

## SPECIFICATION

## Plastics Material Mesh Structure



## Background of the Invention

The present invention relates to plastics material integral mesh structures having mesh openings defined by a generally rectangular grid of substantially parallel, orientated strands and substantially parallel bars generally at right angles to the strands. The structures have in themselves commercial uses, and can also serve as an intermediate structure for the biaxially-stretched structures claimed in Application 79 34944 (Specification GB 2 035 191 A) from which this Application is divided. Application 79 34944 also claims methods of producing the biaxially-stretched structures.

## Definitions

The term "rectangular" includes square.

The term "orientated" means molecularly orientated.

The terms "rows" and "columns" are used for convenience to denote the axes of the rectangular grid. Unless specified otherwise, it does not matter if the rows extend in the machine direction (MD) or in the transverse direction (TD).

The terms "thick", "thin", "thickness", "deep", "depth", and "shallow" refer to the dimension normal to the plane of the starting material or mesh structure and the terms "wide", "narrow", and "width" refer to the appropriate dimension in the plane of the starting material or mesh structure.

The thickness of the starting material or mesh structure is the distance between the extreme faces of the starting material or mesh structure.

The thickness or depth of a strand is the thickness of the strand cross-section, but ignoring raised edges. Particularly if the original holes or depressions have no radiussing where they issue at the faces of the starting material, the strands will have a "pin-cushion" cross-section, with raised edges and lower centres; the thickness or depth will be as measured inwardly of the raised edges.

The normal junction zones of the starting material are notional zones defined by the intersection of the notional parallel-sided zone which lies between and is tangential to two columns of holes or depressions and the notional parallel-sided zone which lies between and is tangential to two rows of holes or depressions.

The term "tangential" includes touching, but not intersecting, a straight sided hole, depression or opening or touching a corner of a hole, depression or opening.

The depressions are not necessarily formed by the application of pressure.

Stretch ratios are either given overall or "on the strands". If they are given on the strands, they are measured by measuring the distance moved by the respective ends of the openings on either side of the strand.

## The Invention

The invention provides methods as set forth in Claims 1, 15, 22 and 26 and structures as set forth in Claims 8, 9, 21 and 24. The remaining Claims set forth preferred features.

In the method of Claim 1, uniaxial orientation is produced and the structures of Claims 8 and 9 are principally uniaxially orientated.

## Description of Preferred Embodiments

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

Figures 1 and 2 show two stages in a method in accordance with the invention;

Figures 3a, 3b and 3c are sections along the corresponding lines shown in Figure 2;

Figure 3d is a section corresponding to that of Figure 3c, but shows a variation;

Figure 4 shows various shapes of holes or depressions that can be used in the starting material;

Figure 5 is a schematic elevation of a plant for making biaxially stretched structures;

Figure 6 is a perspective view of a stabilising or retaining structure in accordance with the invention;

Figure 7 is a vertical section through a wall, earth retained thereby and structures as in Figure 6;

and

Figure 8 is a vertical section through an embankment stabilised in accordance with the invention.

In Figures 2 and 6, the lines which indicate the profile of the structure extend up and down the slope, following the line of maximum gradient, i.e. at right angles to conventional contour lines.

Looking at Figure 1, the starting material is a sheet of plastics material 11 having planar faces and in which are formed circular holes or depressions 12. The "holes" 12 need not pass right through the sheet and can be depressions in one or both sides of the sheet, leaving a continuous membrane, preferably on the median plane of the sheet. Figure 1 shows what is termed herein a notional junction zone 13, namely the notional zone defined by the intersection of the notional parallel-sided zone 14 which lies between and is tangential to two columns of holes or depressions 12, and the notional parallel-sided zone 15 which lies between and is tangential to two rows of holes or depressions 12.



Figure 1 also shows truth lines 14', 15' which would not be used in commercial operation but can be scribed or drawn on the plastics material to show what is happening.

