various embodiments the first material 15 comprises a fine grain material as described above.

15 In various embodiments a perforated pipe 20 for the collection and diversion of rainwater away from the system is placed at the base of the slope.

In various embodiments an impermeable separator 11, 12 capable of separating rainwater is placed between each of the second material 17 and the compacted soil 10.

20 A trial geobarrier was erected in experimental trials during several periods of heavy rainfall. Using earth pressure cells embedded within the compacted soil portion stable readings within the expected range were measured throughout the trial. Healthy plant growth was observed throughout the trial. The pore water pressure in kPa was maintained in all layers after rainwater event in comparison with a control, having bags filled with natural soil of the slope that had increased
25 pore water pressure in kPa after rainwater event in several layers.

In various embodiments, the geobarrier system has a coarse grain layer on top of each layer of geobags. And even further, the geobarrier system has a fine grain layer on top of the coarse grain layer.

30 In various embodiments, the geobarrier system has each layer having a third geobag containing a coarse grain aggregate. Further in various embodiments, the geobarrier has a gravel layer and even further, in various embodiments, the

geobarrier has a perforated pipe sited within the gravel layer for the collection and diversion of rainwater away from the system.

In various embodiments the method of constructing a geobarrier system comprising the steps of forming a first layer using a first geobag containing a soil mix suitable for growing a plant, the bag and having an opening for accommodating the plant and said opening comprising a cover that overlaps said opening and the cover being able to direct the direction of growth of the plant, and a second geobag containing a concrete aggregate placed adjacent to the first geobag, wherein said second geobag is sited on a tendon of the first geobag and covered with a layer coarse-grained material and forming a top layer using a fine-grain material.

Figure 1A provides an embodiment of a Geo Barrier System (GBS), which is a cover system designed to prevent slips and in particular, designed to protect the slope against rainfall-induced failure. It can be seen that the GBS has several layers, and in particular three layers, starting with a top layer having of plant growing medium 13 of an approved soil mix (ASM) enclosed in a geotextile bag 1 with vegetation planted. a second layer comprising fine-grained material 15, for example fine recycled concrete aggregates (RCA), enclosed in a geotextile bag 2, and a third layer comprising coarse-grained material 17, for example coarse recycled concrete aggregates, and this coarse-grained material can be enclosed in a geotextile bag. Further details on the geotextile bag are disclosed later in the specification. This ASM can have the following proportions in terms of volume: 50% top soil, 20% sand, 15% soil conditioner, 15% organic compost. Additional components such as water retention gel can also be added if needed. The top soil can be a free draining soil and may be free of grass or weed growth or any other foreign matter. Top soil is a fertile friable soil that is non-toxic and is capable of sustaining healthy plant growth, thus it is typically free from calcium carbonate, subsoil, refuse, roots, clods, phytotoxic materials and other substances detrimental to plant growth. This top soil typically has pH value of between 5.5 to 7.8 with electrical conductivity not exceeding 1500 microSiemens/cm, and a soil-water extract ratio of 1:2.5. The top soil components include: sand, particle size of

0.05 to 2mm and proportion of 20%-75%; silt, particle size of 0.002 to 0.05mm and proportion of 5%-60%; and clay, particle size of less than 0.002mm and proportion of 5%-30%. The sand used in the ASM should be free of debris, stones or foreign material. The soil conditioner can be peat moss, organic compost or any other fibrous organic matter suitable for mixing with top soil to create a friable growing medium for plants. The soil conditioner should also be resistant to rapid decay and free of large lumps or debris. The organic compost used in the ASM can be derived from organic vegetables or part of vegetables, for example the leaves, and is produced by a horticultural or industrial composting process. The organic compost used should be fine and friable, free from rotting or decaying substances, refuse, clay, visible fungus, pathogens, pests, etc, and can be free of obnoxious odours.

The second layer 5 has of fine-grained material 15, for example fine recycled concrete aggregates (RCA), sand, sandy silt or clayey silt enclosed in a second geotextile bag.

The GBS can also have a third layer that comprising of coarse-grained material, for example coarse recycled concrete aggregates, gravel or granite chips and it can be enclosed in a geotextile bag or it can be spread over the first and second layers and/or compacted soil. The coarse grain aggregate can be contained in a third geobag if the soil condition is very poor. Otherwise the coarse grains are usually not contained within geobag

The geotextile bags can be arranged in various ways and these are described in detail later in the specification.

During a rainfall event, some amount of water is expected to infiltrate into the fine RCA layer and the coarse RCA layer before discharging into the gravel layer 10 located at the base of the slope and collected in the corrugated and perforated pipes. An impermeable separator can be installed within the gravel layer 10 that will separate the water discharged from fine RCA and the water discharged from coarse RCA. This impermeable separator can be a High Density Polyethylene (HDPE) sheet and a typical thickness used is 1-2mm. This HDPE sheet can be installed along the rest of the slope and separate the original soil of the slope from

the GBS across the width of the slope. This HDPE sheet can also be installed along the either or both sides of the GBS, as well as within the gravel layer 10 at the bottom of the slope. It is installed in a way such that water discharging from the coarse RCA is separated from the fine RCA.

5 The GBS at the bottom of the slope ends with corrugated and perforated pipe 120 before the drains that are typically constructed at the base of the slope as shown in detail in Figure 1B. The corrugated and perforated drainage pipe 120 can have an internal diameter of 120mm and can be perforated all the way around the outer surface of the pipe, or only the upper half of the corrugated pipe is
10 perforated. This corrugated and perforated pipe 20 would allow water discharged from the fine RCA layer to be directed to a single outlet for each slope.

 The GBS enables greater variety of plants to be grown in the geobags (that contained Approved Soil Mix) while minimizing soil losses, and at the same time it can achieve higher factor of safety by using the inherent properties of the soil and
15 the combination of Fine Recycled Concrete Aggregates (RCA), Coarse Recycled Concrete Aggregates, Approved Soil Mix and Compacted Fill. The planting pockets and sleeves can be designed (made bigger or smaller etc.) to suit the type of plants intended for planting.

 The size of the geobags used in the system would depend on the types of
20 plants required. These plants are selected for their ability to contribute to the stability of the soil or for aesthetic purposes. For example, the geobag can be sized at 1.5m in length to allow bigger plants to be grown (as they require bigger soil media volume). This is especially important when larger plants such as shrubs, ferns and small trees are required, particularly to achieve steeper slopes.
25 The geobags also enables the aggregates and soil mix to be contained within the bags and prevents migration of the finer soil into the aggregate layers below.

