

HIGH-PROFILE STRUCTURES, E.G. FOR SOIL
RETENTION OR DRAINAGE

Background of the Invention

The present invention relates generally to high-profile
5 bulked multi-layer plastics material structures in which
at least one layer is in a non-planar configuration. A
high-profile structure has a thickness considerably
greater than that of a bulked textile fabric. The
thickness should in general be such as to be capable of
10 restraining the movement of soil or gravel filling the
reentrants in a profiled face of the structure when the
structure is at a steep angle.

In a flexible form, such structures can be used for soil
retention. The structure is placed on e.g. an
15 embankment and may be filled with e.g. soil and grass
seed. The grass seed grows and its roots entwine the
structure, preventing gross erosion by heavy rainfall or
the wave action of a river or sea. The structure itself
can be pegged down to provide firm retention, at least
20 in the initial stages of root growth.

A more rigid structure can for instance be used as a

spacer for soil drainage, particularly when the compression resistance need not be too high. One or both faces of the structure would be provided with a layer of geofilter to prevent the structure filling with soil or silt and to maintain gaps within the structure through which water can drain.

It is desirable to be able to form high-profile structures which are dimensionally stable and fairly regular, in a quick and simple manner in a modern manufacturing plant. It is also desirable to develop a structure which does not have large through-channels which could lead to scouring in soil retention.

The Invention

In the method of the invention, the shrink layer is biaxially heat-shrinkable, the second layer is of mesh structure, and the layers are fixed together at discrete zones which lie on the intersections of a notional, generally square grid, each zone being spaced from adjacent zones along each axis of the grid; on heating the shrink layer shrinks and the second layer bulks to form a high-profile, fairly regular cusped configuration, i.e. having a face formed as an array of pyramid-like projections. Preferably the second layer (the non-shrink layer) does not shrink substantially,

and it can be unorientated or alternatively orientated and then heat-set at a suitable temperature; however what is important is that the shrink layer should shrink much more than the non-shrink layer.

The use of a heat-shrinkable plastics material layer enables relatively high percentage shrinkages to be obtained and thus produces high-profile structures suitable for soil retention or soil drainage and more generally for geotechnical structures. It has been found that the mesh structure of the non-shrink layer enables the cusped structures to be formed because the strands of the mesh structure can move relative to one another, e.g. a type of swivelling movement around the junctions or intersections of the strands of the structure as the non-shrink layer forms the cusps.

It has been appreciated that the steps of fixing the layers together and of heat shrinking can be performed at locations remote from each other, and even in different countries. After fixing the layers together, the structure is relatively dense and can be transported by public road, rail, sea or air in this semi-finished form, for instance as a roll. As significantly less air

is being transported (compared to the bulked final product), a very high percentage of transportation costs can be saved. Thus the relatively dense structure can be secured, e.g. formed into a roll which can be tied, strapped, packaged or containerised at the manufacturing site, transported a substantial distance (which would normally be tens or hundreds of kilometers), and then shrunk, for instance in a warehouse closer to the actual site of use.

Though it is possible to have the shrink layer of imperforate material (such as plastics material film), the layers are preferably all formed of mesh structure. The mesh structures may be integrally-extruded mesh structures, for instance formed in accordance with GB 836 555, GB 1 250 478, GB 1 264 629, SP 396 734 or GB 1 075 487 or pierced film; alternatively, the layers can be formed by weaving or knitting. A whole range of plastics materials can be used, for instance low, medium or high density polyethylene or polypropylene. Though it is possible to arrange for the heat shrinking to occur at relatively low temperature, it is preferred to carry this out at or very close to the boiling point of water as this provides simple temperature control and also

avoids accidental heat shrinkage. Even higher temperatures can be used (utilising say hot air), in particular when the shrink layer is made from polypropylene or if higher shrinkages are required.

- 5 Also, if the shrink layer is not powerful enough, it is an advantage to heat the non-shrink layer sufficiently to soften it and make it more easily deformable. The minimum heat shrinkage may be 5% and the maximum may be 50%, the amount of heat shrinkage depending upon the
10 thickness required in the bulked structure.

- The cusped structures can be relatively strong as well as regular and dimensionally stable, being formed of individual layers each of which can be dimensionally stable. The cusped structure can be made very quickly
15 in a modern manufacturing plant. Cusped structures have no large through-channels and can thus resist scouring when used for soil retention, but nonetheless have two directional drapability.