When the sheet 11 is drawn in the vertical direction (looking at Figure 1) the structure of Figure 2 is formed because the zones 16 (Figure 1) are stretched and orientated into strands 17. The stretching is performed to such an extent, for instance to a ratio of 7:1 on the strands, that the outermost portions of the notional junction zones 13 are orientated and stretched out to form the end portions of the strands 17, which merge smoothly with the remainder of the strand (see Figure 3c); the orientation can pass right through or nearly through the centre of each notional junction zone 13. A notional point 18 (Figure 1), which on the starting sheet 11 lay on the notional straight line 19 which is parallel to and tangential to the rows of holes or depressions 12, has moved into the corresponding strand (Figure 2) so that it is spaced from the corresponding notional straight line 19' by a substantial distance  $x$  (Figures 2 and 3c). This is also illustrated by the truth lines 15' in Figure 2. The distance  $x$  is preferably not less than 25% of the thickness of the mid-point of the strands 17 and more preferably not less than such thickness.

In effect, the notional parallel-sided zones 15 form bars running horizontally as seen looking at Figure 2, each comprising a succession of alternate zones, namely first zones 20 between and interconnecting the ends of aligned strands 17 and second zones 21 between the first zones 20. The second zones 21 are not substantially orientated, and it will be seen from Figure 3a that they still maintain the original thickness of the sheet 11. They have flat outer faces in Figure 3a, and may also have flat outer faces in Figure 3b. However, the first zones 20 have been orientated (see the undulating top and bottom surfaces in Figure 3a); the orientation can pass right through the first zones 20 in the direction of strands 17, forming a trough in the horizontal bar, as can be seen in Figure 3a, all of the first zone 20 being orientated in the direction of the strands 17. The centre of each first zone 20 (corresponding to the mid-point of the notional junction zone 13) is substantially thicker and less orientated than the strands 17 (see Figure 3c); and can have a thickness ranging from just somewhat thicker than the strands 17 to the thickness of the starting material 1.1. If all the first zone 20 is orientated, its central third may be stretched to a ratio of at least 1.5:1. If the central part of the first zone 20 is not stretched, the length of the part that has not been stretched may be for example up to five times its thickness if the bars are wide or not greater than its thickness. In the structure shown in Figure 3c, there is a gradual increase in thickness from the point 18 to the centre of each first zone 20. At 23 in Figure 2, the material of the notional junction zone 13 is drawn out, forming a reentrant on either side of the first zone 20. Thus the outermost portions of the original notional junction zones 13 can have an orientation which is in the direction of the first stretching.

Figure 3d illustrates a variant than can occur. The orientation has passed right through the first zone 20 but there has only been a slight thinning in the centre of the zone 20, there being sharper steps down to the thickness of the strands 17 near the edges of the zone 20.

The starting material can be of any suitable thickness from 0.75 mm upwards; better structures can be produced with starting material thickness of at least 1 mm.

The distance between adjacent holes or depressions 12 in the starting material 11 may be greater than the thickness of the starting material 11 at the same point.

The uniaxially stretched structures can find many uses, as set forth below. By having the orientation passing into the first zones 20, there is a saving of plastics material, by having the orientation passing right through the first zones 20, there is a degree of orientation connecting aligned strands 17 and a reduction in the amount of yield which would occur within the bar under tension in the vertical direction (as seen in Figure 2), and by having the centre of each notional junction zone 13 substantially less orientated, there is a reduced danger of splitting when flexing the bars.

The structure of Figure 2 can alternatively be subjected to a second stretching operation, in the horizontal direction as seen looking at Figure 2. Biaxially-stretched structures are so produced, and, as indicated above, the method of production and the structures themselves are claimed in Application 79 34944. It is believed that if a degree of orientation passes right through or at least nearly right through the notional junction zone 13, a better junction can be produced in a biaxially-stretched product. However, it has been found that orientation need not even pass nearly right through the zone 13.