 The GBS also allows ease of compaction as the fine grain aggregates and soil mix are contained within the bags. The geobags can also be installed with sealable openings by using ties or zips 45 of industrial quality which would enable
30 the geobag to be filled up or topped up with soil mix, nutrients, fertilizer or even changing of the plants entirely.

The Approved Soil Mix and Fine Recycled Concrete Aggregates are contained in geobags and the geobags can be stacked at a steeper angle than current methods like CBS. It allows greater variety of plantings, including fern and shrub type of plants on GeoBarrier System.

5 Prior to the installation of geobags, the base of the slope or the GBS is compacted and filled with gravels to form the gravel layer 10. After which, the slope is covered with compacted fill and coarse recycled concrete aggregates. The first and second geobags for Approved Soil Mix and fine RCA respectively will then be stacked up. This will allow the GBS to be curvilinear, as well as form tight
10 corners.

An example of the geobag 1 can be seen in Figure 2A and 2B, which shows the top or side view and front view respectively. The geobag 1 can contain the approved soil mix (ASM) and be used for the GBS, especially where plants are required. The geobag 1 has an opening 30 covered with a planting sleeve 40 that
15 provides for a plant to reside within, such that the plant is able to grow using the nutrients of the ASM, while forming part of the vegetative cover for the GBS. The geobag 1 can be placed such that the opening is on the top or any of the sides, depending on the requirement of the plant and the slope. The size of the opening is designed to be large enough to accommodate the root balls of the required
20 plant or plants and would be able to support the stem of the plant and direct it to grow in a particular direction. In order to minimize soil loss from the geobag 1, the sleeve 40 can be fitted with a drawstring 50, although other types of securing means such as zip ties, zips, sewing, staples etc can also be used. To aid in recognition, the securing means may be of a different or contrasting colour from
25 the geobag. The drawstring can be pulled and tied to reduce the size of the opening on geobag, which would minimize soil loss without affecting plant growth. The geobag is also shown with stitching 55 at the peripheral of the opening that reinforces the opening and renders easier for a user to use the drawstring without ripping the geobag 1. The geobag 1 is also shown with a reinforcement geogrid
30 60 attached to the base. This geogrid 60 acts as an anchorage tail for the geobag 1 and can comprise of high tenacity polyester yarn fibres that is of sufficiently high

quality with a design life of 120 years. It should have a typical tensile strength of 12kN/m @ 2% strain and 30kN/m @ 5% strain. This geogrid 60 can be attached for geobags 1 with ASM or RCA or both.

5 The geobag 1 can have lifting straps 35 that would aid in the moving, lifting or shifting of the geobag, especially when it is filled with ASM or RCA.

The geobag 1 can also be designed with multiple specially designed loops or handles 35 sewn along the top edges of the bags. This allows the geobag to be kept horizontal while lifting which is important as it keeps the compaction of the aggregates within the geobag uniform and prevent tension cracks. The loops has
10 to be designed to take the weight of the geobag to prevent rupture of loop per se and tearing of the geobag.

The material used for the manufacture of the geobags 1 is made of a woven monofilament fiber weaved to form a stable matrix with high water flow and optimum opening size for soil retention. The material for the geobag 1 should also
15 have wide width tensile strength for main direction and cross direction that is greater or equal to 50kN/m (tested according to ISO 10319 standard). The material has a California Bearing Ratio (CBR) puncture strength of greater than or equal to 5.0kN (tested according to ISO 12236 standard). The material has pore size of O90, which is less than or equal to 600 microns (tested according to ISO
20 12956 standard). This material has water permeability greater than or equal to 200L/m²/s (tested according to ISO11058 standard).

Another example of a geobag 1 is shown in Figures 3A and 3B, which shows the side view and front view respectively. The geobag 1 can contain the approved soil mix (ASM) and be used for the GBS, especially where plants are required.
25 This design is particularly useful where the plants need to be upright while maintaining an opening on the side of the geobag 1 as the planting pocket 40 ensures that the plant is able to absorb the nutrients of the ASM within the geobag 1, yet grow substantially vertically with the angle of the plant being dependent the leeway of the pocket. The other advantage of the pocket is that the soil loss can
30 be further minimized as the ASM is contained within the pocket itself. Similar to the geobag in Figure 2, this geobag 1 can also be installed with lifting straps 35 to

aid in moving of the geobag 1, as well as specially designed loops sewn along the top edges of the bags.

For both example of geobag 1, the opening could be used either on the side or at the top of the bag. Generally it would be more suitable to be implemented at the top if the slope is gentler and there's space on top. The pocket would be more suitable for steeper slopes where there's no space to plant at the top of the bags and hence had to be planted at the side.

A cross section diagram of the geobarrier 90 is shown in Figure 9. The gravel layer or compacted soil 10 sits at the base of the slope or the GBS and contains an impermeable separator 11. There is also another impermeable separator 12 at the back of the slope which sits before the surface drain 25. There are also a surface drain 6 at the top of the slope and a surface drain 7 at the bottom of the slope. A planting media with turfing 70 provides cover over the GBS at the top or head of the slope, followed by a fine grain RCA 15 and then a coarse grain RCA 17 with a geofabric layer 80 in between the layers. A series of corrugated and perforated pipes 21, 22, 23, 24 are situated to allow water discharged from the fine RCA layer to be directed to a single outlet. In this example, a geobag 1 with ASM 13 with its anchorage tail 60 is shown with a shrub contained within the bag via either the opening or the pocket 40. It can be seen how the roots of the plant would grow into the ASM 13 and provide stability to the GBS. A second geobag 5 with fine RCA 15 is shown next to this, which can help secure the structure and provide stability to the slope.

In terms of constructing the GBS, the surface drains 6, 7 are first installed at the top and bottom of the slope and the corrugated and perforated pipes 21, 22, 23, 24 are then sited together with the gravel layer 10 and the impermeable separators 11, 12. Building from the bottom layer upwards, the geobags 1, 5 are filled with the required material and sited, with the anchorage tail or tendon 60 of the geobag 1 installed in layers in the compacted soil. The geofabric layers 80 are installed between the coarse RCA 17 and fine RCA 15, as well between the fine RCA 15 and the planting media for turfing 70.

The first and second geobags 1 and 5 are filled with the requisite material, in this case ASM 13 and RCA 15. The second geobag 5 with RCA 15 should be compacted to a relative density of between 70% to 90% or a required dry density of 1.55Mg/m^3 . The geobags 1 and 5 are then closed up and secured, either via
5 the drawstring or by sewing to minimize the materials within the geobags from being washed away by rainwater. The coarse RCA layer 17 is compacted to a relative density of between 70% to 90% or to the required dry density of 1.8Mg/m^3 . The geofabric layer 80 can be polyfelt TS nonwoven geotextiles TS20 or equivalent.

