

SPECIFICATION

Plastics material mesh structure

- 5 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 junctions therebetween. GB 2 073 090 A (divided herefrom)
- 10 describes and claims an intermediate structure which can be produced when making the final structure and which has in itself commercial uses.
- A problem in all integral mesh structures relates to the junctions. The junction should be sufficiently
- 15 strong without containing too much plastics material.
- U.K. Patent Specification No. 982 036 describes the production of rectangular grid mesh structures by stretching a substantially monoplanar plastics material sheet comprising a pattern of holes whose
- 20 centres lie on a rectangular grid; the sheet is stretched biaxially in two directions parallel to the axes of the grid. The junctions so produced are not stretched and are thick and heavy.
- 25 U.K. Patent Specification No. 1 310 474 describes structures whose junctions are strong enough for the light duty applications with which the Patent Specification is concerned but are not strong enough for heavy duty applications. Figure 5 of the Patent
- 30 Specification shows two pairs of strands running into the junction, and the junction is formed of crotch filaments, a centre filament and thin webs. The webs may be about half the thickness of the strands. It is found that on rupture, the structure very often
- 35 breaks at the junction, a split starting in a web, which acts as a tear starter, and running along the strands. The alternative structure illustrated in Figure 4 is very similar except that the centre filament is absent, and its behaviour is similar.
- 40 U.K. Patent Specification No. 1 544 608 describes structures which are thin and flat, the junctions being no thicker than the strands. It is believed that a flat junction is not the strongest junction as, at the very centre of the junction, there is an area of random molecular arrangement which has less resistance to rupture than the molecularly orientated
- 45 areas which surround it; the surrounding areas have the same thickness as, and are therefore stronger than, the centre area.
- 50 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
- 55 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
- 60 "width" refer to the appropriate dimension in the plane of the starting material or mesh structure.
- The thickness of the starting material or mesh
- 65 structure is the distance between the extreme faces

of the starting material or mesh structure.

- 70 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.

- 75 The notional 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
- 80 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
- 85 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
- 90 measured by measuring the distance moved by the respective ends of the openings on either side of the strand. For the second stretch, the ratios are measured by comparing the stretched lengths with the original starting material and not with the material
- 95 as after the first stretch. The ratios are as measured after relaxation.

- The invention provides methods as set forth in Claims 1, 44 and 48, and structures as set forth in Claims 27, 28, 30, 46 and 54. The remaining Claims
- 100 set forth preferred features.

- In the methods of Claim 1 and 44, biaxial orientation is produced, and the structures of Claims 27, 28, 30 and 46 are biaxially orientated.

- The starting material, when biaxially stretched in
- 105 accordance with the method of Claim 1, produces junctions between the strands which are not flat but do not exhibit any excessive thinning, and there are no marked filaments within the junctions. The whole junction has a minimum thickness which is not less
- 110 than 75% of the thickness of the mid-point of any of the strands passing into the junction. Each junction is a solid junction as opposed to an openwork junction formed by a framework of sub-filaments and film or by an orientated thin film area bounded about
- 115 its perimeter by orientated filaments. The junctions have a central zone which is thicker than orientated lateral zones on at least two opposite sides thereof which central zone can if desired include some unorientated material (or there may be two small,
- 120 spaced unorientated zones on either side of the centre of the junction). This unorientated or random orientated central zone is thicker than the strands and thus can have sufficient strength to prevent rupturing occurring in the centre of the junction. The
- 125 junctions maintain a shape which provides good stress transmission paths and permits the junction to withstand high forces between either pair of aligned strands or between two strands initially at 90° to each other. The structure is strong enough to
- 130 be used for instance as stock fencing, provided the

strands are of sufficiently heavy gauge, or relatively strong light-weight structures can be provided for instance for olive harvesting.