There is a tendency for junctions of the type shown in U.K. Patent Specification No. 1 310 474 to be formed in a biaxially-stretched product if the sheet thicknesses are below 1.5 mm, particularly the  $w:d$  ratio (the ratio of the distance  $w$  between holes or depressions of adjacent columns or rows in the starting sheet to the thickness  $d$  of the sheet) is too high; this tendency increases as the sheet thickness decreases below 1 mm and particularly as the sheet thicknesses decrease into the range 0.75 mm down to 0.5 mm. This tendency can be reduced by avoiding any raised edges around the holes, e.g. caused by embossing, or by reducing the  $w:d$  ratio. However, a preferred lower limit for the thickness of the starting material is 1 mm, for which it has been found that the thickest zone of a junction 26 can be down to about 0.7 mm thick; for 0.75 mm thick starting material, the corresponding junction thickness would be about 0.55 mm.

More generally, it is believed that the behaviour of the material alters at smaller thicknesses because the sizes of the molecules themselves become more relevant. It is believed that one will not

necessarily achieve a desired biaxially-stretched product using a starting material which, compared to that of any of the Examples below, is scaled down (i.e. in thickness, hole size and pitch in each direction), e.g. to thicknesses of 0.5 mm and below.

It is preferred to use stretching temperatures which are below the manufacturer's recommended stretching temperatures, e.g. 97°C for HDPE (high density polyethylene) instead of just below 126°C.

In the (first) stretching operation, the orientation may not pass through the notional junction zones 13 (Figure 1) or may not even pass sufficiently far into the zones 13. This tendency can be avoided or reduced if desired by decreasing the distance between the holes or depressions in the first stretching direction (decreasing the  $w:d$  ratio), decreasing the distance between the holes or depressions in the second stretching direction or decreasing the radius of the corners of the holes or depressions.

In general, decreasing the  $w:d$  ratio increases the tear resistance.

### General

The starting material can be of any suitable thickness from 0.75 mm upwards and in sheet form or tubular. The preferred material is strictly uniplanar, by which is meant that, ignoring any membrane (which may not lie on the median plane), all zones of the starting material are symmetrical about the median plane of the starting material—using such starting material, the structures produced will normally themselves be strictly uniplanar; however, insubstantial departures from uniplanarity are not excluded. The holes (or depressions if suitable) can be formed by punching or by forming them as the starting material itself is formed, obturating a slit die for instance generally as in French Patent Specification No. 368 393. In general, it is preferred to avoid any substantial protruberance around the periphery of the holes or depressions, particularly when producing biaxially stretched structures; thus the zones 21 preferably have flat top and bottom faces, as illustrated in Figures 3c and 3d, and this is believed to reduce any tendency for thin spots to form in the junctions of the biaxially-stretched structures. If depressions are formed, the membrane closing the depressions can be ruptured during stretching and the residual film-like material removed.

The starting material is preferably not substantially orientated, though melt flow orientation can be present.

The starting material can be any suitable thermoplastics material, such as for instance HDPE, low density polyethylene, polypropylene, copolymers of HDPE and polypropylene, and polyamides. The starting material can have a skin on each face containing an ultra-violet stabiliser. To enable the mesh structure to be used for laminating, whether to one or more like mesh structures or to one or more different materials such as fabric or film, the starting material may have a special layer on one or both faces. This layer may be of a substance such as low density polyethylene or ethylene vinyl acetate which melts or becomes tacky at a temperature at which the main component of the structure would not de-orientate. The layer or layers could be produced by extrusion coating or coextrusion.

After stretching, the structures can be annealed in a manner well known.

Figure 4 shows various shapes for the holes or depressions. For producing uniaxially or biaxially stretched structures, the grid on which the centres lie can be square or rectangular.

Depending somewhat on the shape of the holes, in general the area of the holes or depressions is preferably less than 50% of the plan view area of the starting material, and more preferably less than 25%.