10 This GBS system is suitable for slopes with angles up to 80 degrees and can be constructed with varying heights (3m to 50m), particularly with terraced slopes for slopes exceeding 30m. The ground water seepage is controlled by the surface drains and the completed structure when vegetated blends easily with the environment.

15 In comparison, CBS requires a plurality of J-pins to anchor the geocells to the slope surface resulting in puncturing of the separating membrane and hence losing some of the matric suctions overtime. With the GBS, J-pins are not required as there are tendons on the geobags to act as the reinforcement anchorage and the contained compartmentalisation of different materials allows the concept of a
20 capillary barrier system to operate on a steep slope further adding to the stability by preventing water damage to the slope that can lead to slippage.

A further example of the method of constructing the GBS is listed in the following steps:

A. Placement of a first geotextile bag 1 for ASM at the bottom of slope, fill
25 geotextile bag with ASM 13, place and stretch geogrid 60 attached to geotextile bag row 1 up to the maximum length.

B. Placement of a second geotextile bag 5 for fine RCA next to or adjacent to the first geotextile bag 1 at the bottom of slope with the second geotextile bag 5 being on the hillside of the first geotextile bag 1 (see
30 Figure 9), fill geotextile bag with fine RCA 15, compact fine RCA to the

required relative density or dry density, seal the geotextile bag when filling and compaction is completed.

- 5 C. Compact soil 10 a distance behind geotextile bags 1, 5, for example compact 1300mm length of soil behind geotextile bags 1, 5 to the same total density of the existing soil prior to the excavation of the slope, with the compacted soil 10 being trimmed into a slope angle of 45 degrees.
- D. Placement of coarse RCA 17 between compacted soil and behind geotextile bag 5 at the bottom of slope, compact coarse RCA 17 to the required relative density or dry density.
- 10 E. Placement of next row of units 3 consisting of geotextile bags on top of geotextile bags 1, 5 and repeat the same procedure in steps A to D until required height.
- F. Install impermeable separator at top of the slope.
- G. Placement of compacted soil 10 behind geotextile bags at the top of the slope, compacting the soil 1300mm length and 250mm height (half of the height of geotextile bag) of soil behind geotextile bags of the final rows 15 and 16 to the same total density of the existing soil as measured prior to the excavation of the slope. Trim the top level of this compacted soil into 1-2 degrees. Then trim the compacted soil into slope angle of 45 degrees.
- 20 H. Placement of coarse RCA 17 on top of compacted soil and in between compacted soil 10 and geotextile bags at the top of the slope, compact the coarse RCA 17 to the required relative density or dry density.
- I. Lay geofabric layer behind geotextile bag and on top of coarse RCA 17.
- 25 J. Placement of fine RCA 15 on top of geofabric layer and behind geotextile bag and compact fine RCA 15 to the required relative density or dry density, construct surface drain behind geotextile bag.
- K. Placement of planting media 13 with turfing 70 as specified above on top of geofabric layer and on top of geotextile bags, the turfing 70 being graded towards the surface drain 25.
- 30

L. Install impermeable separator at both sides of GeoBarrier System at slope.

M. Construct surface drain at the top, both sides²⁵ and 6 and bottom 7 of slope.

5 N. Construct surface drain to convey the water downstream (not shown).

Throughout this document, unless otherwise indicated to the contrary, the terms “comprising”, “consisting of”, and the like, are to be construed as non-exhaustive, or in other words, as meaning “including, but not limited to”.

10 Furthermore, although individual embodiments have been discussed it is to be understood that the invention covers combinations of the embodiments that have been discussed as well.

The invention described herein may include one or more range of values (e.g. height and diameter). A range of values will be understood to include all values within the range, including the values defining the range, and values
15 adjacent to the range which lead to the same or substantially the same outcome as the values immediately adjacent to that value which defines the boundary to the range.

Claims

1. A container for retaining a slope, comprising a bag capable of containing a plant growing medium, the bag having an opening for accommodating a plant, and the opening having securing means to seal the bag and prevent the plant growing medium from leaking from the bag,

wherein said opening further comprises a cover that overlaps said opening and the cover being positionable to direct the direction of growth of the plant.

2. The container of claim 1, further comprising an anchorage mechanism attached to a base of the bag, wherein said anchorage mechanism is capable of anchoring the bag on a slope.

3. The container of claim 2, wherein the anchorage mechanism is detachably attached to the base of the bag.

4. The container according any one of claims 1 to 3, wherein said securing means comprises a drawstring, wherein the drawstring would restrict the opening around the plant.

5. The container according any one of claims 1 to 4, wherein the bag comprises a plurality of openings each comprising a cover that overlaps said opening.

6. The container according to any one of claims 1-5, further comprising a stiffener.

7. A geobarrier system for retaining a slope, comprising a unit, the unit comprising a first bag capable of containing a plant growing medium, the first bag having an opening for accommodating a plant and said opening comprising a cover that overlaps said opening and the cover being able to direct the direction of growth of the plant, an anchorage mechanism attached to a base of the first bag;

a second bag capable of containing a first material, wherein said second bag locatable on a first portion of the anchorage mechanism adjacent to the first bag; and

5 a second portion of the anchorage mechanism capable of receiving a second material, wherein the second material comprises at least one hydraulic property contrasted with respect to at least one hydraulic property of first material to form a capillary barrier.

10 8. The geobarrier system according to claim 7, wherein the first portion of the anchorage mechanism comprises a larger surface area than the second portion of the anchorage mechanism.

15 9. The geobarrier system according to claim 7 or 8, wherein the anchorage mechanism is detachably attached to the base of the first bag.

10. The geobarrier system according to any one of claims 7 - 9, wherein the opening of the first bag comprises a securing means to close the bag and prevent the plant growing medium from leaking from the bag.

20 11. The geobarrier system according to any one of claims 7-10, wherein said securing means comprises a drawstring to restrict the opening around the plant in a closed position.

25 12. The geobarrier system according to any one of claims 7-11, wherein the first bag comprises a plurality of openings each comprising a cover that overlaps said opening.

13. The geobarrier system according to any one of claims 7-12, wherein the first bag further comprises a stiffener.

14. The geobarrier system according to any one of claims 7-13, wherein the second material comprises a coarse grain material.

15. The geobarrier system according to any one of claims 7-14, wherein
5 the first material comprises a fine grain material.

16. The geobarrier system according to any one of claims 7-15, further comprising a third portion of the anchorage mechanism wherein the third portion is half the length of the anchorage mechanism capable of receiving a third material
10 comprising compacted soil.