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

Figures 1, 2 and 3 show three stages in a method in accordance with the invention;

Figures 4a, 4b and 4c are sections along the corresponding lines shown in Figure 2;

Figure 4d is a section corresponding to that of Figure 4c, but shows a variation;

Figures 5 to 9 show the junctions in five different structures produced by the method;

Figures 9a and 9b are sections taken along the lines IXA-IXA and IXB-IXB of Figure 9;

Figure 10 shows various shapes of holes or depressions that can be used in the starting material;

Figure 11 is a schematic elevation of a plant for making biaxially stretched structures in accordance with the invention;

Figure 12 is a perspective view of a stabilising or retaining structure;

Figure 13 is a vertical section through a wall, earth retained thereby and structures as in Figure 12; and

Figure 14 is a vertical section through an embankment stabilised in accordance with the invention.

In Figures 2, 5 to 9 and 12, 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.

The uniaxially-stretched structures which are about to be described are also described in GB 2 073 090 A, referred to above.

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 stretched 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 4c); 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 4c).

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 4a that they still maintain the original thickness of the sheet 11. They have flat outer faces in Figure 4a, and may also have flat outer faces in Figure 4b. However, the first zones 20 have been orientated (see the undulating top and bottom surfaces in Figure 4a); 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 4a, 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 4c) and can have a thickness ranging from just somewhat thicker than the strands 17 to the thickness of the starting material 11. 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 4c, 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 re-entrant on either side of the first zone 20.

Figure 4d illustrates a variant that 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.

As disclosed in GB 2 073 090 A, the uniaxially stretched structures can find many other uses; for the purposes of the present specification, they are used to form the biaxially stretched structures of the invention, though the possibility of other routes to the biaxially stretched structures of the invention is not excluded.

The structure of Figure 2 is subjected to a second stretching operation, in the horizontal direction as seen looking at Figure 2. The effect of this second stretching operation is to draw out the zones 24 indicated in Figure 1, which correspond to the second zones 21 shown in Figure 2, forming further strands 25. At the same time, it is found that if no tension is applied in the vertical direction (no restraint in vertical direction); the length of the openings in the direc-

tion of the first stretching operation is reduced, possibly by up to 33%, and the end portions of the strands 17 are either partly or fully drawn into the junctions and even drawn out in the direction of the second stretching operation to form end portions of the strands 25 shown in Figure 3, the structure shortening correspondingly in the first direction. This is illustrated by the truth lines 14' in Figure 3. Thus the outermost portions of the original notional junction zones 13, at the end of the first stretching operation, can have an orientation which is in the direction of the first stretching, and, at the end of the second stretching operation, can have a predominant orientation which is in the direction of the second stretching or can have approximately equal orientation in each of these two directions. The amount of this effect depends upon the overall stretch ratios in the two stretching operations, which are discussed further below, and also on the amount of dimension reduction in the first direction which is permitted during the second stretch, i.e. on the amount of restraint in the first direction during the second stretch.

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 the final product. However it has been found that orientation need not even pass nearly right through the zone 13.

Figures 5 to 9 illustrate some examples of junctions 26 which are formed between the strands 17, 25. As indicated above, the first stretch was up and down the sheet of drawings and the second stretch was across the sheet. It will be seen that each of these junctions 26 is of generally lozenge or lenticular shape (particularly in Figures 7 to 9) with its major axis or maximum dimension aligned with the strands 25 formed in the second stretching operation and larger or much larger than its minor axis or minimum dimension, which is aligned with the strands 17. The sides of the junction 26 form curved crotches and merge very gradually with the sides of the strands 25 but merge relatively abruptly with the sides of the strands 17. The size of the junction 26 is much larger than that of the notional intersection zone 26' which would be formed by the intersection of the strands 17, 25 (see Figure 5).

Each junction 26 is substantially symmetrical about a plane parallel to the plane of the mesh structure, namely the median plane of the mesh structure, but each junction 26 is not flat, having a specific contour. The minimum thickness of each junction 26 is not less than 75% of the thickness at the mid-point of any of the strands 17, 25; it is believed that as the minimum thickness decreases below the thickness of the mid-point of the thickest strand 17 or 25, down to 90% or 80% of the value, or below, the strength of the junction decreases. The maximum thickness of the junction is substantially greater than the minimum thickness and substantially greater than the thickness of the mid-point of any of the strands 17, 25.