Preferred Embodiments

- 20 The invention will be further described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is an isometric view of a cusped structure;

Figure 2 is a schematic vertical section through a cusped structure;

Figure 3 is a plan view of the middle layer of the structure of Figure 2;

- 5 Figures 4 and 4a are alternate plan views of the structure of Figure 1, primarily to show alternate heat-welding zones;

Figure 5 is a schematic vertical section through another cusped structure;

- 10 Figure 6 is a schematic side view of plant for making the structure of Figure 1;

Figure 7 is a schematic view of the structure of Figure 1, in use as an embankment stabiliser; and

- 15 Figure 8 is a schematic view of the structure of Figure 1, in use as a drainage structure.

Figures 1 to 5

Figure 1 shows a flat first layer 1 (shrink layer) and a cusped second layer (non-shrink layer) 2. The layers are fixed together at discrete fixing zones 3 which lie

on all the intersections of a notional, generally square grid, as shown in Figure 4 or 4a; each zone 3 is spaced from adjacent zones 3 along each axis of the grid; i.e. along each side of the square. The notional grid is not depicted in Figures 4 and 4a, but the sides of the grid run at 45° to the sheet of the drawing; the grid need not be precisely square, it only being necessary that the grid be generally or roughly square; i.e. one side could be rather larger than the other and/or the corner angles may be rather different from 90°. In Figures 4 and 4a, the machine direction (MD) will be up and down the sheet so that in the finished structure, the cusped grid will be "on the diamond". This is preferred for embankment stabilisation, though if the cusped structure is used as a spacer, one could have the cusped grid "on the square". Having the cusped grid "on the square" can provide good drainage channels extending parallel to the run of the cusped structure.

The material of the shrink layer 1 must be capable of biaxial heat shrinkage, and this is provided by stretching all the strands in ways which are already known, e.g. by bi-axial orientation of a formed mesh structure. Although it is the differential shrinkage that matters, it is highly desirable that the non-shrink layer 2 should not shrink very much during bulking up (but a shrinkage of say 2 to 3% may be acceptable). The

non-shrink layer 2 can thus be of unorientated material, or can be of material which has been stretched and heat set at a temperature appreciably higher than the ultimate shrinking temperature.

- 5 Although it is possible to have the shrink layer 1 of imperforate plastics film, say 0.1 to 1 mm thick (Figure 5), it is preferred that each layer should be formed of plastics mesh. This: lightens the structure; facilitates entanglement of roots when used for
- 10 embankment stabilisation; allows the roots to penetrate into the ground below the structure; and allows rain or water to permeate through the soil or gravel retained by the structure and into the ground below. Though the layers 1, 2 can be knitted or woven, it is preferred
- 15 that the strands should be firmly connected together at the junctions or knots, e.g. with integral strand junctions, as this gives a more dimensionally stable structure whilst allowing the movement required of the non-shrink layer 2 to form the cusped configuration -
- 20 integrally or confluent extruded meshes are preferred. For the shrink layer 1, it is possible to use a mesh with the sides of the meshes generally parallel to the cusped grid (i.e. a diamond mesh if the grid is "on the diamond"). However, as diamond meshes
- 25 are relatively unstable dimensionally, it is preferred in manufacture to use a square or rectangular form, when

the sides of the meshes would normally be substantially parallel to the diagonals of the cusped grid. In addition, to form the shrink layer 1, it is preferred to overlay the mesh structures so that there are two plies, as illustrated in Figure 3. Though separately produced mesh structures can be used, it is possible to fold over the mesh structure with a fold extending in the machine direction so that any one strand runs generally in the same direction in each ply (i.e. the MD strands continue to run in the MD direction and the transverse direction (TD) strands continue to run in the transverse direction). In practice, it is very expensive to provide mesh structures which are precisely accurate geometrically, though the MD strands are usually fairly parallel with the machine direction; the TD strands are not strictly at 90° to the machine direction, being at a small amount less than 90° , say at about 70° or about 80° ; this causes irregular cusping on heat shrinkage. By overlaying, the small amounts are fairly equal and in opposite directions so that the MD components of the transverse shrinkage forces of the TD strands of one ply are largely compensated for by the opposite MD components of those of the other ply and good cusped structures can be achieved.