17. The geobarrier system according to any one of claims 7-16, further comprising a perforated pipe for the collection and diversion of rainwater away from the system.
15

18. The geobarrier system according to any one of claims 7-17, further comprising a plurality of units that may be placed side by side and/or stacked on top of each other when containing plant growing medium, first material, second material and compacted soil in use, whereby a unit stacked on top of another unit
20 is offset wherein a first bag of the unit on top sits over a join where the first bag is adjacent to the second bag of the other unit below.

19. A method of constructing a geobarrier for retaining a slope, comprising the steps of:

25 forming a first layer by placing an anchorage mechanism attached to a base of a first bag at the base of a slope;

filling the first bag with a plant growing medium, the first bag having an opening for accommodating a plant and said opening comprising a cover that overlaps said opening and the cover being positionable to direct the direction of
30 growth of the plant;

placing a second bag on a first portion of the anchorage mechanism adjacent to the first bag;

filling the second bag with first material;

5 placing a second material comprising a contrasting hydraulic property with respect to the first material on a second portion of the anchorage mechanism;

placing compacted soil on a third portion of the anchorage mechanism; and

forming a second or subsequent layer on top of the first or below layer wherein a first bag of the second or subsequent layer sits over a join where the first bag is adjacent to the second bag of the first or below layer.

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20. The method according to claim 19, wherein the first layer is formed by placing a plurality of units side by side wherein each unit is adjacent to each next unit and each unit comprises a first bag attached to an anchorage mechanism at a base of the first bag and a second bag placed on a first portion of the anchorage mechanism, filling each of the first bags with the plant growing medium, filling each of the second bags with the first material, placing the second material on each of the second portions, placing compacted soil on each of the third portions; placing a second layer on top of the first layer wherein the second layer comprises a plurality of units side by side on top and inset to the first layer such that each first bag of the second layer sits over a join where the first bag is adjacent to the second bag of the first layer and/or the unit on top sits over a join where the first bag is adjacent to a first bag of an adjacent unit.

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21. The method according to claim 19 or 20, wherein a plant is secured in the opening.

25

22. The method according to any one of claim 19-21, wherein each anchorage mechanism is detachably attached to the base of each first bag.

23. The method according to any one of claim 19-22, wherein the opening of the first bag comprises a securing means to close the bag and prevent

30

the plant growing medium from leaking from the first bag, wherein said securing means comprises a drawstring to restrict the opening around the plant in a closed position.

5 24. The method according to any one of claims 19-23, wherein the first bag comprises a plurality of openings each comprising a cover that overlaps said opening wherein a plant is secured in each opening.

10 25. The method according to any one of claims 19-24, wherein each first bag further comprises a stiffener.

 26. The method according to any one of claims 19-25, wherein the second material comprises a coarse grain material.

15 27. The method according to any one of claims 19-26, wherein the first material comprises a fine grain material.

20 28. The method according to any one of claims 19-27, wherein a perforated pipe for the collection and diversion of rainwater away from the system is placed at the base of the slope.

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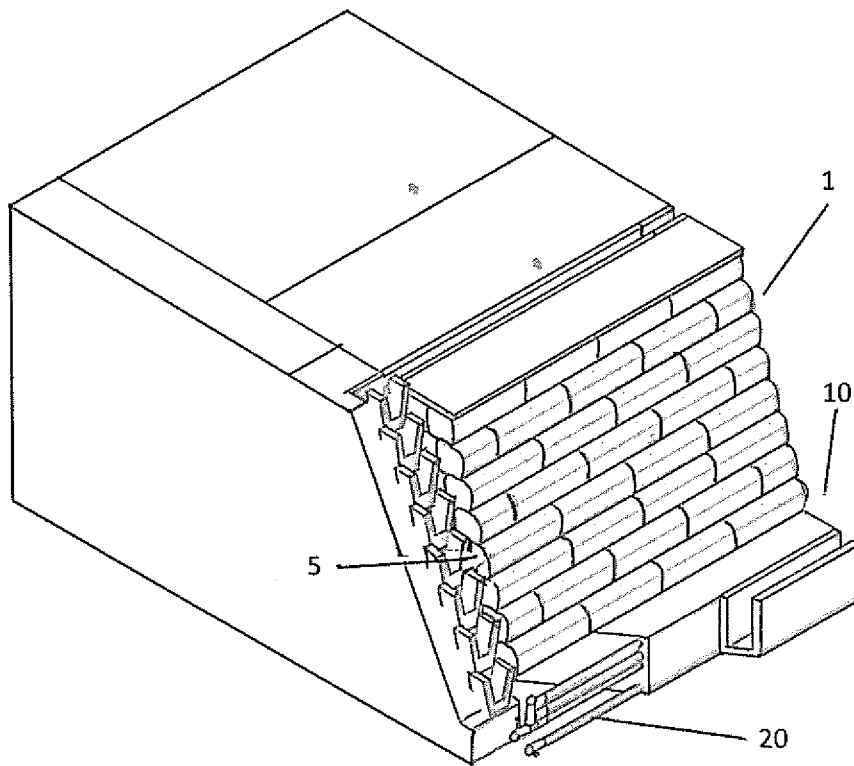