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.

Each junction 26 has a central zone 27 which is thicker than orientated lateral zones 28 (or zones 28 and other zones adjacent the reentrants 28') on at least two opposite sides thereof and normally thicker than the mid-points of at least two of the strands 17, 25. Thus, in Figures 5 to 9, there is a substantial increase in thickness as one passes through the junction 26 from one strand 17 to the aligned strand 17. If the orientation did not pass right through the first zones 20 during the first stretch, the central zone 27 would tend to be thicker. In general, the central zone 27 will be substantially less orientated than the lateral zones 28, 28' and the centre part of the central zone 27 may not even be orientated though the major part of the junction should be orientated. In the worst case, only 70% of the plan area of the junction would be orientated. There is a high degree of orientation in the direction running around the crotches between adjacent strands 17, 25.

As noted above, the junction 26 of Figures 7 to 9 has its major axis aligned with the direction of the second stretching operation, i.e. of the strands 25, and the structure will have greater strength in this direction if the cross-sections and spacings of the strands 17 and 25 are equal. The ratio of the major to minor dimensions of the junction 26 can be varied and a more balanced orientation and shape produced by careful selection of the stretch ratios in the two stretching operations. Although the ratio applied during the second stretching operation can be greater than that applied during the first stretch operation, some of the second stretching is involved in pulling out the junctions and shortening the strands 17. Increasing the stretch ratio in the second stretching direction increases the strength in that direction but can reduce the strength in the other direction.

In Figure 5, the second zones 21 (see Figure 2) have stretched before the first zones 20, and the first zones 20 have not been fully stretched (or even a small centre zone of unorientated material was left in each of the zones 20), leaving the central zone 27 of the junction 26 in the form of a lump. In more detail, it is believed that the second zones 21 "yield" before the first zones 20, and as the second zones 21 orientate, the orientation proceeds into the first zones 20 and around the crotches between the second zones 21 (or the orientated strands 25 which are being formed), so that stretching can be terminated when orientation has passed right round the crotches but before the junction 26 has thinned down excessively. The maximum thickness of the junction 26 is in the lump or central zone 26, and the lump is surrounded by thinner, orientated zones with which the lump merges. The lateral zones 28 are orientated and can be substantially flat with a thickness (the minimum thickness of the junction 26) which is slightly greater than that of any of the strands 17 or 25, where they pass into the junction 26, and roughly equal to or slightly greater than the thickness of the mid-point of the strands 17 and 25. There are substantially flat marginal zones around each crotch, and each crotch

is a smooth curve with no bulges, i.e. concave for its whole length. The structure can have approximately the same strength along each axis if the cross-section and spacings of the strands 17 and 25 are equal. The formation of the type of junction 26 shown in Figure 5 is facilitated by not allowing the material to shorten in the second stretching direction during the first stretch, allowing the orientation to pass well into but not right through the first zones 20, or alternatively by allowing the material to shorten in the second stretching direction (no restraint) during the first stretch and applying some restraint, though not complete restraint, in the first stretching direction during the second stretch.

Figure 6 illustrates a junction 26, generally as that of Figure 5 would appear on further stretching in the second direction. The central zone 27 is rather more rectangular in appearance. The central zone 27 has a reentrant 28' at each of two opposite ends thereof, which reentrants 28' are on the axis of the two aligned strands 25 entering the junction 26 from opposite sides. The crotches are still curved smoothly, with orientation in their edge zones running round the crotches, but are bulged outwardly at the corners of the central zone 27. Thus the major part of the length of the edge of each crotch is a concave curve, but a minor part is in the form of a convex curve. Where the slope lines extend as far as the edge of the junction 26, the edge zone of each crotch has a portion which is substantially thicker than the thickness of the mid-points of the two respective strands 17, 25 between which the crotch extends.