Although the shrink layer 1 can be less robust than the non-shrink layer 2, the shrink layer 1 must have enough

strength and sufficient shrinkage to pull the non-shrink layer 2 into the type of cuspatation required.

The material chosen for the shrink layer 1 will also depend upon the material chosen for the other layer(s).
5 Though medium density polyethylene is one possible material, the preferred material is linear low density polyethylene for the shrink layer 1 in association with low, medium or high density polyethylene for the other layer(s). In an alternative, polypropylene can be used
10 for the shrink layer 1 and the non-shrink layer 2 can be made of polyethylene, which softens at a lower temperature than polypropylene and will tend to enrobe the polypropylene during heat welding, giving good weld strength. Nonetheless, all the layers can be formed of
15 the same material, if desired.

The non-shrink layer 2 can be in a single ply (as shown in Figure 1) or of multi-ply construction (as shown in Figure 2). It is found that one heavy ply is harder to cuspatate than two lighter plies, and the two plies also
20 provide more filaments for the entanglement of roots in an embankment stabilisation application. It is preferred that the non-shrink layer 2 should be of square or rectangular form mesh structure with the sides of the meshes generally parallel to the cuspatate grid (as
25 shown in Figure 1); in the preferred form of production

used, this will mean that the non-shrink layer 2 will be termed a diamond mesh. This gives more pronounced troughing on shrinkage, even if the mesh sizes of the two plies are different, and it is believed that the strands swivel slightly to enable the pyramids of the cusped structure to be formed. In addition, the fact that the strands are running parallel to the grid of the cusped structure gives good crush resistance and a relatively stiff material. Though not illustrated, the non-shrink layer 2 could however have its strands running parallel to the diagonals of the cusped grid, e.g. being of square or rectangular mesh on the production plant.

The non-shrink layer 2 may alternatively have the form of a trellis net (parallelogram mesh openings), or of double-laid plies of trellis net.

The non-shrink layer 2 shown is formed of a normal thermoplastics material, but it may be formed of a thermoplastic elastomer.

The layers 1,2 are fixed together while they are in substantially planar form. Although any suitable fixing can be used, it is generally preferred to use a material which enrobes the shrink layer 1 as this provides a locked seal (i.e. a fixing which prevents printing

between the layers 1, 2 at the fixing zone) and causes a more regular cusped form to be produced; the fixing can be by melt fusion and the subsequent solidifying of the material, e.g. by ultrasonic welding or hot melt printing, or preferably hot welding. It is important that the welding zone 3 should extend over enough strands to ensure fixing; as a result, though circular zones 3 can give good results (see Figure 4), elongate zones 3 are preferred (see Figure 4a) as they will extend over more than one strand but will not have a very large area because they are narrow. If the shrink layer 1 has its strands generally aligned with the diagonals of the cusped grid, satisfactory structures can be formed if the gaps between the welding zones 3 in each row are approximately equal to the lengths of the welding zones 3 themselves. However, if the strands of the shrink layer 1 extend roughly parallel to the sides of the cusped grid, it is preferred that the gaps should be substantially longer, the gaps being about double the lengths of the welding zones 3 or more specifically the welding zones 3 representing about 34% of the total length of the row.

The preferred mesh pitch for the shrink layer 1 is 3 to 15 mm and the preferred mesh pitch for the non-shrink layer 2 is 5 to 11 mm.

As shown in Figure 2, there may be a third, non-shrink layer 5 on the other side of the first layer 1, which third layer 5 would normally be identical to the non-shrink layer 2 (though not necessarily so). The
5 third layer 5 will also assume a cusped form. It is also possible to put the shrink layer 1 on both sides of the non-shrink layer 2. The cusped structure so formed would have less height as the non-shrink layer 2 is constricted and both faces would be nearly planar,
10 but the structure could provide a good bond for woven or non-woven geotextiles filter materials on one or both faces, to form drainage structures.