Figure 1A

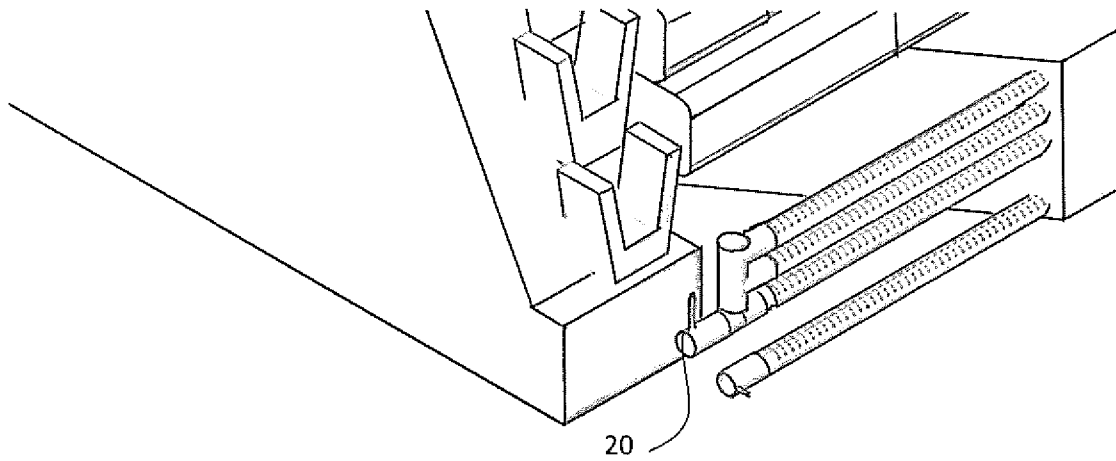


Figure 1B

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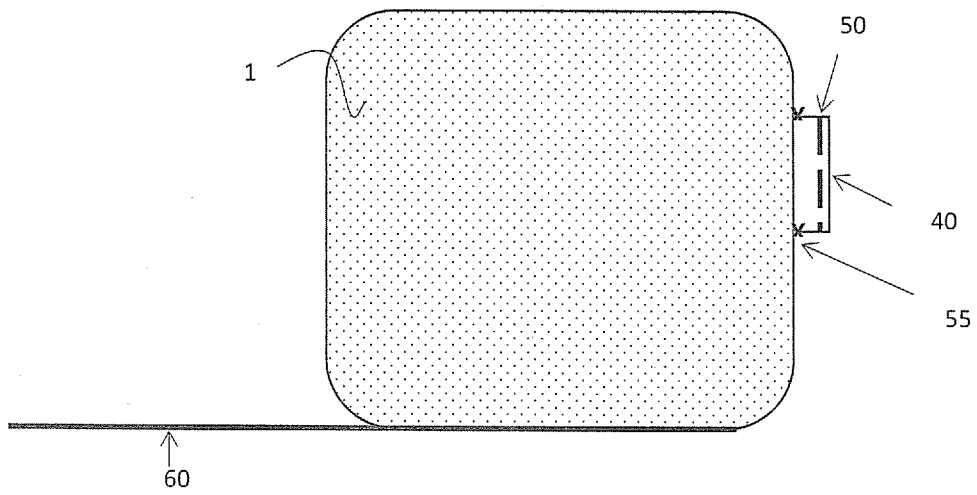