Figure 7 illustrates a junction 26 generally as that of Figure 6 would appear on further stretching in the second direction. The raised central zone 27 is long-shaped and aligned with the strands 25, and extends into zones or lumps 29 at each end, which lumps 29 are thicker than the central zone 27 and adjacent the ends of the strands 25, the whole forming a dog-bone-like shape as can be seen in the Figure. As shown in the junction of Figure 6, the central zone 27 of the junction has a reentrant 28' at each of two opposite ends thereof, which reentrants 28' are on the axis of the two aligned strands 25 entering the junction 26 from opposite sides. Also as in the junction of Figure 6, the major part of the length of the edge of each crotch is a concave curve, but a minor part is in the form of a convex curve, as shown in Figure 7.

Figure 8 illustrates a junction 26 generally as that of Figure 7 would appear on further stretching in the second direction. The central zone 27 extends into lumps 30, the whole forming a dumb-bell-like shape but generally similar to the dog-bone of Figure 7. As in the junction of Figure 6, the major part of the length of the edge of each crotch is a concave curve, but a minor part is in the form of a convex curve, as shown in Figure 8.

Figure 9 illustrates a junction 26 generally as that of Figure 8 would appear on further stretching in the second direction. The central zone 27 is long-shaped and merges smoothly with each of the strands 25 with no rapid decrease in thickness, though there is a slight thickening in the zones 31. Two sections

through the junctions 26 are shown in Figures 9a and 9b. The minimum thickness of the junction 26 is in the flat zones 28. As indicated by the slope lines, the zones 31 do not slope down very significantly to the adjacent parts of the crotches so that the edge zone of each crotch has a portion which is substantially thicker than the thickness of the mid-points of the two respective strands 17, 25 between which the crotch extends.

Production of the junctions 26 described above depends upon the shapes and spacings of the holes or depressions, stretching conditions such as the temperature, and the plastics material. The details given below are given for guidance and not to limit the invention.

There is a tendency for junctions of the type shown in U.K. Patent Specification No. 1 310 474 to be formed if the sheet thicknesses are below 1.5mm, 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 structure like that of the invention 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 possible 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. However the $w:d$ ratio is preferably greater than 1:1, a preferred maximum value being 6.35:1 or 4.23:1 and values of 2.11:1 or less or 1.41:1 or less being suitable.

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 uniaxially and biaxially stretched 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; thus the zones 21 preferably have flat top and bottom faces, as illustrated in Figures 4c and 4d, 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 in the starting material, 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 10 shows various shapes for the holes or depressions. 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%.

The plant is shown schematically in Figure 11 but the units themselves are conventional units.

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, a machine direction orientation (stretching) machine 46 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, although some restraint will be exercised; the degree of restraint can be controlled by the distance between the nips.

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

70 Examples

Tables 1 and 2 set out the procedure and results, respectively for 11 different Examples. 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. The thinnest point (zone 28) of the junction of each Example 5 to 11 is recorded.

In all the Examples except Example 11, there was no restraint 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 restraint, though not complete restraint, in the direction at right angles to the stretching direction during the second stretch, the first stretch being unrestrained.

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.

Examples 1 to 4 do not disclose biaxially-stretched structures in accordance with the present invention. Tables 1 and 2 are also included in GB 2 073 090 A, referred to above.

Table 1

No.	Mat- erial	Start- ing thick- ness.	Hole size	Hole shape	w/d	Pitch in 1st stretch direc- tion	Pitch in other stretch direc- tion	1st stretch ratio	2nd stretch ratio	Temp °C.
1	HDPE	4.5	6.35	Circ- ular	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 radi- ussed corners	2.12	25.4	15.88	4.5:1	0	"
4	"	1	6.35	Circ- ular	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	—	—

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 thickness were equal.