### Plant

The plant is shown schematically in Figure 5, but the units themselves are conventional units. The plant produces biaxially-stretched structures and the same Figure is reproduced in Application 79 34944, referred to above.

There is a let-off unit 41 supporting a roll 42 of unperforated starting material which passes through the plant along the path indicated by the dashed lines and arrows. The starting material passes through a sheet flattening unit 43, a perforator 44, a transverse direction orientation (stretching) machine 45 (producing a uniaxially-stretched structure), a machine direction orientation (stretching) machine 46 (producing a biaxially-stretched structure), and is wound up on a wind-up unit 47. In the second orientation machine 46, one should avoid too short a distance between the nips in order to allow some sideways contraction of the mesh structure.

It is believed that, in theory, it does not matter whether the first stretching operation (the uniaxial stretching operation) is carried out in the transverse direction or in the machine direction in a continuous plant.

### Examples

Tables 1 and 2 set out the procedure and results, respectively for 11 different Examples. The Tables illustrate both uniaxially and biaxially stretched structures, and the same Tables are reproduced in Application 79 34944, referred to above. All dimensions are in mm—"—" means that the value was not recorded. Stretch ratios are overall. For the  $w:d$  ratios in Table 1,  $w$  was measured at right angles to the first stretch direction. In Table 1, the hole size is the hole diameter (or width in the case of Example 3).



In Table 2, all but the first two and fifth columns record thickness. It is normal practice to measure the thickness of a mesh strand at its mid-point and this is the point one would naturally choose. However, it has been observed that, particularly if the original holes or depressions were circular, the mid-point of a strand may not be its thinnest point.

5 In all the Examples except Example 11, there was no restriction of the material in the direction at right angles to the stretching direction, both in the first stretch and in the second stretch. However, in Example 11, there was some restriction, though not complete restriction, in the direction at right angles to the stretching direction during the second stretch, the first stretch being unrestricted. 5

10 In the Examples, there were variations across the sample due to small changes in thickness of the starting material and other reasons, but the results given are believed to be representative of the structures obtained. 10



Table 1

| No. | Material | Starting thickness | Hole size | Hole shape                | w/d   | Pitch in 1st stretch direction | Pitch in other stretch direction | 1st stretch ratio       | 2nd stretch ratio | Temp °C. |
|-----|----------|--------------------|-----------|---------------------------|-------|--------------------------------|----------------------------------|-------------------------|-------------------|----------|
| 1   | HDPE     | 4.5                | 6.35      | Circular                  | 1.056 | 12.7                           | 11.1                             | 4.5:1 relaxed to 4.25:1 | 0                 | 97       |
| 2   | "        | "                  | "         | "                         | 4.23  | 19.05                          | 25.4                             | 3:1                     | 0                 | "        |
| 3   | "        | 1.5                | 12.7      | square, radiussed corners | 2.12  | 25.4                           | 15.88                            | 4.5                     | 0                 | "        |
| 4   | "        | 1                  | 6.35      | Circular                  | 6.35  | 12.7                           | 12.7                             | 6:1                     | 0                 | "        |
| 5   | "        | 4.5                | "         | "                         | 1.41  | "                              | "                                | 4:1                     | 3.5:1             | "        |
| 6   | "        | "                  | 12.7      | "                         | 2.11  | 22.2                           | 22.2                             | "                       | 3.8:1             | "        |
| 7   | "        | "                  | 6.35      | "                         | 3.52  | 12.7                           | "                                | "                       | 4.5:1             | "        |
| 8   | "        | "                  | 12.7      | "                         | 2.11  | 22.2                           | 22.2                             | "                       | 5.5:1             | "        |
| 9   | "        | 1.5                | 6.35      | "                         | 4.23  | 12.7                           | 12.7                             | 5:1                     | 5:1               | 110      |
| 10  | "        | "                  | "         | "                         | 4.23  | "                              | "                                | "                       | "                 | 120      |
| 11  | "        | 4.5                | 3.18      | "                         | 0.71  | 6.35                           | 6.35                             | 3.5:1                   | 3.75:1            | 97       |