Figure 2A

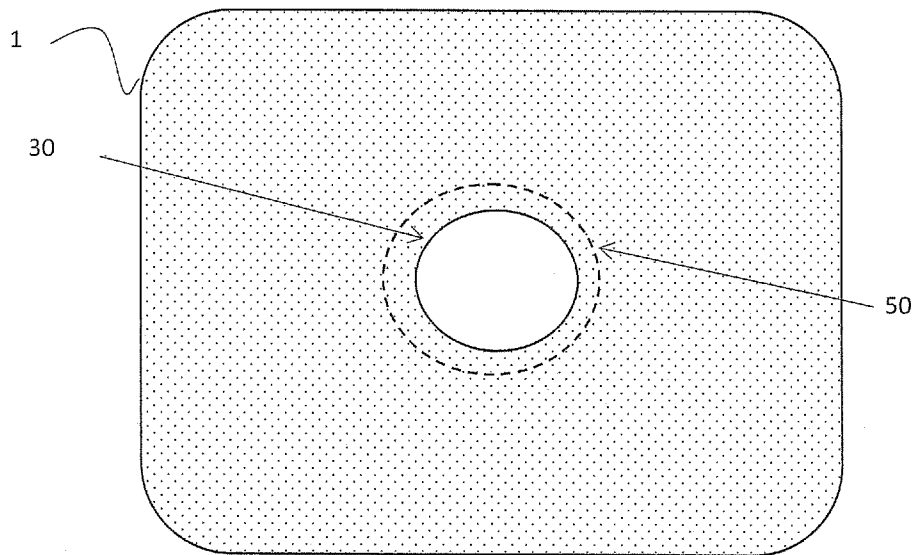


Figure 2B

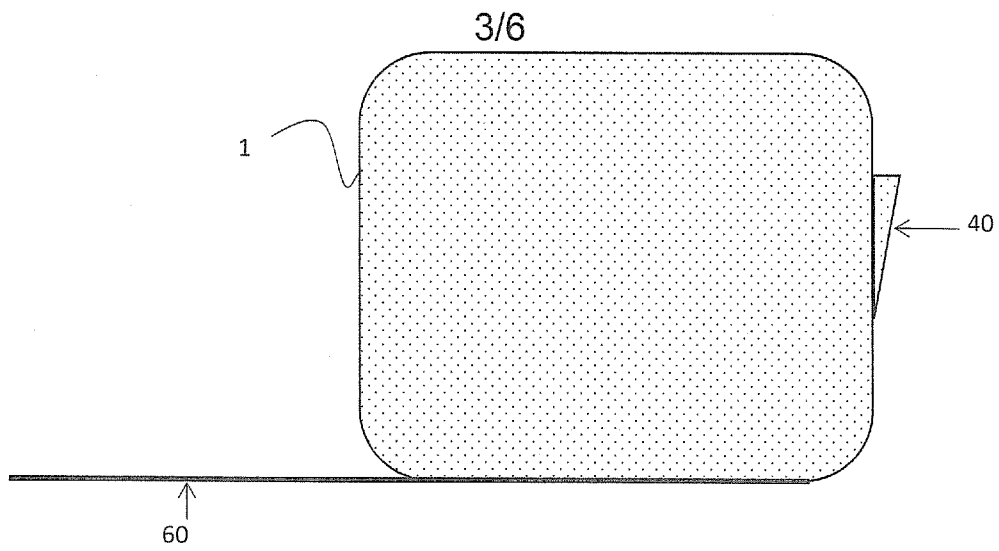


Figure 3A

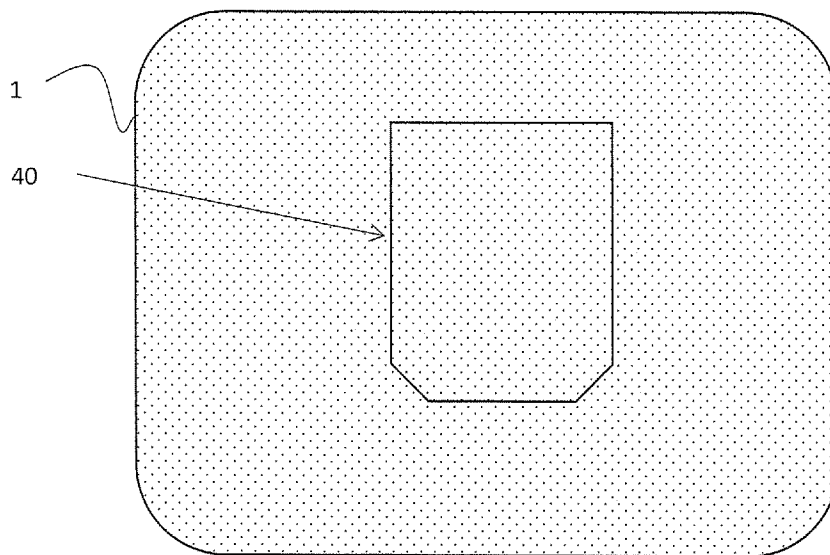


Figure 3B

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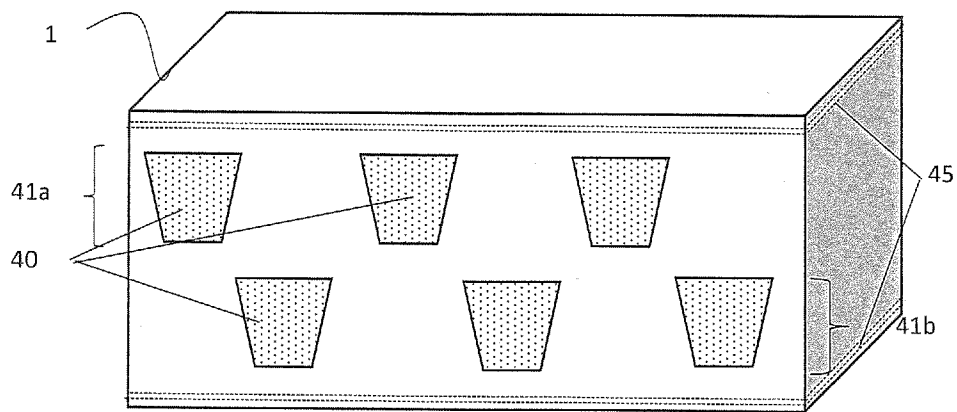


Figure 4

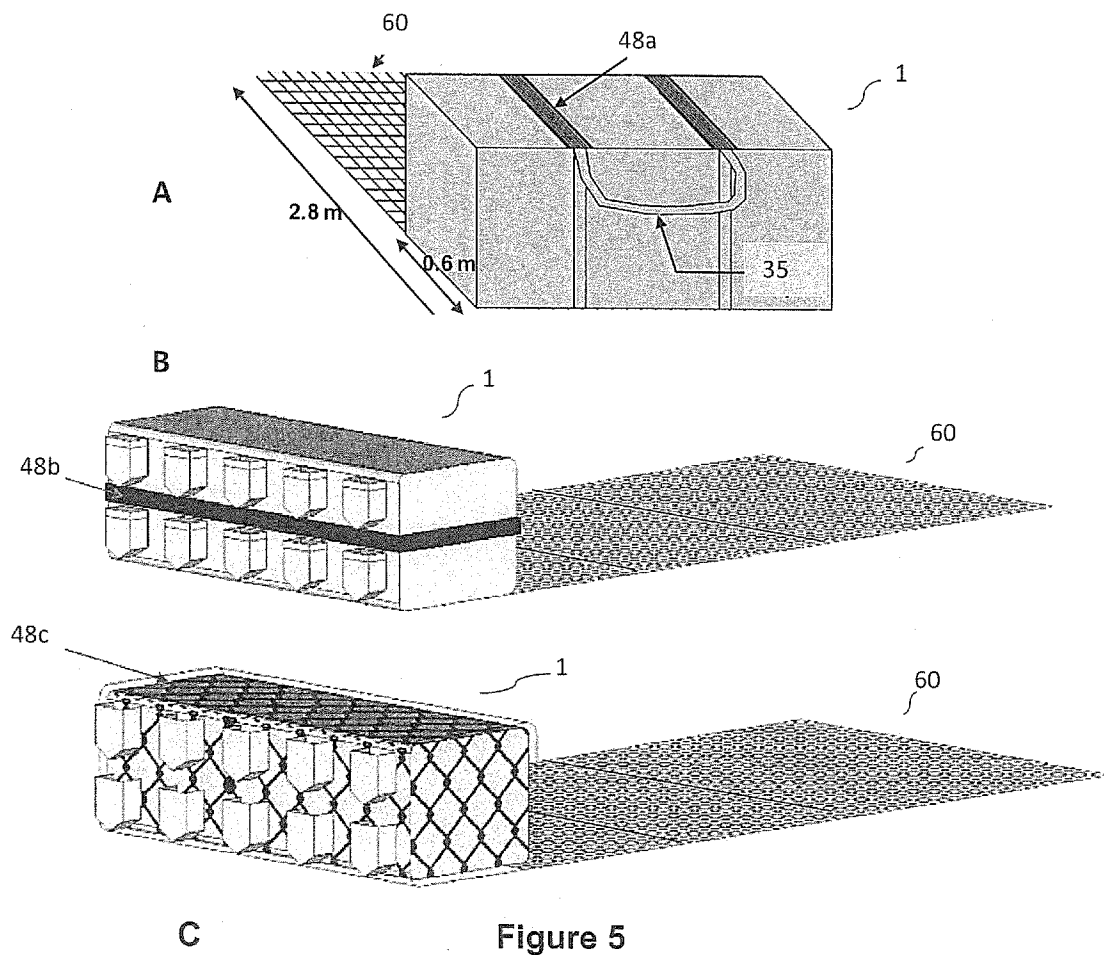


Figure 5

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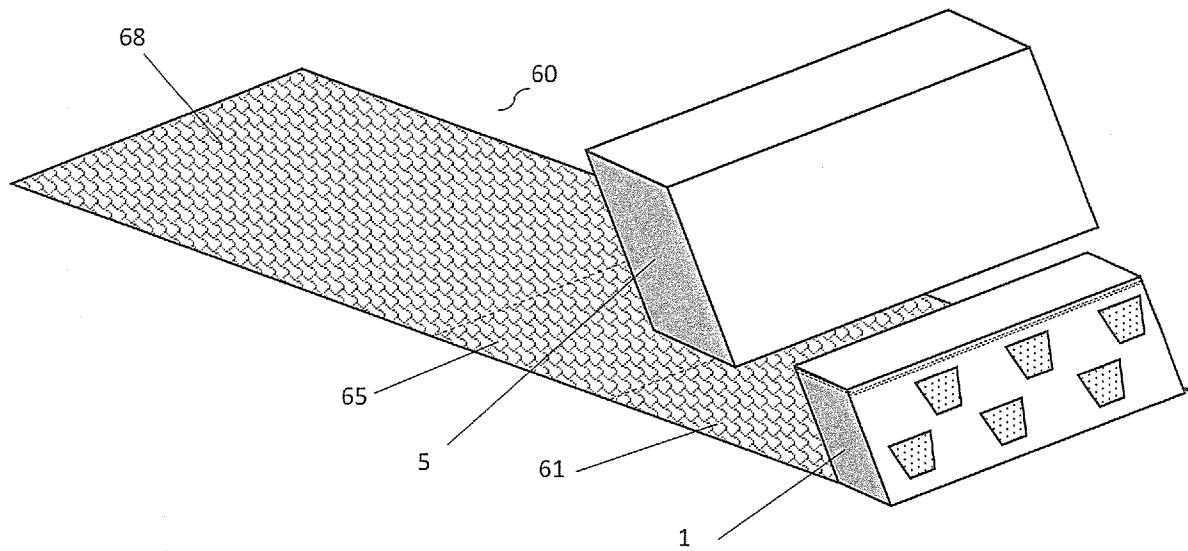