In Example 11, there was a $w:d$ ratio of less than unity, and it will be noted that although the stretch ratios were relatively low, the whole of the junction 26 was orientated.

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 in accordance with GB 2 073 090 A, a tubular structure is in the form of sections of uniaxially (machine direction) stretched mesh structure (as in Figure 2) separated by pieces of unstretched plastics material which when the tubular structure is cut into suitable lengths, form the tops, or tops and bottoms, of carrier bags. Analogous structures can be produced using the biaxially-stretched mesh structures of the present invention.

The biaxially stretched structures can be used for instance for stock fencing, horticultural use, civil engineering use, olive harvesting and reinforcing between laminated sheets.

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.

Though the preferred structure for retaining or stabilising is the uniaxially stretched structure of GB 2 073 090 A, the biaxially stretched structure of the present invention can be used.

The mesh structure will normally be placed roughly parallel to the surface of the particulate material, eg. 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 eg. along one edge of the mesh structure could be a retaining wall.

Figure 12 shows a uniaxially stretched structure in accordance with GB 2 073 090A, but is retained in the

5 present specification as a biaxially stretched structure of the present invention can be used in an analogous manner. A mesh structure 51 has had two opposite edge zones cast into substantially rigid concrete members or beams 52. The uniaxially stretched mesh structure illustrated has parallel, orientated strands 53 and parallel bars 54, the mesh structure being 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 13 shows the application of the structure of Figure 12, 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 13. 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.

35 In Figure 14, spaced layers of a uniaxially stretched structure 61, as described for instance with reference to Figure 2 and Example 1, are buried in an earth embankment.

CLAIMS

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

providing a substantially uniplanar 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

45 stretching the starting material in a direction substantially parallel to the columns and also stretching in a direction substantially parallel to the rows, to form a generally rectangular grid of orientated strands interconnected by orientated junctions each of which has a minimum thickness not less than 75% of the thickness of the mid-point of any of the strands passing into the junction, has a maximum thickness substantially greater than the thickness of the mid-point of any of the strands passing into the junction, and has a central zone which is substantially thicker than orientated zones on two opposite sides thereof, the edge zones of the crotches which extend between respective adjacent pairs of strands passing into the junction being orientated in the direction running around the respective crotch.

2. The method of Claim 1, wherein each of the junctions is substantially symmetrical about a plane parallel to the plane of the mesh structure.

3. The method of Claim 1 or 2, wherein said central zone is long-shaped and aligned with two of the strands passing into the junction.

4. The method of Claim 3, wherein the thickness of the mid-point of the central zone is substantially equal to that of the mid-points of the strands with which the central zone is aligned.

5. The method of any one of the preceding Claims, wherein the central zone extends into respective zones at the ends thereof, which latter zones are thicker than the central zone and are adjacent the ends of two respective aligned strands.

6. The method of any one of the preceding Claims, wherein, as measured in the plane of the mesh structure, the maximum dimension of each junction is substantially aligned with two of the strands and is significantly greater than the minimum dimension, which is aligned with the other two strands, the sides of the junction merging very gradually with the sides of the strands aligned with the maximum dimension and merging more abruptly with the sides of the other strands.

7. The method of any one of the preceding Claims, wherein the starting material is stretched in a direction substantially parallel to the columns (first stretch) and the structure so formed is subsequently stretched in a direction substantially parallel to the rows (second stretch).

8. The method of Claim 7, wherein during the second stretch, the structure is restrained in a direction substantially parallel to the columns.

9. The method of Claim 7 or 8, wherein, during the second stretch, the structure is allowed to shorten in a direction substantially parallel to the columns.

10. The method of any one of Claims 7 to 9, wherein, during the first stretch, the structure is restrained in a direction substantially parallel to the rows.

11. The method of any one of Claim 7 to 10, wherein, during the first stretch, the material is allowed to shorten substantially in the direction parallel to the rows.