Table 2

| No. | Most similar Figure | Mid-point zone 20 | Mid-point strand 17, uniax | x | Mid-point strand 17, biax | Mid-point strand 25 | Mid-point zone 27 | Zone 28 | Zone 28' | Zone 29, 30 or 31 |
|-----|---------------------|-------------------|----------------------------|---|---------------------------|---------------------|-------------------|---------|----------|-------------------|
| 1   | 2                   | 4.23              | 1.35                       | 4 | —                         | —                   | —                 | —       | —        | —                 |
| 2   | *                   | 4.5               | 1.39                       | — | —                         | —                   | —                 | —       | —        | —                 |
| 3   | *                   | 1.5               | 0.51                       | — | —                         | —                   | —                 | —       | —        | —                 |
| 4   | *                   | 1                 | 0.23                       | — | —                         | —                   | —                 | —       | —        | —                 |
| 5   | 6                   | —                 | —                          | — | 1.37                      | 1.61                | 4.33              | 1.63    | 2.43     | —                 |
| 6   | 7                   | —                 | —                          | — | 1.3                       | 1.8                 | 2.7               | 1.4     | —        | 3.8               |
| 7   | 8                   | —                 | —                          | — | 1.5                       | 2                   | 2                 | 1.5     | —        | 3.2               |
| 8   | 9                   | —                 | —                          | — | 1.2                       | 1.8                 | 1.6               | 1.36    | —        | 2.4               |
| 9   | 9                   | 1.3               | 0.33                       | — | 0.35                      | 0.43                | 0.58              | 0.37    | —        | 1.15              |
| 10  | 9                   | 1.33              | 0.33                       | — | 0.4                       | 0.38                | 0.62              | 0.37    | —        | 1.12              |
| 11  | 5                   | —                 | —                          | — | 1.85                      | 1.7                 | 3.22              | 2.2     | —        | —                 |

The structure of Example 1 was especially suitable for embankment stabilisation (see below) and had excellent properties in respect of break load per metre width and tensile deformation.

5 The structures of Examples 2, 3 and 4 are uniaxially stretched structures, but the orientation does not pass right through the zones 20. In Examples 2, 3 and 4 the lengths of the part of the zone 20 which has not been stretched is 7, 10.5 and 2.5 mm respectively, these values being 1.56, 7 and 2.5 times the thickness of the material respectively.

10 In Example 7, the mid-point of the zone 27 was very slightly thicker than the mid-point of the strands 25, but in substance the thicknesses were equal.

In Example 11, there was a  $w:d$  ratio of less than unity, and it will be noted that the stretch ratios were relatively low.

#### Non-Uniform Structures

15 The mesh structures of this invention need not be uniform along the whole of their length, and specific non-uniformities can be introduced for specific purposes, for instance to produce a carrier bag.

In one example, a tubular structure is in the form of sections of uni-axially (machine direction) orientated mesh (as in Figure 2) separated by pieces of unstretched plastics material which when the tubular structure is cut into suitable lengths, from the tops, or tops and bottoms, of carrier bags.

#### Uses

20 The uniaxially stretched structures of the invention can be used for instance for sunshades, crop shading, snow fencing, windbreaks, cladding material, anti-dazzle screens, insect screening or ground retaining or stabilising.

#### Retaining or Stabilising Particulate Material

25 Structures generally in accordance with the invention can be used for retaining or stabilising particulate material of any suitable form, such as soil, earth, sand, clay or gravel, and in any suitable location, such as on the side of a cutting or embankment, beneath a road surface, runway surface or railway track, beneath a building or beneath a quay; it is considered that the structure can be specially suitable for preventing retaining walls being forced out of position by the pressure of particulate material behind them. Retaining is a specific instance of stabilising.