Figure 6

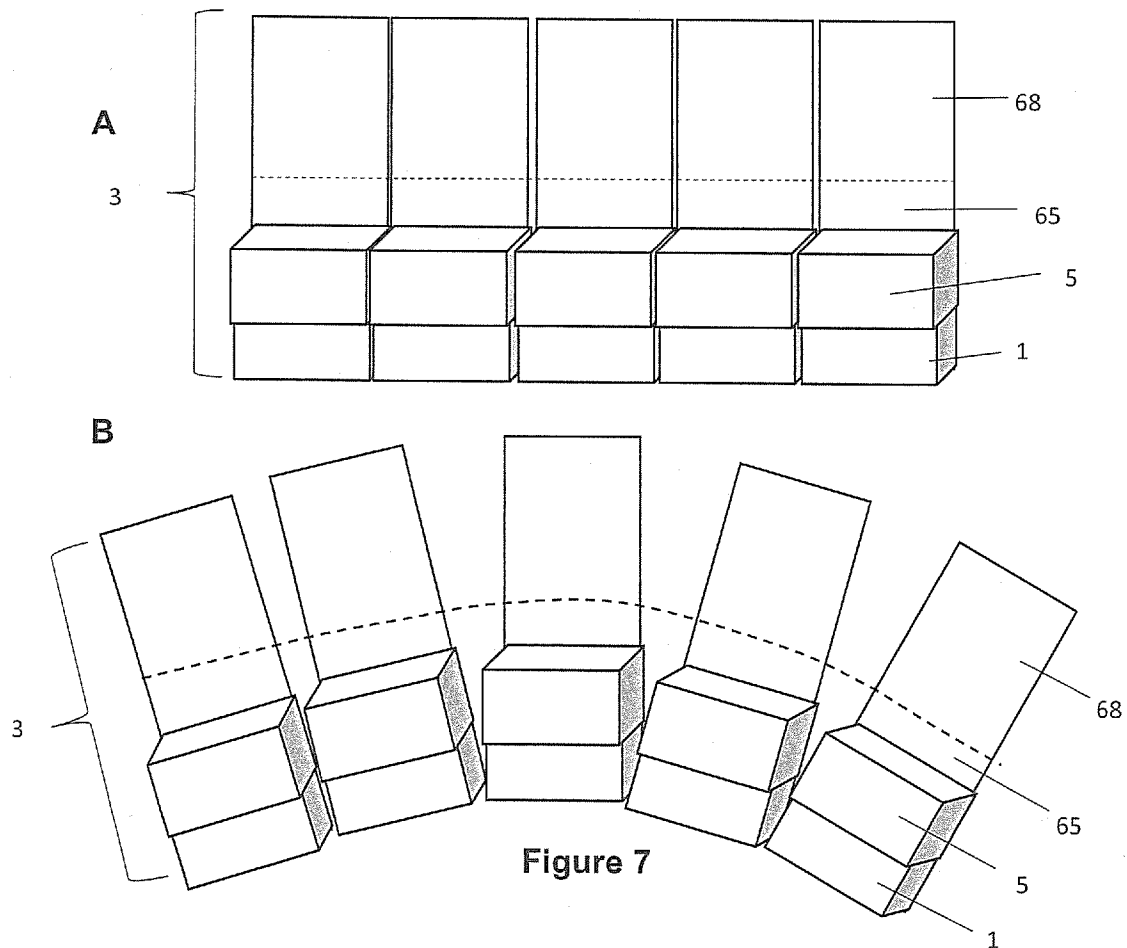


Figure 7

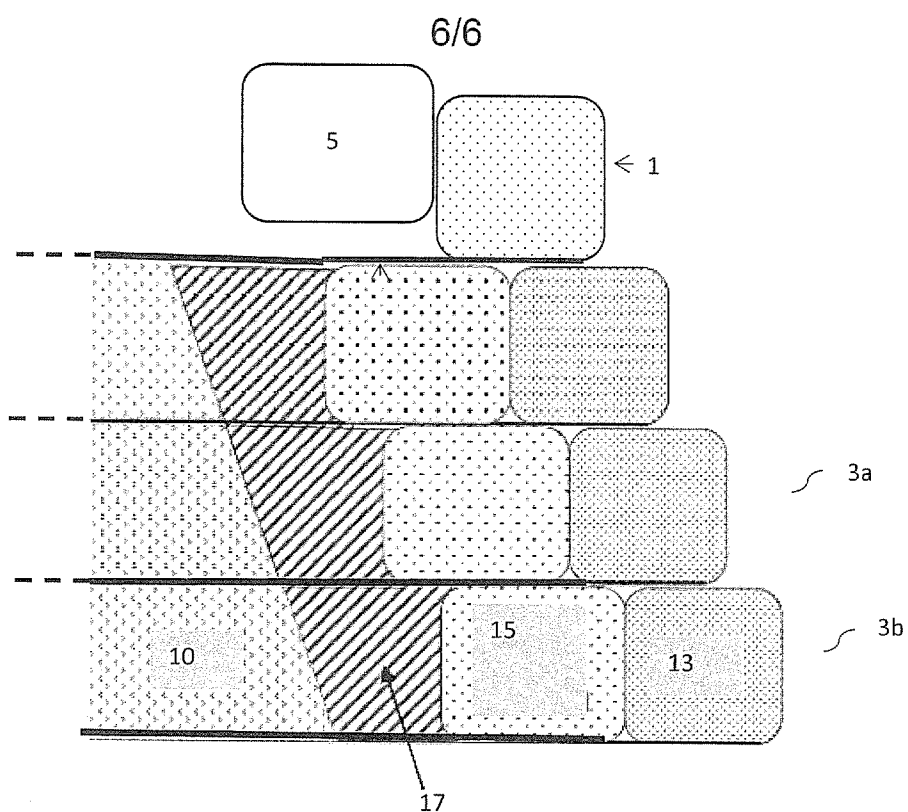


Figure 8

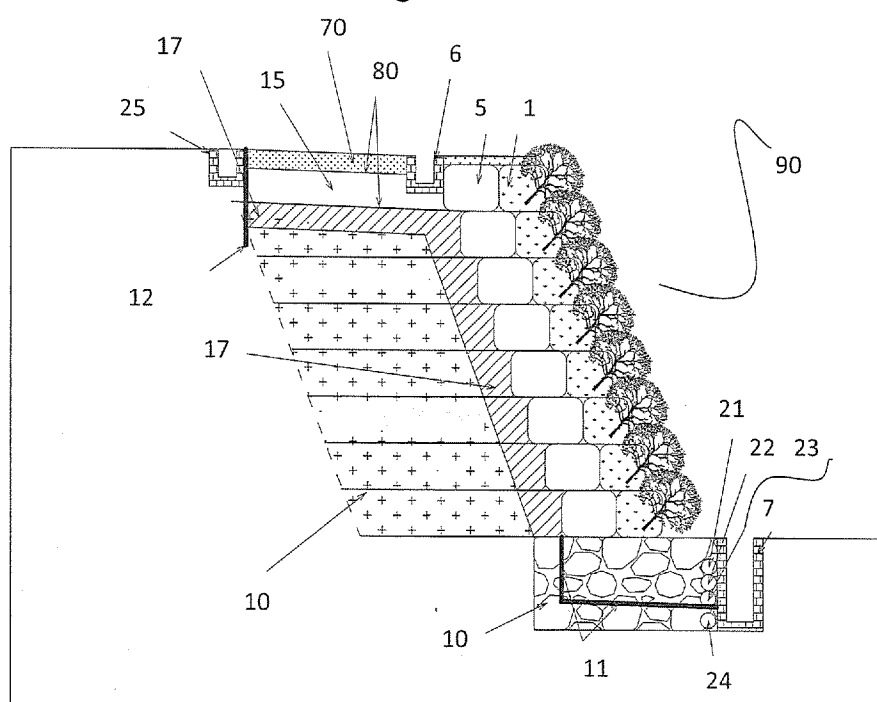


Figure 9

PATENT COOPERATION TREATY
PCT
INTERNATIONAL SEARCH REPORT
(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference YF2016P00434	FOR FURTHER ACTION See Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. PCT/SG2016/050470	International filing date (<i>day/month/year</i>) 23/09/2016	(Earliest) Priority Date (<i>day/month/year</i>) 25/09/2015
Applicant HOUSING AND DEVELOPMENT BOARD et al.		

This international search report has been prepared by this International Search Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purpose of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☐ the text is approved as submitted by the applicant.

☒ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 9

☐ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☒ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050470

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

The present invention relates to a bag, associated system and method for covering, retaining and/or stabilising a slope or embankment. The said bag has an opening for accommodating a plant, securing means to seal the bag, and a cover that overlaps the opening wherein the cover is positionable to direct the direction of growth of the plant. The said bag is utilised in the construction of a geobarrier system which comprises of a plurality of units placed side by side and/or stacked on top of each other wherein each unit comprises of an anchorage mechanism attached to a base of the said bag; a first portion of the anchorage mechanism adjacent to the said bag capable of receiving a second bag containing a first material; a second portion of the anchorage mechanism capable of receiving a second material, wherein the second material comprises at least one hydraulic property contrasted with respect to at least one hydraulic property of first material to form a capillary barrier, and a third portion of the anchorage mechanism capable of receiving a third material comprising compacted soil.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050470

A. CLASSIFICATION OF SUBJECT MATTER

E02D 17/20 (2006.01) A01G 9/00 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: E02D, A01G

F-term: 2D044