12. The method of any one of Claims 1 to 6, wherein the starting material is stretched in a direction substantially parallel to the columns (first stretch) 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 until 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, and the structure so formed is subsequently stretched in the direction substantially parallel to the rows (second stretch).



or more steel plates. The member eg. along one edge of the mesh structure could be a retaining wall.

Figure 12 shows a uniaxially stretched structure in accordance with GB 2 073 090A, but is retained in the

5 present specification as a biaxially stretched structure of the present invention can be used in an analogous manner. A mesh structure 51 has had two opposite edge zones cast into substantially rigid concrete members or beams 52. The uniaxially
10 stretched mesh structure illustrated has parallel, orientated strands 53 and parallel bars 54, the mesh structure being 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
15 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 13 shows the application of the structure of Figure 12, to prevent a retaining wall 55 being forced
20 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
25 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 13. The mesh structure itself has good slip
30 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.

35 In Figure 14, spaced layers of a uniaxially stretched structure 61, as described for instance with reference to Figure 2 and Example 1, are buried in an earth embankment.

CLAIMS

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

providing a substantially uniplanar starting material having a thickness of not less than 0.75 mm and having a pattern of holes or depressions whose
45 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 and also stretching in a direction substantially parallel to the rows, to
50 form a generally rectangular grid of orientated strands interconnected by orientated junctions each of which has a minimum thickness not less than 75% of the thickness of the mid-point of any of the strands passing into the junction, has a maximum
55 thickness substantially greater than the thickness of the mid-point of any of the strands passing into the junction, and has a central zone which is substantially thicker than orientated zones on two opposite sides thereof, the edge zones of the crotches which
60 extend between respective adjacent pairs of strands passing into the junction being orientated in the direction running around the respective crotch.

2. The method of Claim 1, wherein each of the junctions is substantially symmetrical about a plane
65 parallel to the plane of the mesh structure.

3. The method of Claim 1 or 2, wherein said central zone is long-shaped and aligned with two of the strands passing into the junction.

4. The method of Claim 3, wherein the thickness
70 of the mid-point of the central zone is substantially equal to that of the mid-points of the strands with which the central zone is aligned.

5. The method of any one of the preceding Claims, wherein the central zone extends into
75 respective zones at the ends thereof, which latter zones are thicker than the central zone and are adjacent the ends of two respective aligned strands.

6. The method of any one of the preceding Claims, wherein, as measured in the plane of the
80 mesh structure, the maximum dimension of each junction is substantially aligned with two of the strands and is significantly greater than the minimum dimension, which is aligned with the other
85 two strands, the sides of the junction merging very gradually with the sides of the strands aligned with the maximum dimension and merging more abruptly with the sides of the other strands.

7. The method of any one of the preceding Claims, wherein the starting material is stretched in
90 a direction substantially parallel to the columns (first stretch) and the structure so formed is subsequently stretched in a direction substantially parallel to the rows (second stretch).

8. The method of Claim 7, wherein during the
95 second stretch, the structure is restrained in a direction substantially parallel to the columns.

9. The method of Claim 7 or 8, wherein, during
100 the second stretch, the structure is allowed to shorten in a direction substantially parallel to the columns.

10. The method of any one of Claims 7 to 9, wherein, during the first stretch, the structure is
restrained in a direction substantially parallel to the rows.

105 11. The method of any one of Claim 7 to 10, wherein, during the first stretch, the material is allowed to shorten substantially in the direction parallel to the rows.

12. The method of any one of Claims 1 to 6,
110 wherein the starting material is stretched in a direction substantially parallel to the columns (first stretch) 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
115 strands, the stretching being effected until 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,
120 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-
125 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, and the structure so formed is subsequently stretched in the direction substantially
130 parallel to the rows (second stretch).



13. The method of any one of Claims 1 to 6, wherein the starting material is stretched in a direction substantially parallel to the columns (first stretch) 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 until the orientation extends into the notional junction zone (as defined herein), but does not pass right through the notional junction zone, and the structure so formed is subsequently stretched in the direction substantially parallel to the rows (second stretch).