30 The mesh structure will normally be placed roughly parallel to the surface of the particulate material, e.g. horizontally below a roadway or inclined if near an embankment or cutting surface. The mesh structure is preferably substantially rectilinear in section normal to its "plane", at least in the section taken parallel to the orientated strands which will normally be parallel to the line of expected

tension on the mesh structure. This enables the tensile strength of the mesh structure to be fully exploited.

The mesh structure can have practical utility without specific fixed retention, but it is preferably fixed to at least one substantially rigid member. There may be just a single member for instance running along one edge of the mesh structure, or there may be two spaced, parallel members, for instance along opposite edges of the mesh structure, or there may be a number of parallel members spaced at intervals. The member(s) can be substantially normal to the orientated strands referred to above.

The or each substantially rigid member is preferably made of a cast material into which the mesh structure has been incorporated before setting, a suitable material being concrete, but alternatively the mesh structure could be fixed in other ways to one or more pre-cast members or to for instance one or more steel plates. The member e.g. along one edge of the mesh structure could be a retaining wall.

In Figure 6 a mesh structure 51 has had two opposite edge zones cast into substantially rigid concrete members or beams 52. The mesh structure has parallel, orientated strands 53 and parallel bars 54, the mesh structure being a uniaxially stretched structure as described for instance with reference to Figure 2 and Example 1. It will be seen that the bars 54 are incorporated in the beams 52 and during the moulding of the beams 52, the concrete is vibrated so that it passes in between the strands 53 and locks firmly around the bars 54.

Figure 7 shows the application of the structure of Figure 6, to prevent a retaining wall 55 being forced out of position by the pressure of earth 56. There are a number of parallel layers of the mesh structure 51, spaced one above the other, buried in the earth 56, the end beam 52 of each layer being incorporated in the retaining wall 55. It will be seen that the beams 52 of one layer are positioned directly above the beams 52 of the next layer. The expected tension on the mesh structure 51 is in the direction of the strands 53, and each layer is rectilinear in the section of Figure 7. The mesh structure itself has good slip resistance properties with respect to the earth 56, but the beams 52 (other than those in the wall 55) increase the slip resistance so that the mesh structures 51 act as a tie to prevent the retaining wall 55 being forced out of its vertical position.

In Figure 8, spaced layers of uniaxially stretched structure 61, as described for instance with reference to Figure 2 and Example 1, are buried in an earth embankment.

### Claims

1. A method of producing a plastics material mesh structure, comprising:

Providing a substantially uniplanar plastics starting material having a thickness of not less than 0.75 mm and having a pattern of holes or depressions whose centres lie on a notional, substantially rectangular grid of rows and columns; and

stretching the starting material in a direction substantially parallel to the columns to stretch, into orientated strands, zones between adjacent holes or depressions of each row, the strands being interconnected by a set of substantially parallel bars generally at right angles to the strands, the stretching being effected to such an extent that a notional point which on the starting material, lay on the notional straight line which is parallel to the rows and is tangential to respective holes or depressions, moves into the corresponding strand so that, on the mesh structure, the point is substantially spaced from the corresponding notional straight line which is parallel to the rows of mesh openings and is tangential to respective mesh openings, the mid-point of the zone of the bar which interconnects the ends of aligned strands being substantially thicker than the mid-point of either of the strands interconnected by the zone.

2. The method of Claim 1, wherein the stretching operation is effected to such an extent that a notional point which on the starting sheet lay on the notional straight line which is parallel to the rows and is tangential to respective holes or depressions, moved into the corresponding strand so that, on the mesh structure, the point is spaced from the corresponding notional straight line which is parallel to the rows of mesh openings and is tangential to respective mesh openings, by a distance which is not less than 25% of the thickness of the mid-point of the respective strand.

3. The method of Claim 2, wherein the stretching operation is effected to such an extent that the orientation passes right through each notional junction zone (as defined herein), from one strand to the aligned strand on the other side of the notional junction zone.