Figure 2 illustrates that at the selvedge, the shrink layer 1 can project e.g. 5 cms out beyond the non-shrink
15 layers 2 and 5. This enables lengths of the structure to be sewn or fixed together side-by-side (in a sewing or welding machine) as the shrink layer 1 at the selvedges remains fairly flat. An alternative is just to have the fixing zones a suitable distance from the
20 edges. Another alternative is just to compress the cuspatations in the sewing or welding machine. Once side-by-side lengths have been joined together, they can be folded over down the sew lines.

Plant (Figure 6)

Figure 6 illustrates a manufacturing process for making the cusped structures. The part between the vertical dashed lines may include an accumulator (for continuous manufacture), or may be represented by collecting the semi-finished product and securing it (e.g. by rolling it up tightly in a dense roll and strapping it), and either bulking it later on the same site or transporting it a long distance (represented by the schematic, smaller scale illustration of a truck) and then bulking it.

The initial part of the plant operates step-wise. Shrinkable and non-shrinkable materials are fed from rolls 11,12 respectively, united by nip rolls 13 and are fixed together by transversely-spaced welding tools 14 which cooperate with a heated or (preferably) unheated bar 15 or tools 15 of the same shape as the tools 14; the tools 15 are preferably temperature-controlled to a temperature below, say 10°C below, that of the tools 14, and below the melt temperature of the non-shrink layer 12. As the tools 14 contact the non-shrink layer 12, the material in contact with the tools 14 melts and adheres to the shrink layer 11, preferably flowing and enrobing the shrink layer 11. On the next step forward, cold tools 16, similar in shape to the welding tools 14,

hold the welding zones 3 against a second unheated bar 17 and prevent the layers pulling apart before the material has cooled. An alternative is to use cooperating soft rubber rolls instead of the tools 16 and the bar 17. Continuous systems are however possible, such as using welding heads cooperating with rollers or with transport chains.

In order to bulk up the structure, the structure is passed through the nip of input rolls 21, through a hot bath 22 containing water at 95-100°C, under a bar 23 and under a stiff brush roll 24 which is geared to rolls 21 and determines the MD shrink; the roll 24 can have steel or nylon bristles. Though not shown, converging fine chains or belts can be used to predetermine TD shrinkage. A cold air blast may be applied by nozzles 25. As alternatives, hot air or infra-red can be used for shrinking, and the material may be on a continuously-moving conveyor.

Uses (Figures 7 and 8)

There are many end uses for the structure, such as carpet underlay, mattresses and other cushioning applications, and side safety mats for the edges of swimming baths. However, the structures are primarily designed for geoen지니어ing (geotechnical) use such as

embankment stabilisation (Figure 7) and drainage (Figure 8). In Figure 7, a single-sided structure 31 (as in Figure 1) is laid on the bank 32 of a river or sea wall or road, with the cusped layer 2 uppermost. The structure 31 is pegged down and fine soil and suitable seed are spread over the structure 31 so as to pass down into the interstices of the structure 31.

In Figure 8, a double-sided structure 33 as in Figure 2 has a geotextile 34 applied to the upper side and an imperforate plastics film 35 applied to the lower side - the geotextile 34 and film 35 may be applied and preferably attached during manufacture (after bulking). As an alternative, the geotextile 34 may be applied to the structure of Figure 5. The material 33,34,35 is shown lining a pit containing refuse 36, for draining foul water from the refuse 36. In other applications, for instance as a vertical drainage core, geofabrics could be applied to each side of the structure 33.

Example

A structure similar to that illustrated in Figure 1 was made in the laboratory. The shrink layer 1 was formed of two plies; each ply is a linear low density polyethylene square mesh extruded as in GB 1 250 478 and each ply biaxially orientated by stretching 4:1 overall

in both the MD and the TD at 60°C. In each ply there was a square mesh pitch of 7 to 8 mm, the weight being 38 g/m². The non-shrink layer 2 was formed of two plies; each ply is an unorientated low density polyethylene diamond mesh with equal diagonal pitches of 11 mm. The weight of each ply was 135 g/m². Although in general terms the weight of the shrink layer 1 can be equal to or less than (or even more than) that of the non-shrink layer 2, in this case the weight of the shrink layer 1 before shrinkage was less than a third of the weight of the non-shrink layer 2.