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT, Scopus: bag, container, plant, vegetation, shrub, cover, close, secure, seal, fasten, slope, embankment, landslide, capillary barrier system, anchor, and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001-090077 A (IBIDEN GREENTEC CO LTD) 3 April 2001 Abstract; paras. [0013]-[0014], [0017], [0045]-[0046]; figs. 1-2, 4, 6-7 of the machine translation	1-6
X	JP 2006-104861 A (DAITO TECHNO GREEN KK) 20 April 2006 Abstract; paras. [0036], [0051]; figs. 2, 6, 7 of the machine translation	1-6
A	CN 104532857 A (CHINA RAILWAY ERYUAN ENG GROUP) 22 April 2015 whole document of the machine translation	7-28
A	CN 204356788 U (CHINA RAILWAY ERYUAN ENG GROUP) 27 May 2015 whole document of the machine translation	7-28
A	JP H03-51426 A (KAJIMA CORP) 5 March 1991 whole document of the machine translation	7-28

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

25/11/2016

(day/month/year)

Date of mailing of the international search report

02/12/2016

(day/month/year)

Name and mailing address of the ISA/SG

IPOS Intellectual Property Office of Singapore
51 Bras Basah Road
#01-01 Manulife Centre
Singapore 189554

Email: pct@ipos.gov.sg

Authorized officer

Angelina Lim (Dr)

IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2016/050470

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP H07-247550 A (OYO KIKAKU:KK) 26 September 1995 whole document of the machine translation	7-28
A	KR 101463552 B1 (TAE HA CO LTD) 20 November 2014 whole document of the machine translation	7-28
A	RAHARDJO H. ET AL., Unsaturated Soil Mechanics for Slope Stabilization. <i>Geotechnical Engineering Journal of the SEAGS & AGSSEA</i> , March 2012, Vol. 43, No. 1, pages 48-58 [Retrieved on 2016-11-25] <DOI: 10.1520/GTJ11431> whole document	7-28
A	AUBERTIN, M. ET AL., Analyses of water diversion along inclined covers with capillary barrier effects. <i>Canadian Geotechnical Journal</i> , 10 October 2009, Vol. 46, No. 10, pages 1146-1164 [Retrieved on 2016-11-25] <DOI: 10.1139/T09-050> whole document	7-28
P,X	RAHARDJO, H. ET AL., Numerical simulation of Geobarrier System under rainfall infiltration. Landslides and Engineered Slopes. <i>Experience, Theory and Practice</i> , 8 June 2016, pages 1699-1706 [Retrieved on 2016-11-25] <DOI: 10.1201/B21520-211>	1-28

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2016/050470

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2001-090077 A	03/04/2001	NONE	NONE
JP 2006-104861 A	20/04/2006	NONE	NONE
CN 104532857 A	22/04/2015	NONE	NONE
CN 204356788 U	27/05/2015	NONE	NONE
JP H03-51426 A	05/03/1991	NONE	NONE
JP H07-247550 A	26/09/1995	NONE	NONE
KR 101463552 B1	20/11/2014	NONE	NONE