4. The method of Claim 3, wherein the stretching operation is effected to such an extent that the central third of each notional junction zone (as defined herein) is drawn to a ratio of at least 1.5:1.

5. The method of any one of the preceding Claims, wherein the starting grid is a substantially square grid.

6. The method of any one of the preceding Claims, wherein the thickness of the starting material is at least 1 mm.

7. The method of any one of the preceding Claims, wherein the distance between adjacent holes or depressions in the same row is not substantially greater than the thickness of the starting material at the same point.

8. A plastics material mesh structure produced by the method of any one of the preceding Claims.

9. A plastics material mesh structure having a thickness of not less than 0.75 mm at its thickest



tension on the mesh structure. This enables the tensile strength of the mesh structure to be fully exploited.

The mesh structure can have practical utility without specific fixed retention, but it is preferably fixed to at least one substantially rigid member. There may be just a single member for instance running along one edge of the mesh structure, or there may be two spaced, parallel members, for instance along opposite edges of the mesh structure, or there may be a number of parallel members spaced at intervals. The member(s) can be substantially normal to the orientated strands referred to above.

The or each substantially rigid member is preferably made of a cast material into which the mesh structure has been incorporated before setting, a suitable material being concrete, but alternatively the mesh structure could be fixed in other ways to one or more pre-cast members or to for instance one or more steel plates. The member e.g. along one edge of the mesh structure could be a retaining wall.

In Figure 6 a mesh structure 51 has had two opposite edge zones cast into substantially rigid concrete members or beams 52. The mesh structure has parallel, orientated strands 53 and parallel bars 54, the mesh structure being a uniaxially stretched structure as described for instance with reference to Figure 2 and Example 1. It will be seen that the bars 54 are incorporated in the beams 52 and during the moulding of the beams 52, the concrete is vibrated so that it passes in between the strands 53 and locks firmly around the bars 54.

Figure 7 shows the application of the structure of Figure 6, to prevent a retaining wall 55 being forced out of position by the pressure of earth 56. There are a number of parallel layers of the mesh structure 51, spaced one above the other, buried in the earth 56, the end beam 52 of each layer being incorporated in the retaining wall 55. It will be seen that the beams 52 of one layer are positioned directly above the beams 52 of the next layer. The expected tension on the mesh structure 51 is in the direction of the strands 53, and each layer is rectilinear in the section of Figure 7. The mesh structure itself has good slip resistance properties with respect to the earth 56, but the beams 52 (other than those in the wall 55) increase the slip resistance so that the mesh structures 51 act as a tie to prevent the retaining wall 55 being forced out of its vertical position.

In Figure 8, spaced layers of uniaxially stretched structure 61, as described for instance with reference to Figure 2 and Example 1, are buried in an earth embankment.

### 30 Claims

1. A method of producing a plastics material mesh structure, comprising:

Providing a substantially uniplanar plastics starting material having a thickness of not less than 0.75 mm and having a pattern of holes or depressions whose centres lie on a notional, substantially rectangular grid of rows and columns; and

stretching the starting material in a direction substantially parallel to the columns to stretch, into orientated strands, zones between adjacent holes or depressions of each row, the strands being interconnected by a set of substantially parallel bars generally at right angles to the strands, the stretching being effected to such an extent that a notional point which on the starting material, lay on the notional straight line which is parallel to the rows and is tangential to respective holes or depressions, moves into the corresponding strand so that, on the mesh structure, the point is substantially spaced from the corresponding notional straight line which is parallel to the rows of mesh openings and is tangential to respective mesh openings, the mid-point of the zone of the bar which interconnects the ends of aligned strands being substantially thicker than the mid-point of either of the strands interconnected by the zone.