14. The method of Claim 12 or 13, wherein the starting material is stretched in the first stretch until the orientation passes right through, or nearly right through, each notional junction zone (as defined herein), material originally in the notional junction zone being stretched out to form the end portions of the strands, merging smoothly with the remainder of the respective strands.

15. The method of Claim 12, wherein the starting material is stretched in the first stretch until said notional point is spaced from said corresponding notional straight line by a distance which is not less than 25% of the thickness of the mid-point of the respective strand.

16. The method of Claim 12 or 13, wherein the starting material is stretched in the first stretch until the central third of each notional junction zones (as defined herein) is drawn to a ratio of at least 1.5:1.

17. The method of Claim 12 or 13, wherein the central part of each bar between aligned strands is not stretched in the first stretch, the length of the part which has not been stretched being not greater than five times its thickness.

18. The method of Claim 12 or 13, wherein the central part of each bar between aligned strands is not stretched in the first stretch, the length of the part which has not been stretched being not greater than its thickness.

19. The method of any one of Claims 7 to 18, wherein, during the second stretch, orientation begins in those parts of the structure which do not lie between the ends of aligned orientated strands formed in the first stretch.

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

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

22. The method of any one of the preceding Claims, wherein the ratio of the distance between adjacent holes or depressions in the same row to the thickness of the starting material at the same point is greater than 1.

23. The method of any one of the preceding Claims, wherein the ratio of the distance between adjacent holes or depressions in the same row to the thickness of the starting material at the same point is substantially equal to 2.11:1 or less.

24. The method of claim 23, wherein said ratio is substantially equal to 1.41:1 or less.

25. The method of any one of Claims 6 to 9, modified in that there is provided 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, (first) 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, and such mesh structure is stretched in the direction substantially at right angles to the first orientated strands to form said grid of orientated strands.

26. The methods of any one of the preceding Claims, wherein each junction has a minimum thickness not less than the thickness of the mid-point of any of the strands passing into the junction.

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

28. A plastics material mesh structure produced by stretching a substantially uniplanar starting material having a thickness of not less than 0.75 mm at its thickest part, which mesh structure has generally rectangular mesh openings defined by a generally rectangular grid of orientated strands and orientated junctions therebetween, substantially each of which junctions interconnects four strands, has a minimum thickness not less than 75% of the thickness of the mid-point of any of the strands passing into the junction has a maximum thickness substantially greater than its minimum thickness and substantially greater than the thickness of the mid-point of any of the strands passing into the junction, and has a central zone which is substantially thicker than orientated zones on at least two opposite sides thereof, the edge zones of the crotches which extend between all the respective adjacent pairs of strands passing into the junction being orientated in the direction running around the respective crotch.

29. The structure of Claim 28, and produced by stretching a starting material having a thickness of not less than 1 mm.

30. A plastics material mesh structure having a thickness of not less than 0.55 mm at its thickest part and having generally rectangular mesh openings defined by a generally rectangular grid of orientated strands and orientated junctions therebetween, substantially each of which junctions interconnects four strands, has a minimum thickness not less than 75% of the thickness of the mid-point of any of the strands passing into the junction, has a maximum thickness substantially greater than its minimum thickness and substantially greater than the thickness of the mid-point of any of the strands passing into the junction, and has a central zone which is substantially thicker than orientated zones on at least two opposite sides thereof, the edge zones of

the crotches which extend between all the respective adjacent pairs of strands passing into the junction being orientated in the direction running around the respective crotch.

5 31. The structure of any one of Claims 28 to 30, wherein said central zone is long-shaped and aligned with two of the strands passing into the junction.

32. The structure of Claim 31, wherein the thickness of the mid-point of the central zone is substantially equal to that of the mid-points of the strands with which the central zone is aligned.

33. The structure of any one of Claims 28 to 32, wherein the central zone extends into respective zones at the ends thereof, which latter zones are thicker than the central zone and are adjacent the ends of two respective aligned strands.