The layers 1,2 were heat welded together using welding tools with rectangular faces, as in Figure 4a; the tools contacting the shrink layer 1 were at a temperature 10°C less than the tools contacting the non-shrink layer 2. The welding zones were staggered in rows, each welding zone being 17 mm long and 6 mm wide, the pitching of the welding zones and of the rows being 50 mm and 25 mm respectively. The plastics of the non-shrink layer 2 melted in the welding zones and enrobed the strands of the shrink layer 1 to a certain extent in those zones.

The unbulked material had a weight of about 350 g/m² and a thickness of about 3 mm.

The structure was bulked by being passed through a water

bath at 98°C. The shrink layer 1 shrank 16% in both MD and TD directions; the non-shrink layer 2 had substantially no shrinkage. The structure bulked to form a high-profile, regular, cusped structure which had a weight of about 490 g/m² and a thickness of about 18 mm (taken as the thickness from the tops of the cusps). In general, it is preferred that the thickness of the structure should not be less than around 12 mm, but the maximum thickness could be considerable, say 30, 40 or 50 mm. As the maximum thickness of a bulked fabric is around 6 mm, and bulked fabrics are normally significantly thinner than 6 mm, the bulked structure of the invention can be considered as having a thickness of at least double that of a bulked fabric and in general terms around an order greater than that of a bulked fabric.

A test has been devised for ensuring that the bulked structure of the invention is capable of restraining soil movement. A 1 m x 1 m square of the structure is secured to a base board. While the board is horizontal, aggregate of sieve size 3-6 mm is poured on the structure and is levelled off, and the dry weight of the aggregate noted. The board and structure are then tilted to 45° - some aggregate will fall off, but the loss should not be too great, say not more than 50% w/w. The dry weight of aggregate remaining is

calculated. Using a weir, a flow of 22.5 litres per minute per metre width is distributed across the top of the structure and continued for five minutes. The aggregate washed out was dried and weighed. A
5 substantial amount of aggregate should remain, say at least 50% w/w (of weight after tilting up) but preferably up to 80% w/w.

The test was carried out on the bulked structure of the Example above, but made using circular welding zones 3
10 (Figure 4); it is believed that the results for the Example strictly as described, would be very similar. 14.7 Kg/m² of aggregate was loaded on. On tilting, the load of aggregate reduced to 10.4 Kg/m² (29% loss); on flowing the water the load of aggregate was
15 reduced to 8.5 Kg/m² (18% loss, of weight after tilting up).

A layer of filter material can be attached to one or both faces of the bulked structure, and/or an impervious layer attached to one face, for instance by glueing or
20 hot melt printing or flame bonding.

In full scale production, as in the plant of Figure 6, the layers 1, 2 can be continuous and of 3 m width.

The unbulked material can be bulked in the same

manufacturing line. Alternatively, the material can be rolled into rolls each containing e.g. 100 m, and either bulked later on the same site or transported away for bulking elsewhere - before transporting, the material
5 would be tied, strapped, packaged or containerised in order to secure it. By transporting before bulking, only about one sixth of the bulked space is required.

The present invention has been described above purely by way of example. Modifications can be made within the
10 scope of the invention.

Claims

1. A method of making a high-profile structure, comprising:

providing a first, substantially planar, biaxially
5 heat-shrinkable, plastics material (shrink) layer;

providing a second, substantially planar, plastics material layer, the second layer being of mesh structure;

fixing the first (shrink) and second layers together at discrete zones which lie on the intersection of a
10 notional, generally square grid, each zone being spaced from adjacent zones along each axis of the grid; and

heating the structure so formed to cause the first (shrink) layer to shrink biaxially with respect to the second layer and cause the second layer to assume a
15 fairly regular cusped configuration.

2. The method of Claim 1, wherein the first (shrink) layer is a mesh structure.

3. The method of Claim 2, wherein the first (shrink) layer has integral strand junctions or intersections.



4. The method of Claim 2 or 3, wherein the first (shrink) layer is a square or rectangular form, bi-axially molecularly orientated mesh structure with the sides of the meshes substantially parallel to the diagonals of said grid.
5. The method of Claim 4, wherein the first (shrink) layer comprises a first ply and a second ply, each ply being formed of a mesh structure comprising a first set of strands and a second set of strands which makes an angle which is a small amount less than 90° to the first set, the first set of the first ply being substantially parallel to the first set of the second ply and said small amount in respect of the second set of the first ply being in the opposite direction to that of the second set of the second ply.
6. The method of Claim 1, wherein the first (shrink) layer is substantially imperforate.
7. The method of any of the preceding Claims, wherein the second layer is a square or rectangular form mesh structure with the sides of the meshes generally parallel to said grid.
8. The method of any of the preceding Claims, wherein the second layer is composite, being formed of at least



two plies of mesh structure.