2. The method of Claim 1, wherein the stretching operation is effected to such an extent that a notional point which on the starting sheet lay on the notional straight line which is parallel to the rows and is tangential to respective holes or depressions, moved into the corresponding strand so that, on the mesh structure, the point is spaced from the corresponding notional straight line which is parallel to the rows of mesh openings and is tangential to respective mesh openings, by a distance which is not less than 25% of the thickness of the mid-point of the respective strand.

3. The method of Claim 2, wherein the stretching operation is effected to such an extent that the orientation passes right through each notional junction zone (as defined herein), from one strand to the aligned strand on the other side of the notional junction zone.

4. The method of Claim 3, wherein the stretching operation is effected to such an extent that the central third of each notional junction zone (as defined herein) is drawn to a ratio of at least 1.5:1.

5. The method of any one of the preceding Claims, wherein the starting grid is a substantially square grid.

6. The method of any one of the preceding Claims, wherein the thickness of the starting material is at least 1 mm.

7. The method of any one of the preceding Claims, wherein the distance between adjacent holes or depressions in the same row is not substantially greater than the thickness of the starting material at the same point.

8. A plastics material mesh structure produced by the method of any one of the preceding Claims.

9. A plastics material mesh structure having a thickness of not less than 0.75 mm at its thickest

- point and having mesh openings defined by a generally rectangular grid of substantially parallel, orientated strands and a set of substantially parallel bars generally at right angles to the strands, each bar comprising a succession of alternate zones, namely first zones between and interconnecting the ends of aligned strands and second zones between the first zones, each bar (as seen in section normal to the structure and along a notional line which is parallel to the bars and is tangential to respective mesh openings) having undulating top and bottom surfaces with the second zones substantially thicker than the first zones, and the mid-point of each said first zone being substantially thicker than the mid-point of either of the strands interconnected by the first zone.
- 5 10. The structure of Claim 9, wherein all of each first zone is orientated in the direction of the strands.
- 10 11. The structure of Claim 10, wherein the central third of each first zone is stretched to a ratio of at least 1.5:1.
- 15 12. The structure of Claim 9, wherein the central part of each said first zone has not been stretched, the length of the part which has not been stretched being not greater than five times its thickness.
13. The structure of Claim 9, wherein the central part of each said first zone has not been stretched, the length of the part which has not been stretched being not greater than its thickness
14. The structure of any one of Claims 9 to 13, and having a thickness of not less than 1 mm at its thickest part.
- 20 15. A method of retaining or stabilising particulate material such as soil, comprising burying in the particulate material a plastics material mesh structure as claimed in any one of Claims 8 to 14.
16. The method of Claim 15, wherein the mesh structure is fixed to at least one solid member.
17. The method of Claim 16, wherein the mesh structure extends between generally parallel, spaced solid members.
- 25 18. The method of Claim 16 or 17, wherein the or each solid member is made of a cast material into which the mesh structure has been incorporated before setting.
19. The method of any one of Claims 16 to 18, wherein the or one of the solid members is or forms part of a wall which retains the particulate material.
- 30 20. The method of Claim 19, wherein there are at least two layers of the mesh structure, spaced one above the other with the particulate material in between, each of said layers being fixed to the retaining wall.
21. A structure comprising particulate material such as soil, which has been retained or stabilised by the method of any one of Claims 15 to 20 and 26.
- 35 22. A method of producing a uniaxially-stretched plastics material mesh structure, substantially as herein described with reference to Figures 1 to 3c or Figure 3d of the accompanying drawings or any of the foregoing Examples.
23. Any method of Claim 1 of producing a uniaxially-stretched plastics material mesh structure and substantially as herein described.
- 40 24. A uniaxially-stretched plastics material mesh structure, substantially as herein described with reference to, and as shown in, any of Figures 2 to 2c or Figure 2d of the accompanying drawings or any of the foregoing Examples.
25. Any structure of Claim 9 and substantially as herein described.
26. A method of retaining or stabilising particulate material, substantially as herein described with reference to Figures 6 and 7 or Figure 8 of the accompanying drawings.