34. The structure of any one of Claims 28 to 33, wherein, as measured in the plane of the mesh structure, the maximum dimension of each junction is substantially aligned with two of the strands and is significantly greater than the minimum dimension, which is aligned with the other two strands; the sides of the junction merging very gradually with the sides of the strands aligned with the maximum dimension and merging more abruptly with the sides of the other strands.

35. The structure of any one of Claims 28 to 34, wherein the central zone of the junction has a reentrant at each of two opposite ends thereof, which reentrants are on the axis of two aligned strands entering the junction from opposite sides.

36. The structure of any one of Claims 28 to 35, wherein the edge zone of each said crotch has intermediate its ends a portion which is substantially thicker than the thickness of the mid-points of the two respective strands between which the crotch extends.

37. The structure of any one of Claims 28 to 36, wherein the major part of the length of the edge of each said crotch is a concave curve, but a minor part is in the form of a convex curve.

38. The structure of any one of Claims 28 to 37, wherein the edge zone of each said crotch has intermediate its ends a portion which is substantially thicker than the thickness of the mid-points of the two respective strands between which the crotch extends.

39. The structure of any one of Claims 28 to 30, wherein the maximum thickness of the junction is in the central zone, which central zone is in the form of a lump which is surrounded by thinner, orientated zones with which the lump merges.

40. The structure of any one of Claims 28 to 30 and 39, wherein the central zone of the junction is surrounded by thinner lateral zones which are substantially flat.

41. The structure of any one of Claims 28 to 30, 39 and 40, in which each crotch is a smooth concave curve, merging with the sides of the respective strands between which the crotch extends.

42. The structure of any one of Claims 28 to 41, wherein each junction has a minimum thickness not less than the thickness of the mid-point of any of the strands passing into the junction.

43. The structure of any one of Claims 28 to 42, and having a thickness of not less than 0.7 mm at its thickest part.

44. A method of producing a biaxially stretched plastics material mesh structure, substantially as herein described with reference to any of Figures 1 to 11 of the accompanying drawings or any of the foregoing Examples 5 to 11.

45. Any method of Claim 1 and substantially as herein described.

46. A plastics material mesh structure, substantially as herein described with reference to, and as shown in, any of Figures 3 and 5 to 9 of the accompanying drawings or any of the foregoing Examples 5 to 11.

47. Any structure of Claim 28 or 30 and substantially as herein described.

48. 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 27 to 43, 46 and 47.

49. The method of Claim 48, wherein the mesh structure is fixed to at least one solid member.

50. The method of Claim 49, wherein the mesh structure extends between generally parallel, spaced solid members.

51. The method of Claim 49 or 50, wherein the or each solid member is made of a cast material into which the mesh structure has been incorporated before setting.

52. The method of any one of Claims 49 to 51, wherein the or one of the solid members is or forms part of a wall which retains the particulate material.

53. The method of Claim 52, 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.

53. A structure comprising particulate material such as soil, which has been retained or stabilised by the method of any one of Claims 48 to 53.

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The following amendments were allowed under Section 27 on 22 June 1983.

Page 1, line 98, *for 44 and 48 read 43 and 47*

Page 1, line 99, *for 46 and 54 read 45 and 53*

Page 1, line 101, *for 44 read 43*

Page 1, line 103, *for 46 read 45*

Page 10 *delete lines 43 to 48*

Page 10 *for claims 39 to 53 read 38 to 52*

Page 10, line 62, *for 41 read 40*

Page 10, line 66, *for 42 read 41*

Page 10, lines 86 and 87 *for 43, 46 and 47 read 42, 45 and 46*

Page 10, line 88, *for 48 read 47*

Page 10, line 90, *for 49 read 48*

Page 10, line 93, *for 49 or 50 read 48 or 49*

Page 10, line 97, *for 49 to 51 read 48 to 50*

Page 10, line 100, *for 52 read 51*

Page 10, line 107, *for 48 to 53 read 47 to 52*

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