9. The method of any of the preceding Claims, wherein the second layer does not shrink substantially during said heating.

5 10. The method of any of the preceding Claims, wherein the fixing zones are each elongate, a fixing zone being aligned with other, spaced fixing zones in a first row, the next, second row of fixing zones being staggered with respect to the fixing zones of the first row so
10 that the mid-points of the second row of fixing zones are substantially half way between the first row fixing zones, the next, third row of fixing zones being staggered with respect to the second row of fixing zones so that the mid-points of the third row of fixing zones
15 are opposite the mid-points of the first row of fixing zones, and so on.

11. The method of Claim 10, wherein the gaps between the fixing zones in each row are roughly equal to the lengths of the fixing zones themselves.

20 12. The method of Claim ¹⁰~~11~~, wherein the gaps between the fixing zones in each row are substantially longer than the lengths of the fixing zones themselves.



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13. The method of any of Claims 1 to 9, wherein the fixing zones are circular.

14. The method of any of the preceding Claims, which the fixing is performed by a material which enrobes parts of
5 the first (shrink) layer at the fixing zones.

15. The method of any of the preceding Claims, wherein the fixing is performed by melt fusion and the subsequent hardening of the melted material.

16. The method of any of the preceding Claims, wherein
10 the fixing is performed by heat welding.

17. The method of Claim 16, wherein, to fix the first (shrink) and second layers together, heated tools are applied to the second layer while the first (shrink) layer is supported by at least one surface at a lower
15 temperature than the tools.

18. The method of Claim 16 or 17, wherein, after heat welding, the layers are held together at the fixing zones by cold tools.

19. The method of any of the preceding Claims, wherein
20 there is a third layer on the other side of the first (shrink) layer to the second layer, the third layer



being as defined for the second layer in any of Claims 1 and 7 to 9.

20. The method of any of Claims 1 to 16, wherein there is a third (shrink) layer on the other side of the second layer to the first (shrink) layer, the third (shrink) layer being as defined for the first (shrink) layer in any of Claims 1 to 6.

21. The method of any of the preceding Claims, wherein, along at least one margin of the cusped structure formed by the method, the first (shrink) layer extends beyond the second layer and beyond the third layer if present.

22. The method of any of the preceding Claims, wherein, when the first and second layers have been fixed together, the relatively dense composite structure so formed is transported by vehicle away from the site at which the layers were fixed together, the structure being heated at another site.

23. The method of Claim 22, wherein the relatively dense composite structure is tied, strapped, packaged or containerized prior to the transporting.



24. The method of any of Claims 1 to 21, wherein after heating to form the cuspatations, a further layer is attached to one or both faces of the structure.

25. A high-profile bulked structure made by the method of any of the preceding Claims.

26. A method of making a high-profile bulked structure, substantially as herein described with reference to any of Figures 1 to 6 of the accompanying drawings.

27. A high-profile bulked structure, substantially as herein described with reference to, and as shown in, any of Figures 1 and 4 or 4a, Figure 2, Figure 3, or Figure 5, of the accompanying drawings.

28. A method of making a high-profile bulked structure, substantially as herein described in the foregoing Example.

29. A high-profile bulked structure, substantially as herein described in the foregoing Example.



30. A geotechnical structure incorporating the high-profile bulked structure of any of Claims 25, 27 or 29.

31. The geotechnical structure of Claim 30, and comprising an embankment covered by the high-profile bulked structure.

32. The geotechnical structure of Claim 30, and comprising ground into which the high-profile bulked structure has been inserted as a drainage material.

33. A method of providing a geotechnical structure, comprising incorporating the high-profile bulked structure of any of Claims 25, 27 and 29.

34. A geotechnical structure, substantially as herein described with reference to, and as shown in, Figure 7 or Figure 8 of the accompanying drawings.

35. A method of providing a geotechnical structure, substantially as herein described with reference to Figure 7 or Figure 8 of the accompanying drawings.

